APPENDIX D

SEDIMENT CHEMISTRY CHARACTERISTICS IN THE UCR

CONTENTS

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ACRONYMS AND ABBREVIATIONS

B-P	Breusch-Pagan test for heteroscedasticity
BERA	baseline ecological risk assessment
COPC	chemicals of potential concern
DF	degrees of freedom
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
IRM	iterative regression model
NURE-HSSR	National Uranium Resource Evaluation Hydrogeochemical and Stream Sediment Reconnaissance
PCA	principal components analysis
PCB	polychlorinated biphenyl
QA/QC	quality assurance and quality control
RESET	Ramsey Regression Equation Specification Error Test
RI/FS	remedial investigation and feasibility study
RM	river mile
RPD	relative percent difference
TOC	total organic carbon
UCR	Upper Columbia River
USGS	U.S. Geological Survey
Zn/V	zinc to vanadium

UNITS OF MEASURE

cm	centimeter(s)
ft	foot (feet)
in.	inch(es)
kg	kilogram(s)
m	meter(s)
mg	milligram(s)
μm	micrometer(s)

1 INTRODUCTION

Sediment from the Site was collected by U.S. Environmental Protection Agency (EPA) contractors during Phase I of the remedial investigation and feasibility study (RI/FS) in 2005. In addition, several other investigators have collected sediment from the Site since 1986.

The studies evaluated in this appendix are historical and were not necessarily conducted for the Upper Columbia River (UCR) RI/FS and baseline ecological risk assessment (BERA) and may not meet the current standards of practice and/or the data quality requirements necessary for completion of the BERA. However, for purposes of this BERA Work Plan, the data and analyses are assumed to be adequate to assist in identifying data gaps and describing general site characteristics, but may not be acceptable for use in future deliverables in their current form.

As the BERA progresses, the quality of the existing data, data analysis procedures, and suitability for inclusion in the BERA will be assessed according to procedures that will be reviewed and approved by the EPA. In addition, clear explanations of the data used in evaluations, evaluation methodology, and statistical analysis documentation will be provided in future documents."

The purpose of the work reported herein is to address questions related to characterization of site sediment, with the following specific objectives:

- Evaluate data quality of historical sediment studies other than the 2005 Phase I study (the Phase I data are assumed to be of good quality for characterizing site conditions [CH2M Hill 2006])
- Assess whether any sediment characteristics, such as ratios of concentrations, may be indicative of the presence of different sediment (and contaminant) types
- Identify the presence of any spatial and/or temporal trends in concentrations of sediment types and chemical constituents
- Assess whether distributions of chemicals appear to be associated with either the mass or the surface area of sediment particles (i.e., are part of the sediment matrix or are sorbed to the sediment surface).

The structure of the remaining sections of this document follows this set of objectives.

2 SEDIMENT DATA SETS

2.1 DATA SETS

The following data sets were used in the evaluations presented herein:

- EPA Phase I sediment data set (CH2M Hill 2006)
- Metal concentrations in sediment from 16 locations in the UCR in 1986 (Johnson et al. 1989)
- Metal concentrations in sediment from six locations in Lake Roosevelt in 1989 (Johnson 1991)
- Metal concentrations in sediment from 102 locations in the Spokane River Basin in 1989 and 1999 (Grosbois et al. 2001)
- Metal and semivolatile concentrations in sediment from 66 locations in the UCR in 1992; the data set includes measurements on the fine fraction of sediment as well as whole sediment, but only data for whole sediment are evaluated herein (Bortleson et al. 2001)
- Metal concentrations in sediment from one location in Lake Roosevelt in 1993 (Johnson et al. 1994)
- Metal concentrations in sediment from three locations in the Spokane Arm in 1998 (Johnson 1999)
- Metal concentrations in sediment from 168 locations in the UCR in 2001 (START-2 2003)
- Metal concentrations in sediment from 10 locations in the UCR in 2001 (Era and Serdar 2001)
- Metal and radionuclide concentrations in sediment from nine locations in the UCR in 2002 (Cox et al. 2005)
- Metal and radionuclide concentrations in sediment from 11 locations in the UCR in 2002 to 2004 (Paulson et al. 2006)
- Metal concentrations in sediment from 8 upstream locations in the UCR in 2007 (Dowling 2007).

General characteristics of the studies are summarized in Table 1. The locations of sediment samples from these studies are shown in Maps 1 through 7. The number of locations sampled by reach and study is summarized in Table 2. Surface sediment was collected at all of these locations, and cores at a subset of the locations. Altogether, these studies constitute a comprehensive data set for the evaluation of conditions throughout the UCR.

The above-listed studies have been described in greater detail within Section 3 of this work plan. The data sets are summarized in Table 3, with notes on the documents used to assess each data set.

3 METAL CONCENTRATIONS, CLASSES, AND DISTRIBUTIONS

Exploratory analyses of sediment chemistry data obtained from the Site were carried out to evaluate whether subsets of sediments have distinct characteristics that provide a basis to understand the distribution of inorganic chemical of potential concern (COPC) concentrations, thereby helping to refine our understanding of the Site and focus further evaluations. These analyses were carried out using statistical and graphical tools to examine potential relationships among chemicals, chemical concentrations, and physical characteristics. Resulting from these analyses, three classes of sediment with distinguishing characteristics were identified. The remainder of this section describes the process that was followed to evaluate sediment characteristics, the characteristics of the distinct sediment classes that were identified, and the spatial distribution of those sediment classes. Subsequent analyses were carried out with consideration given to these three classes of sediment.

3.1 CLASSIFICATION OF SEDIMENT BY CHEMICAL CHARACTERISTICS

Evaluation of metal relationships and other sediment characteristics was carried out using the Phase I surface sediment data (CH2M Hill 2006). Only the Phase I data were used for this analysis because 1) use of a single data set provides assurance of internal consistency; 2) it has the largest number of sampling locations (332 samples) with the greatest spatial coverage; and 3) it includes the largest number of analytes, is the most recent, and is of good quality. Other data sets were not included in the development of a sediment classification system to minimize the potential that inclusion of such data might introduce difficulties in analysis and interpretation because of missing data (i.e., the same suite of analytes was not measured in all studies); differences in field or laboratory methods; or possible data quality differences.

Analyses of the relative concentrations of chemicals in Phase I sediment samples, as well as comparisons with the chemical composition of background sediment (refer to Appendix H) and of granulated slag from the Trail facility, were used to help identify and distinguish three sediment classes

- Class I—Slag influenced
- Class II—Not strongly influenced by slag
- Class III—Other, not corresponding to either class I or class II.

These classes were identified following a comprehensive evaluation of characteristic element ratios. Details of the approach are described below. It is important to note that the descriptions used above are not full or complete characterizations. For instance, class I represents samples that appear to be influenced by granulated slag; however, it should not be interpreted to mean that a sample represents granulated slag itself, or that a sample necessarily contains a high fraction of slag. Similarly, class II represents samples that appear to have little or no influence of slag, but are not necessarily free of even trace amounts of slag.

Granulated slag has a very distinctive chemical composition and can be characterized by the systematic co-variation of metals with which it is enriched compared to typical soil and sediment concentrations.

Granulated slag from the Trail facility is enriched in zinc, lead, iron, and copper, but not in vanadium, aluminum, and nickel (Cominco Metals 1991; Dames & Moore 1992; Sigma Engineering 1992; USEPA 2004a). These relationships provide a basis for evaluating the presence of a "signal" of granulated slag in Phase I sediment samples. Although in-river weathering may have altered these relationships somewhat, the extent of any potential alteration is anticipated to be minor because of the low leachability of metals from granulated slag as reported by others (Koren et al. 1996; USEPA 2004b).

Concentrations of iron and aluminum are commonly used to represent the contribution of crustal minerals to the composition of a sediment sample. In particular, changes in the ratios of other metals to iron and aluminum are often indicative of the presence of anthropogenic sources. However, for this analysis there are factors that confound use of either iron or aluminum as a "baseline" metal. For instance, iron is unsuitable because it is itself elevated in granulated slag. Aluminum may be unsuitable because concentrations of sediment aluminum in the Phase I data set were generally lower than expected from this area (mean ± SD = 1.01 percent ± 0.54) based on typical concentrations reported in the National Uranium Resource Evaluation Hydrogeochemical and Stream Sediment Reconnaissance (NURE-HSSR) (5.78 percent ± 1.1 percent). Consequently, an assessment of ratios among all metals was carried out to evaluate which ones provide the greatest ability to distinguish relative elevations of concentrations of slag-associated metals from regional background conditions.

Metal concentrations in the Phase I data typically exhibited skewed distributions with a tail of concentrations that are much higher than the most frequently measured concentrations. Some metals exhibit bimodal or trimodal distributions (Figures 1 through 20). When considered in combination, several pairs of metals show distinctively bivariate bimodal distributions (Figure 21[1]). For example, the plot of zinc and vanadium in Figure 21 has a strong bimodal distribution. These features of the data set strongly suggest that there are different classes of sediment present in the UCR.

Using data from Cominco Metals (1991), Dames & Moore (1992), Sigma Engineering (1992), and USEPA (2004a), the relative distribution of metals in granulated slag was compiled into a slag "signal." Although there is some variation in the measured concentrations of metals in granulated slag, concentrations of the principal slag-associated metals (zinc, lead, and copper) are generally orders of magnitude greater than the concentrations in the NURE-HSSR data set. The variation among measurements of granulated slag is relatively small relative to these differences. The most representative metric for this signal was an elevated zinc to vanadium (Zn/V) ratio compared to the NURE-HSSR data, which is similar in soil and sediment (Figure 22). Because extraction of the maximum practical quantity of zinc is a goal of the smelting process, the zinc content of granulated slag from the Trail smelter is regulated at about 2 percent. For the purposes of this evaluation, it is assumed that sampling locations where metal concentrations in sediment are dominated (or otherwise strongly influenced) by slag will have distributions of zinc and vanadium closely associated with the slag signal.

A linear regression estimate was fitted to describe the Zn/V relationship of the EPA Phase I data set (all statistical analyses were carried out with R [R 2007]). Although a linear model was not expected to

[1] Whereas a bimodal distribution for a single analyte shows two centers of density on a single scale or line, a bivariate bimodal distribution shows two centers of density on a plane formed by orthogonal scales.

describe this relationship, it is a useful data analysis approach in this context because studentized residuals of the linear model (Fox 1997) can be used to distinguish relatively high zinc samples (presumably slag influenced, or class I samples) from those of other types (Figure 23). As part of classification system development, samples falling more than one studentized residual above the regression line were placed in class I and removed from the data set used for regression (Figure 23 charts a and b). This procedure was repeated in an iterative regression model (IRM), until the entire zinc-rich upper arm of the bimodal Zn/V distribution was identified as class I sediments (Figure 23).

The remaining data (of which all were less than one studentized residual above the IRM regression line) did not display features clearly characteristic of the slag signal, but do not appear to represent a single, clearly defined population (Figure 23). To obtain a coherent subset of the data, further separation of these data was attempted based on the relative abundance of zinc and vanadium using the same IRM procedure. Because no unambiguous method to separate these subsets using the IRM method exists, a conservative cutoff value was chosen for this distinction at the zinc sediment screening level. Specifically, samples with a zinc concentration greater than 121 mg/kg or a Zn/V ratio greater than 10 were identified as a separate class (Figure 23). By elimination, the remaining samples were considered to be significantly free of the influence of slag and showed a good fit between zinc and vanadium using linear regression (adjusted $R^2 = 0.46$, $p < 0.001$) (Figure 23 chart d).

Thus, the EPA Phase I data set was divided into three sediment classes:

- One class with a high Zn/V ratio and high zinc concentrations (class I, N = 87)
- Another class with a low Zn/V and low zinc concentrations (class II, N = 180)
- A third class, which did not fit the distribution of either class I or class II samples, but displayed a continuum of zinc concentrations and Zn/V values spanning the gap between the two (class III, N = 92).

These distinctions with respect to zinc and the Zn/V ratio are shown in Figure 23 charts e and f. The distributions of zinc and vanadium in each of these classes are summarized in Table 4.

Class I sediments were initially identified as being potentially influenced by granulated slag based on the Zn/V ratio, and this tentative association was further evaluated by comparing the distributions of multiple metals in class I sediments to the corresponding distributions in granulated slag. Figure 24 illustrates the pattern of concentrations characteristic of granulated slag and of each of the sediment classes. The pattern of relative concentrations in class I sediments is much more similar to that of the granulated slag signal than either of the other two classes. This subjective conclusion was evaluated in a quantitative fashion by carrying out linear regressions of the mean values of metal concentrations within each class against the mean values of the slag signal. These regression lines are shown in Figure 25. Mean metal concentrations in class I sediment are highly correlated with the slag signal ($R^2 = 0.98$), whereas those of classes II and III are not ($R^2 = 0.53$). Furthermore, the distribution of the Zn/V ratio data within the class I samples are not significantly different from that of granulated slag (two-sided Wilcoxon rank sum test, $p = 0.06$), while those for class II and III are different ($p < 0.001$). Absolute concentrations of metals in class I sediment, however, are well below those in granulated slag itself (Figures 24 and 25). Therefore, although class I sediment may be influenced by the presence of granulated slag, it is not actually equivalent to slag. Because concentrations of copper, lead, zinc, and other metals are 10 to 100 times (or more) higher in granulated slag than in background sediments, a relatively small fraction (by mass) of slag in the sediment can have a dominant influence on the pattern of metal concentrations measured in a sample.

Concentrations of most COPCs are higher in both the class I and class III samples than in the class II samples (Figures 26a through 26d[2]). Concentrations of many metals are also higher in class I than in class III, but aluminum, beryllium, cadmium, magnesium, mercury, nickel, potassium, and vanadium have median concentrations that are higher in class III than in class I. The distributions of concentrations of each metal in each sediment class were compared statistically to determine whether there are overall systematic similarities or differences between classes for any metal. These comparisons were carried out using pairwise Wilcoxon rank sum tests, with statistical significance recognized at $p < 0.05$. Comparisons were carried out for aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, uranium, vanadium, and zinc—a total of 72 comparisons. The results of these comparisons are summarized in Table 5. The distributions of all metals were statistically significantly different for each pair of classes except for nickel and thallium in classes I and II, and potassium and uranium in classes I and III. Overall, these comparisons provide strong affirmation that the classes identified on the basis of the relationship of zinc to vanadium represent clearly distinct classes of sediment within the UCR.

Nevertheless, it is acknowledged that statistical analyses showing differences among sediment classes based on Zn/V ratios are only one potentially useful way to evaluate the sediment data. Therefore, additional analyses were carried out to evaluate the overall applicability of these sediment classes. These analyses included visualizations of the three different sediment classes overlain on two- and three-dimensional plots of several different combinations of sediment COPCs and grain size fractions. Figure 27 shows the distribution of grain size by sediment class. In addition, a principal components analysis (PCA) was carried out using sediment metal and grain size data, and the results visualized with respect to the class assignments based on zinc and vanadium. Figure 28 illustrates the PCA results, showing the Phase I data with respect to the first three principal components, and including three-dimensional ellipses that bound 70 percent of the samples in each of the three sediment classes. In all cases where two or three different groups of samples are distinguishable using these other visualization methods, classes I, II, and III conform to those groups. These additional analyses confirm that the sediment classes reliably represent different sediment classes within the UCR.

3.2 SPATIAL DISTRIBUTIONS OF SEDIMENT CLASSES

Because of the chemical differences among sediment classes I, II, and III, the spatial distributions of these classes were evaluated to determine if classification of the sediment contributes to a better understanding of the distribution of COPCs within the Site. This evaluation was carried out both for Phase I sediments alone (which were used to develop the classification tool), and also for all surface sediment samples from the Site to which the classification criteria could be applied (i.e., that had detected concentrations of both

[2] These figures show Tukey boxplots (Cleveland 1993) in which the box encompasses the second and third quartiles, the horizontal line is at the median, and the whiskers extend to the data value that is at or within 1.5 times the inter-quartile range from the end of the box.

zinc and vanadium—this consisted of the Phase I study, EPA START data, and data collected by Grosbois et al. [2001], Cox et al. [2005], and Paulson et al. [2006]). Map 8 illustrates the spatial distribution of sediment classes among Phase I samples, and Table 6 summarizes the spatial distribution, by reach, of classes from all sediment studies.

Samples in class I contain a relatively high fraction of coarse particle sizes and are exclusively located above river mile (RM) 701, in Reaches 1, 2, and 3. Only one class I sediment sample was identified downstream of Marcus Flats (at approximately RM 701).

Samples in classes II and III are predominantly located downstream of Marcus Flats. Sediment classes II and III are intermingled in the lower reaches of the river. Reaches 4a and 4b are predominantly class II sediment. In Reaches 5 and 6, there appears to be a fairly consistent lateral pattern consisting of class II sediment closer to shore and class III sediment in the deeper water.

4 PATTERNS OF VARIATION IN SEDIMENT CLASSIFICATIONS AND COPCs

The spatial distribution of COPCs along the length of the UCR was evaluated in terms of variation between river reaches. Surface samples from all studies are included, because they provide the best estimate of current exposure conditions to ecological receptors and to people interacting with the sediment surface. Although surface sampling depths vary between and within the studies included, all samples are generally within the top 15 cm of sediment. However, it should be noted that in addition to samples being collected from different locations within the Site at different times, differences in sample collection and analytical protocols also exist between the data from each study. Consequently, identification and interpretation of any spatial (or temporal) trends that may occur are confounded by factors related to natural spatial heterogeneity, changes in conditions over time, or analytical differences.

Concentrations of most COPCs exhibit systematic longitudinal spatial variation in surface sediment. Plots showing the distribution of each chemical in surface sediment, by RM, are shown in Figures 29 through 126 (with nondetects taken at one-half the detection limit). The detection frequency and minimum, maximum, and mean detected value of each measured COPC in each river reach are summarized in Table 7. Use of the mean detected concentration for analytes with low detection frequencies provides a conservative upper-bound estimate of the concentration. Several different patterns of variation are exhibited within this data set. In most cases, these patterns are characterized by changes in the range of the highest concentrations in different reaches; the lowest concentrations are usually similar in all reaches. The distinctive patterns, and the chemicals that follow each of them, are as follows:

- **Pattern 1—Maximum concentrations that are highest upstream and decrease downstream.** This pattern is exhibited by most of the common metals and metalloids (e.g., lead, as shown in Figure 95). Specifically, this pattern is shown by antimony, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, silver, uranium, and zinc. Exceptions among the common metals/metalloids are aluminum, beryllium, cadmium, mercury, nickel, potassium, sodium, titanium, and vanadium. The identities of the metals that are highest in the upstream reaches indicate that this pattern is a result of the presence of class I sediments in the upstream reaches.
- **Pattern 2—Maximum concentrations that are lowest upstream and increase downstream.** This pattern is exhibited by all of the semivolatile organic compounds, pesticides, and dioxins and furans, and most of the exotic metals. Figure 107 illustrates this pattern (for octachlorodibenzo-*p*-dioxin). Detection limits for organic compounds also increase downstream.
- **Pattern 3—Nonsystematic variation.** A few chemicals show little longitudinal variation, or variations that do not represent a monotonic trend of either increasing or decreasing concentrations with reach. These chemicals are beryllium, bismuth, cadmium, gallium, lanthanum, mercury, selenium, sodium, strontium, and vanadium.

4.1 LONGITUDINAL VARIATION IN CONCENTRATIONS BY SEDIMENT CLASS

Spatial distributions of COPCs and relationships between sediment classes can be further understood by evaluating COPC concentrations in relation to both sediment class and river reach. Figures 127 through 146 show the relationships among reaches, classes, and concentrations for metal and metalloid COPCs from all studies for which sediment classes can be assigned. From these figures, the following were observed:

- Concentrations in class I sediments are higher than in class II and III sediments for most metals.
- Concentrations in class I sediments are similar in reaches in which they occur (Reaches 1 through 3). There is no clear spatial trend within class I sediments.
- Very little longitudinal spatial trend is apparent in class II sediments. The most common deviation from uniformity across reaches within this class consists of an increase in variability—and therefore an increase in the maximum concentration—that occurs in Reach 4b or 5 for many chemicals.
- Longitudinal spatial trends are clearer in class III for many metals than they are in either of the other classes. In most cases, this pattern consists of concentrations that increase with reach. For aluminum, antimony, beryllium, cadmium, chromium, cobalt, iron, manganese, nickel, selenium, thallium, uranium, and vanadium, maximum concentrations for class III sediments are found in Reach 5 or 6. For arsenic, lead, magnesium, mercury, silver, and zinc, maximum concentrations for class III sediments are found in Reach 4a or 4b.

It is worth noting that the strong pattern of an overall decrease in concentrations with reach that is observed for many metals (as noted previously) does not occur when spatial patterns in individual sediment classes are evaluated. Within each sediment class, concentrations are relatively uniform. Thus, the pattern of an overall decrease in concentrations is the result of two factors: 1) many metals have higher concentrations in class I sediments, and 2) class I sediments are restricted to upper reaches of the river. Understanding the distribution of sediment classes in the river can therefore be used to better understand the distribution of COPCs.

4.2 INVESTIGATION OF POTENTIAL RELATIONSHIPS BETWEEN SEDIMENT METAL CONCENTRATIONS AND PARTICLE SIZE

Although the sediment classes were defined on the basis of COPC concentrations, these classes may also be distinguished by the sediment particle size characteristic of each. class I contains the highest fraction of sand-sized particles, class III contains the highest fraction of clay- and silt-sized particles, and class II contains an intermediate distribution of particle sizes, with the greatest fraction in the sand-sized category. class I is also distinct from the other classes with regard to particle type. Any granulated slag material present in this class would have a different mineralogical composition than particles in sediments of the other classes.

Differences in particle type and size potentially have implications for COPC bioavailability[3]. In particular, the total mass of metal (or other COPC) in a sediment may not be bioaccessible.[4] For example, it is important to separate the total metal content of a sediment into a fraction that is potentially exchangeable, including a fraction that is part of a crystalline matrix but which is not exchangeable (i.e., a residual fraction)[5]. Similarly, smaller particles, relative to larger particles, would be expected to have greater surface areas relative to their volume or mass. Consequently, different particle size fractions may have different capacities to hold or bind metals. It should be noted that one limitation of the Phase I database is that the majority of metal concentration measurements for sediments are total concentrations and do not necessarily distinguish between exchangeable and residual fractions.

Nevertheless, and understanding the above-mentioned limitations, potential relationships between sediment metal concentrations and particle size, correlations between metal concentrations and sediment grain-size fraction (i.e., clay, silt, or sand) by weight and by relative surface area were evaluated. The relative surface area of each grain size class in each sediment sample was estimated using the average diameter of each grain size class to calculate a characteristic surface area of a particle of that class (assuming spherical particles). The relative number of particles in each class was estimated based on the measured mass (assuming a uniform density). It is acknowledged that not all sediment particles are spherical, and therefore interpreting trends with grain size as a function of surface area has associated uncertainty. Mineralogy may also be another possible cause of compositional differences.

Following the partitioning of the Phase I data set into three classes, the normality of each subset was evaluated individually. This analysis also indicated that the three different sediment classes represent distinct populations. These populations overlap in the entire data set, with the consequence that the entire data set cannot be transformed to fit a normal distribution. However, when the sediment classes are treated individually, concentrations of all chemicals can be transformed to conform reasonably well to a normal distribution. Box-Cox transformations (Sokal and Rohlf 1981) were performed (using log-likelihood λ optimization) for each COPC within each of the three subsets of the data. All data were anchored at 1 and subjected to a Box-Cox transformation:

$$y' = \frac{y^{\lambda} - 1}{\lambda}$$

Where:

[3] Bioavailability refers to the extent to which bioaccessible metals absorb onto, or into, and across biological membranes of organisms, expressed as a fraction of the total amount of metal the organism is proximately exposed to (at the sorption surface) during a given time and under defined conditions.

[4] Bioaccessibility refers to the amount of environmentally available metal that actually interacts with the organism's contact surface (e.g., membrane) and is potentially available for absorption (or adsorption if bioactive upon contact).

[5] It is important to recognize that due to differences in sediment and porewater chemistries (e.g., the presence of acid-volatile sulfides, organic matter, hardness, hydroxides, etc.), the exchangeable fraction of metals is not necessarily expected to be bioavailable.

λ = transformation parameter

Following these transformations, all COPC concentrations reasonably fit assumptions of normality (Shapiro-Wilk tests) and equal variance for the purposes of analysis by linear models.

For the purposes of this analysis, surface areas of each sediment grain size fraction were estimated based on their respective mass percent relative abundance and assumed mean grain sizes of 1.0 µm for clay, 24 µm for silt, and 975 µm for sand (Plumb 1981); densities for all particle sizes were assumed to be equal. Linear regressions were then fitted on the transformed data (for each subset separately) between COPC concentrations and sediment grain size weight fraction or the corresponding estimated surface areas. The weight-based and area-based linear models were compared for each COPC based on their modeled slope, adjusted correlation coefficients (R^2), goodness of fit statistics (Ramsey Regression Equation Specification Error Tests [RESET], and Breusch-Pagan (B-P) tests for heteroscedasticity.

Sediment grain size fractions for samples in classes I and II were dominated by sand-sized particles (> 77 percent) and had a relatively low proportion of fines, whereas class III samples were predominantly clay- and silt-sized particles (65 percent fines, 14 percent sand). Because of the higher fraction of fine particle sizes in class III sediments, this class was considered to be most likely to show stronger relationships with surface area than with mass, if any such relationships were to exist in these data. Analyses of the relationship of metal content to particle mass and surface area were therefore carried out for class III sediments.

Correlations between metal concentrations and sediment grain size fractions in class III sediment did not show a consistent response for all COPCs (Table 8). In particular, metals associated with granulated slag had variable or contradictory associations with either grain size weight fraction or surface area. For example, zinc, copper, and lead did not correlate with the weight-based or area-based sediment grain size fractions. In contrast, antimony had significant positive correlation with the weight of the clay fraction (slope = 0.33, adj. $R^2 = 0.52$; $p < 0.01$; RESET $p = 0.8$; B-P $p = 0.3$), and cadmium had a marginal, yet significant, positive relationship with the estimated surface area associated with the fraction of total fines (slope = 1.2×10^{-4}, adj. $R^2 = 0.44$; $p < 0.01$; RESET $p = 0.08$; B-P $p = 0.82$). Similarly, iron had a slight association with the weight of the clay fraction (adjusted $R^2 = 0.48$), whereas selenium did not display strong correlations with either weight or estimated surface area of sediment grain size fractions.

It should be noted that the above analyses do not preclude the possibility that relationships among weight, surface area, and particle size exist or could be defined using alternative data analysis methods or that other factors (e.g., total organic carbon[TOC]) may contribute to the associations in addition to grain size. Nonetheless, an important facet of this evaluation is the recognition that efforts to determine relationships between particle characteristics and the metal content of sediment are complicated by numerous factors (e.g., separation of the total mass of metal in sediment into exchangeable and residual pools, and/or variations in the sample-specific composition of the particulate and solution phases themselves).

4.3 TEMPORAL TRENDS IN CONCENTRATIONS

To assess whether temporal trends in sediment metal concentrations are apparent, Phase I and older data were compared. It is important to note that because the same locations were generally not sampled by multiple studies, samples from different studies were grouped over some area that may be presumed to represent equivalent conditions. Additionally, the various studies had different collection and analysis methods, and may have varying levels of data quality. For the purposes of this evaluation, data were grouped using a radius of 750 m (i.e., the average half-width of the river) around Phase I sampling locations. Selection of this distance is based on the assumption that different depositional processes may affect opposite banks of the river in different ways (e.g., bank erosion does not occur uniformly in space or time along both banks).

Each group included two, three, or more points that were measured in different years. Within each group, differences between samples collected in different years were assumed to be the result of changes in conditions over time, rather than the result of spatial heterogeneity or analytical variability (i.e., differences in methods used to collect samples and determine concentrations). To evaluate temporal trends Site-wide rather than on a group-by-group basis (which in many cases would be difficult to do quantitatively because of sample size), all of the groups were analyzed together using a mixed-effects linear approach. The following formula represents this approach:

Concentration = Analyte * Year | co-location block / depth

In this formula, “Concentration” is the dependent variable, “Analyte” and “Year” are independent (fixed effects), and “co-location block” and “depth” are nested random effects. “Depth” is a binary variable describing whether the sample was located within the original river channel. Each historical sample was assigned a “co-location block” code corresponding to the closest Phase I sediment sampling location. Specifying these co-location block and depth variables as nested random effects allows for a comparison of temporal trends for co-located sediment samples while accounting for possible differences between channel and bank samples. This statistical approach allows the evaluation of whether there are temporal changes in COPC concentrations throughout the Site, taking sampling location into account.

The above-described statistical approach does not include sediment class as an explanatory variable because the class of sediments may have changed over time within some groups. The approach therefore allows the identification of statistical trends regardless of whether these trends occur within a single class of sediment at a location, or whether they occur as a result of changes in sediment classes. Phase I study locations from throughout the Site were included in this analysis as focal points for the groups; there were 31, 14, 12, 52, 4, and 14 locations in Reaches 1 through 6, respectively. This analysis therefore applies Site-wide, although results were also interpreted with respect to individual reaches, as described below.

Because a parametric linear approach is used, concentrations of metals in sediment were log-transformed to satisfy assumptions of normality. This evaluation produces the estimated probability for a Site-wide temporal trend (increasing or decreasing). Post hoc multiple comparisons were conducted to evaluate whether temporal trends are apparent for each individual metal. The overall level of statistical significance (nominally 0.05) for these comparisons was adjusted using the Bonferroni correction (Fox

1997). For analytes with significant temporal trends, an additional multiple comparisons step was performed to test which stepwise temporal increment resulted in a significant chemistry change within the UCR.

The result of the overall evaluation was statistically significant ($p < 0.0001$, Table 9), indicating that at least some analytes displayed significant changes over time. In the multiple comparison results, 16 of 39 analytes displayed significant temporal variation. With the exception of beryllium, strontium, and uranium, the analyses identified that sediment concentrations of metals had decreased over time (Table 10). The concentrations of slag-associated metals (e.g., zinc, lead, copper, iron) all had significant decreasing trends over time, whereas metals associated with crustal materials (e.g., aluminum, vanadium) did not. Mercury did not have a significant temporal trend ($p = 1$).

Both upward and downward temporal trends (of statistical significance) appeared to be primarily driven by differences between data from 2004 and 2005 (Figures 147 through 185, Table 10). However, it is important to remember these differences (trends) may be attributable to differences in sampling or analysis methods, rather than changes in sediment chemistry within the time interval between the USGS (2004) and Phase I (2005) studies. This factor should also be considered in conjunction with the apparent indication that there is a trend of decreasing concentrations of slag-associated metals.

The pattern of metal concentration changes over time appeared to differ by RM (Table 10, Figures 186 through 420). As discussed for temporal variation over the entire Site, concentration changes by reach were also most notable between 2004 and 2005, having stayed relatively constant (seldom positive) prior to 2004. Metals associated with erosion of crustal material (e.g., aluminum; Figures 186, 223, 260, 297, 327, 360, and 397) follow the same trends, when examined on a reach-by-reach basis, with more pronounced changes between 2004 and 2005 than when examined Site-wide. Other metals did not show significant temporal trends.

Uranium (Figures 182, 219, 256, 293, 318, 356, and 393) was the only metal with overall and 2004 to 2005 upward trend both Site-wide and within all reaches (except Reach 6, Figure 418). Even though it may appear that thallium shares the same pattern, its overall trend is driven by a large drop between 2003 and 2004 (Table 10, Figure 179).

Acknowledging that there may be study-specific differences (e.g., sampling locations, methods, etc.) that complicate the above-described analysis, the inferred temporal trends suggest that decreases in the concentrations of slag-associated metals occur, particularly in Reach 1, whereas concentrations of crustal elements do not show any temporal trends. Trends were generally not consistent in magnitude or direction across all successive time periods for most elements, and study-specific differences in analytical methods may have an influence on the results.

5 SUBSURFACE DISTRIBUTIONS OF SEDIMENT CLASSIFICATIONS

Two recent investigations have collected sediment cores from the Site. They are:

- Cox et al. (2005) study, during which six cores were collected in 2002
- The Phase I study, during which nine cores were collected in 2005.

These cores are located in Reaches 3 through 6, as shown in Map 9. Collection of additional cores upstream of Reach 3 was attempted during the Phase I study, but was not successful because of cobble on the river bottom and the swift current (CH2M Hill 2006). Similarly, Cox et al. (2005) reported that sediment depositional areas could not be identified in the upper reaches of the UCR. Based on previous studies, although the available core data sets do not include Reaches 1 and 2, they represent all of the reaches where sediment accumulation is reasonably expected to occur and coring is feasible.

Phase I cores were collected at nine locations throughout the Site, at RM 605, 622, 637, 644, 661, 676, 692, 704, and 708. The topmost core segment was generally 1 ft in length, and deeper segments were generally 2 ft in length. Three to five segments were collected, depending on total core penetration. Separate surface samples, to a depth of 6 in. (15 cm), were also collected at core locations. The surface samples were included in this analysis of vertical concentration profiles because, in combination with the surface segments of the cores, the additional data provide a more accurate estimate of concentrations at the sediment surface. Phase I core samples were analyzed for all the chemical groups included in the COPC list for sediments: metals and metalloids, polycyclic aromatic hydrocarbons, pesticides, other semivolatile compounds, and dioxins and furans. The spatial and chemical coverage of this data set therefore provides a good basis for the evaluation of vertical gradients of COPC concentrations in each of the reaches.

The vertical distributions of COPCs were examined both graphically and statistically. Figures 421 through 1160 display the vertical profile of each COPC measured at each core location. In these figures, each sample is represented by a line that extends between the upper and lower sample depths. Values below the detection limit are distinguished from detected measurements and are shown at half the detection limit. Visual examination of these plots does not clearly show the presence of consistent and systematic patterns of depth profiles across chemicals or cores.

A nonparametric trend test (a runs test; Zar 1996) was carried out for each analyte in each core to determine whether there are patterns, or any form of nonrandom vertical distribution, for individual analytes and cores. This test evaluates whether or not the pattern of successive increases and decreases in concentration with depth is random—that is, whether there is a systematic increase or decrease in concentrations within the core. A one-sided test was carried out in which the null hypothesis was that increases and decreases were distributed randomly, and the alternate hypothesis was that increases and decreases were clustered. The value of the runs test in comparison to other techniques such as a linear regression of concentrations on depth are that a) it is nonparametric, so data need not be either assumed or transformed to fit a normal distribution; and b) it can identify the presence of trends even when there are several opposing trends within a core, such as an increase followed by a decrease. This test was carried out for the Phase I cores using only detected data for all cases where there were at least four detected measurements of an analyte in a core.

The trend tests could be carried out only for the metals and metalloids, and for the dioxins and furans, because of the high frequency of nondetect values for other COPCs. A total of 186 tests were carried out, and the results are shown in Table 11. The *p*-value in this table represents the probability that the observed pattern of increasing and decreasing concentrations with depth would be observed if there is actually no trend. There are 10 cases in which the *p*-value is less than 0.05 (5 percent). These are aluminum, arsenic, beryllium, calcium, copper, lead, magnesium, manganese, and zinc at RM 704, and cadmium at RM 708 (Figures 428, 443, 461, 479, 506, 524, 533, 542, 630, and 471, respectively). With a critical *p*-value of 0.05, 5 percent of the 186 samples, or between 9 and 10 samples, would be expected to be found statistically significant even when there is actually no trend. The number of samples found to have significant trends is therefore consistent with the number to be expected by chance alone if there is actually no trend. However, 9 of the 10 cases are from the same core (RM 704C1), and examination of the profiles for this core shows that all of the 9 chemicals show the same pattern of a decrease from the surface concentration followed by an increase at greater depths. Other chemicals measured in the same core do not show this pattern (Figures 421 through 1160). These results provide an indication of systematic variation in concentrations of slag-associated metals (and others) with depth within the Marcus Flats area (i.e., at RM 704), but provide no evidence of systematic vertical profiles of concentrations at other locations. As noted previously, slag-influenced sediment (class I) is primarily found at and upstream of Marcus Flats. Vertical variation of slag-associated metals is therefore observed only in the one core collected in a depositional area containing granulated slag-influenced sediment.

The reason for the absence of systematic statistically significant vertical trends in COPC concentrations throughout the other sediment profiles measured in Phase I may be the result of any one or more of the following factors:

- Absence of systematic historical loading of COPCs to the sediment
- Relatively constant loading of COPCs to the sediment
- Relatively large sampling depth intervals (e.g., 2 ft)
- Low number of depth intervals analyzed for each core
- A nonmonotonic variation with depth that is not adequately captured by the small number of relatively wide sediment segments collected in 2005—as might result, for example, from episodic inputs of sediments of various types in the past.

Cores collected by Cox et al. (2005) in 2002 were sectioned more finely than the Phase I cores and therefore provide greater vertical resolution for the evaluation of concentration trends. Cores collected by Cox et al. (2005) were generally 40 to 50 cm in length, although some were as long as 150 cm. Cores were sectioned at 2- to 5-cm intervals. Vertical profiles of all COPCs measured in these cores are shown in Figures 1161 through 1400. Tests (a runs test: Zar 1996) were carried out for each analyte in each core, just as for the Phase I data. Of the total of 237 tests, 125 statistically significant ($p < 0.05$) results were found. With a critical *p*-value of 0.05, between 11 and 12 samples would be expected to be found statistically significant even when there is actually no trend. Because a much larger number of statistically significant trends were identified, these trends are not all attributable to chance. These results are shown in Table 12. The profile of each of these significant results was visually examined and characterized as having concentrations that increased with depth, decreased with depth, showed some other clear pattern of successive increases and decreases, or showed no distinct pattern. The pattern of concentration changes with depth is not consistent for all metal/metalloid COPCs within any core. For example, in the core taken at RM 705, close to the Phase I core RM 704C1, 21 metals showed nonrandom variation with depth. Among these, six different trend patterns are represented (Table 13).

The greater vertical resolution of the Cox et al. (2005) core data, and the observation of significant (though varying) trends in many of the cores, suggest that vertical trends cannot be observed in the Phase I cores because the sample segments are too few in number and too wide. Further evaluations of vertical variations in COPC concentrations were carried out using only the data from Cox et al. (2005).

Cox et al. (2005) attributed some of the variation in the vertical concentration profiles to the effect of landslides, by which bank materials were deposited to the core location and thereby caused the concentration decreases observed at intermediate depths in many cores. An alternative explanation for the vertical distribution of COPCs in the Cox et al. (2005) cores is that different core segments contain different classes of sediment with inherently different sediment characteristics. That is, the sediment deposited at each core location was not a consistent mixture of smelter (and other) sources, periodically interrupted by landslides. To evaluate this hypothesis, each Cox et al. (2005) core sample was categorized with respect to the three sediment classes described previously. Vertical profiles for all cores and COPCs with significant vertical trends, including the sediment class of each segment, are shown in Figures 1401 through 1525. Only sediment classes II and III are found in these cores; sediment class I is not found at any location. The vertical distributions of sediment classes in these cores can be described as follows:

- **Core CCR-624.** Both classes II and III are present in this core, with three depth ranges corresponding to class II and two depth ranges corresponding to class III. In general, neither class represents primarily low or high concentrations of any metal, except that zinc concentrations are highest in class III samples—but it is the Zn/V ratio that is used to distinguish classes II and III, so this is to be expected. Concentrations in the two depth ranges for class III samples are different from one another for many metals.
- **Core CCR-643.** All but two segments in this core are categorized as class II. The other two are categorized as class III. The two class III segments are not adjacent; they have the highest concentrations of arsenic, cadmium, lead, molybdenum, and zinc, but are not consistently high or low for any of the other 14 metals with significant vertical trends in this core.
- **Core CCR-668.** The uppermost and deepest segments in this core are categorized as class II, with a band of class III segments in the middle. A little overlap of the bottom two classes is apparent. The two different classes are generally reflected in two different concentration ranges in this core for aluminum, barium, beryllium, calcium, cobalt, gallium, lead, magnesium, molybdenum, potassium, rubidium, scandium, vanadium, and zinc. This core therefore exhibits a clear vertical variation in sediment classes, and this variation is often associated with differences in concentrations.

- **Core CCR-692.** The surface segments in this core are categorized as class II, and the deeper segments as class III. A little overlap of the two classes is apparent. Concentration ranges in these two classes overlap for most chemicals, although class III segments (which are greater in number) generally have a broader range than class II segments. The strongest vertical concentration trends are generally found within the class III segments, rather than as a result of differences between the class II and class III segments. Some separation of the concentration ranges by class is apparent for antimony, cadmium, copper, lanthanum, lead, mercury, selenium, yttrium, and zinc (out of a total of 25 metals with significant trends). This core therefore exhibits a clear vertical variation in sediment classes, and this variation is associated with differences in concentration ranges for a number of metals.
- **Core CCR-705.** Most of the segments in this core are categorized as class II, but there are two bands within the core that appear to be class III sediment, each consisting of two segments. Concentrations for the class III sediments are most often within the range of the class II sediments. Concentrations in the upper band of class III sediments are sometimes outside the range of class II sediments when concentrations in the lower band of class III sediments are within the range of class II sediments. Only for arsenic, cadmium, and lead there appears to be a clear distinction between concentrations in the two different sediment classes (out of a total of 21 metals with significant trends). Thus, although this core appears to exhibit vertical variation in sediment classes, this variation is not clearly associated with different concentration ranges.
- **Core CSA-8.** This core is in the Spokane Arm of Lake Roosevelt. All of the segments in this core are categorized as class III, except for the second segment from the surface, which appears to be class II. No clear distinctions can be made between the concentration ranges associated with the two sediment classes in this core.

Two of the six cores (CCR-668 and CCR-692) have variations in sediment classes within the cores that are fairly consistently associated with variations in COPC concentrations. Three of the cores (CCR-643, CCR-705, and CSA-8) appear to be predominantly a single class and therefore provide little ability to evaluate co-variation between sediment classes and concentrations within the cores. The remaining core (CCR-624) seems to show variations in sediment classes within the core, but these are not associated with consistent variations in concentrations. These data therefore provide limited evidence suggesting that changes in COPC concentrations throughout the vertical profiles of cores are the consequence of changes in the classes of sediment that have been deposited over time. The surface segments of all the cores in the main stem of the UCR are of class II, and only core CSA-8 (in the Spokane Arm) has class III sediment at the surface.

Subsurface concentrations of COPCs in the Phase I and Cox et al. (2005) cores can be either higher or lower than surface concentrations, varying by core and chemical. To allow an overall comparison of surface sediment concentrations to concentration in the entire sediment column, as represented by the cores, chemical concentrations in all core samples were summarized by reach. Table 14 presents this summary, showing the detection frequency and the minimum, maximum, and mean value for each COPC in each reach. A similar summary for surface sediment was previously presented in Table 7, and data from both of these tables are integrated in Table 15. Only data for metals and metalloids are shown in Table 15. If organic COPCs were included, their low detection frequencies would result in a comparison largely between detection limits. The last column in Table 15 shows the ratio of COPC concentrations throughout the sediment column to COPC concentrations in surface sediment. This value is generally in the range of 1 to 3. The ratios in upstream reaches are generally a little higher than ratios in downstream reaches.

6 SUMMARY

Analysis of the existing database of sediment data resulted in many observations that are expected to help guide development of the ecological risk assessment approach and future sampling plans. The most important of these are:

- Surface sediment data sets characterize sediment chemistry in all reaches of the river.
- Sediments in the Site can be categorized into three classes based on the zinc/vanadium ratio. One of these classes (class I) appears to potentially reflect the influence of smelter slag, another class (class II) appears to reflect the absence of a slag influence, and the third class (class III) is unlike either of the other two.
- The distinction between the three sediment classes can also effectively be a distinction between sediment grain sizes—class III is predominantly fine (clay- and silt-sized) sediment, and class I is predominantly coarse (sand-sized) sediment.
- COPC concentration ranges are similar within all samples of a given sediment class, wherever that class appears in the river. Apparent longitudinal trends in chemical concentrations may be represented as the product of differences in chemical concentrations between classes and different frequencies of occurrence of different classes in different reaches. Only class III shows longitudinal trends for a number of metals and organic compounds, with higher concentrations appearing in downstream reaches. The overall longitudinal spatial gradient in concentrations of many metals is primarily the result of higher concentrations in class I sediment, and the predominance of class I sediment in upper reaches of the river.

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FIGURES

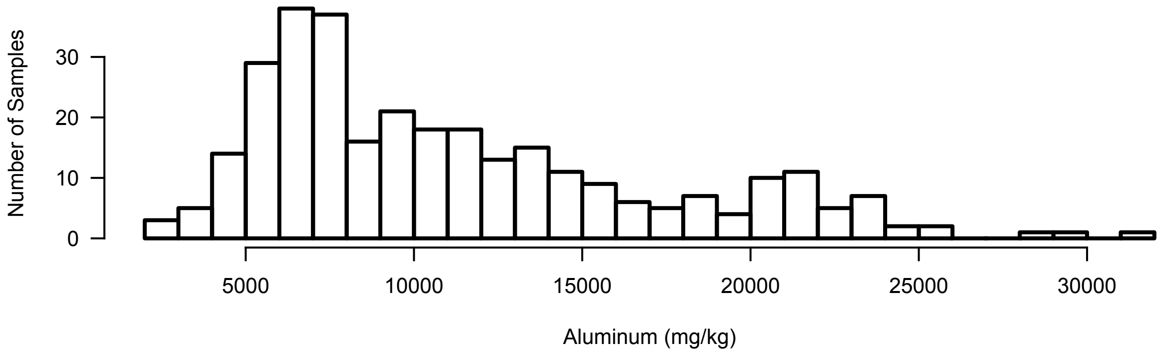


Figure 1. Aluminum Distribution in Phase 1 Surface Sediment

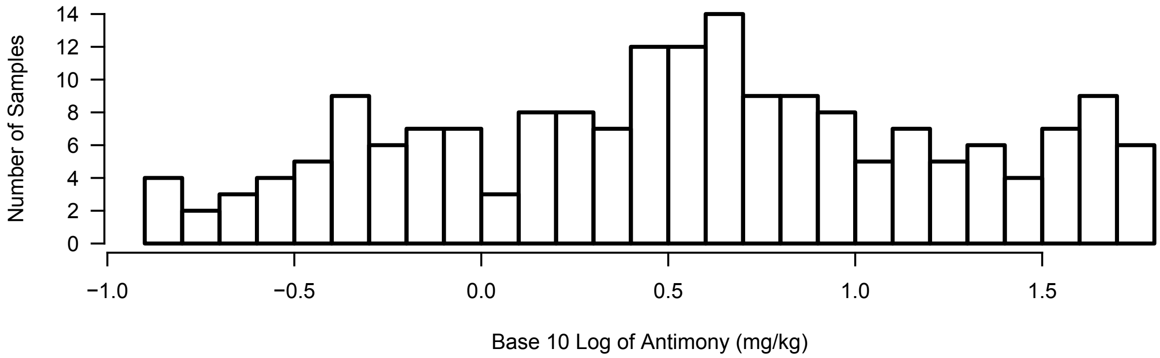


Figure 2. Antimony Distribution in Phase 1 Surface Sediment

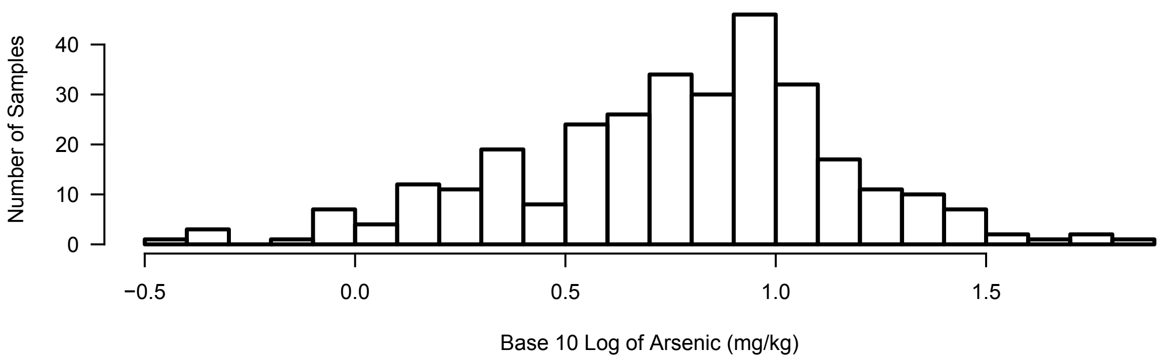


Figure 3. Arsenic Distribution in Phase 1 Surface Sediment

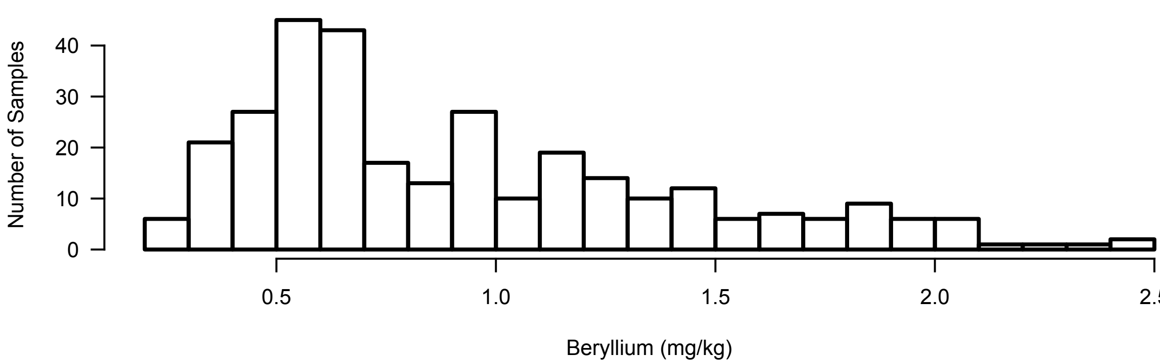


Figure 4. Beryllium Distribution in Phase 1 Surface Sediment

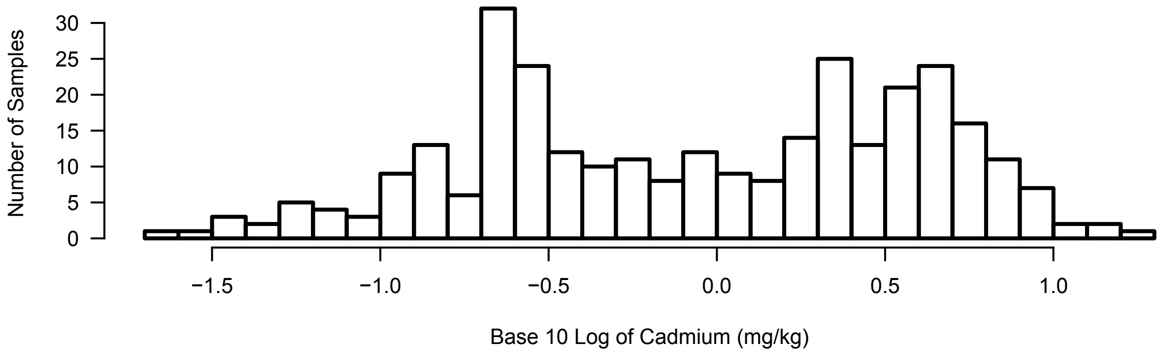


Figure 5. Cadmium Distribution in Phase 1
Surface Sediment

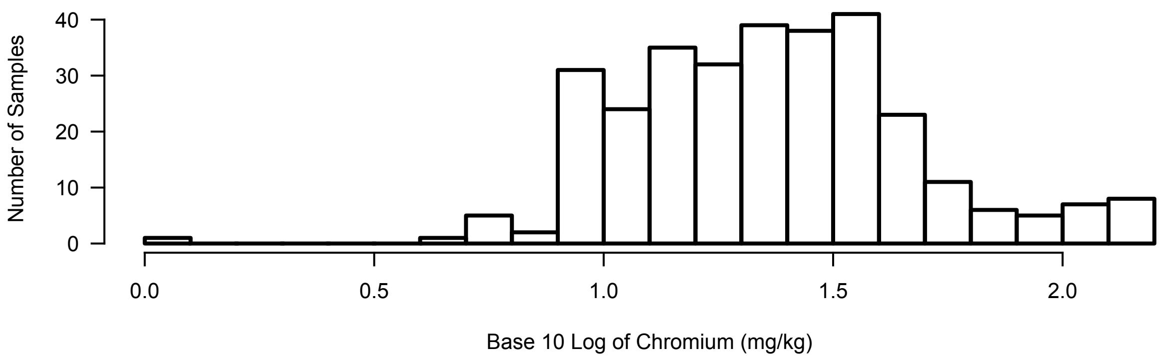


Figure 6. Chromium Distribution in Phase 1
Surface Sediment

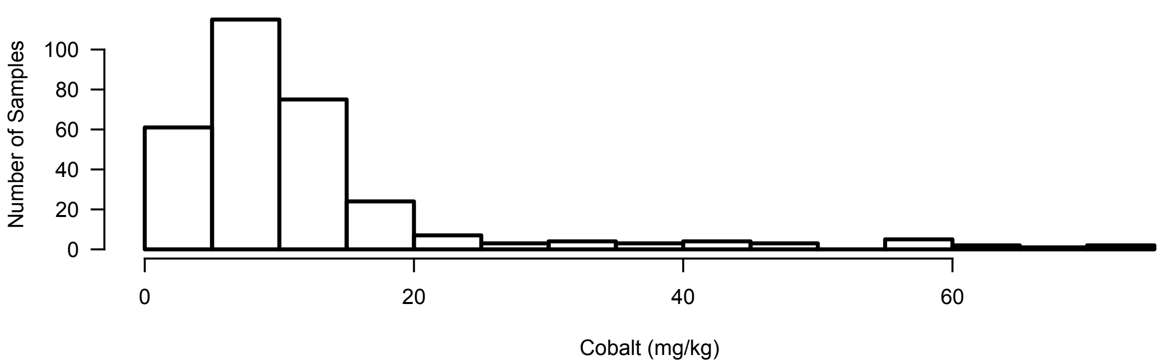


Figure 7. Cobalt Distribution in Phase 1
Surface Sediment

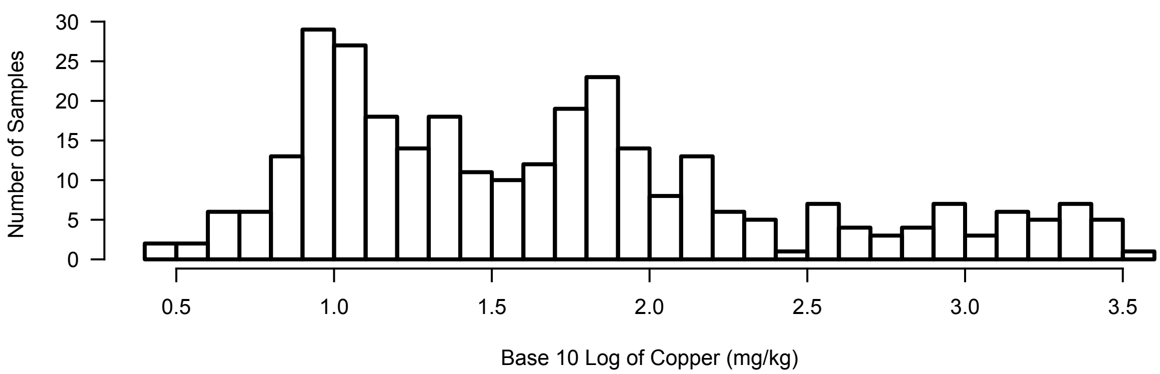


Figure 8. Copper Distribution in Phase 1
Surface Sediment

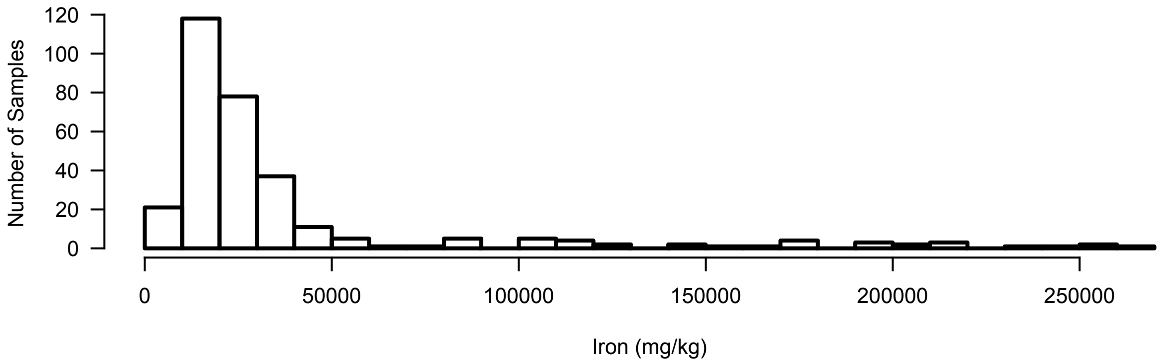


Figure 9. Iron Distribution in Phase 1 Surface Sediment

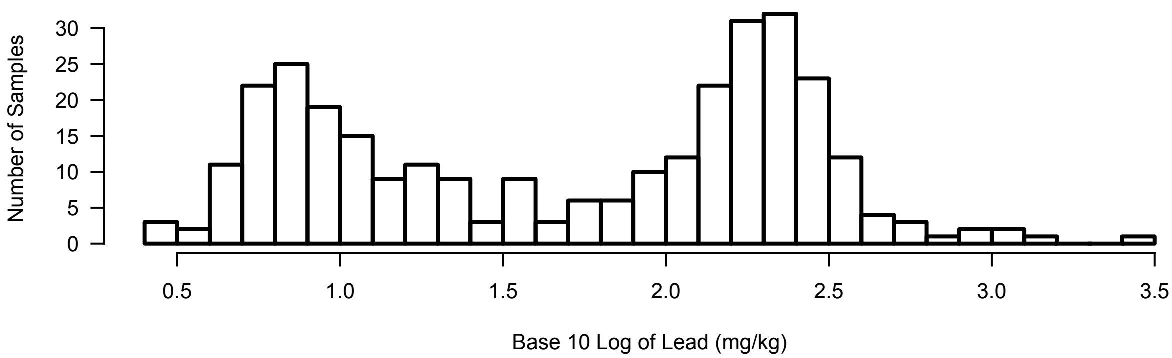


Figure 10. Lead Distribution in Phase 1 Surface Sediment

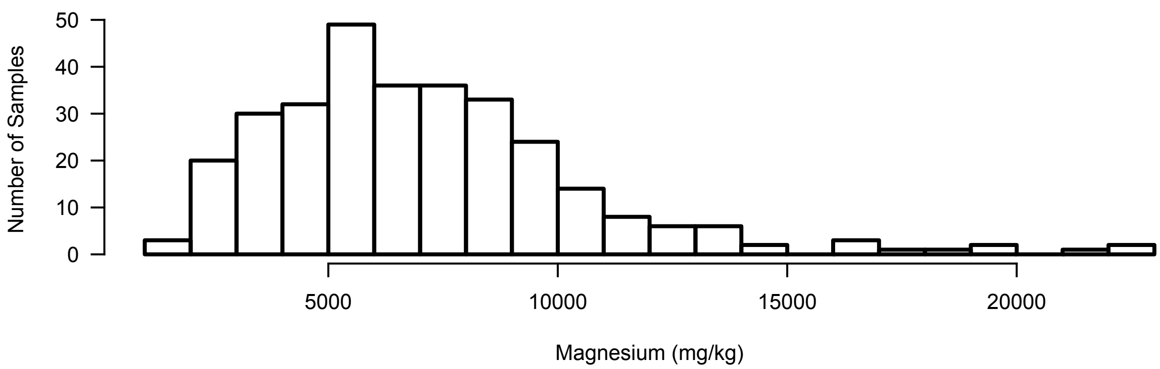


Figure 11. Magnesium Distribution in Phase 1 Surface Sediment

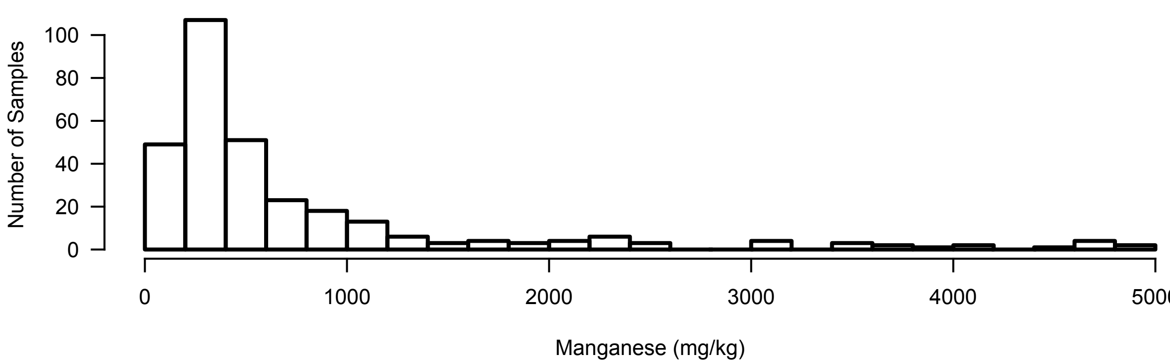


Figure 12. Manganese Distribution in Phase 1 Surface Sediment

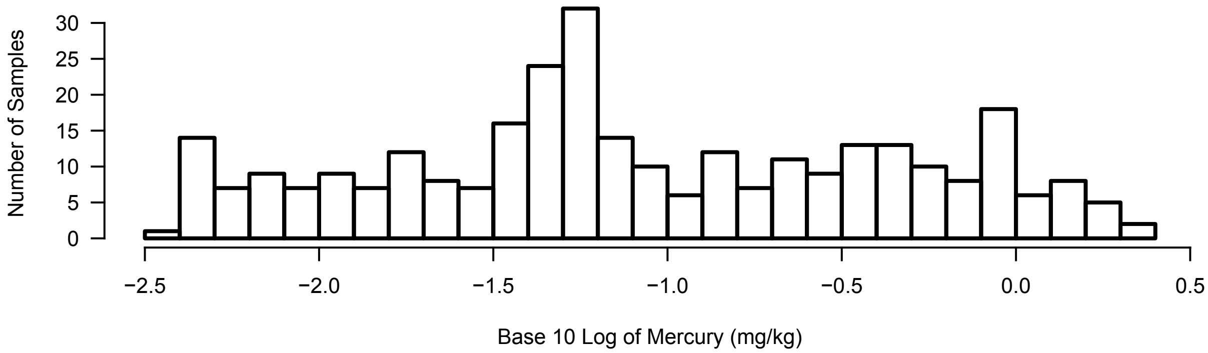


Figure 13. Mercury Distribution in Phase 1 Surface Sediment

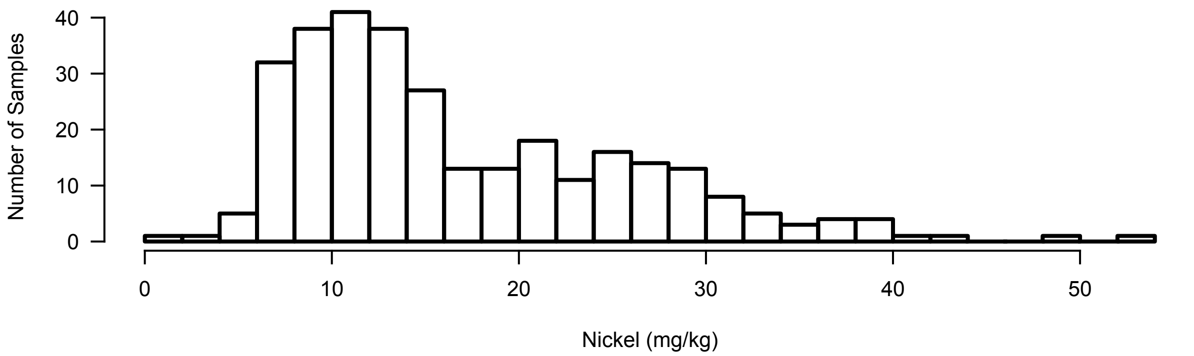


Figure 14. Nickel Distribution in Phase 1 Surface Sediment

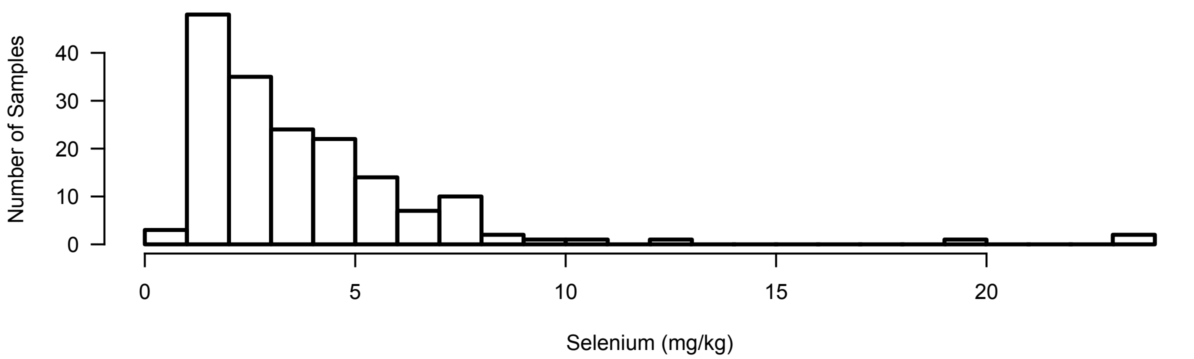


Figure 15. Selenium Distribution in Phase 1 Surface Sediment

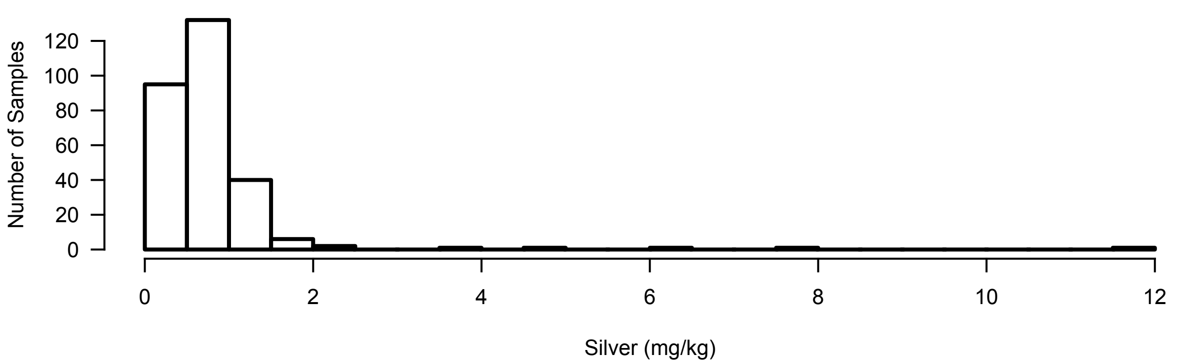


Figure 16. Silver Distribution in Phase 1 Surface Sediment

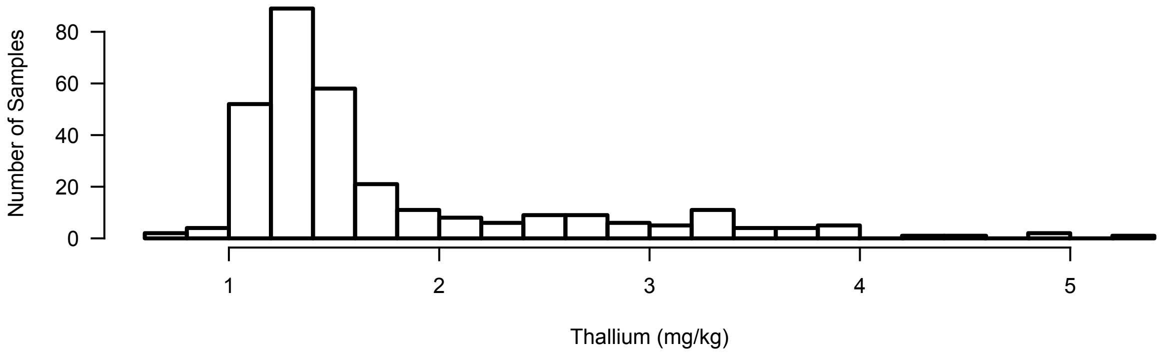


Figure 17. Thallium Distribution in Phase 1 Surface Sediment

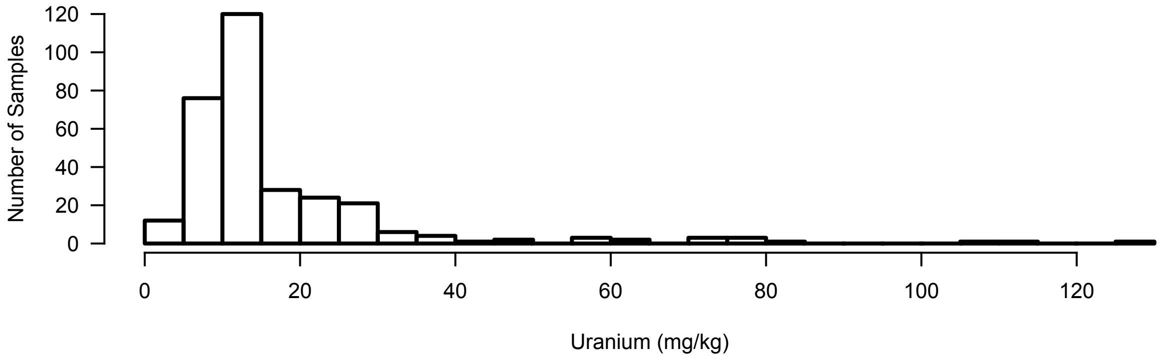


Figure 18. Uranium Distribution in Phase 1 Surface Sediment

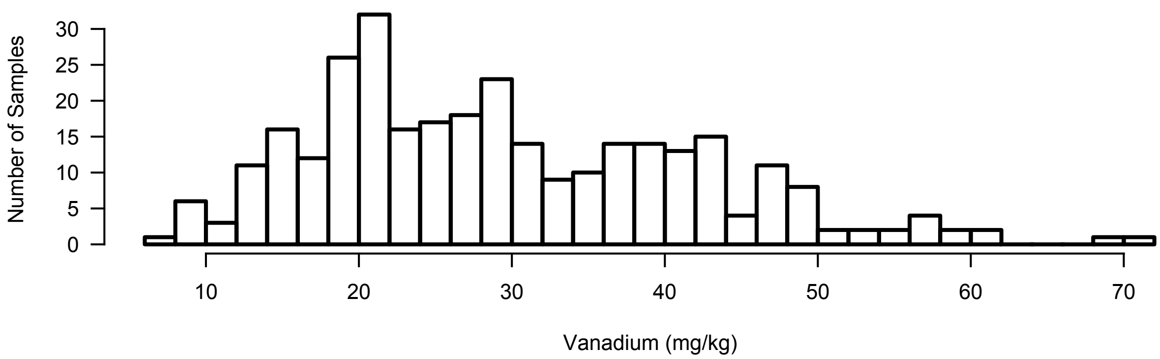


Figure 19. Vanadium Distribution in Phase 1 Surface Sediment

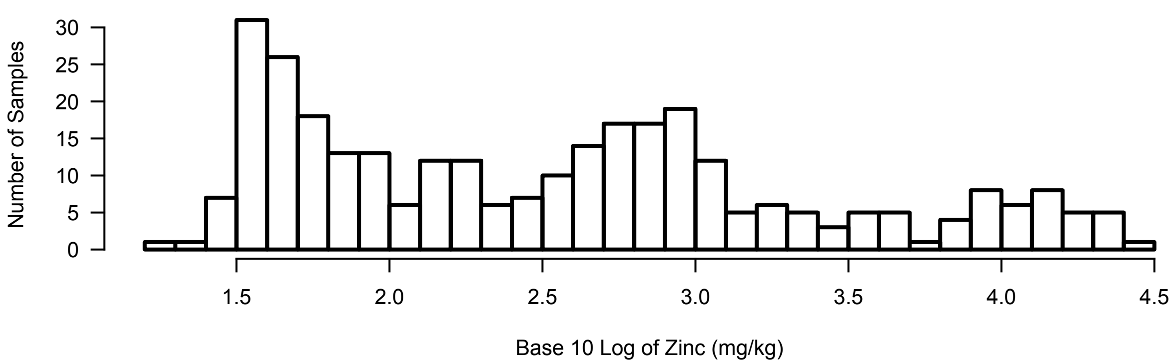


Figure 20. Zinc Distribution in Phase 1 Surface Sediment

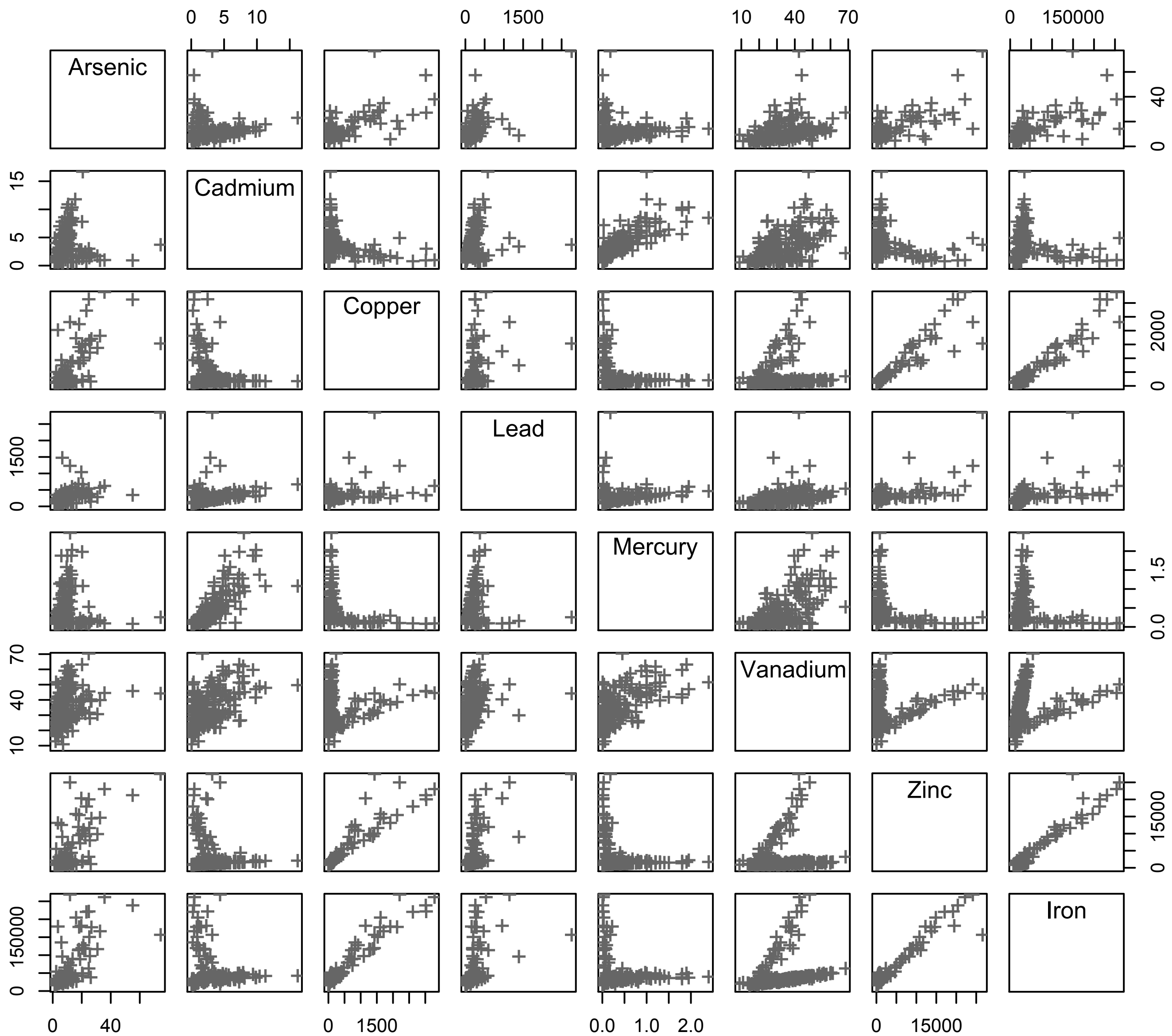


Figure 21. Scatterplot Matrix for Concentrations of Phase 1 Sediment Metals
All concentrations in mg/kg.

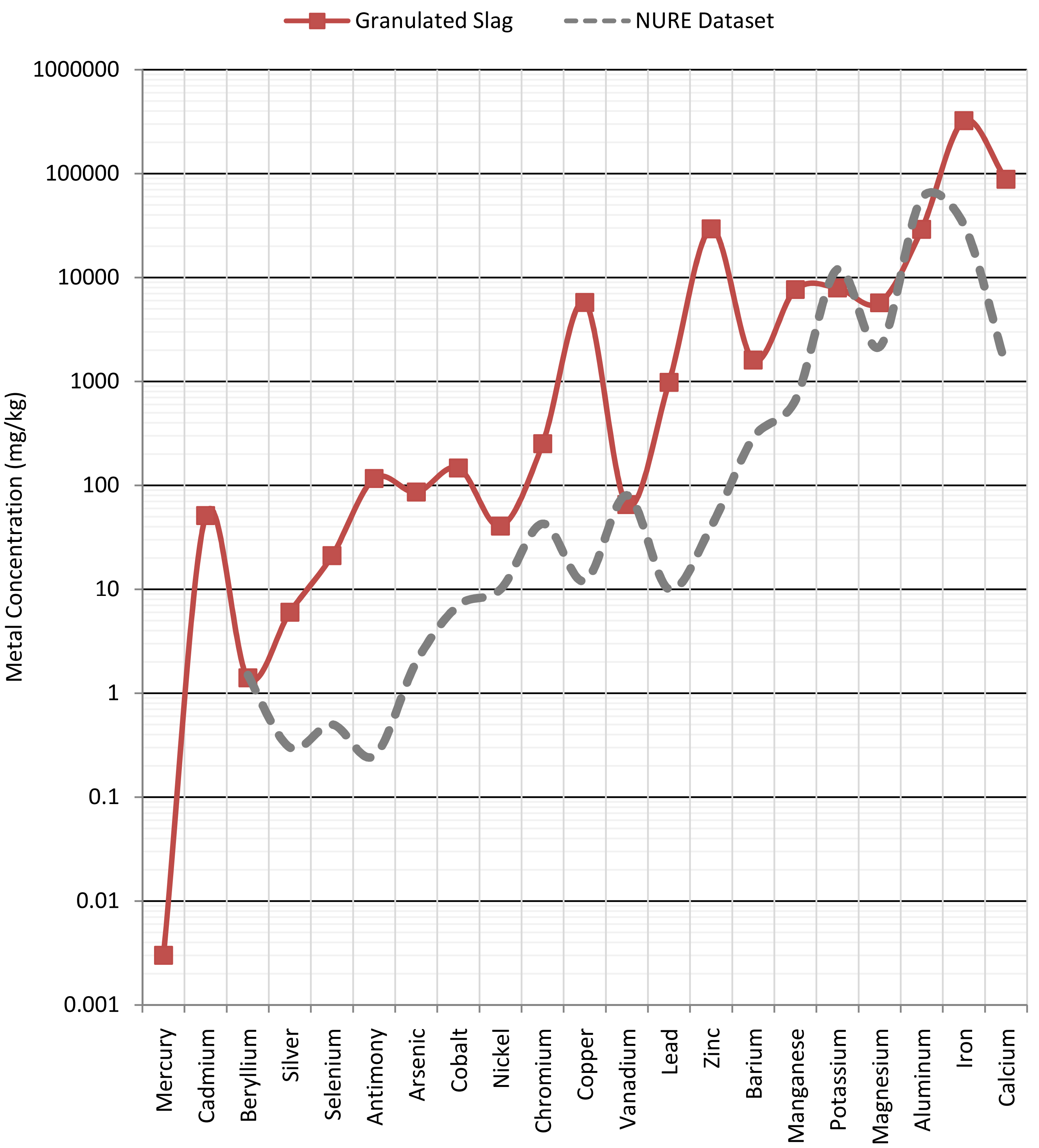


Figure 22. Relationship Between the Metal Concentration Signal of Granulated Slag and the NURE Background Sediment Dataset

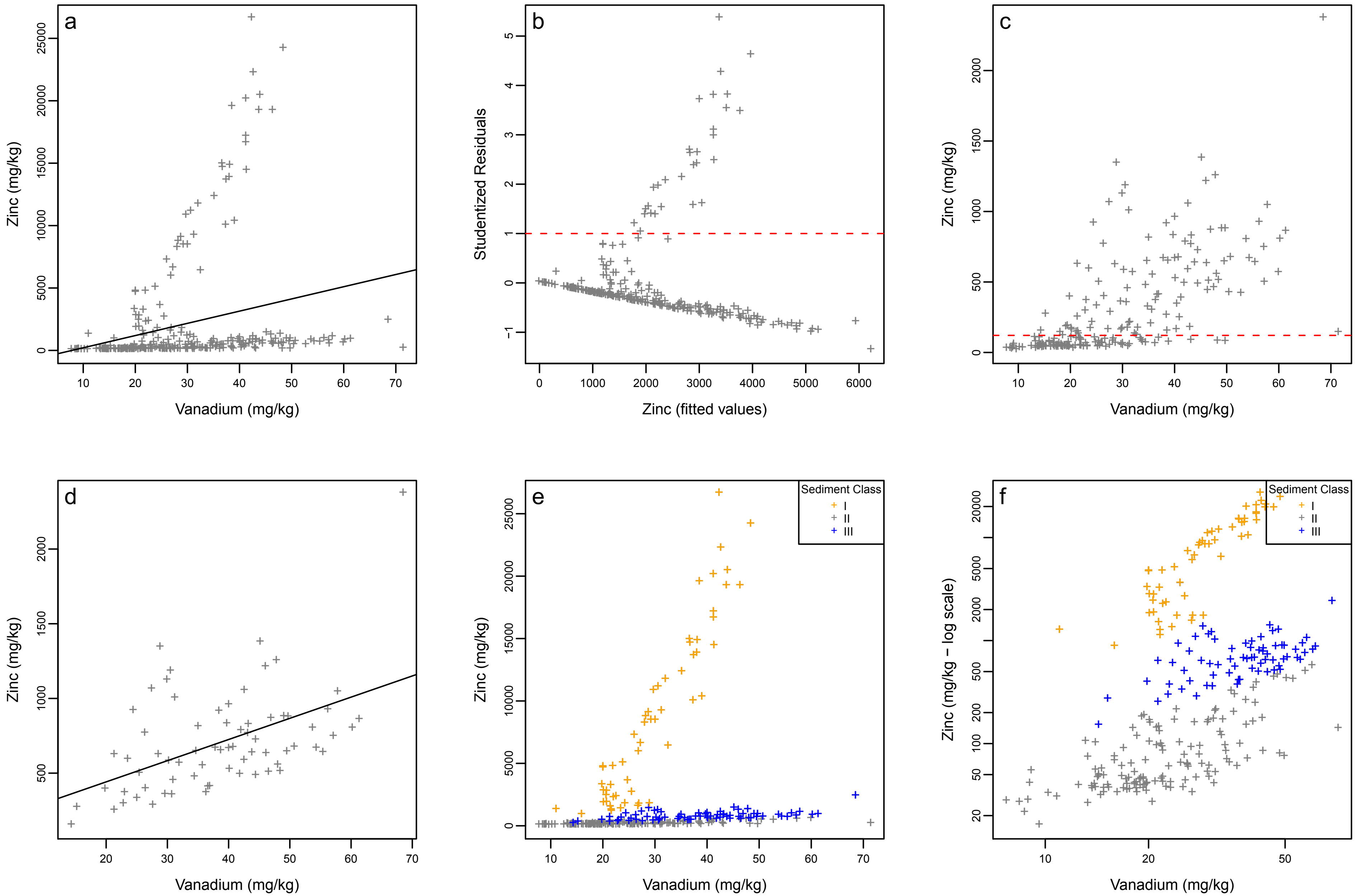


Figure 23. Defining Sediment Classes Based on the Bimodal Zinc−Vanadium Relationship, using Iterative Regression
a) First iteration (with regression line); b) High residual cut−off for Class I (dashed line); c) Low−end cut−off for Class II (dashed line);
d) Remaining points after previous two steps (Class III; with regression line); e) All data after classification; f) Same as previous panel with [Zn] on a log−scale.

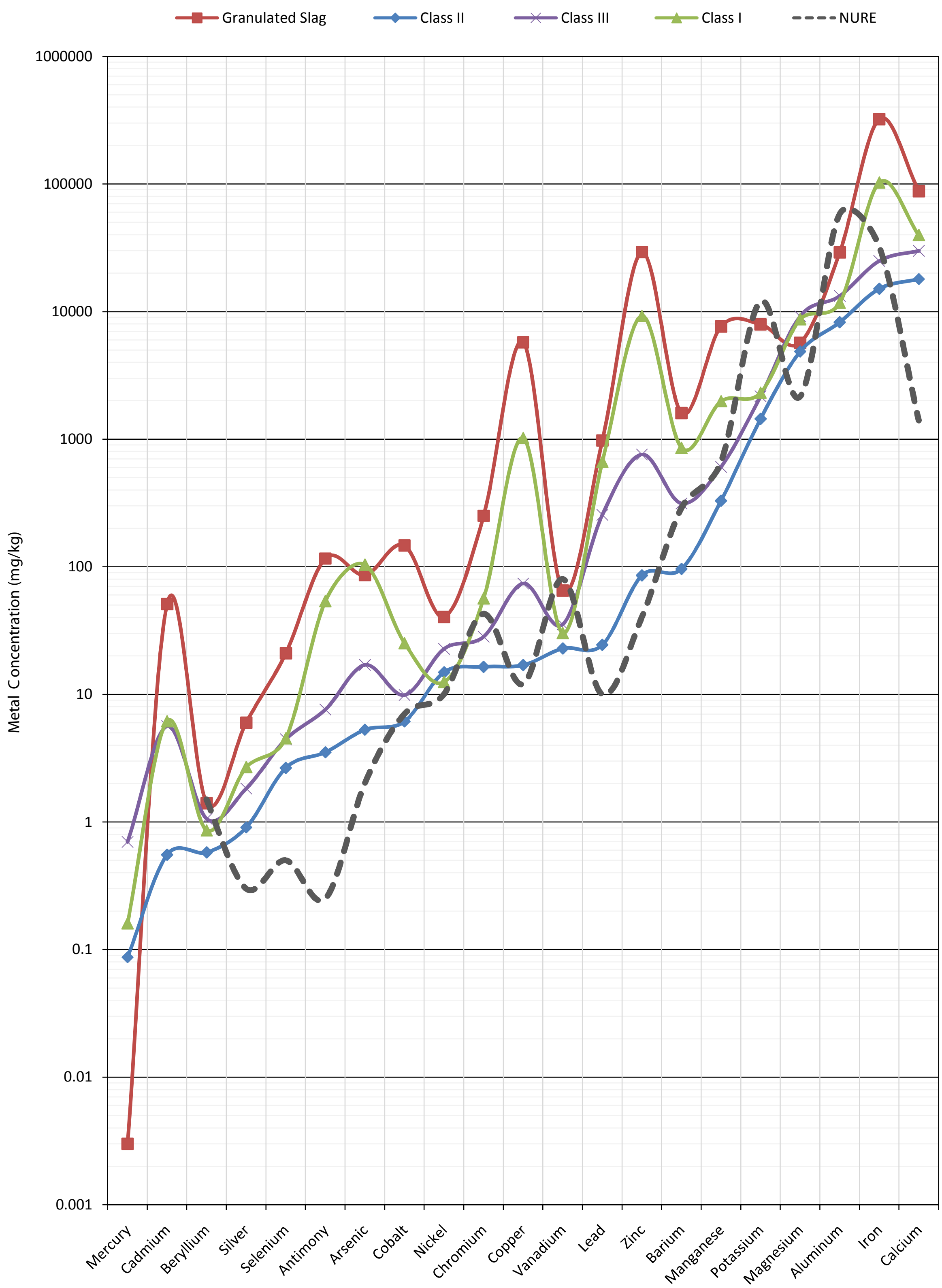


Figure 24. Relationship Among the Metal Concentration Signal of Granulated Slag and the Three EPA Phase 1 Sediment Classes

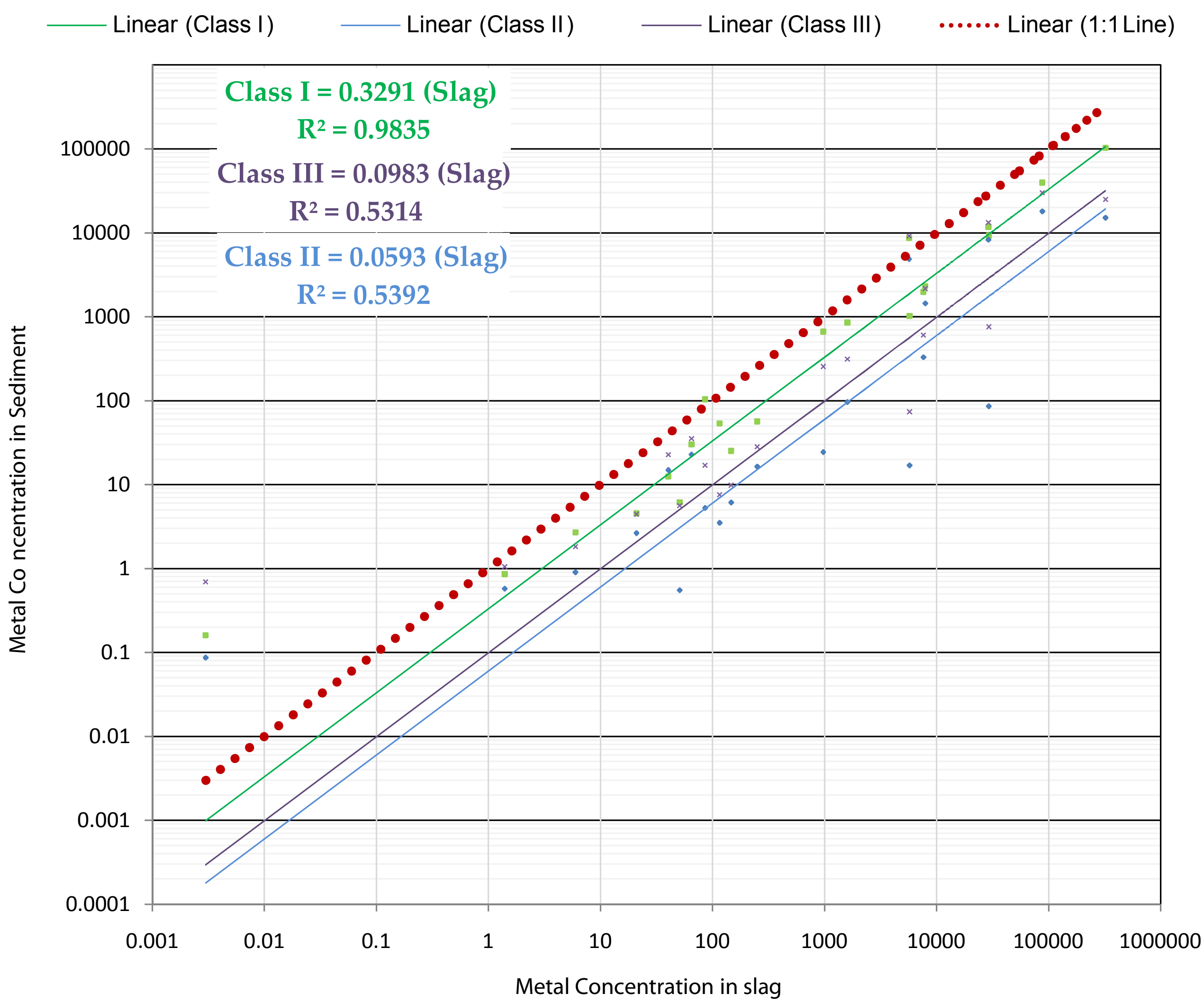


Figure 25. Regression of the Metal Concentration Signal of the Three EPA Phase 1 Sediment Classes Against the Metal Concentration Signal of Granulated Slag.

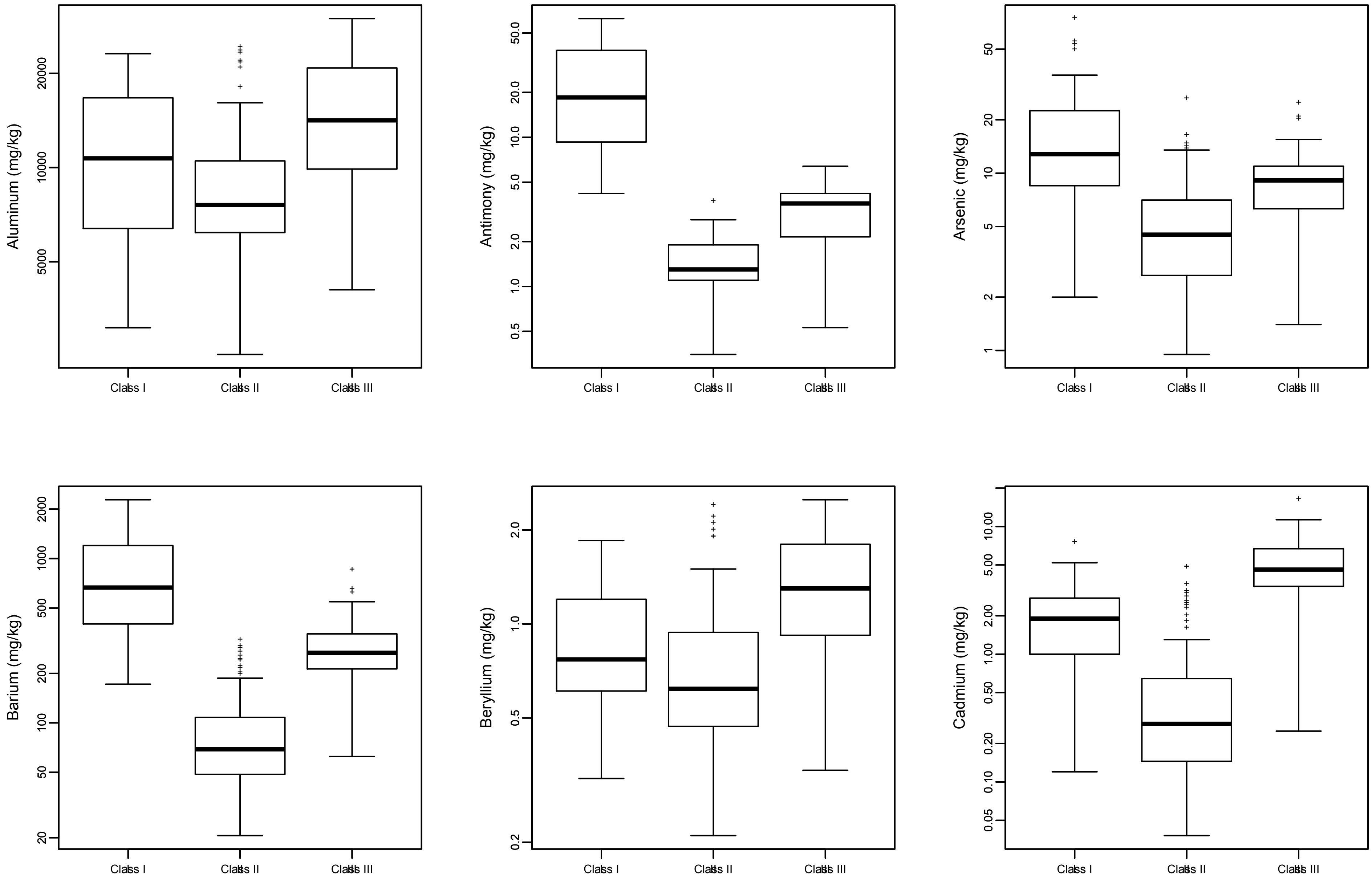


Figure 26a. Distribution of Concentrations of Phase I Sediment Analytes by Sediment Class

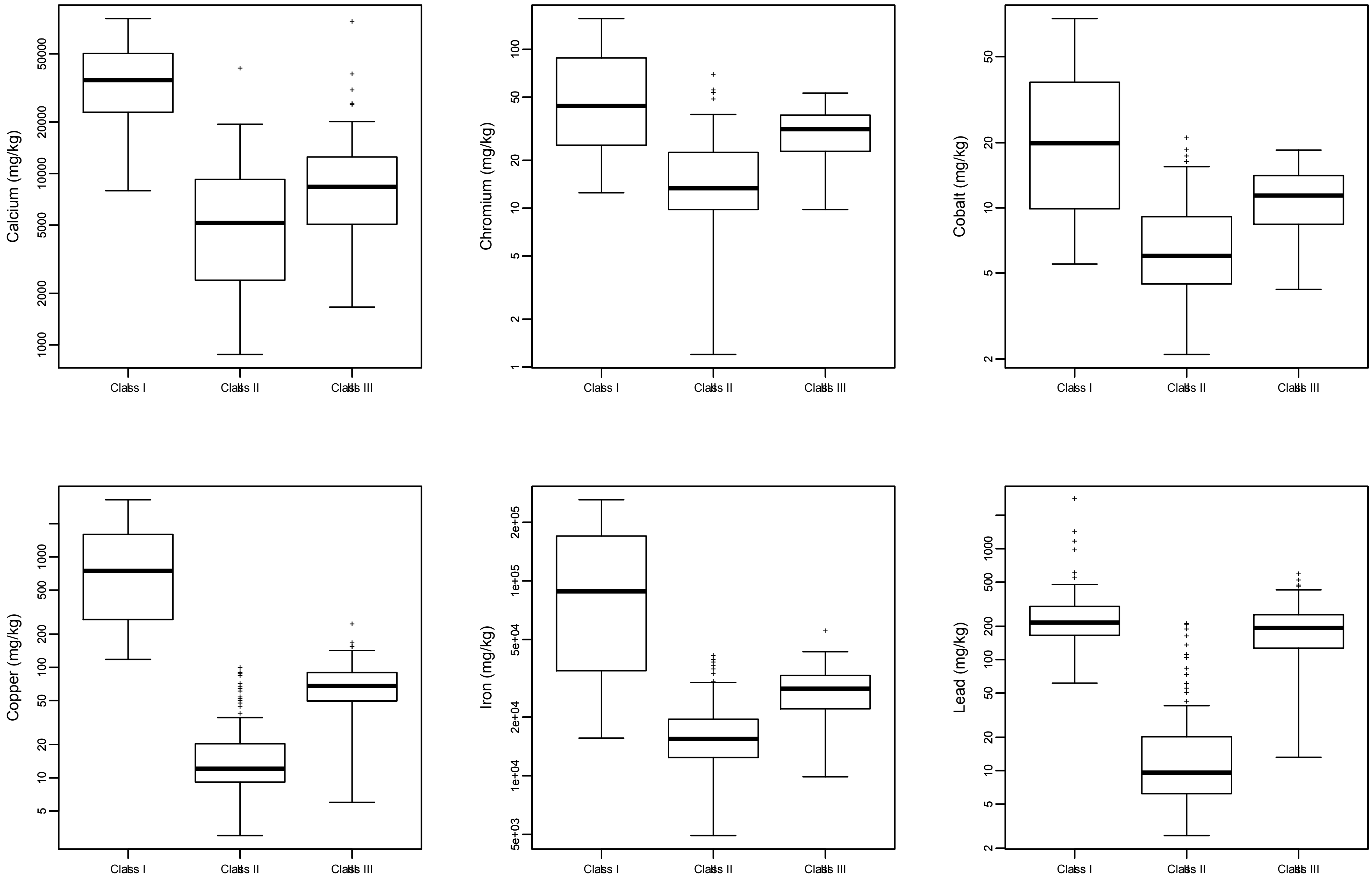


Figure 26b. Distribution of Concentrations of Phase I Sediment Analytes by Sediment Class

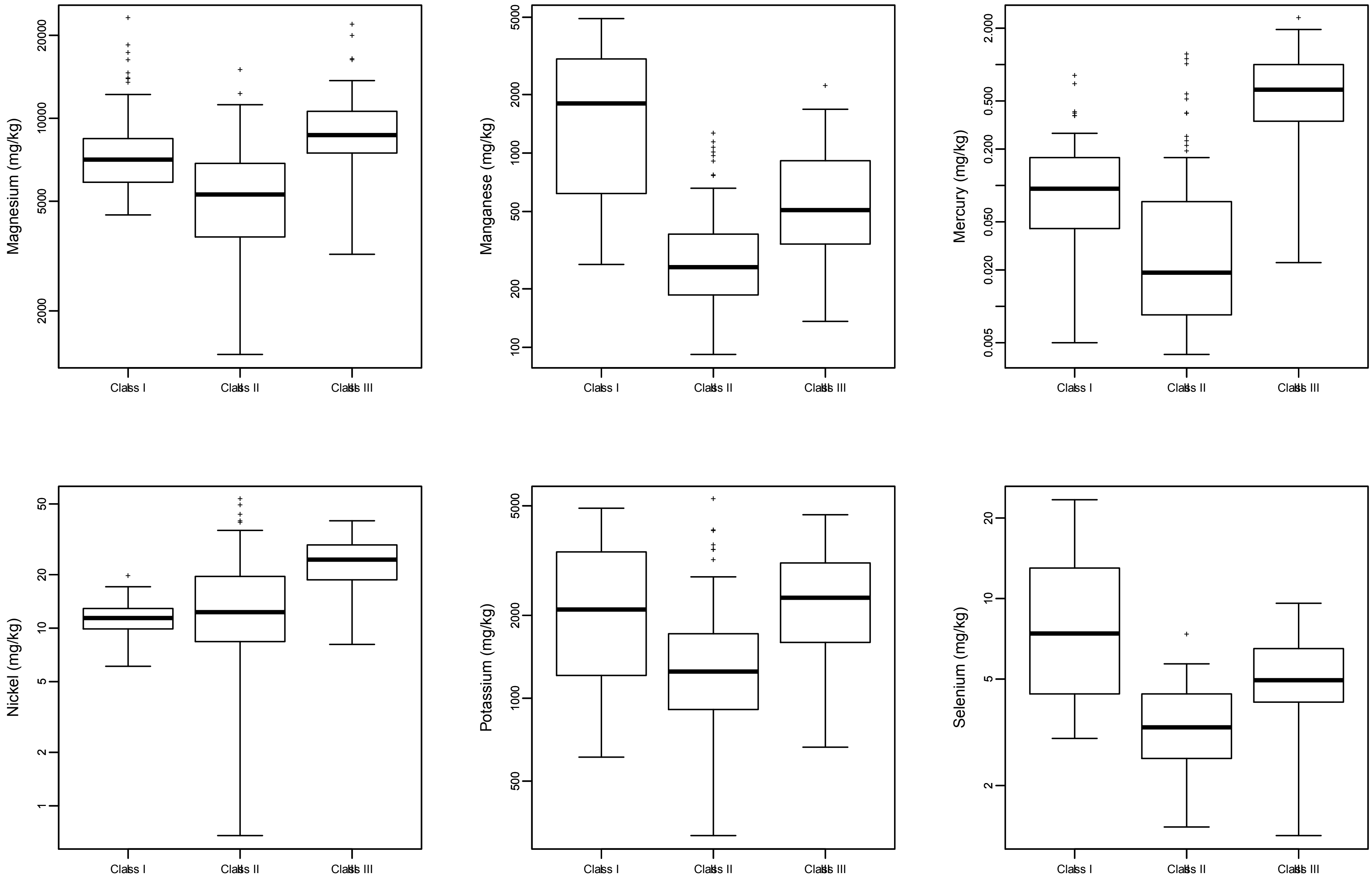


Figure 26c. Distribution of Concentrations of Phase I Sediment Analytes by Sediment Class

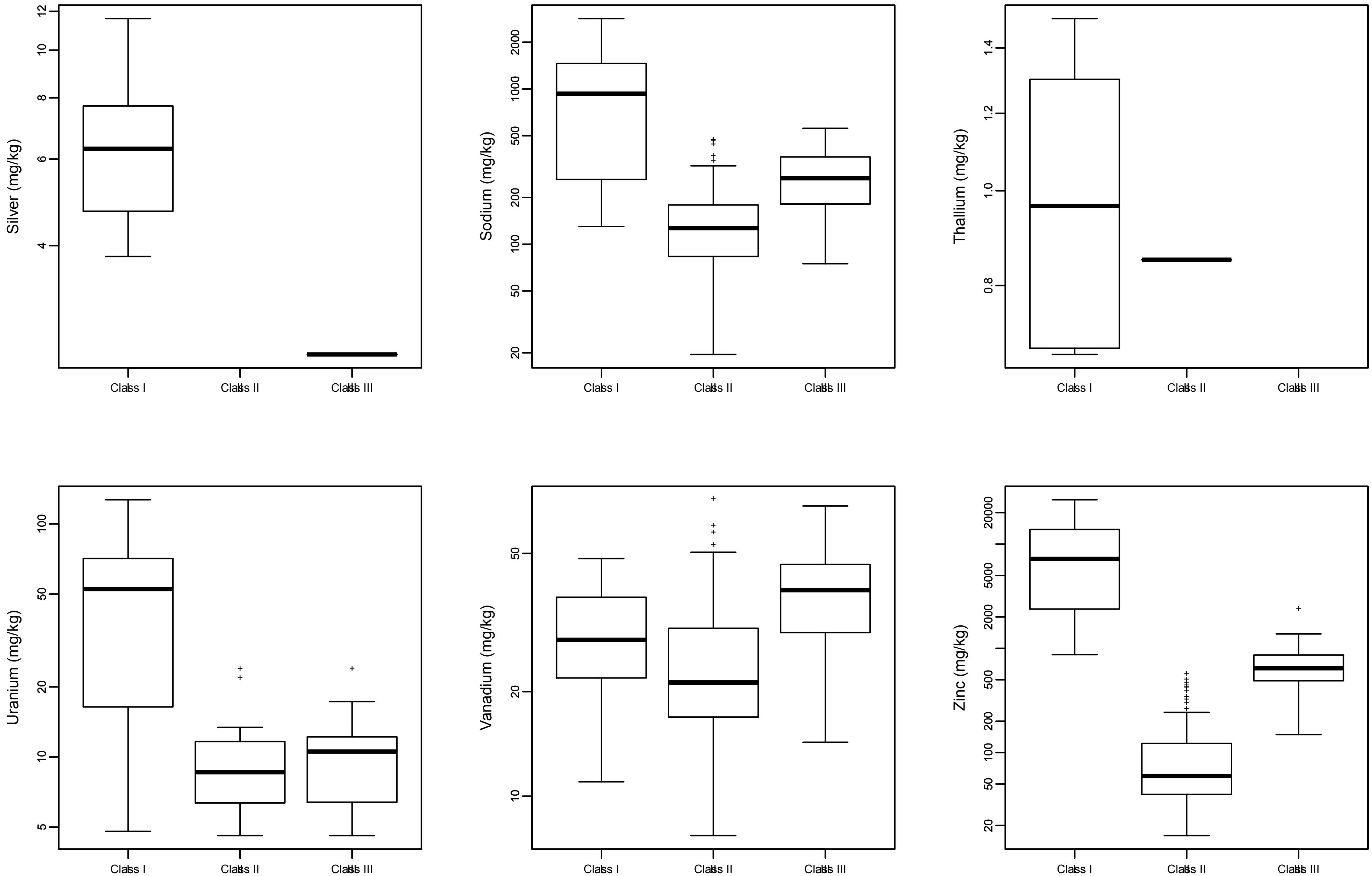


Figure 26d. Distribution of Concentrations of Phase I Sediment Analytes by Sediment Class

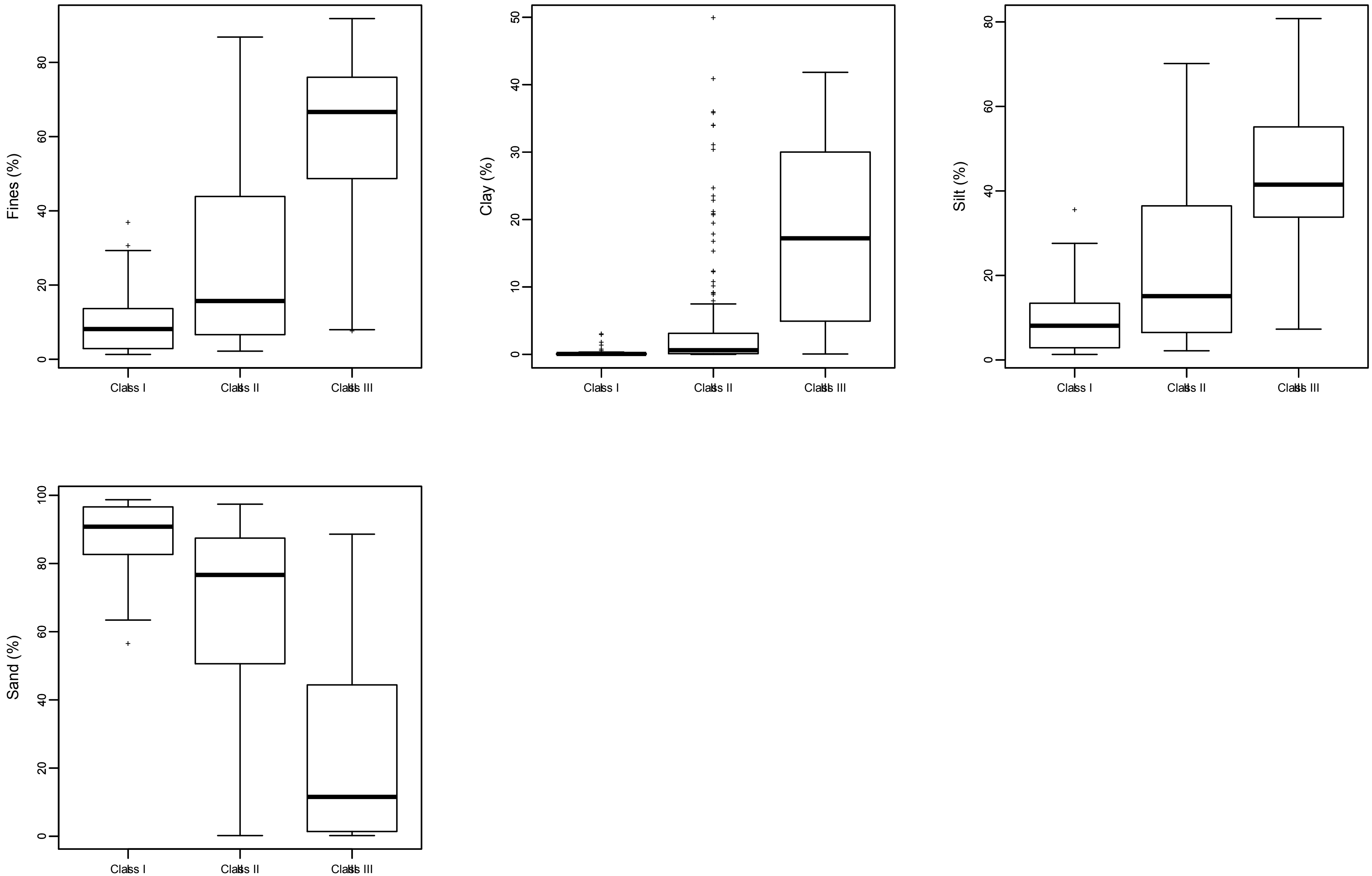


Figure 27. Distribution of Concentrations of Phase I Sediment Grain Size by Sediment Class

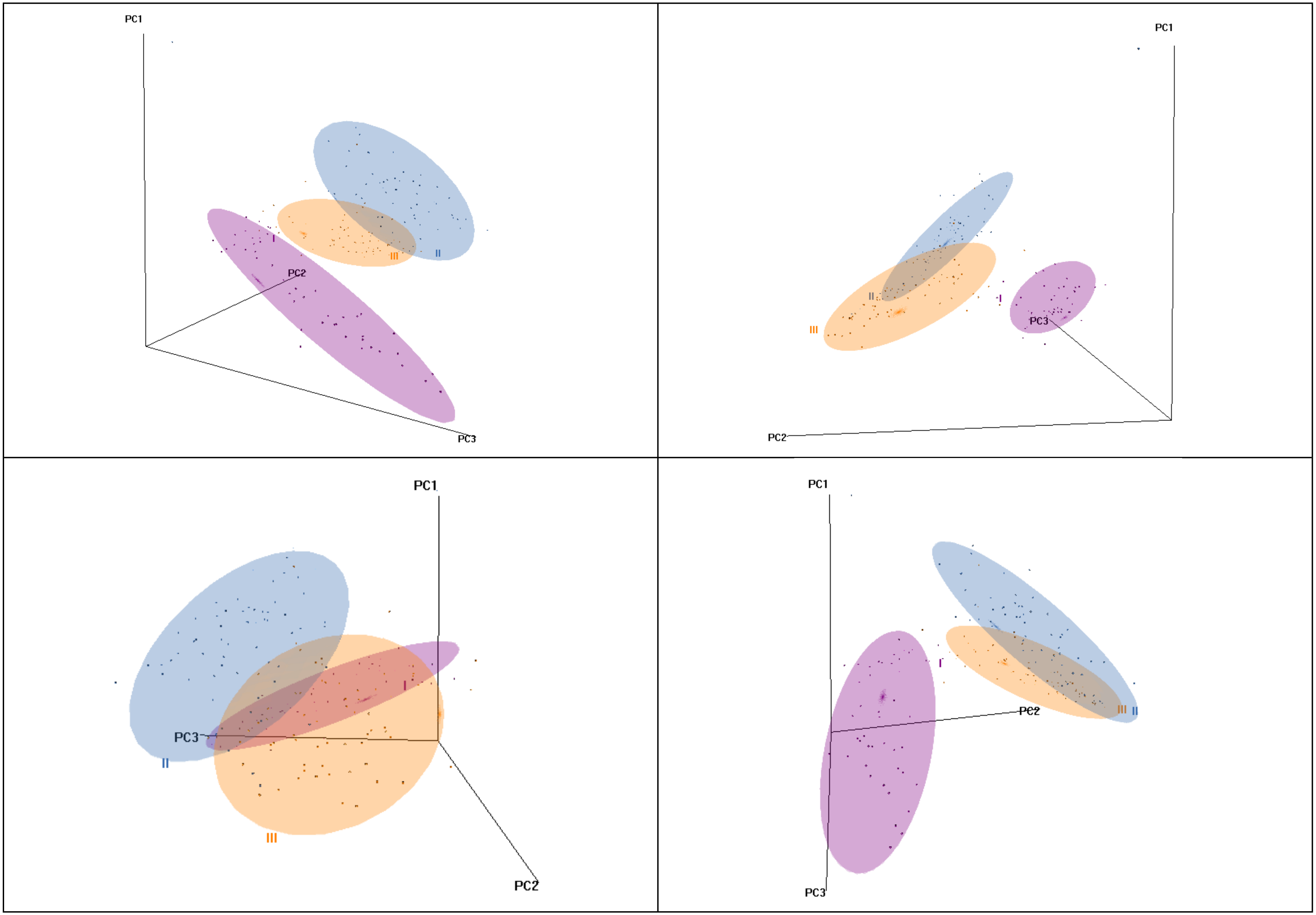


Figure 28. Results of a Principal Component Analysis of Phase 1 Data, with Ellipses Around Sediment Classes I, II, and III

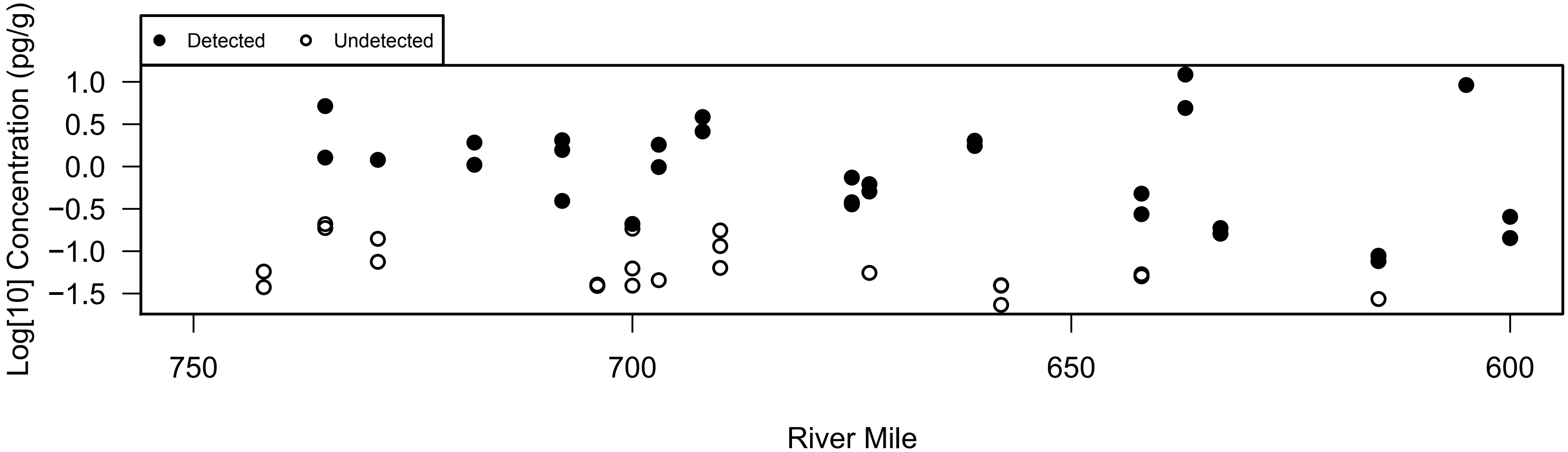


Figure 29. 1,2,3,4,6,7,8−HpCDD in Phase 1 Surface Sediment by River Mile

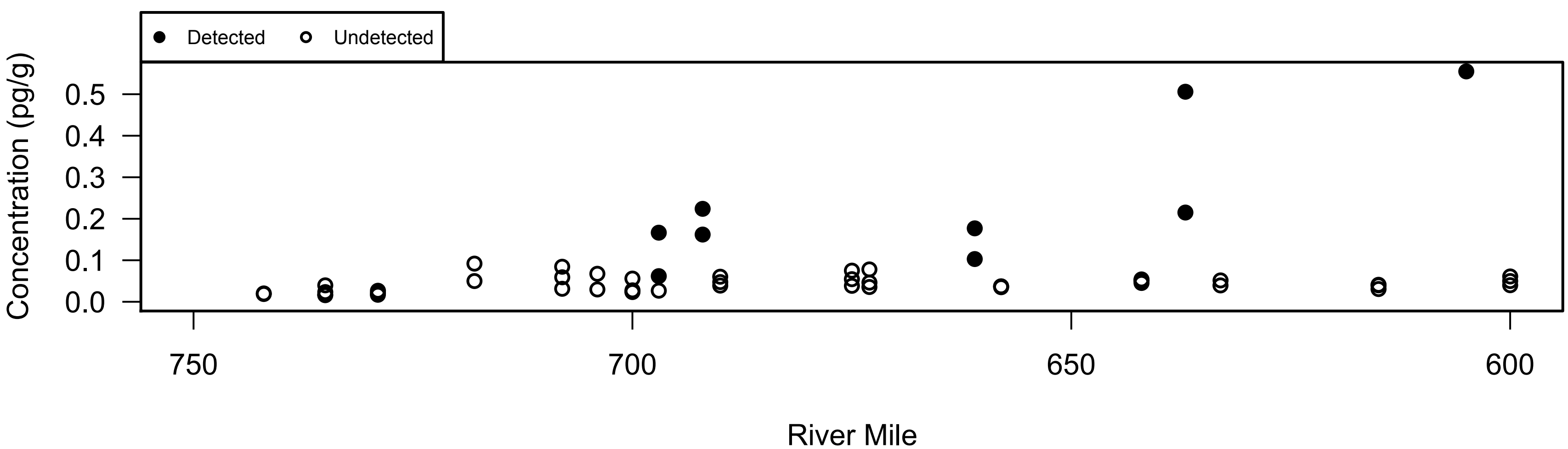


Figure 30. 1,2,3,4,7,8,9−HpCDF in Phase 1 Surface Sediment by River Mile

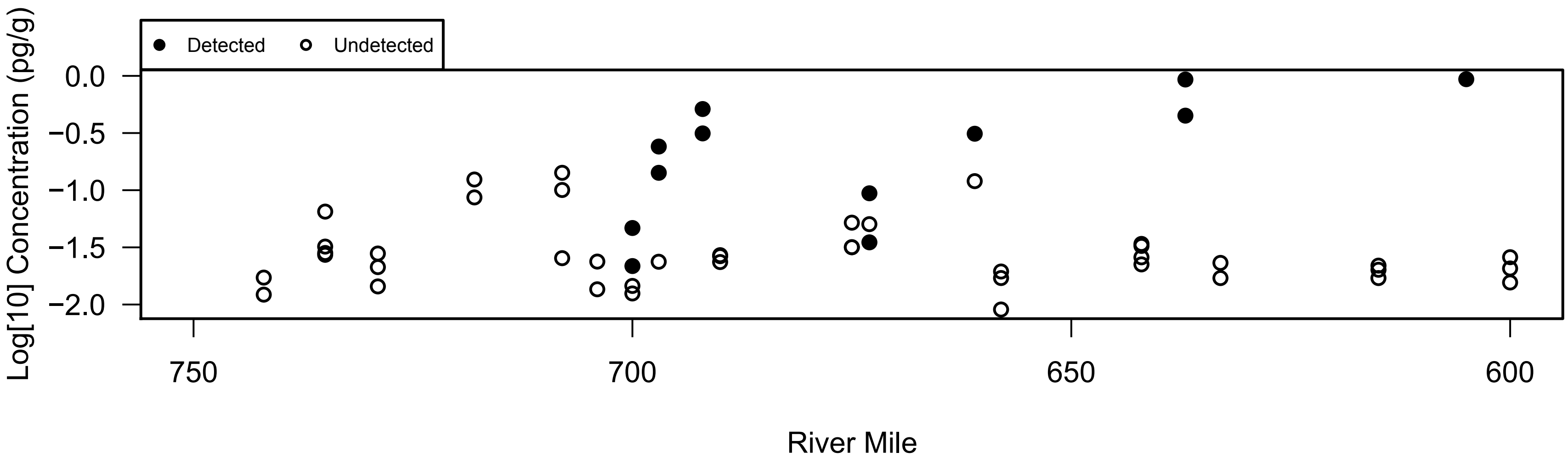


Figure 31. 1,2,3,4,7,8−HxCDD in Phase 1 Surface Sediment by River Mile

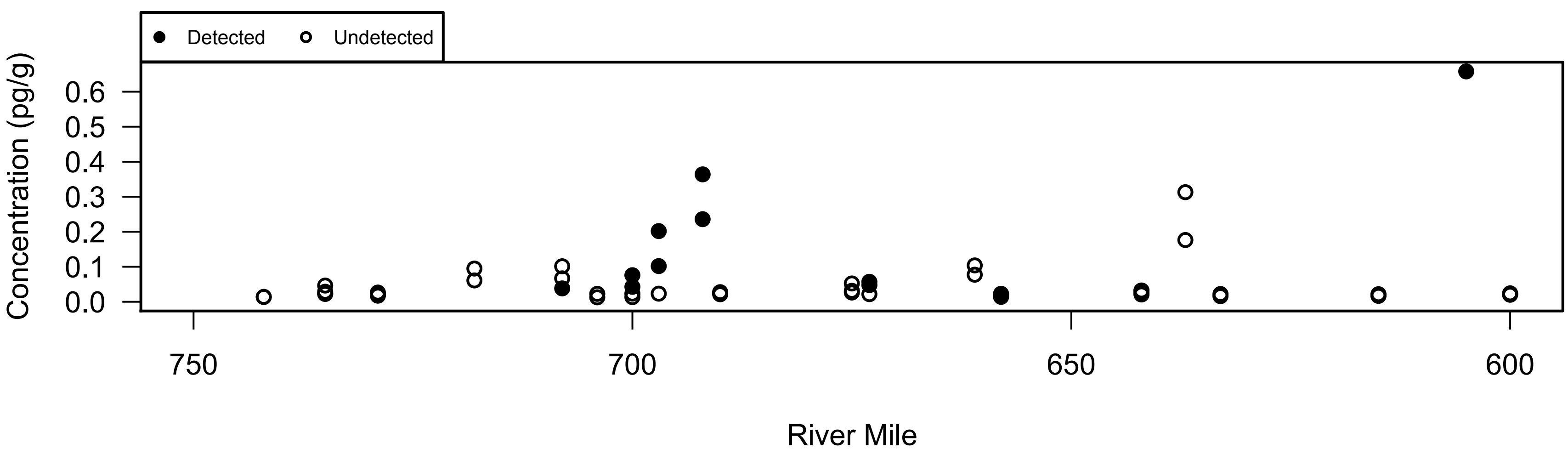


Figure 32. 1,2,3,6,7,8−HxCDD in Phase 1 Surface Sediment by River Mile

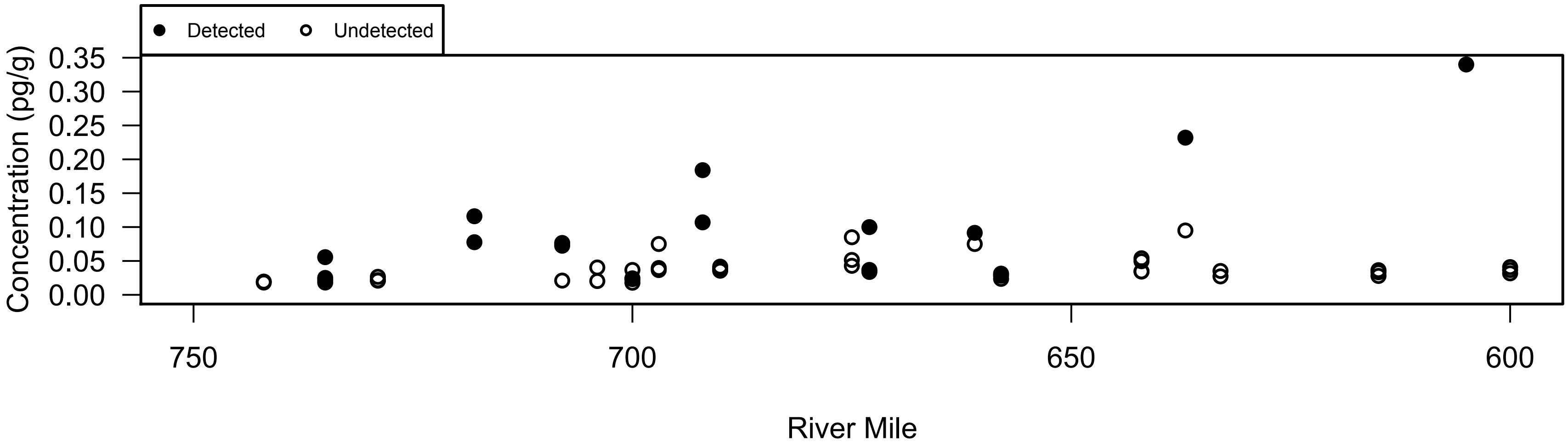


Figure 33. 1,2,3,7,8,9−HxCDD in Phase 1 Surface Sediment
by River Mile

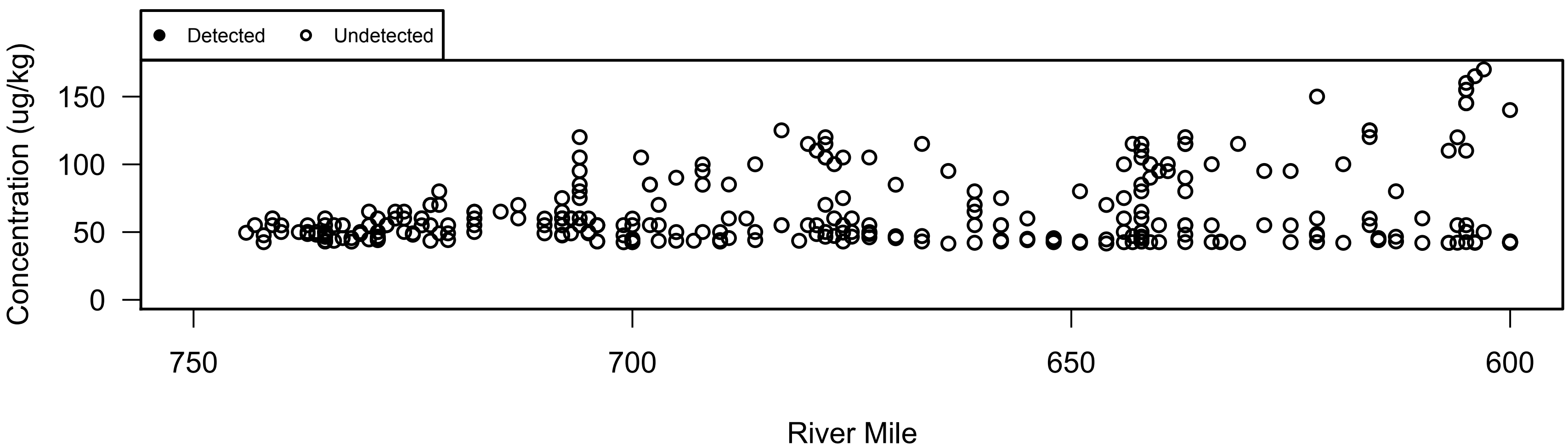


Figure 34. 2,2'−Oxybis(1−chloropropane) in Phase 1 Surface Sediment
by River Mile

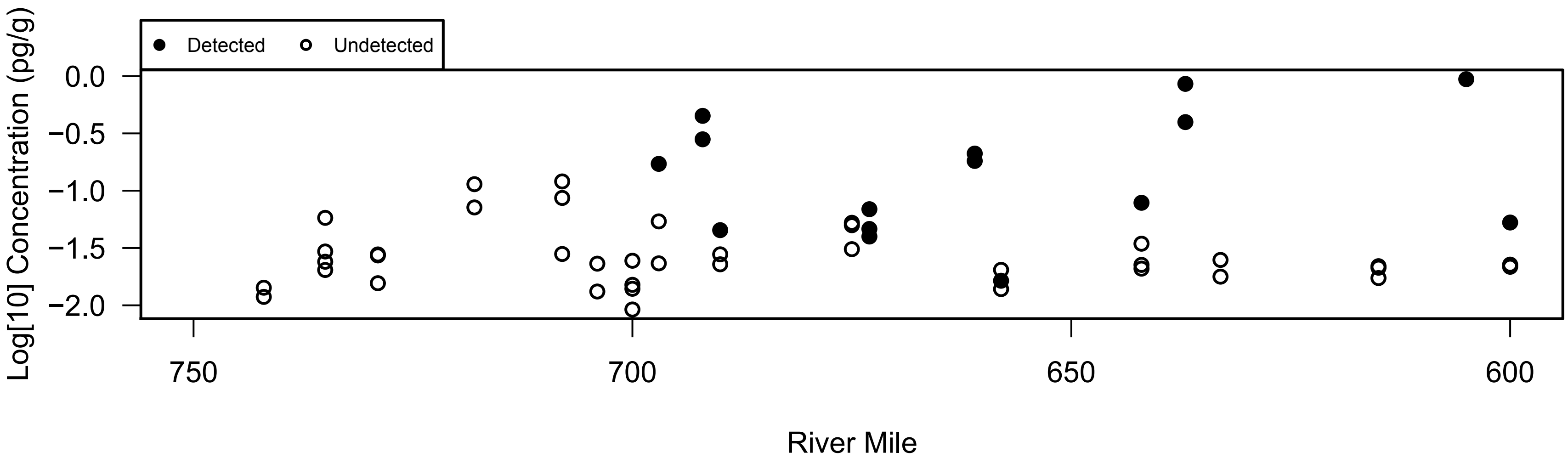


Figure 35. 2,3,4,6,7,8−HxCDF in Phase 1 Surface Sediment by River Mile

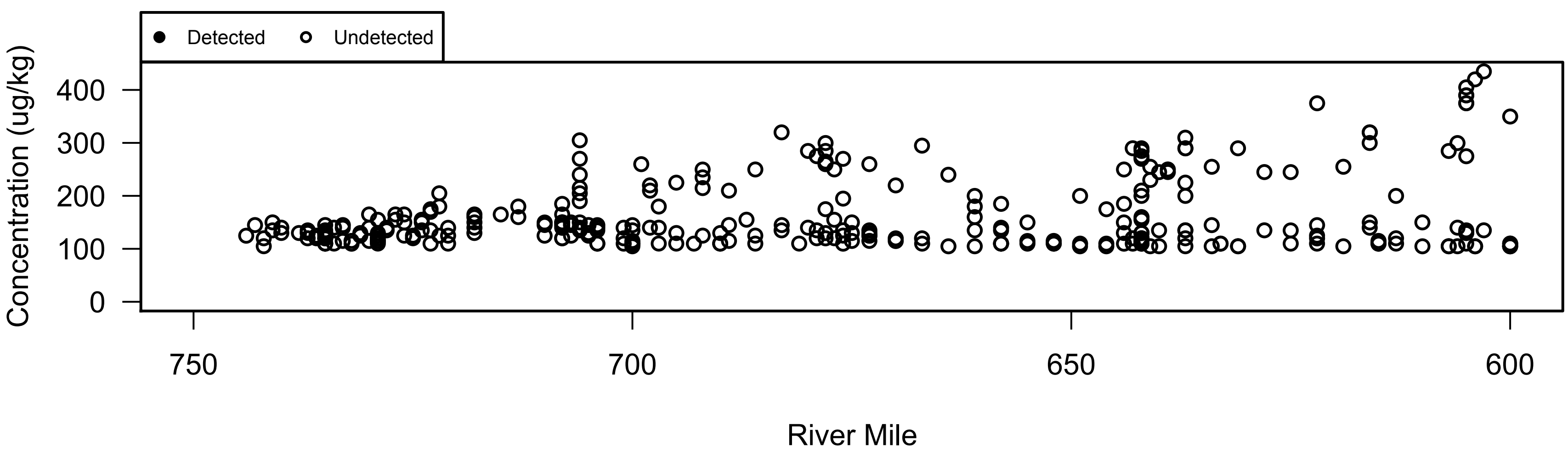


Figure 36. 2,4,5−Trichlorophenol in Phase 1 Surface Sediment by River Mile

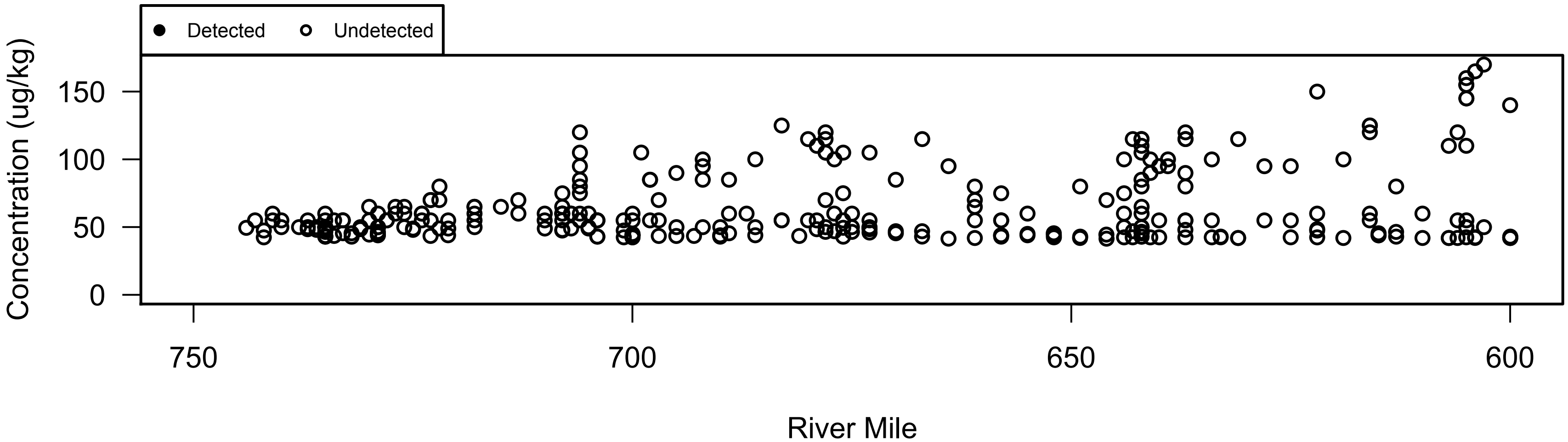


Figure 37. 2,4,6−Trichlorophenol in Phase 1 Surface Sediment by River Mile

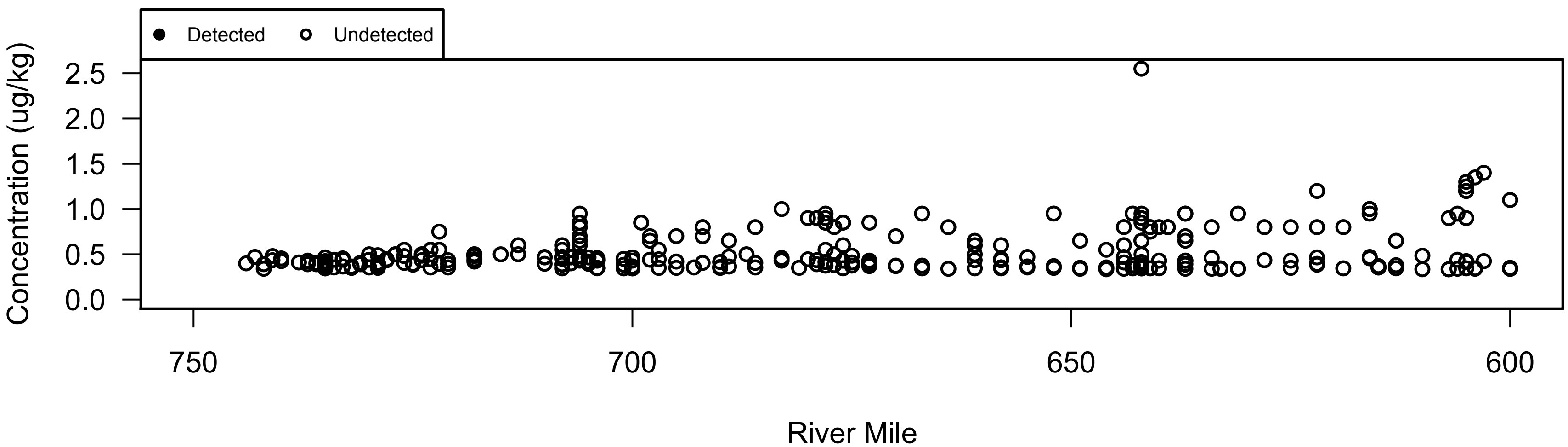


Figure 38. 2,4−DDD in Phase 1 Surface Sediment by River Mile

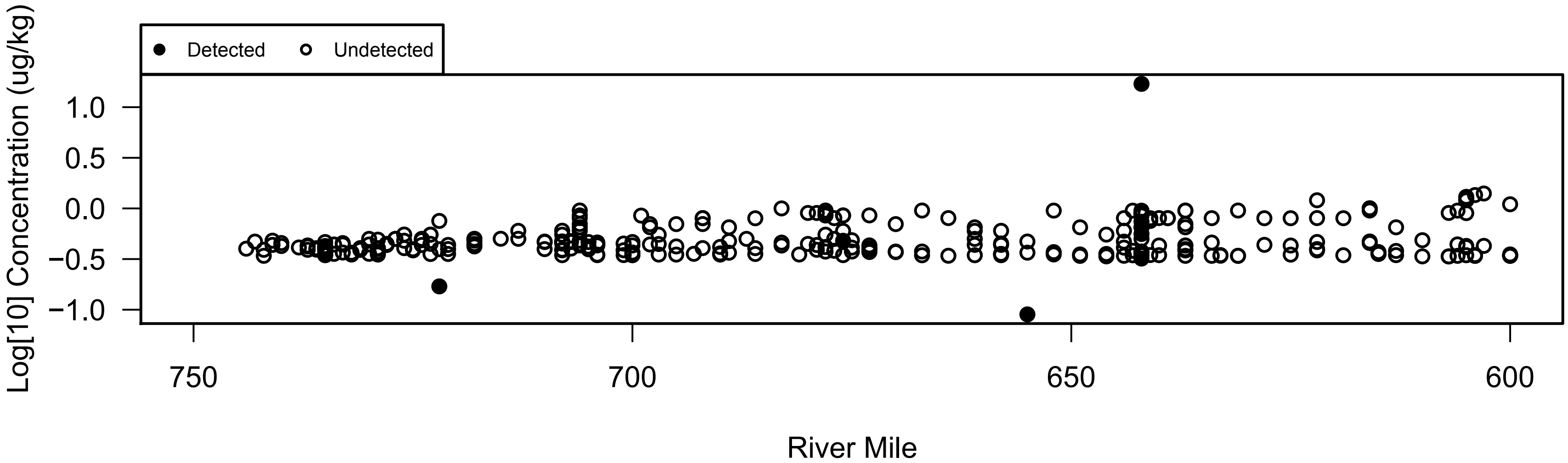


Figure 39. 2,4−DDE in Phase 1 Surface Sediment by River Mile

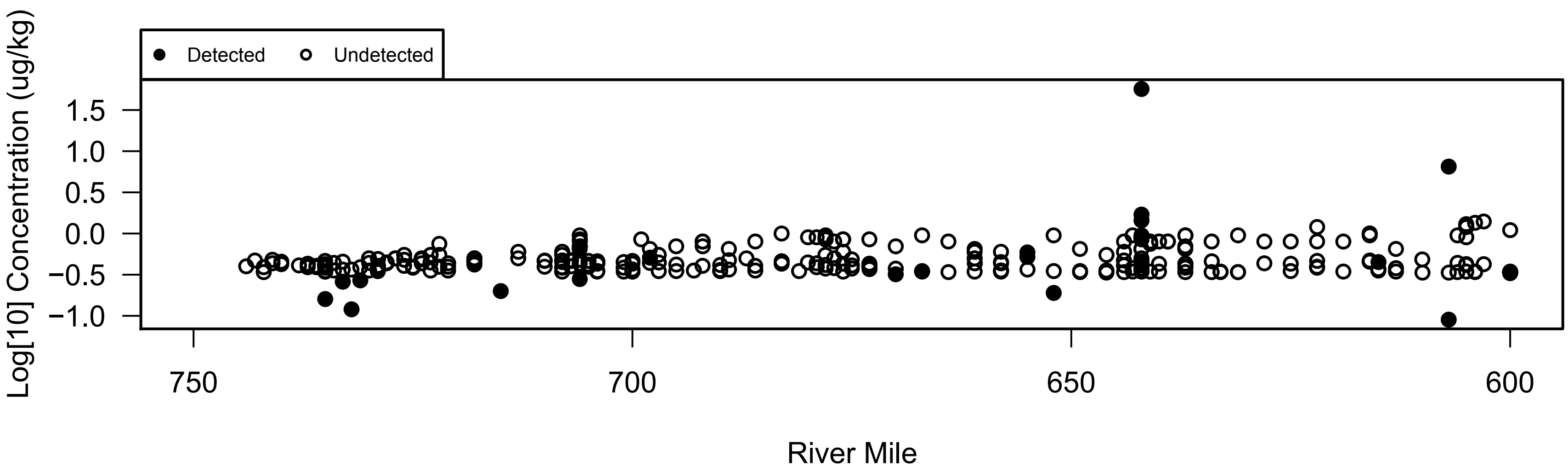


Figure 40. 2,4−DDT in Phase 1 Surface Sediment by River Mile

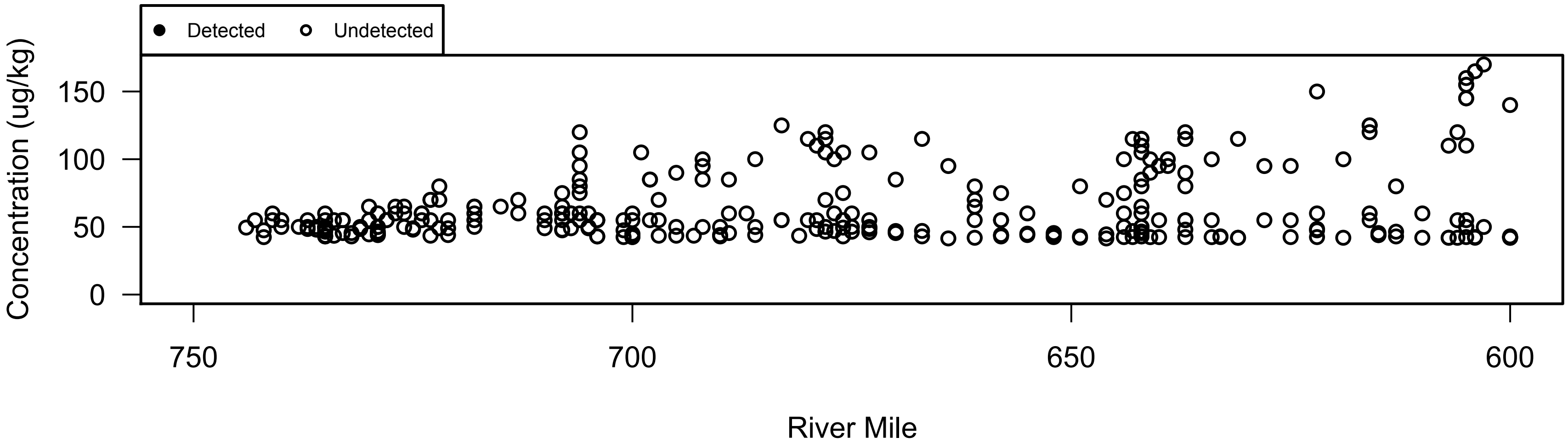


Figure 41. 2,4−Dichlorophenol in Phase 1 Surface Sediment by River Mile

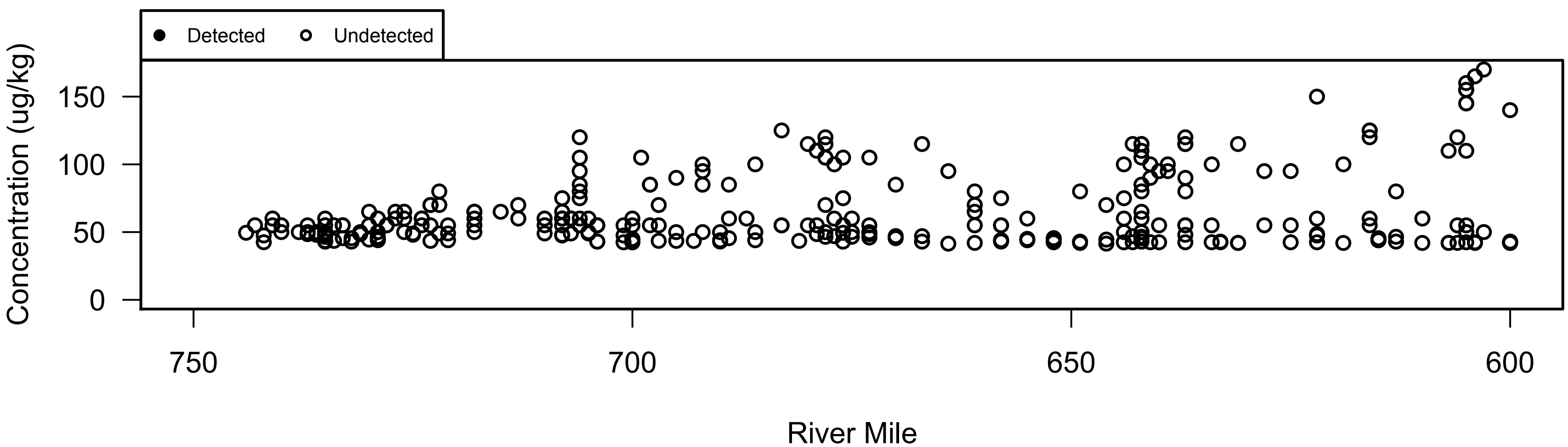


Figure 42. 2,4−Dimethylphenol in Phase 1 Surface Sediment by River Mile

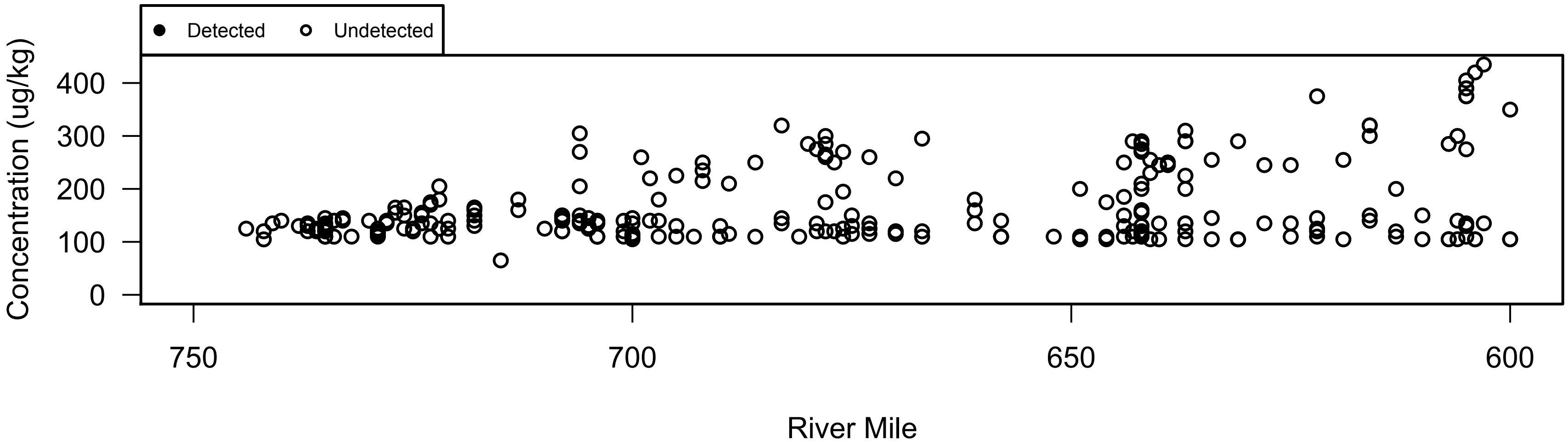


Figure 43. 2,4−Dinitrophenol in Phase 1 Surface Sediment by River Mile

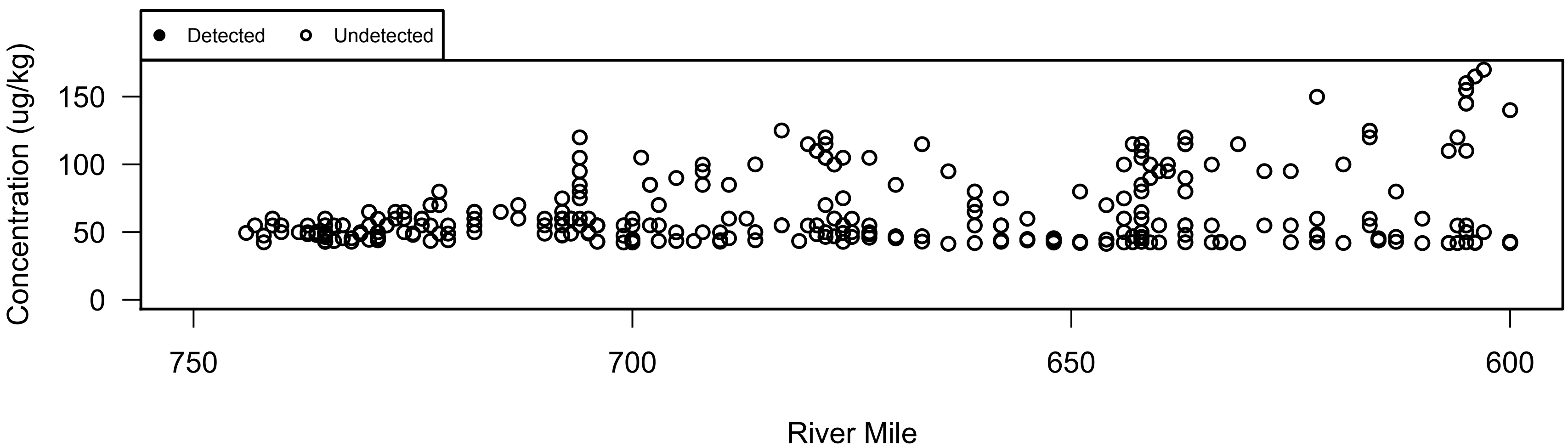


Figure 44. 2,4−Dinitrotoluene in Phase 1 Surface Sediment by River Mile

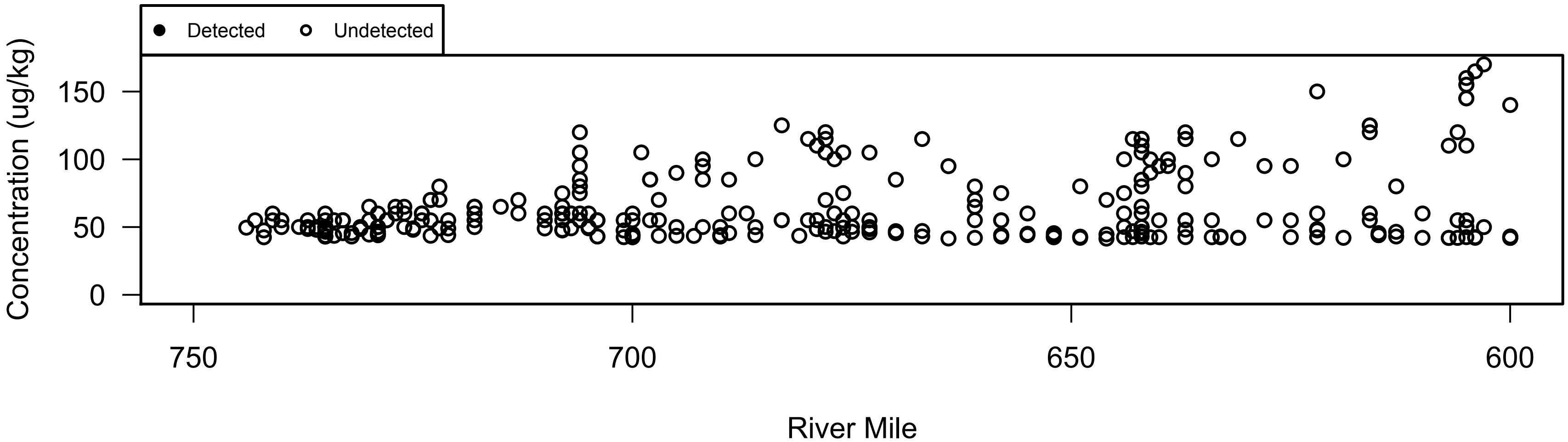


Figure 45. 2,6−Dinitrotoluene in Phase 1 Surface Sediment by River Mile

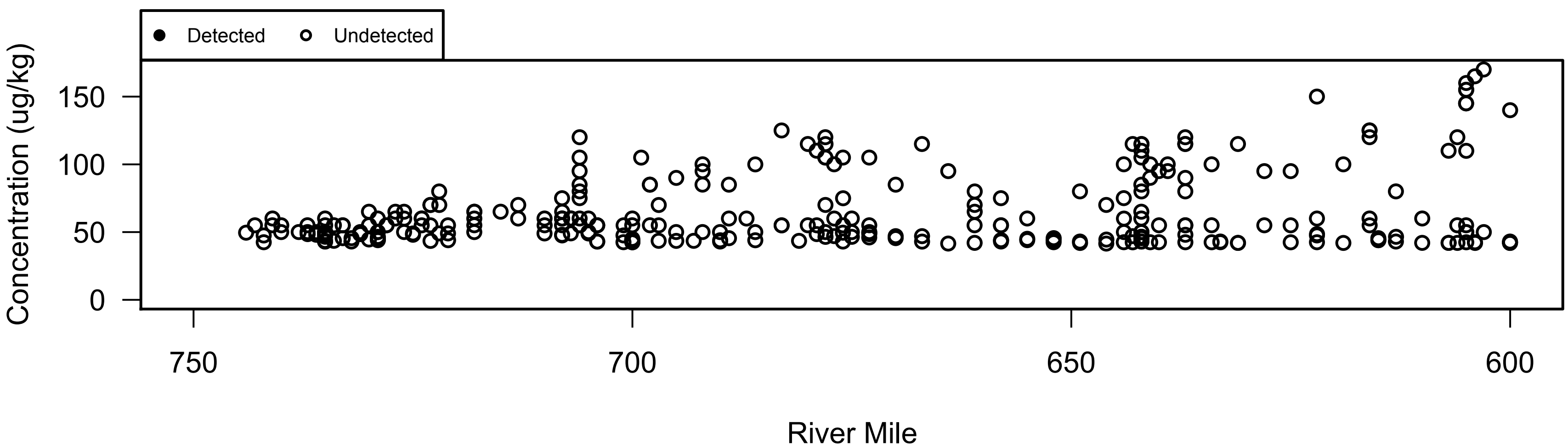


Figure 46. 2−Chloronaphthalene in Phase 1 Surface Sediment by River Mile

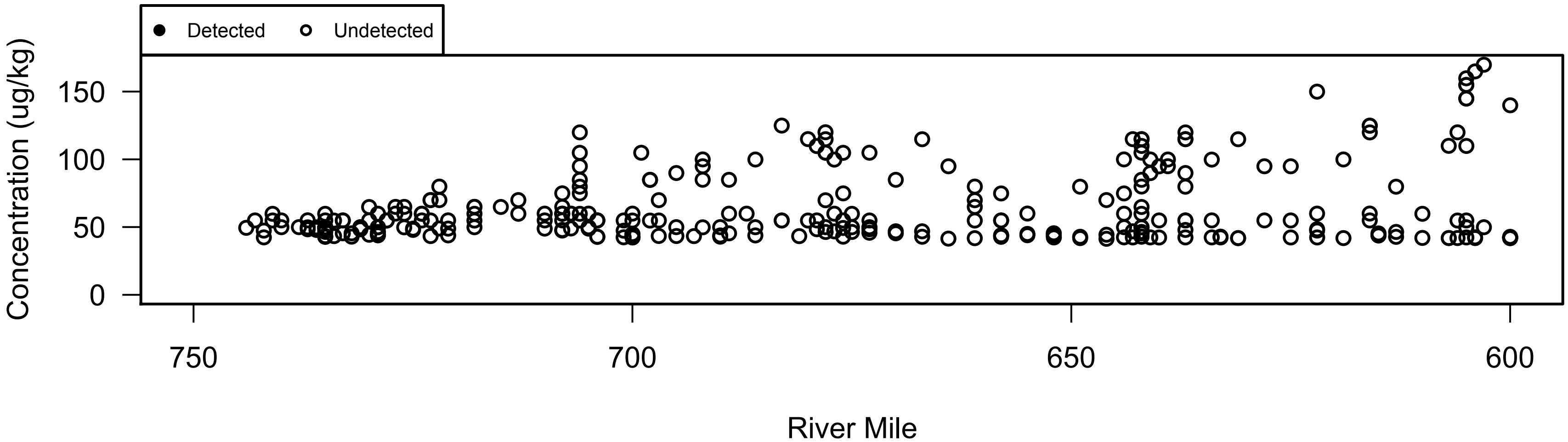


Figure 47. 2−Chlorophenol in Phase 1 Surface Sediment by River Mile

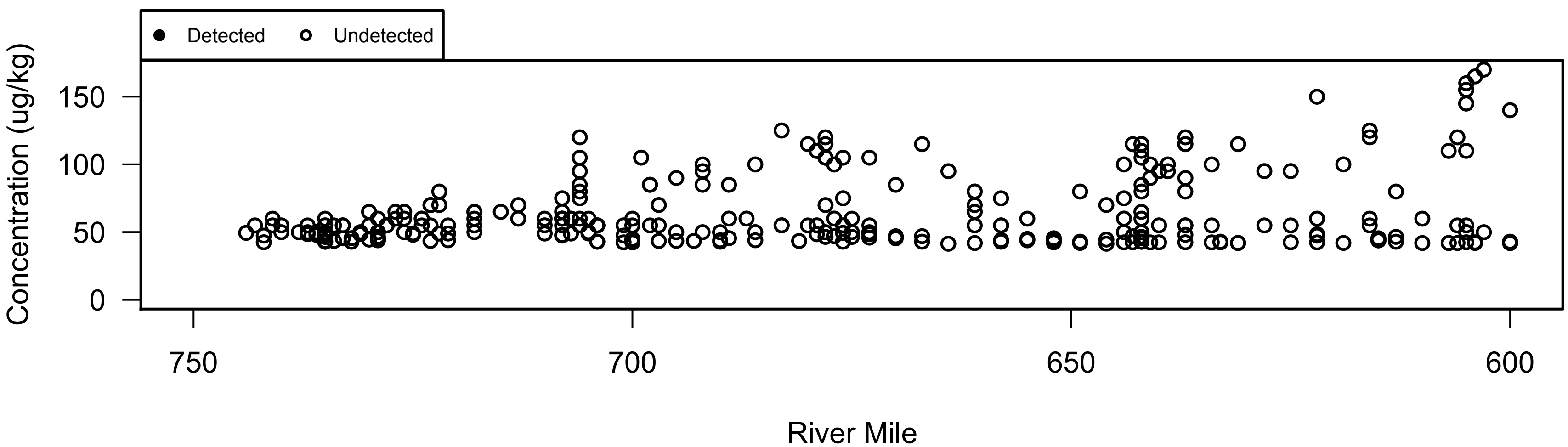


Figure 48. 2−Methylphenol (o−cresol) in Phase 1 Surface Sediment by River Mile

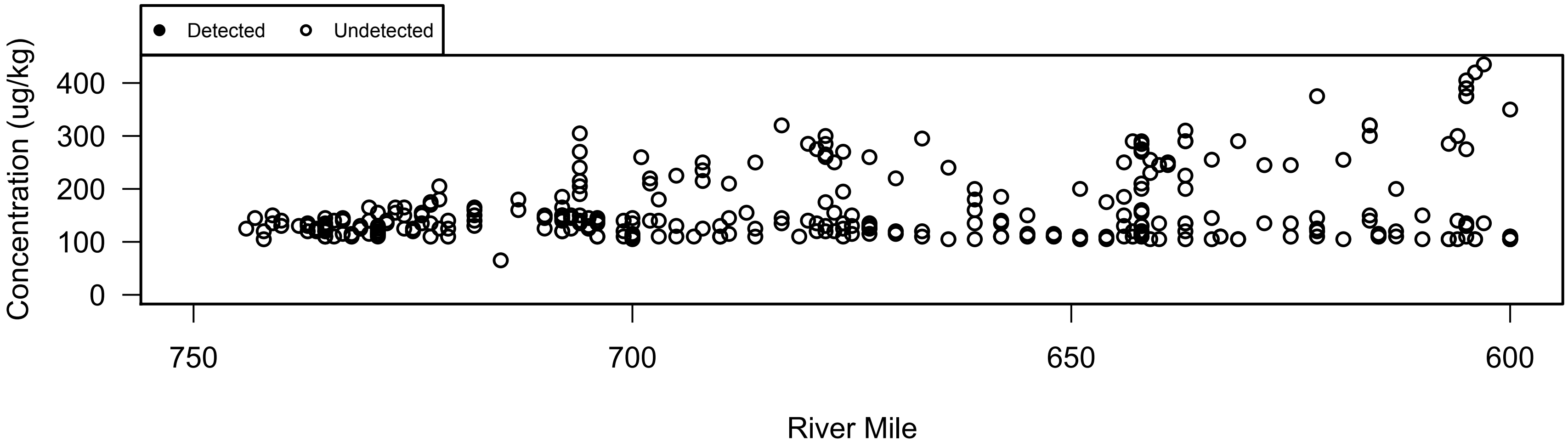


Figure 49. 2−Nitroaniline in Phase 1 Surface Sediment by River Mile

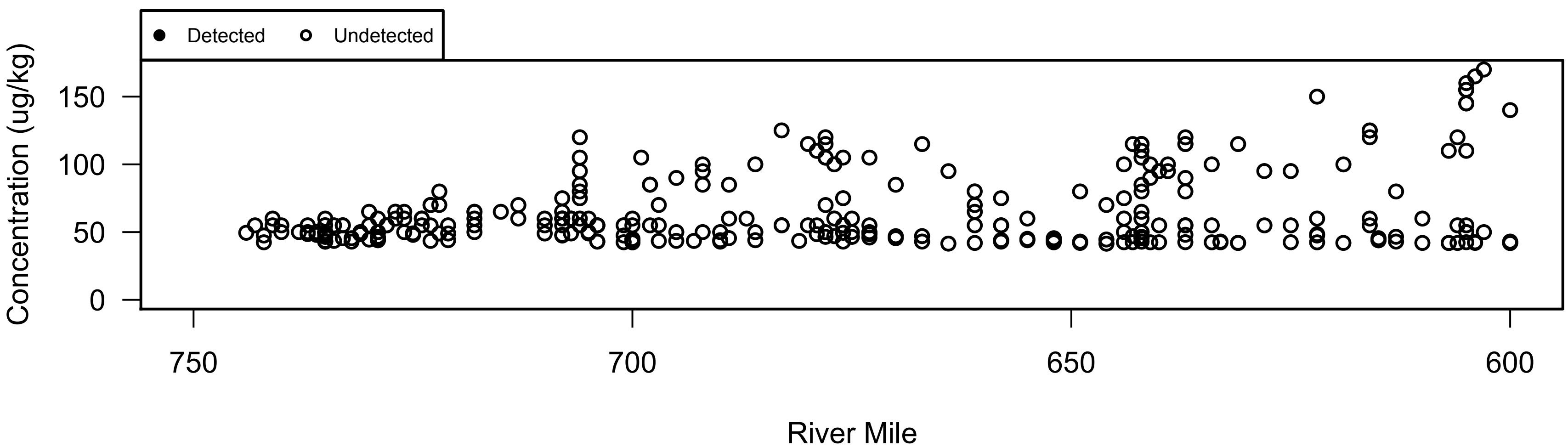


Figure 50. 2−Nitrophenol in Phase 1 Surface Sediment by River Mile

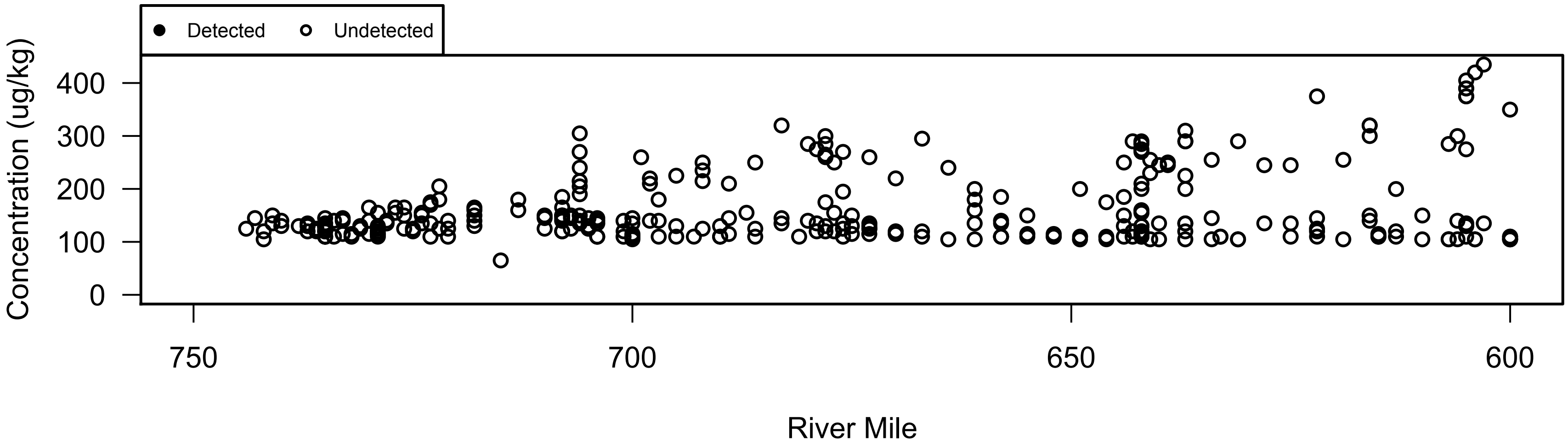


Figure 51. 3−Nitroaniline in Phase 1 Surface Sediment by River Mile

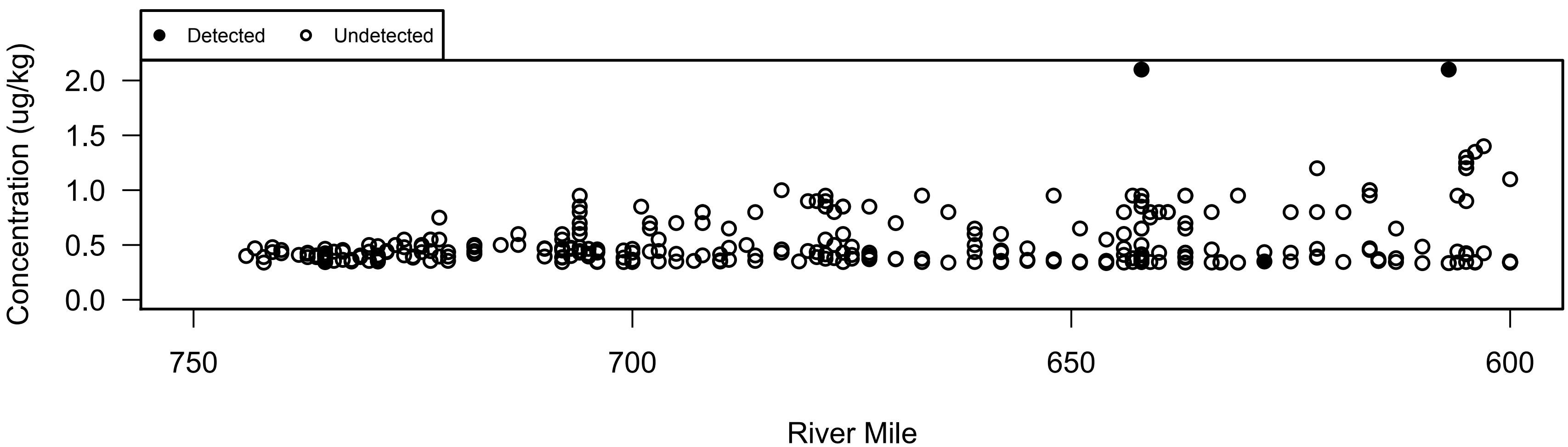


Figure 52. 4,4−DDD in Phase 1 Surface Sediment by River Mile

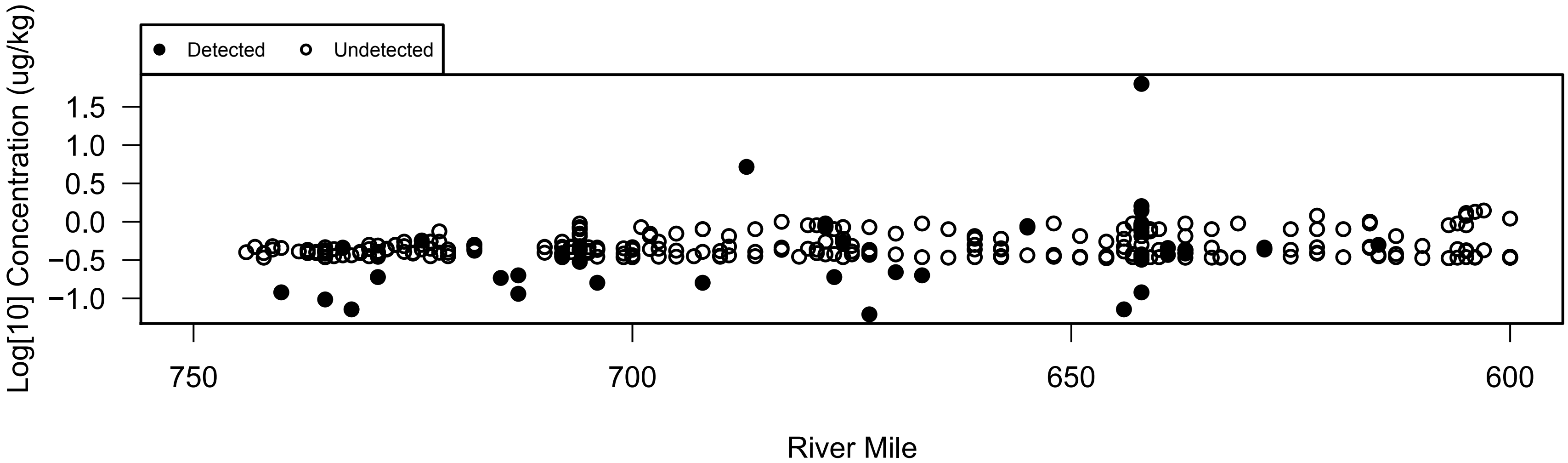


Figure 53. 4,4−DDE in Phase 1 Surface Sediment by River Mile

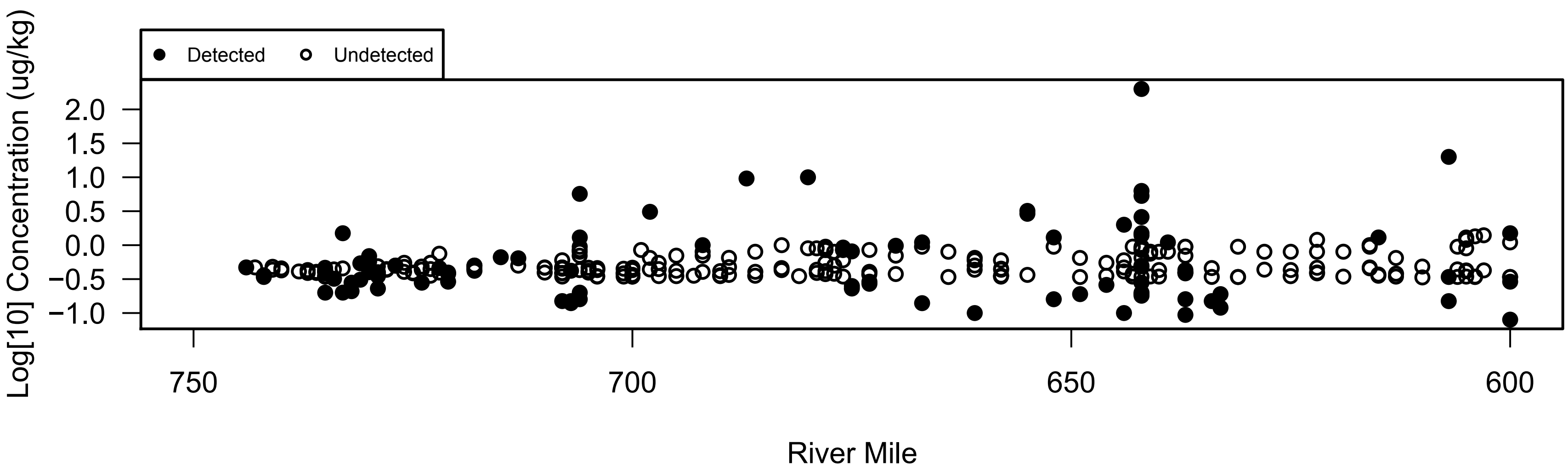


Figure 54. 4,4−DDT in Phase 1 Surface Sediment by River Mile

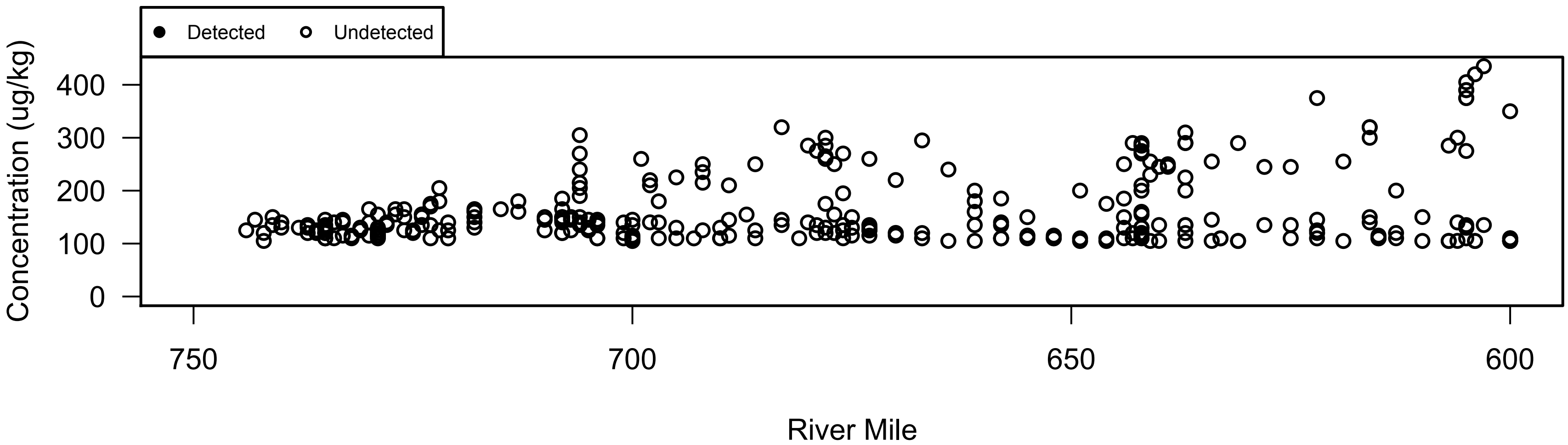


Figure 55. 4,6−Dinitro−2−methylphenol in Phase 1 Surface Sediment by River Mile

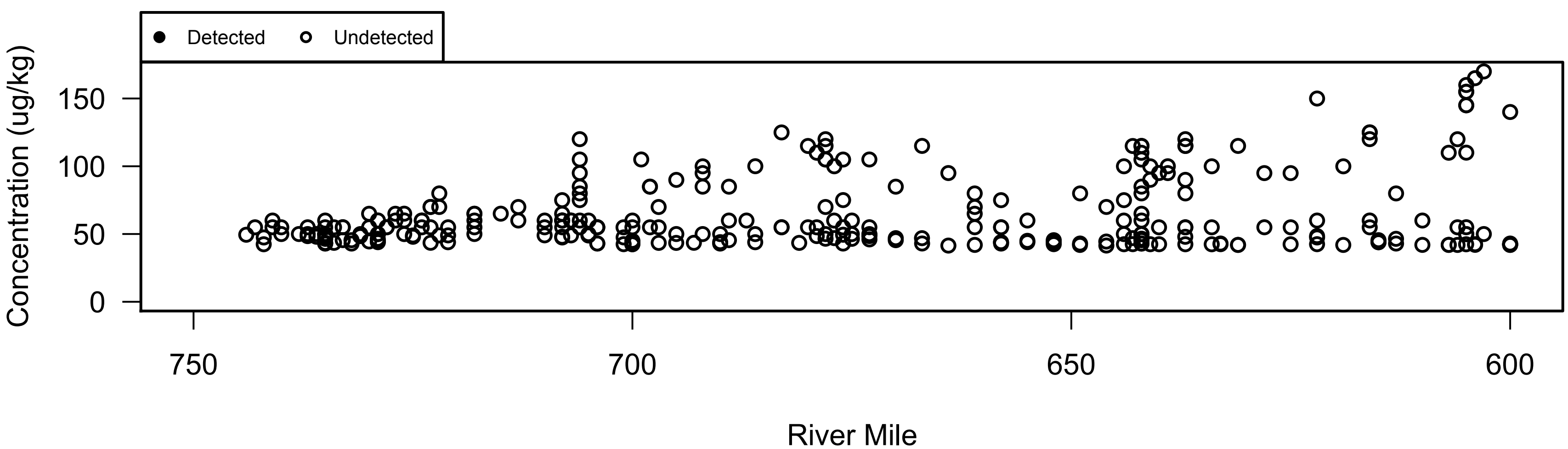


Figure 56. 4−Chloro−3−methylphenol in Phase 1 Surface Sediment by River Mile

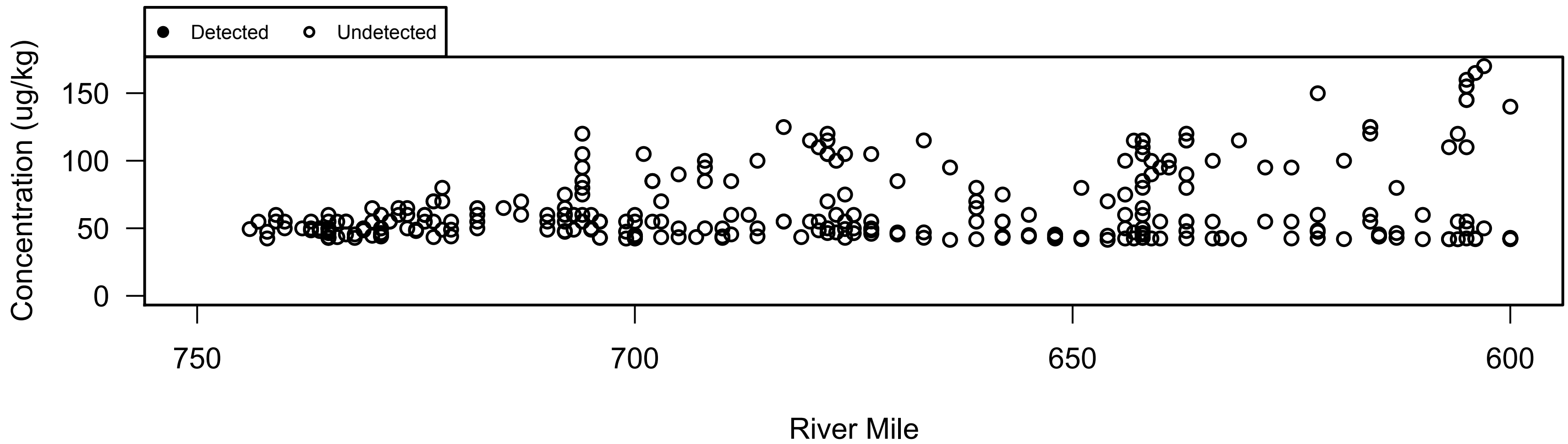


Figure 57. 4−Chloroaniline in Phase 1 Surface Sediment by River Mile

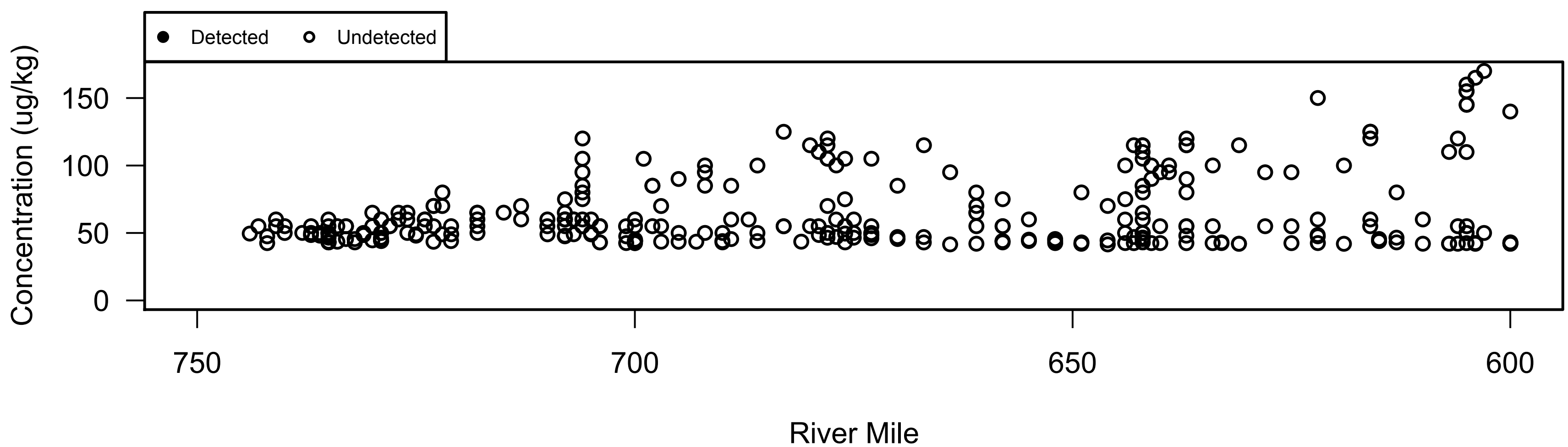


Figure 58. 4−Chlorophenyl−phenyl ether in Phase 1 Surface Sediment by River Mile

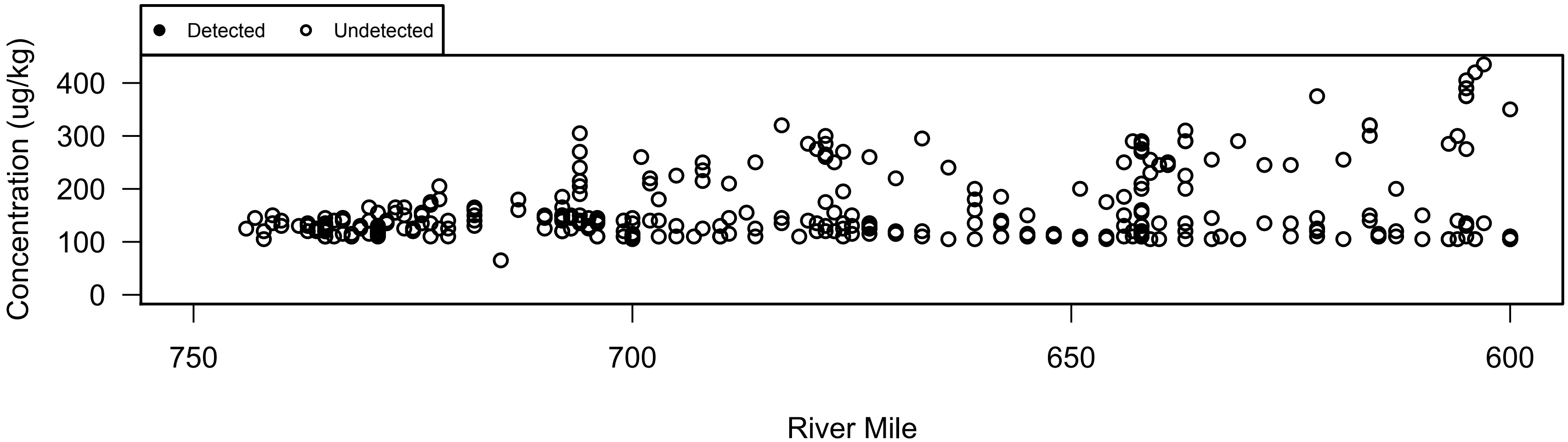


Figure 59. 4−Nitroaniline in Phase 1 Surface Sediment by River Mile

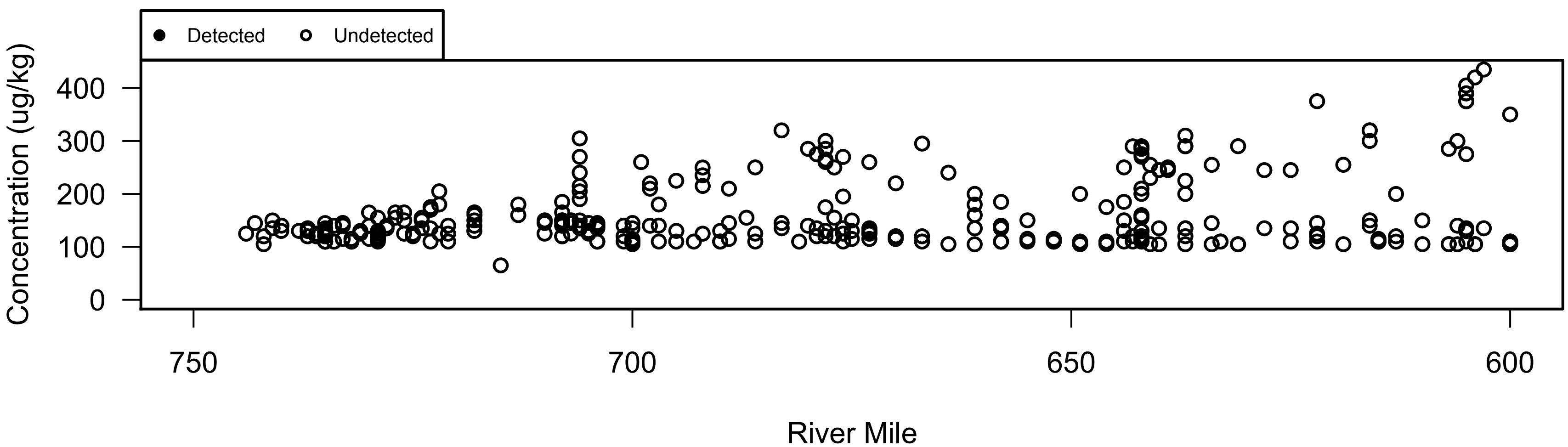


Figure 60. 4−Nitrophenol in Phase 1 Surface Sediment by River Mile

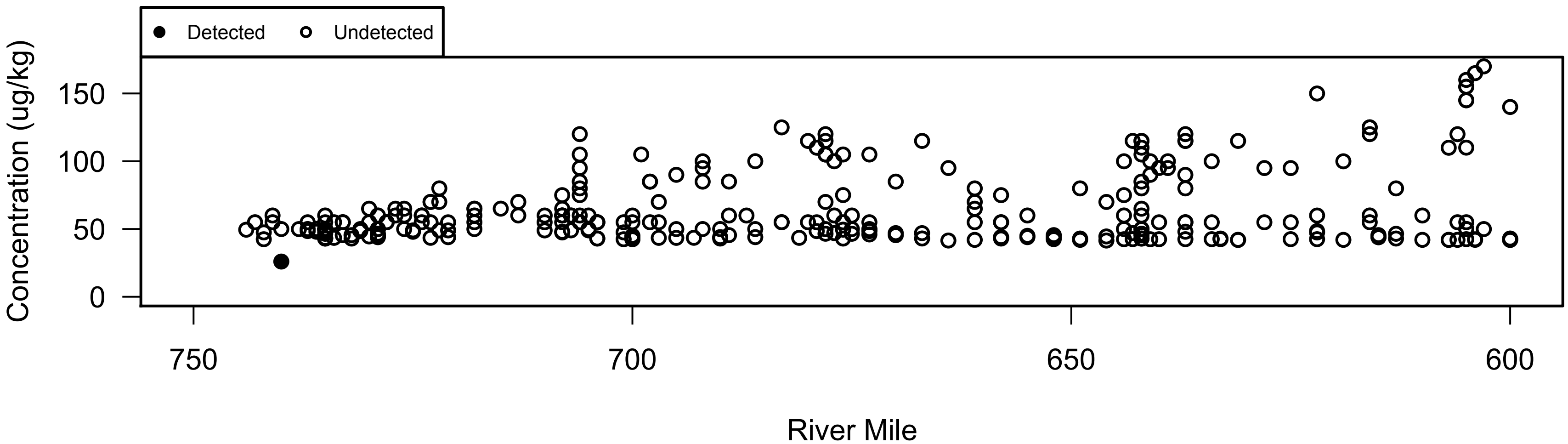


Figure 61. Acetophenone in Phase 1 Surface Sediment by River Mile

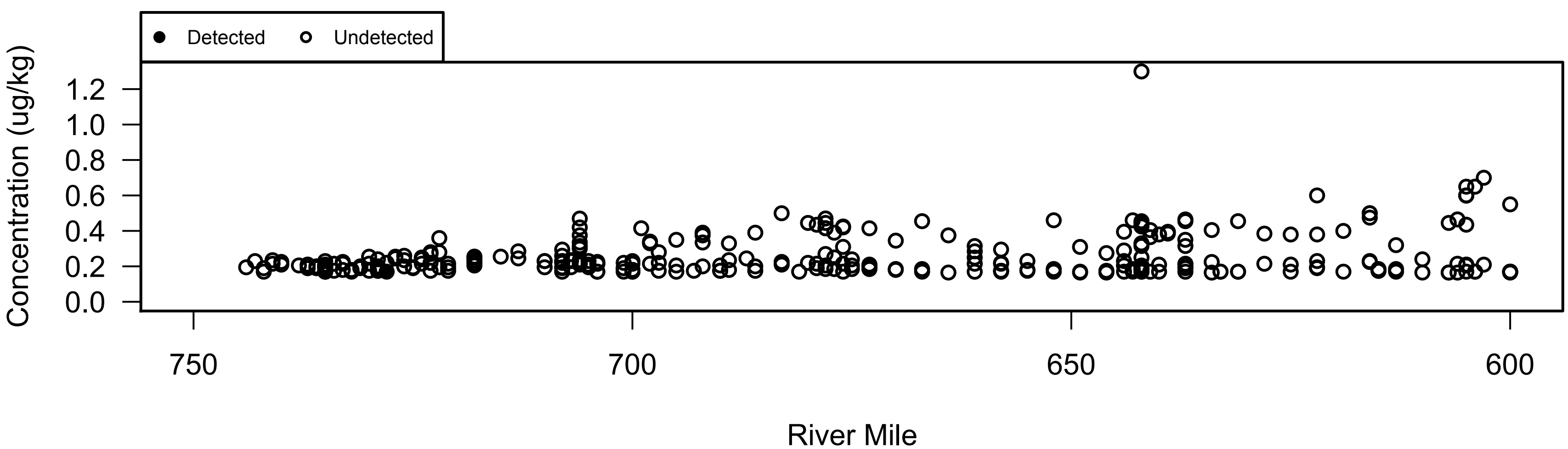


Figure 62. Aldrin in Phase 1 Surface Sediment by River Mile

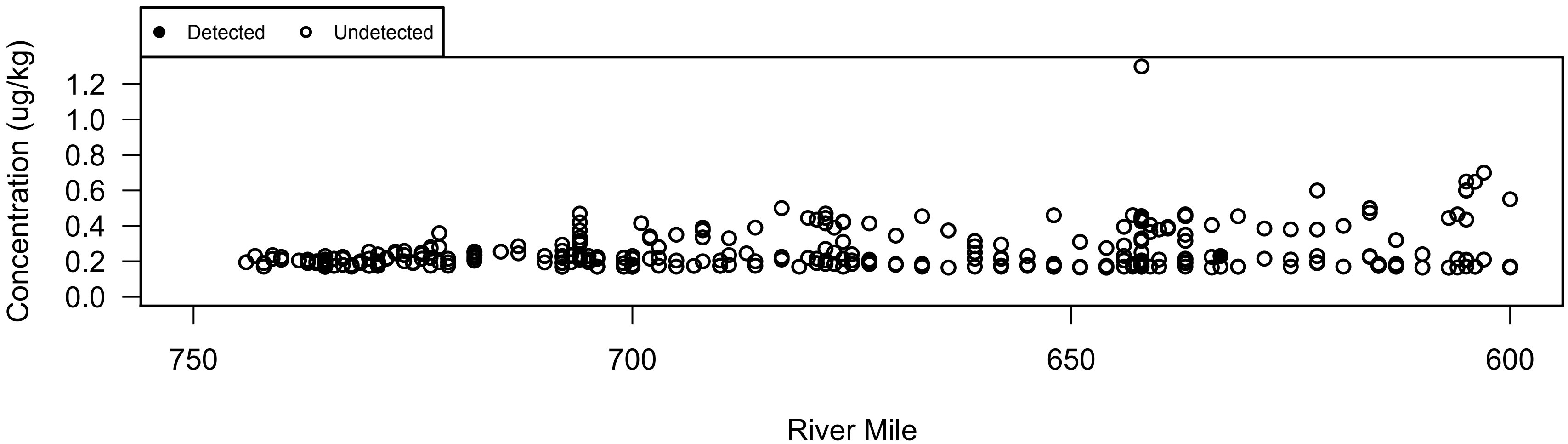


Figure 63. Alpha−BHC in Phase 1 Surface Sediment by River Mile

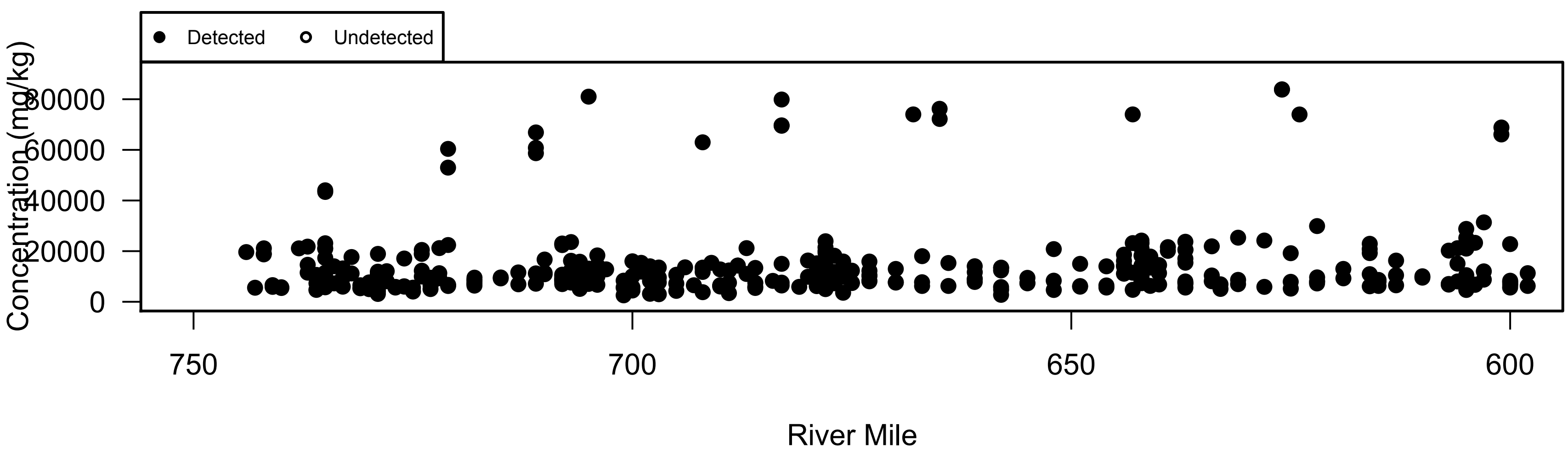


Figure 64. Aluminum in Phase 1 Surface Sediment by River Mile

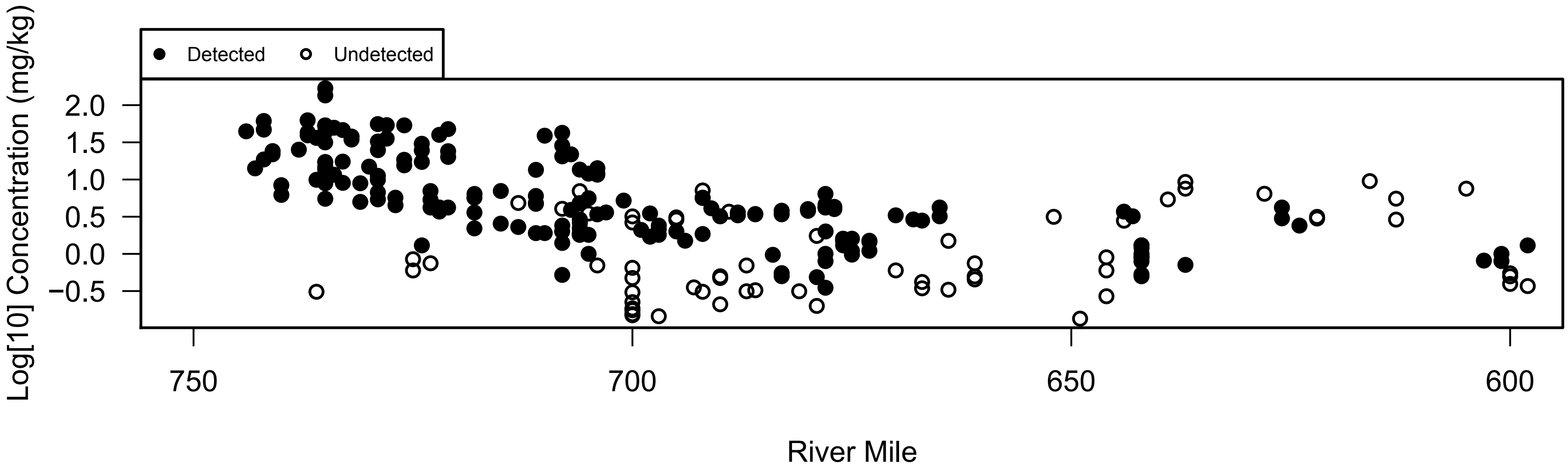


Figure 65. Antimony in Phase 1 Surface Sediment by River Mile

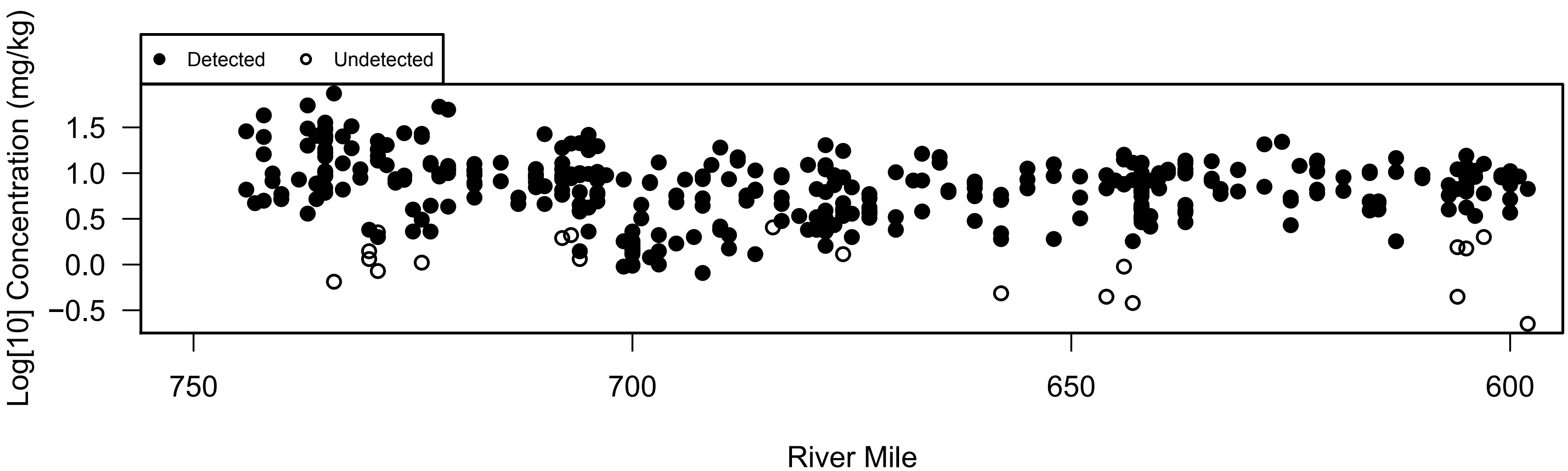


Figure 66. Arsenic in Phase 1 Surface Sediment by River Mile

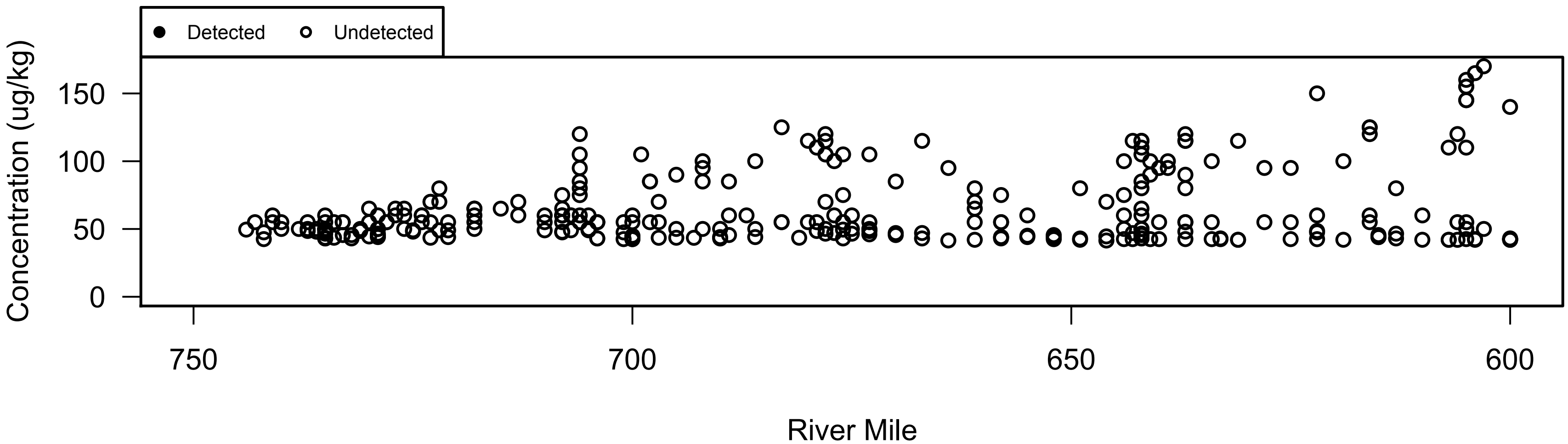


Figure 67. Atrazine in Phase 1 Surface Sediment by River Mile

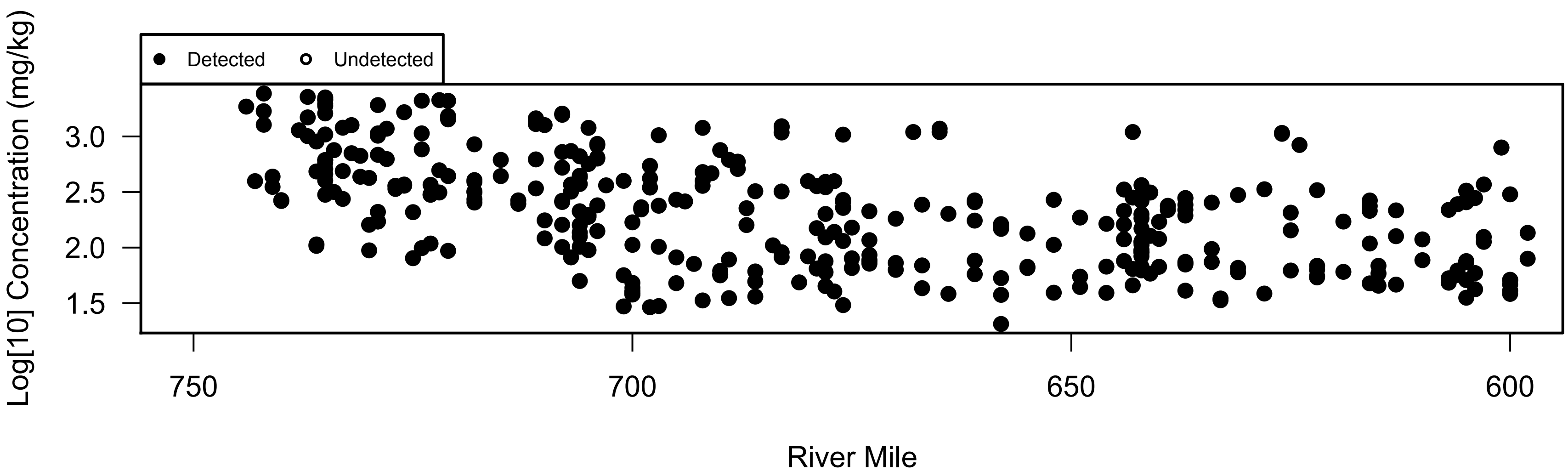


Figure 68. Barium in Phase 1 Surface Sediment by River Mile

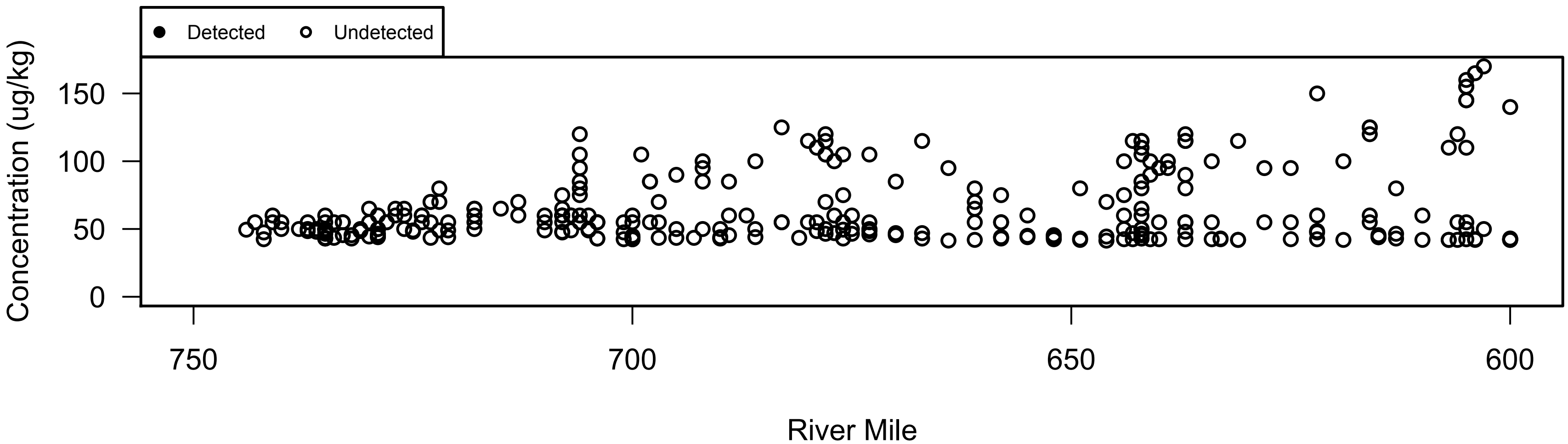


Figure 69. Benzaldehyde in Phase 1 Surface Sediment by River Mile

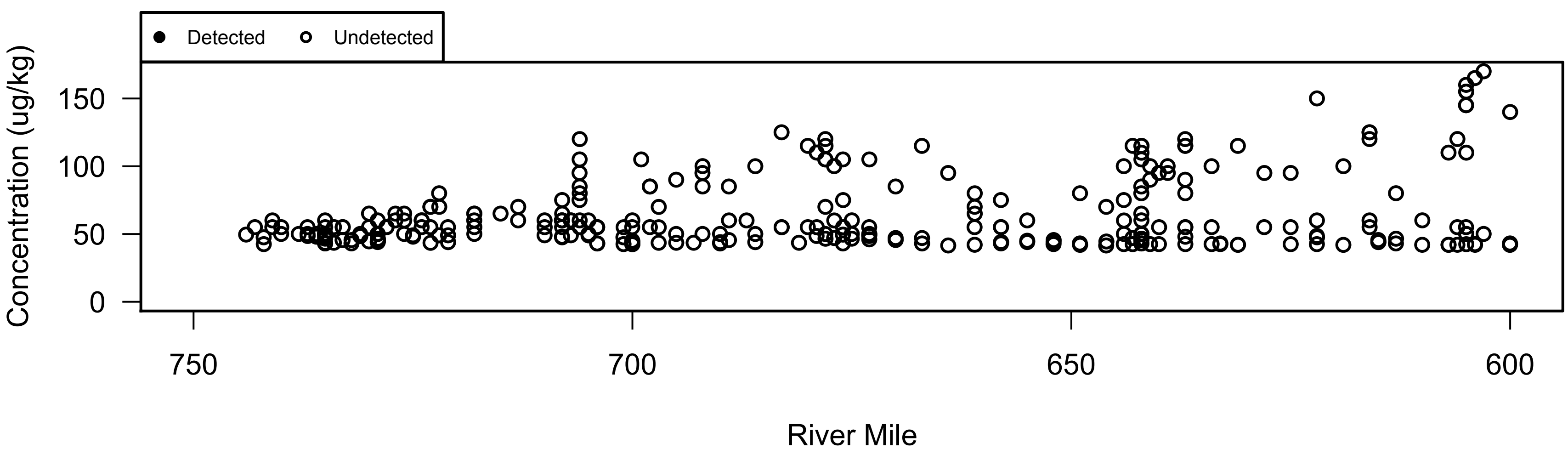


Figure 70. Benzyl alcohol in Phase 1 Surface Sediment by River Mile

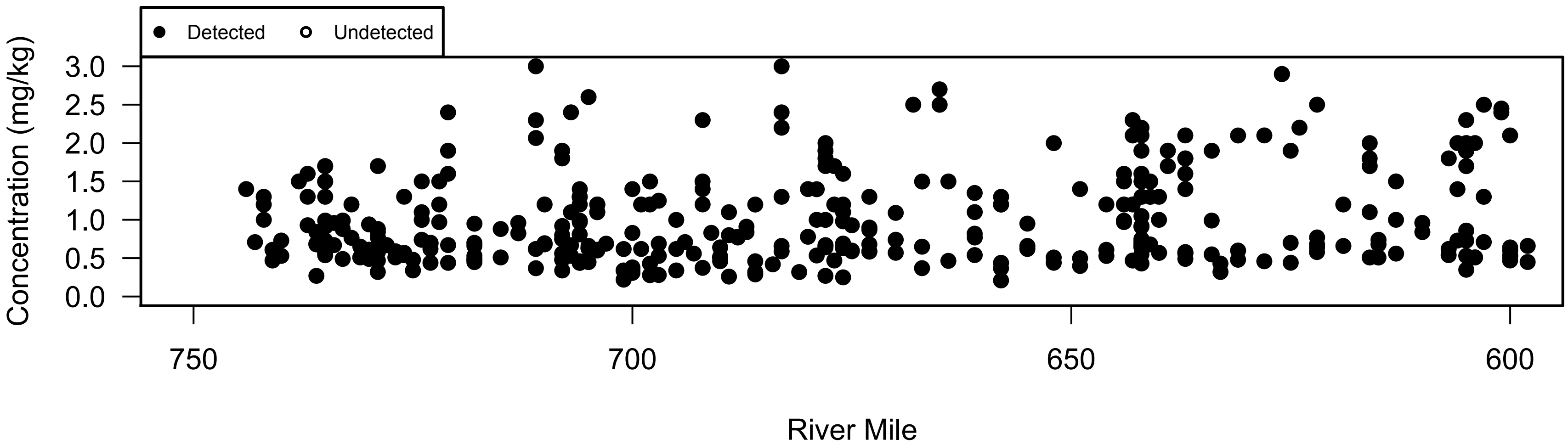


Figure 71. Beryllium in Phase 1 Surface Sediment by River Mile

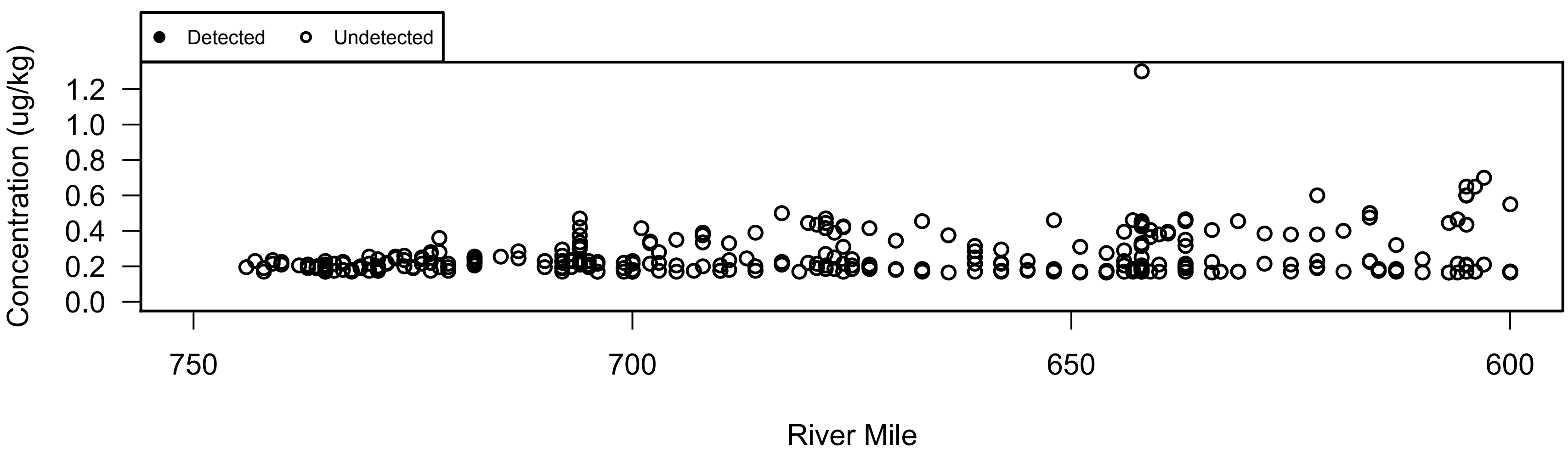


Figure 72. Beta−BHC in Phase 1 Surface Sediment by River Mile

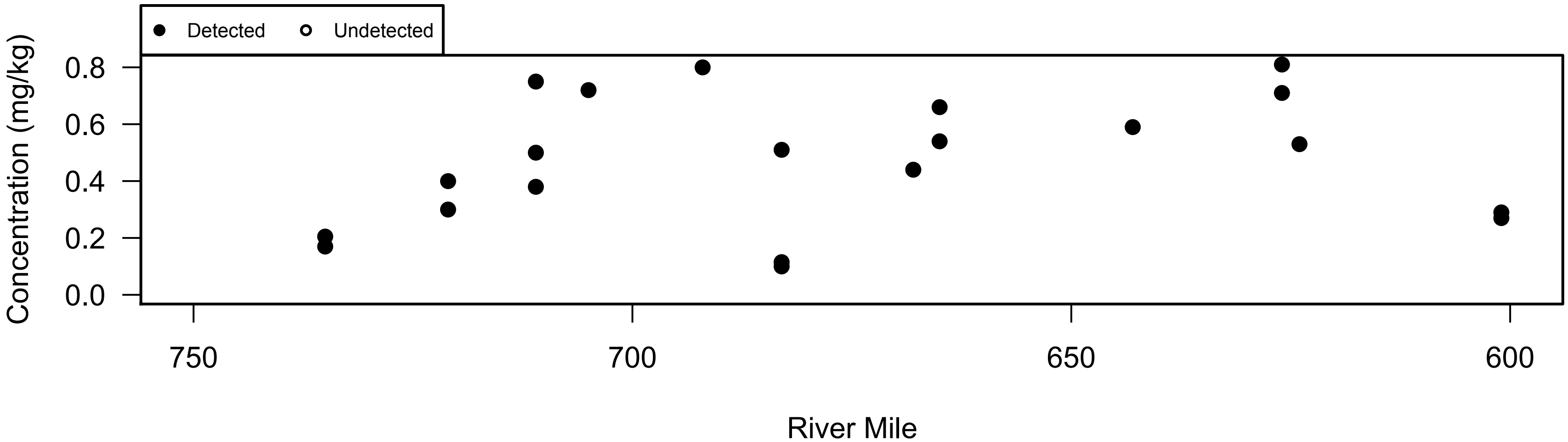


Figure 73. Bismuth in Phase 1 Surface Sediment by River Mile

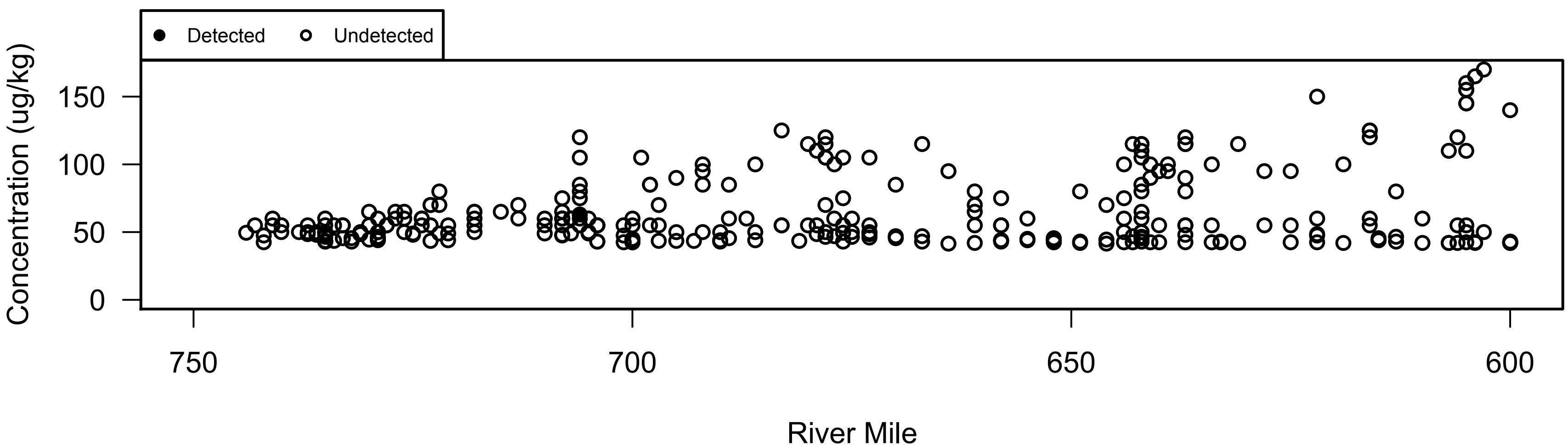


Figure 74. bis(2−Chloroethyl)ether in Phase 1 Surface Sediment by River Mile

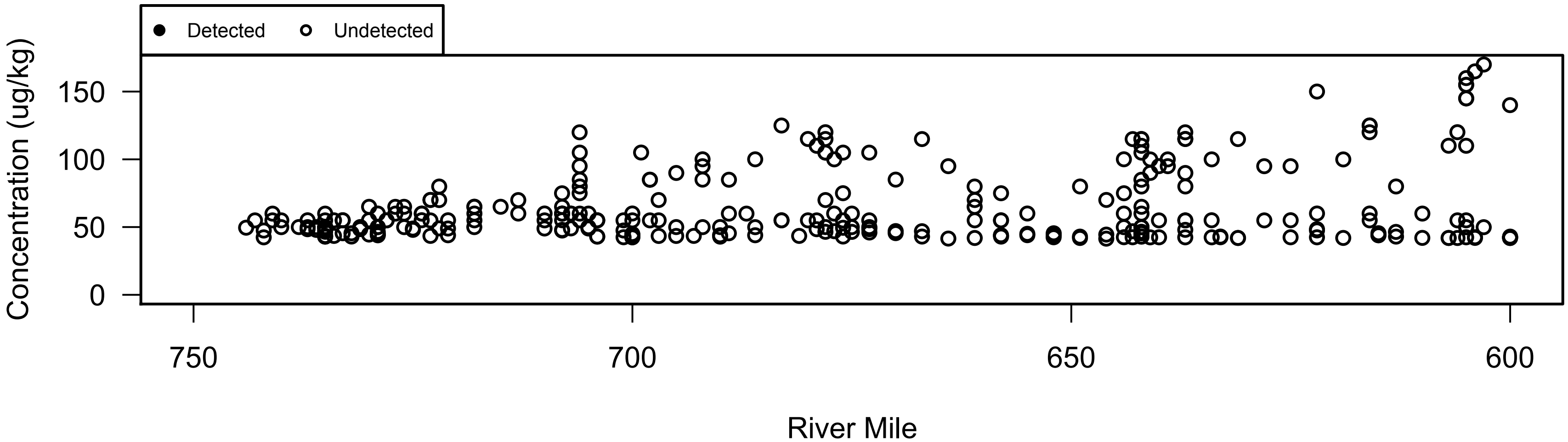


Figure 75. bis(2−Chloroethoxy)methane in Phase 1 Surface Sediment by River Mile

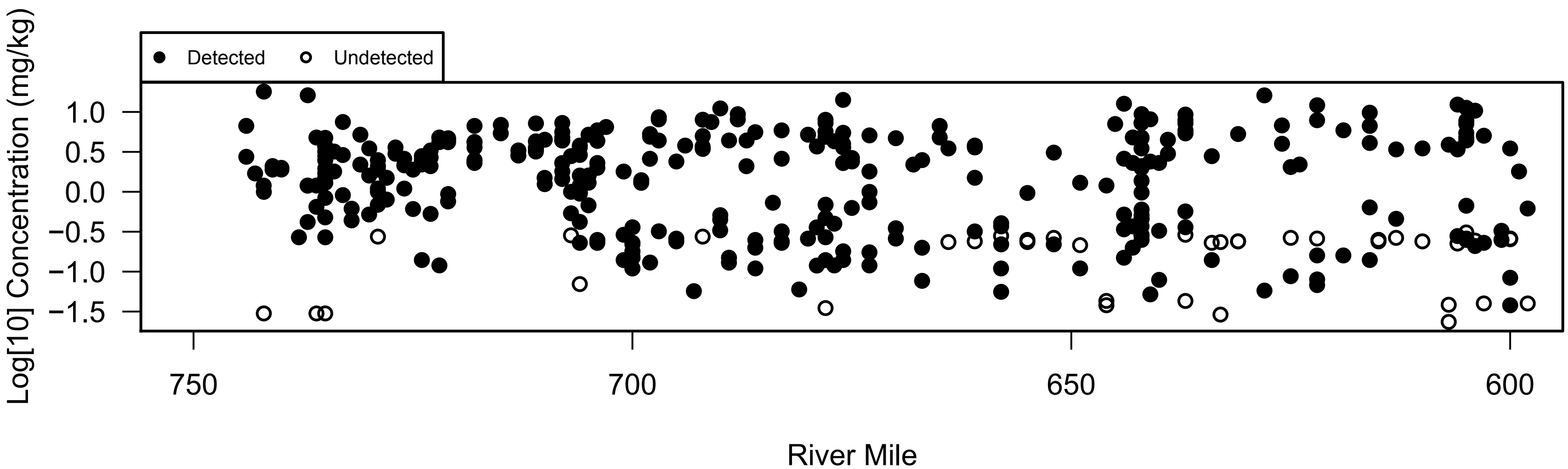


Figure 76. Cadmium in Phase 1 Surface Sediment by River Mile

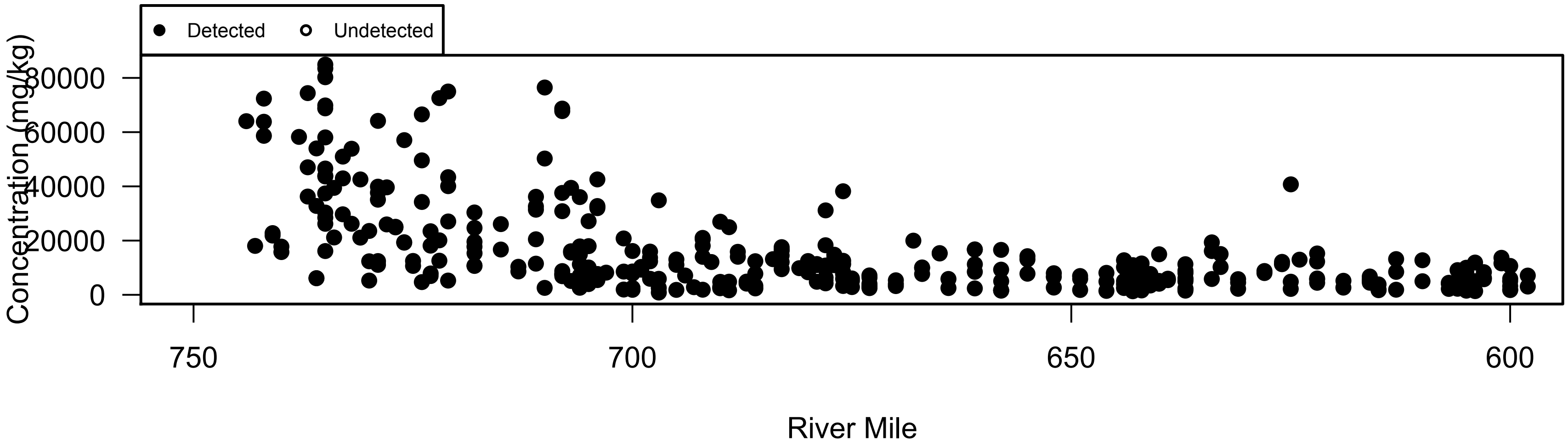


Figure 77. Calcium in Phase 1 Surface Sediment by River Mile

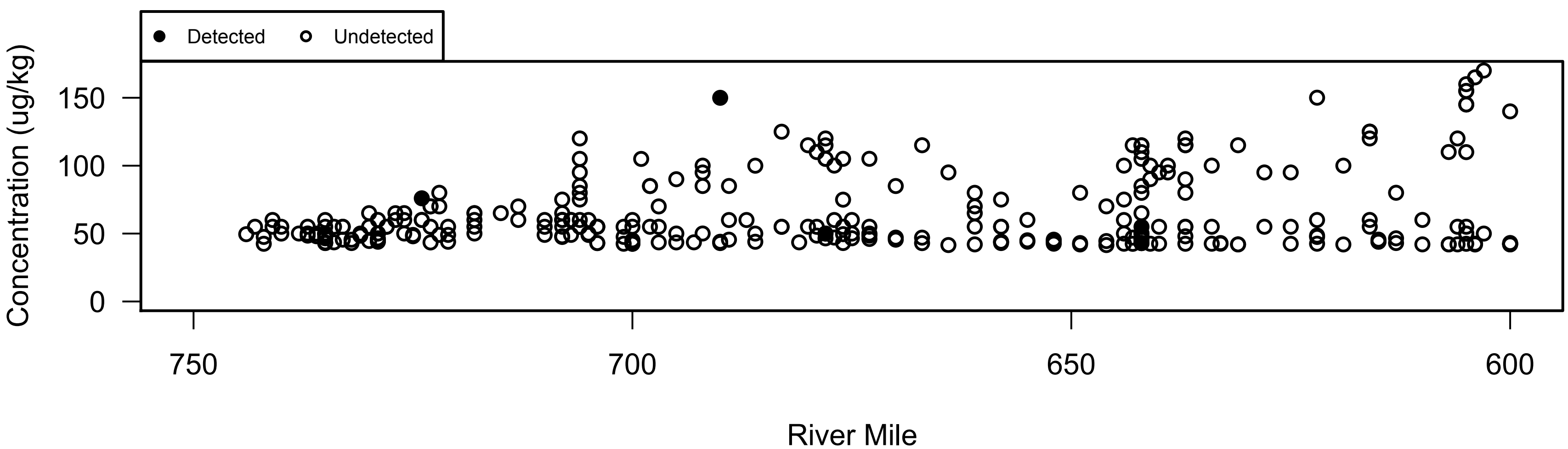


Figure 78. Caprolactam in Phase 1 Surface Sediment by River Mile

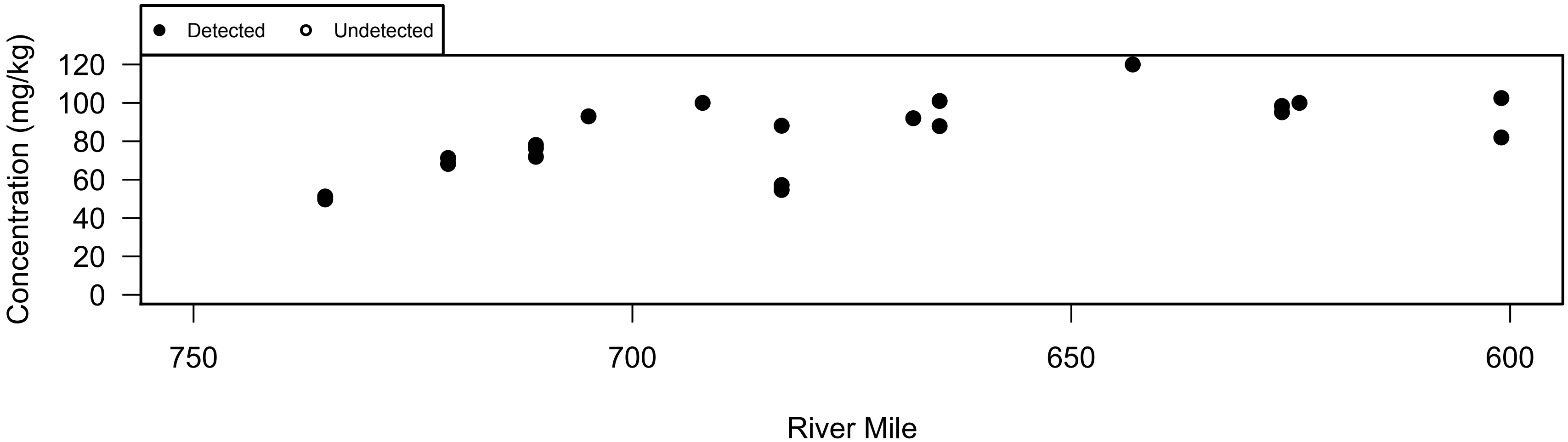


Figure 79. Cerium in Phase 1 Surface Sediment by River Mile

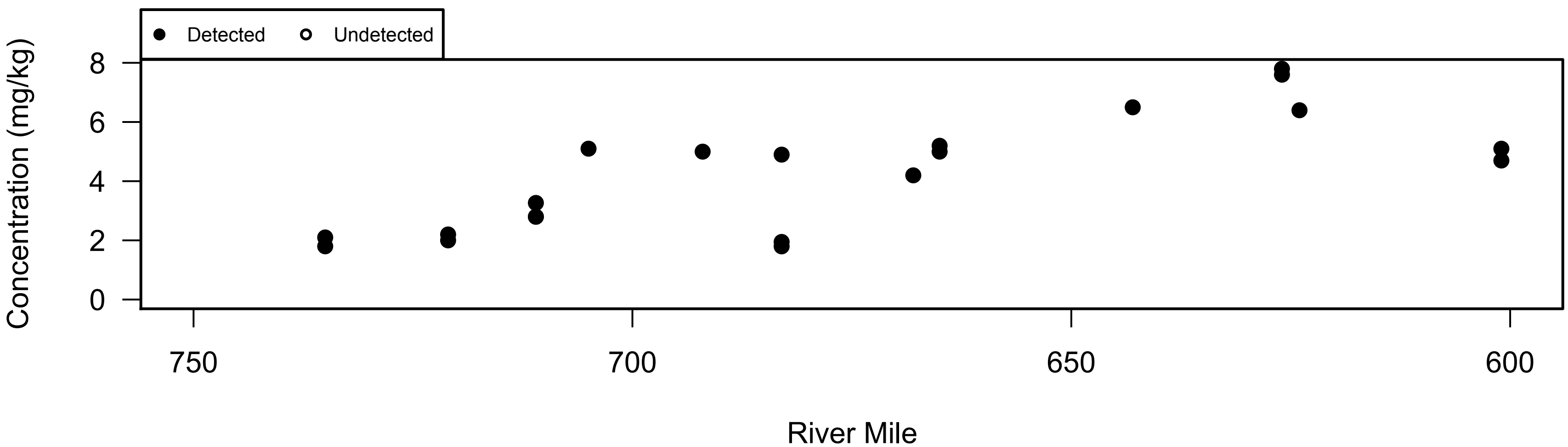


Figure 80. Cesium in Phase 1 Surface Sediment by River Mile

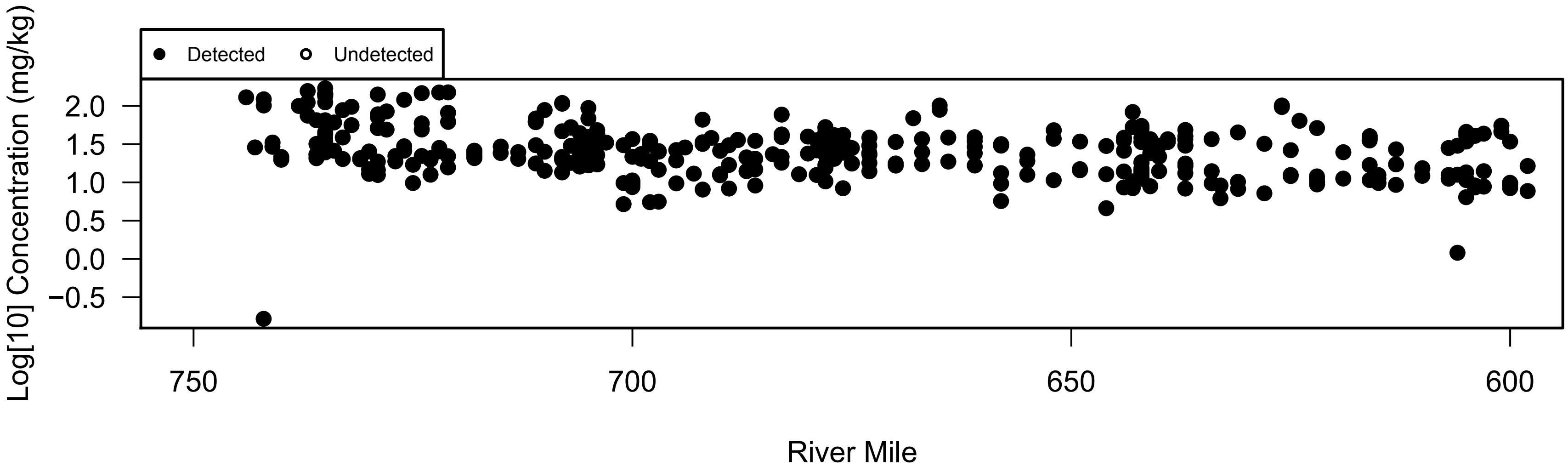


Figure 81. Chromium in Phase 1 Surface Sediment by River Mile

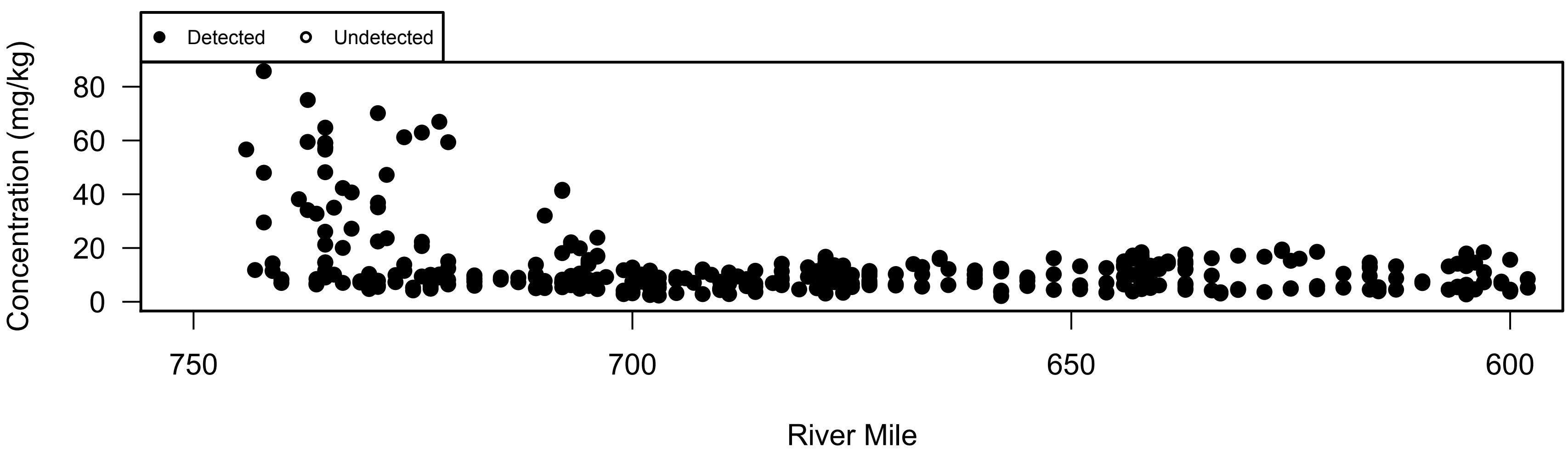


Figure 82. Cobalt in Phase 1 Surface Sediment by River Mile

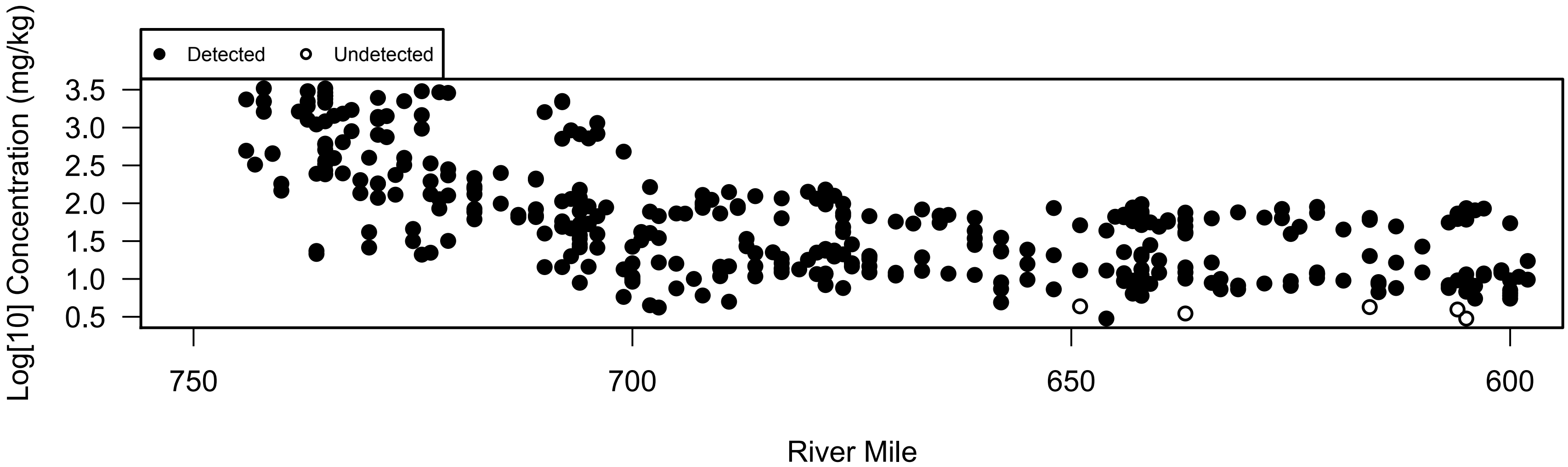


Figure 83. Copper in Phase 1 Surface Sediment
by River Mile

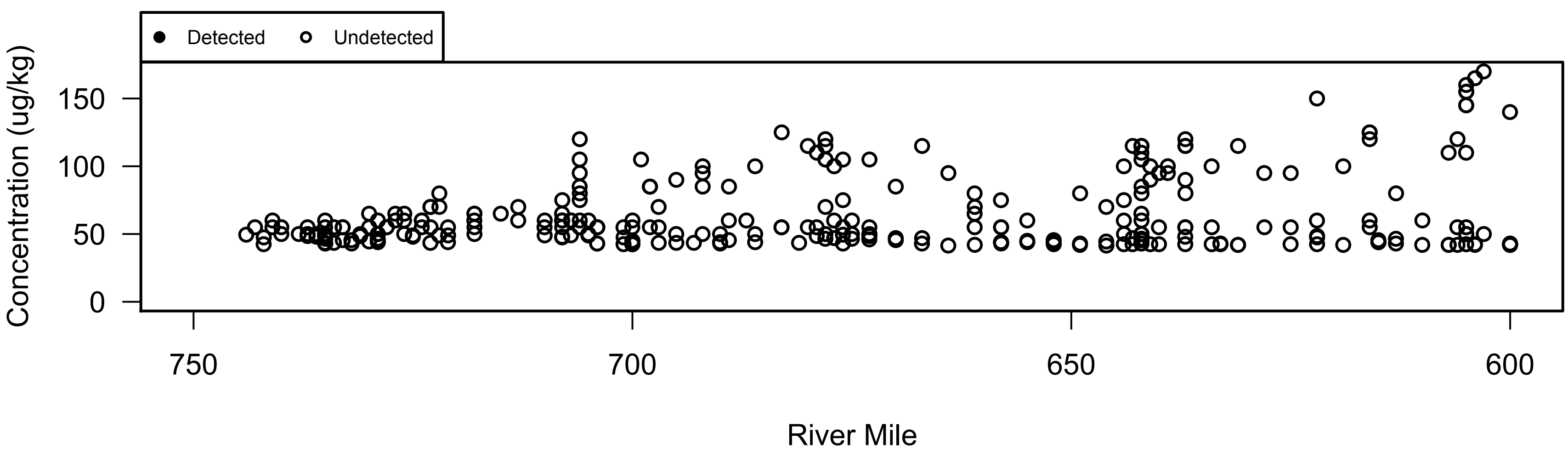


Figure 84. Dimethyl phthalate in Phase 1 Surface Sediment
by River Mile

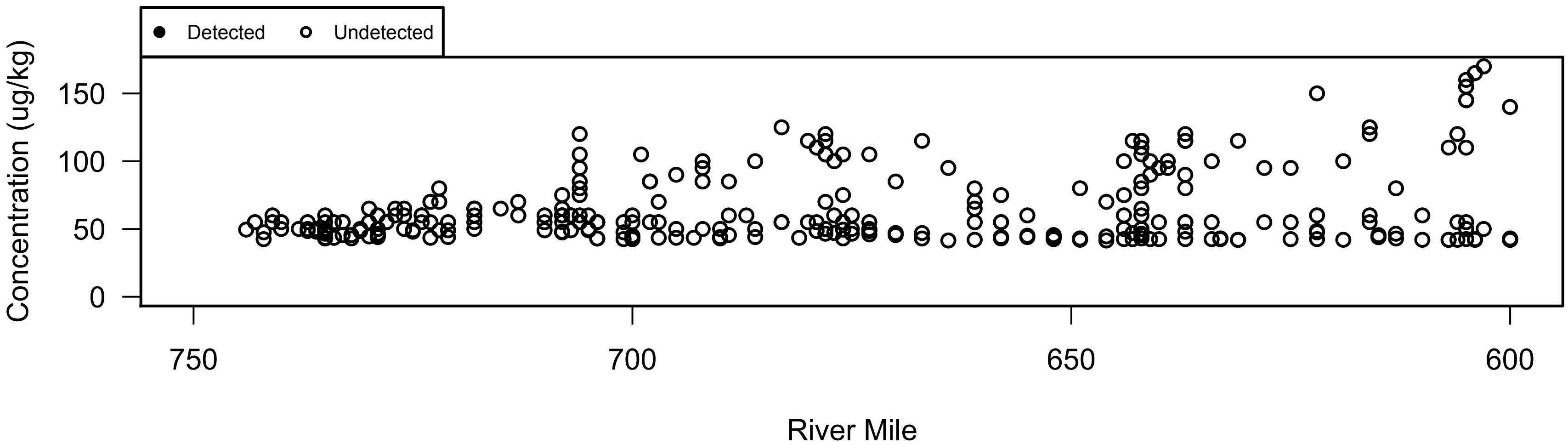


Figure 85. Di−N−octylphthalate in Phase 1 Surface Sediment by River Mile

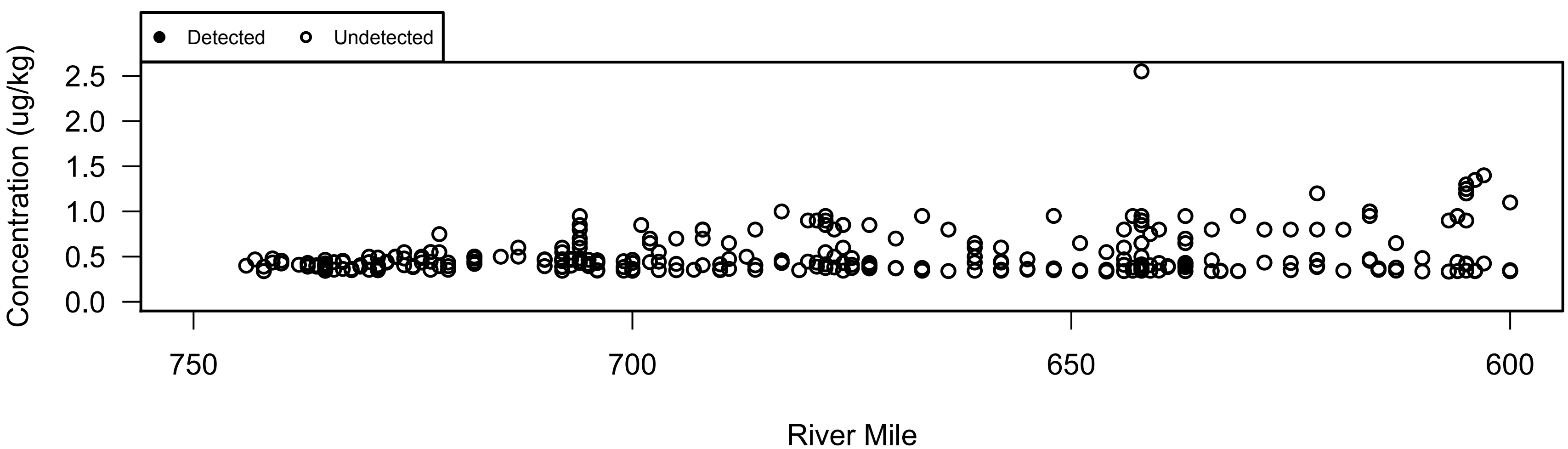


Figure 86. Endrin aldehyde in Phase 1 Surface Sediment by River Mile

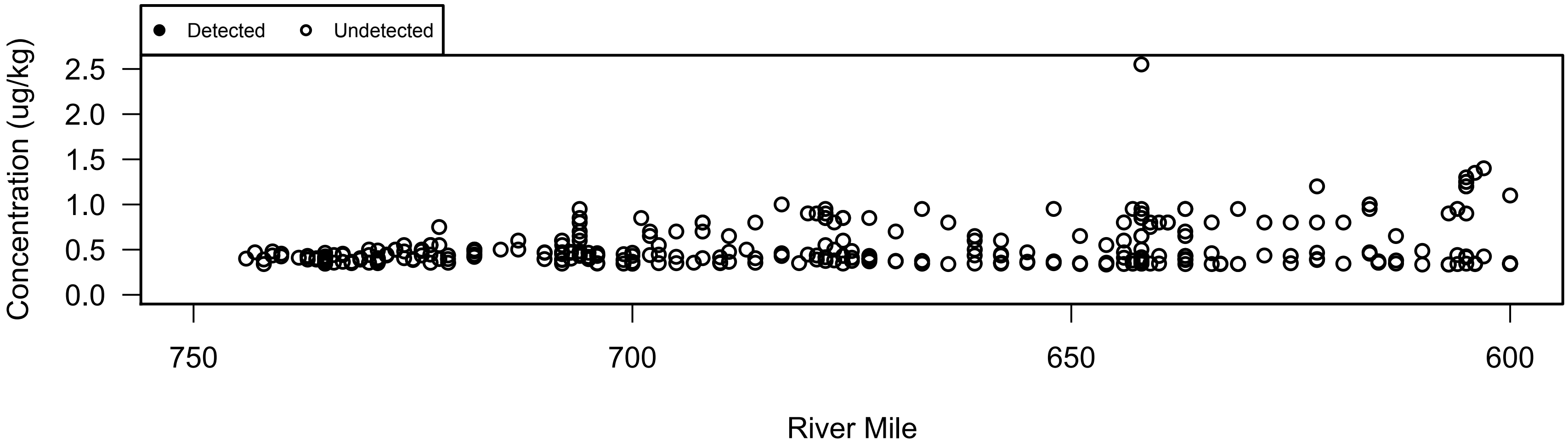


Figure 87. Endrin ketone in Phase 1 Surface Sediment
by River Mile

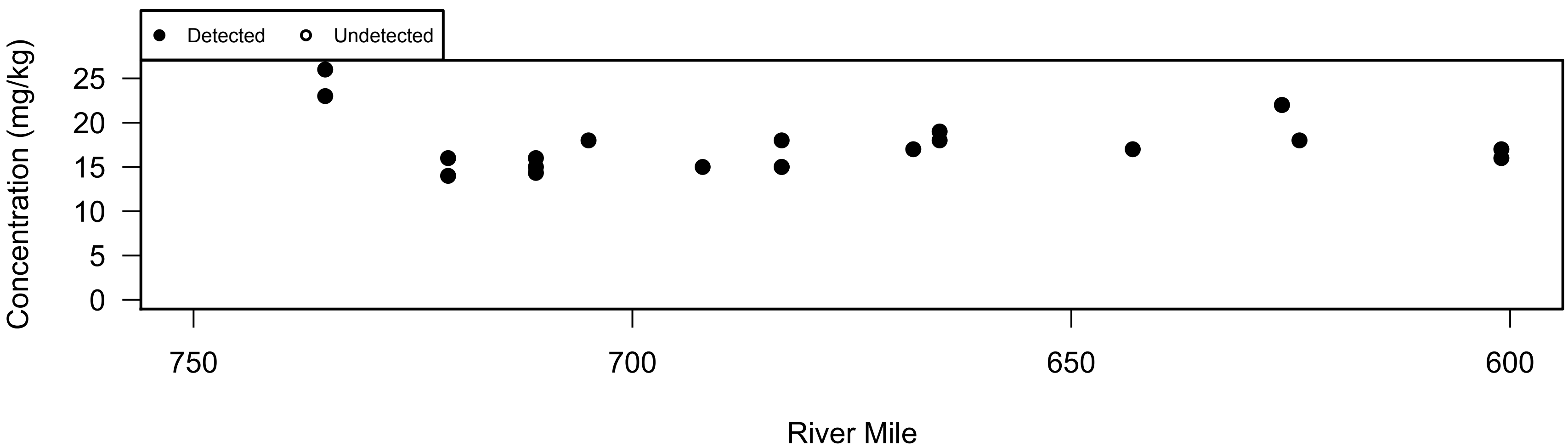


Figure 88. Gallium in Phase 1 Surface Sediment
by River Mile

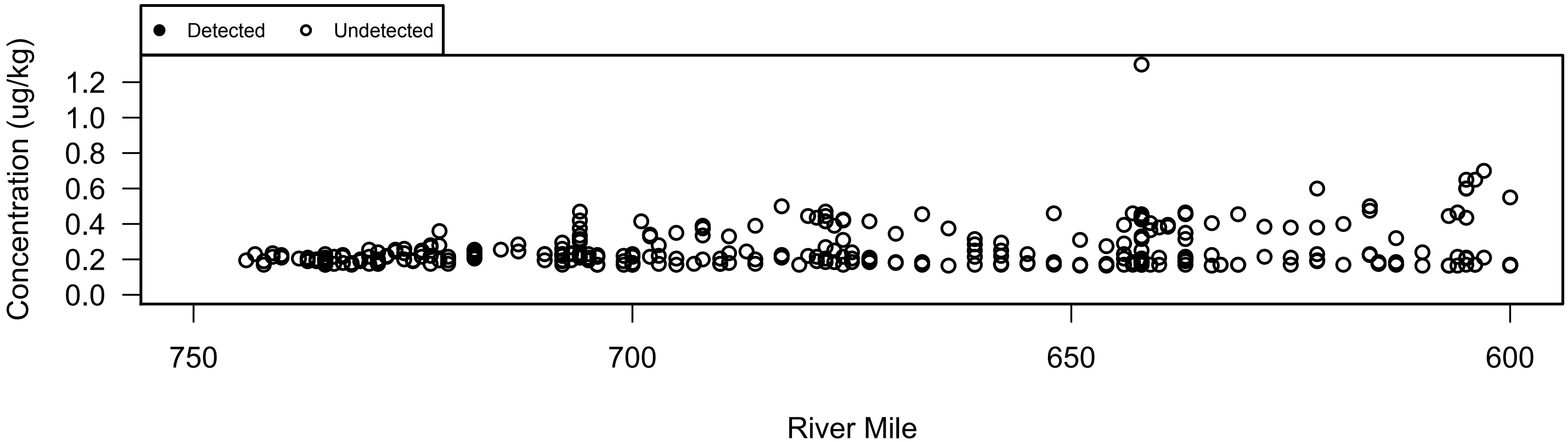


Figure 89. Heptachlor in Phase 1 Surface Sediment
by River Mile

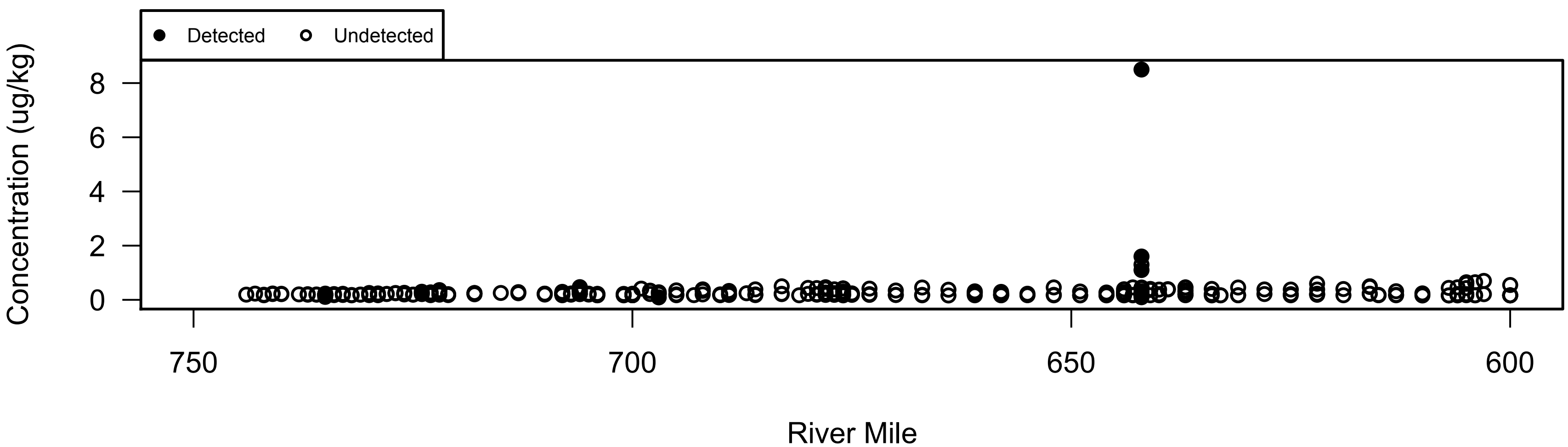


Figure 90. Hexachlorobenzene in Phase 1 Surface Sediment
by River Mile

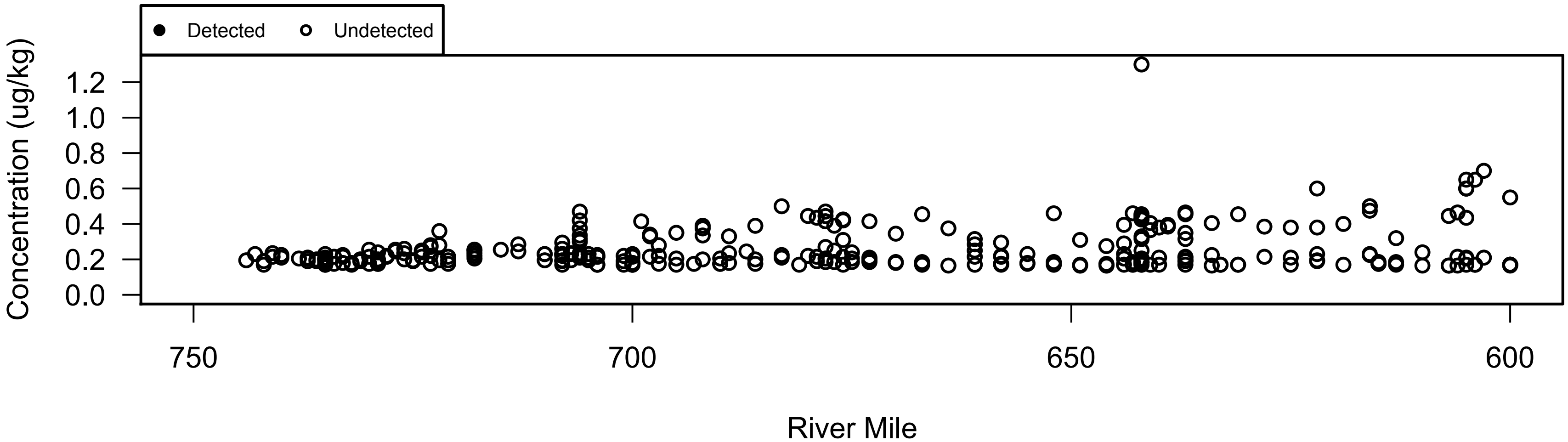


Figure 91. Hexachlorobutadiene in Phase 1 Surface Sediment by River Mile

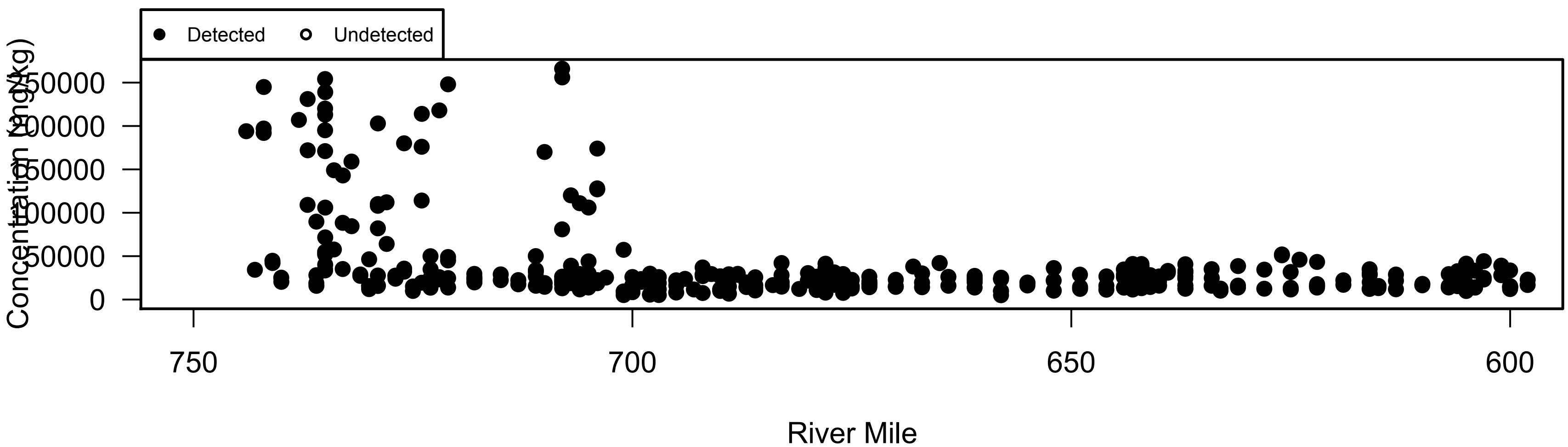


Figure 92. Iron in Phase 1 Surface Sediment by River Mile

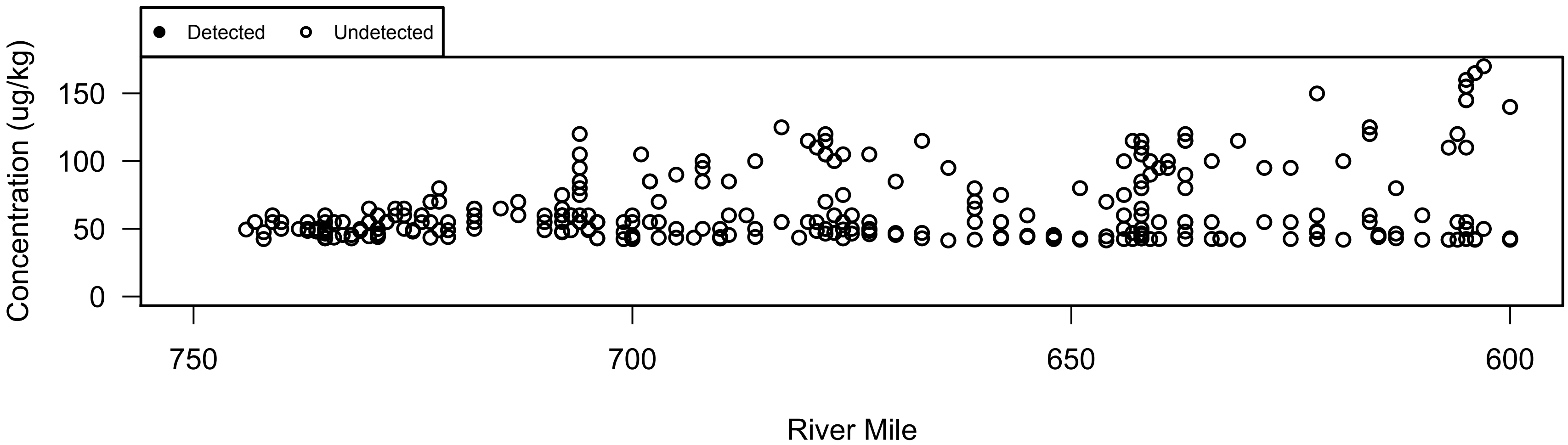


Figure 93. Isophorone in Phase 1 Surface Sediment by River Mile

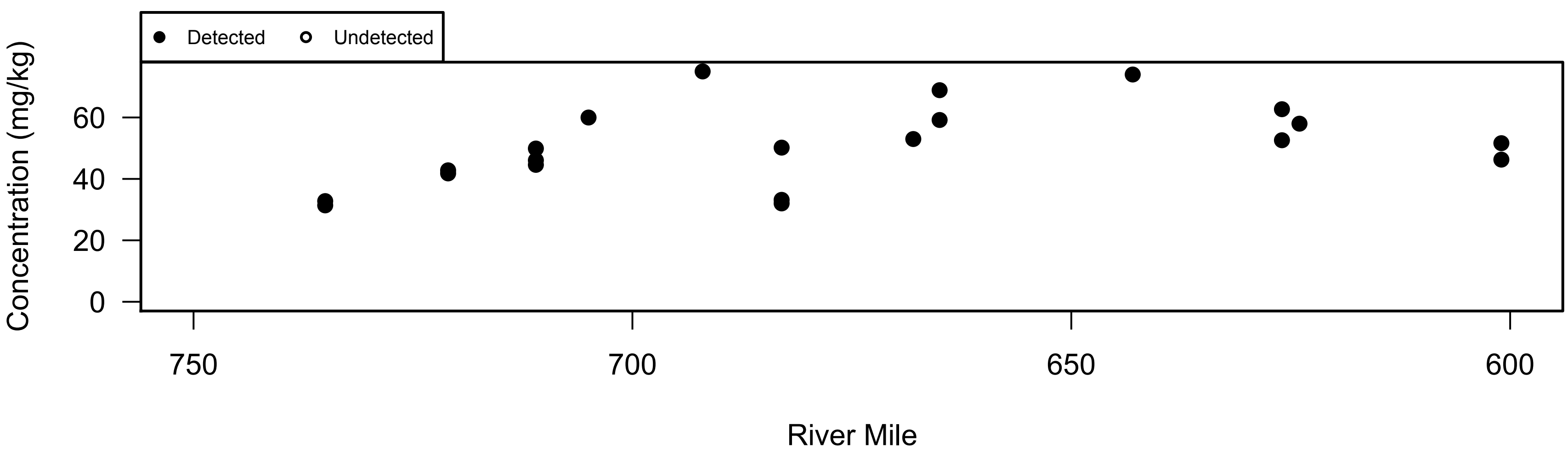


Figure 94. Lanthanum in Phase 1 Surface Sediment by River Mile

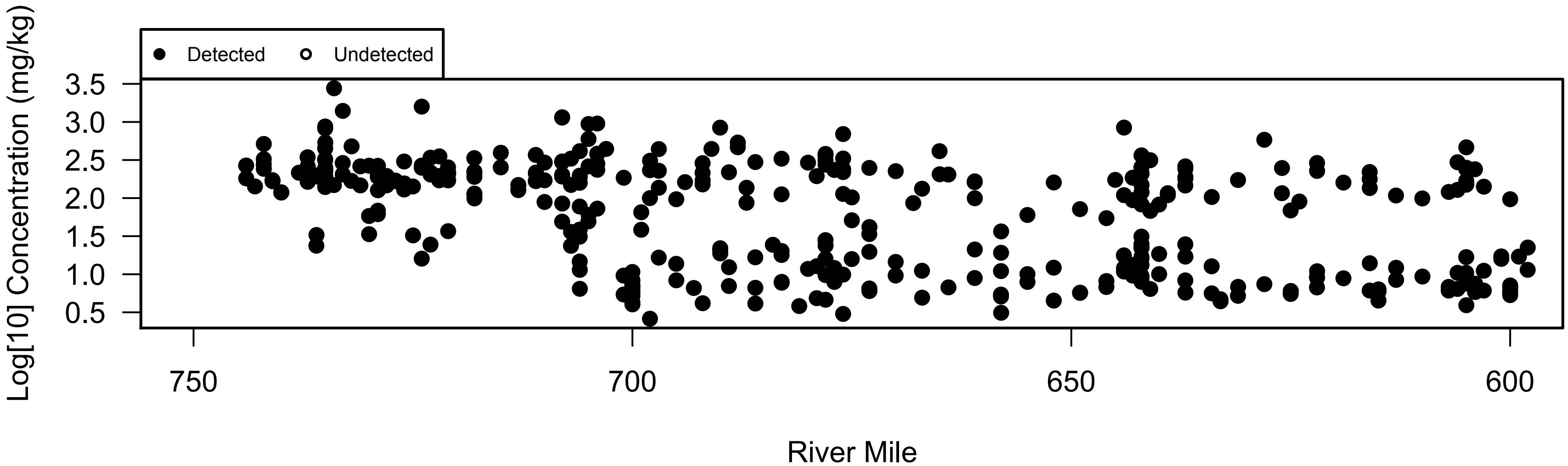


Figure 95. Lead in Phase 1 Surface Sediment by River Mile

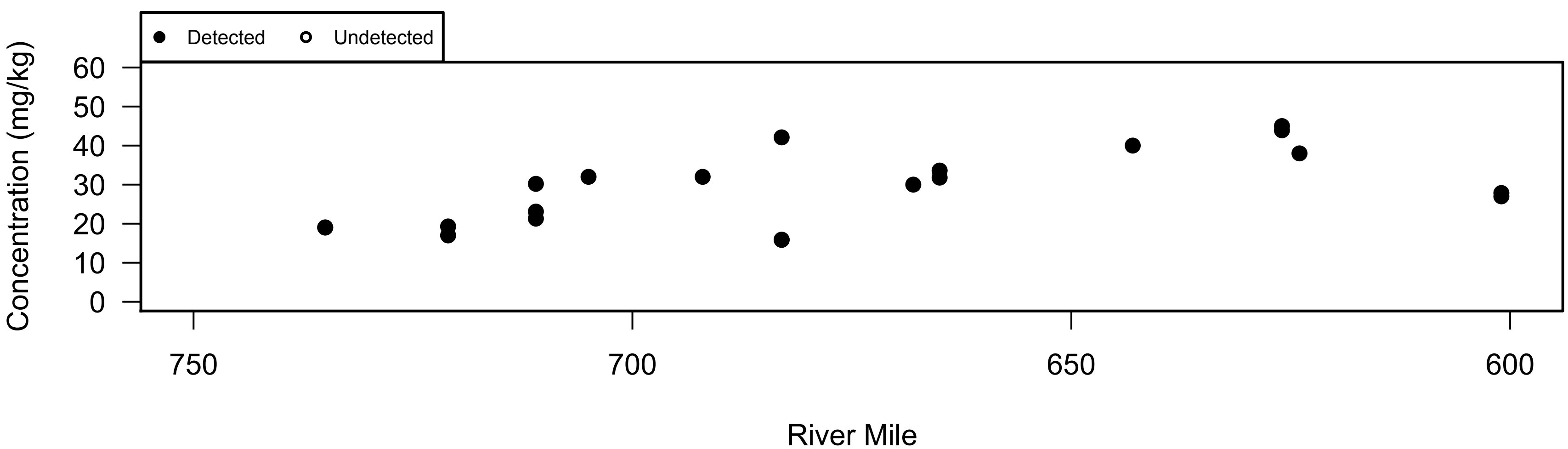


Figure 96. Lithium in Phase 1 Surface Sediment by River Mile

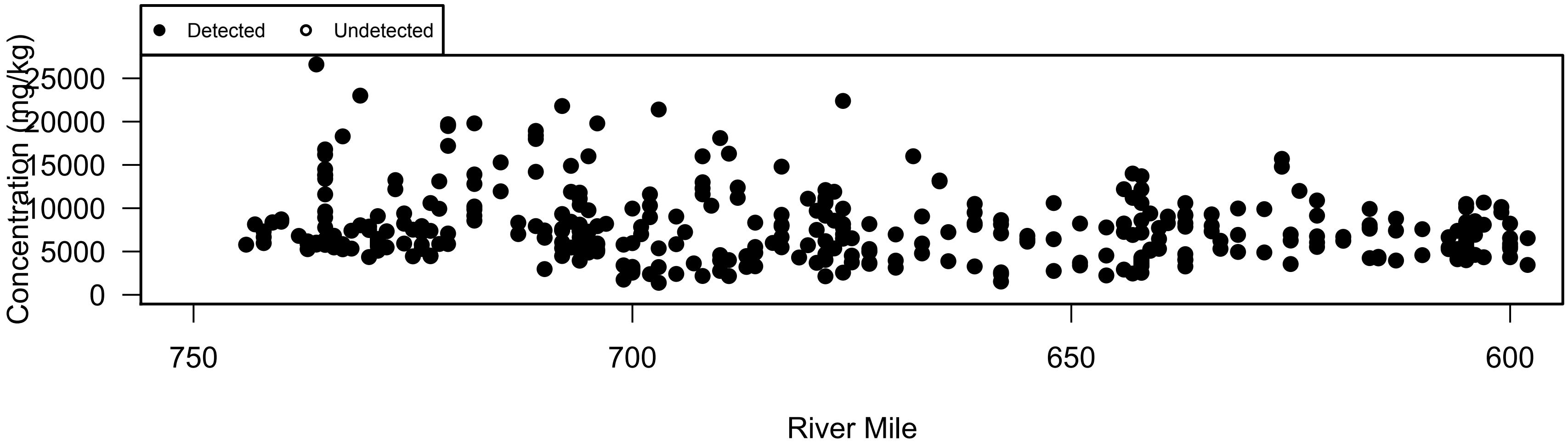


Figure 97. Magnesium in Phase 1 Surface Sediment
by River Mile

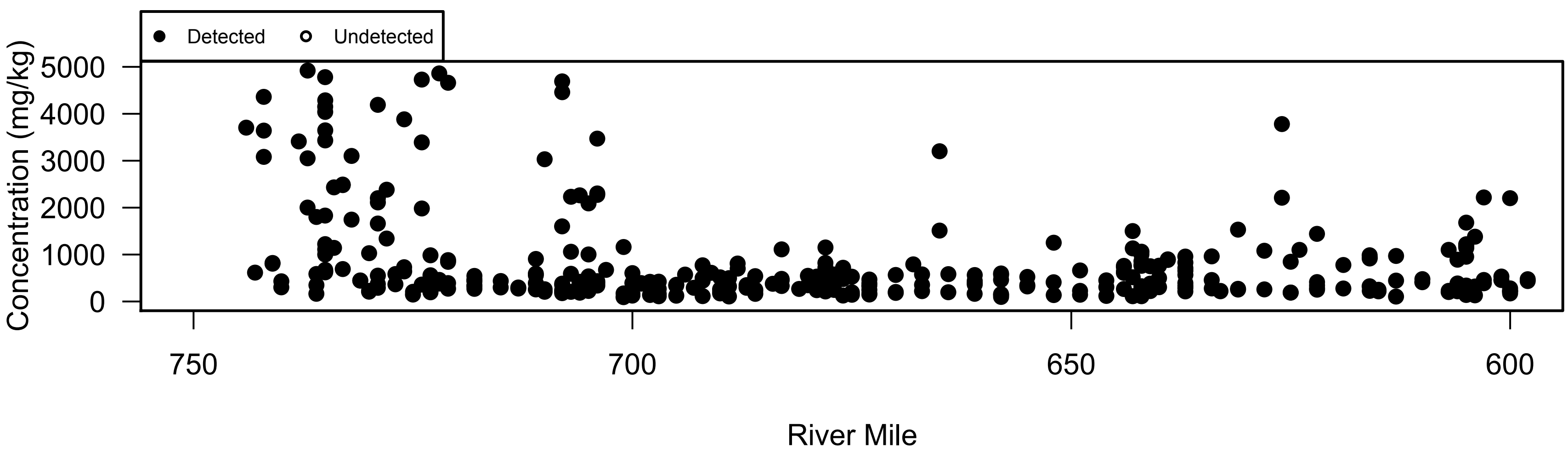


Figure 98. Manganese in Phase 1 Surface Sediment
by River Mile

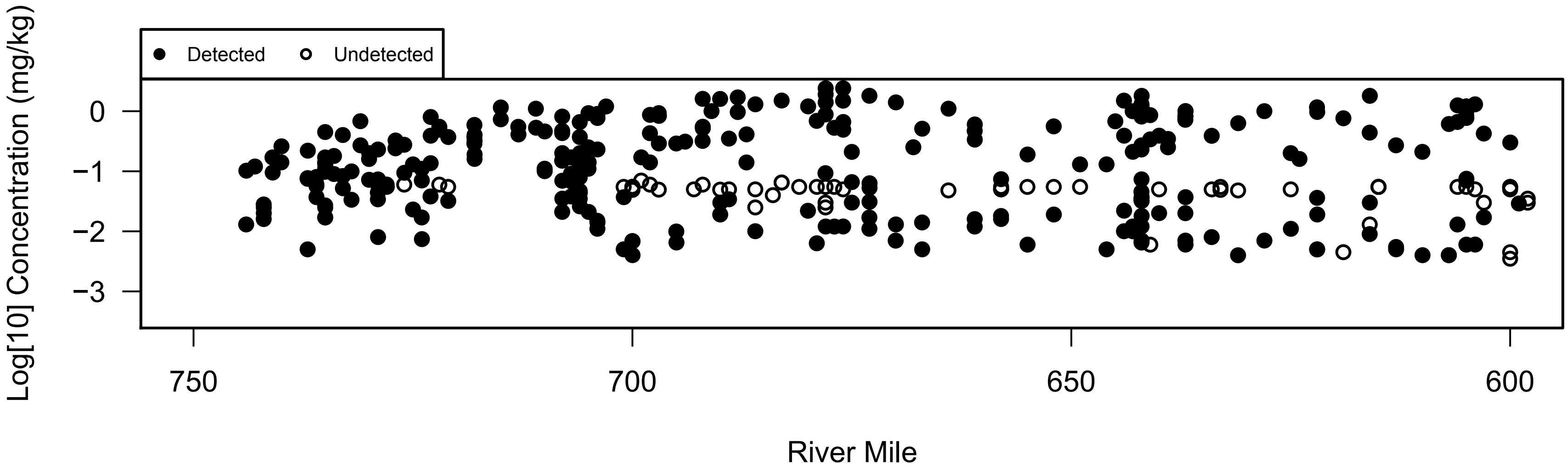


Figure 99. Mercury in Phase 1 Surface Sediment by River Mile

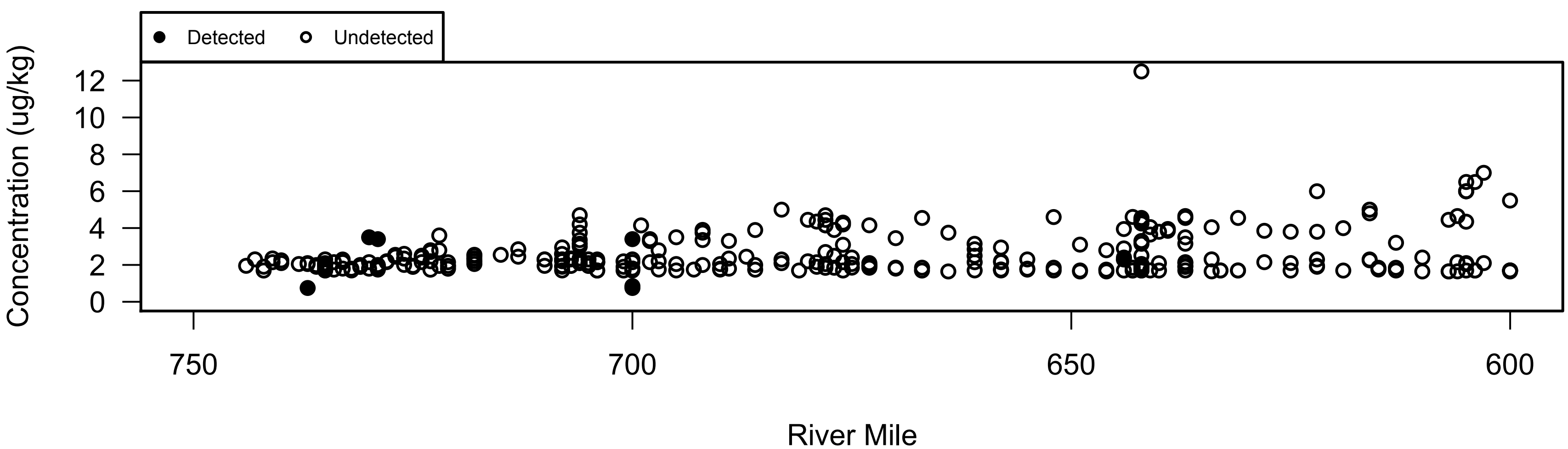


Figure 100. Methoxychlor in Phase 1 Surface Sediment by River Mile

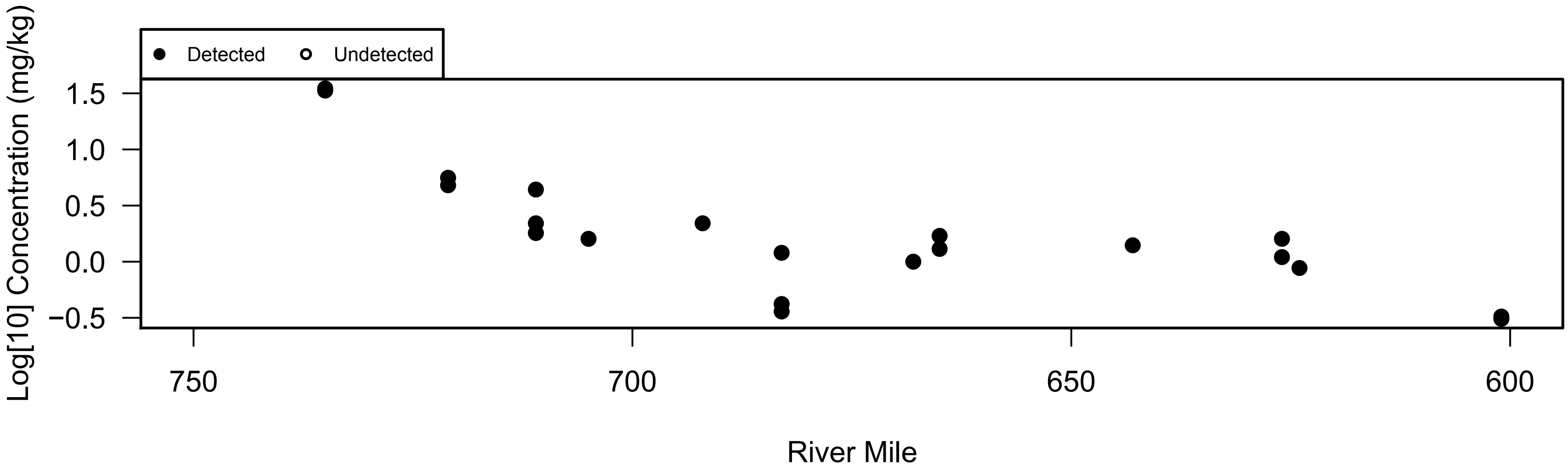


Figure 101. Molybdenum in Phase 1 Surface Sediment by River Mile

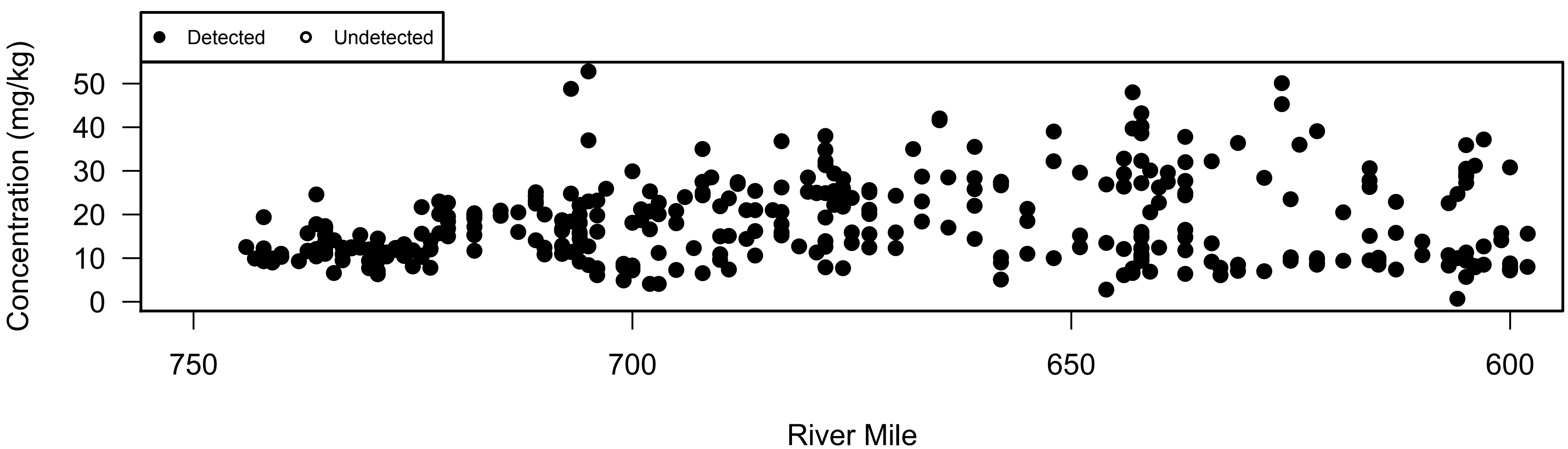


Figure 102. Nickel in Phase 1 Surface Sediment by River Mile

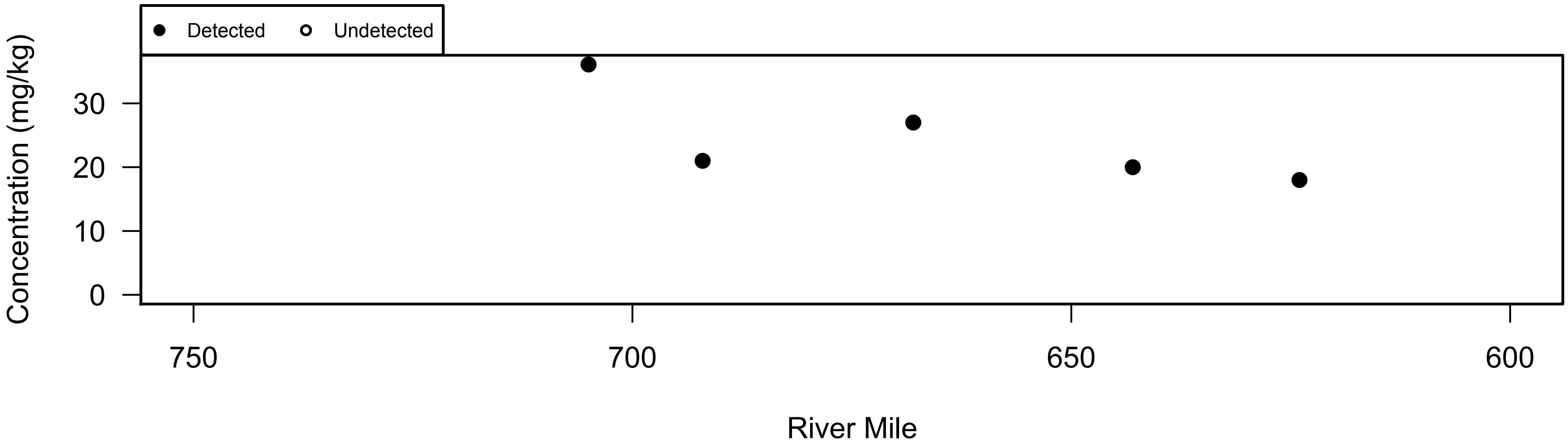


Figure 103. Niobium in Phase 1 Surface Sediment by River Mile

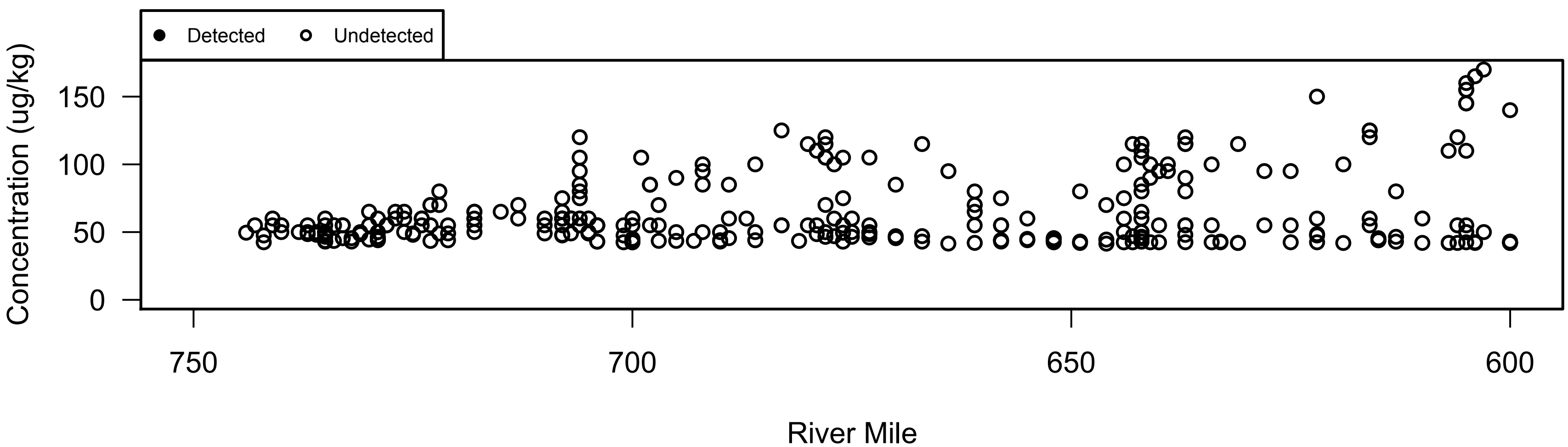


Figure 104. Nitrobenzene in Phase 1 Surface Sediment by River Mile

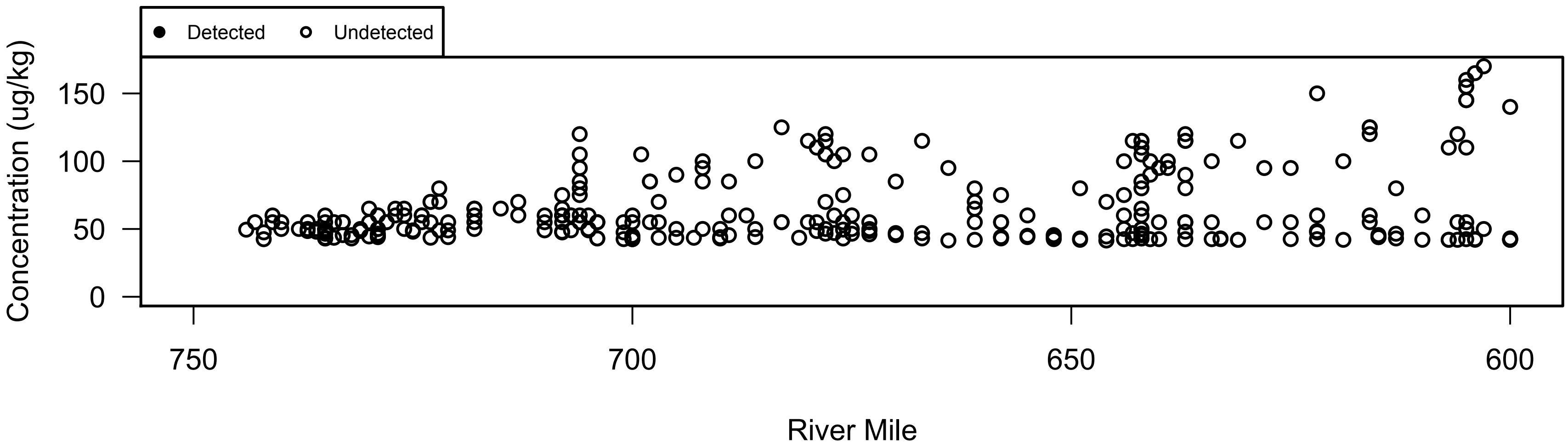


Figure 105. N−nitrosodi−N−propylamine in Phase 1 Surface Sediment by River Mile

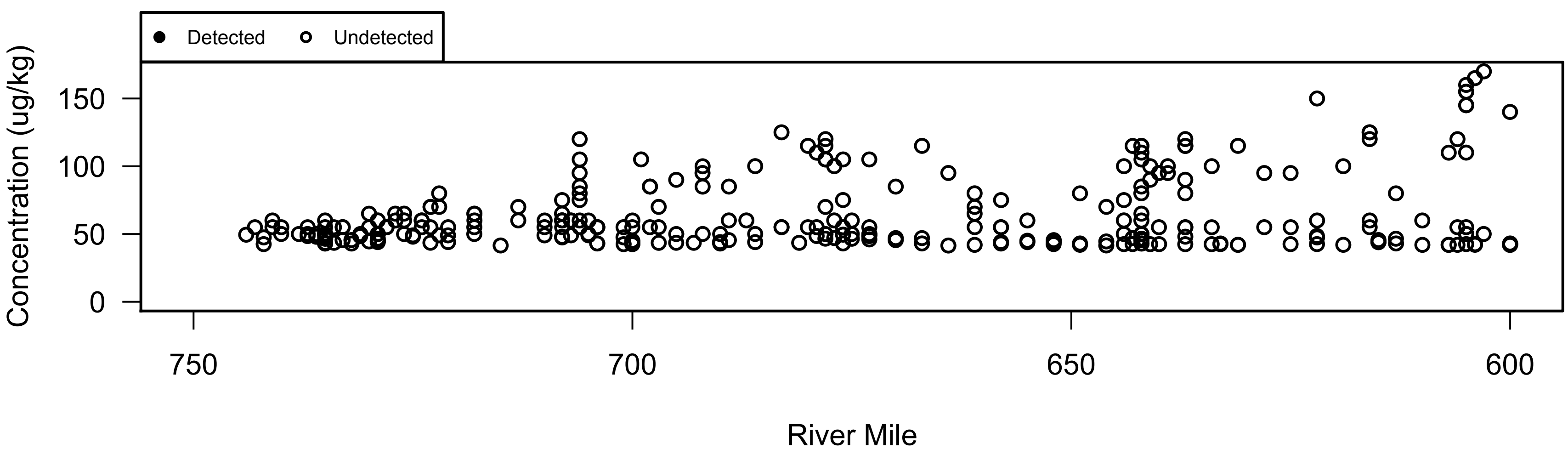


Figure 106. N−nitrosodiphenylamine in Phase 1 Surface Sediment by River Mile

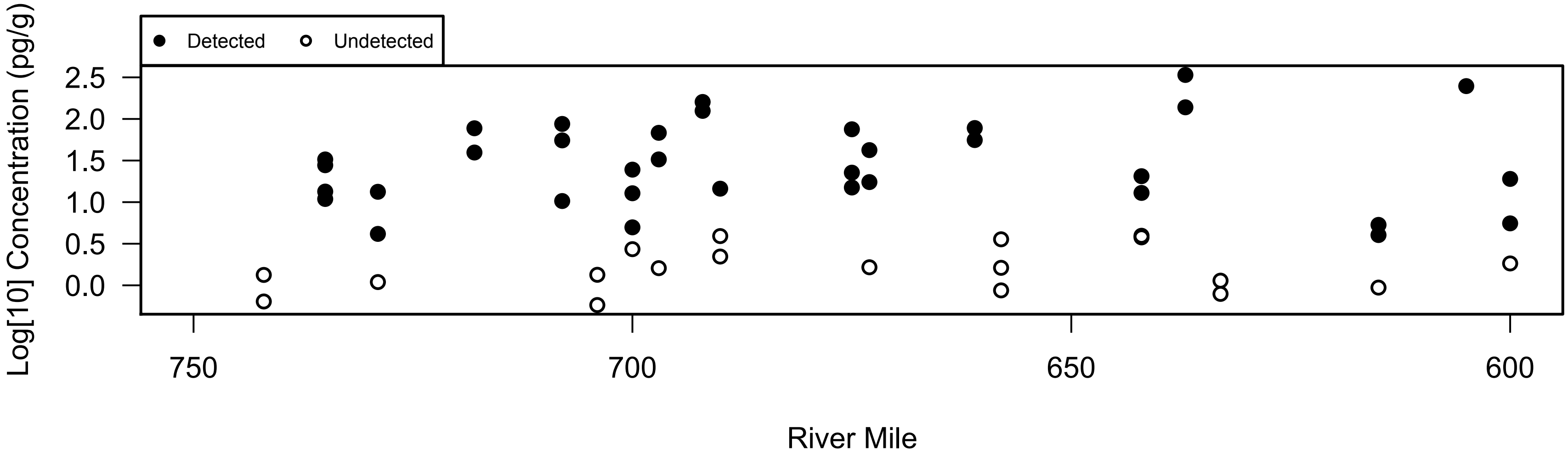


Figure 107. Octachlorodibenzodioxin in Phase 1 Surface Sediment by River Mile

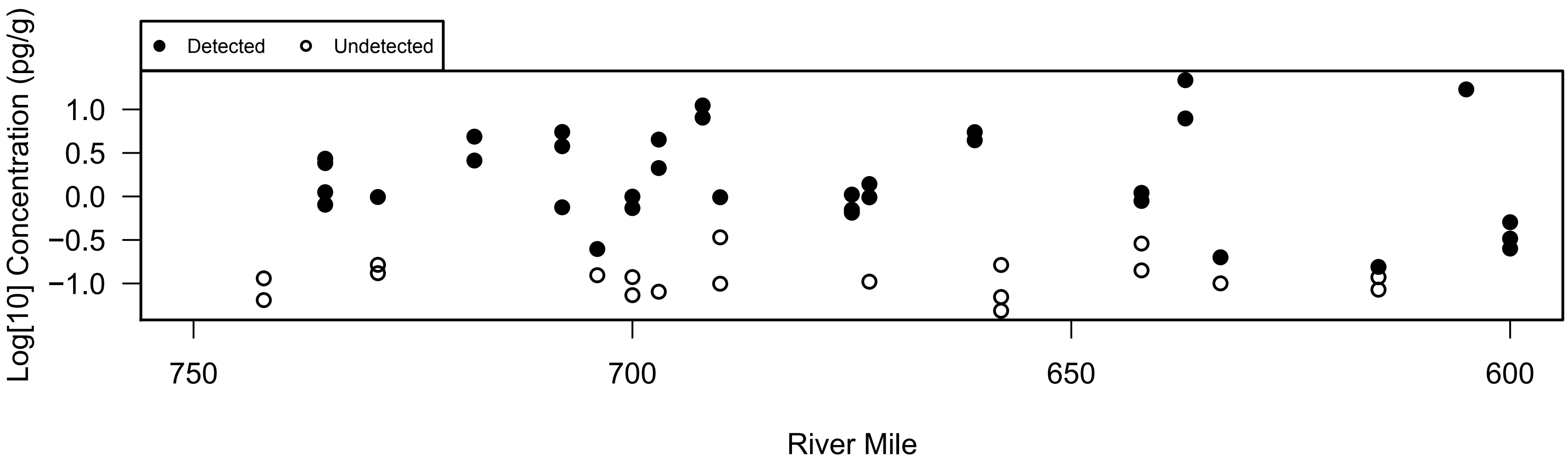


Figure 108. Octachlorodibenzofuran in Phase 1 Surface Sediment by River Mile

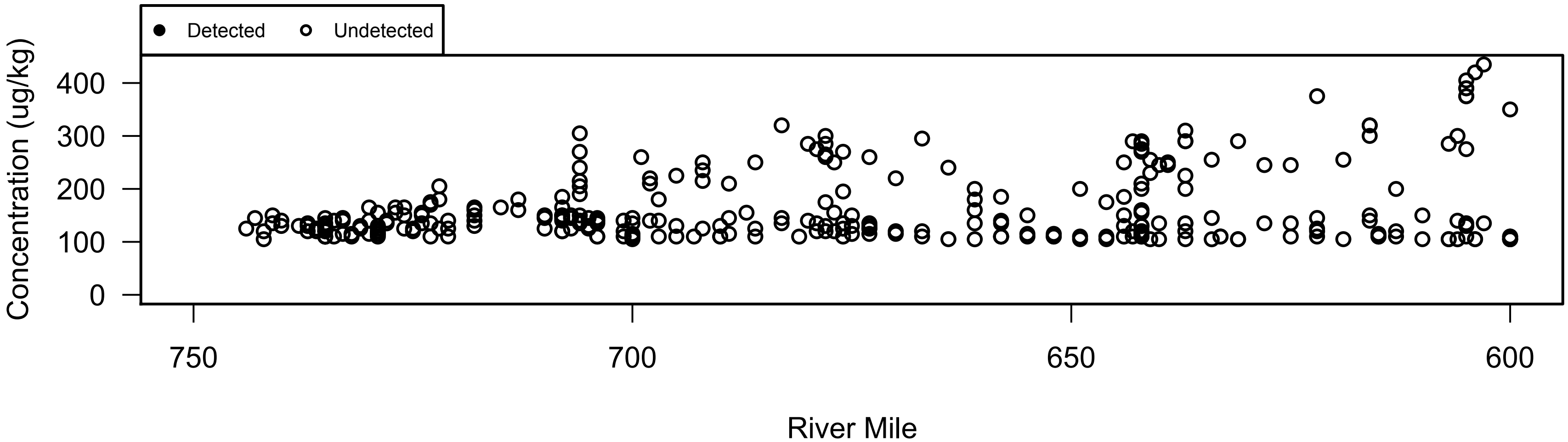


Figure 109. Pentachlorophenol in Phase 1 Surface Sediment by River Mile

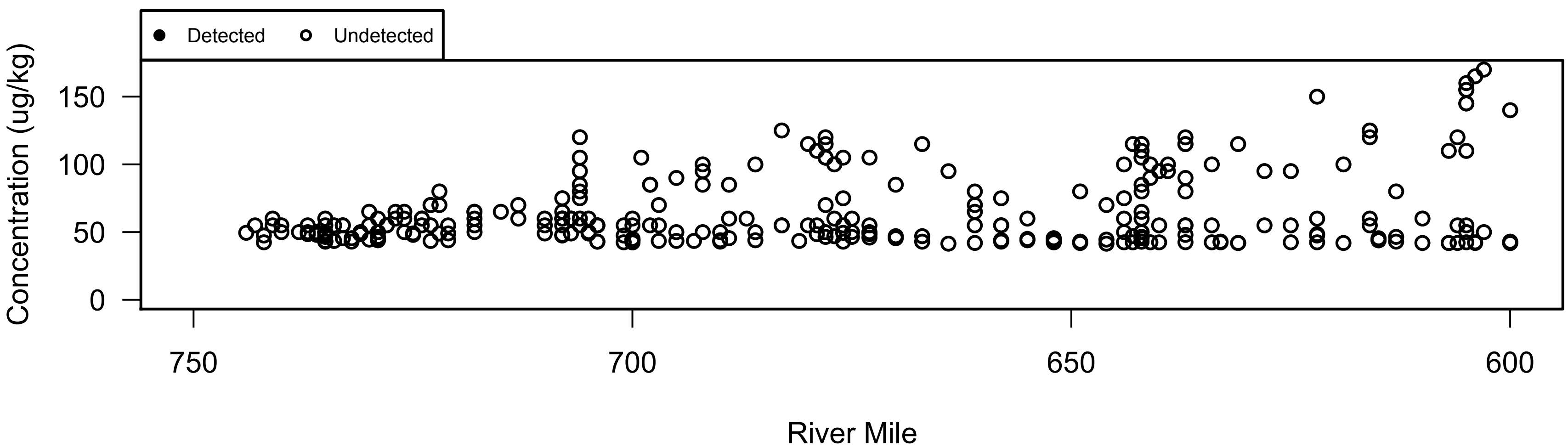


Figure 110. Phenol in Phase 1 Surface Sediment by River Mile

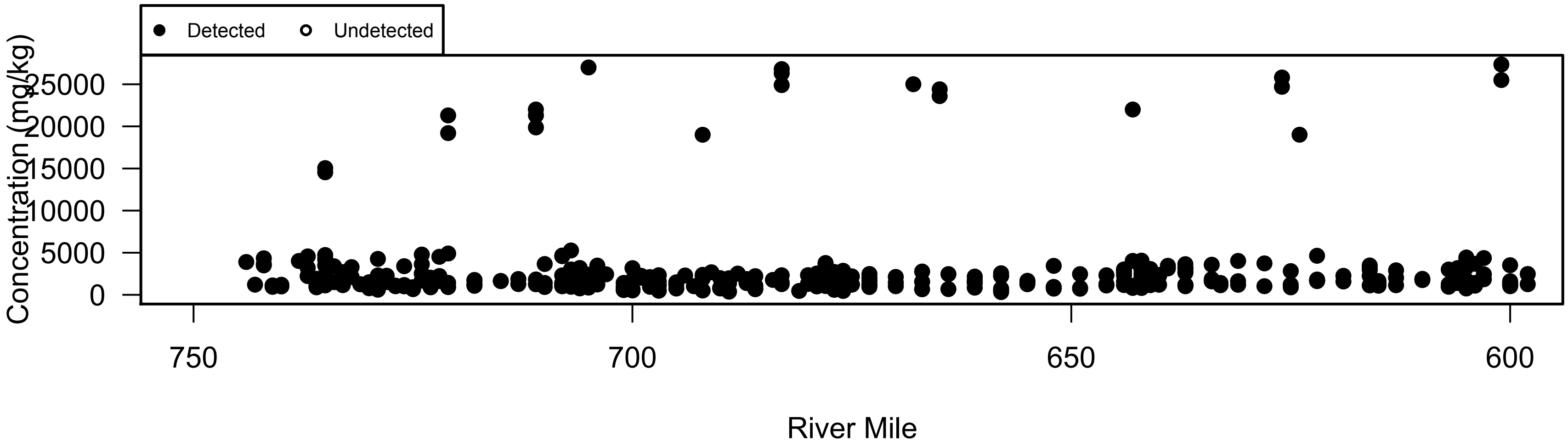


Figure 111. Potassium in Phase 1 Surface Sediment by River Mile

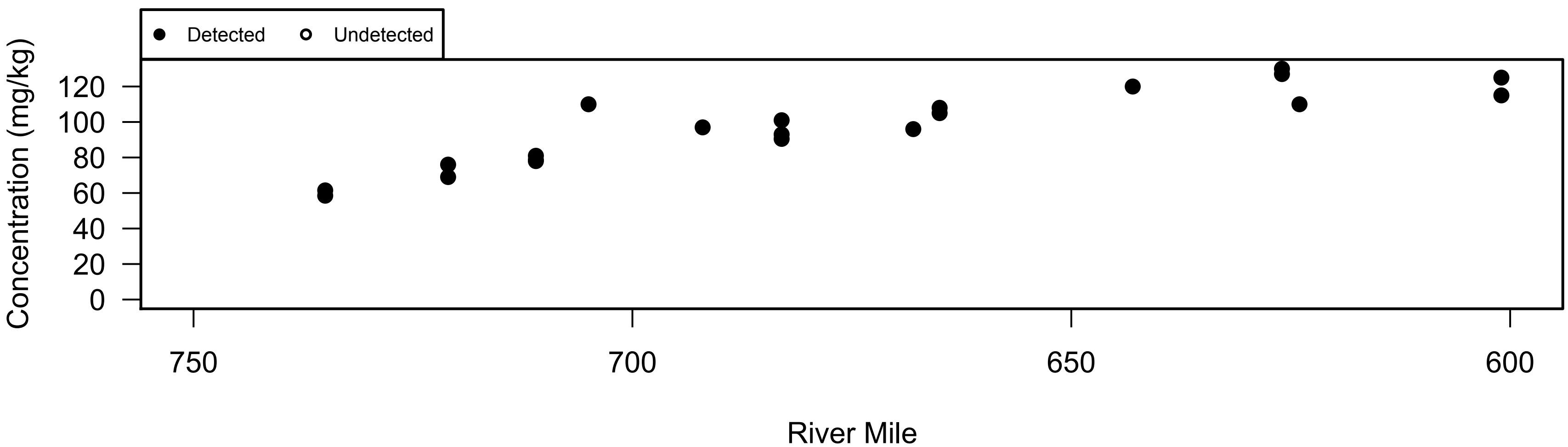


Figure 112. Rubidium in Phase 1 Surface Sediment by River Mile

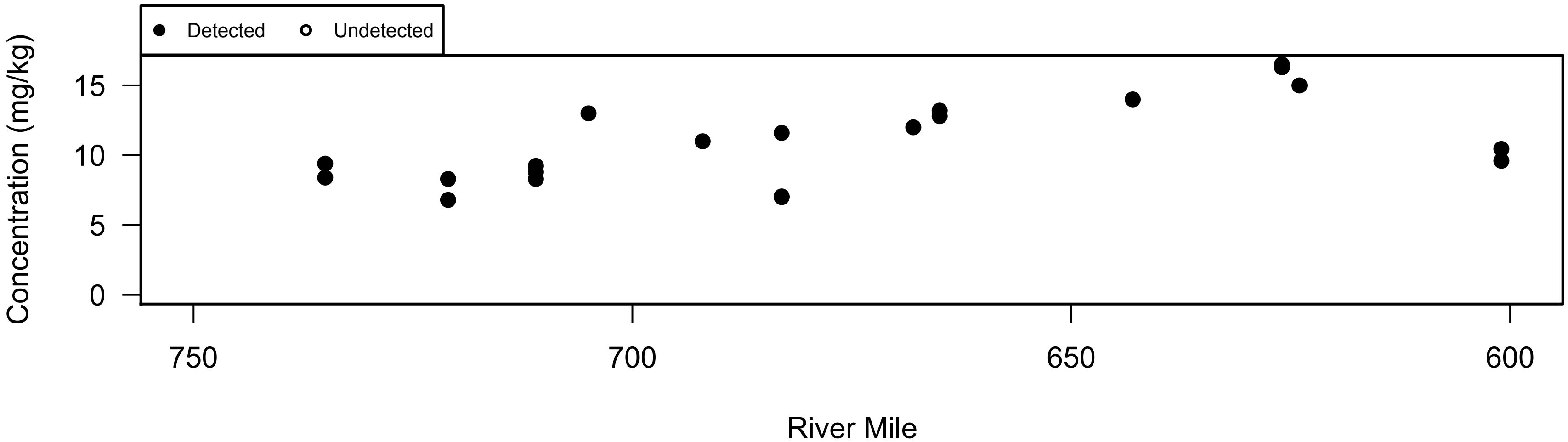


Figure 113. Scandium in Phase 1 Surface Sediment by River Mile

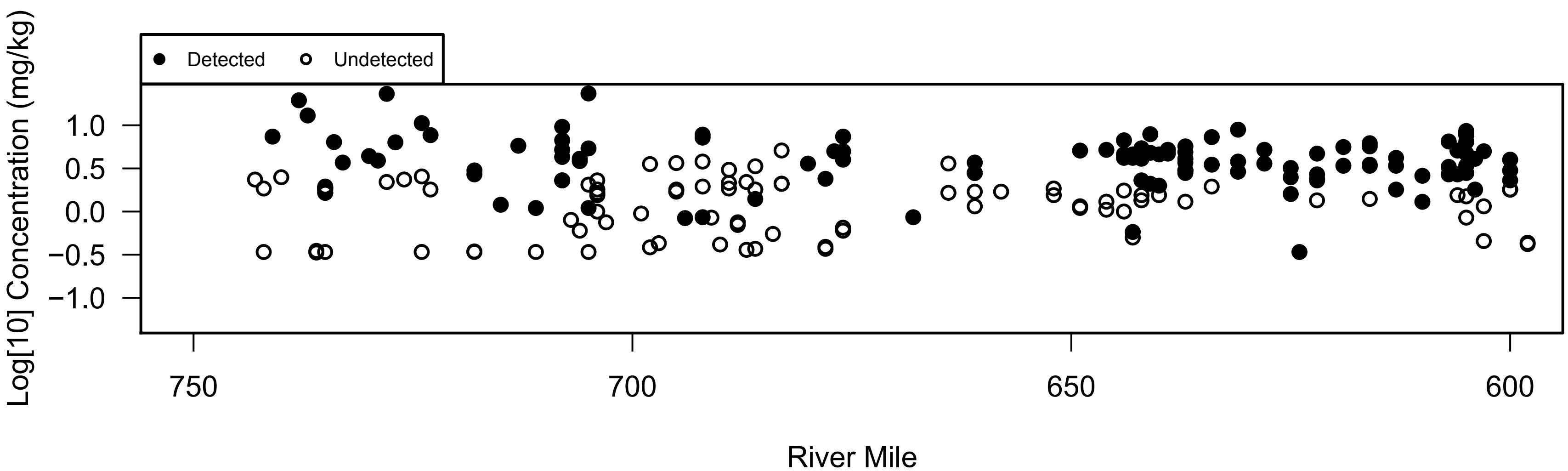


Figure 114. Selenium in Phase 1 Surface Sediment by River Mile

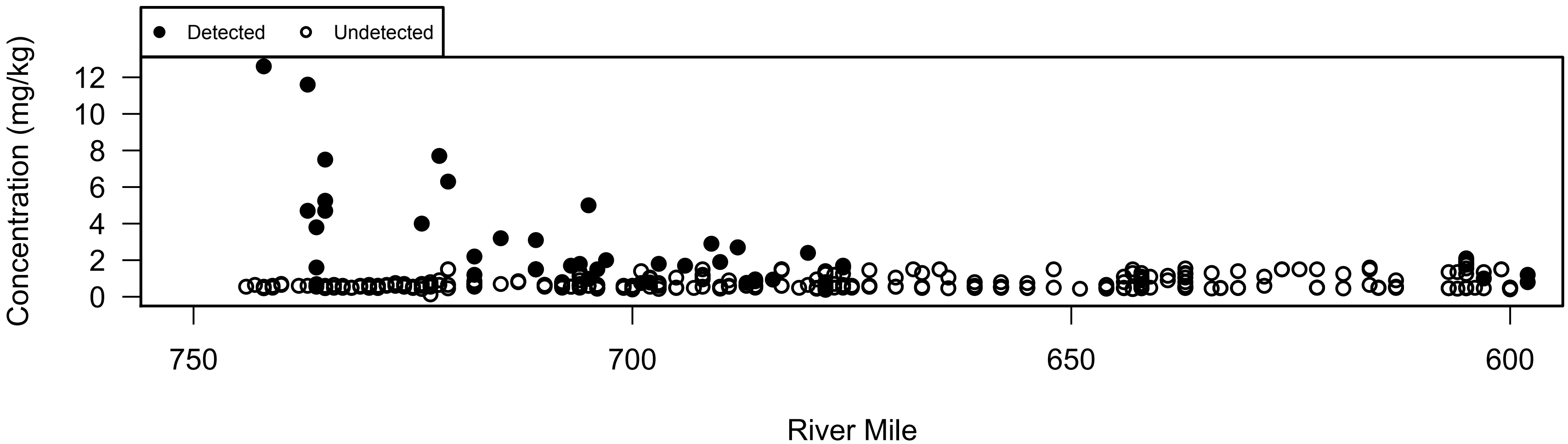


Figure 115. Silver in Phase 1 Surface Sediment by River Mile

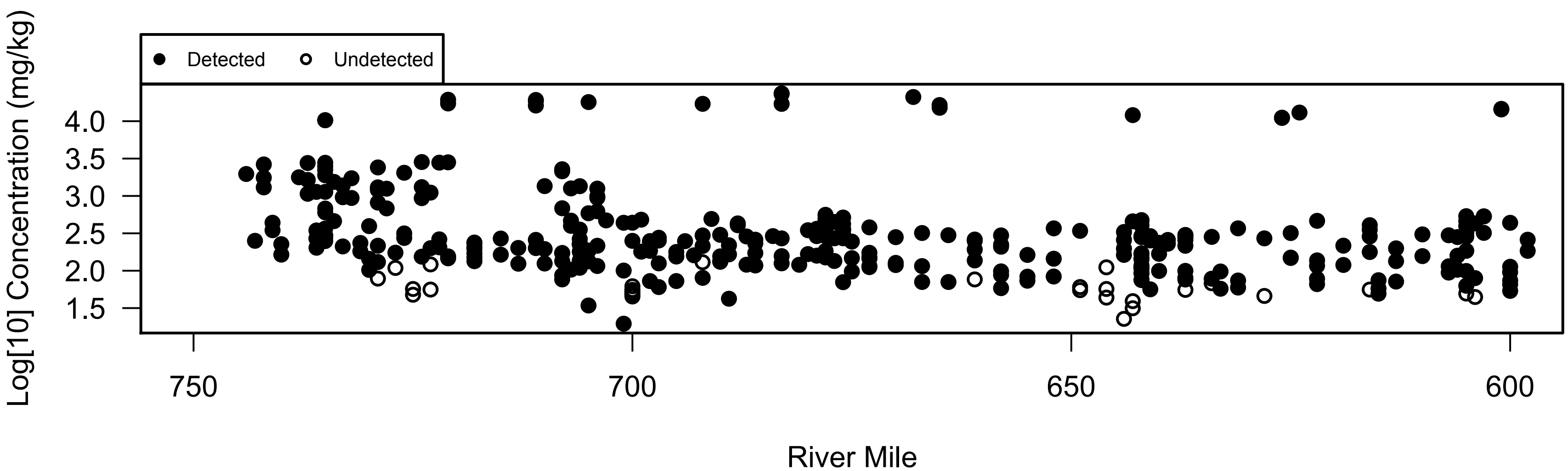


Figure 116. Sodium in Phase 1 Surface Sediment by River Mile

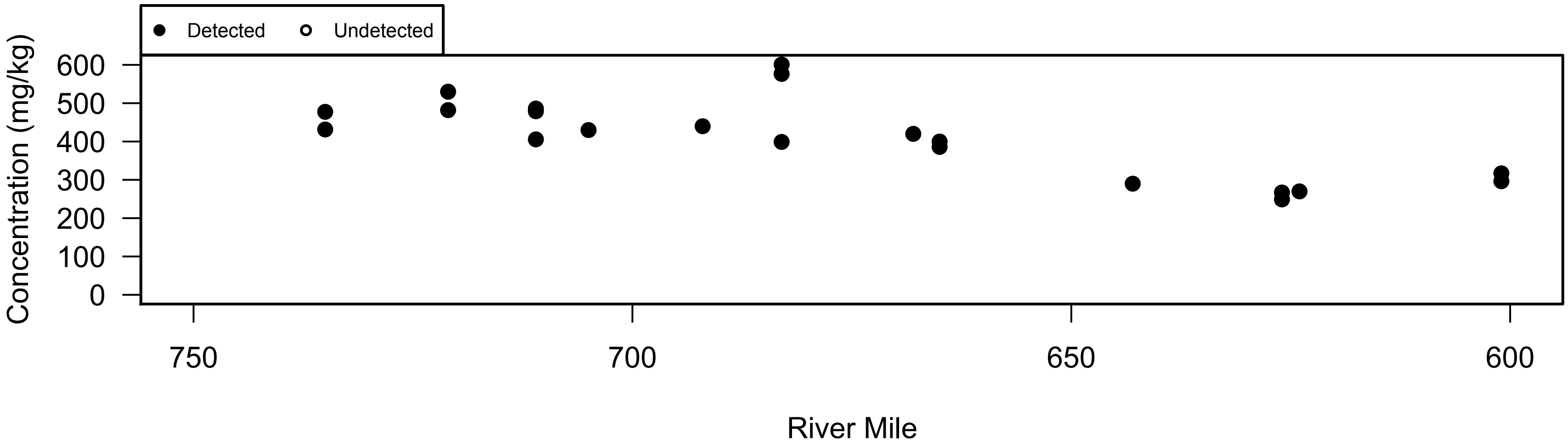


Figure 117. Strontium in Phase 1 Surface Sediment by River Mile

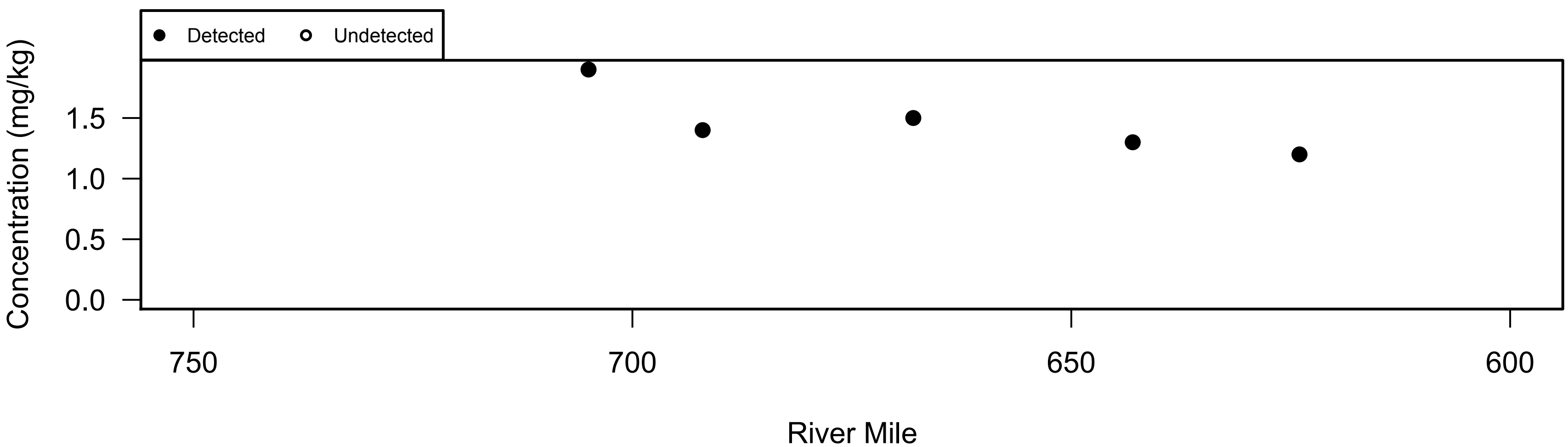


Figure 118. Tantalum in Phase 1 Surface Sediment by River Mile

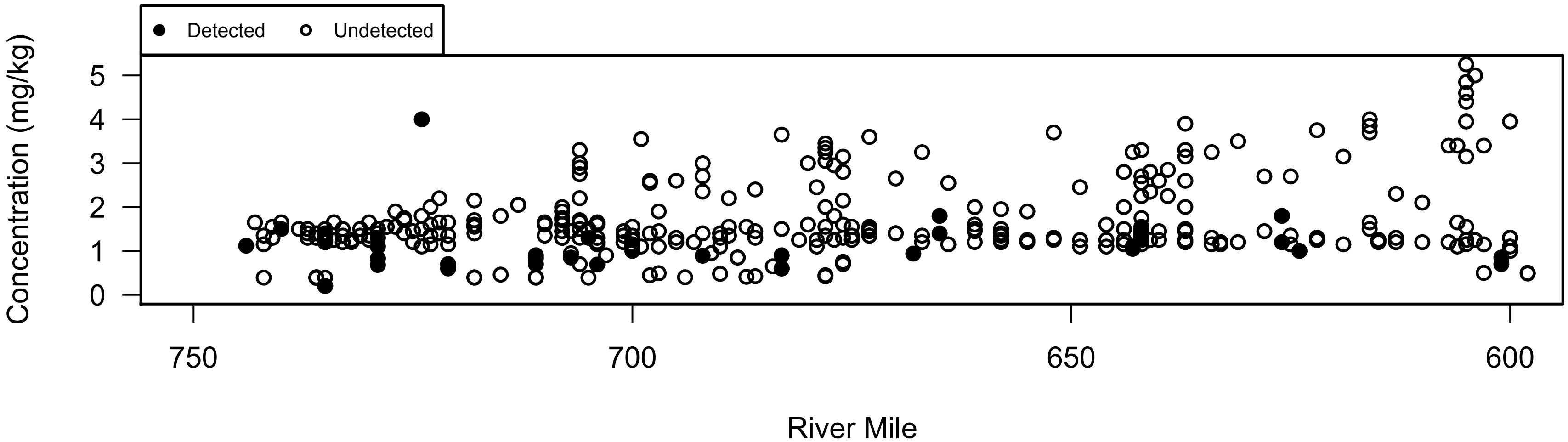


Figure 119. Thallium in Phase 1 Surface Sediment by River Mile

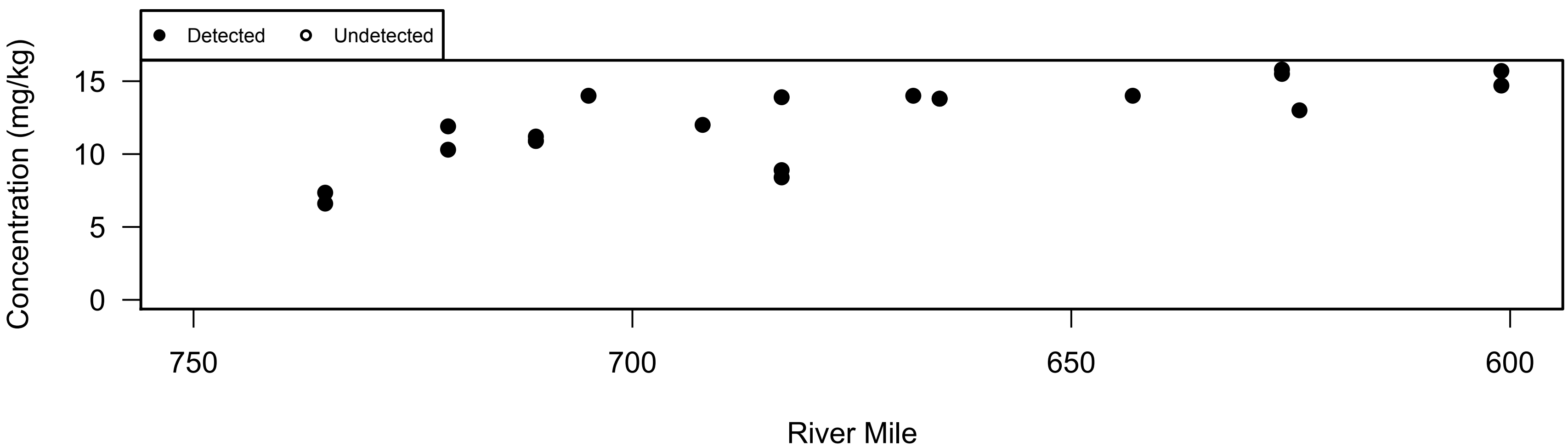


Figure 120. Thorium in Phase 1 Surface Sediment by River Mile

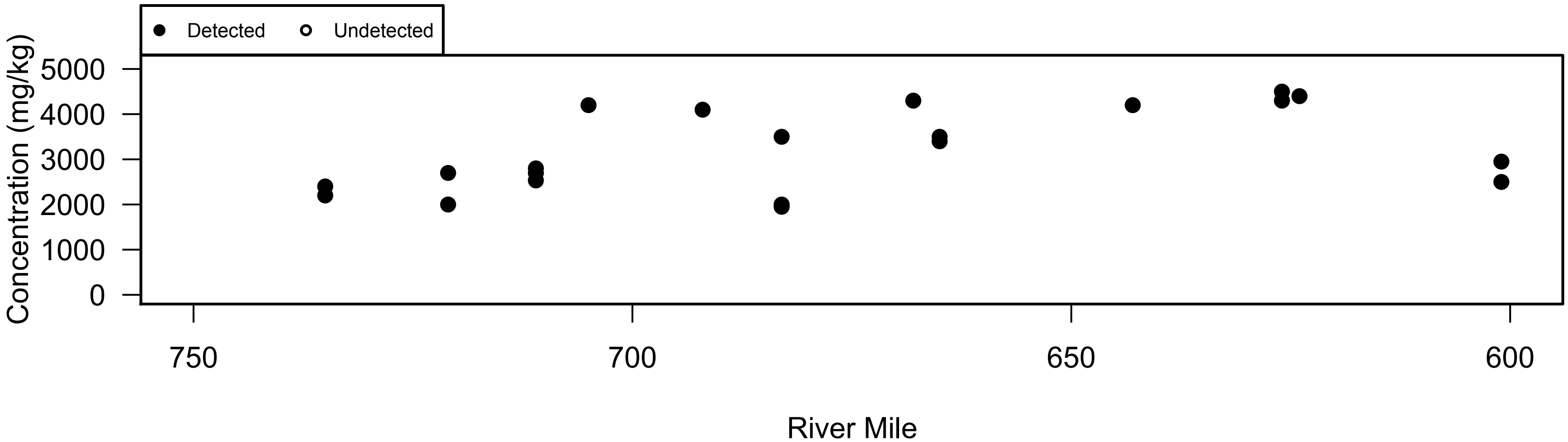


Figure 121. Titanium in Phase 1 Surface Sediment by River Mile

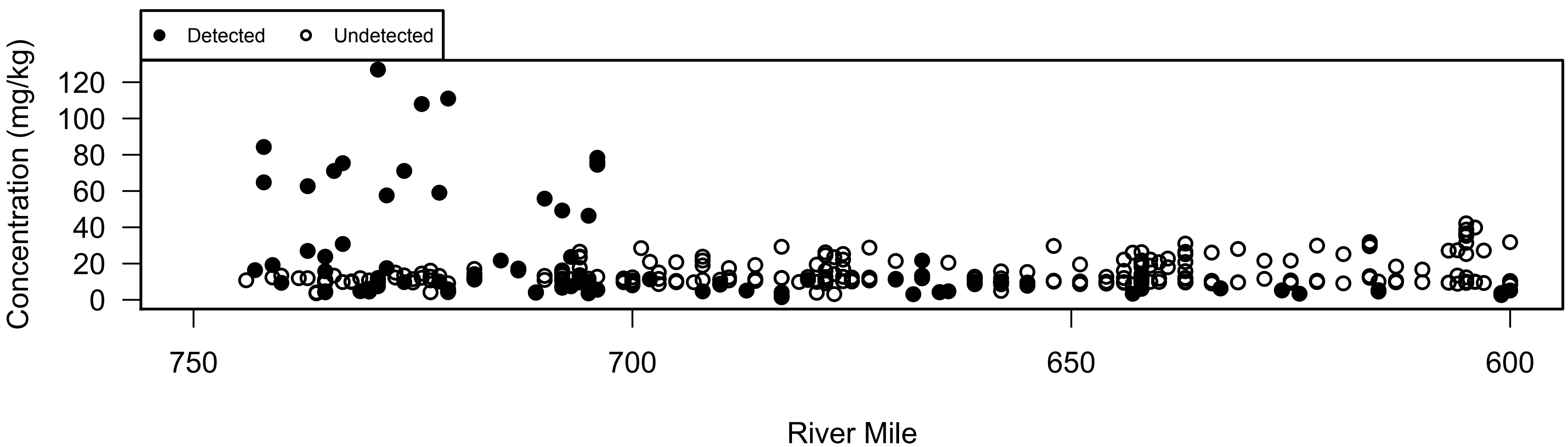


Figure 122. Uranium in Phase 1 Surface Sediment by River Mile

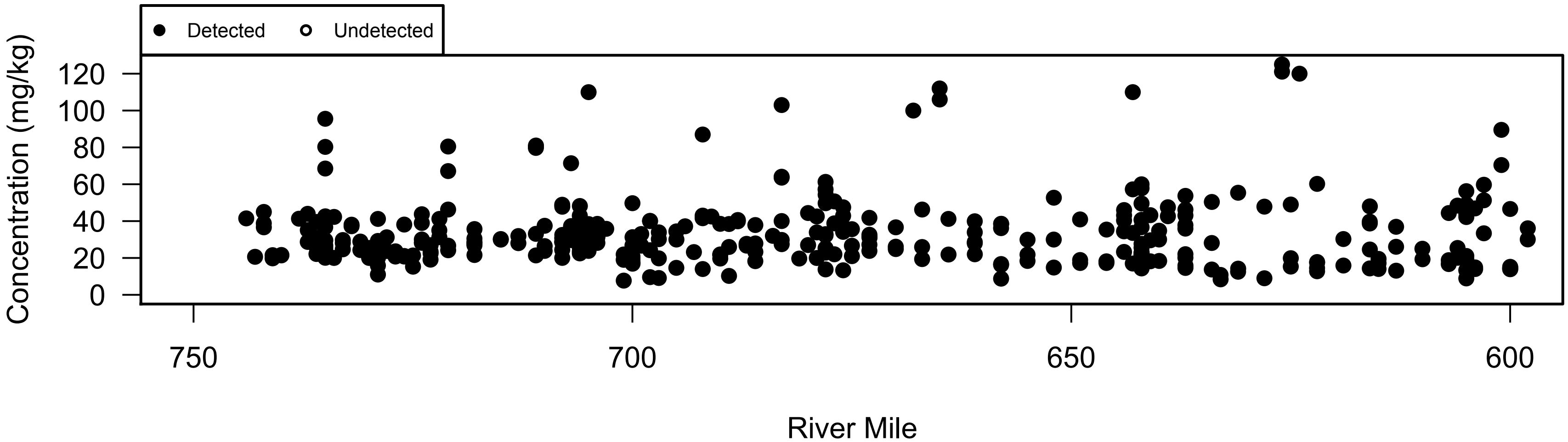


Figure 123. Vanadium in Phase 1 Surface Sediment by River Mile

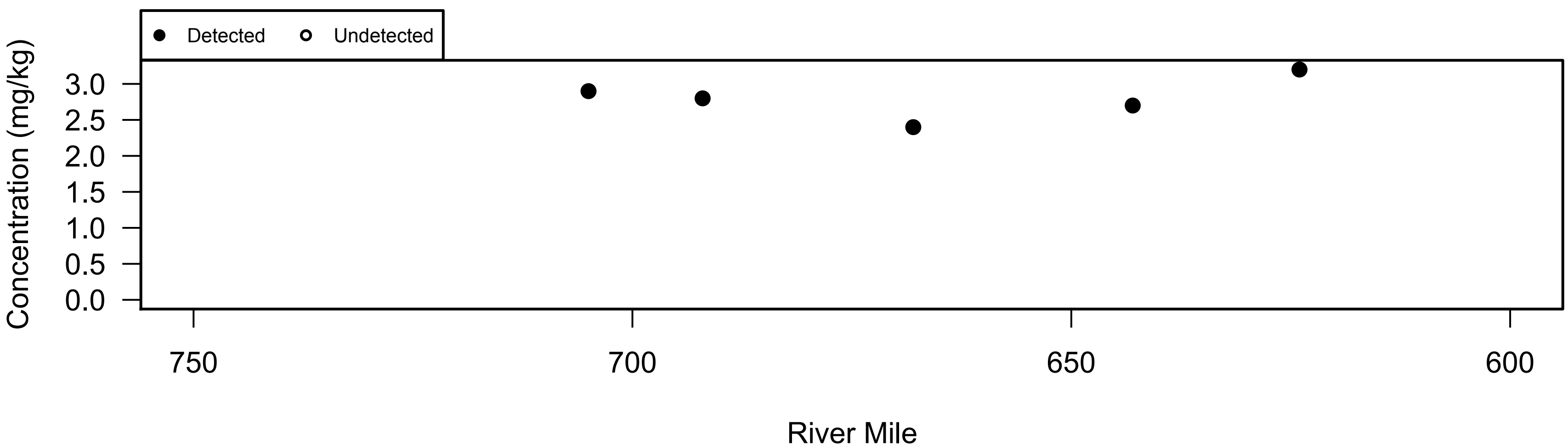


Figure 124. Ytterbium in Phase 1 Surface Sediment by River Mile

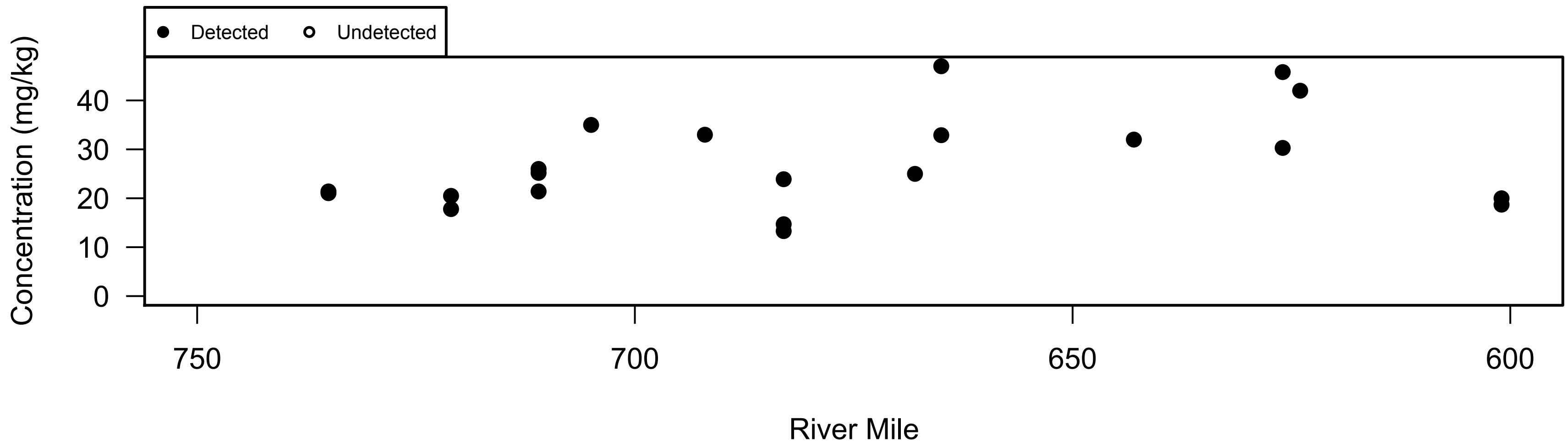


Figure 125. Yttrium in Phase 1 Surface Sediment
by River Mile

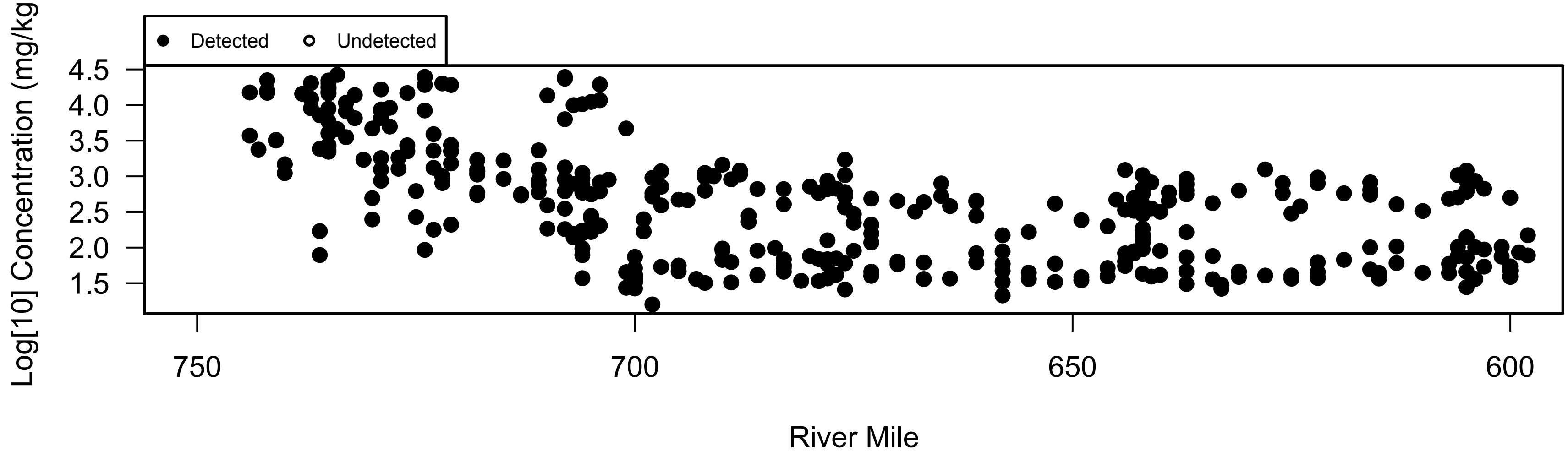


Figure 126. Zinc in Phase 1 Surface Sediment
by River Mile

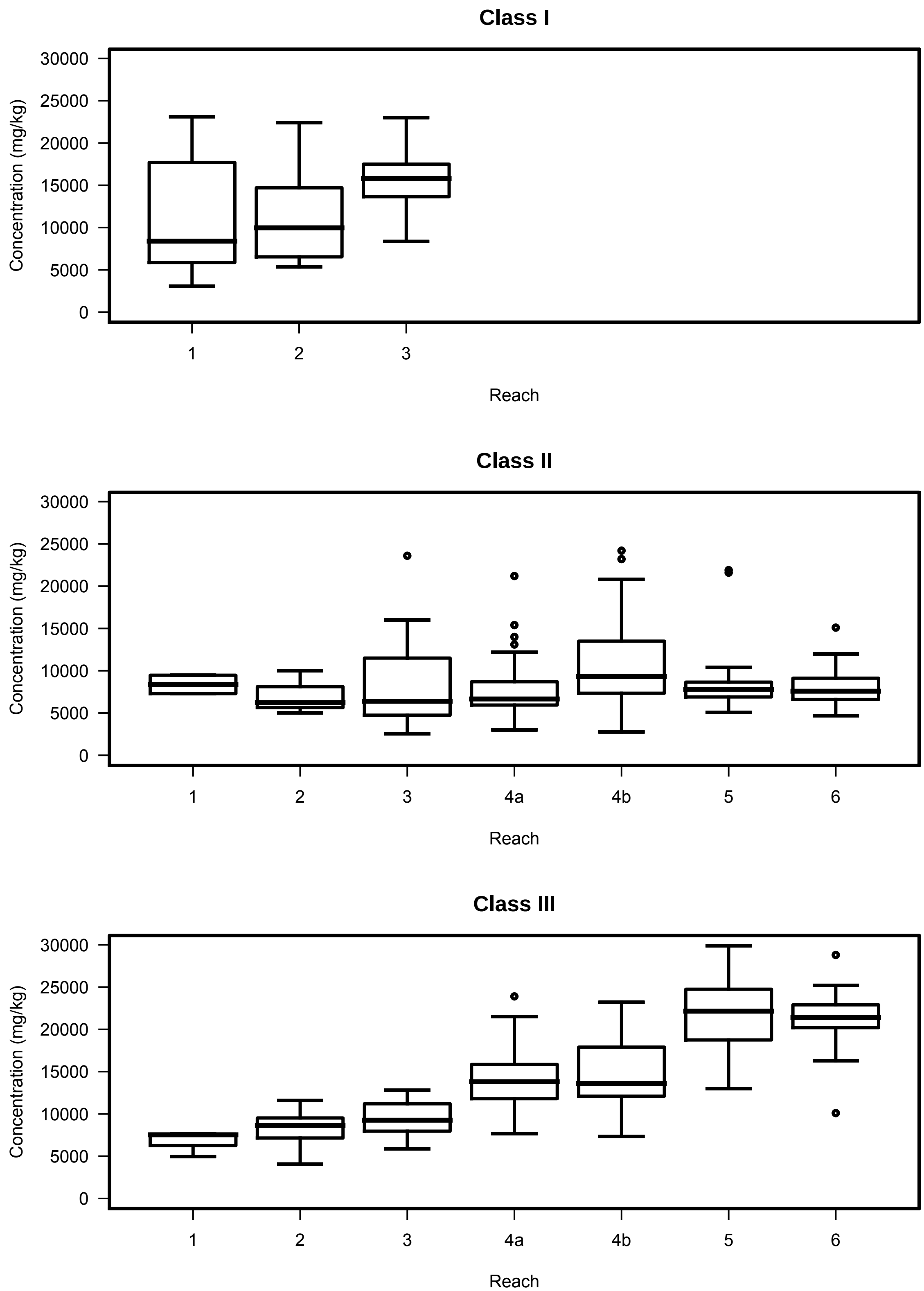


Figure 127. Concentration of Aluminum by Reach and Class

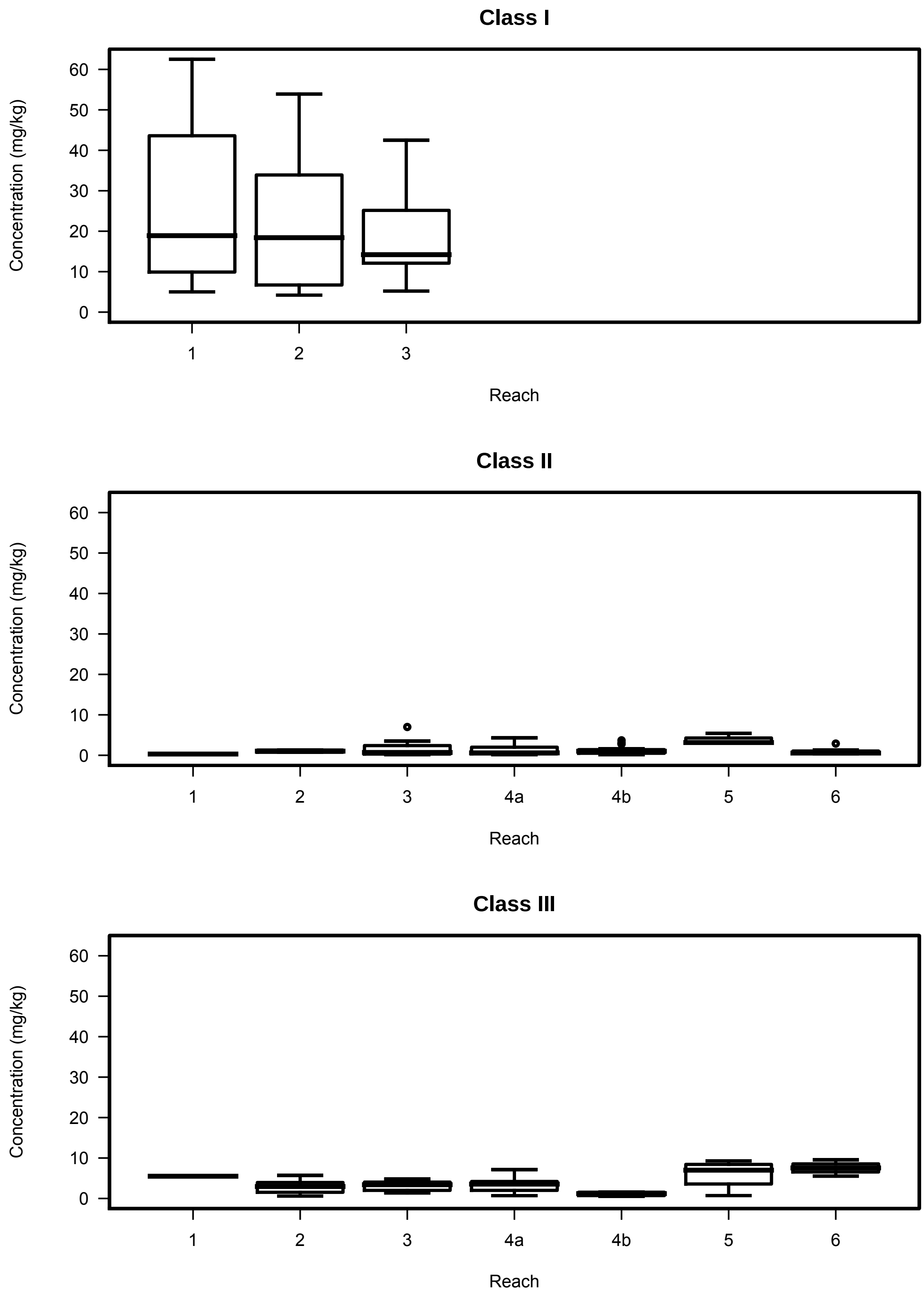


Figure 128. Concentration of Antimony by Reach and Class

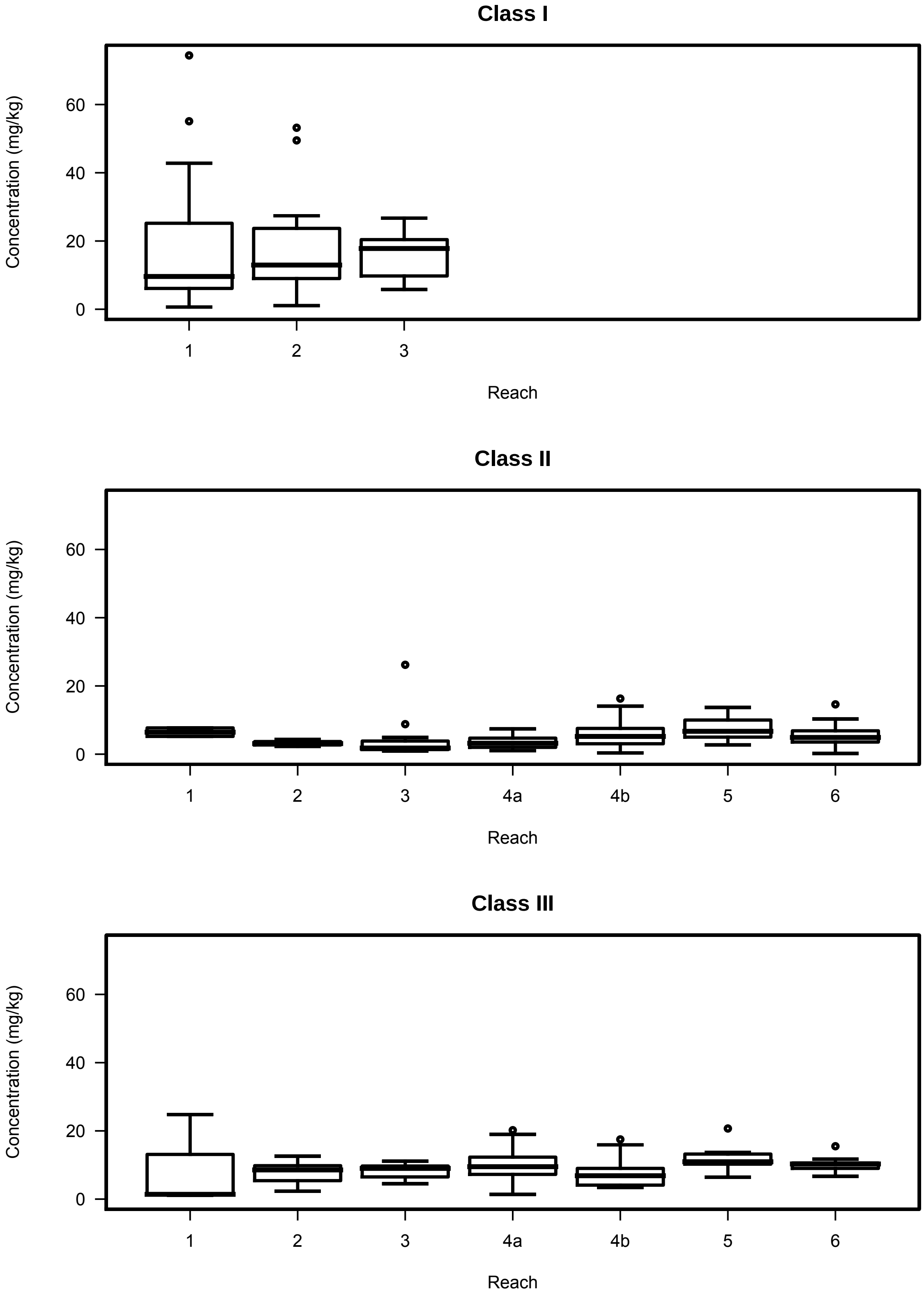


Figure 129. Concentration of Arsenic by Reach and Class

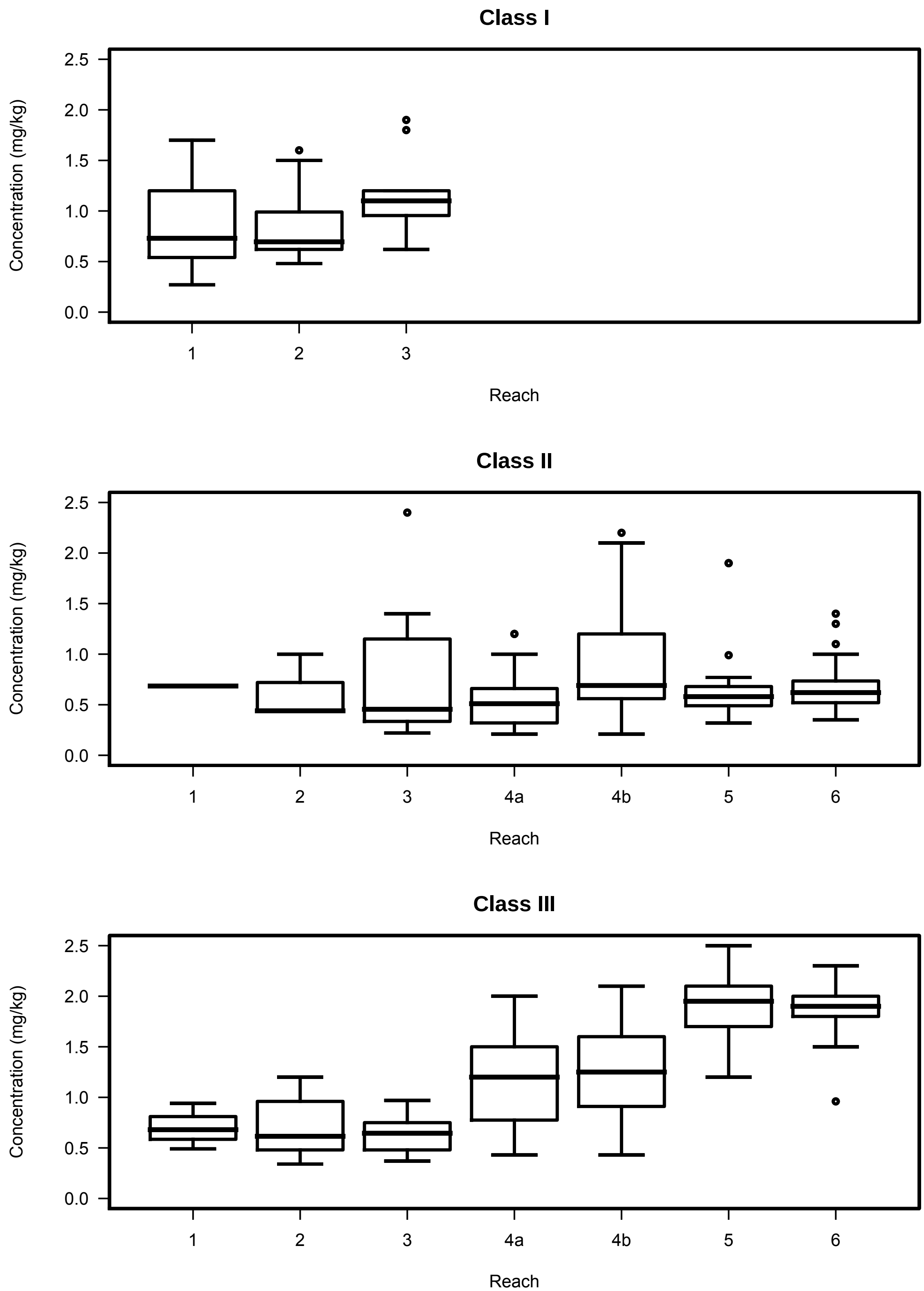


Figure 130. Concentration of Beryllium by Reach and Class

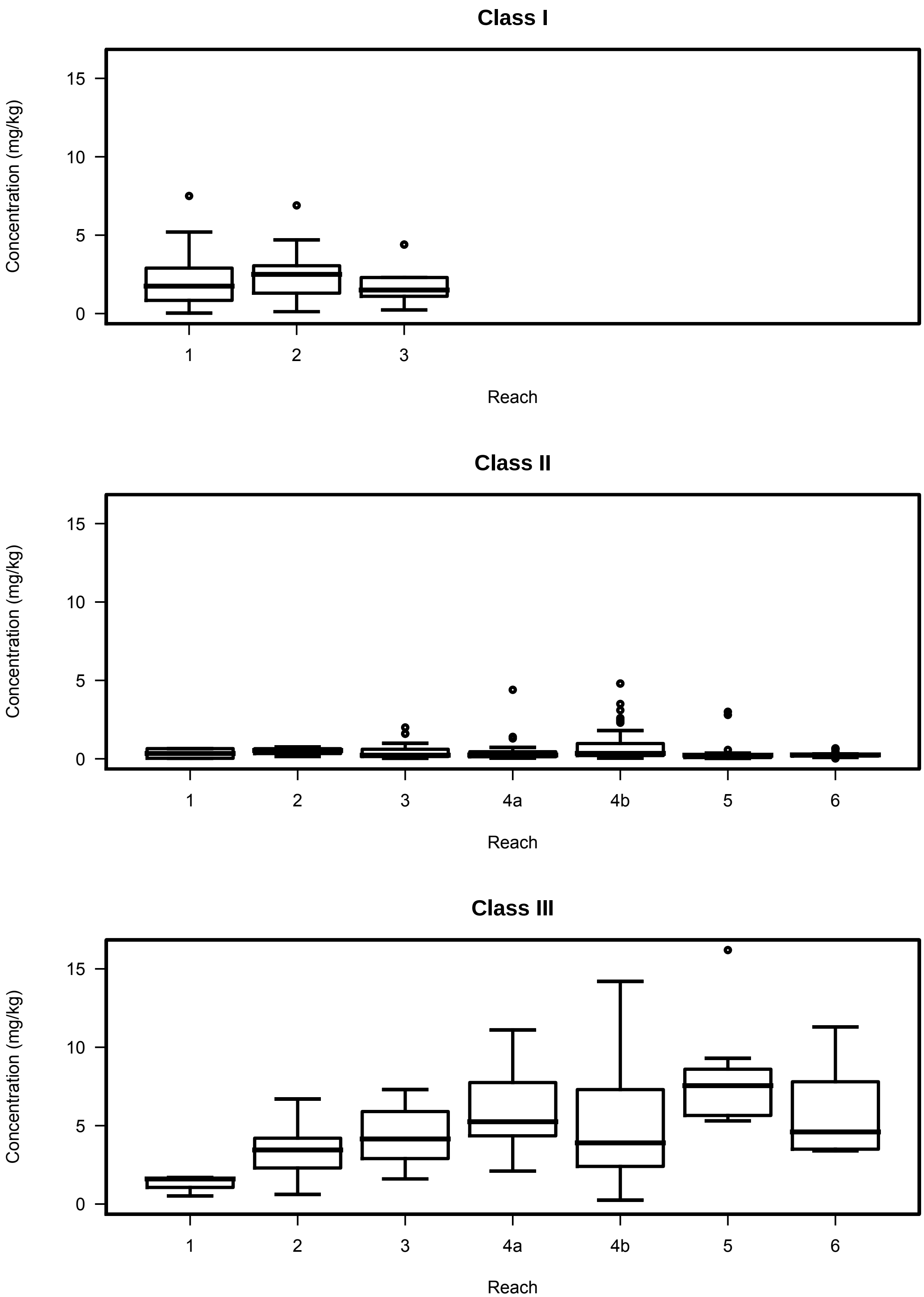


Figure 131. Concentration of Cadmium by Reach and Class

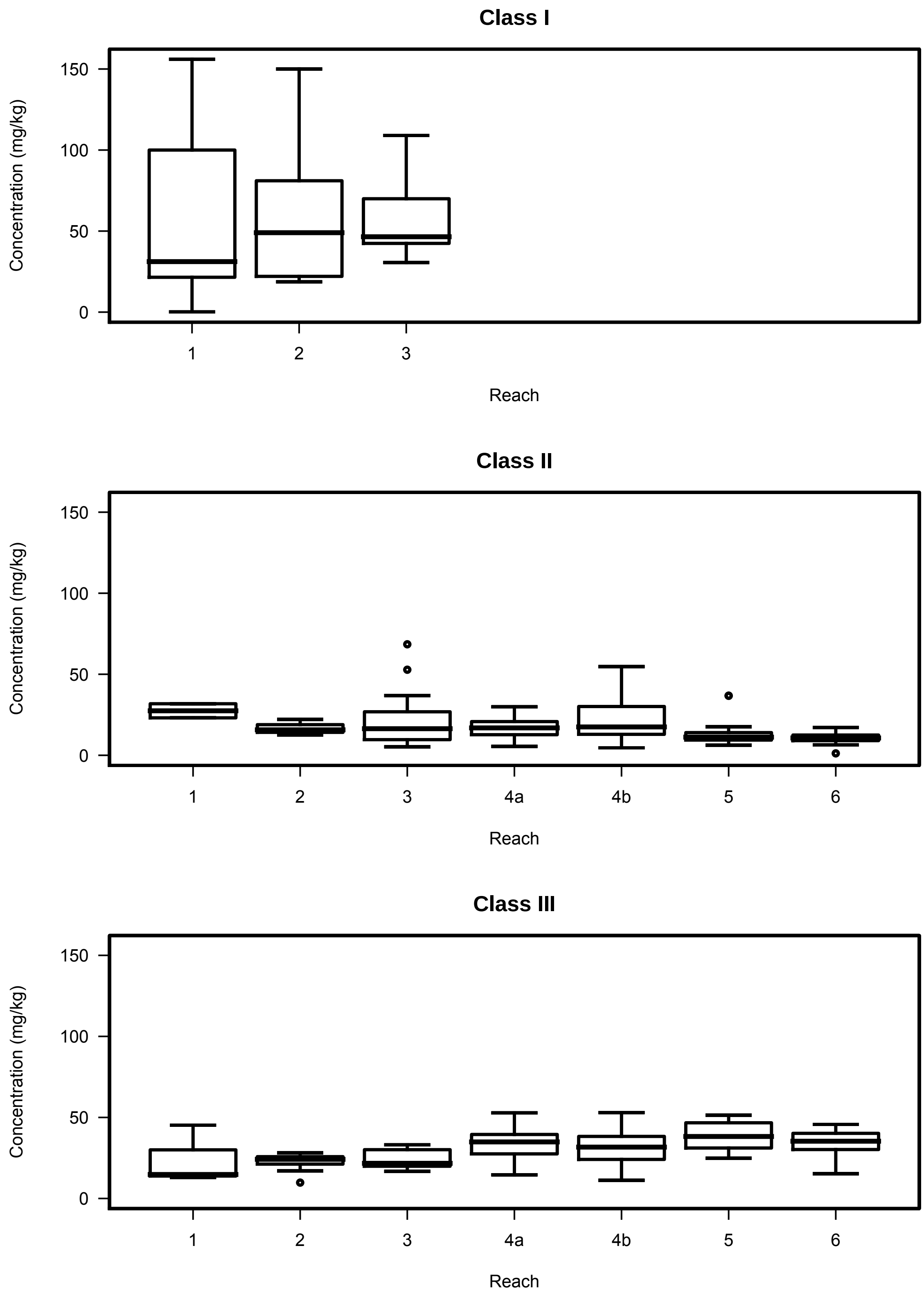


Figure 132. Concentration of Chromium
by Reach and Class

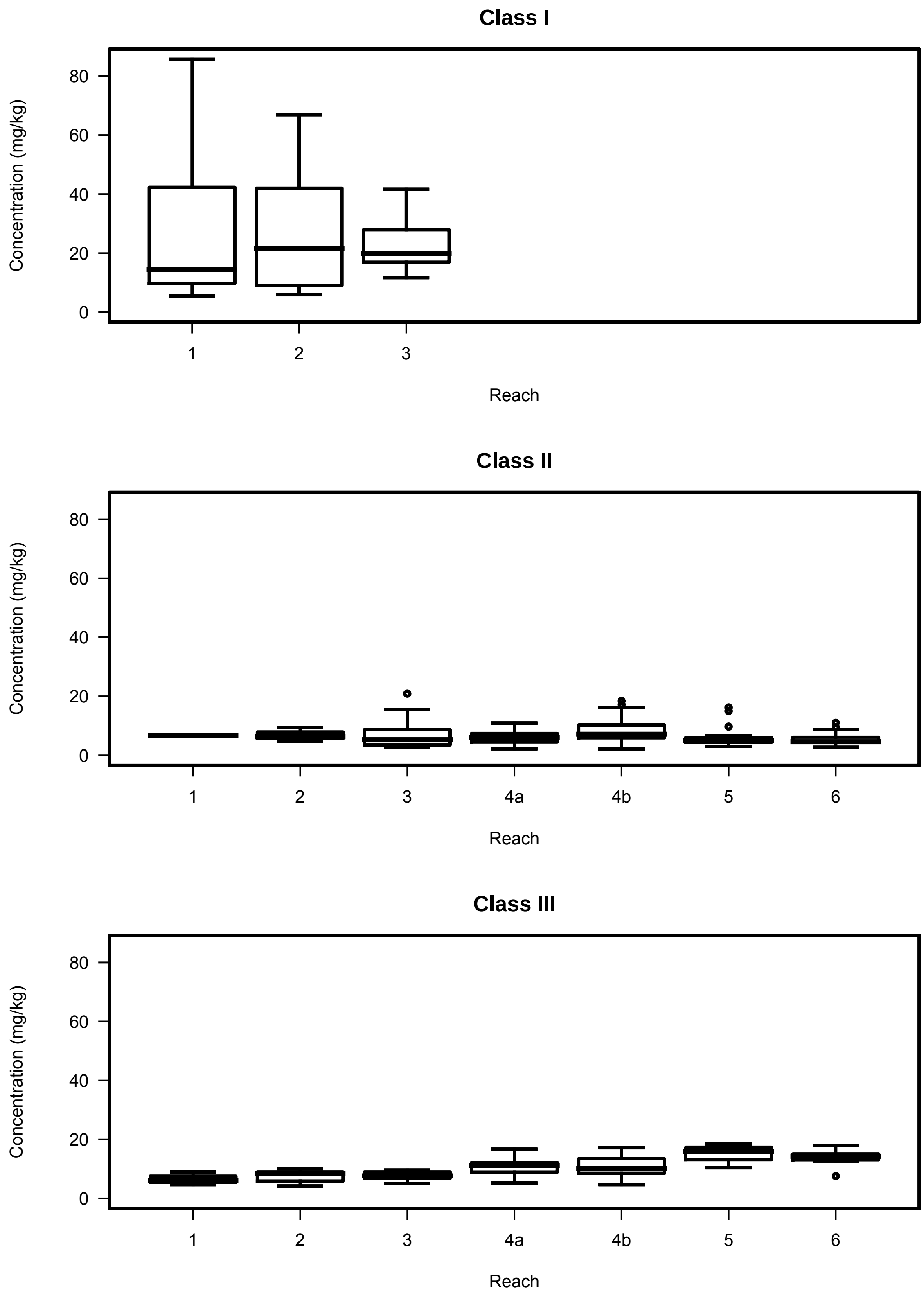


Figure 133. Concentration of Cobalt by Reach and Class

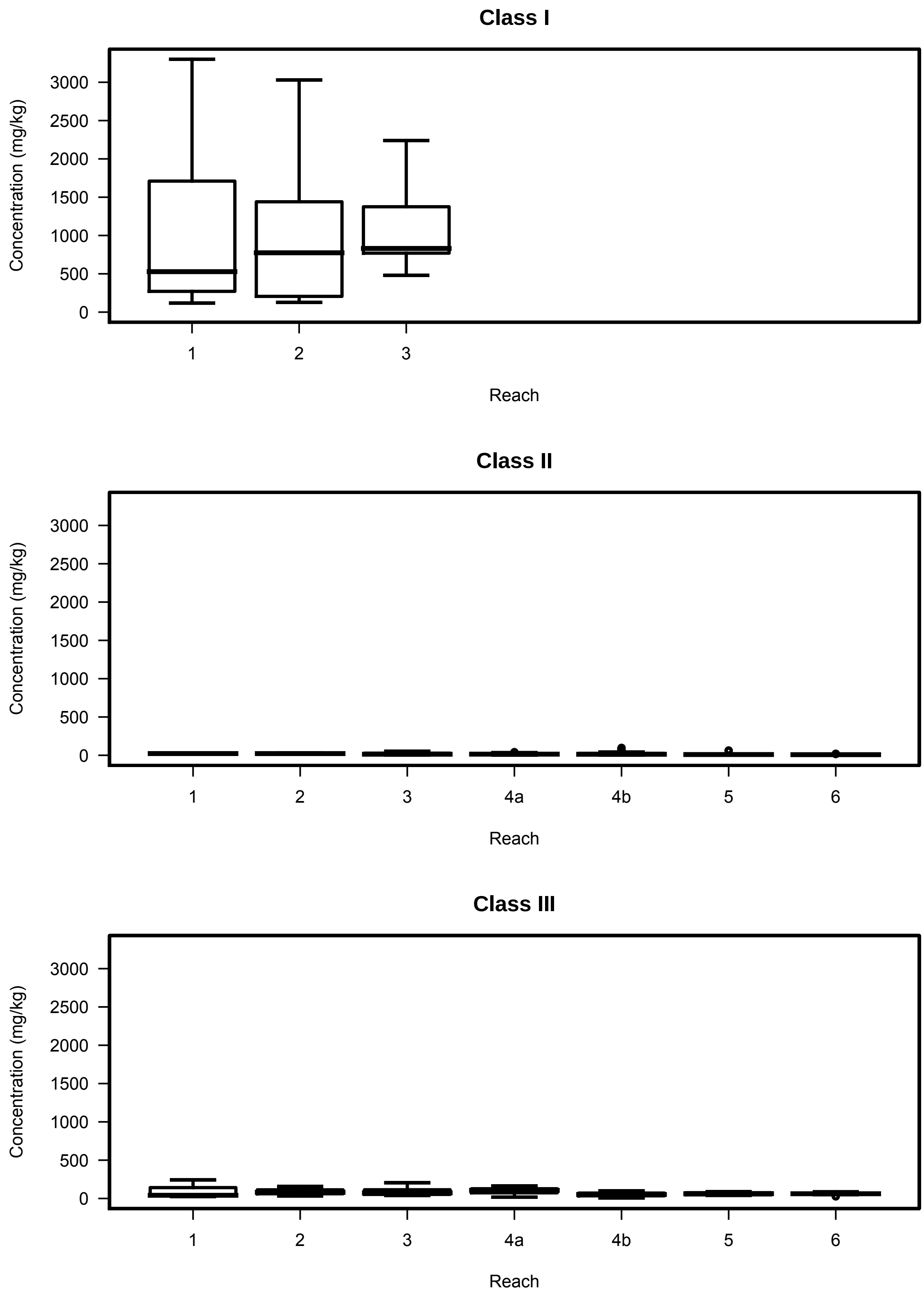


Figure 134. Concentration of Copper by Reach and Class

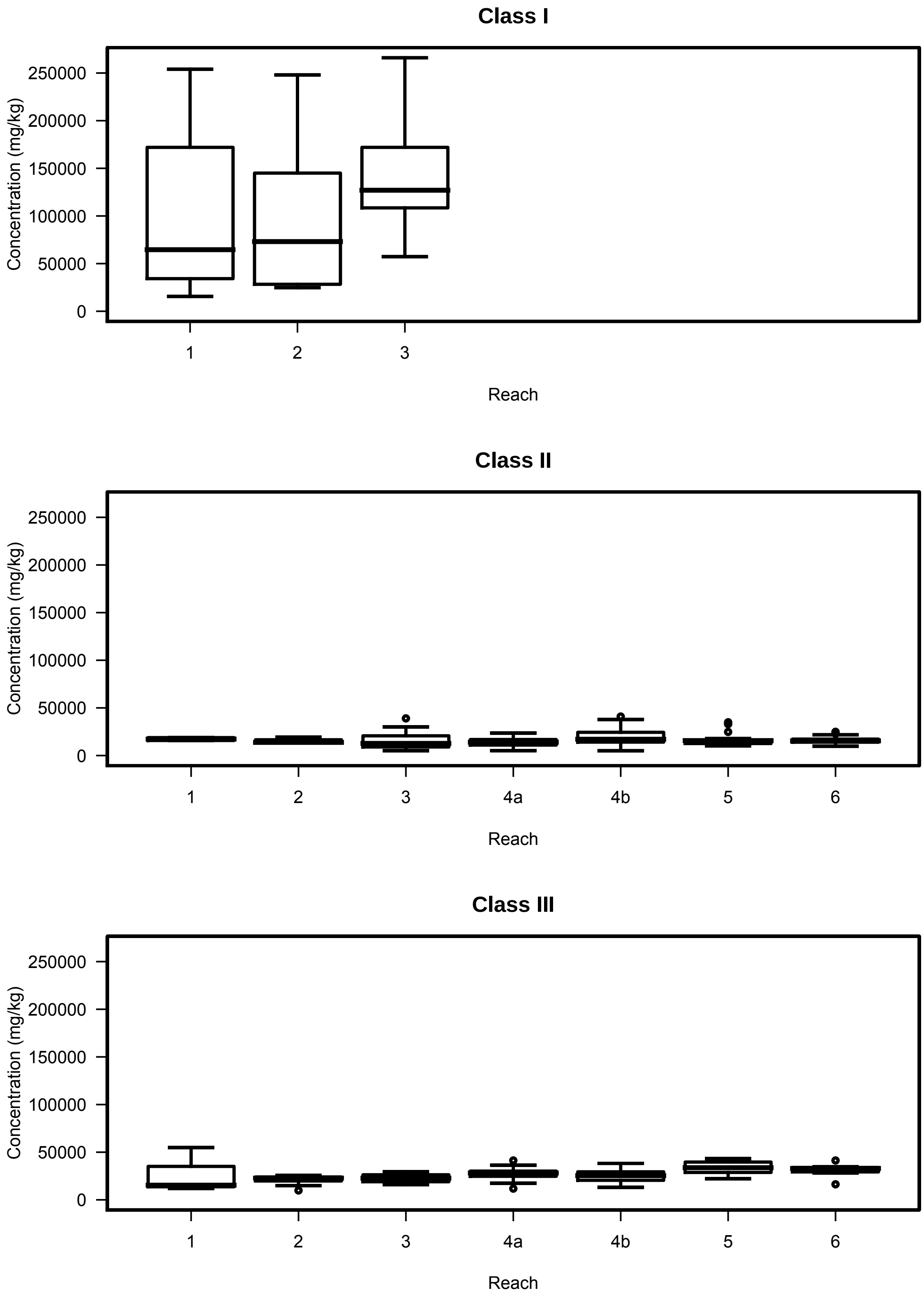
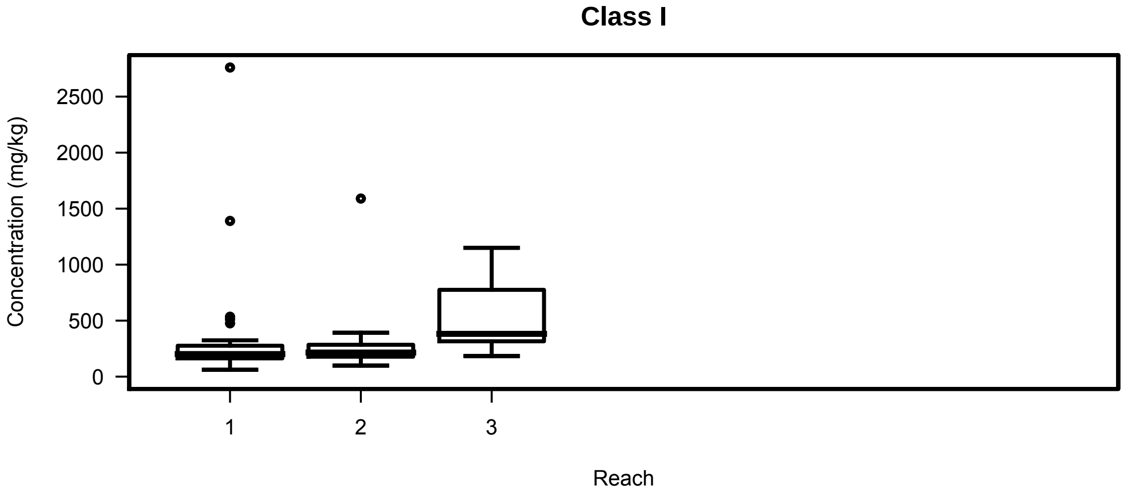
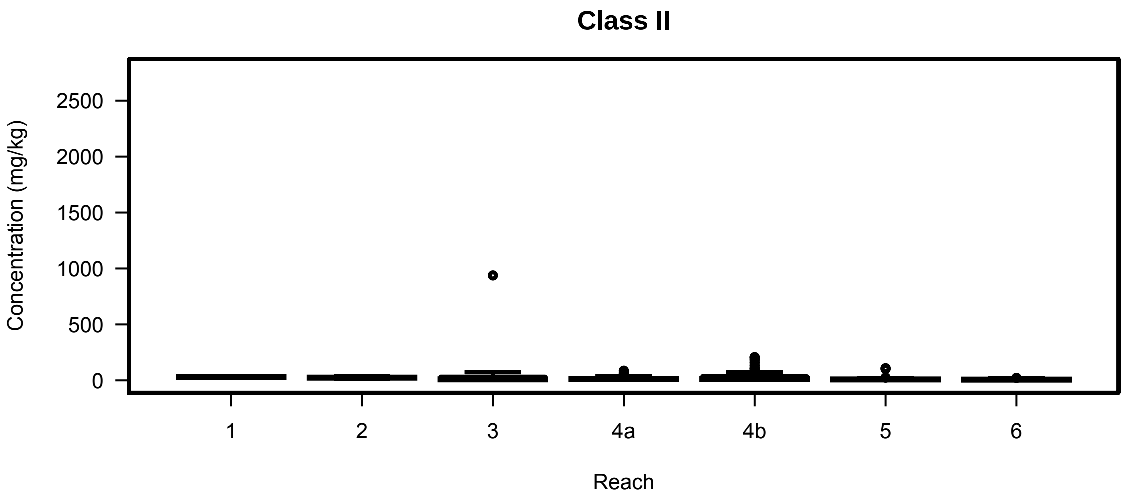


Figure 135. Concentration of Iron
by Reach and Class





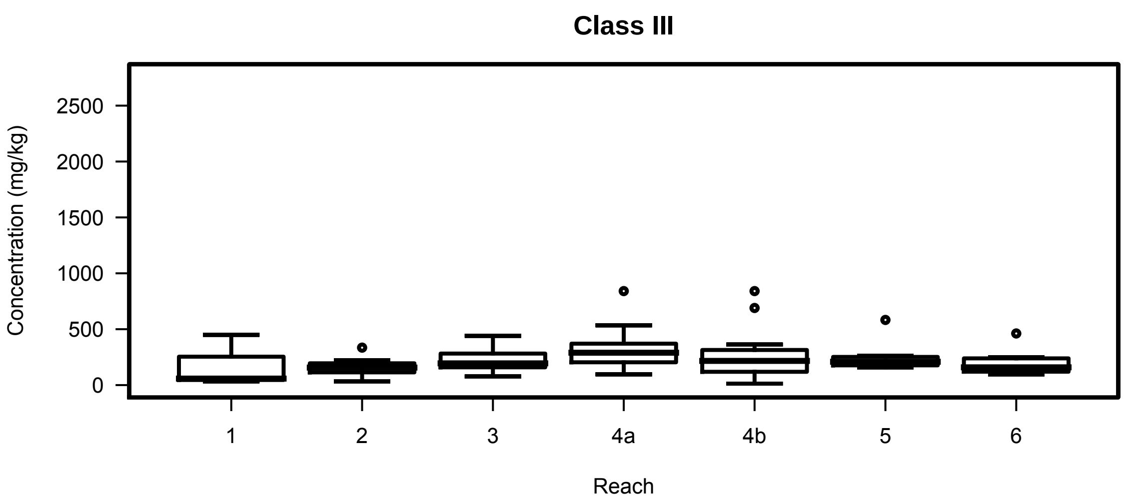


Figure 136. Concentration of Lead by Reach and Class

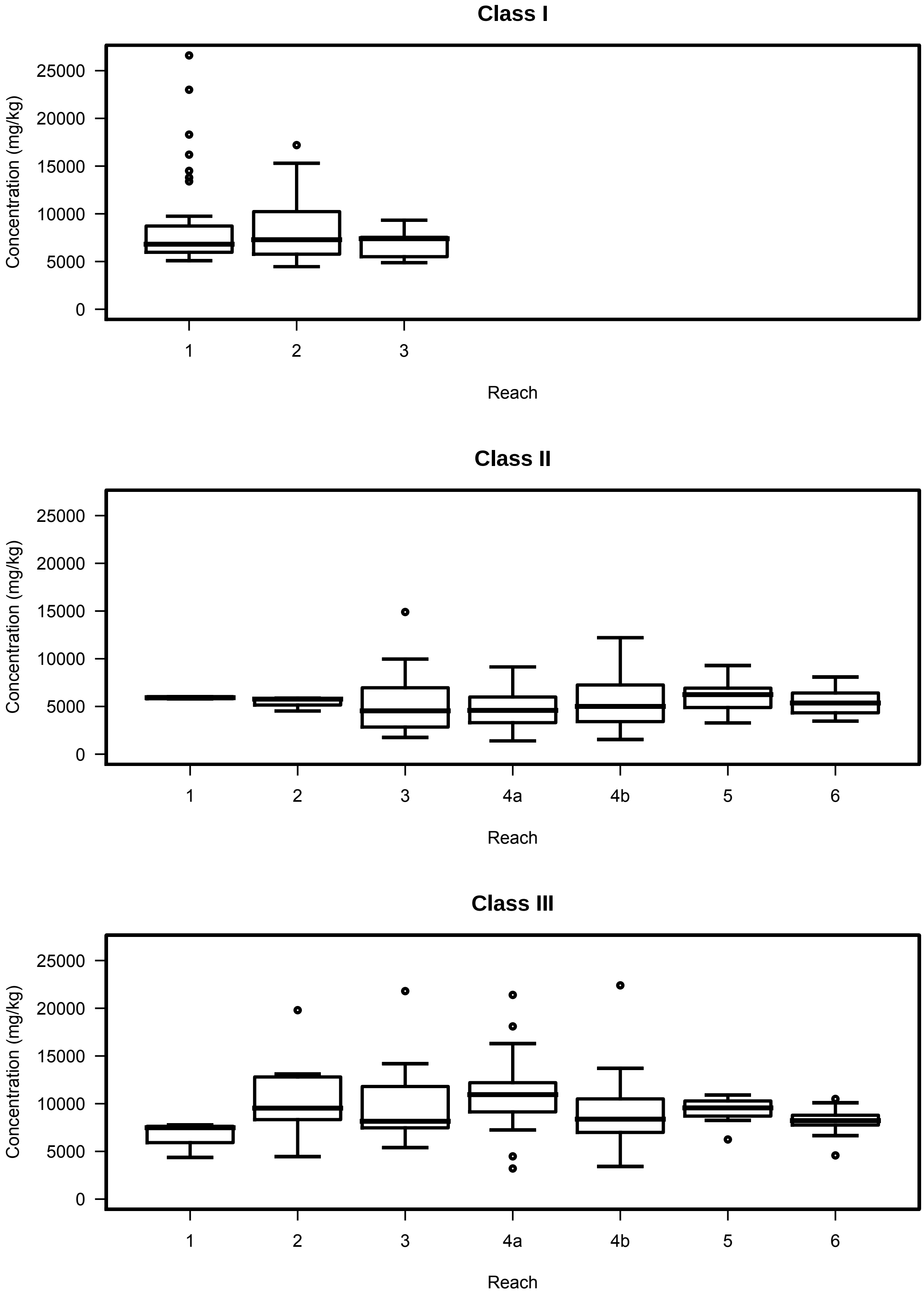


Figure 137. Concentration of Magnesium by Reach and Class

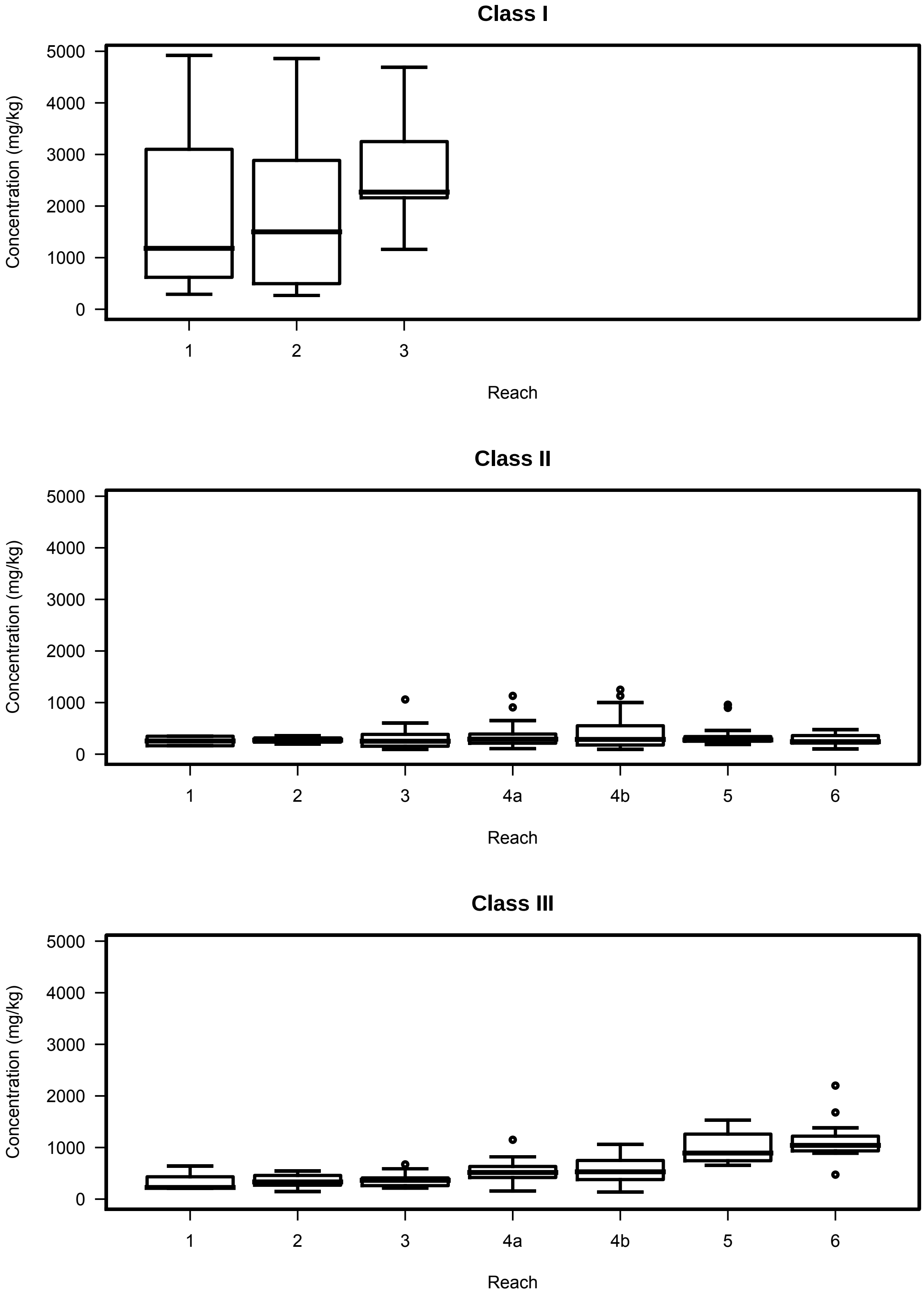


Figure 138. Concentration of Manganese by Reach and Class

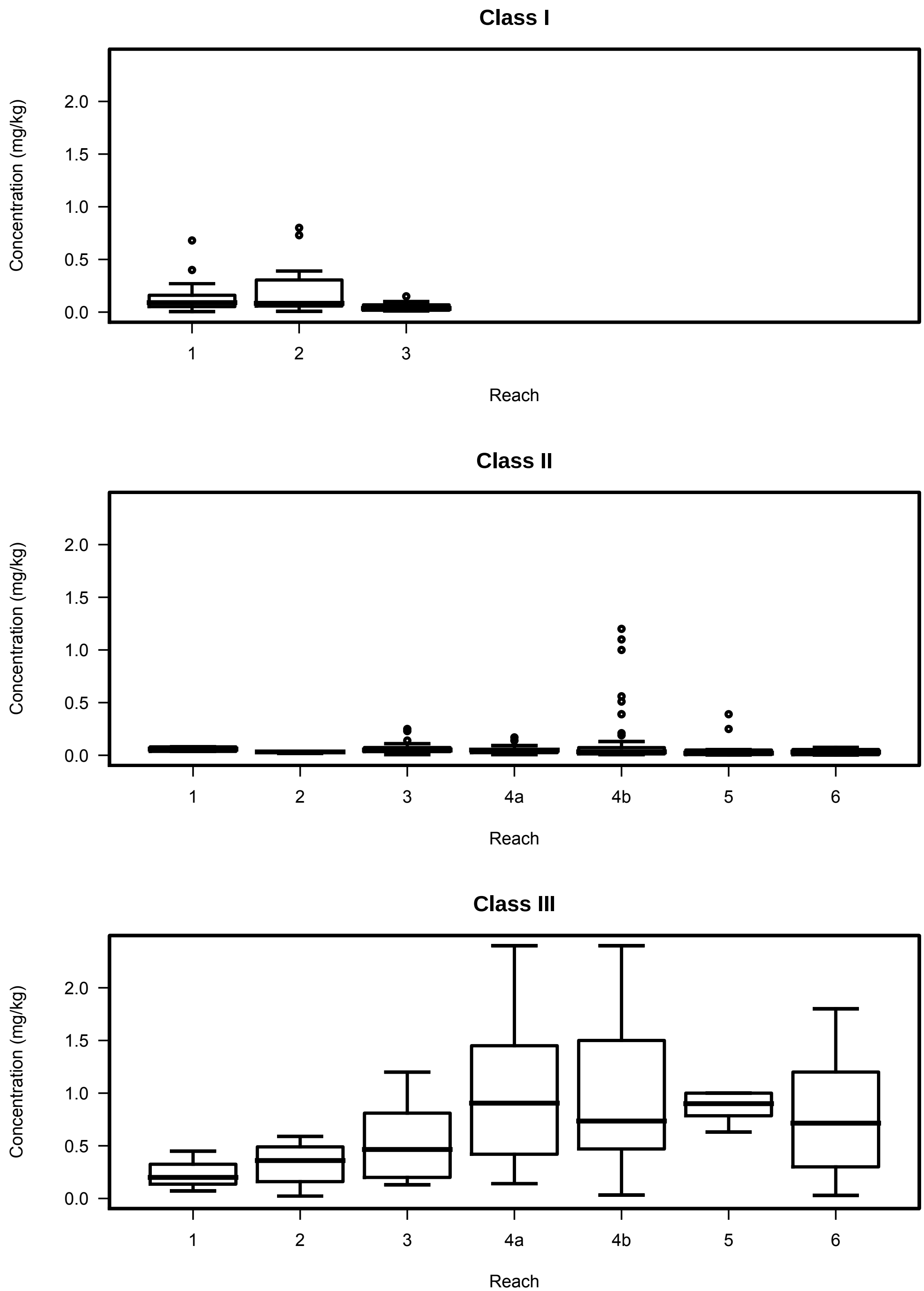


Figure 139. Concentration of Mercury by Reach and Class

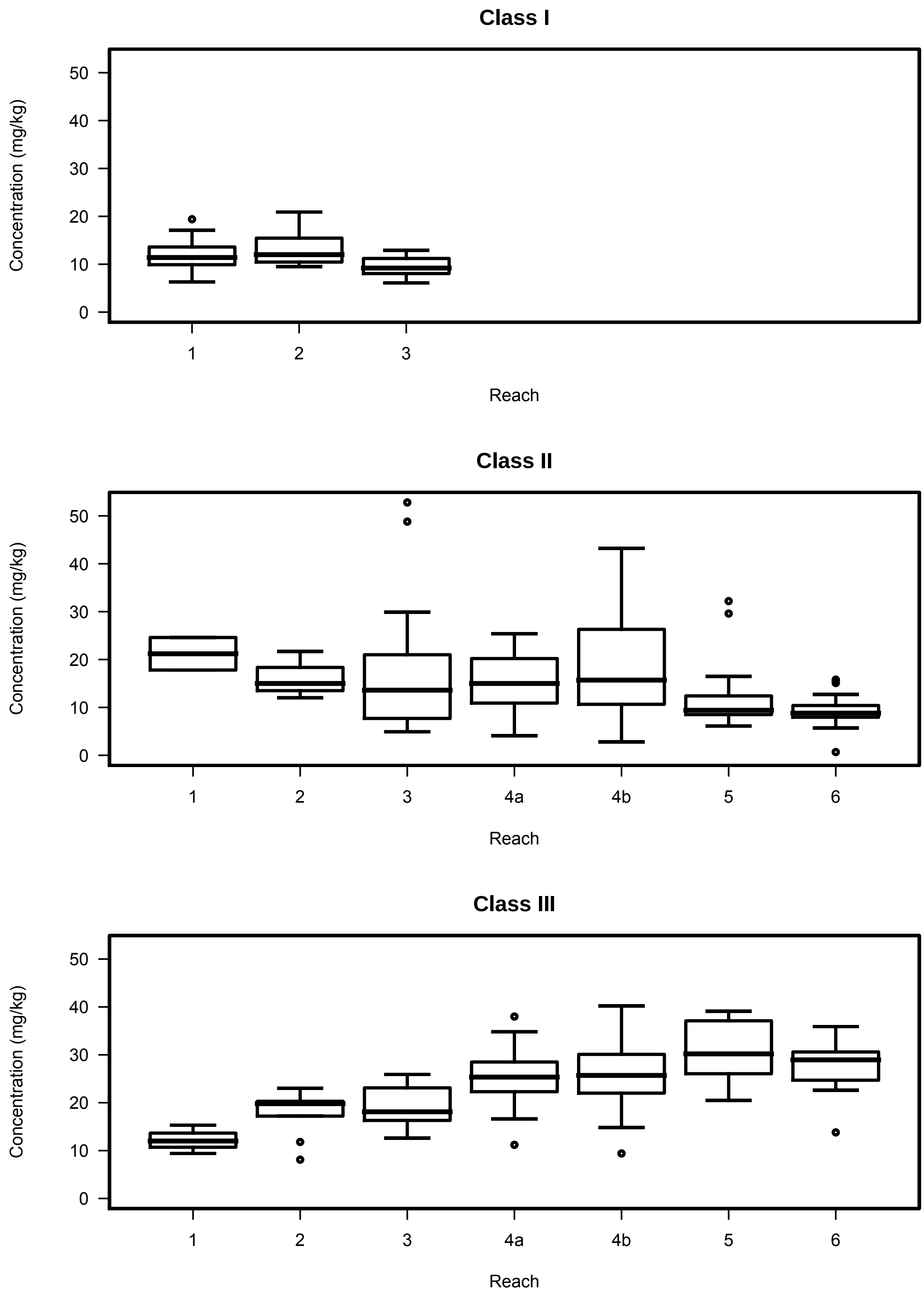


Figure 140. Concentration of Nickel by Reach and Class

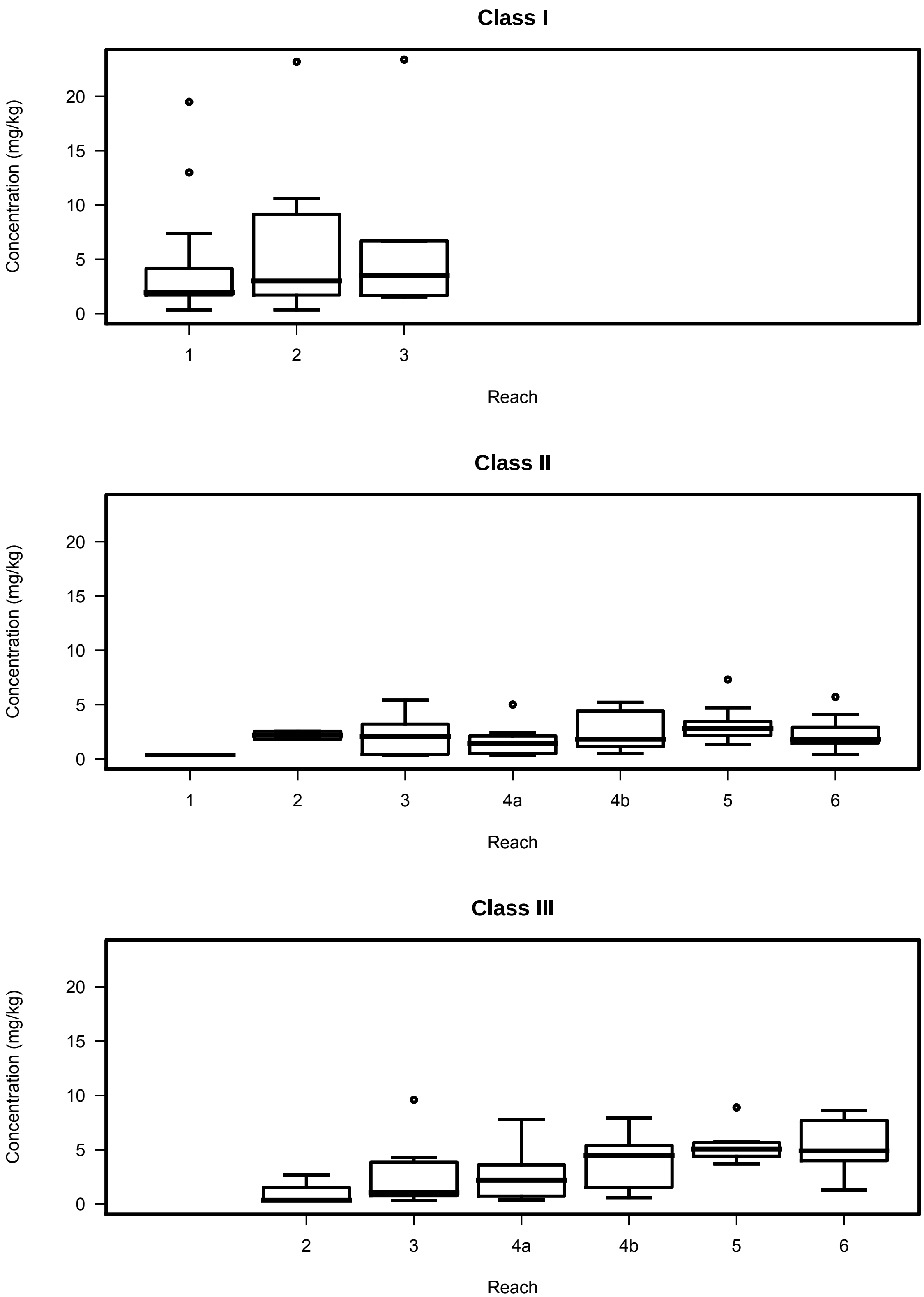


Figure 141. Concentration of Selenium by Reach and Class

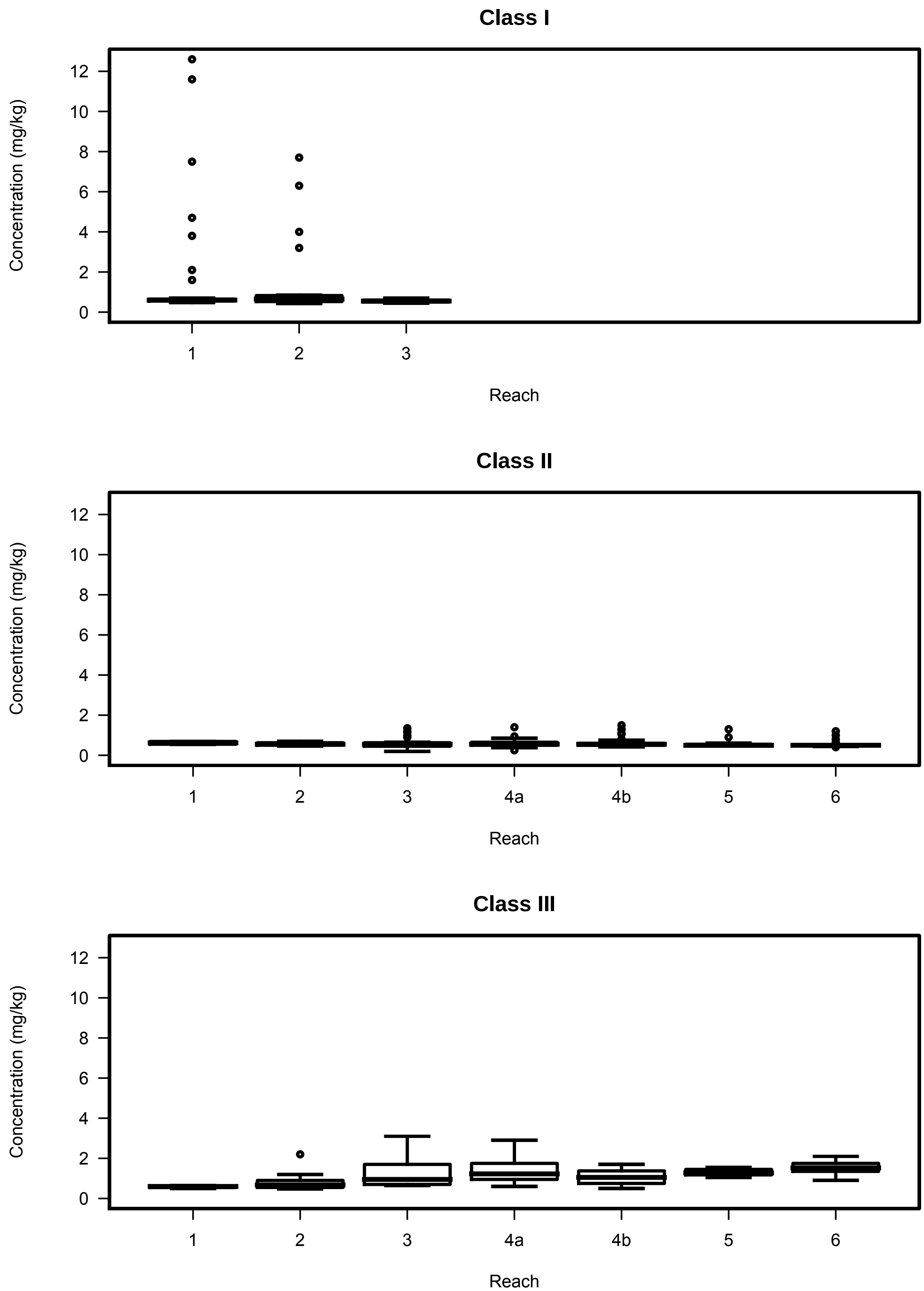


Figure 142. Concentration of Silver
by Reach and Class

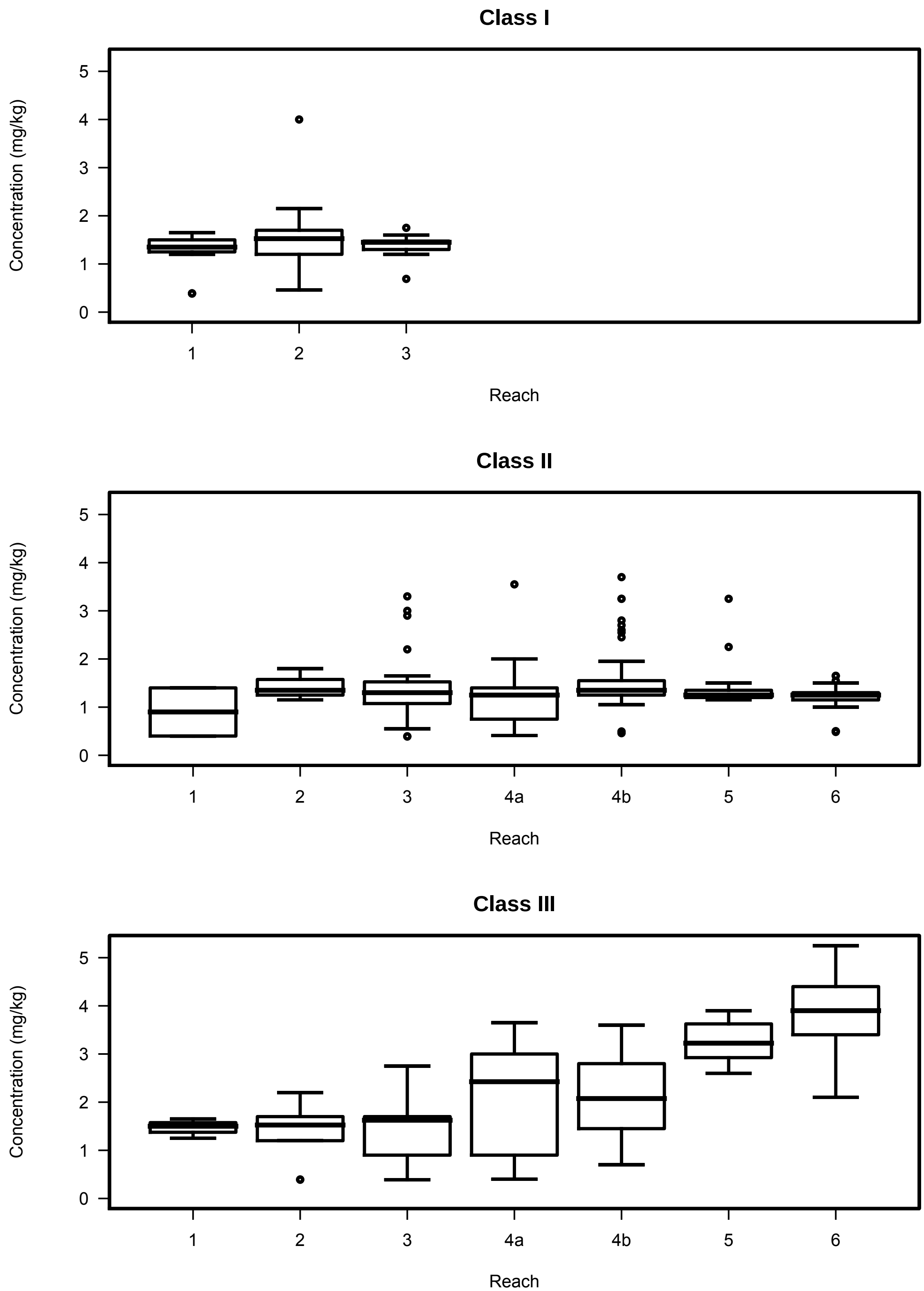


Figure 143. Concentration of Thallium by Reach and Class

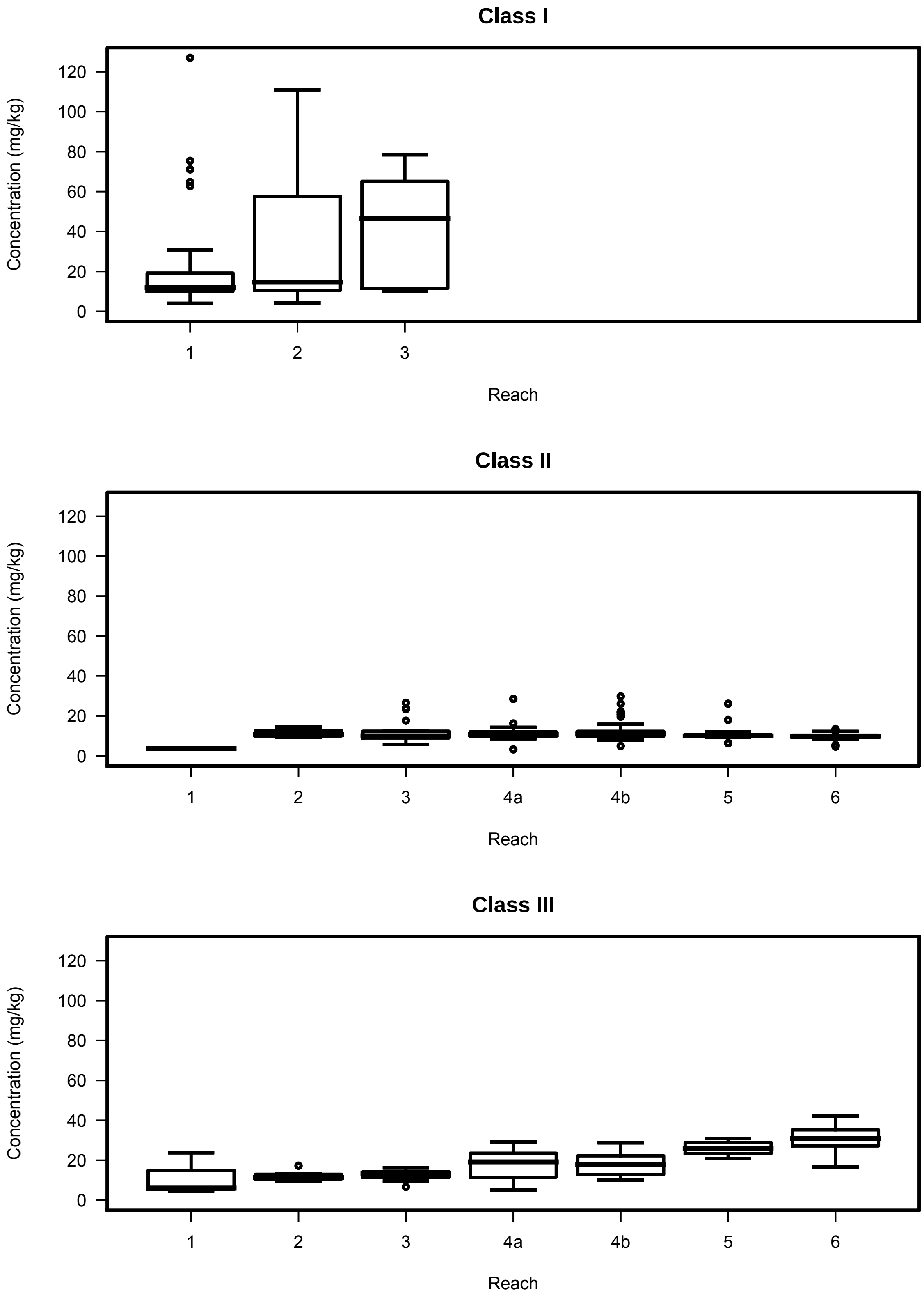


Figure 144. Concentration of Uranium by Reach and Class

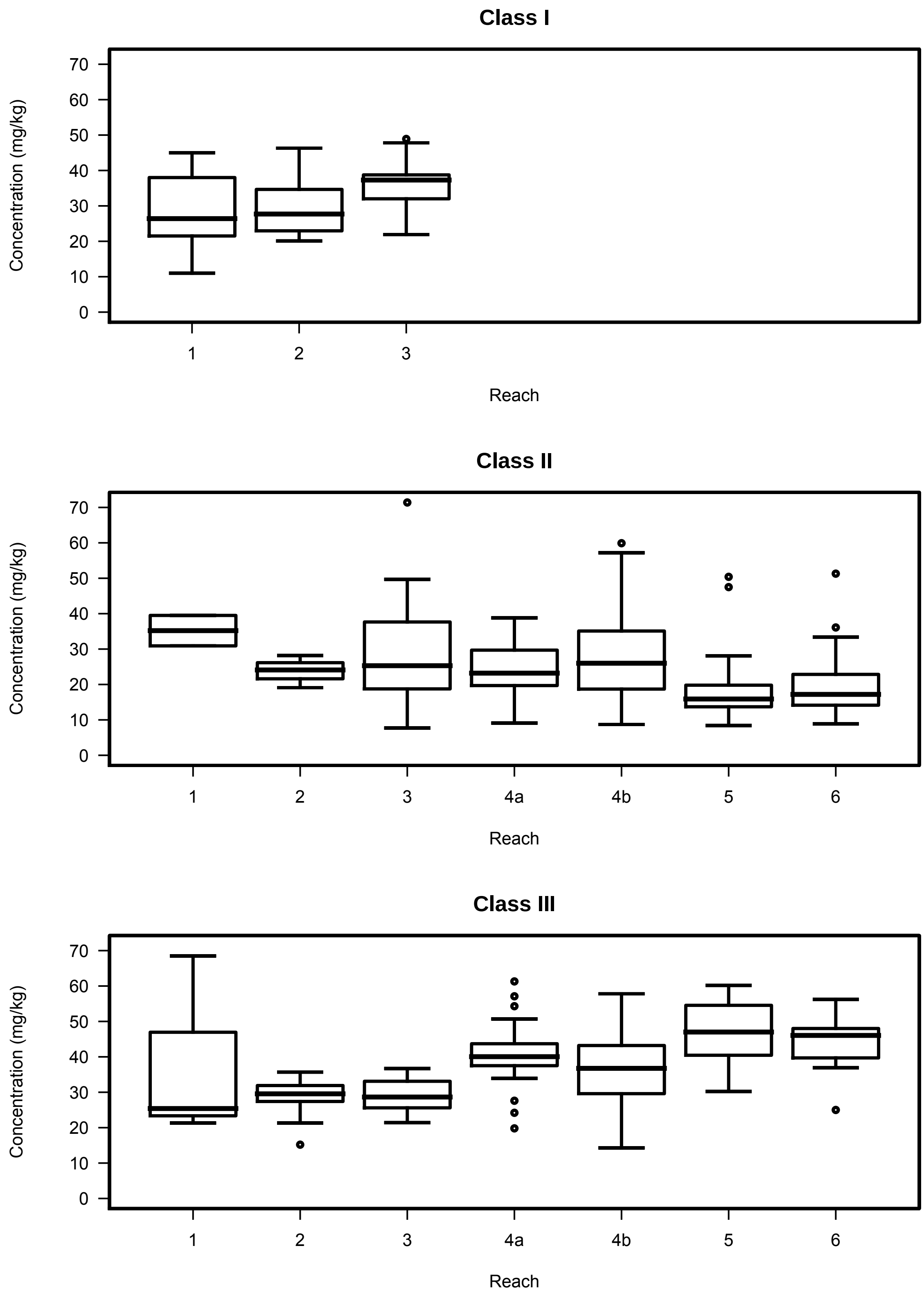


Figure 145. Concentration of Vanadium
by Reach and Class

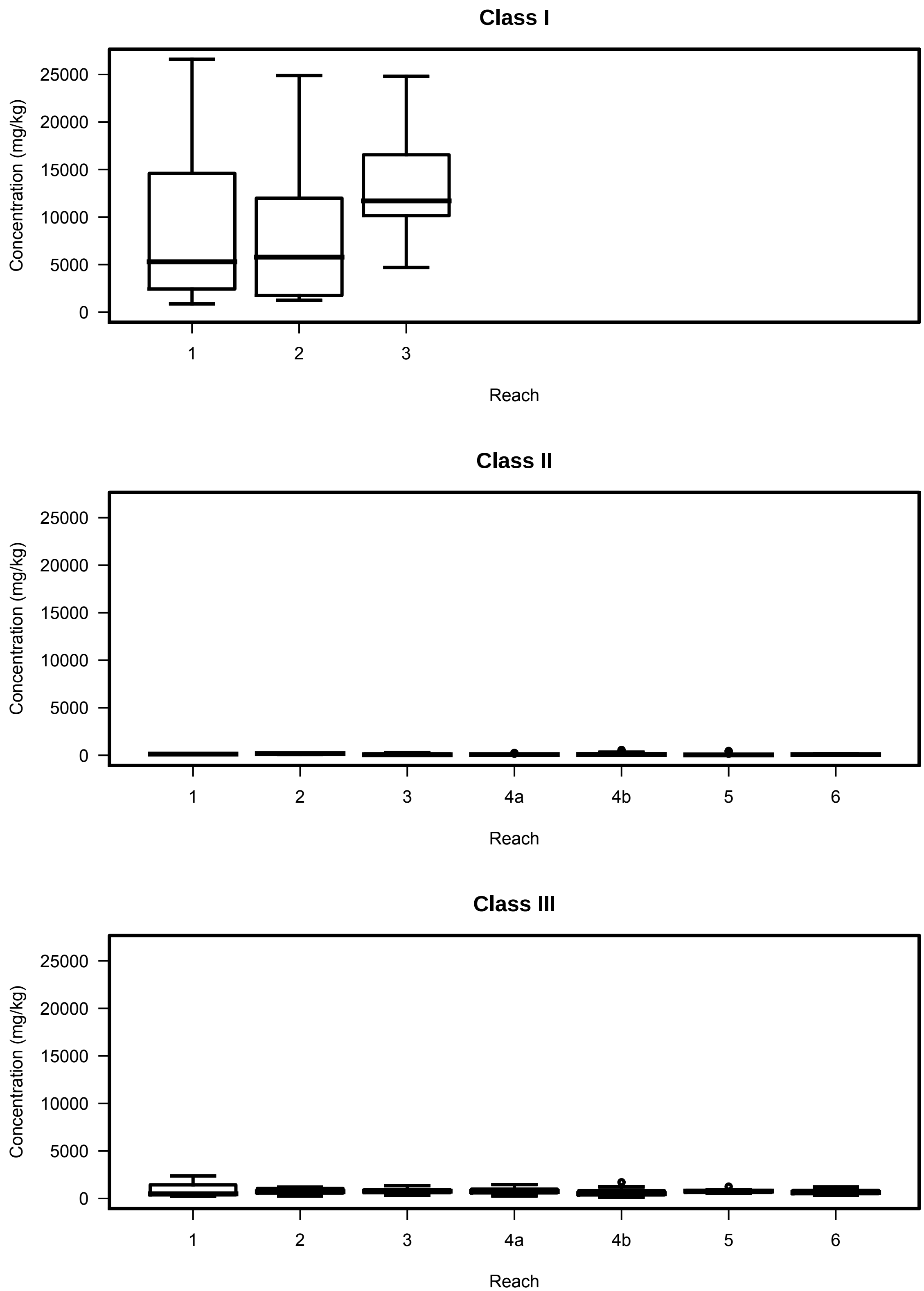


Figure 146. Concentration of Zinc by Reach and Class

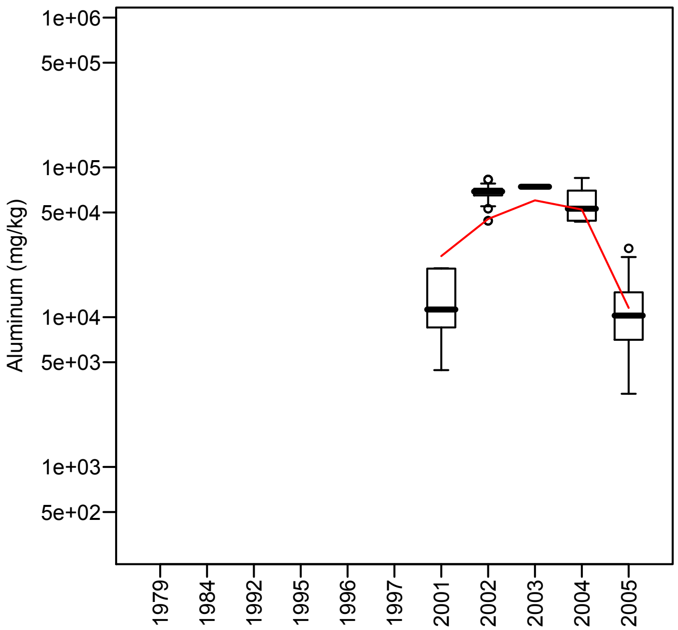


Figure 147. Temporal trend for Aluminum within the entire UCR study area. The line indicates mean tendency.

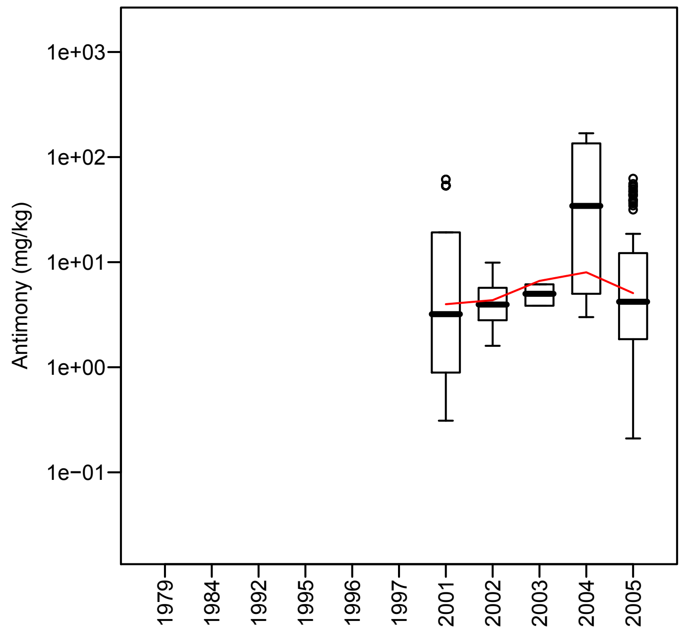


Figure 148. Temporal trend for Antimony within the entire UCR study area. The line indicates mean tendency.

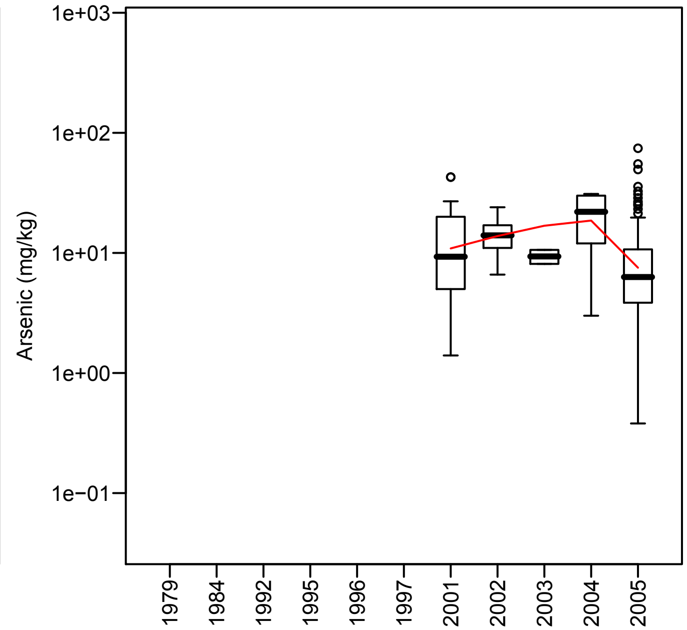


Figure 149. Temporal trend for Arsenic within the entire UCR study area. The line indicates mean tendency.

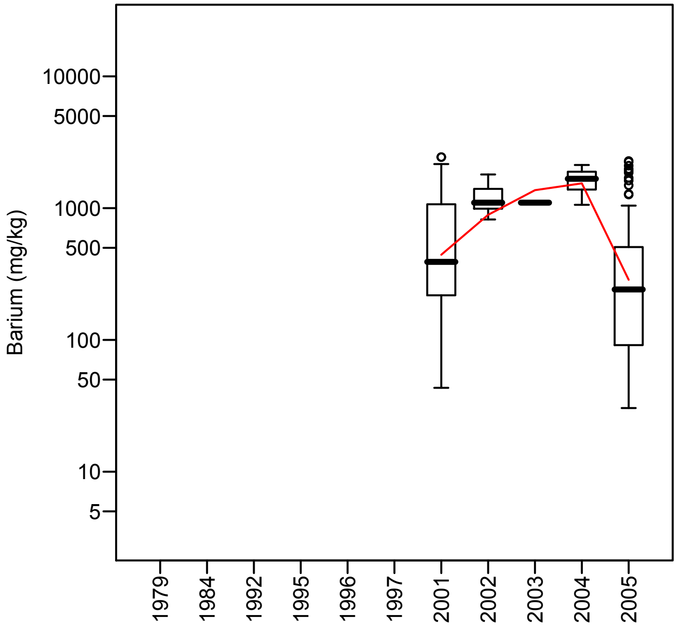


Figure 150. Temporal trend for Barium within the entire UCR study area. The line indicates mean tendency.

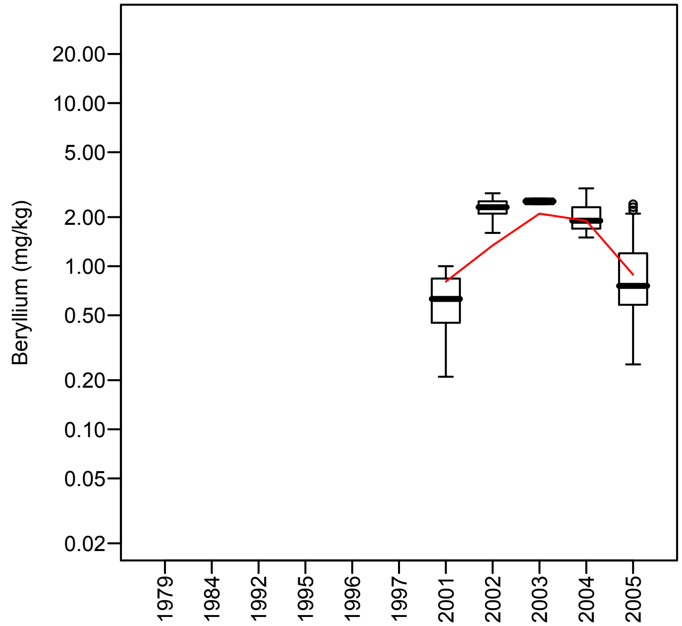


Figure 151. Temporal trend for Beryllium within the entire UCR study area. The line indicates mean tendency.

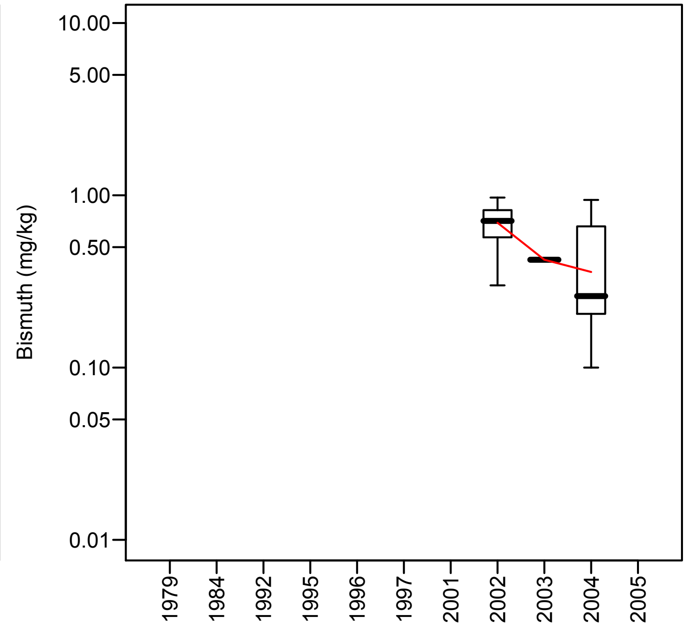


Figure 152. Temporal trend for Bismuth within the entire UCR study area. The line indicates mean tendency.

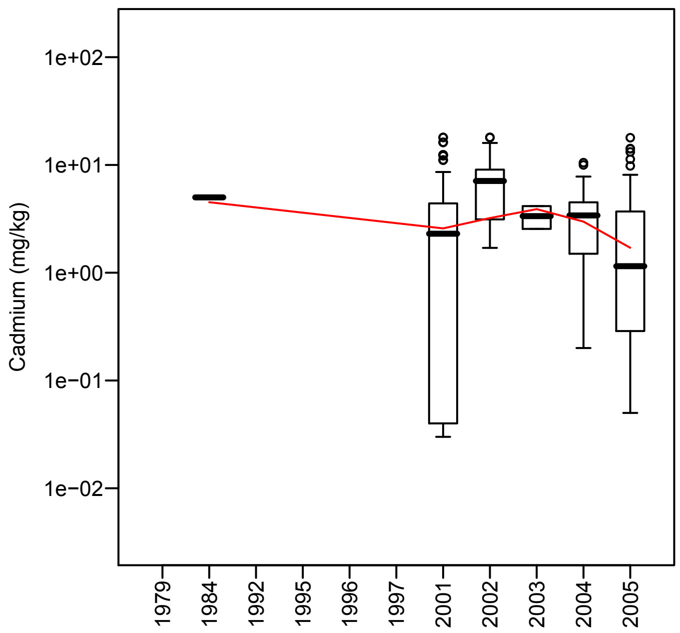


Figure 153. Temporal trend for Cadmium within the entire UCR study area. The line indicates mean tendency.

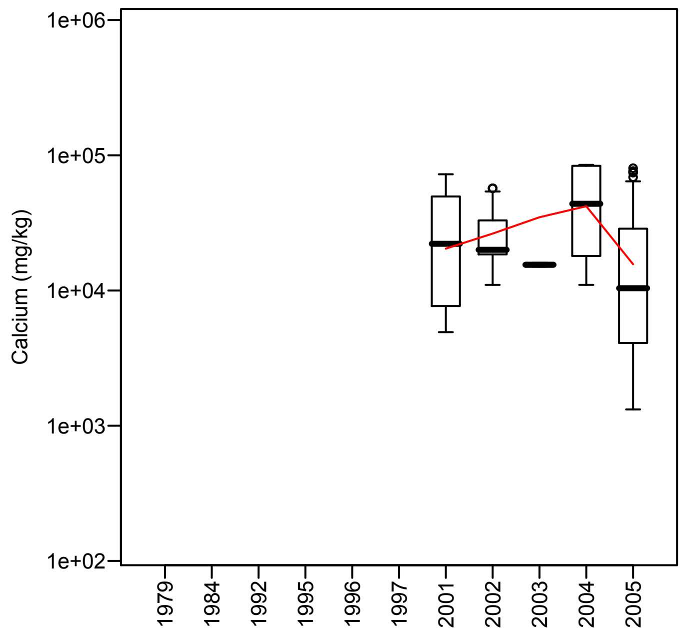


Figure 154. Temporal trend for Calcium within the entire UCR study area. The line indicates mean tendency.

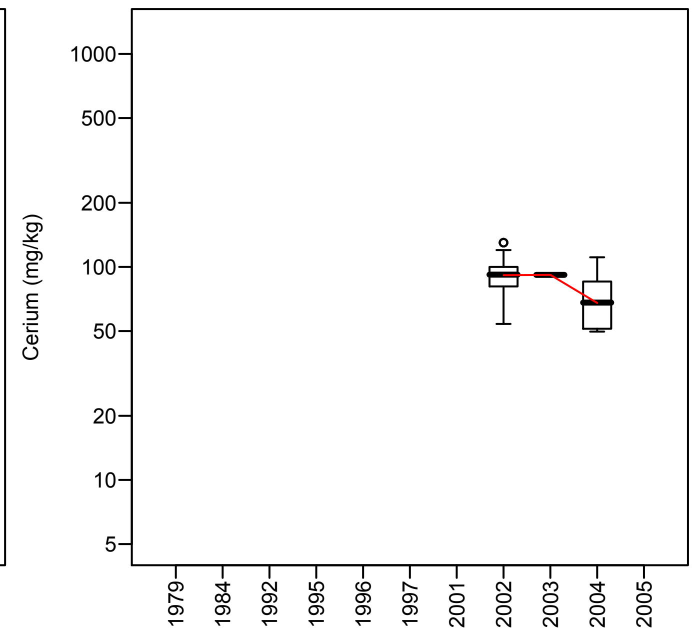


Figure 155. Temporal trend for Cerium within the entire UCR study area. The line indicates mean tendency.

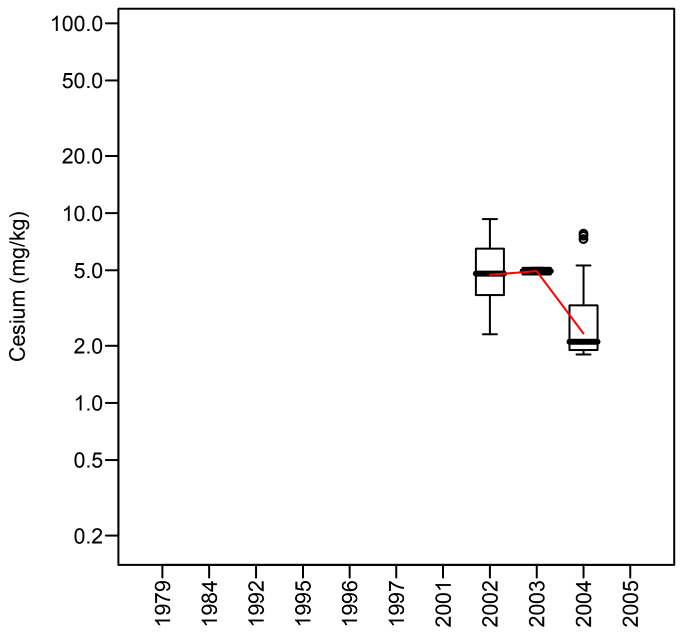


Figure 156. Temporal trend for Cesium within the entire UCR study area. The line indicates mean tendency.

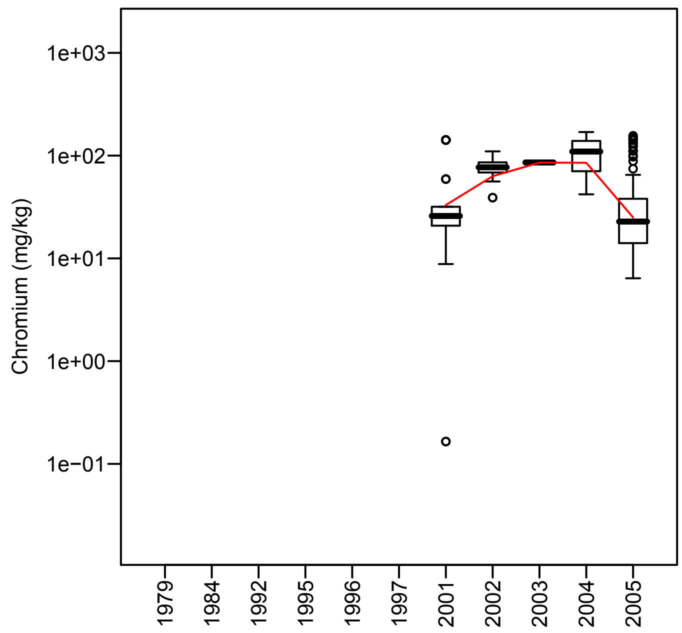


Figure 157. Temporal trend for Chromium within the entire UCR study area. The line indicates mean tendency.

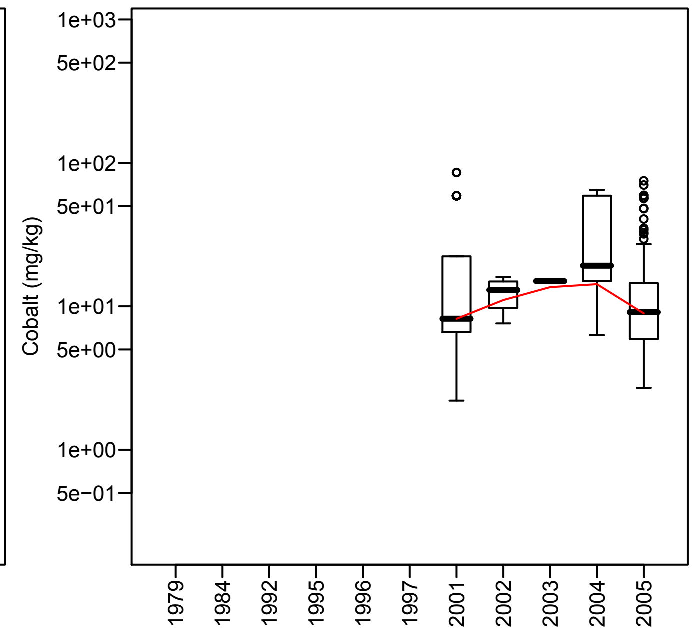


Figure 158. Temporal trend for Cobalt within the entire UCR study area. The line indicates mean tendency.

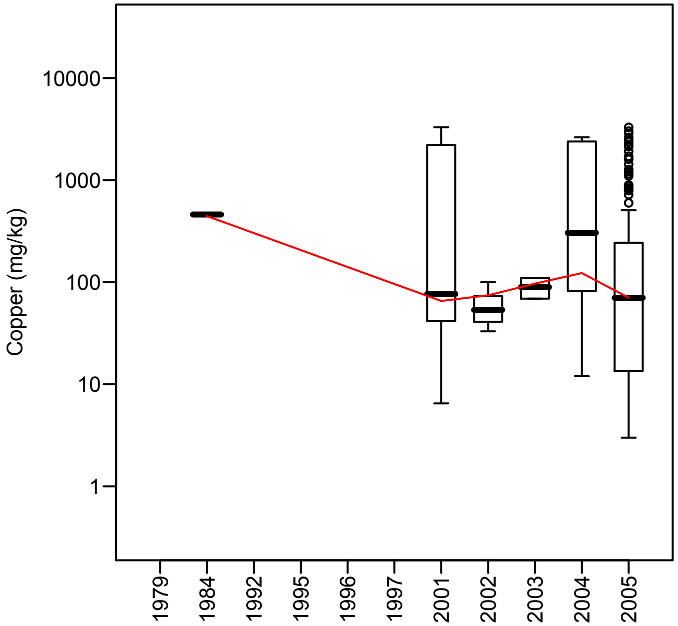


Figure 159. Temporal trend for Copper
within the entire UCR study area.
The line indicates mean tendency.

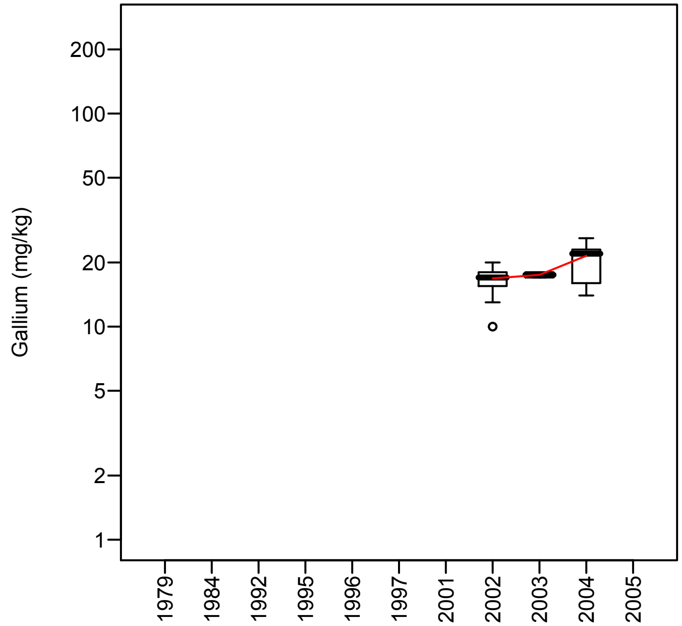


Figure 160. Temporal trend for Gallium
within the entire UCR study area.
The line indicates mean tendency.

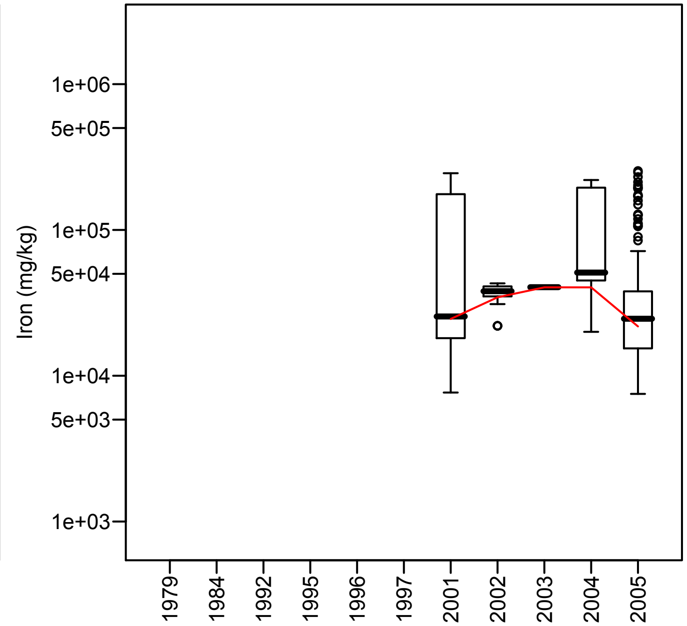


Figure 161. Temporal trend for Iron
within the entire UCR study area.
The line indicates mean tendency.

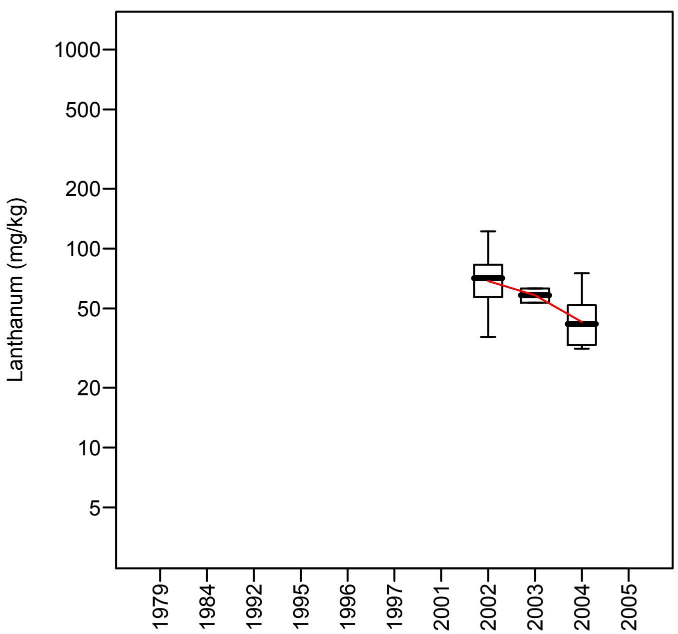


Figure 162. Temporal trend for Lanthanum
within the entire UCR study area.
The line indicates mean tendency.

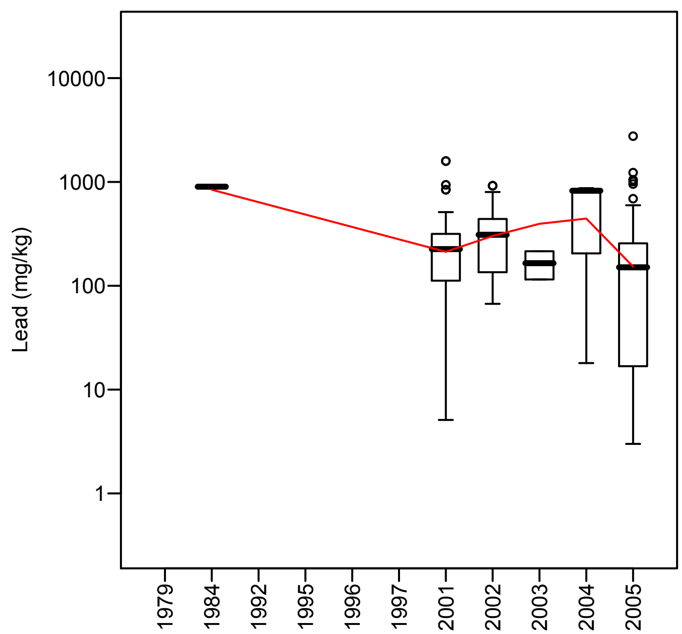


Figure 163. Temporal trend for Lead
within the entire UCR study area.
The line indicates mean tendency.

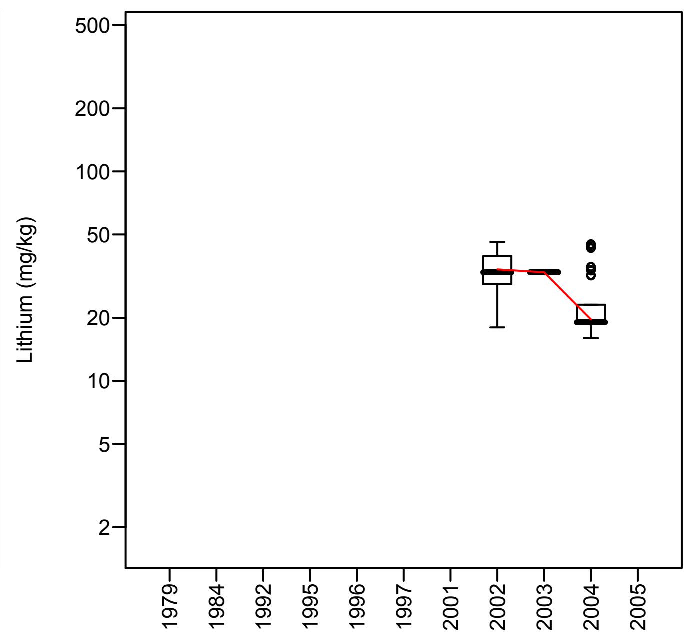


Figure 164. Temporal trend for Lithium
within the entire UCR study area.
The line indicates mean tendency.

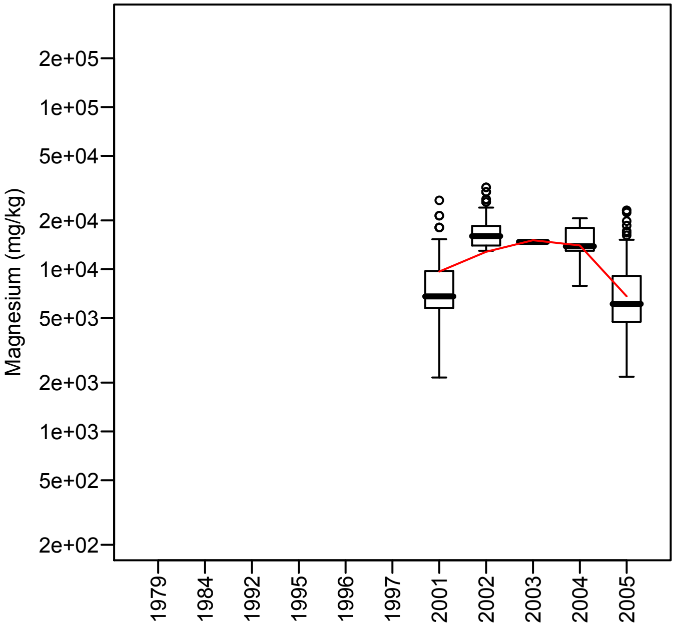


Figure 165. Temporal trend for Magnesium within the entire UCR study area. The line indicates mean tendency.

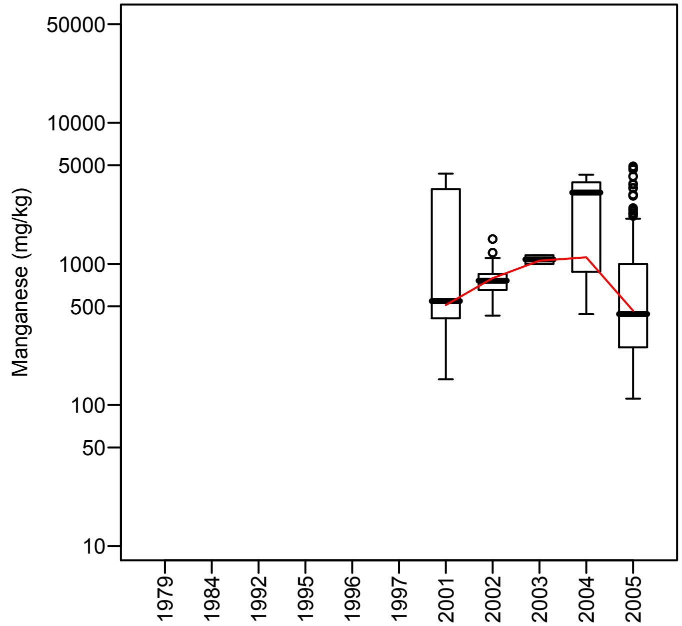


Figure 166. Temporal trend for Manganese within the entire UCR study area. The line indicates mean tendency.

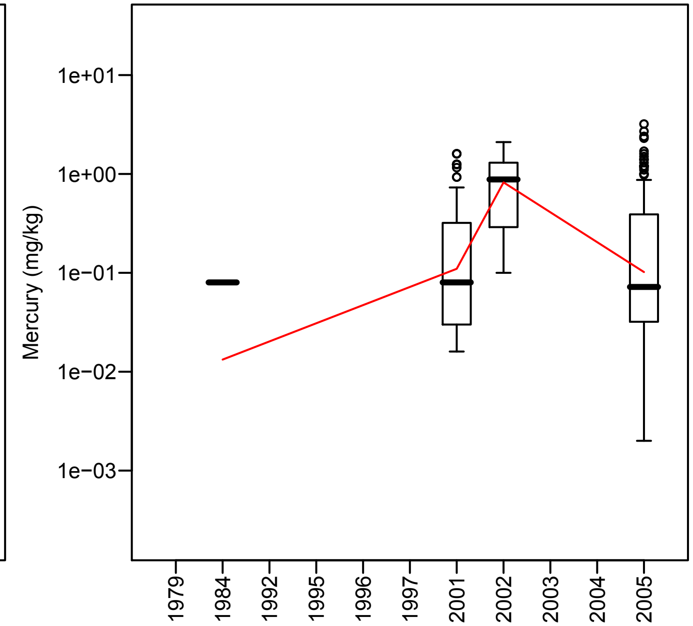


Figure 167. Temporal trend for Mercury within the entire UCR study area. The line indicates mean tendency.

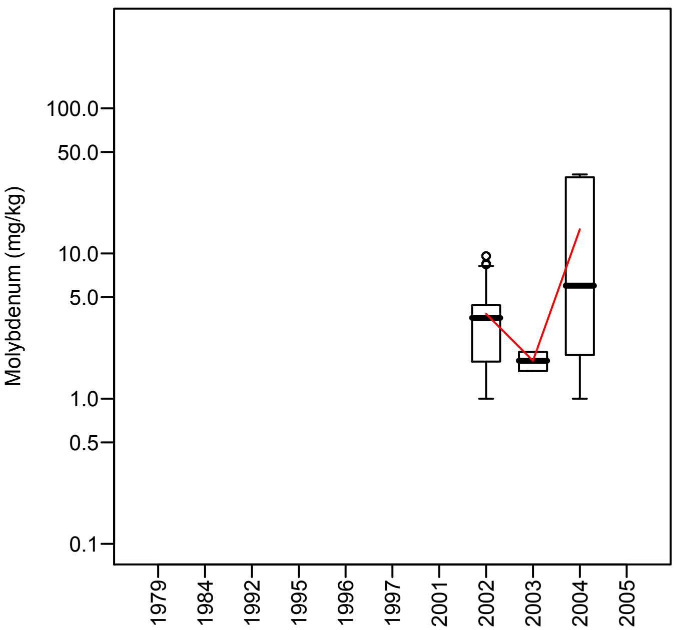


Figure 168. Temporal trend for Molybdenum within the entire UCR study area. The line indicates mean tendency.

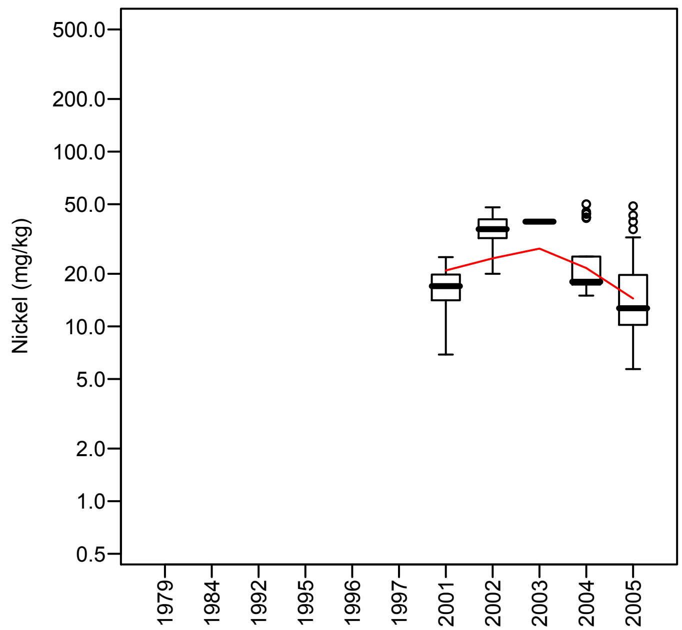


Figure 169. Temporal trend for Nickel within the entire UCR study area. The line indicates mean tendency.

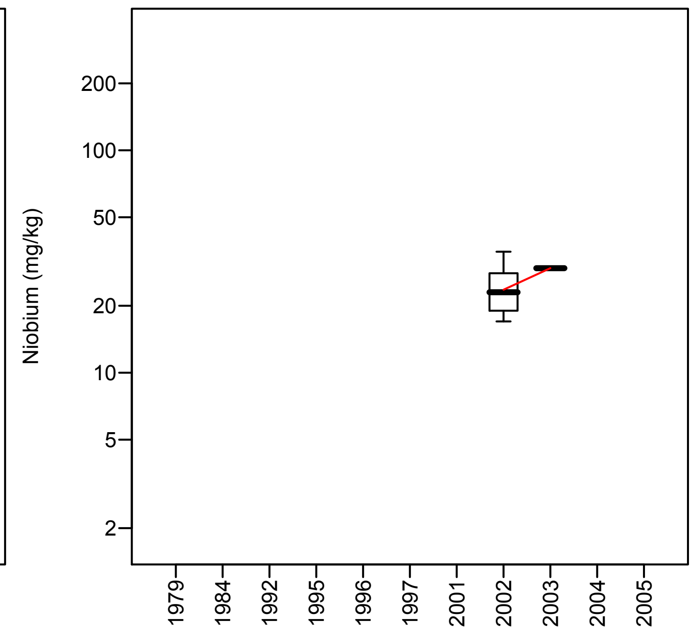


Figure 170. Temporal trend for Niobium within the entire UCR study area. The line indicates mean tendency.

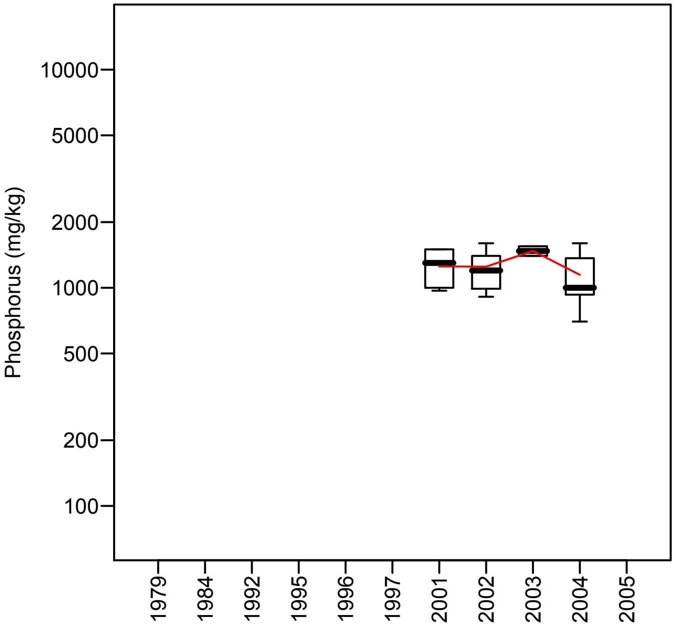


Figure 171. Temporal trend for Phosphorus
within the entire UCR study area.
The line indicates mean tendency.

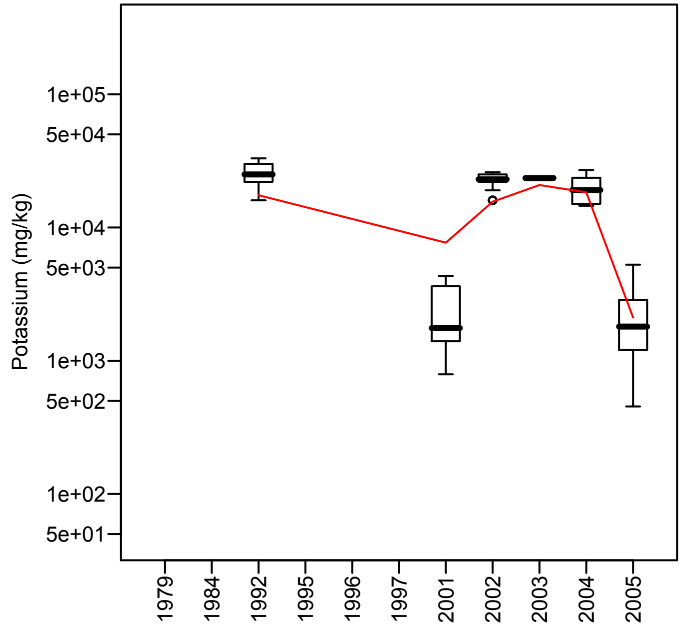


Figure 172. Temporal trend for Potassium
within the entire UCR study area.
The line indicates mean tendency.

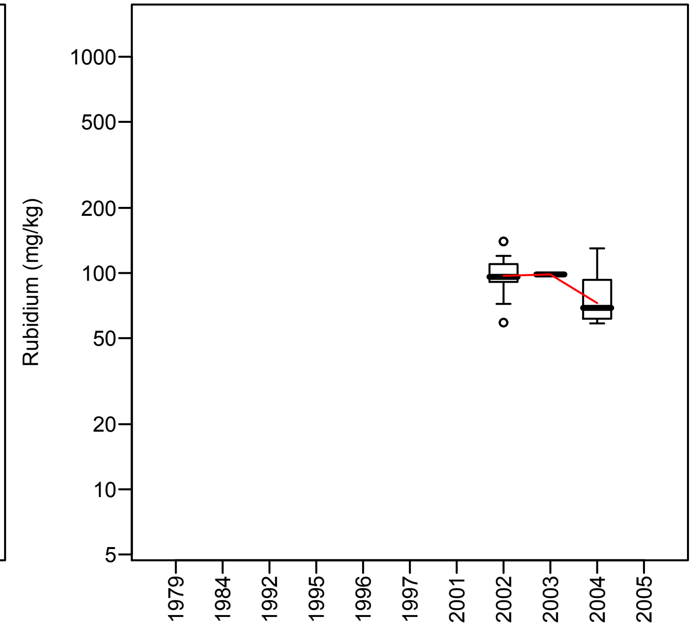


Figure 173. Temporal trend for Rubidium
within the entire UCR study area.
The line indicates mean tendency.

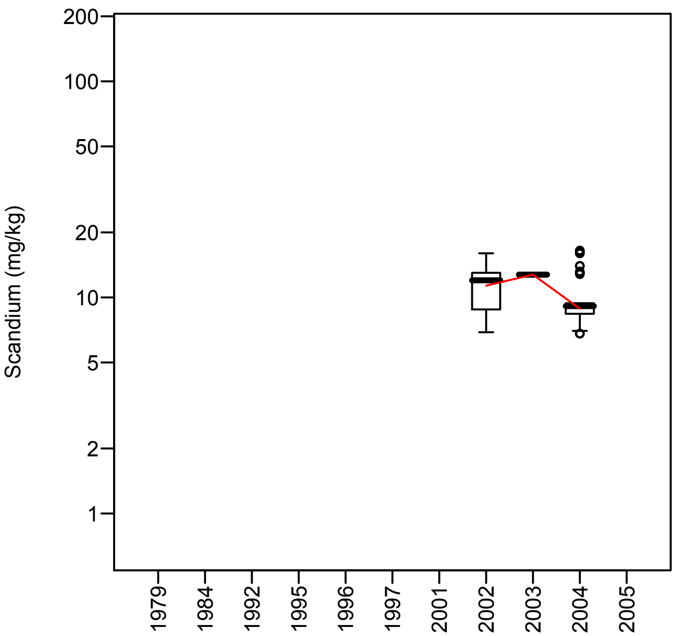


Figure 174. Temporal trend for Scandium
within the entire UCR study area.
The line indicates mean tendency.

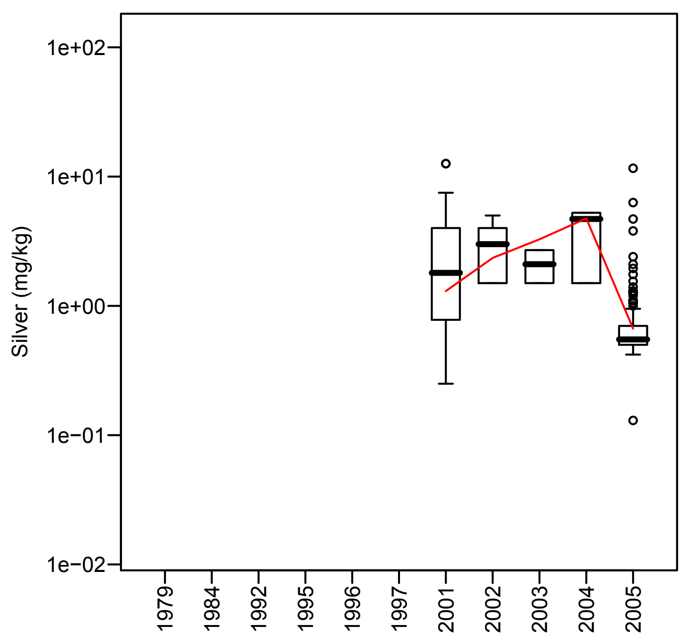


Figure 175. Temporal trend for Silver
within the entire UCR study area.
The line indicates mean tendency.

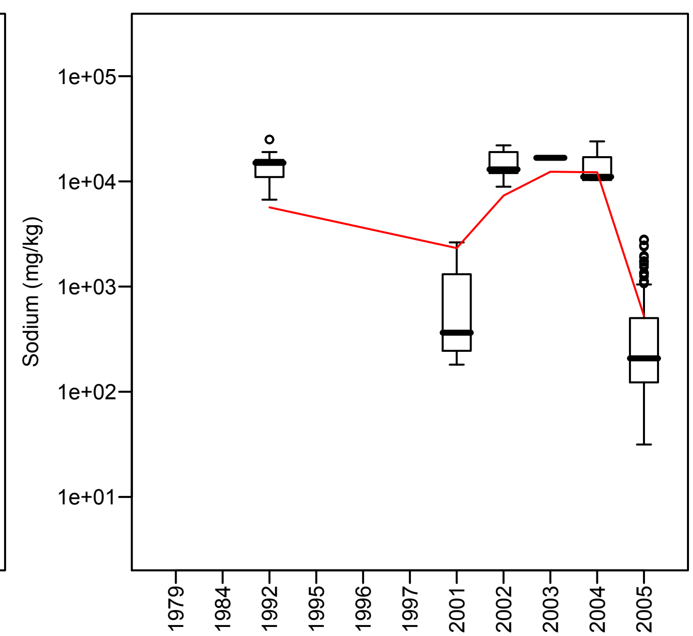


Figure 176. Temporal trend for Sodium
within the entire UCR study area.
The line indicates mean tendency.

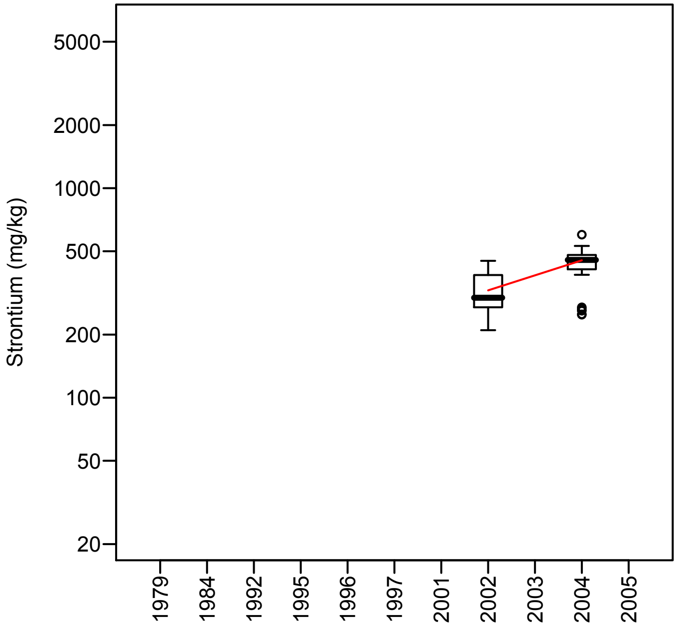


Figure 177. Temporal trend for Strontium within the entire UCR study area. The line indicates mean tendency.

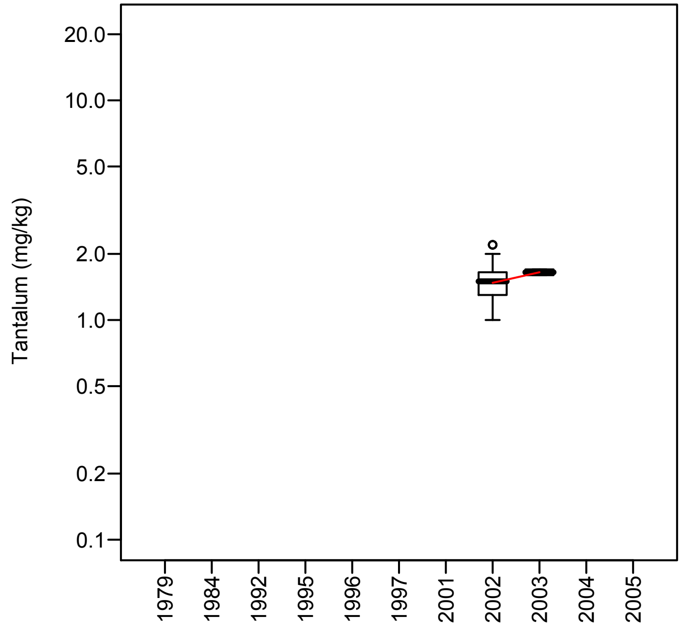


Figure 178. Temporal trend for Tantalum within the entire UCR study area. The line indicates mean tendency.

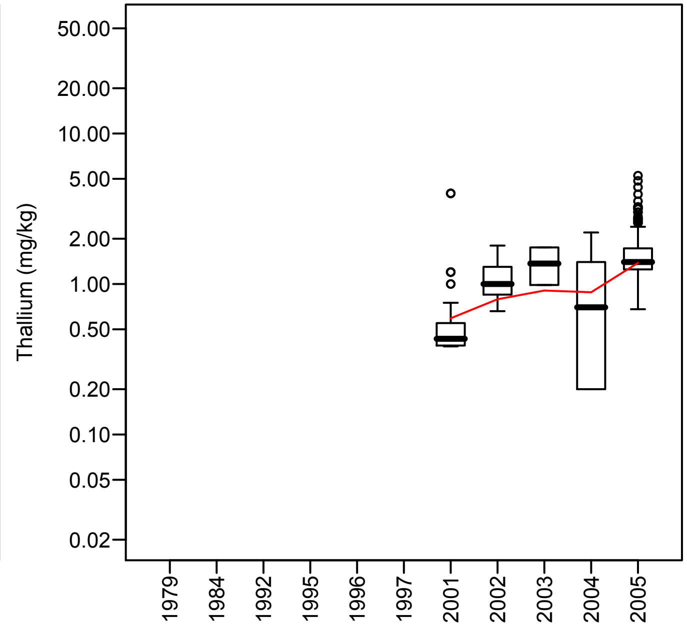


Figure 179. Temporal trend for Thallium within the entire UCR study area. The line indicates mean tendency.

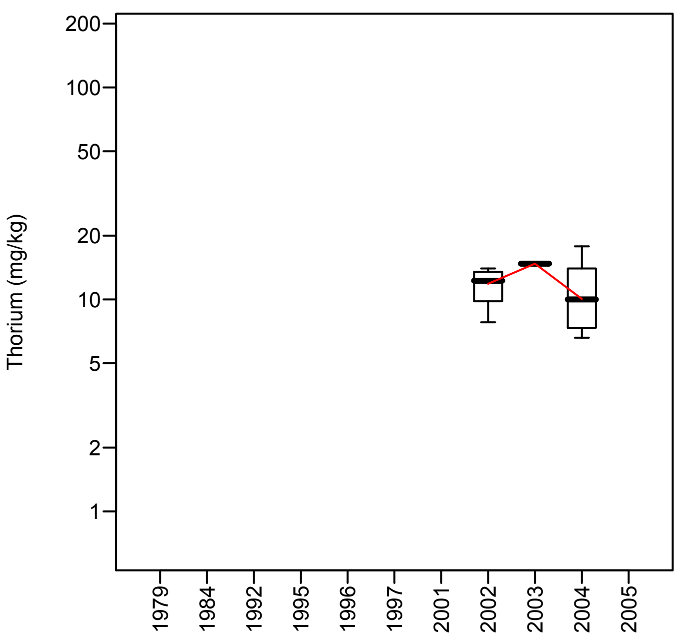


Figure 180. Temporal trend for Thorium within the entire UCR study area. The line indicates mean tendency.

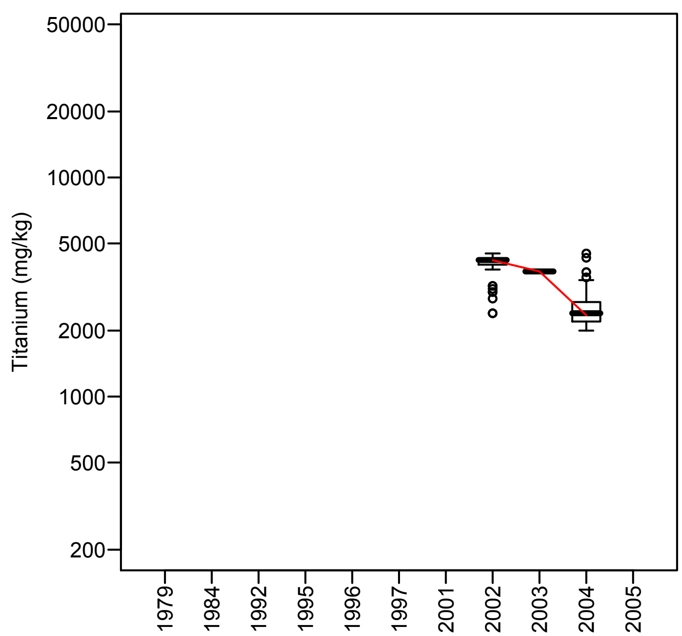


Figure 181. Temporal trend for Titanium within the entire UCR study area. The line indicates mean tendency.

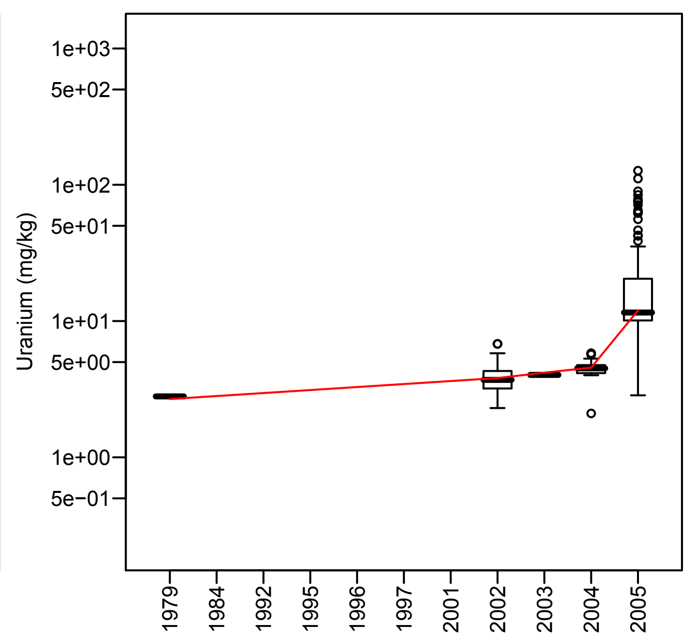


Figure 182. Temporal trend for Uranium within the entire UCR study area. The line indicates mean tendency.

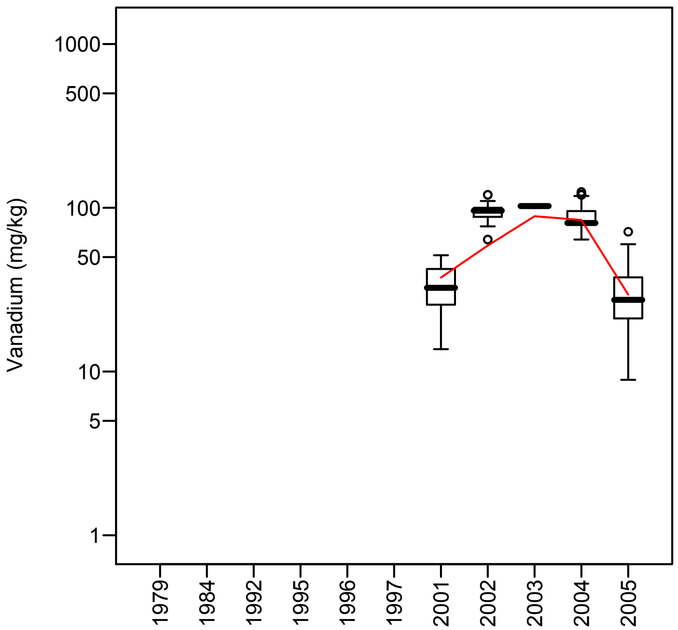


Figure 183. Temporal trend for Vanadium within the entire UCR study area. The line indicates mean tendency.

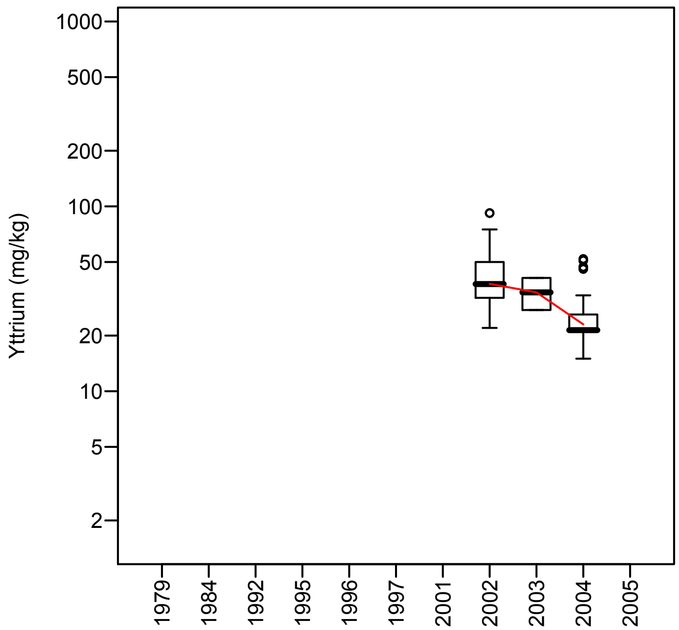


Figure 184. Temporal trend for Yttrium within the entire UCR study area. The line indicates mean tendency.

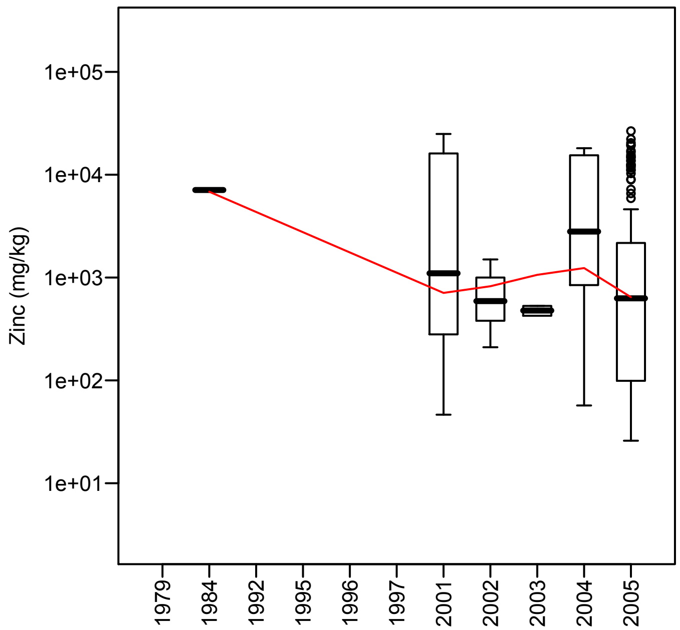


Figure 185. Temporal trend for Zinc within the entire UCR study area. The line indicates mean tendency.

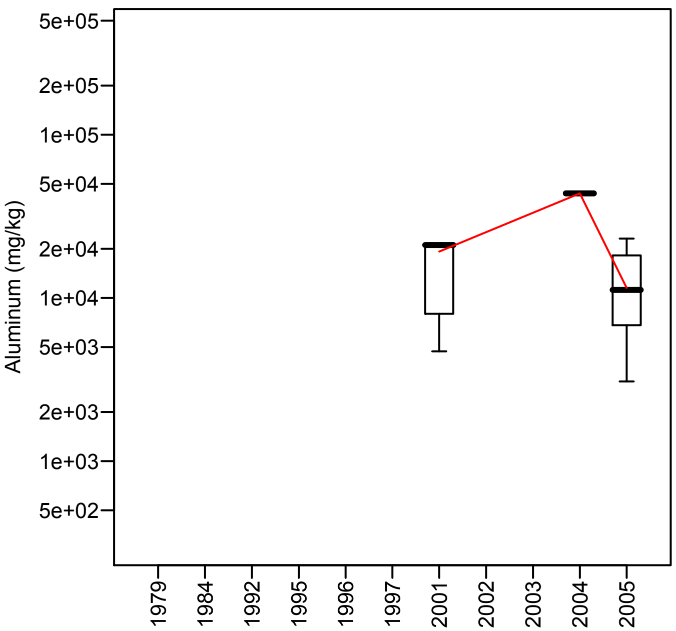


Figure 186. Temporal trend for Aluminum concentrations within Reach #1. Red line indicates mean tendency.

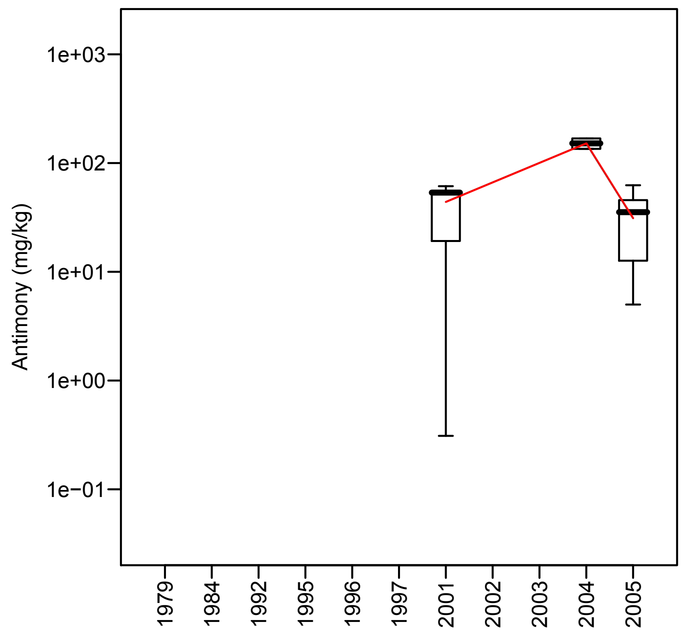


Figure 187. Temporal trend for Antimony concentrations within Reach #1. Red line indicates mean tendency.

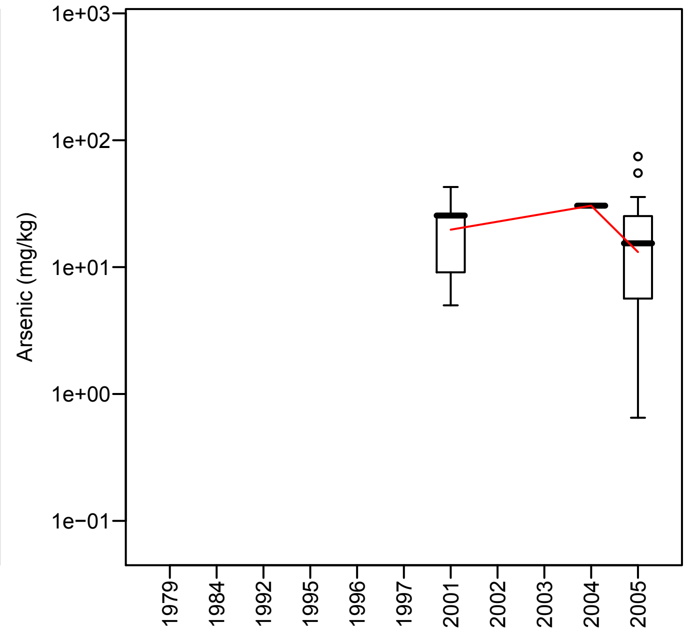


Figure 188. Temporal trend for Arsenic concentrations within Reach #1. Red line indicates mean tendency.

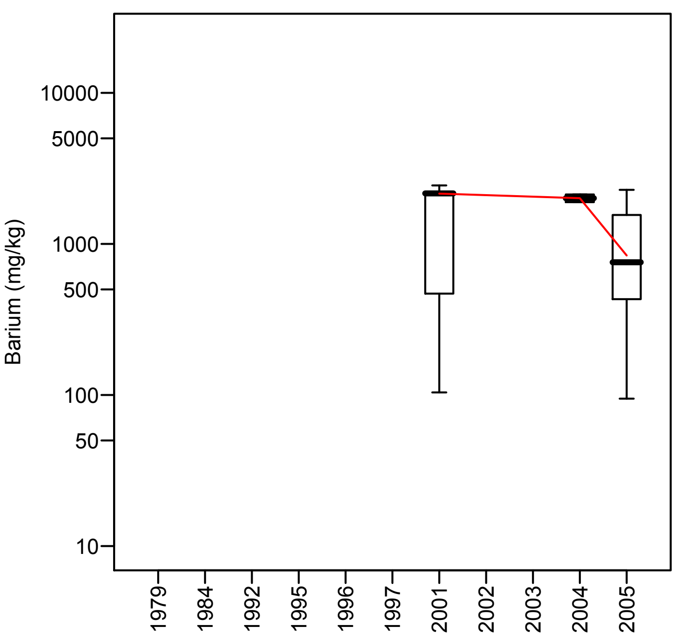


Figure 189. Temporal trend for Barium concentrations within Reach #1. Red line indicates mean tendency.

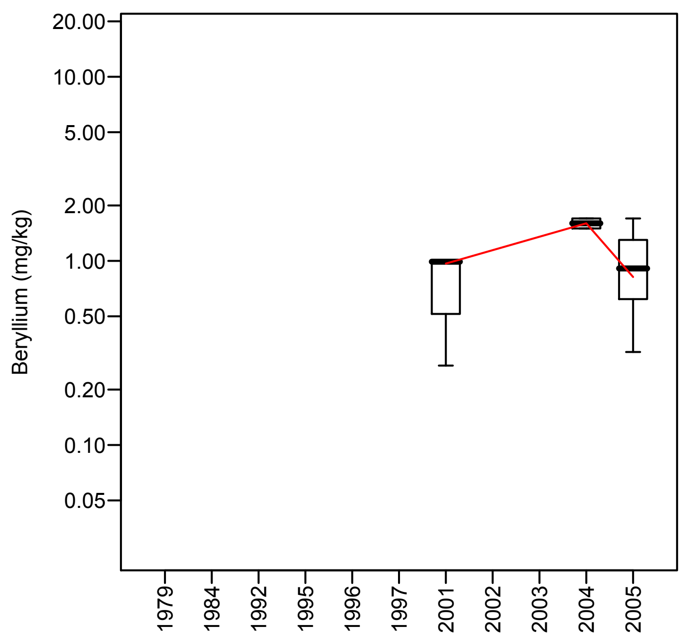


Figure 190. Temporal trend for Beryllium concentrations within Reach #1. Red line indicates mean tendency.

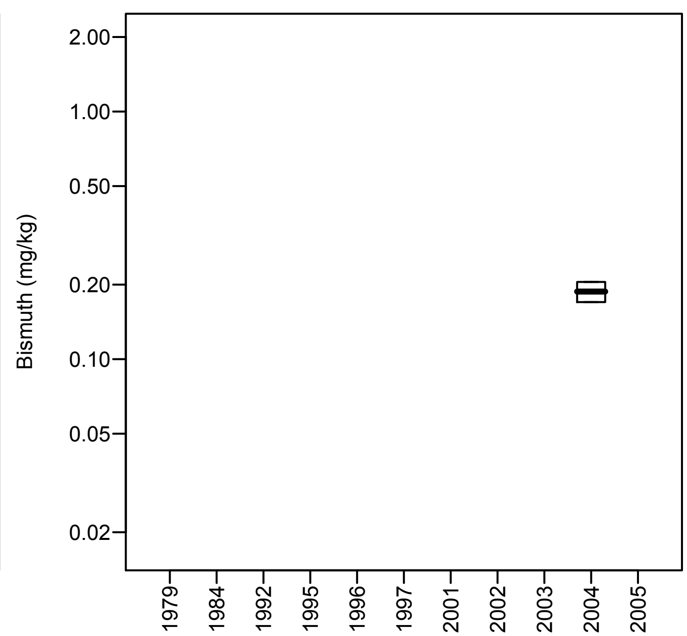


Figure 191. Temporal trend for Bismuth concentrations within Reach #1. Red line indicates mean tendency.

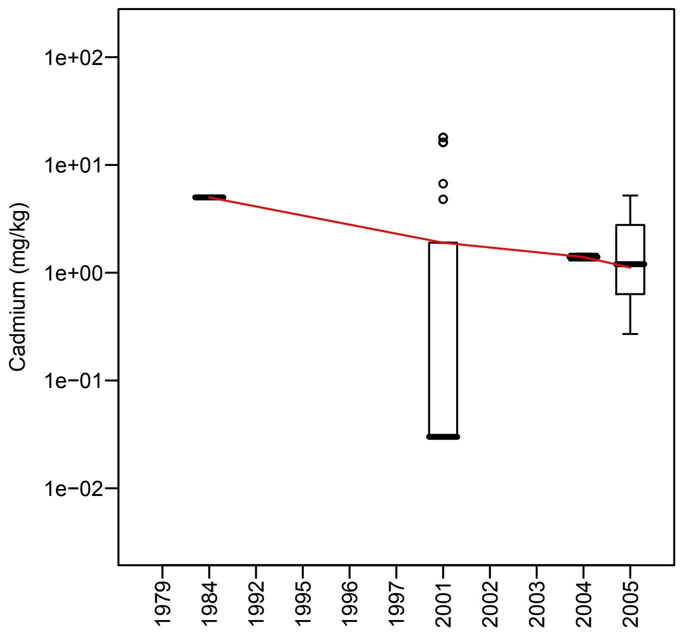


Figure 192. Temporal trend for Cadmium concentrations within Reach #1. Red line indicates mean tendency.

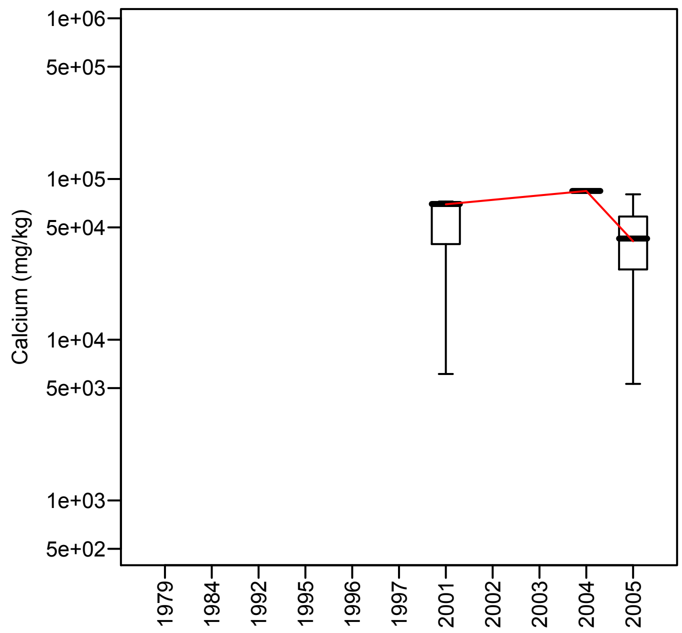


Figure 193. Temporal trend for Calcium concentrations within Reach #1. Red line indicates mean tendency.

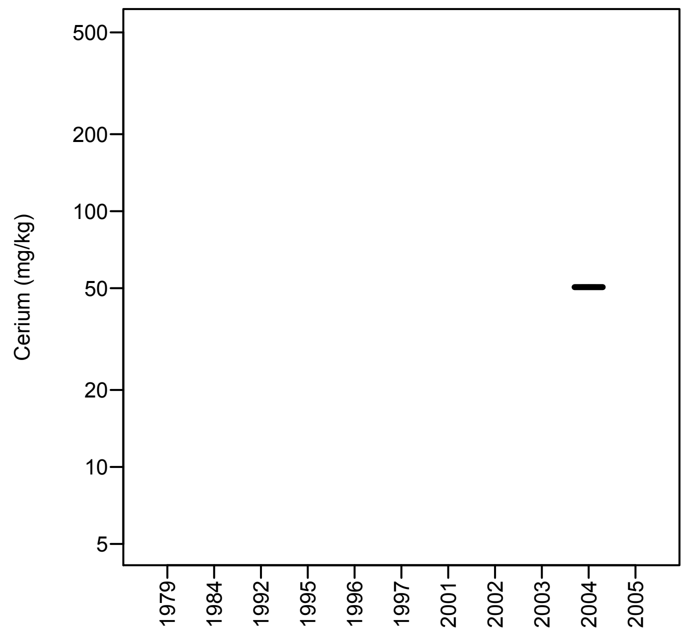


Figure 194. Temporal trend for Cerium concentrations within Reach #1. Red line indicates mean tendency.

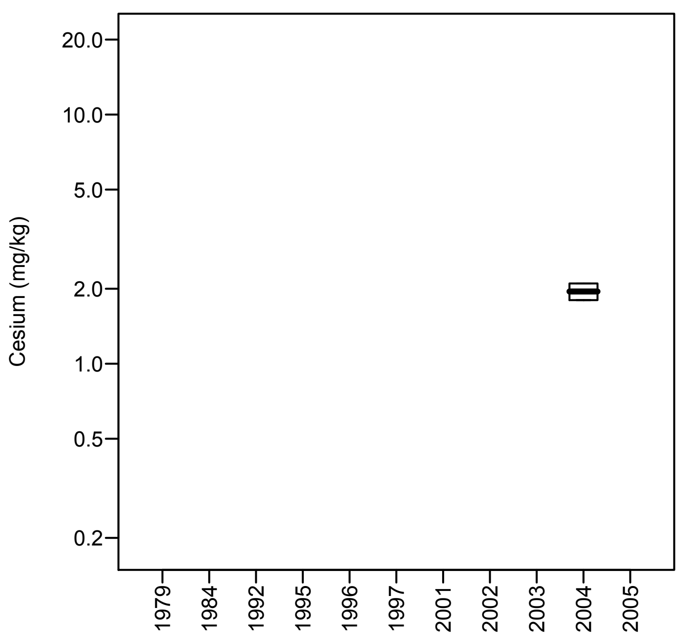


Figure 195. Temporal trend for Cesium concentrations within Reach #1. Red line indicates mean tendency.

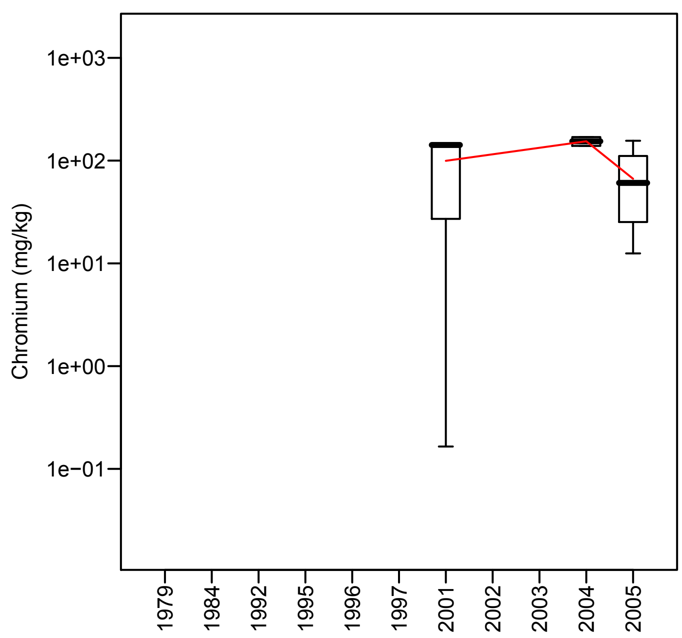


Figure 196. Temporal trend for Chromium concentrations within Reach #1. Red line indicates mean tendency.

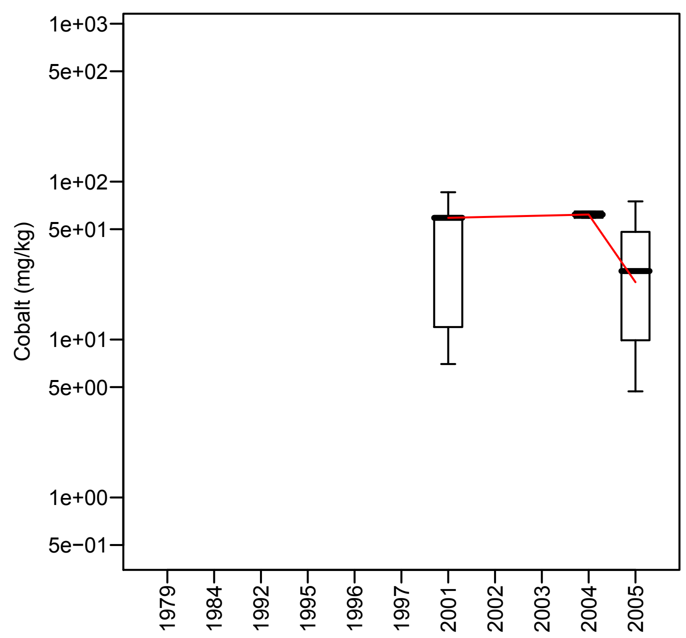


Figure 197. Temporal trend for Cobalt concentrations within Reach #1. Red line indicates mean tendency.

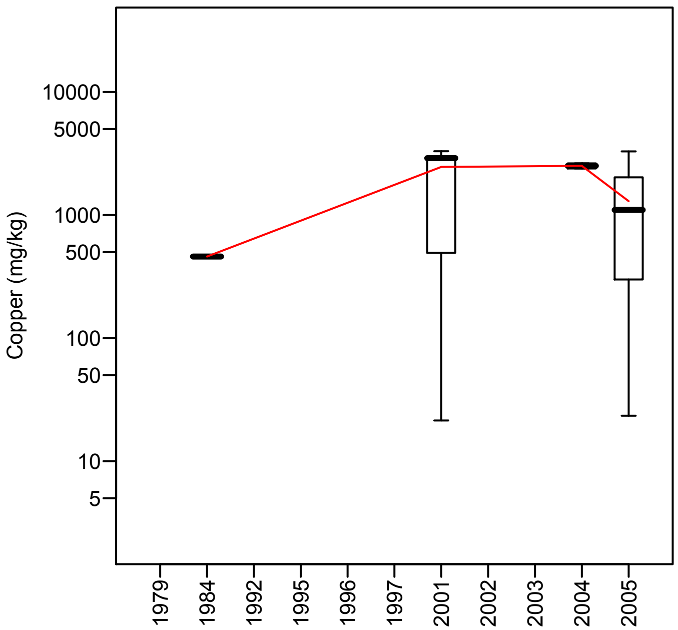


Figure 198. Temporal trend for Copper
concentrations within Reach #1.
Red line indicates mean tendency.

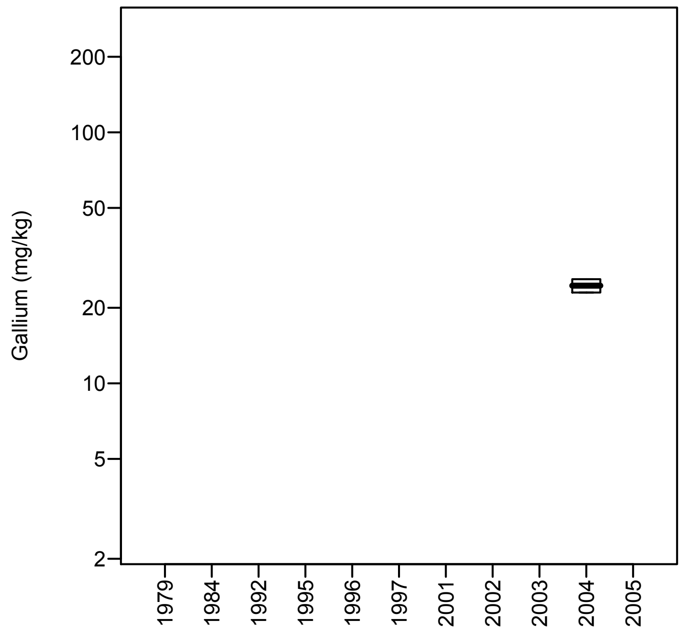


Figure 199. Temporal trend for Gallium
concentrations within Reach #1.
Red line indicates mean tendency.

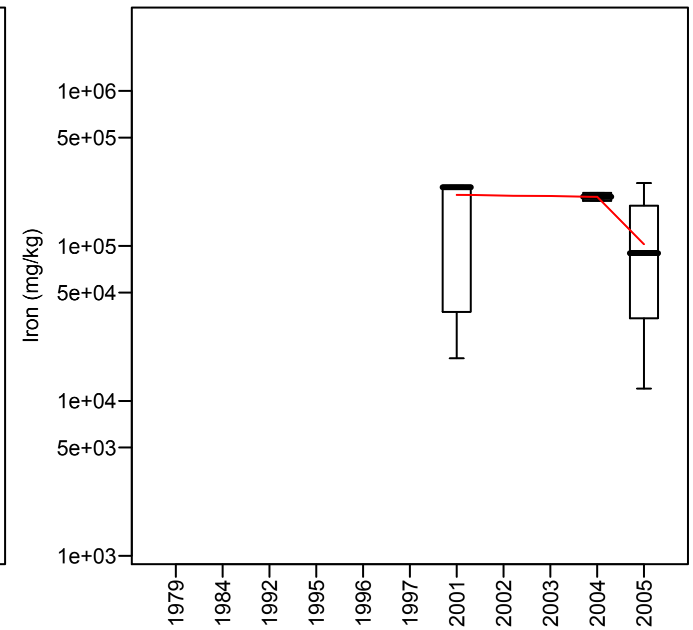


Figure 200. Temporal trend for Iron
concentrations within Reach #1.
Red line indicates mean tendency.

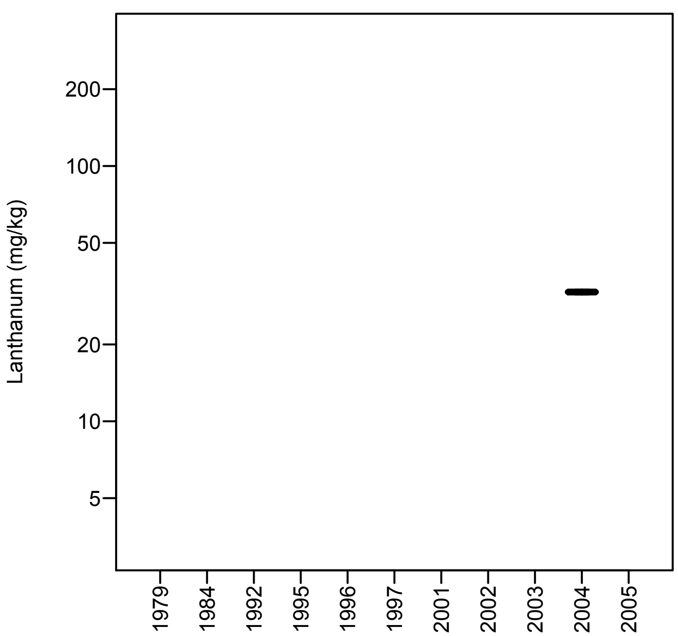


Figure 201. Temporal trend for Lanthanum
concentrations within Reach #1.
Red line indicates mean tendency.

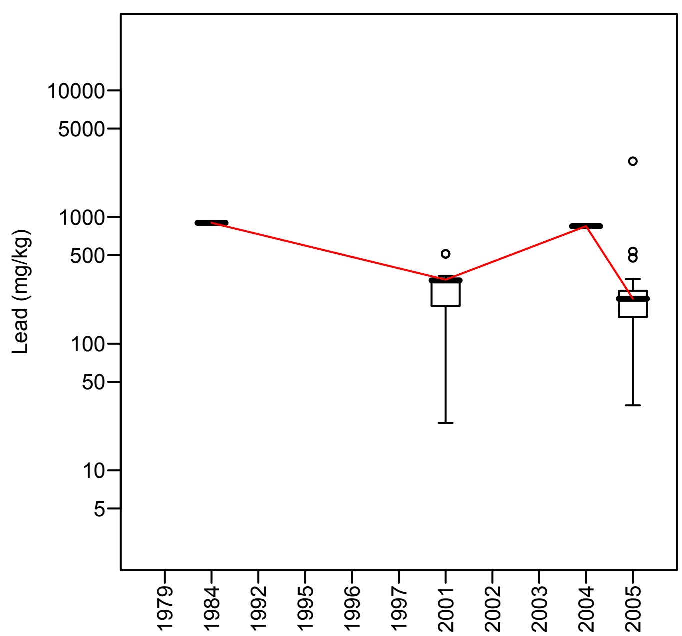


Figure 202. Temporal trend for Lead
concentrations within Reach #1.
Red line indicates mean tendency.

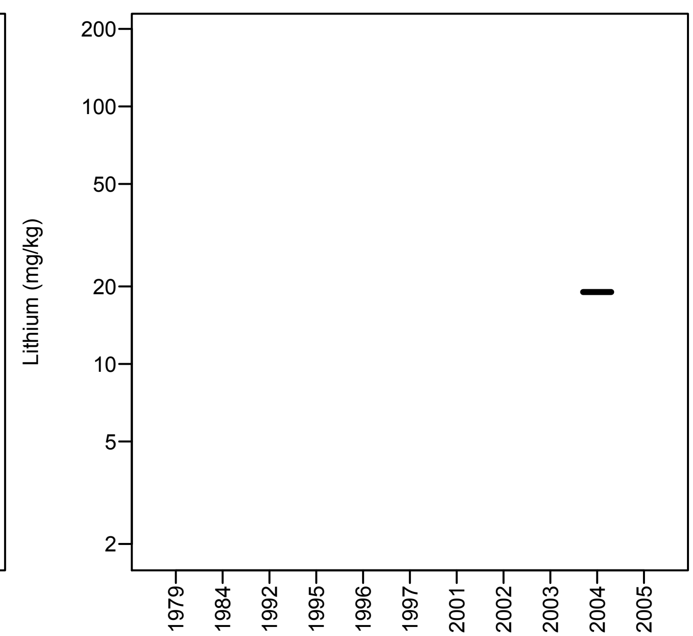


Figure 203. Temporal trend for Lithium
concentrations within Reach #1.
Red line indicates mean tendency.

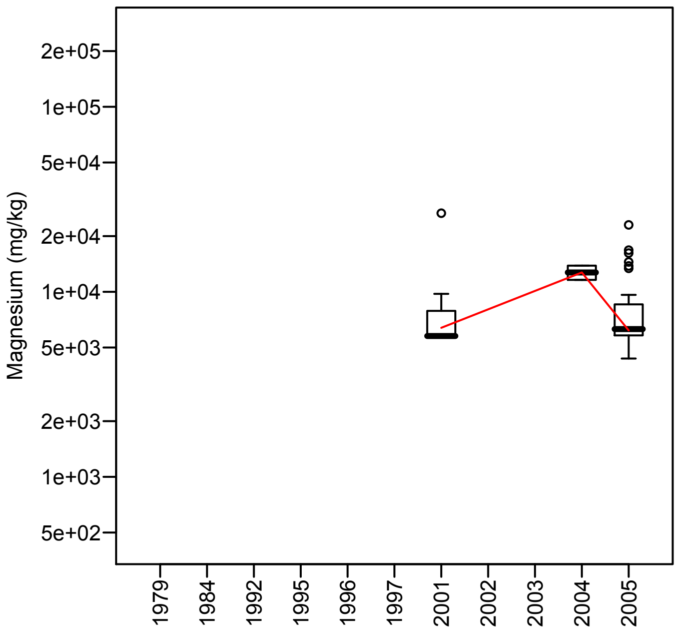


Figure 204. Temporal trend for Magnesium concentrations within Reach #1. Red line indicates mean tendency.

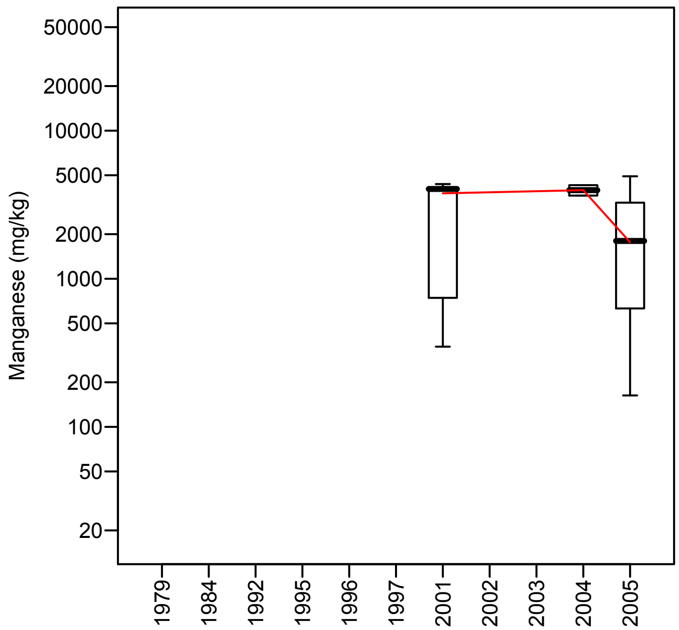


Figure 205. Temporal trend for Manganese concentrations within Reach #1. Red line indicates mean tendency.

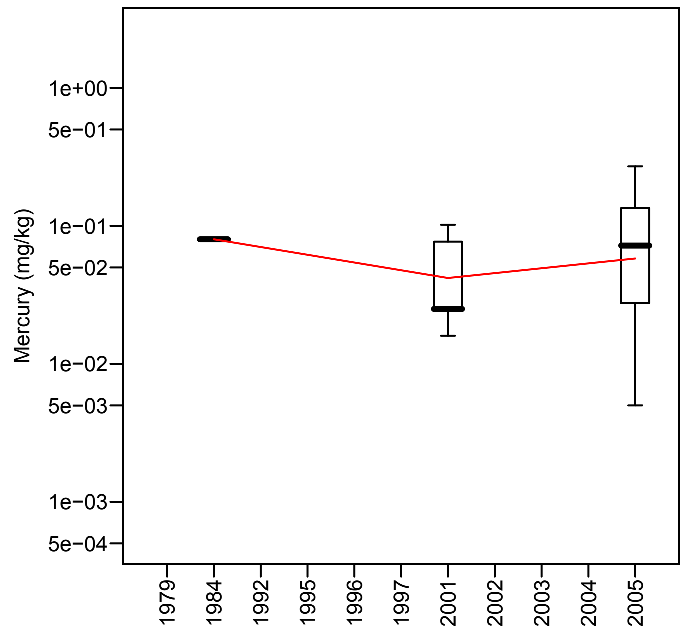


Figure 206. Temporal trend for Mercury concentrations within Reach #1. Red line indicates mean tendency.

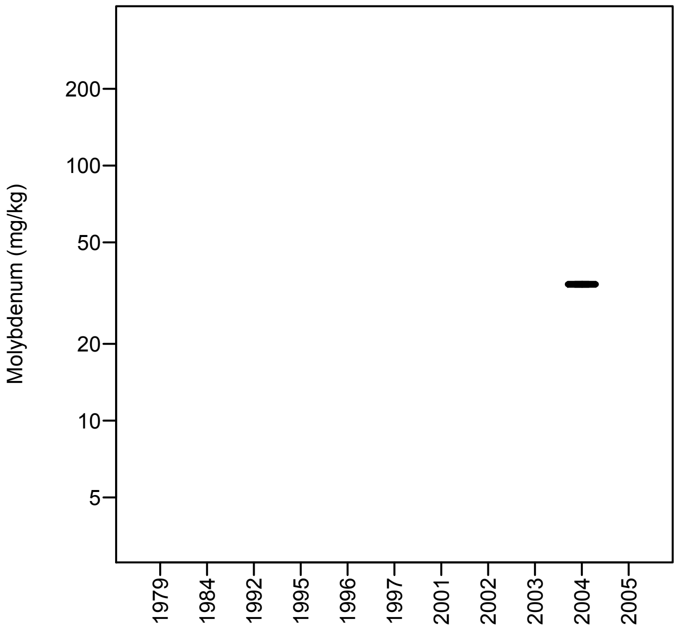


Figure 207. Temporal trend for Molybdenum concentrations within Reach #1. Red line indicates mean tendency.

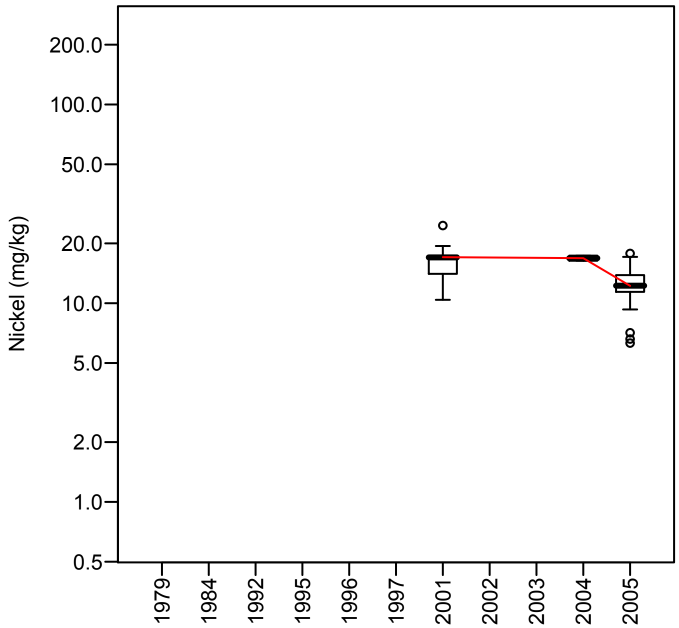


Figure 208. Temporal trend for Nickel concentrations within Reach #1. Red line indicates mean tendency.

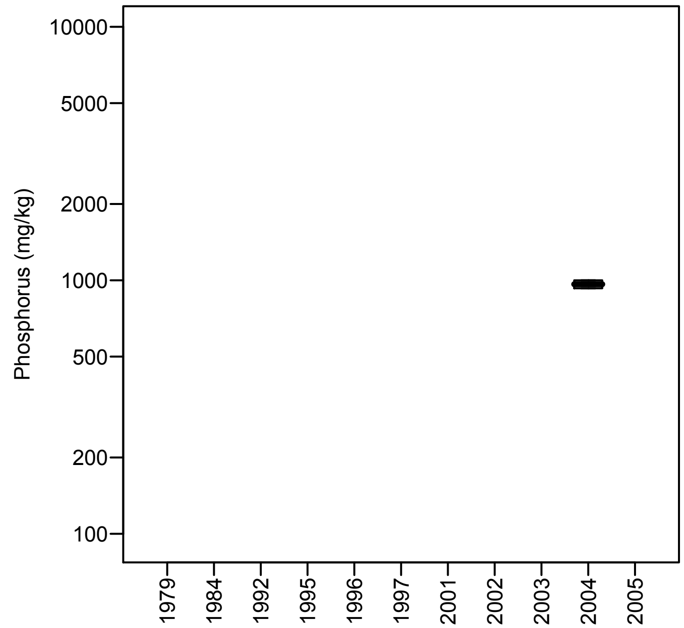


Figure 209. Temporal trend for Phosphorus concentrations within Reach #1. Red line indicates mean tendency.

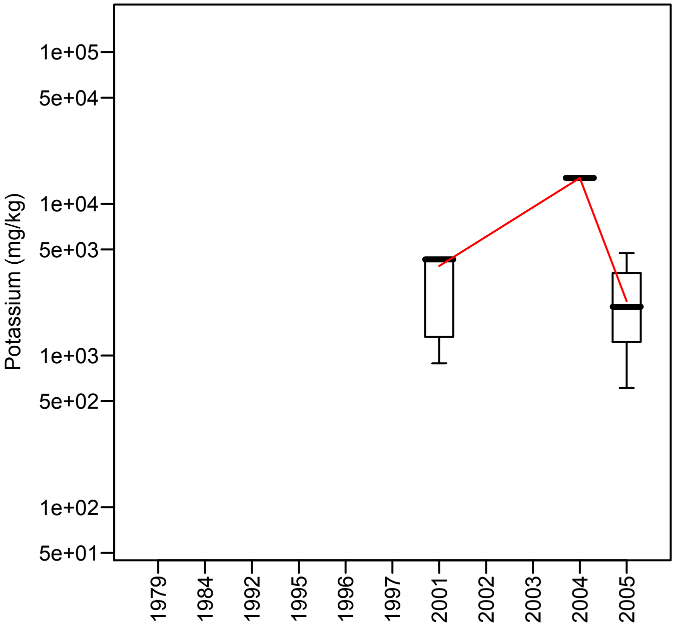


Figure 210. Temporal trend for Potassium concentrations within Reach #1. Red line indicates mean tendency.

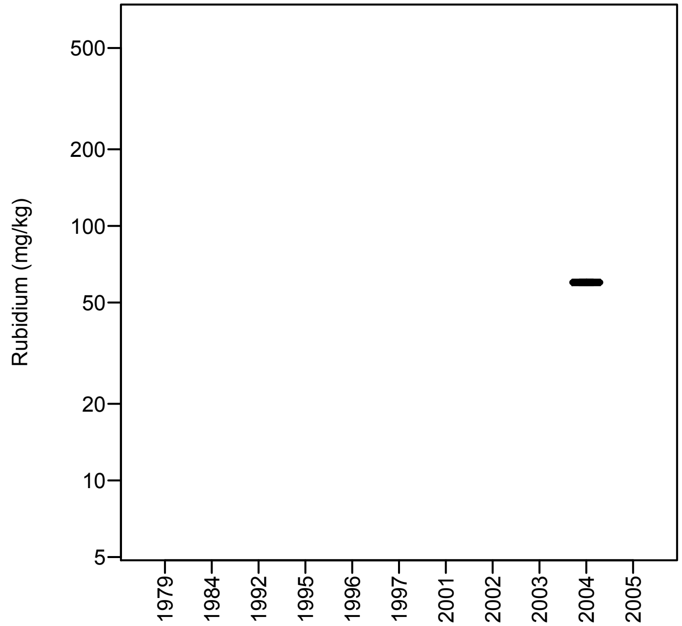


Figure 211. Temporal trend for Rubidium concentrations within Reach #1. Red line indicates mean tendency.

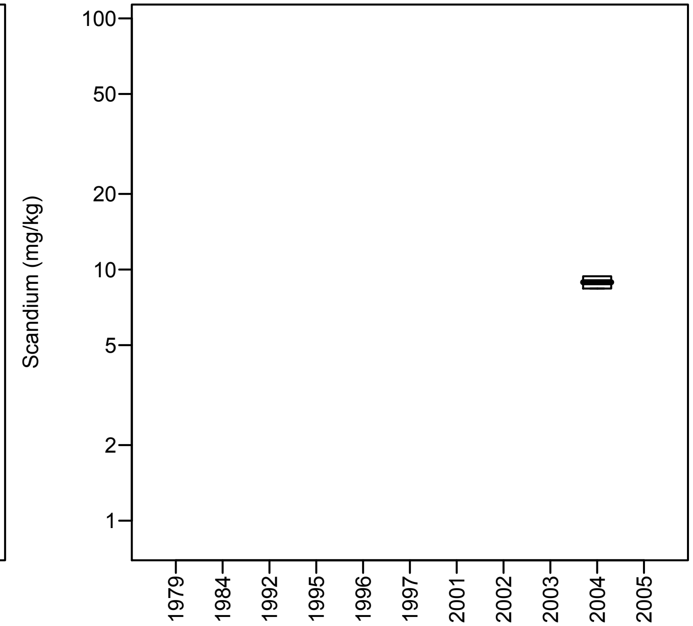


Figure 212. Temporal trend for Scandium concentrations within Reach #1. Red line indicates mean tendency.

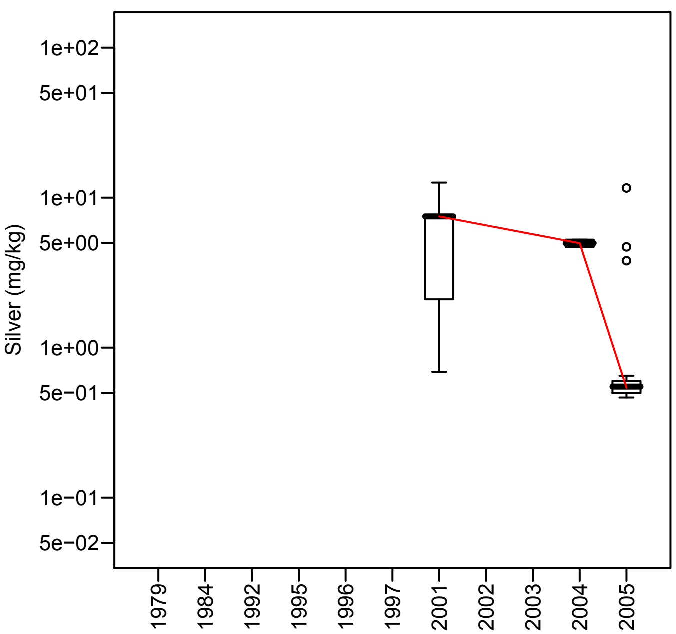


Figure 213. Temporal trend for Silver concentrations within Reach #1. Red line indicates mean tendency.

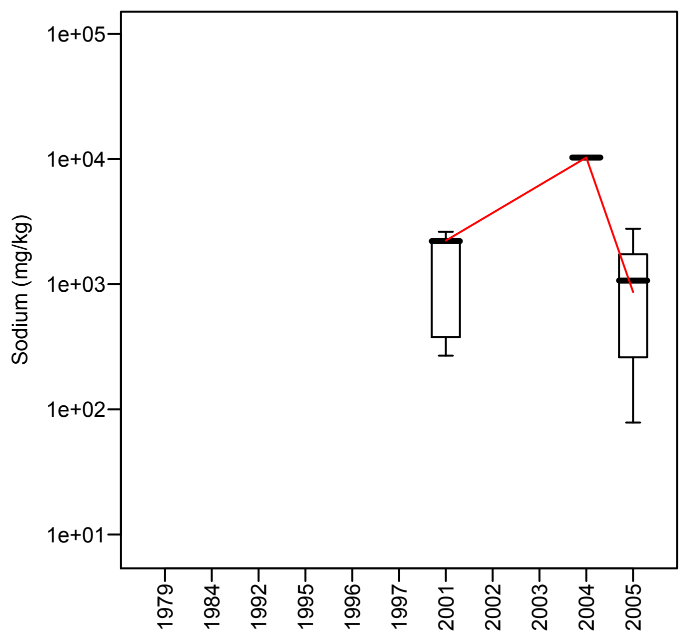


Figure 214. Temporal trend for Sodium concentrations within Reach #1. Red line indicates mean tendency.

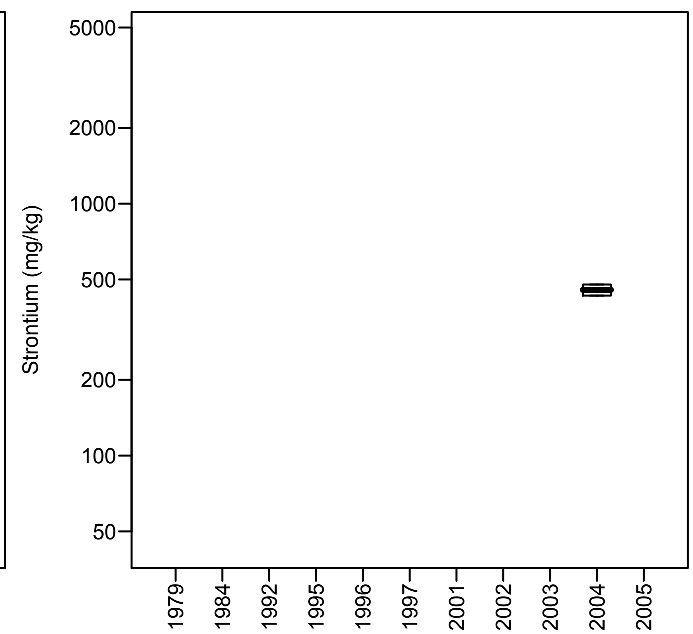


Figure 215. Temporal trend for Strontium concentrations within Reach #1. Red line indicates mean tendency.

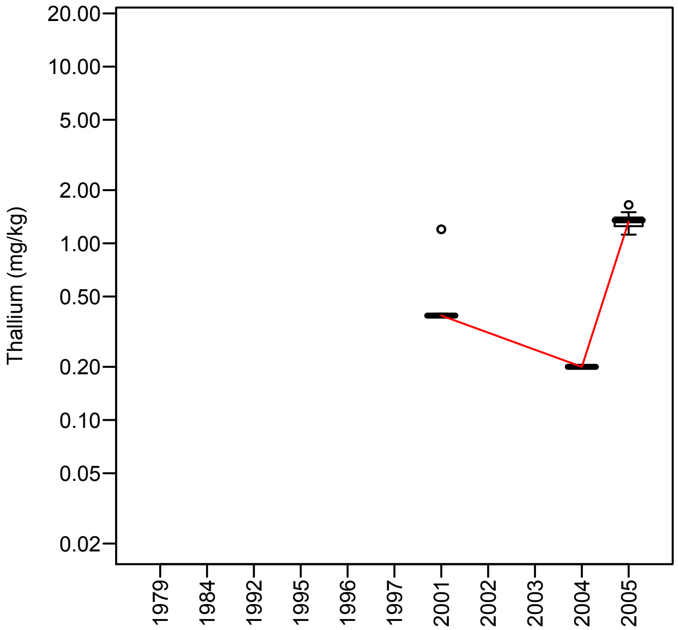


Figure 216. Temporal trend for Thallium concentrations within Reach #1. Red line indicates mean tendency.

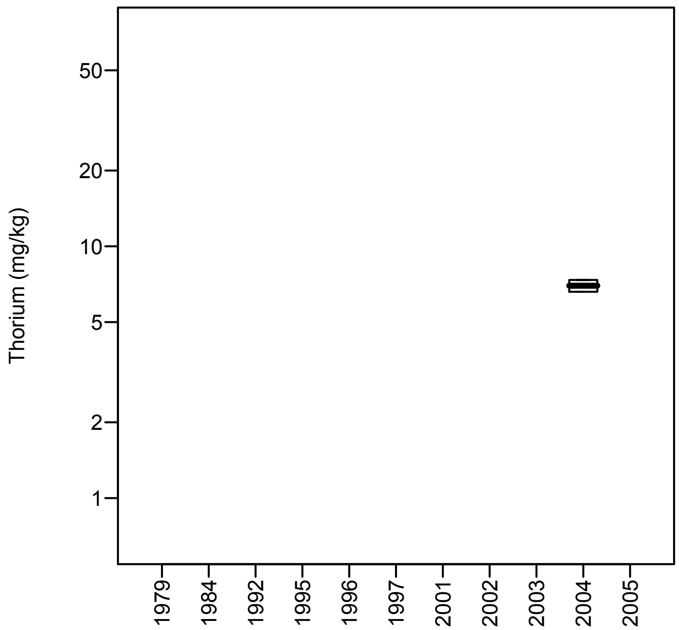


Figure 217. Temporal trend for Thorium concentrations within Reach #1. Red line indicates mean tendency.

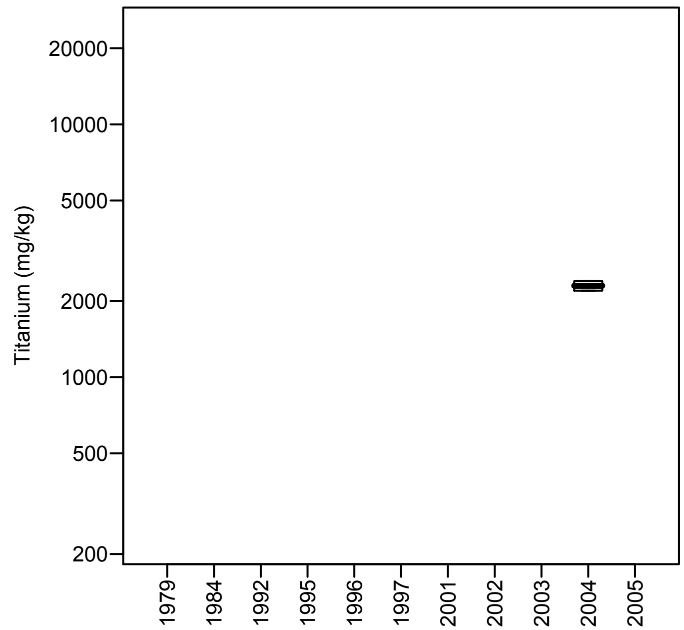


Figure 218. Temporal trend for Titanium concentrations within Reach #1. Red line indicates mean tendency.

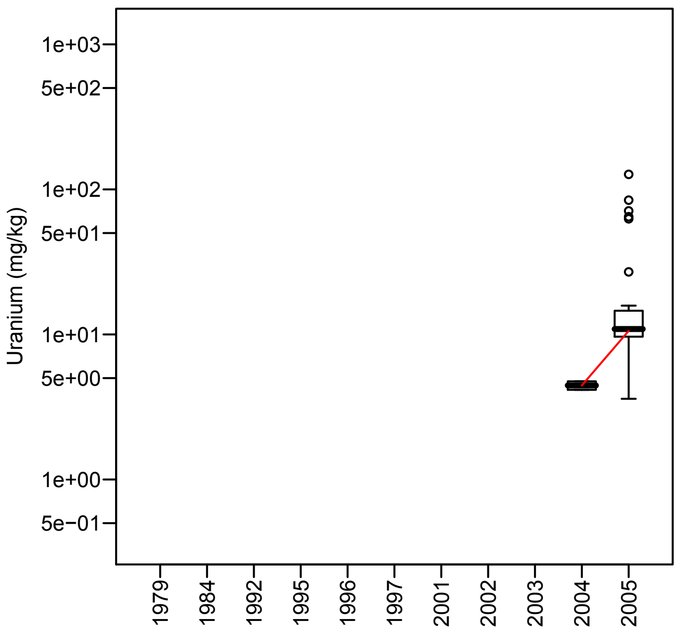


Figure 219. Temporal trend for Uranium concentrations within Reach #1. Red line indicates mean tendency.

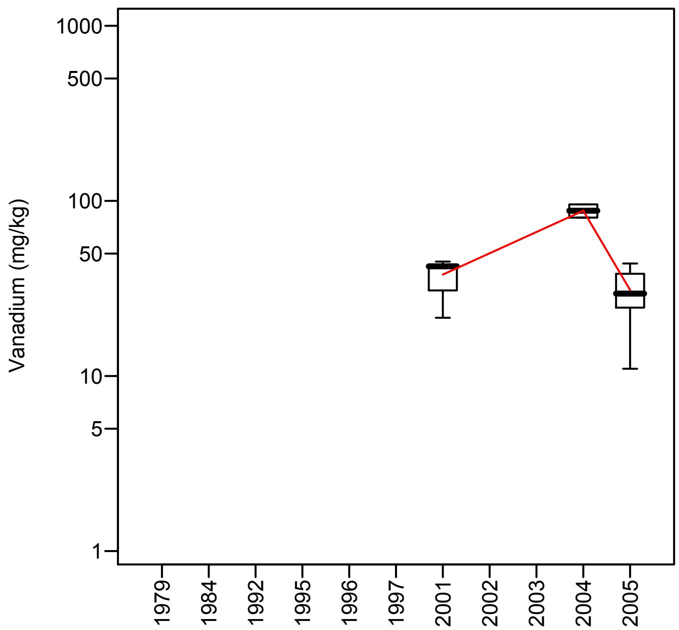


Figure 220. Temporal trend for Vanadium concentrations within Reach #1. Red line indicates mean tendency.

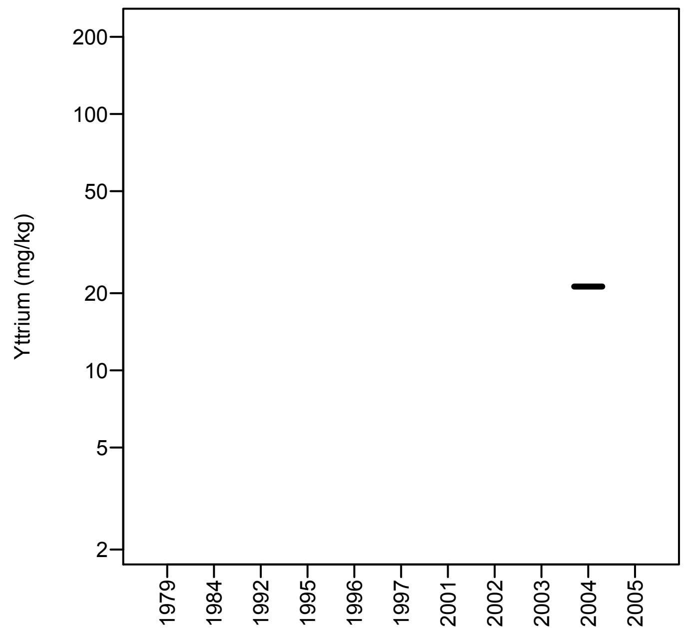


Figure 221. Temporal trend for Yttrium concentrations within Reach #1. Red line indicates mean tendency.

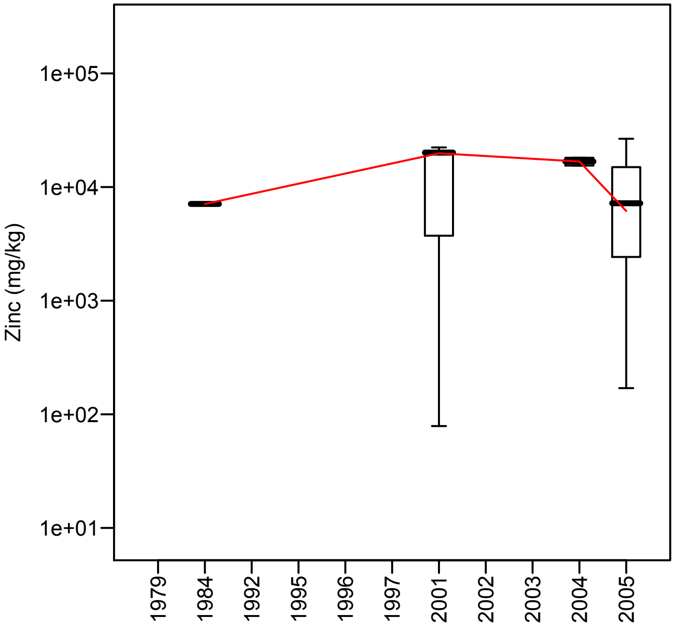


Figure 222. Temporal trend for Zinc concentrations within Reach #1. Red line indicates mean tendency.

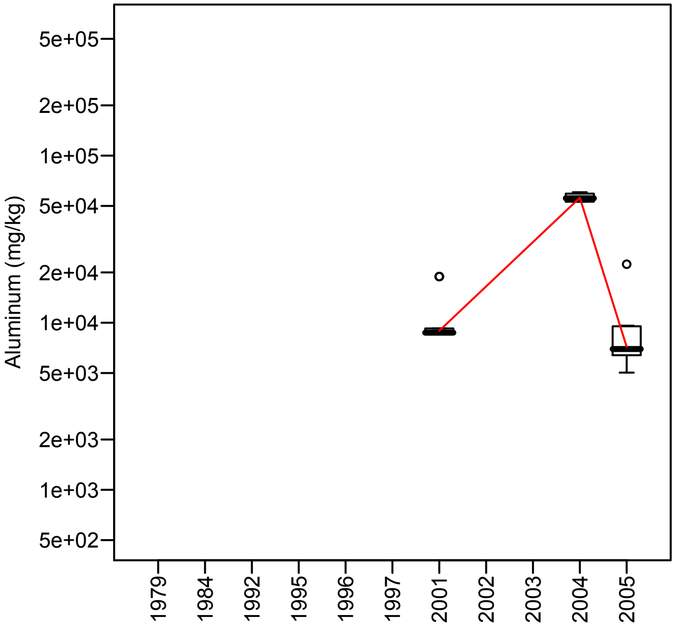


Figure 223. Temporal trend for Aluminum concentrations within Reach #2. Red line indicates mean tendency.

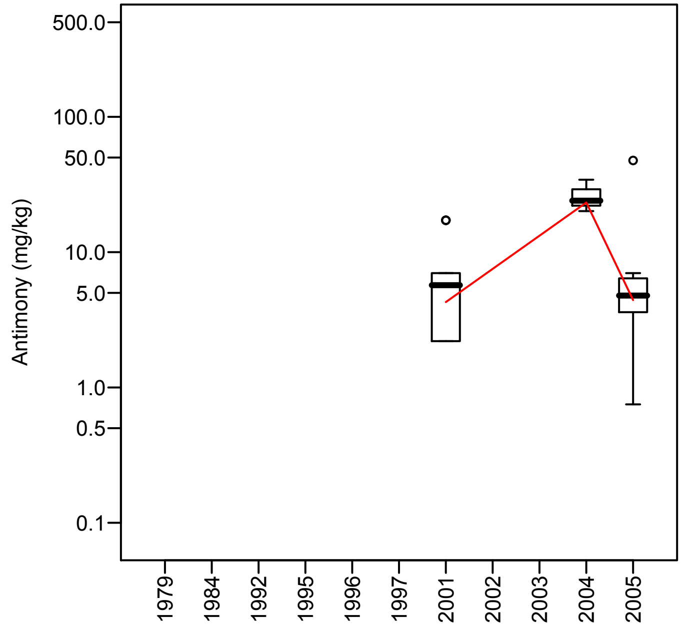


Figure 224. Temporal trend for Antimony concentrations within Reach #2. Red line indicates mean tendency.

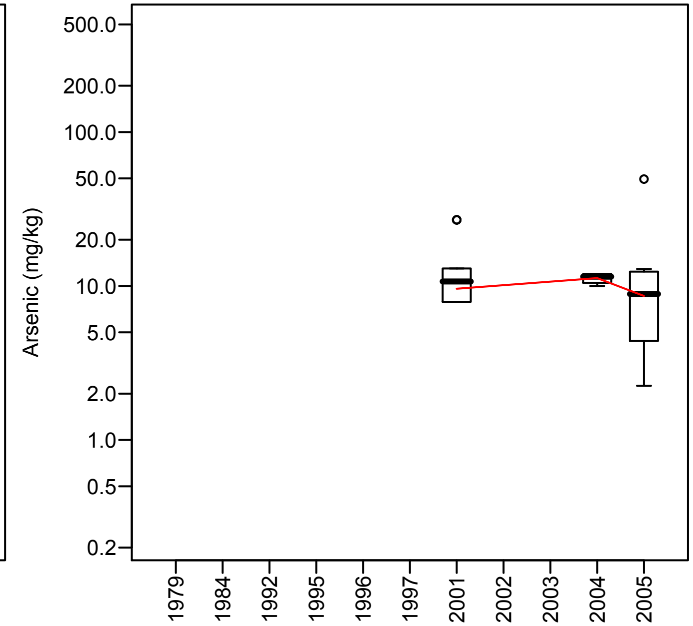


Figure 225. Temporal trend for Arsenic concentrations within Reach #2. Red line indicates mean tendency.

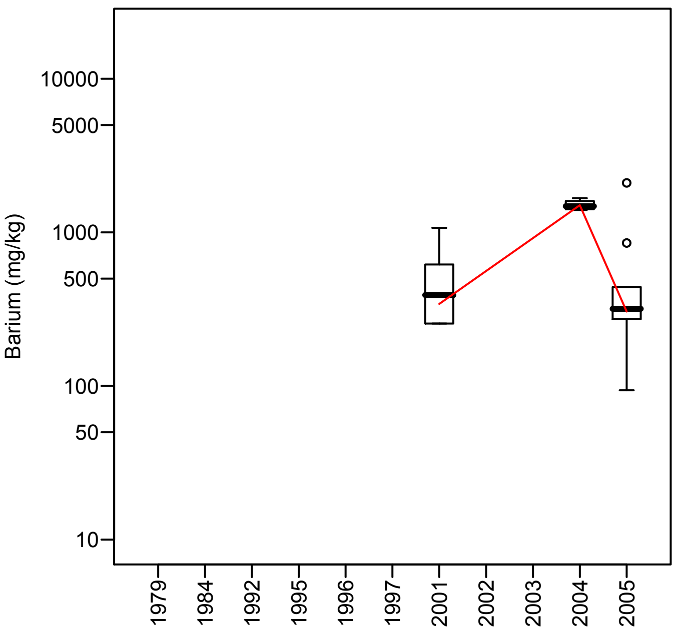


Figure 226. Temporal trend for Barium concentrations within Reach #2. Red line indicates mean tendency.

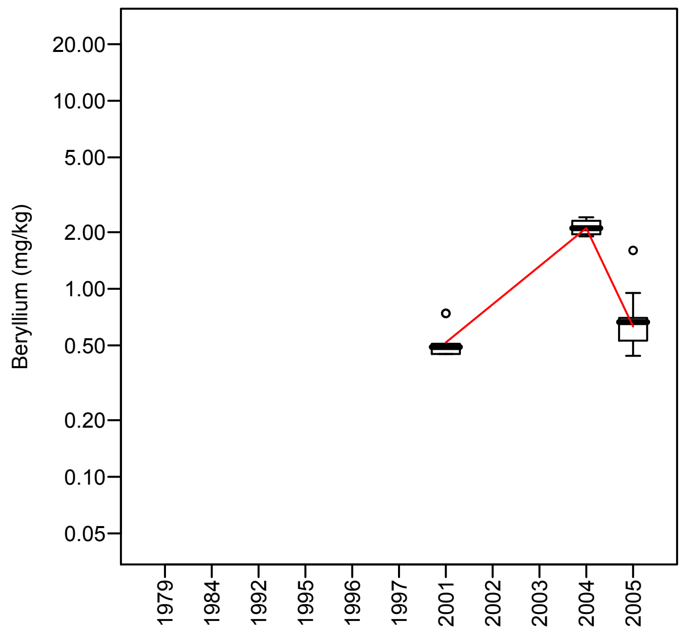


Figure 227. Temporal trend for Beryllium concentrations within Reach #2. Red line indicates mean tendency.

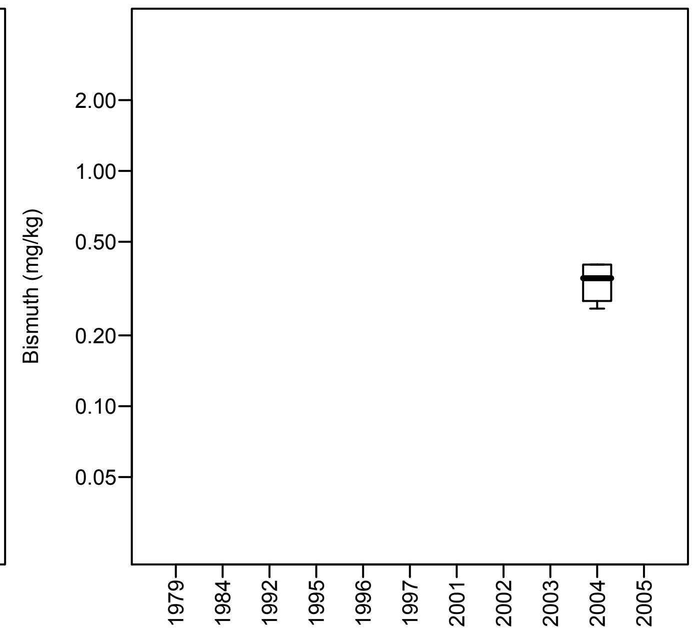


Figure 228. Temporal trend for Bismuth concentrations within Reach #2. Red line indicates mean tendency.

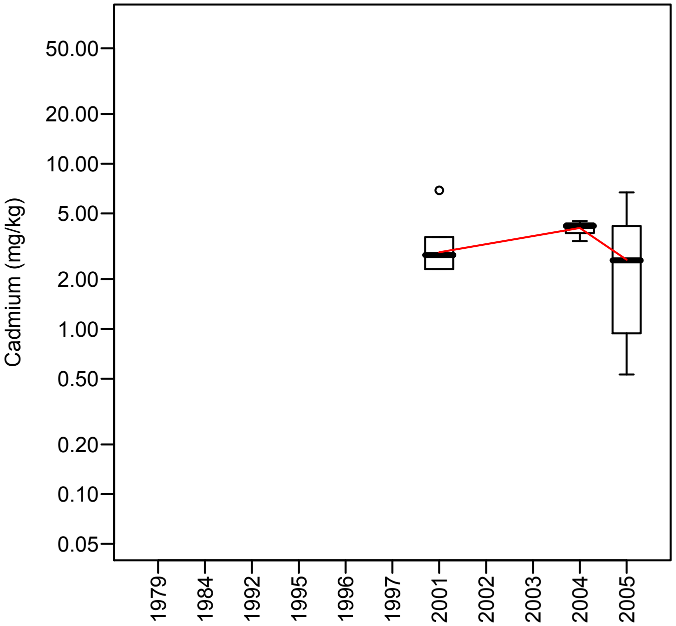


Figure 229. Temporal trend for Cadmium concentrations within Reach #2. Red line indicates mean tendency.

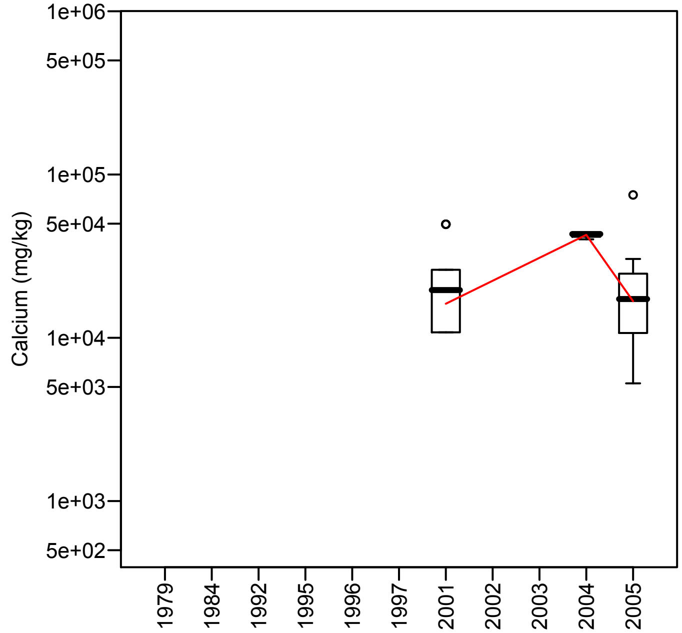


Figure 230. Temporal trend for Calcium concentrations within Reach #2. Red line indicates mean tendency.

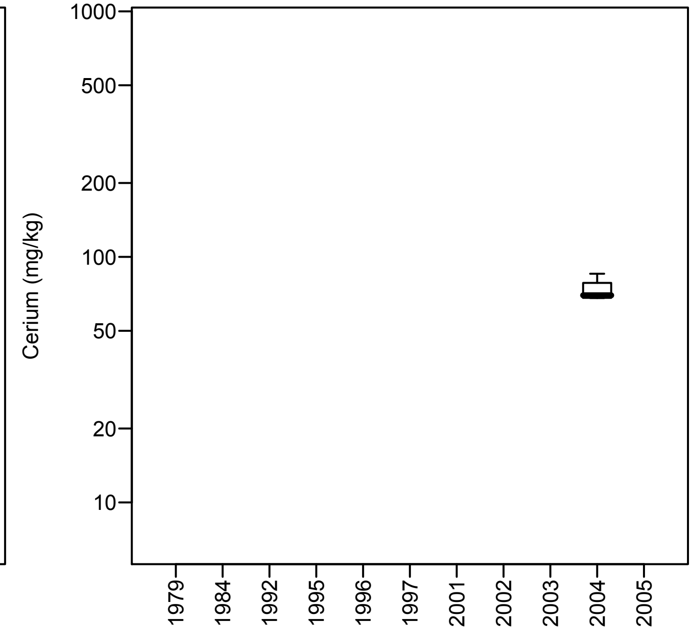


Figure 231. Temporal trend for Cerium concentrations within Reach #2. Red line indicates mean tendency.

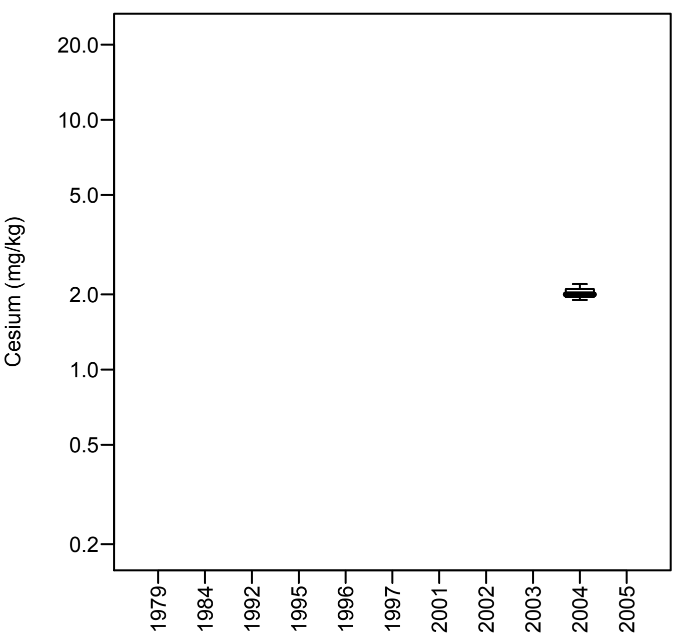


Figure 232. Temporal trend for Cesium concentrations within Reach #2. Red line indicates mean tendency.

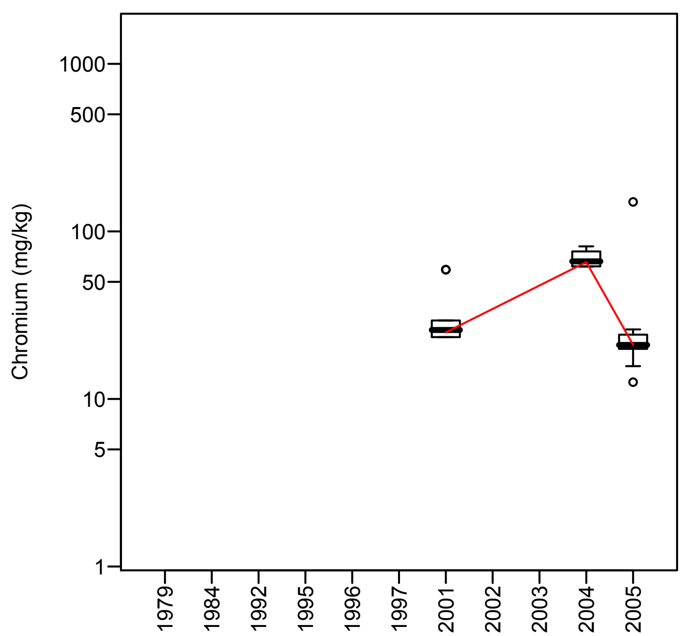


Figure 233. Temporal trend for Chromium concentrations within Reach #2. Red line indicates mean tendency.

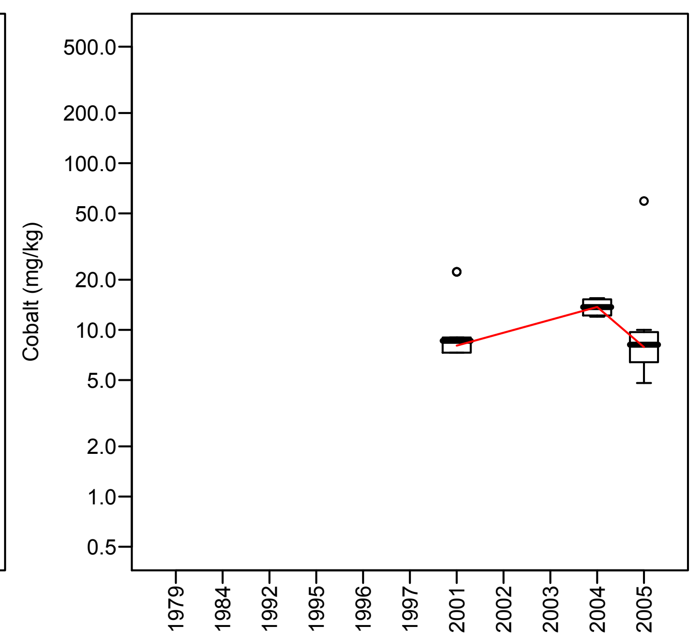


Figure 234. Temporal trend for Cobalt concentrations within Reach #2. Red line indicates mean tendency.

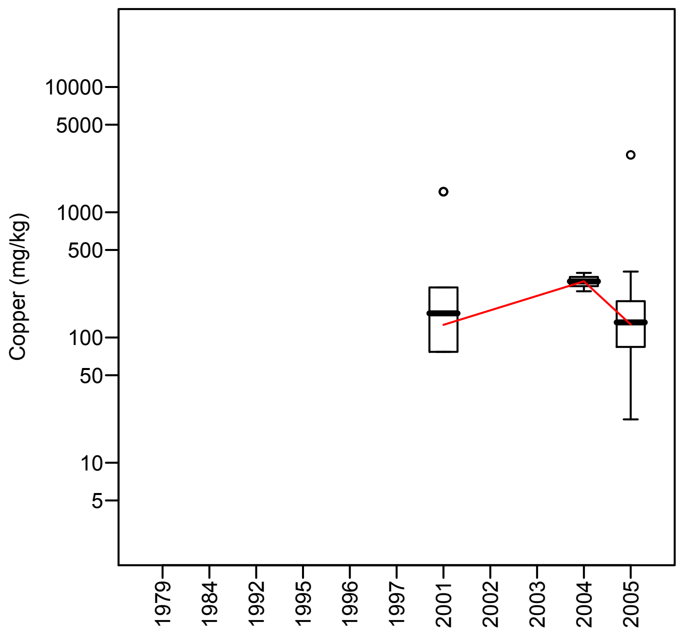


Figure 235. Temporal trend for Copper concentrations within Reach #2. Red line indicates mean tendency.

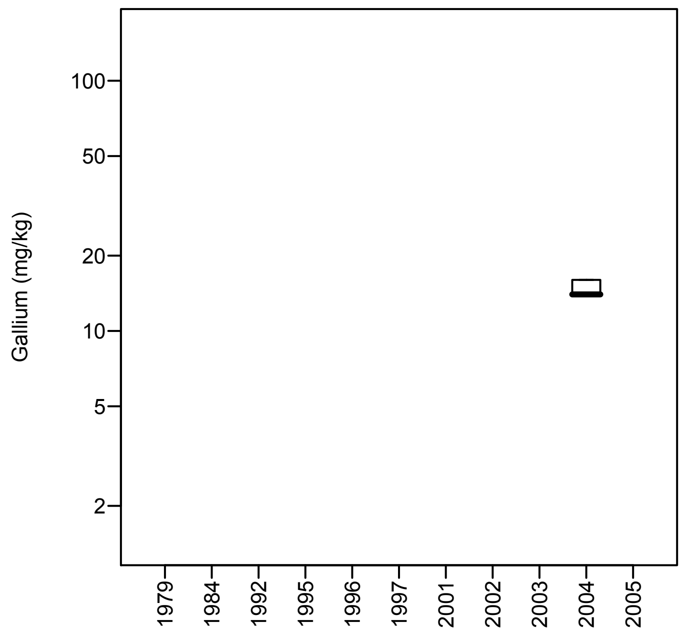


Figure 236. Temporal trend for Gallium concentrations within Reach #2. Red line indicates mean tendency.

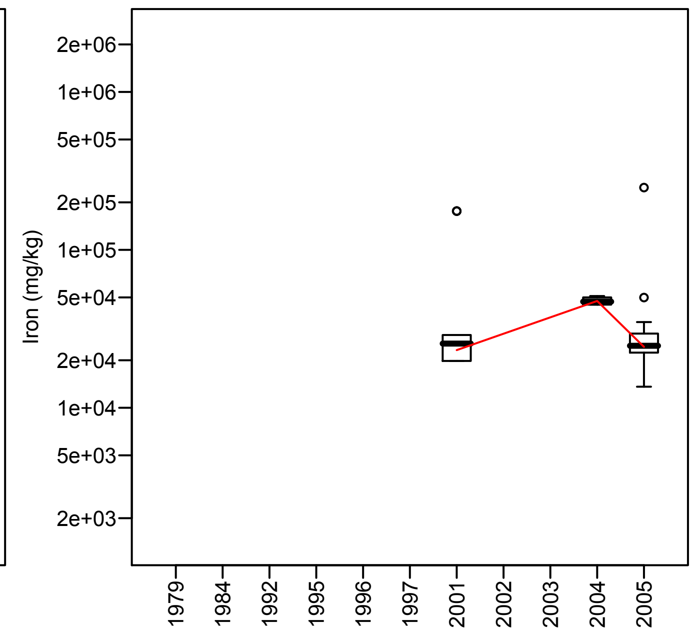


Figure 237. Temporal trend for Iron concentrations within Reach #2. Red line indicates mean tendency.

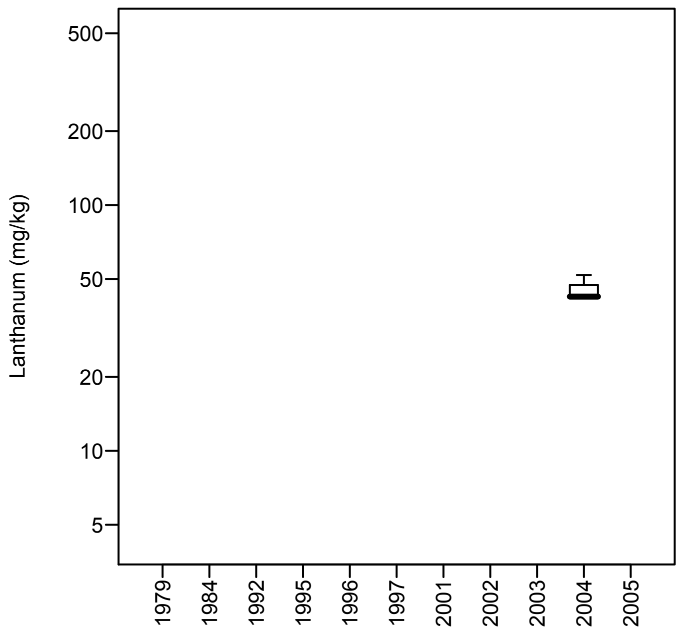


Figure 238. Temporal trend for Lanthanum concentrations within Reach #2. Red line indicates mean tendency.

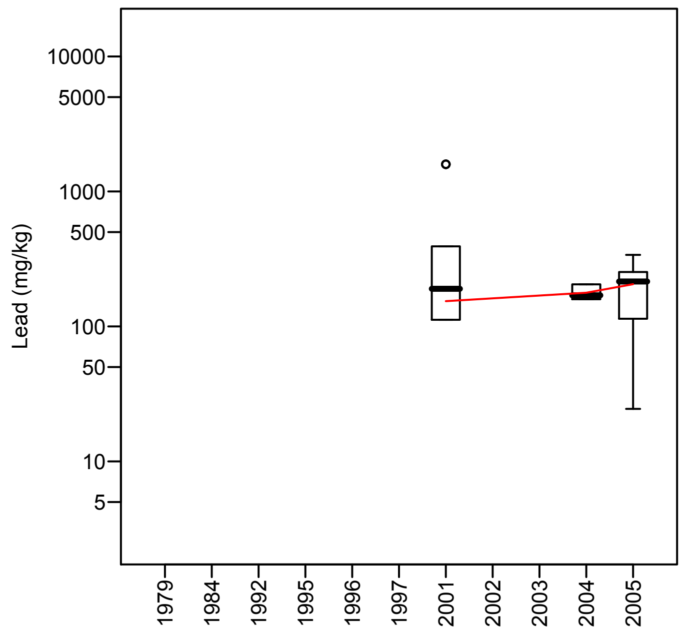


Figure 239. Temporal trend for Lead concentrations within Reach #2. Red line indicates mean tendency.

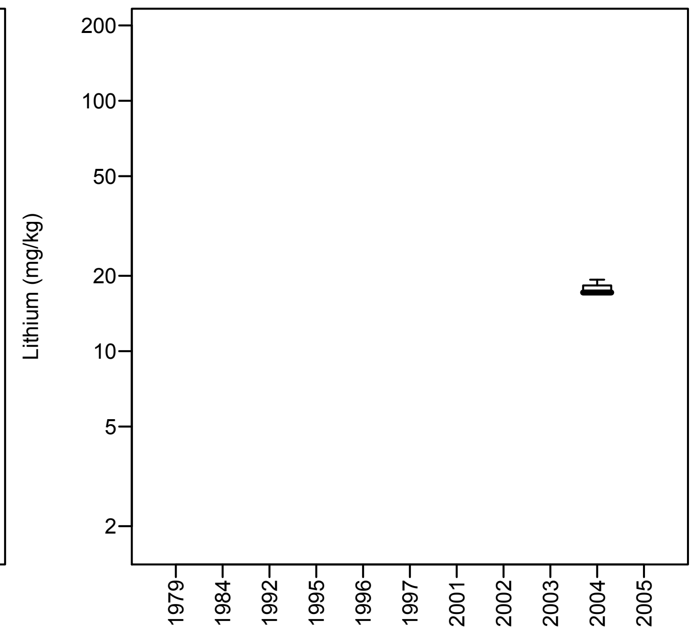


Figure 240. Temporal trend for Lithium concentrations within Reach #2. Red line indicates mean tendency.

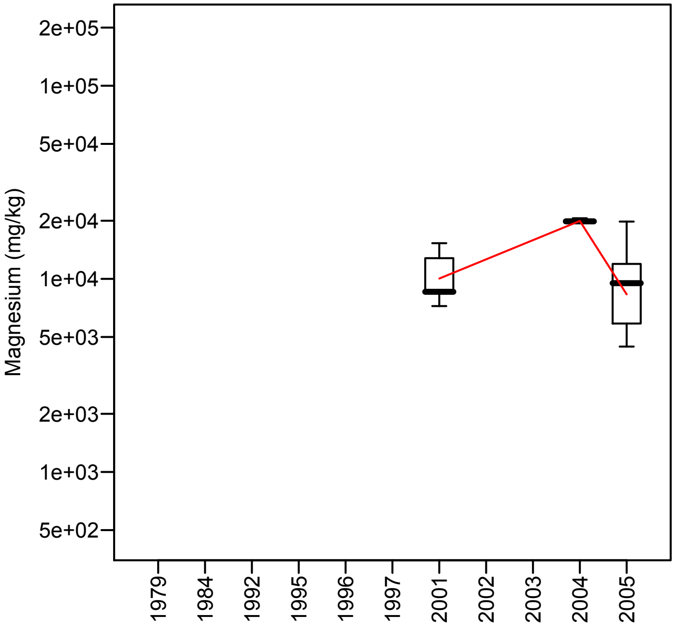


Figure 241. Temporal trend for Magnesium concentrations within Reach #2. Red line indicates mean tendency.

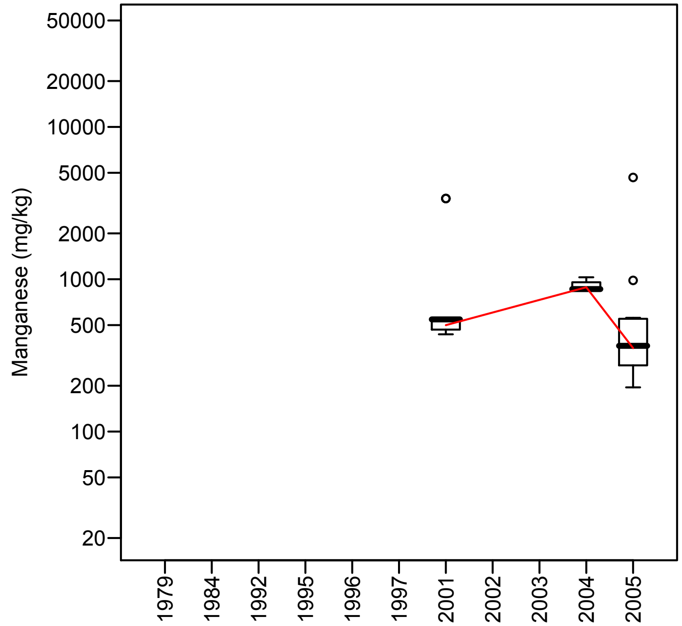


Figure 242. Temporal trend for Manganese concentrations within Reach #2. Red line indicates mean tendency.

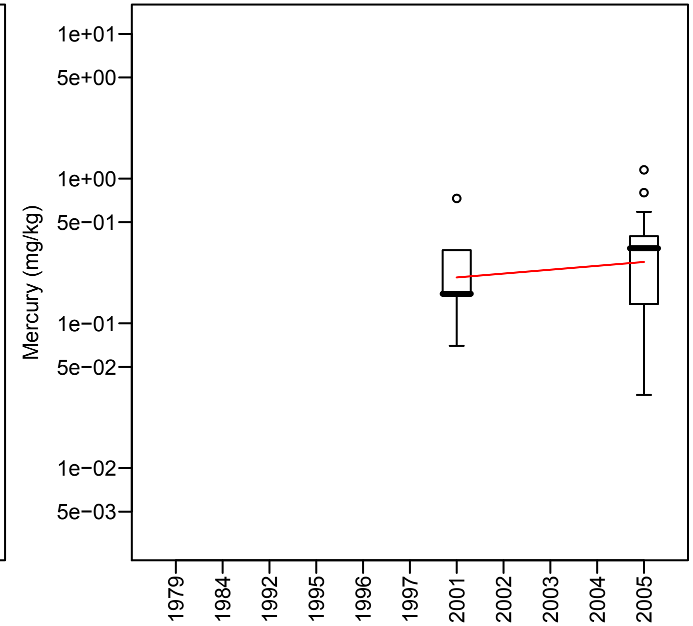


Figure 243. Temporal trend for Mercury concentrations within Reach #2. Red line indicates mean tendency.

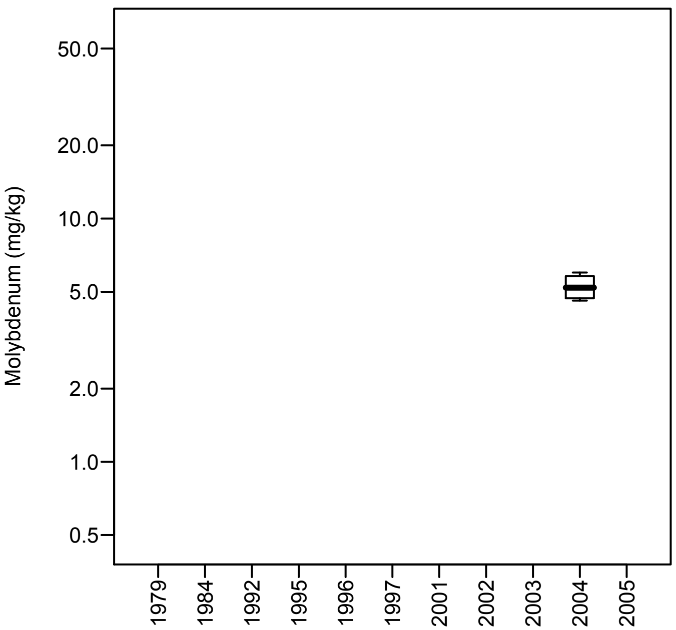


Figure 244. Temporal trend for Molybdenum concentrations within Reach #2. Red line indicates mean tendency.

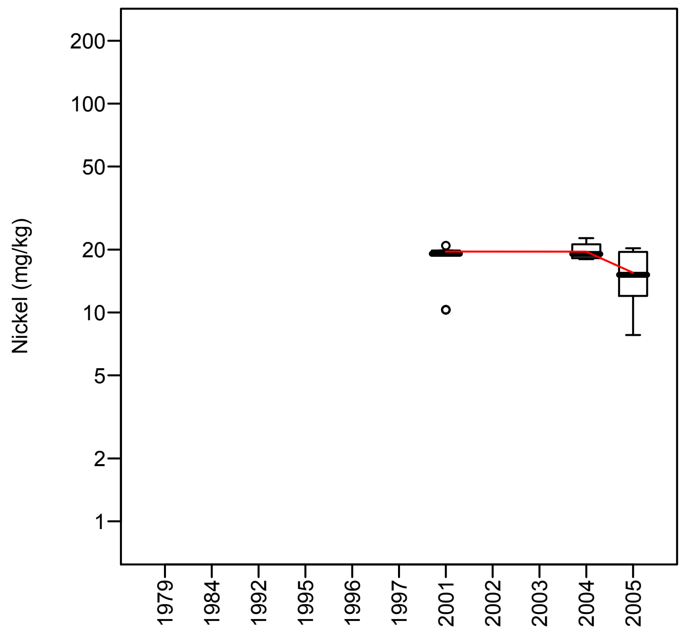


Figure 245. Temporal trend for Nickel concentrations within Reach #2. Red line indicates mean tendency.

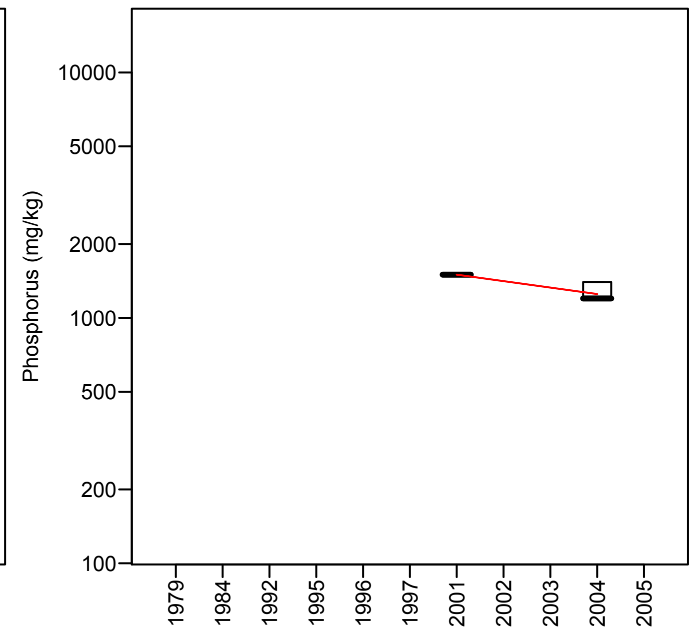


Figure 246. Temporal trend for Phosphorus concentrations within Reach #2. Red line indicates mean tendency.

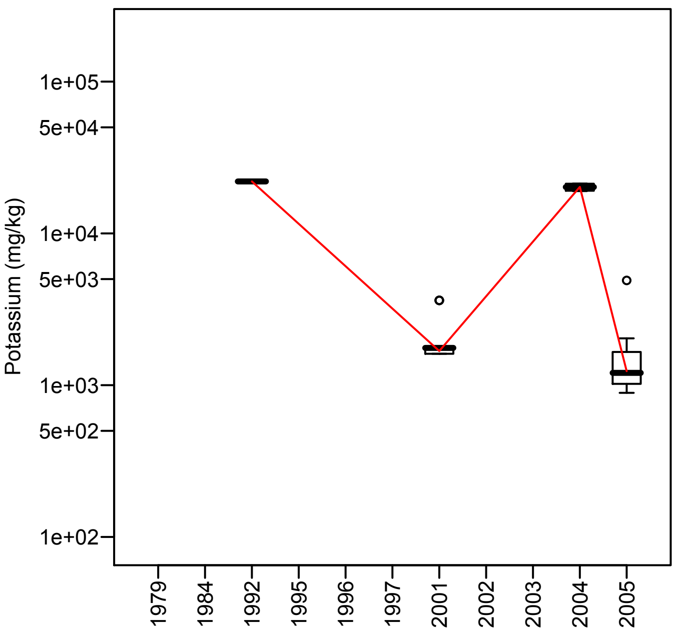


Figure 247. Temporal trend for Potassium concentrations within Reach #2. Red line indicates mean tendency.

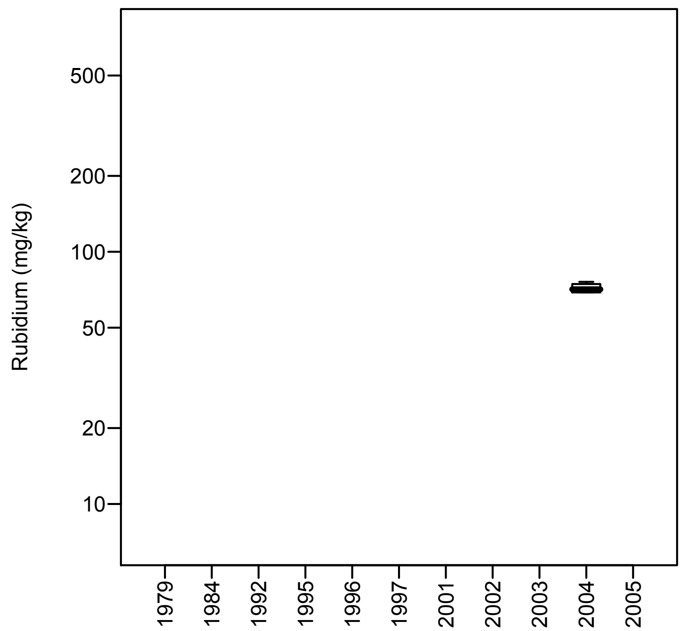


Figure 248. Temporal trend for Rubidium concentrations within Reach #2. Red line indicates mean tendency.

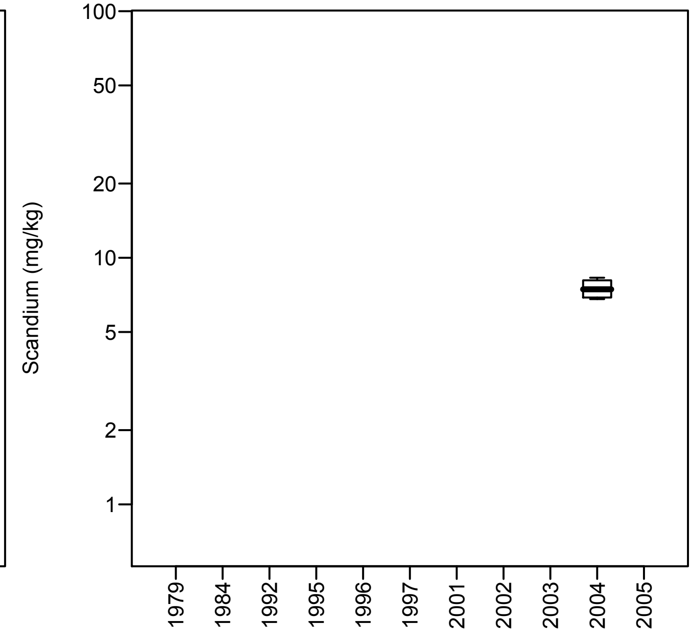


Figure 249. Temporal trend for Scandium concentrations within Reach #2. Red line indicates mean tendency.

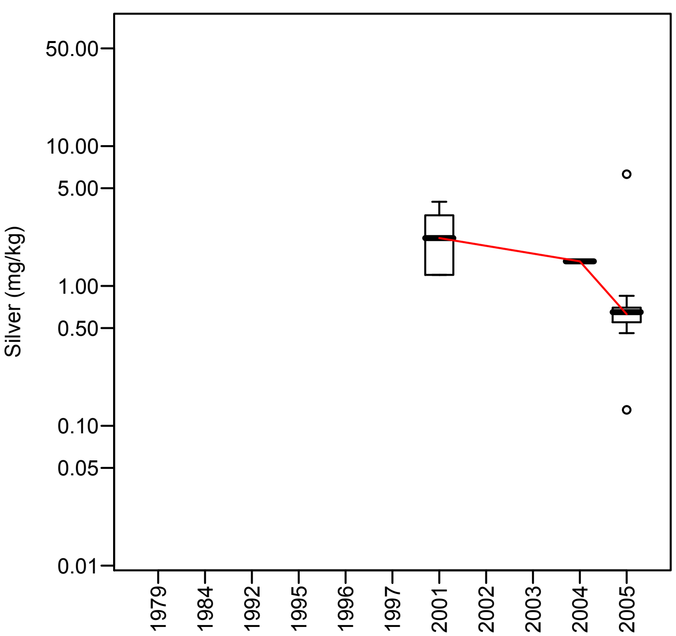


Figure 250. Temporal trend for Silver concentrations within Reach #2. Red line indicates mean tendency.

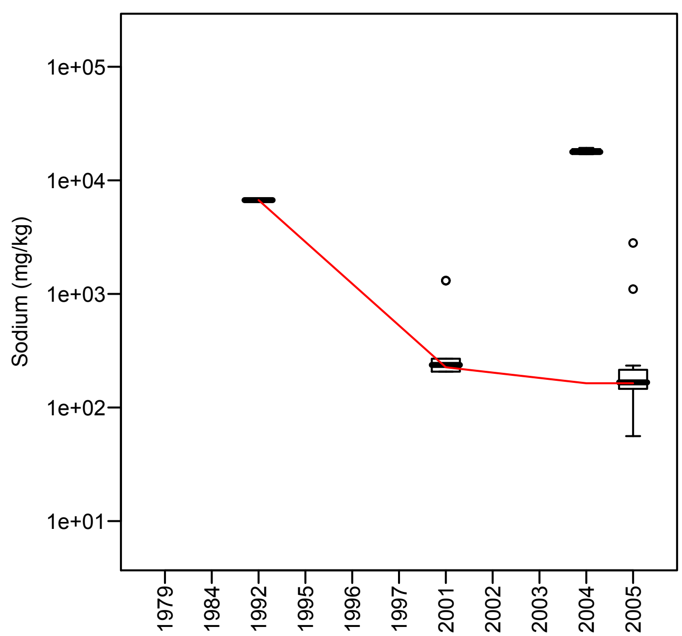


Figure 251. Temporal trend for Sodium concentrations within Reach #2. Red line indicates mean tendency.

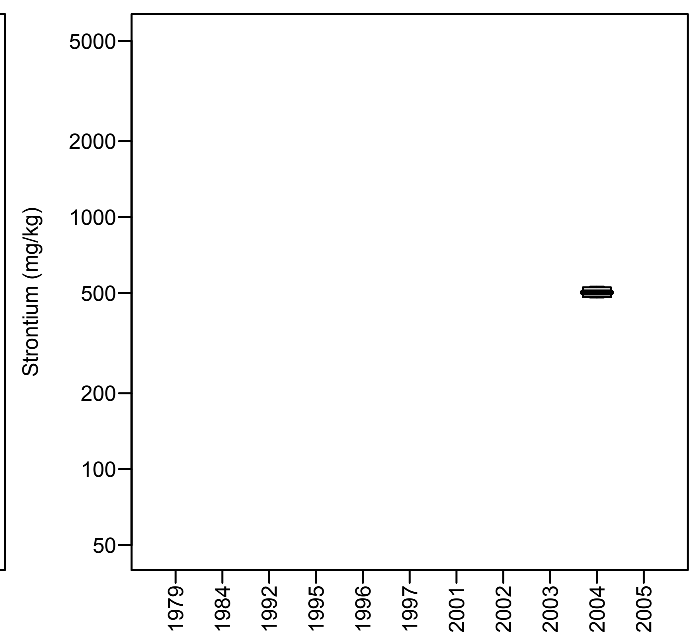


Figure 252. Temporal trend for Strontium concentrations within Reach #2. Red line indicates mean tendency.

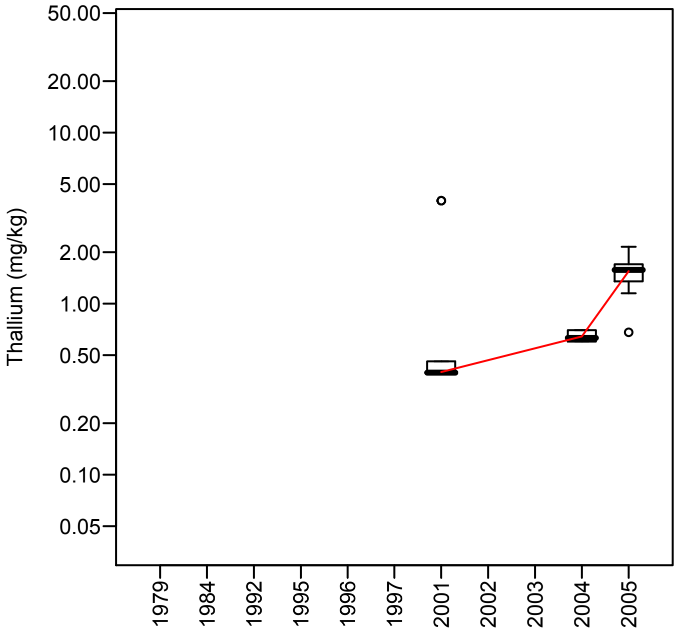


Figure 253. Temporal trend for Thallium concentrations within Reach #2. Red line indicates mean tendency.

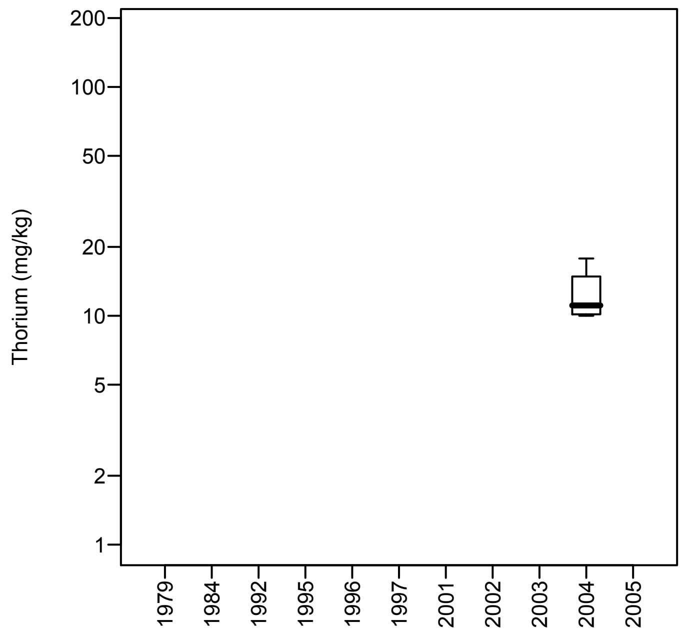


Figure 254. Temporal trend for Thorium concentrations within Reach #2. Red line indicates mean tendency.

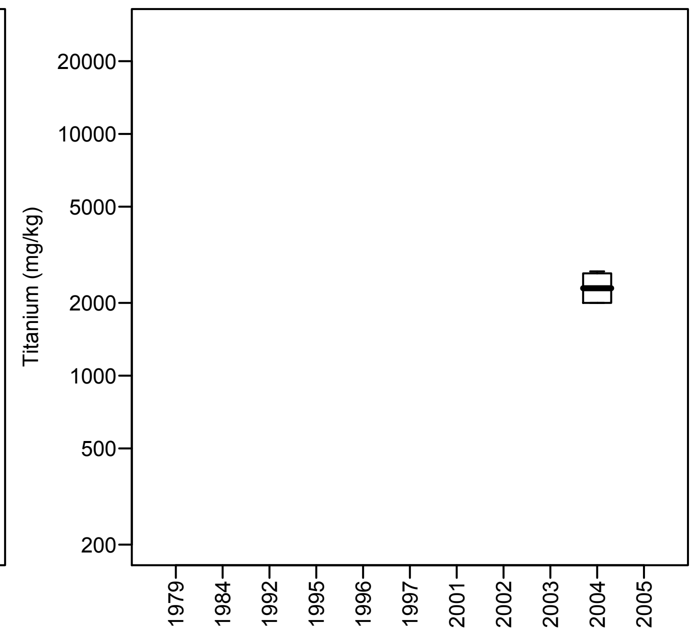


Figure 255. Temporal trend for Titanium concentrations within Reach #2. Red line indicates mean tendency.

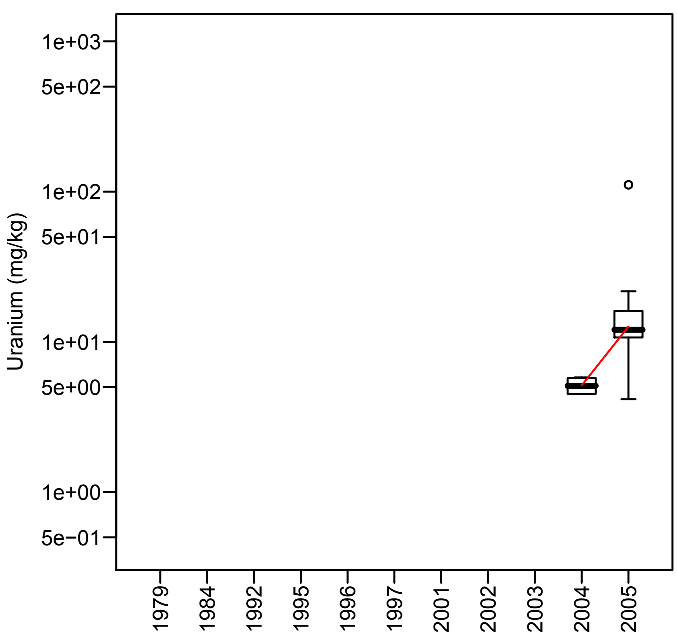


Figure 256. Temporal trend for Uranium concentrations within Reach #2. Red line indicates mean tendency.

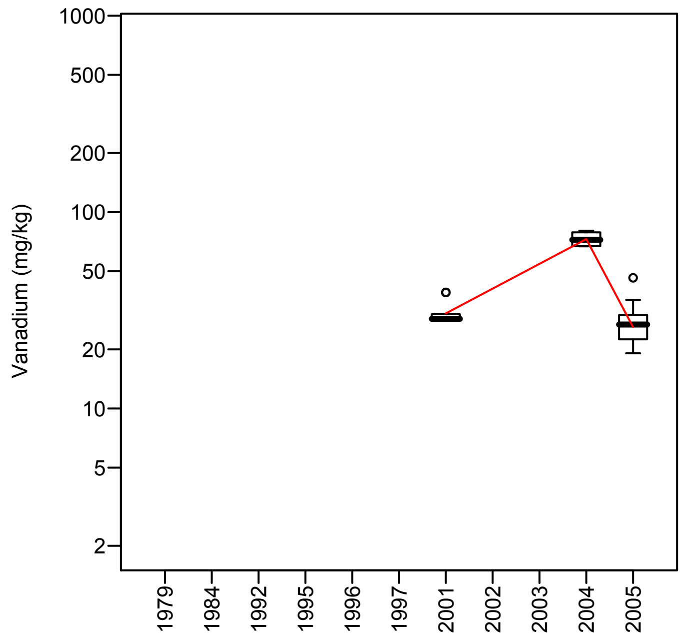


Figure 257. Temporal trend for Vanadium concentrations within Reach #2. Red line indicates mean tendency.

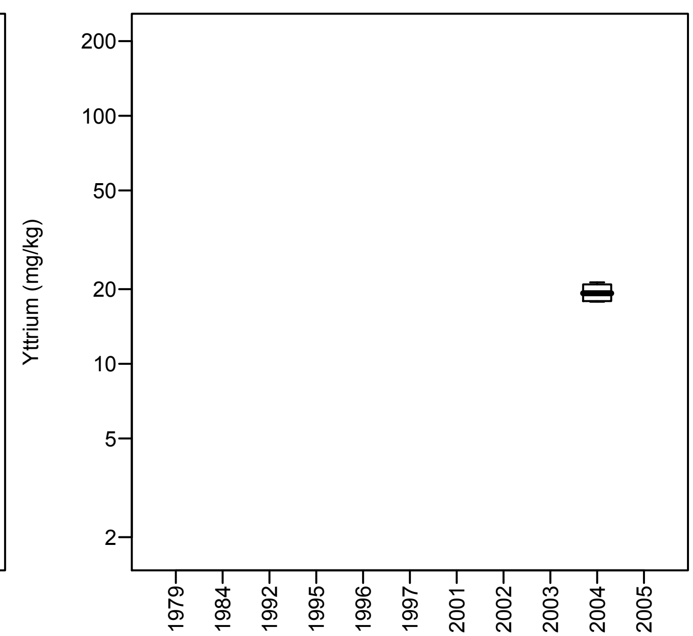


Figure 258. Temporal trend for Yttrium concentrations within Reach #2. Red line indicates mean tendency.

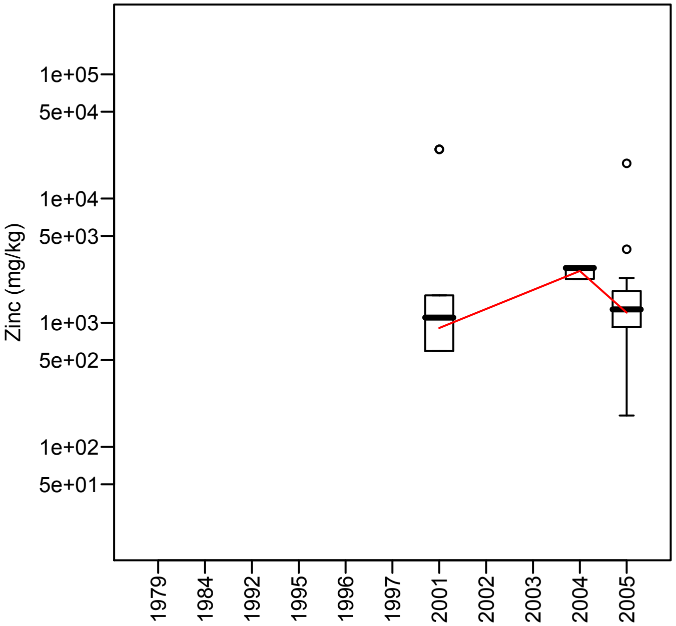


Figure 259. Temporal trend for Zinc concentrations within Reach #2. Red line indicates mean tendency.

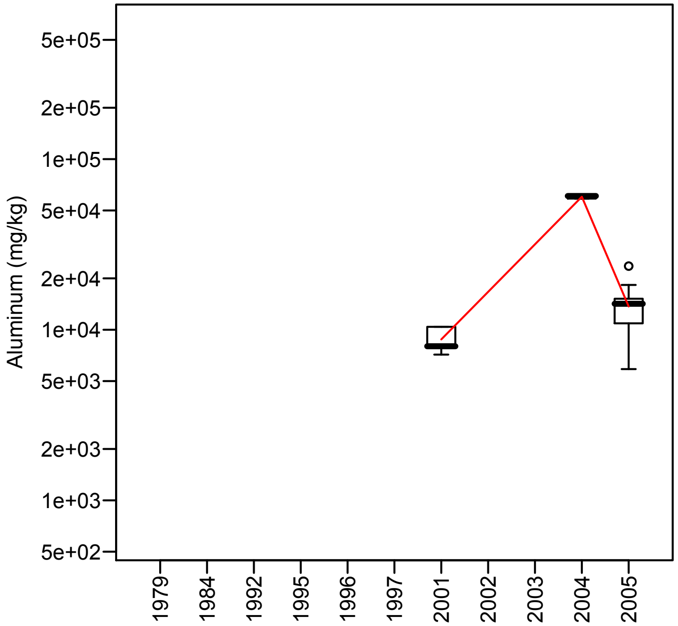


Figure 260. Temporal trend for Aluminum concentrations within Reach #3. Red line indicates mean tendency.

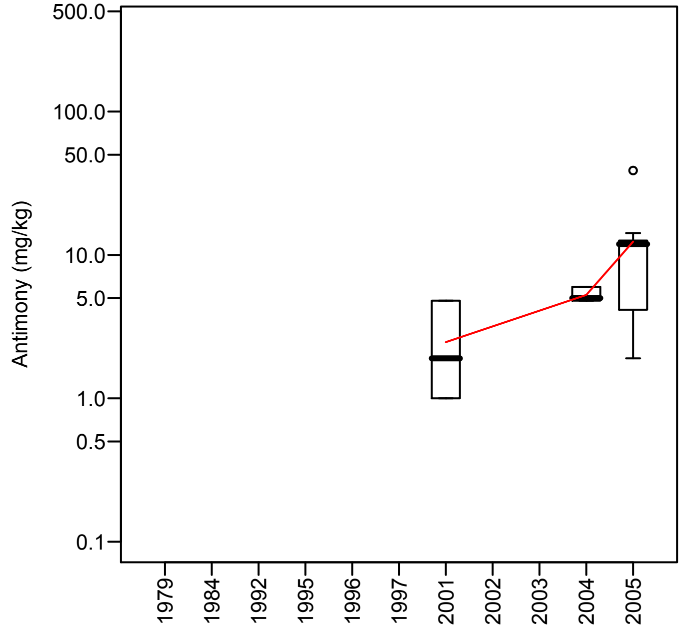


Figure 261. Temporal trend for Antimony concentrations within Reach #3. Red line indicates mean tendency.

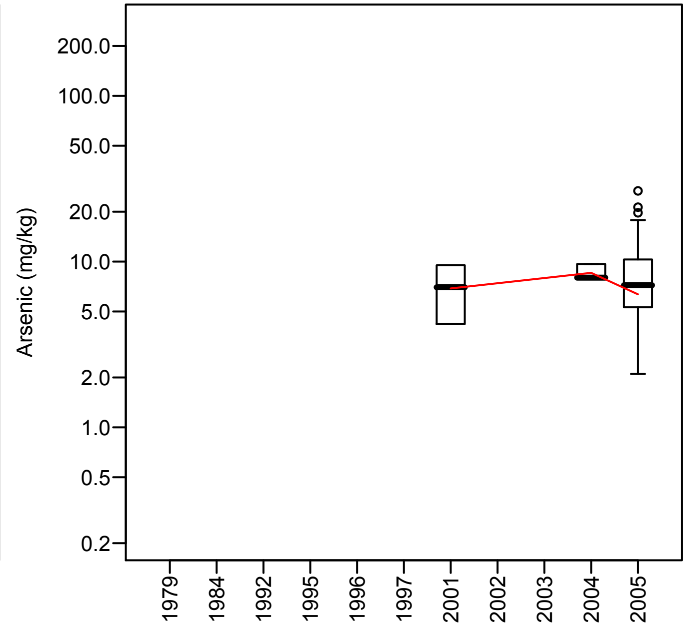


Figure 262. Temporal trend for Arsenic concentrations within Reach #3. Red line indicates mean tendency.

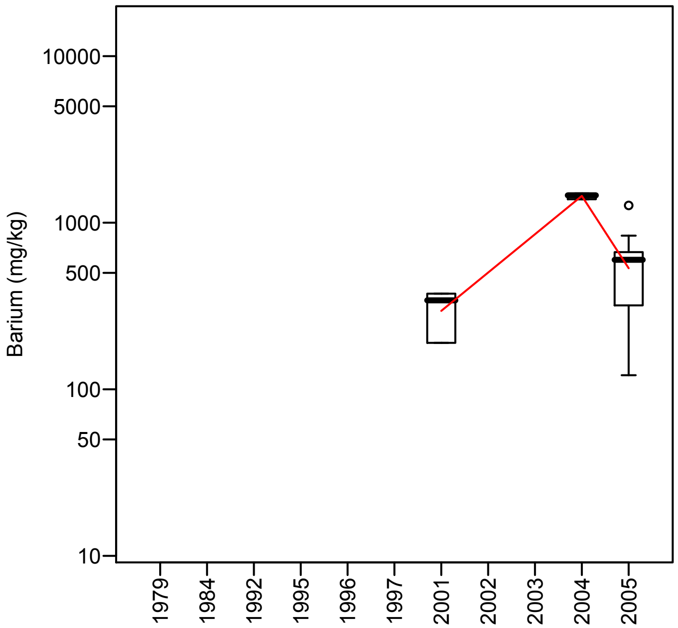


Figure 263. Temporal trend for Barium concentrations within Reach #3. Red line indicates mean tendency.

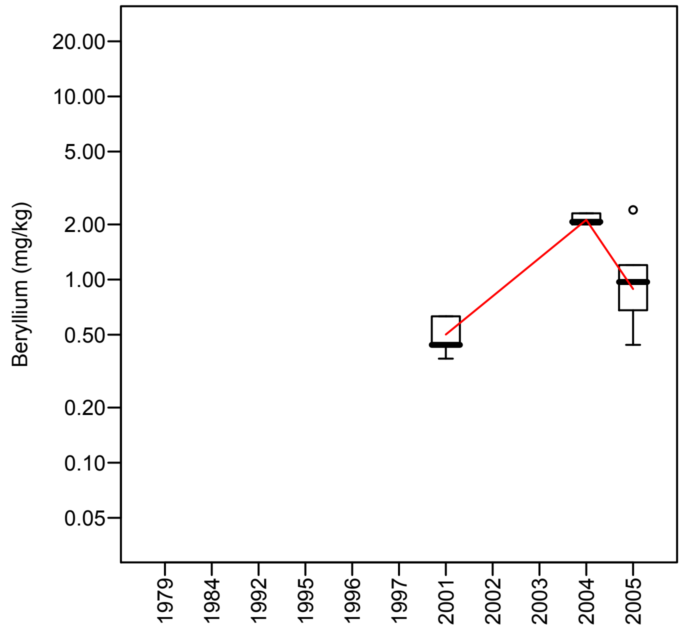


Figure 264. Temporal trend for Beryllium concentrations within Reach #3. Red line indicates mean tendency.

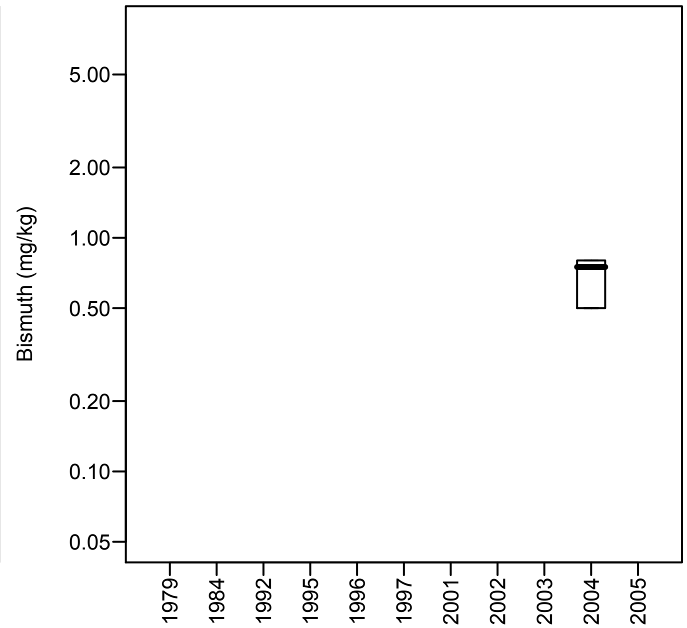


Figure 265. Temporal trend for Bismuth concentrations within Reach #3. Red line indicates mean tendency.

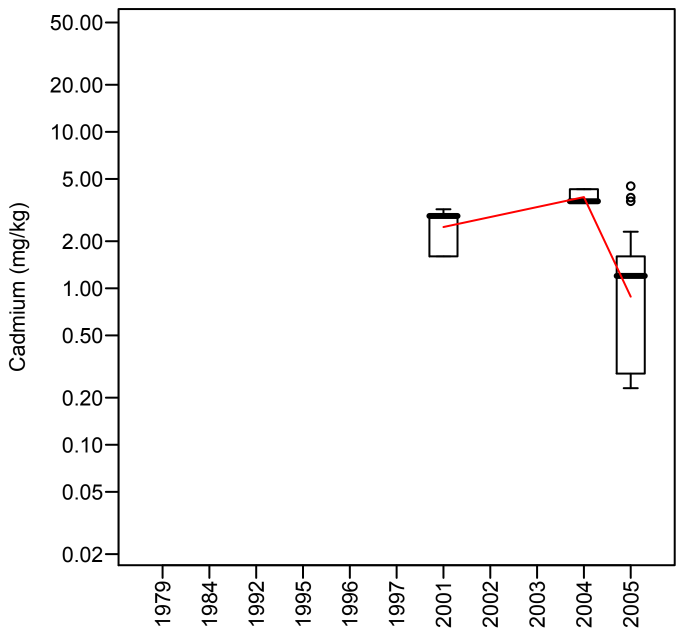


Figure 266. Temporal trend for Cadmium concentrations within Reach #3. Red line indicates mean tendency.

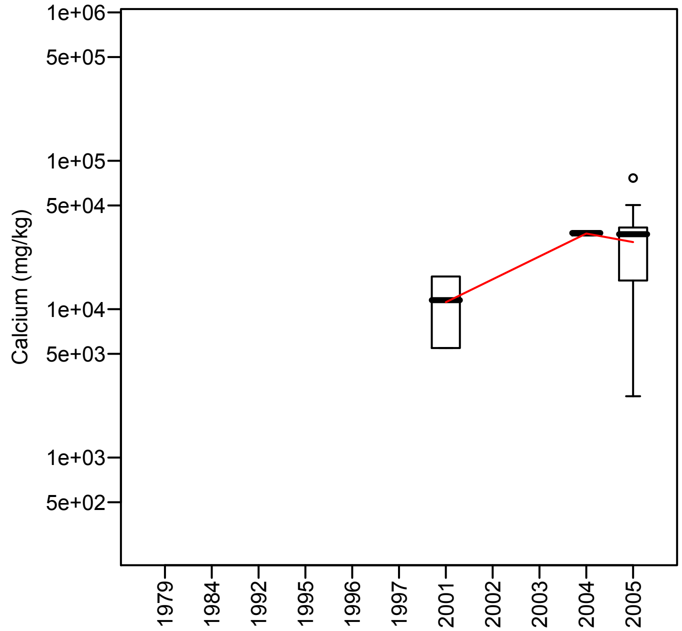


Figure 267. Temporal trend for Calcium concentrations within Reach #3. Red line indicates mean tendency.

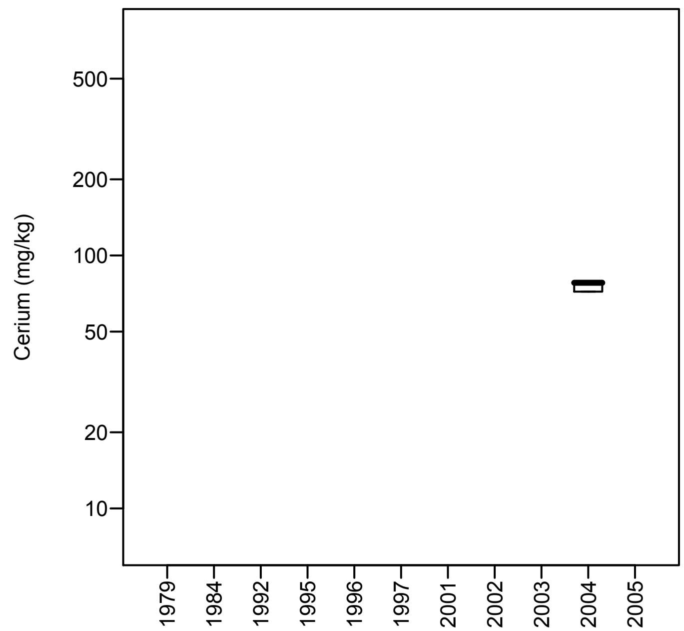


Figure 268. Temporal trend for Cerium concentrations within Reach #3. Red line indicates mean tendency.

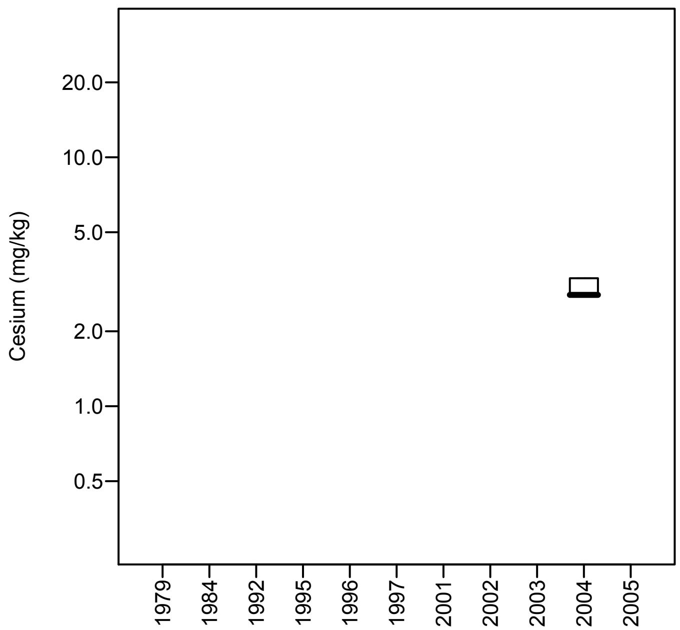


Figure 269. Temporal trend for Cesium concentrations within Reach #3. Red line indicates mean tendency.

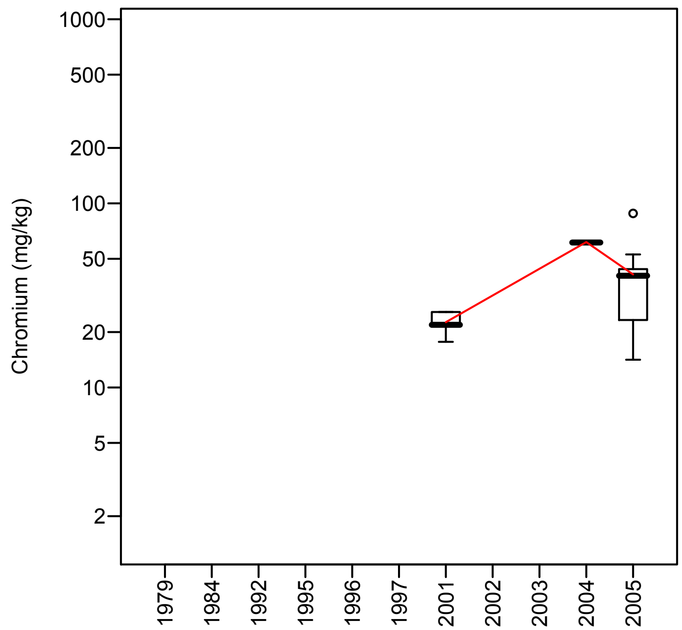


Figure 270. Temporal trend for Chromium concentrations within Reach #3. Red line indicates mean tendency.

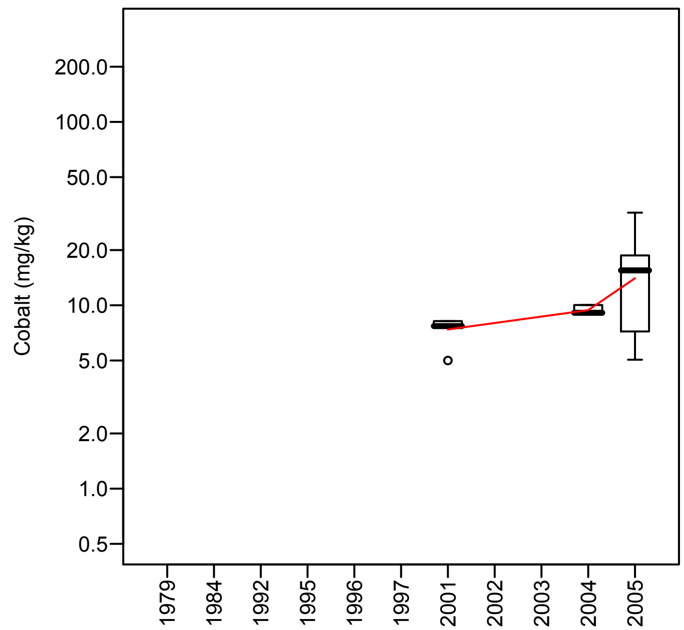


Figure 271. Temporal trend for Cobalt concentrations within Reach #3. Red line indicates mean tendency.

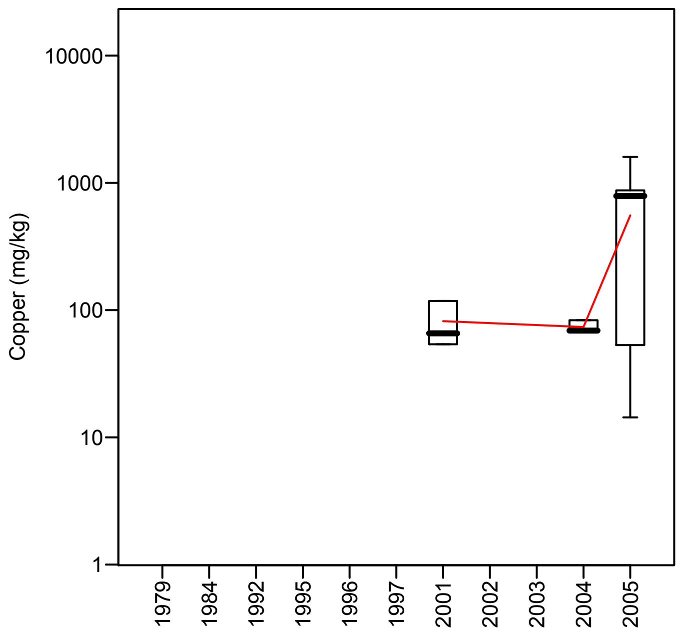


Figure 272. Temporal trend for Copper concentrations within Reach #3. Red line indicates mean tendency.

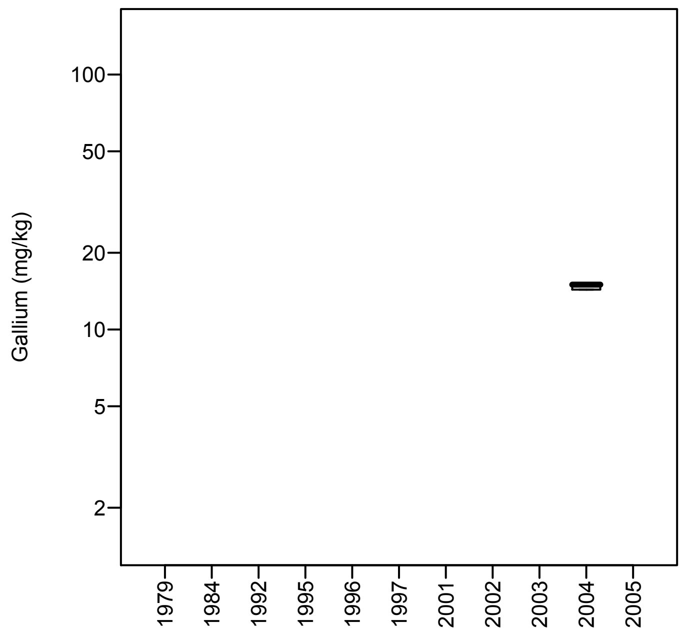


Figure 273. Temporal trend for Gallium concentrations within Reach #3. Red line indicates mean tendency.

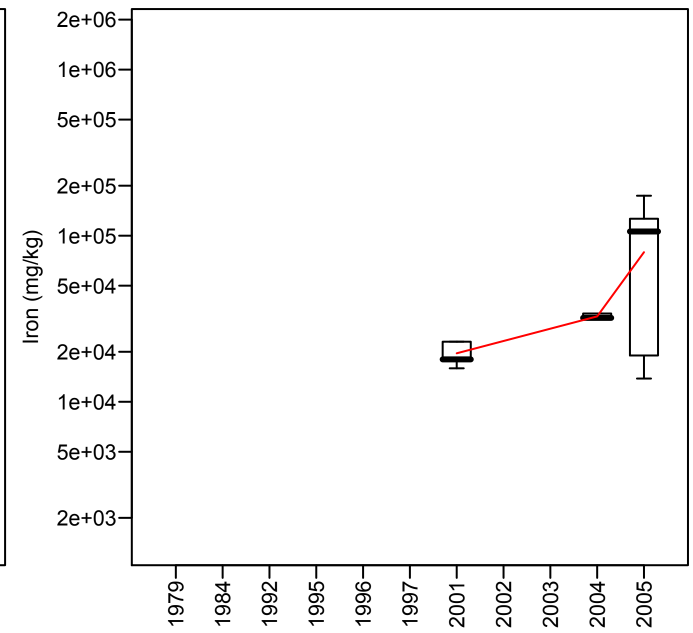


Figure 274. Temporal trend for Iron concentrations within Reach #3. Red line indicates mean tendency.

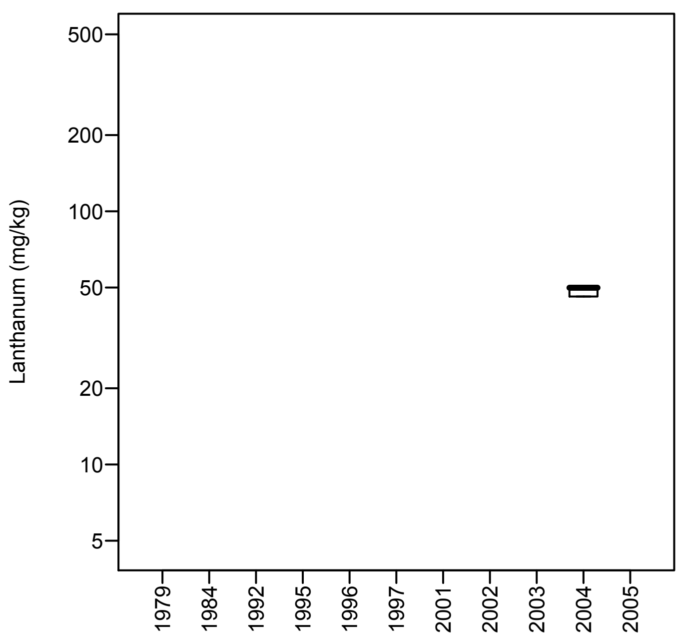


Figure 275. Temporal trend for Lanthanum concentrations within Reach #3. Red line indicates mean tendency.

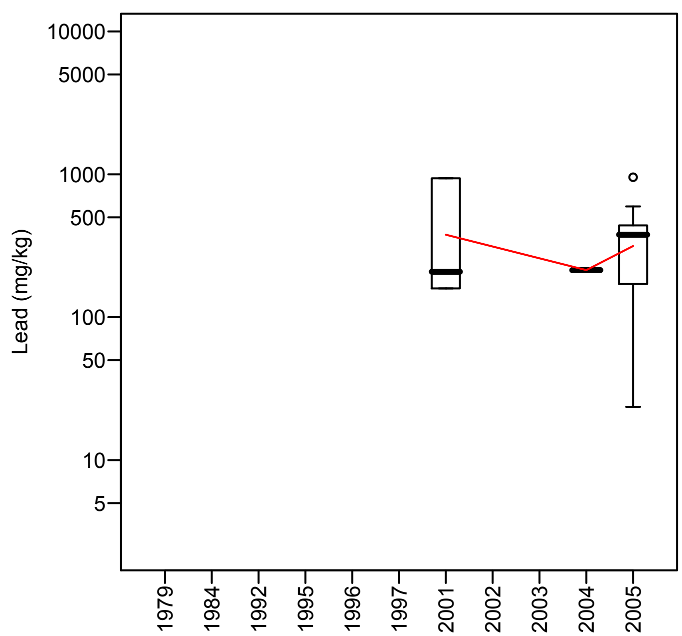


Figure 276. Temporal trend for Lead concentrations within Reach #3. Red line indicates mean tendency.

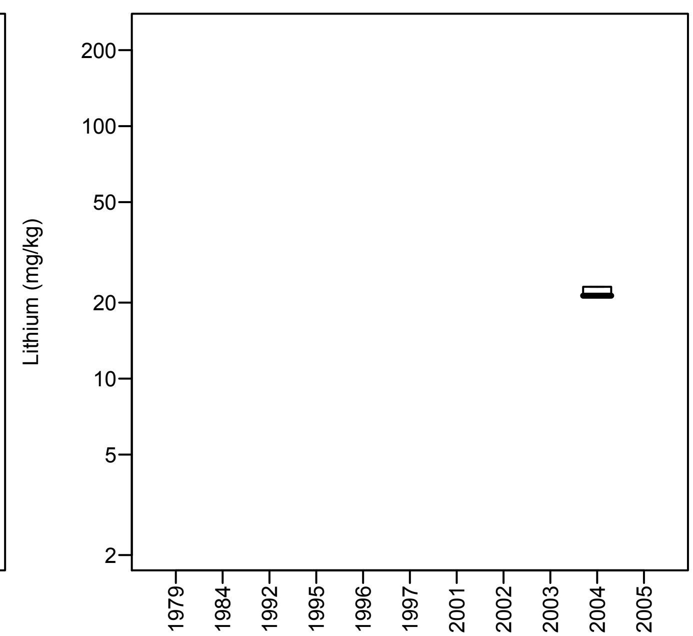


Figure 277. Temporal trend for Lithium concentrations within Reach #3. Red line indicates mean tendency.

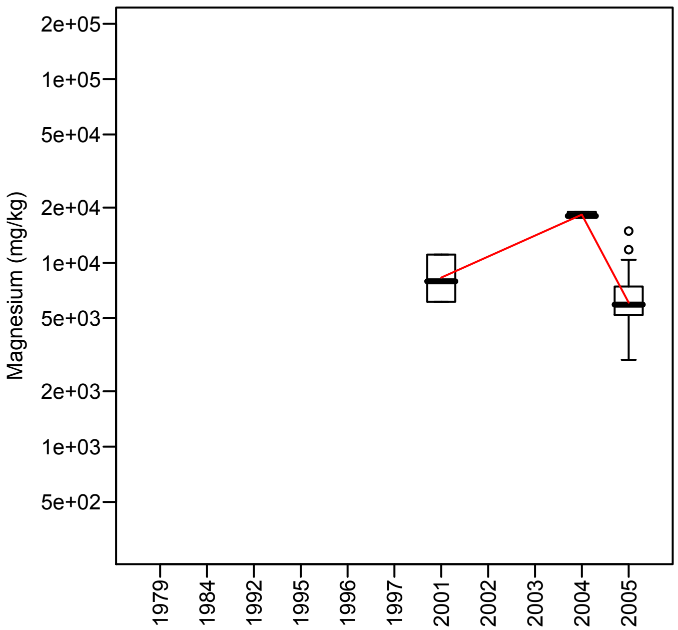


Figure 278. Temporal trend for Magnesium concentrations within Reach #3. Red line indicates mean tendency.

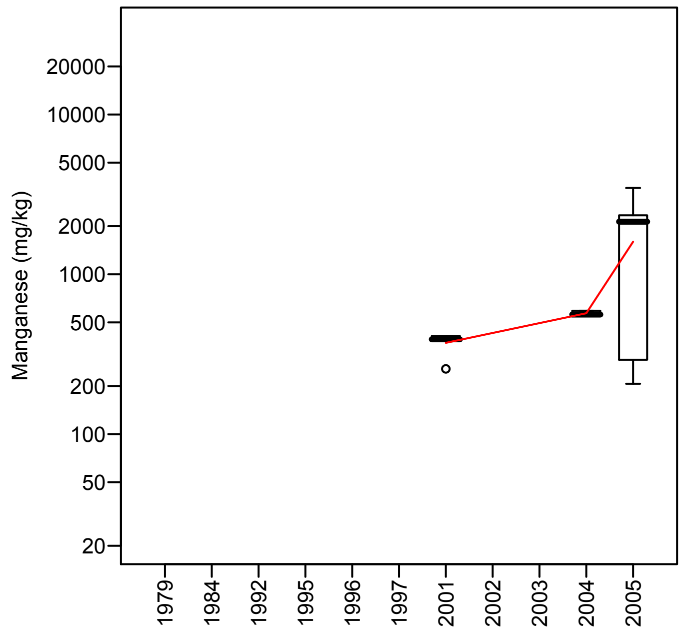


Figure 279. Temporal trend for Manganese concentrations within Reach #3. Red line indicates mean tendency.

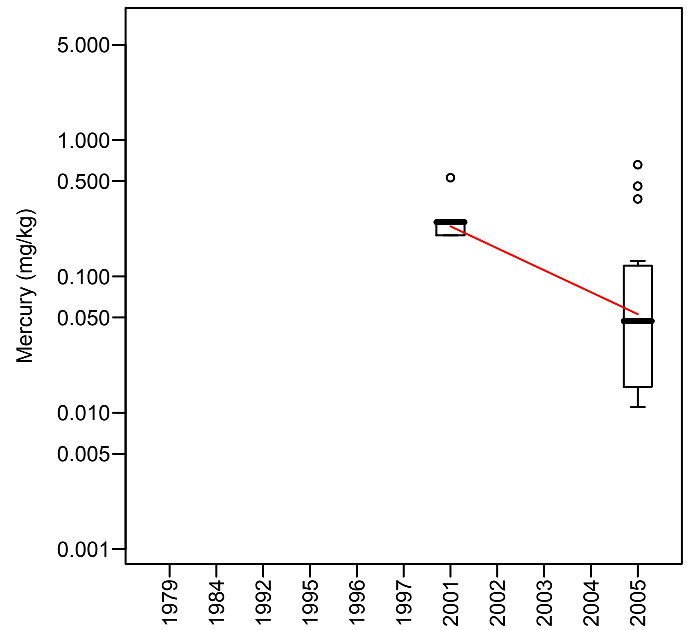


Figure 280. Temporal trend for Mercury concentrations within Reach #3. Red line indicates mean tendency.

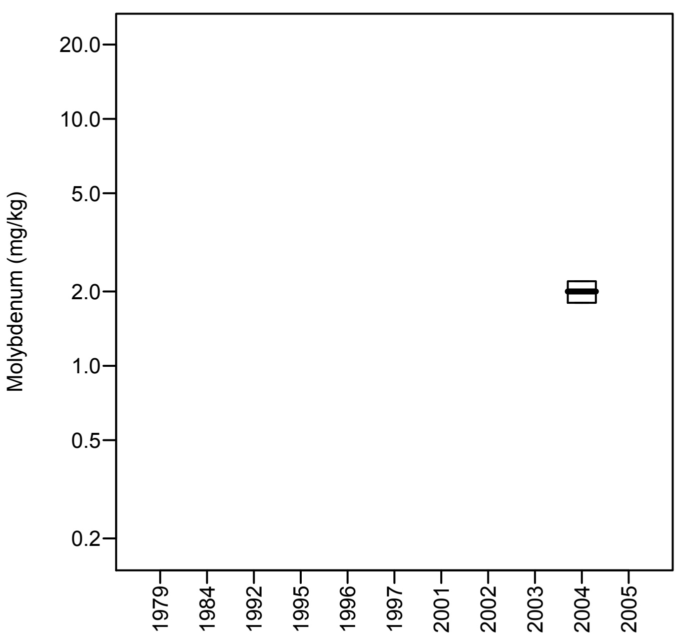


Figure 281. Temporal trend for Molybdenum concentrations within Reach #3. Red line indicates mean tendency.

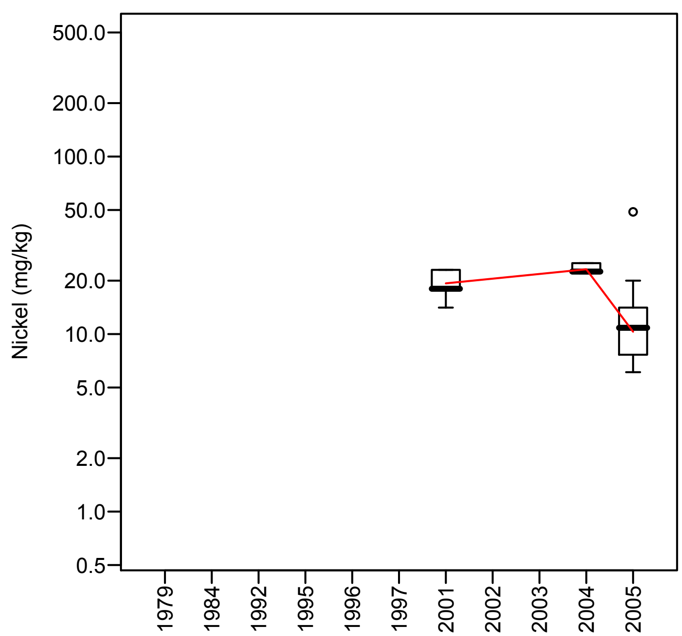


Figure 282. Temporal trend for Nickel concentrations within Reach #3. Red line indicates mean tendency.

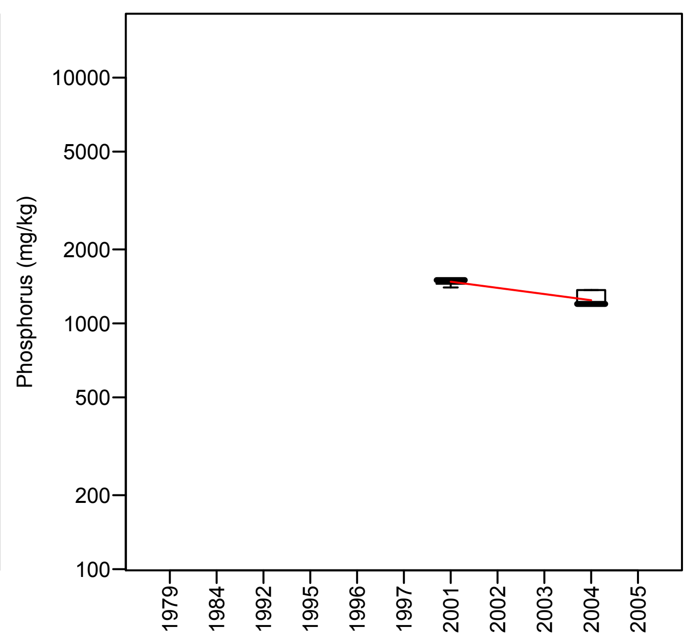


Figure 283. Temporal trend for Phosphorus concentrations within Reach #3. Red line indicates mean tendency.

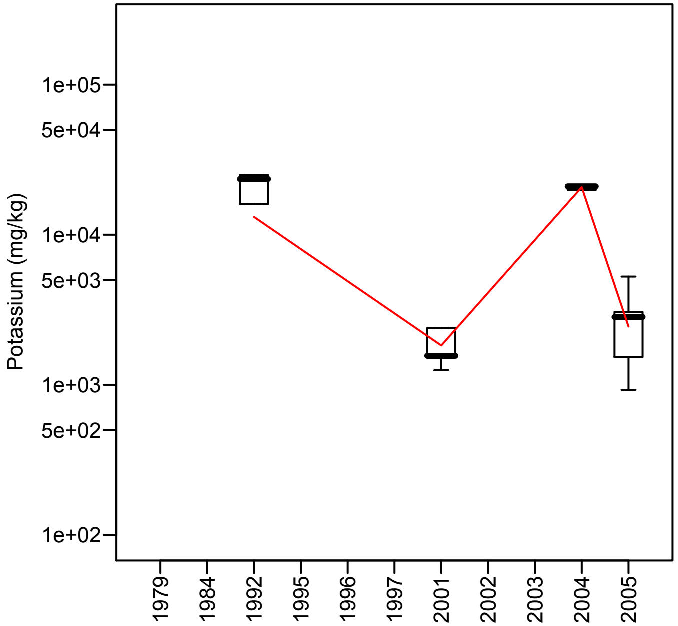


Figure 284. Temporal trend for Potassium concentrations within Reach #3. Red line indicates mean tendency.

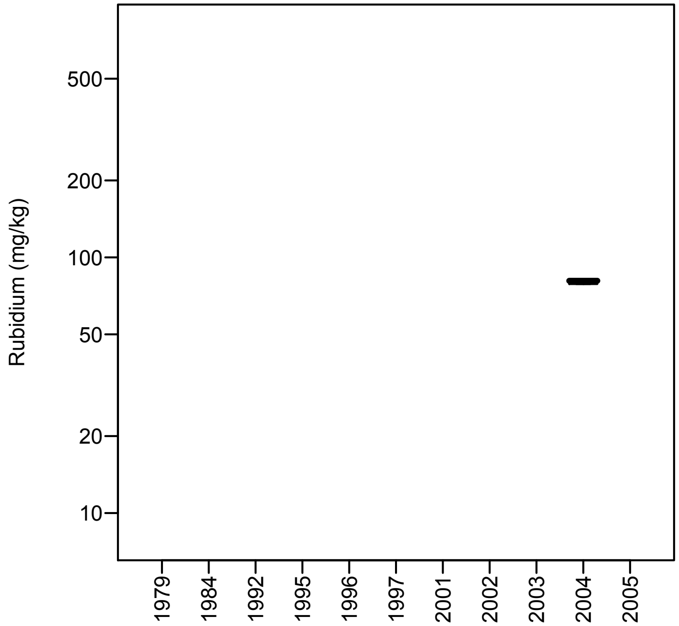


Figure 285. Temporal trend for Rubidium concentrations within Reach #3. Red line indicates mean tendency.

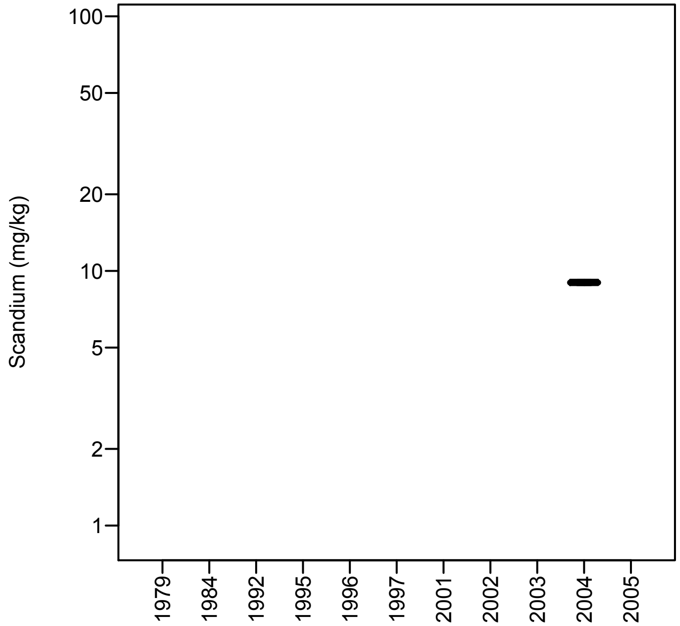


Figure 286. Temporal trend for Scandium concentrations within Reach #3. Red line indicates mean tendency.

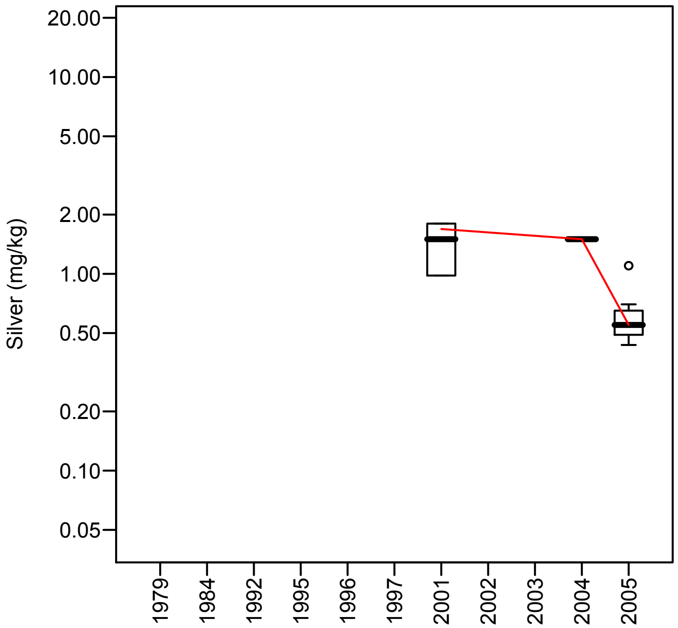


Figure 287. Temporal trend for Silver concentrations within Reach #3. Red line indicates mean tendency.

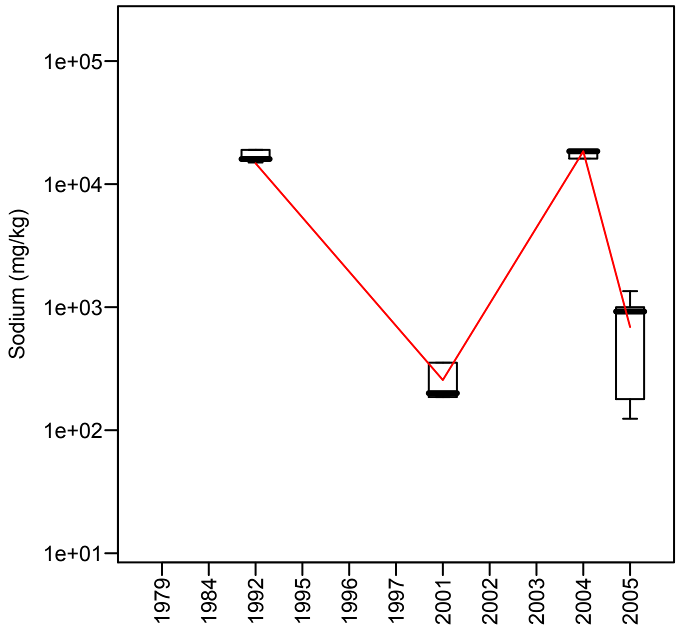


Figure 288. Temporal trend for Sodium concentrations within Reach #3. Red line indicates mean tendency.

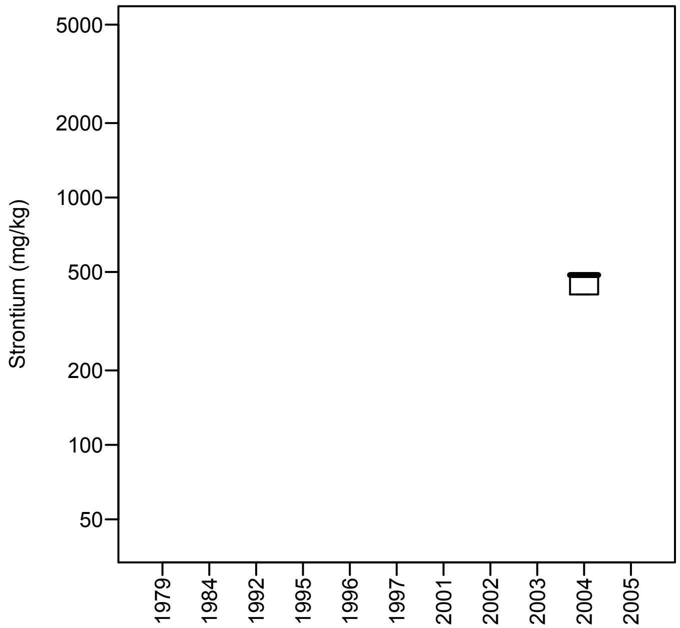


Figure 289. Temporal trend for Strontium concentrations within Reach #3. Red line indicates mean tendency.

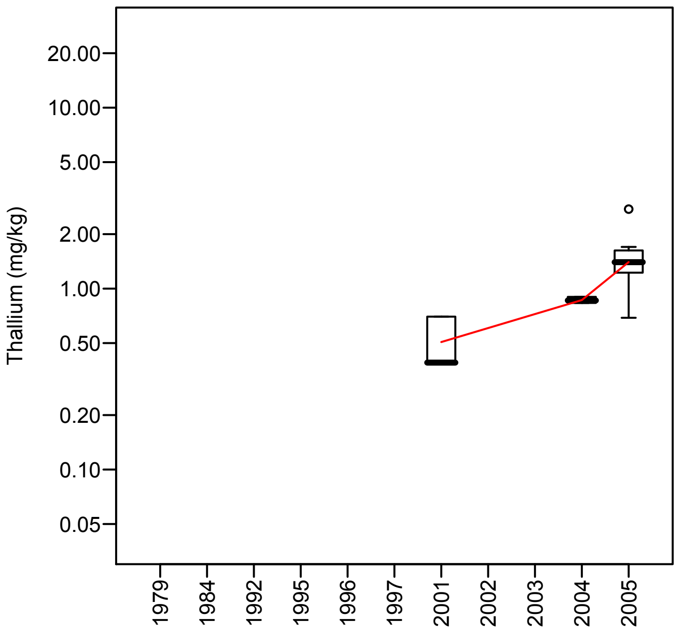


Figure 290. Temporal trend for Thallium concentrations within Reach #3. Red line indicates mean tendency.

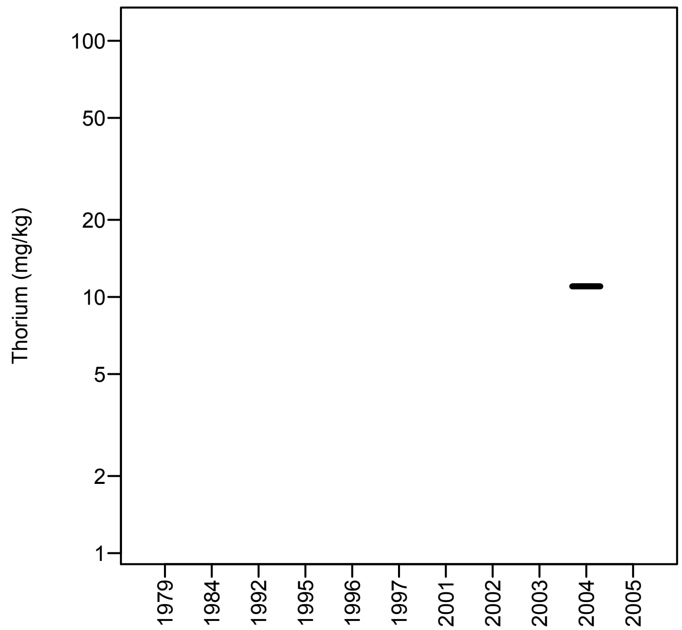


Figure 291. Temporal trend for Thorium concentrations within Reach #3. Red line indicates mean tendency.

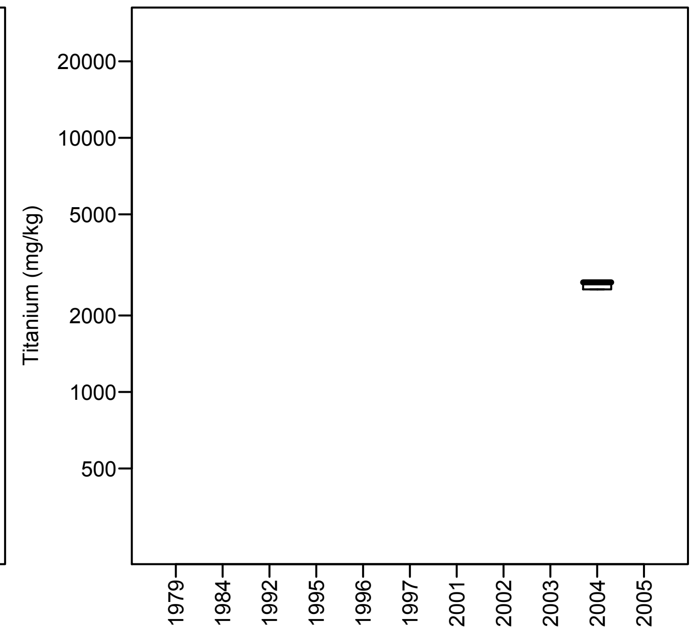


Figure 292. Temporal trend for Titanium concentrations within Reach #3. Red line indicates mean tendency.

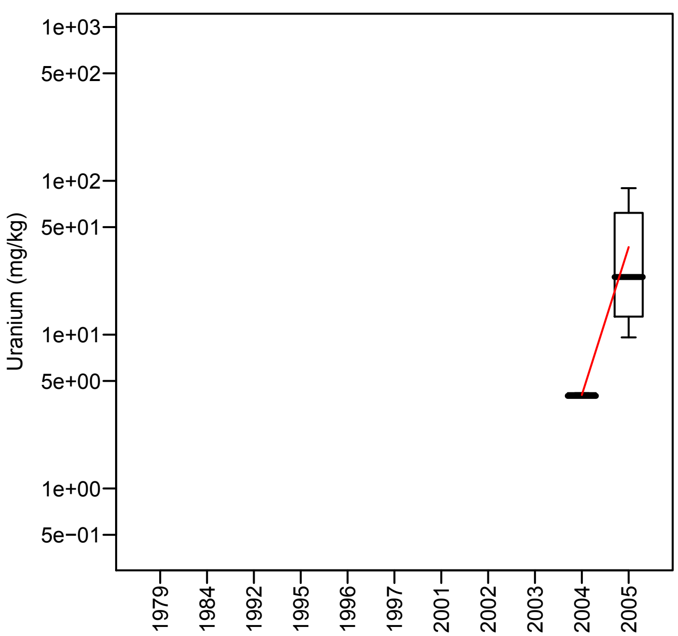


Figure 293. Temporal trend for Uranium concentrations within Reach #3. Red line indicates mean tendency.

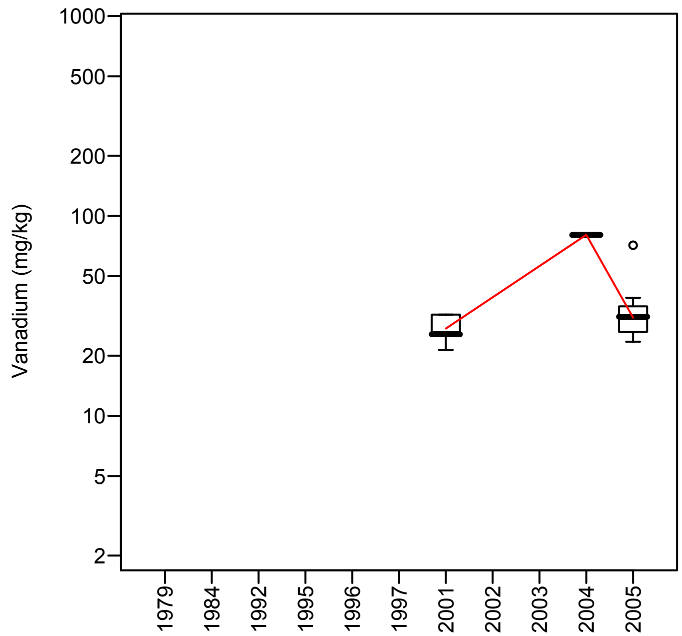


Figure 294. Temporal trend for Vanadium concentrations within Reach #3. Red line indicates mean tendency.

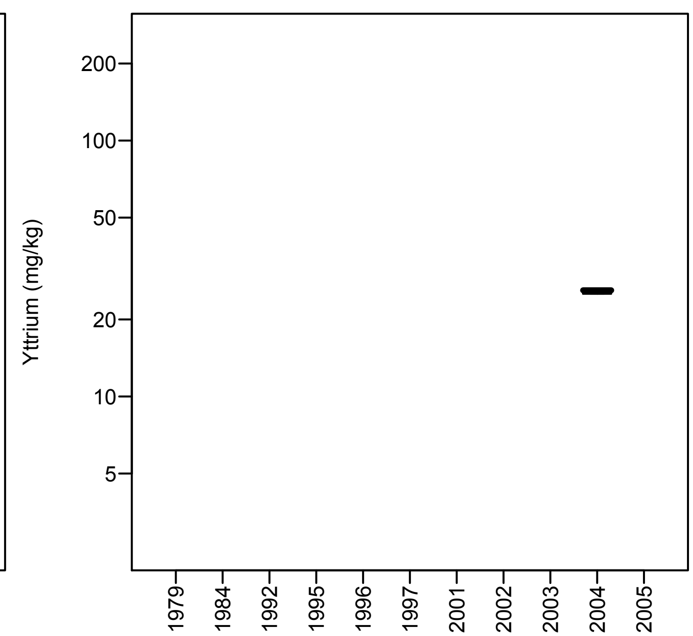


Figure 295. Temporal trend for Yttrium concentrations within Reach #3. Red line indicates mean tendency.

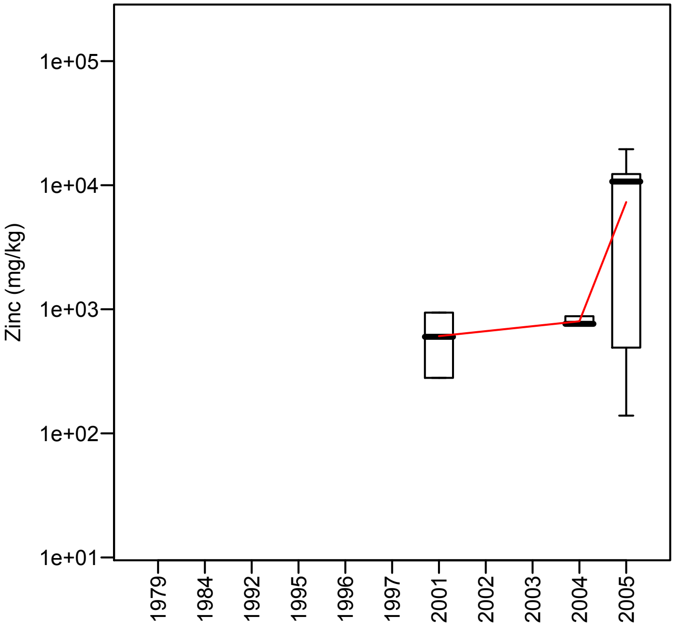


Figure 296. Temporal trend for Zinc concentrations within Reach #3. Red line indicates mean tendency.

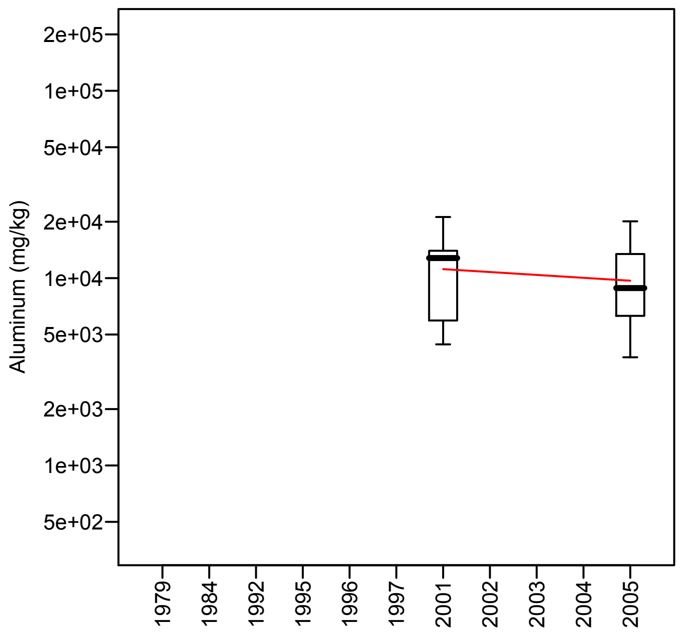


Figure 297. Temporal trend for Aluminum concentrations within Reach #4a. Red line indicates mean tendency.

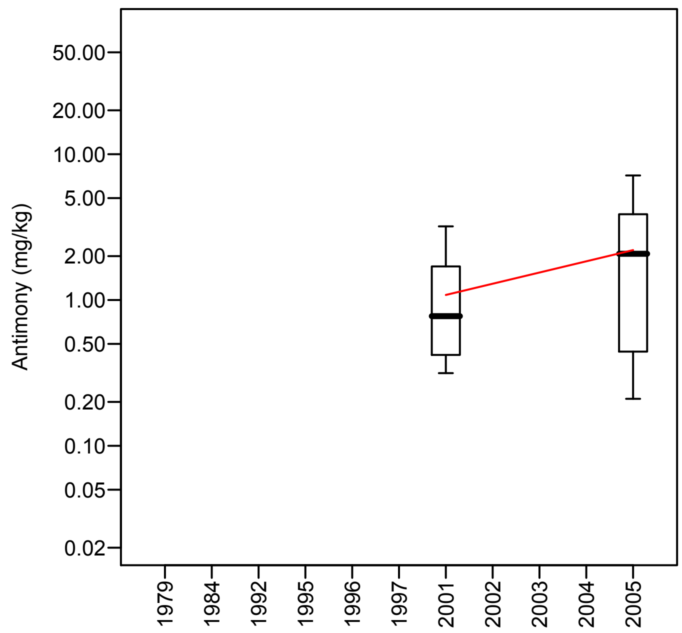


Figure 298. Temporal trend for Antimony concentrations within Reach #4a. Red line indicates mean tendency.

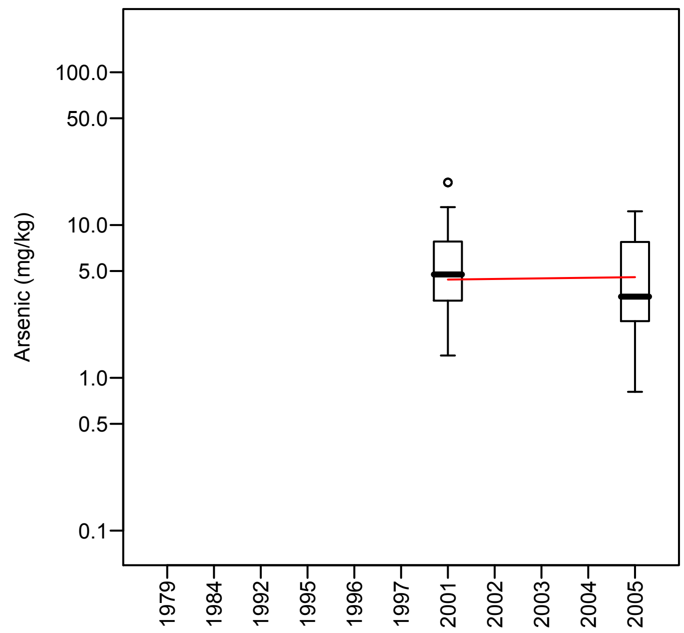


Figure 299. Temporal trend for Arsenic concentrations within Reach #4a. Red line indicates mean tendency.

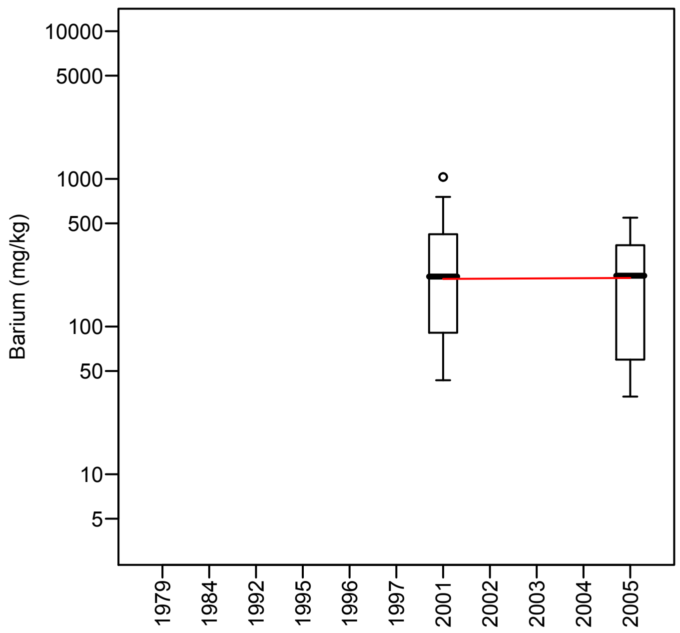


Figure 300. Temporal trend for Barium concentrations within Reach #4a. Red line indicates mean tendency.

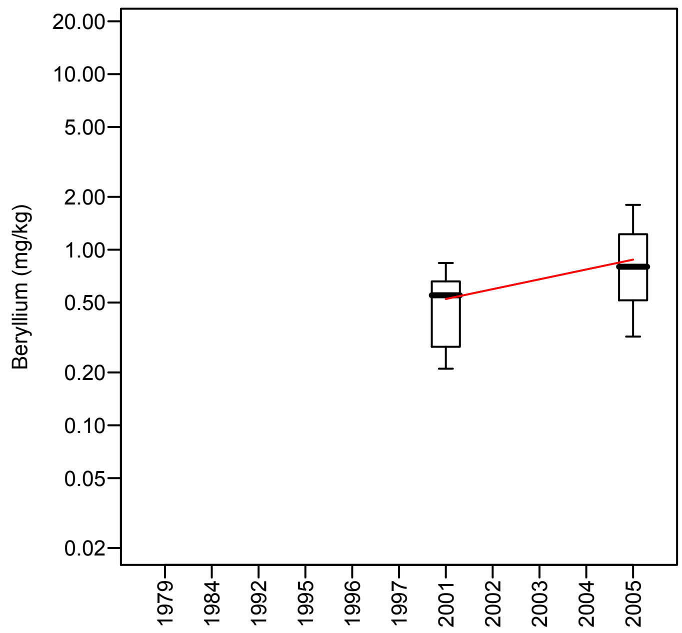


Figure 301. Temporal trend for Beryllium concentrations within Reach #4a. Red line indicates mean tendency.

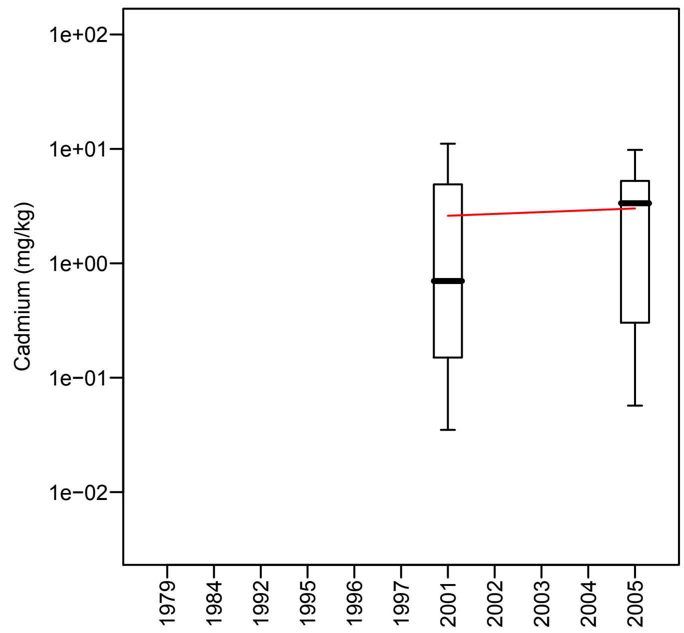


Figure 302. Temporal trend for Cadmium concentrations within Reach #4a. Red line indicates mean tendency.

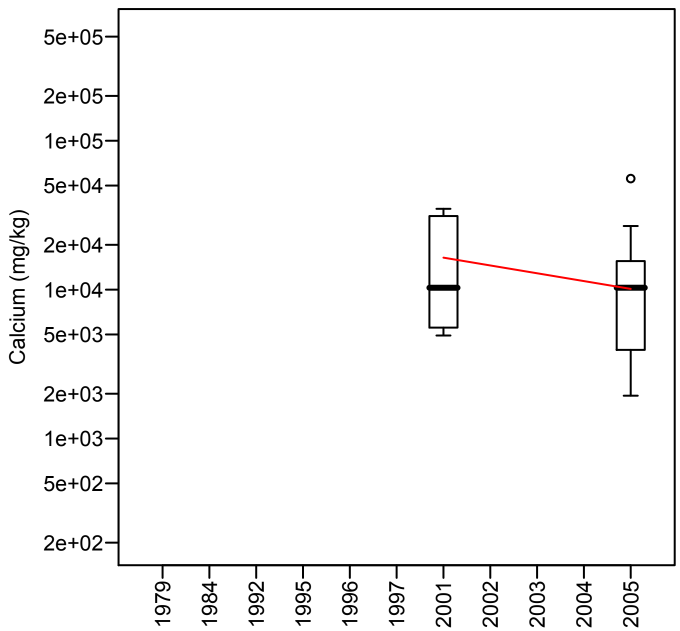


Figure 303. Temporal trend for Calcium concentrations within Reach #4a. Red line indicates mean tendency.

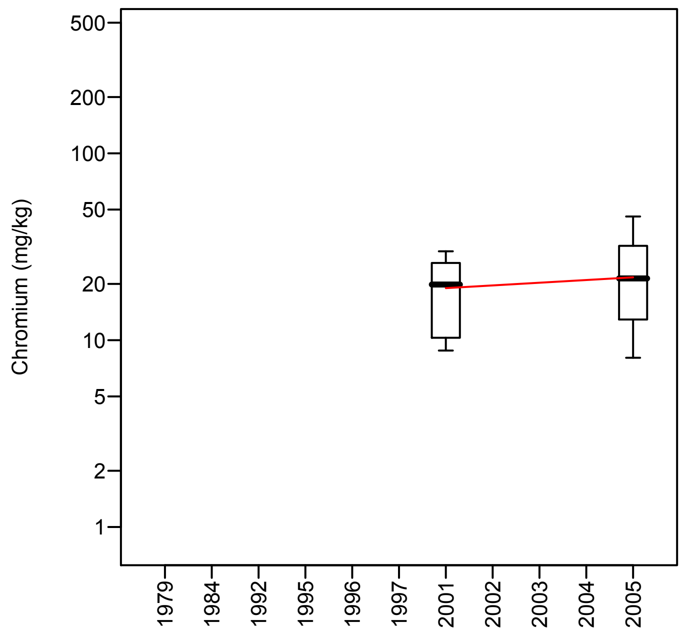


Figure 304. Temporal trend for Chromium concentrations within Reach #4a. Red line indicates mean tendency.

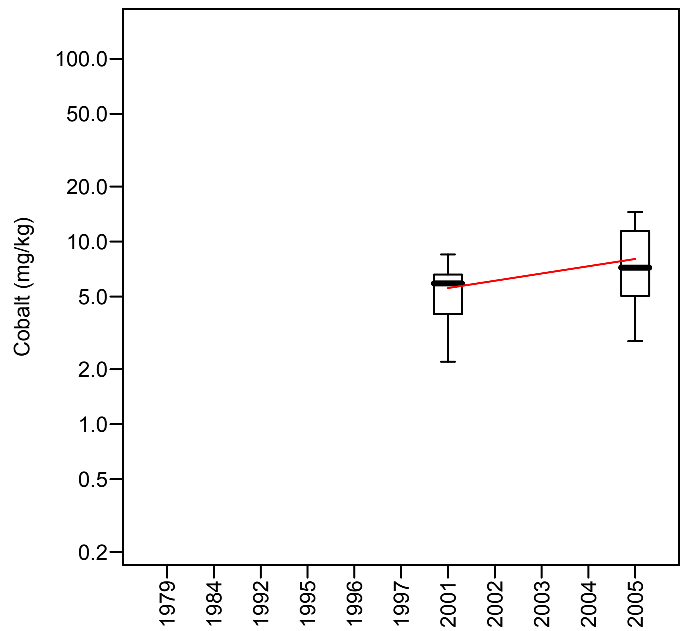


Figure 305. Temporal trend for Cobalt concentrations within Reach #4a. Red line indicates mean tendency.

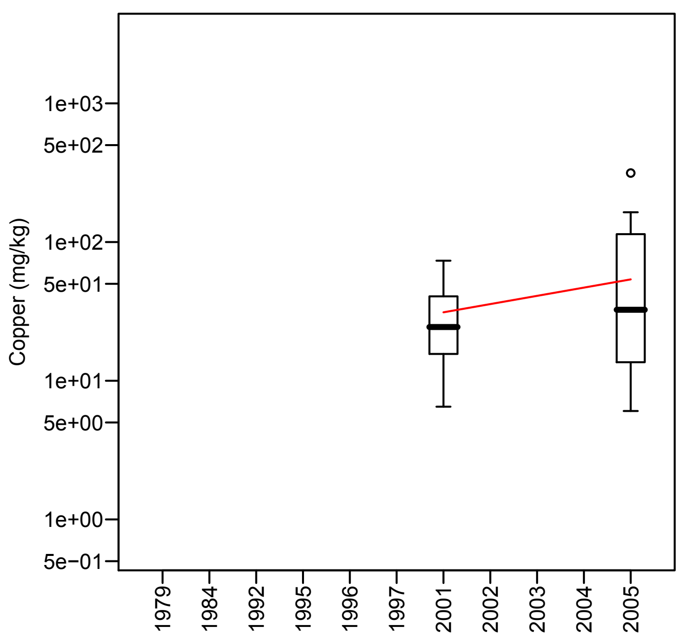


Figure 306. Temporal trend for Copper concentrations within Reach #4a. Red line indicates mean tendency.

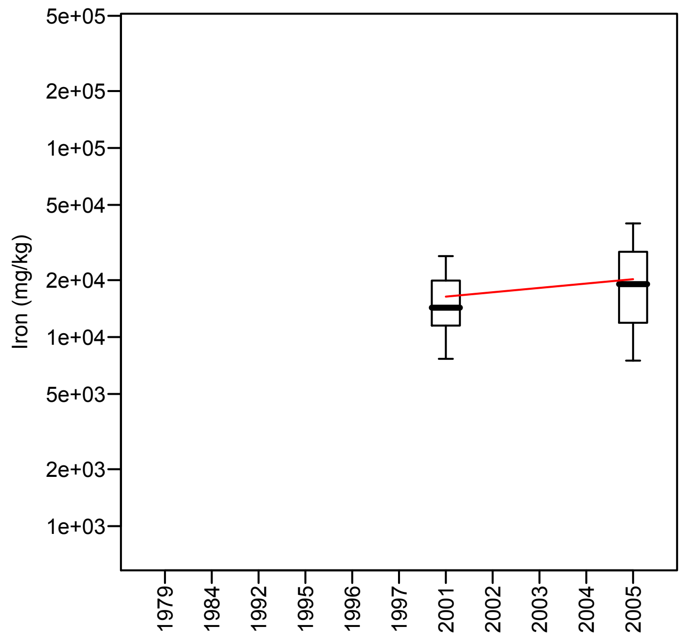


Figure 307. Temporal trend for Iron concentrations within Reach #4a. Red line indicates mean tendency.

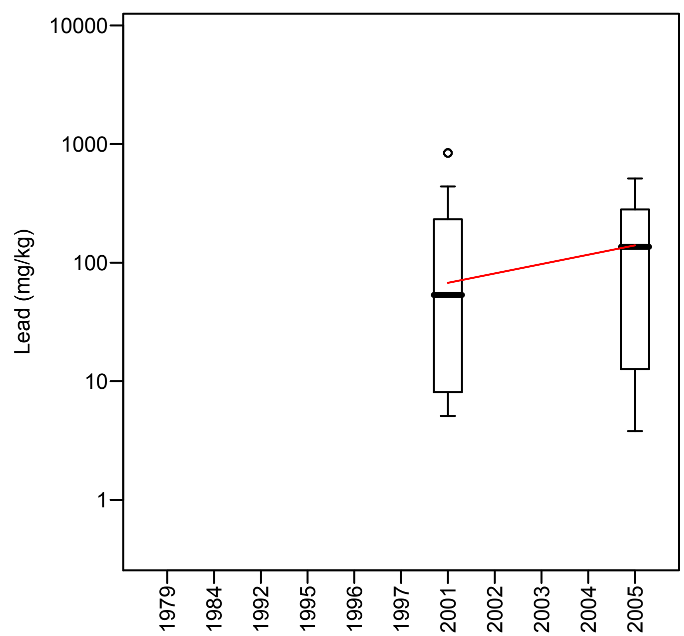


Figure 308. Temporal trend for Lead concentrations within Reach #4a. Red line indicates mean tendency.

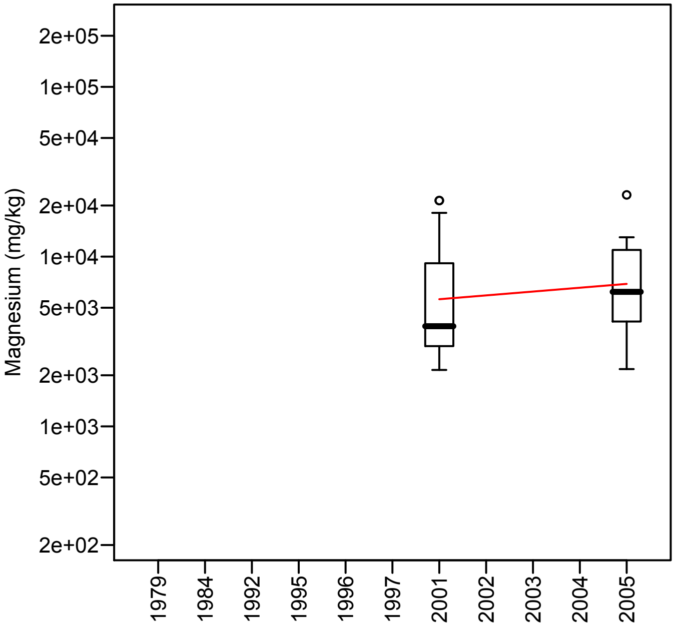


Figure 309. Temporal trend for Magnesium concentrations within Reach #4a. Red line indicates mean tendency.

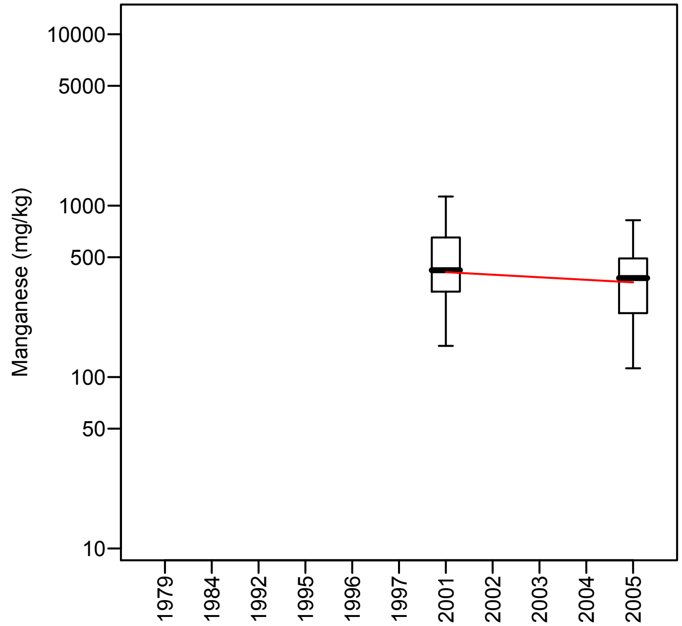


Figure 310. Temporal trend for Manganese concentrations within Reach #4a. Red line indicates mean tendency.

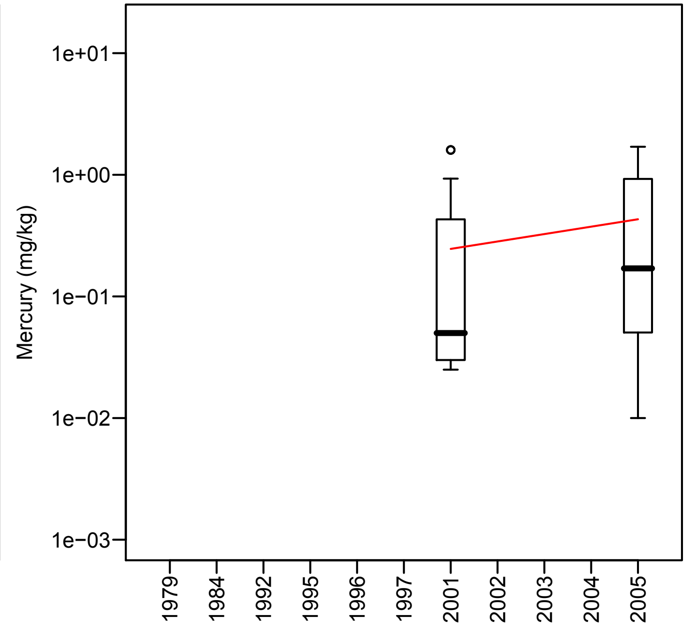


Figure 311. Temporal trend for Mercury concentrations within Reach #4a. Red line indicates mean tendency.

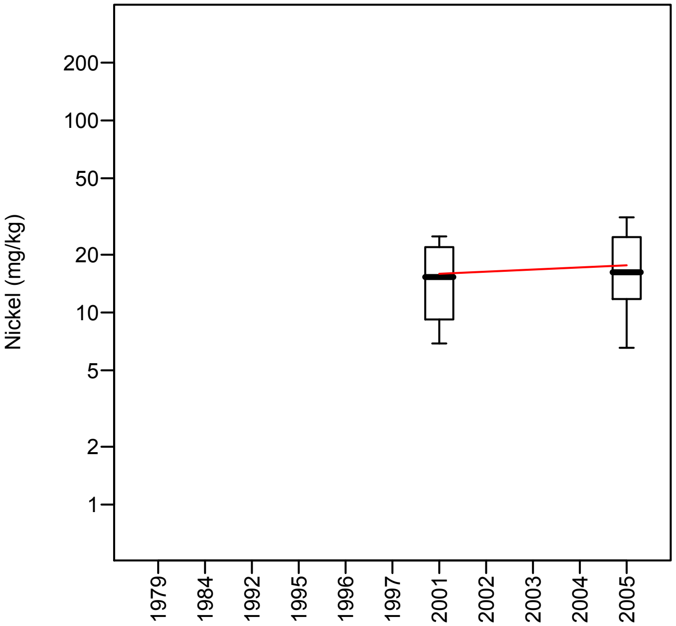


Figure 312. Temporal trend for Nickel concentrations within Reach #4a. Red line indicates mean tendency.

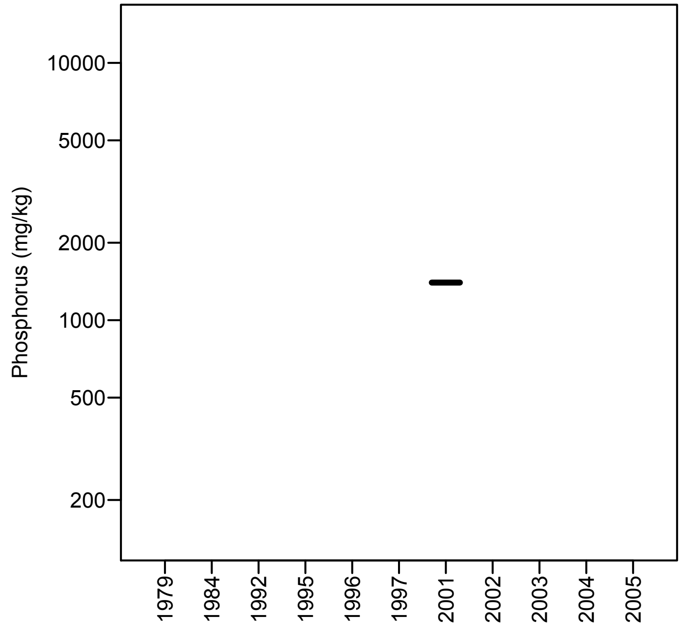


Figure 313. Temporal trend for Phosphorus concentrations within Reach #4a. Red line indicates mean tendency.

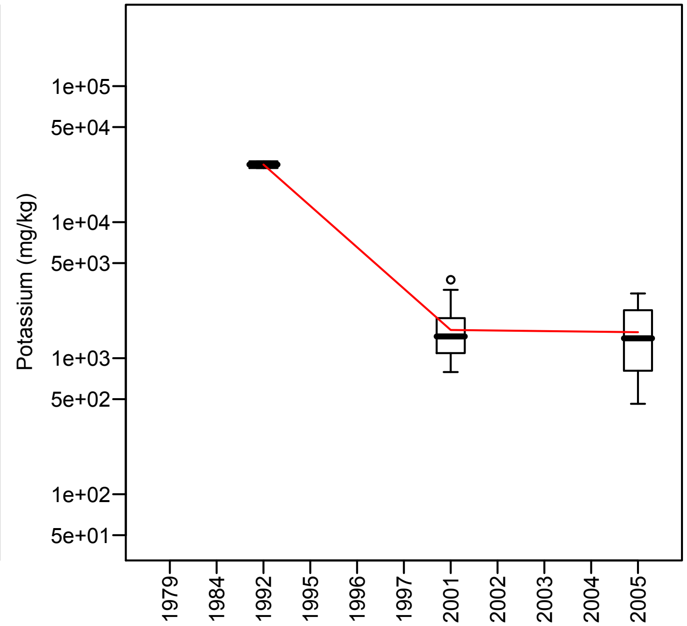


Figure 314. Temporal trend for Potassium concentrations within Reach #4a. Red line indicates mean tendency.

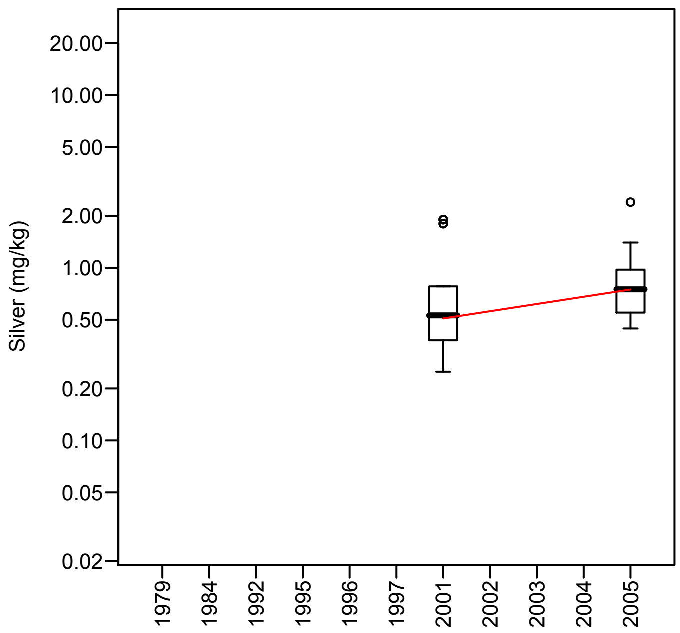


Figure 315. Temporal trend for Silver concentrations within Reach #4a. Red line indicates mean tendency.

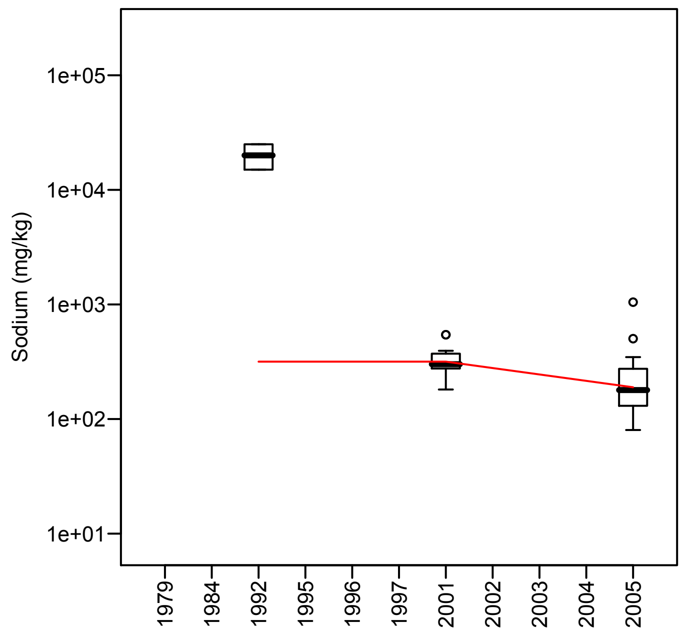


Figure 316. Temporal trend for Sodium concentrations within Reach #4a. Red line indicates mean tendency.

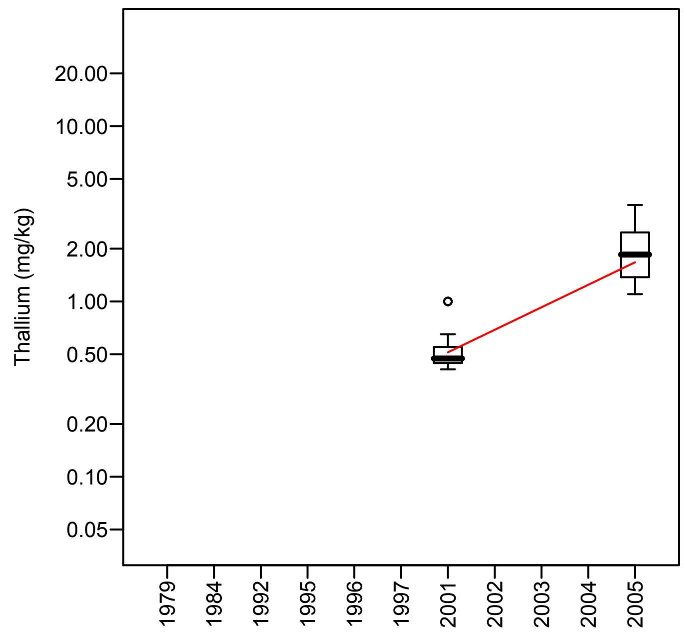


Figure 317. Temporal trend for Thallium concentrations within Reach #4a. Red line indicates mean tendency.

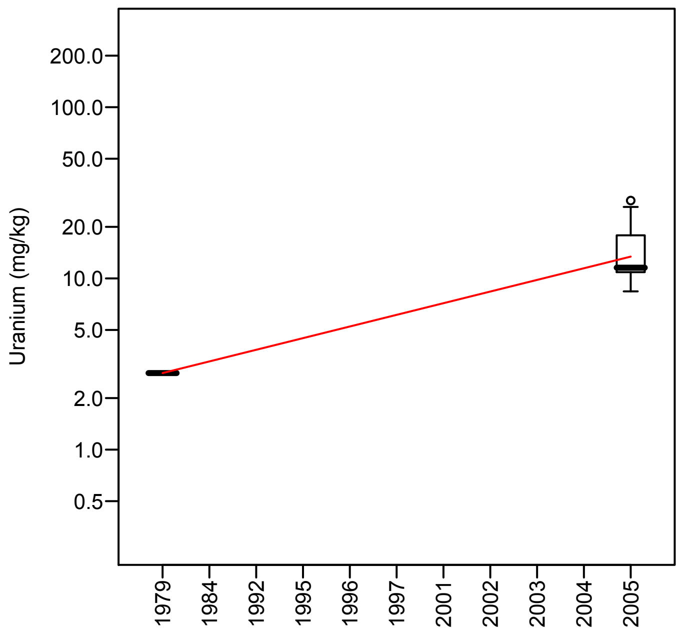


Figure 318. Temporal trend for Uranium concentrations within Reach #4a. Red line indicates mean tendency.

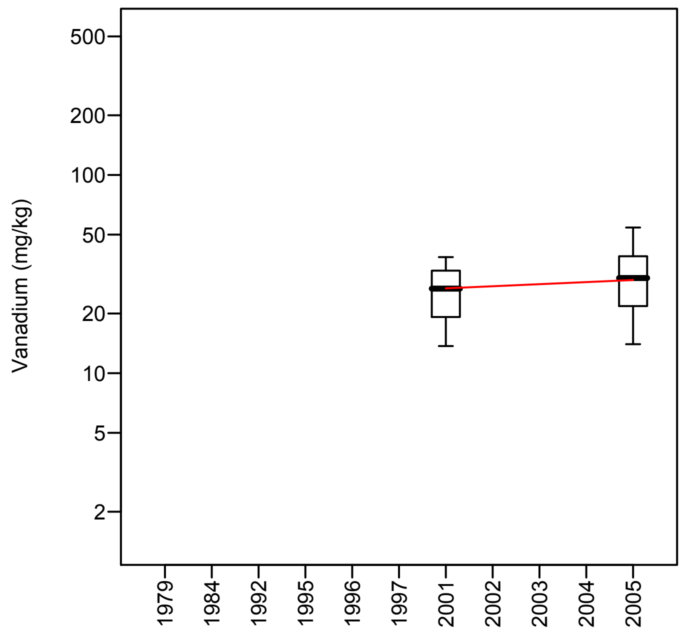


Figure 319. Temporal trend for Vanadium concentrations within Reach #4a. Red line indicates mean tendency.

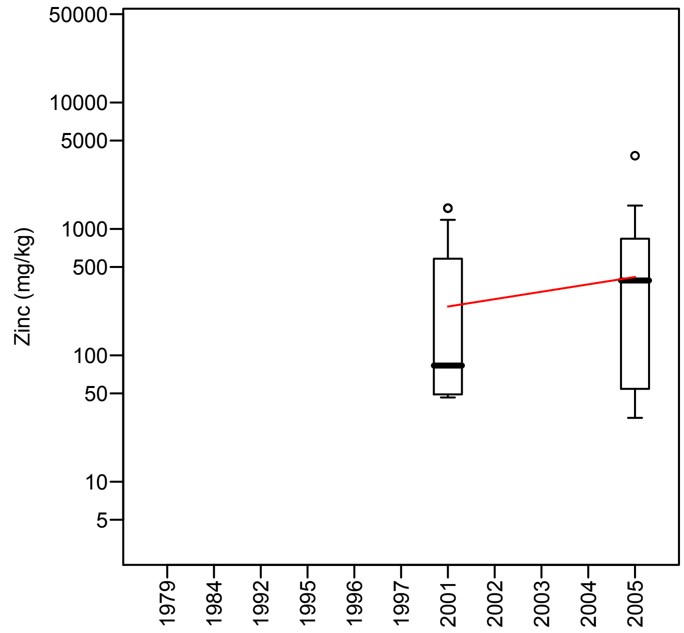


Figure 320. Temporal trend for Zinc concentrations within Reach #4a. Red line indicates mean tendency.

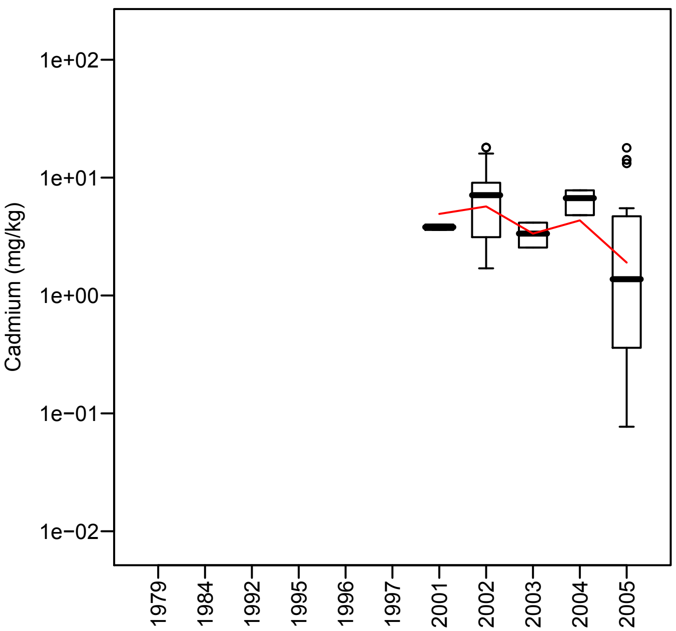


Figure 321. Temporal trend for Cadmium concentrations within Reach #4b. Red line indicates mean tendency.

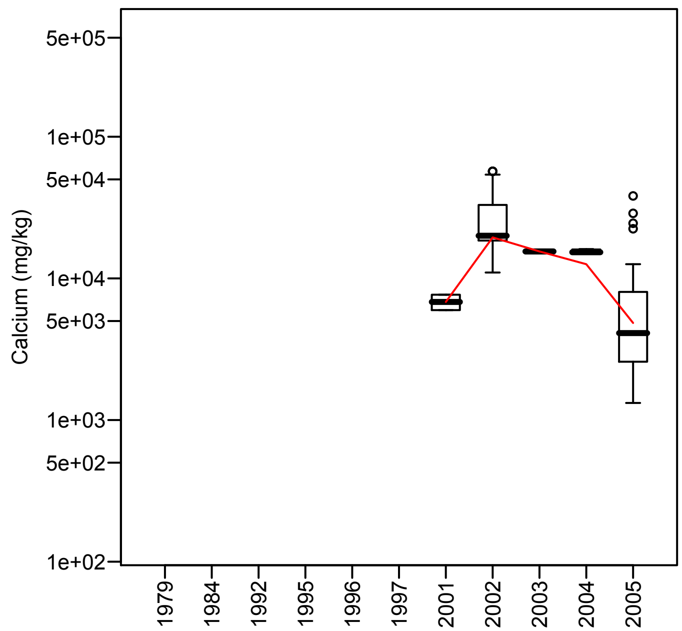


Figure 322. Temporal trend for Calcium concentrations within Reach #4b. Red line indicates mean tendency.

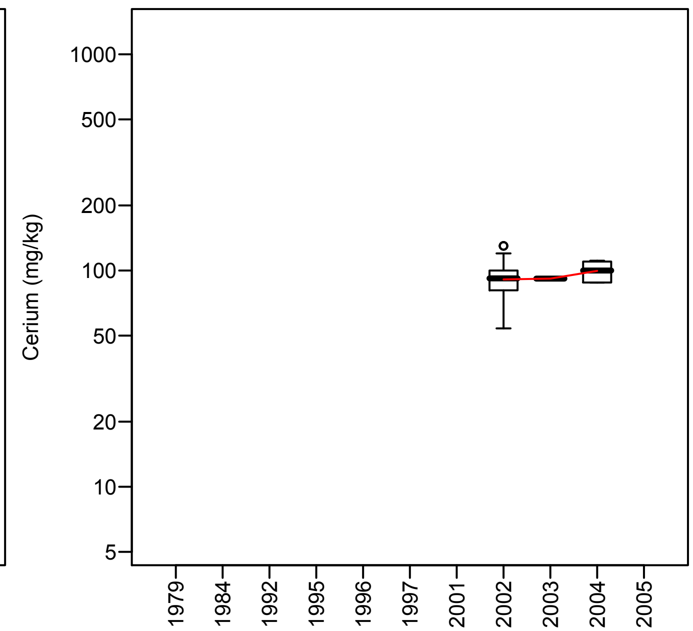


Figure 323. Temporal trend for Cerium concentrations within Reach #4b. Red line indicates mean tendency.

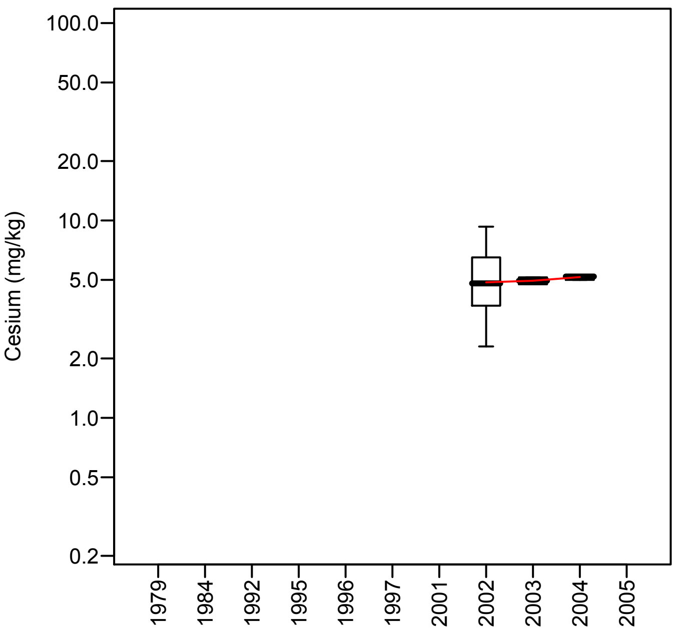


Figure 324. Temporal trend for Cesium concentrations within Reach #4b. Red line indicates mean tendency.

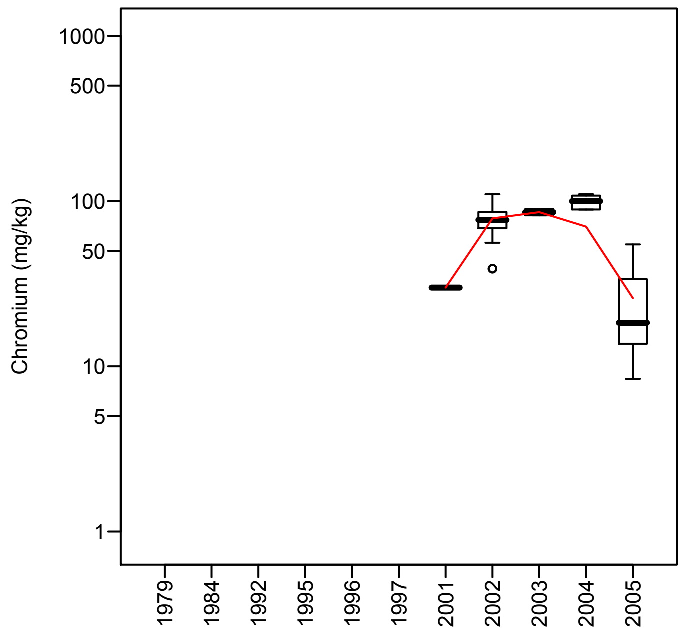


Figure 325. Temporal trend for Chromium concentrations within Reach #4b. Red line indicates mean tendency.

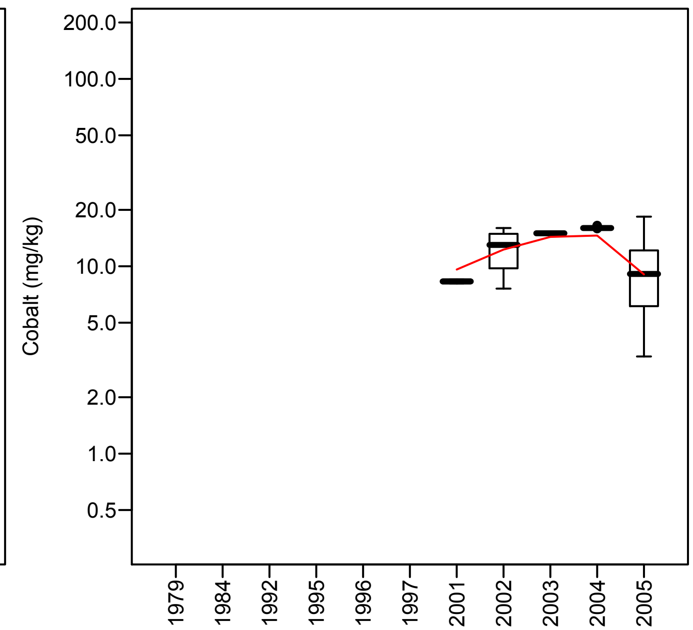


Figure 326. Temporal trend for Cobalt concentrations within Reach #4b. Red line indicates mean tendency.

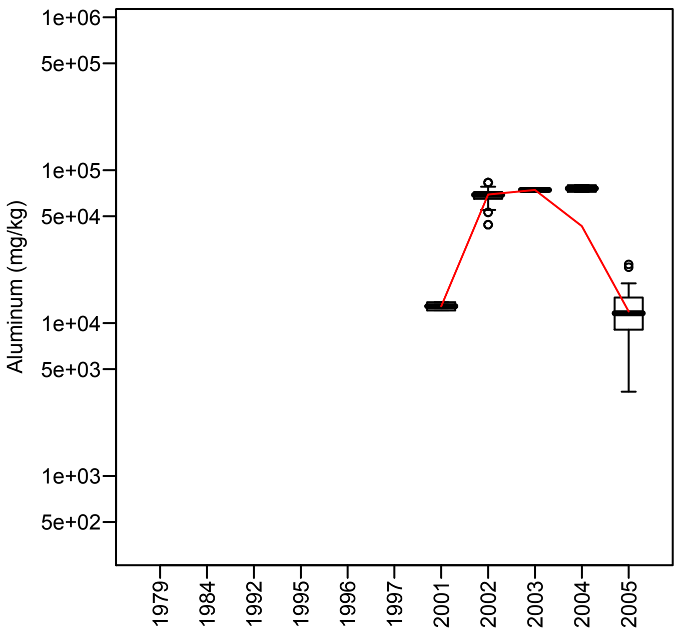


Figure 327. Temporal trend for Aluminum concentrations within Reach #4b. Red line indicates mean tendency.

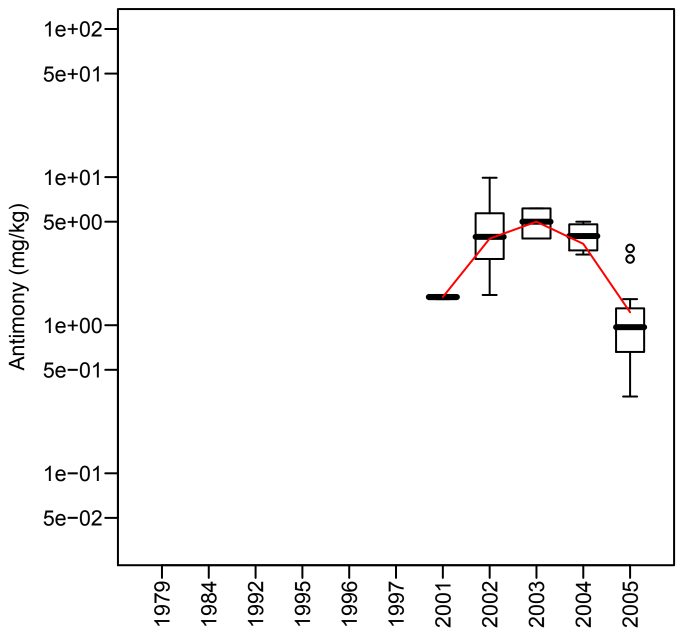


Figure 328. Temporal trend for Antimony concentrations within Reach #4b. Red line indicates mean tendency.

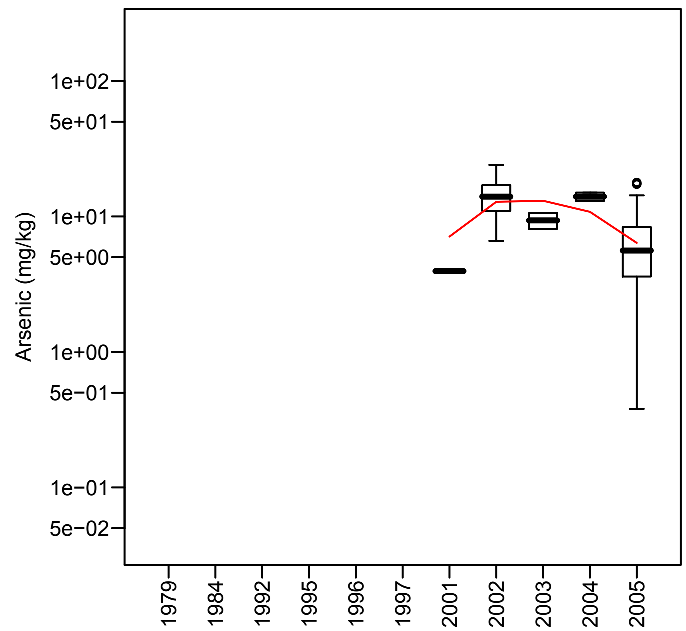


Figure 329. Temporal trend for Arsenic concentrations within Reach #4b. Red line indicates mean tendency.

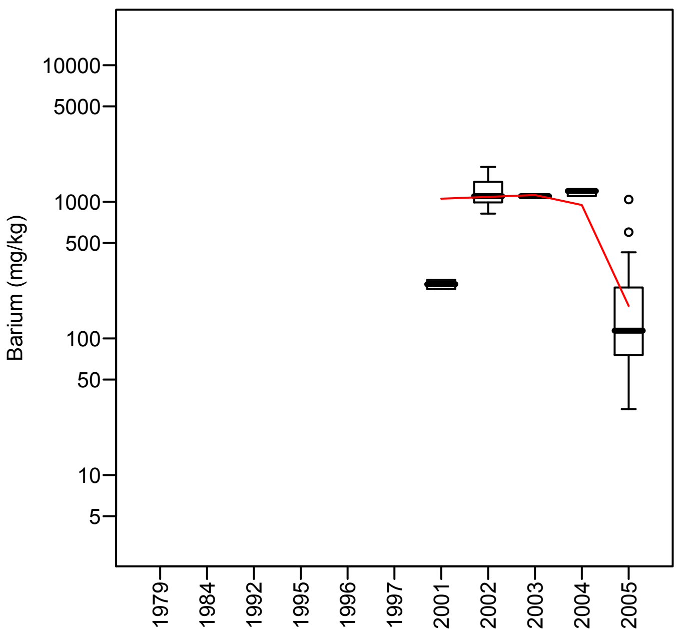


Figure 330. Temporal trend for Barium concentrations within Reach #4b. Red line indicates mean tendency.

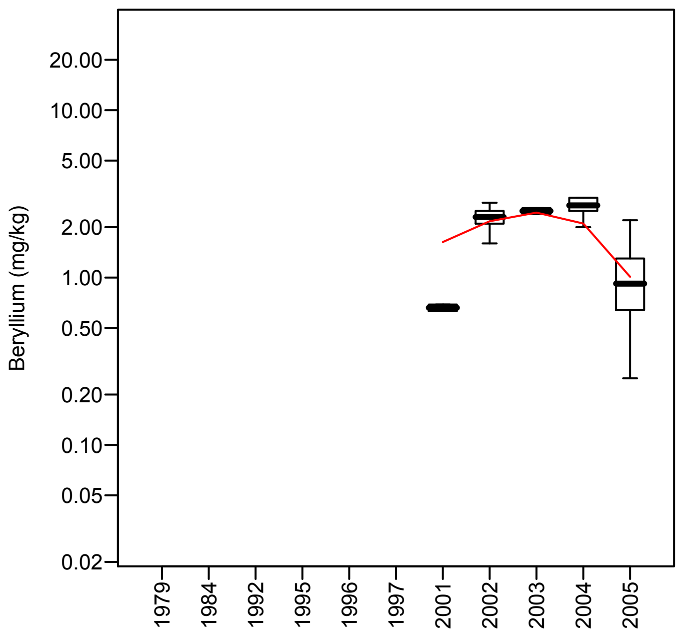


Figure 331. Temporal trend for Beryllium concentrations within Reach #4b. Red line indicates mean tendency.

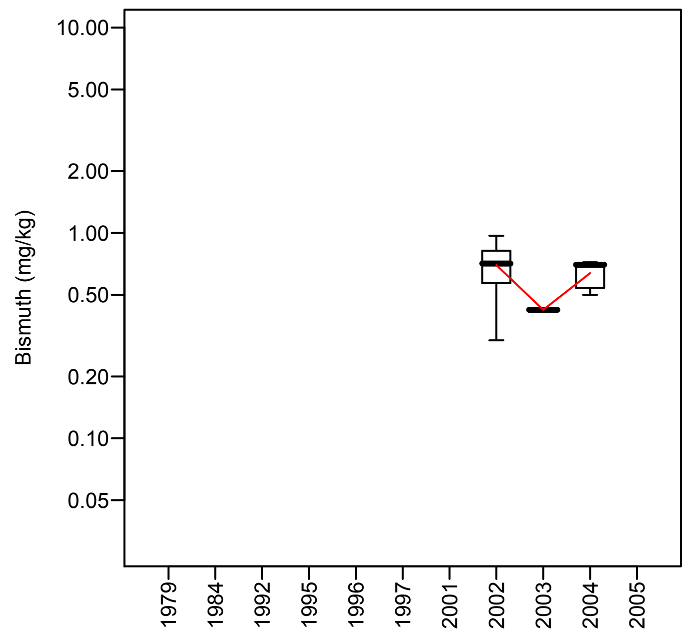


Figure 332. Temporal trend for Bismuth concentrations within Reach #4b. Red line indicates mean tendency.

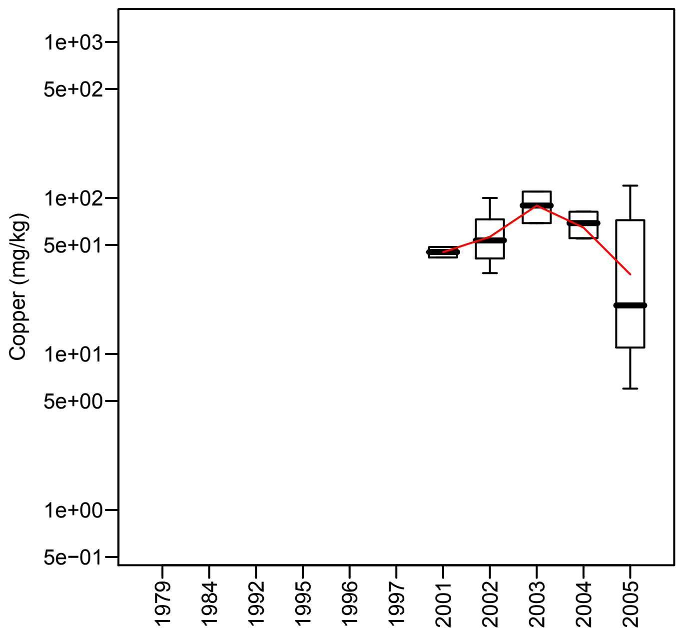


Figure 333. Temporal trend for Copper concentrations within Reach #4b. Red line indicates mean tendency.

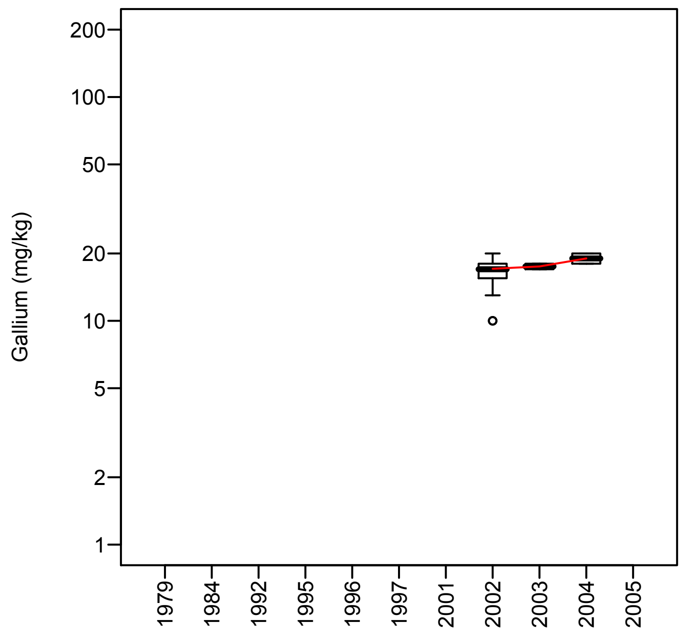


Figure 334. Temporal trend for Gallium concentrations within Reach #4b. Red line indicates mean tendency.

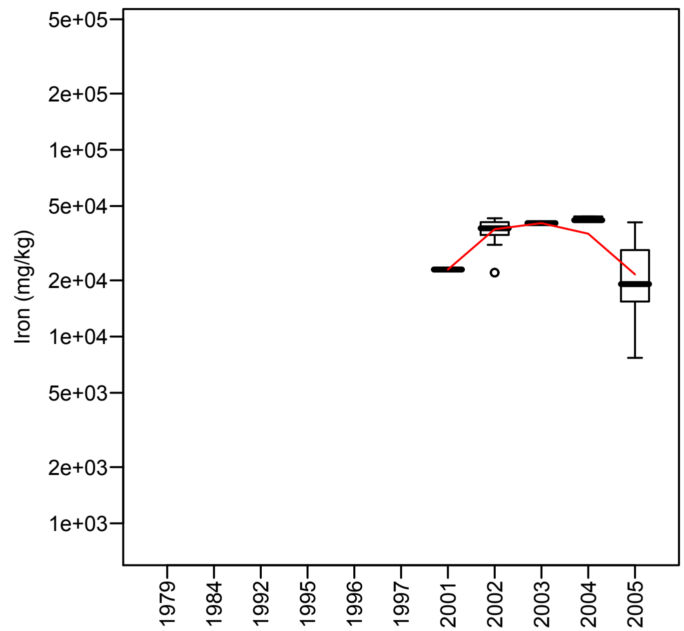


Figure 335. Temporal trend for Iron concentrations within Reach #4b. Red line indicates mean tendency.

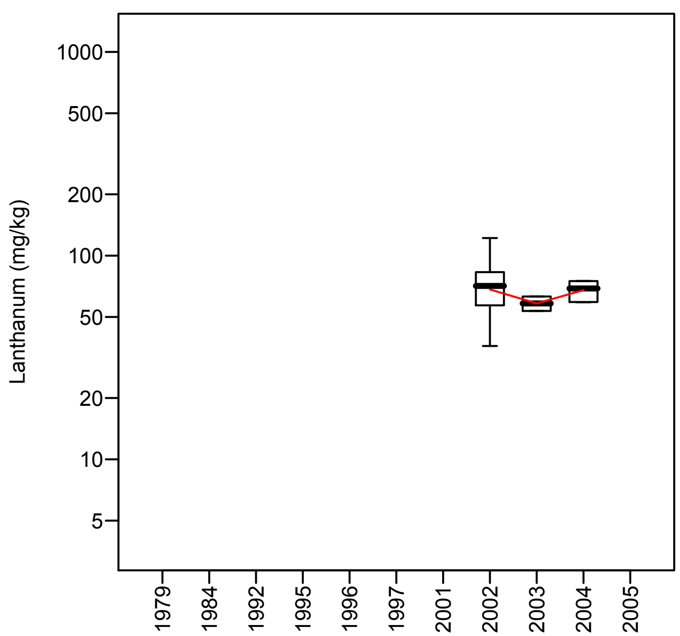


Figure 336. Temporal trend for Lanthanum concentrations within Reach #4b. Red line indicates mean tendency.

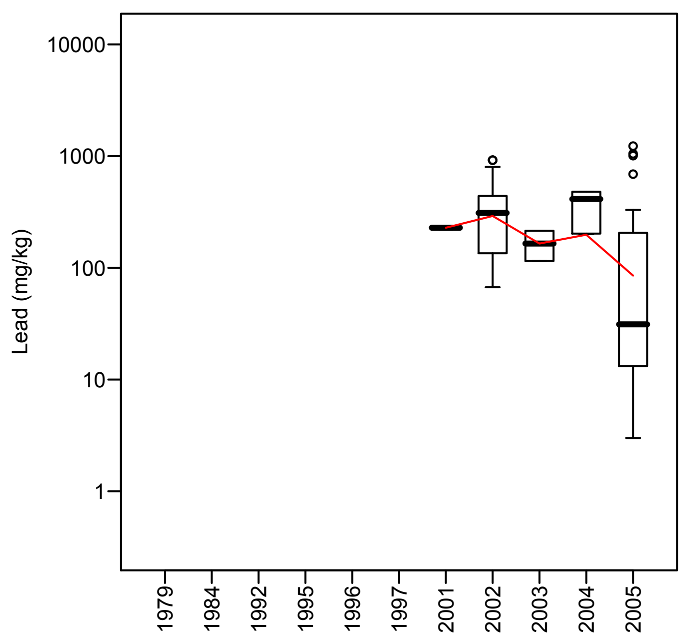


Figure 337. Temporal trend for Lead concentrations within Reach #4b. Red line indicates mean tendency.

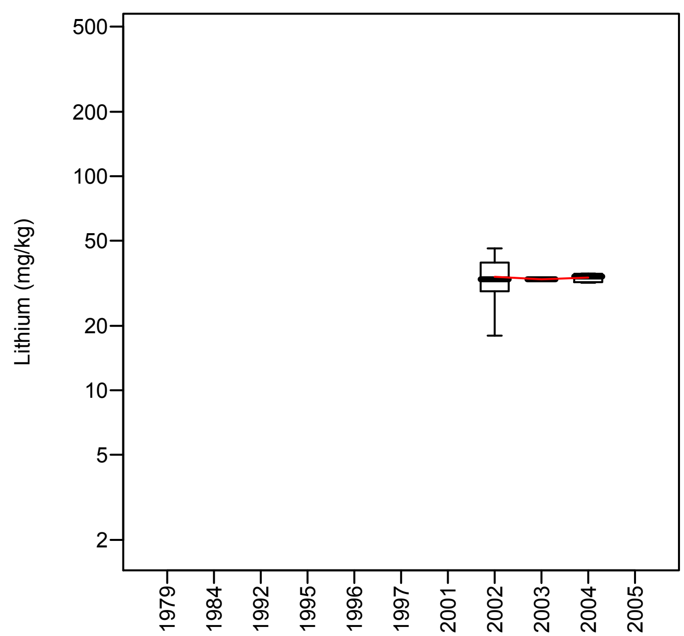


Figure 338. Temporal trend for Lithium concentrations within Reach #4b. Red line indicates mean tendency.

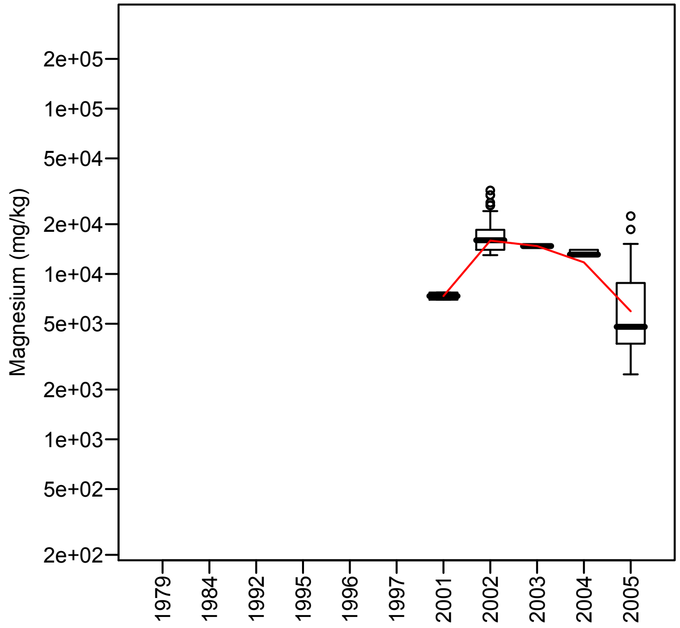


Figure 339. Temporal trend for Magnesium concentrations within Reach #4b. Red line indicates mean tendency.

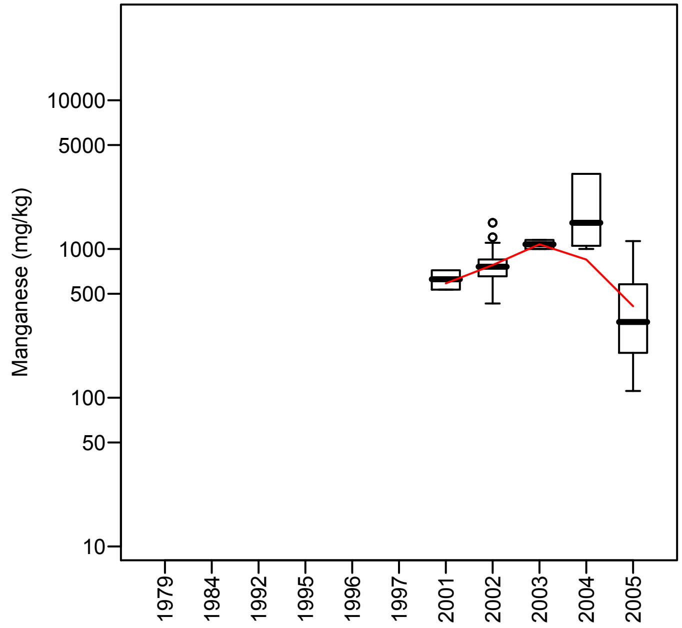


Figure 340. Temporal trend for Manganese concentrations within Reach #4b. Red line indicates mean tendency.

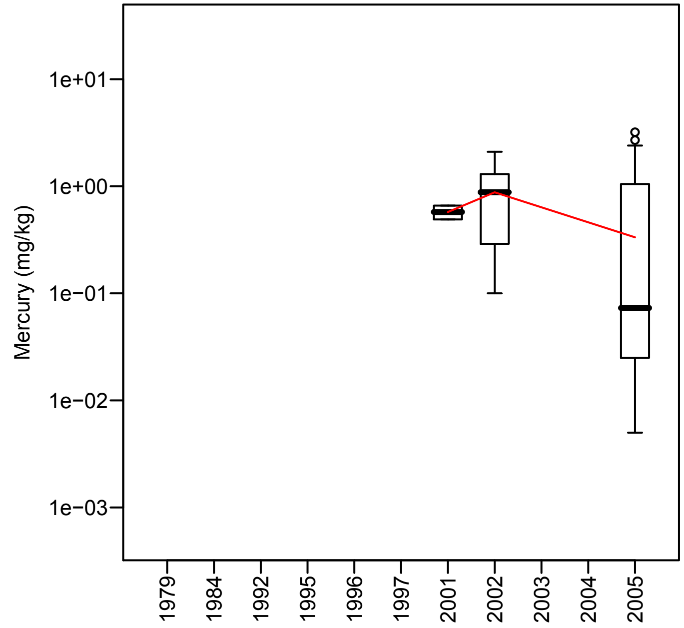


Figure 341. Temporal trend for Mercury concentrations within Reach #4b. Red line indicates mean tendency.

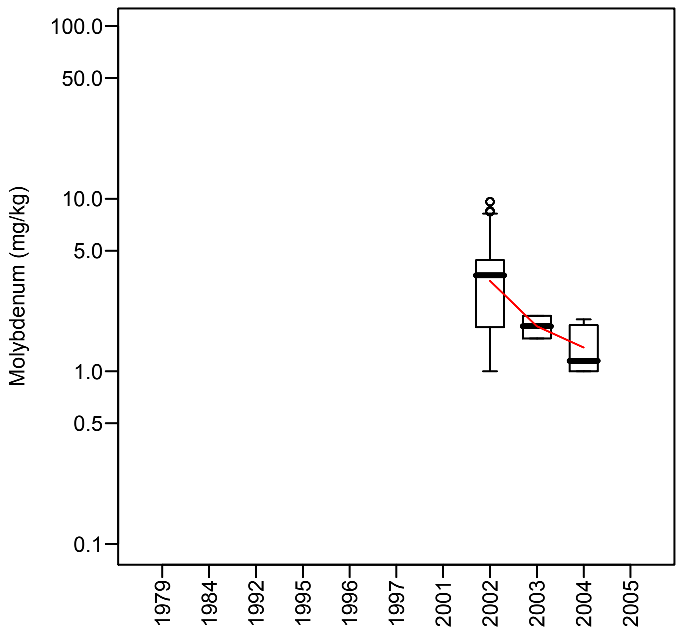


Figure 342. Temporal trend for Molybdenum concentrations within Reach #4b. Red line indicates mean tendency.

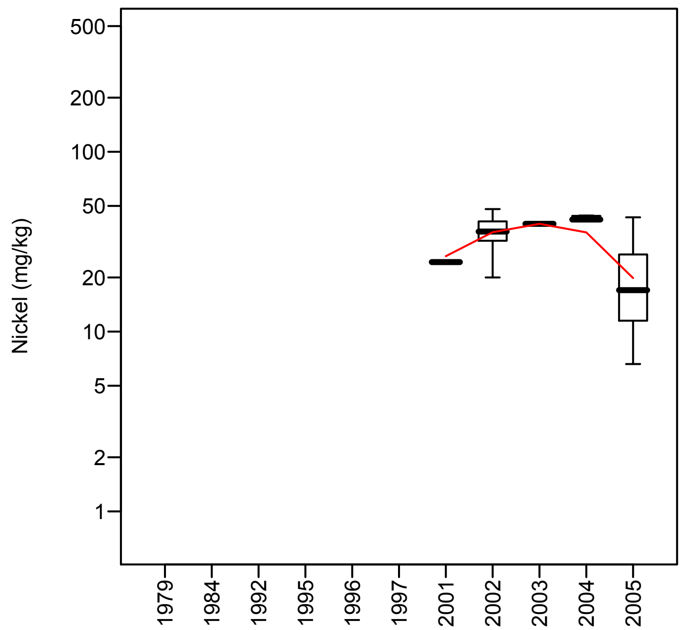


Figure 343. Temporal trend for Nickel concentrations within Reach #4b. Red line indicates mean tendency.

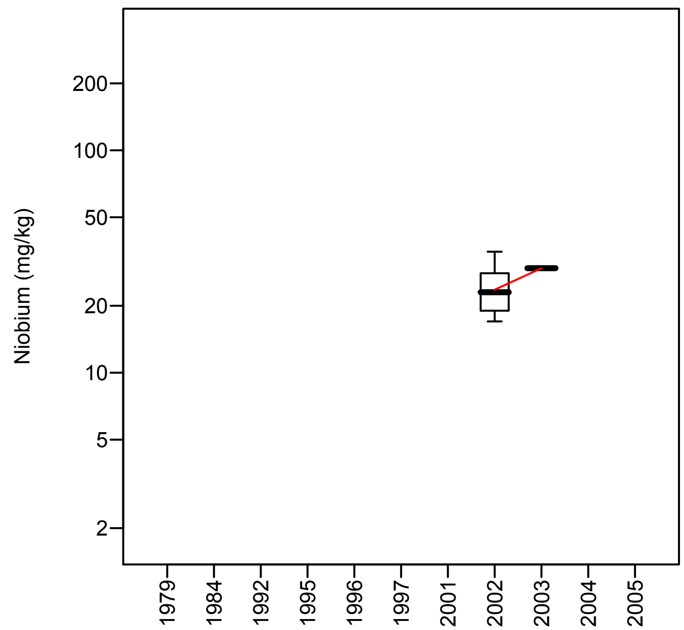


Figure 344. Temporal trend for Niobium concentrations within Reach #4b. Red line indicates mean tendency.

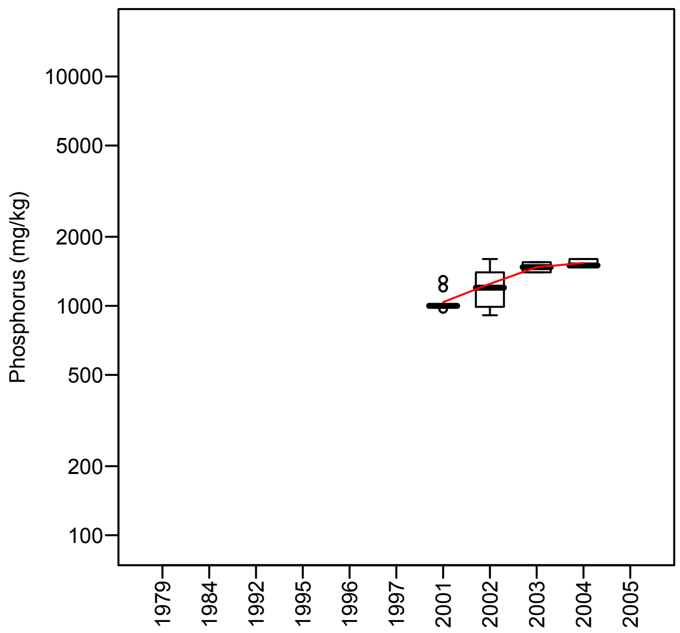


Figure 345. Temporal trend for Phosphorus concentrations within Reach #4b. Red line indicates mean tendency.

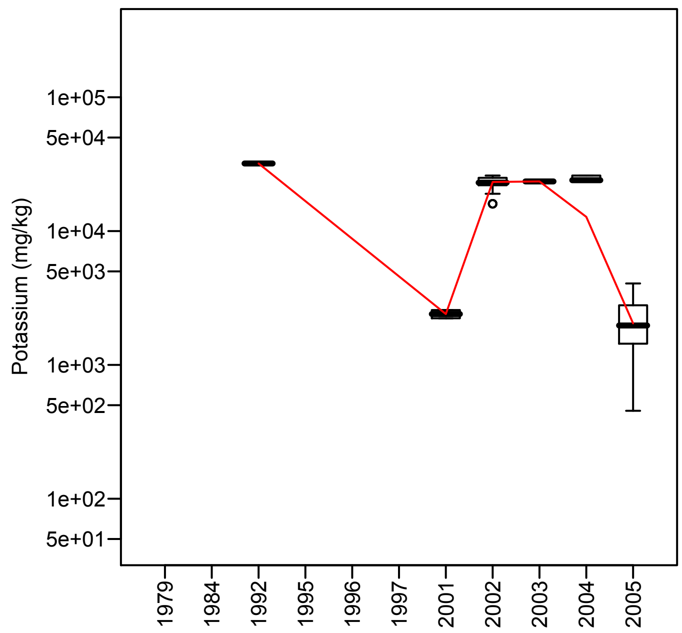


Figure 346. Temporal trend for Potassium concentrations within Reach #4b. Red line indicates mean tendency.

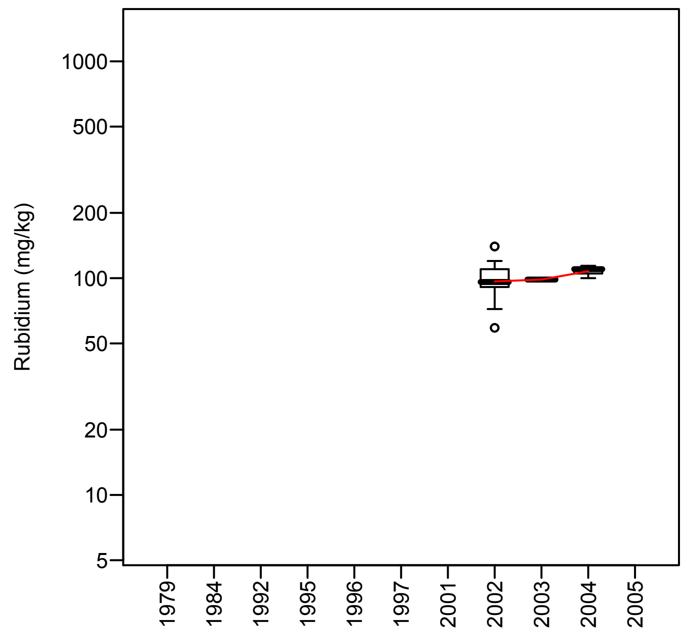


Figure 347. Temporal trend for Rubidium concentrations within Reach #4b. Red line indicates mean tendency.

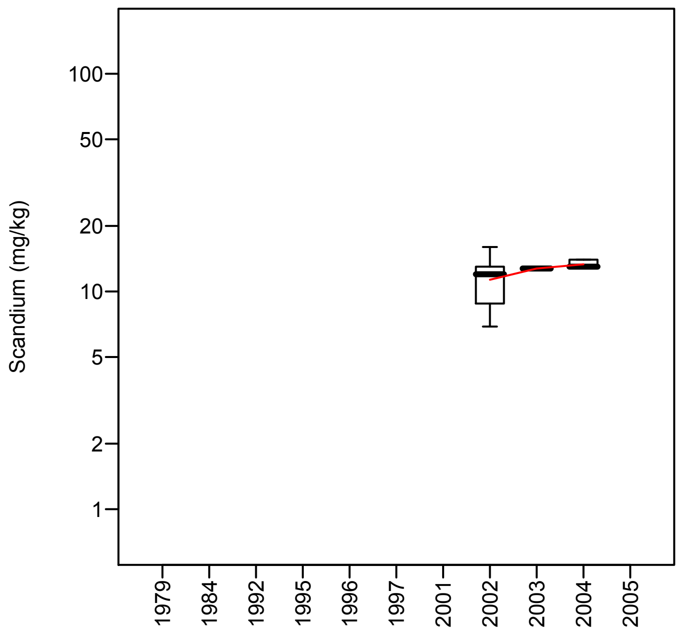


Figure 348. Temporal trend for Scandium concentrations within Reach #4b. Red line indicates mean tendency.

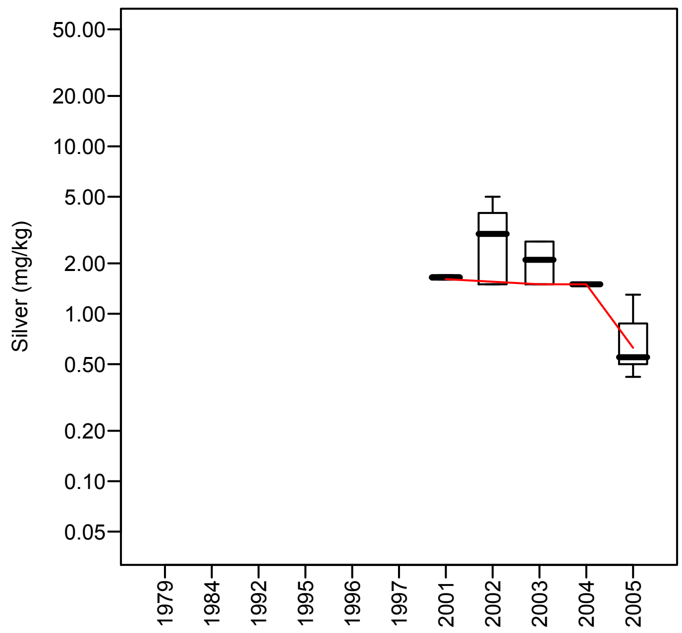


Figure 349. Temporal trend for Silver concentrations within Reach #4b. Red line indicates mean tendency.

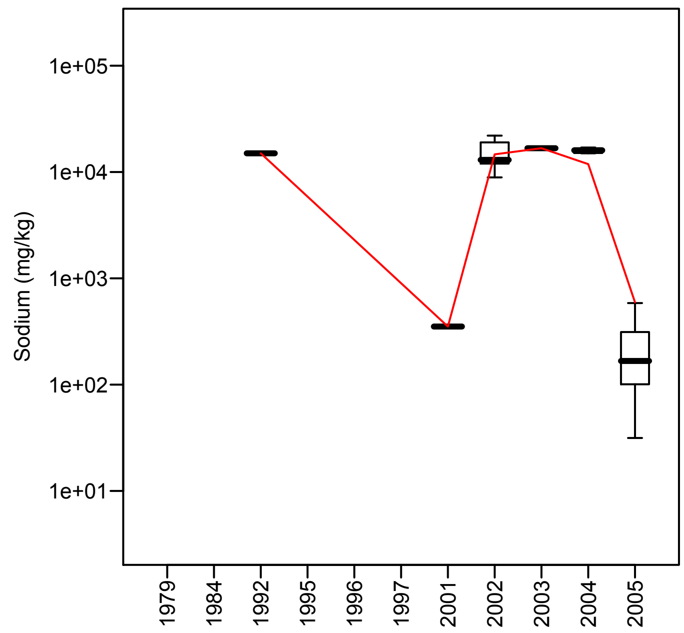


Figure 350. Temporal trend for Sodium concentrations within Reach #4b. Red line indicates mean tendency.

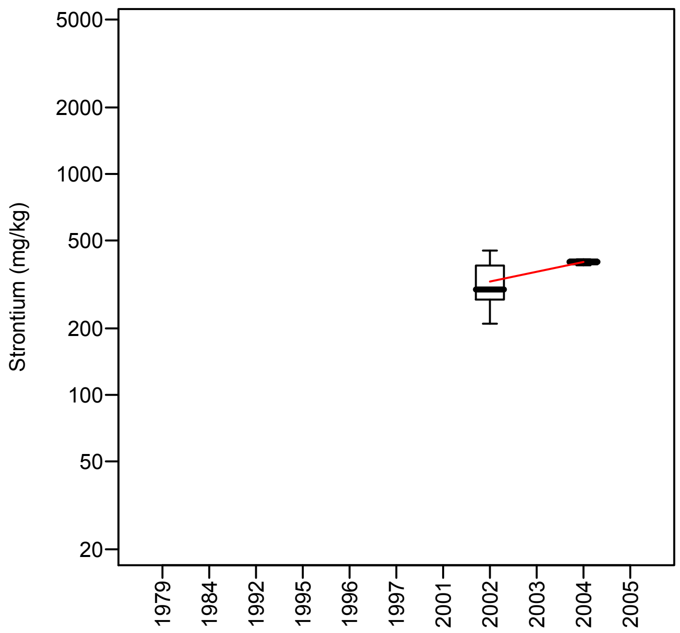


Figure 351. Temporal trend for Strontium concentrations within Reach #4b. Red line indicates mean tendency.

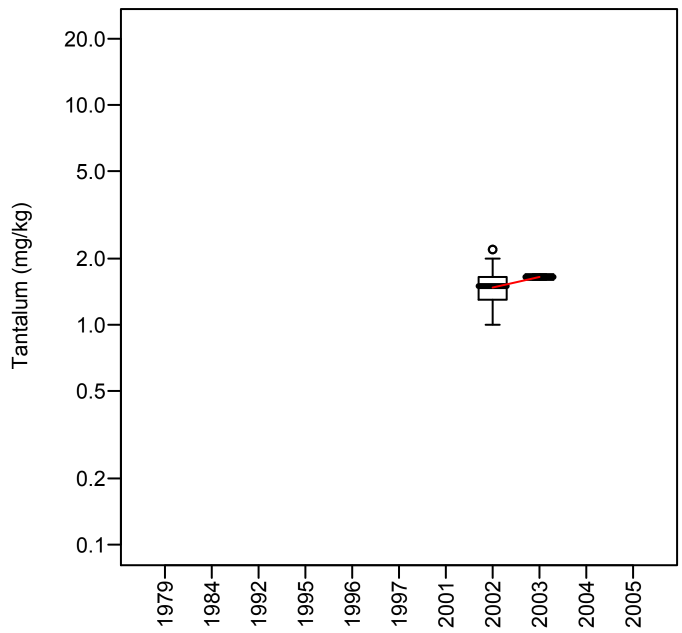


Figure 352. Temporal trend for Tantalum concentrations within Reach #4b. Red line indicates mean tendency.

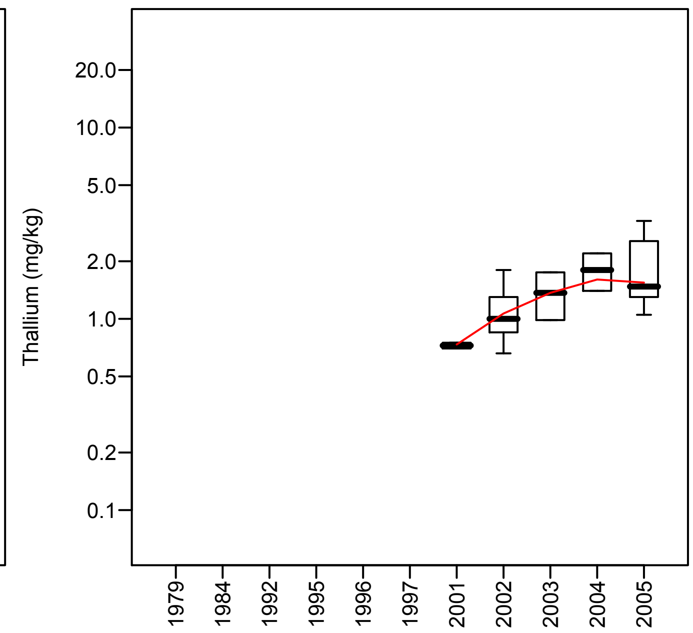


Figure 353. Temporal trend for Thallium concentrations within Reach #4b. Red line indicates mean tendency.

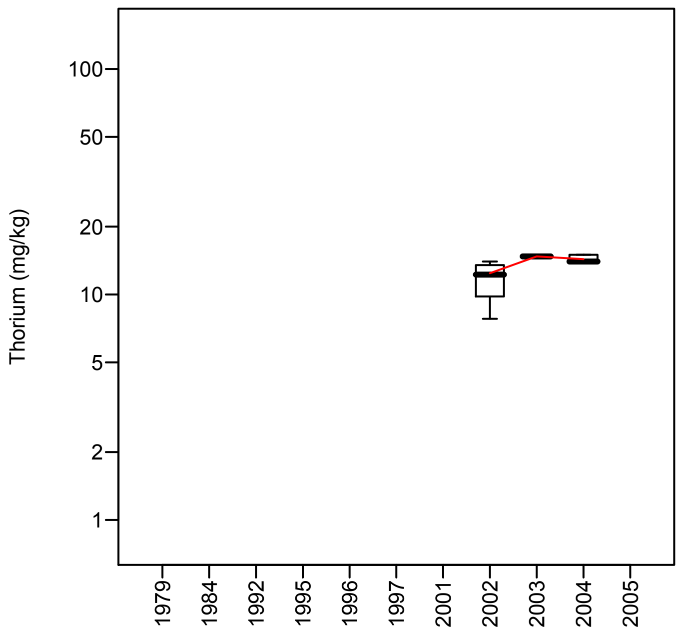


Figure 354. Temporal trend for Thorium concentrations within Reach #4b. Red line indicates mean tendency.

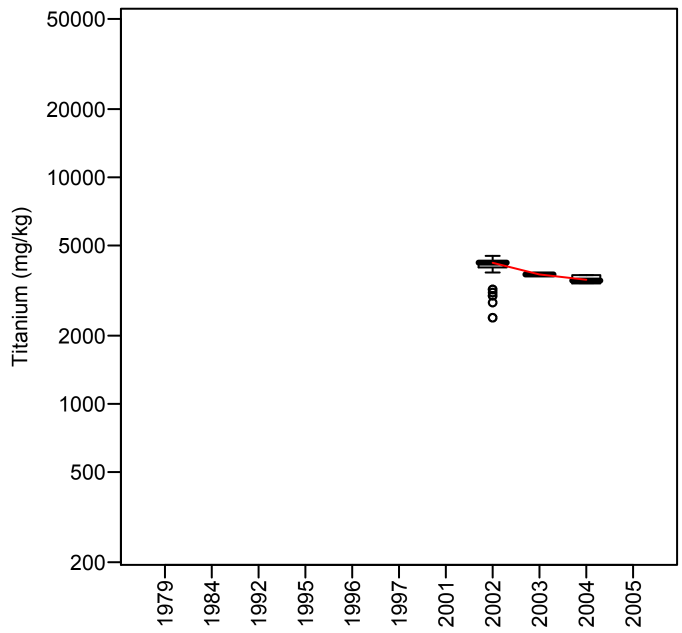


Figure 355. Temporal trend for Titanium concentrations within Reach #4b. Red line indicates mean tendency.

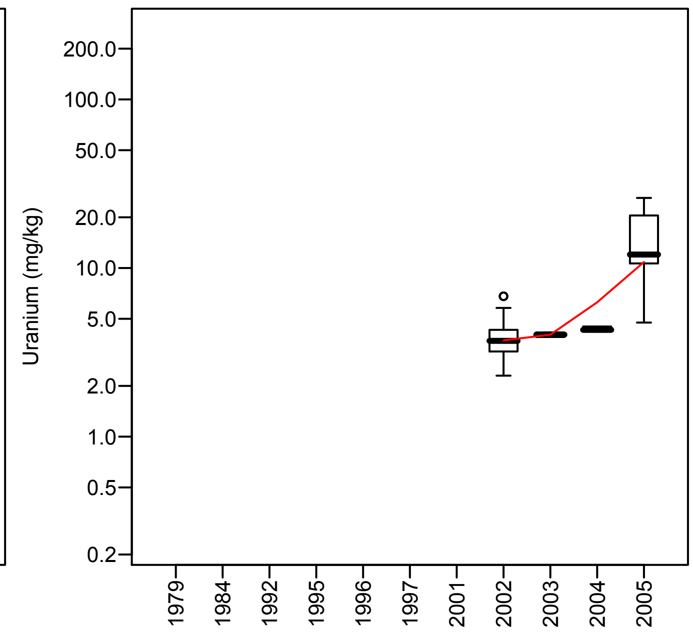


Figure 356. Temporal trend for Uranium concentrations within Reach #4b. Red line indicates mean tendency.

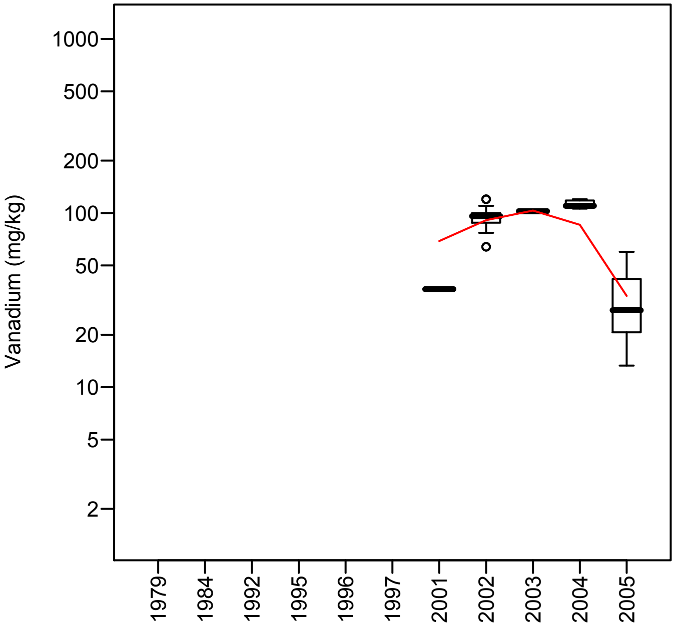


Figure 357. Temporal trend for Vanadium concentrations within Reach #4b. Red line indicates mean tendency.

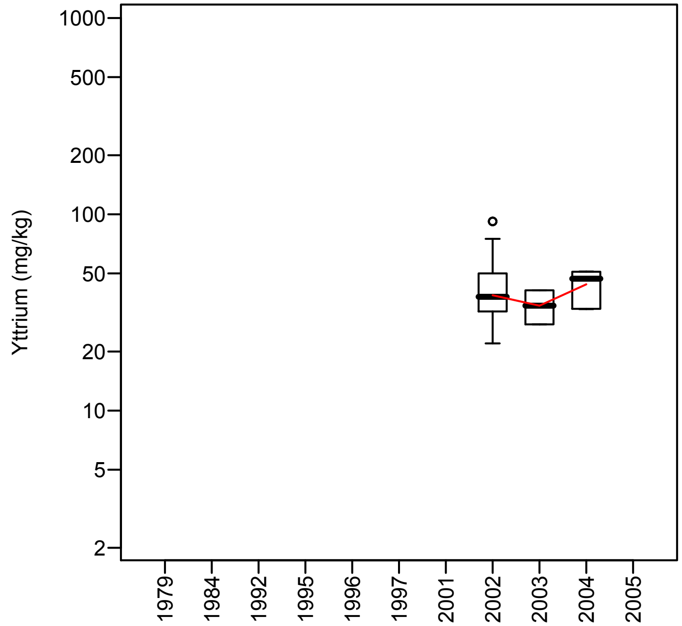


Figure 358. Temporal trend for Yttrium concentrations within Reach #4b. Red line indicates mean tendency.

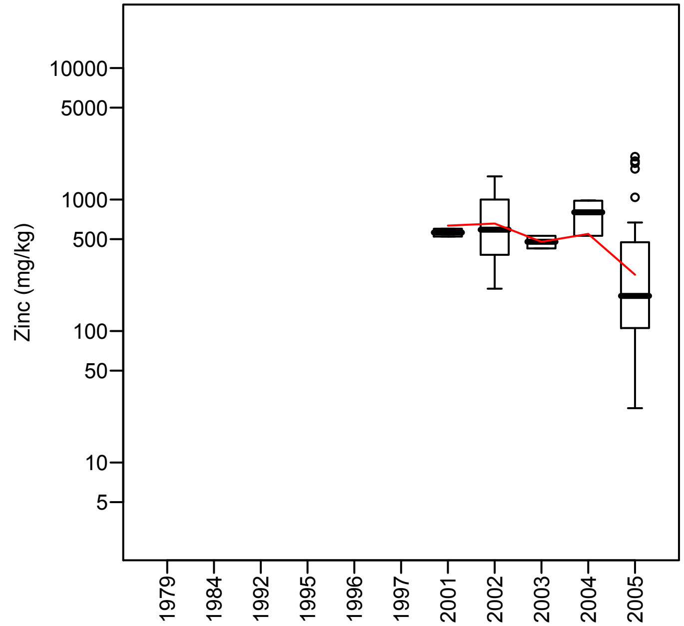


Figure 359. Temporal trend for Zinc concentrations within Reach #4b. Red line indicates mean tendency.

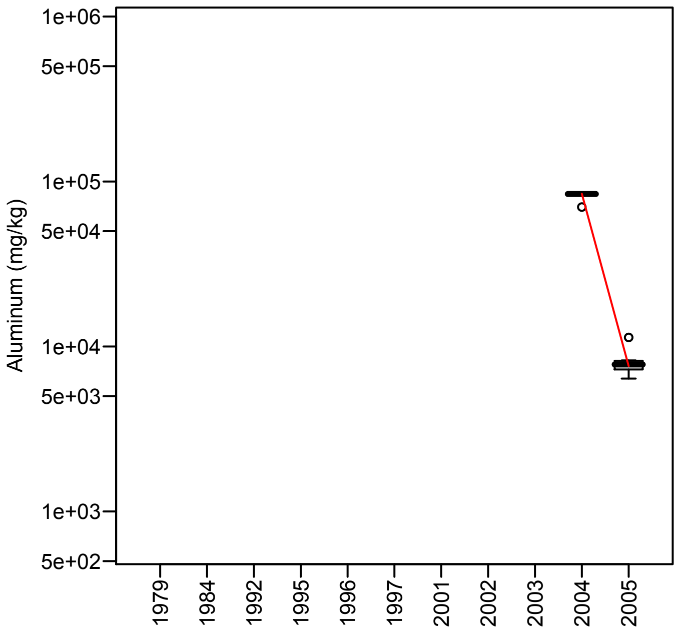


Figure 360. Temporal trend for Aluminum concentrations within Reach #5. Red line indicates mean tendency.

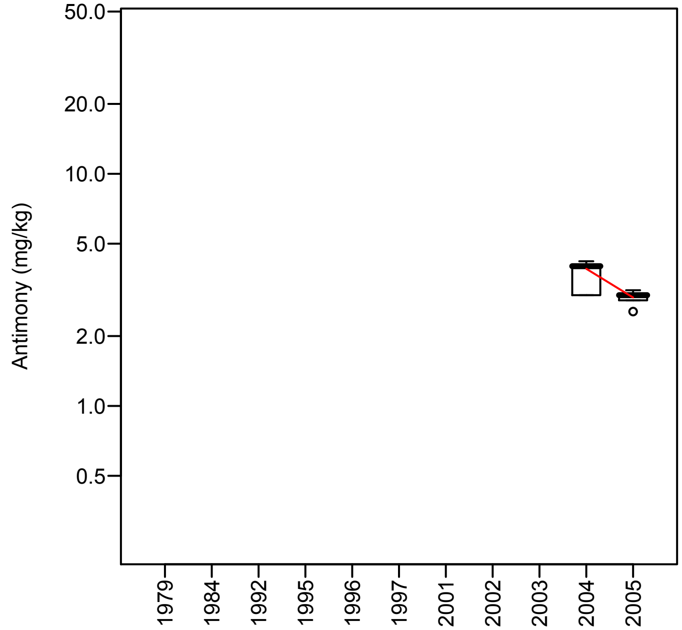


Figure 361. Temporal trend for Antimony concentrations within Reach #5. Red line indicates mean tendency.

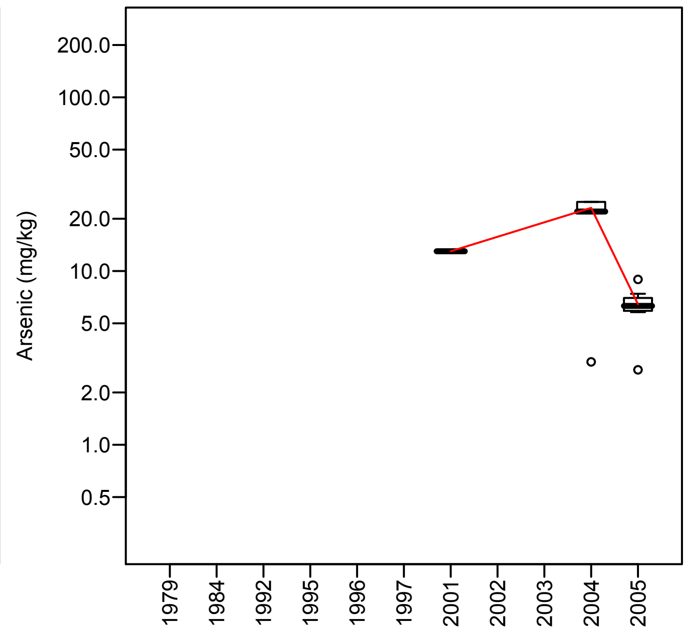


Figure 362. Temporal trend for Arsenic concentrations within Reach #5. Red line indicates mean tendency.

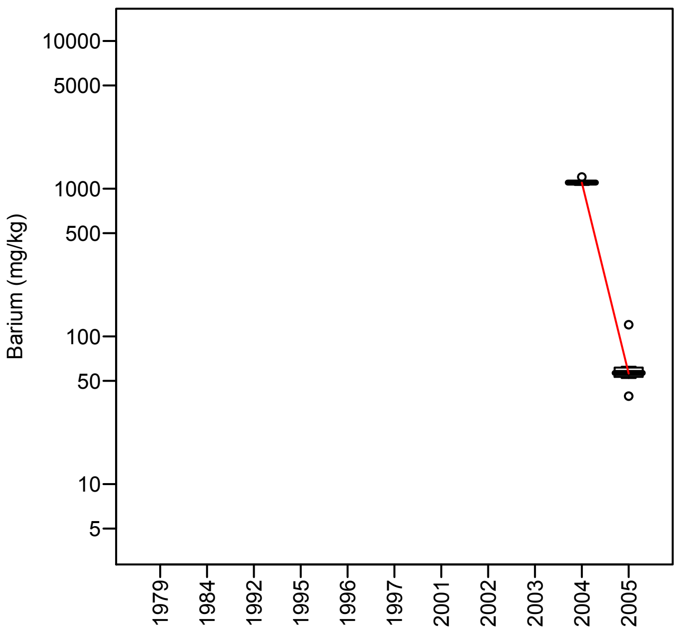


Figure 363. Temporal trend for Barium concentrations within Reach #5. Red line indicates mean tendency.

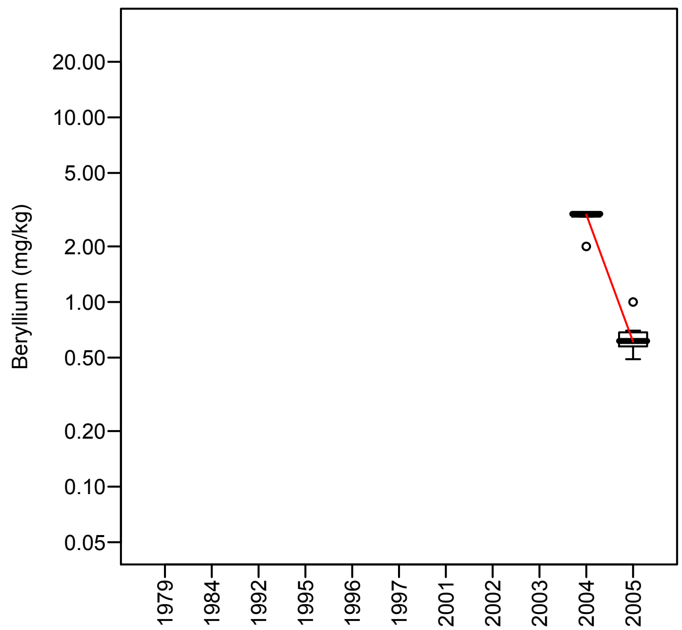


Figure 364. Temporal trend for Beryllium concentrations within Reach #5. Red line indicates mean tendency.

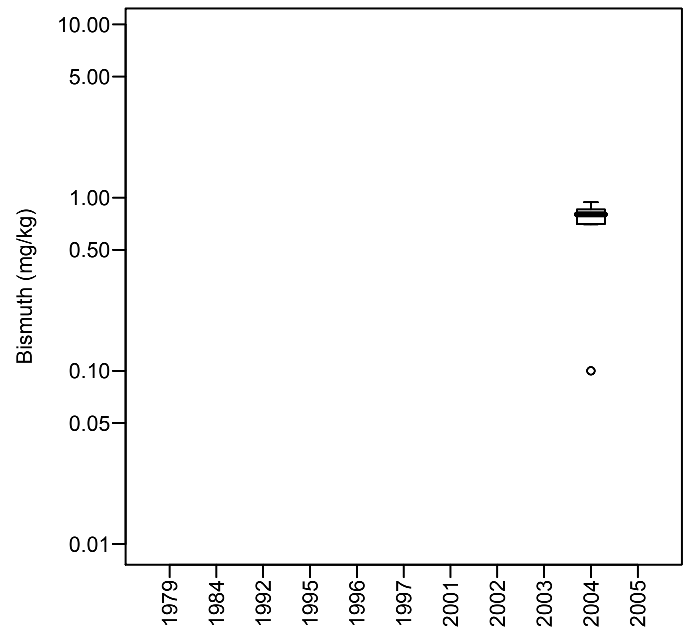


Figure 365. Temporal trend for Bismuth concentrations within Reach #5. Red line indicates mean tendency.

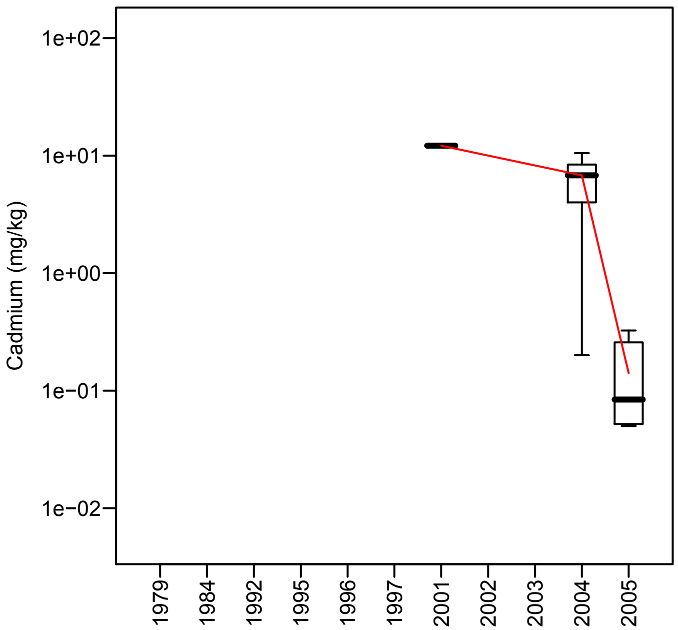


Figure 366. Temporal trend for Cadmium concentrations within Reach #5. Red line indicates mean tendency.

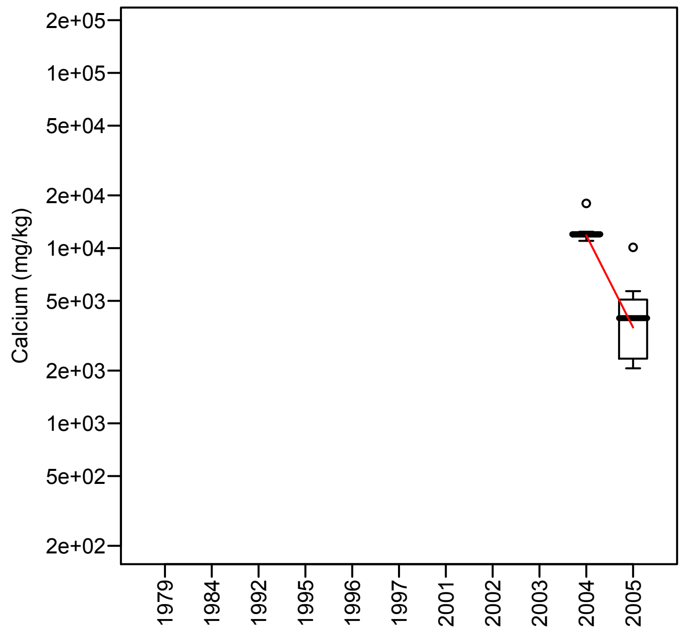


Figure 367. Temporal trend for Calcium concentrations within Reach #5. Red line indicates mean tendency.

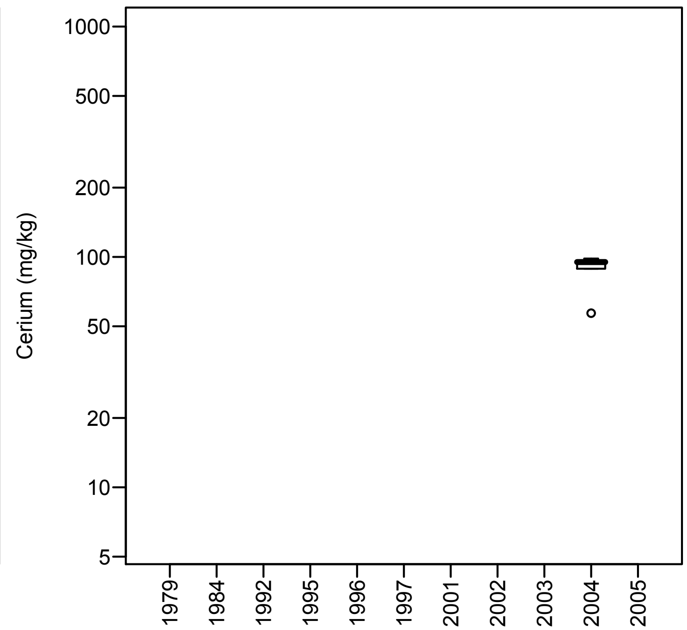


Figure 368. Temporal trend for Cerium concentrations within Reach #5. Red line indicates mean tendency.

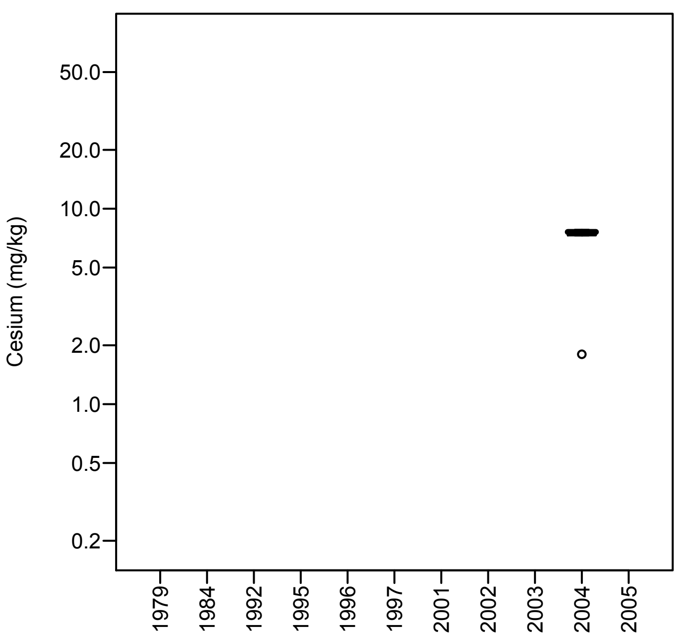


Figure 369. Temporal trend for Cesium concentrations within Reach #5. Red line indicates mean tendency.

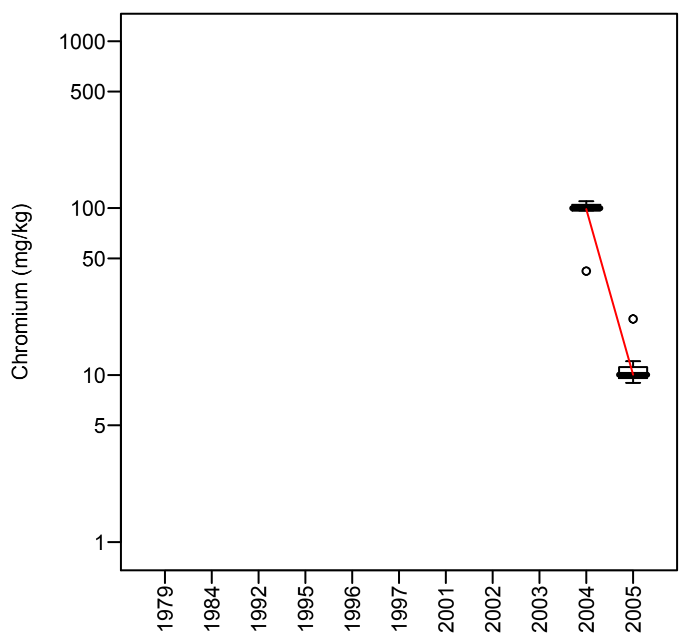


Figure 370. Temporal trend for Chromium concentrations within Reach #5. Red line indicates mean tendency.

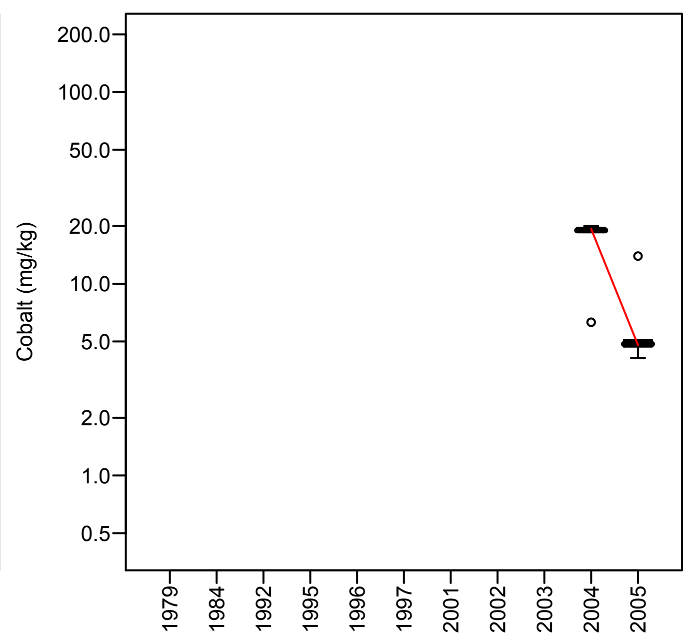


Figure 371. Temporal trend for Cobalt concentrations within Reach #5. Red line indicates mean tendency.

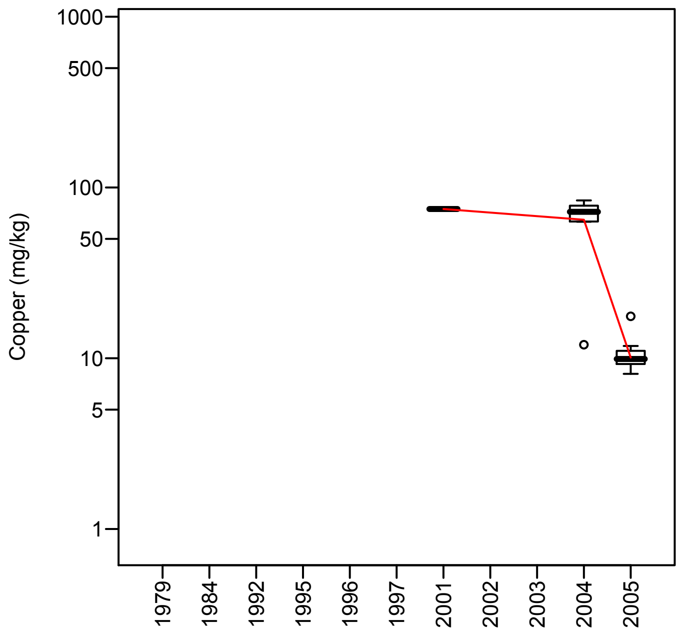


Figure 372. Temporal trend for Copper concentrations within Reach #5. Red line indicates mean tendency.

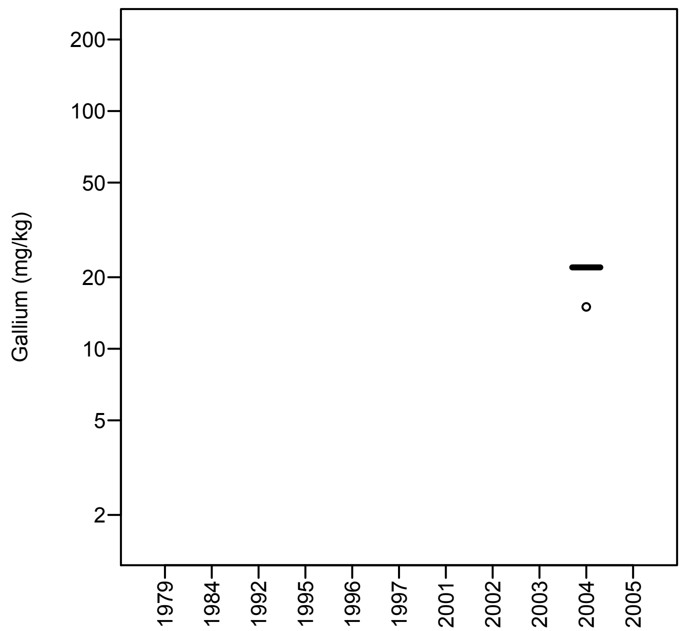


Figure 373. Temporal trend for Gallium concentrations within Reach #5. Red line indicates mean tendency.

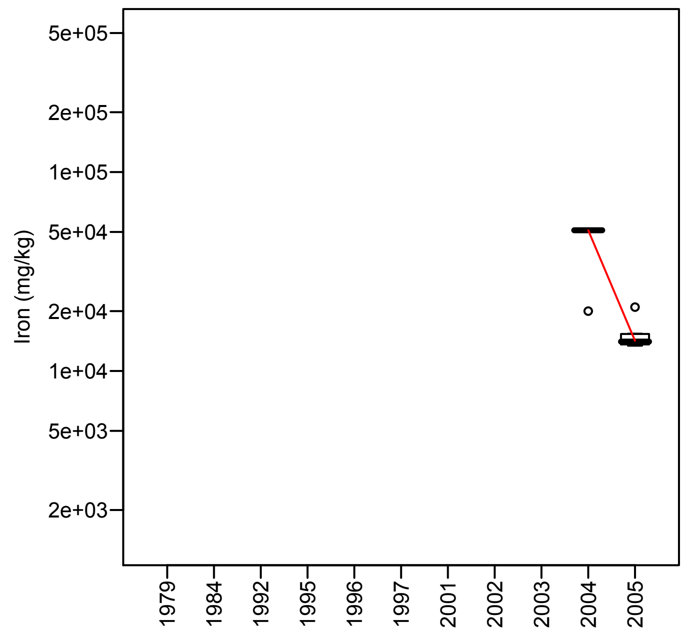


Figure 374. Temporal trend for Iron concentrations within Reach #5. Red line indicates mean tendency.

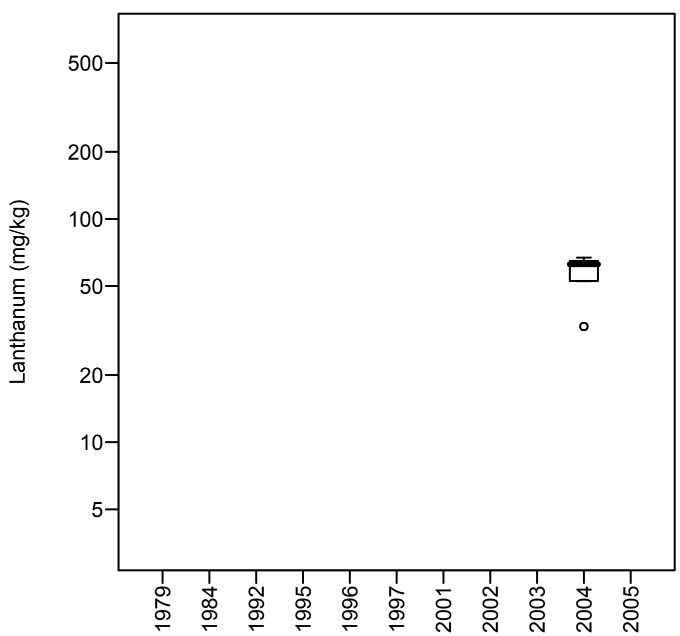


Figure 375. Temporal trend for Lanthanum concentrations within Reach #5. Red line indicates mean tendency.

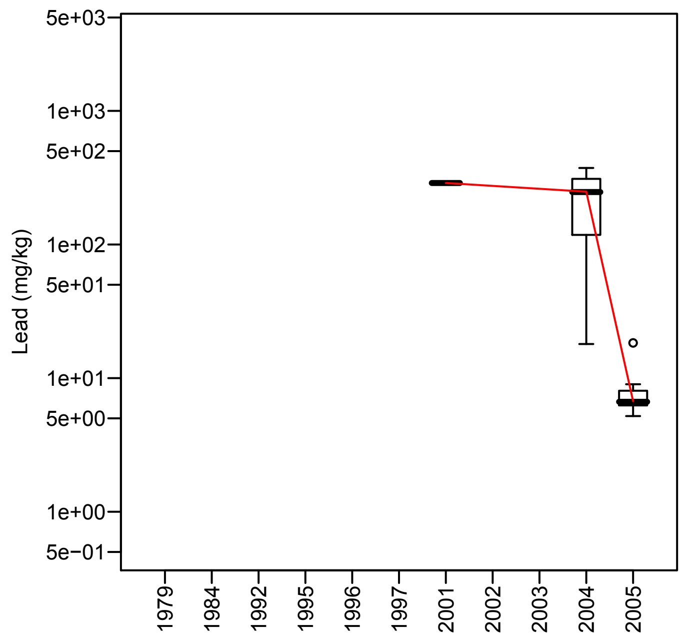


Figure 376. Temporal trend for Lead concentrations within Reach #5. Red line indicates mean tendency.

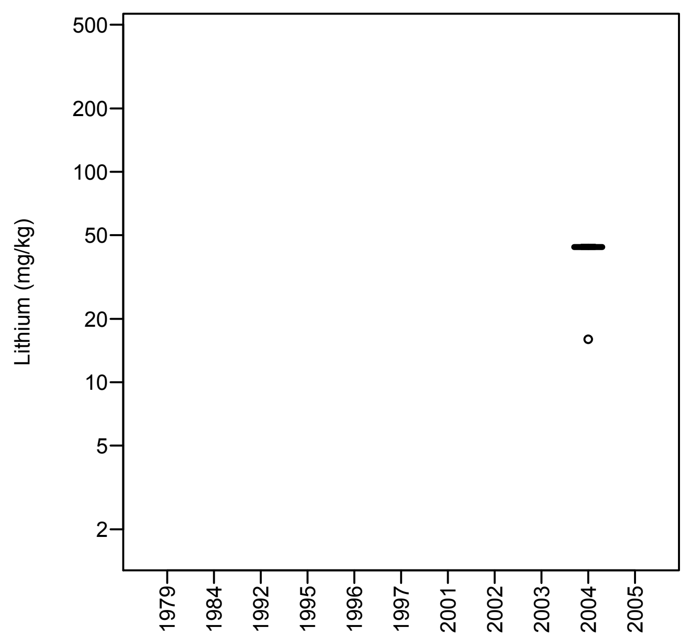


Figure 377. Temporal trend for Lithium concentrations within Reach #5. Red line indicates mean tendency.

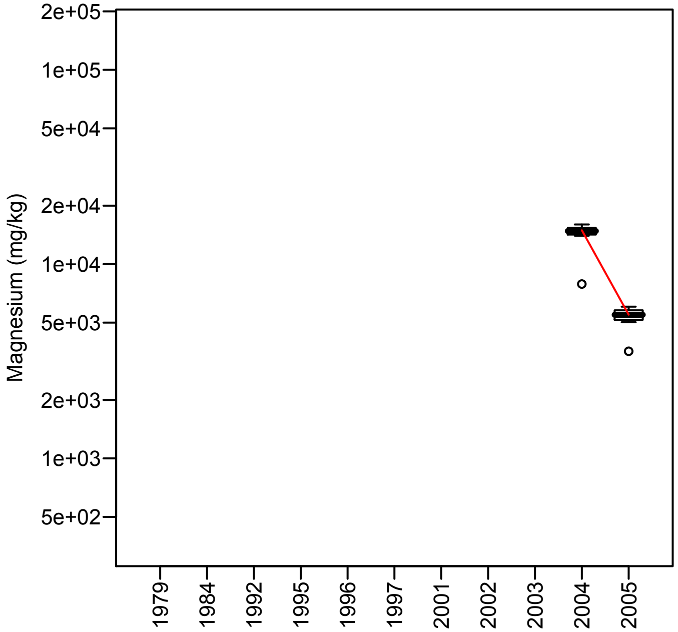


Figure 378. Temporal trend for Magnesium concentrations within Reach #5. Red line indicates mean tendency.

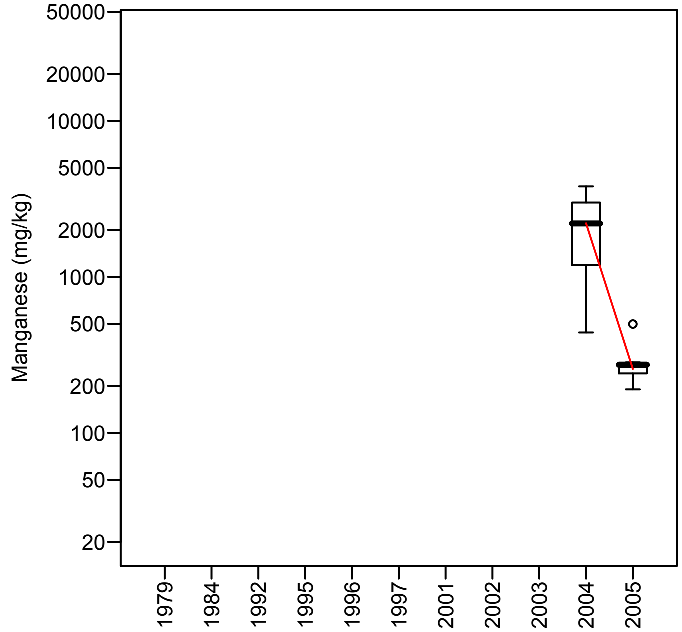


Figure 379. Temporal trend for Manganese concentrations within Reach #5. Red line indicates mean tendency.

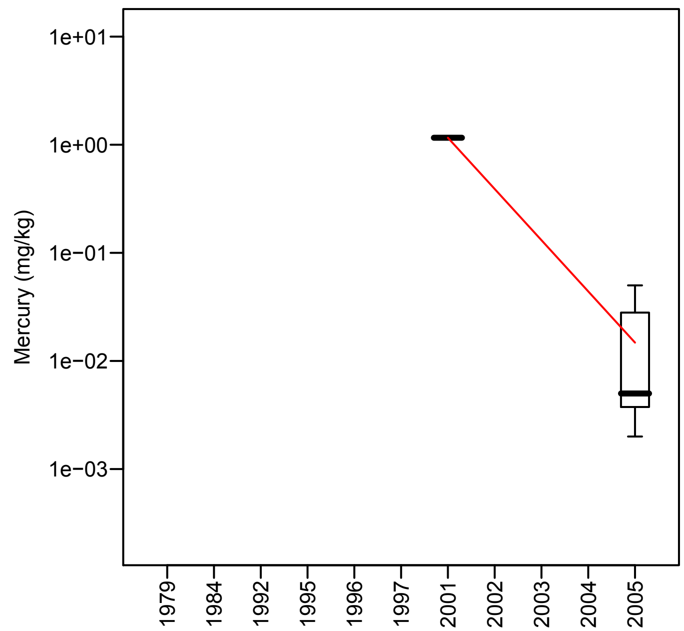


Figure 380. Temporal trend for Mercury concentrations within Reach #5. Red line indicates mean tendency.

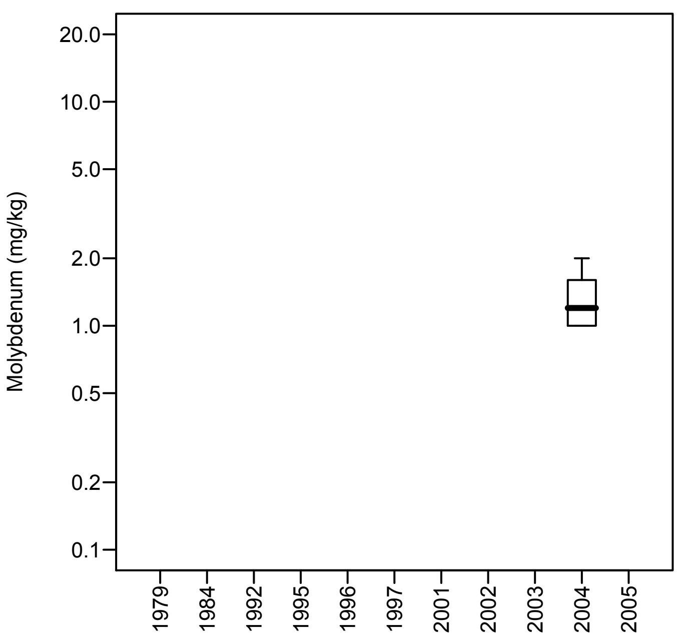


Figure 381. Temporal trend for Molybdenum concentrations within Reach #5. Red line indicates mean tendency.

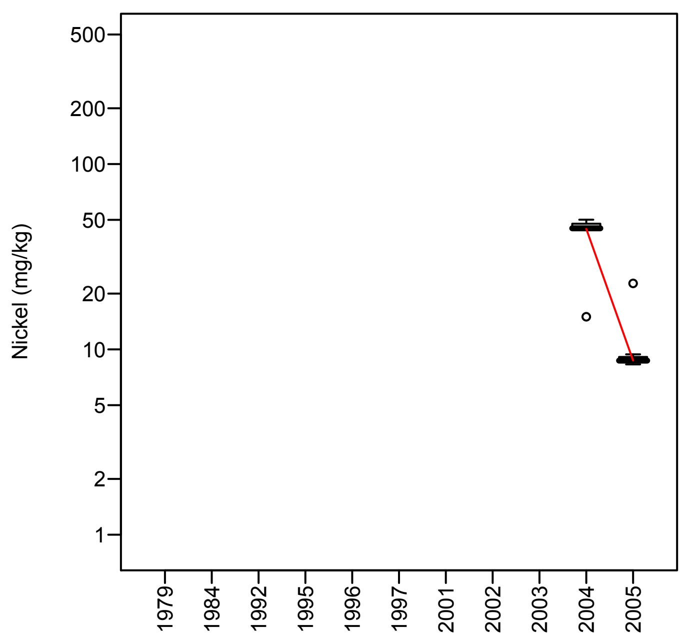


Figure 382. Temporal trend for Nickel concentrations within Reach #5. Red line indicates mean tendency.

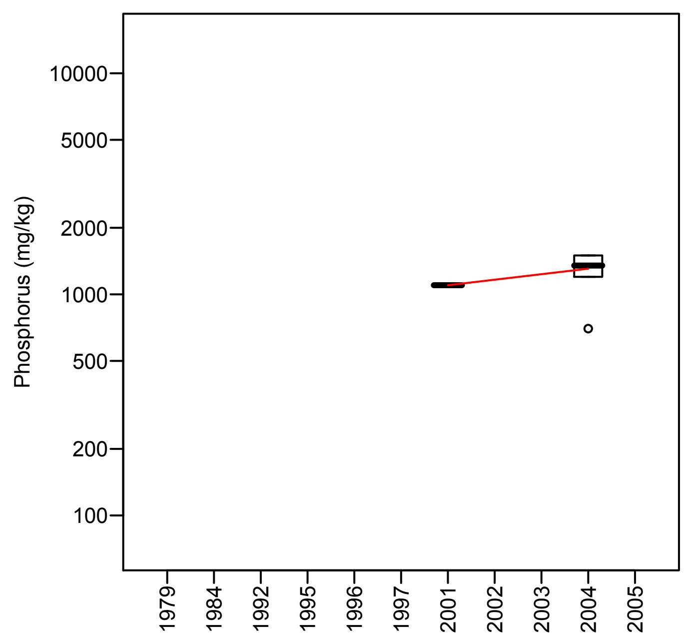


Figure 383. Temporal trend for Phosphorus concentrations within Reach #5. Red line indicates mean tendency.

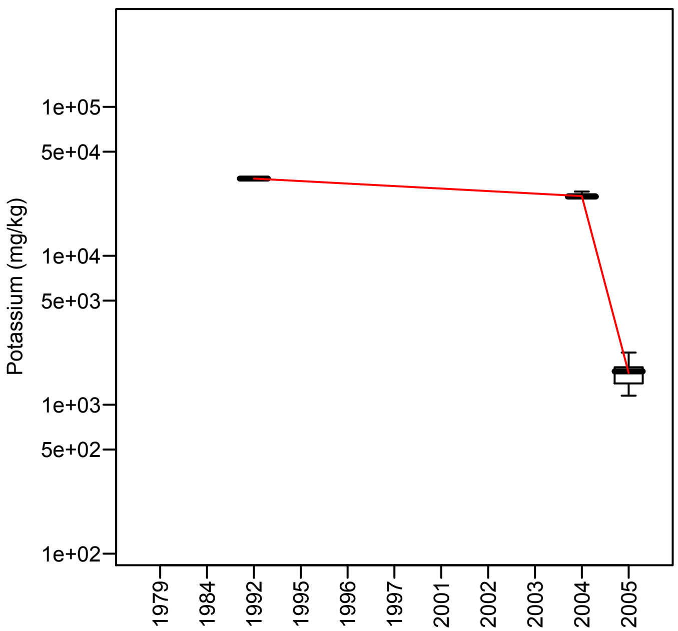


Figure 384. Temporal trend for Potassium concentrations within Reach #5. Red line indicates mean tendency.

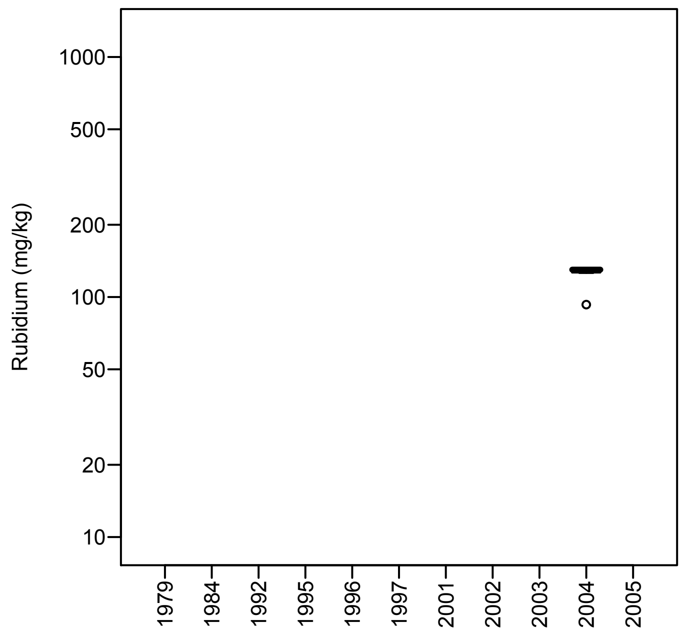


Figure 385. Temporal trend for Rubidium concentrations within Reach #5. Red line indicates mean tendency.

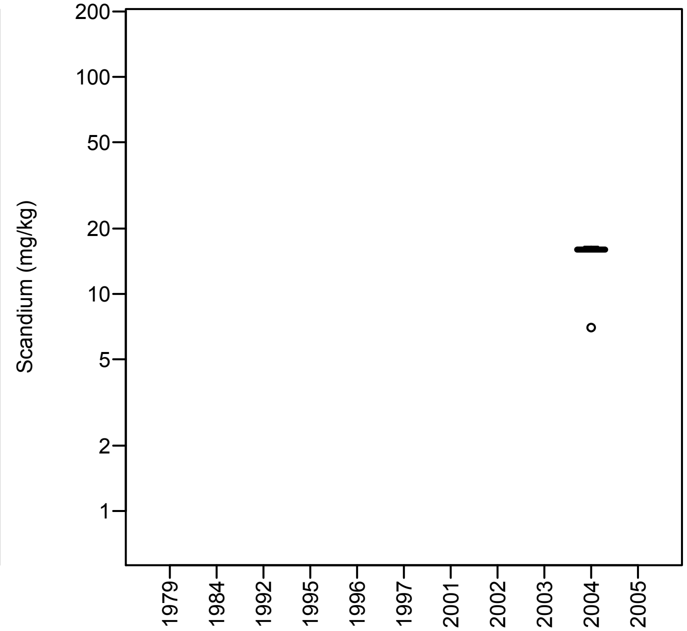


Figure 386. Temporal trend for Scandium concentrations within Reach #5. Red line indicates mean tendency.

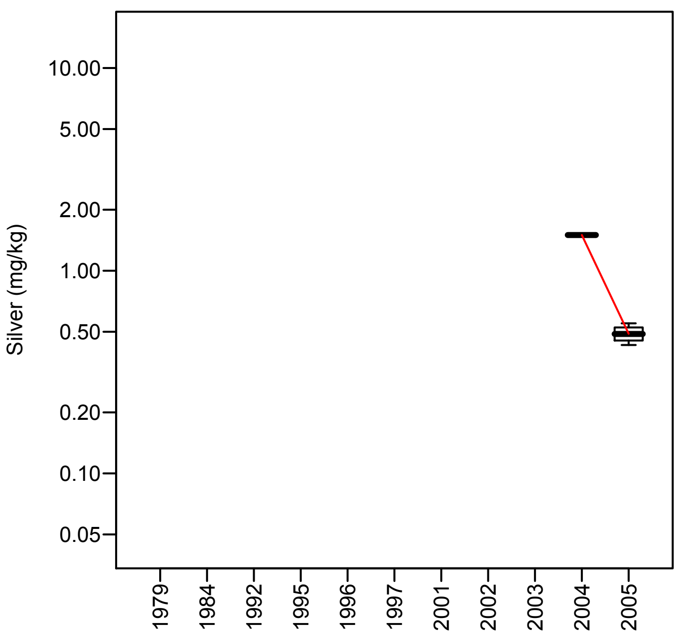


Figure 387. Temporal trend for Silver concentrations within Reach #5. Red line indicates mean tendency.

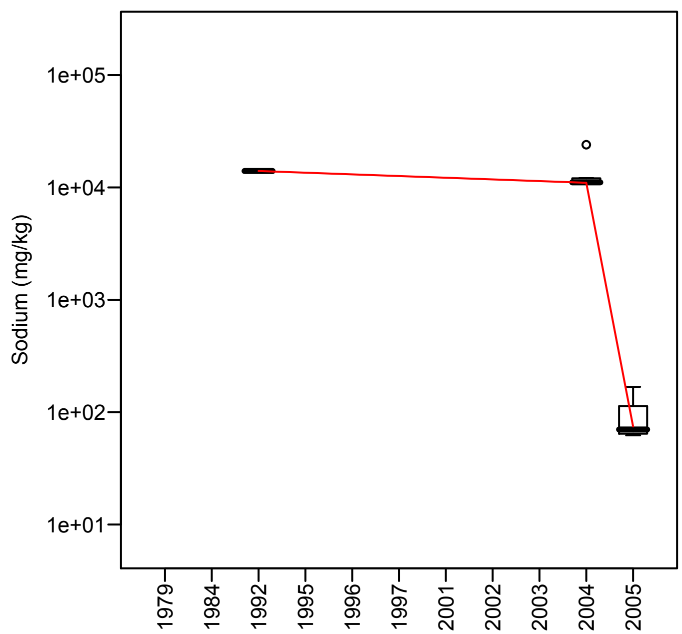


Figure 388. Temporal trend for Sodium concentrations within Reach #5. Red line indicates mean tendency.

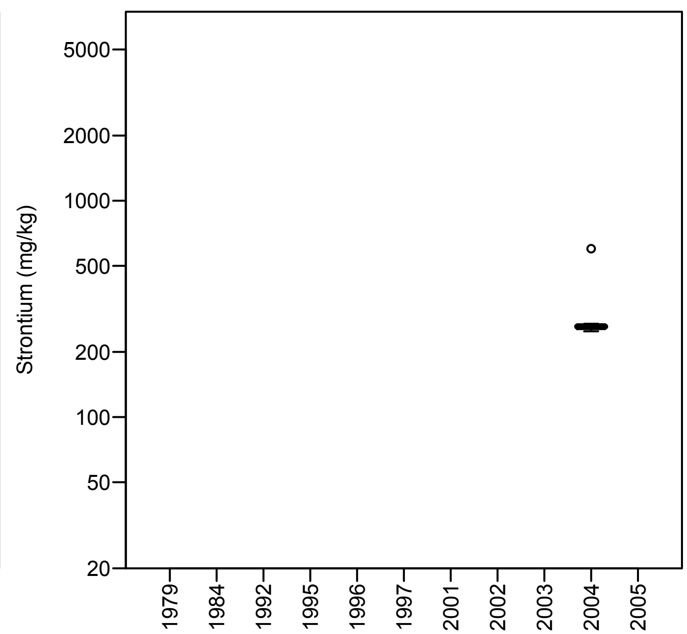


Figure 389. Temporal trend for Strontium concentrations within Reach #5. Red line indicates mean tendency.

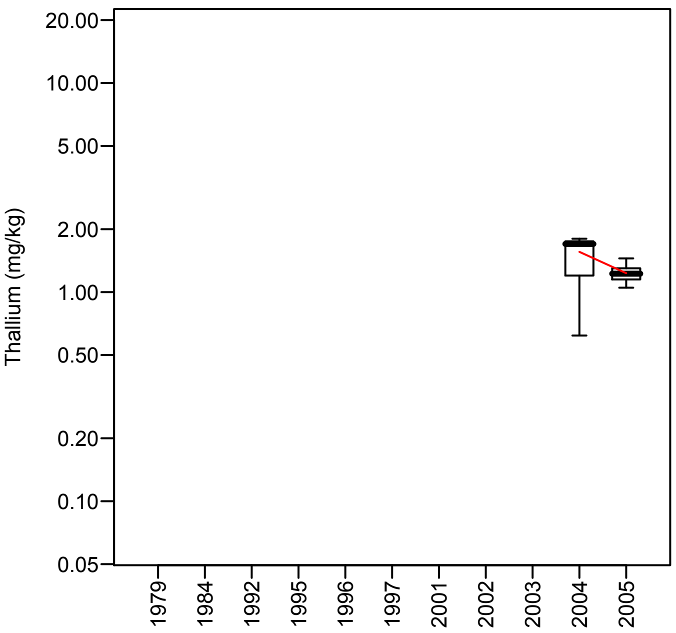


Figure 390. Temporal trend for Thallium concentrations within Reach #5. Red line indicates mean tendency.

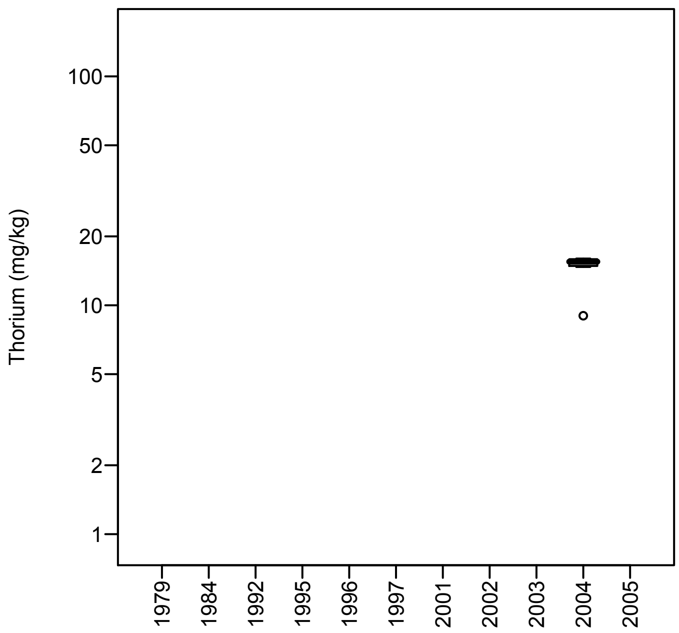


Figure 391. Temporal trend for Thorium concentrations within Reach #5. Red line indicates mean tendency.

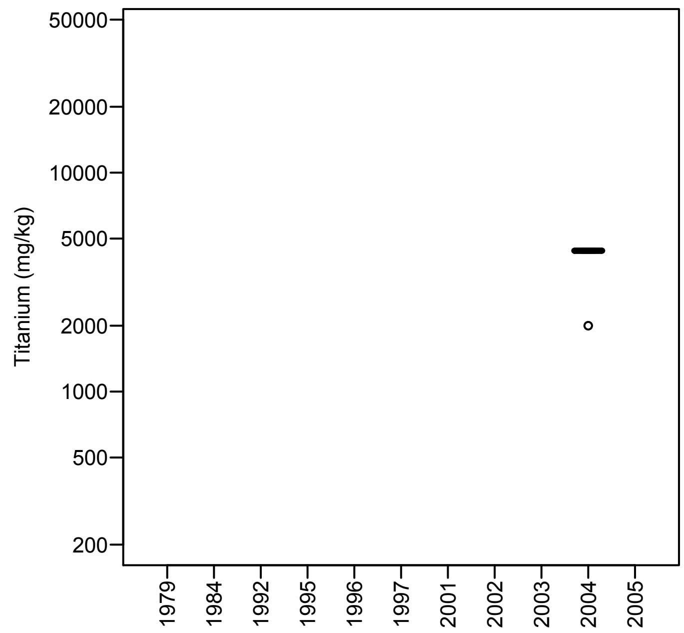


Figure 392. Temporal trend for Titanium concentrations within Reach #5. Red line indicates mean tendency.

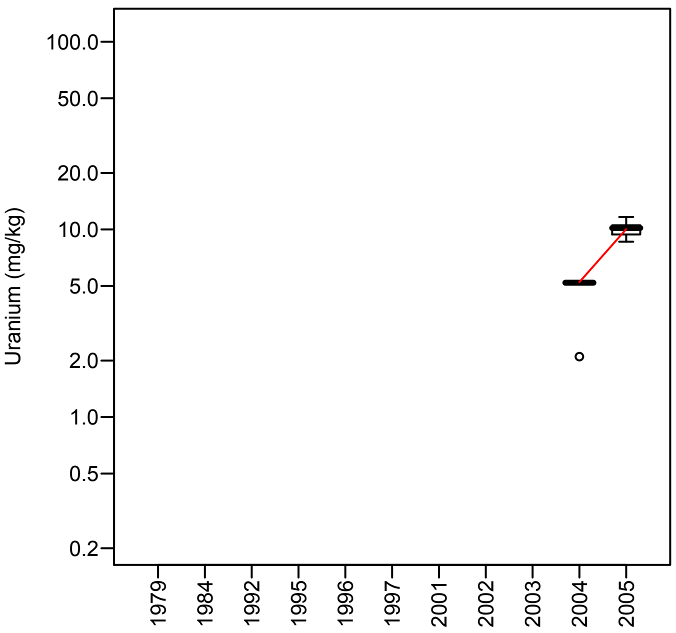


Figure 393. Temporal trend for Uranium concentrations within Reach #5. Red line indicates mean tendency.

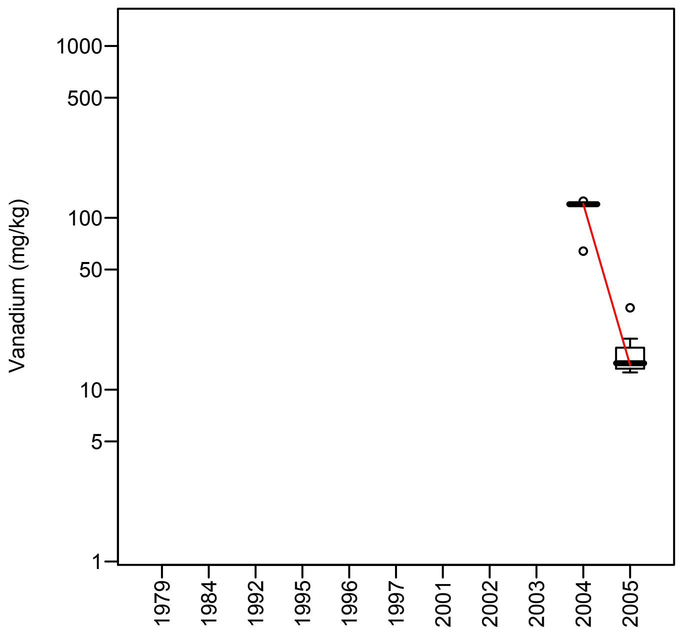


Figure 394. Temporal trend for Vanadium concentrations within Reach #5. Red line indicates mean tendency.

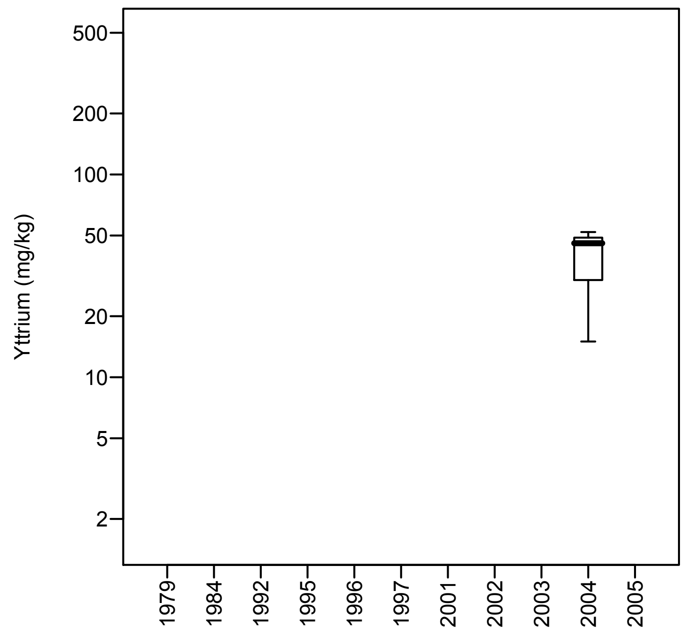


Figure 395. Temporal trend for Yttrium concentrations within Reach #5. Red line indicates mean tendency.

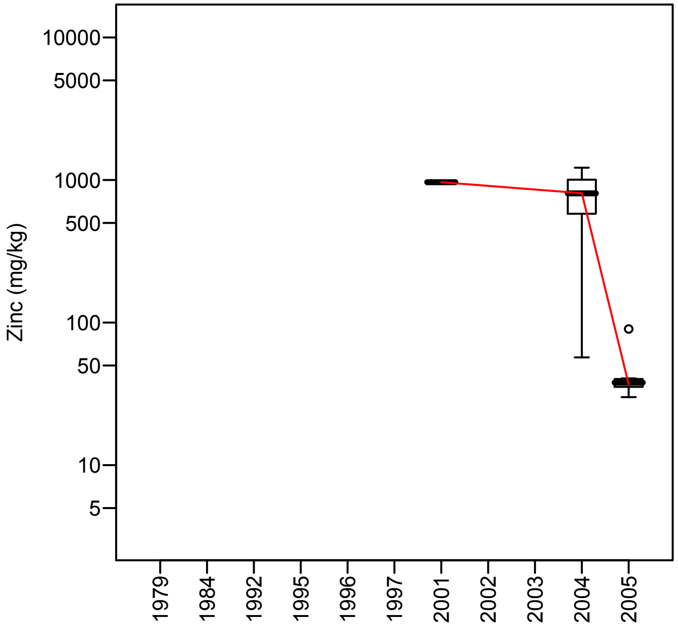


Figure 396. Temporal trend for Zinc concentrations within Reach #5. Red line indicates mean tendency.

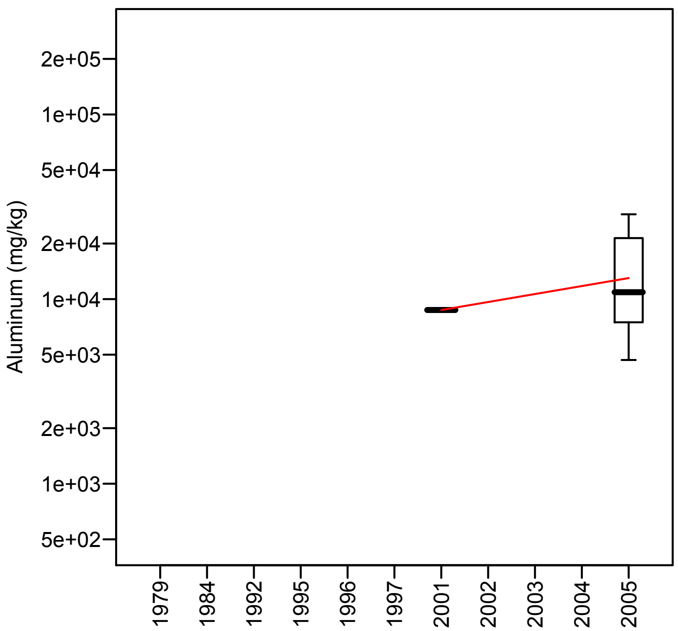


Figure 397. Temporal trend for Aluminum concentrations within Reach #6. Red line indicates mean tendency.

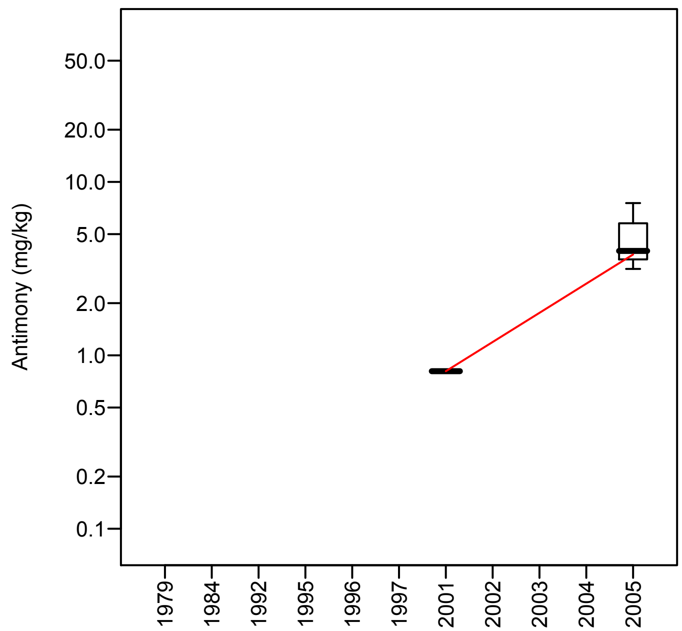


Figure 398. Temporal trend for Antimony concentrations within Reach #6. Red line indicates mean tendency.

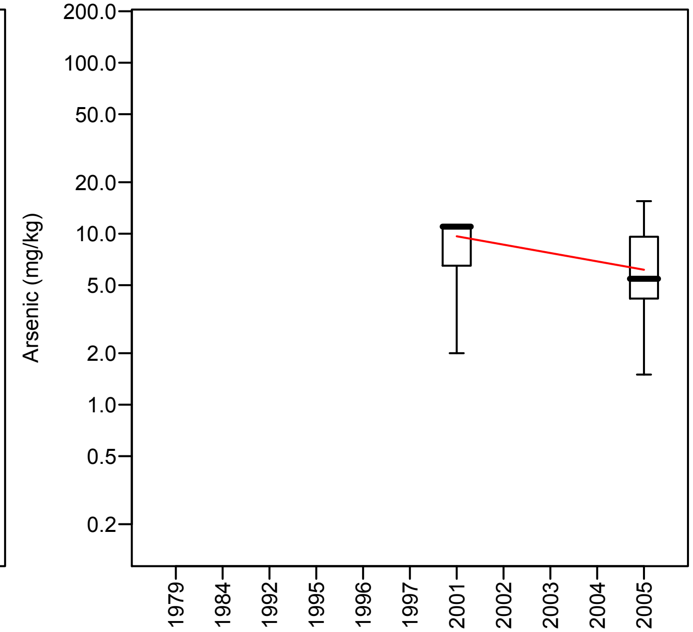


Figure 399. Temporal trend for Arsenic concentrations within Reach #6. Red line indicates mean tendency.

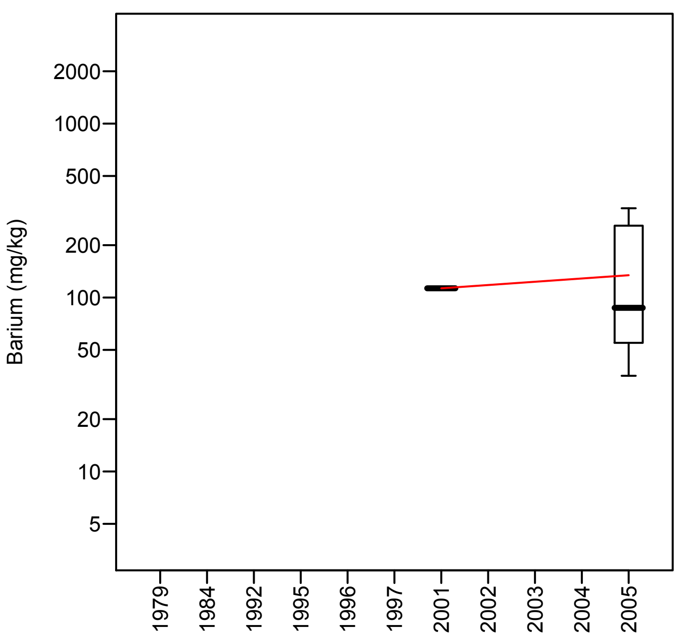


Figure 400. Temporal trend for Barium concentrations within Reach #6. Red line indicates mean tendency.

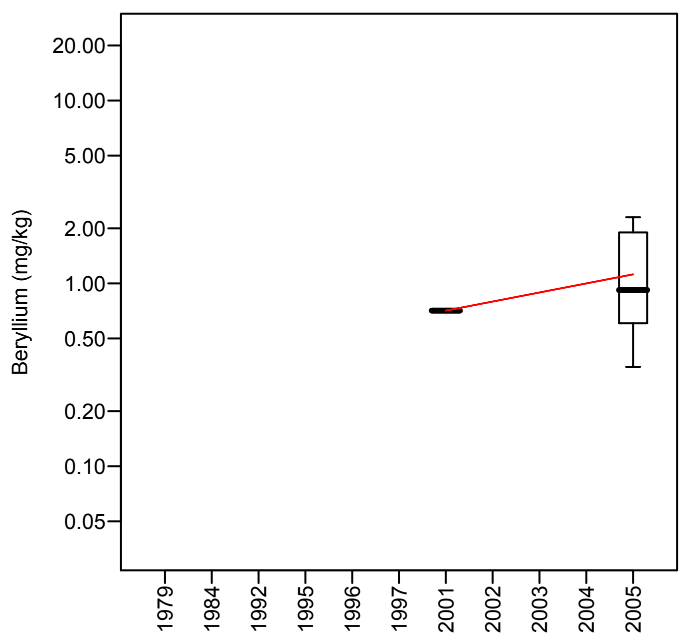


Figure 401. Temporal trend for Beryllium concentrations within Reach #6. Red line indicates mean tendency.

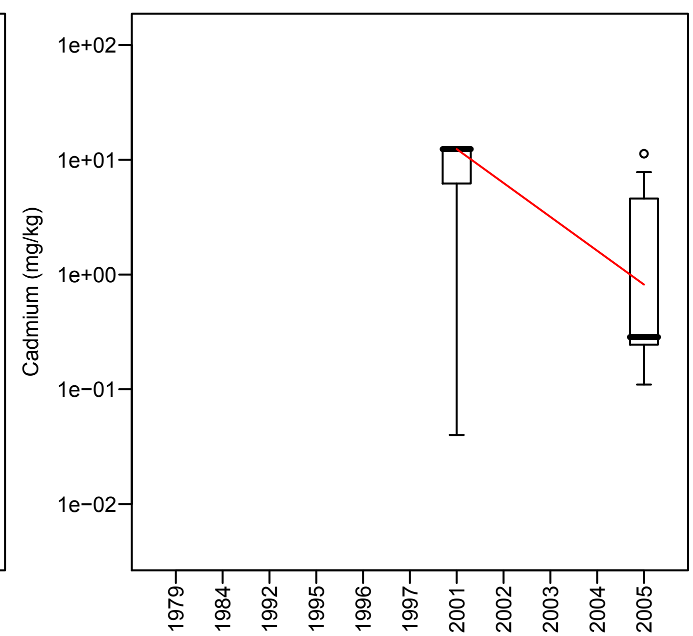


Figure 402. Temporal trend for Cadmium concentrations within Reach #6. Red line indicates mean tendency.

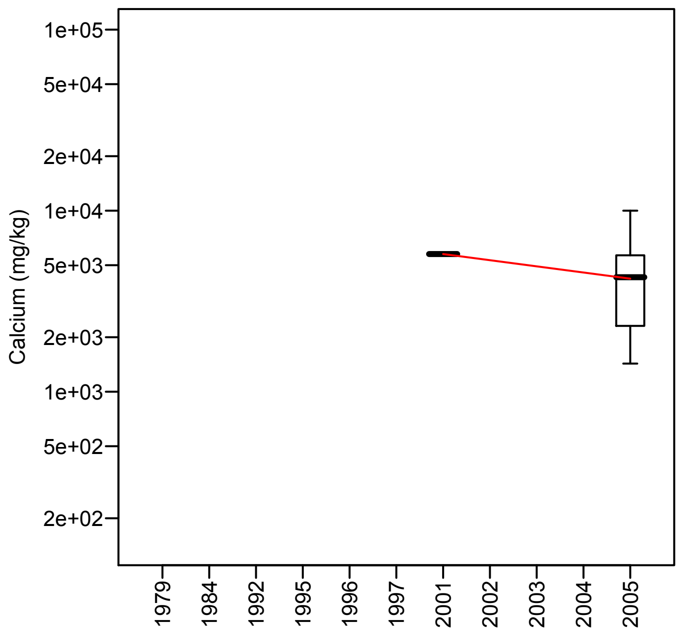


Figure 403. Temporal trend for Calcium concentrations within Reach #6. Red line indicates mean tendency.

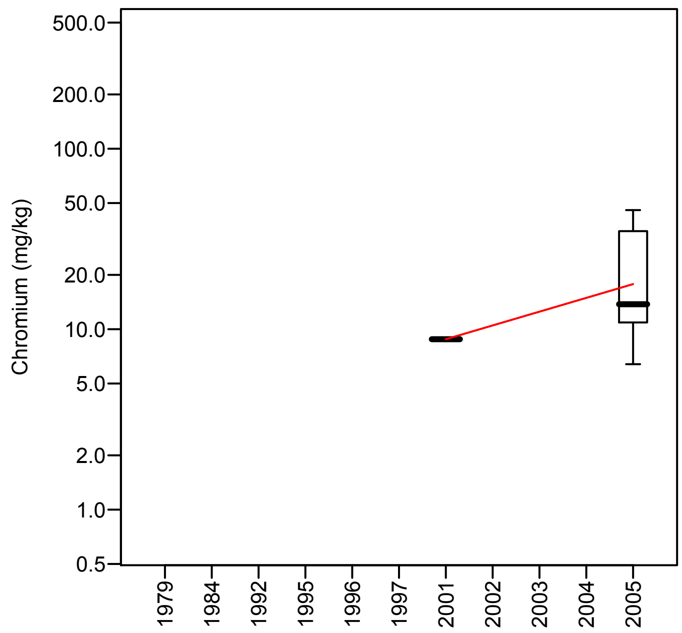


Figure 404. Temporal trend for Chromium concentrations within Reach #6. Red line indicates mean tendency.

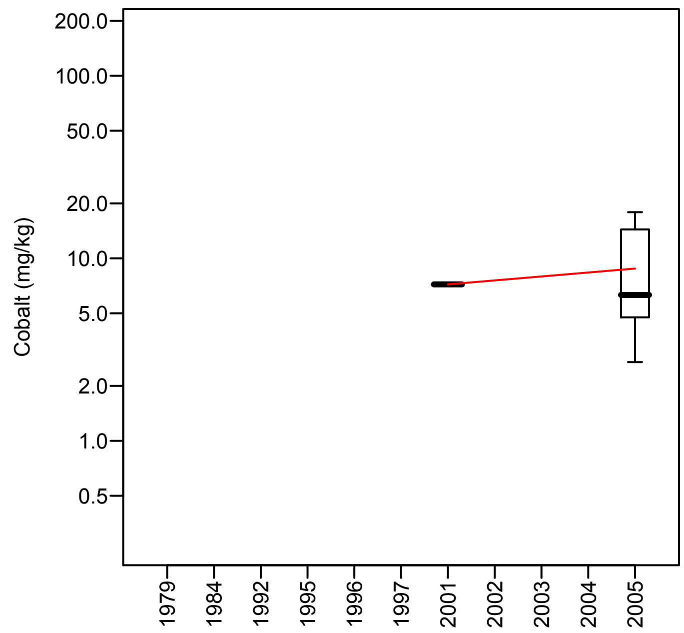


Figure 405. Temporal trend for Cobalt concentrations within Reach #6. Red line indicates mean tendency.

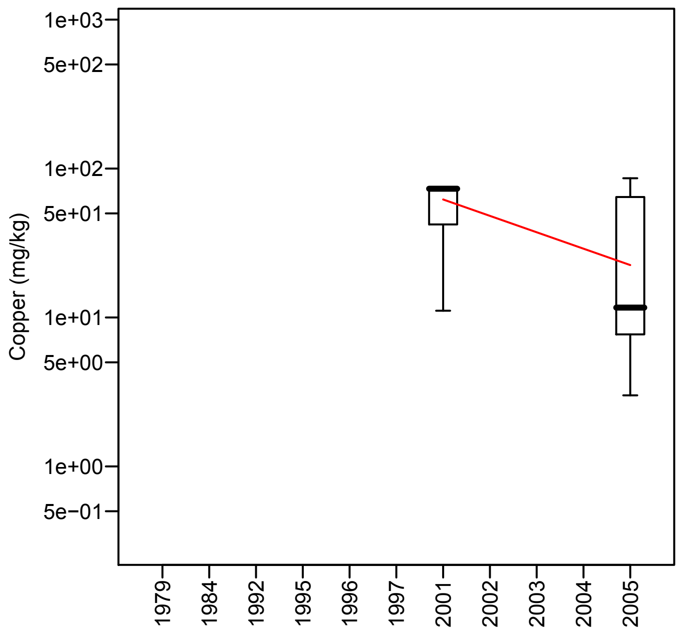


Figure 406. Temporal trend for Copper concentrations within Reach #6. Red line indicates mean tendency.

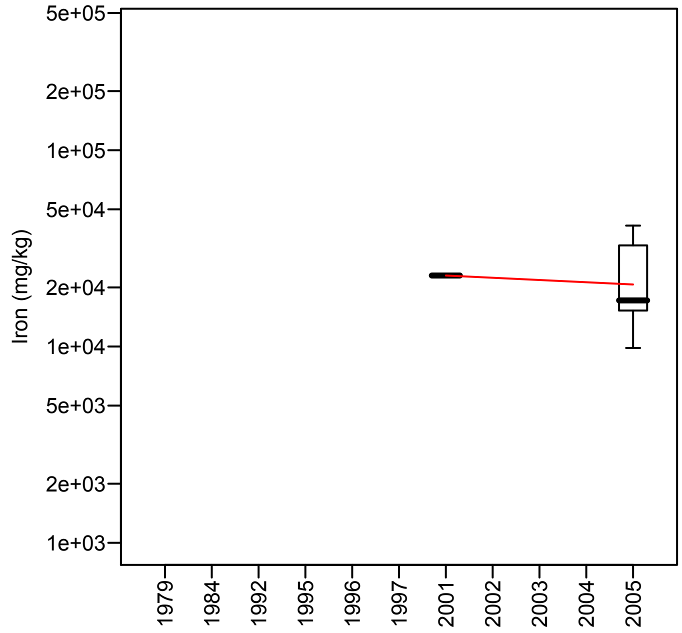


Figure 407. Temporal trend for Iron concentrations within Reach #6. Red line indicates mean tendency.

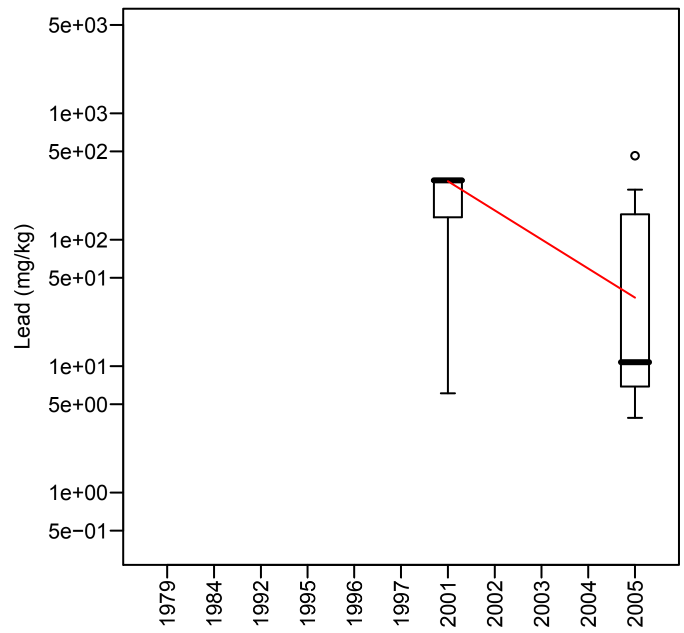


Figure 408. Temporal trend for Lead concentrations within Reach #6. Red line indicates mean tendency.

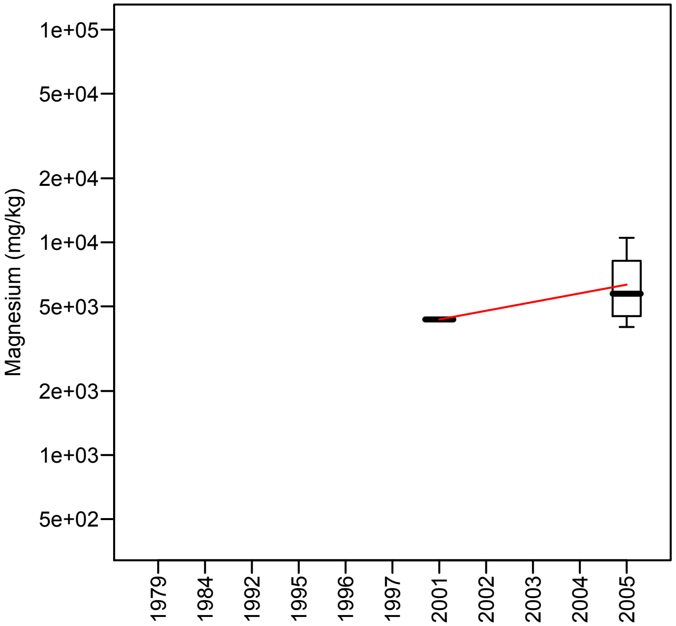


Figure 409. Temporal trend for Magnesium concentrations within Reach #6. Red line indicates mean tendency.

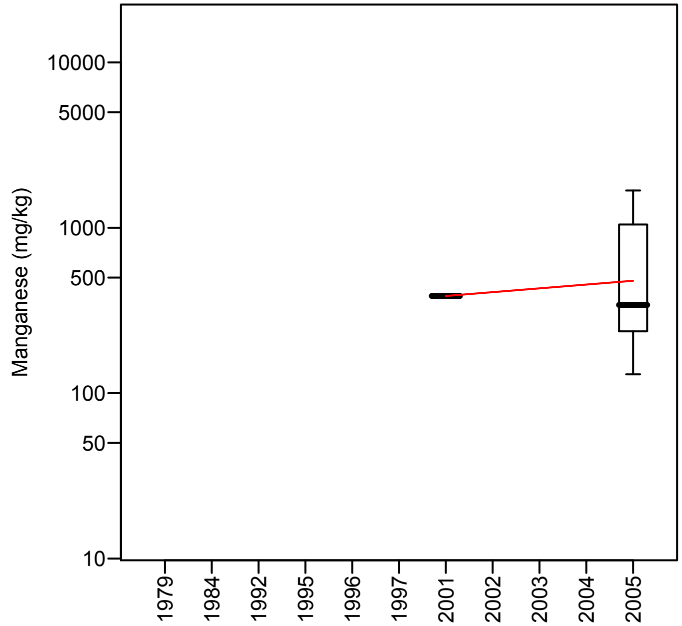


Figure 410. Temporal trend for Manganese concentrations within Reach #6. Red line indicates mean tendency.

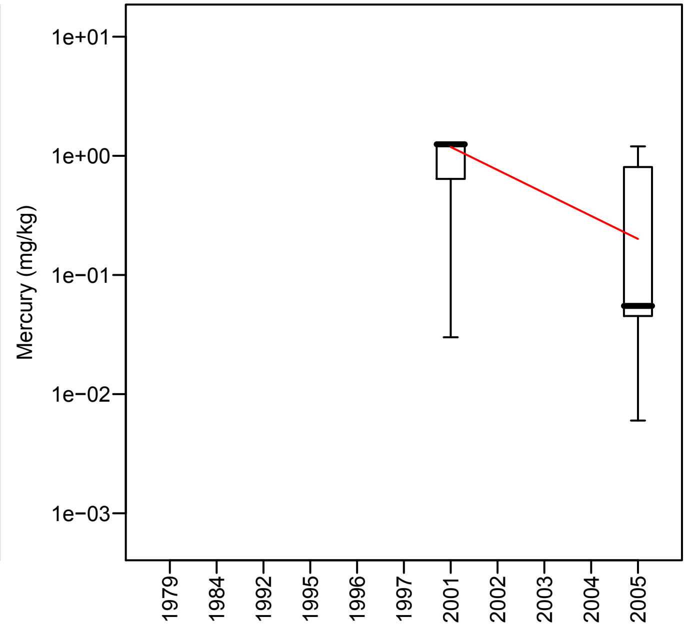


Figure 411. Temporal trend for Mercury concentrations within Reach #6. Red line indicates mean tendency.

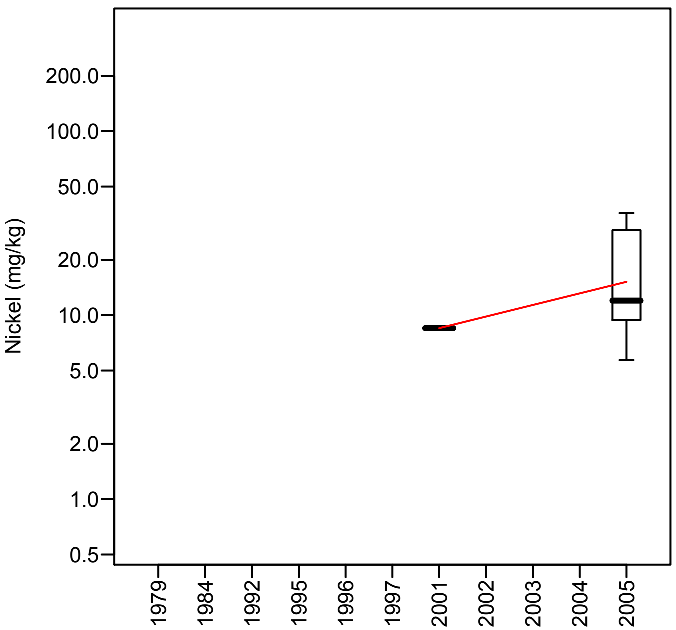


Figure 412. Temporal trend for Nickel concentrations within Reach #6. Red line indicates mean tendency.

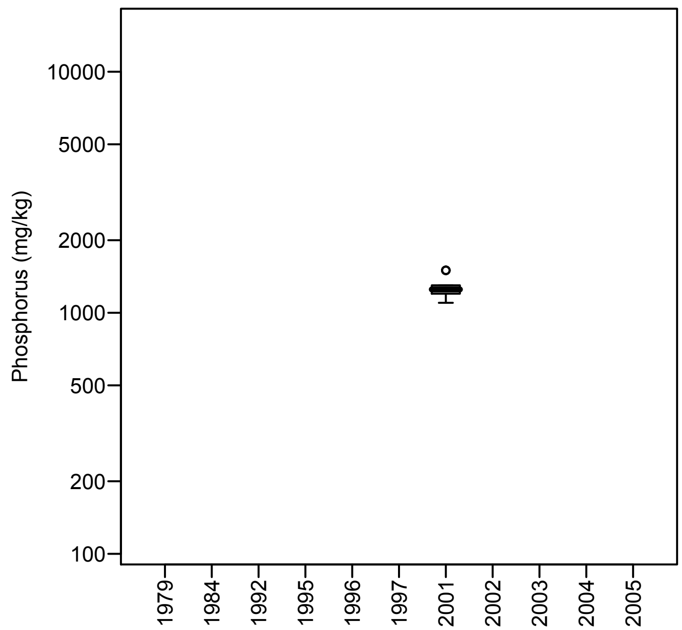


Figure 413. Temporal trend for Phosphorus concentrations within Reach #6. Red line indicates mean tendency.

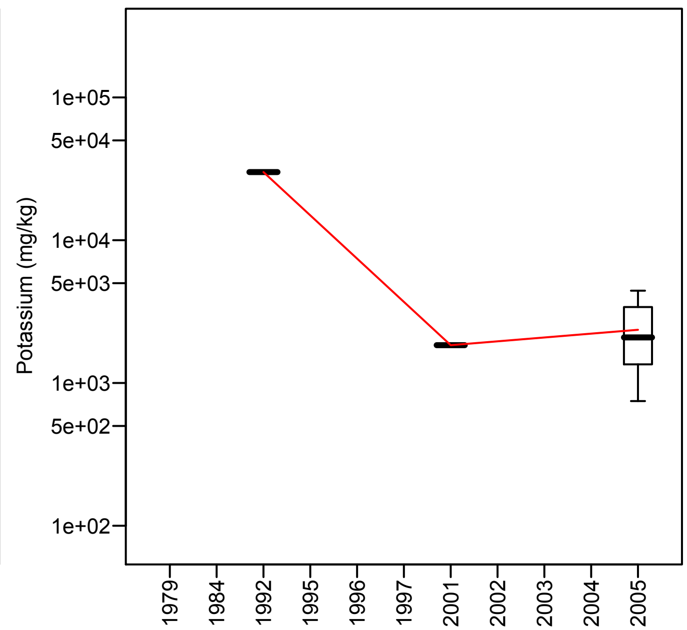


Figure 414. Temporal trend for Potassium concentrations within Reach #6. Red line indicates mean tendency.

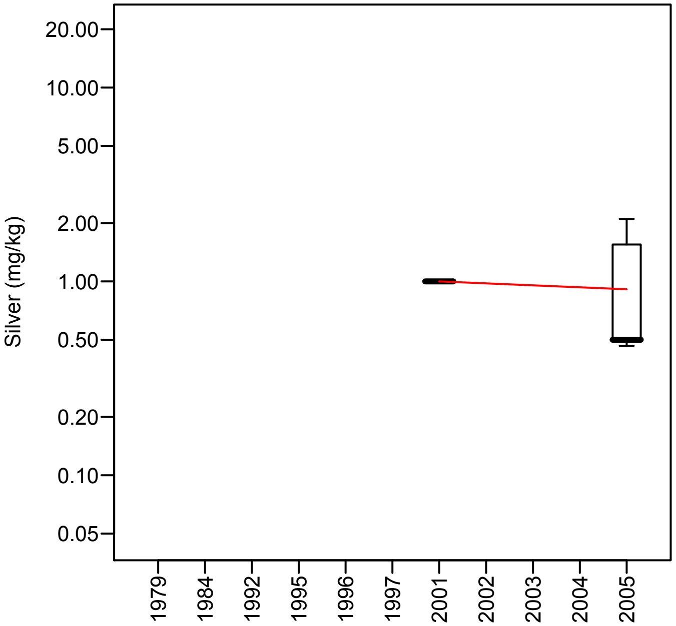


Figure 415. Temporal trend for Silver concentrations within Reach #6. Red line indicates mean tendency.

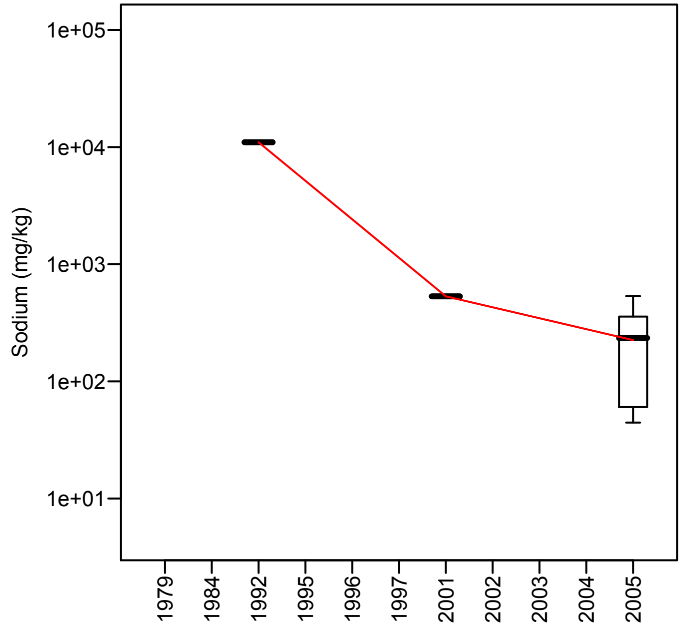


Figure 416. Temporal trend for Sodium concentrations within Reach #6. Red line indicates mean tendency.

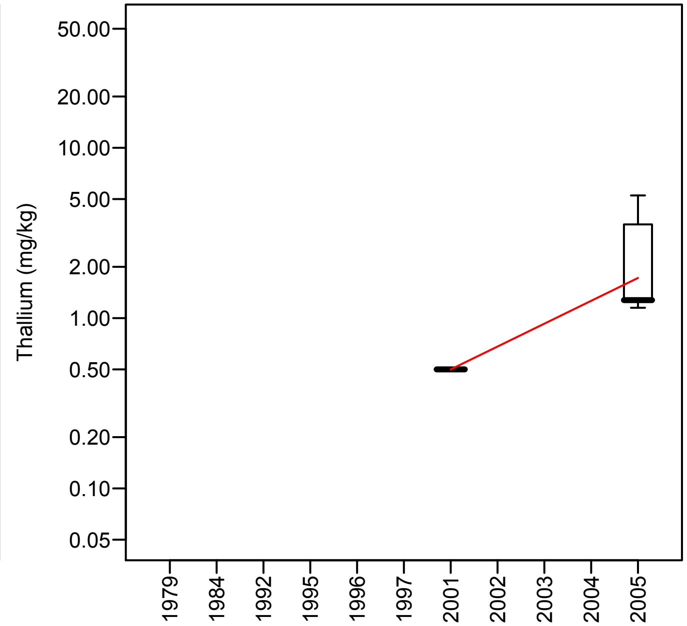


Figure 417. Temporal trend for Thallium concentrations within Reach #6. Red line indicates mean tendency.

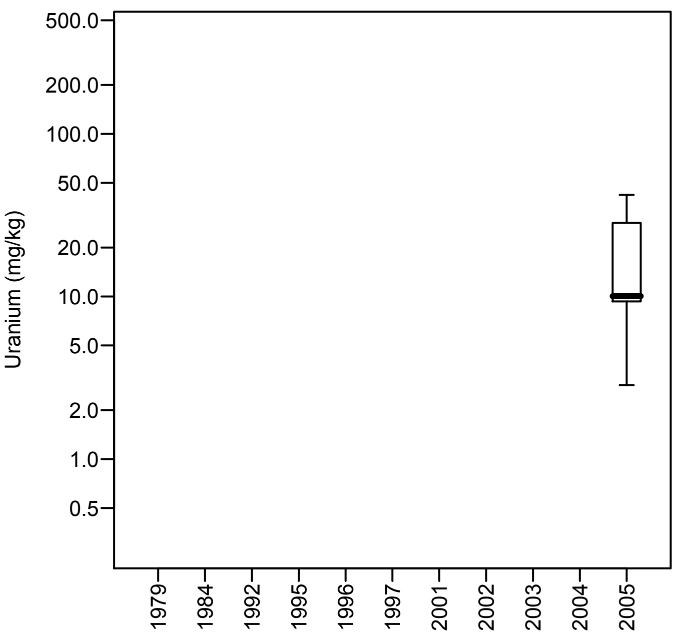


Figure 418. Temporal trend for Uranium concentrations within Reach #6. Red line indicates mean tendency.

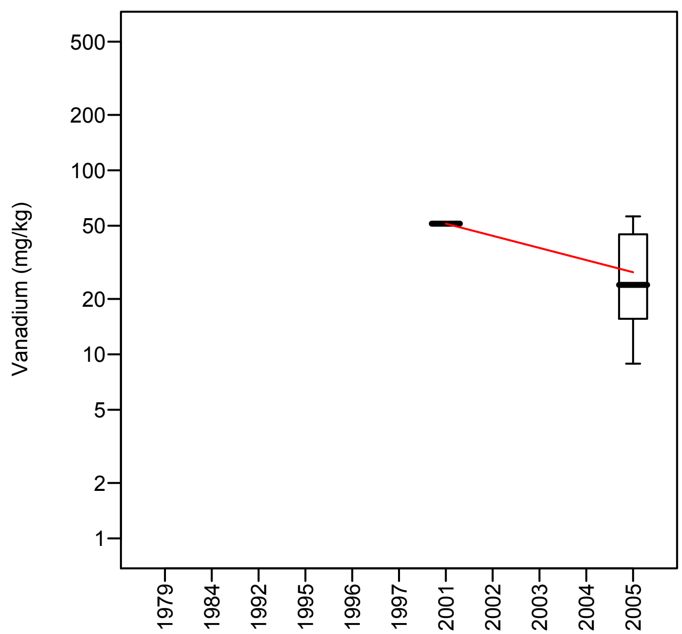


Figure 419. Temporal trend for Vanadium concentrations within Reach #6. Red line indicates mean tendency.

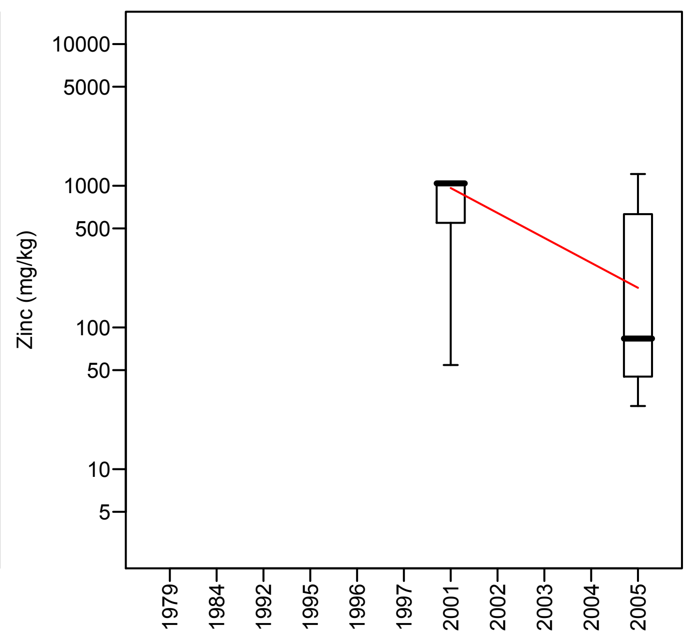


Figure 420. Temporal trend for Zinc concentrations within Reach #6. Red line indicates mean tendency.

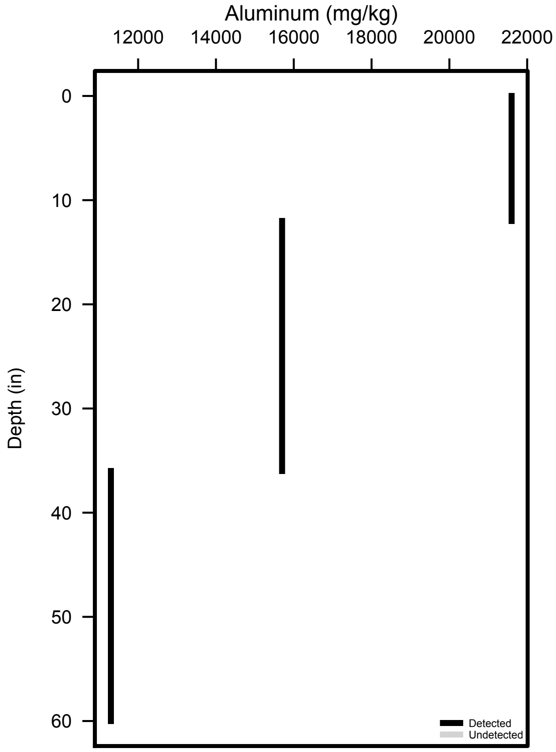


Figure 421. Aluminum
at Core Location RM605C1.

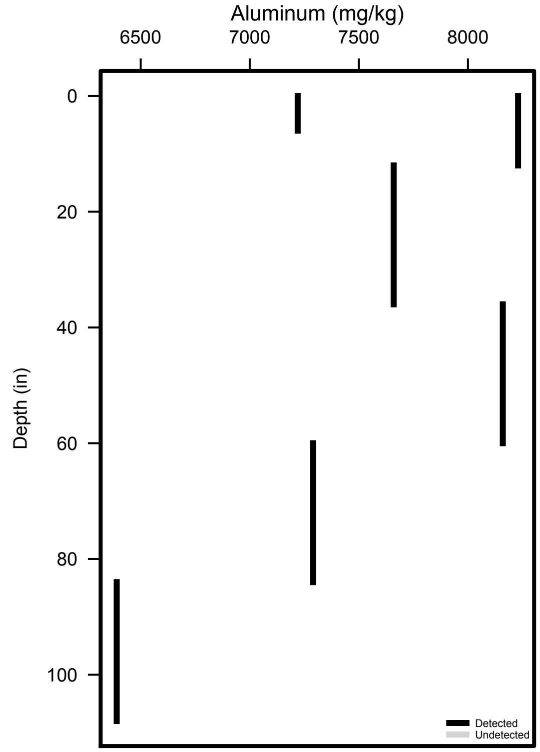


Figure 422. Aluminum
at Core Location RM622C1.

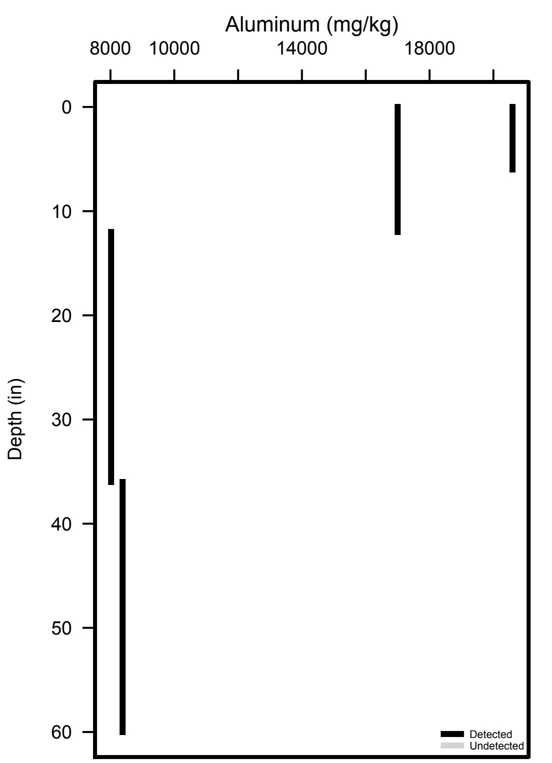


Figure 423. Aluminum
at Core Location RM637C1.

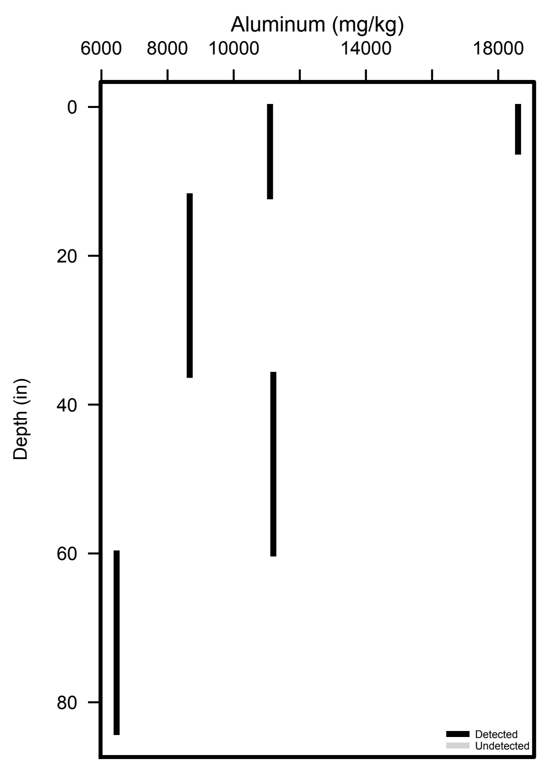


Figure 424. Aluminum
at Core Location RM644C1.

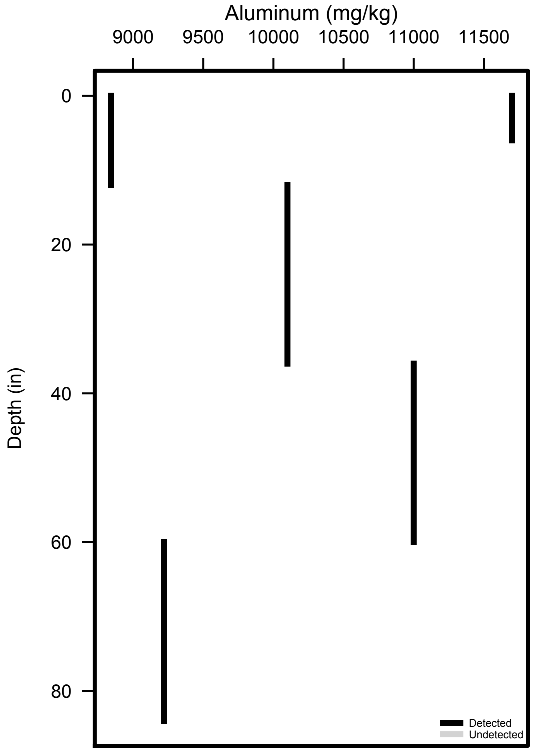


Figure 425. Aluminum
at Core Location RM661C1.

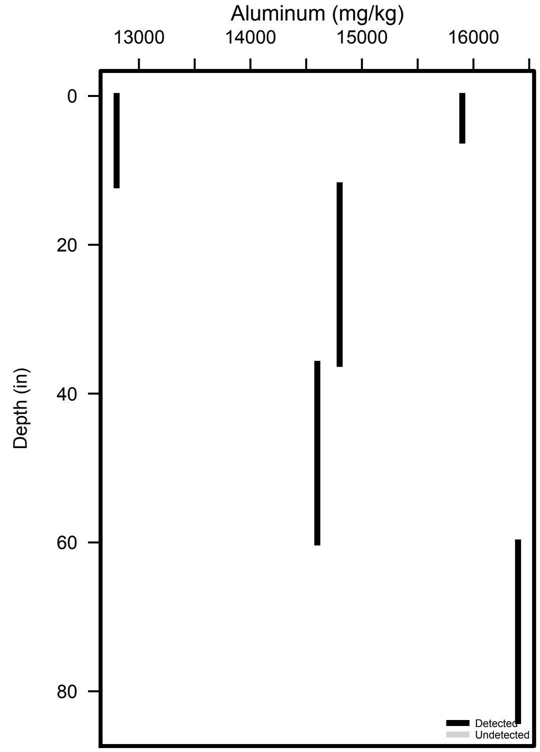


Figure 426. Aluminum
at Core Location RM676C1.

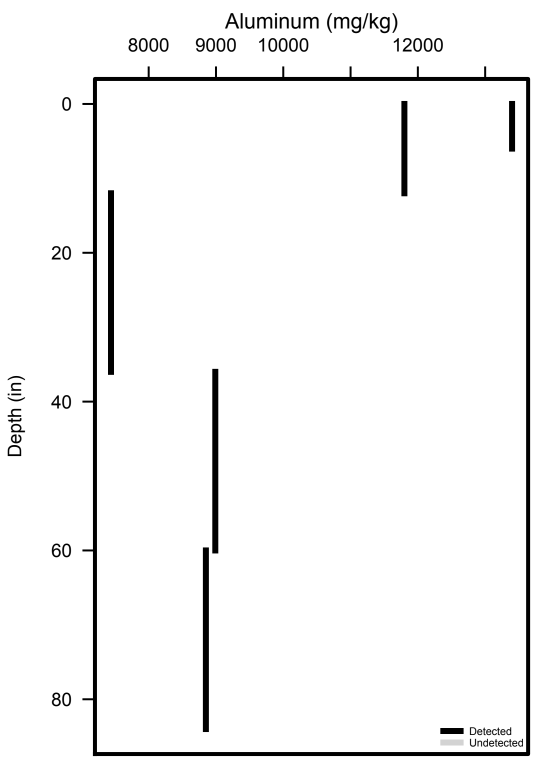


Figure 427. Aluminum
at Core Location RM692C1.

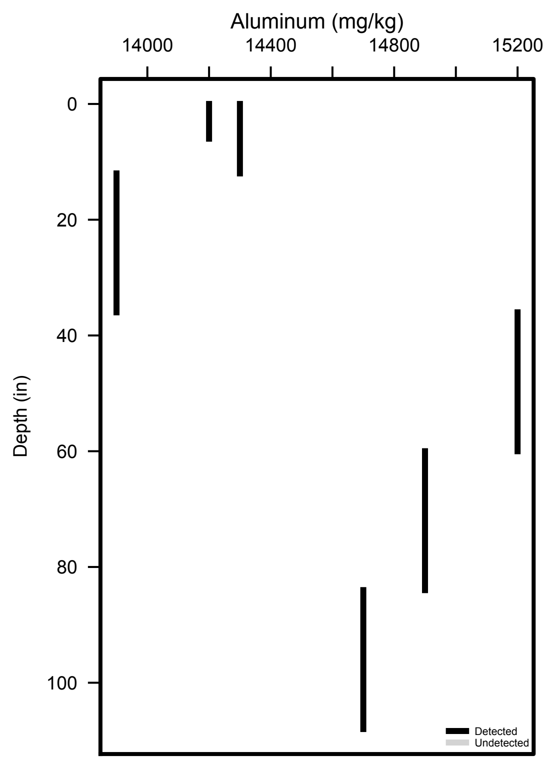


Figure 428. Aluminum
at Core Location RM704C1.

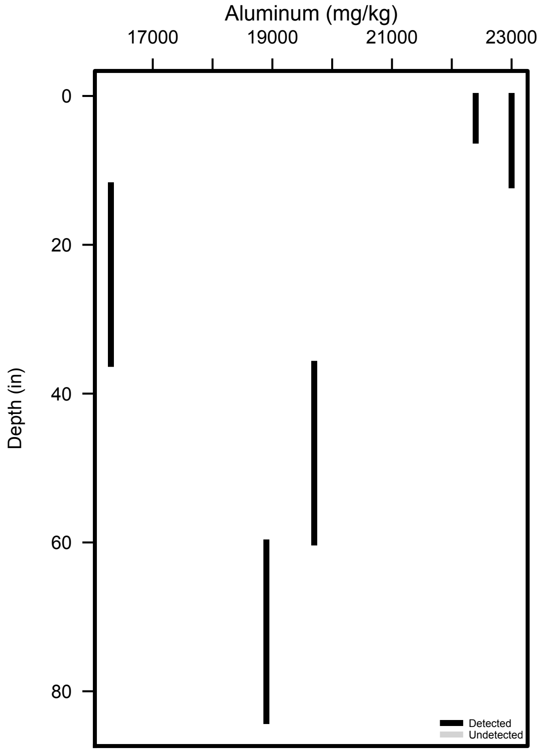


Figure 429. Aluminum
at Core Location RM708C1.

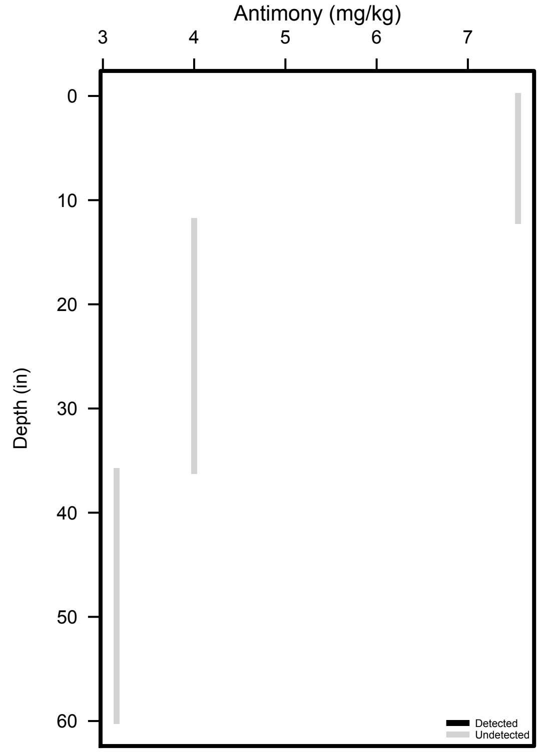


Figure 430. Antimony
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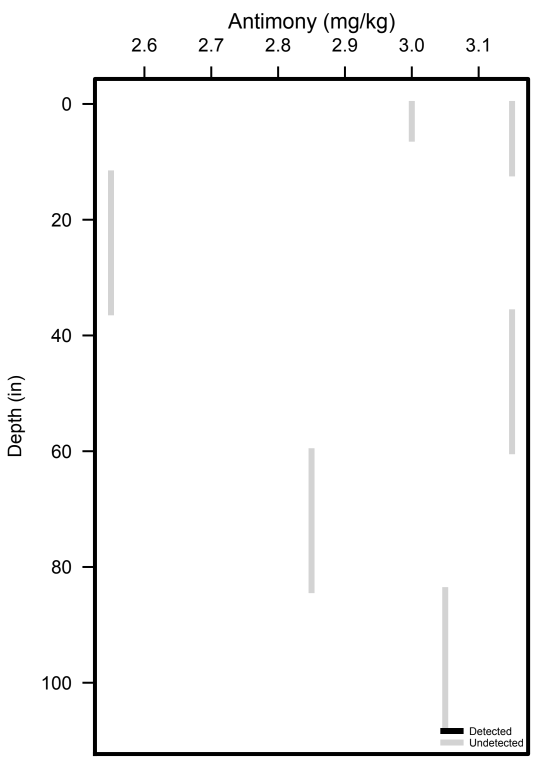

Figure 431. Antimony
at Core Location RM622C1.

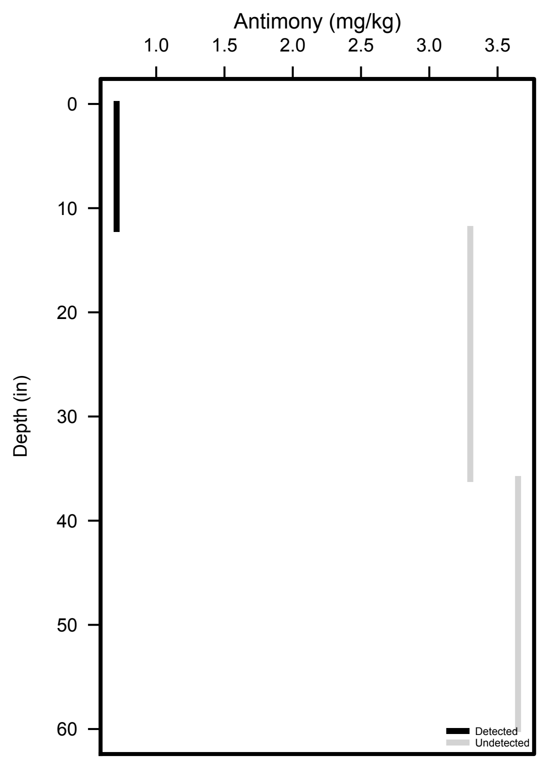

Figure 432. Antimony
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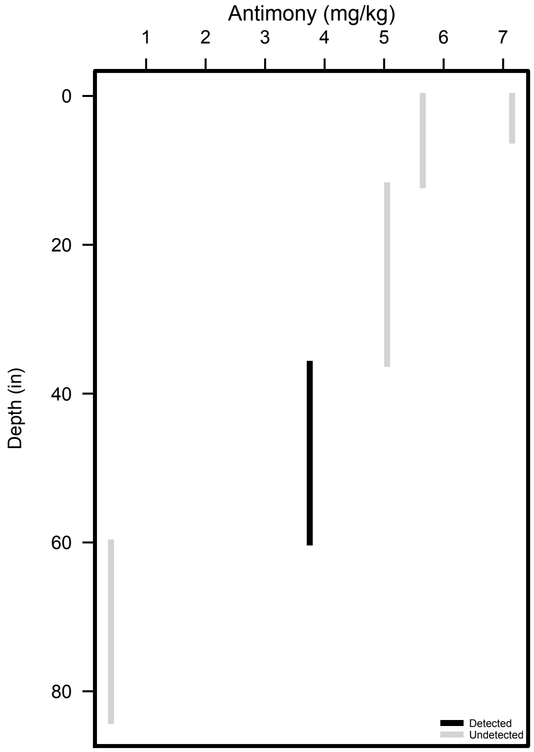

Figure 433. Antimony
at Core Location RM692C1.

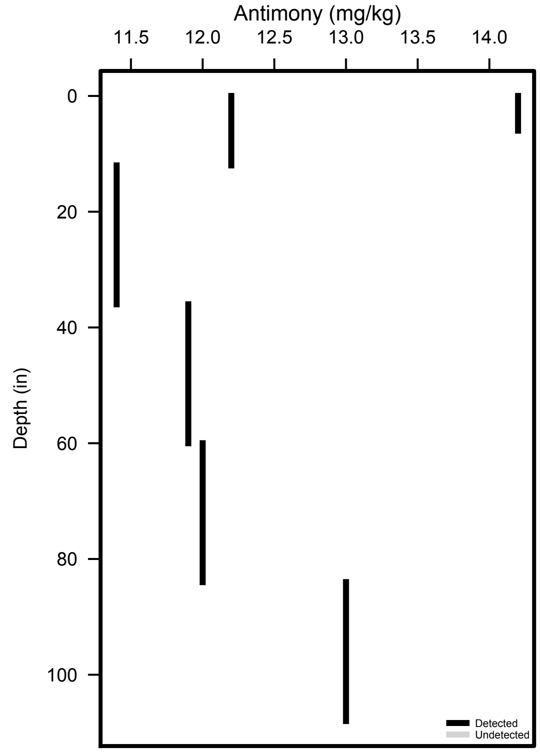

Figure 434. Antimony
at Core Location RM704C1.

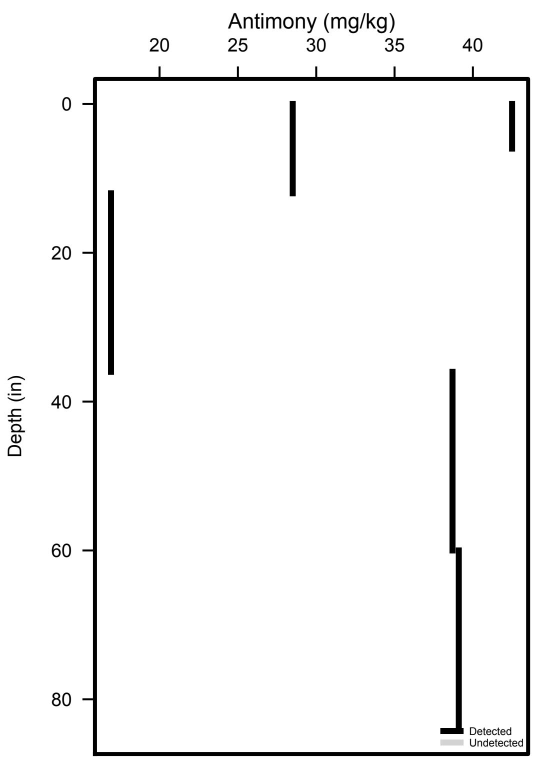

Figure 435. Antimony
at Core Location RM708C1.

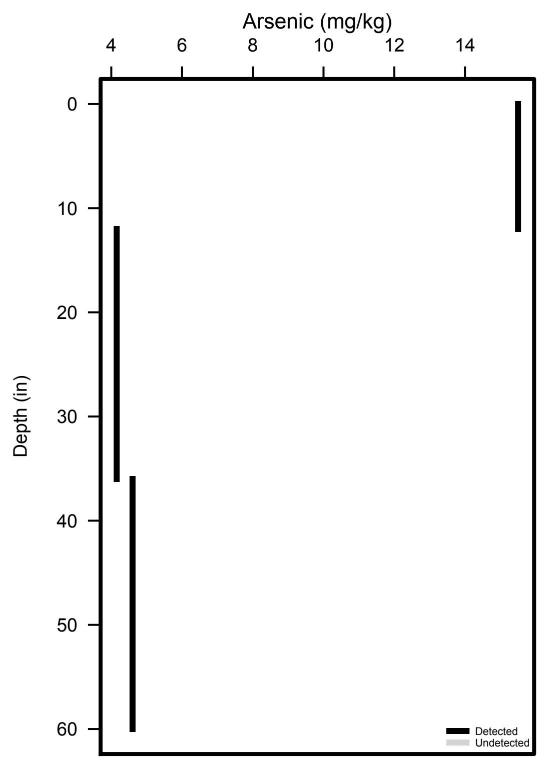

Figure 436. Arsenic
at Core Location RM605C1.

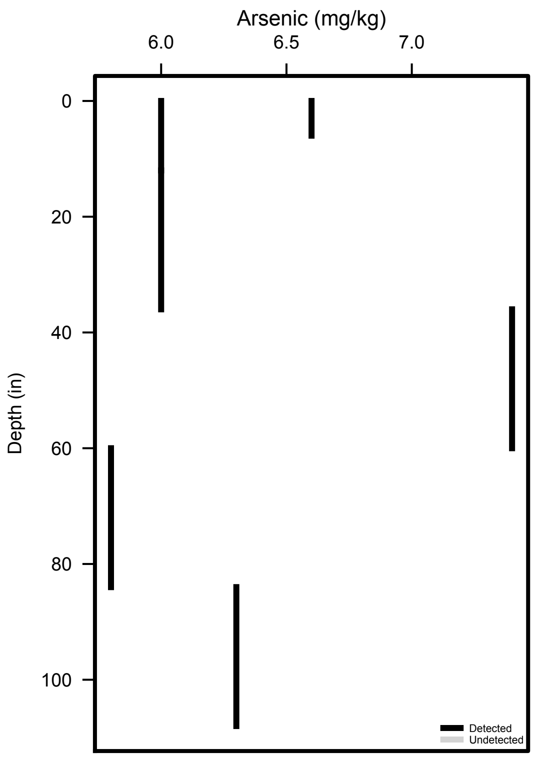

Figure 437. Arsenic
at Core Location RM622C1.

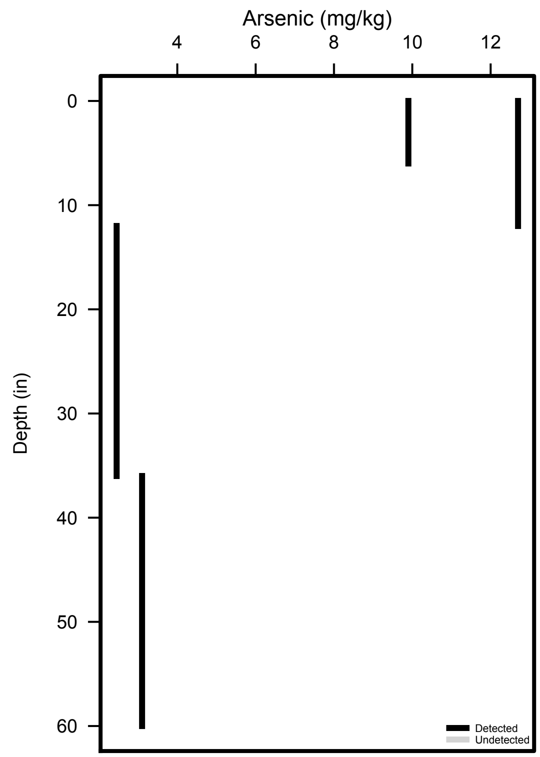

Figure 438. Arsenic
at Core Location RM637C1.

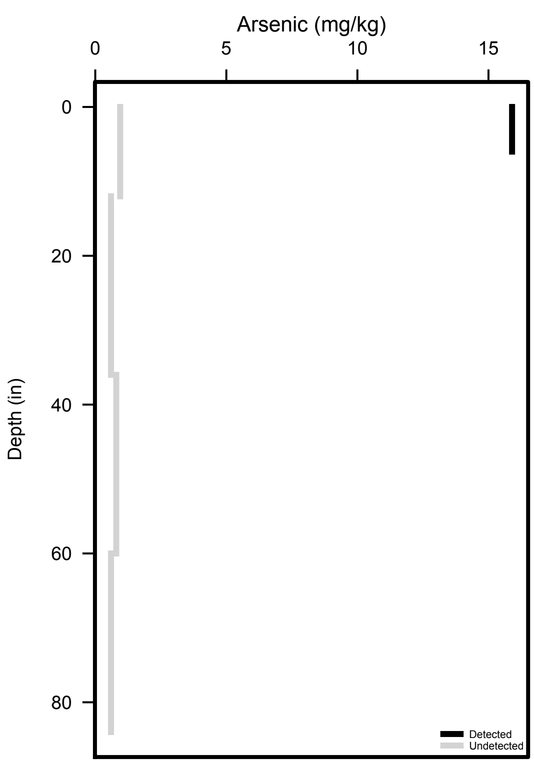

Figure 439. Arsenic
at Core Location RM644C1.

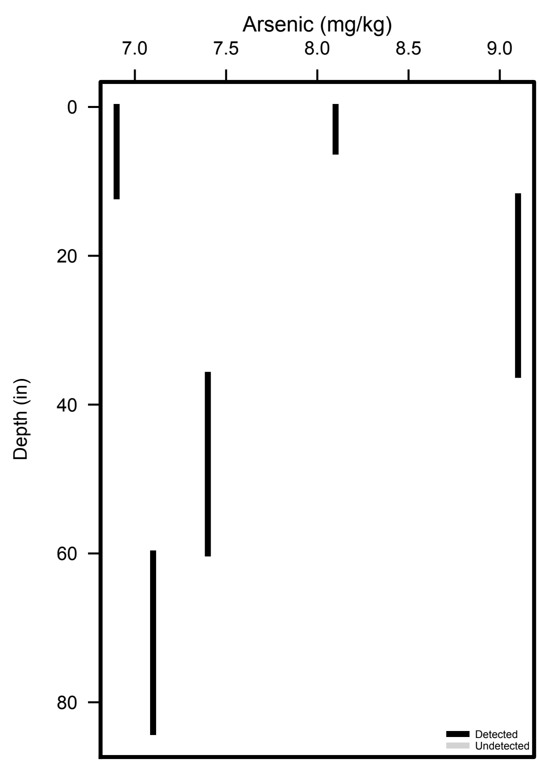

Figure 440. Arsenic
at Core Location RM661C1.

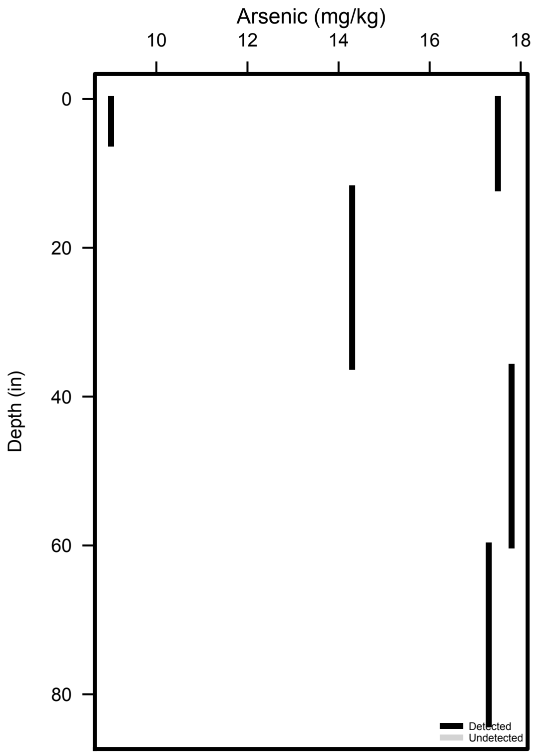

Figure 441. Arsenic
at Core Location RM676C1.

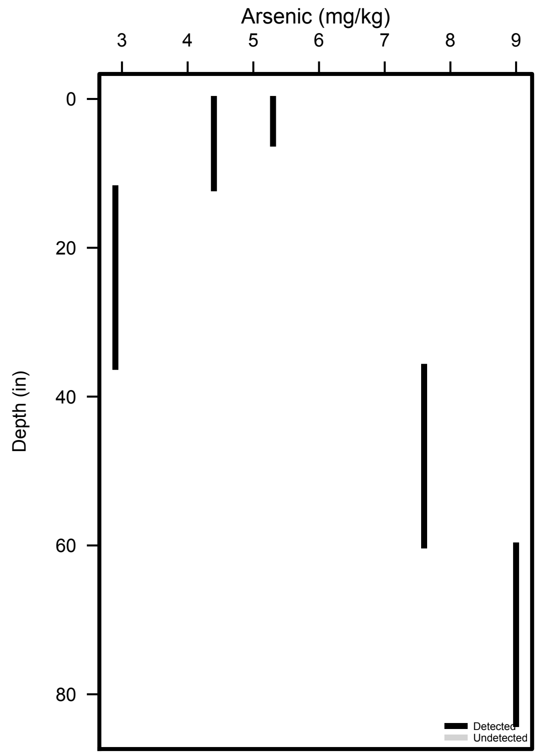

Figure 442. Arsenic
at Core Location RM692C1.

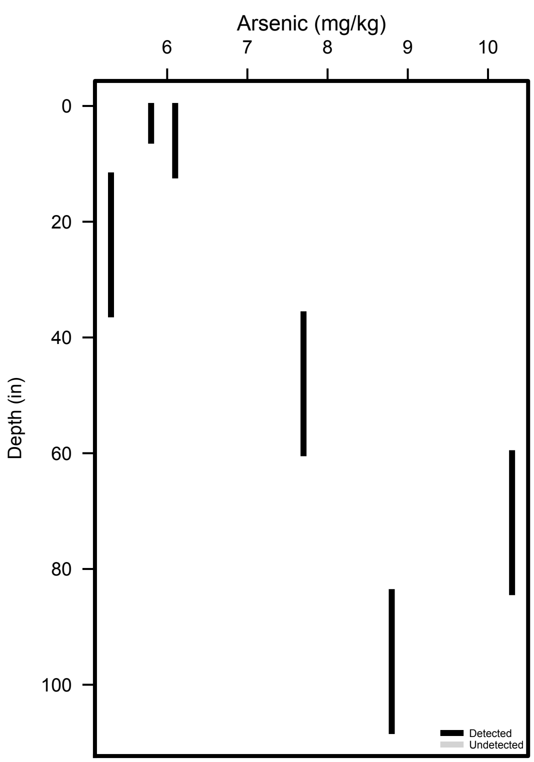

Figure 443. Arsenic
at Core Location RM704C1.

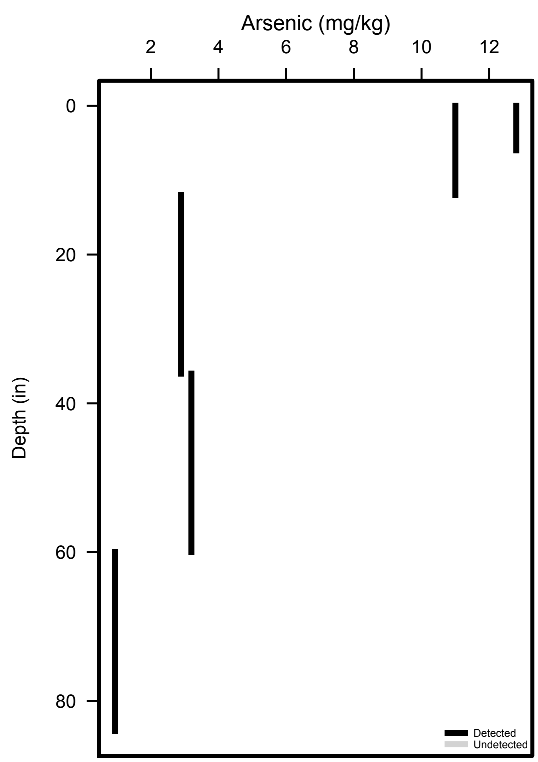

Figure 444. Arsenic
at Core Location RM708C1.

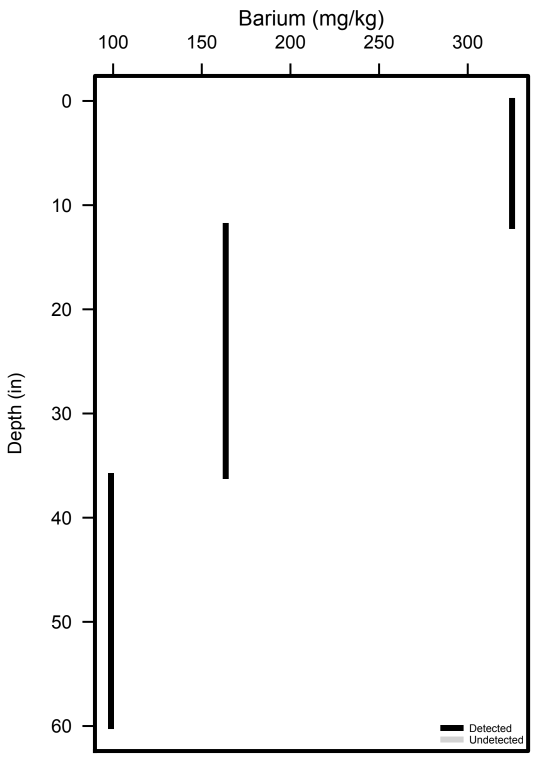

Figure 445. Barium
at Core Location RM605C1.

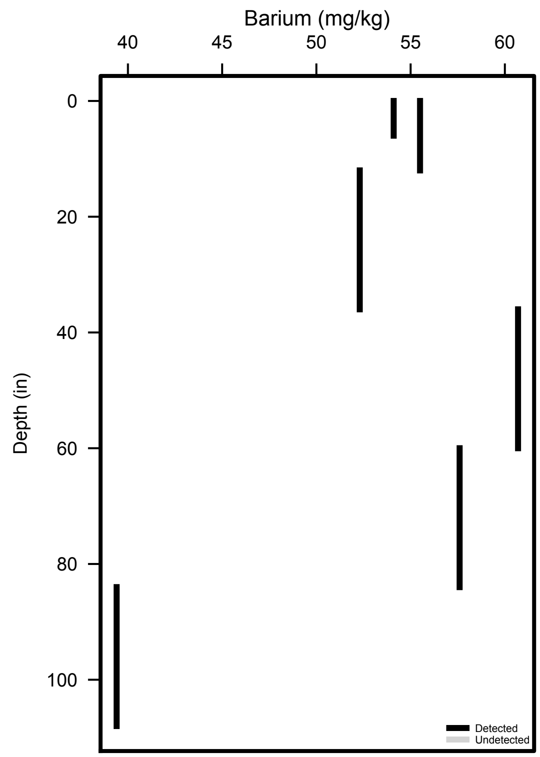

Figure 446. Barium
at Core Location RM622C1.

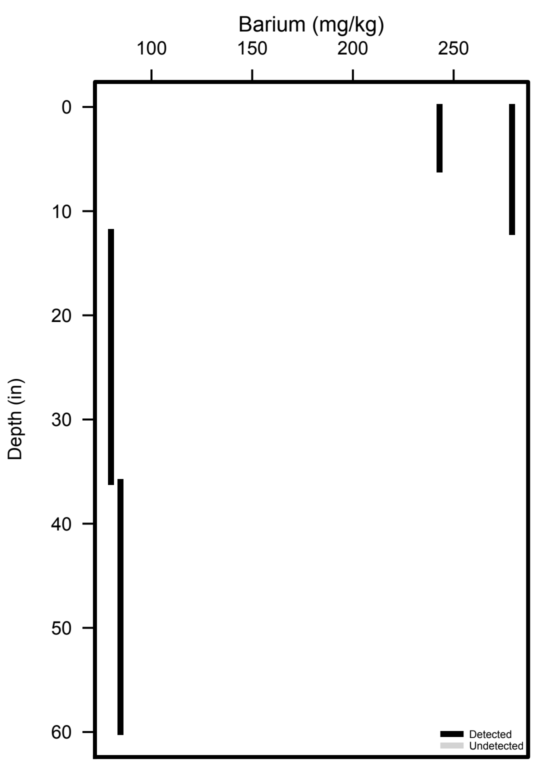

Figure 447. Barium
at Core Location RM637C1.

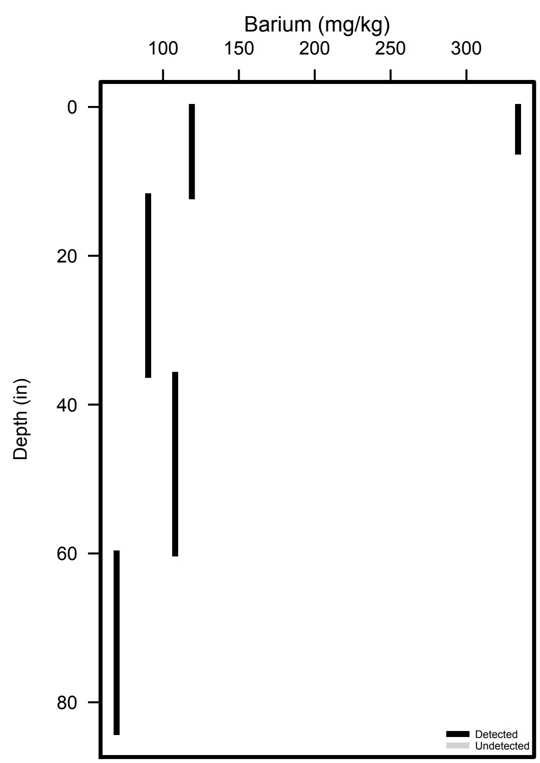

Figure 448. Barium
at Core Location RM644C1.

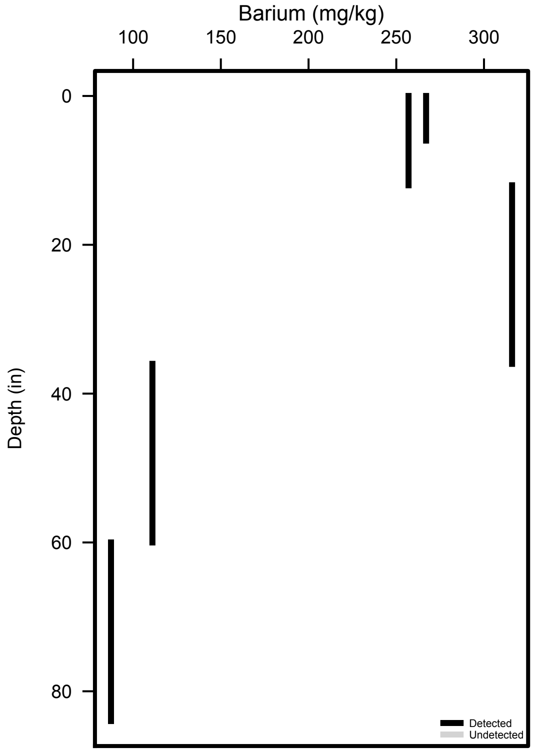

Figure 449. Barium
at Core Location RM661C1.

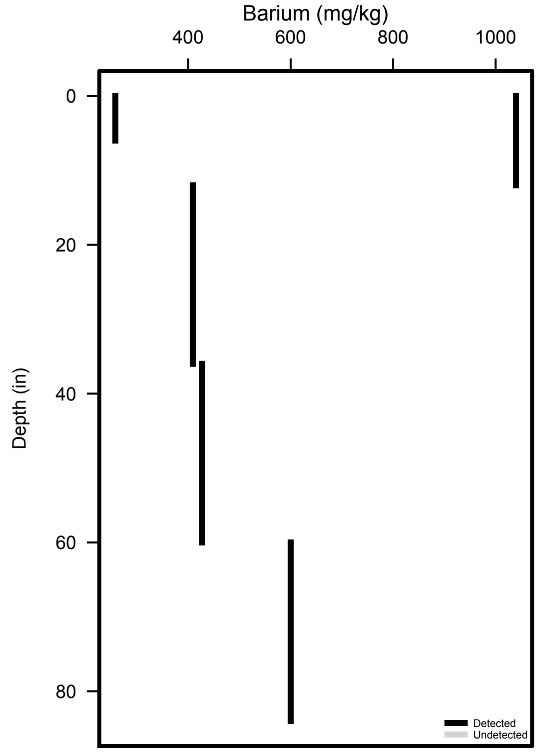

Figure 450. Barium
at Core Location RM676C1.

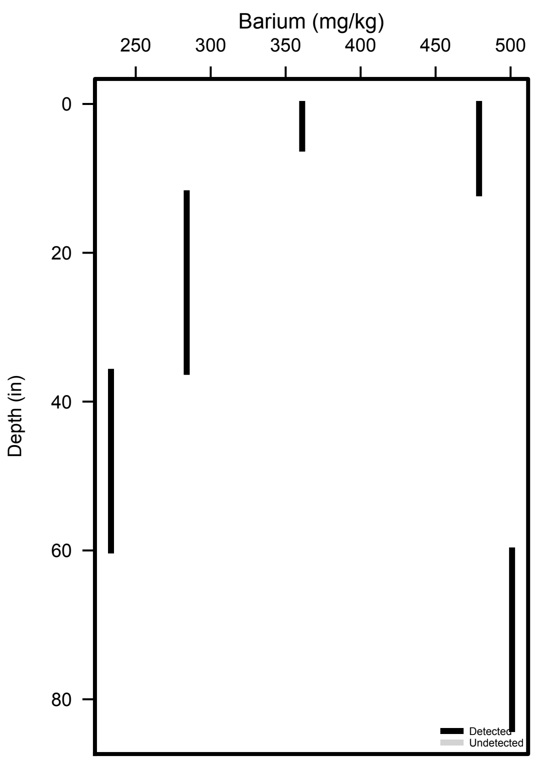

Figure 451. Barium
at Core Location RM692C1.

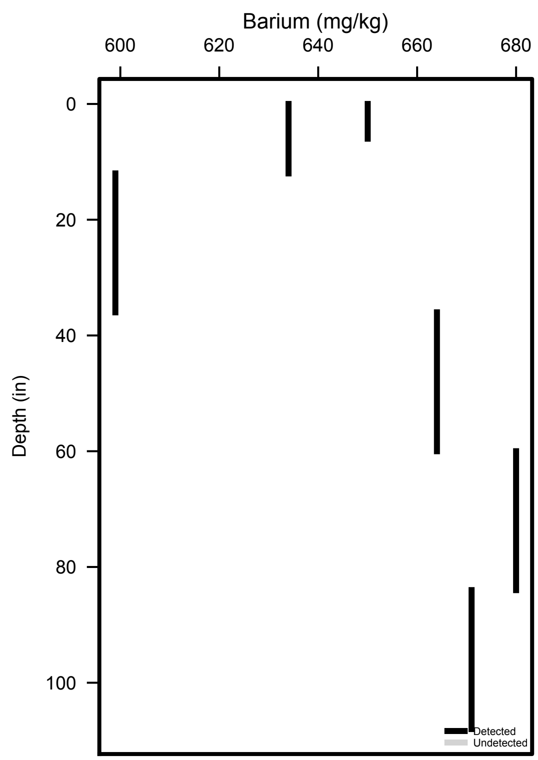

Figure 452. Barium
at Core Location RM704C1.

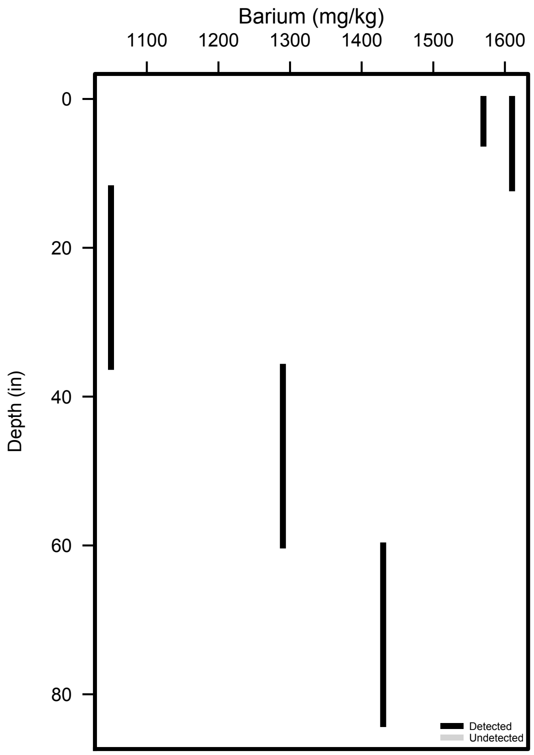

Figure 453. Barium
at Core Location RM708C1.

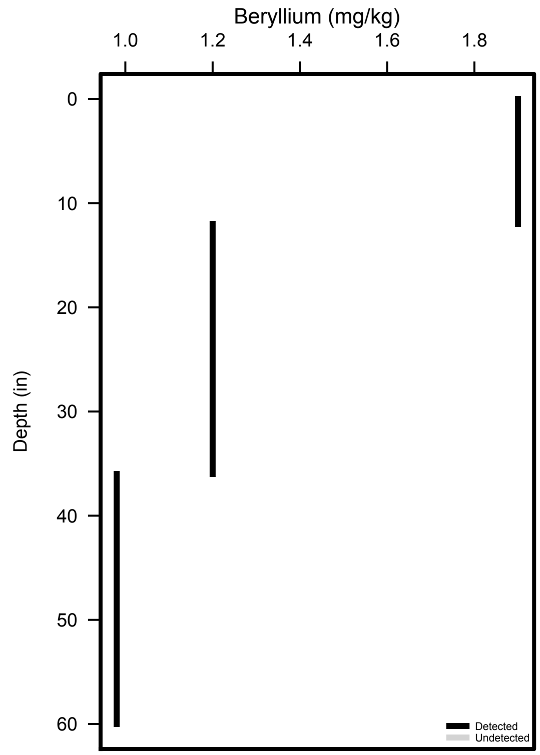

Figure 454. Beryllium
at Core Location RM605C1.

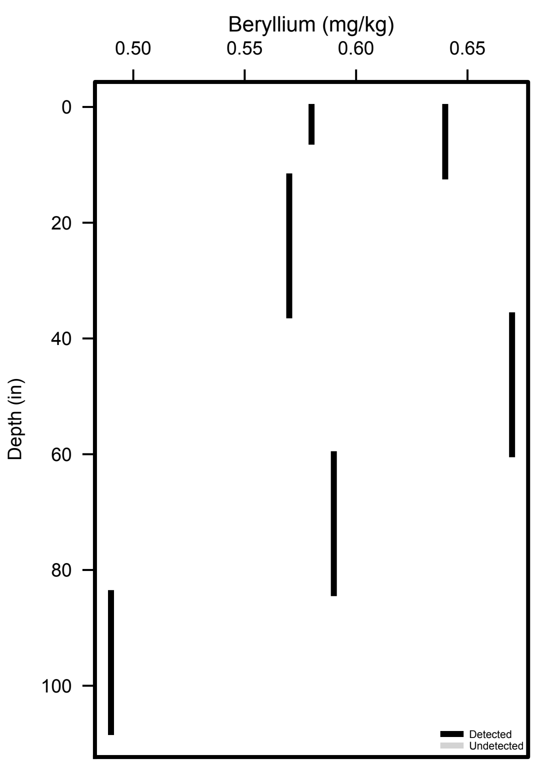

Figure 455. Beryllium
at Core Location RM622C1.

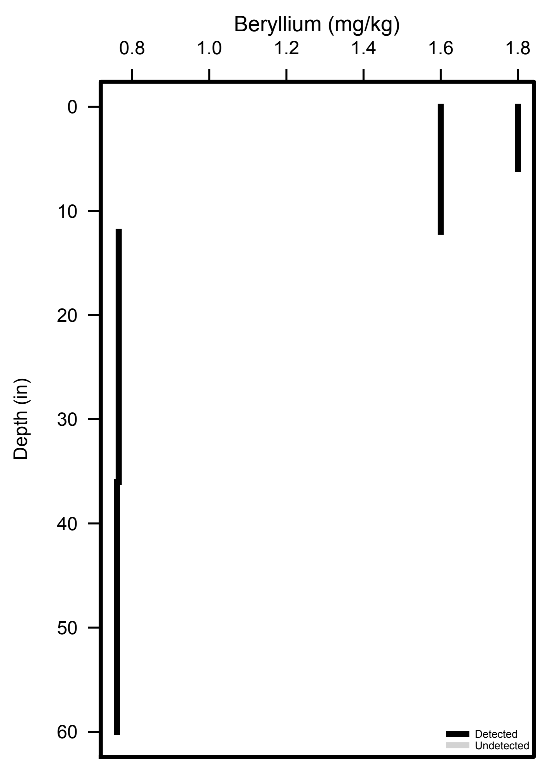

Figure 456. Beryllium
at Core Location RM637C1.

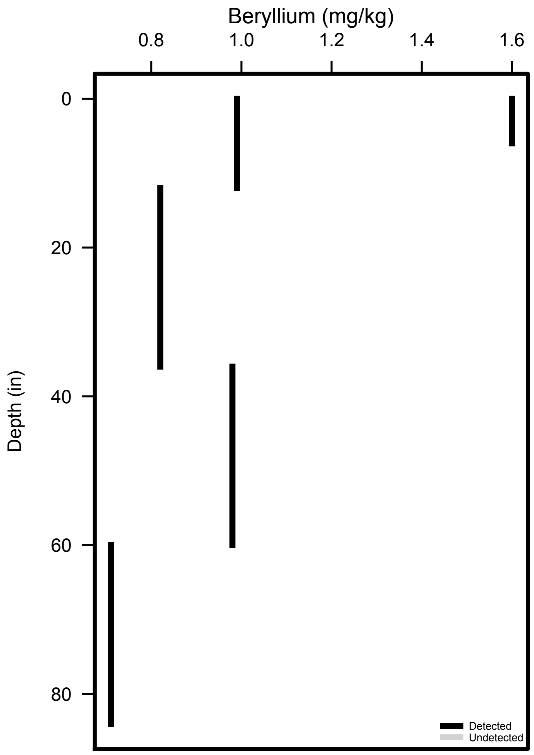

Figure 457. Beryllium
at Core Location RM644C1.

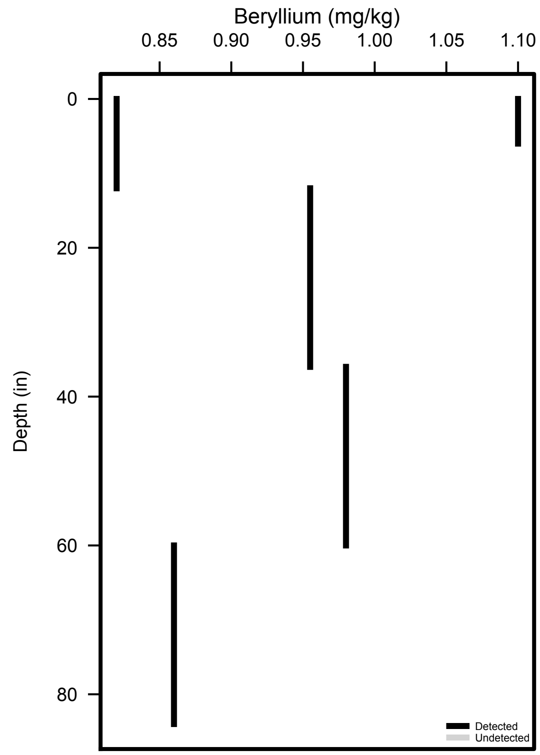

Figure 458. Beryllium
at Core Location RM661C1.

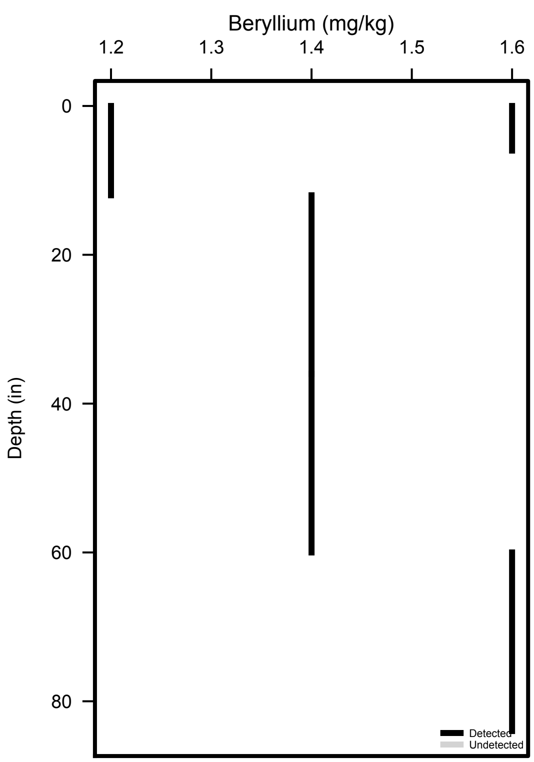

Figure 459. Beryllium
at Core Location RM676C1.

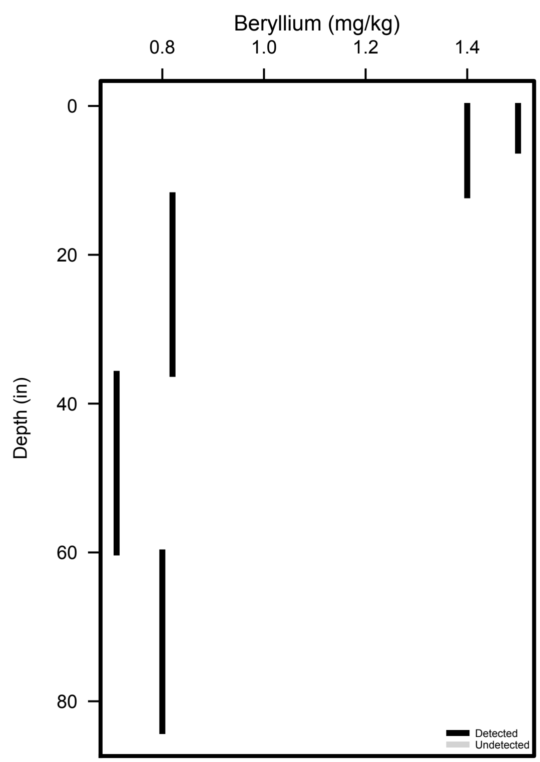

Figure 460. Beryllium
at Core Location RM692C1.

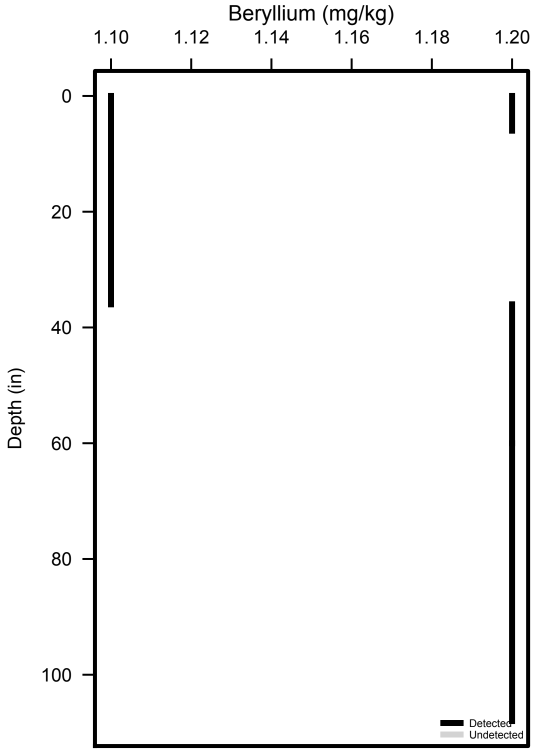

Figure 461. Beryllium
at Core Location RM704C1.

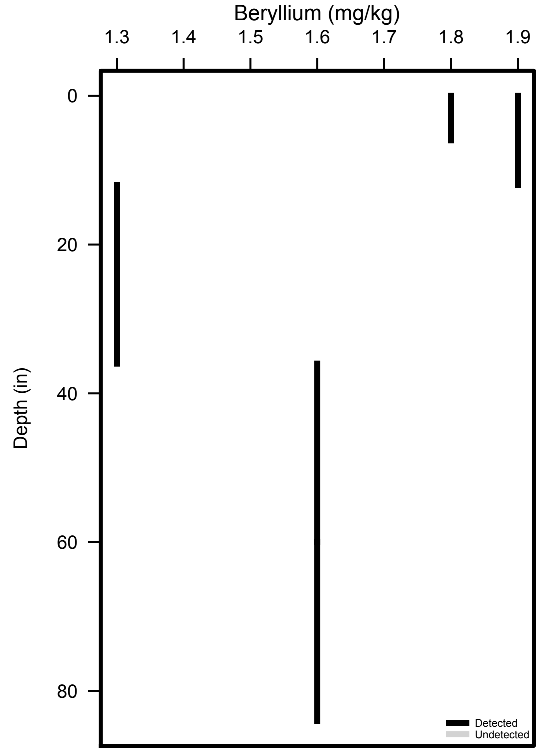

Figure 462. Beryllium
at Core Location RM708C1.

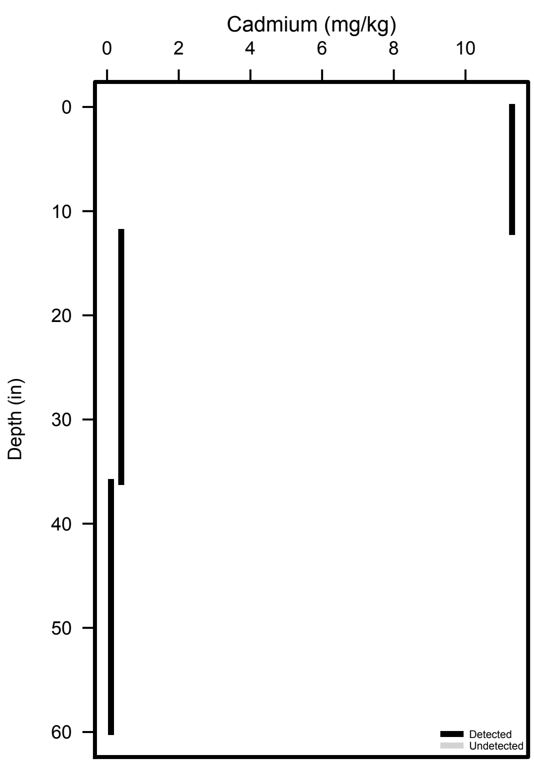

Figure 463. Cadmium
at Core Location RM605C1.

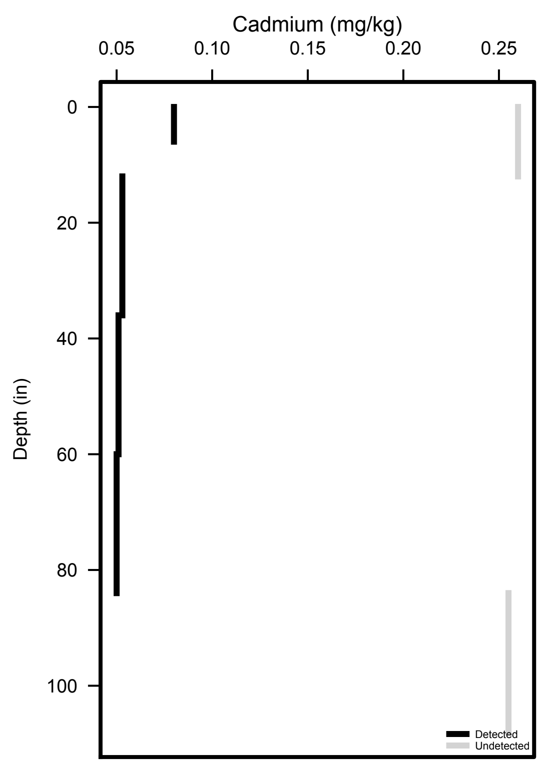

Figure 464. Cadmium
at Core Location RM622C1.

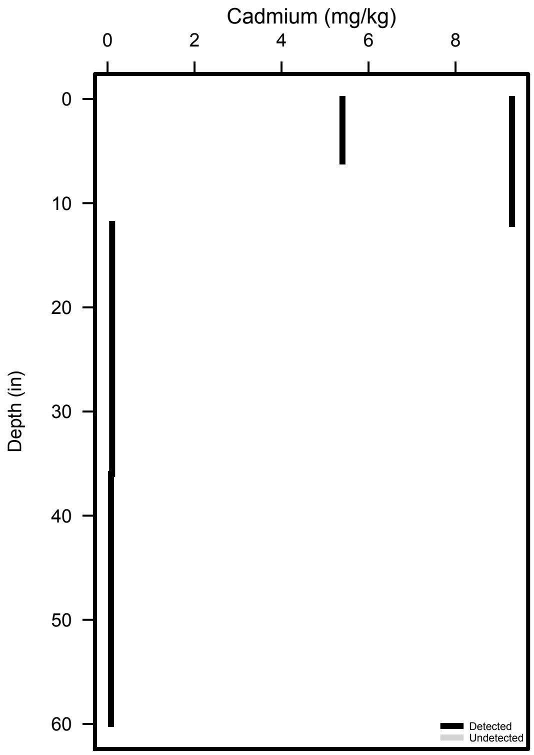

Figure 465. Cadmium
at Core Location RM637C1.

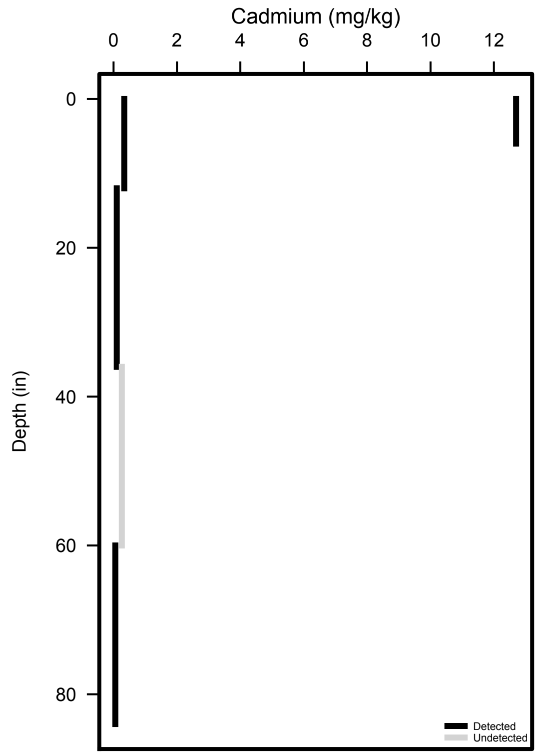

Figure 466. Cadmium
at Core Location RM644C1.

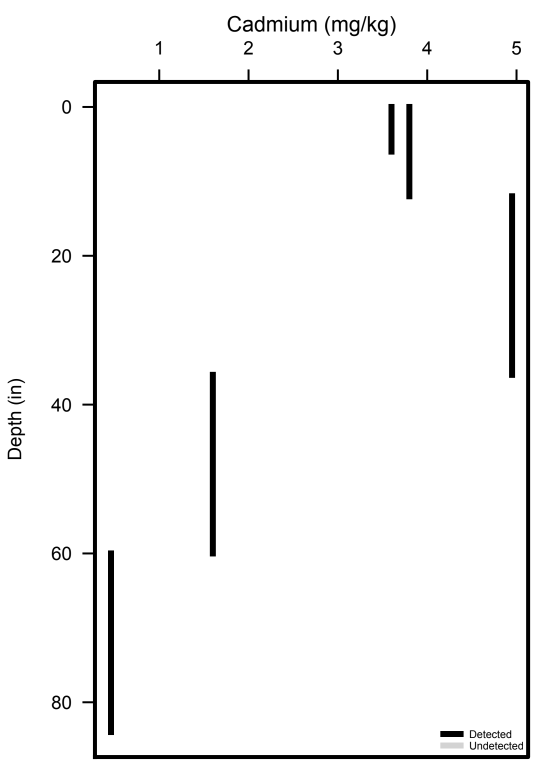

Figure 467. Cadmium
at Core Location RM661C1.

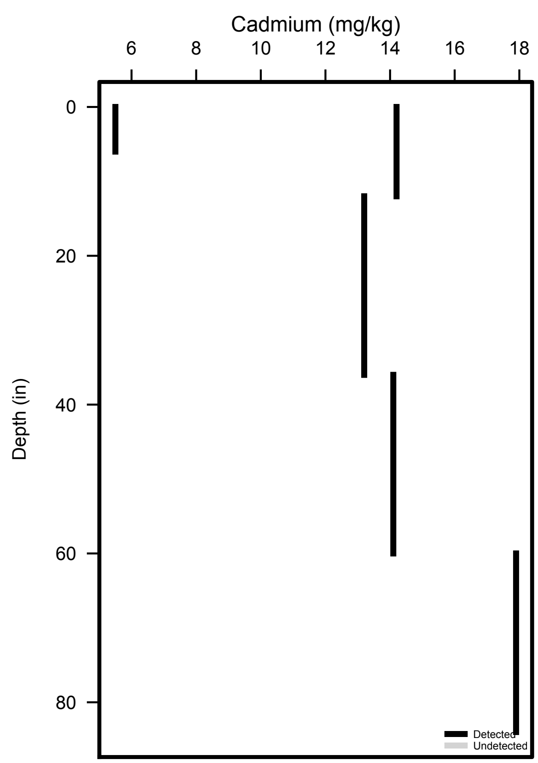

Figure 468. Cadmium
at Core Location RM676C1.

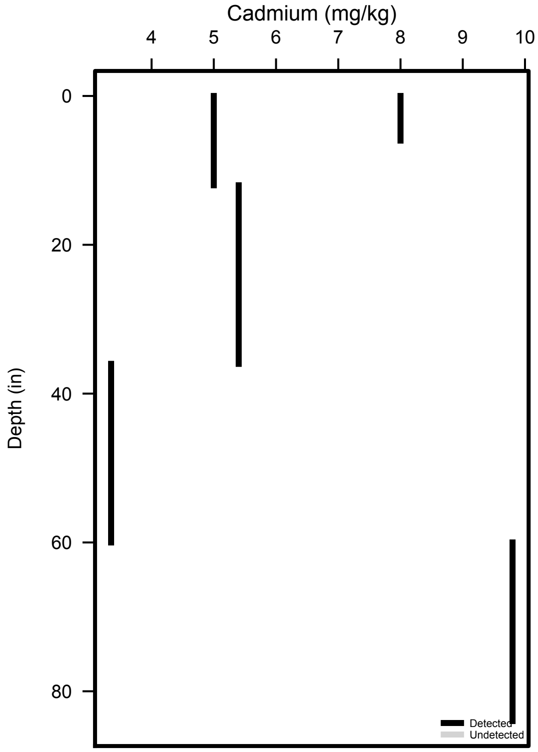

Figure 469. Cadmium
at Core Location RM692C1.

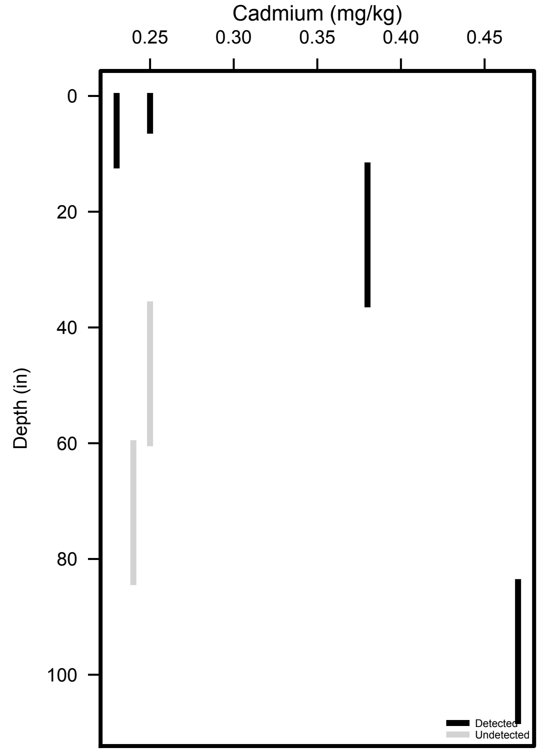

Figure 470. Cadmium
at Core Location RM704C1.

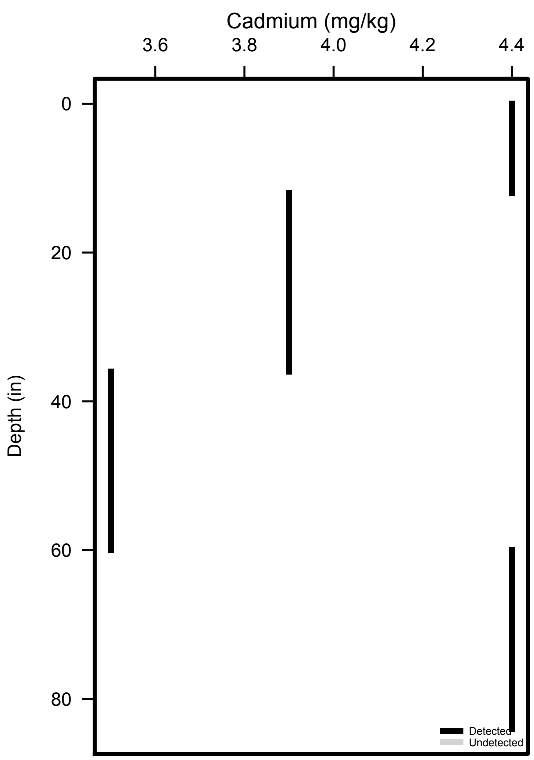

Figure 471. Cadmium
at Core Location RM708C1.

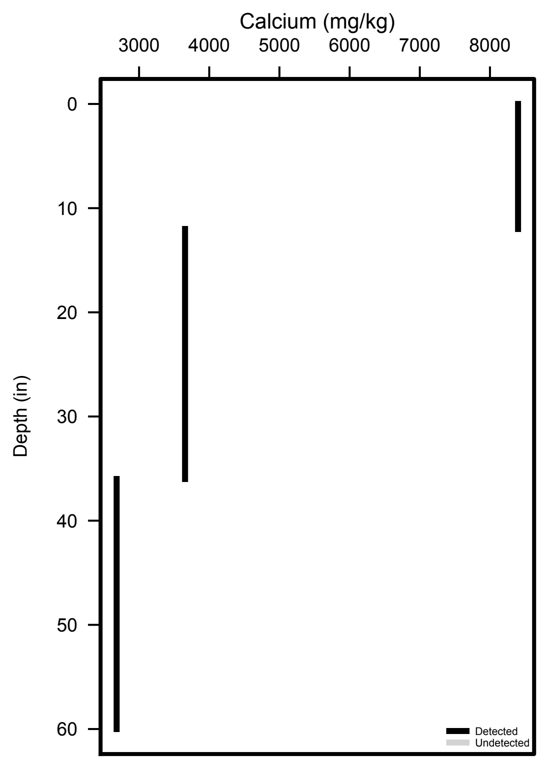

Figure 472. Calcium
at Core Location RM605C1.

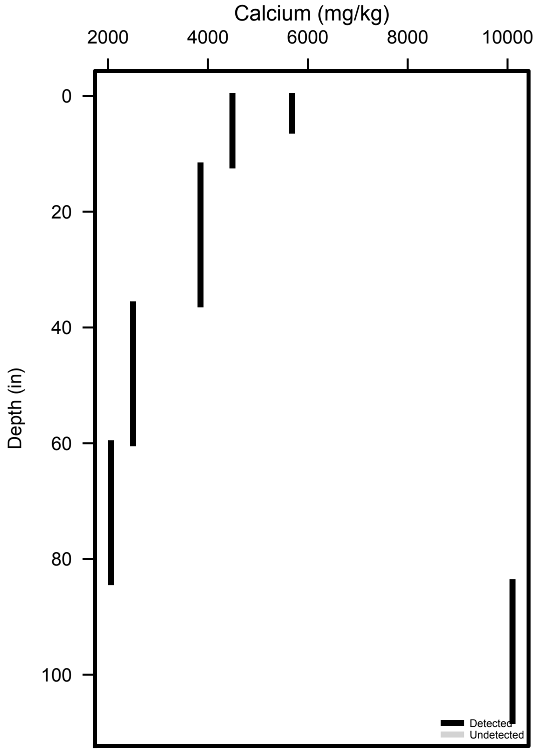

Figure 473. Calcium
at Core Location RM622C1.

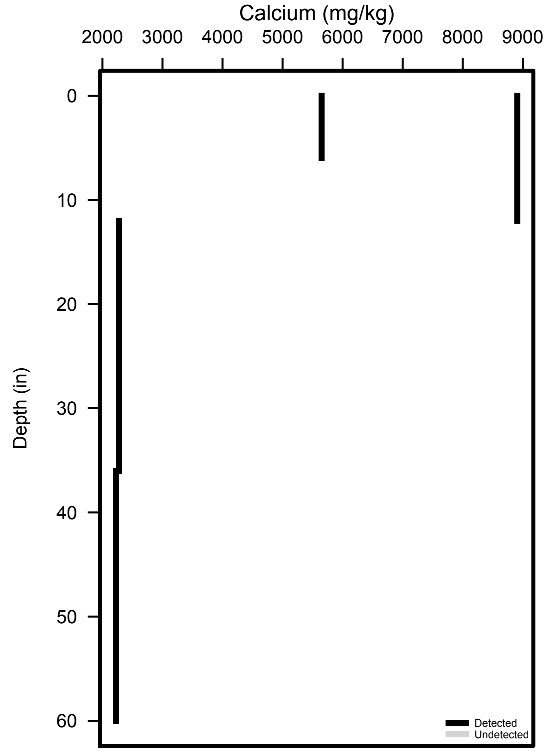

Figure 474. Calcium
at Core Location RM637C1.

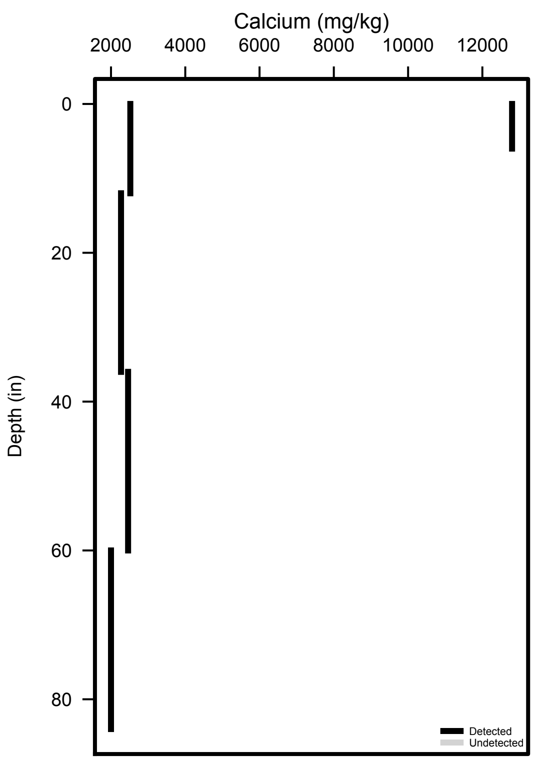

Figure 475. Calcium
at Core Location RM644C1.

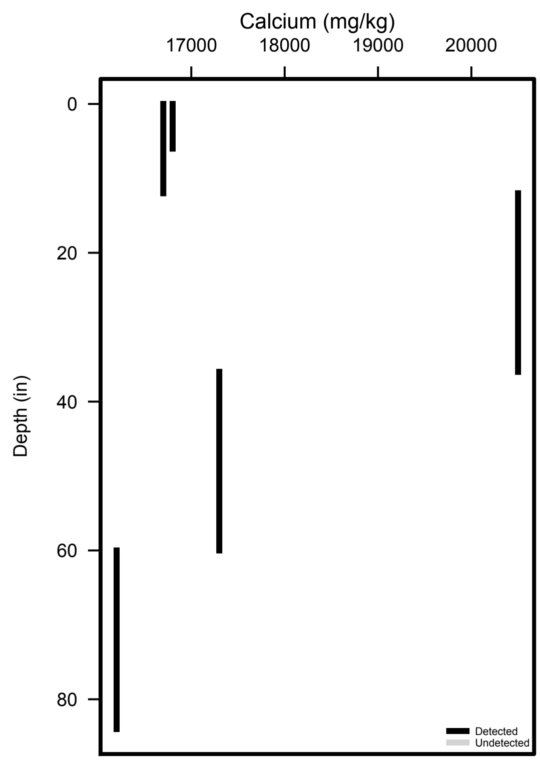

Figure 476. Calcium
at Core Location RM661C1.

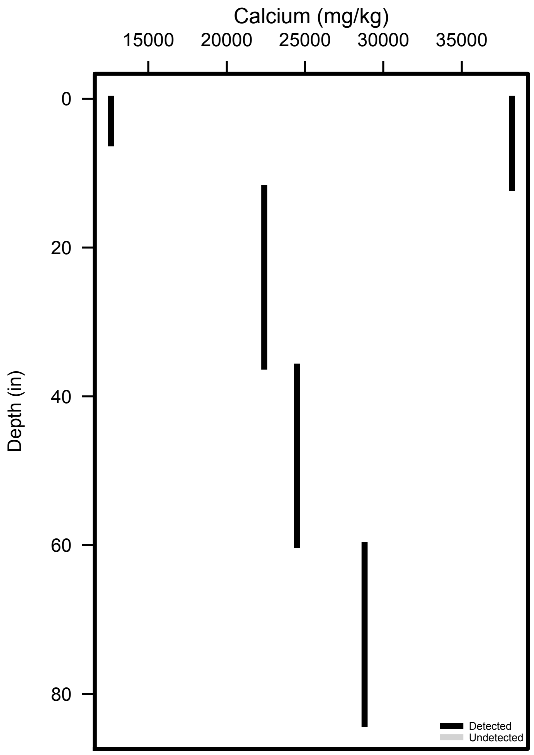

Figure 477. Calcium
at Core Location RM676C1.

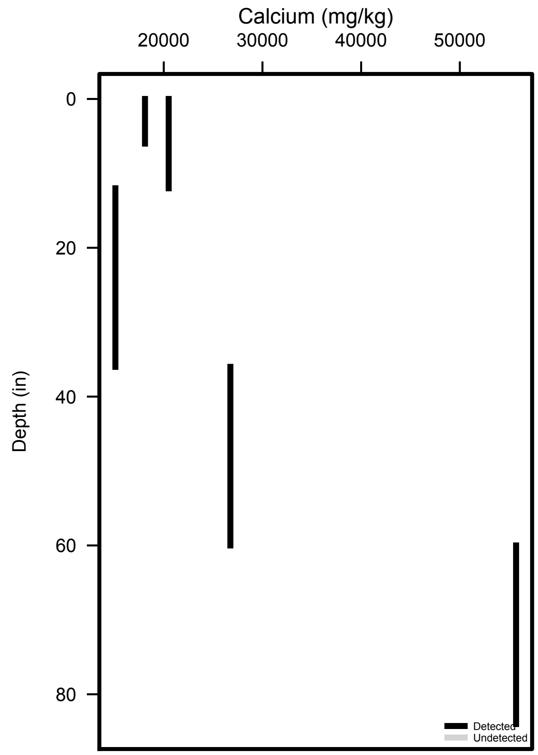

Figure 478. Calcium
at Core Location RM692C1.

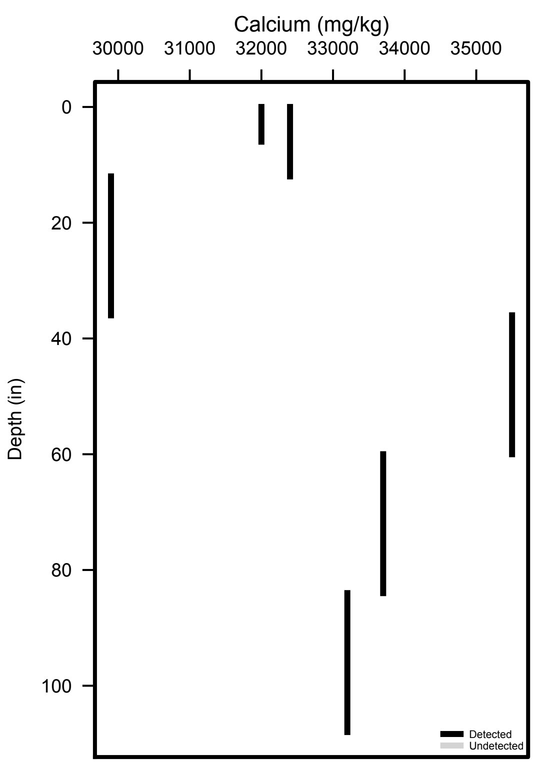

Figure 479. Calcium
at Core Location RM704C1.

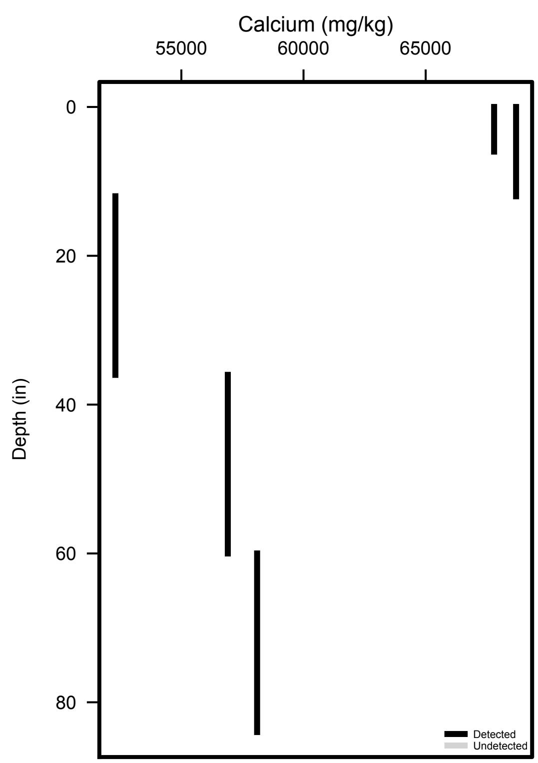

Figure 480. Calcium
at Core Location RM708C1.

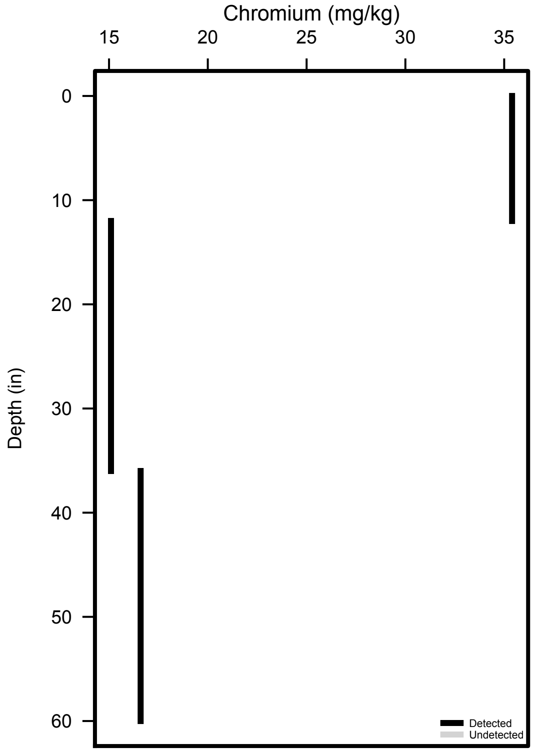

Figure 481. Chromium
at Core Location RM605C1.

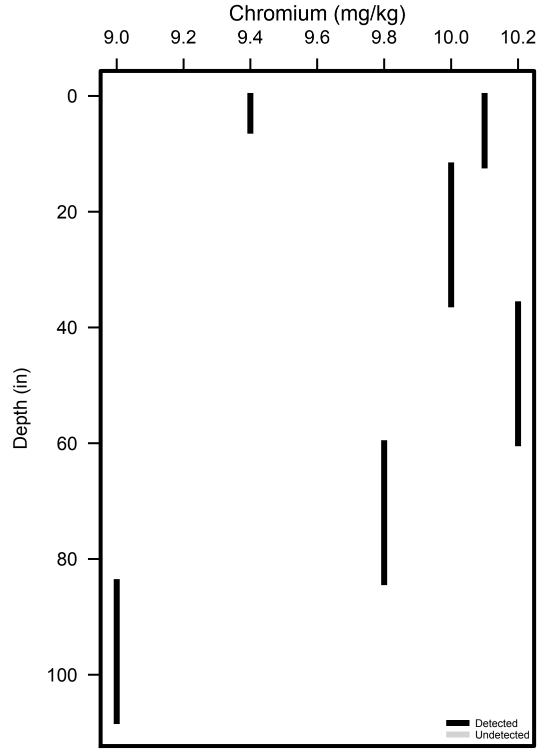

Figure 482. Chromium
at Core Location RM622C1.

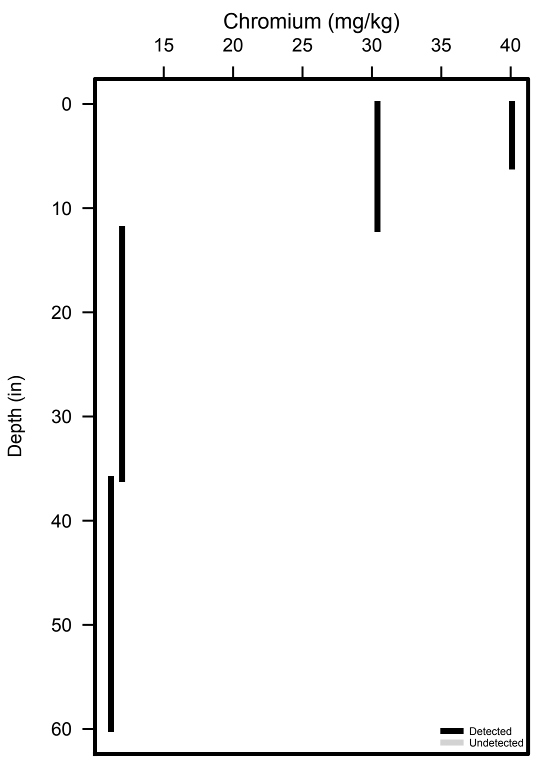

Figure 483. Chromium
at Core Location RM637C1.

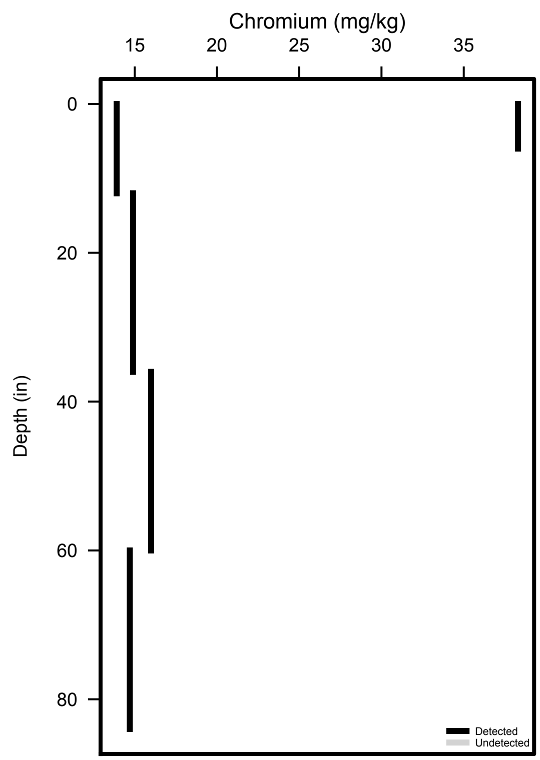

Figure 484. Chromium
at Core Location RM644C1.

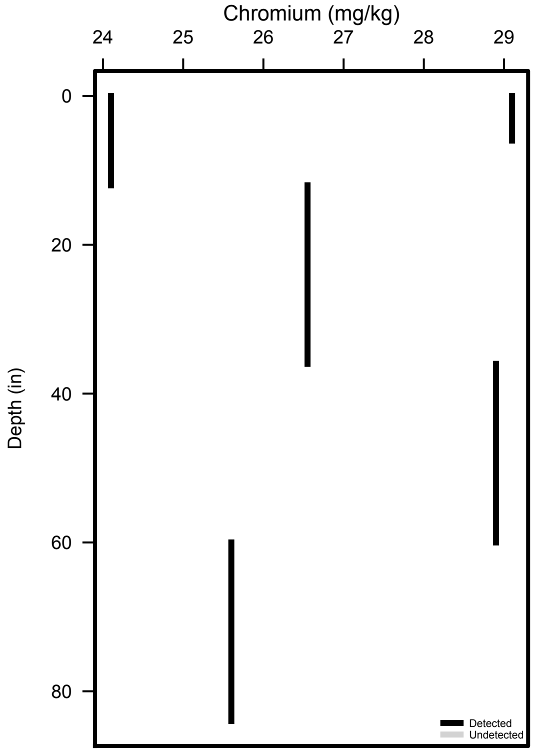

Figure 485. Chromium
at Core Location RM661C1.

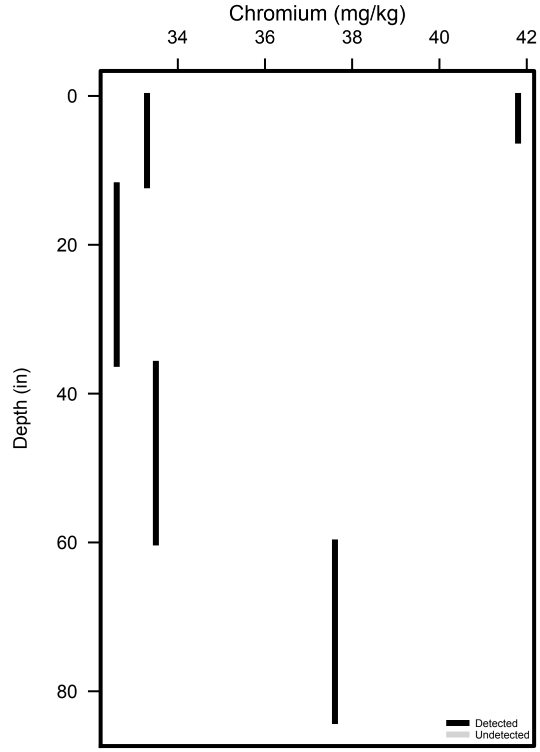

Figure 486. Chromium
at Core Location RM676C1.

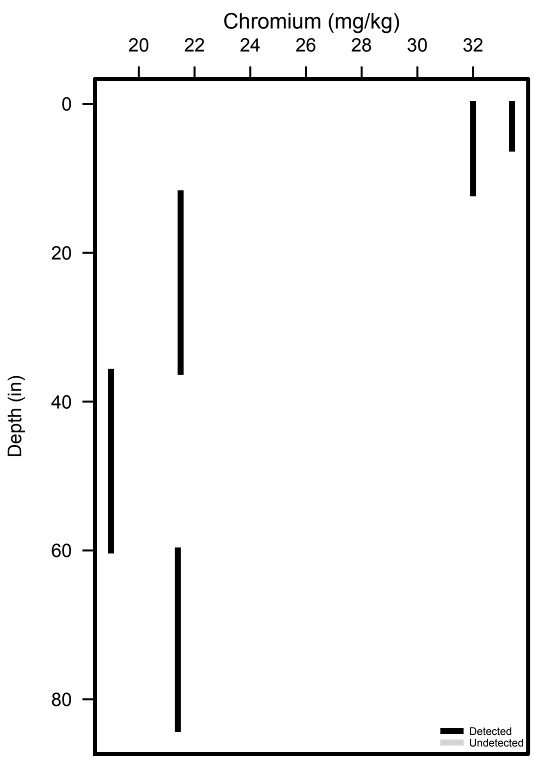

Figure 487. Chromium
at Core Location RM692C1.

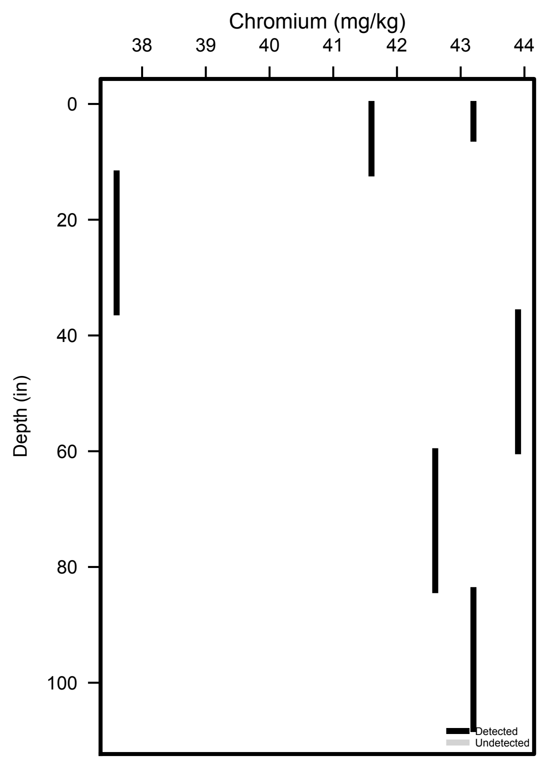

Figure 488. Chromium
at Core Location RM704C1.

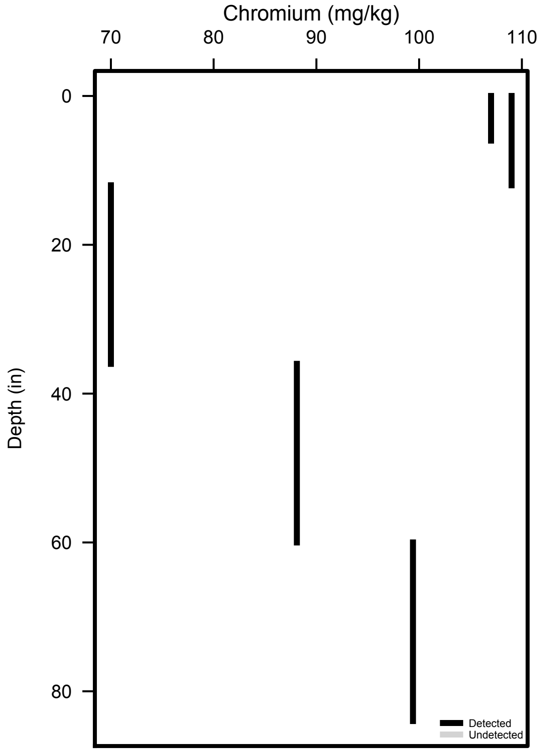

Figure 489. Chromium
at Core Location RM708C1.

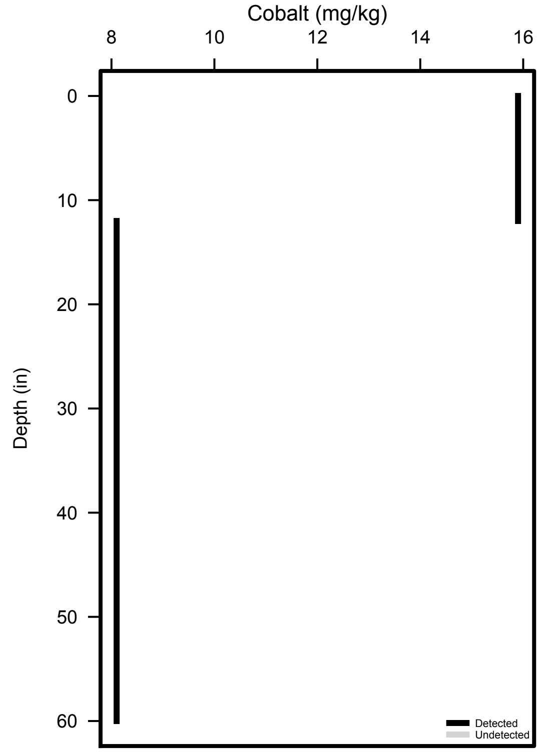

Figure 490. Cobalt
at Core Location RM605C1.

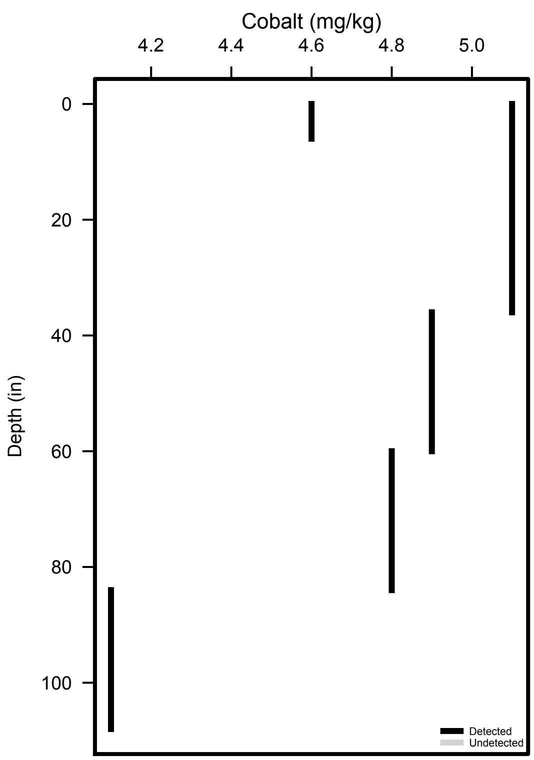

Figure 491. Cobalt
at Core Location RM622C1.

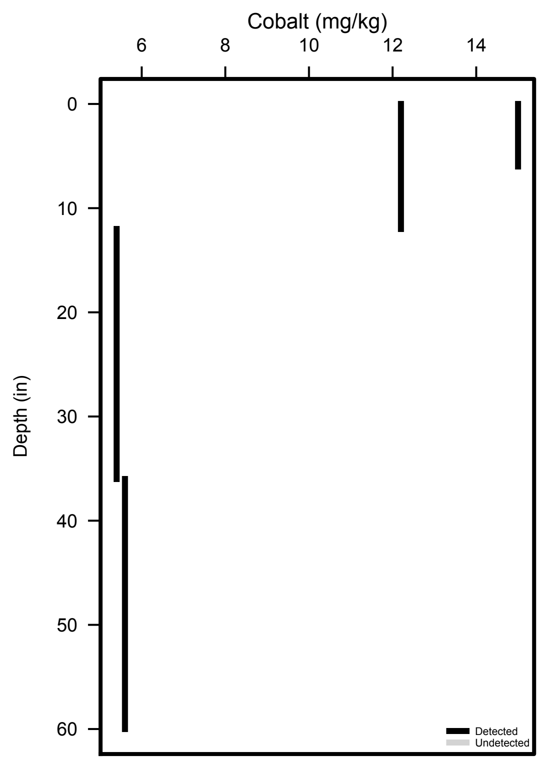

Figure 492. Cobalt
at Core Location RM637C1.

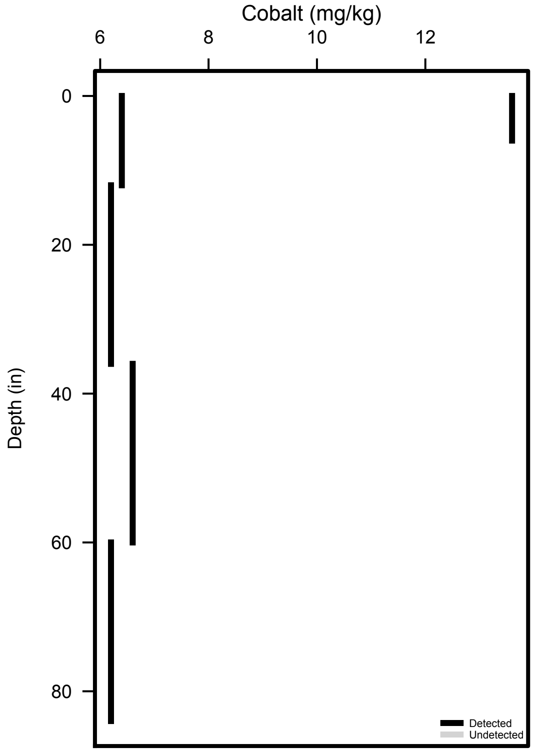

Figure 493. Cobalt
at Core Location RM644C1.

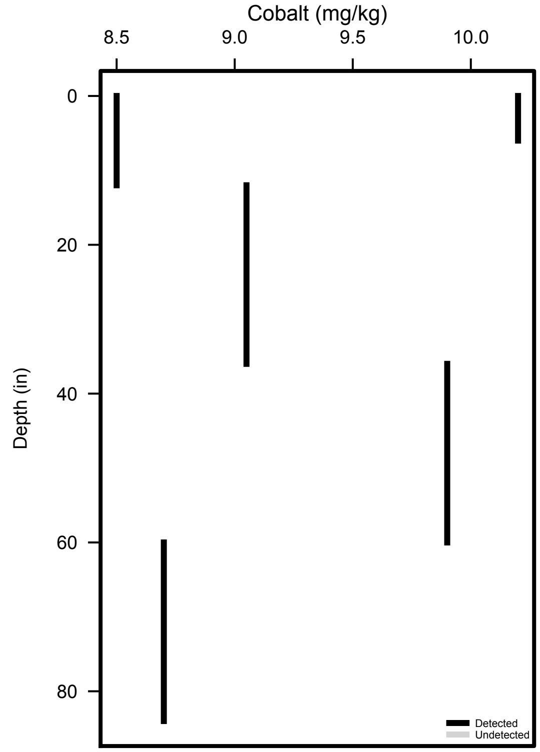

Figure 494. Cobalt
at Core Location RM661C1.

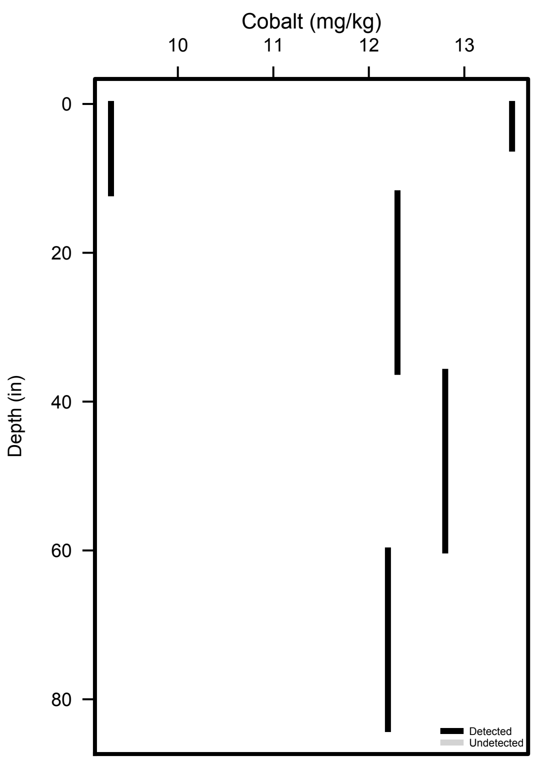

Figure 495. Cobalt
at Core Location RM676C1.

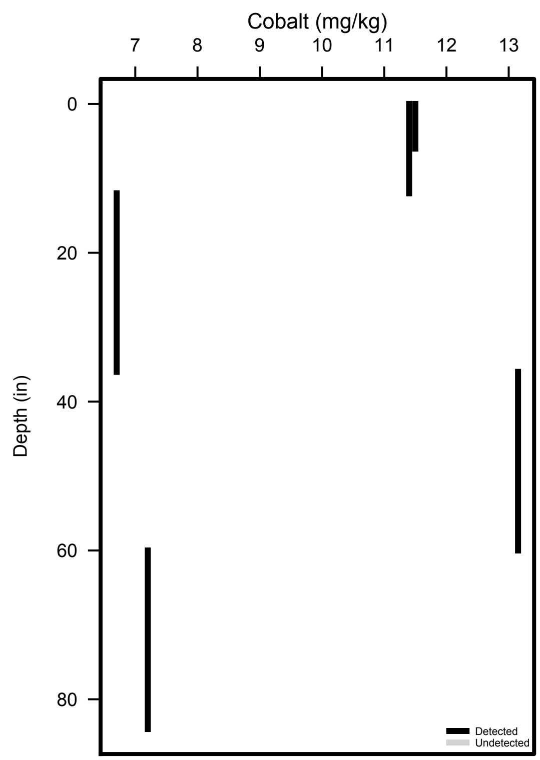

Figure 496. Cobalt
at Core Location RM692C1.

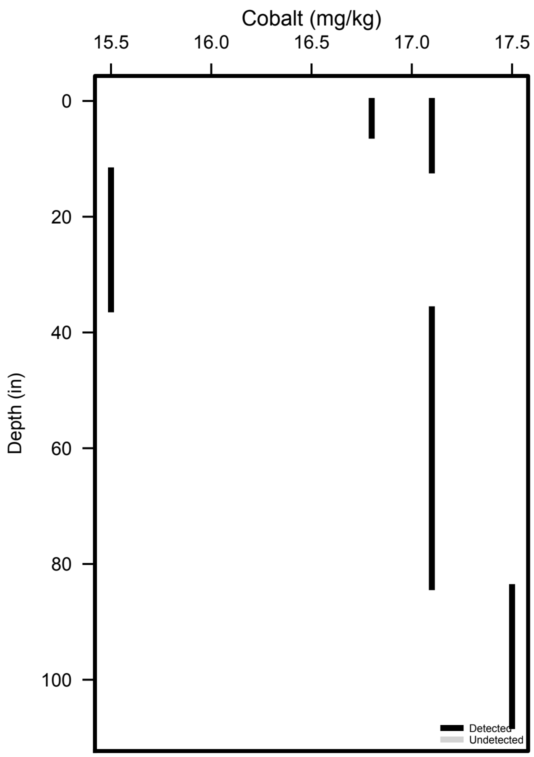

Figure 497. Cobalt
at Core Location RM704C1.

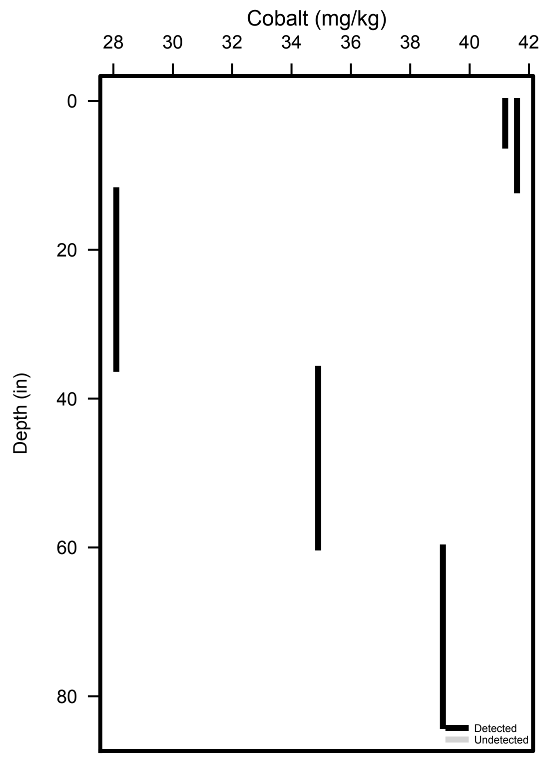

Figure 498. Cobalt
at Core Location RM708C1.

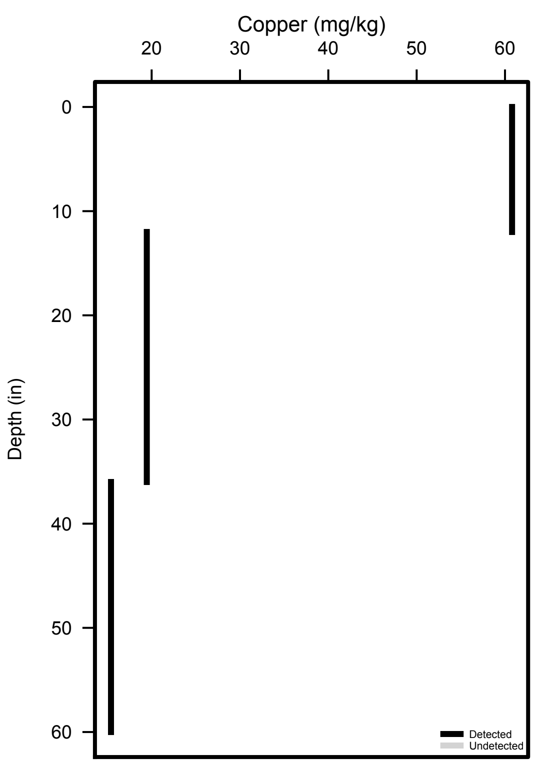

Figure 499. Copper
at Core Location RM605C1.

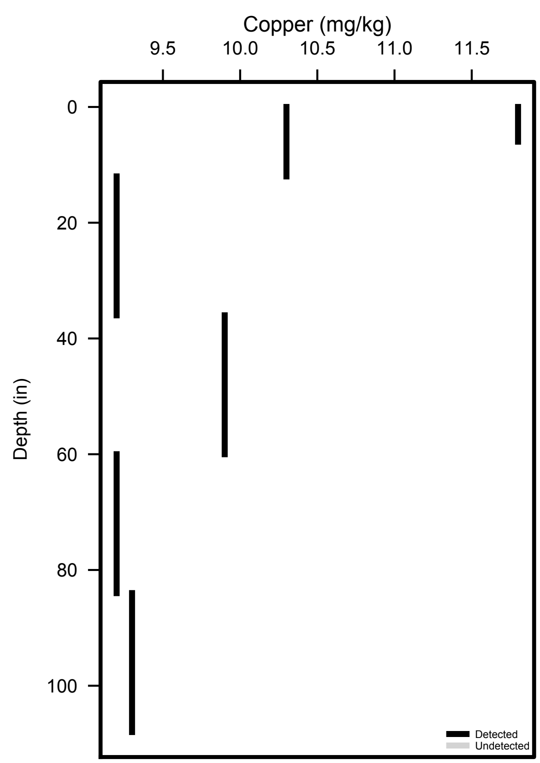

Figure 500. Copper
at Core Location RM622C1.

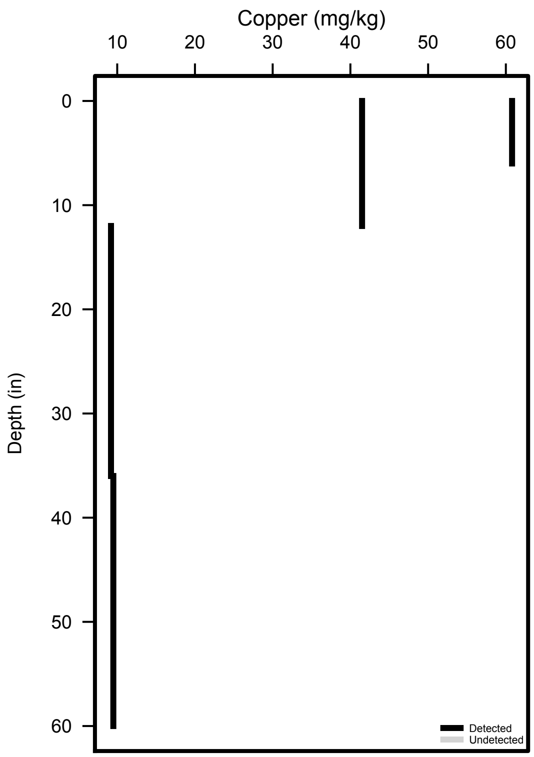

Figure 501. Copper
at Core Location RM637C1.

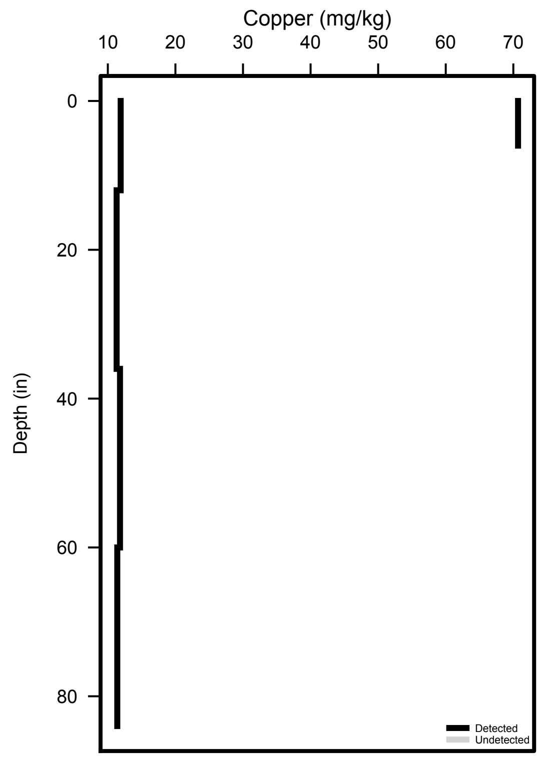

Figure 502. Copper
at Core Location RM644C1.

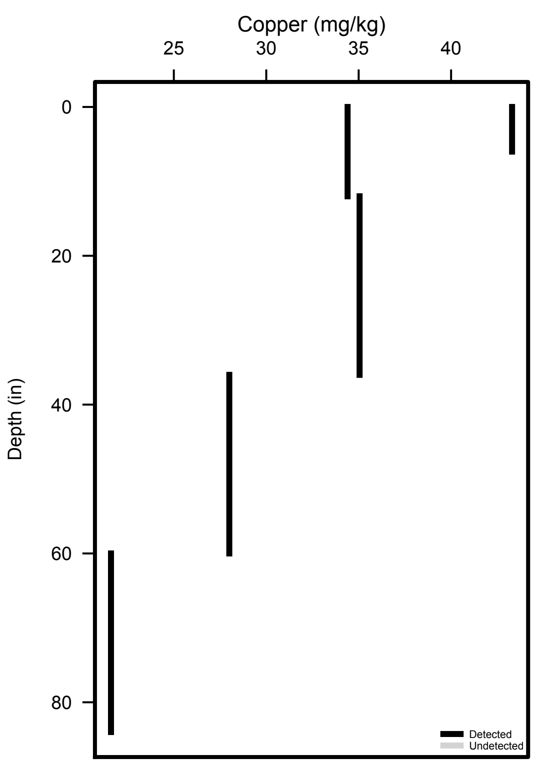

Figure 503. Copper
at Core Location RM661C1.

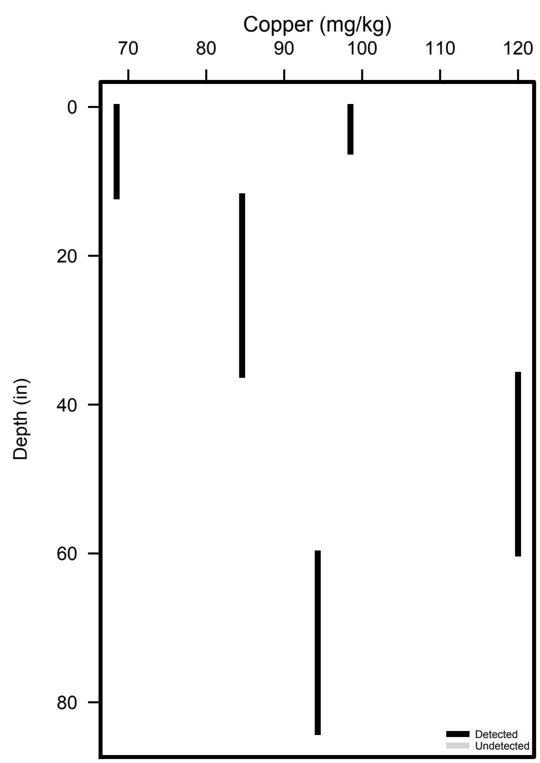

Figure 504. Copper
at Core Location RM676C1.

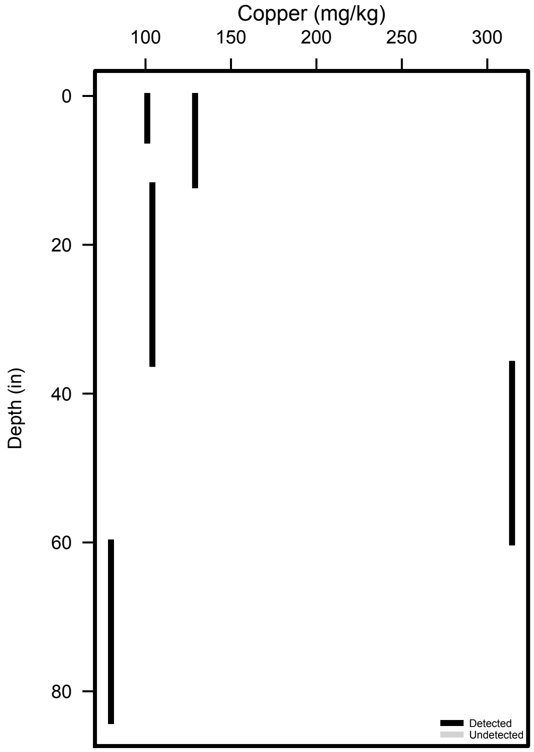

Figure 505. Copper
at Core Location RM692C1.

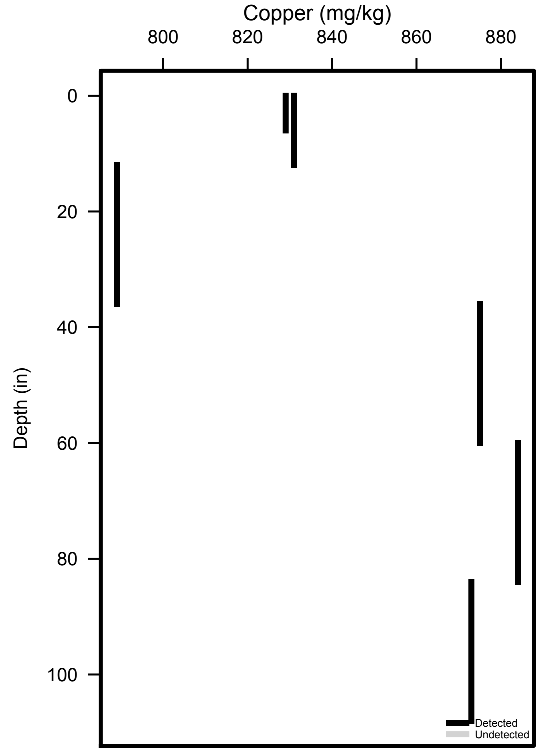

Figure 506. Copper
at Core Location RM704C1.

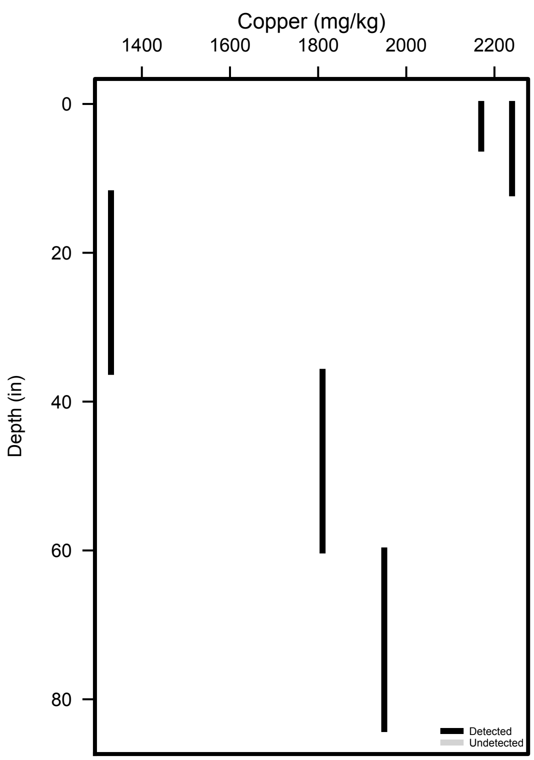

Figure 507. Copper
at Core Location RM708C1.

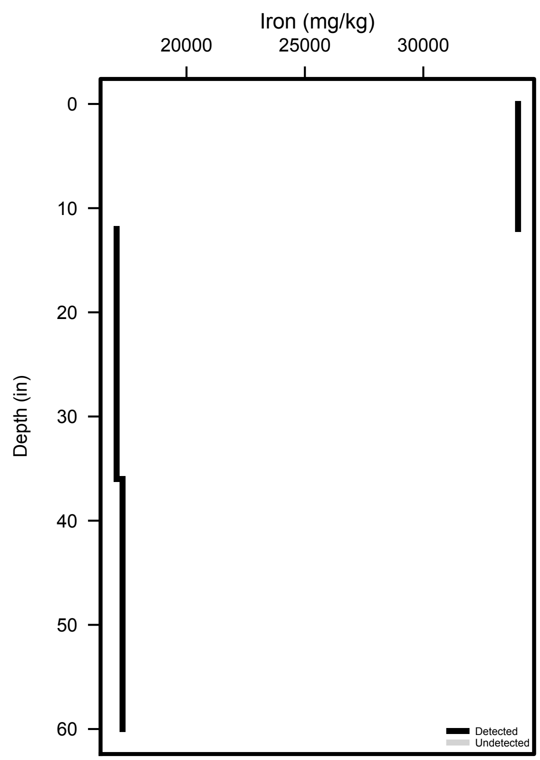

Figure 508. Iron
at Core Location RM605C1.

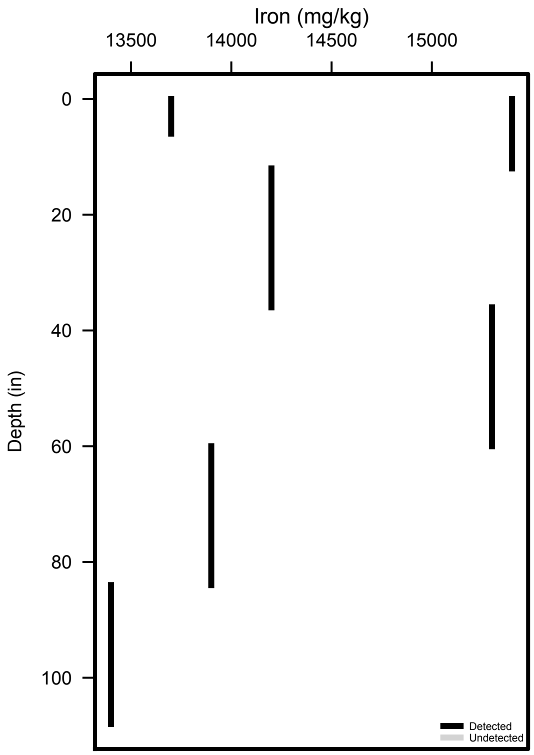

Figure 509. Iron
at Core Location RM622C1.

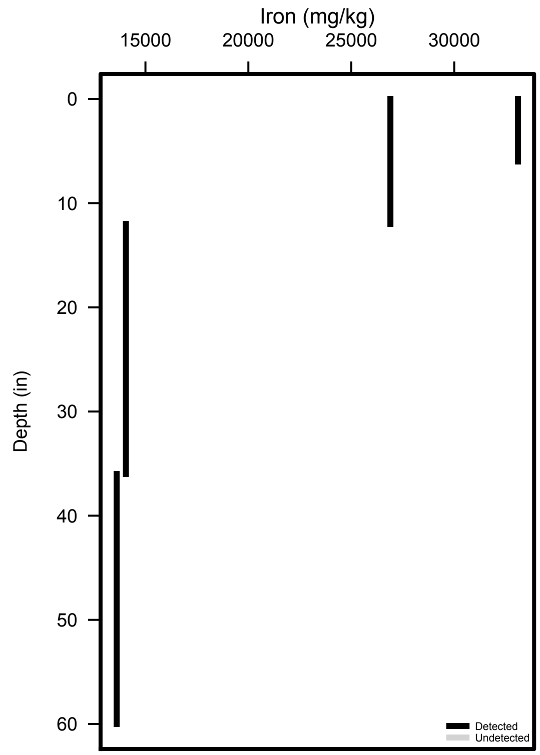

Figure 510. Iron
at Core Location RM637C1.

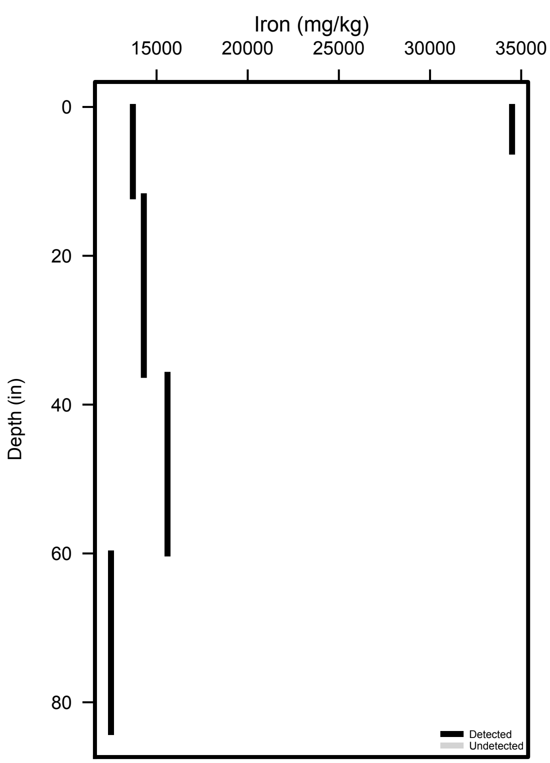

Figure 511. Iron
at Core Location RM644C1.

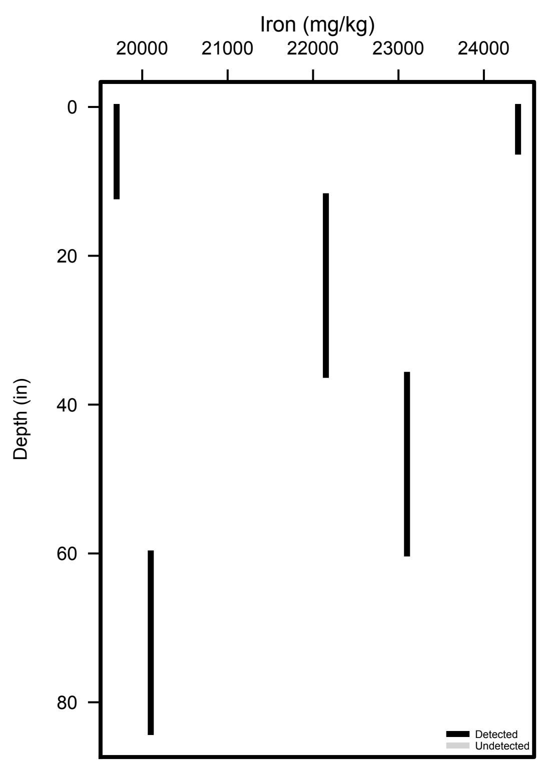

Figure 512. Iron
at Core Location RM661C1.

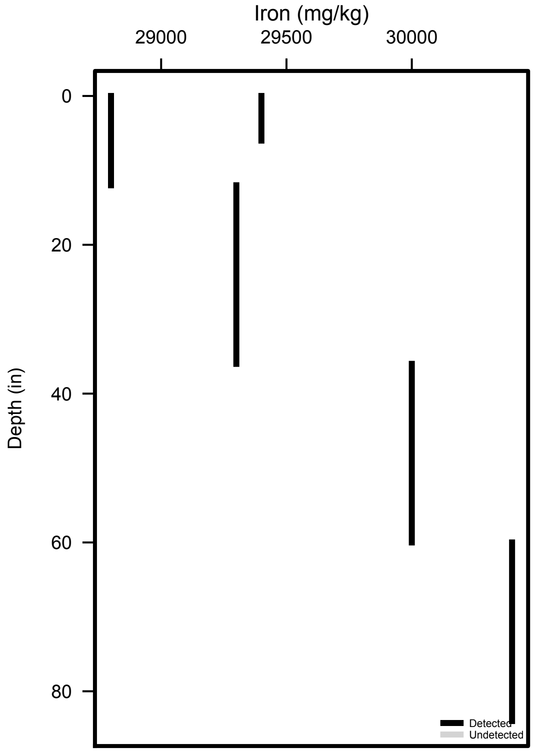

Figure 513. Iron
at Core Location RM676C1.

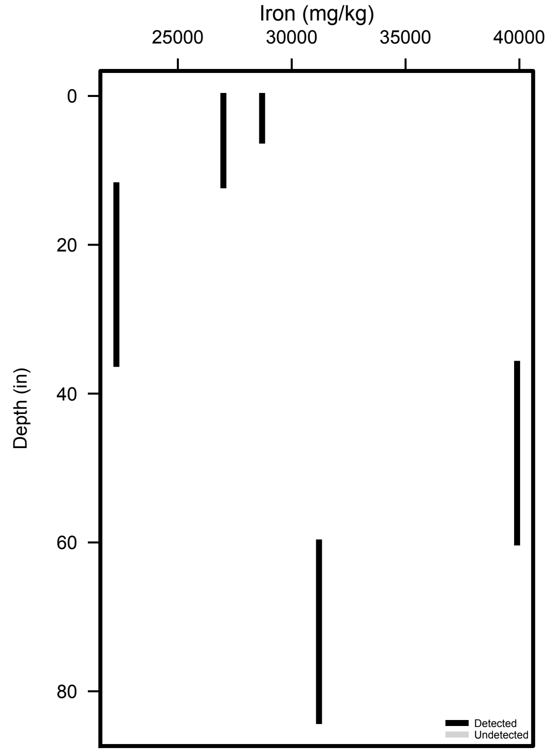

Figure 514. Iron
at Core Location RM692C1.

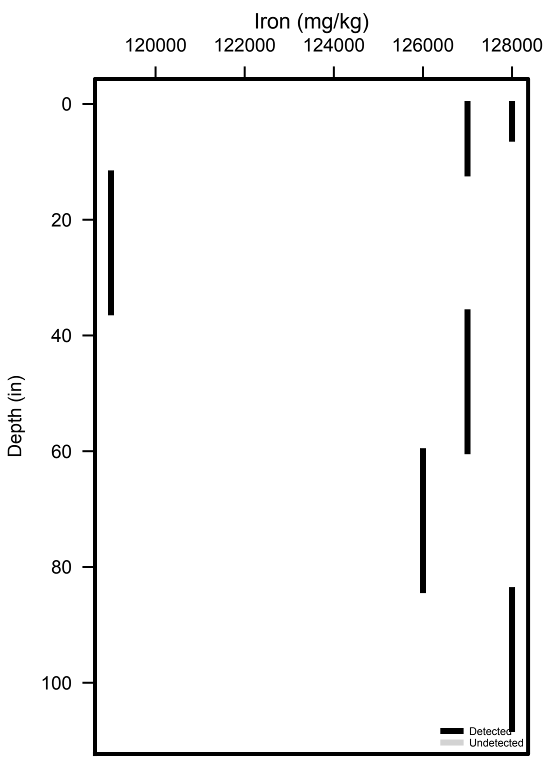

Figure 515. Iron
at Core Location RM704C1.

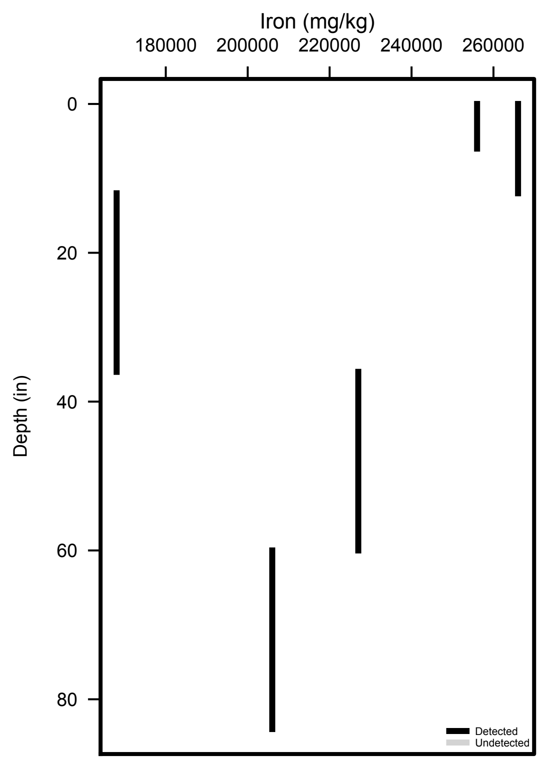

Figure 516. Iron
at Core Location RM708C1.

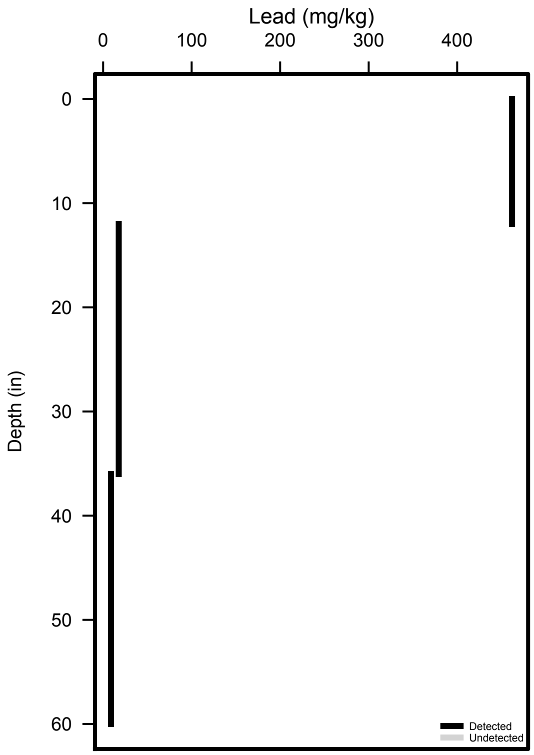

Figure 517. Lead
at Core Location RM605C1.

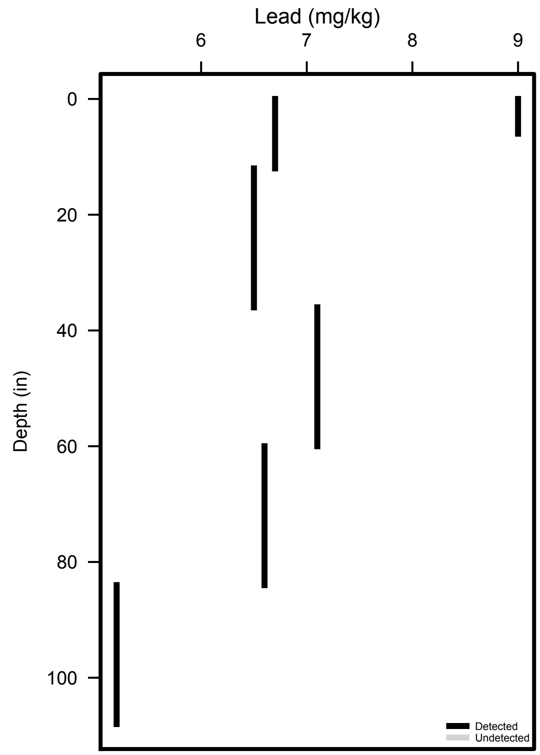

Figure 518. Lead
at Core Location RM622C1.

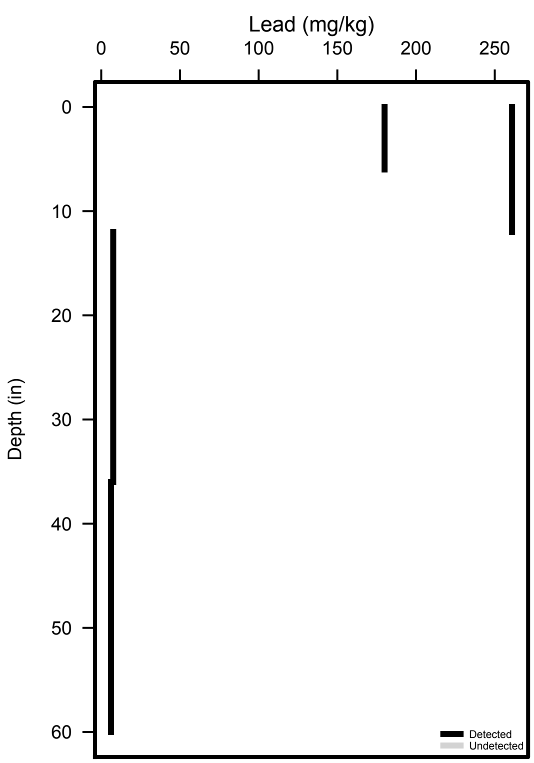

Figure 519. Lead
at Core Location RM637C1.

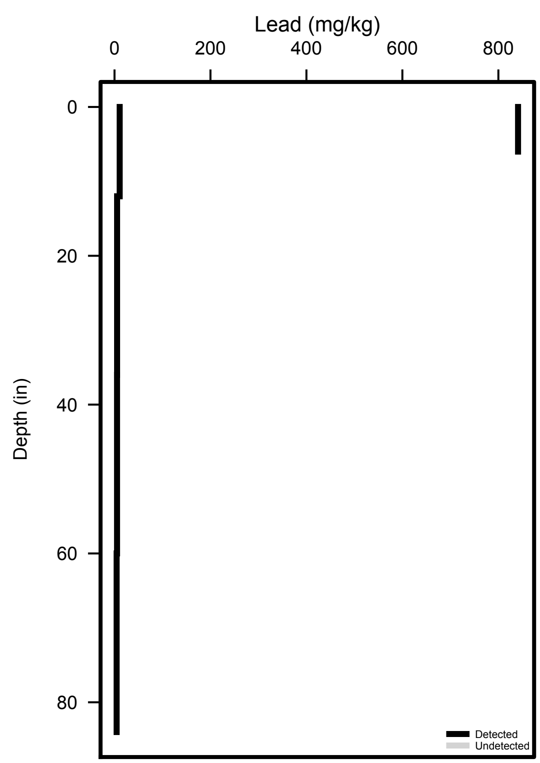

Figure 520. Lead
at Core Location RM644C1.

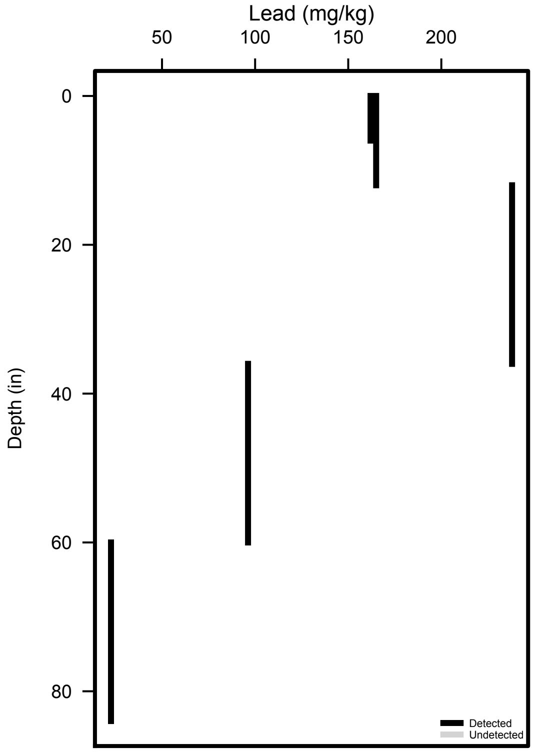

Figure 521. Lead
at Core Location RM661C1.

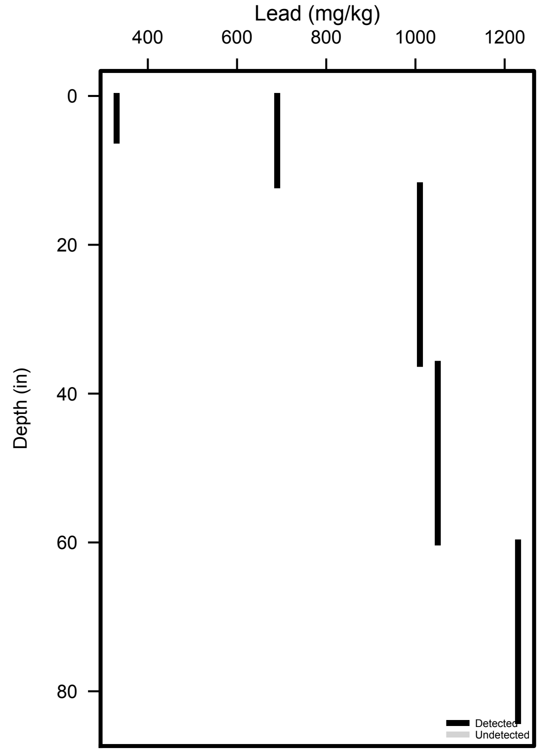

Figure 522. Lead
at Core Location RM676C1.

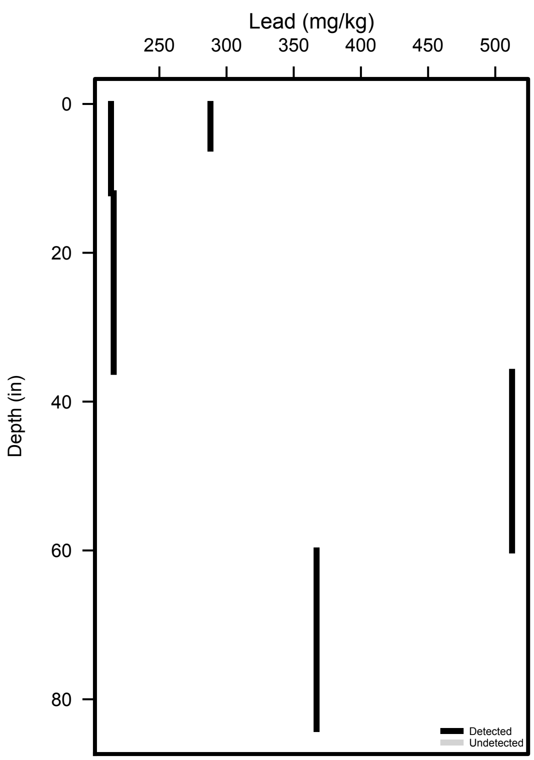

Figure 523. Lead
at Core Location RM692C1.

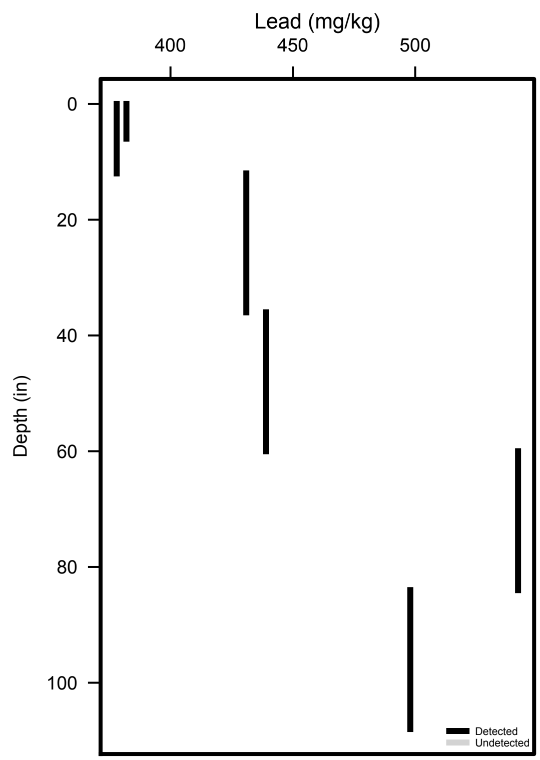

Figure 524. Lead
at Core Location RM704C1.

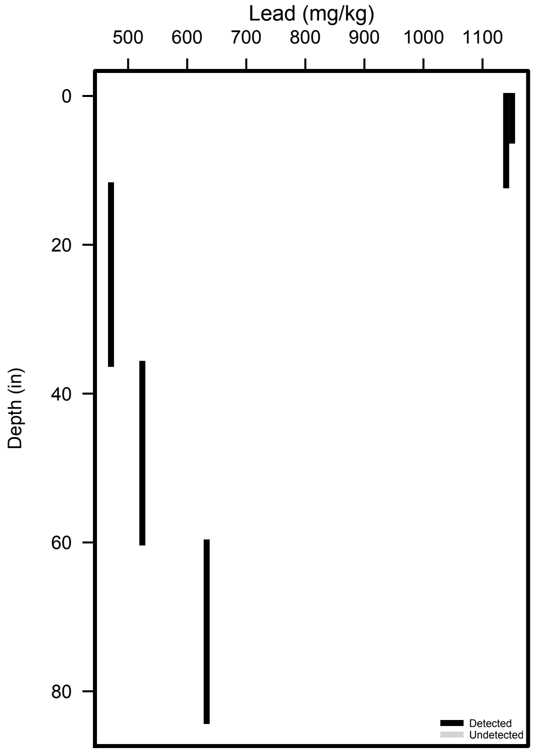

Figure 525. Lead
at Core Location RM708C1.

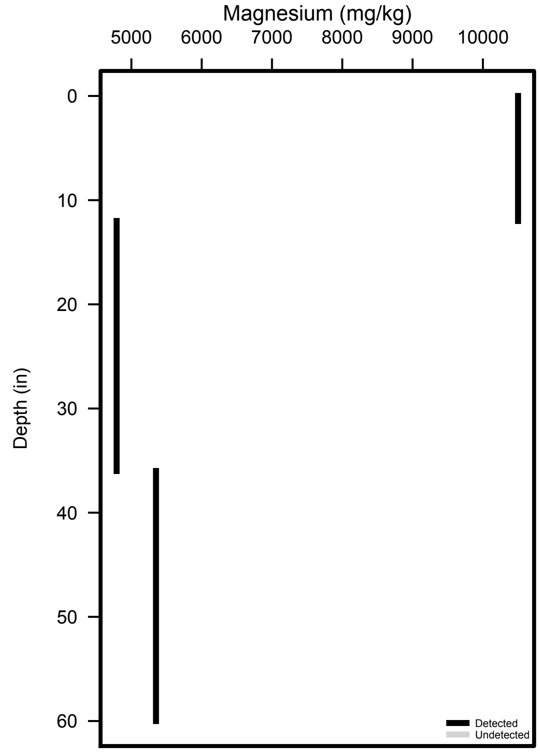

Figure 526. Magnesium
at Core Location RM605C1.

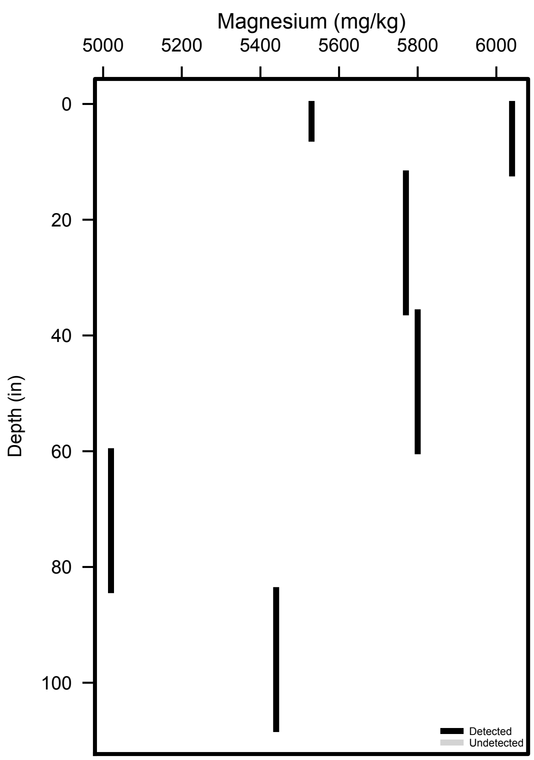

Figure 527. Magnesium
at Core Location RM622C1.

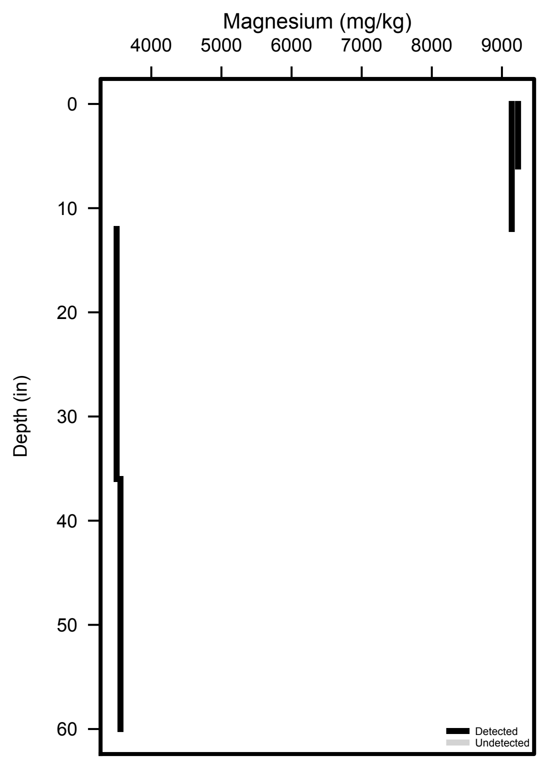

Figure 528. Magnesium
at Core Location RM637C1.

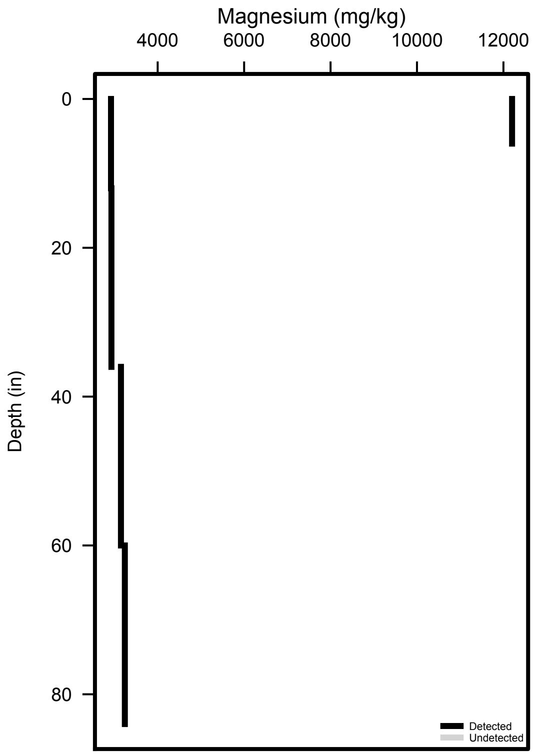

Figure 529. Magnesium
at Core Location RM644C1.

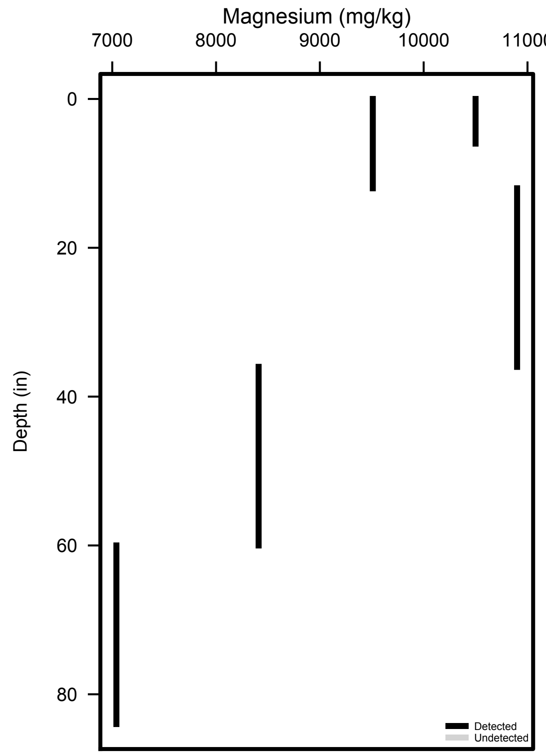

Figure 530. Magnesium
at Core Location RM661C1.

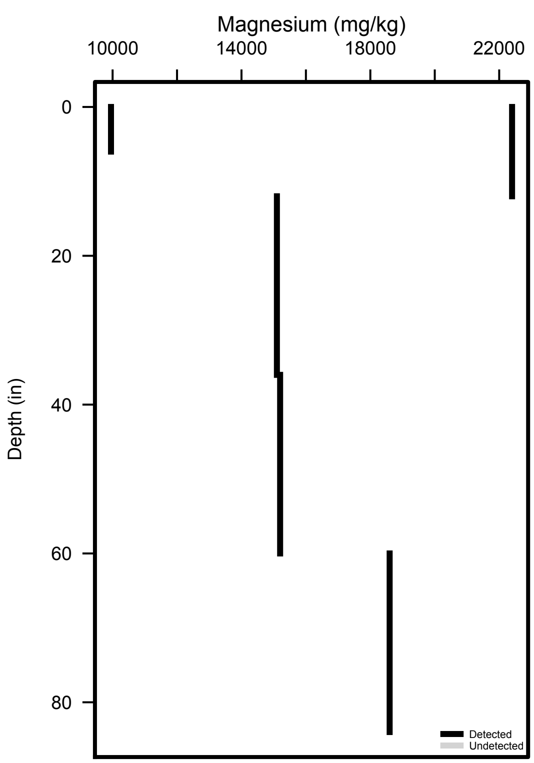

Figure 531. Magnesium
at Core Location RM676C1.

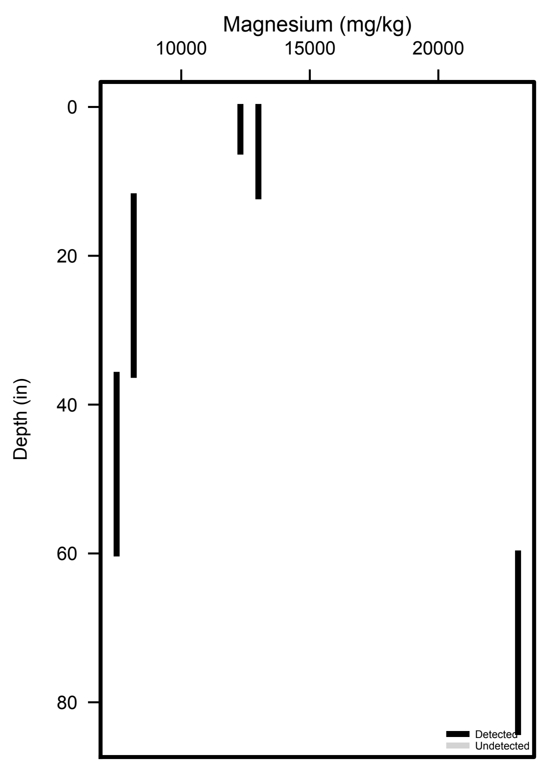

Figure 532. Magnesium
at Core Location RM692C1.

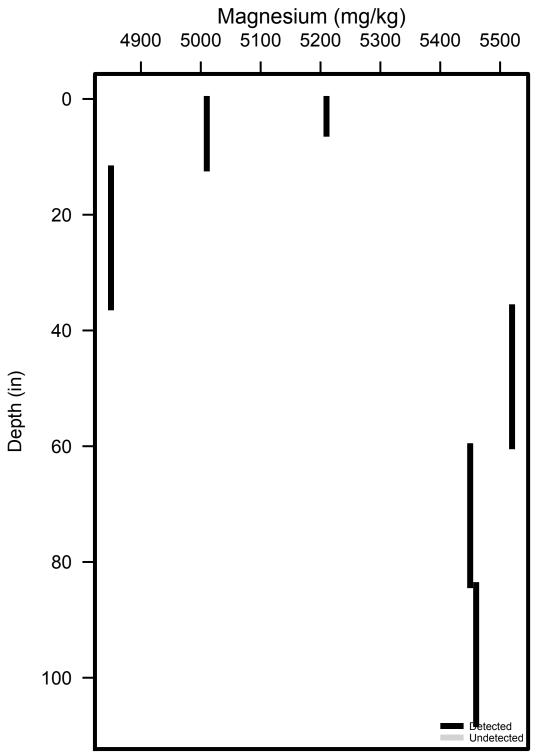

Figure 533. Magnesium
at Core Location RM704C1.

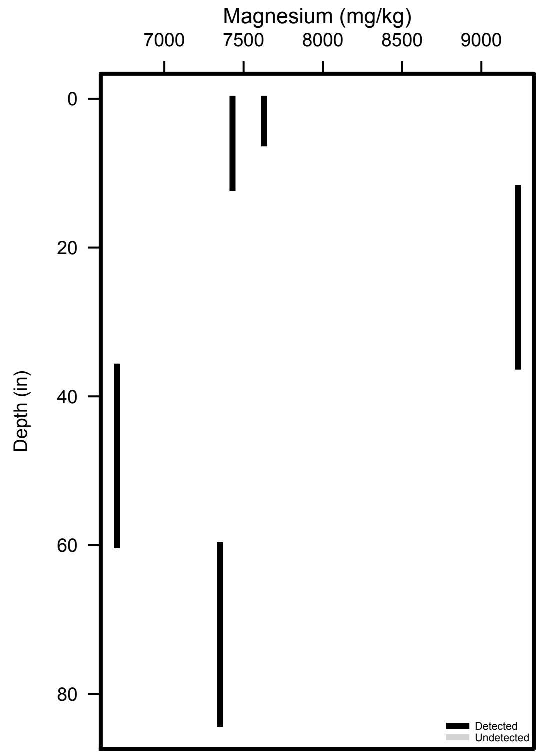

Figure 534. Magnesium
at Core Location RM708C1.

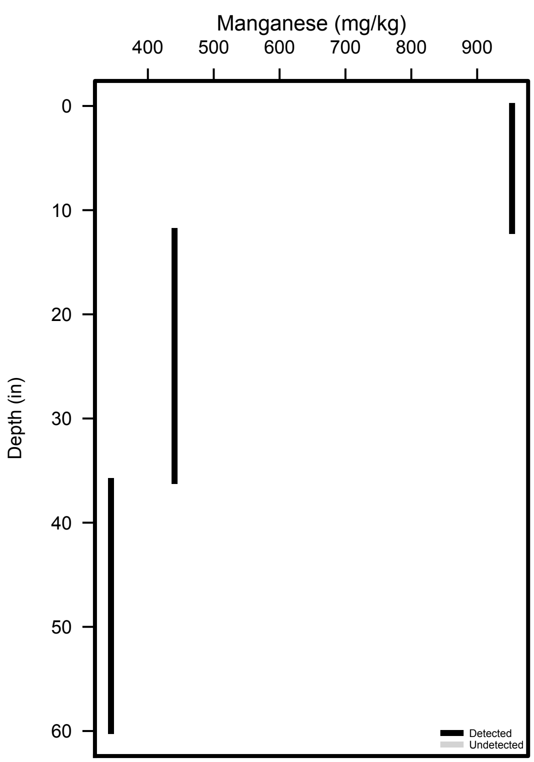

Figure 535. Manganese
at Core Location RM605C1.

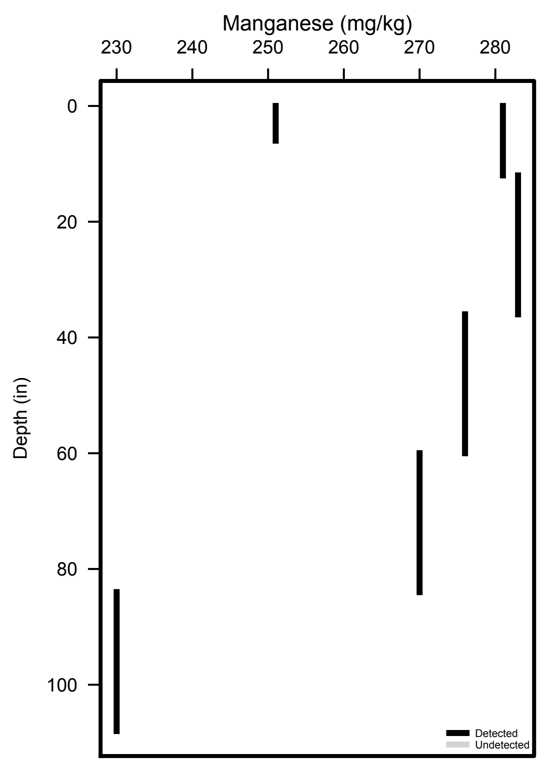

Figure 536. Manganese
at Core Location RM622C1.

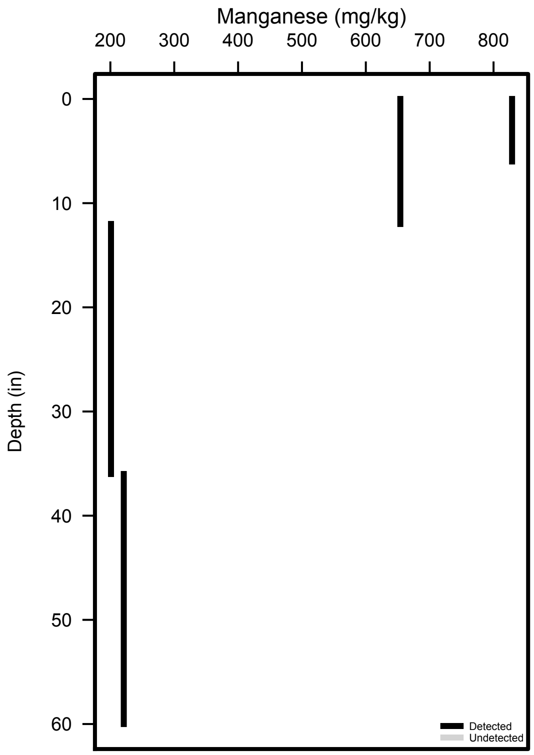

Figure 537. Manganese
at Core Location RM637C1.

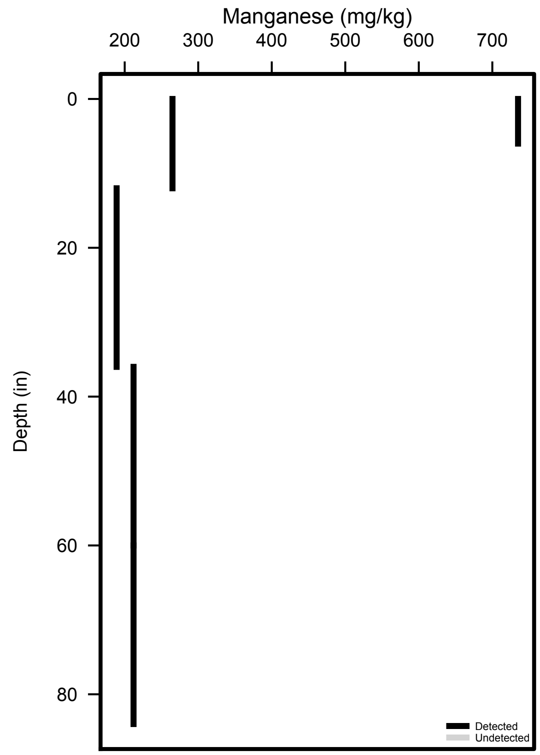

Figure 538. Manganese
at Core Location RM644C1.

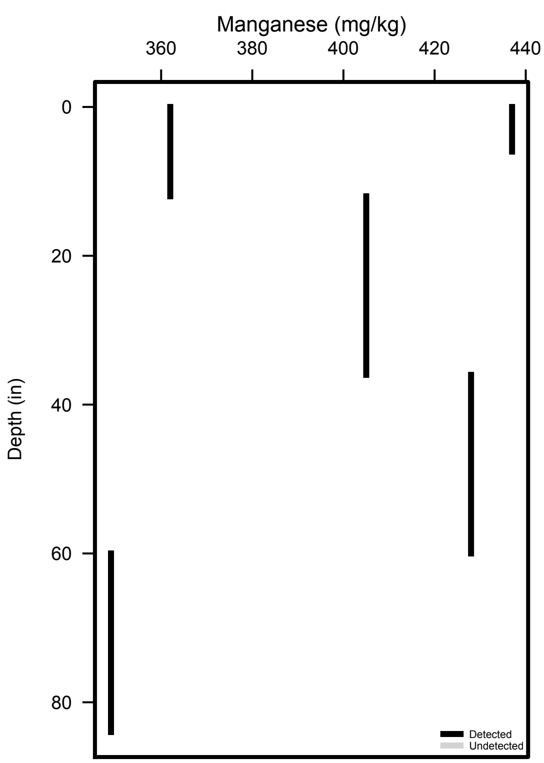

Figure 539. Manganese
at Core Location RM661C1.

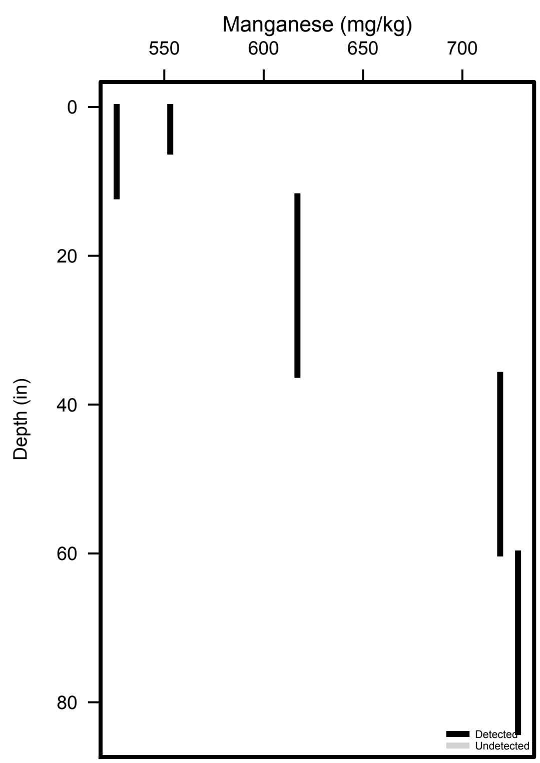

Figure 540. Manganese
at Core Location RM676C1.

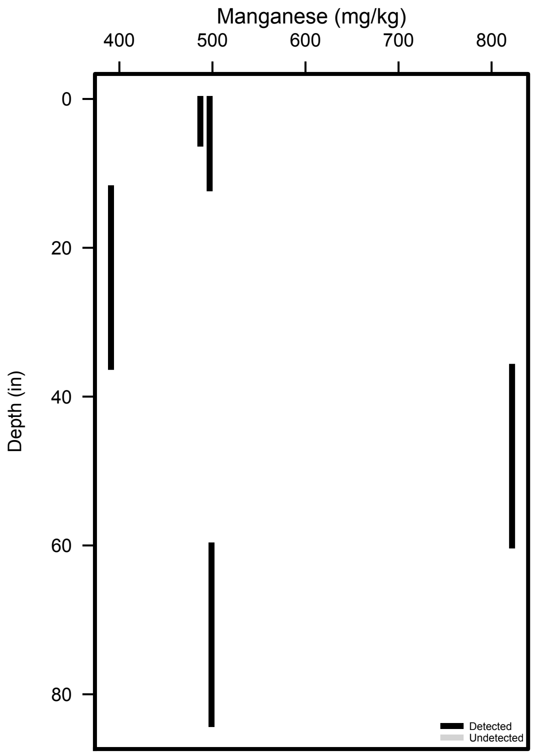

Figure 541. Manganese
at Core Location RM692C1.

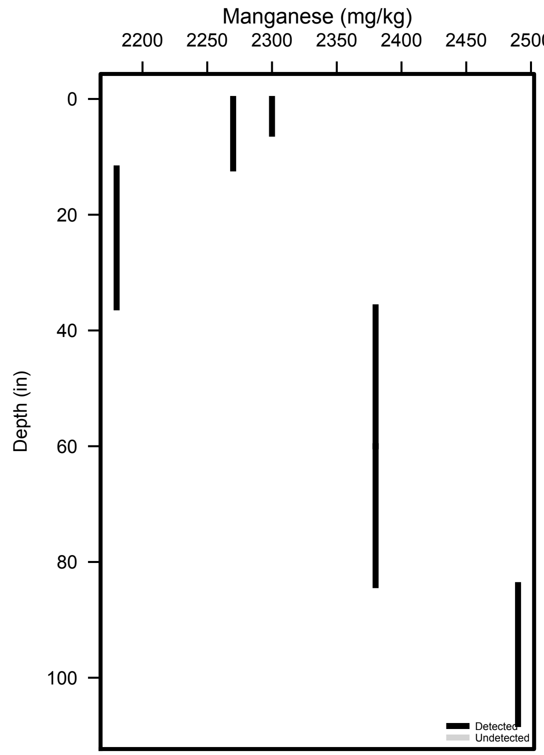

Figure 542. Manganese
at Core Location RM704C1.

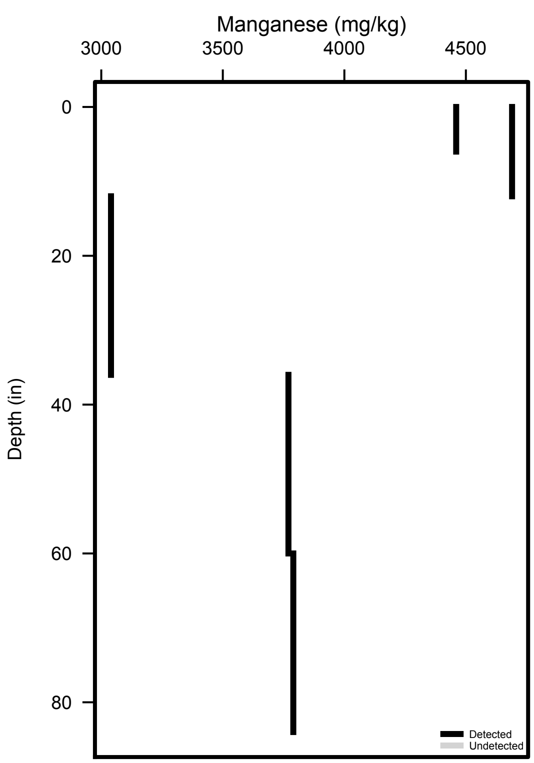

Figure 543. Manganese
at Core Location RM708C1.

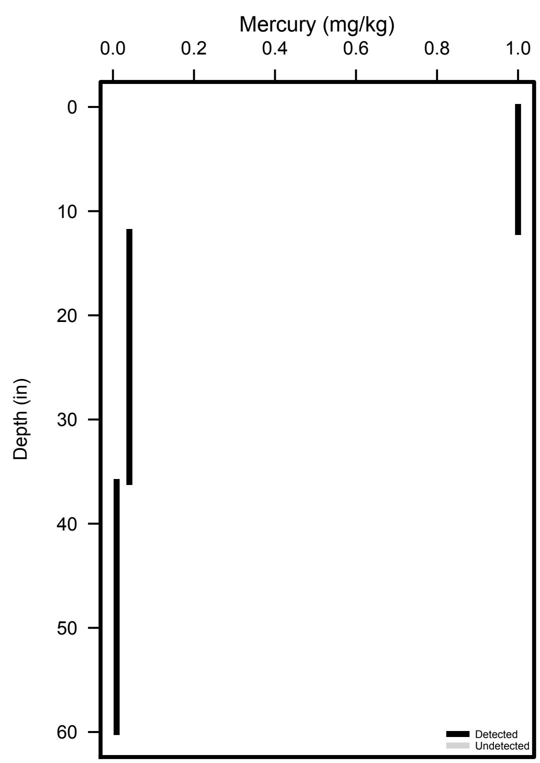

Figure 544. Mercury
at Core Location RM605C1.

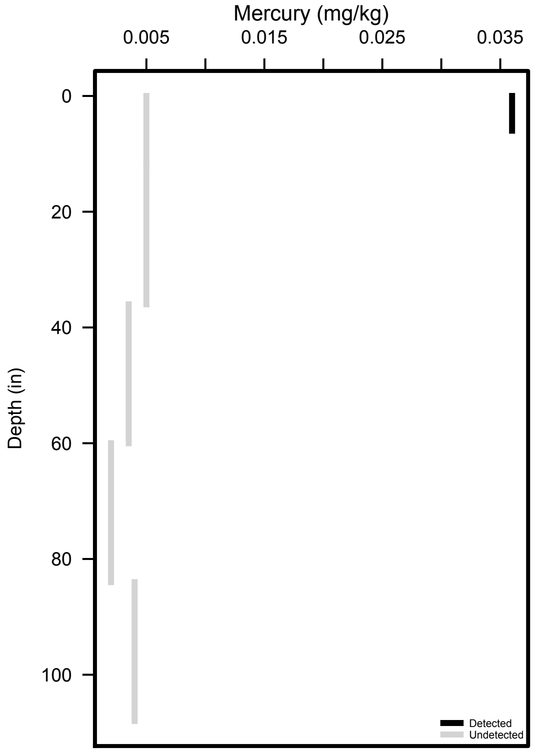

Figure 545. Mercury
at Core Location RM622C1.

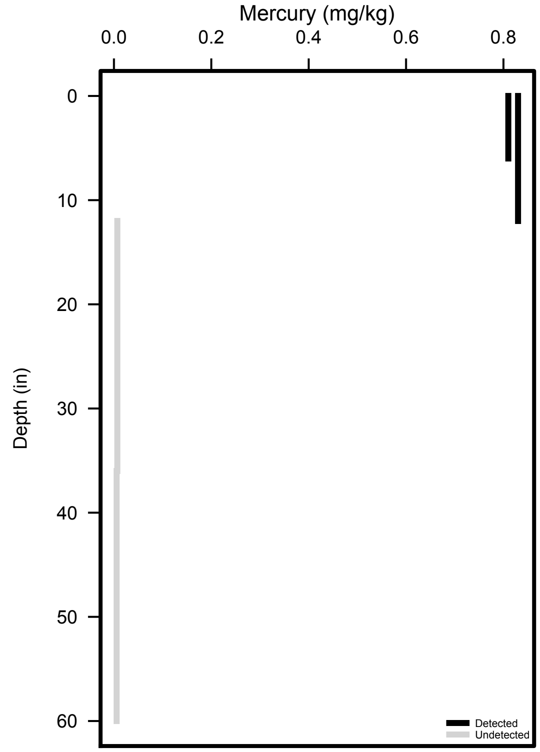

Figure 546. Mercury
at Core Location RM637C1.

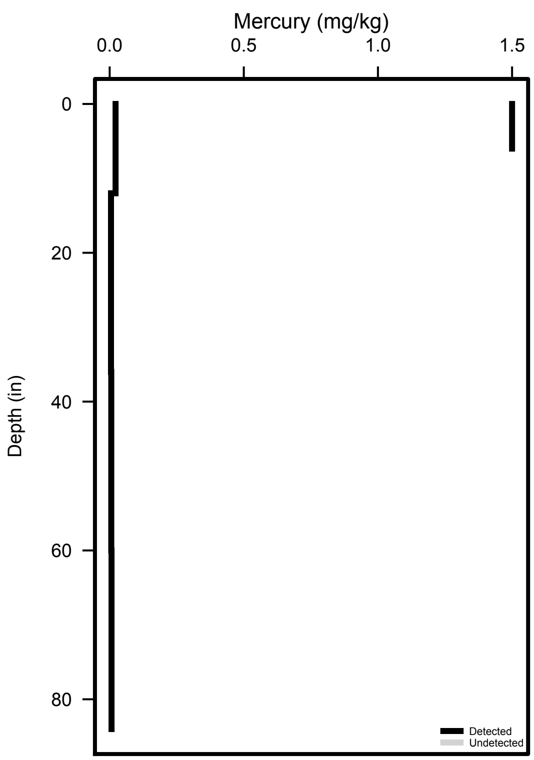

Figure 547. Mercury
at Core Location RM644C1.

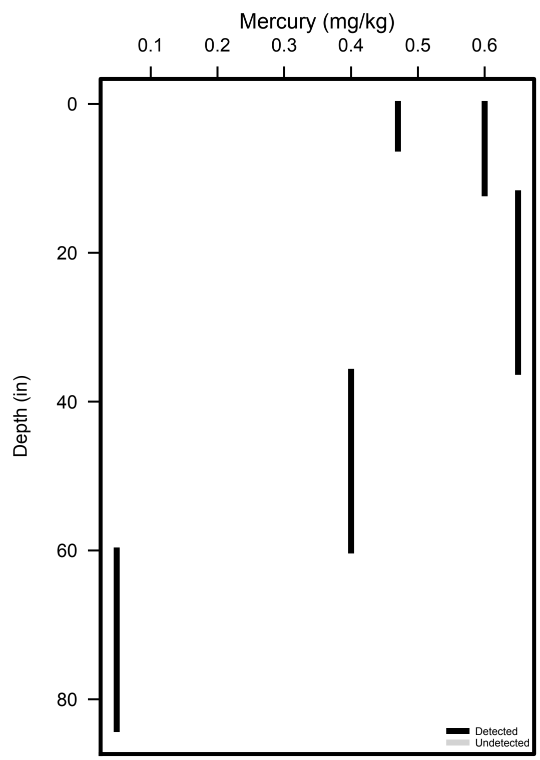

Figure 548. Mercury
at Core Location RM661C1.

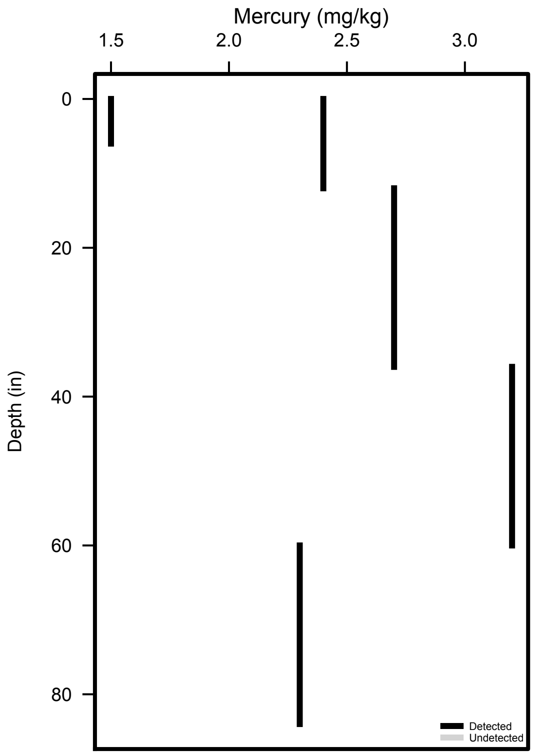

Figure 549. Mercury
at Core Location RM676C1.

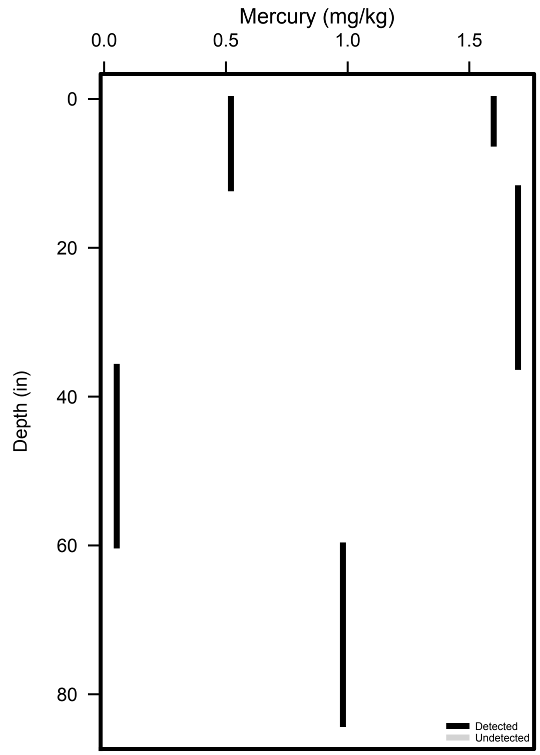

Figure 550. Mercury
at Core Location RM692C1.

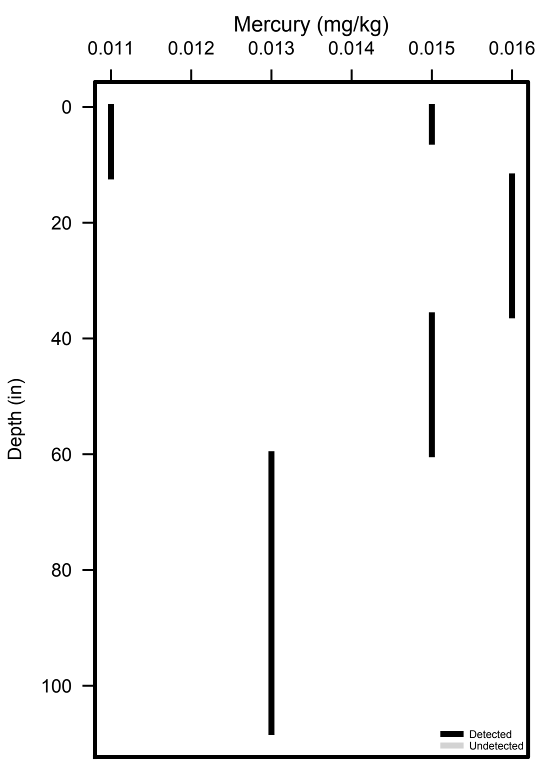

Figure 551. Mercury
at Core Location RM704C1.

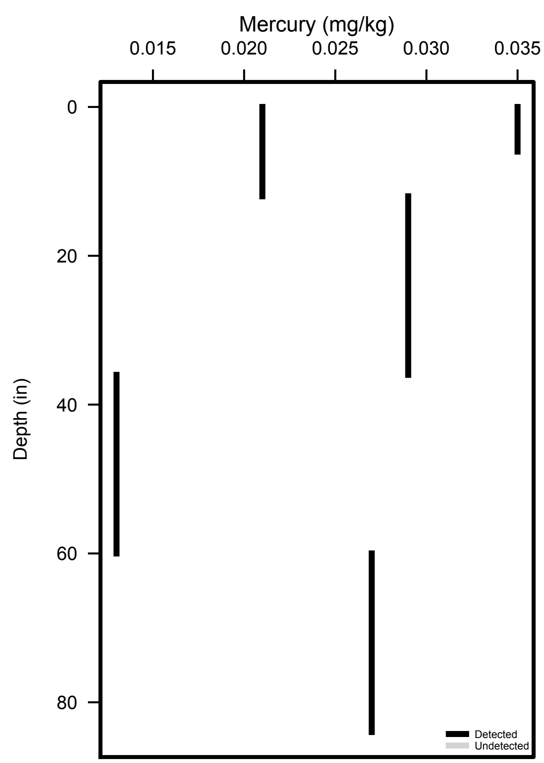

Figure 552. Mercury
at Core Location RM708C1.

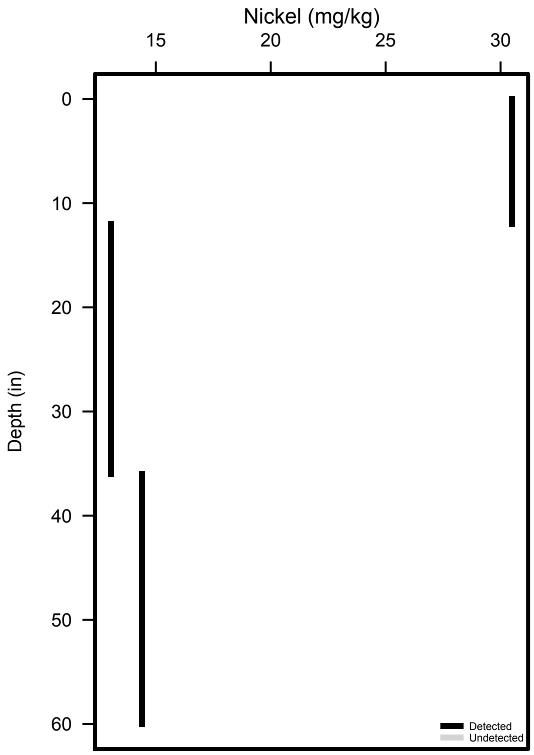

Figure 553. Nickel
at Core Location RM605C1.

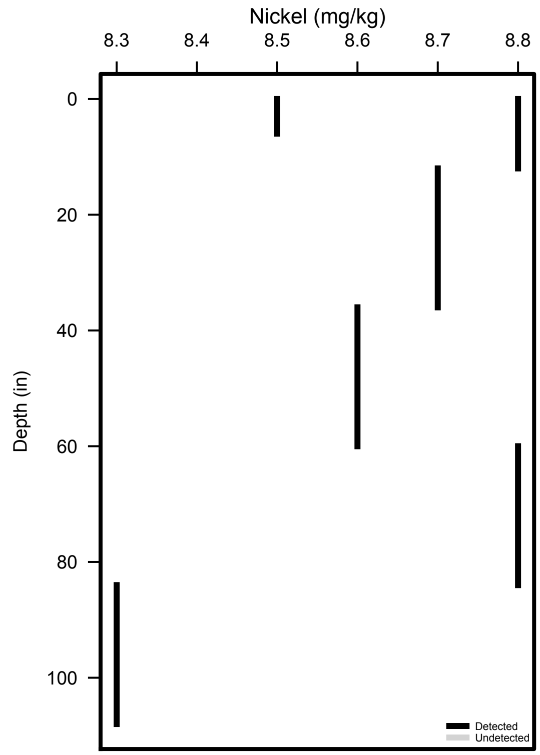

Figure 554. Nickel
at Core Location RM622C1.

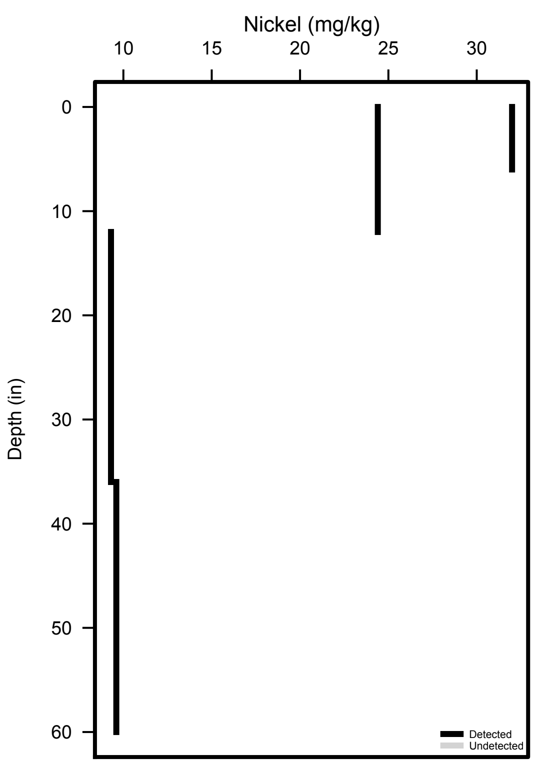

Figure 555. Nickel
at Core Location RM637C1.

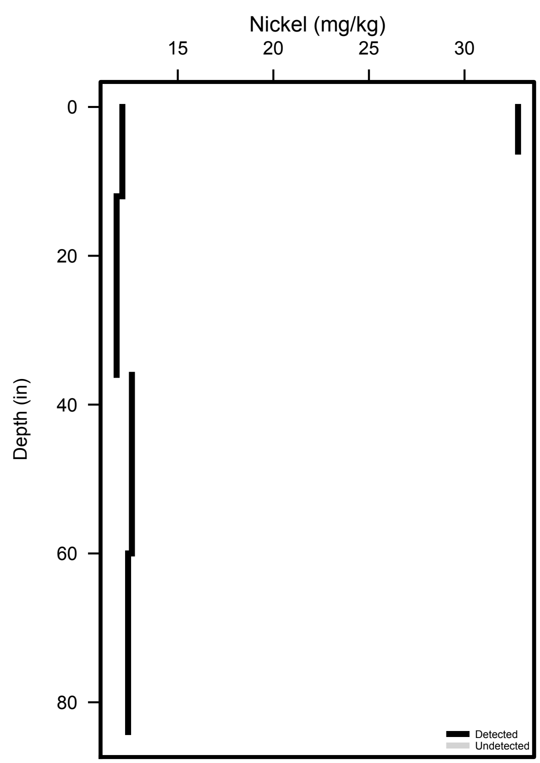

Figure 556. Nickel
at Core Location RM644C1.

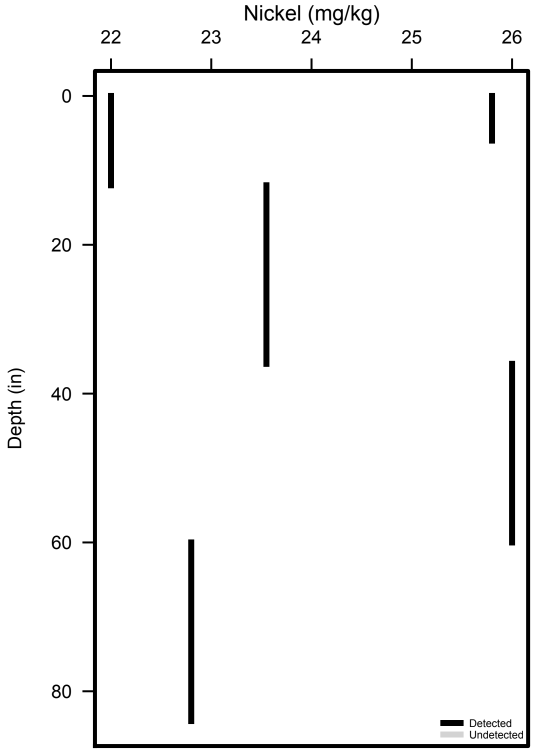

Figure 557. Nickel
at Core Location RM661C1.

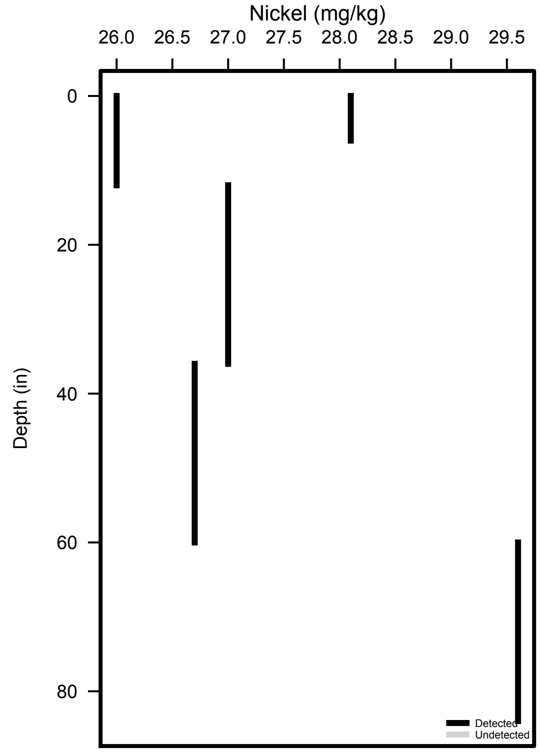

Figure 558. Nickel
at Core Location RM676C1.

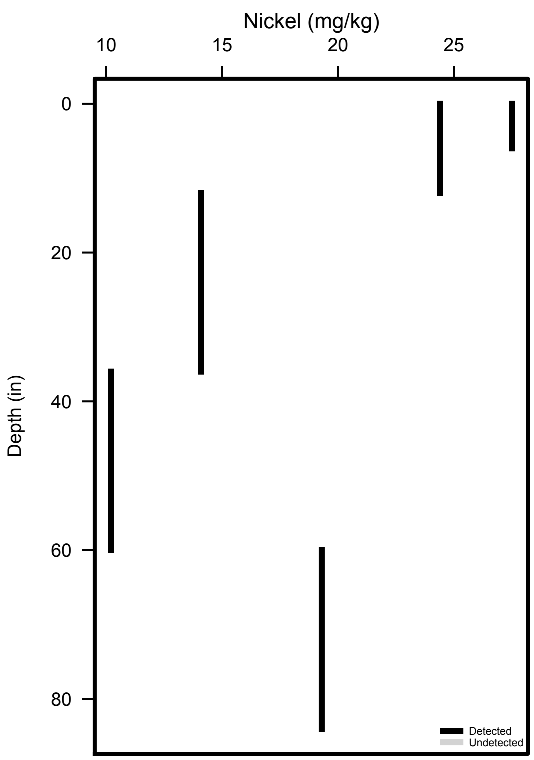

Figure 559. Nickel
at Core Location RM692C1.

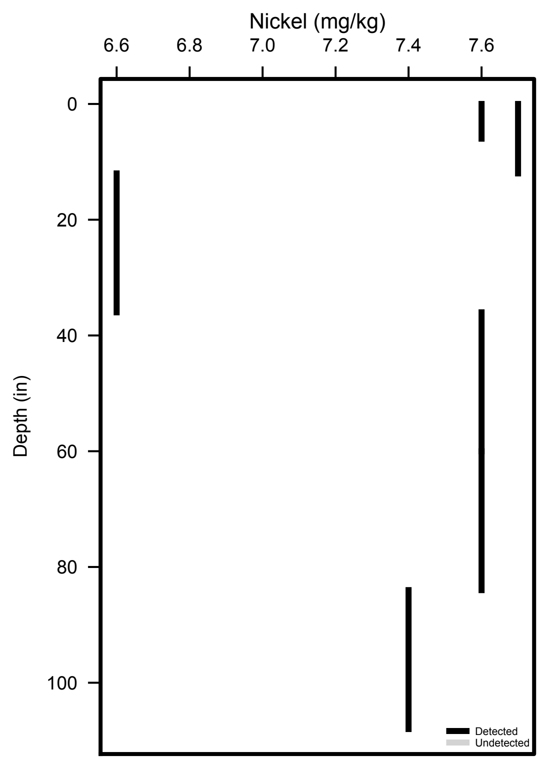

Figure 560. Nickel
at Core Location RM704C1.

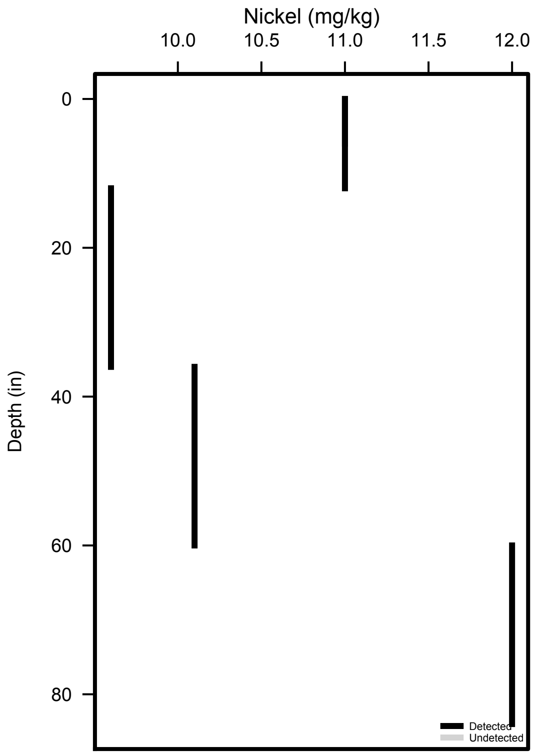

Figure 561. Nickel
at Core Location RM708C1.

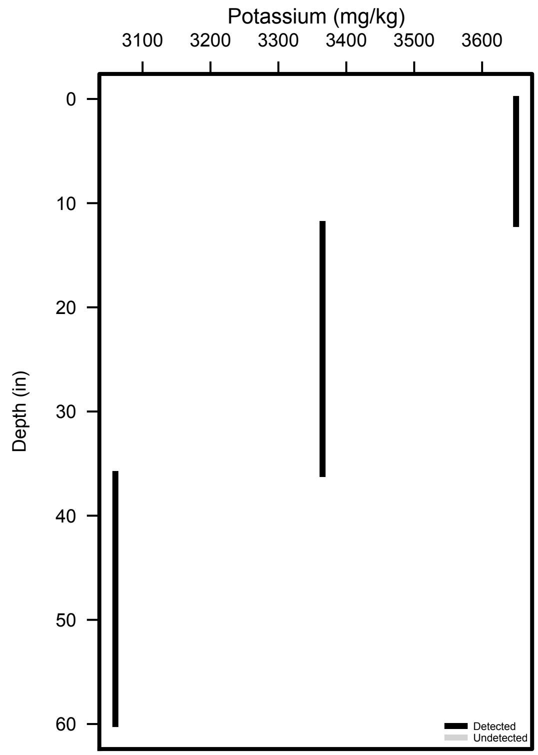

Figure 562. Potassium
at Core Location RM605C1.

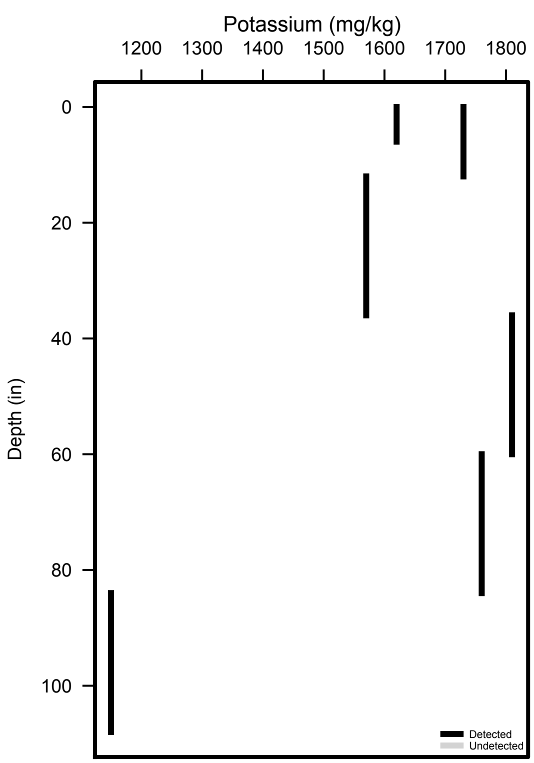

Figure 563. Potassium
at Core Location RM622C1.

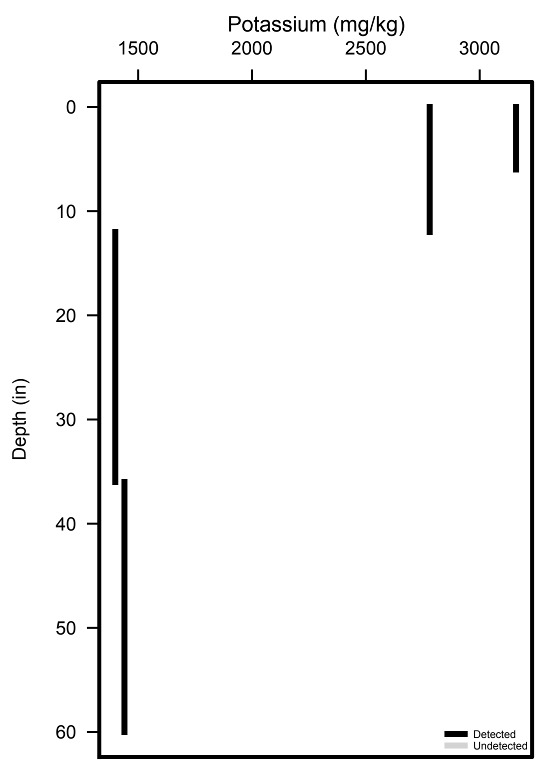

Figure 564. Potassium
at Core Location RM637C1.

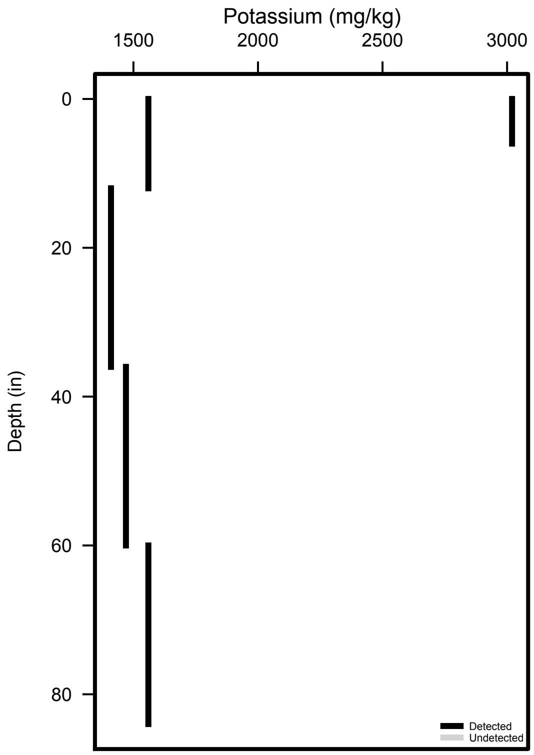

Figure 565. Potassium
at Core Location RM644C1.

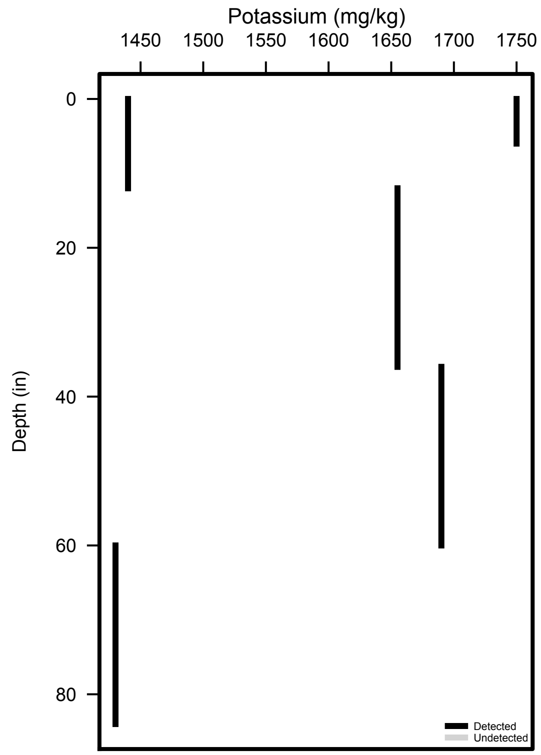

Figure 566. Potassium
at Core Location RM661C1.

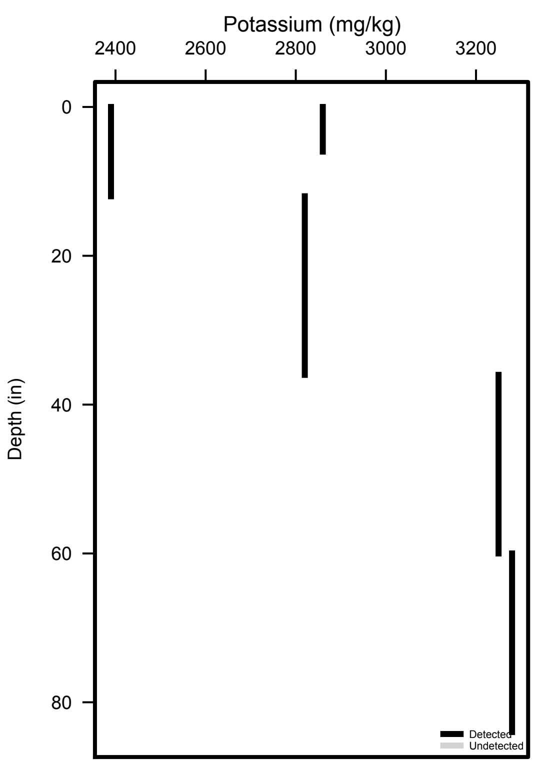

Figure 567. Potassium
at Core Location RM676C1.

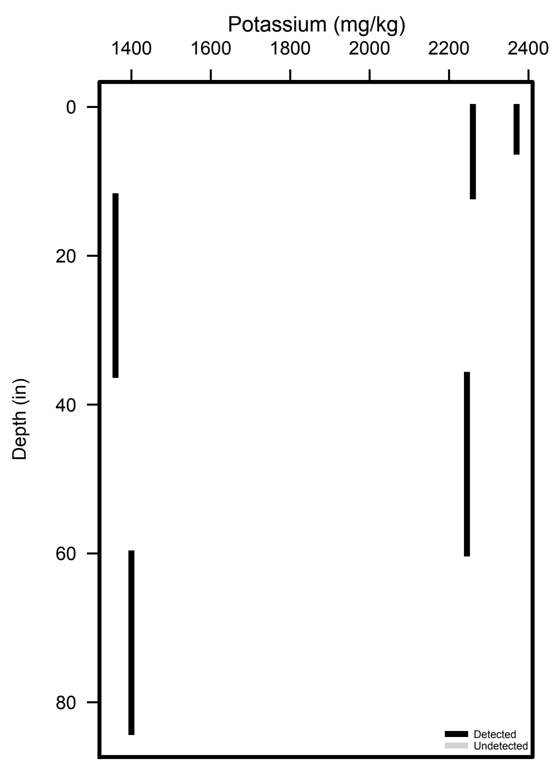

Figure 568. Potassium
at Core Location RM692C1.

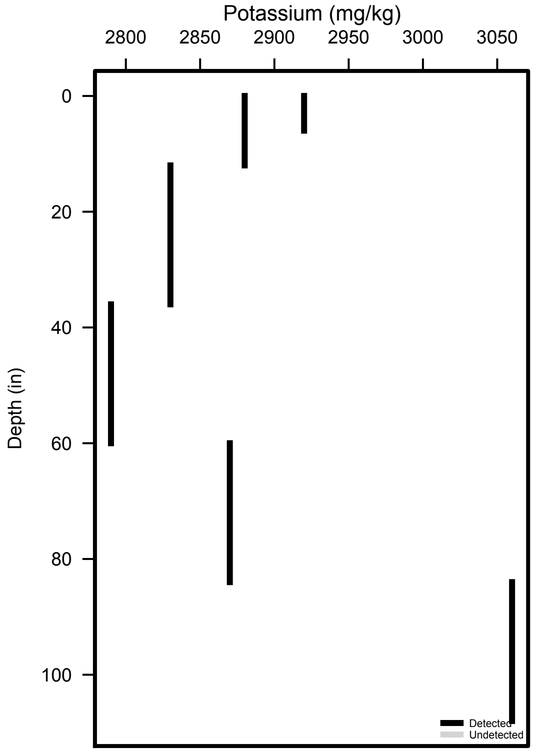

Figure 569. Potassium
at Core Location RM704C1.

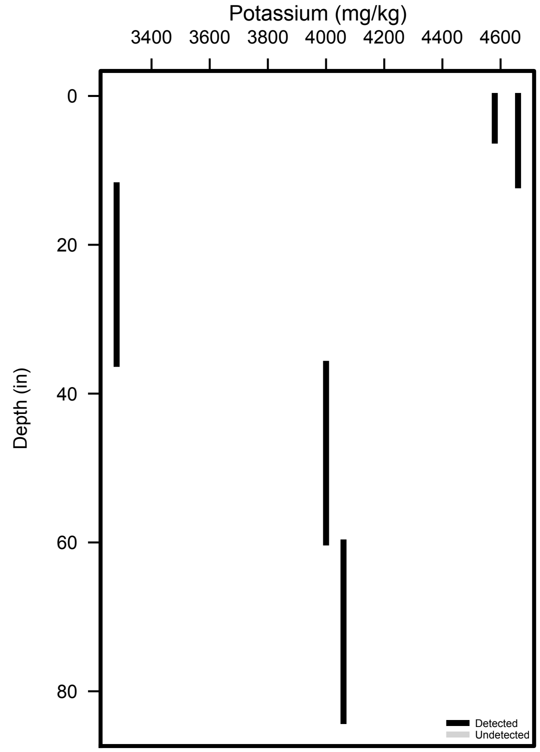

Figure 570. Potassium
at Core Location RM708C1.

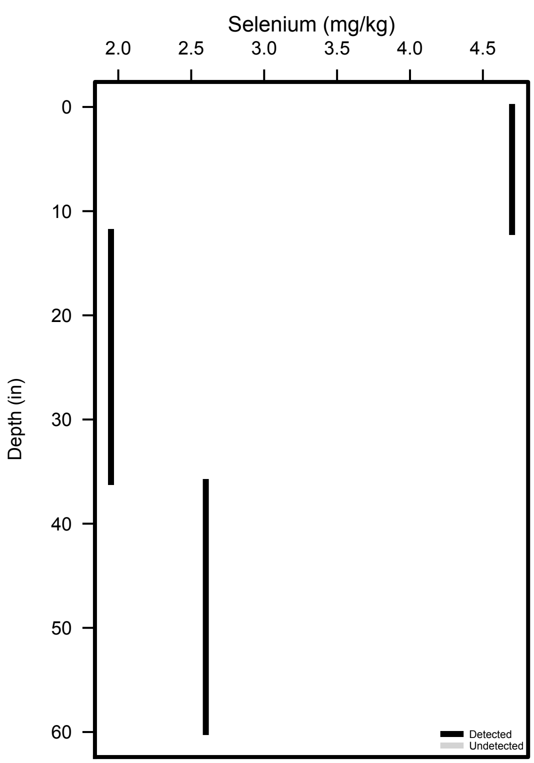

Figure 571. Selenium
at Core Location RM605C1.

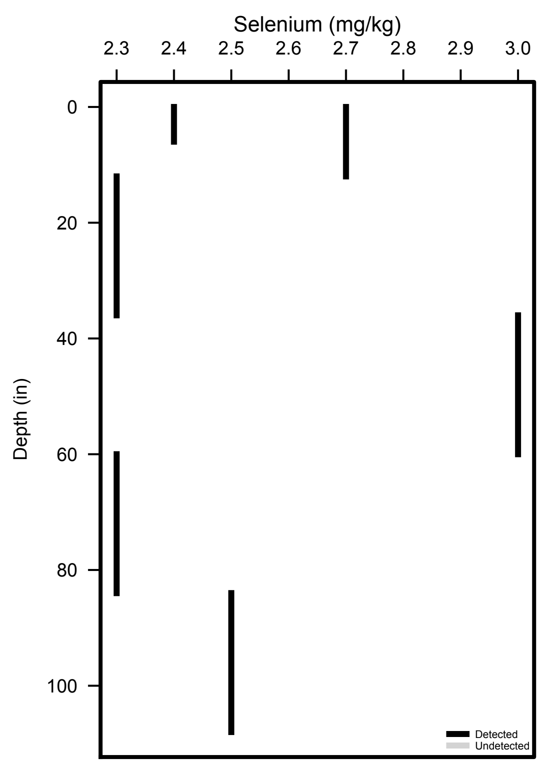

Figure 572. Selenium
at Core Location RM622C1.

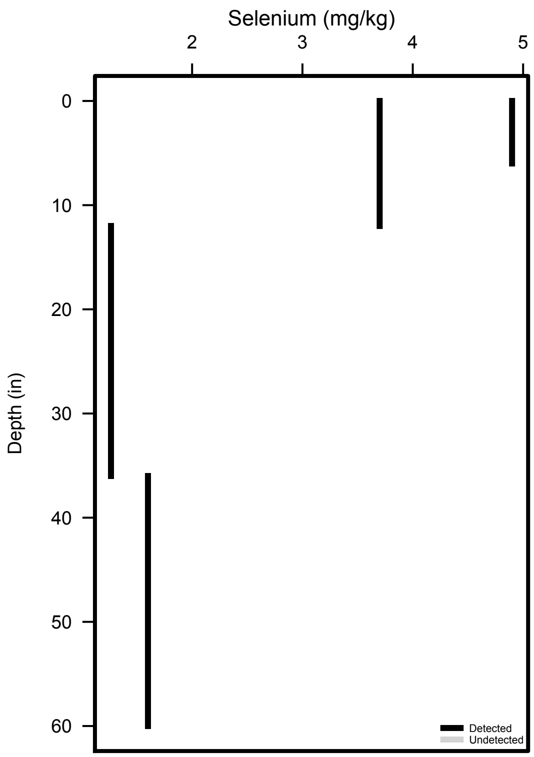

Figure 573. Selenium
at Core Location RM637C1.

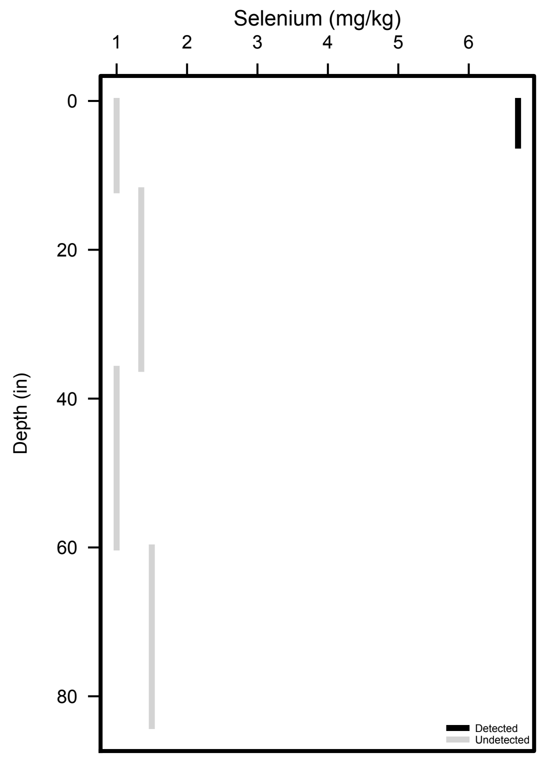

Figure 574. Selenium
at Core Location RM644C1.

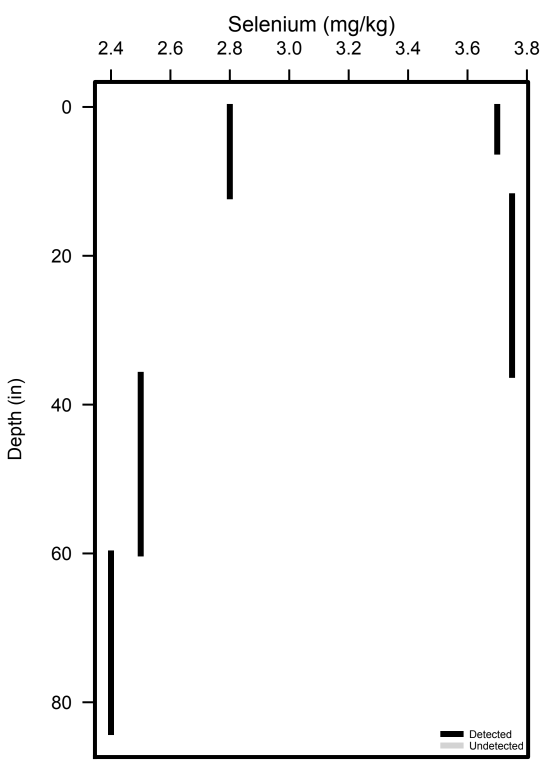

Figure 575. Selenium
at Core Location RM661C1.

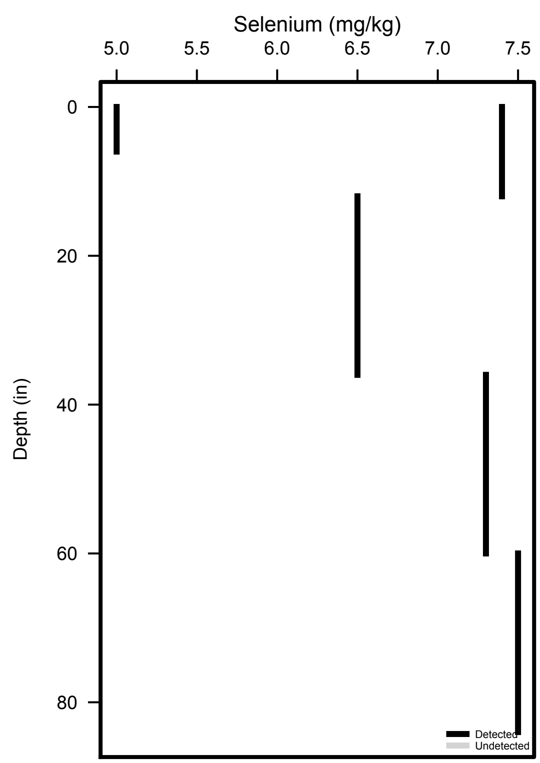

Figure 576. Selenium
at Core Location RM676C1.

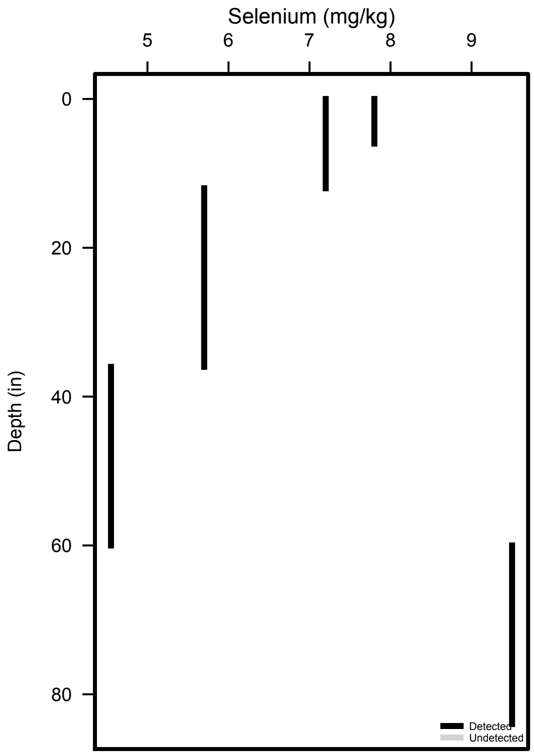

Figure 577. Selenium
at Core Location RM692C1.

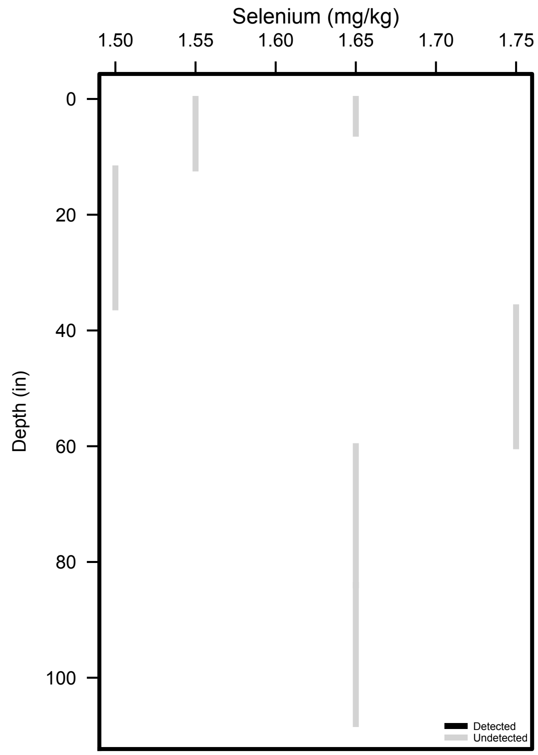

Figure 578. Selenium
at Core Location RM704C1.

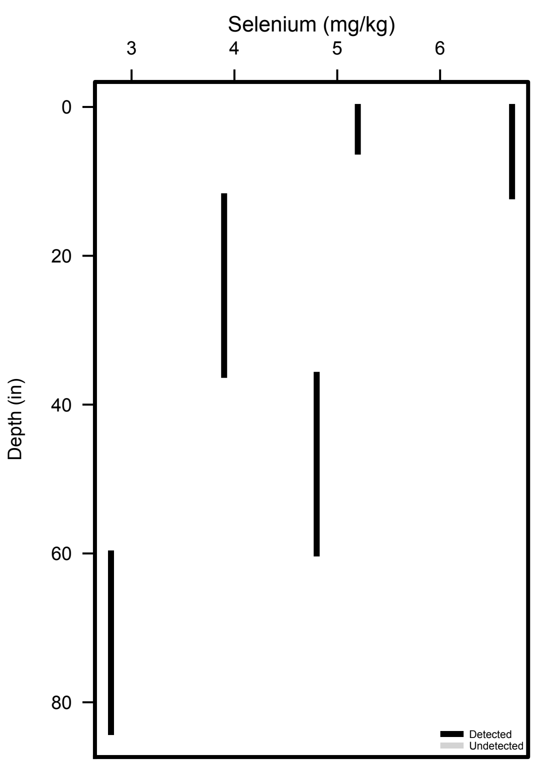

Figure 579. Selenium
at Core Location RM708C1.

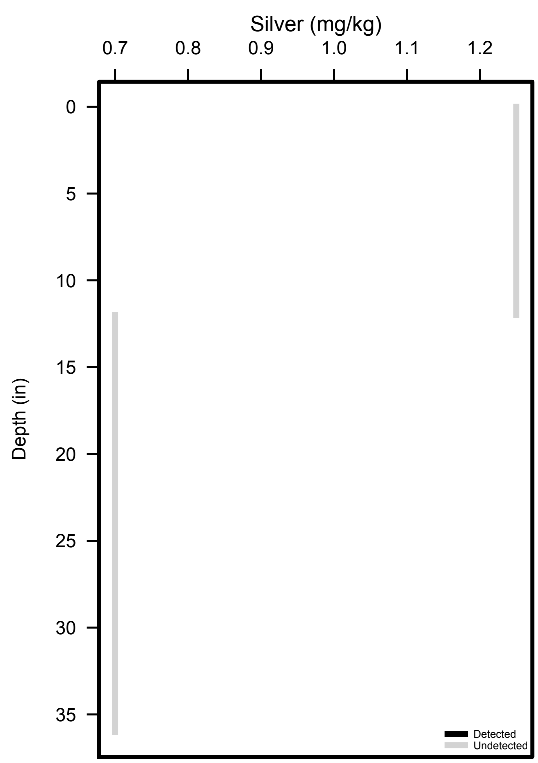

Figure 580. Silver
at Core Location RM605C1.

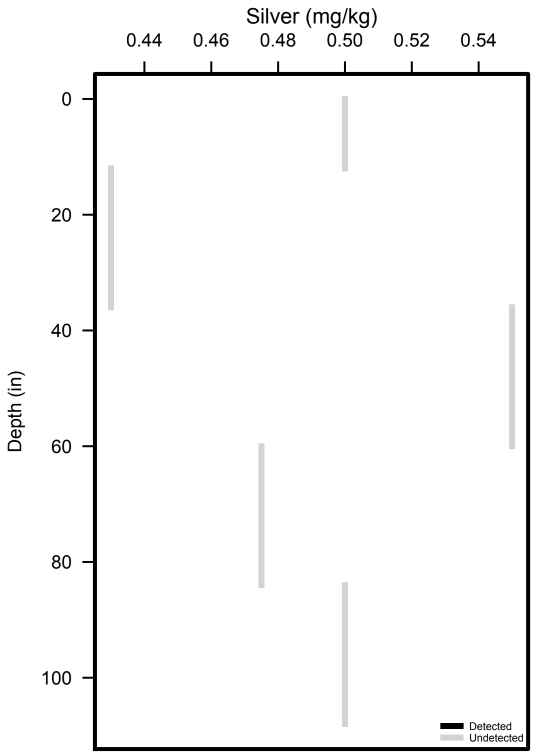

Figure 581. Silver
at Core Location RM622C1.

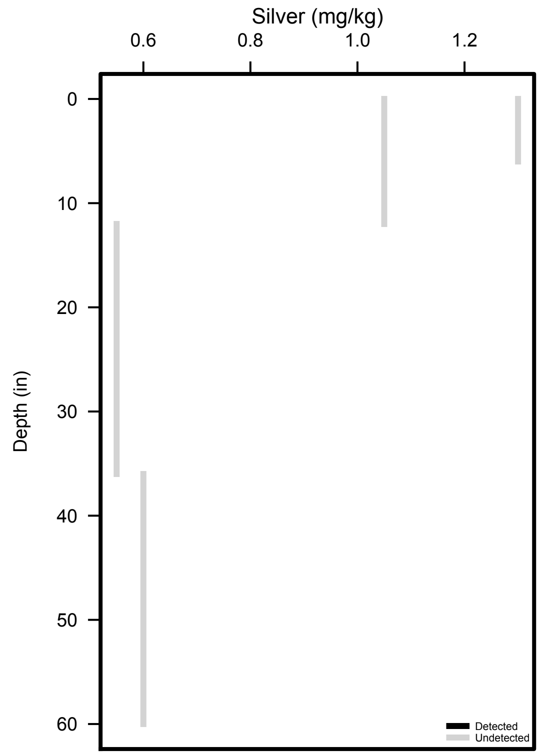

Figure 582. Silver
at Core Location RM637C1.

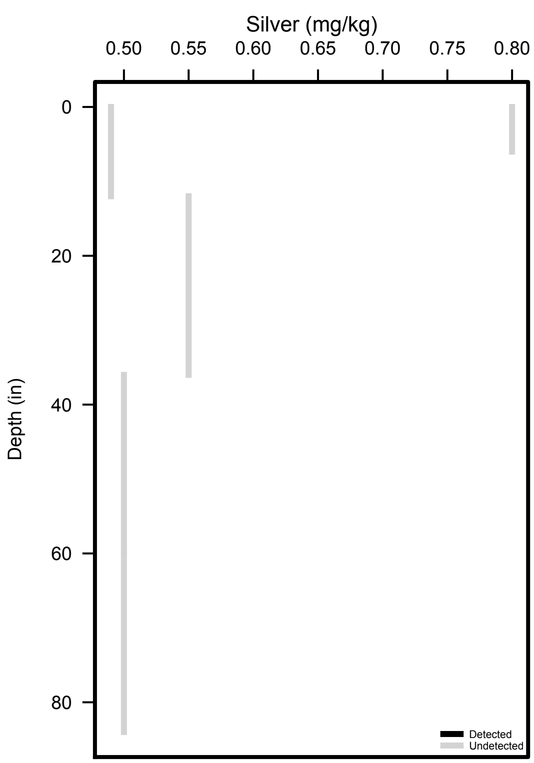

Figure 583. Silver
at Core Location RM644C1.

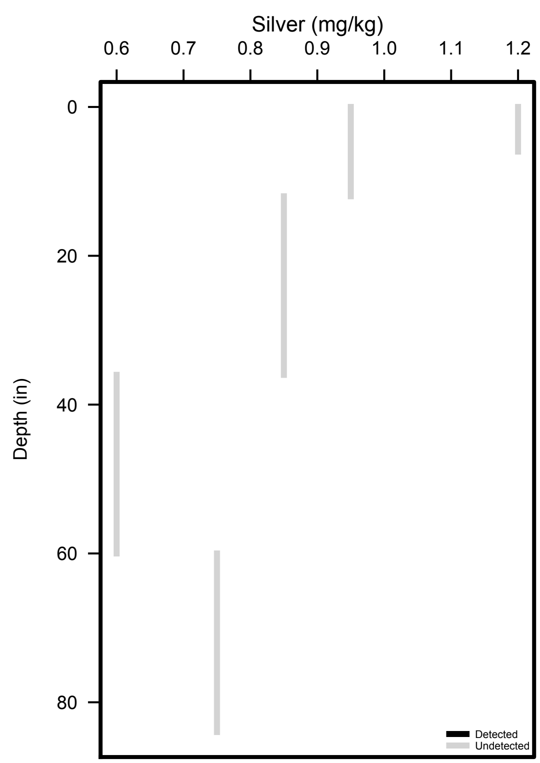

Figure 584. Silver
at Core Location RM692C1.

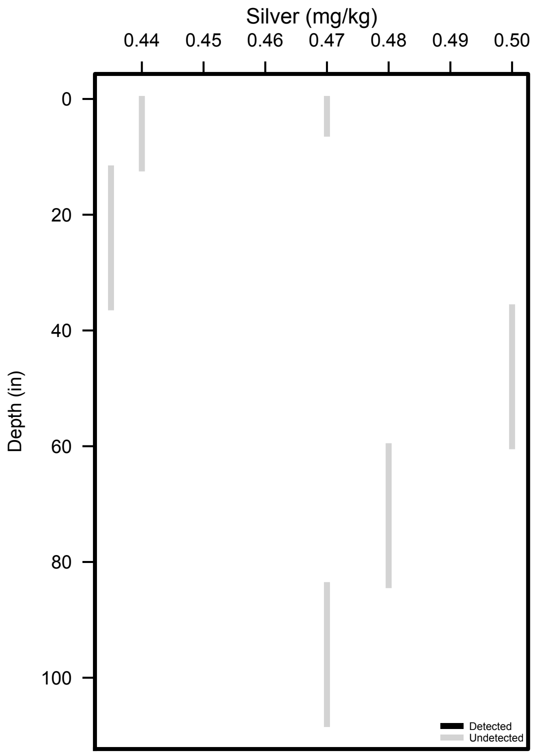

Figure 585. Silver
at Core Location RM704C1.

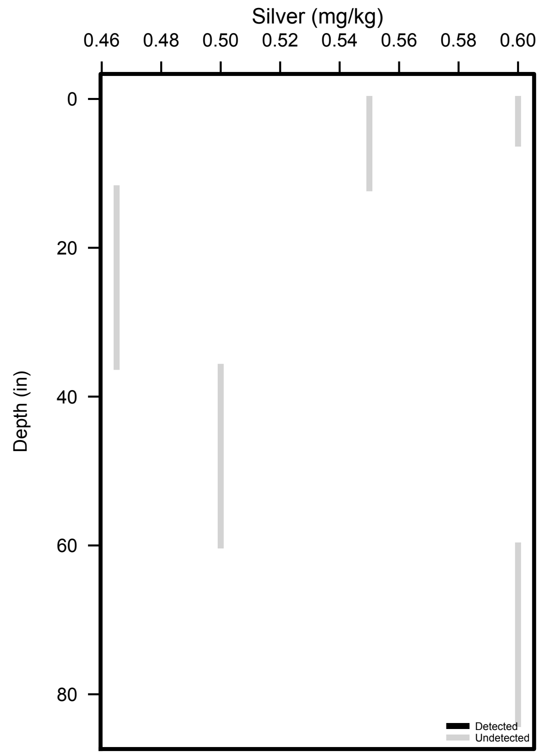

Figure 586. Silver
at Core Location RM708C1.

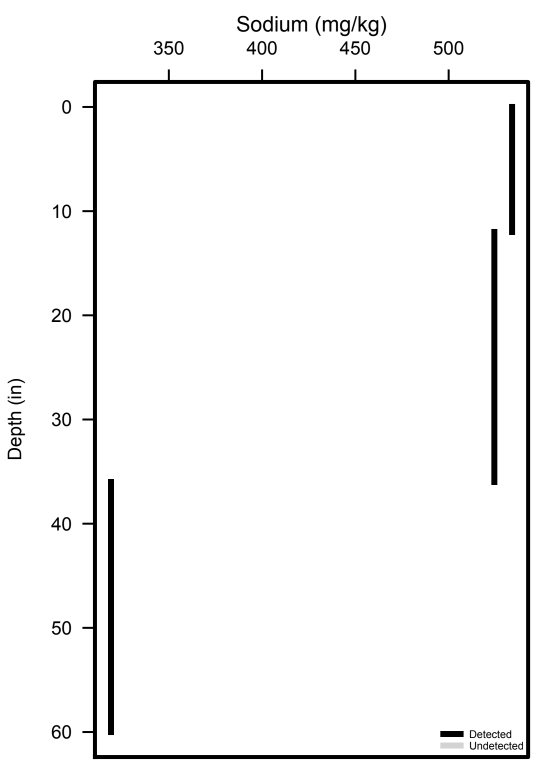

Figure 587. Sodium
at Core Location RM605C1.

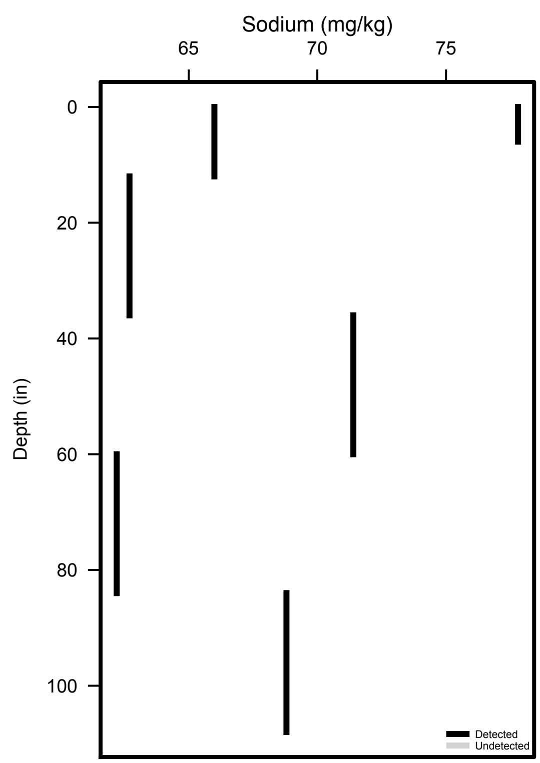

Figure 588. Sodium
at Core Location RM622C1.

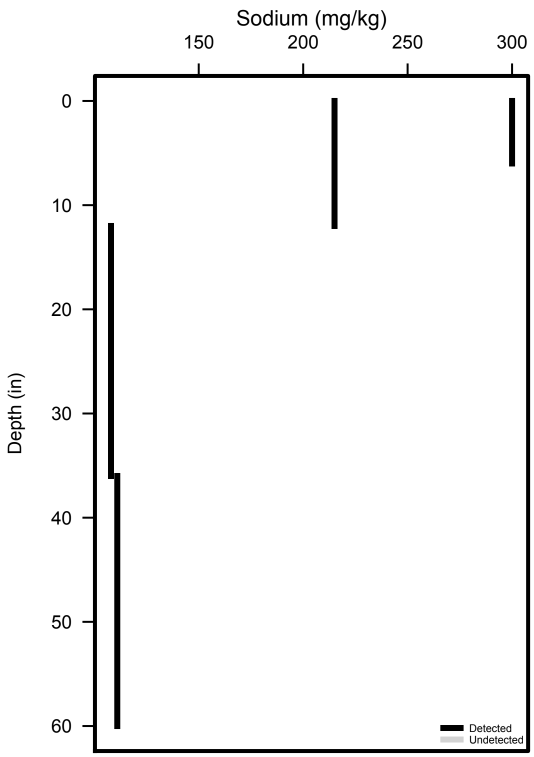

Figure 589. Sodium
at Core Location RM637C1.

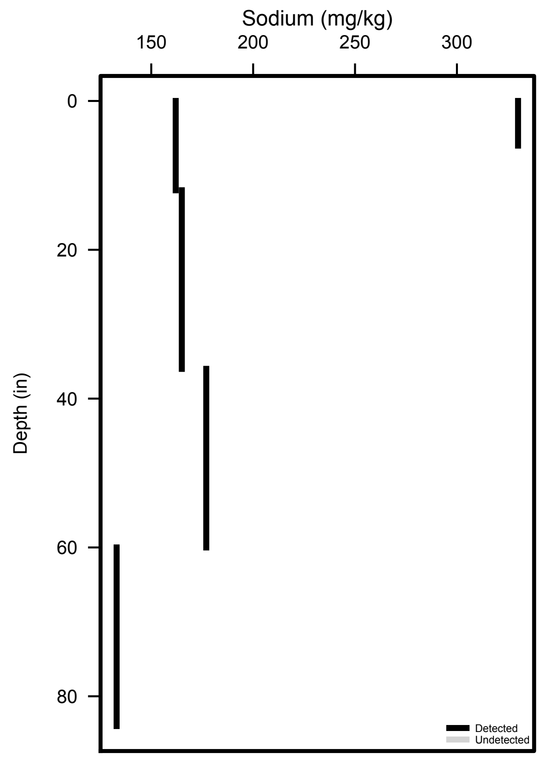

Figure 590. Sodium
at Core Location RM644C1.

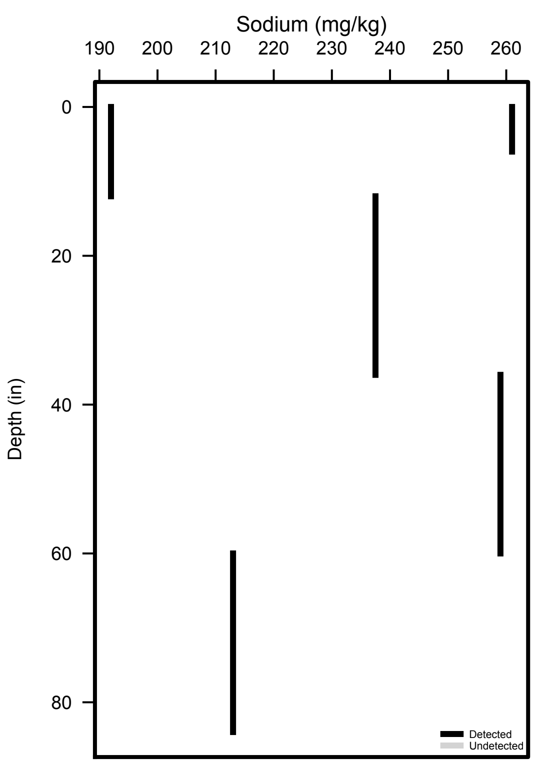

Figure 591. Sodium
at Core Location RM661C1.

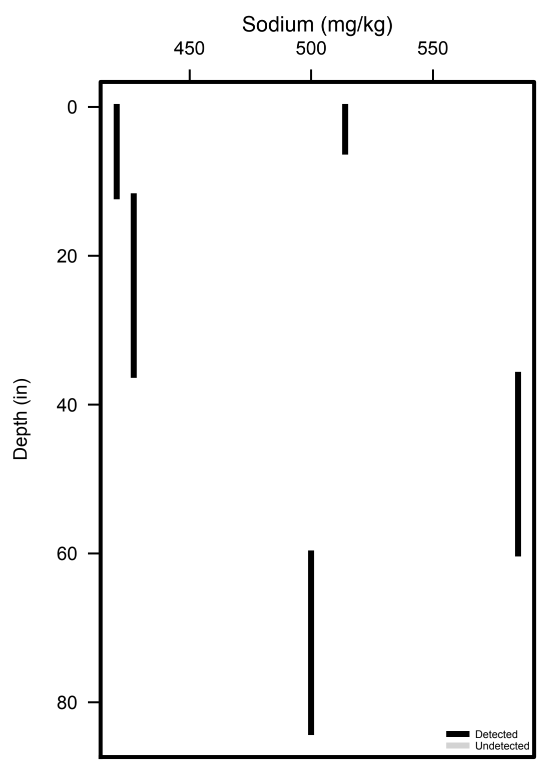

Figure 592. Sodium
at Core Location RM676C1.

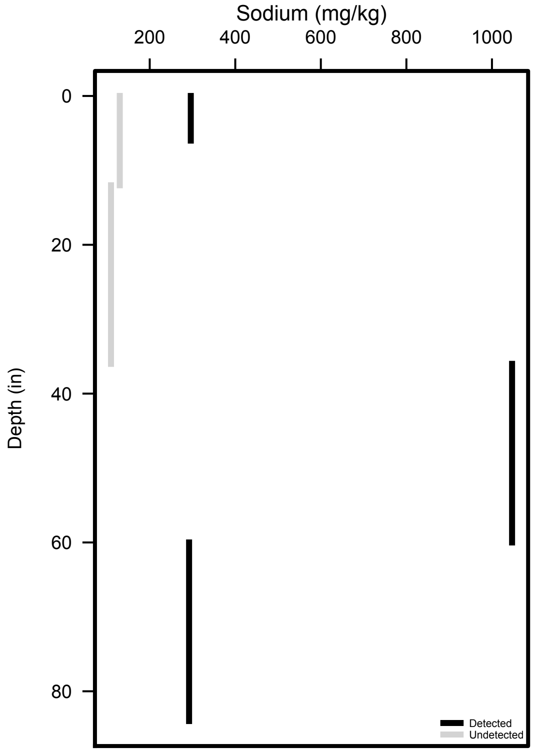

Figure 593. Sodium
at Core Location RM692C1.

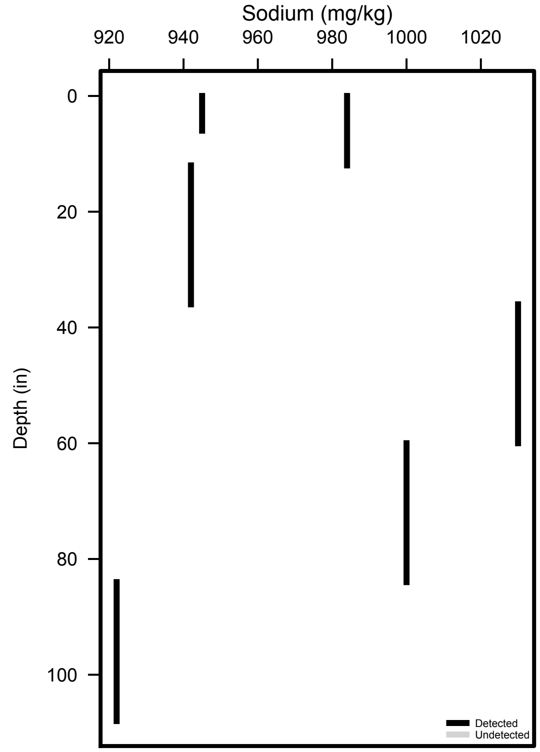

Figure 594. Sodium
at Core Location RM704C1.

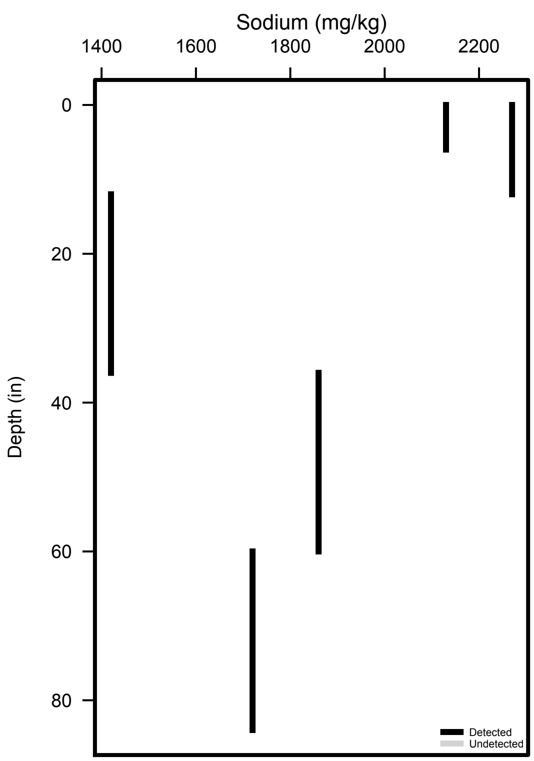

Figure 595. Sodium
at Core Location RM708C1.

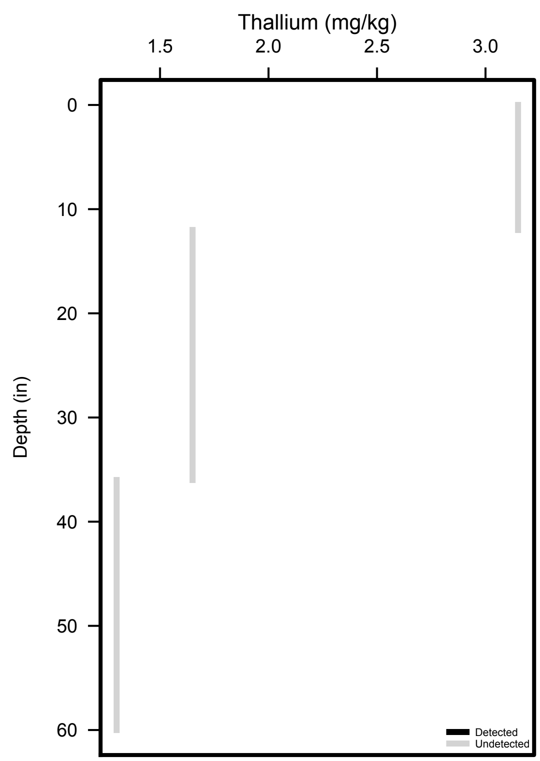

Figure 596. Thallium
at Core Location RM605C1.

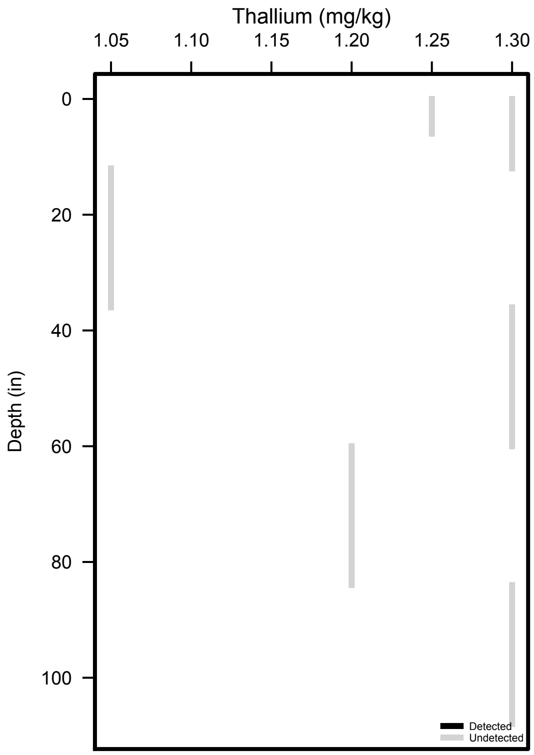

Figure 597. Thallium
at Core Location RM622C1.

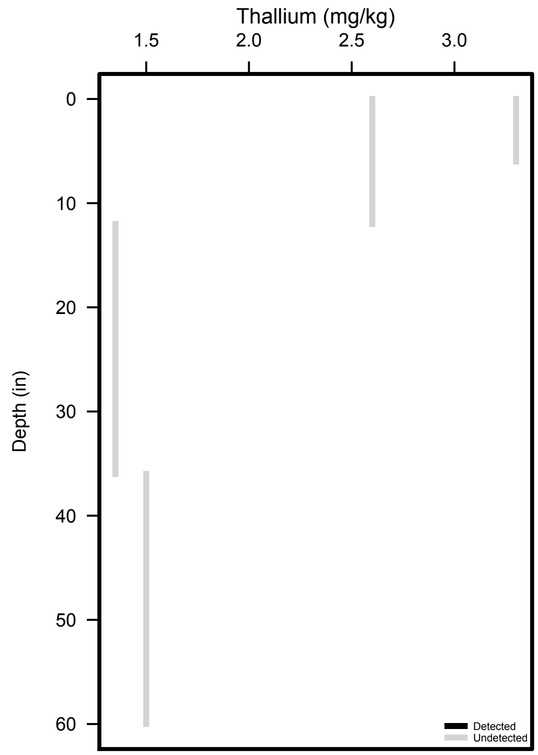

Figure 598. Thallium
at Core Location RM637C1.

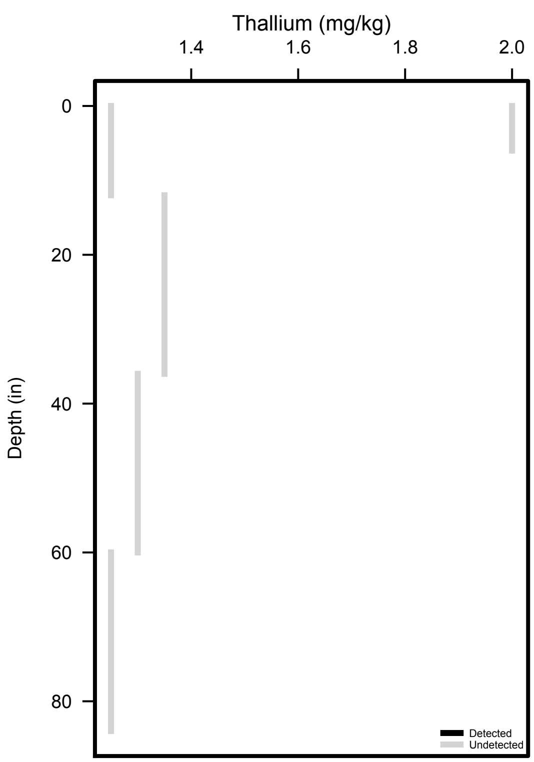

Figure 599. Thallium
at Core Location RM644C1.

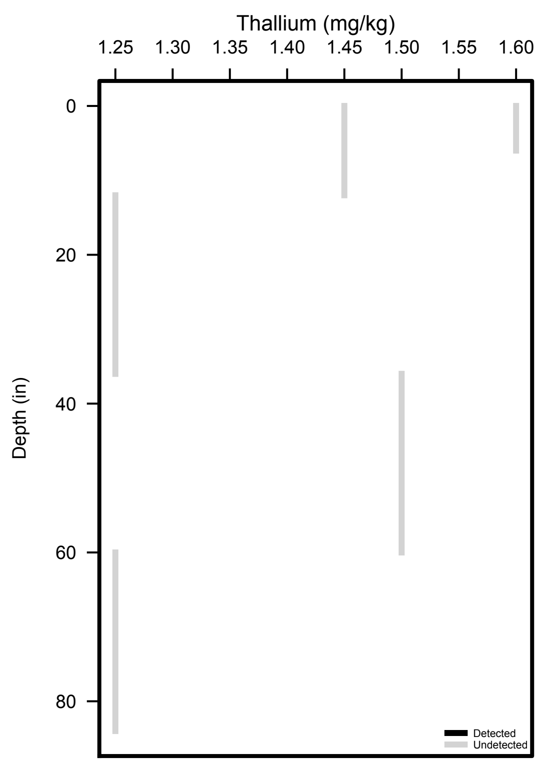

Figure 600. Thallium
at Core Location RM661C1.

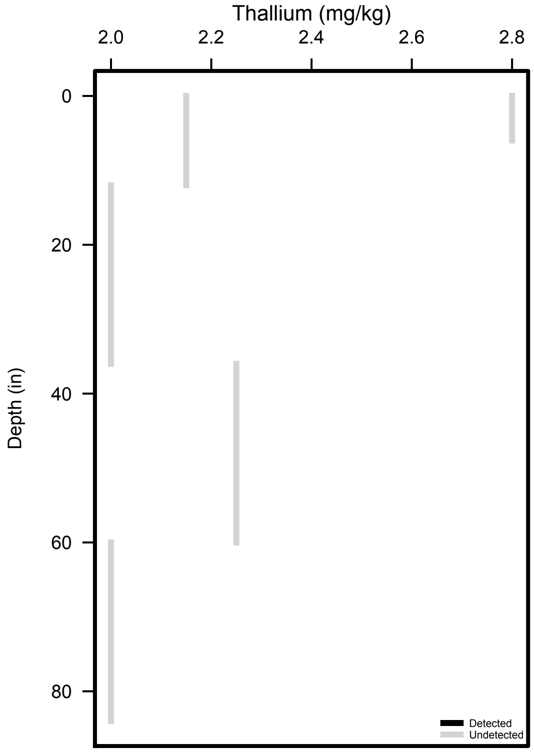

Figure 601. Thallium
at Core Location RM676C1.

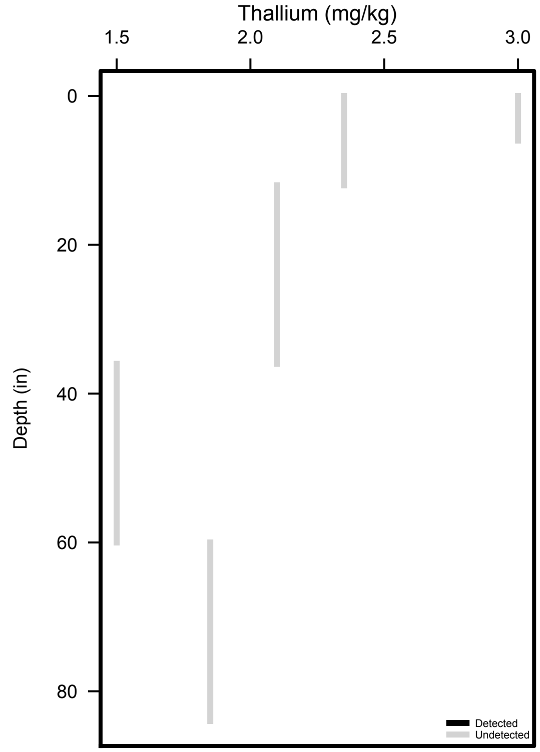

Figure 602. Thallium
at Core Location RM692C1.

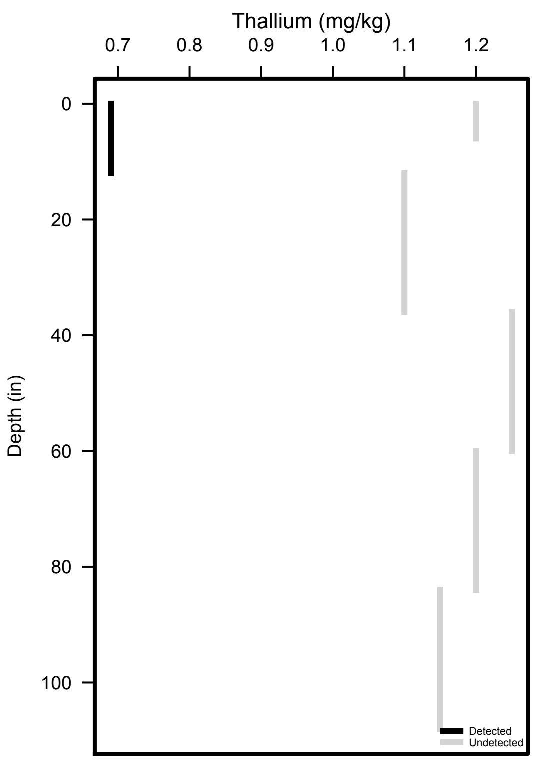

Figure 603. Thallium
at Core Location RM704C1.

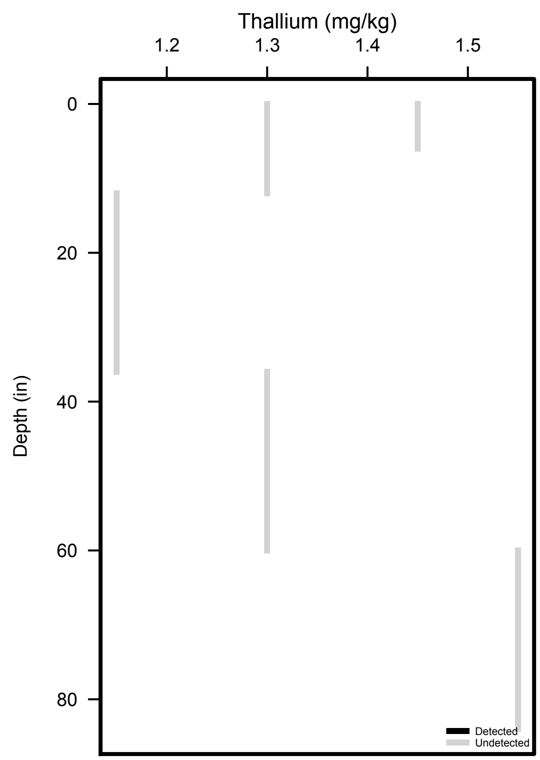

Figure 604. Thallium
at Core Location RM708C1.

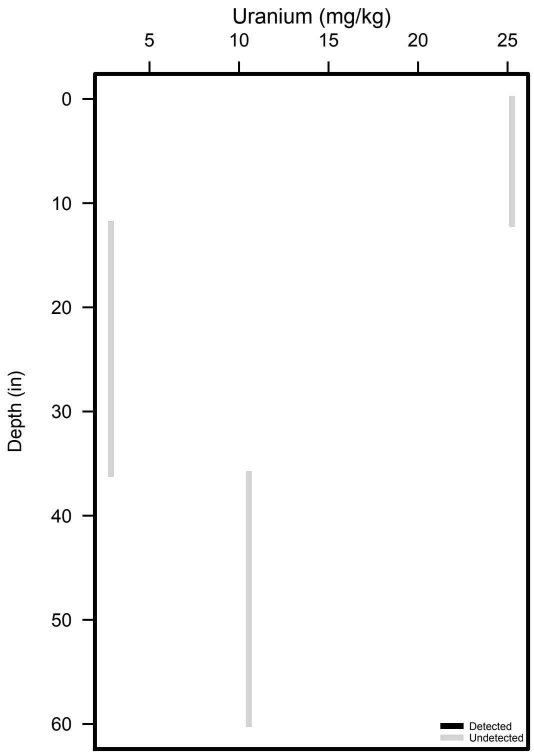

Figure 605. Uranium
at Core Location RM605C1.

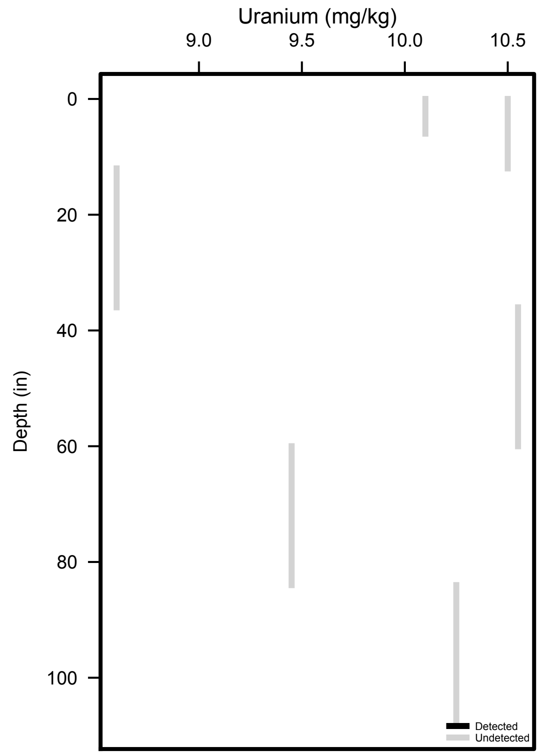

Figure 606. Uranium
at Core Location RM622C1.

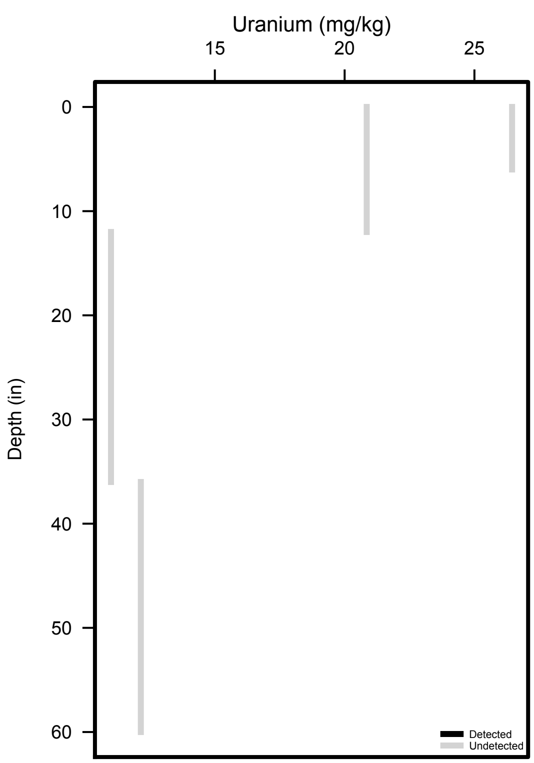

Figure 607. Uranium
at Core Location RM637C1.

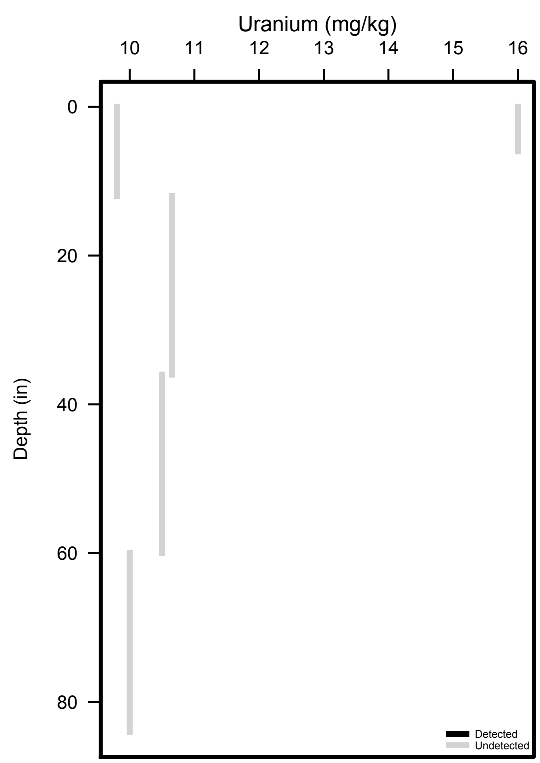

Figure 608. Uranium
at Core Location RM644C1.

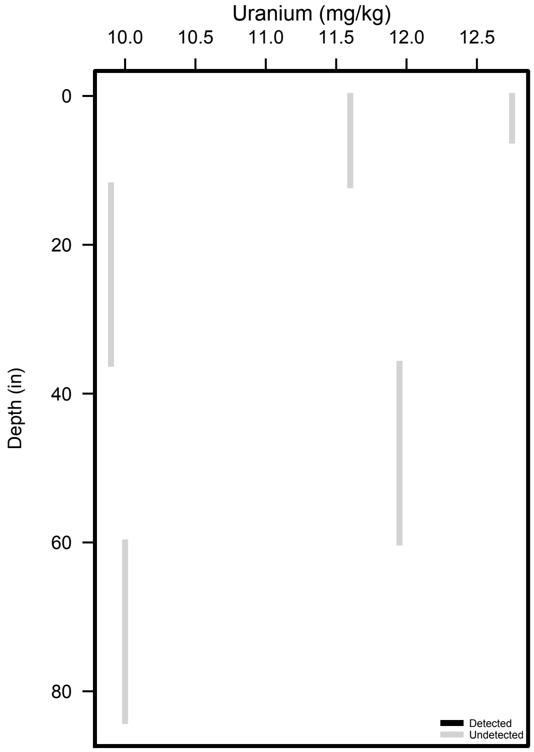

Figure 609. Uranium
at Core Location RM661C1.

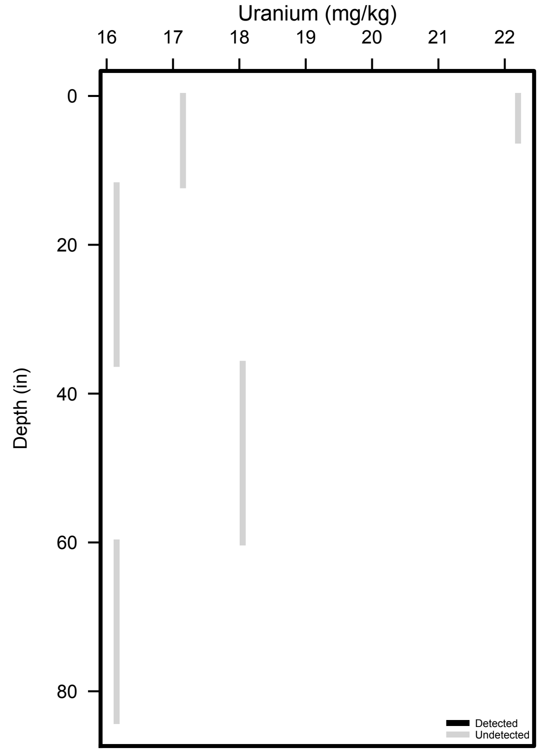

Figure 610. Uranium
at Core Location RM676C1.

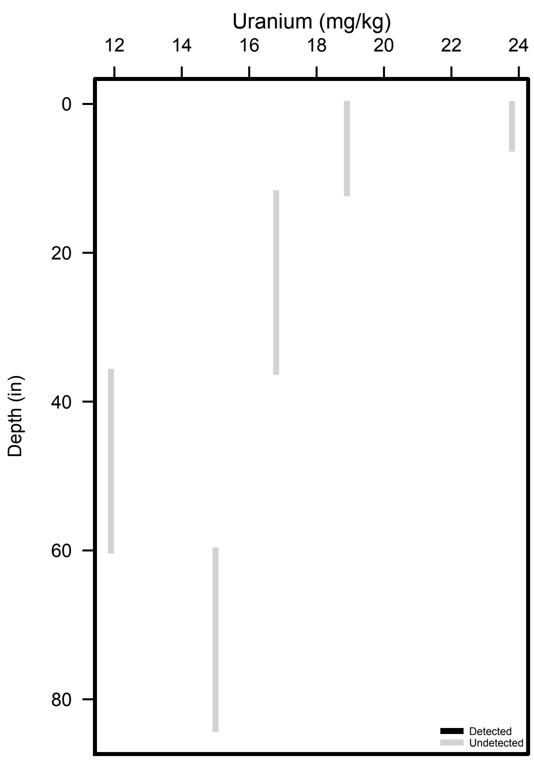

Figure 611. Uranium
at Core Location RM692C1.

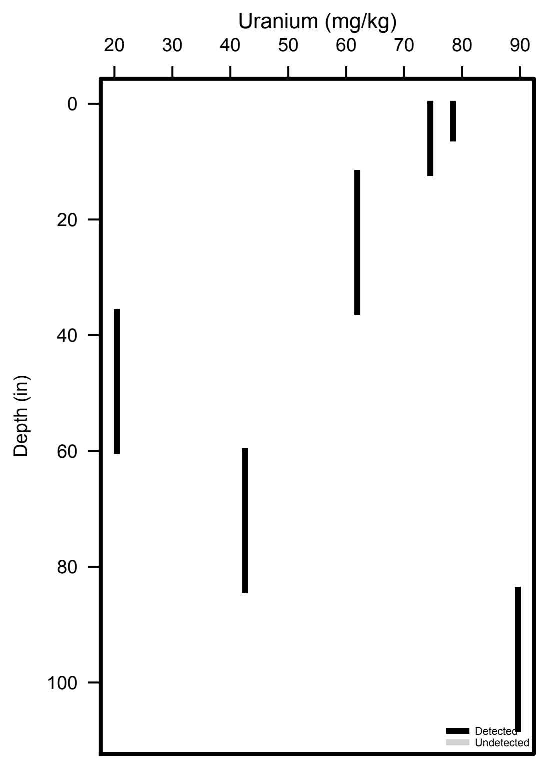

Figure 612. Uranium
at Core Location RM704C1.

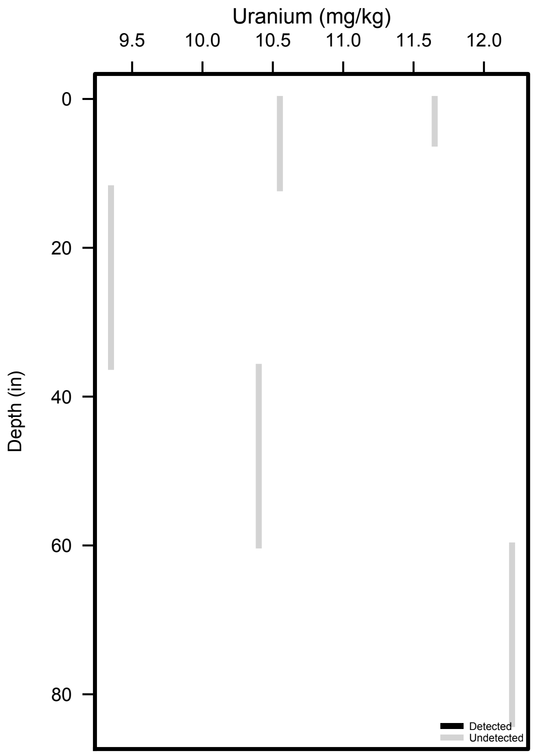

Figure 613. Uranium
at Core Location RM708C1.

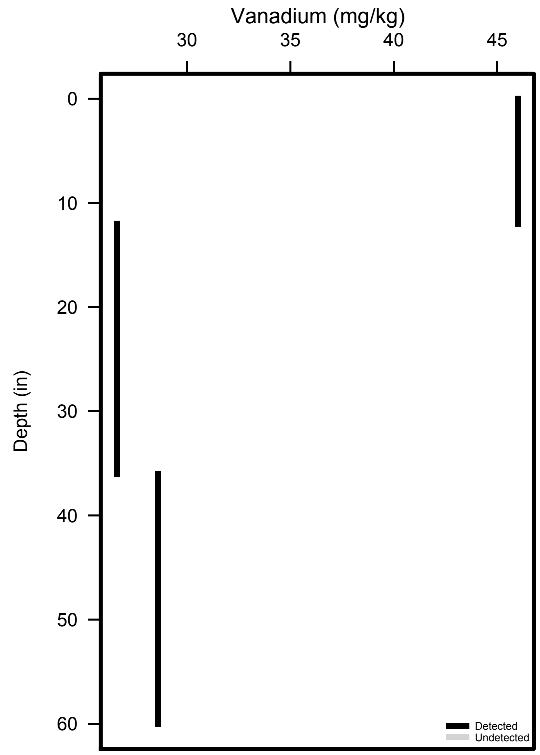

Figure 614. Vanadium
at Core Location RM605C1.

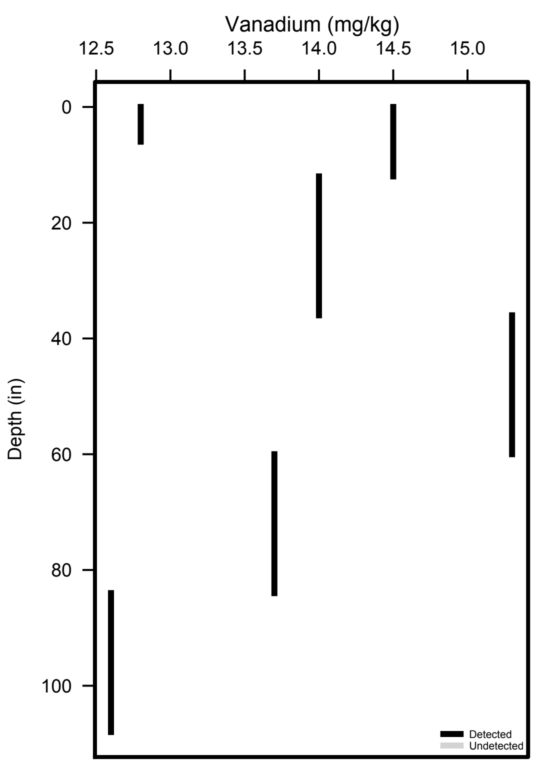

Figure 615. Vanadium
at Core Location RM622C1.

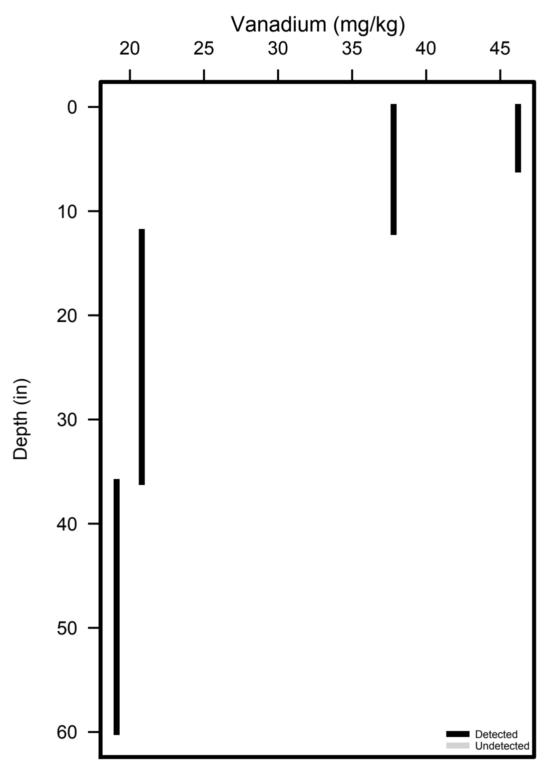

Figure 616. Vanadium
at Core Location RM637C1.

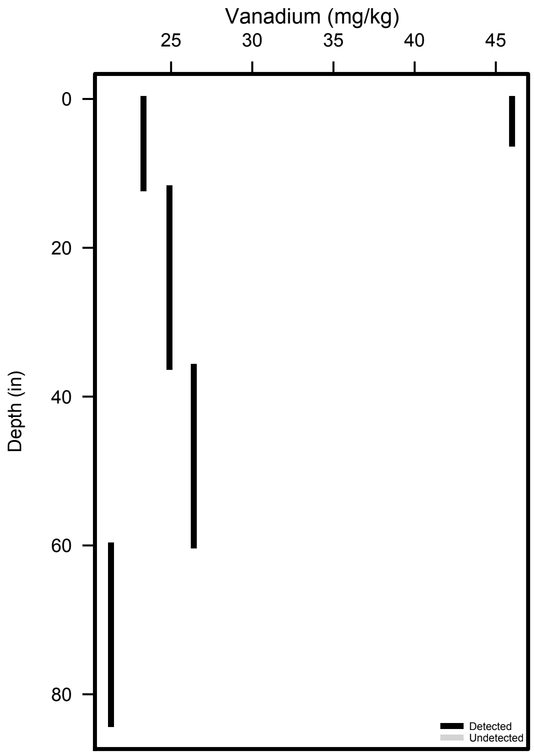

Figure 617. Vanadium
at Core Location RM644C1.

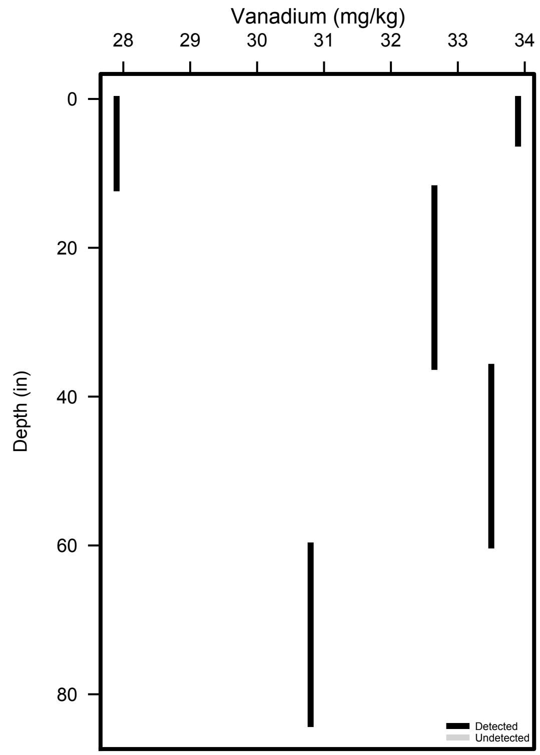

Figure 618. Vanadium
at Core Location RM661C1.

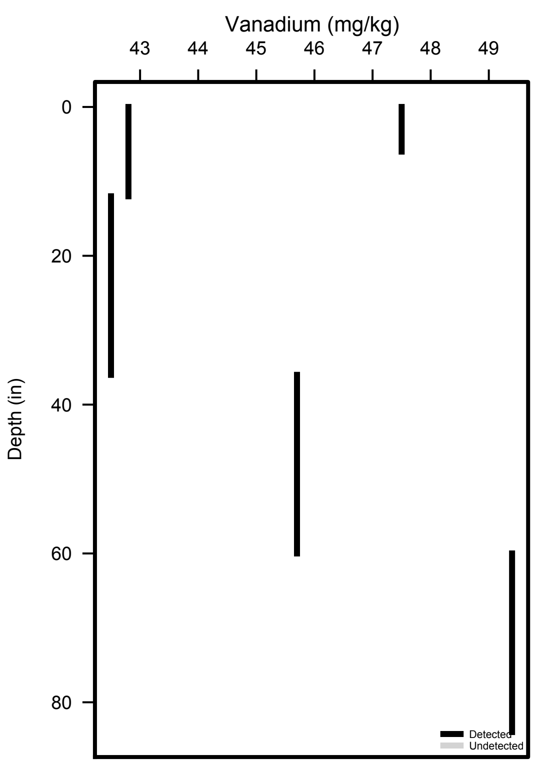

Figure 619. Vanadium
at Core Location RM676C1.

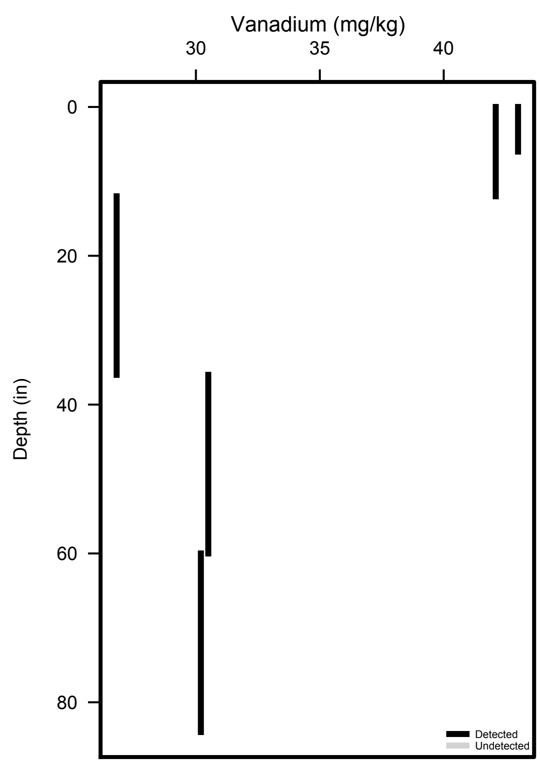

Figure 620. Vanadium
at Core Location RM692C1.

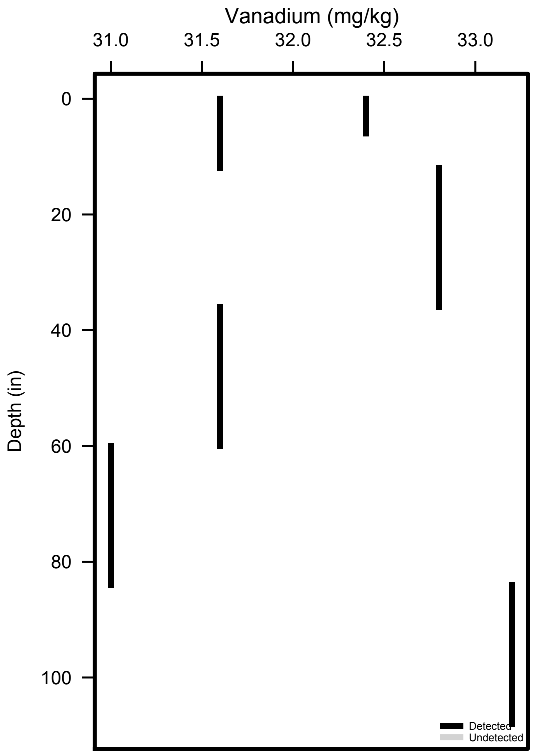

Figure 621. Vanadium
at Core Location RM704C1.

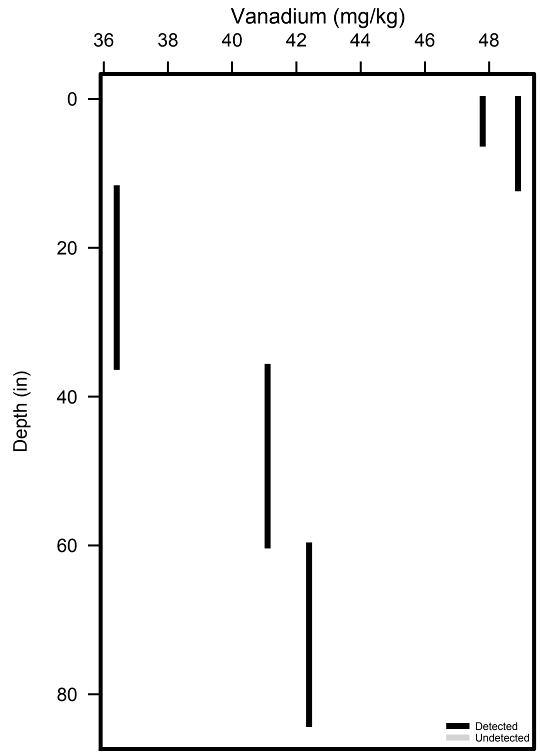

Figure 622. Vanadium
at Core Location RM708C1.

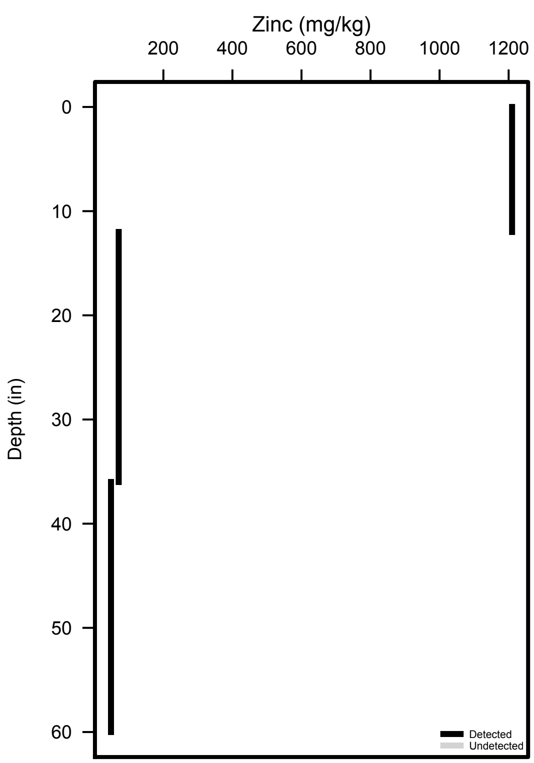

Figure 623. Zinc
at Core Location RM605C1.

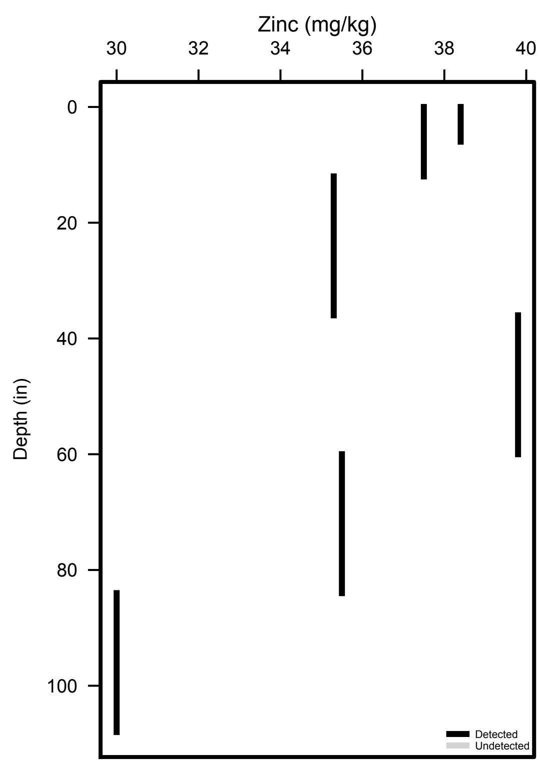

Figure 624. Zinc
at Core Location RM622C1.

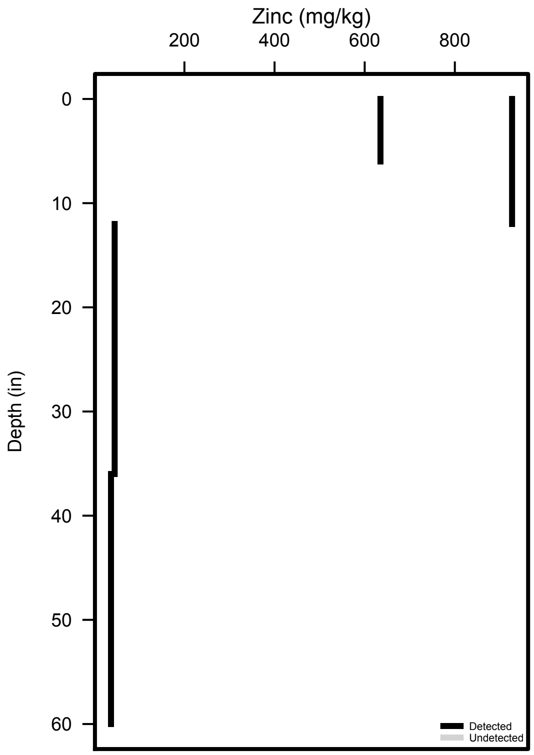

Figure 625. Zinc
at Core Location RM637C1.

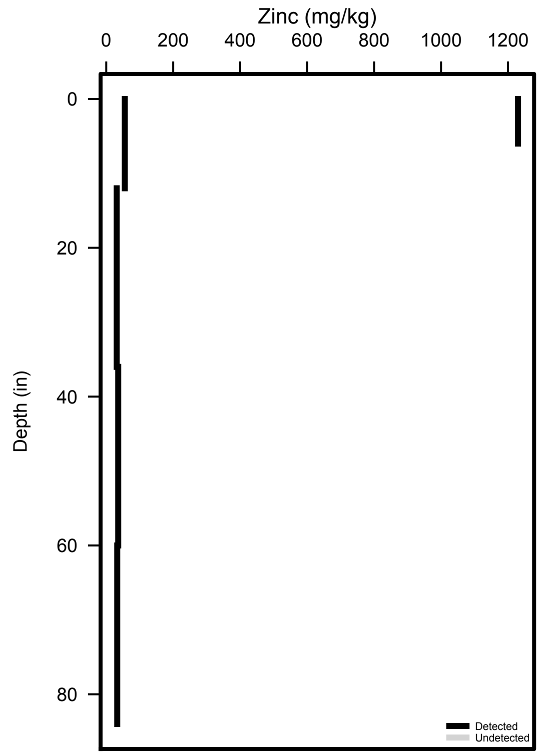

Figure 626. Zinc
at Core Location RM644C1.

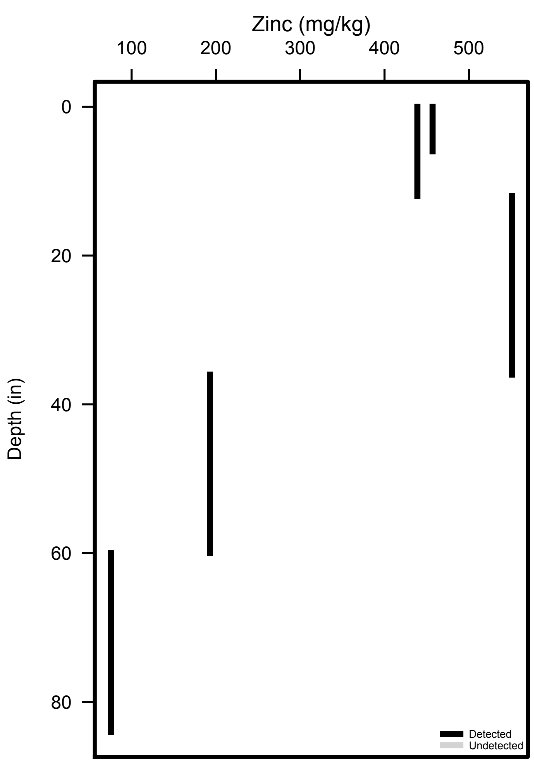

Figure 627. Zinc
at Core Location RM661C1.

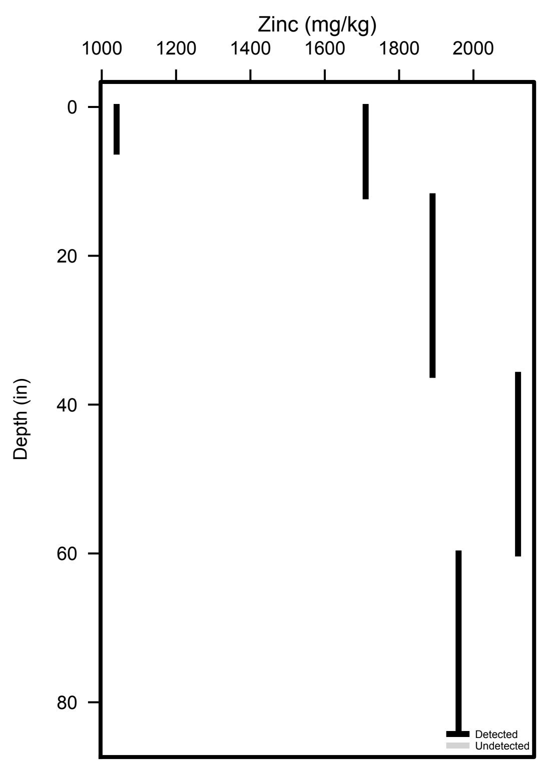

Figure 628. Zinc
at Core Location RM676C1.

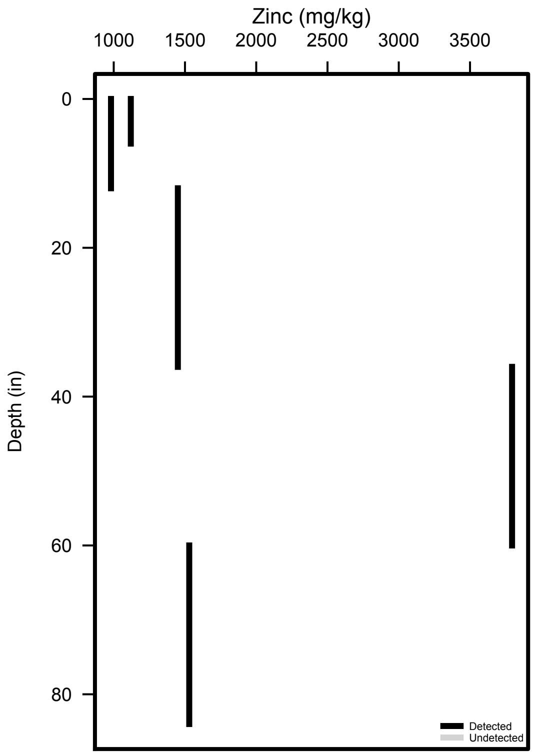

Figure 629. Zinc
at Core Location RM692C1.

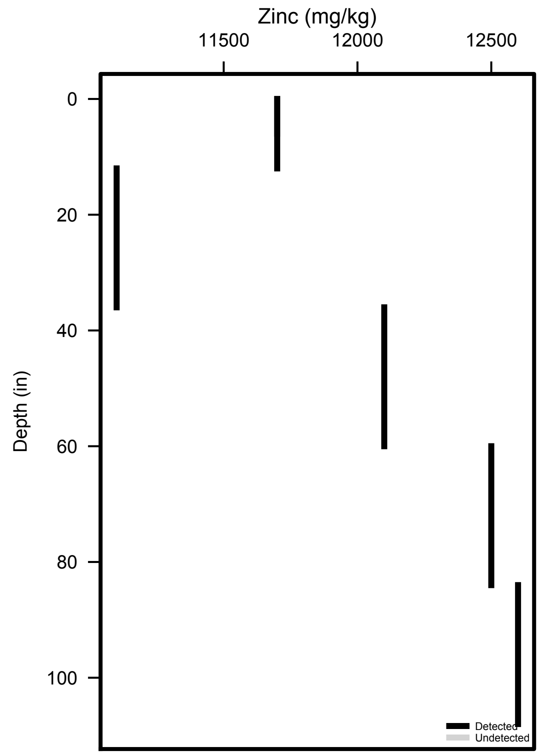

Figure 630. Zinc
at Core Location RM704C1.

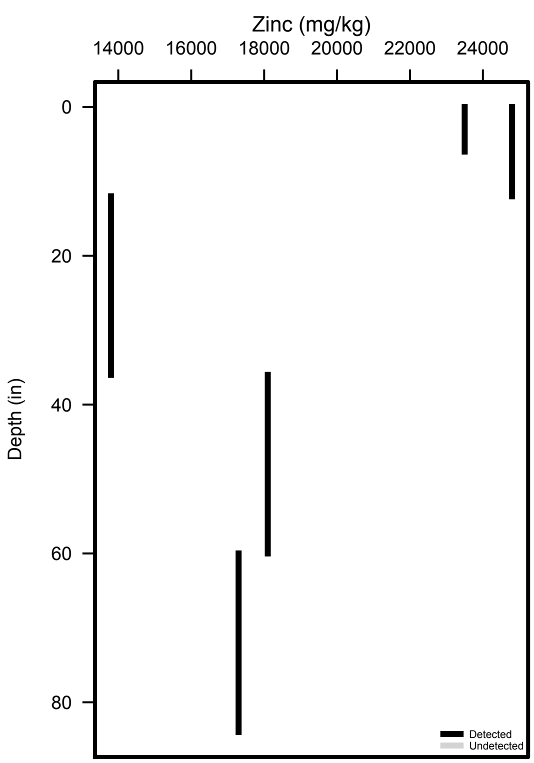

Figure 631. Zinc
at Core Location RM708C1.

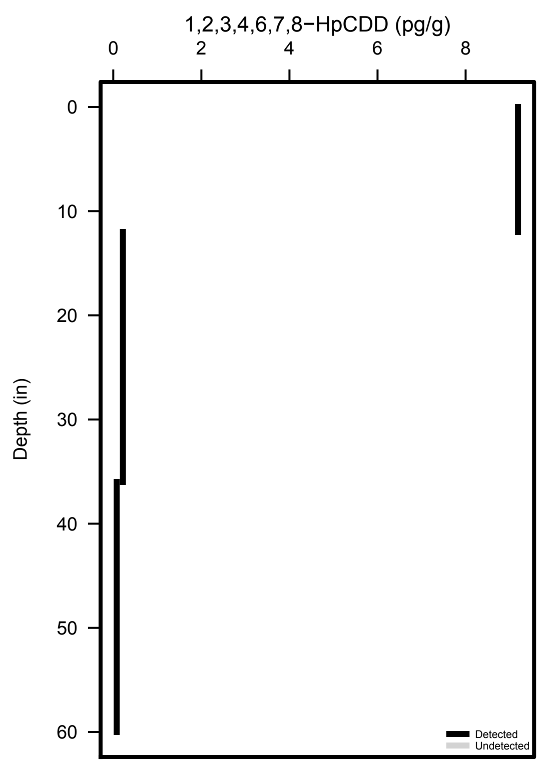

Figure 632. 1,2,3,4,6,7,8−HpCDD
at Core Location RM605C1.

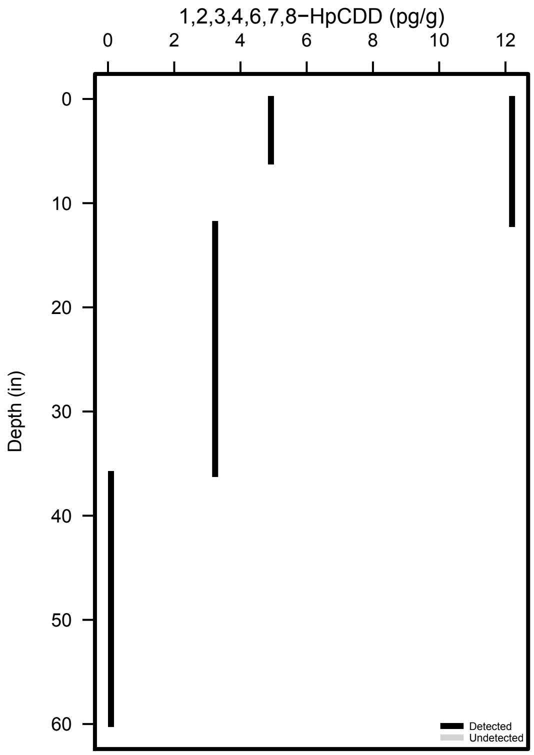

Figure 633. 1,2,3,4,6,7,8−HpCDD
at Core Location RM637C1.

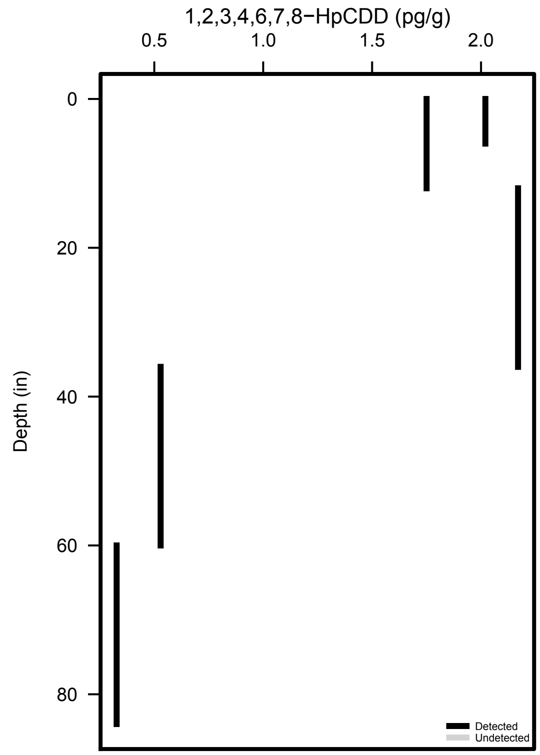

Figure 634. 1,2,3,4,6,7,8−HpCDD
at Core Location RM661C1.

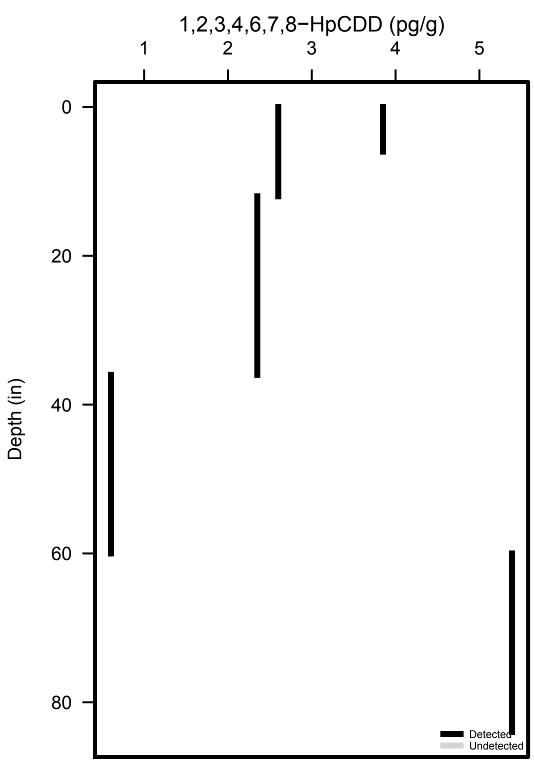

Figure 635. 1,2,3,4,6,7,8−HpCDD
at Core Location RM692C1.

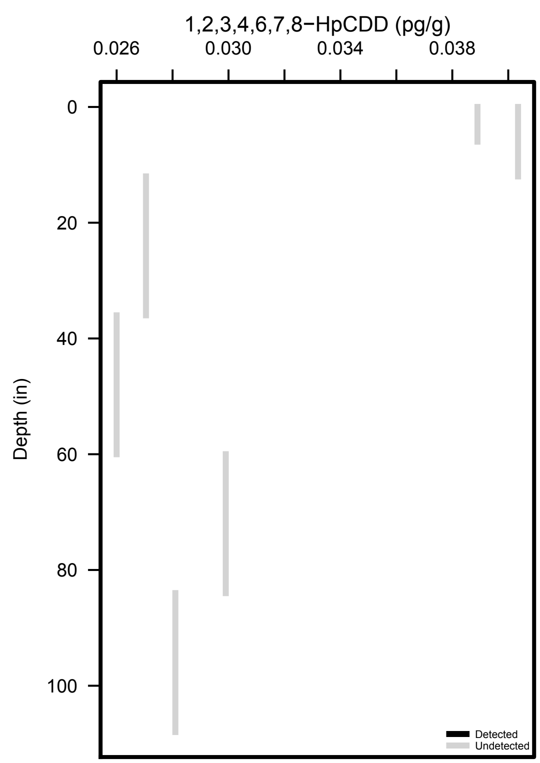

Figure 636. 1,2,3,4,6,7,8−HpCDD
at Core Location RM704C1.

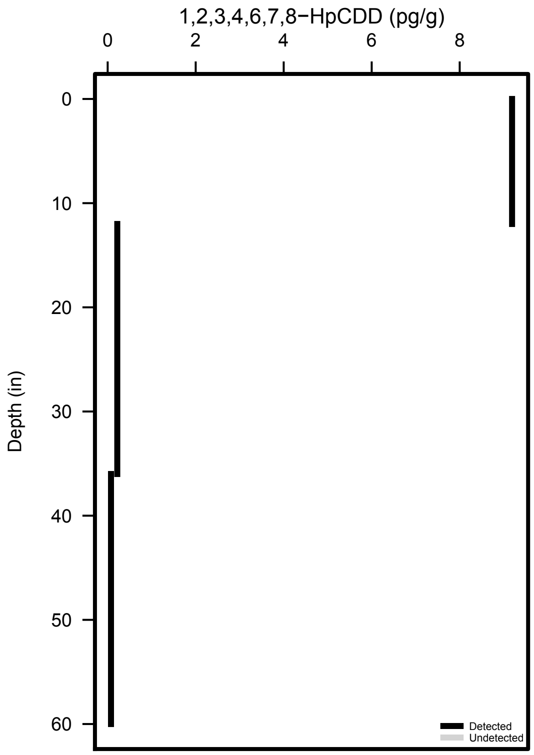

Figure 637. 1,2,3,4,6,7,8−HpCDD
at Core Location RM605C1.

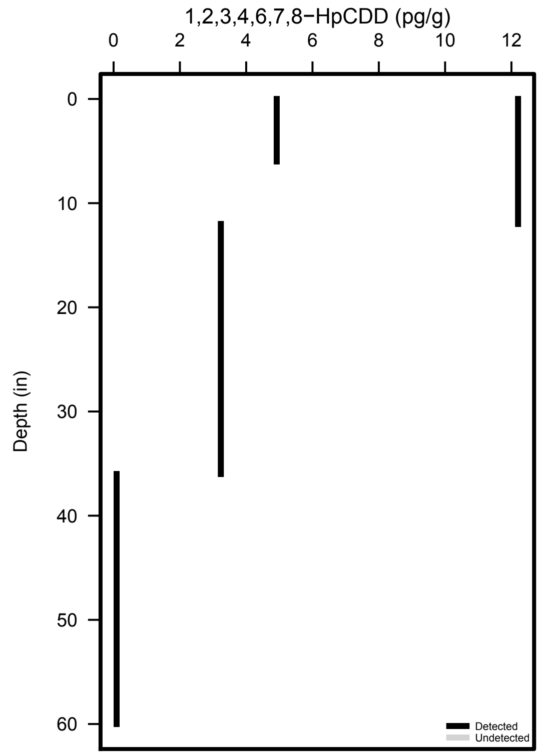

Figure 638. 1,2,3,4,6,7,8−HpCDD
at Core Location RM637C1.

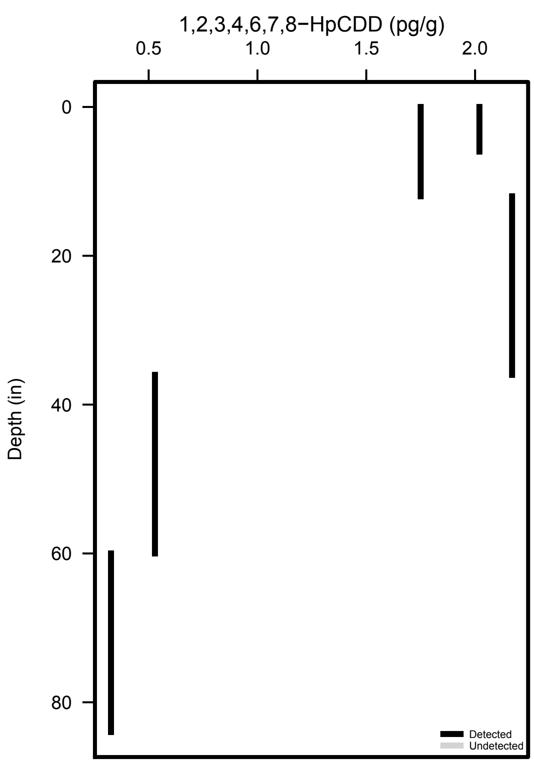

Figure 639. 1,2,3,4,6,7,8−HpCDD
at Core Location RM661C1.

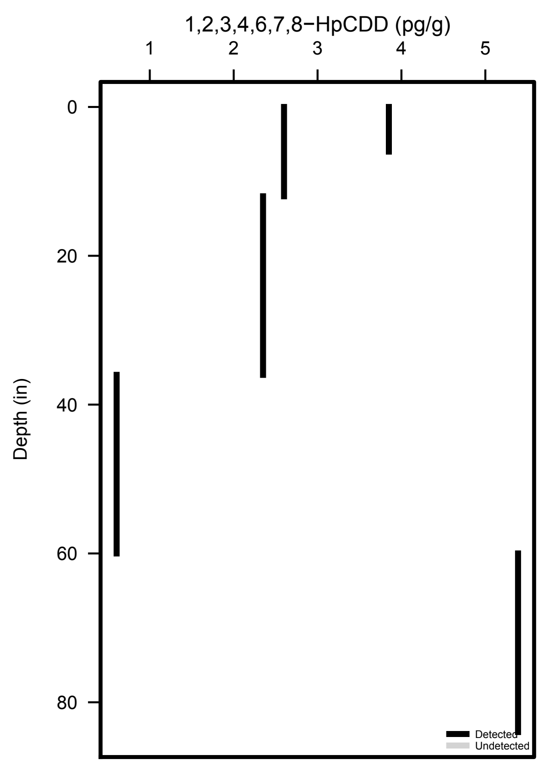

Figure 640. 1,2,3,4,6,7,8−HpCDD
at Core Location RM692C1.

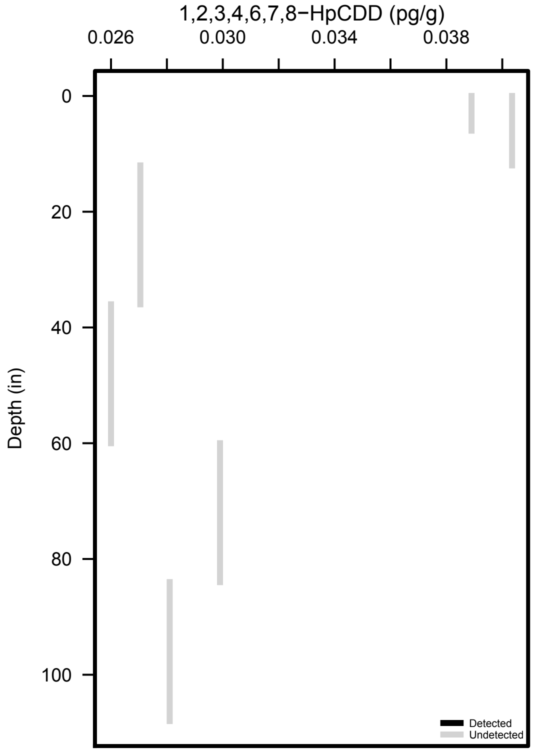

Figure 641. 1,2,3,4,6,7,8−HpCDD
at Core Location RM704C1.

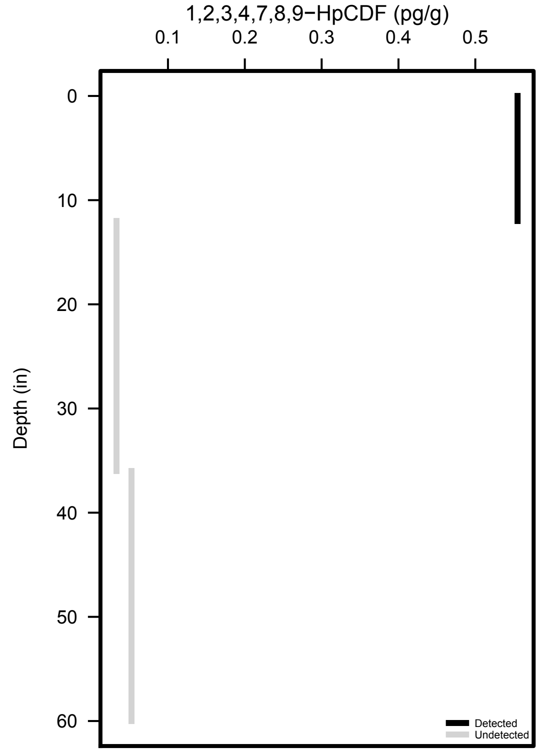

Figure 642. 1,2,3,4,7,8,9−HpCDF
at Core Location RM605C1.

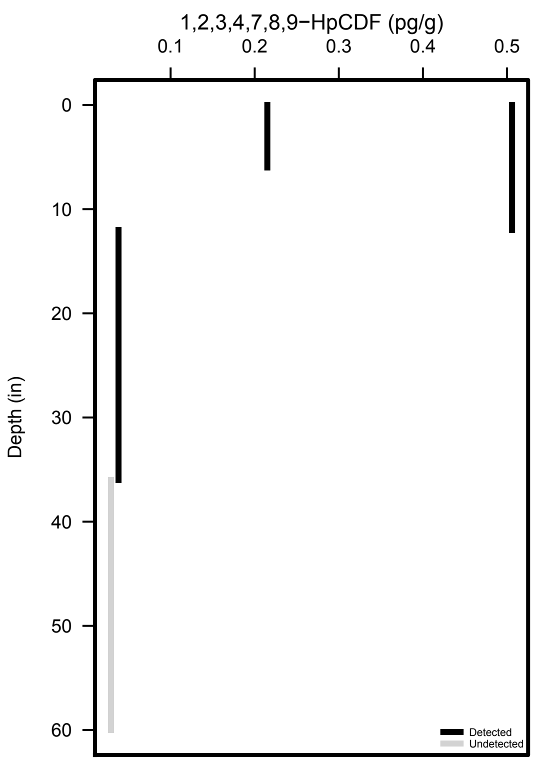

Figure 643. 1,2,3,4,7,8,9−HpCDF
at Core Location RM637C1.

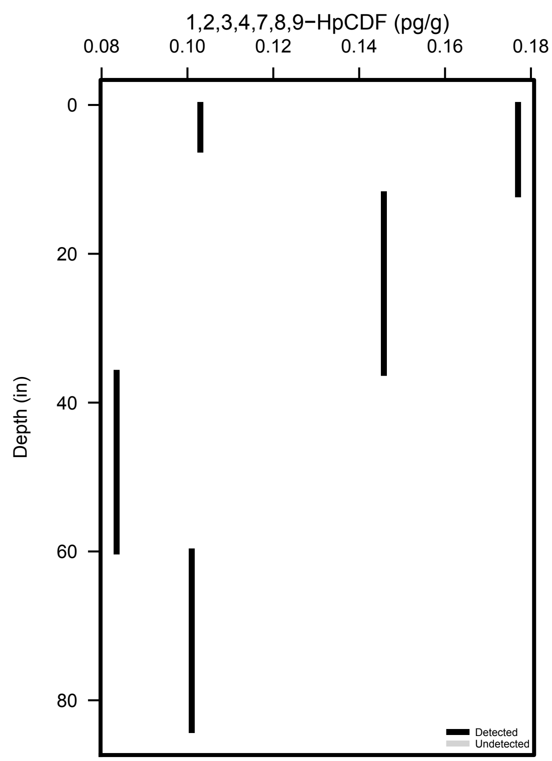

Figure 644. 1,2,3,4,7,8,9−HpCDF
at Core Location RM661C1.

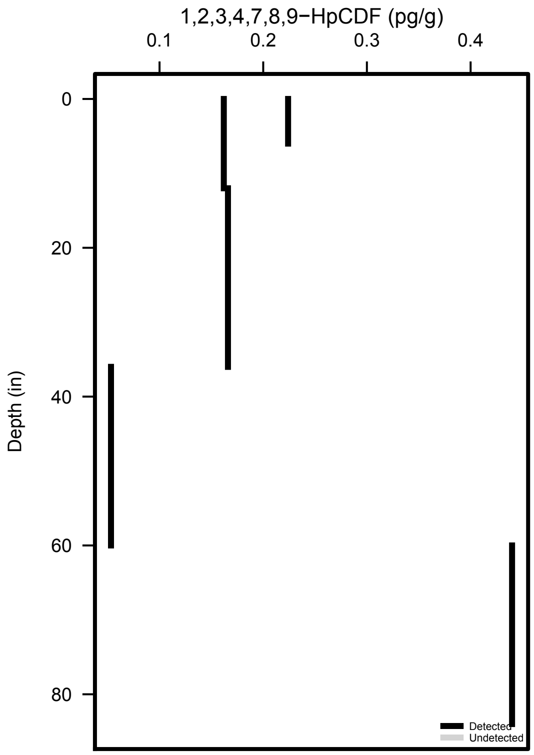

Figure 645. 1,2,3,4,7,8,9−HpCDF
at Core Location RM692C1.

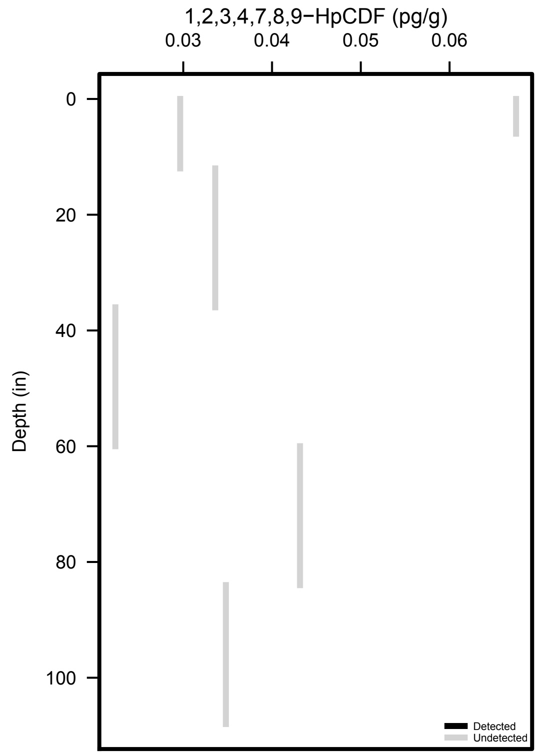

Figure 646. 1,2,3,4,7,8,9−HpCDF
at Core Location RM704C1.

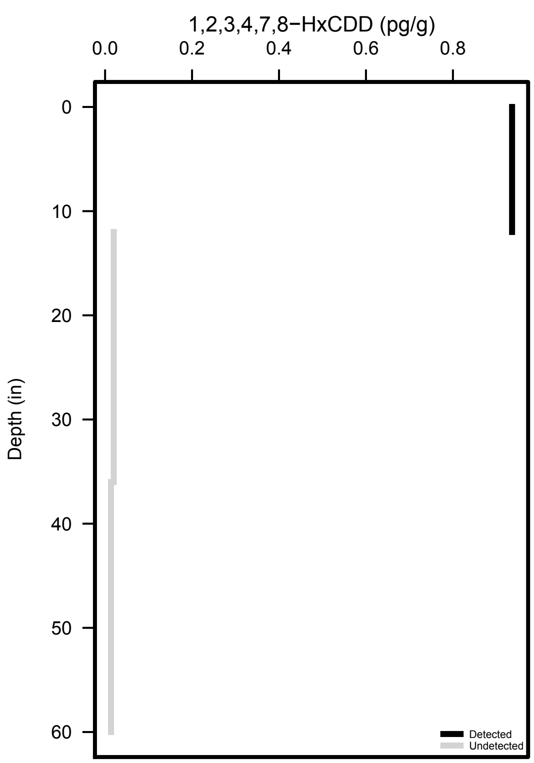

Figure 647. 1,2,3,4,7,8−HxCDD
at Core Location RM605C1.

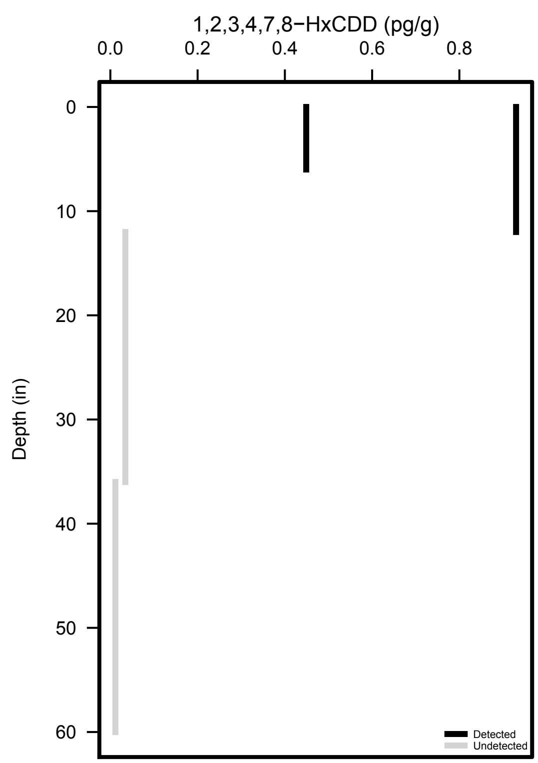

Figure 648. 1,2,3,4,7,8−HxCDD
at Core Location RM637C1.

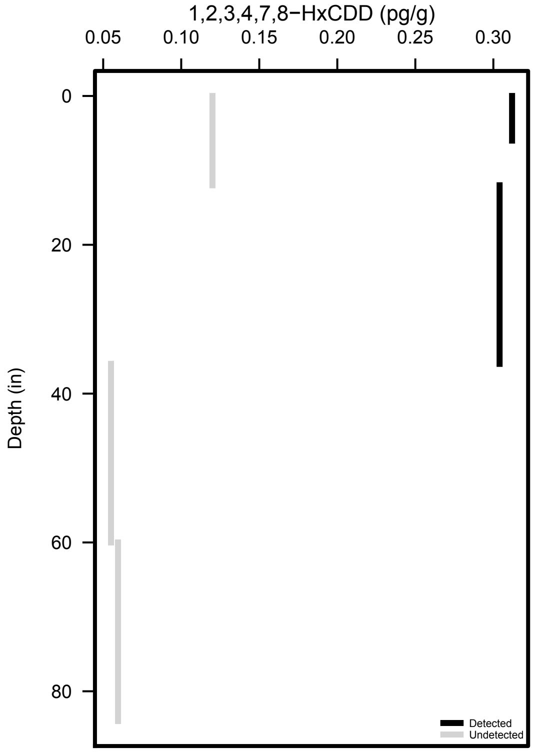

Figure 649. 1,2,3,4,7,8−HxCDD
at Core Location RM661C1.

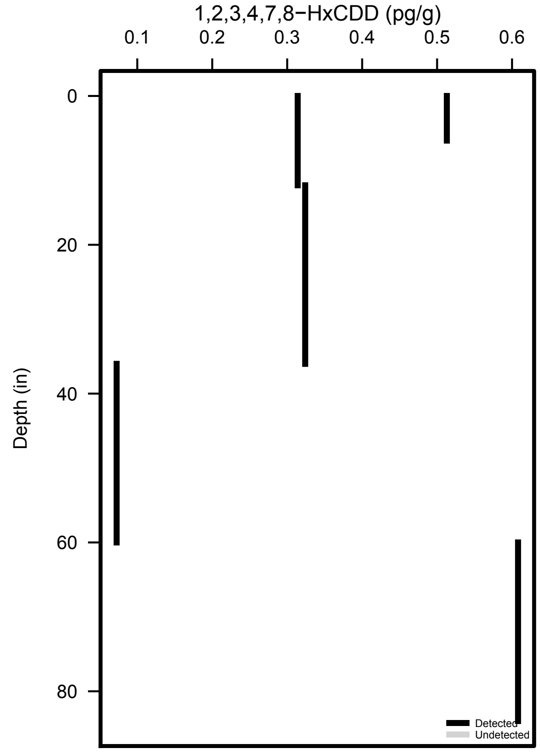

Figure 650. 1,2,3,4,7,8−HxCDD
at Core Location RM692C1.

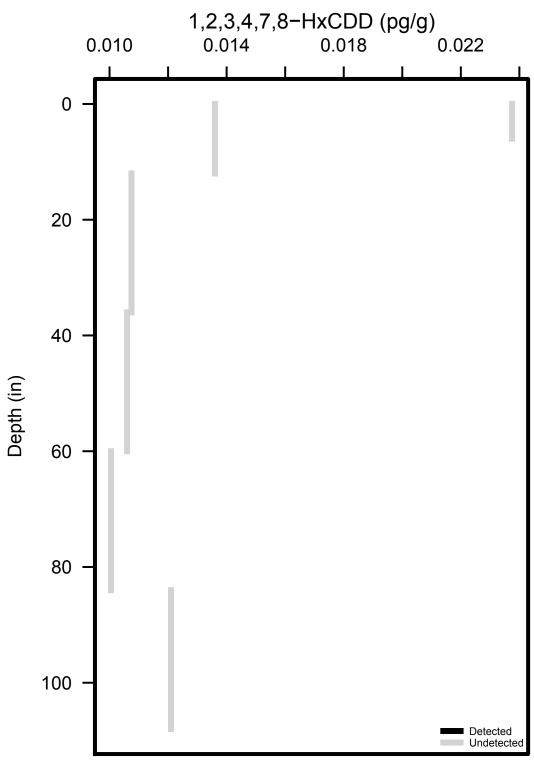

Figure 651. 1,2,3,4,7,8−HxCDD
at Core Location RM704C1.

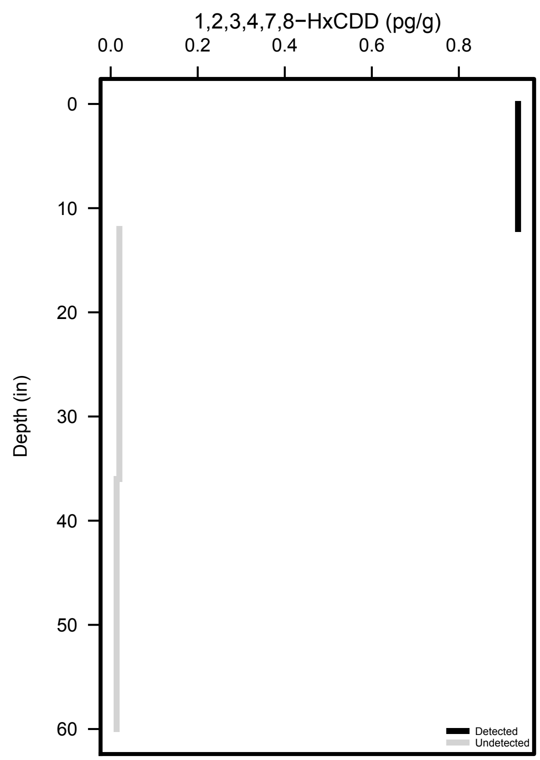

Figure 652. 1,2,3,4,7,8−HxCDD
at Core Location RM605C1.

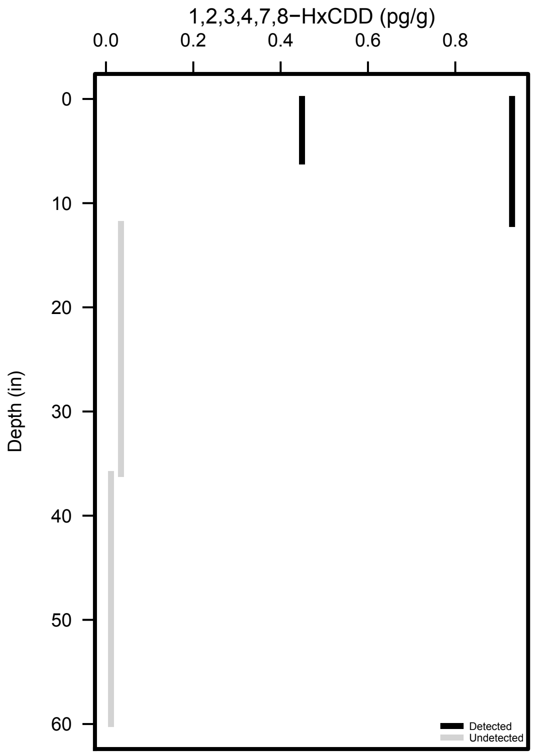

Figure 653. 1,2,3,4,7,8−HxCDD
at Core Location RM637C1.

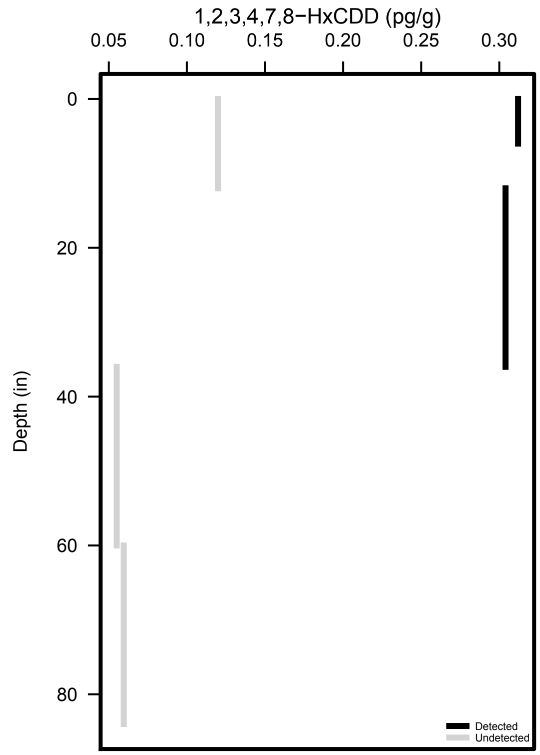

Figure 654. 1,2,3,4,7,8−HxCDD
at Core Location RM661C1.

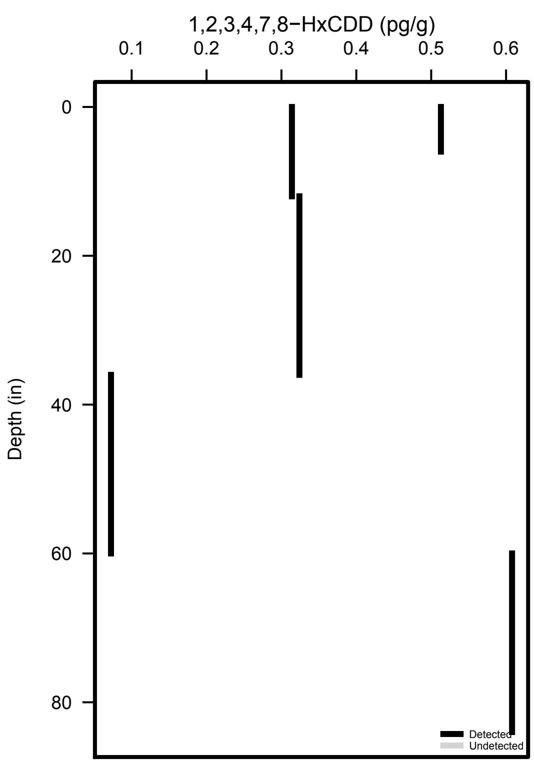

Figure 655. 1,2,3,4,7,8−HxCDD
at Core Location RM692C1.

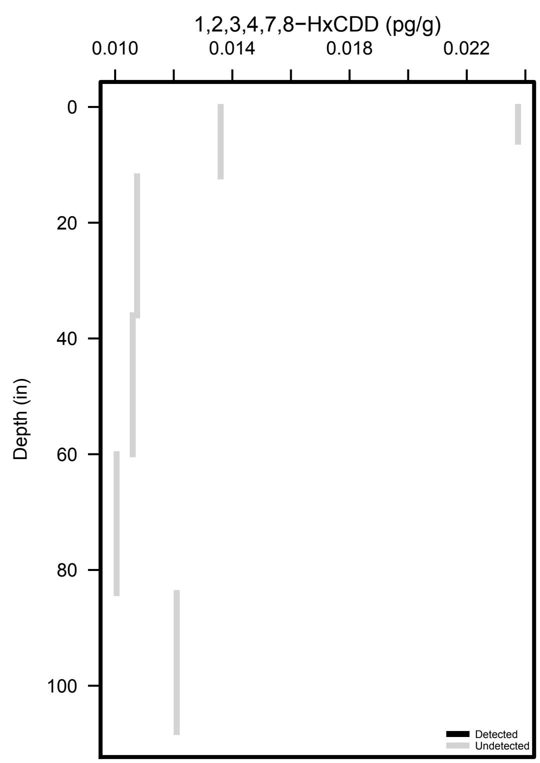

Figure 656. 1,2,3,4,7,8−HxCDD
at Core Location RM704C1.

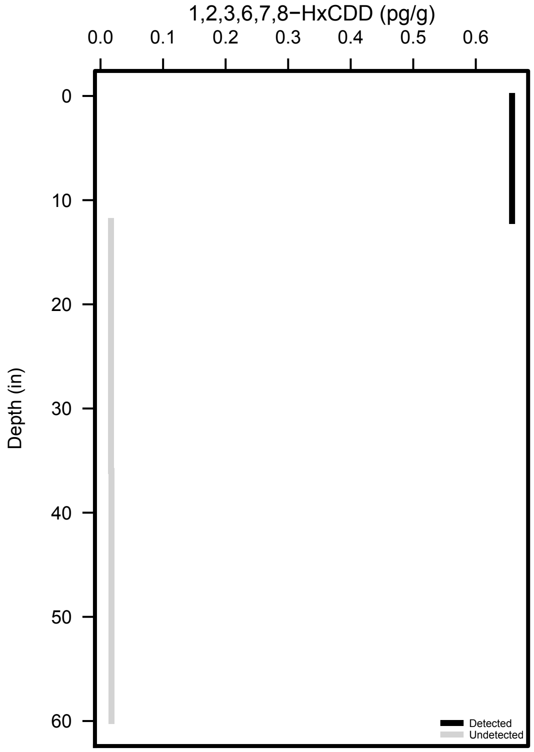

Figure 657. 1,2,3,6,7,8−HxCDD
at Core Location RM605C1.

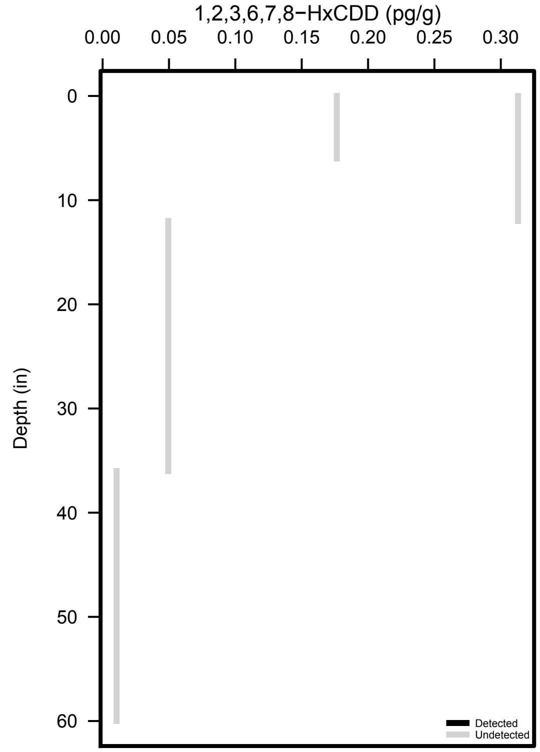

Figure 658. 1,2,3,6,7,8−HxCDD
at Core Location RM637C1.

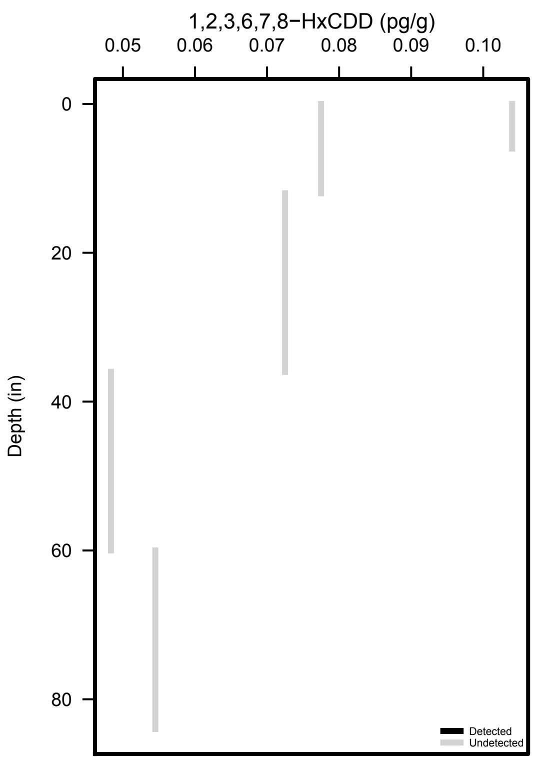

Figure 659. 1,2,3,6,7,8−HxCDD
at Core Location RM661C1.

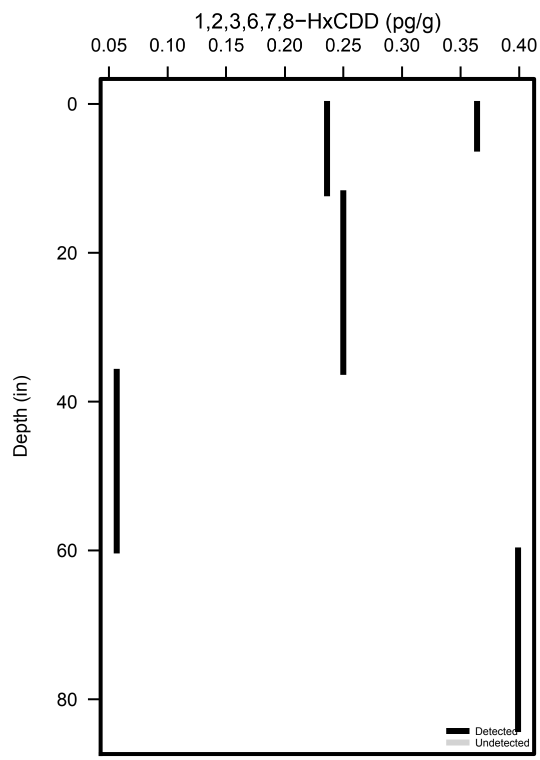

Figure 660. 1,2,3,6,7,8−HxCDD
at Core Location RM692C1.

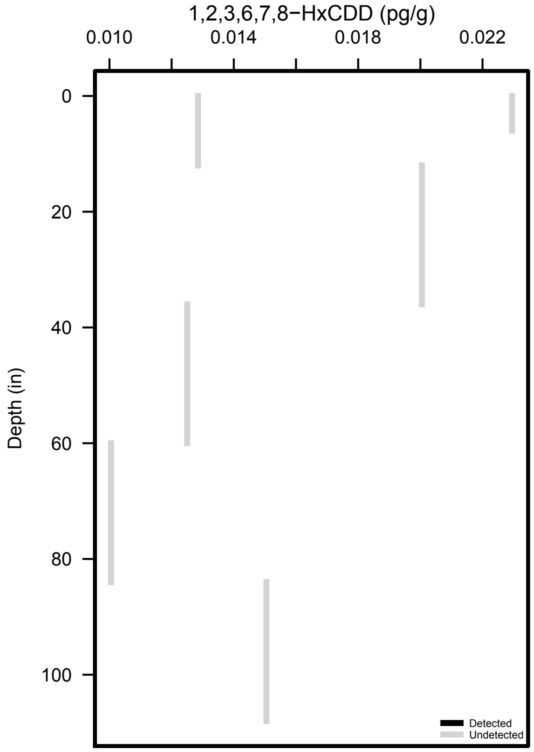

Figure 661. 1,2,3,6,7,8−HxCDD
at Core Location RM704C1.

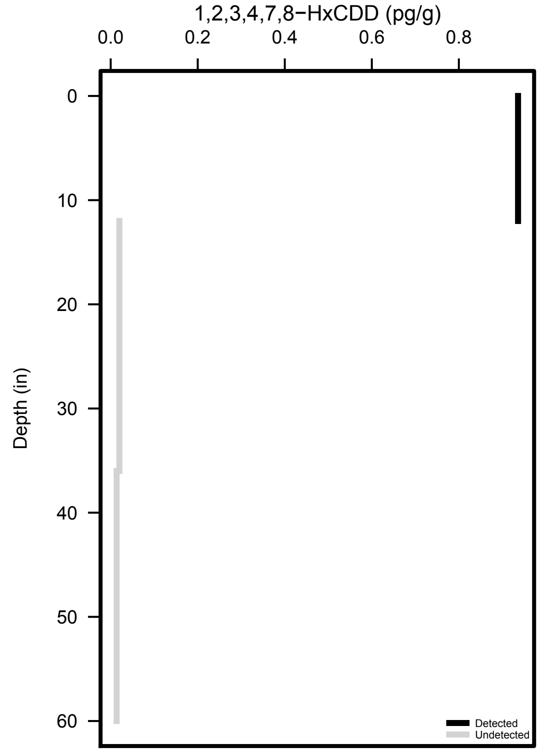

Figure 662. 1,2,3,4,7,8−HxCDD
at Core Location RM605C1.

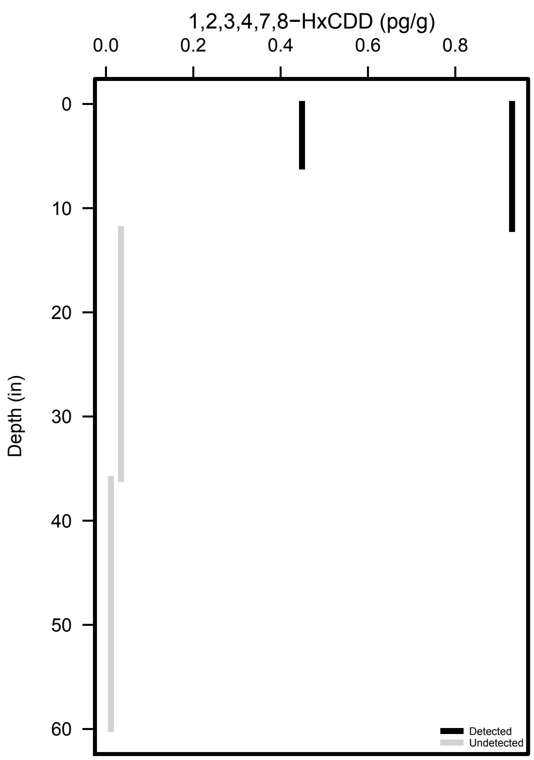

Figure 663. 1,2,3,4,7,8−HxCDD
at Core Location RM637C1.

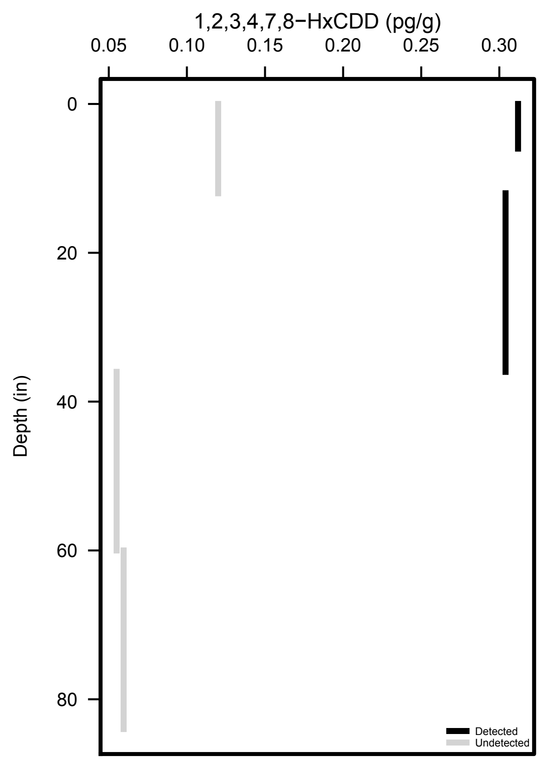

Figure 664. 1,2,3,4,7,8−HxCDD
at Core Location RM661C1.

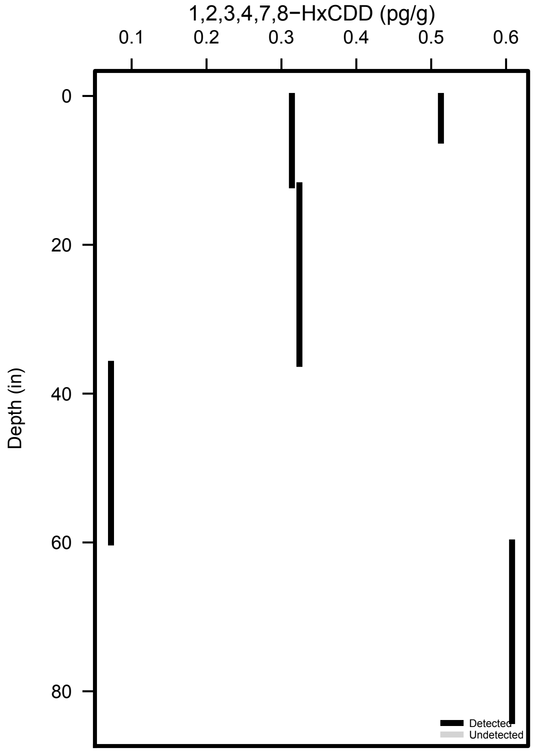

Figure 665. 1,2,3,4,7,8−HxCDD
at Core Location RM692C1.

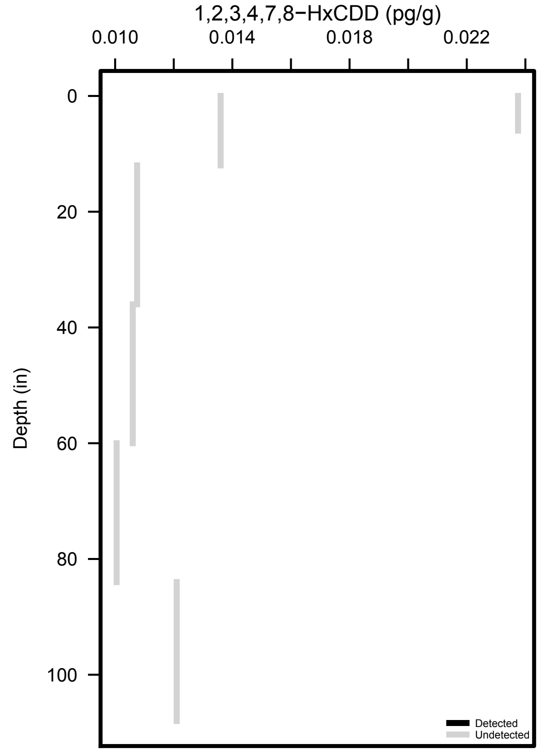

Figure 666. 1,2,3,4,7,8−HxCDD
at Core Location RM704C1.

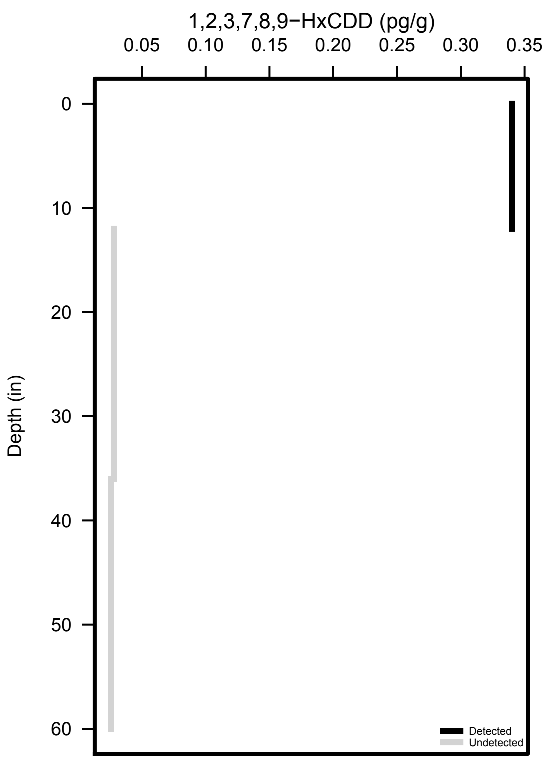

Figure 667. 1,2,3,7,8,9−HxCDD
at Core Location RM605C1.

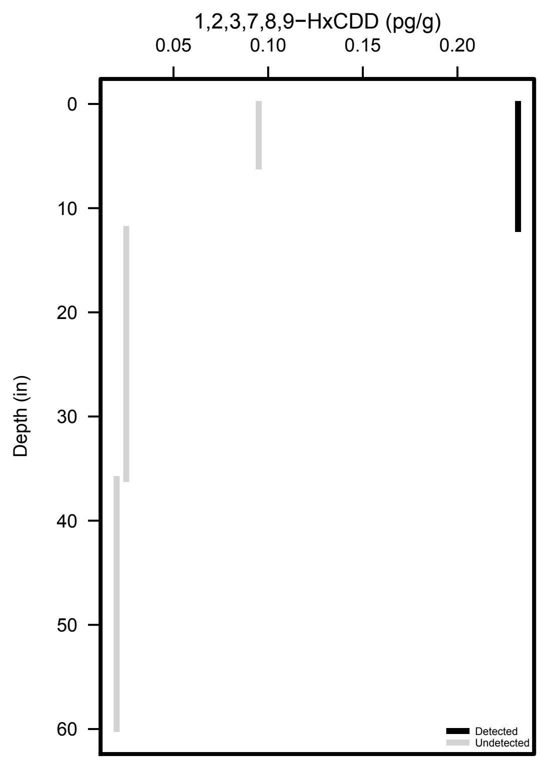

Figure 668. 1,2,3,7,8,9−HxCDD
at Core Location RM637C1.

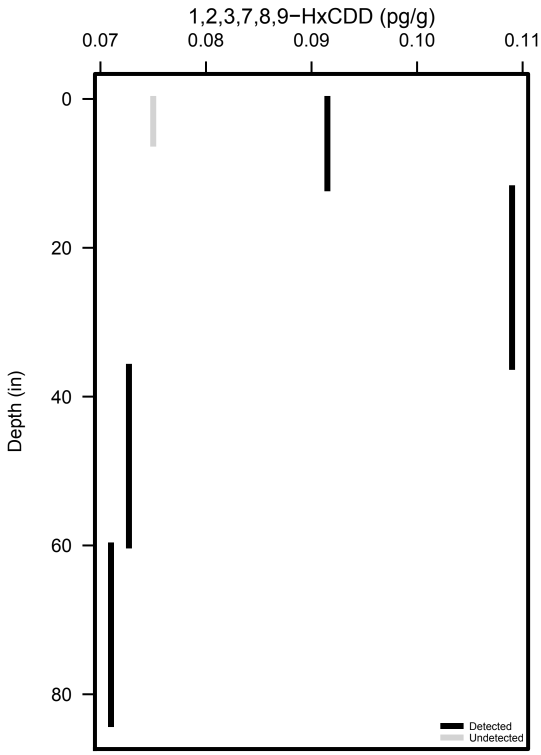

Figure 669. 1,2,3,7,8,9−HxCDD
at Core Location RM661C1.

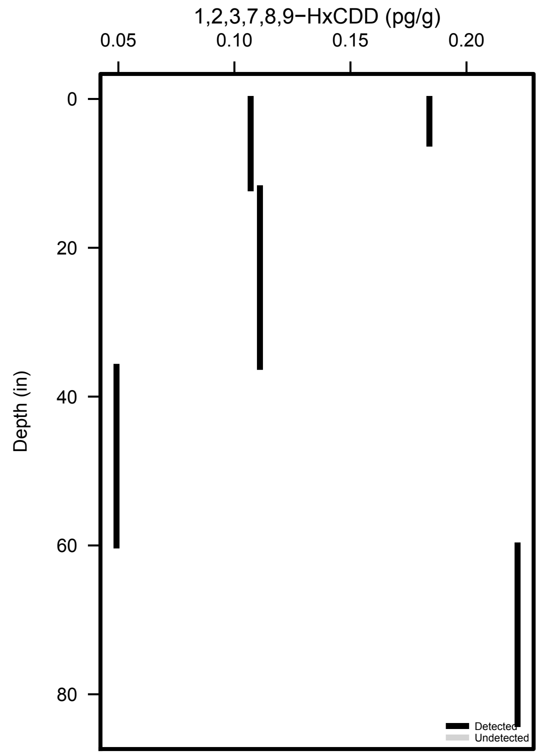

Figure 670. 1,2,3,7,8,9−HxCDD
at Core Location RM692C1.

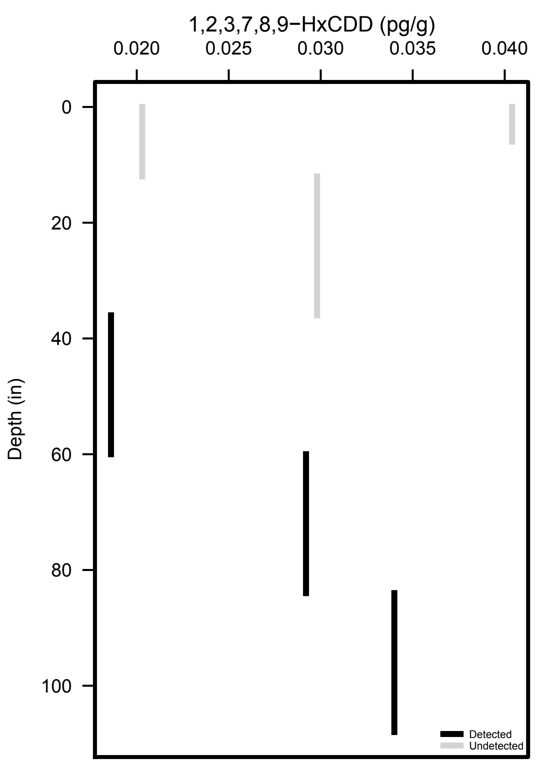

Figure 671. 1,2,3,7,8,9−HxCDD
at Core Location RM704C1.

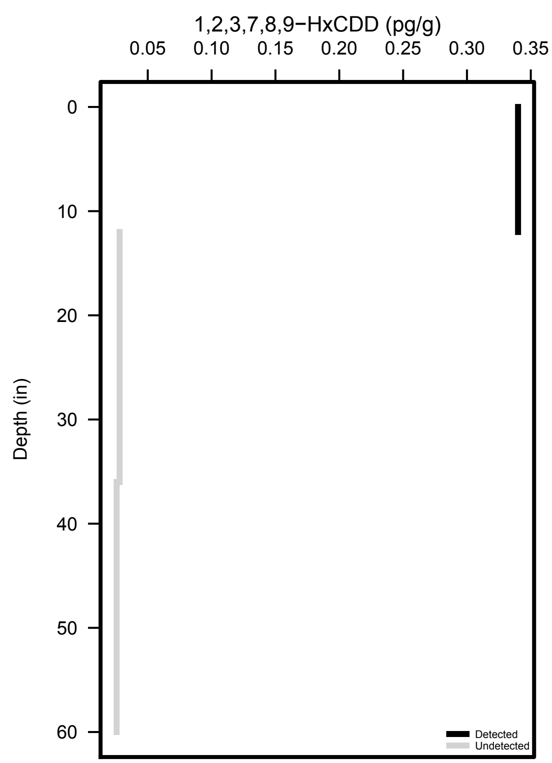

Figure 672. 1,2,3,7,8,9−HxCDD
at Core Location RM605C1.

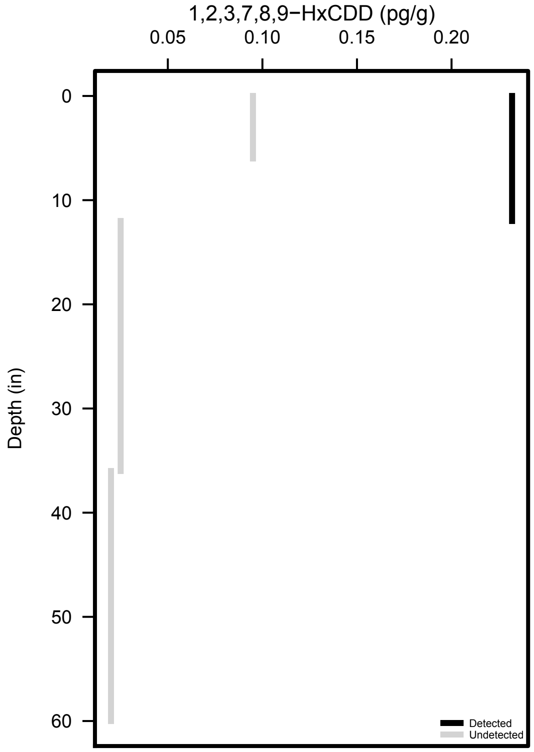

Figure 673. 1,2,3,7,8,9−HxCDD
at Core Location RM637C1.

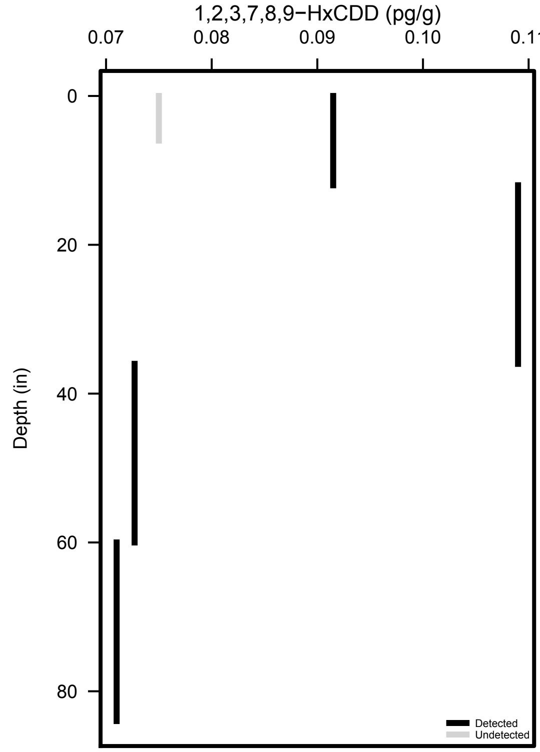

Figure 674. 1,2,3,7,8,9−HxCDD
at Core Location RM661C1.

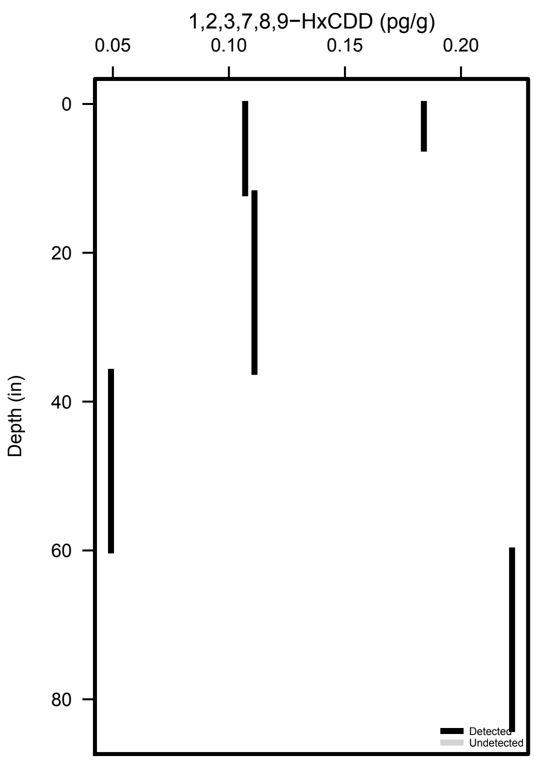

Figure 675. 1,2,3,7,8,9−HxCDD
at Core Location RM692C1.

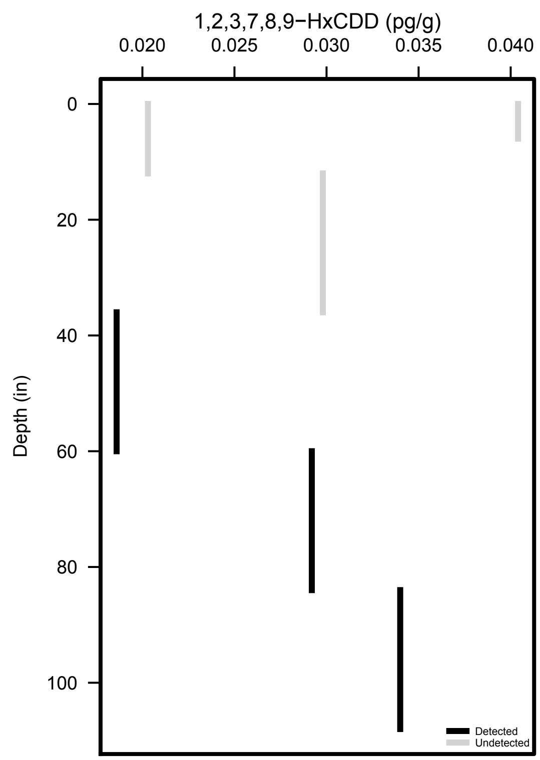

Figure 676. 1,2,3,7,8,9−HxCDD
at Core Location RM704C1.

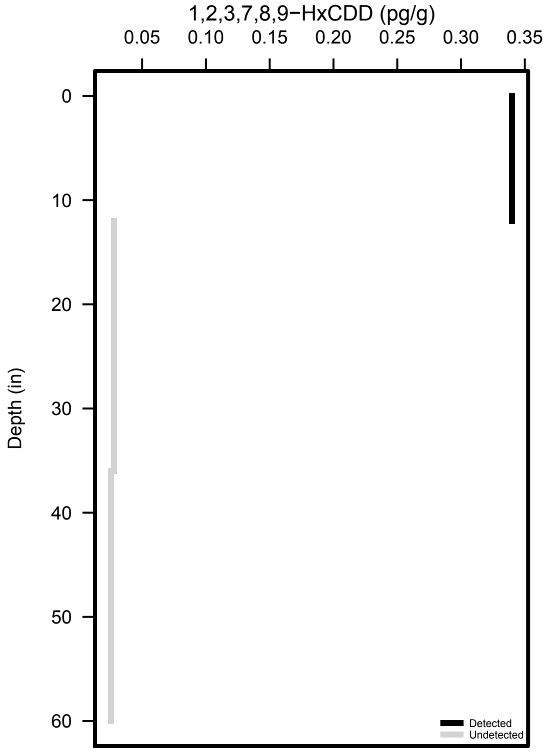

Figure 677. 1,2,3,7,8,9−HxCDD
at Core Location RM605C1.

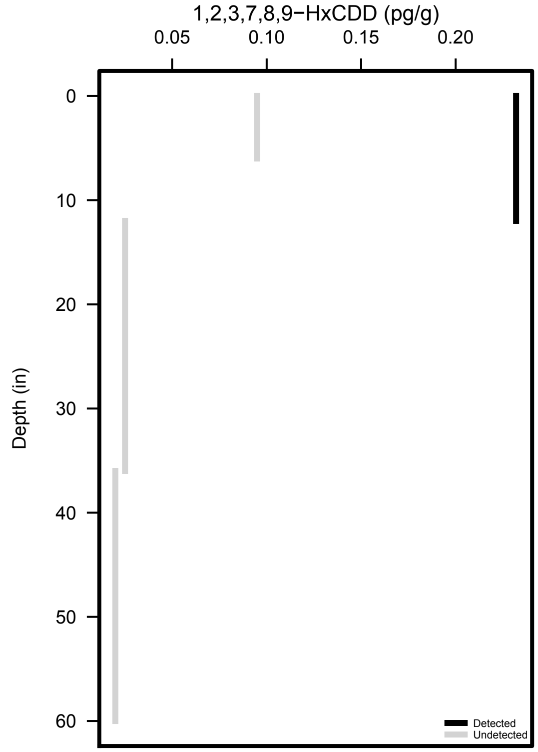

Figure 678. 1,2,3,7,8,9−HxCDD
at Core Location RM637C1.

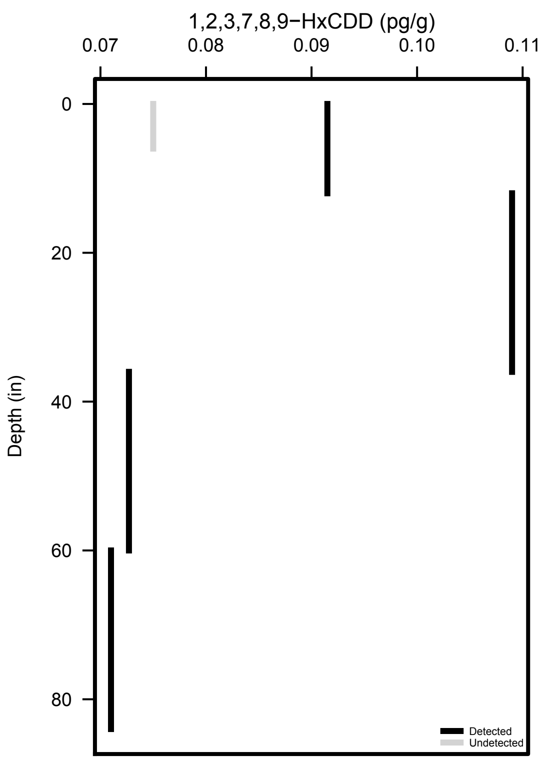

Figure 679. 1,2,3,7,8,9−HxCDD
at Core Location RM661C1.

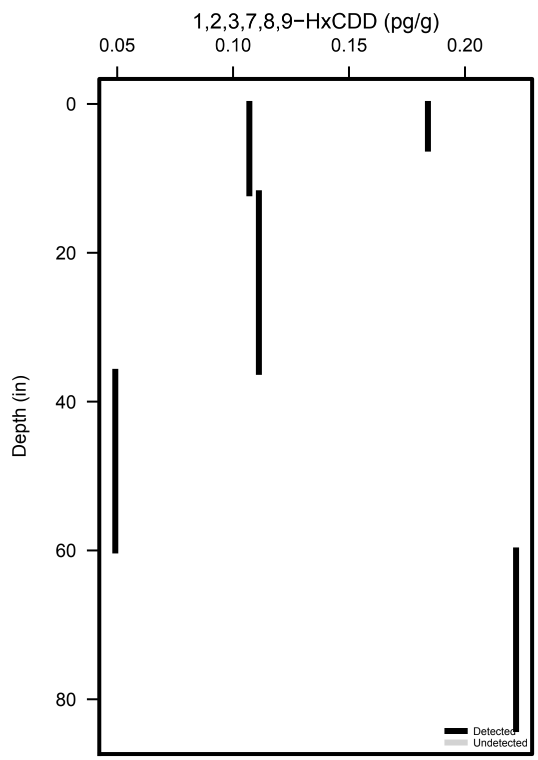

Figure 680. 1,2,3,7,8,9−HxCDD
at Core Location RM692C1.

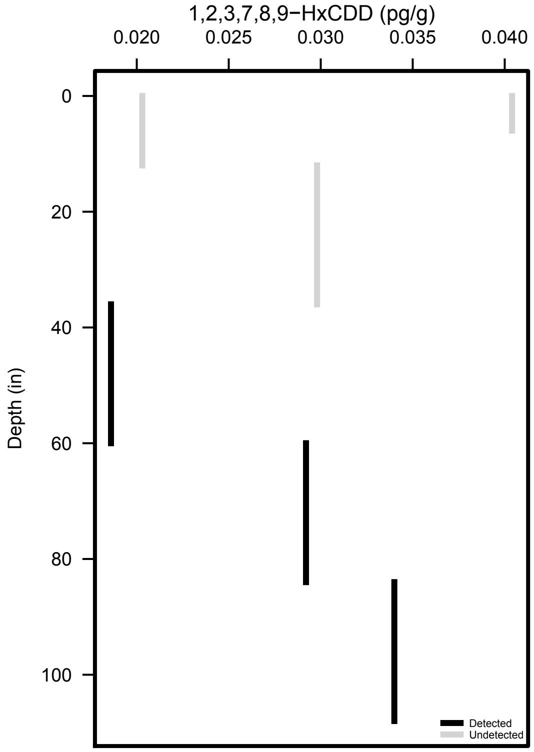

Figure 681. 1,2,3,7,8,9−HxCDD at Core Location RM704C1.

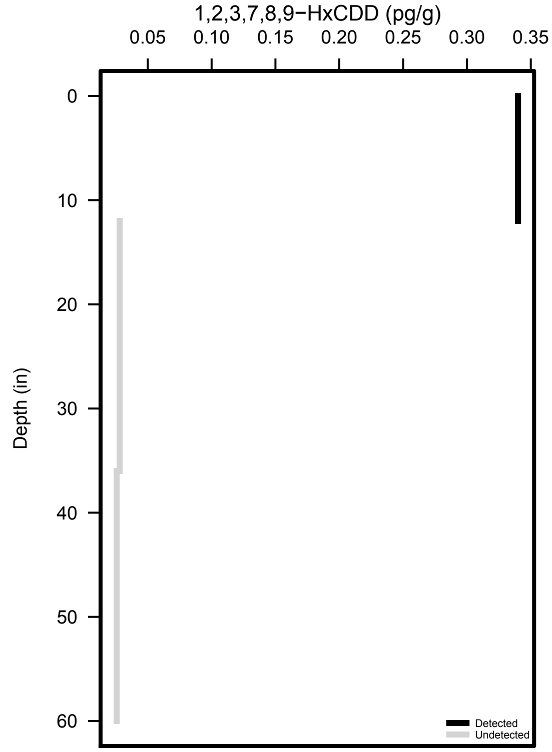

Figure 682. 1,2,3,7,8,9−HxCDD at Core Location RM605C1.

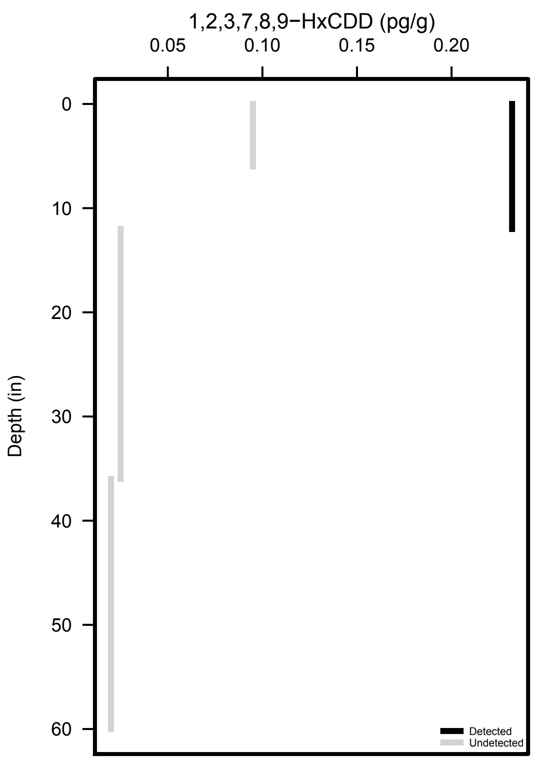

Figure 683. 1,2,3,7,8,9−HxCDD at Core Location RM637C1.

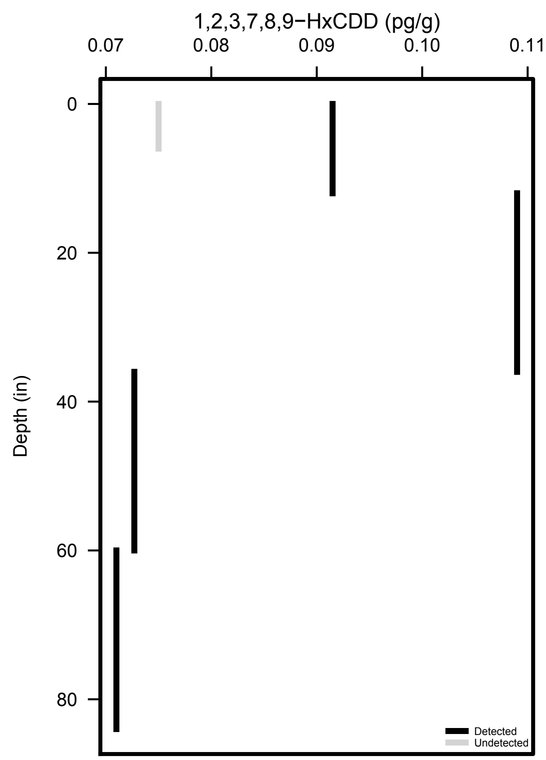

Figure 684. 1,2,3,7,8,9−HxCDD at Core Location RM661C1.

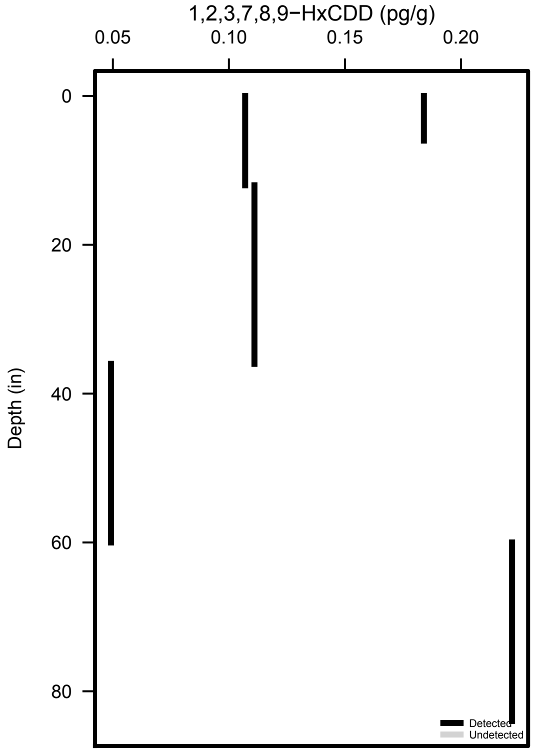

Figure 685. 1,2,3,7,8,9−HxCDD
at Core Location RM692C1.

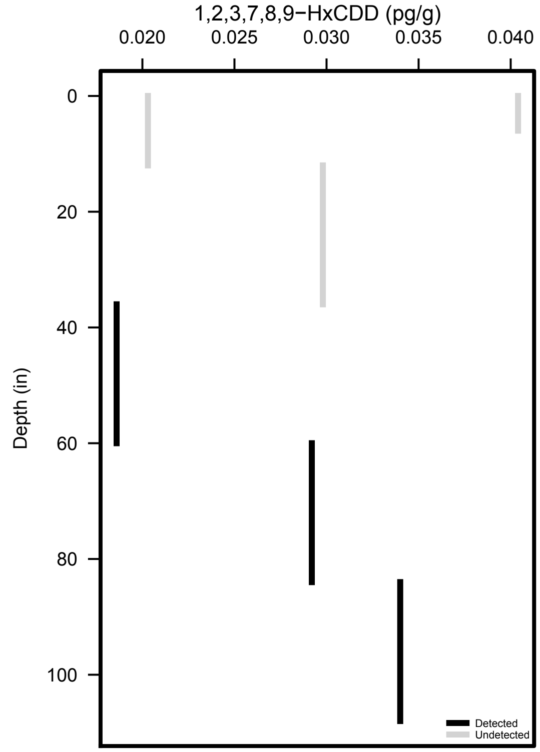

Figure 686. 1,2,3,7,8,9−HxCDD
at Core Location RM704C1.

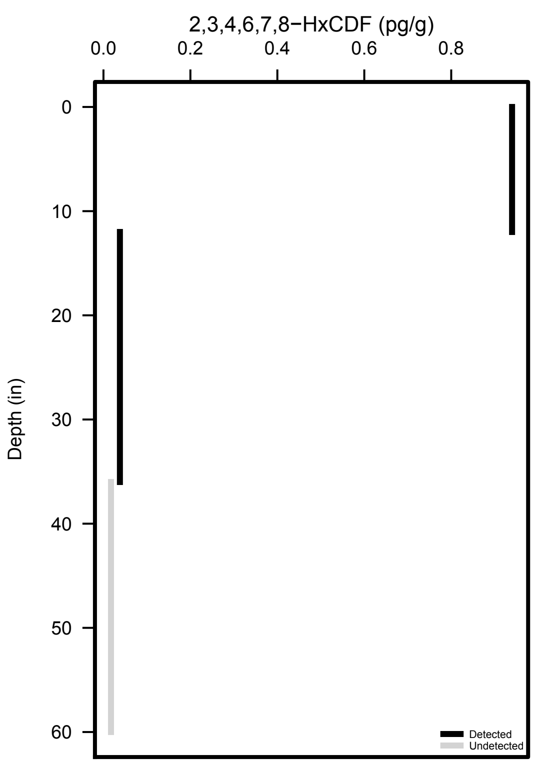

Figure 687. 2,3,4,6,7,8−HxCDF
at Core Location RM605C1.

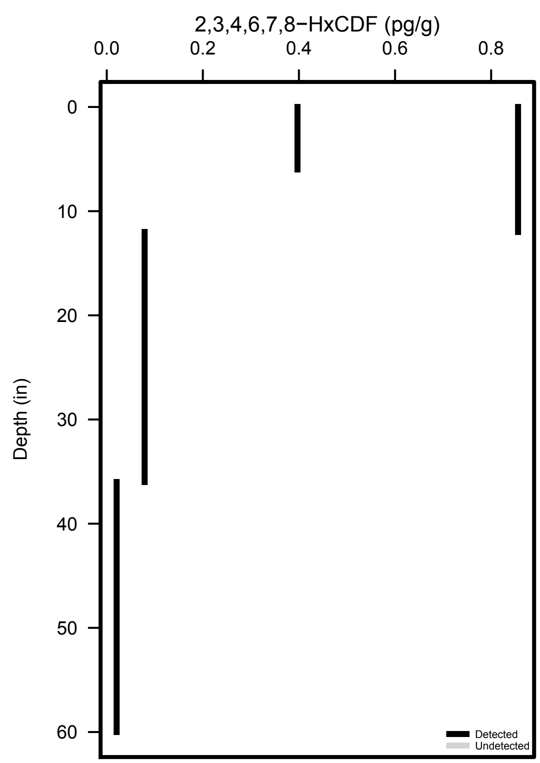

Figure 688. 2,3,4,6,7,8−HxCDF
at Core Location RM637C1.

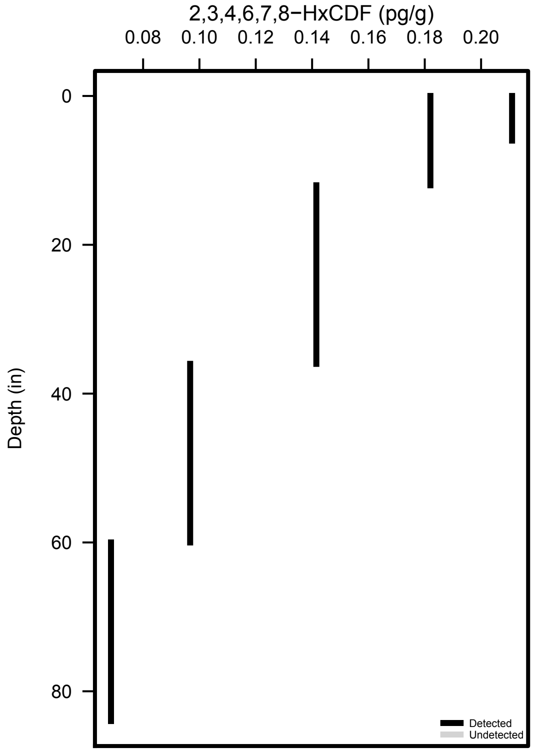

Figure 689. 2,3,4,6,7,8−HxCDF
at Core Location RM661C1.

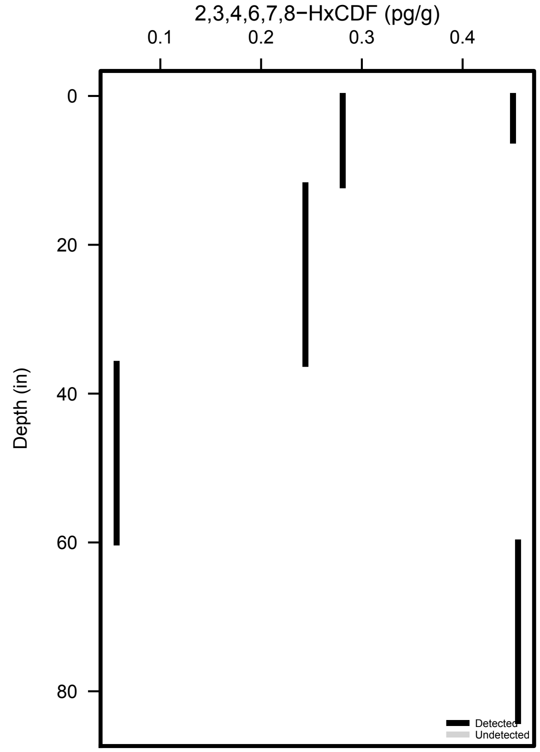

Figure 690. 2,3,4,6,7,8−HxCDF
at Core Location RM692C1.

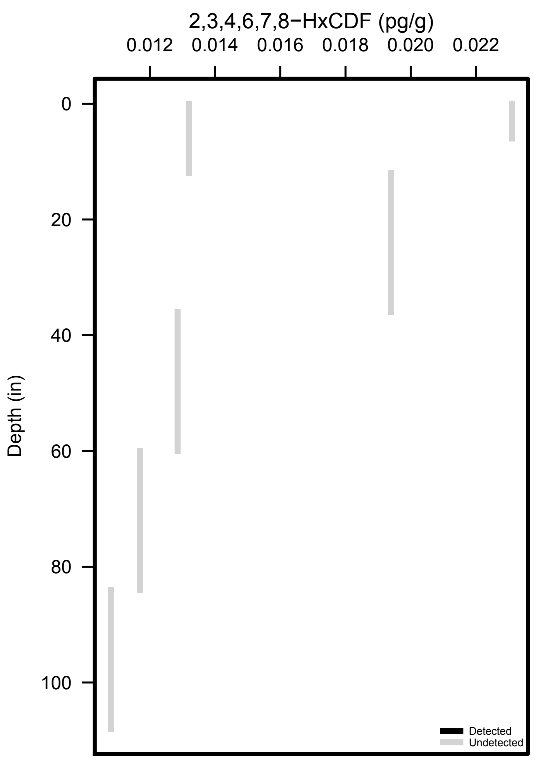

Figure 691. 2,3,4,6,7,8−HxCDF
at Core Location RM704C1.

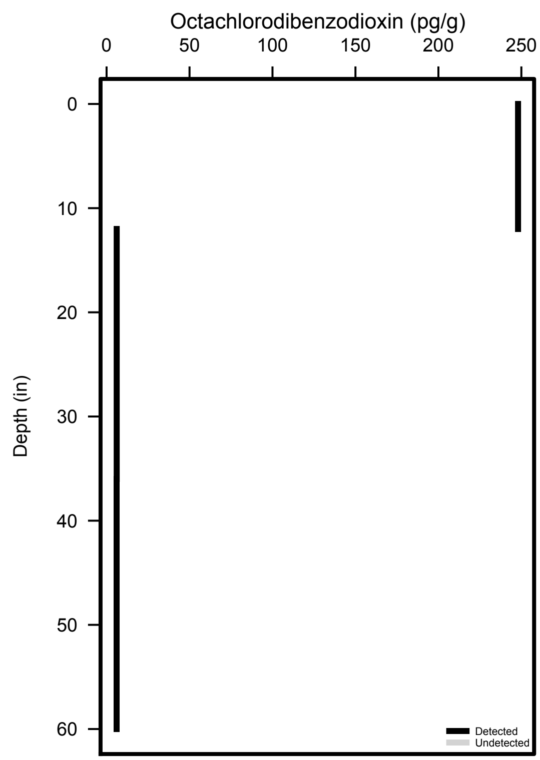

Figure 692. Octachlorodibenzodioxin
at Core Location RM605C1.

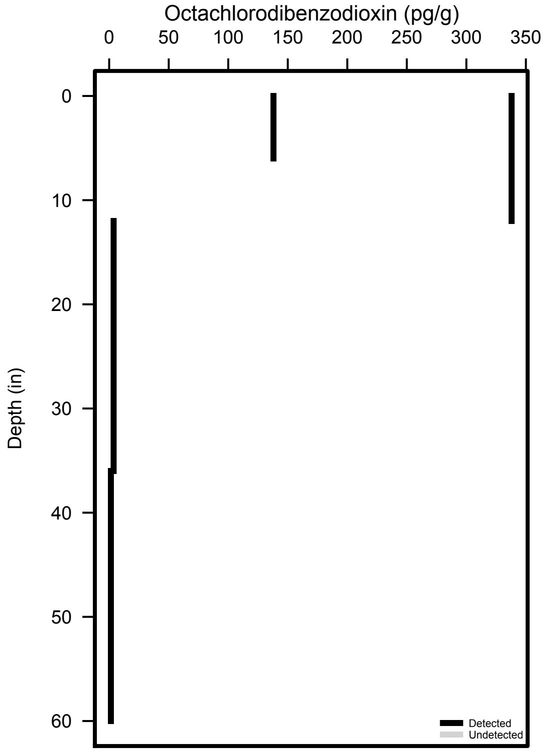

Figure 693. Octachlorodibenzodioxin
at Core Location RM637C1.

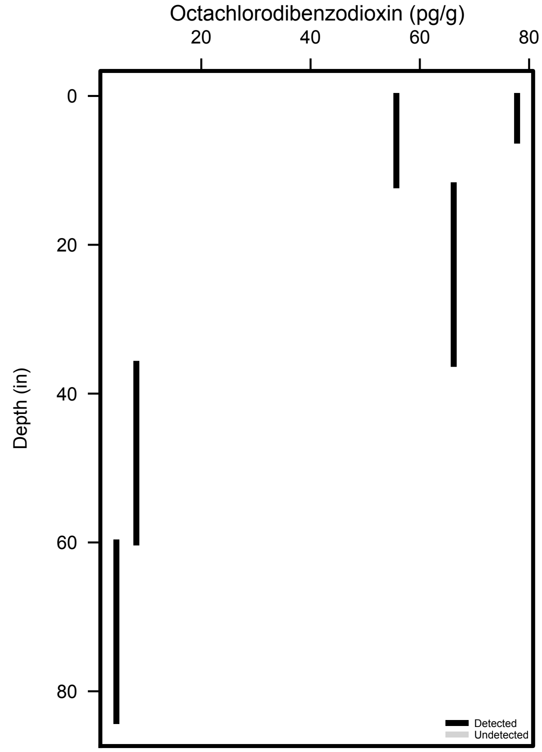

Figure 694. Octachlorodibenzodioxin
at Core Location RM661C1.

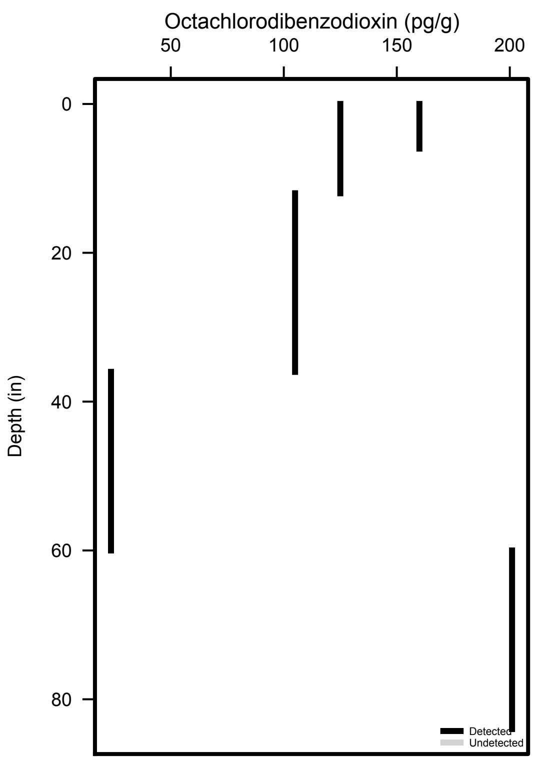

Figure 695. Octachlorodibenzodioxin
at Core Location RM692C1.

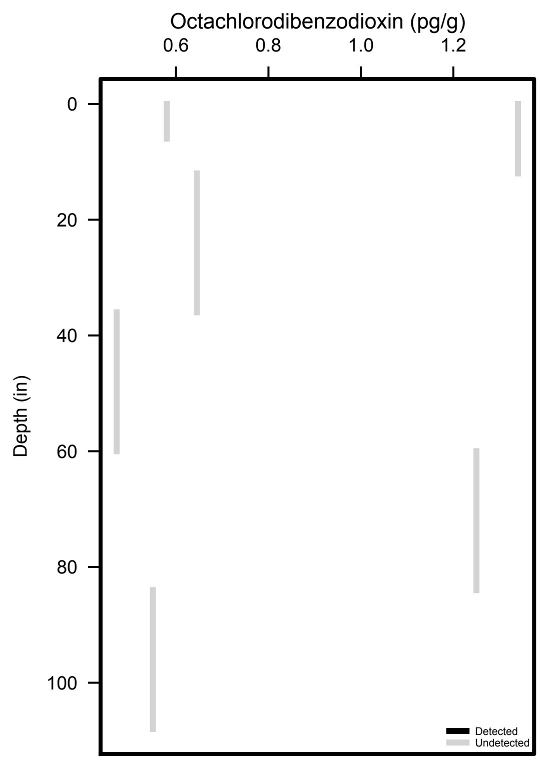

Figure 696. Octachlorodibenzodioxin
at Core Location RM704C1.

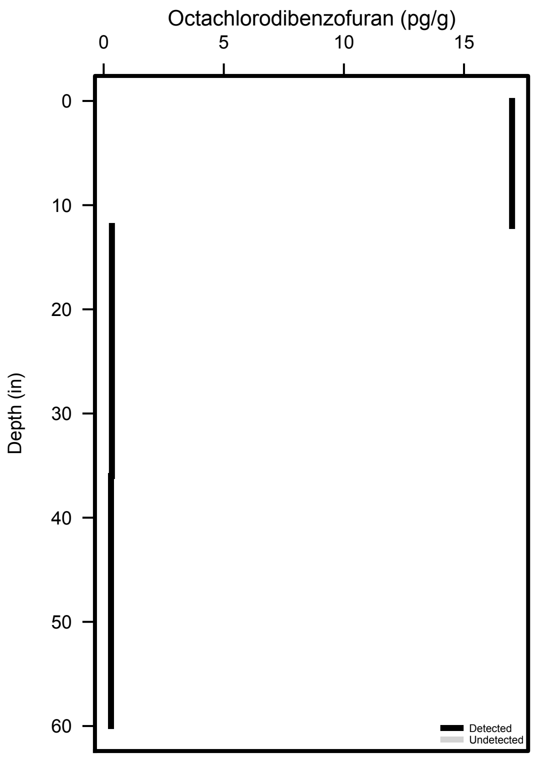

Figure 697. Octachlorodibenzofuran at Core Location RM605C1.

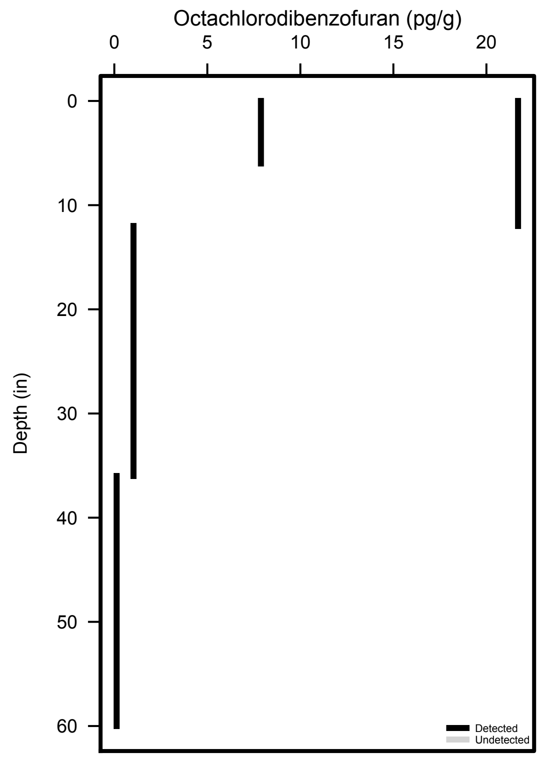

Figure 698. Octachlorodibenzofuran at Core Location RM637C1.

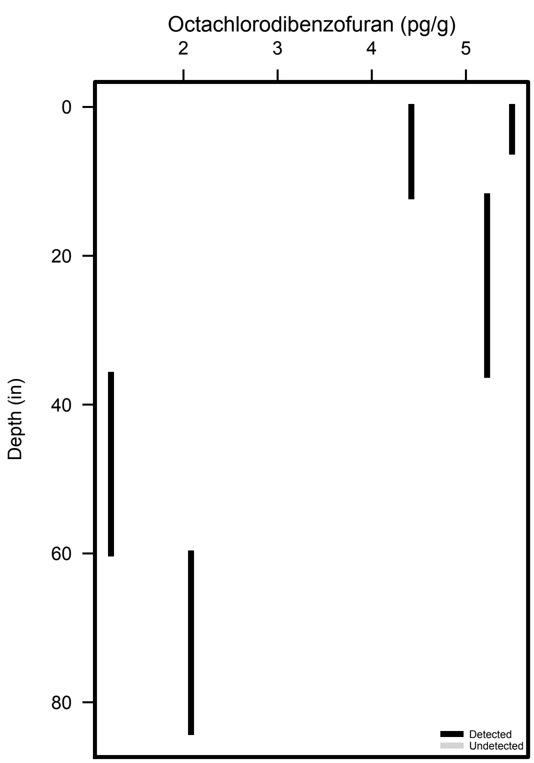

Figure 699. Octachlorodibenzofuran at Core Location RM661C1.

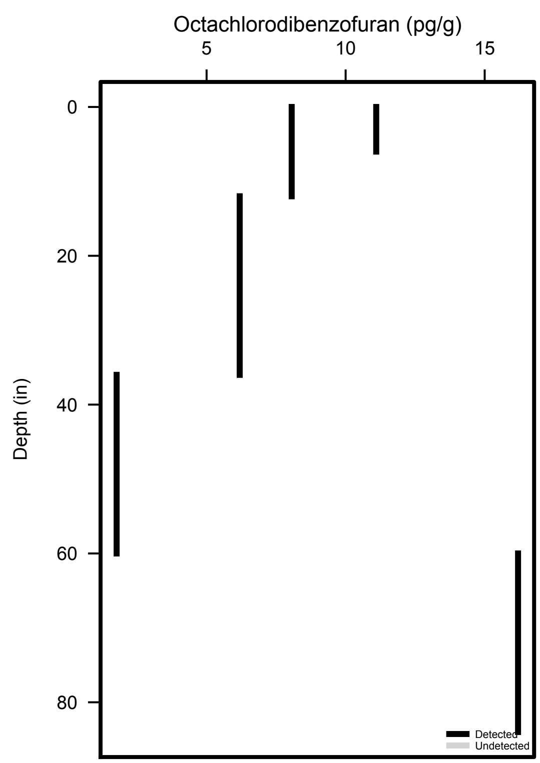

Figure 700. Octachlorodibenzofuran at Core Location RM692C1.

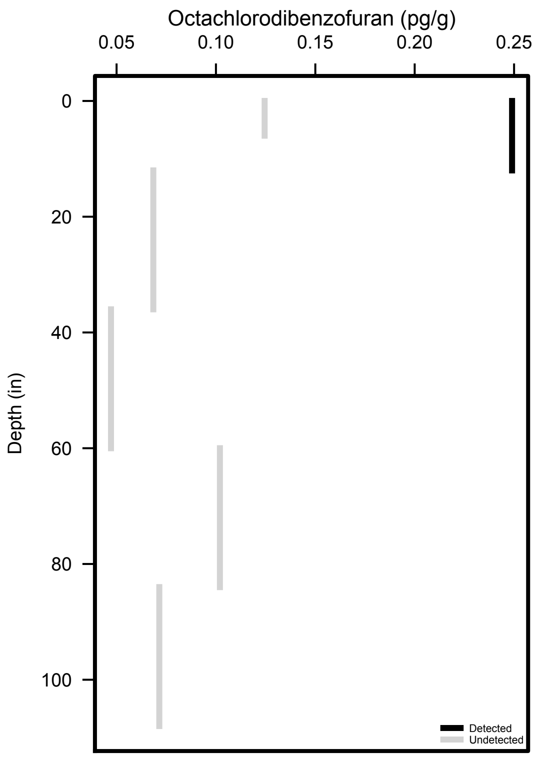

Figure 701. Octachlorodibenzofuran
at Core Location RM704C1.

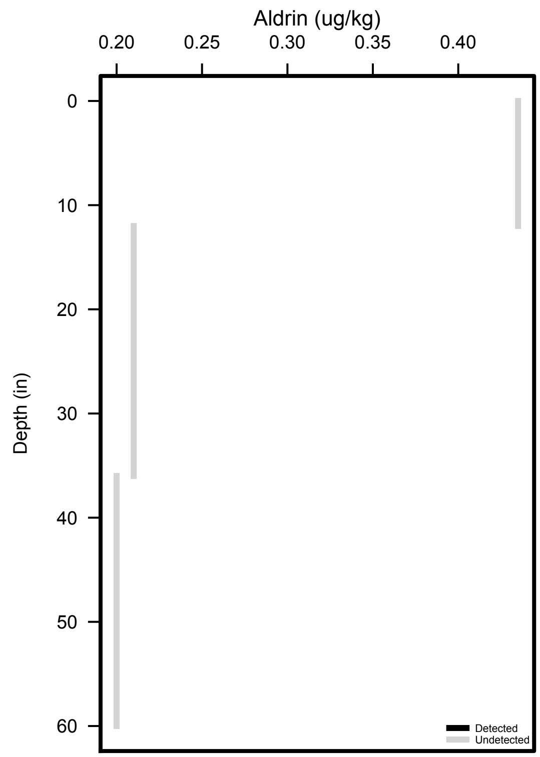

Figure 702. Aldrin
at Core Location RM605C1.

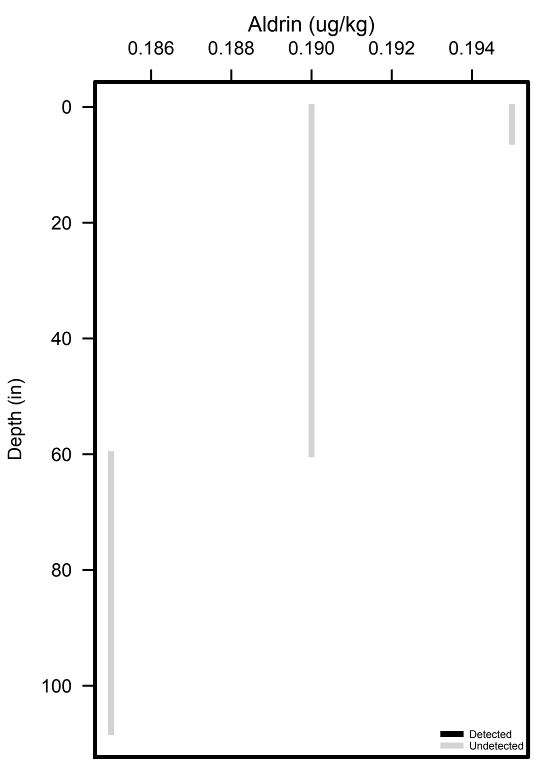

Figure 703. Aldrin
at Core Location RM622C1.

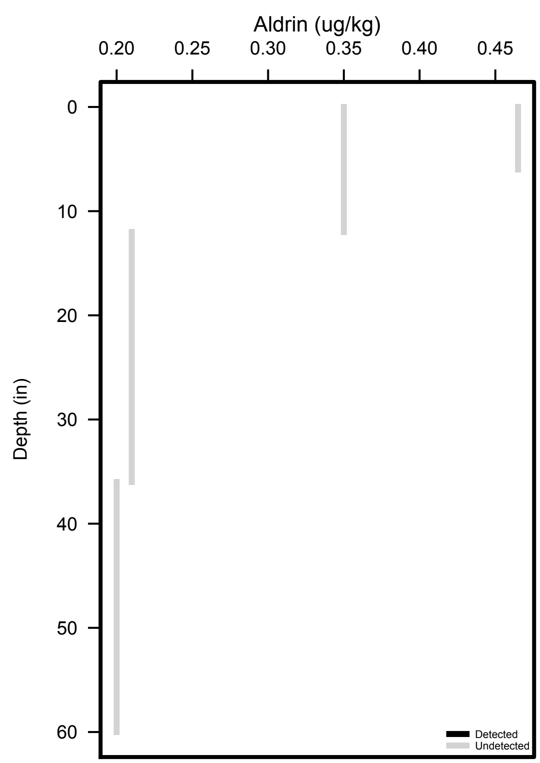

Figure 704. Aldrin
at Core Location RM637C1.

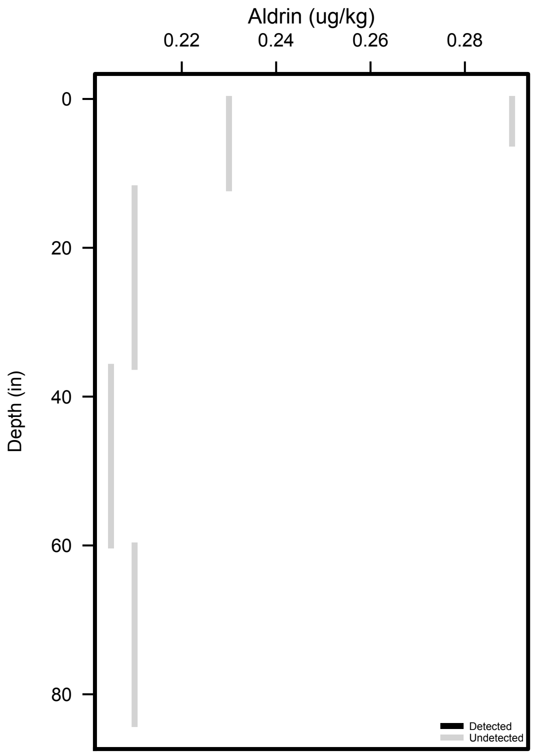

Figure 705. Aldrin
at Core Location RM644C1.

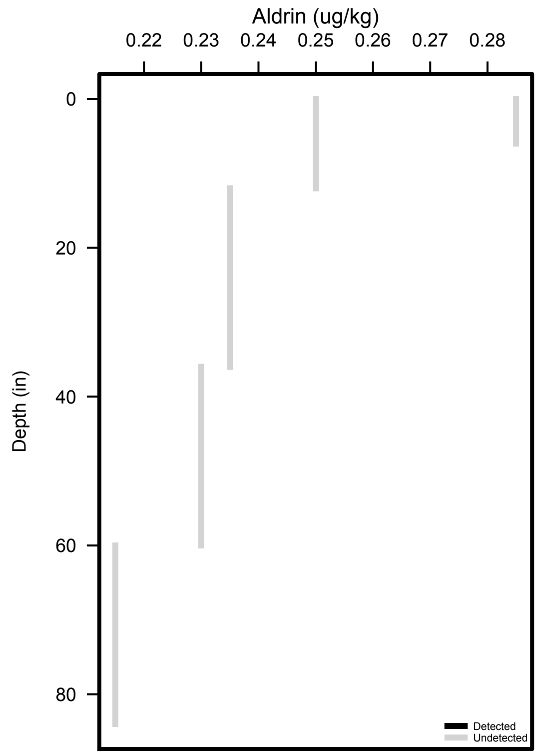

Figure 706. Aldrin
at Core Location RM661C1.

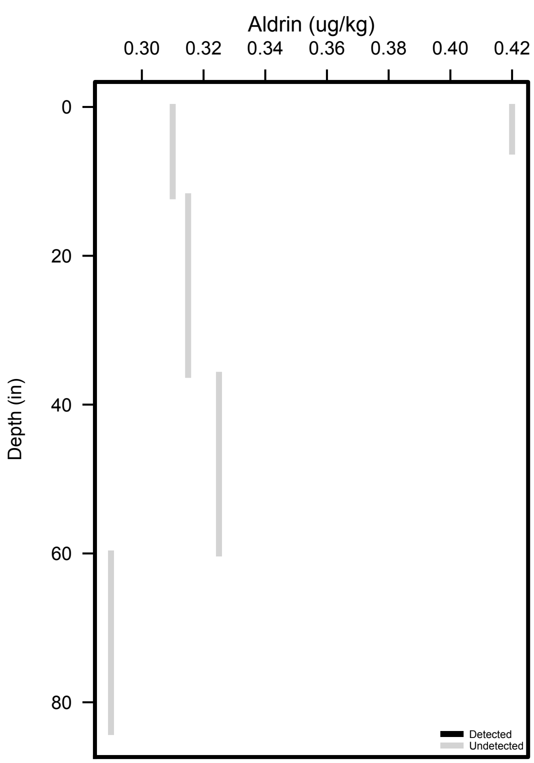

Figure 707. Aldrin
at Core Location RM676C1.

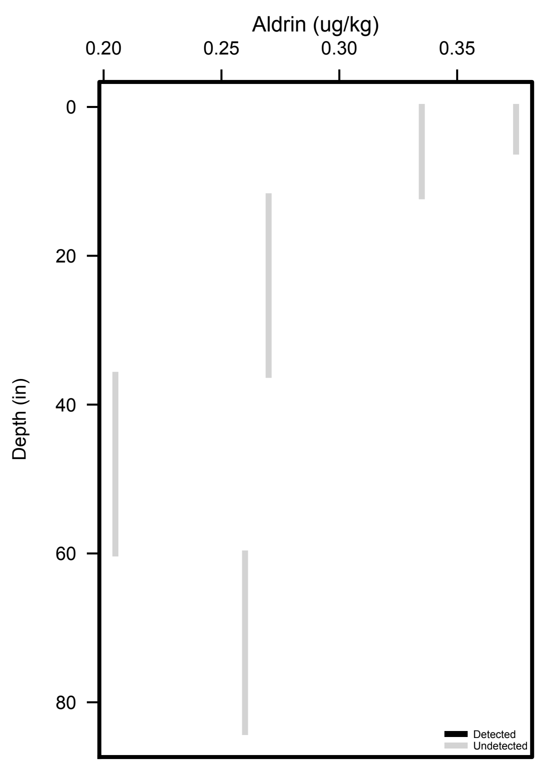

Figure 708. Aldrin
at Core Location RM692C1.

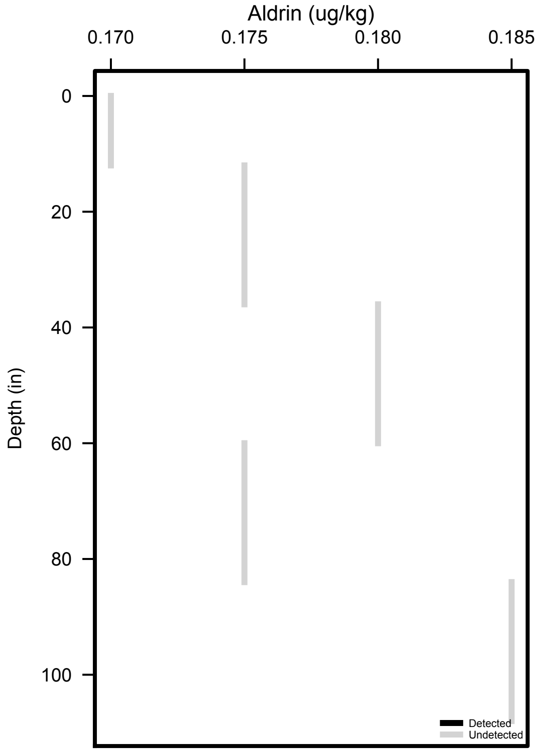

Figure 709. Aldrin
at Core Location RM704C1.

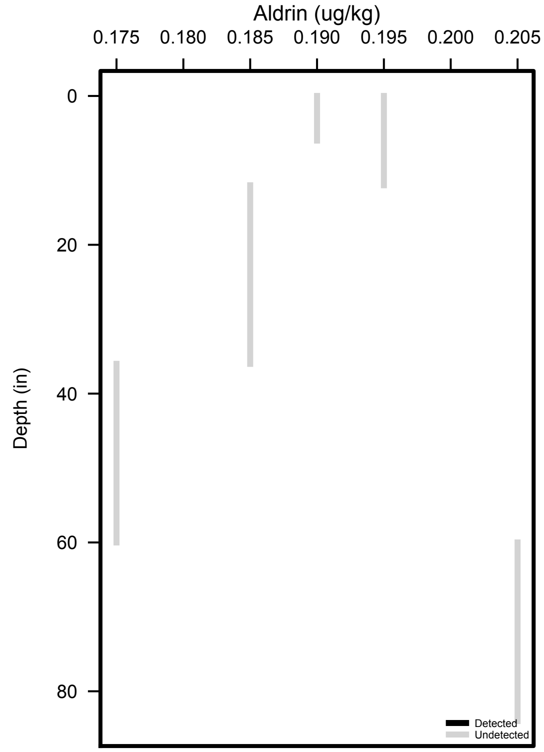

Figure 710. Aldrin
at Core Location RM708C1.

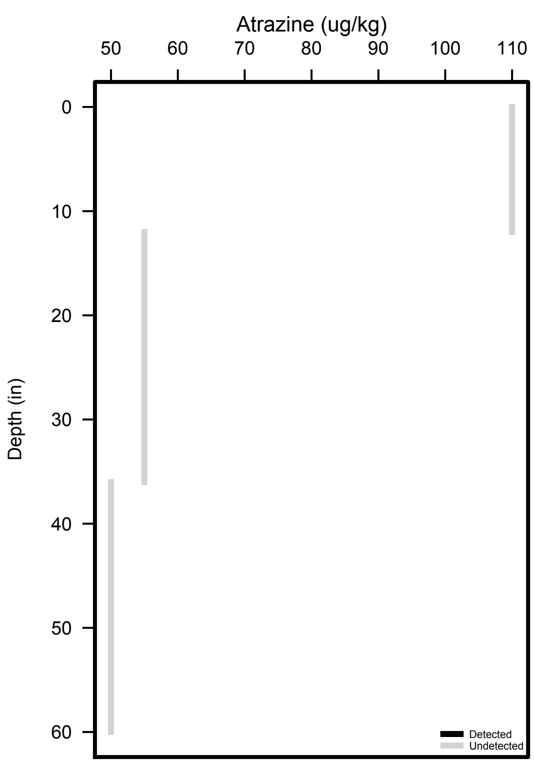

Figure 711. Atrazine
at Core Location RM605C1.

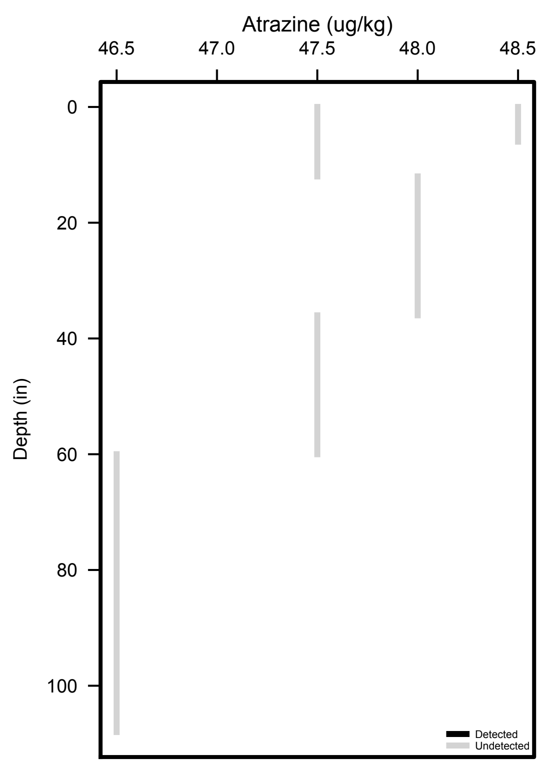

Figure 712. Atrazine
at Core Location RM622C1.

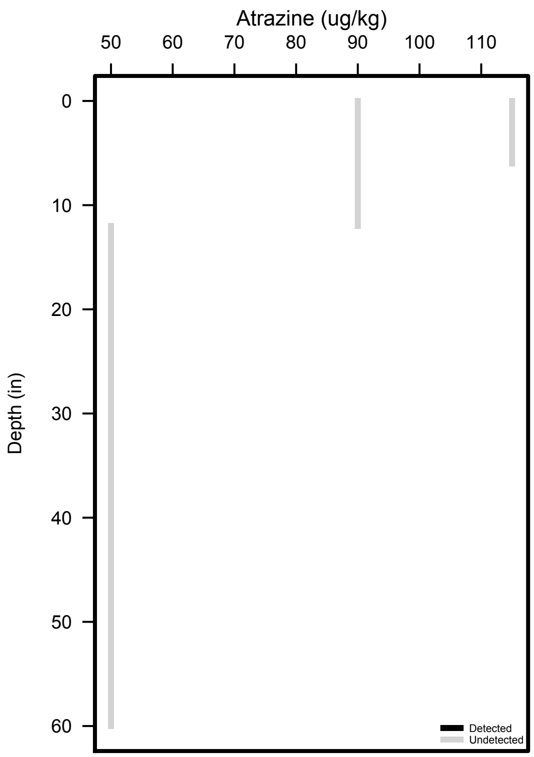

Figure 713. Atrazine
at Core Location RM637C1.

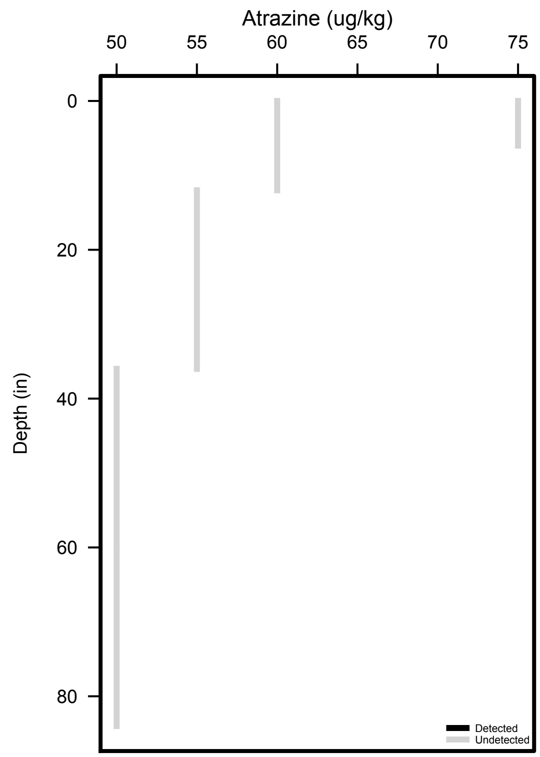

Figure 714. Atrazine
at Core Location RM644C1.

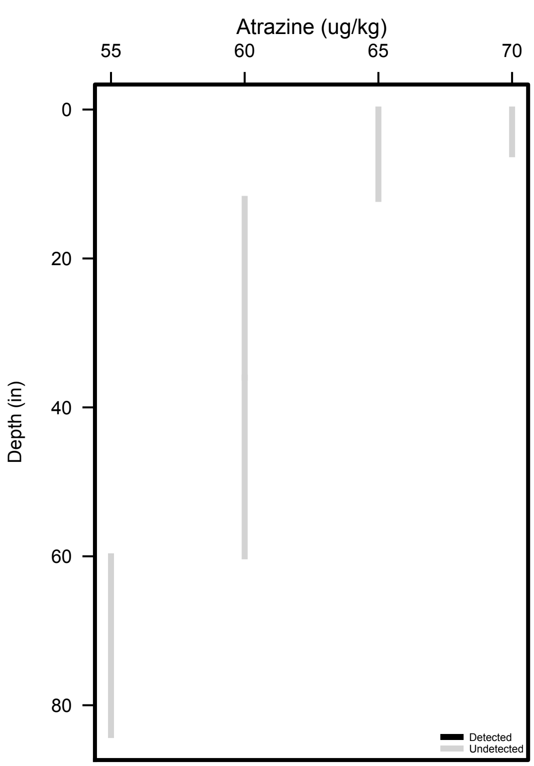

Figure 715. Atrazine
at Core Location RM661C1.

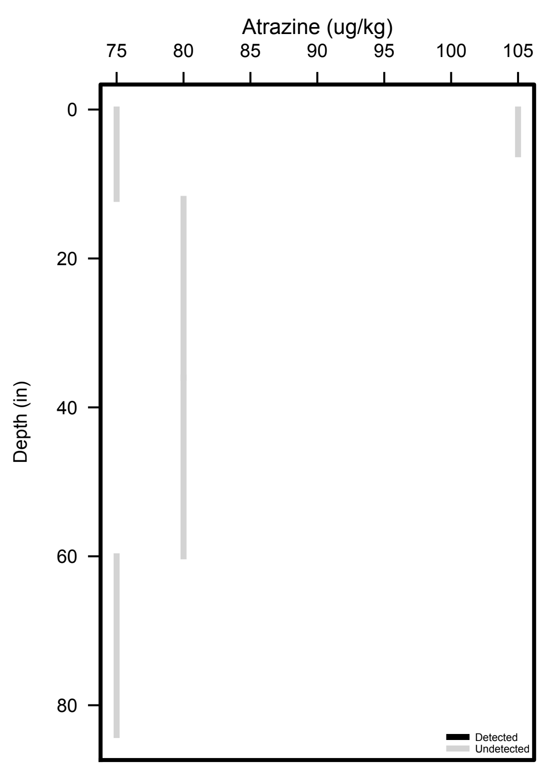

Figure 716. Atrazine
at Core Location RM676C1.

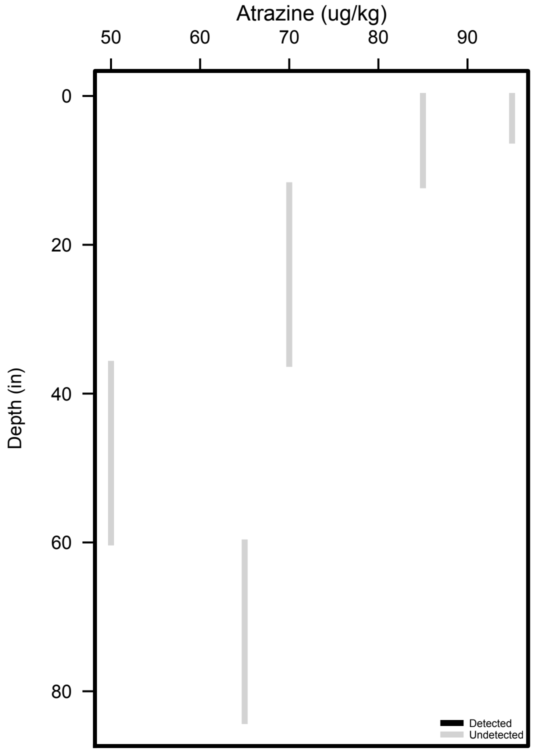

Figure 717. Atrazine
at Core Location RM692C1.

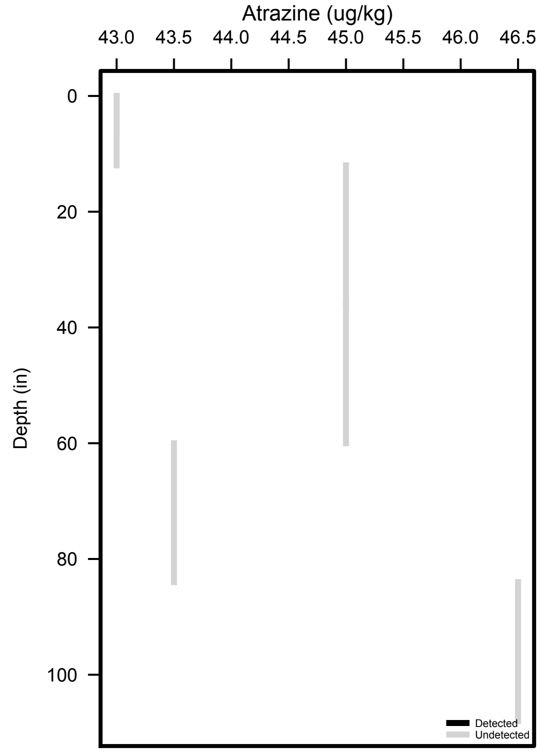

Figure 718. Atrazine
at Core Location RM704C1.

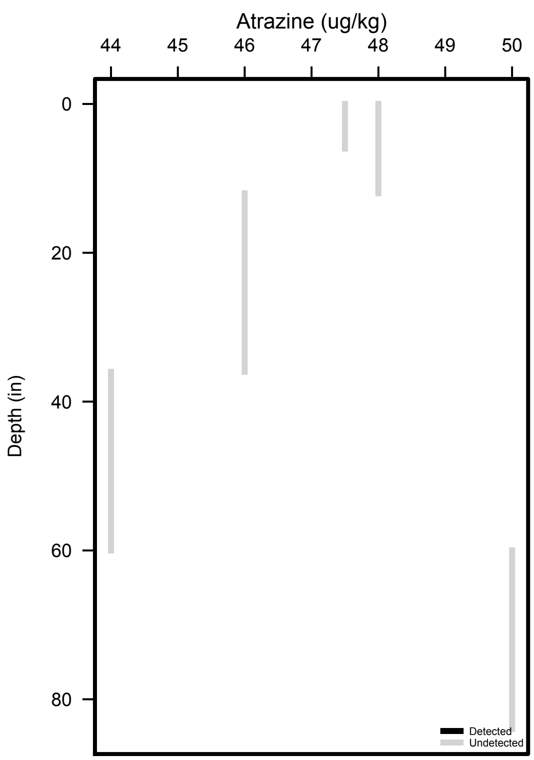

Figure 719. Atrazine
at Core Location RM708C1.

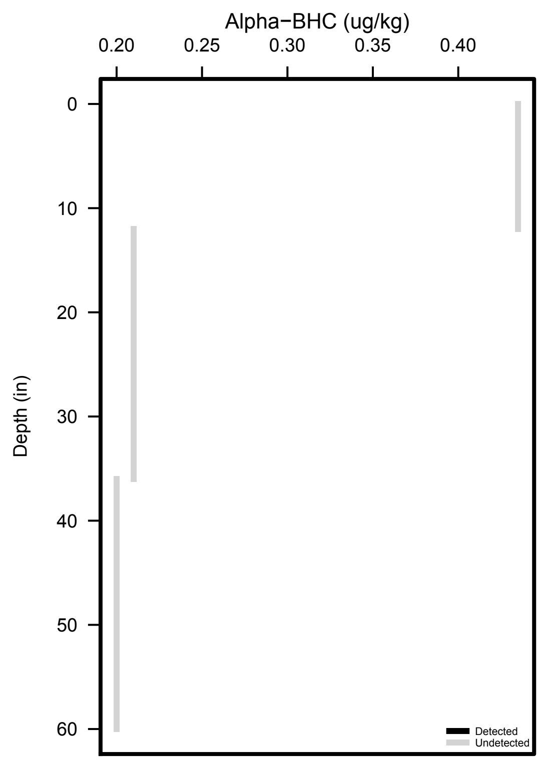

Figure 720. Alpha−BHC
at Core Location RM605C1.

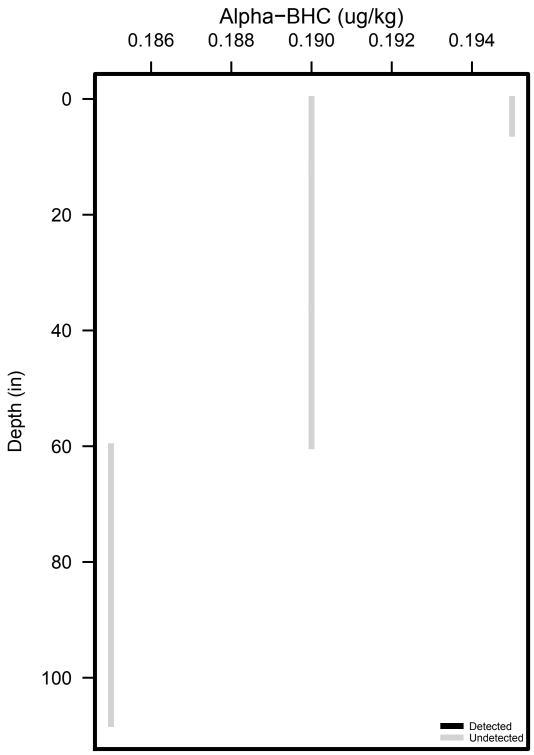

Figure 721. Alpha−BHC
at Core Location RM622C1.

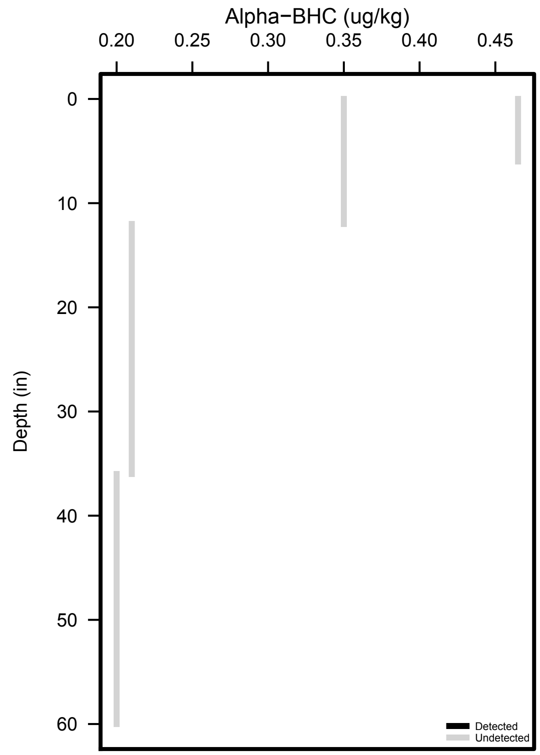

Figure 722. Alpha−BHC
at Core Location RM637C1.

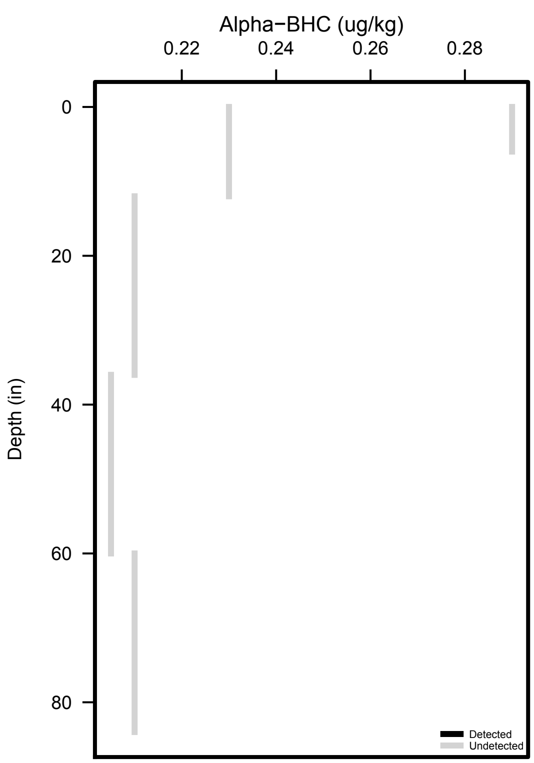

Figure 723. Alpha−BHC
at Core Location RM644C1.

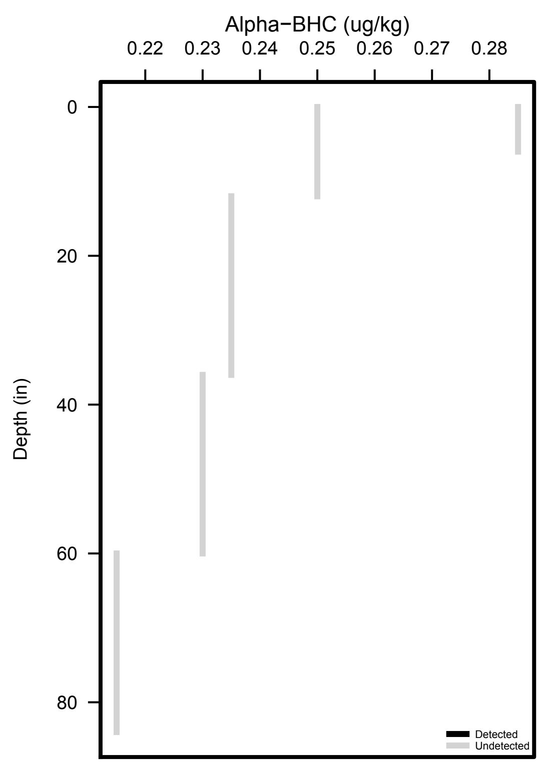

Figure 724. Alpha−BHC
at Core Location RM661C1.

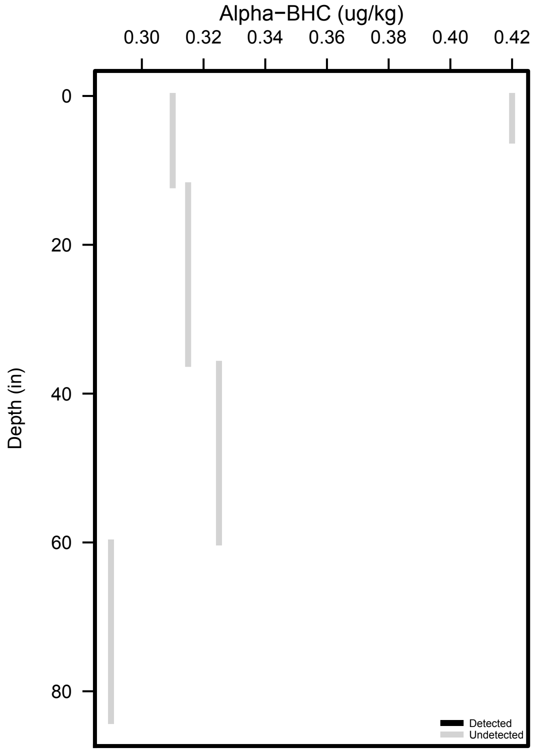

Figure 725. Alpha−BHC
at Core Location RM676C1.

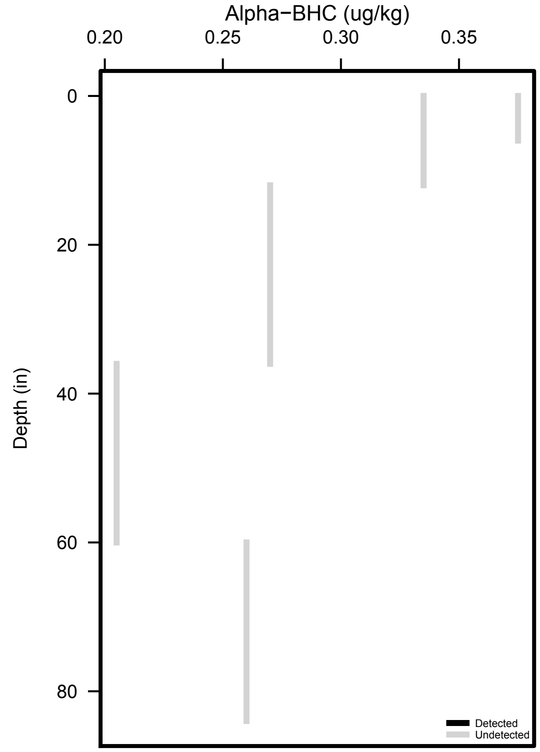

Figure 726. Alpha−BHC
at Core Location RM692C1.

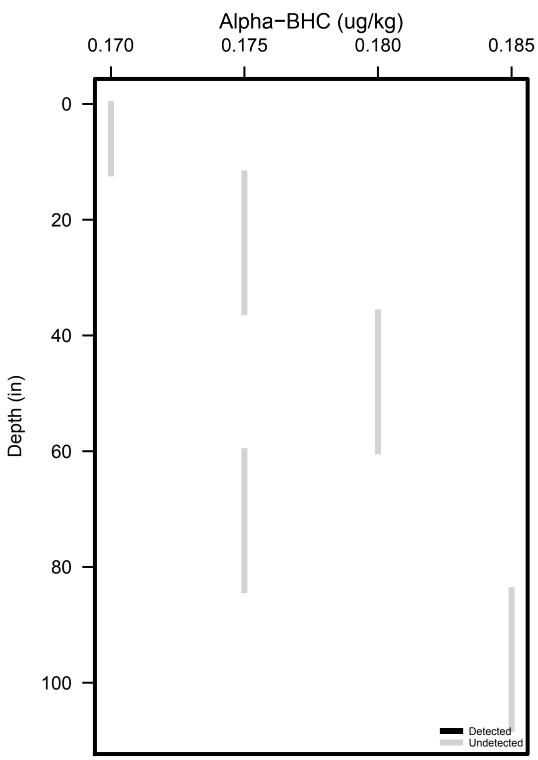

Figure 727. Alpha−BHC
at Core Location RM704C1.

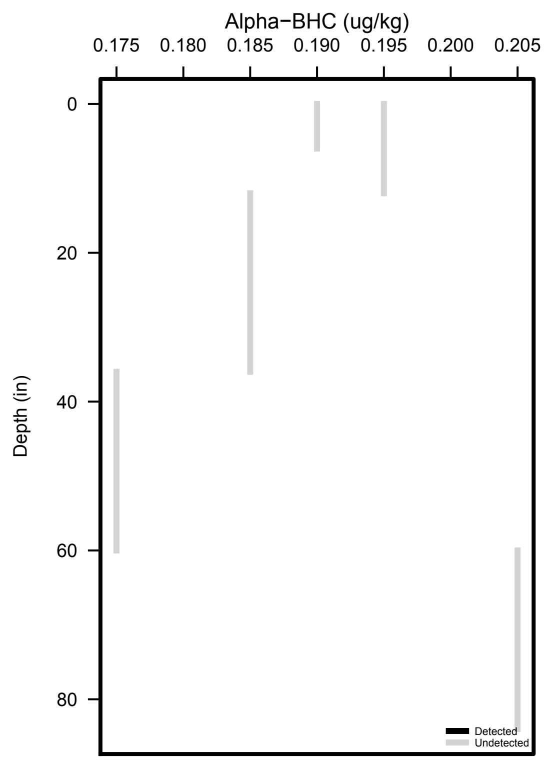

Figure 728. Alpha−BHC
at Core Location RM708C1.

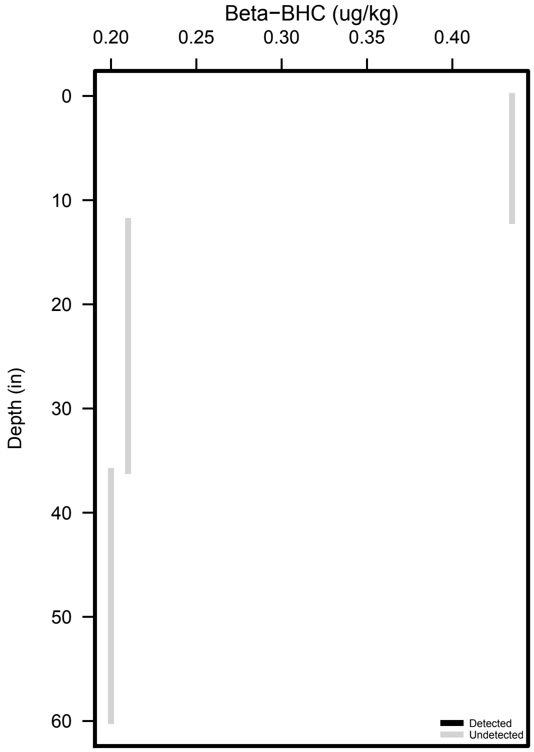

Figure 729. Beta−BHC
at Core Location RM605C1.

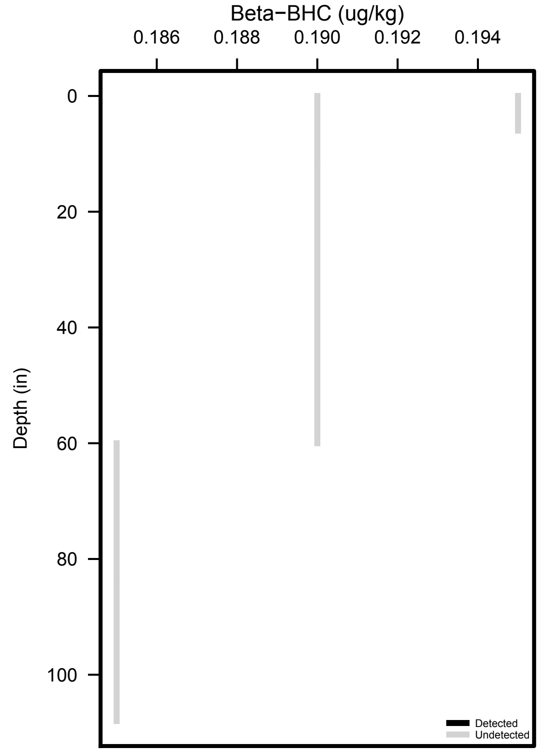

Figure 730. Beta−BHC
at Core Location RM622C1.

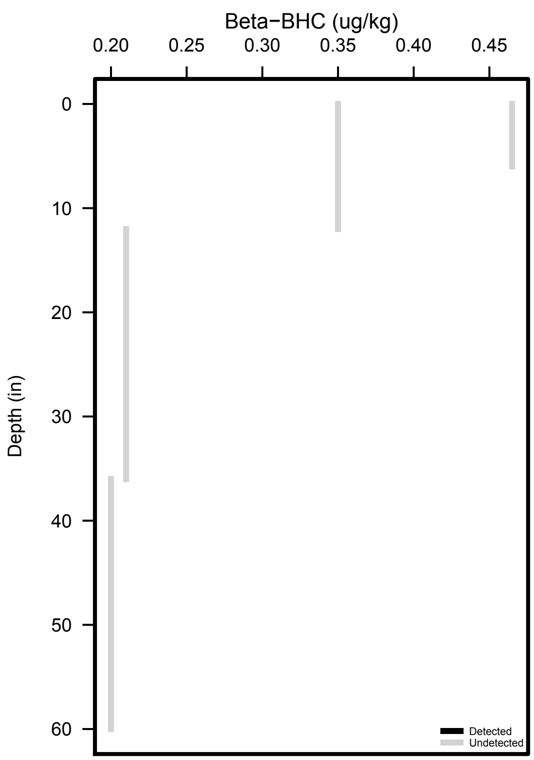

Figure 731. Beta−BHC
at Core Location RM637C1.

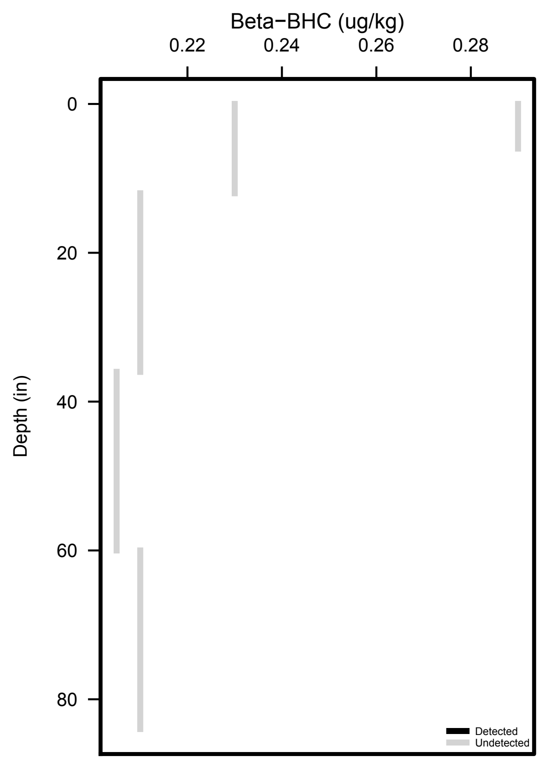

Figure 732. Beta−BHC
at Core Location RM644C1.

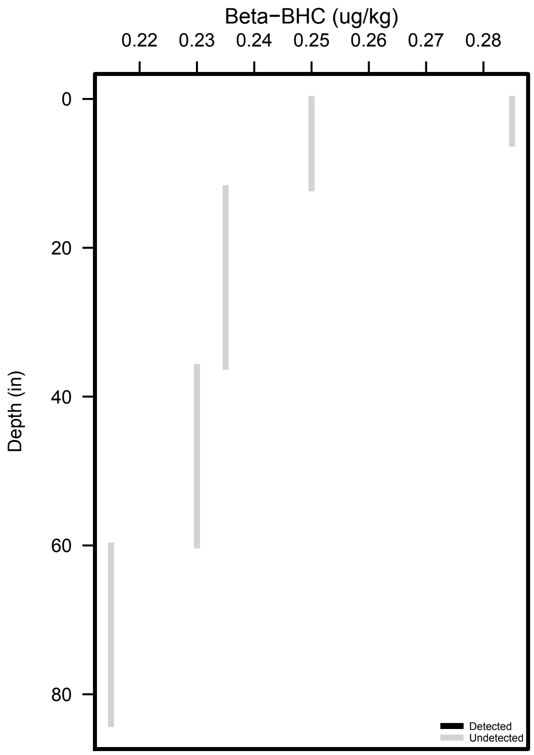

Figure 733. Beta−BHC
at Core Location RM661C1.

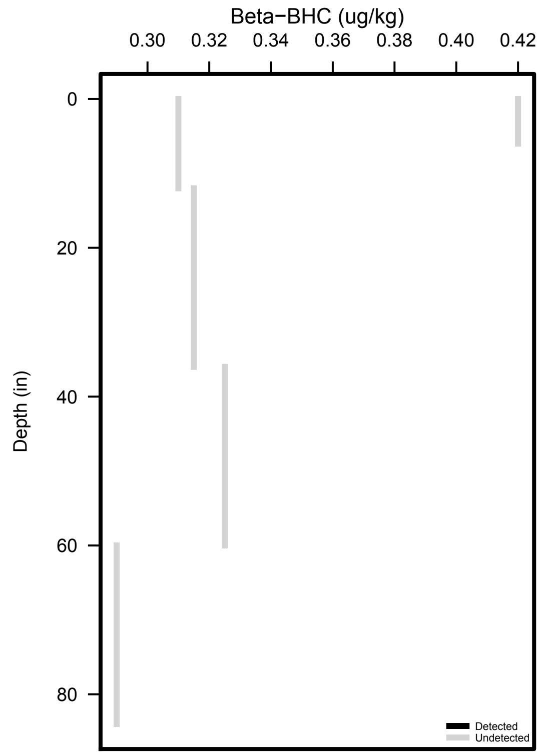

Figure 734. Beta−BHC
at Core Location RM676C1.

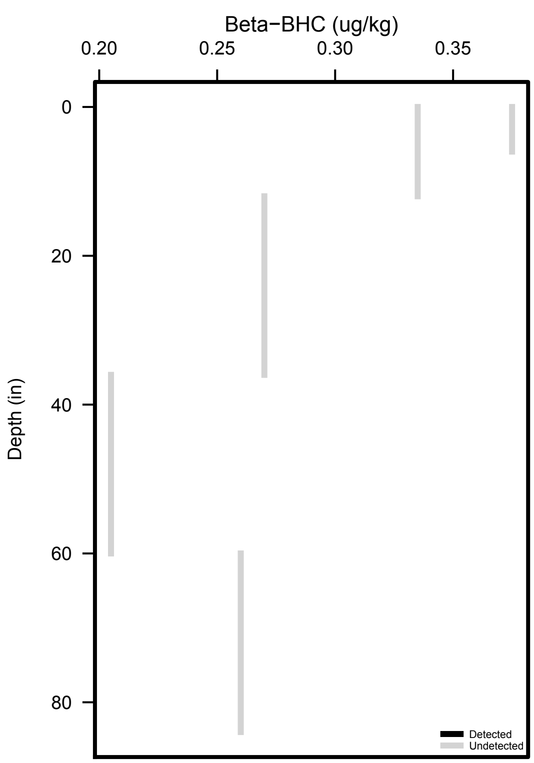

Figure 735. Beta−BHC
at Core Location RM692C1.

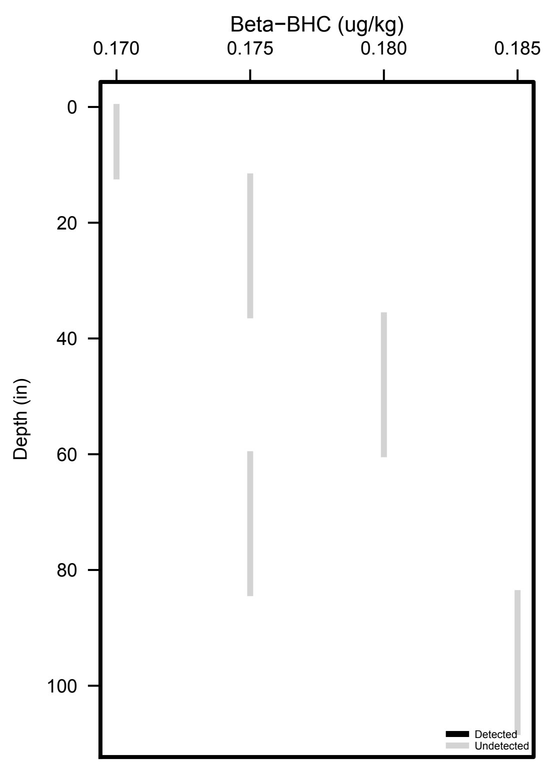

Figure 736. Beta−BHC
at Core Location RM704C1.

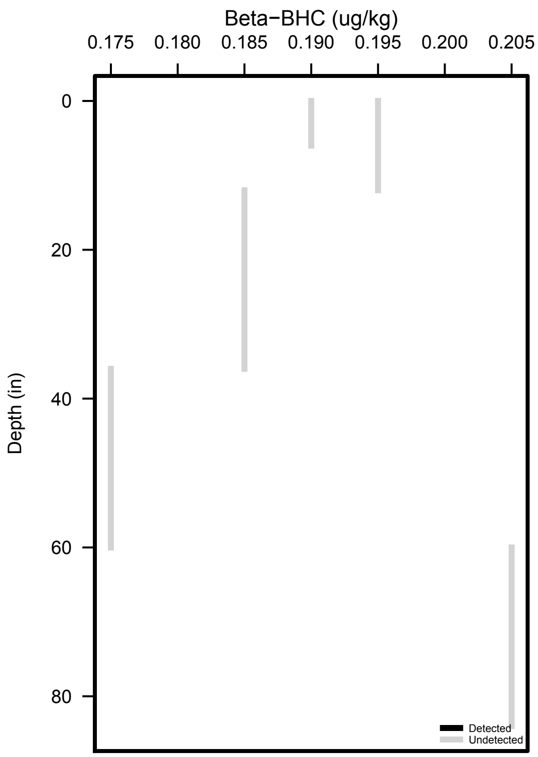

Figure 737. Beta−BHC
at Core Location RM708C1.

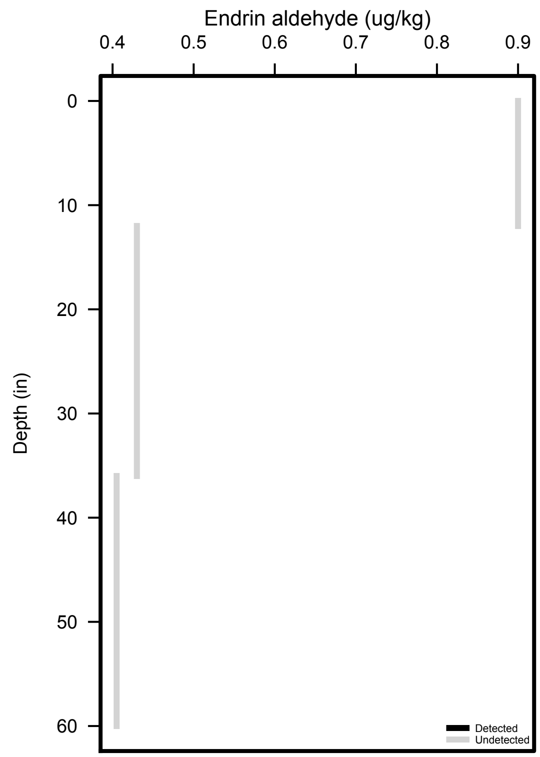

Figure 738. Endrin aldehyde
at Core Location RM605C1.

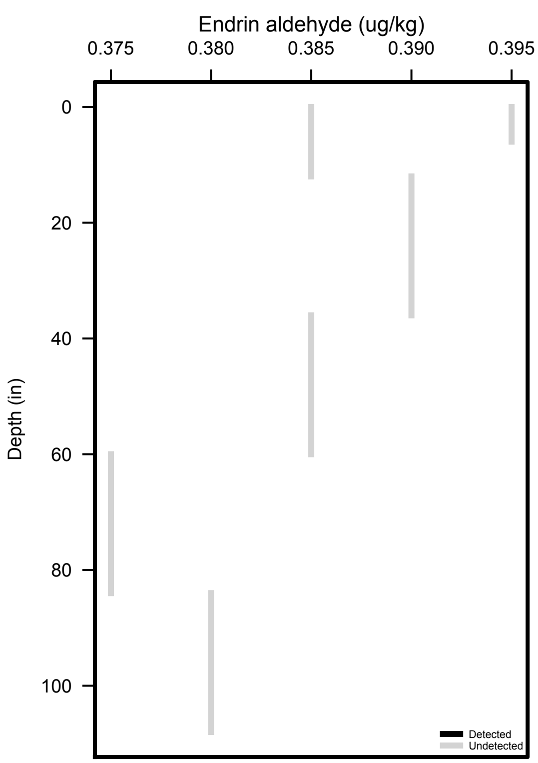

Figure 739. Endrin aldehyde
at Core Location RM622C1.

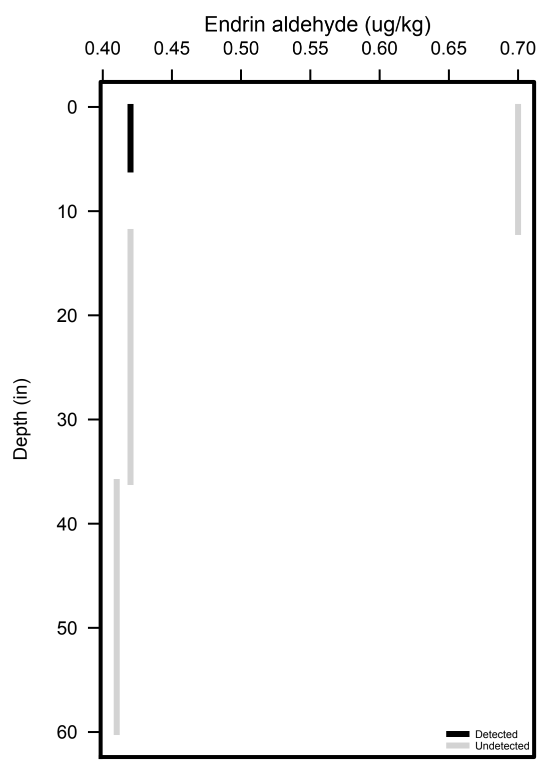

Figure 740. Endrin aldehyde
at Core Location RM637C1.

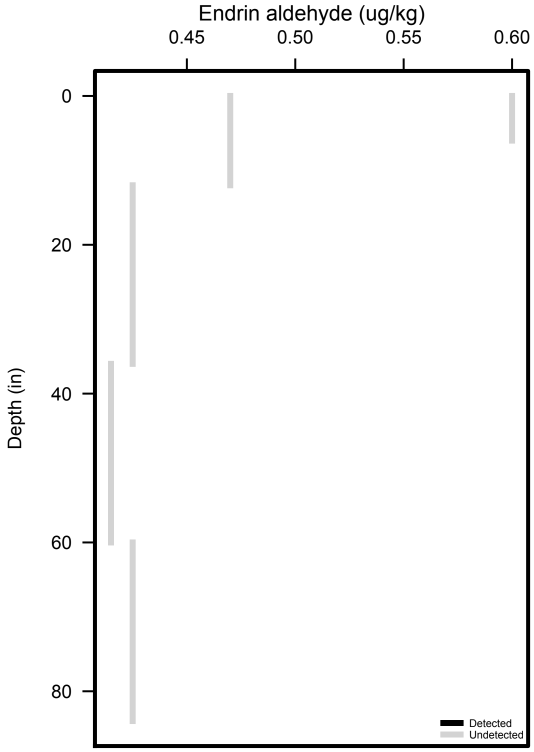

Figure 741. Endrin aldehyde at Core Location RM644C1.

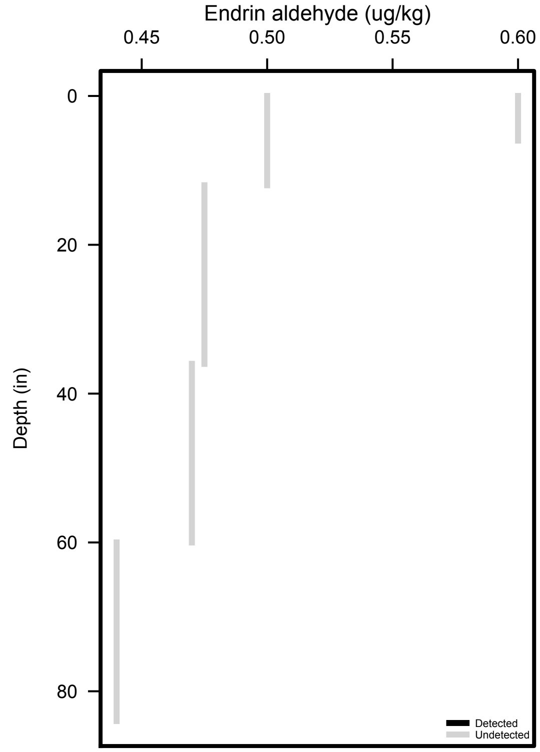

Figure 742. Endrin aldehyde at Core Location RM661C1.

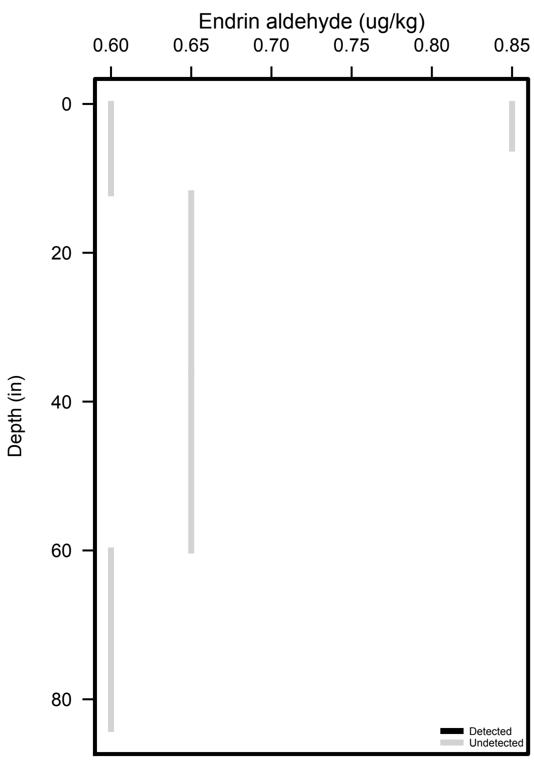

Figure 743. Endrin aldehyde at Core Location RM676C1.

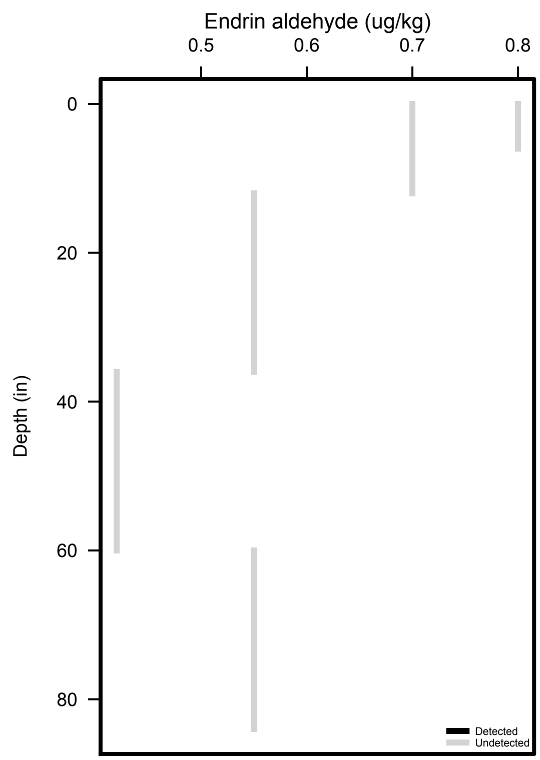

Figure 744. Endrin aldehyde at Core Location RM692C1.

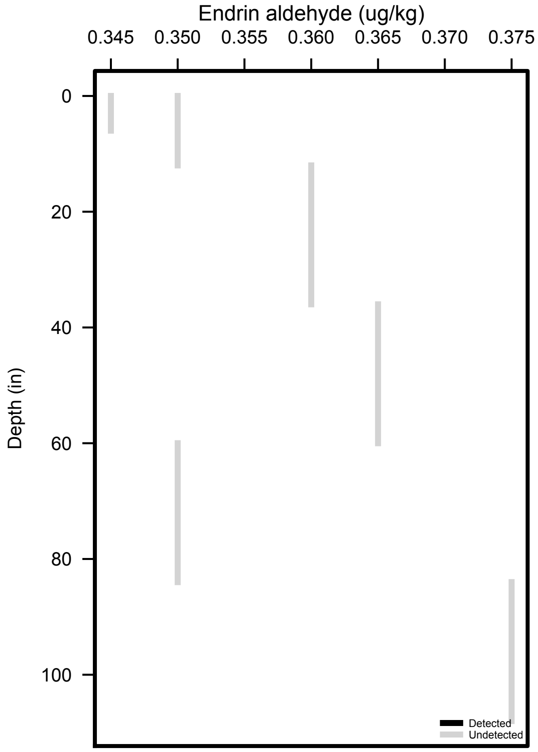

Figure 745. Endrin aldehyde
at Core Location RM704C1.

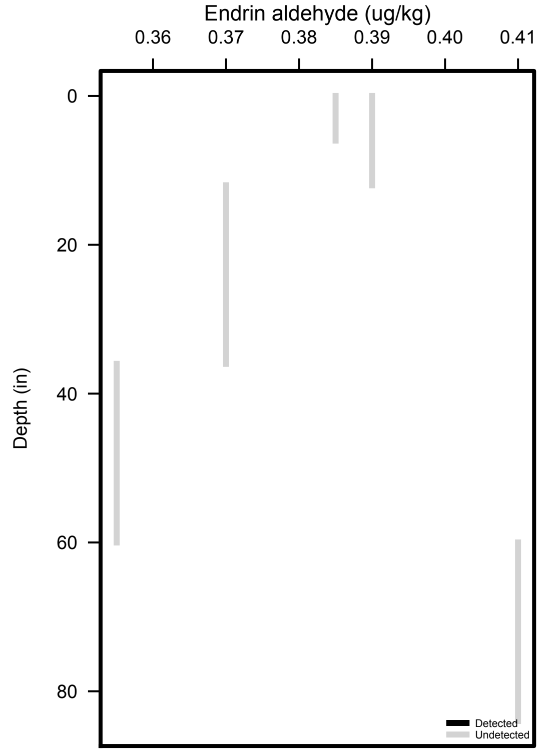

Figure 746. Endrin aldehyde
at Core Location RM708C1.

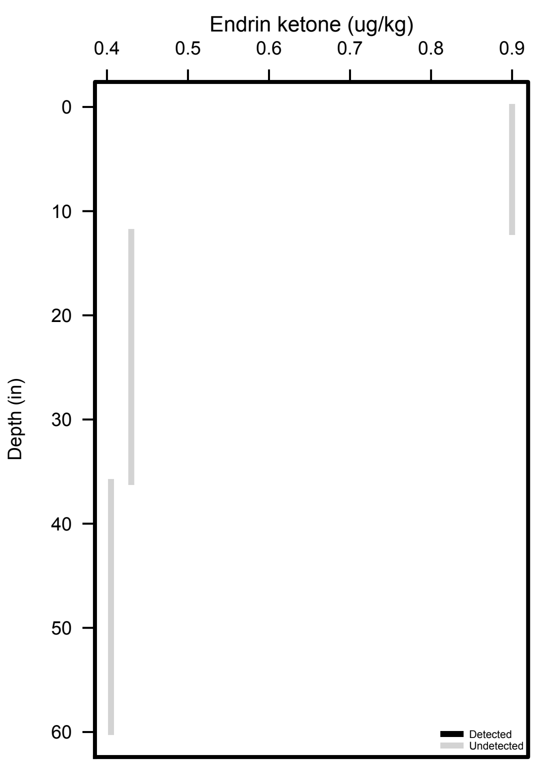

Figure 747. Endrin ketone
at Core Location RM605C1.

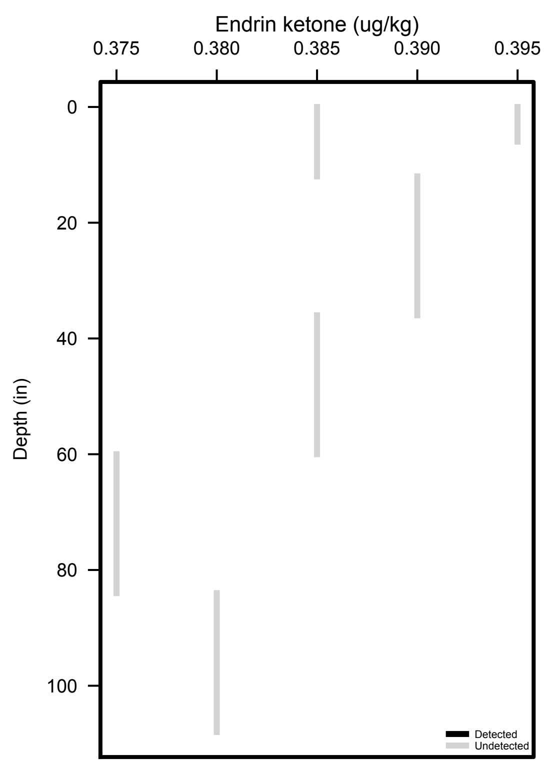

Figure 748. Endrin ketone
at Core Location RM622C1.

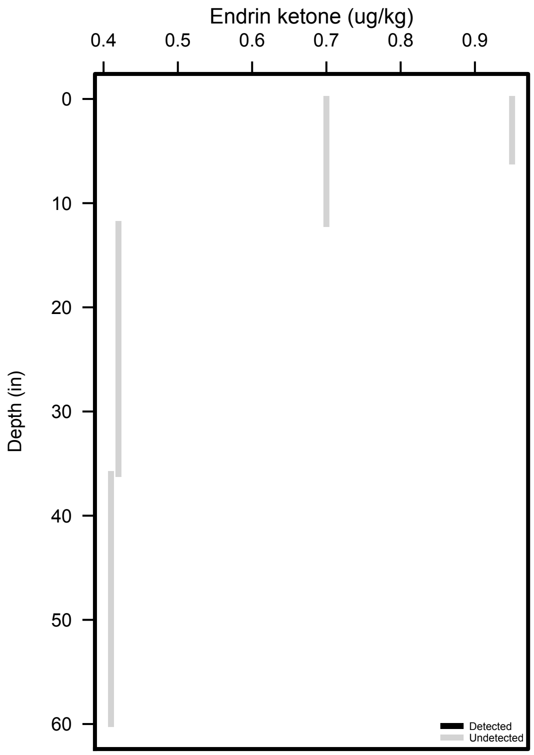

Figure 749. Endrin ketone
at Core Location RM637C1.

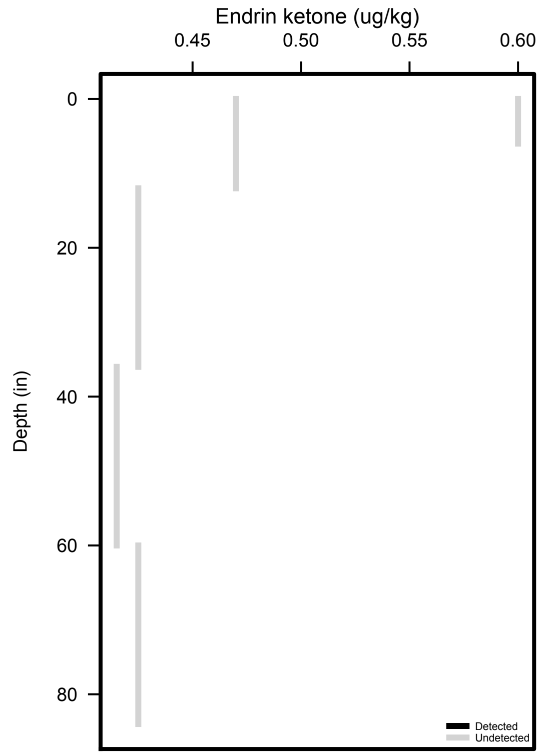

Figure 750. Endrin ketone
at Core Location RM644C1.

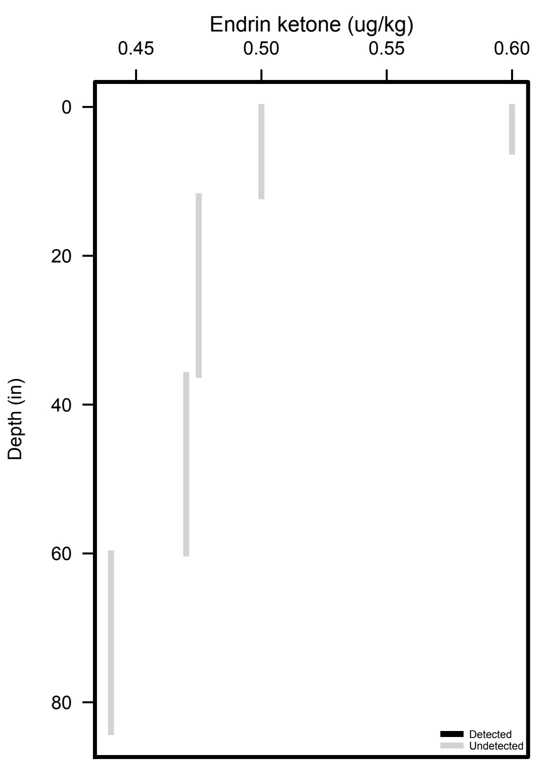

Figure 751. Endrin ketone
at Core Location RM661C1.

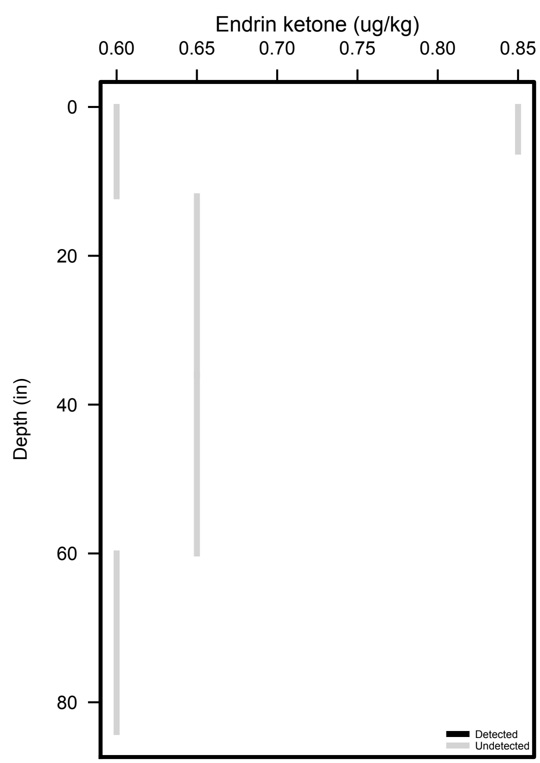

Figure 752. Endrin ketone
at Core Location RM676C1.

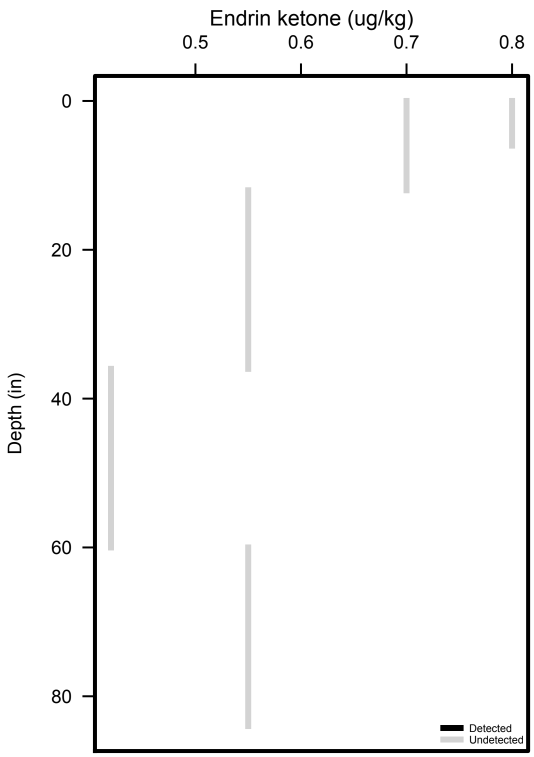

Figure 753. Endrin ketone
at Core Location RM692C1.

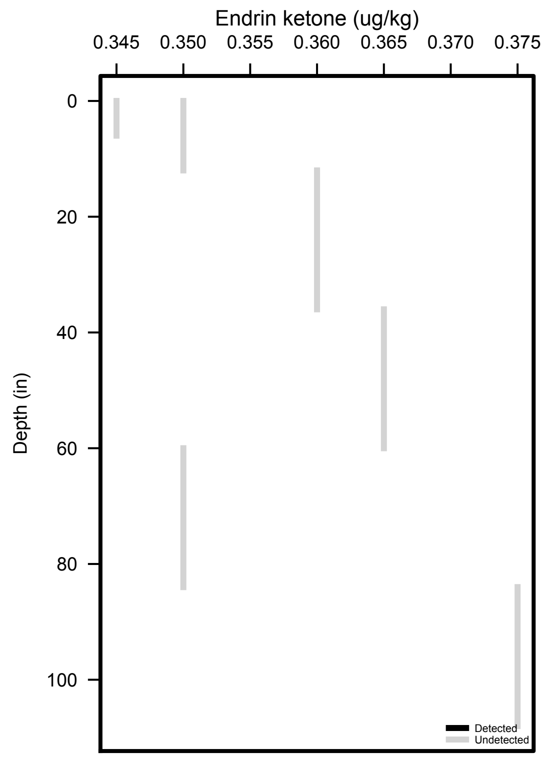

Figure 754. Endrin ketone
at Core Location RM704C1.

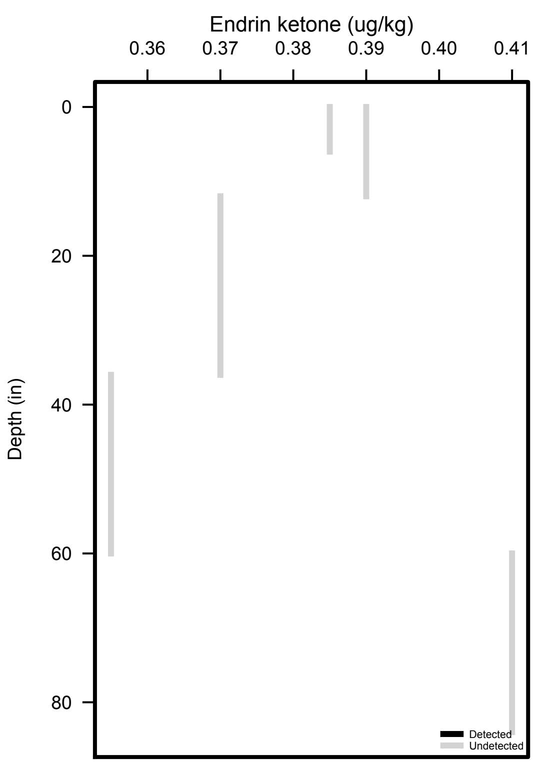

Figure 755. Endrin ketone
at Core Location RM708C1.

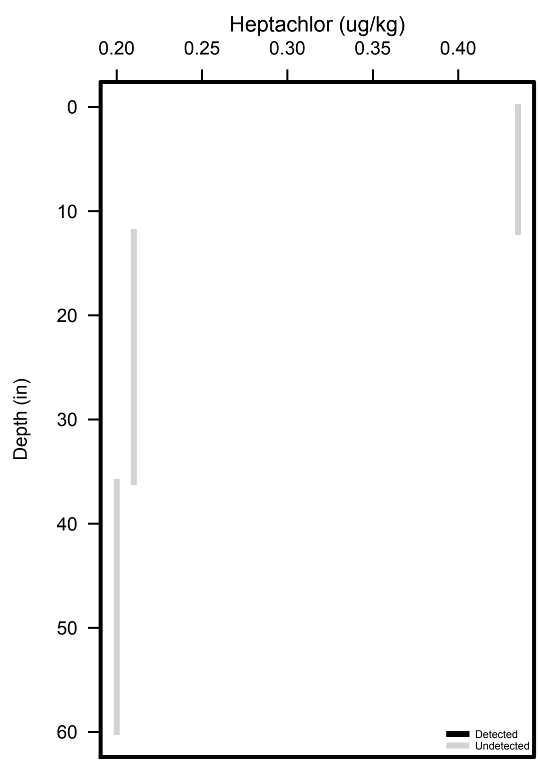

Figure 756. Heptachlor
at Core Location RM605C1.

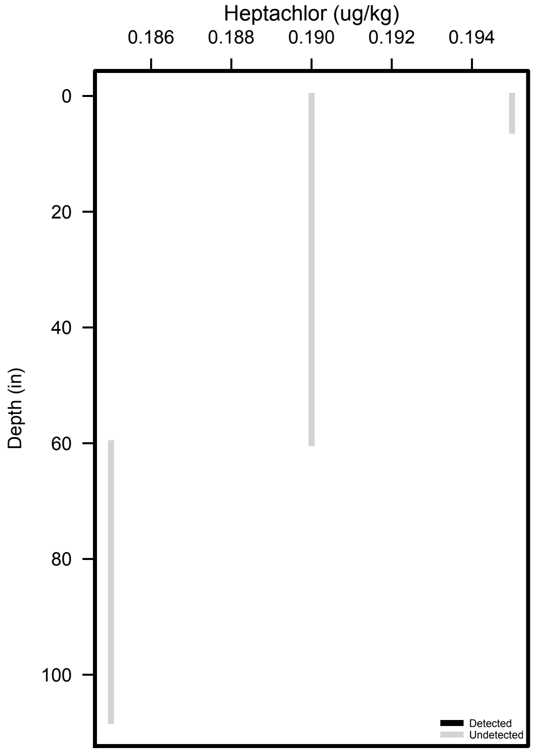

Figure 757. Heptachlor
at Core Location RM622C1.

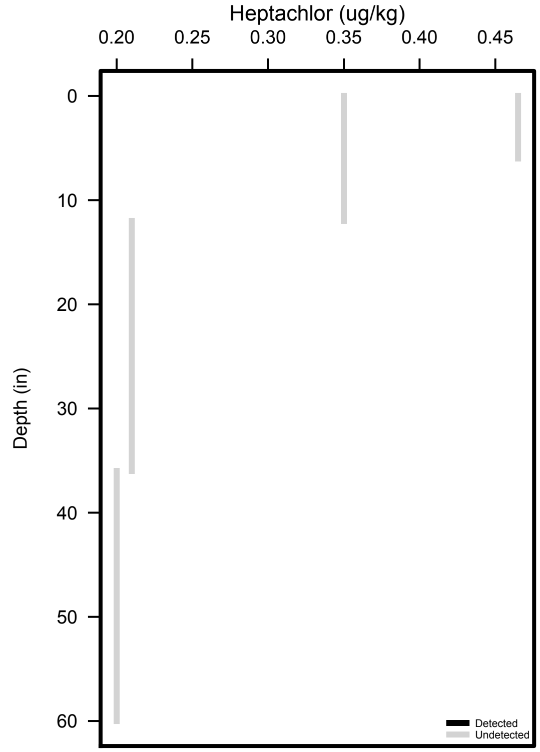

Figure 758. Heptachlor
at Core Location RM637C1.

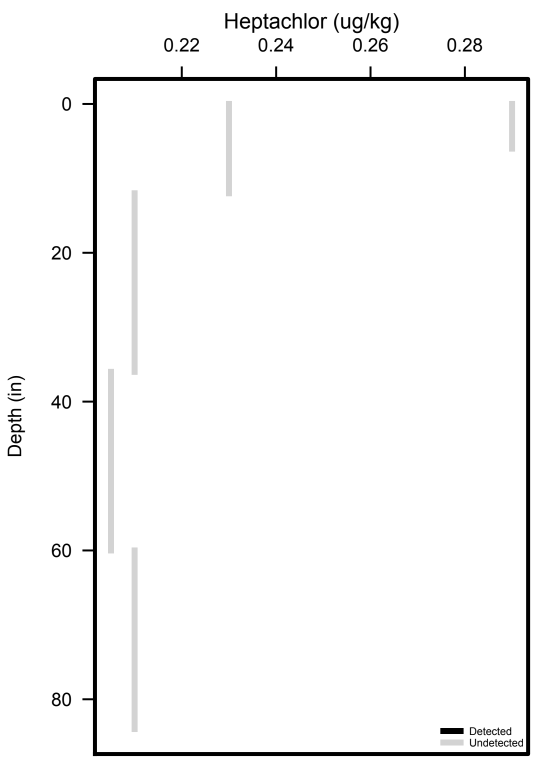

Figure 759. Heptachlor
at Core Location RM644C1.

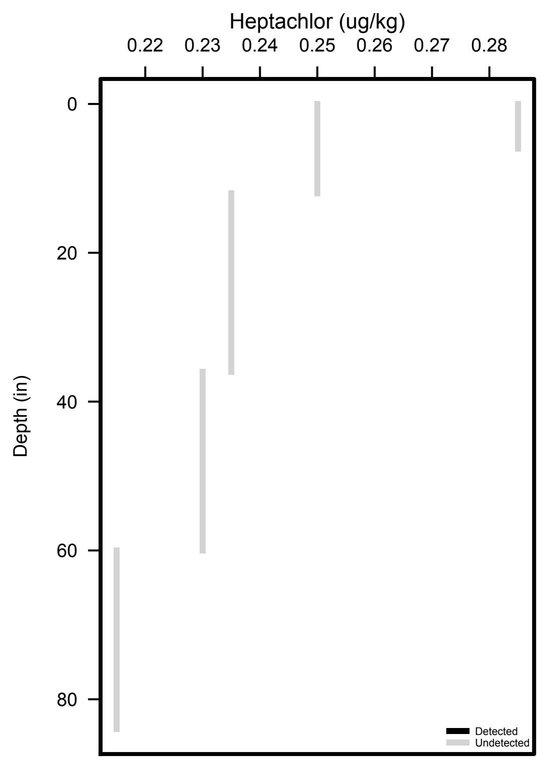

Figure 760. Heptachlor
at Core Location RM661C1.

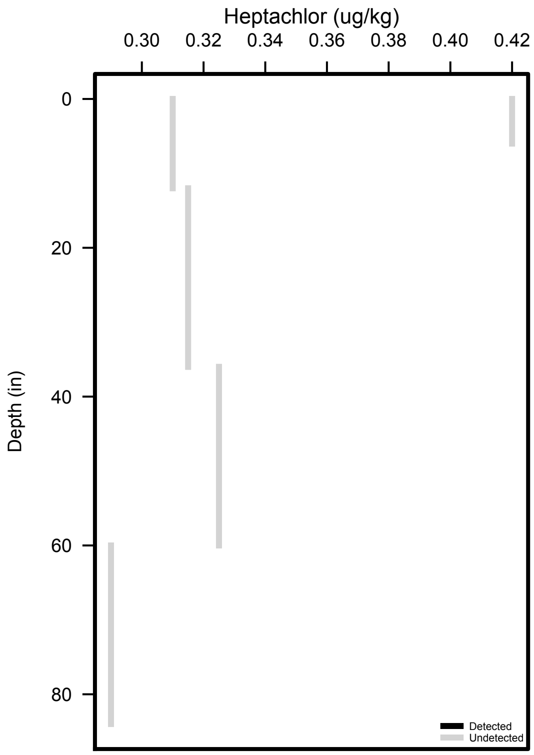

Figure 761. Heptachlor
at Core Location RM676C1.

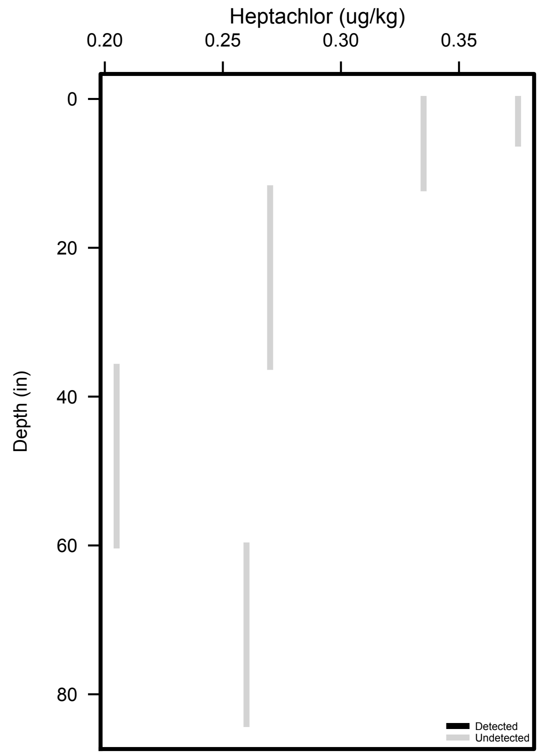

Figure 762. Heptachlor
at Core Location RM692C1.

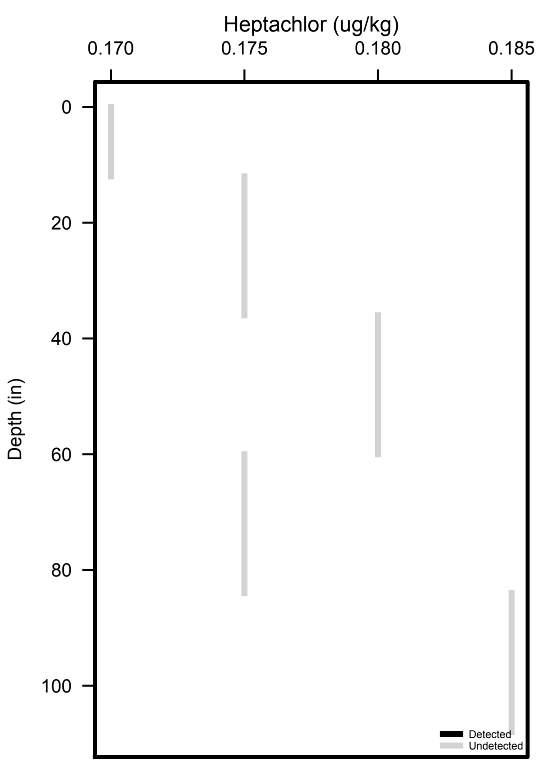

Figure 763. Heptachlor
at Core Location RM704C1.

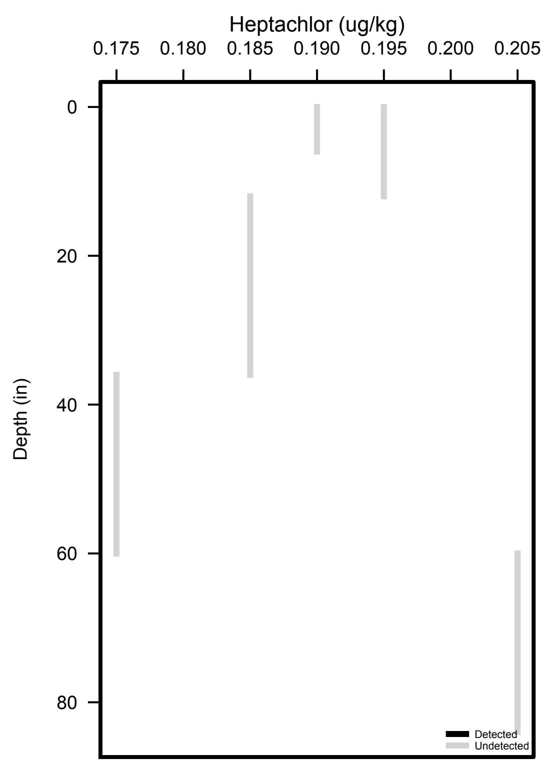

Figure 764. Heptachlor
at Core Location RM708C1.

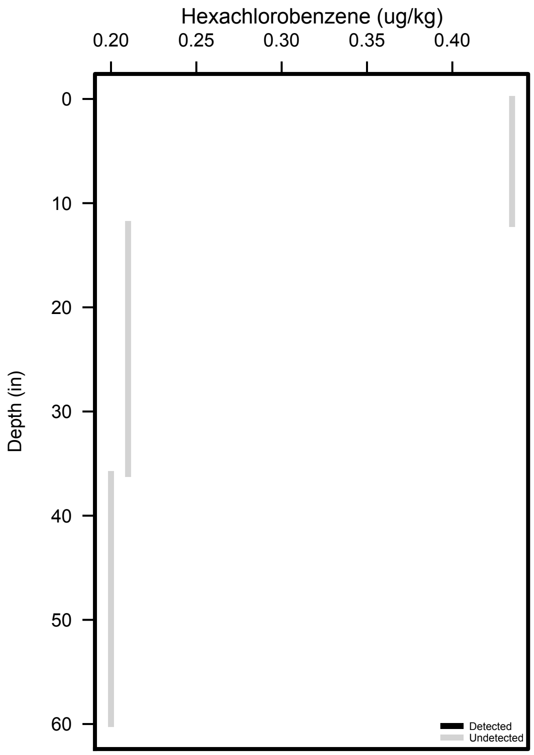

Figure 765. Hexachlorobenzene
at Core Location RM605C1.

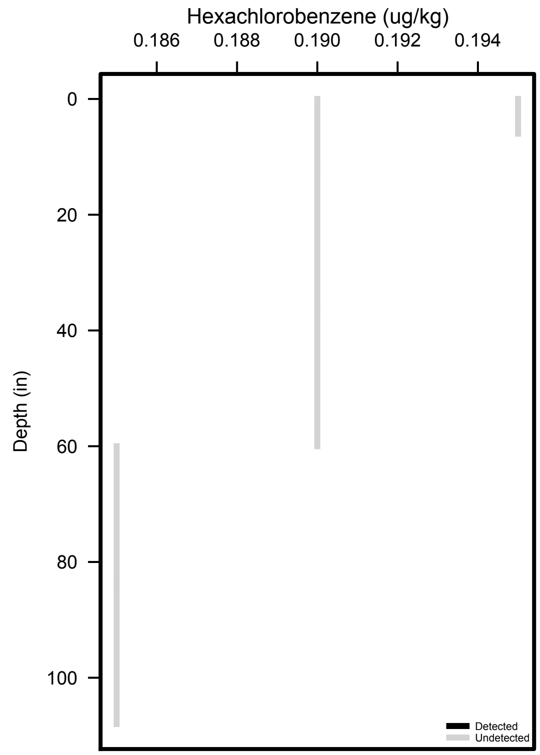

Figure 766. Hexachlorobenzene
at Core Location RM622C1.

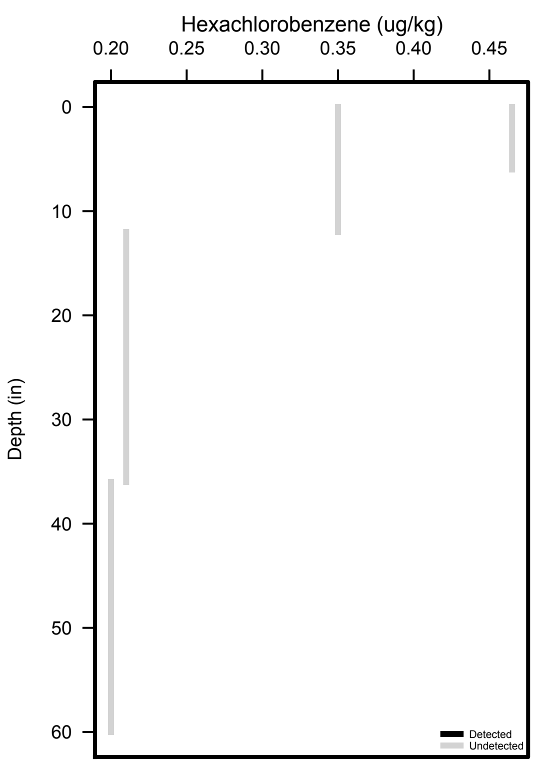

Figure 767. Hexachlorobenzene
at Core Location RM637C1.

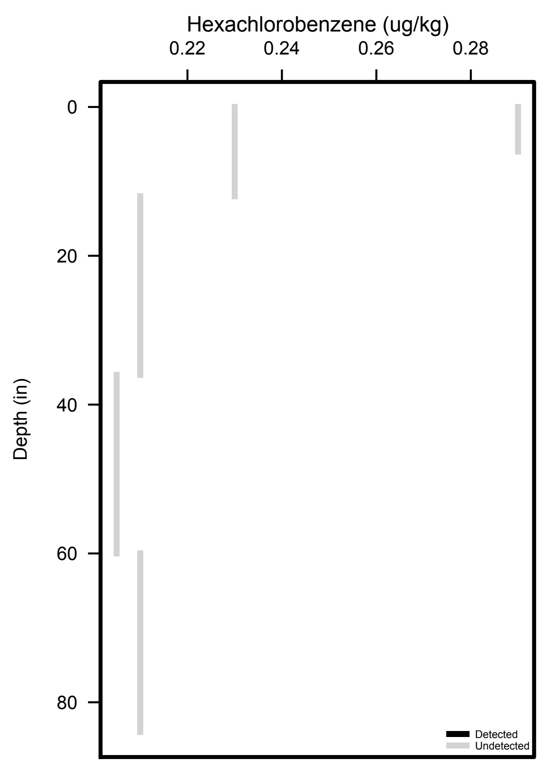

Figure 768. Hexachlorobenzene
at Core Location RM644C1.

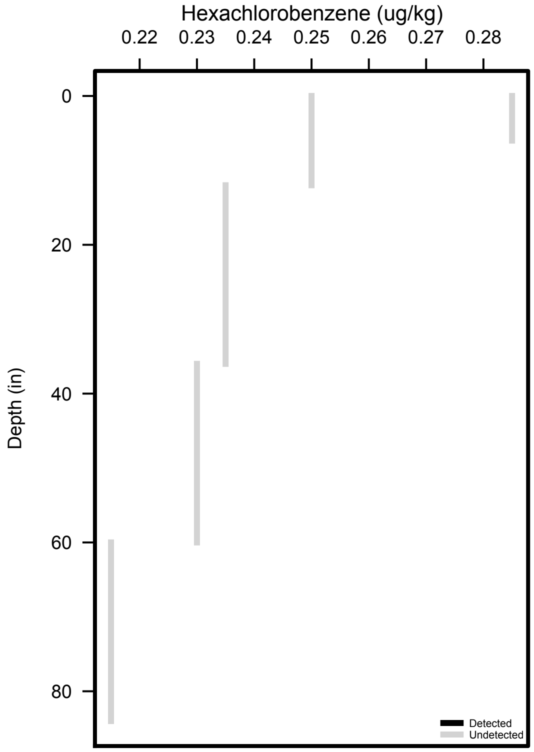

Figure 769. Hexachlorobenzene
at Core Location RM661C1.

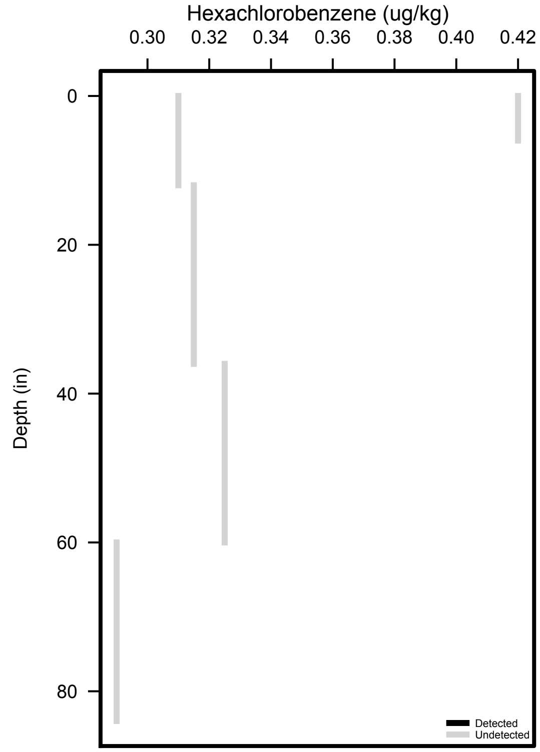

Figure 770. Hexachlorobenzene
at Core Location RM676C1.

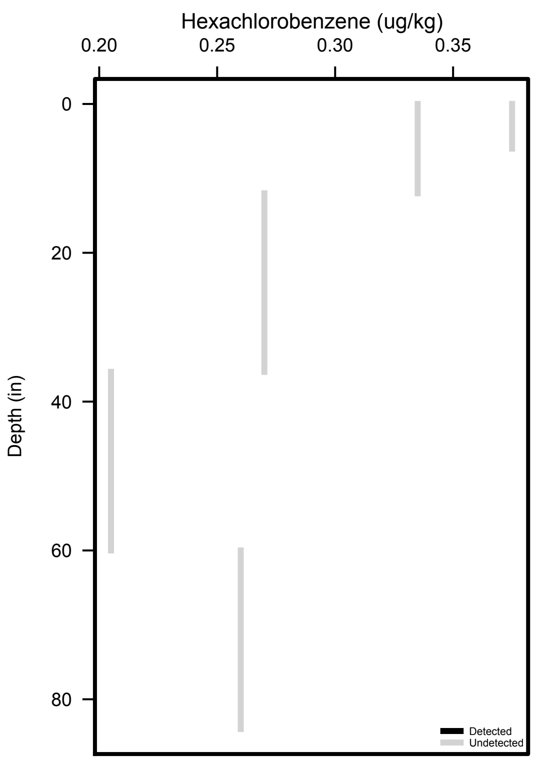

Figure 771. Hexachlorobenzene
at Core Location RM692C1.

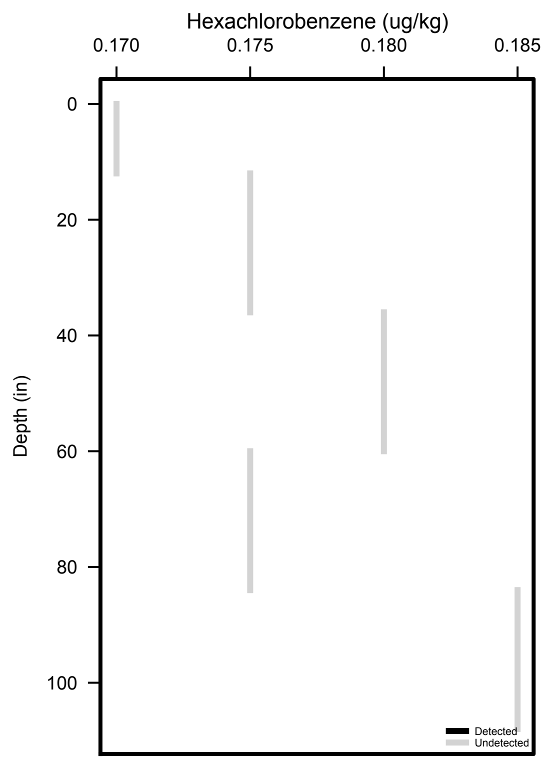

Figure 772. Hexachlorobenzene
at Core Location RM704C1.

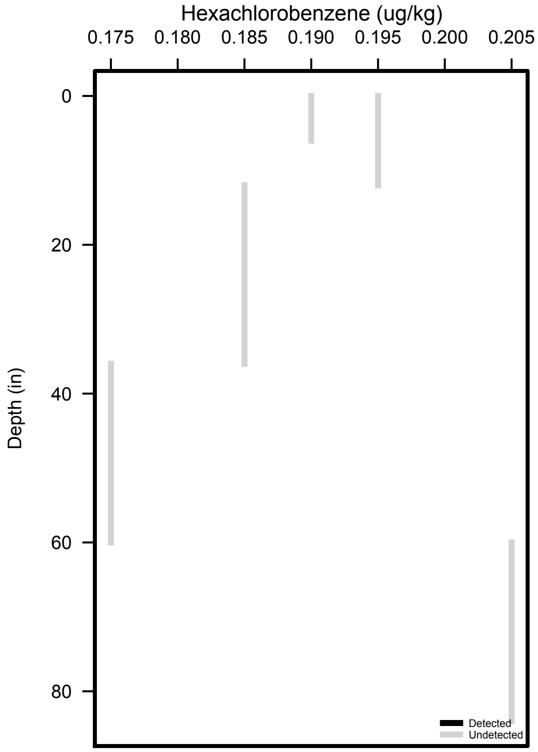

Figure 773. Hexachlorobenzene at Core Location RM708C1.

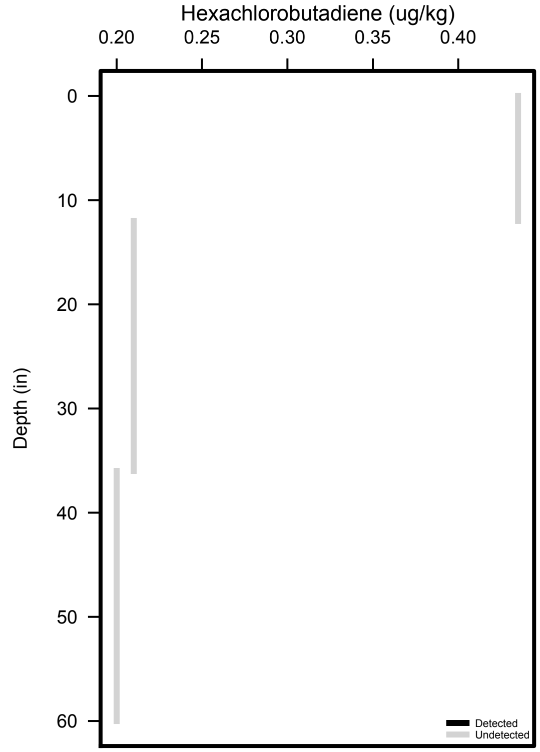

Figure 774. Hexachlorobutadiene at Core Location RM605C1.

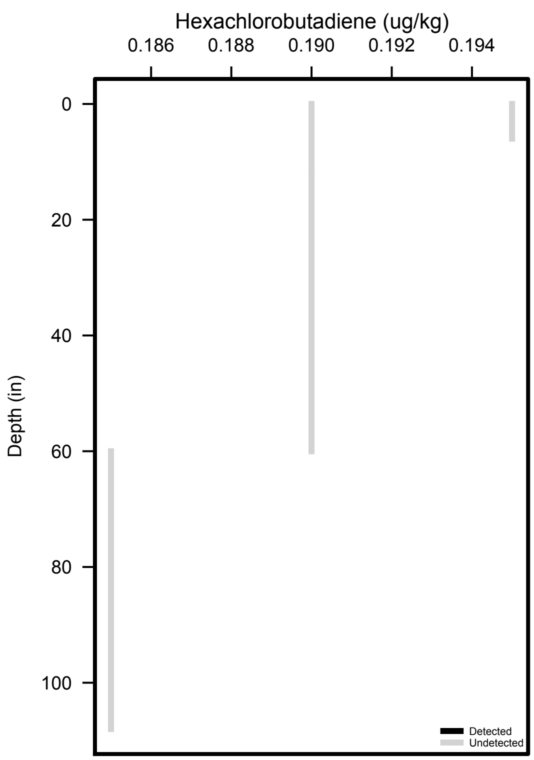

Figure 775. Hexachlorobutadiene at Core Location RM622C1.

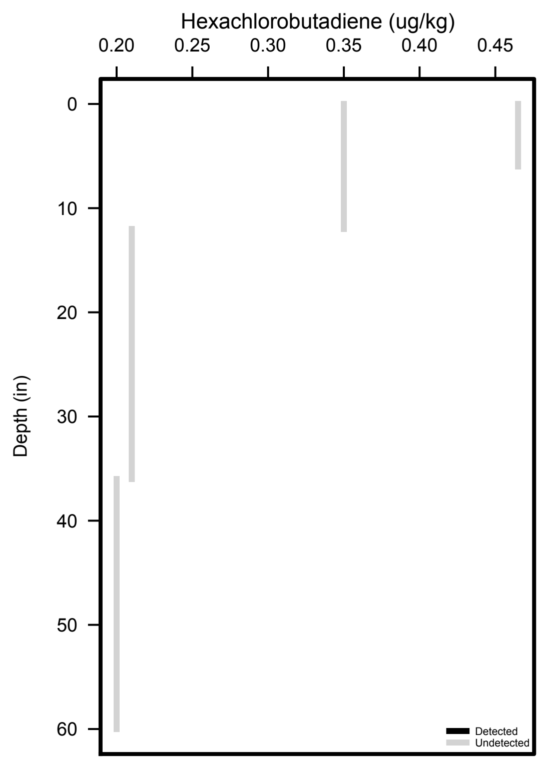

Figure 776. Hexachlorobutadiene at Core Location RM637C1.

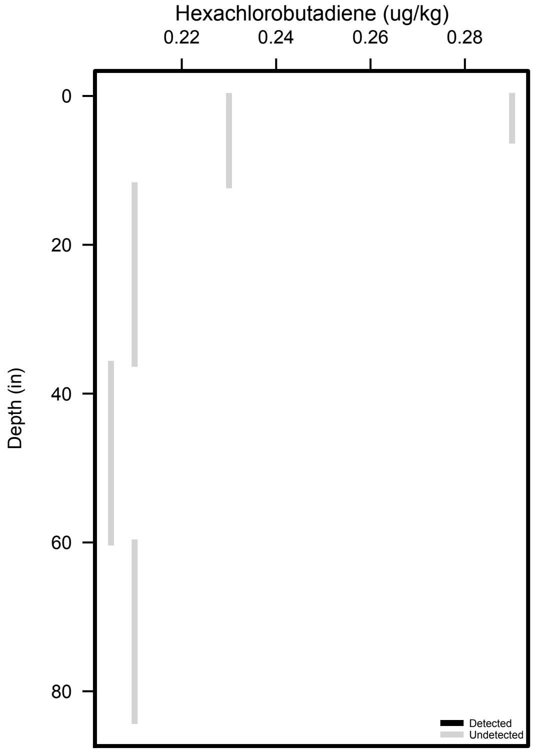

Figure 777. Hexachlorobutadiene at Core Location RM644C1.

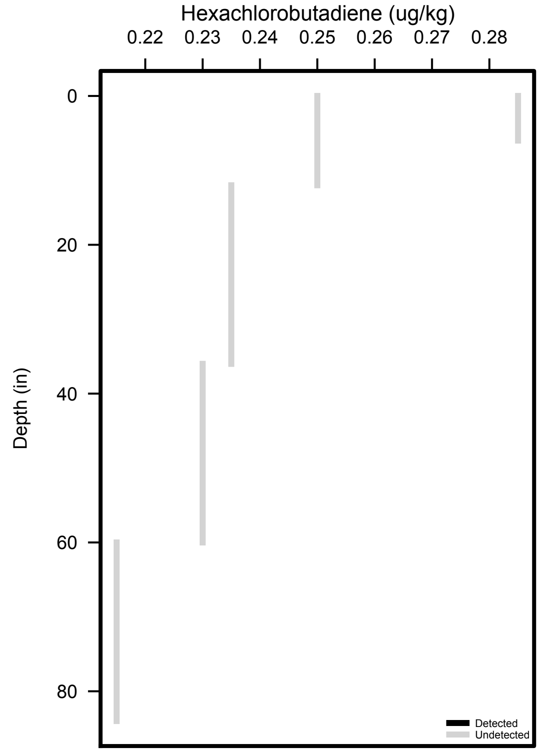

Figure 778. Hexachlorobutadiene at Core Location RM661C1.

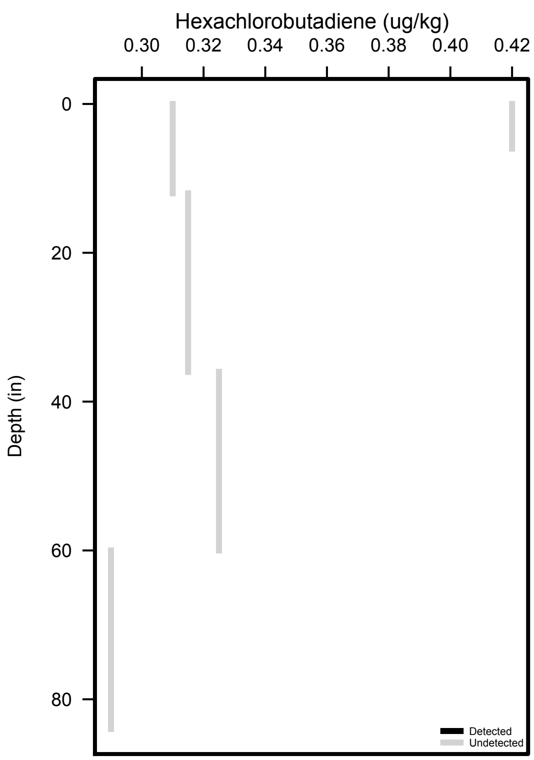

Figure 779. Hexachlorobutadiene at Core Location RM676C1.

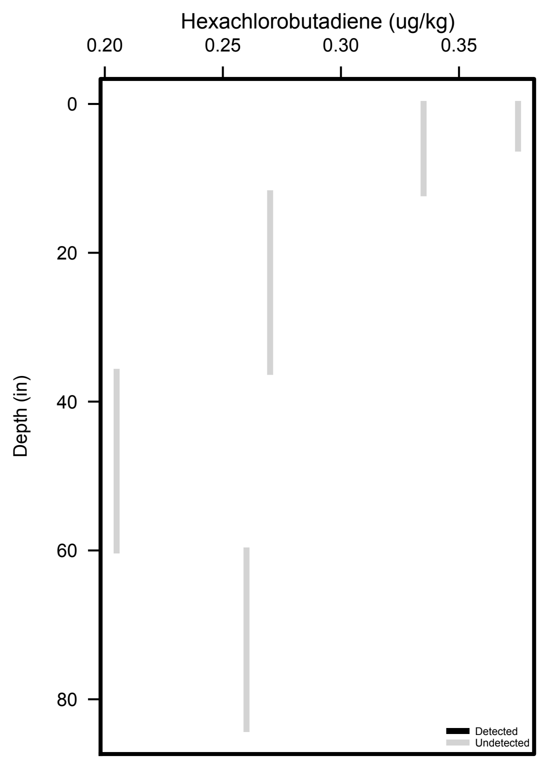

Figure 780. Hexachlorobutadiene at Core Location RM692C1.

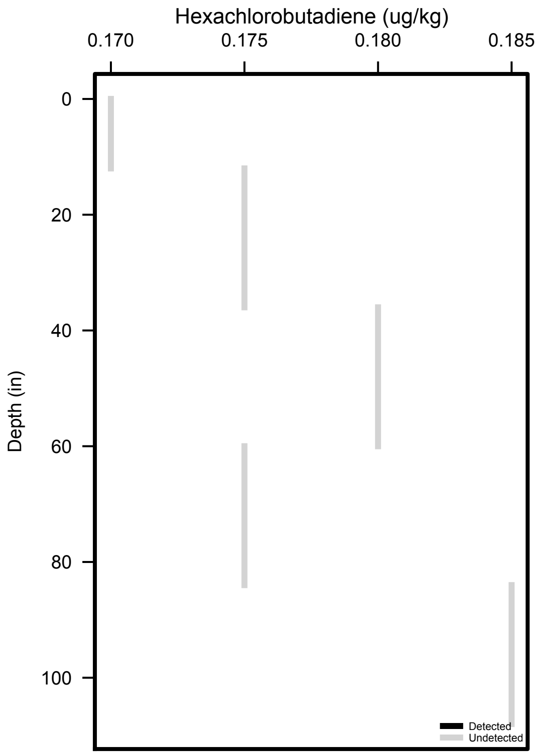

Figure 781. Hexachlorobutadiene
at Core Location RM704C1.

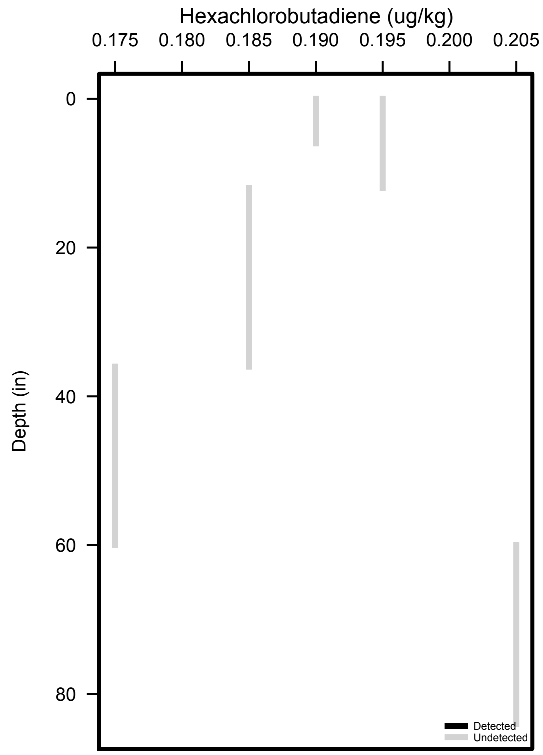

Figure 782. Hexachlorobutadiene
at Core Location RM708C1.

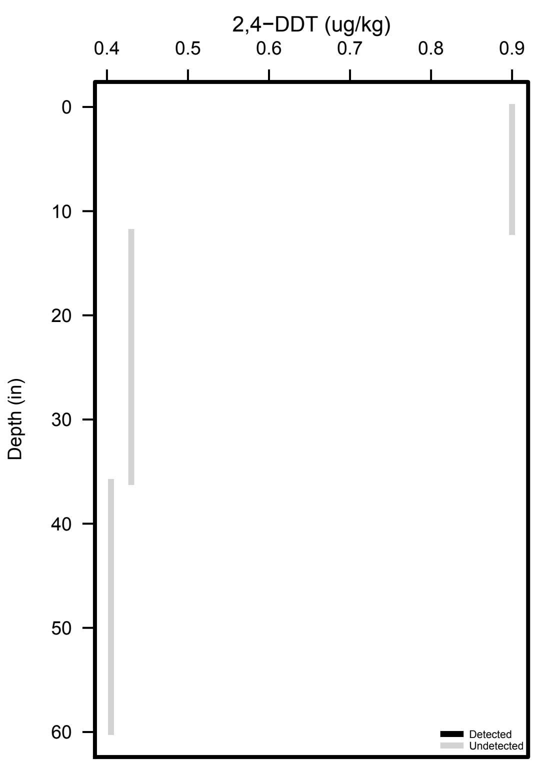

Figure 783. 2,4−DDT
at Core Location RM605C1.

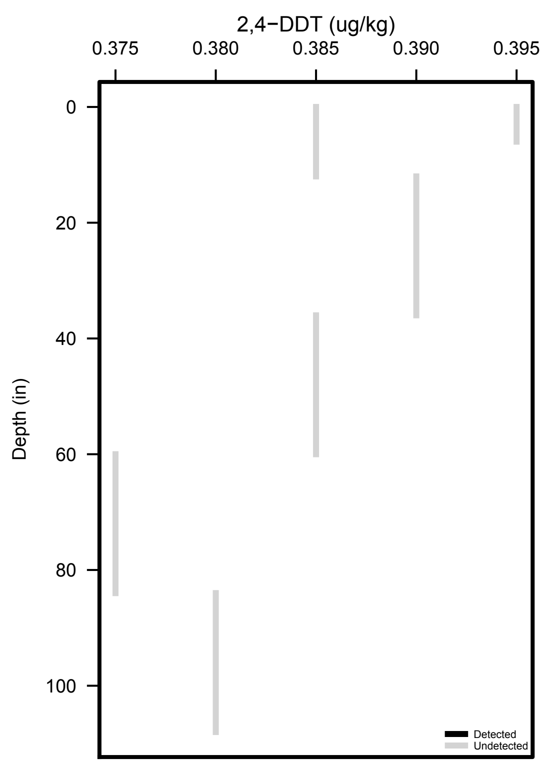

Figure 784. 2,4−DDT
at Core Location RM622C1.

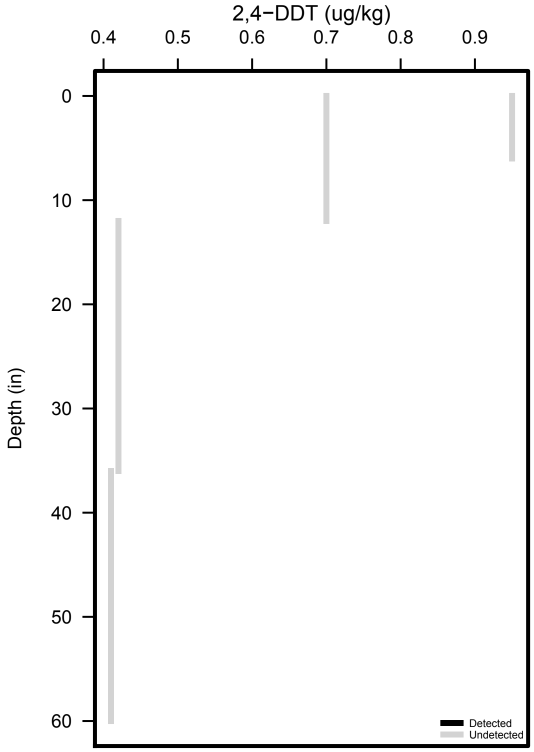

Figure 785. 2,4−DDT
at Core Location RM637C1.

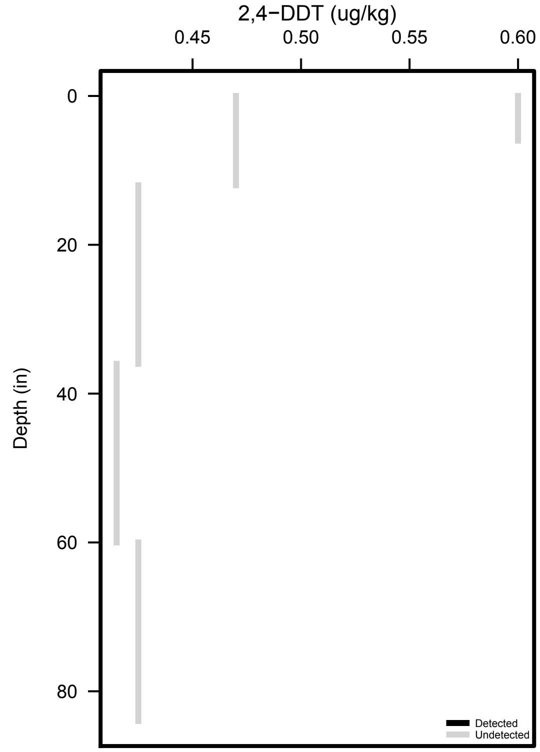

Figure 786. 2,4−DDT
at Core Location RM644C1.

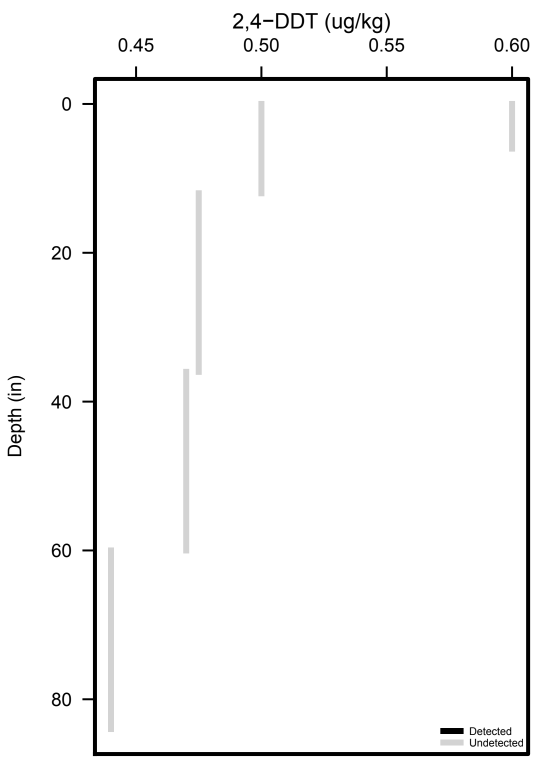

Figure 787. 2,4−DDT
at Core Location RM661C1.

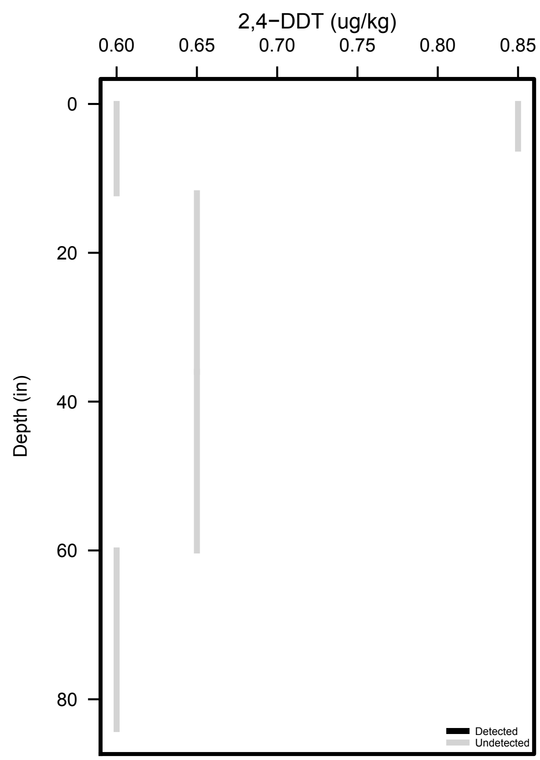

Figure 788. 2,4−DDT
at Core Location RM676C1.

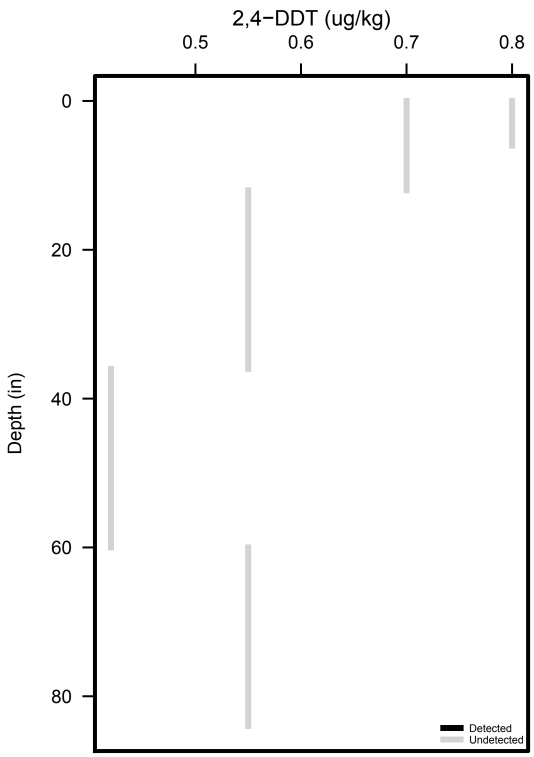

Figure 789. 2,4−DDT
at Core Location RM692C1.

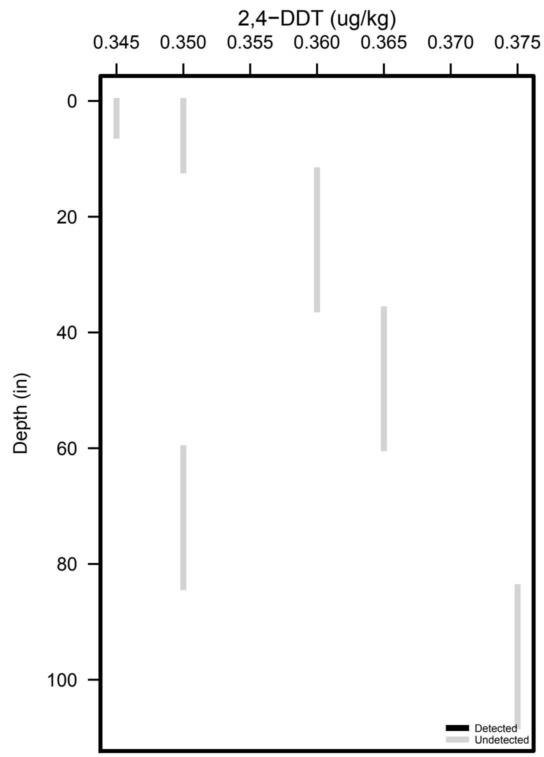

Figure 790. 2,4−DDT
at Core Location RM704C1.

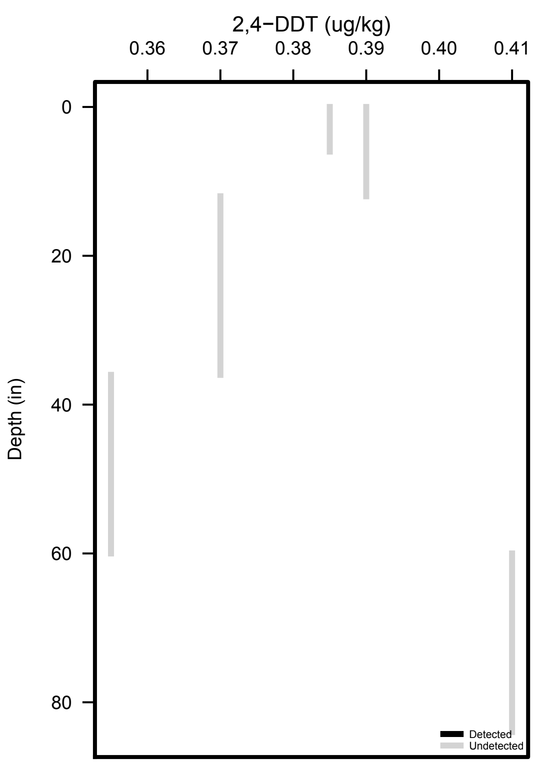

Figure 791. 2,4−DDT
at Core Location RM708C1.

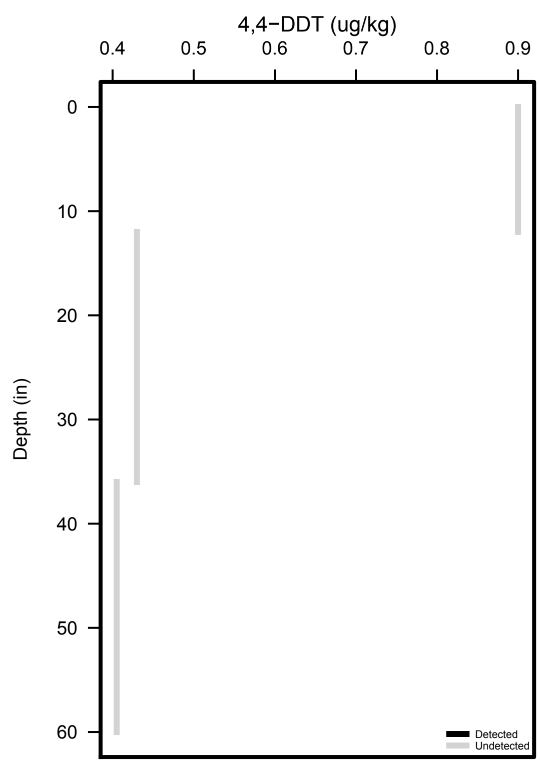

Figure 792. 4,4−DDT
at Core Location RM605C1.

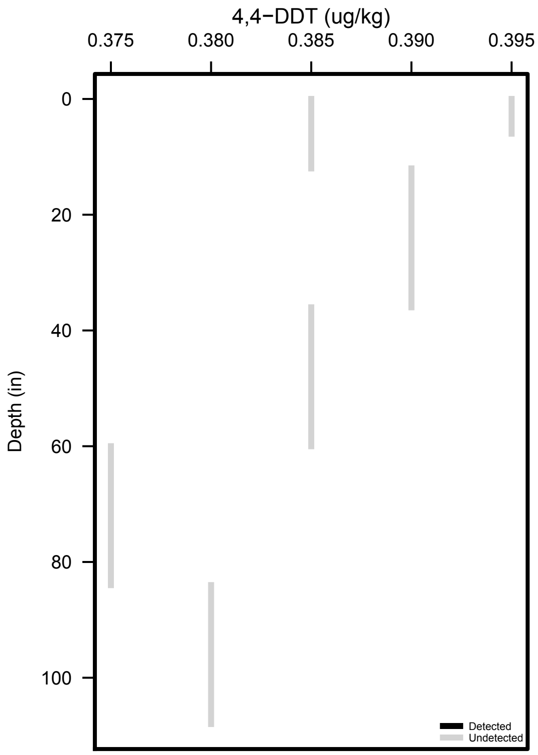

Figure 793. 4,4−DDT
at Core Location RM622C1.

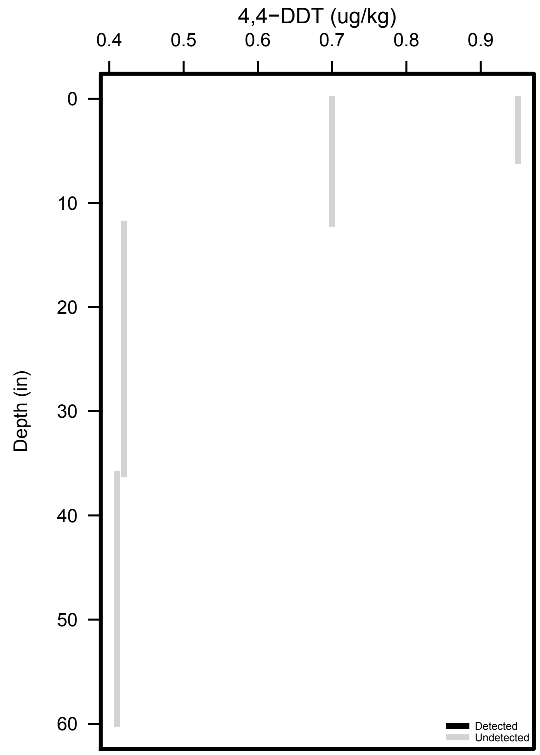

Figure 794. 4,4−DDT
at Core Location RM637C1.

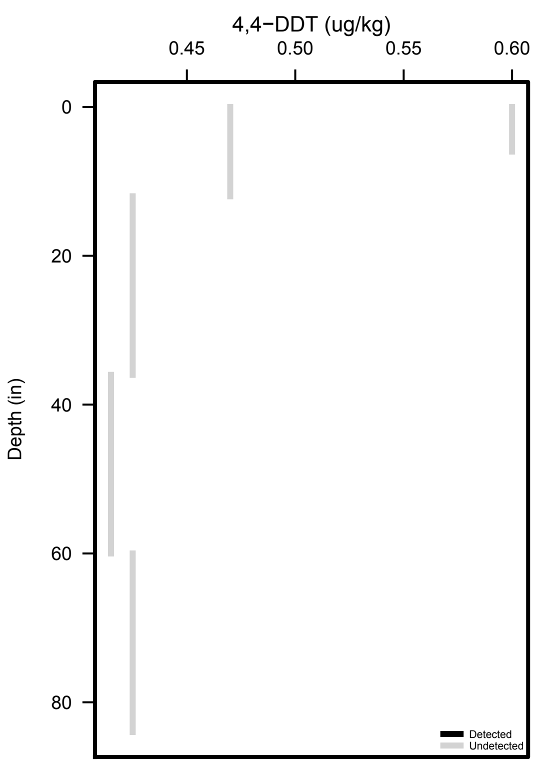

Figure 795. 4,4−DDT
at Core Location RM644C1.

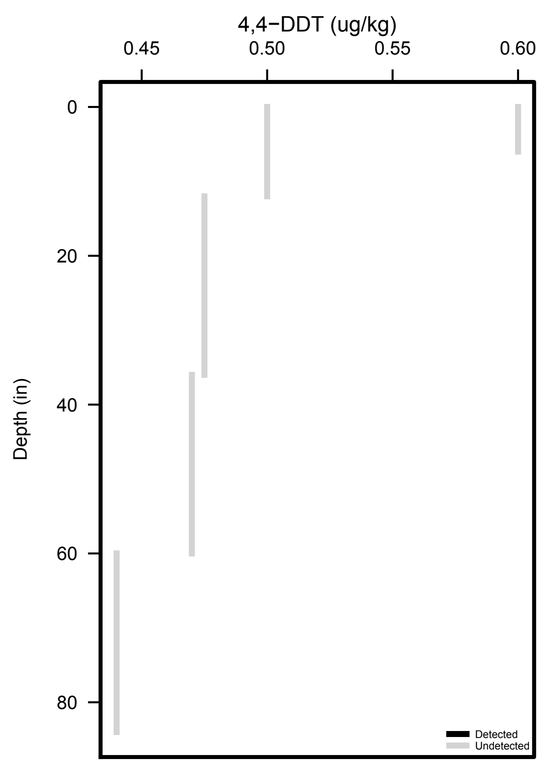

Figure 796. 4,4−DDT
at Core Location RM661C1.

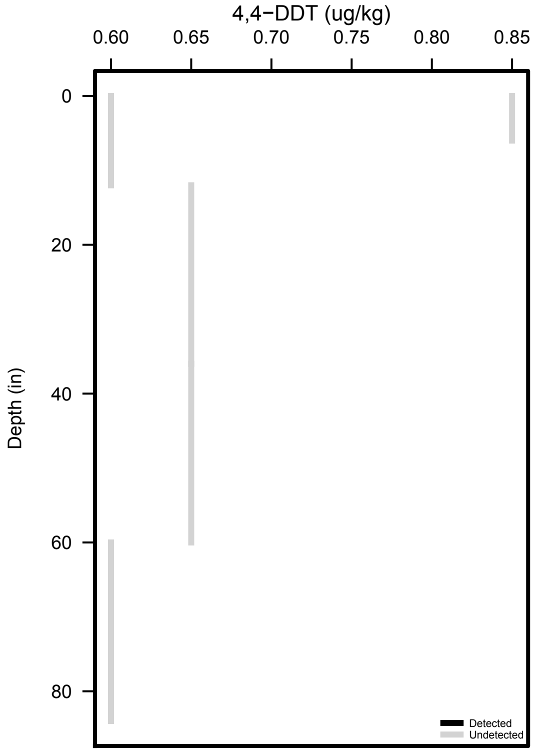

Figure 797. 4,4−DDT
at Core Location RM676C1.

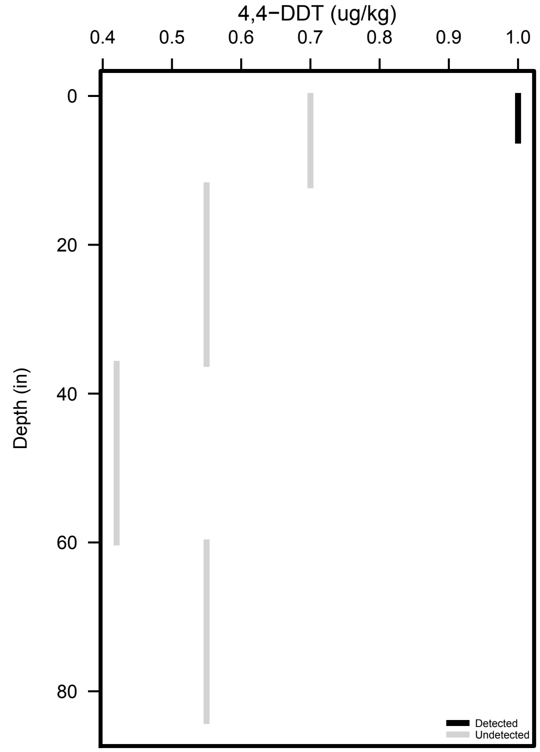

Figure 798. 4,4−DDT
at Core Location RM692C1.

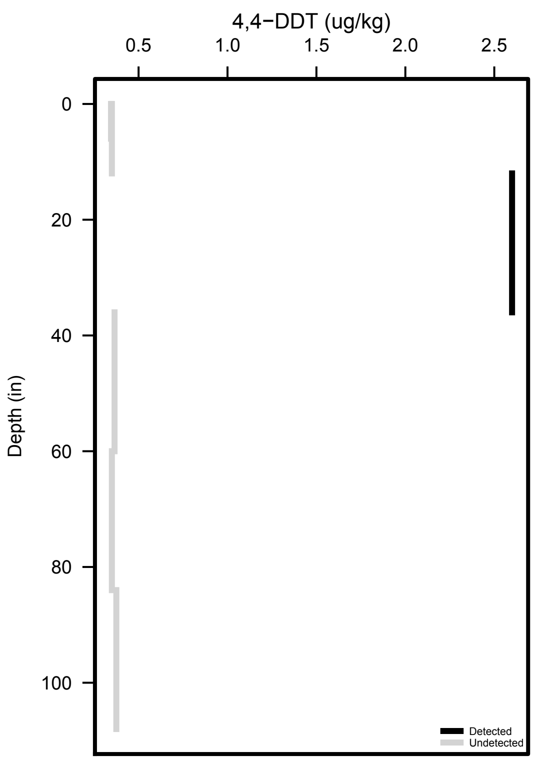

Figure 799. 4,4−DDT
at Core Location RM704C1.

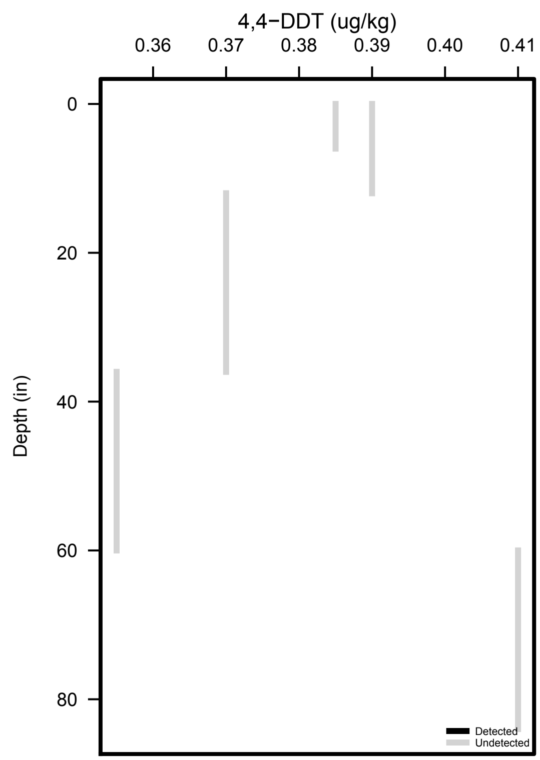

Figure 800. 4,4−DDT
at Core Location RM708C1.

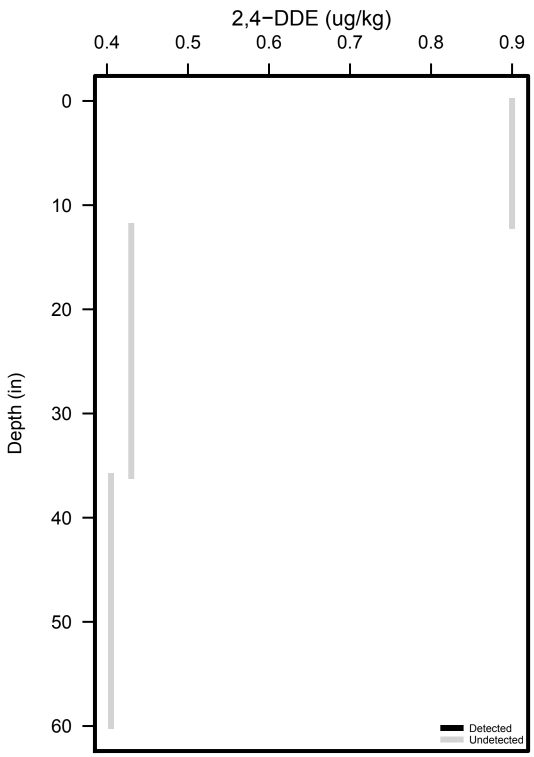

Figure 801. 2,4−DDE
at Core Location RM605C1.

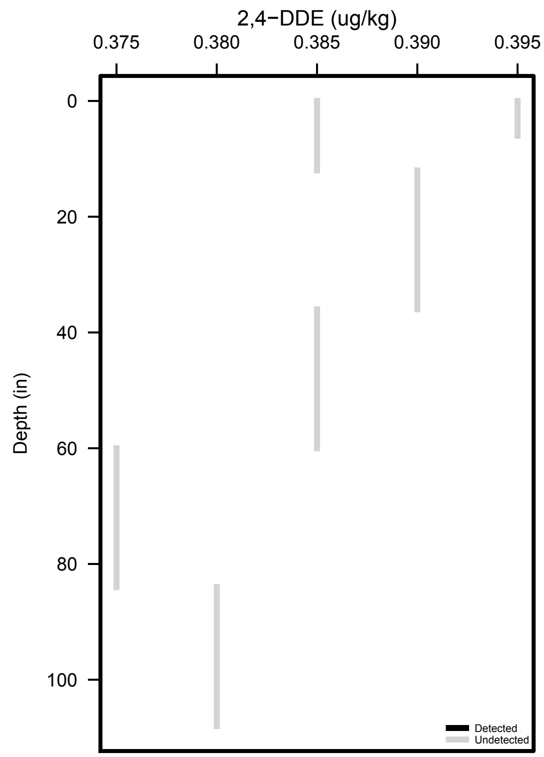

Figure 802. 2,4−DDE
at Core Location RM622C1.

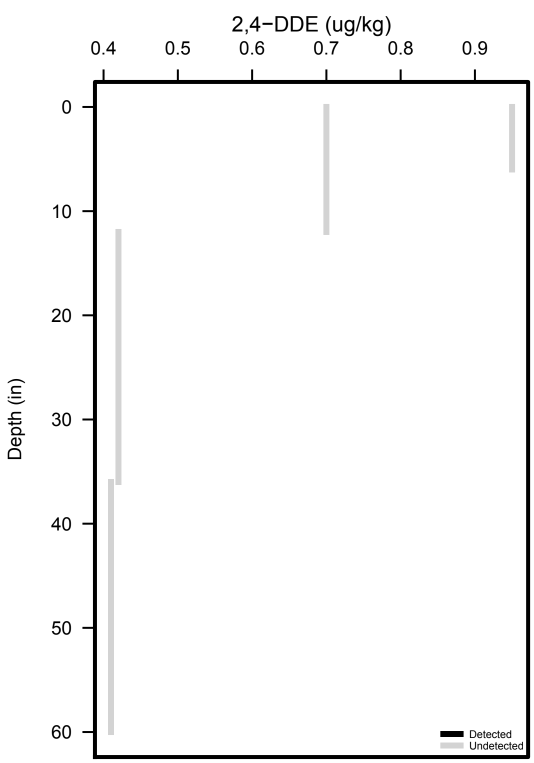

Figure 803. 2,4−DDE
at Core Location RM637C1.

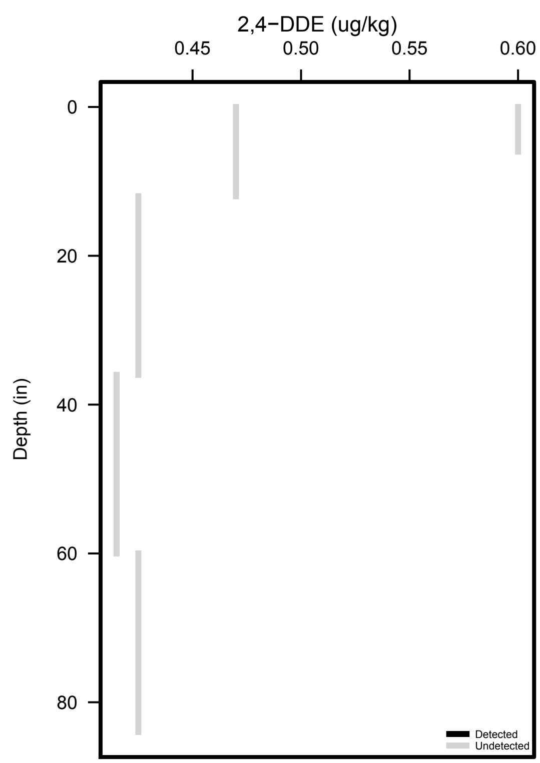

Figure 804. 2,4−DDE
at Core Location RM644C1.

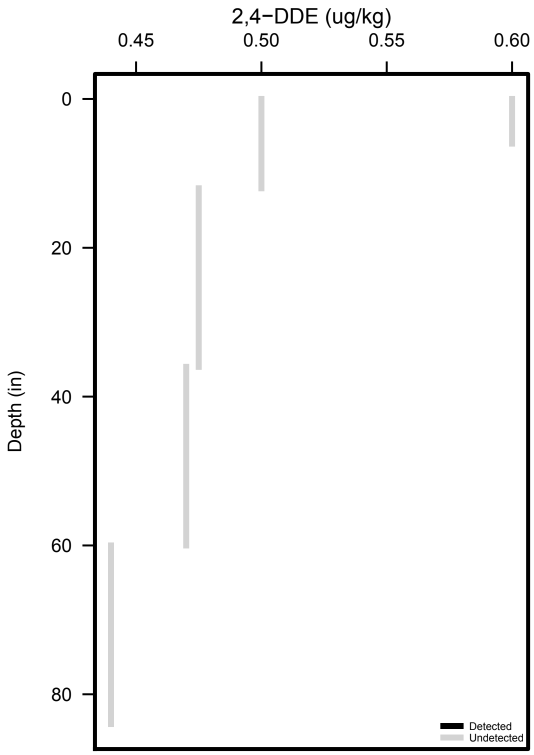

Figure 805. 2,4−DDE
at Core Location RM661C1.

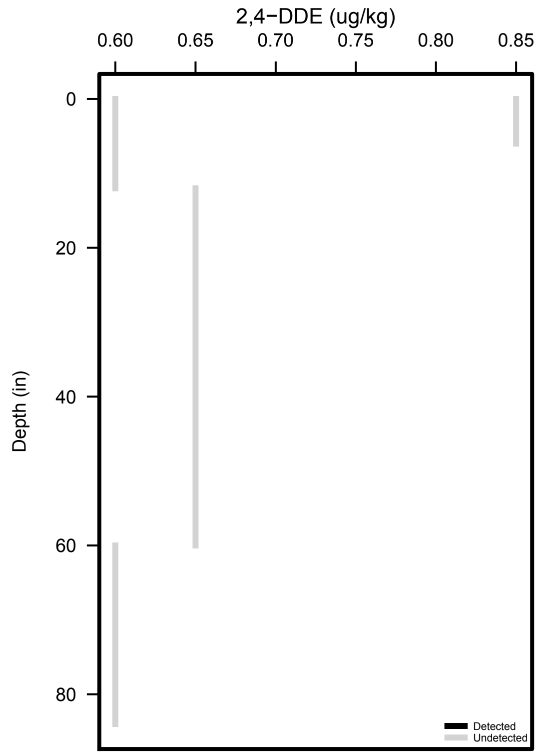

Figure 806. 2,4−DDE
at Core Location RM676C1.

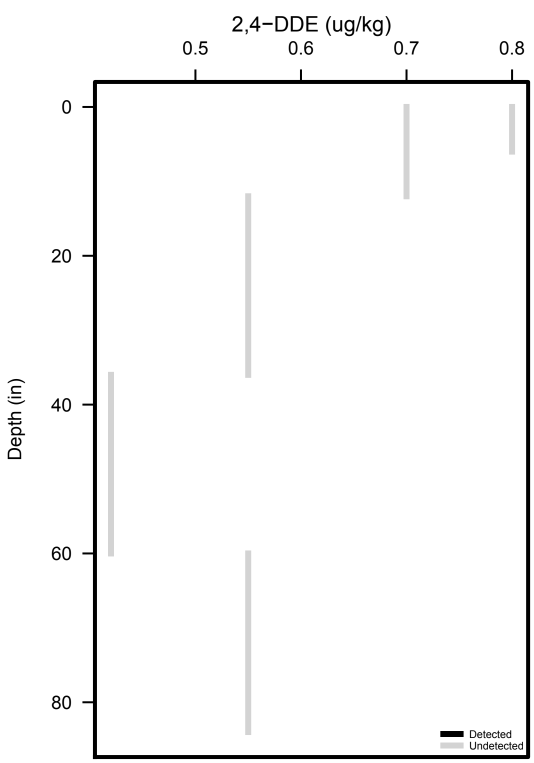

Figure 807. 2,4−DDE
at Core Location RM692C1.

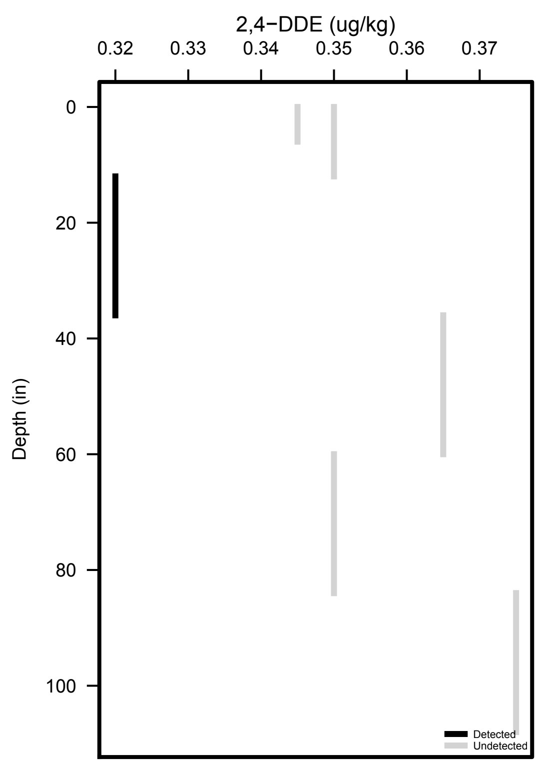

Figure 808. 2,4−DDE
at Core Location RM704C1.

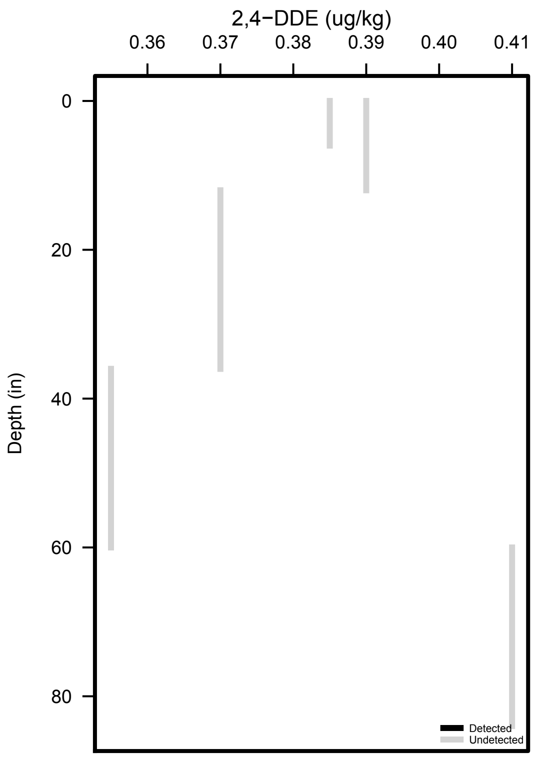

Figure 809. 2,4−DDE
at Core Location RM708C1.

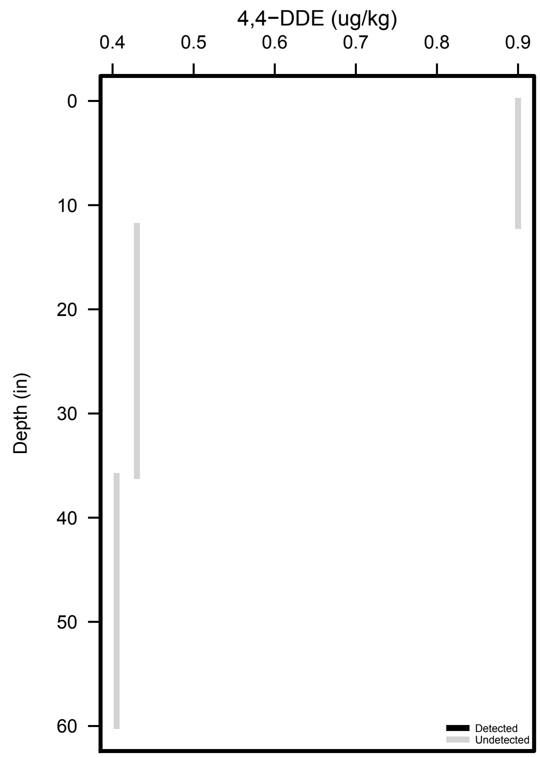

Figure 810. 4,4−DDE
at Core Location RM605C1.

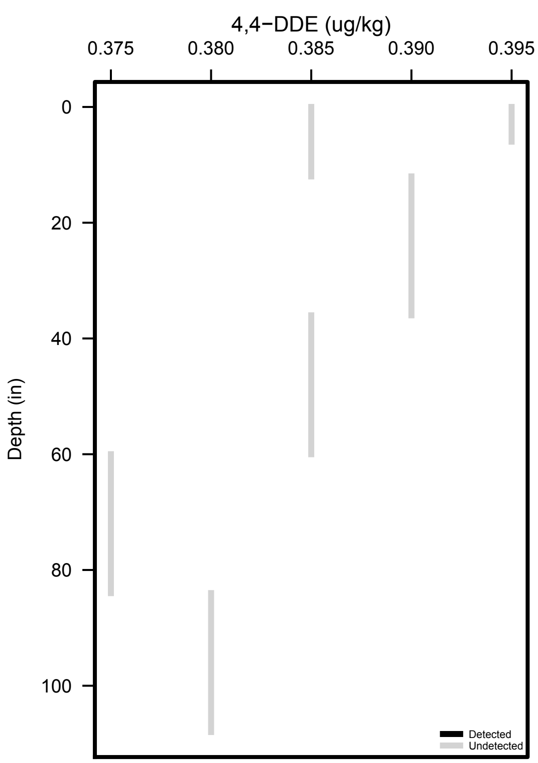

Figure 811. 4,4−DDE
at Core Location RM622C1.

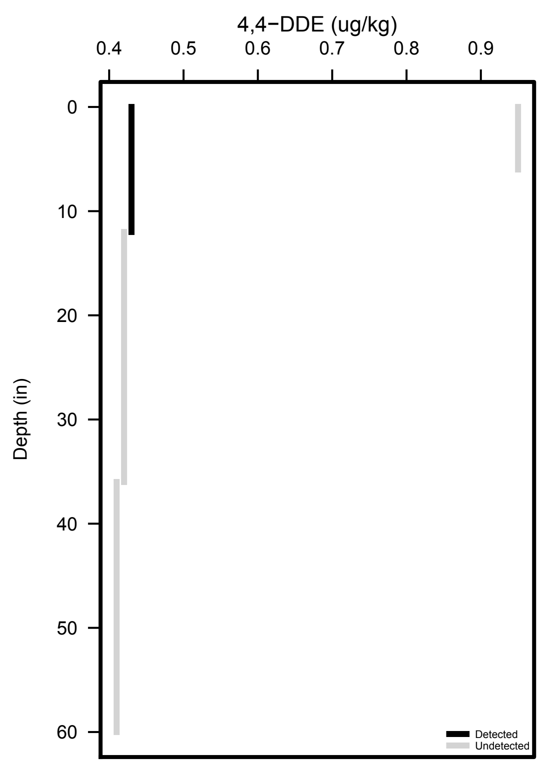

Figure 812. 4,4−DDE
at Core Location RM637C1.

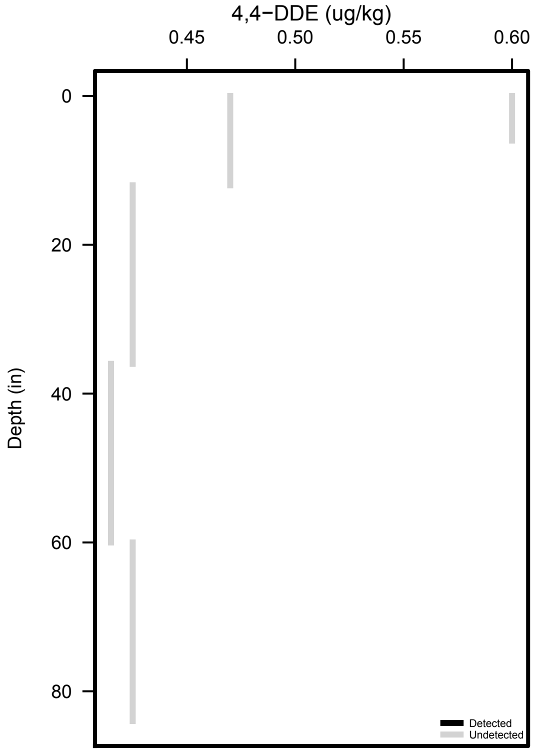

Figure 813. 4,4−DDE
at Core Location RM644C1.

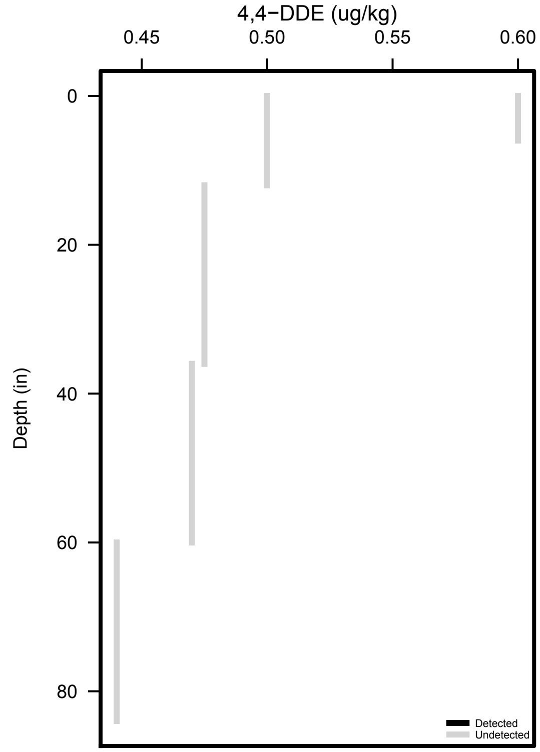

Figure 814. 4,4−DDE
at Core Location RM661C1.

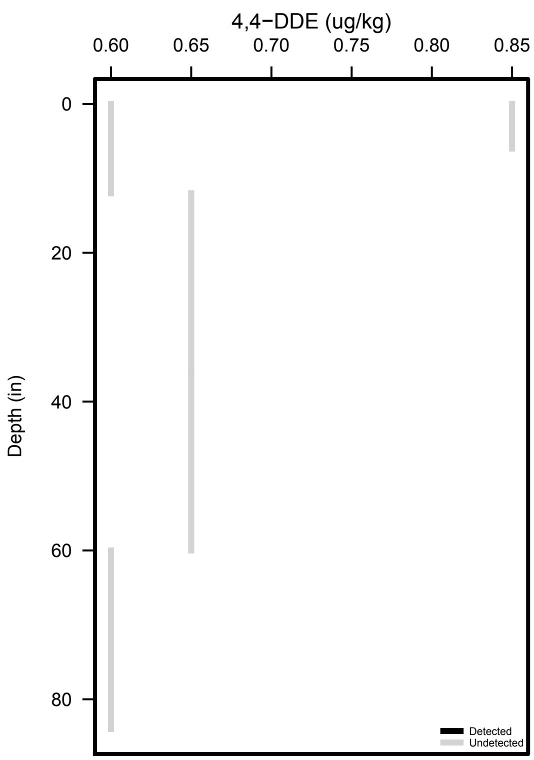

Figure 815. 4,4−DDE
at Core Location RM676C1.

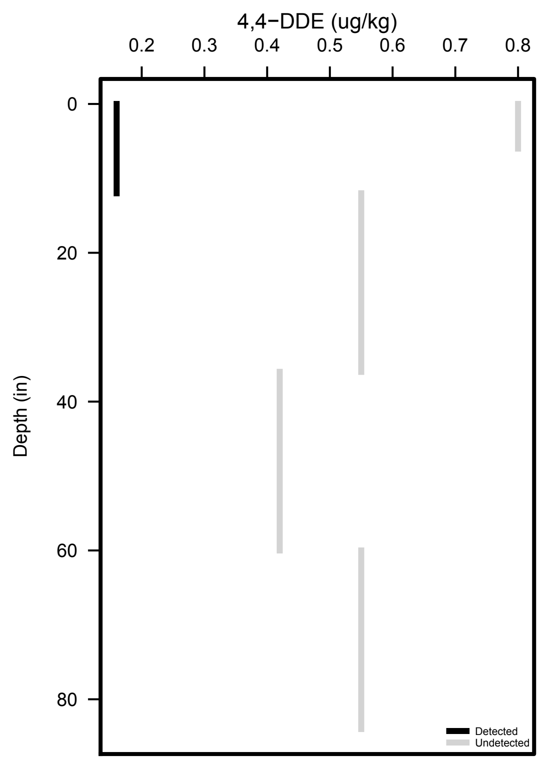

Figure 816. 4,4−DDE
at Core Location RM692C1.

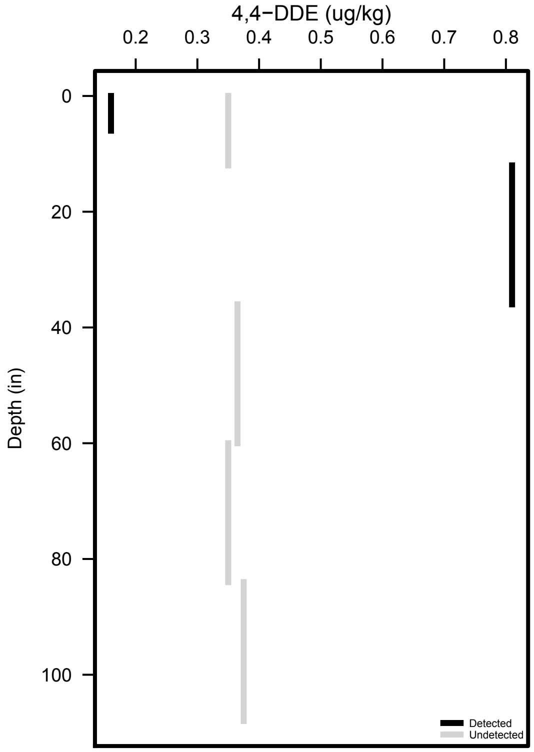

Figure 817. 4,4−DDE
at Core Location RM704C1.

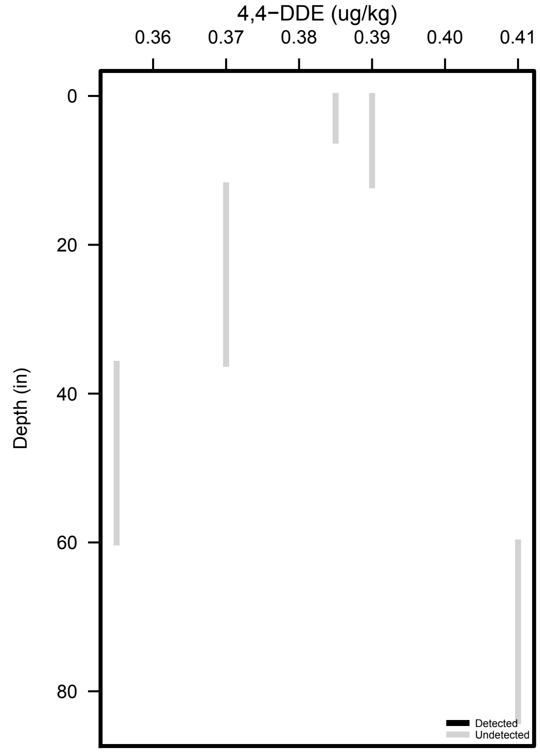

Figure 818. 4,4−DDE
at Core Location RM708C1.

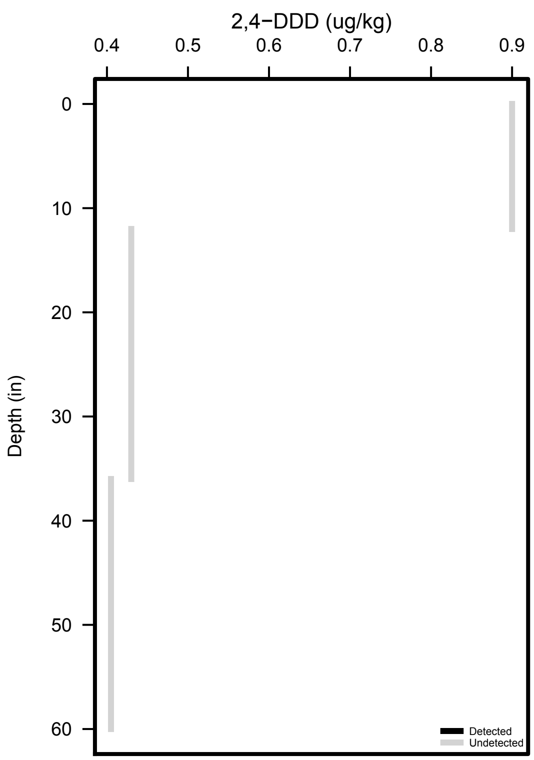

Figure 819. 2,4−DDD
at Core Location RM605C1.

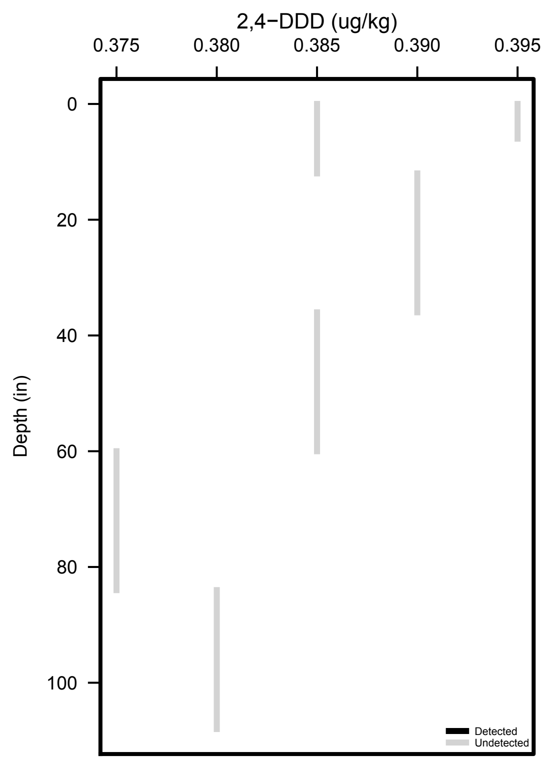

Figure 820. 2,4−DDD
at Core Location RM622C1.

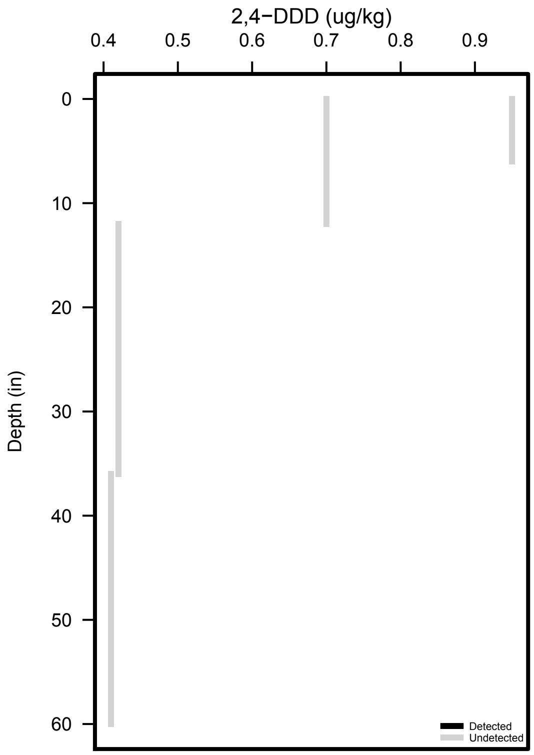

Figure 821. 2,4−DDD
at Core Location RM637C1.

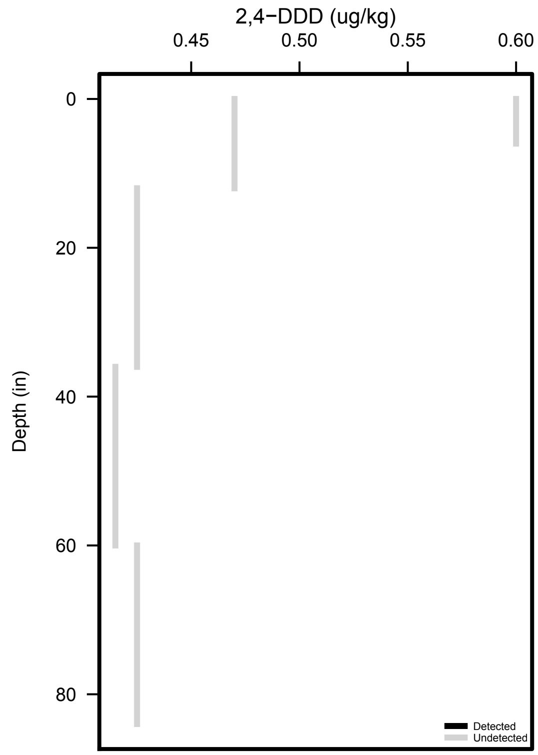

Figure 822. 2,4−DDD
at Core Location RM644C1.

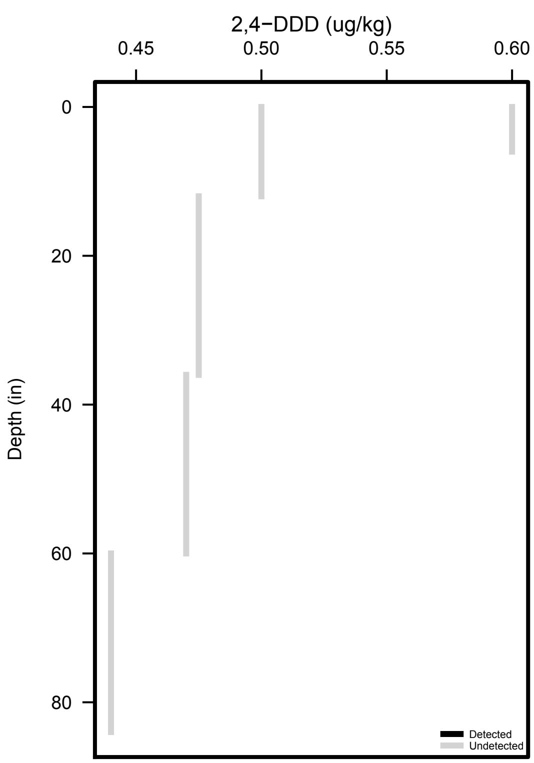

Figure 823. 2,4−DDD
at Core Location RM661C1.

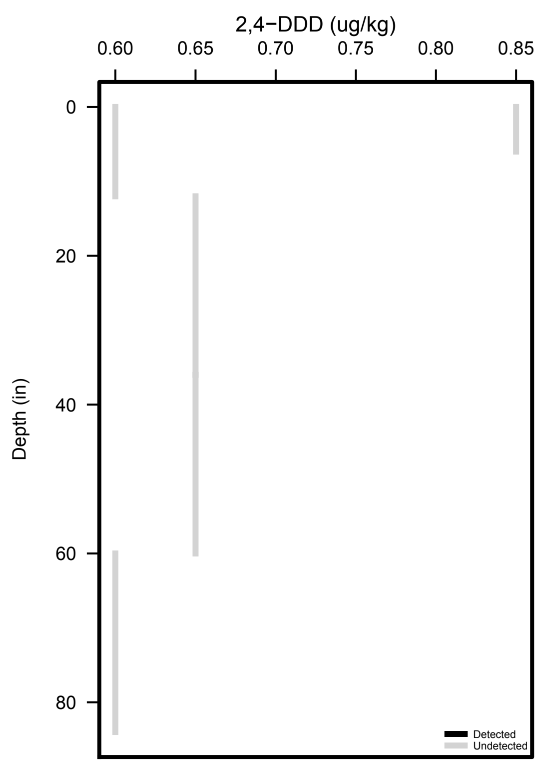

Figure 824. 2,4−DDD
at Core Location RM676C1.

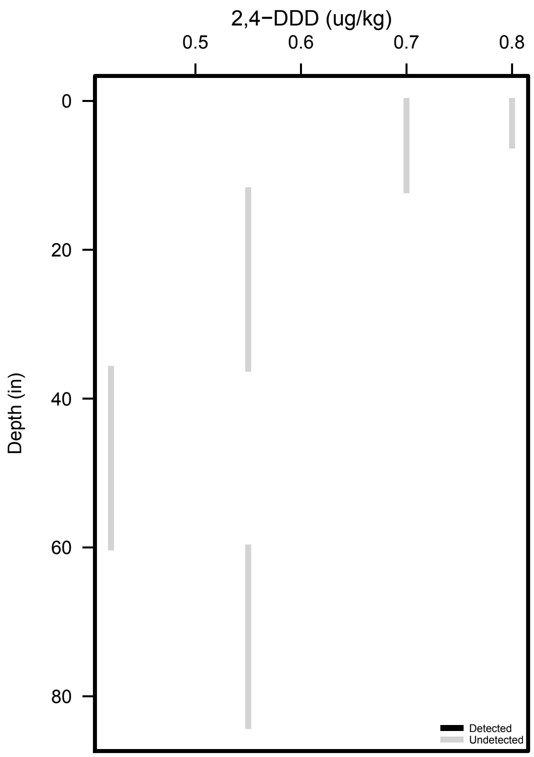

Figure 825. 2,4−DDD
at Core Location RM692C1.

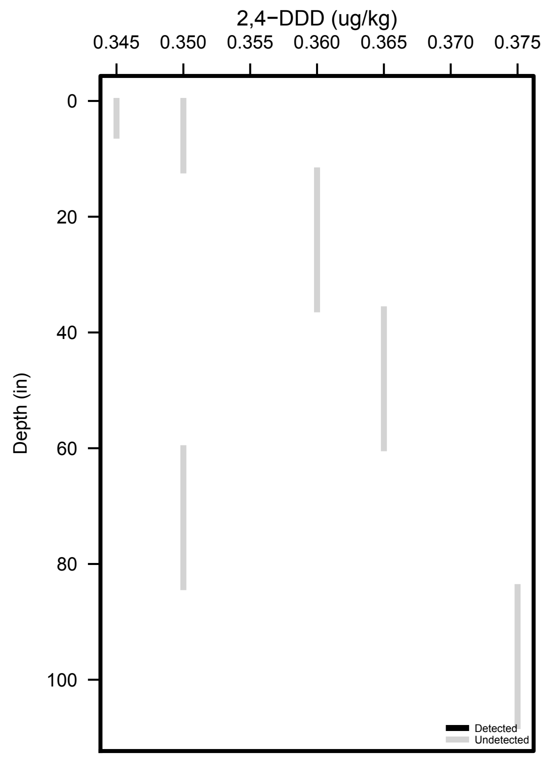

Figure 826. 2,4−DDD
at Core Location RM704C1.

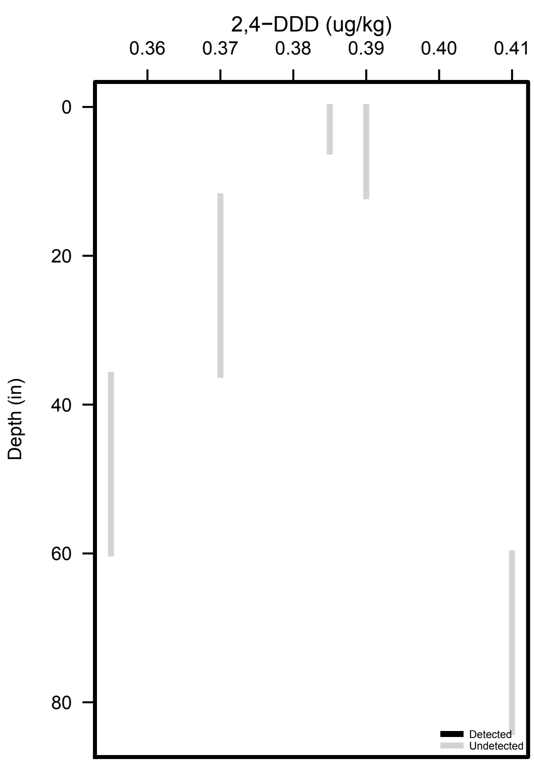

Figure 827. 2,4−DDD
at Core Location RM708C1.

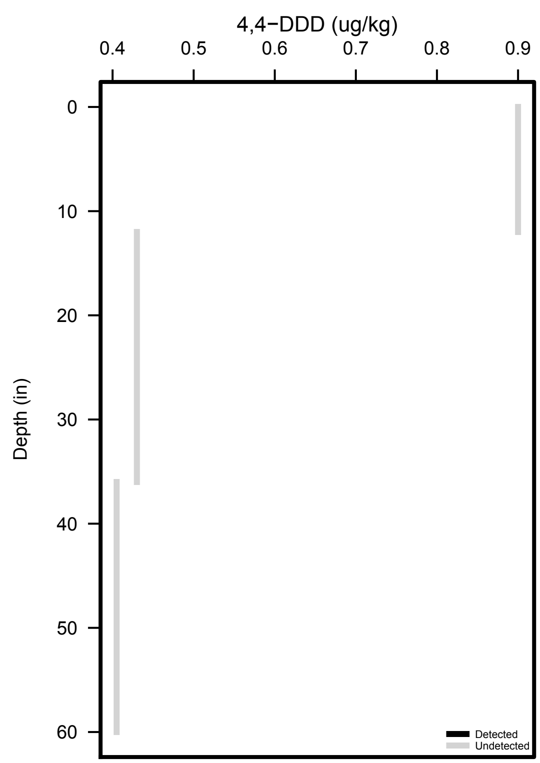

Figure 828. 4,4−DDD
at Core Location RM605C1.

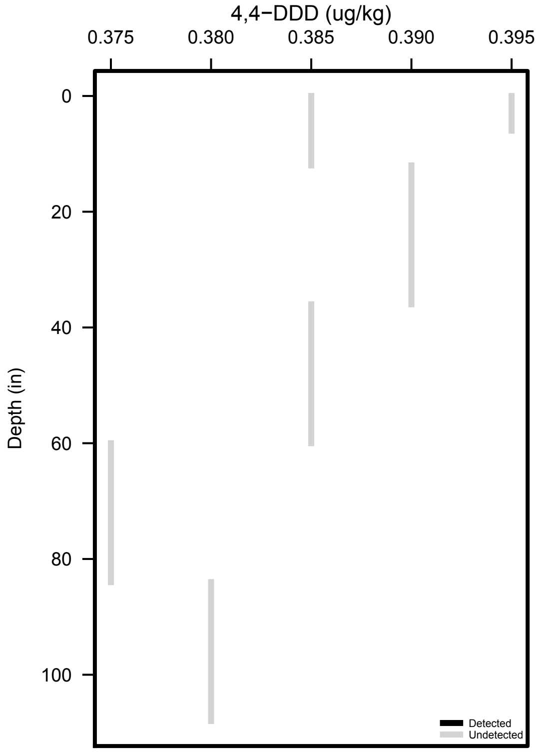

Figure 829. 4,4−DDD
at Core Location RM622C1.

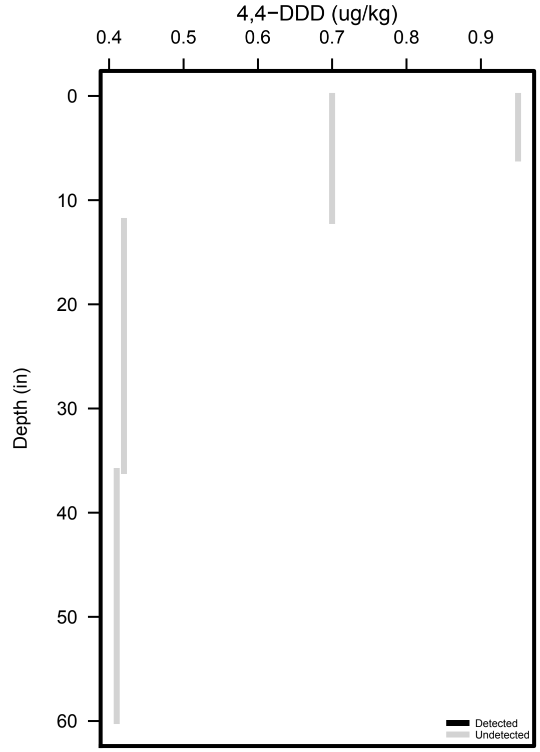

Figure 830. 4,4−DDD
at Core Location RM637C1.

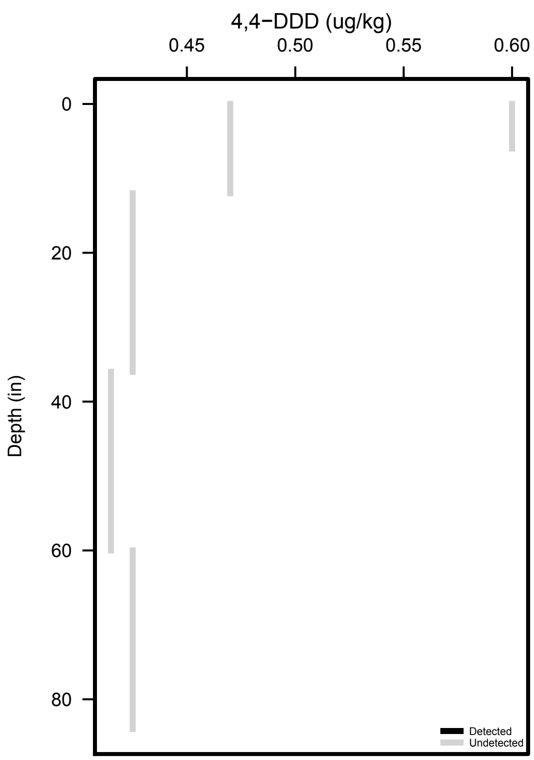

Figure 831. 4,4−DDD
at Core Location RM644C1.

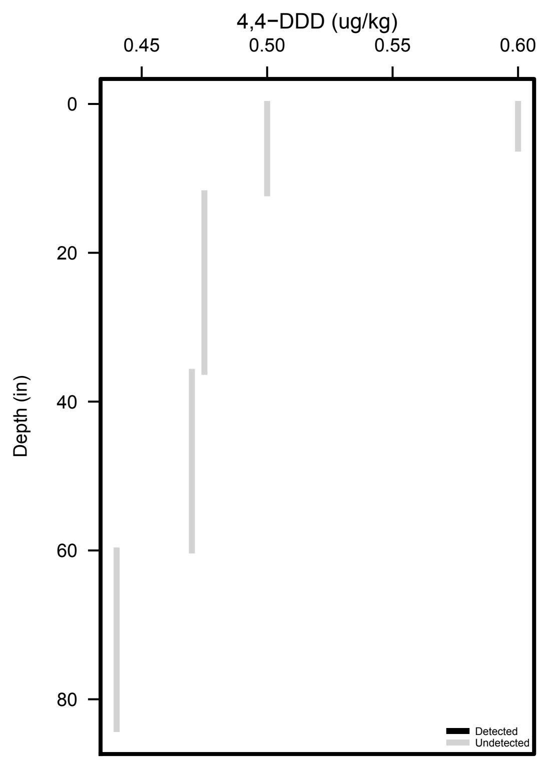

Figure 832. 4,4−DDD
at Core Location RM661C1.

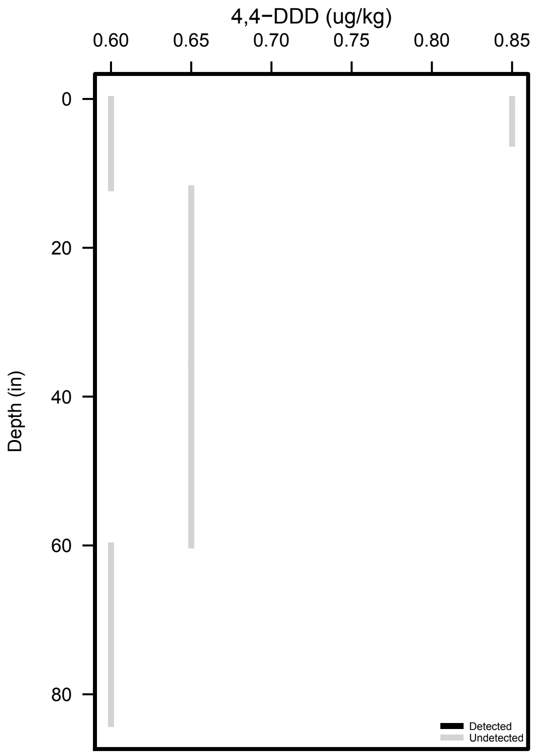

Figure 833. 4,4−DDD
at Core Location RM676C1.

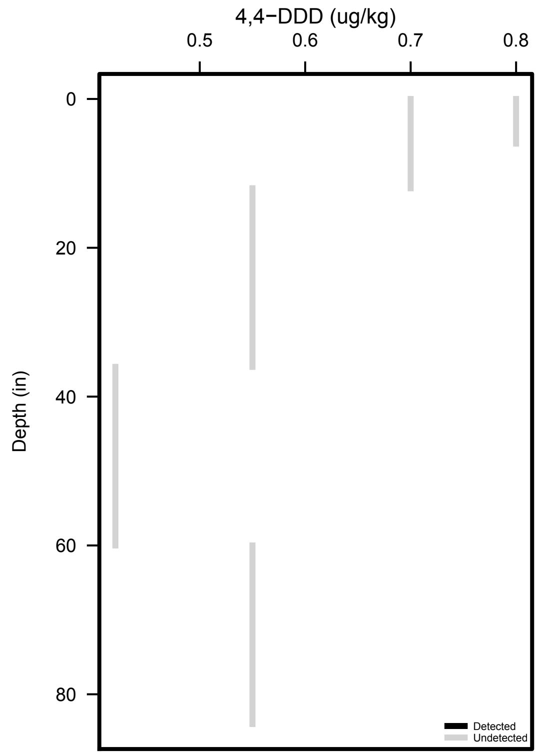

Figure 834. 4,4−DDD
at Core Location RM692C1.

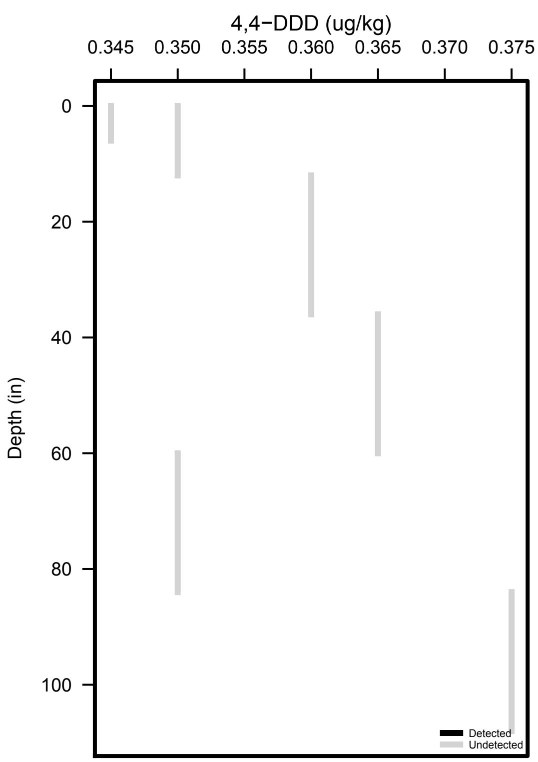

Figure 835. 4,4−DDD
at Core Location RM704C1.

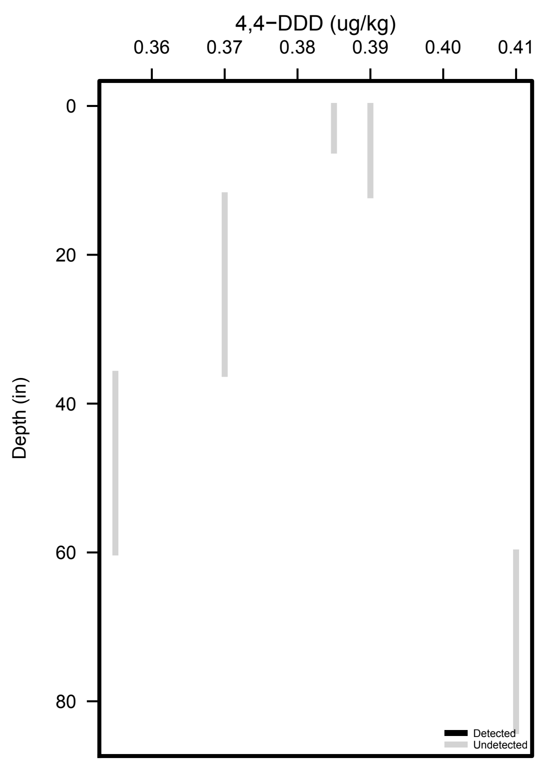

Figure 836. 4,4−DDD
at Core Location RM708C1.

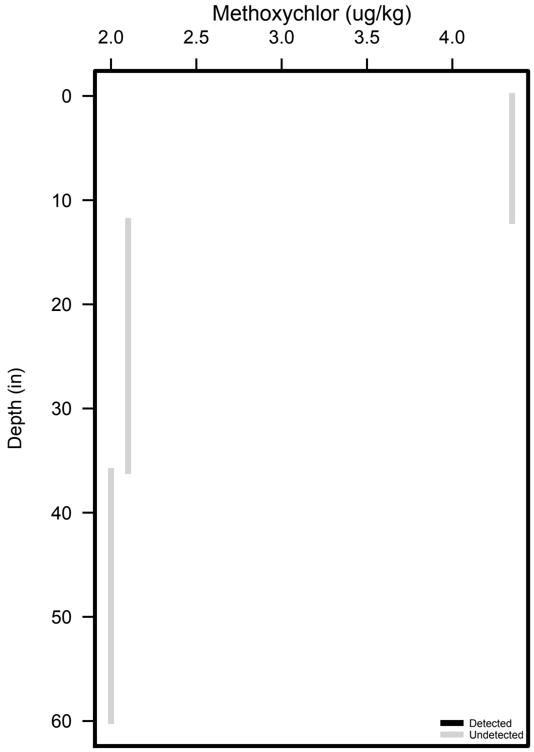

Figure 837. Methoxychlor at Core Location RM605C1.

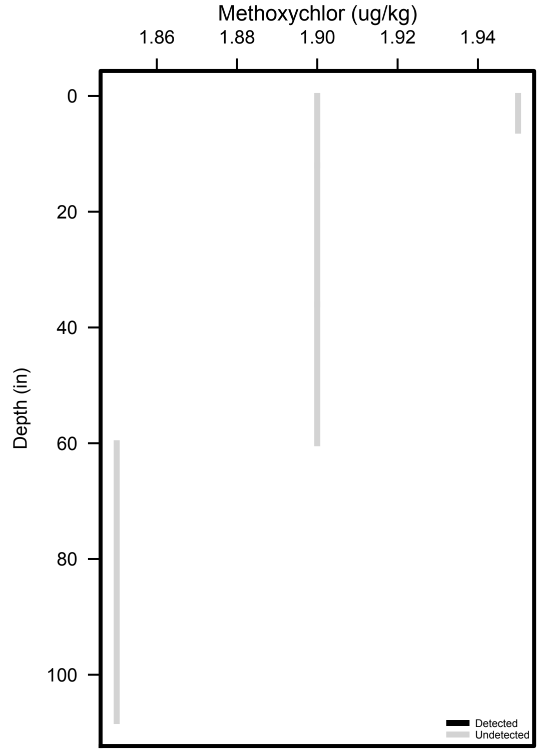

Figure 838. Methoxychlor at Core Location RM622C1.

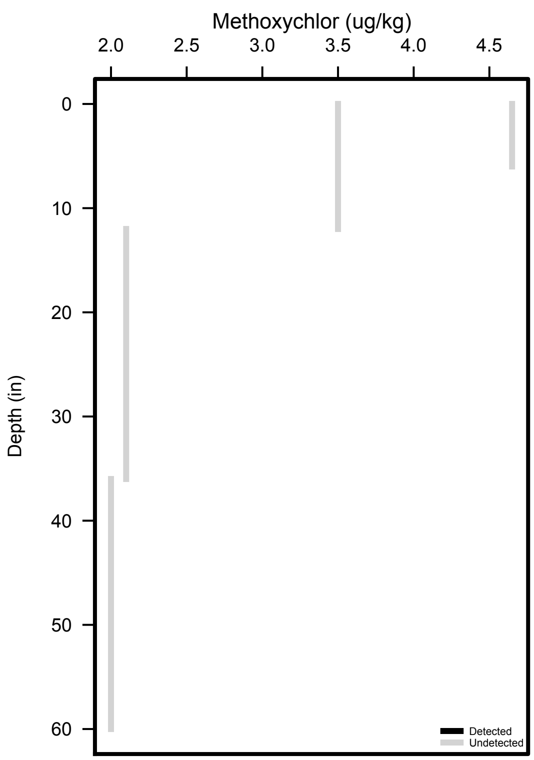

Figure 839. Methoxychlor at Core Location RM637C1.

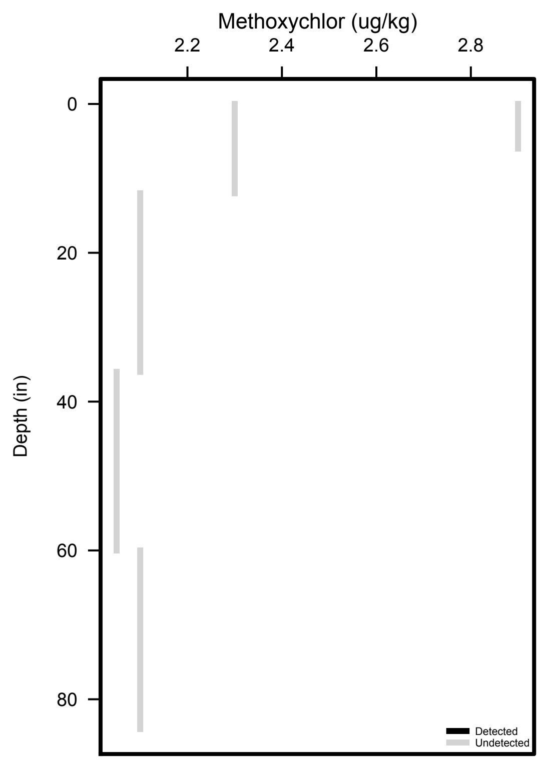

Figure 840. Methoxychlor at Core Location RM644C1.

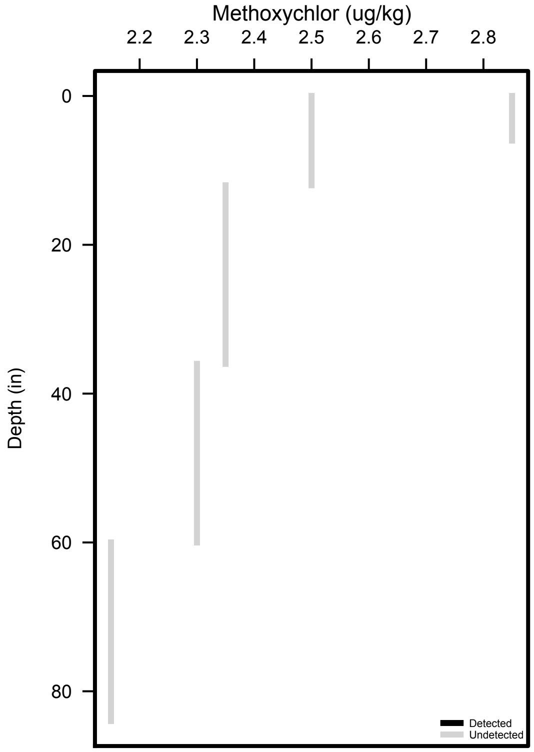

Figure 841. Methoxychlor
at Core Location RM661C1.

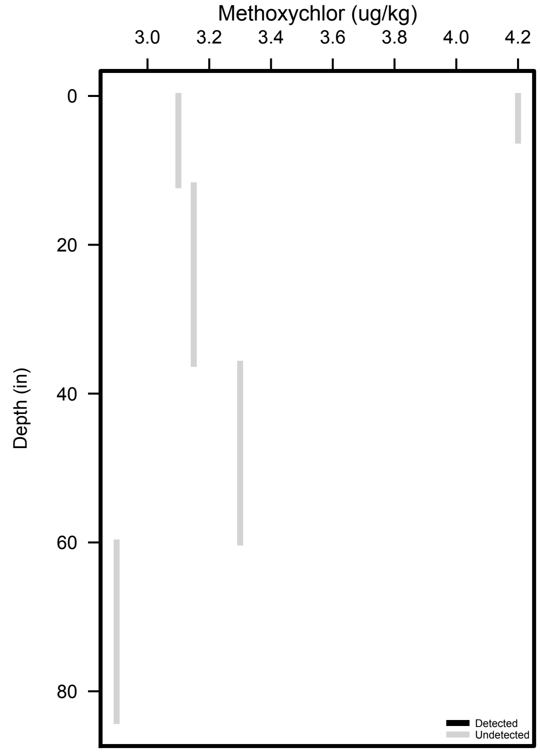

Figure 842. Methoxychlor
at Core Location RM676C1.

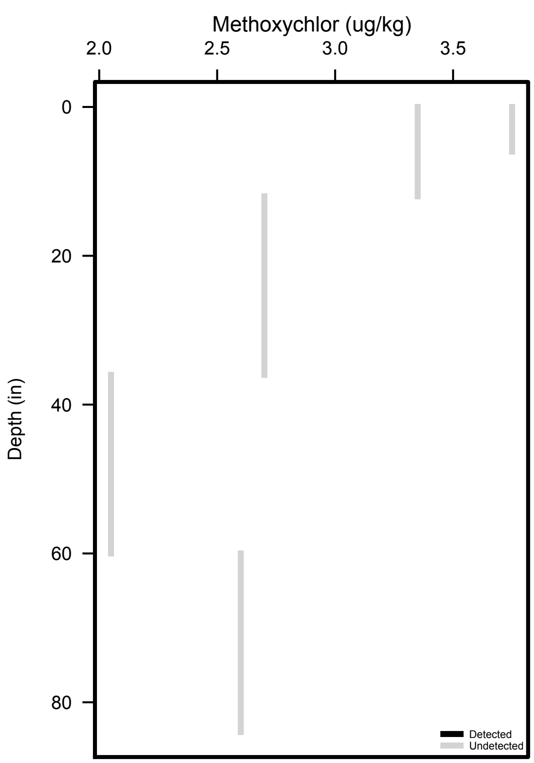

Figure 843. Methoxychlor
at Core Location RM692C1.

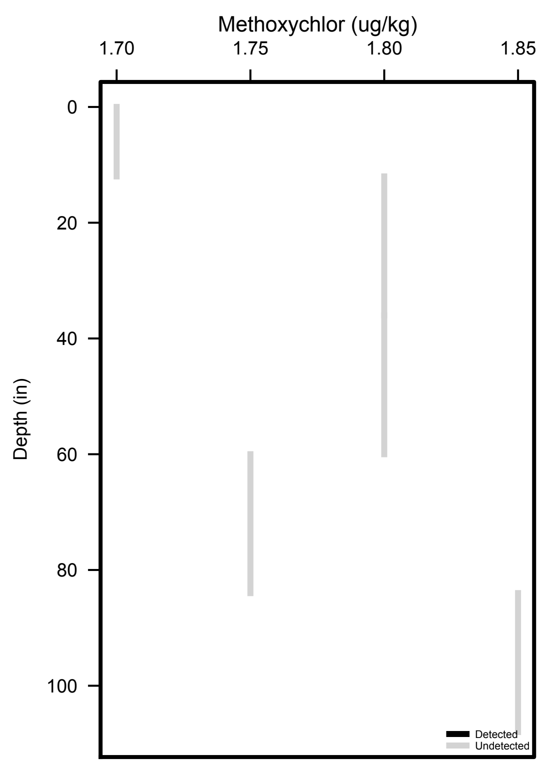

Figure 844. Methoxychlor
at Core Location RM704C1.

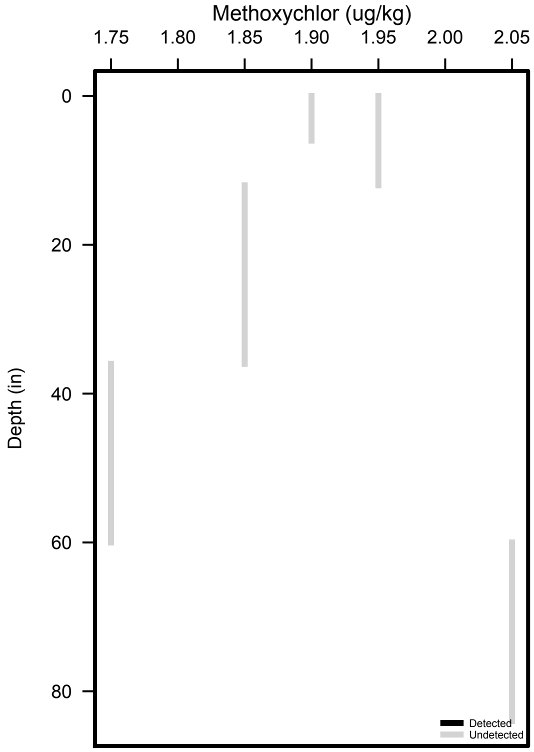

Figure 845. Methoxychlor
at Core Location RM708C1.

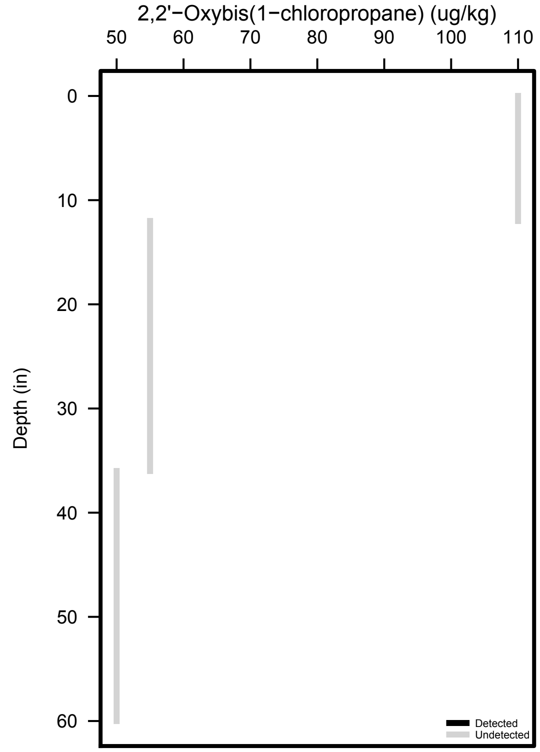

Figure 846. 2,2'−Oxybis(1−chloropropane)
at Core Location RM605C1.

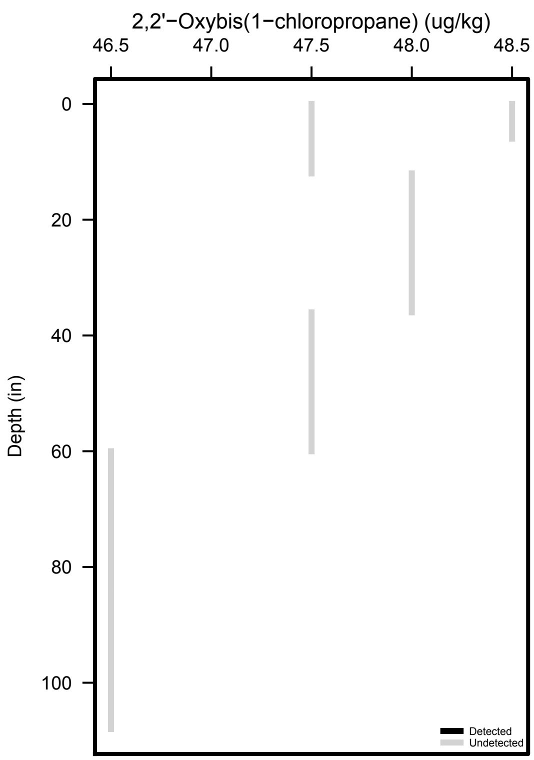

Figure 847. 2,2'−Oxybis(1−chloropropane)
at Core Location RM622C1.

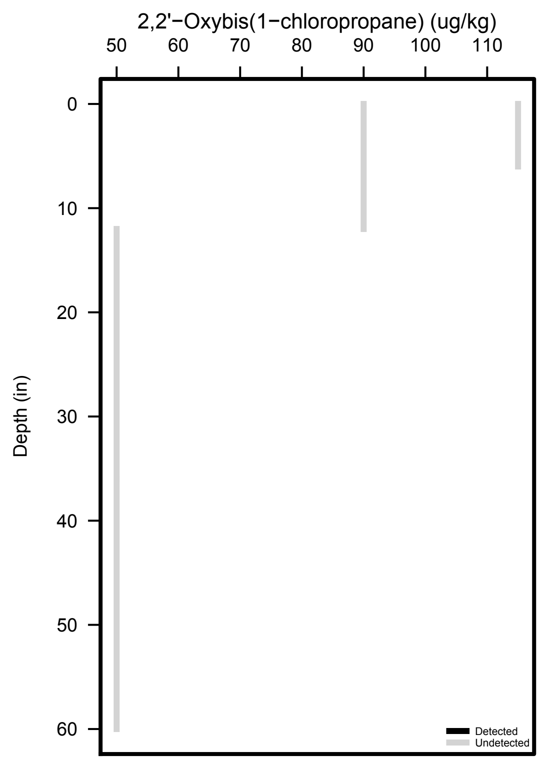

Figure 848. 2,2'−Oxybis(1−chloropropane)
at Core Location RM637C1.

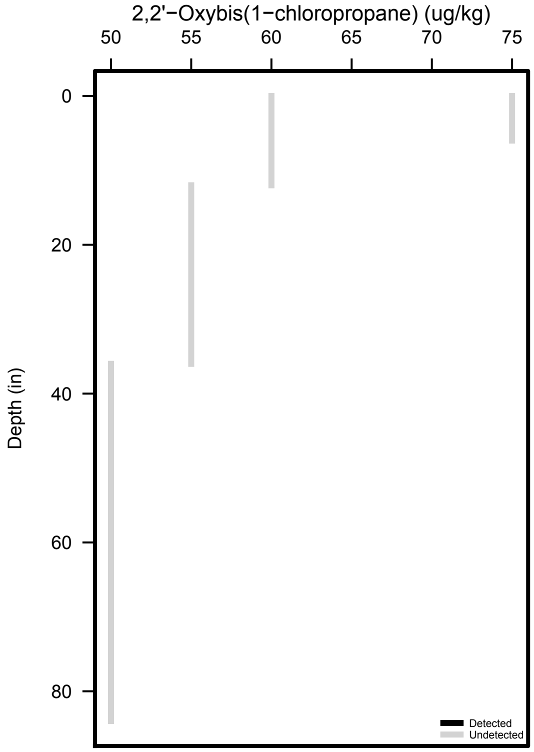

Figure 849. 2,2'−Oxybis(1−chloropropane) at Core Location RM644C1.

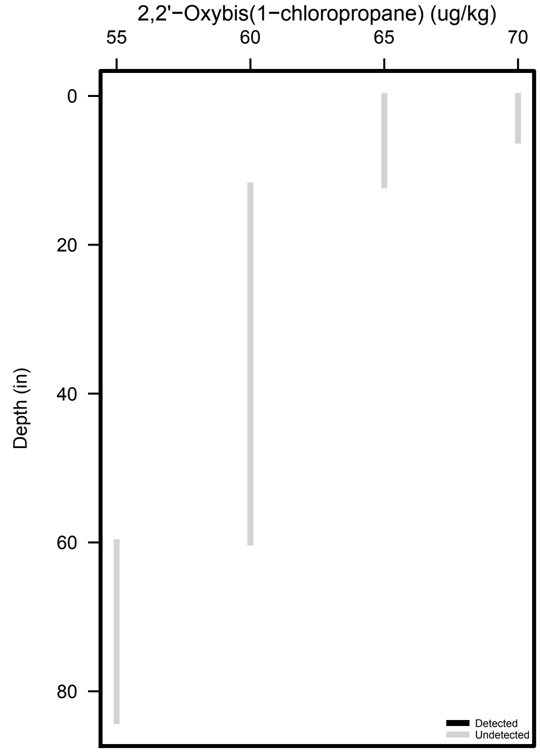

Figure 850. 2,2'−Oxybis(1−chloropropane) at Core Location RM661C1.

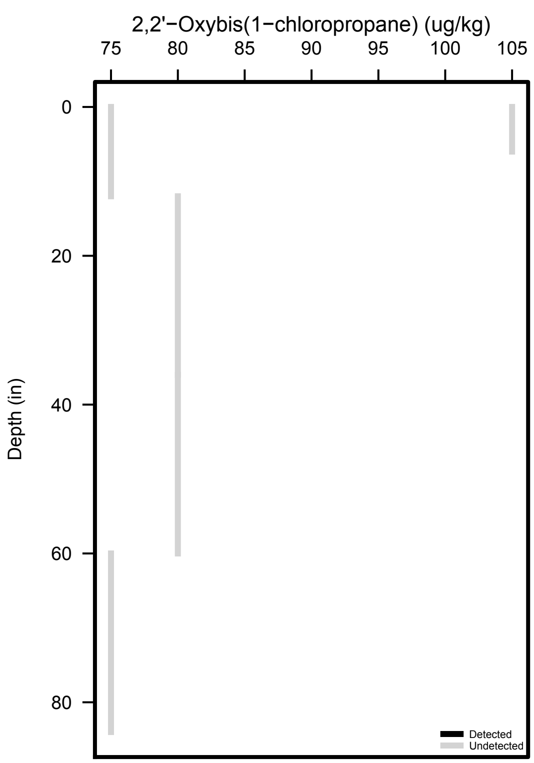

Figure 851. 2,2'−Oxybis(1−chloropropane) at Core Location RM676C1.

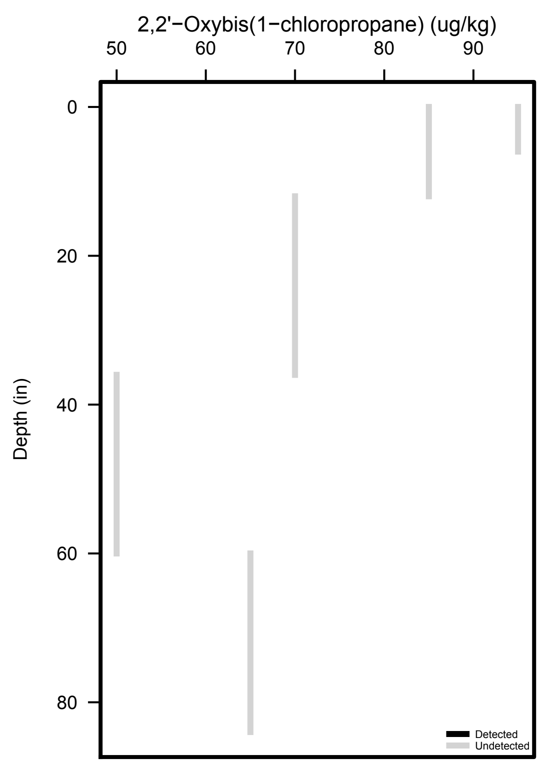

Figure 852. 2,2'−Oxybis(1−chloropropane) at Core Location RM692C1.

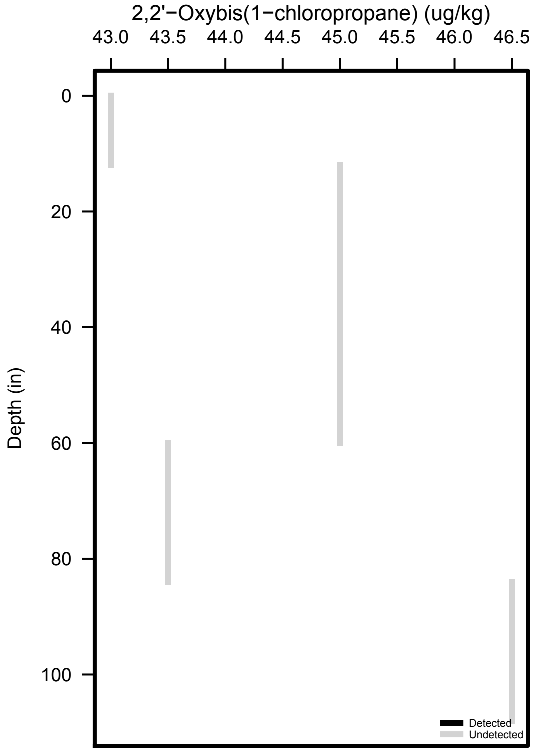

Figure 853. 2,2'−Oxybis(1−chloropropane)
at Core Location RM704C1.

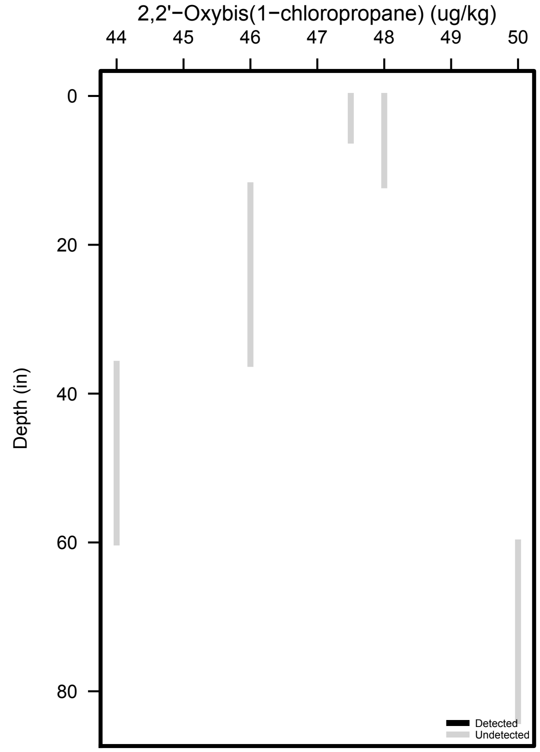

Figure 854. 2,2'−Oxybis(1−chloropropane)
at Core Location RM708C1.

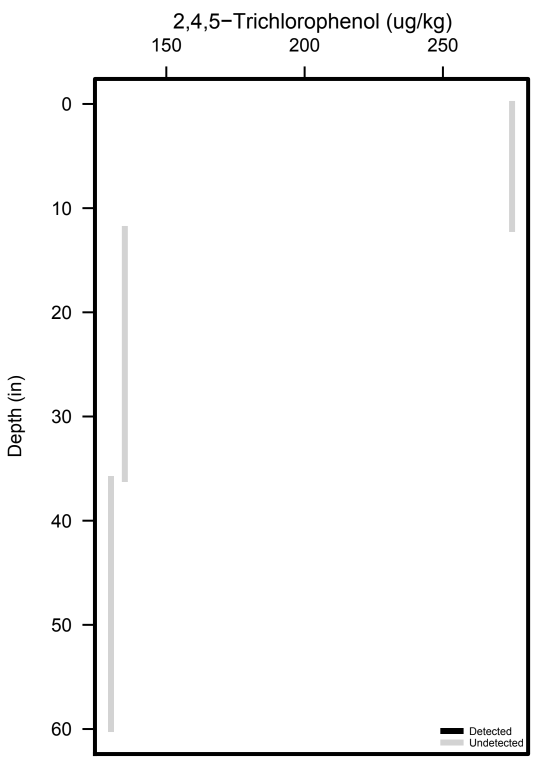

Figure 855. 2,4,5−Trichlorophenol
at Core Location RM605C1.

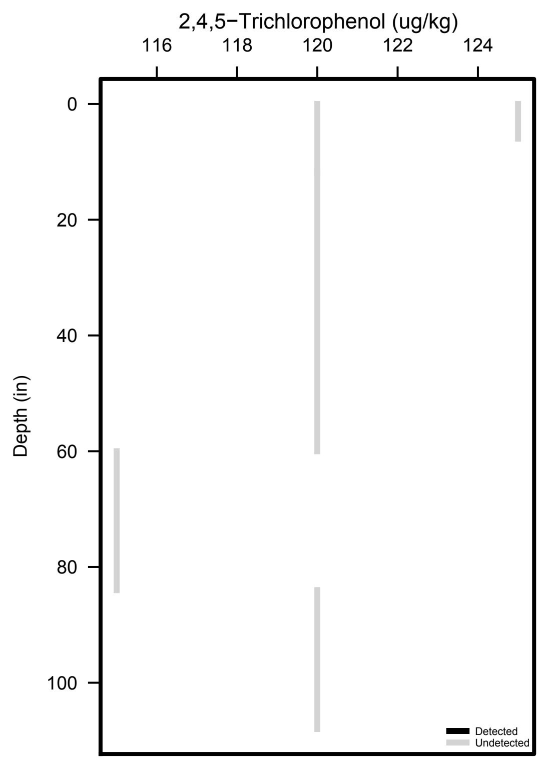

Figure 856. 2,4,5−Trichlorophenol
at Core Location RM622C1.

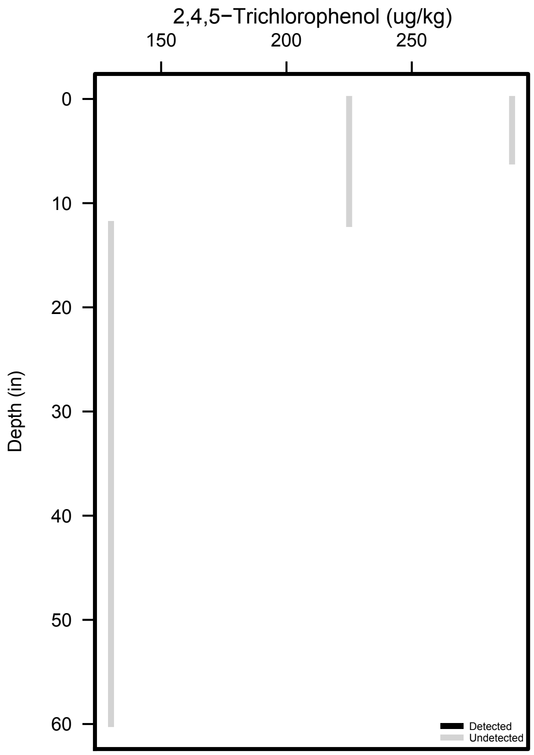

Figure 857. 2,4,5−Trichlorophenol at Core Location RM637C1.

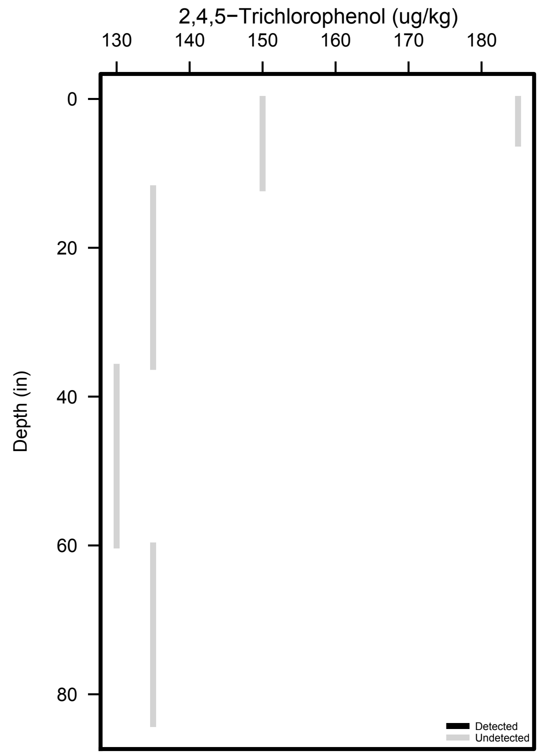

Figure 858. 2,4,5−Trichlorophenol at Core Location RM644C1.

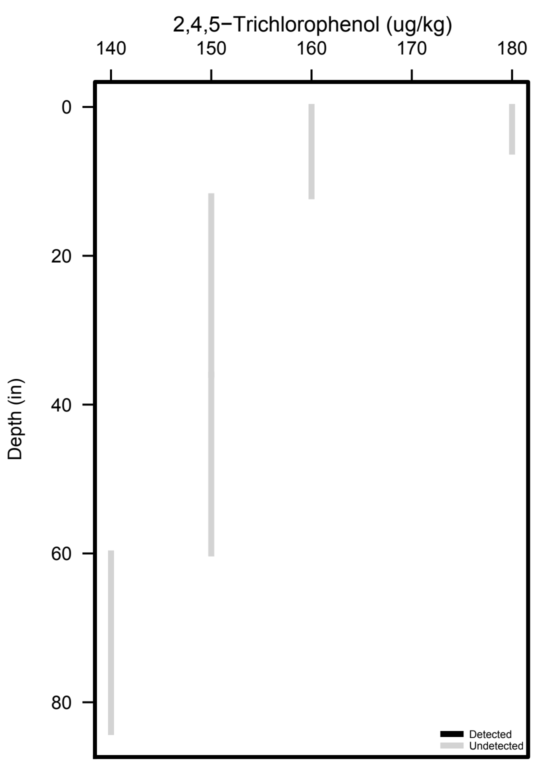

Figure 859. 2,4,5−Trichlorophenol at Core Location RM661C1.

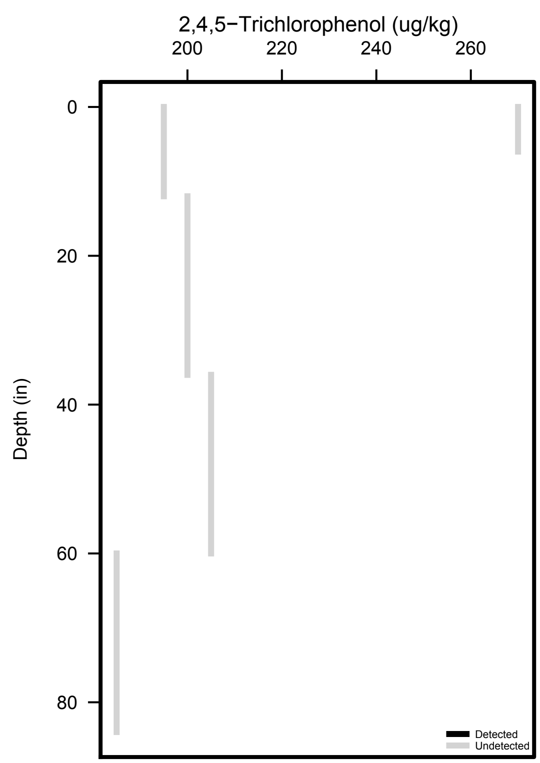

Figure 860. 2,4,5−Trichlorophenol at Core Location RM676C1.

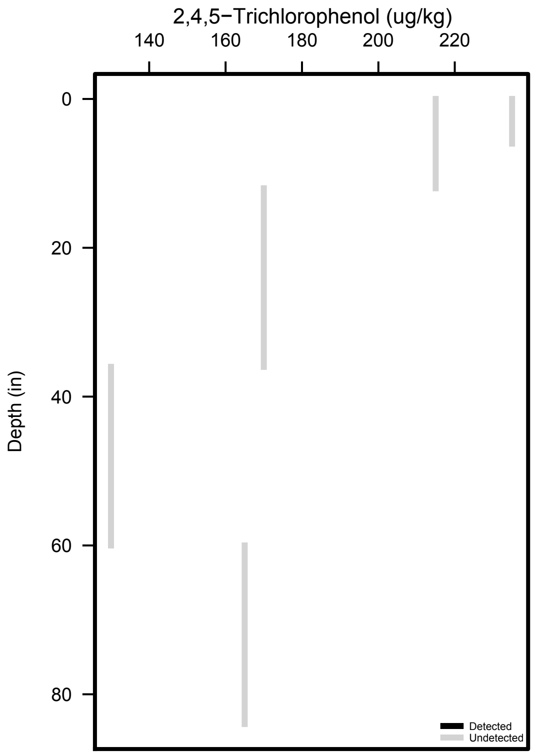

Figure 861. 2,4,5−Trichlorophenol at Core Location RM692C1.

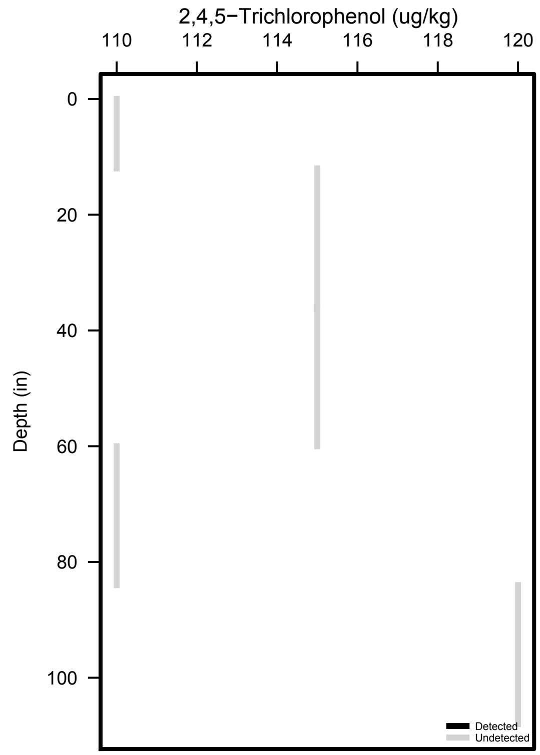

Figure 862. 2,4,5−Trichlorophenol at Core Location RM704C1.

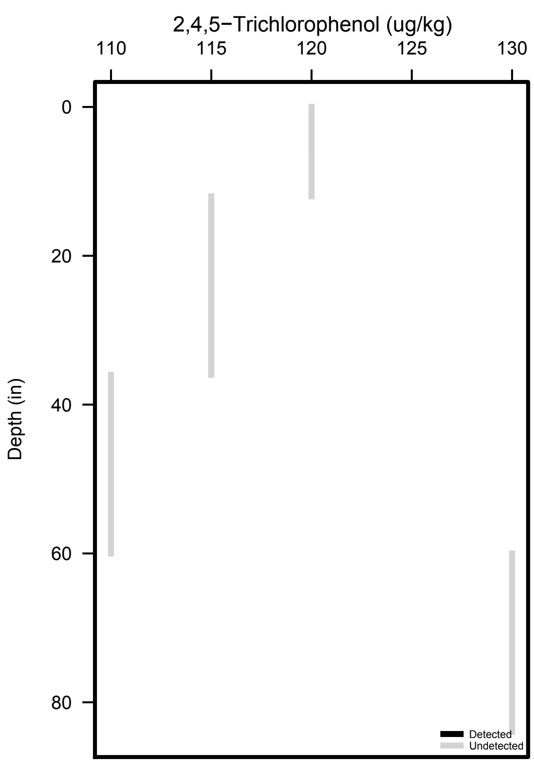

Figure 863. 2,4,5−Trichlorophenol at Core Location RM708C1.

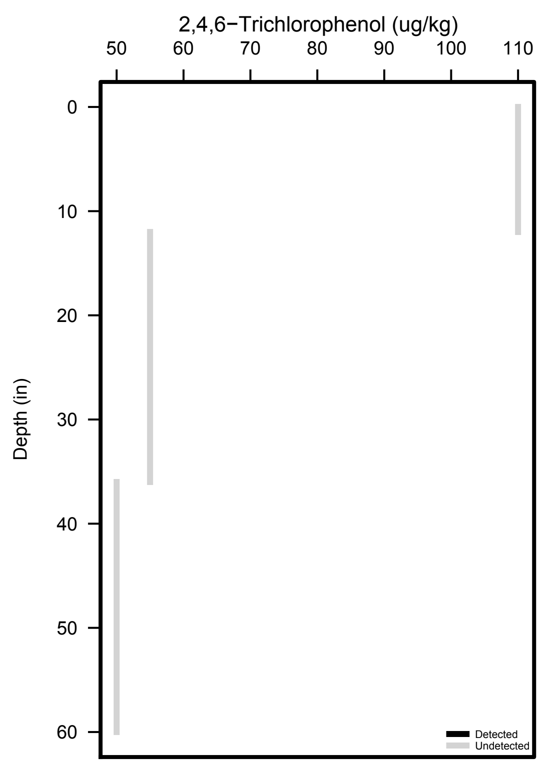

Figure 864. 2,4,6−Trichlorophenol at Core Location RM605C1.

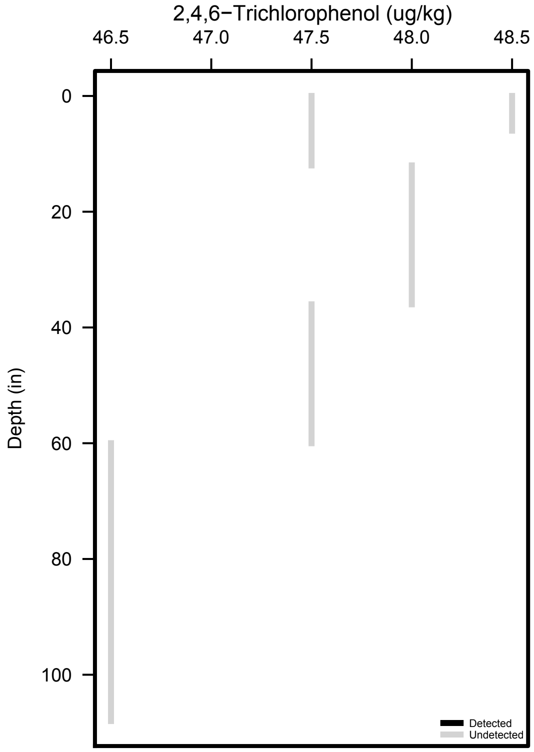

Figure 865. 2,4,6−Trichlorophenol
at Core Location RM622C1.

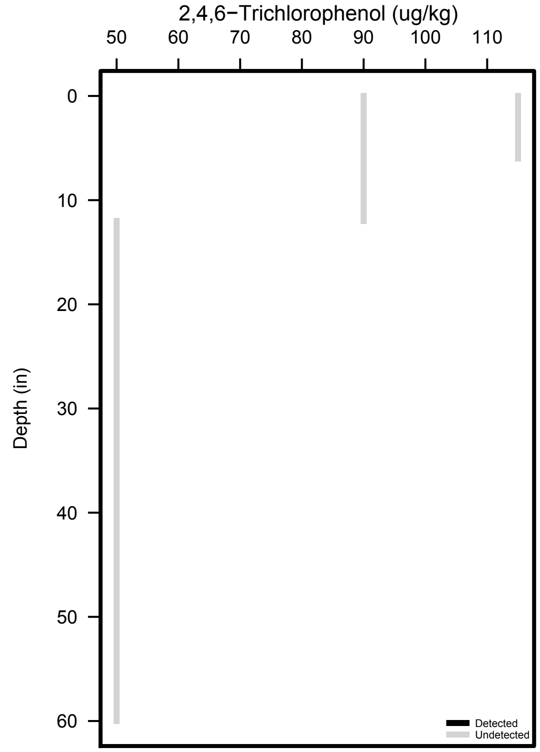

Figure 866. 2,4,6−Trichlorophenol
at Core Location RM637C1.

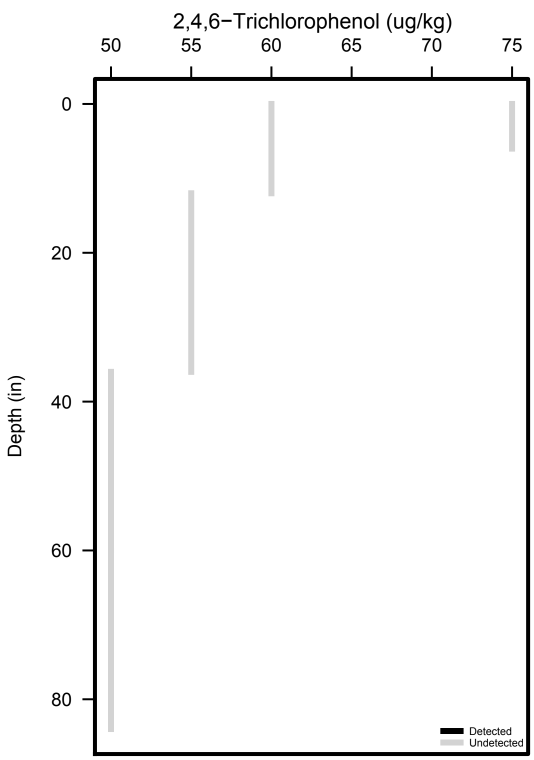

Figure 867. 2,4,6−Trichlorophenol
at Core Location RM644C1.

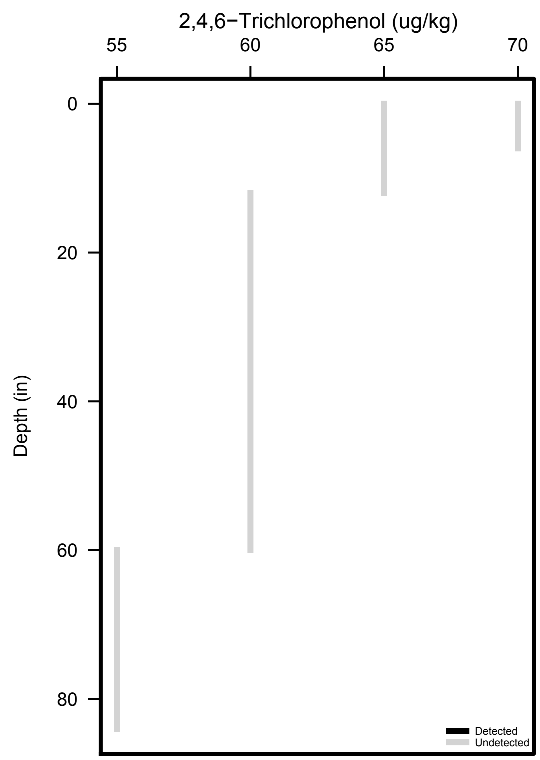

Figure 868. 2,4,6−Trichlorophenol
at Core Location RM661C1.

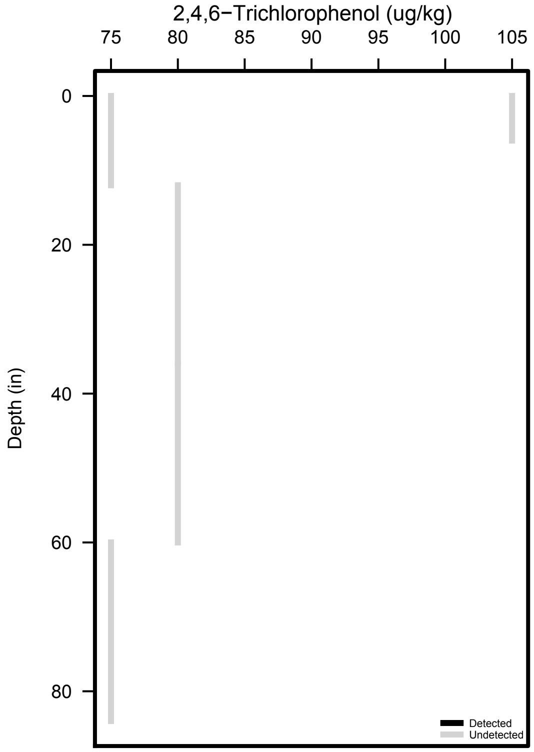

Figure 869. 2,4,6−Trichlorophenol
at Core Location RM676C1.

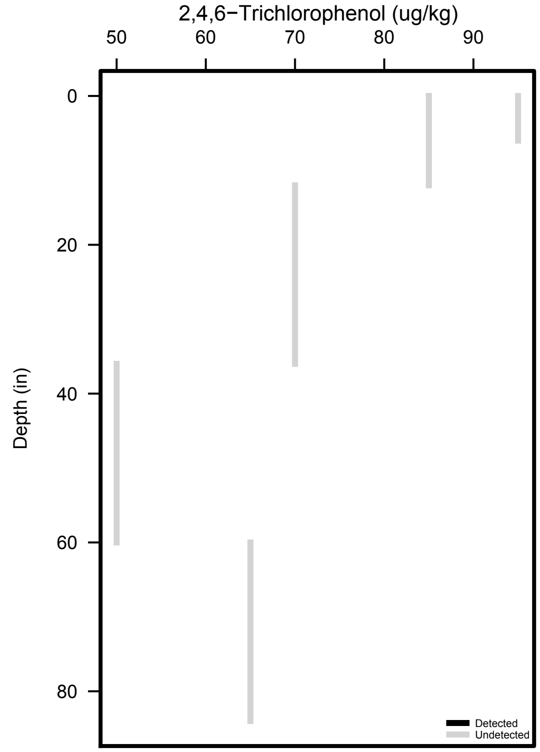

Figure 870. 2,4,6−Trichlorophenol
at Core Location RM692C1.

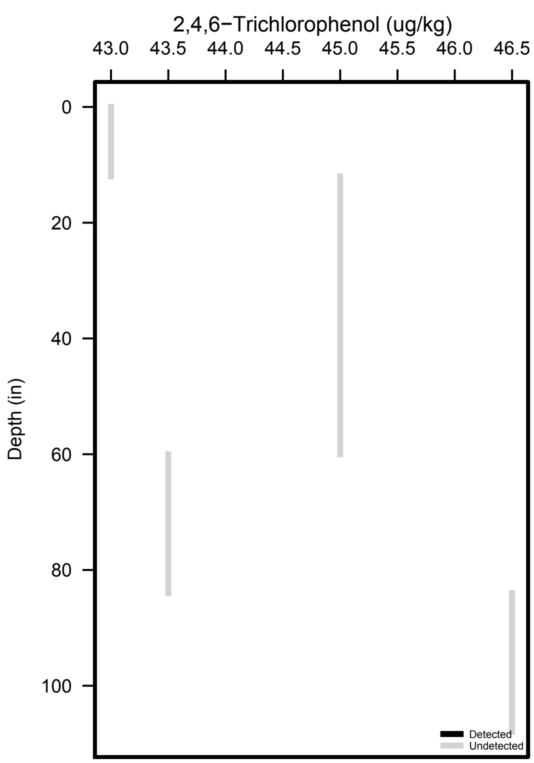

Figure 871. 2,4,6−Trichlorophenol
at Core Location RM704C1.

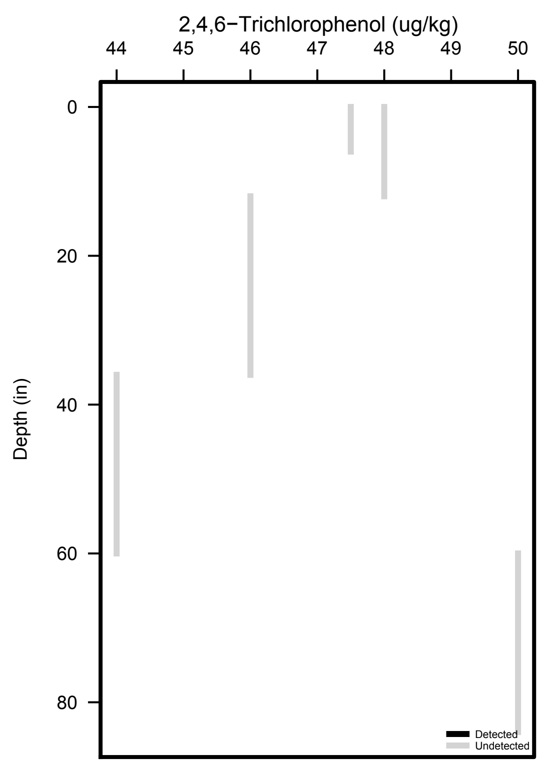

Figure 872. 2,4,6−Trichlorophenol
at Core Location RM708C1.

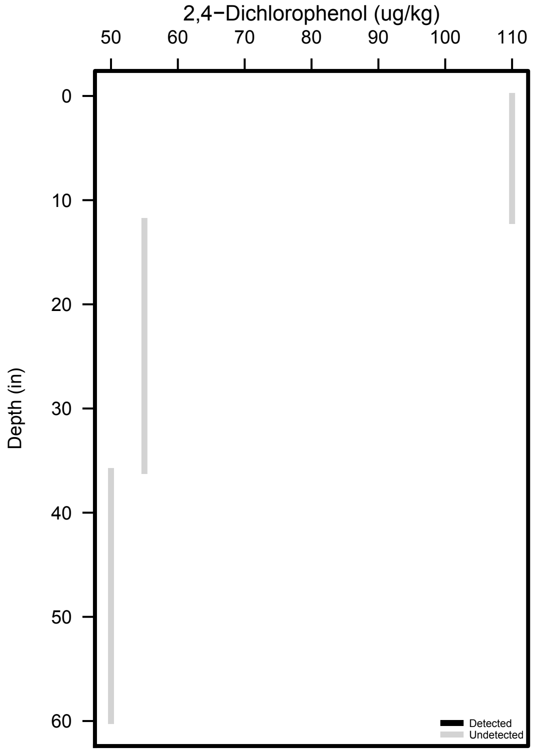

Figure 873. 2,4−Dichlorophenol at Core Location RM605C1.

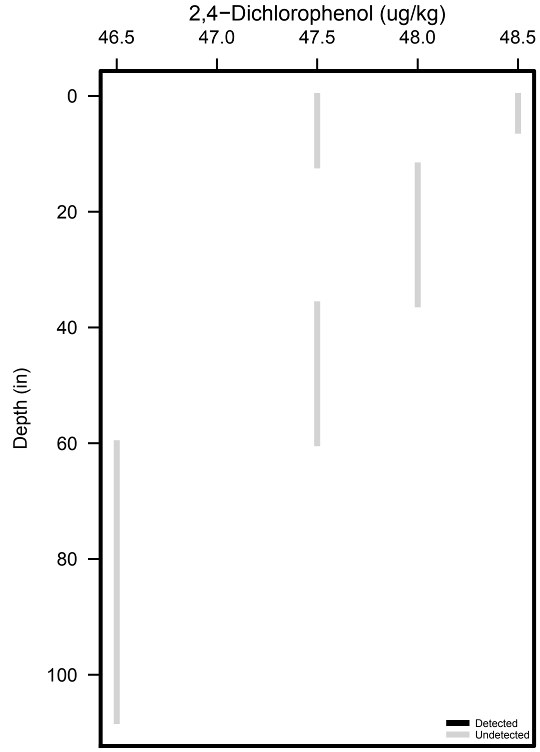

Figure 874. 2,4−Dichlorophenol at Core Location RM622C1.

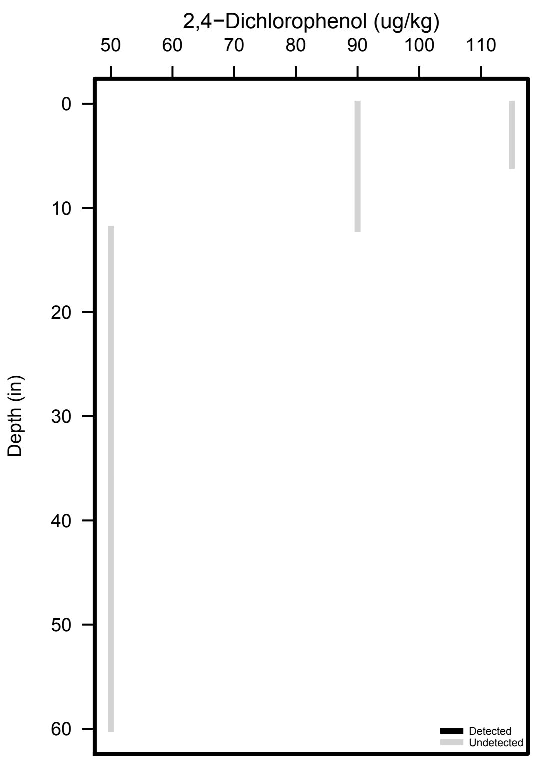

Figure 875. 2,4−Dichlorophenol at Core Location RM637C1.

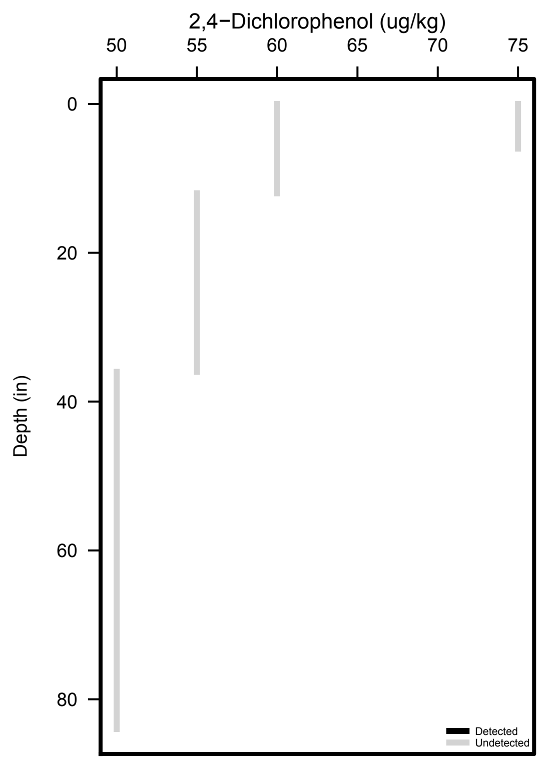

Figure 876. 2,4−Dichlorophenol at Core Location RM644C1.

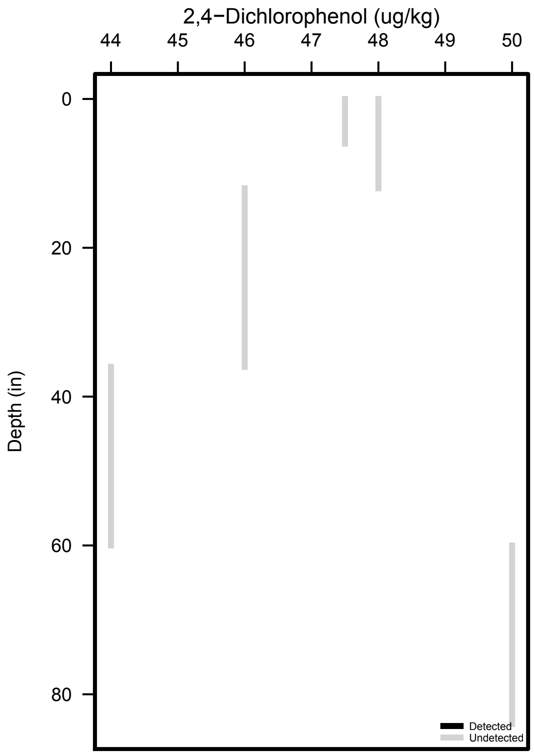

Figure 877. 2,4−Dichlorophenol
at Core Location RM708C1.

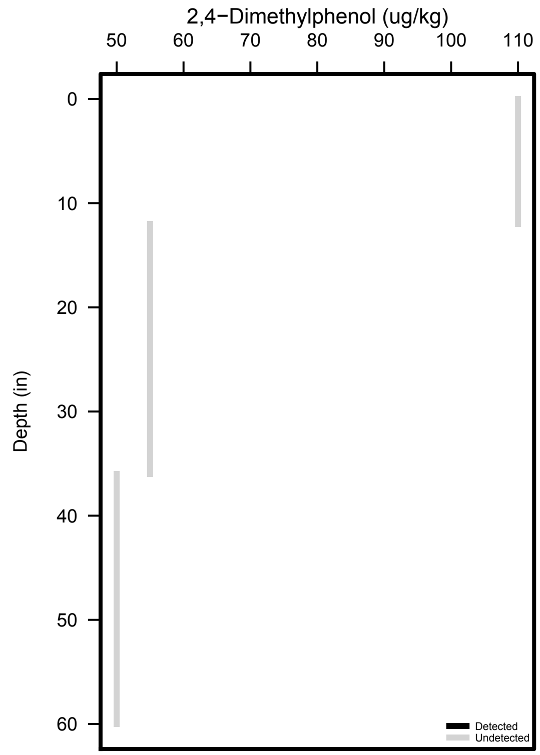

Figure 878. 2,4−Dimethylphenol
at Core Location RM605C1.

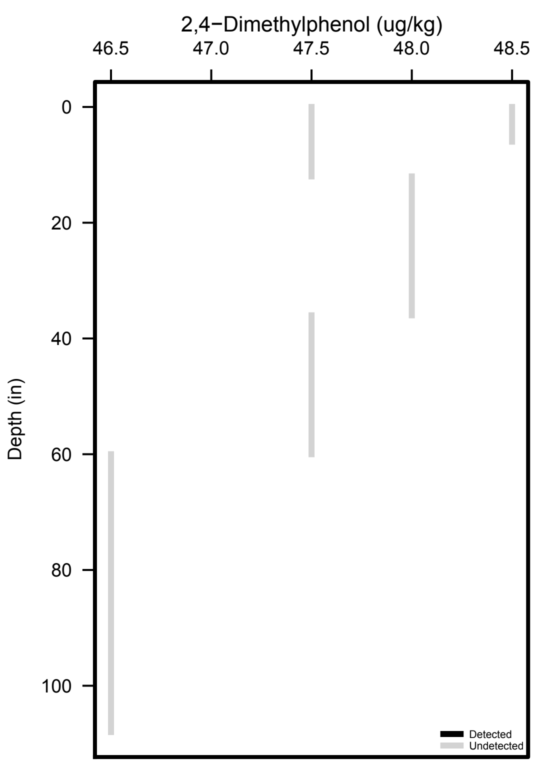

Figure 879. 2,4−Dimethylphenol
at Core Location RM622C1.

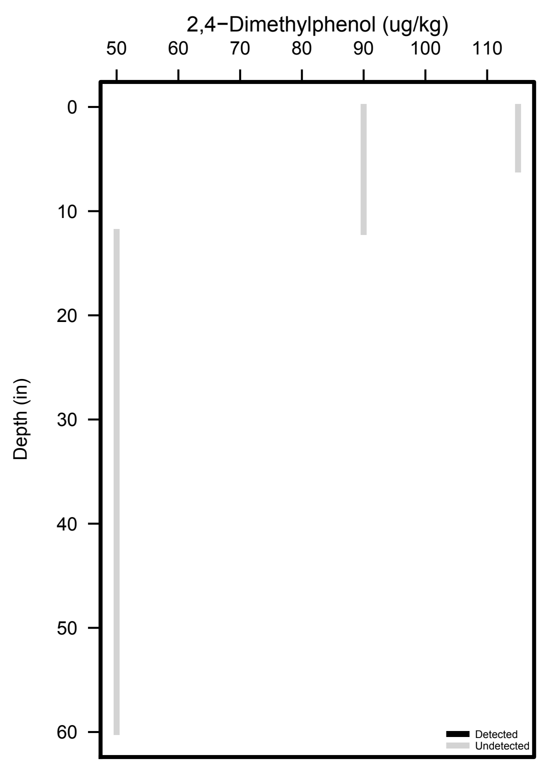

Figure 880. 2,4−Dimethylphenol
at Core Location RM637C1.

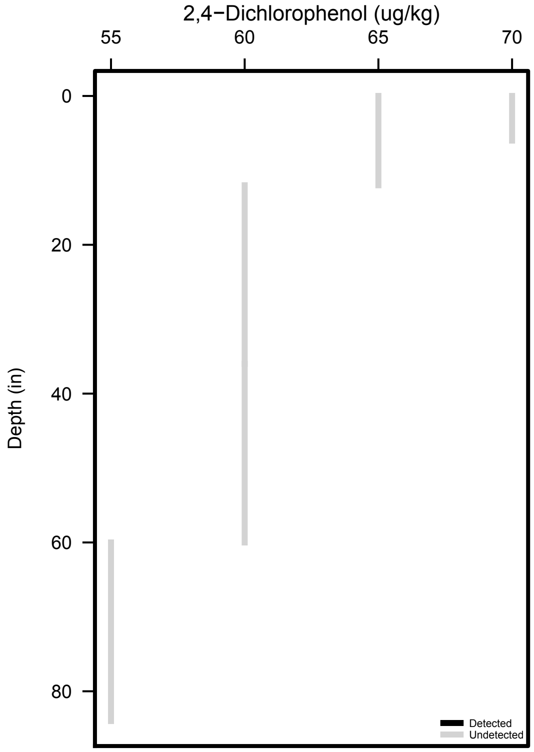

Figure 881. 2,4−Dichlorophenol at Core Location RM661C1.

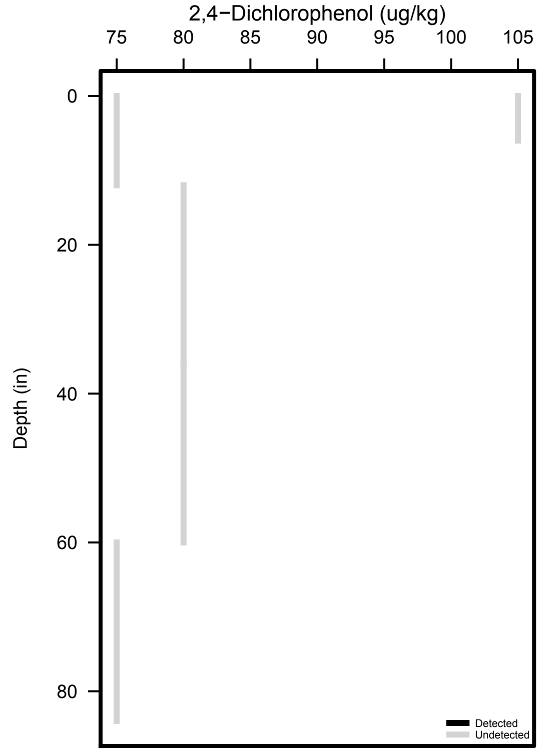

Figure 882. 2,4−Dichlorophenol at Core Location RM676C1.

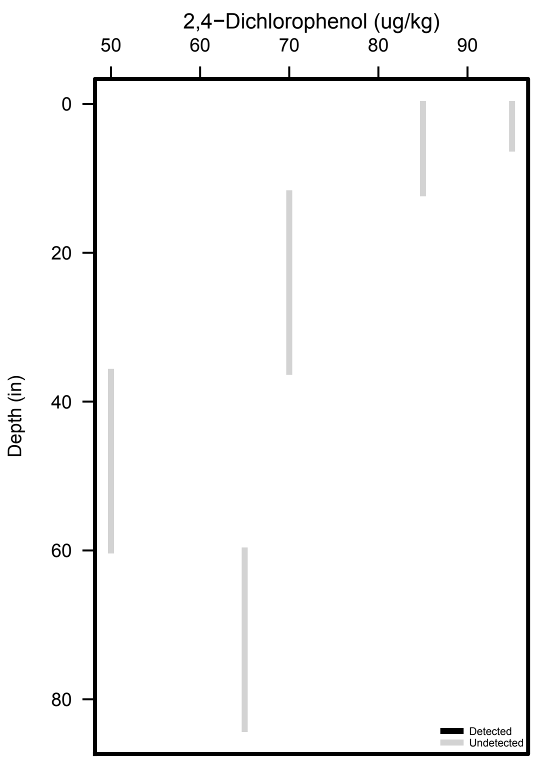

Figure 883. 2,4−Dichlorophenol at Core Location RM692C1.

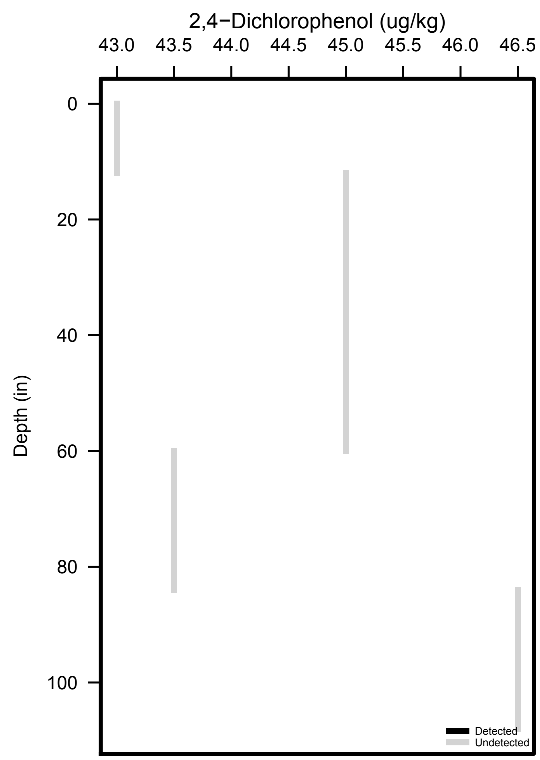

Figure 884. 2,4−Dichlorophenol at Core Location RM704C1.

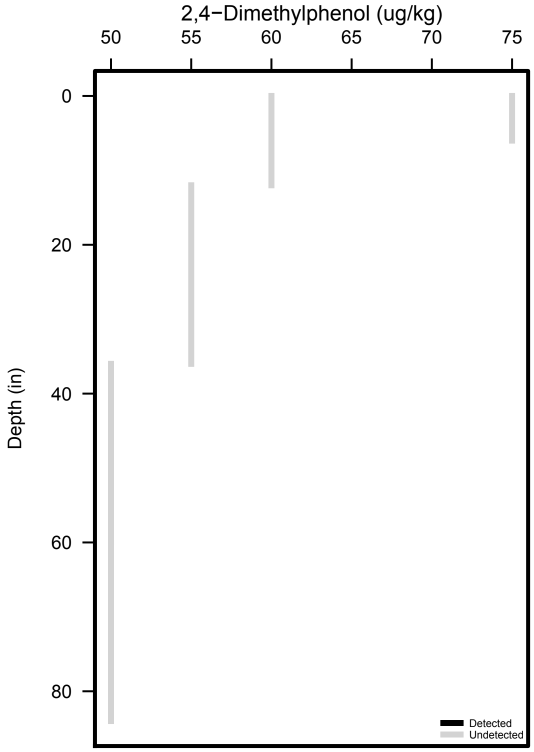

Figure 885. 2,4−Dimethylphenol at Core Location RM644C1.

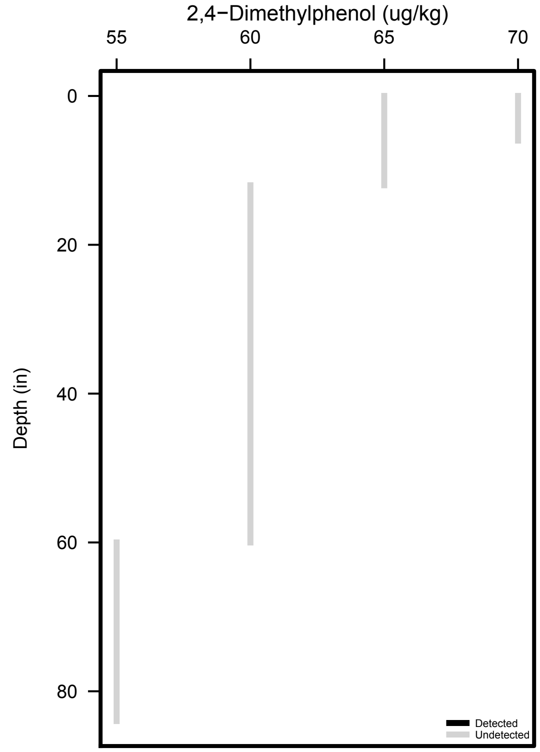

Figure 886. 2,4−Dimethylphenol at Core Location RM661C1.

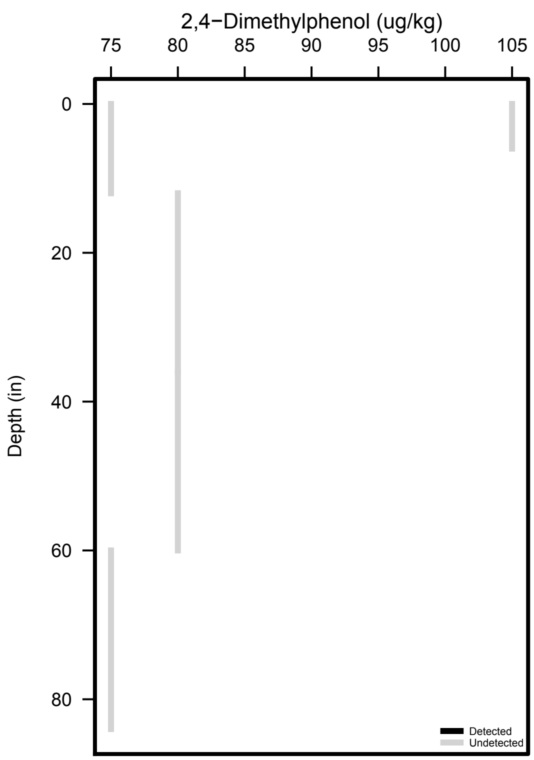

Figure 887. 2,4−Dimethylphenol at Core Location RM676C1.

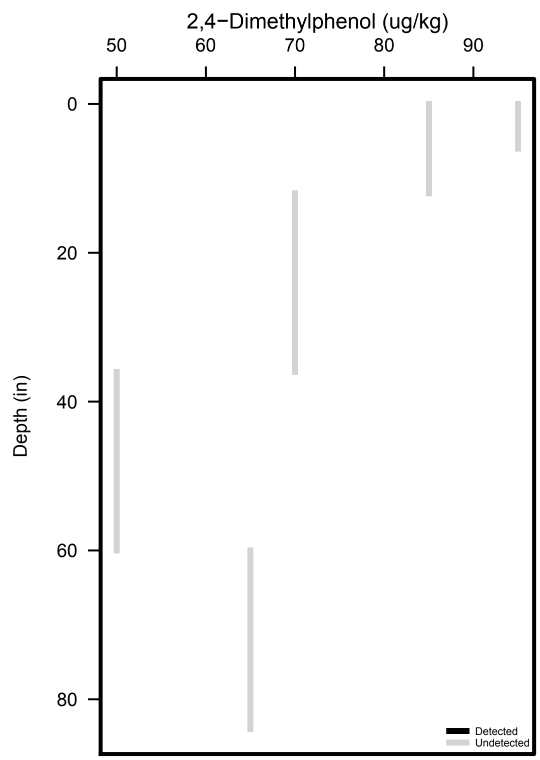

Figure 888. 2,4−Dimethylphenol at Core Location RM692C1.

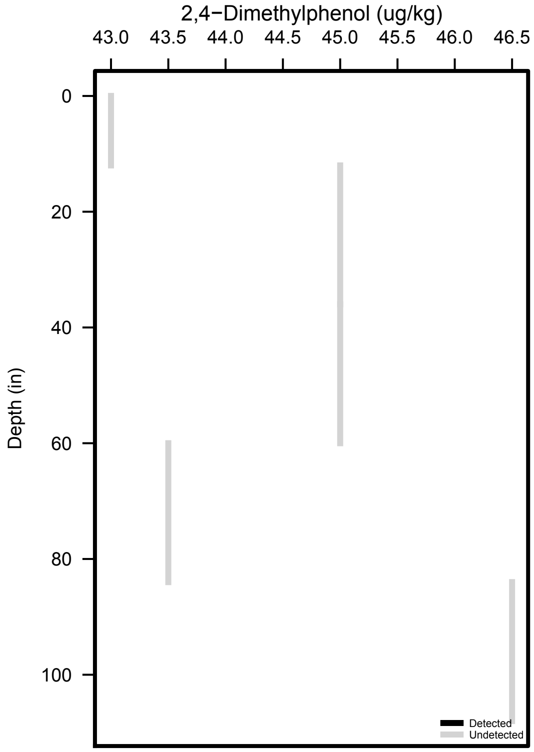

Figure 889. 2,4−Dimethylphenol
at Core Location RM704C1.

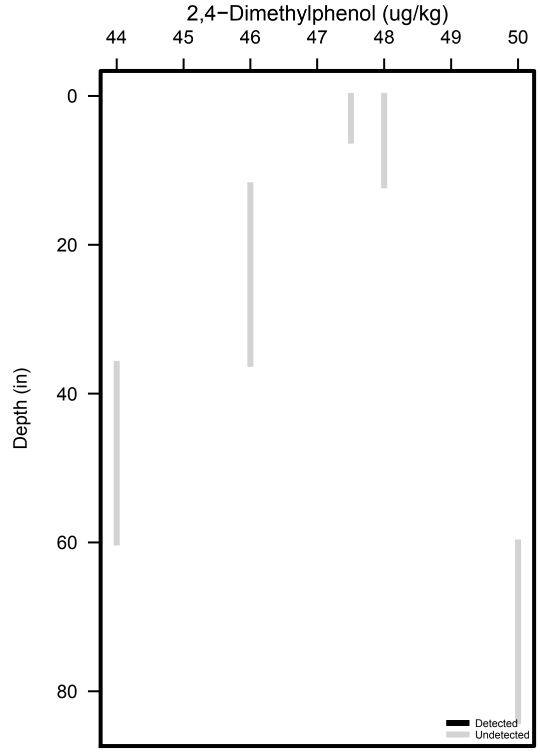

Figure 890. 2,4−Dimethylphenol
at Core Location RM708C1.

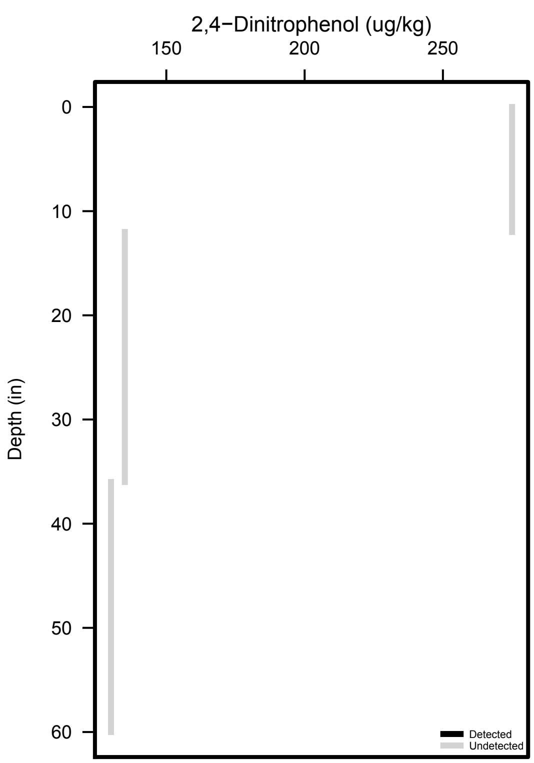

Figure 891. 2,4−Dinitrophenol
at Core Location RM605C1.

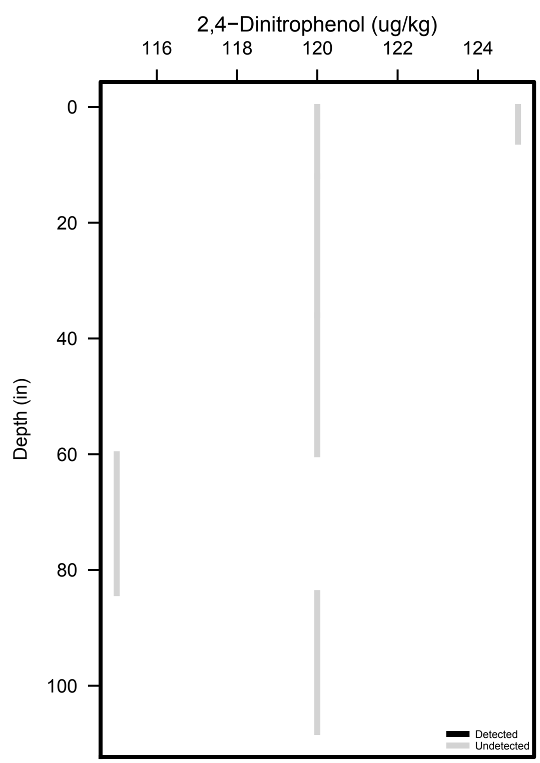

Figure 892. 2,4−Dinitrophenol
at Core Location RM622C1.

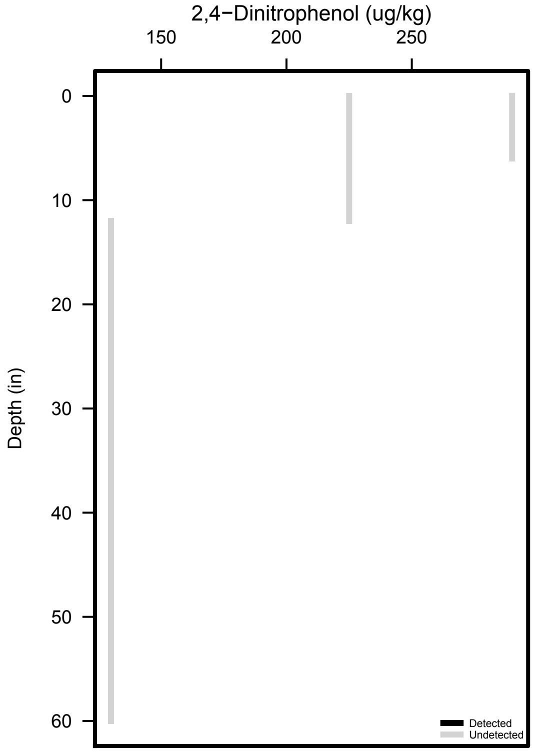

Figure 893. 2,4−Dinitrophenol
at Core Location RM637C1.

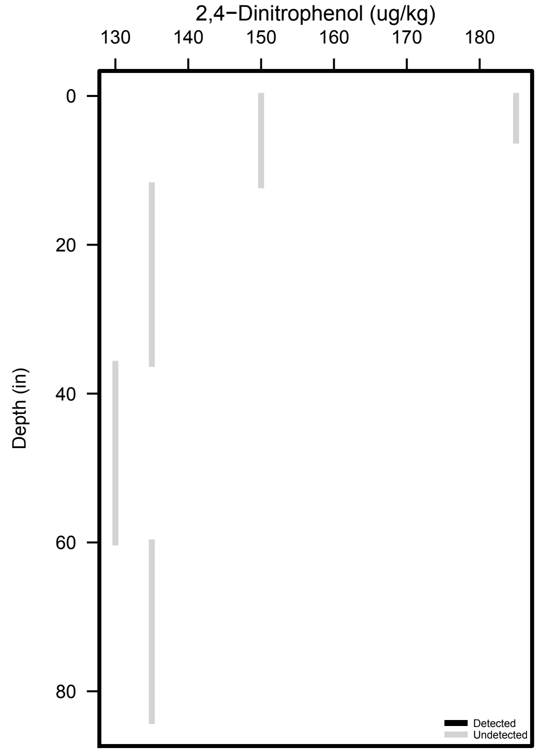

Figure 894. 2,4−Dinitrophenol
at Core Location RM644C1.

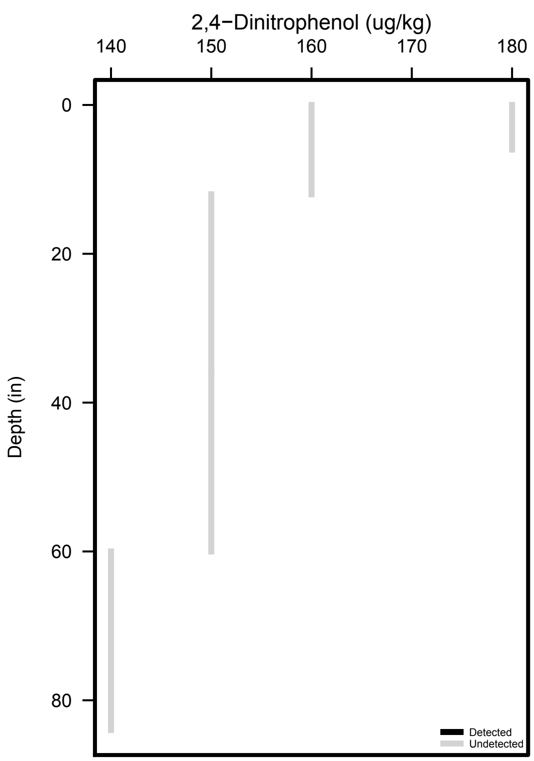

Figure 895. 2,4−Dinitrophenol
at Core Location RM661C1.

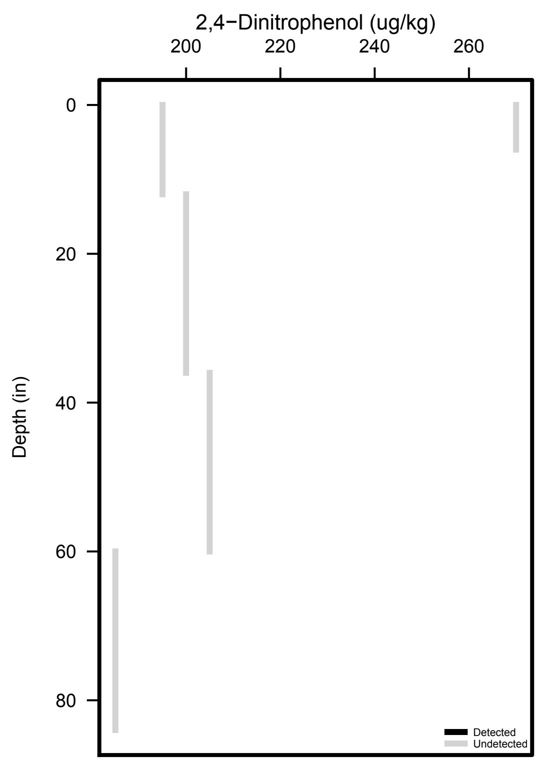

Figure 896. 2,4−Dinitrophenol
at Core Location RM676C1.

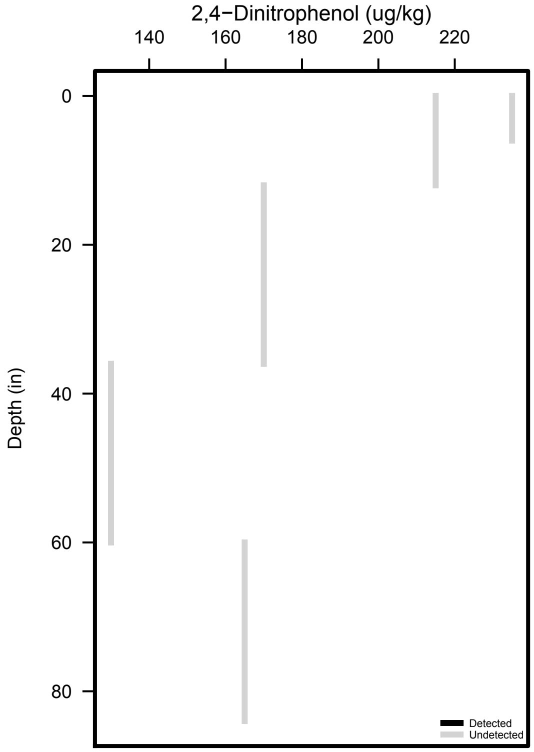

Figure 897. 2,4−Dinitrophenol
at Core Location RM692C1.

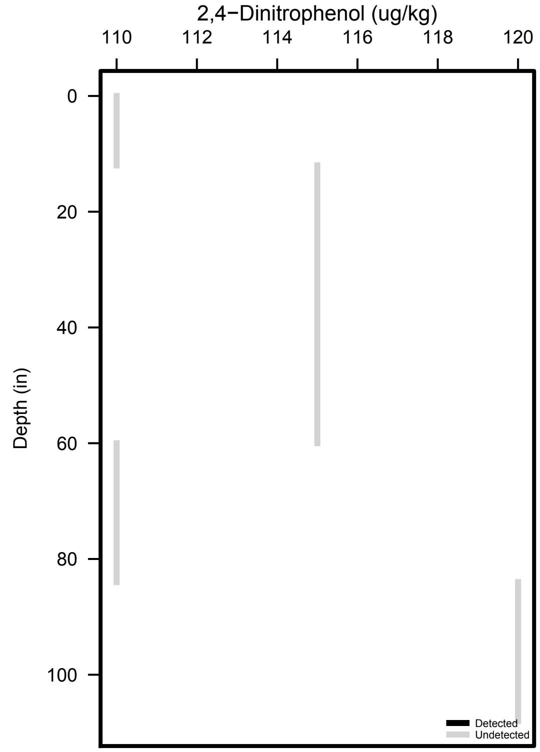

Figure 898. 2,4−Dinitrophenol
at Core Location RM704C1.

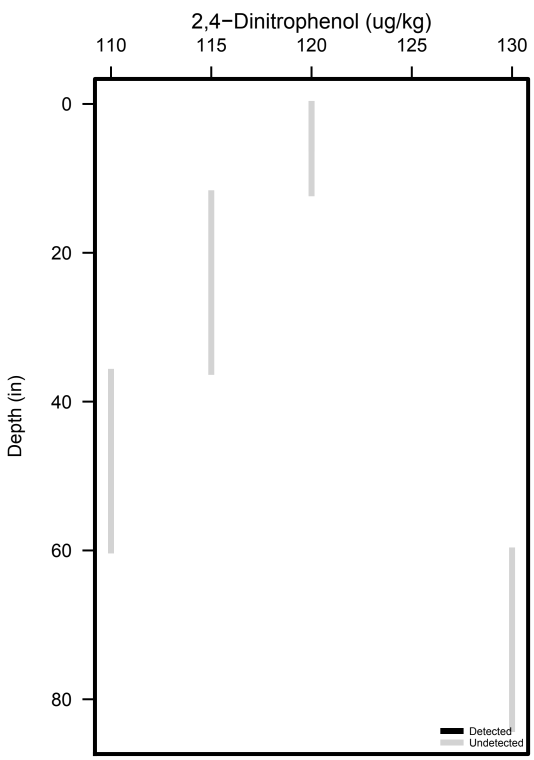

Figure 899. 2,4−Dinitrophenol
at Core Location RM708C1.

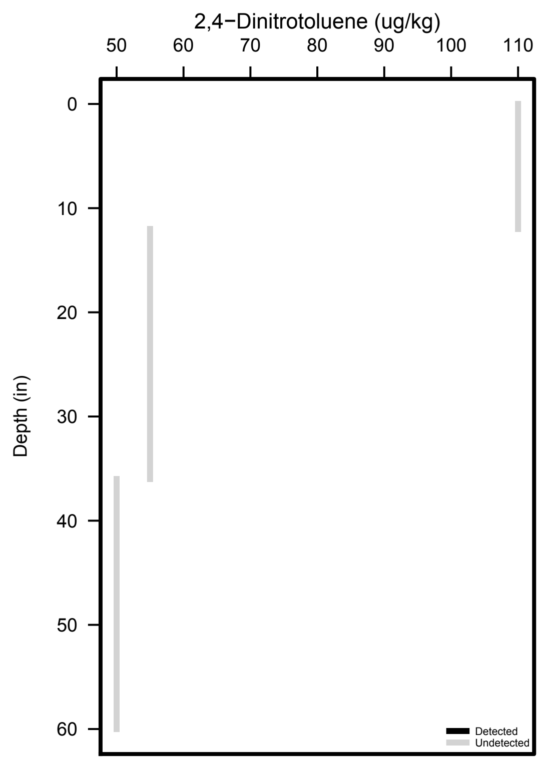

Figure 900. 2,4−Dinitrotoluene
at Core Location RM605C1.

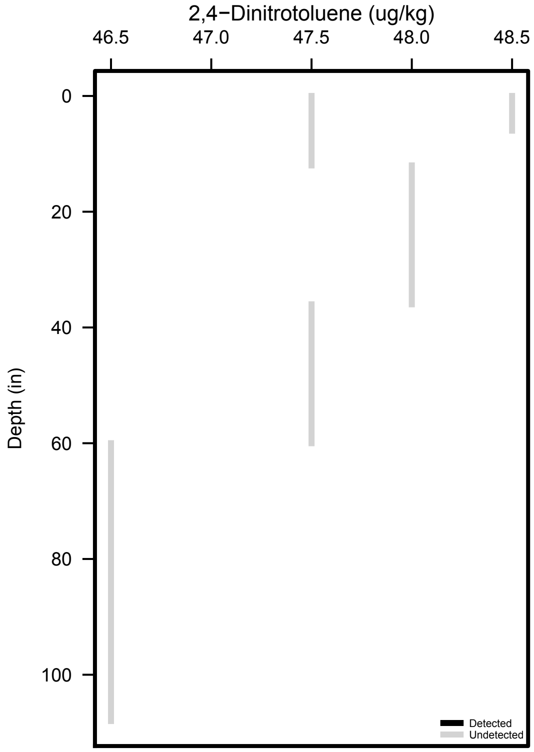

Figure 901. 2,4−Dinitrotoluene
at Core Location RM622C1.

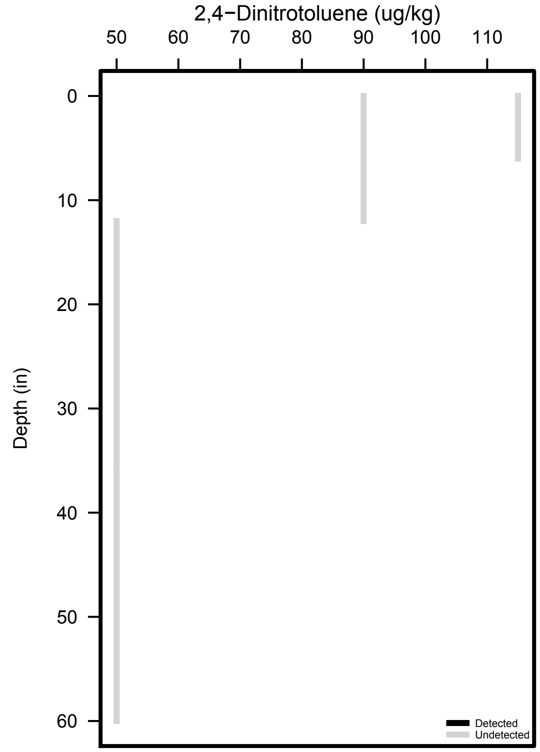

Figure 902. 2,4−Dinitrotoluene
at Core Location RM637C1.

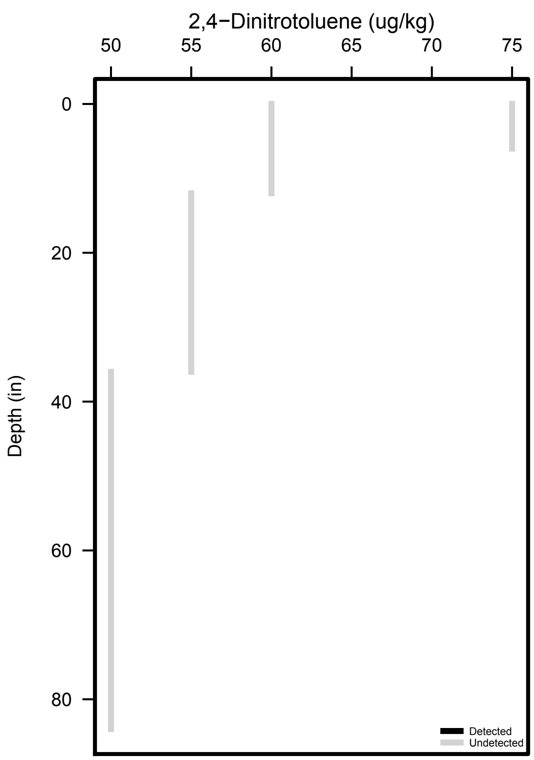

Figure 903. 2,4−Dinitrotoluene
at Core Location RM644C1.

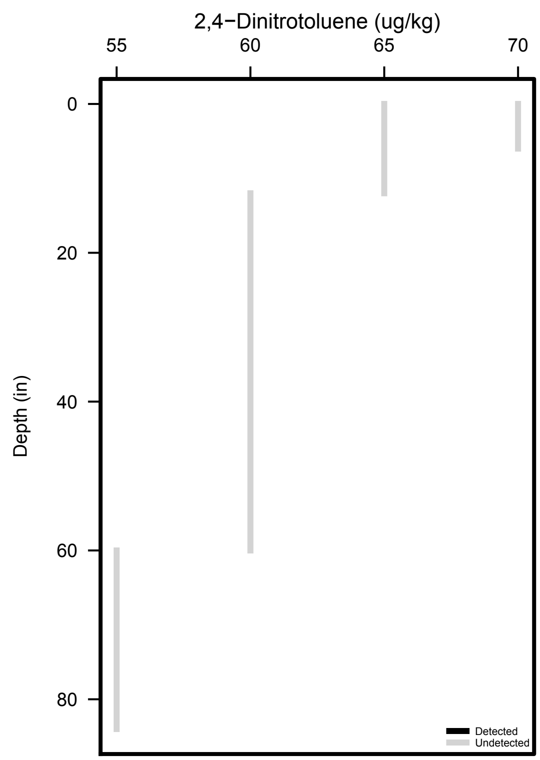

Figure 904. 2,4−Dinitrotoluene
at Core Location RM661C1.

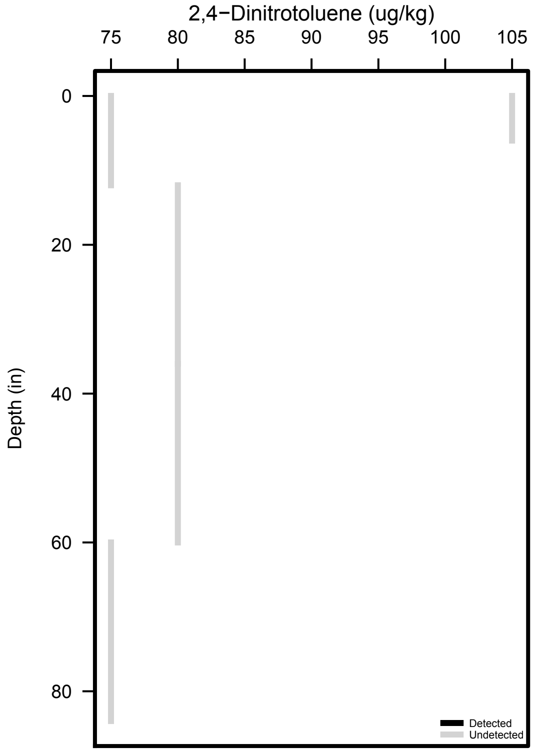

Figure 905. 2,4−Dinitrotoluene
at Core Location RM676C1.

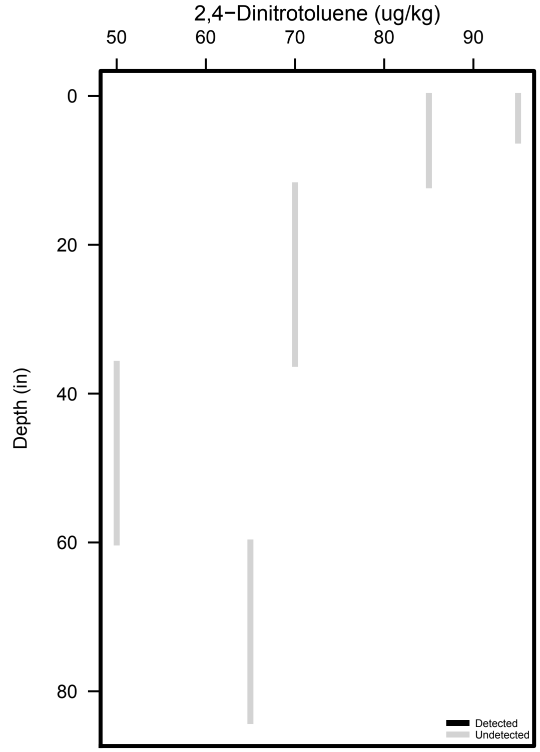

Figure 906. 2,4−Dinitrotoluene
at Core Location RM692C1.

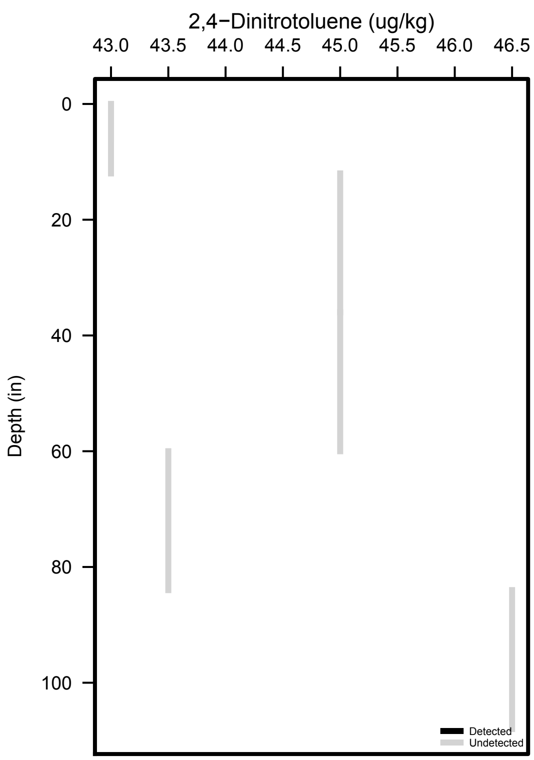

Figure 907. 2,4−Dinitrotoluene
at Core Location RM704C1.

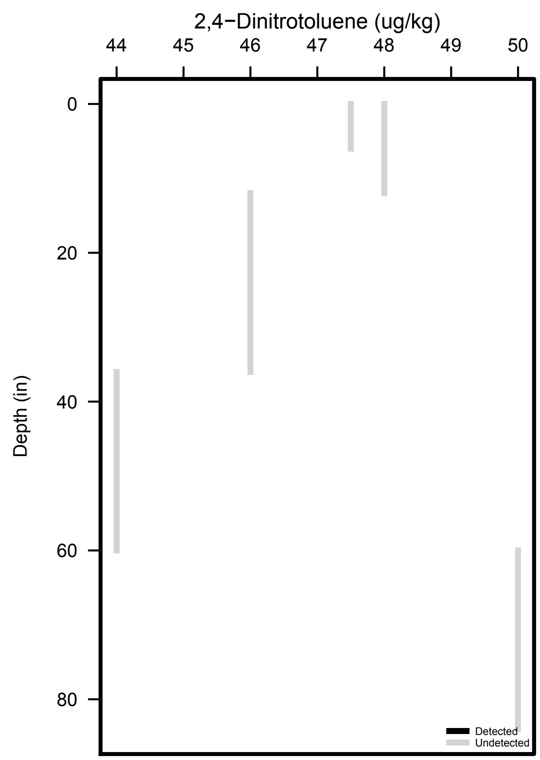

Figure 908. 2,4−Dinitrotoluene
at Core Location RM708C1.

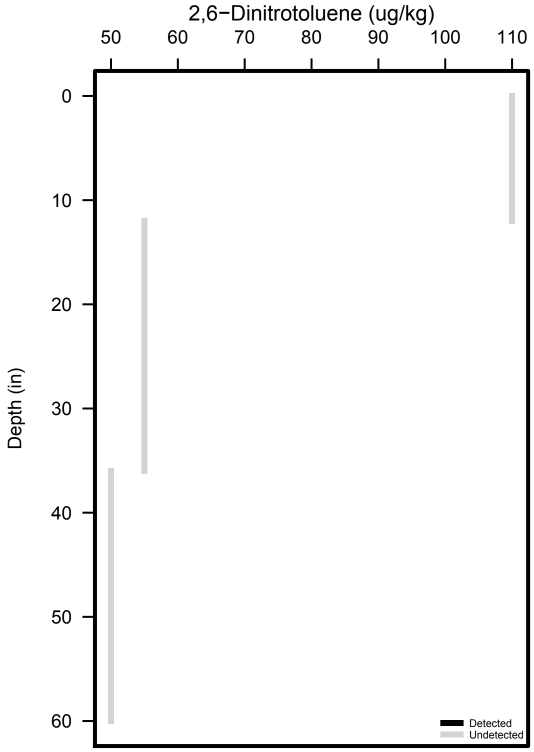

Figure 909. 2,6−Dinitrotoluene
at Core Location RM605C1.

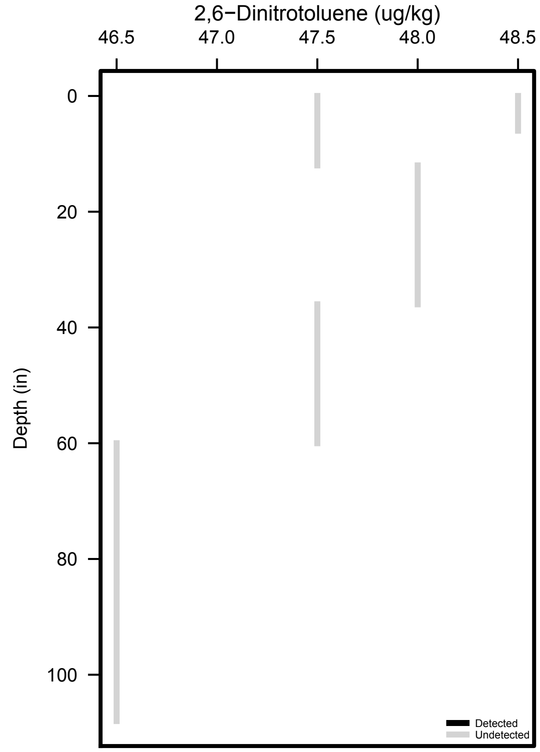

Figure 910. 2,6−Dinitrotoluene
at Core Location RM622C1.

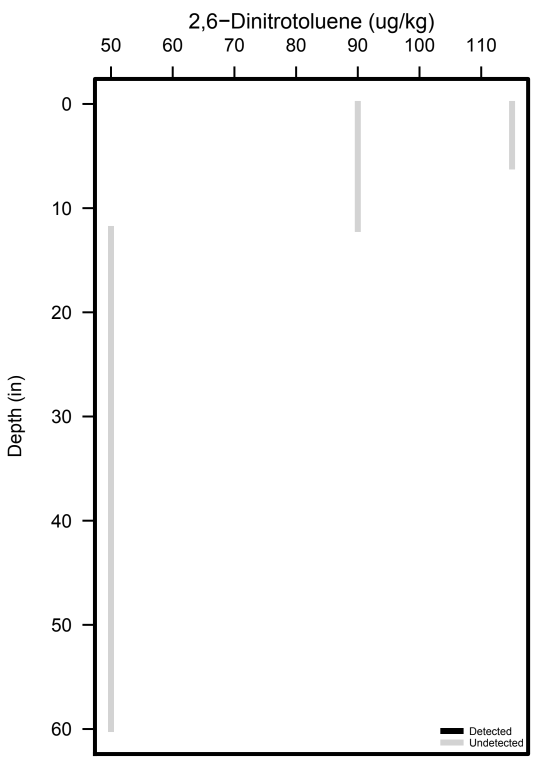

Figure 911. 2,6−Dinitrotoluene
at Core Location RM637C1.

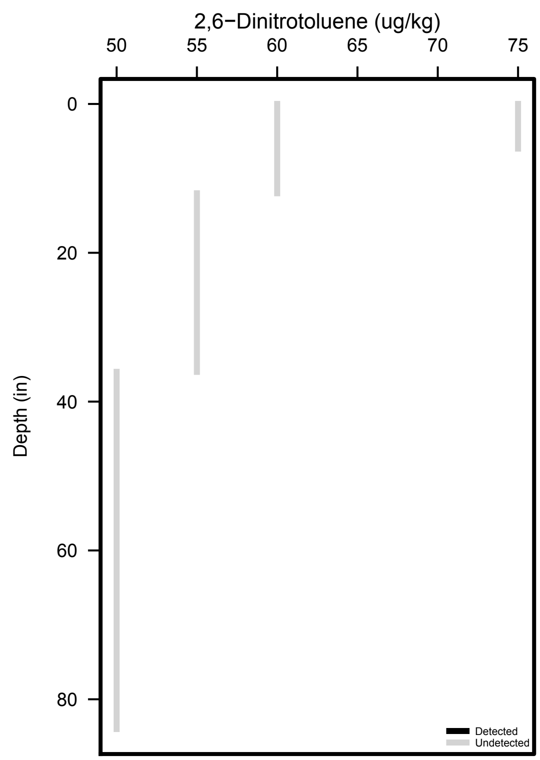

Figure 912. 2,6−Dinitrotoluene
at Core Location RM644C1.

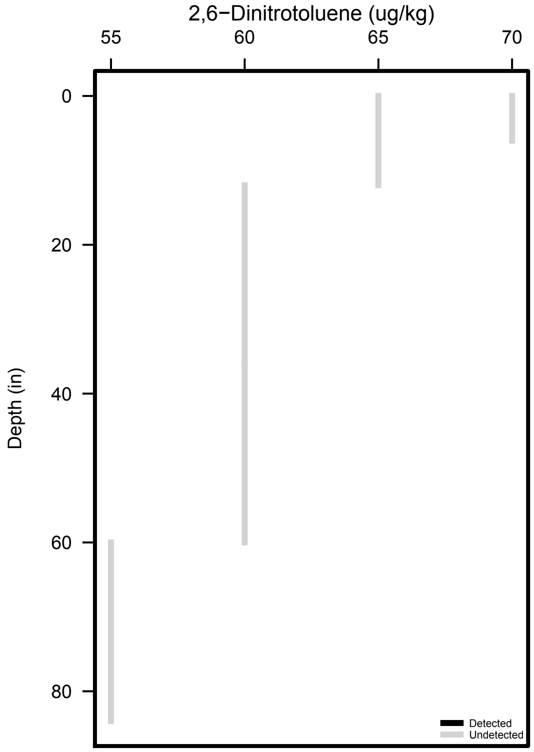

Figure 913. 2,6−Dinitrotoluene at Core Location RM661C1.

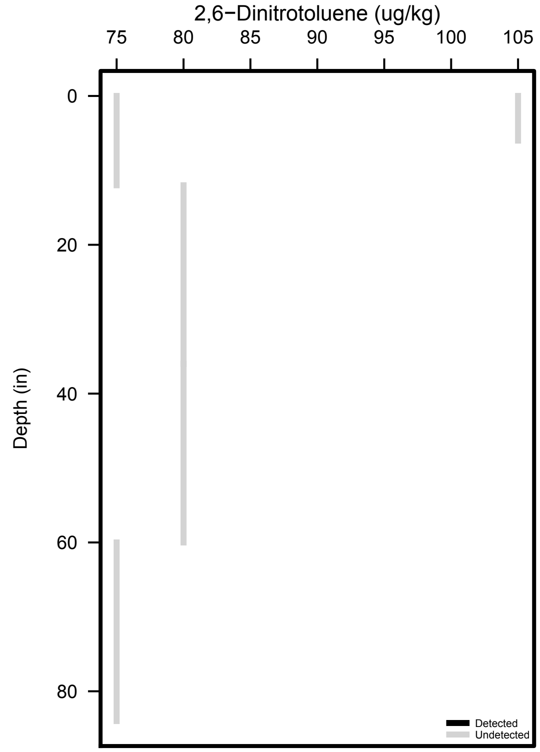

Figure 914. 2,6−Dinitrotoluene at Core Location RM676C1.

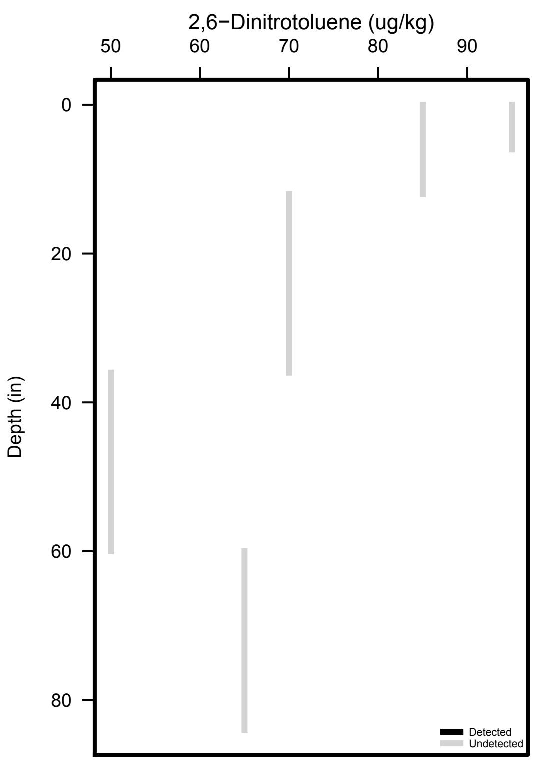

Figure 915. 2,6−Dinitrotoluene at Core Location RM692C1.

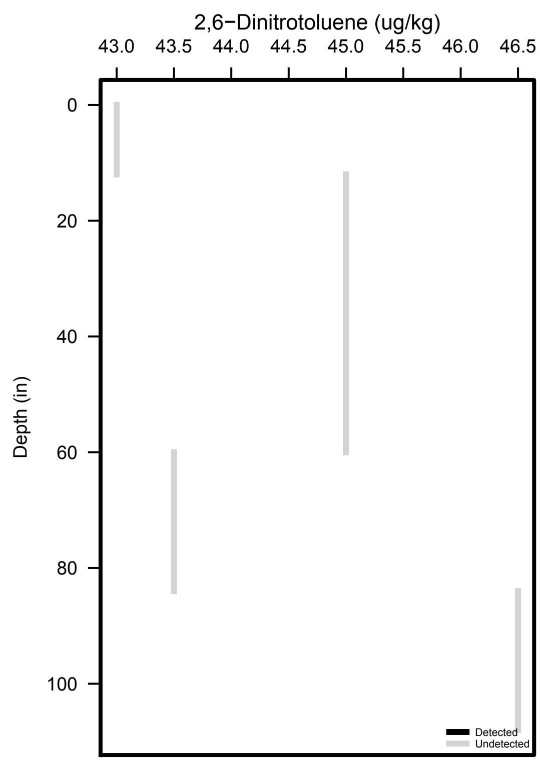

Figure 916. 2,6−Dinitrotoluene at Core Location RM704C1.

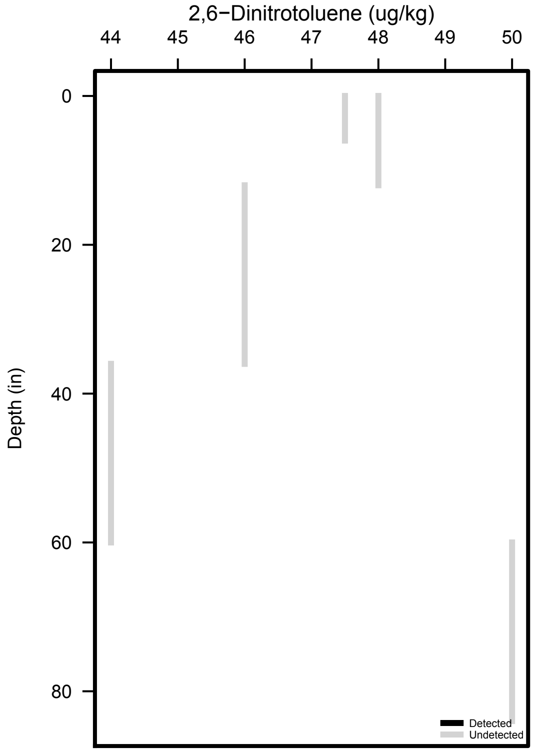

Figure 917. 2,6−Dinitrotoluene
at Core Location RM708C1.

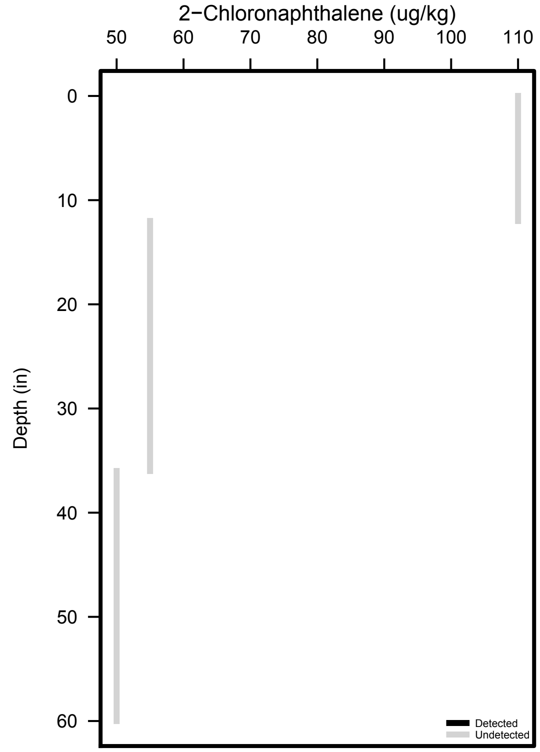

Figure 918. 2−Chloronaphthalene
at Core Location RM605C1.

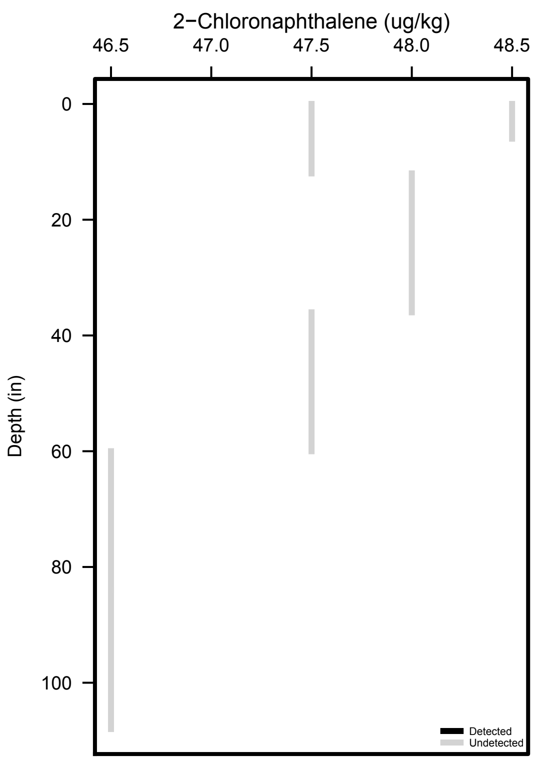

Figure 919. 2−Chloronaphthalene
at Core Location RM622C1.

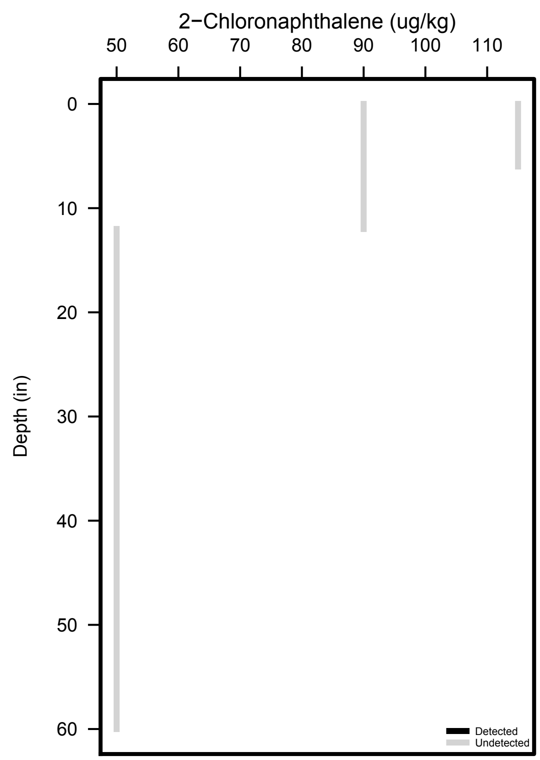

Figure 920. 2−Chloronaphthalene
at Core Location RM637C1.

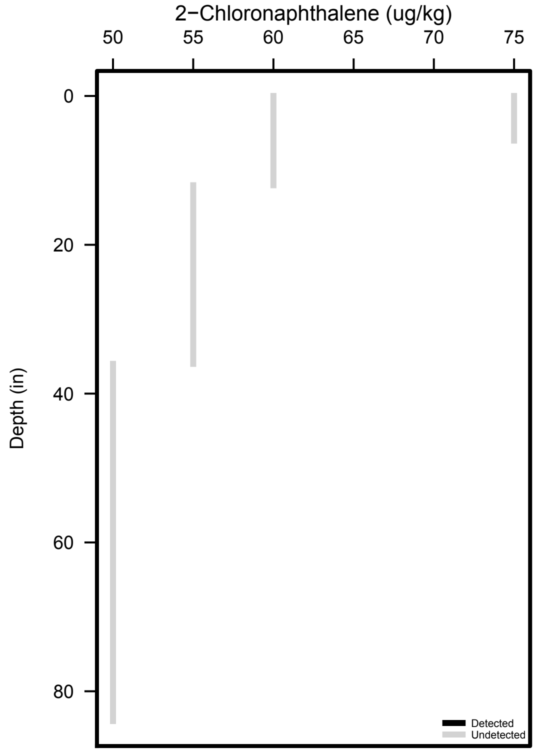

Figure 921. 2−Chloronaphthalene
at Core Location RM644C1.

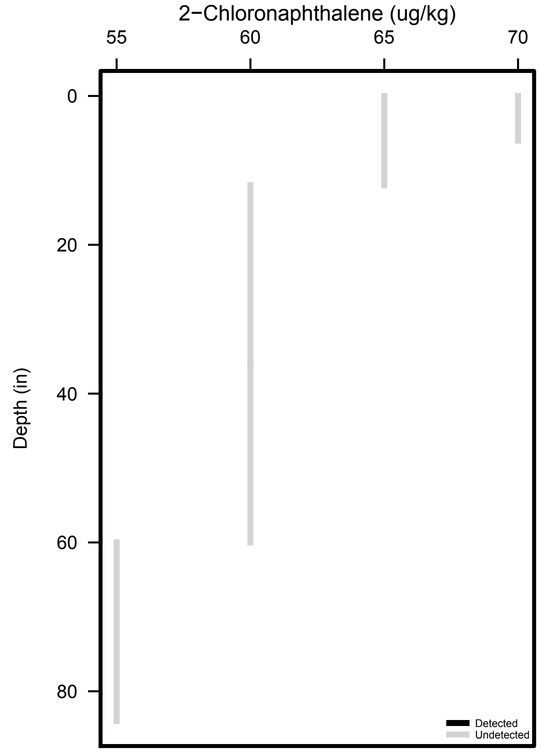

Figure 922. 2−Chloronaphthalene
at Core Location RM661C1.

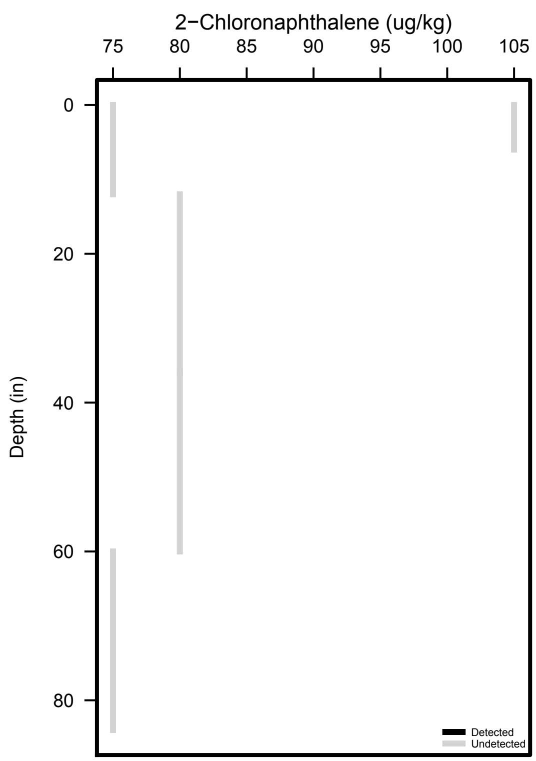

Figure 923. 2−Chloronaphthalene
at Core Location RM676C1.

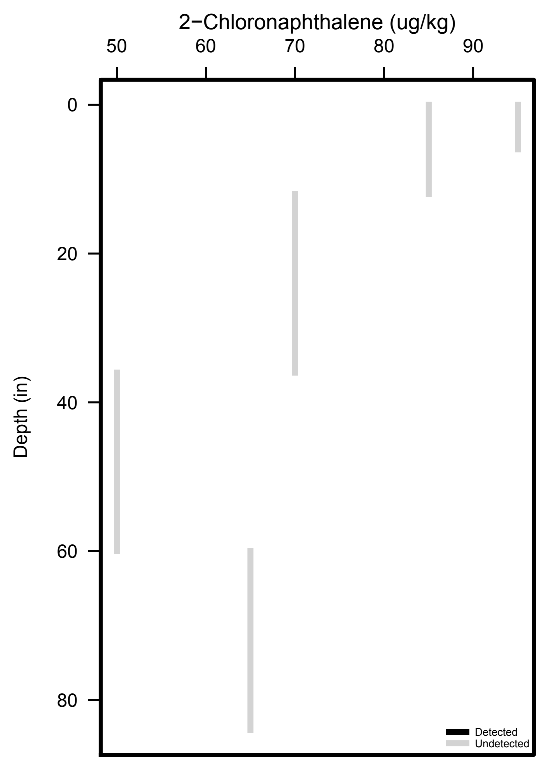

Figure 924. 2−Chloronaphthalene
at Core Location RM692C1.

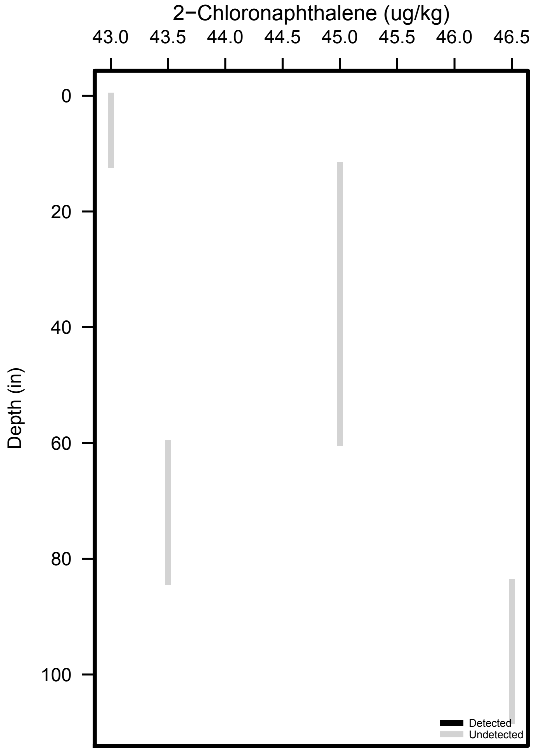

Figure 925. 2−Chloronaphthalene
at Core Location RM704C1.

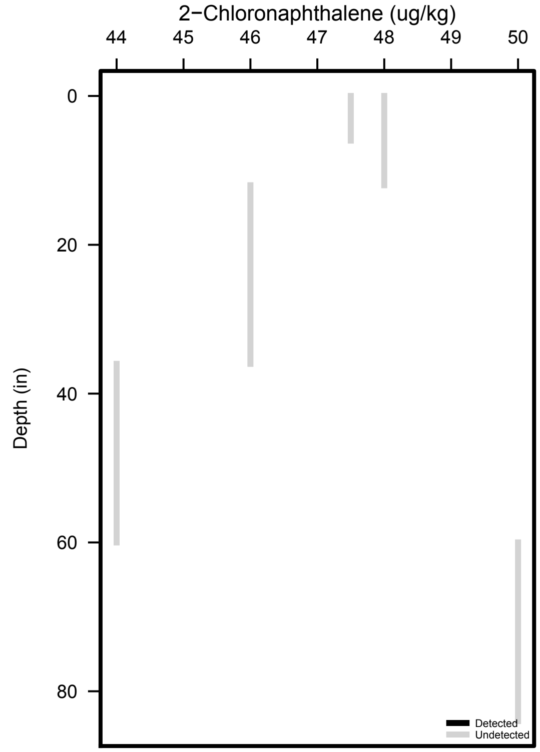

Figure 926. 2−Chloronaphthalene
at Core Location RM708C1.

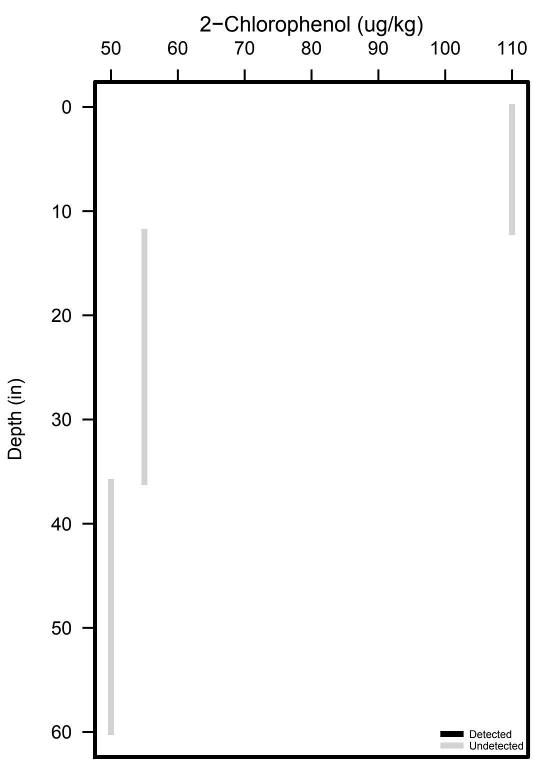

Figure 927. 2−Chlorophenol
at Core Location RM605C1.

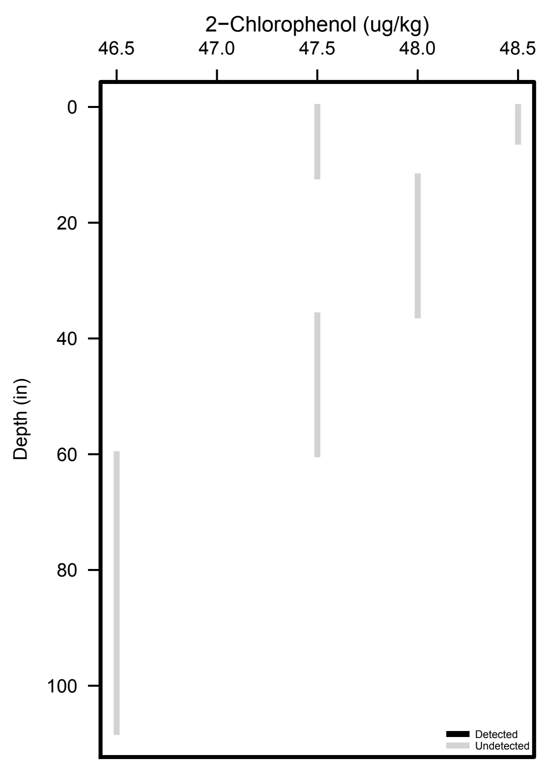

Figure 928. 2−Chlorophenol
at Core Location RM622C1.

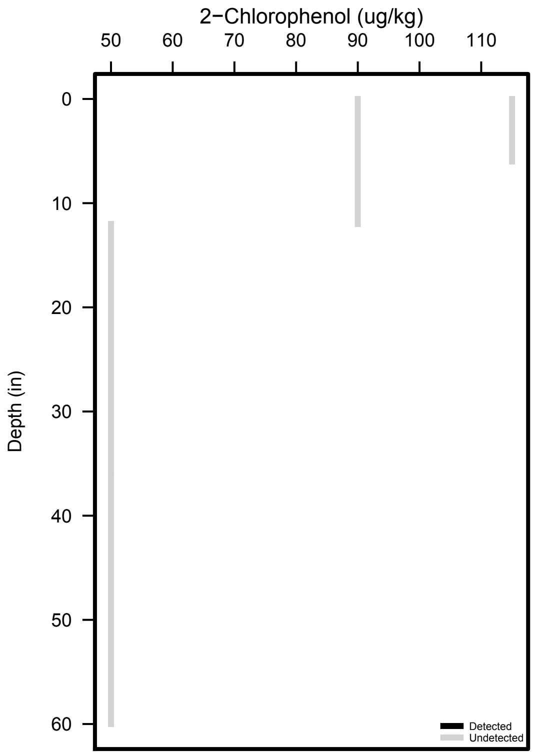

Figure 929. 2−Chlorophenol at Core Location RM637C1.

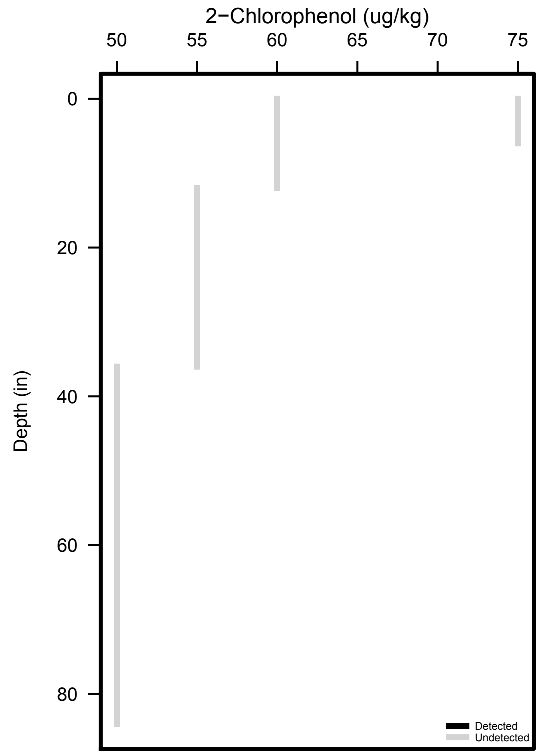

Figure 930. 2−Chlorophenol at Core Location RM644C1.

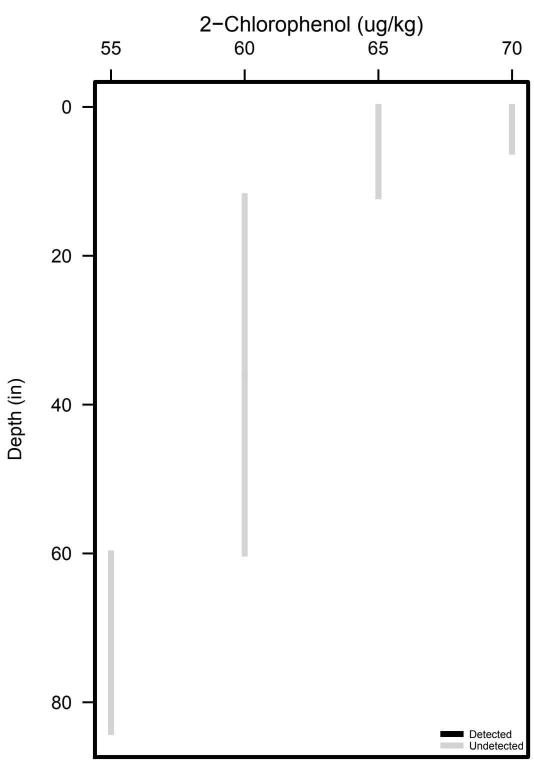

Figure 931. 2−Chlorophenol at Core Location RM661C1.

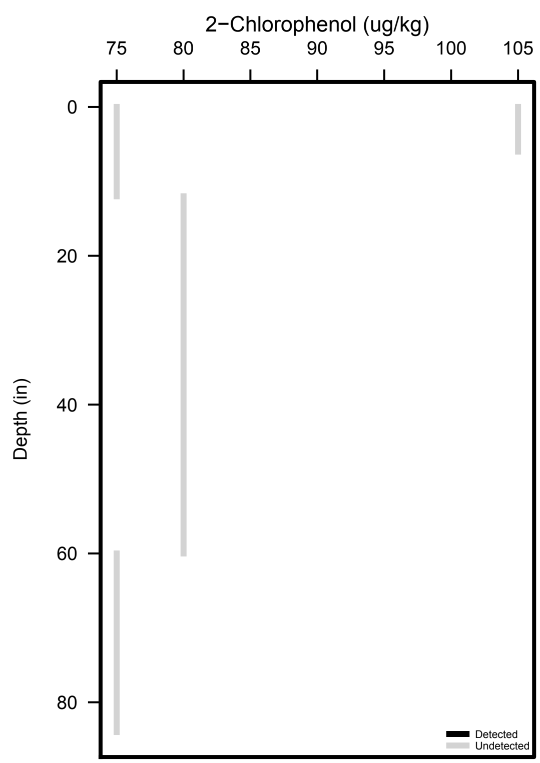

Figure 932. 2−Chlorophenol at Core Location RM676C1.

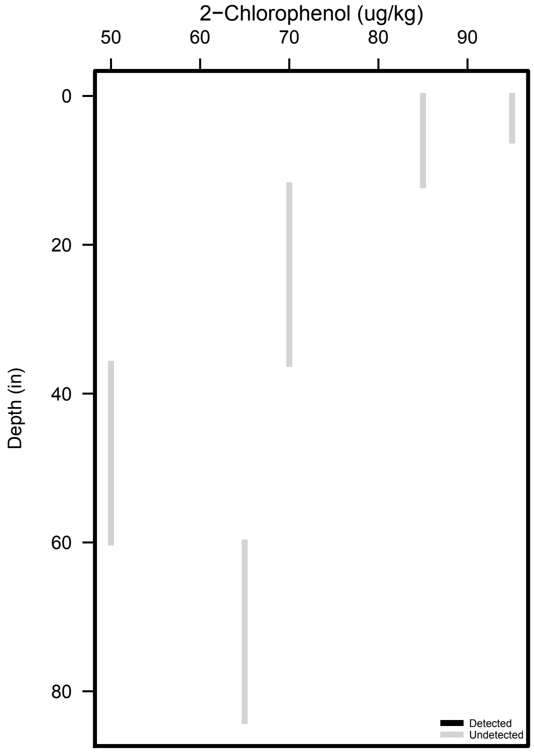

Figure 933. 2−Chlorophenol at Core Location RM692C1.

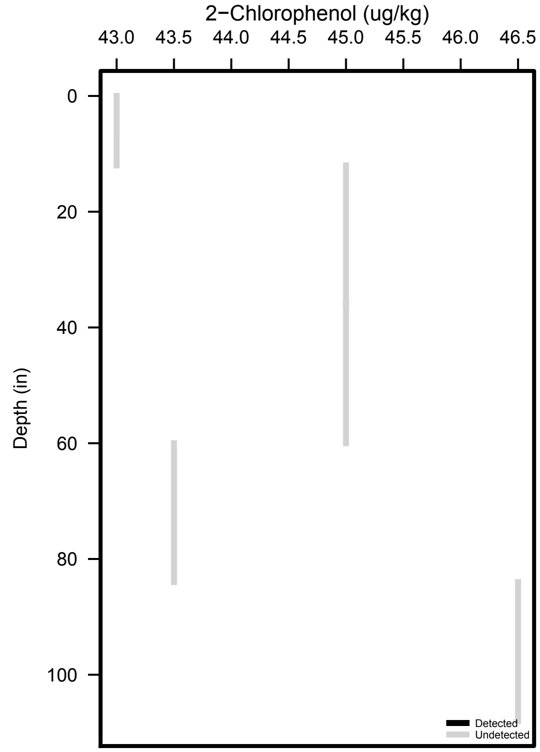

Figure 934. 2−Chlorophenol at Core Location RM704C1.

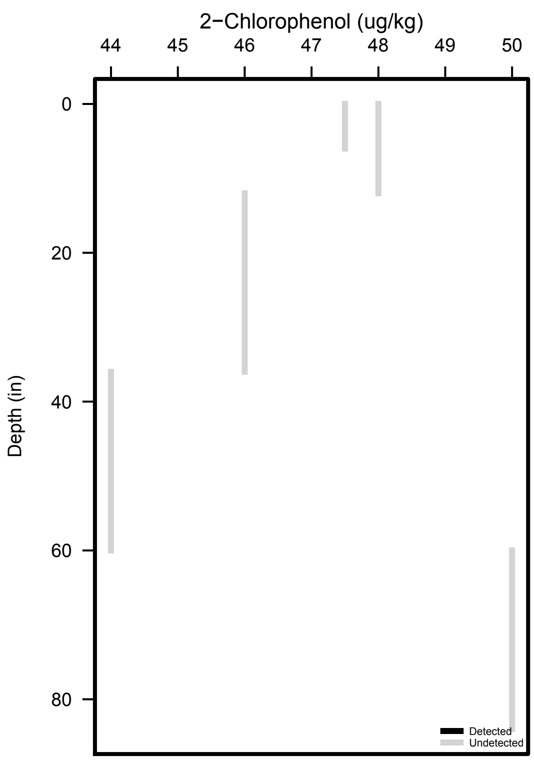

Figure 935. 2−Chlorophenol at Core Location RM708C1.

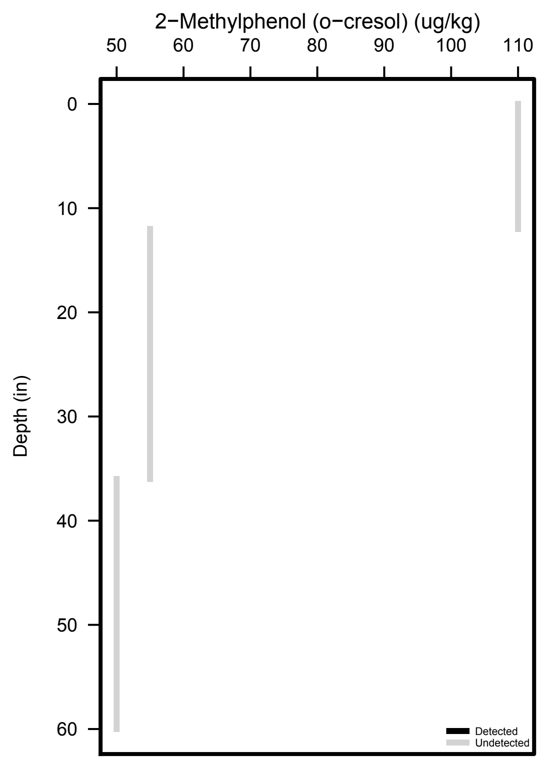

Figure 936. 2−Methylphenol (o−cresol) at Core Location RM605C1.

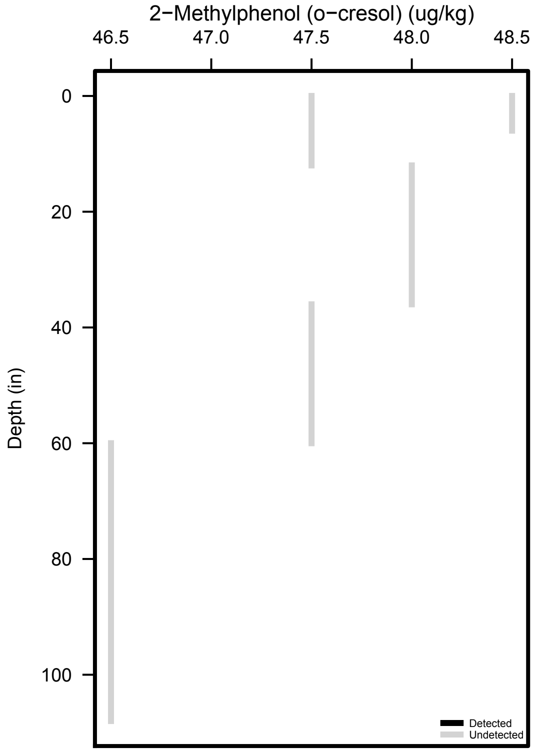

Figure 937. 2−Methylphenol (o−cresol) at Core Location RM622C1.

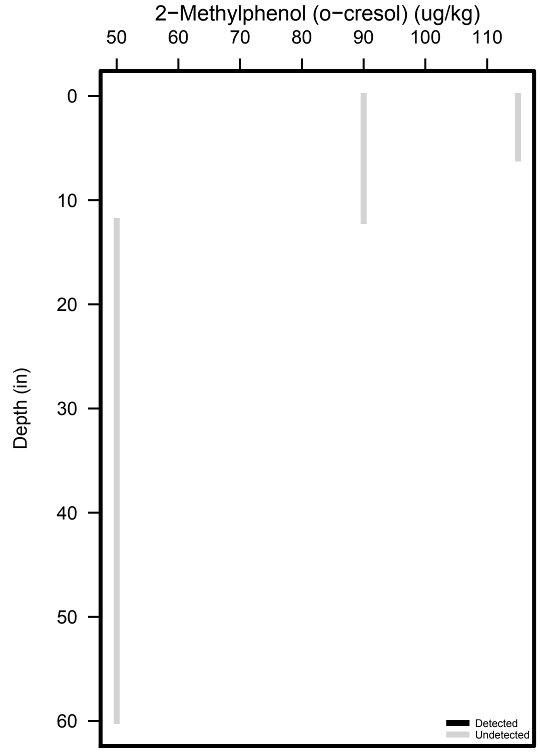

Figure 938. 2−Methylphenol (o−cresol) at Core Location RM637C1.

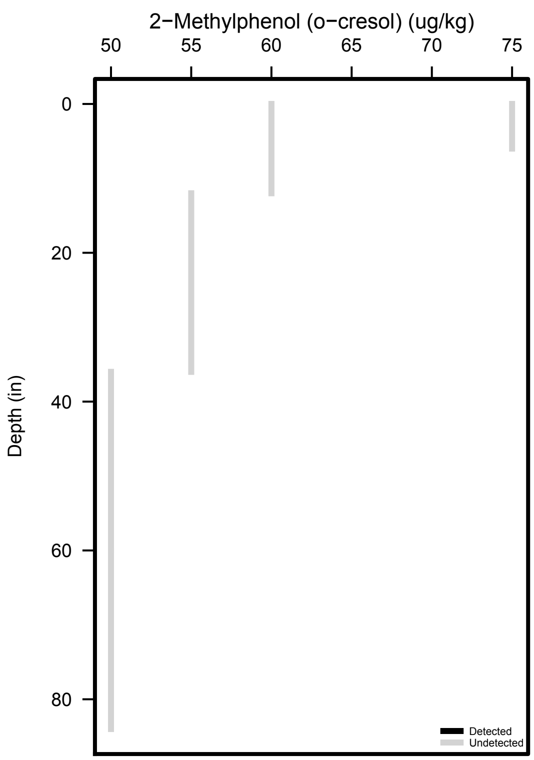

Figure 939. 2−Methylphenol (o−cresol) at Core Location RM644C1.

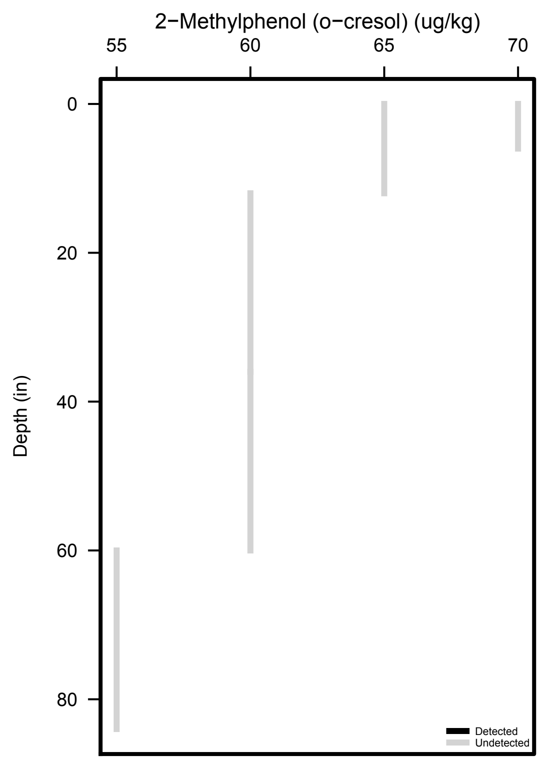

Figure 940. 2−Methylphenol (o−cresol) at Core Location RM661C1.

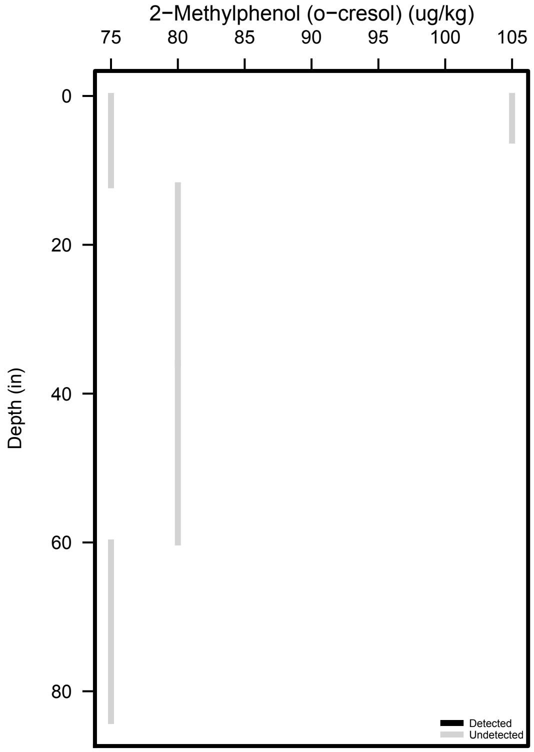

Figure 941. 2−Methylphenol (o−cresol) at Core Location RM676C1.

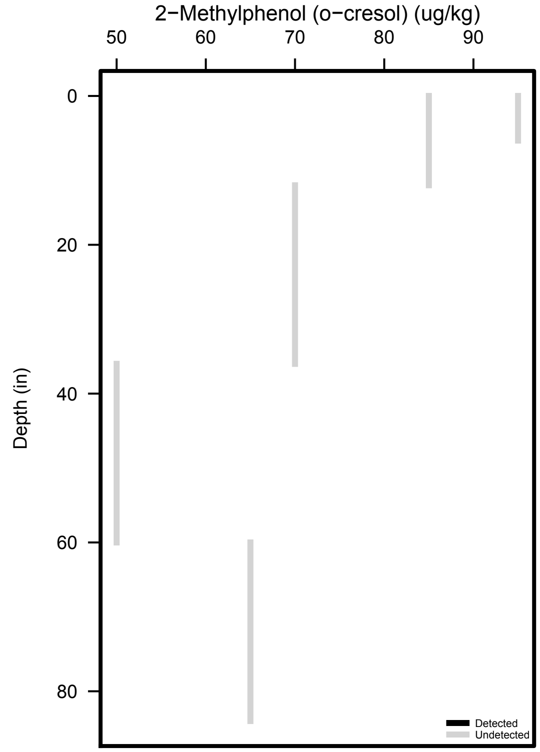

Figure 942. 2−Methylphenol (o−cresol) at Core Location RM692C1.

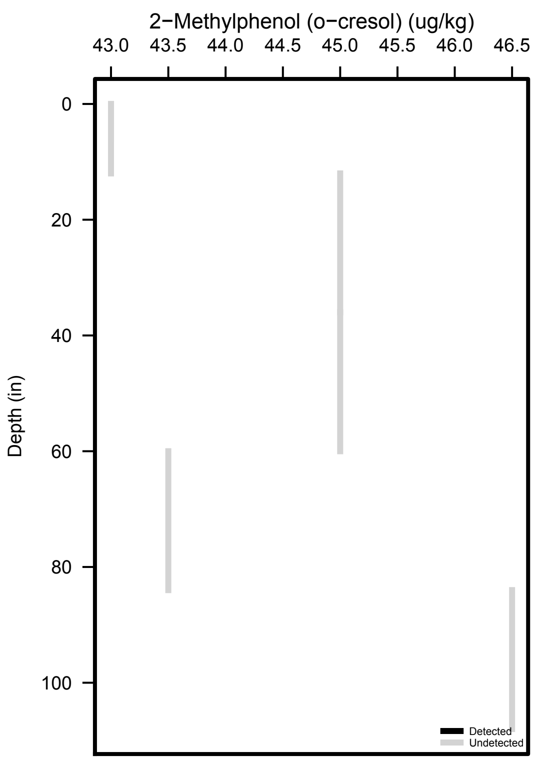

Figure 943. 2−Methylphenol (o−cresol) at Core Location RM704C1.

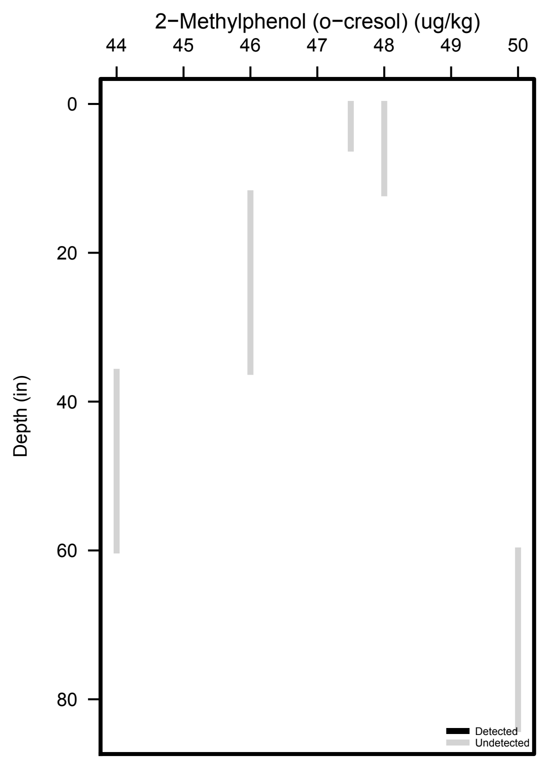

Figure 944. 2−Methylphenol (o−cresol) at Core Location RM708C1.

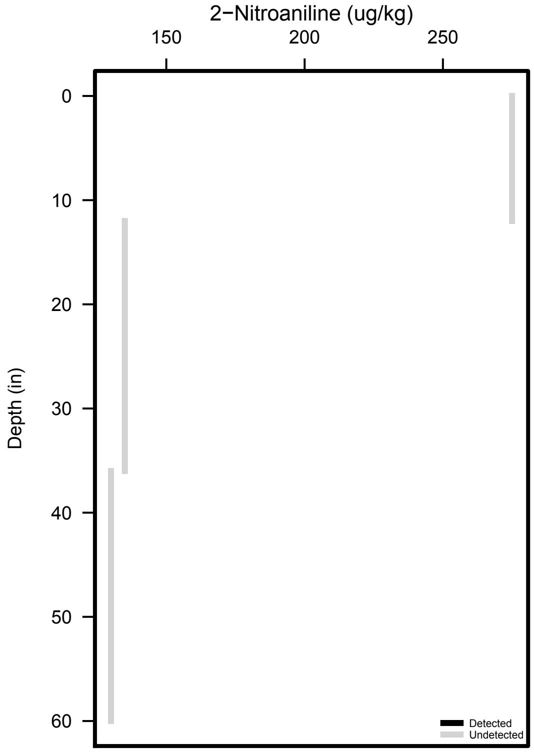

Figure 945. 2−Nitroaniline
at Core Location RM605C1.

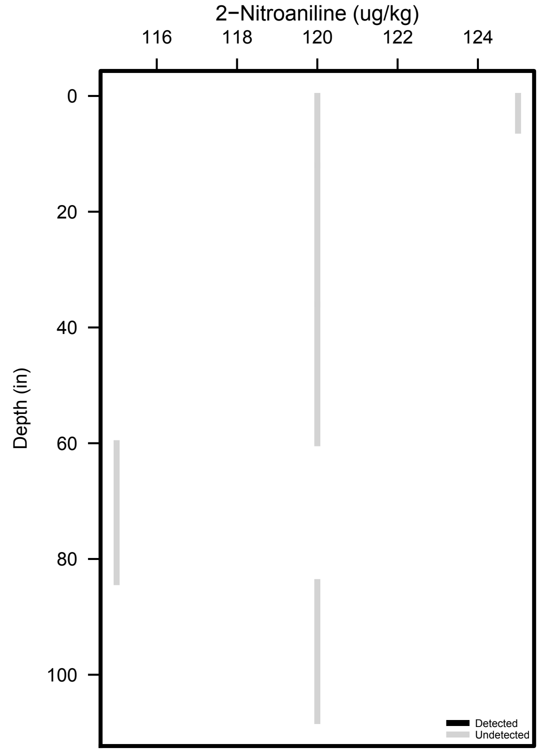

Figure 946. 2−Nitroaniline
at Core Location RM622C1.

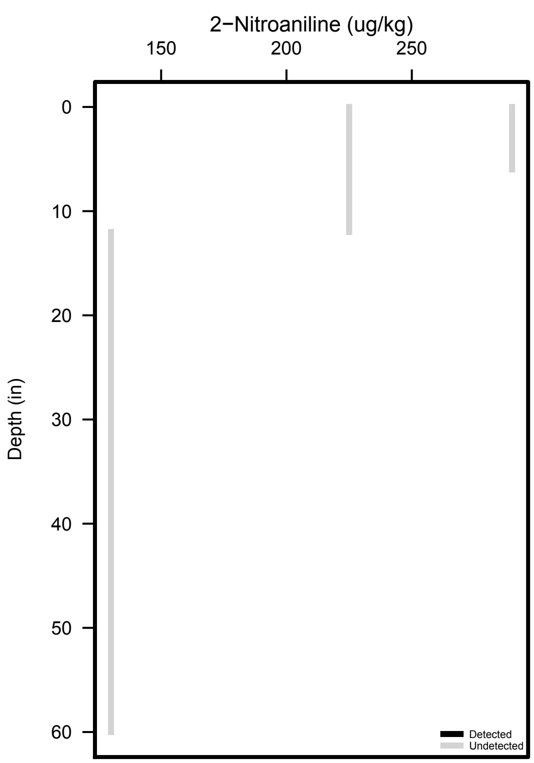

Figure 947. 2−Nitroaniline
at Core Location RM637C1.

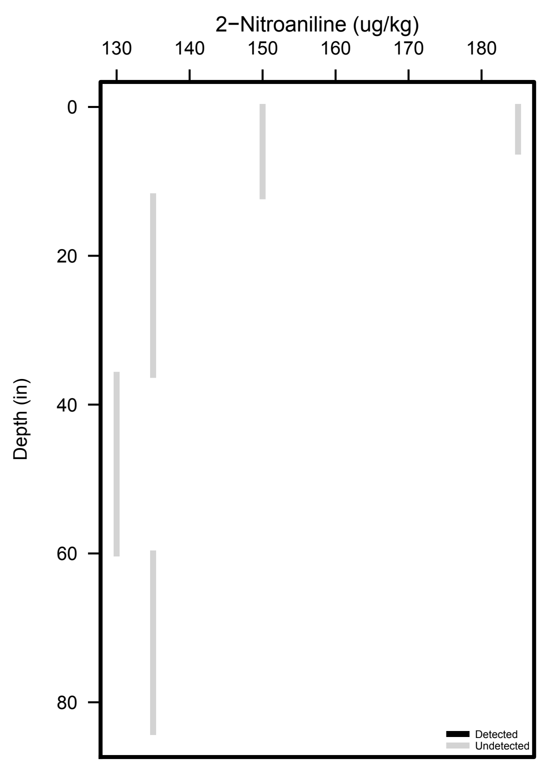

Figure 948. 2−Nitroaniline
at Core Location RM644C1.

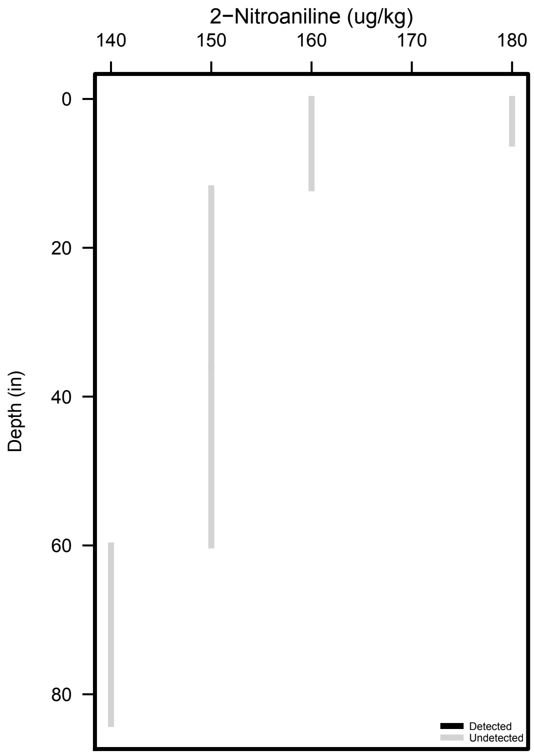

Figure 949. 2−Nitroaniline
at Core Location RM661C1.

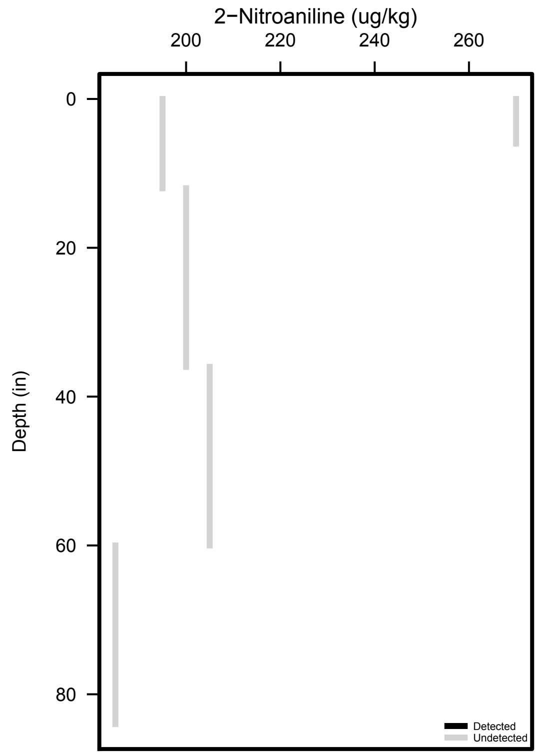

Figure 950. 2−Nitroaniline
at Core Location RM676C1.

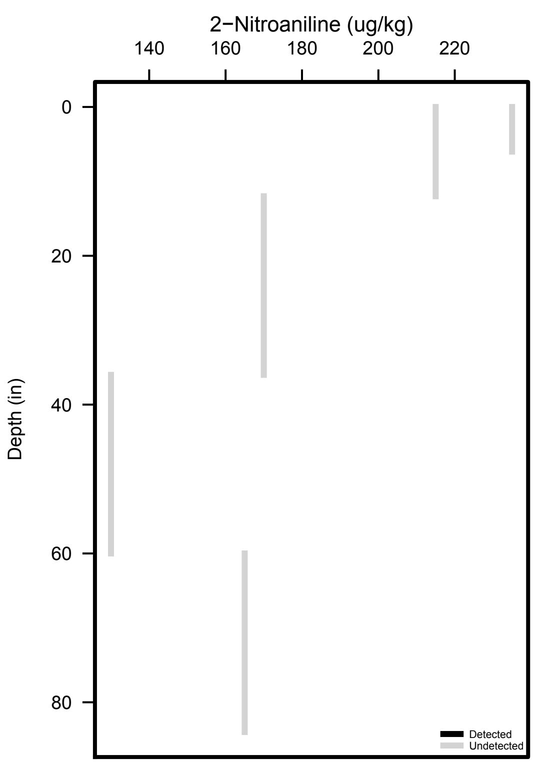

Figure 951. 2−Nitroaniline
at Core Location RM692C1.

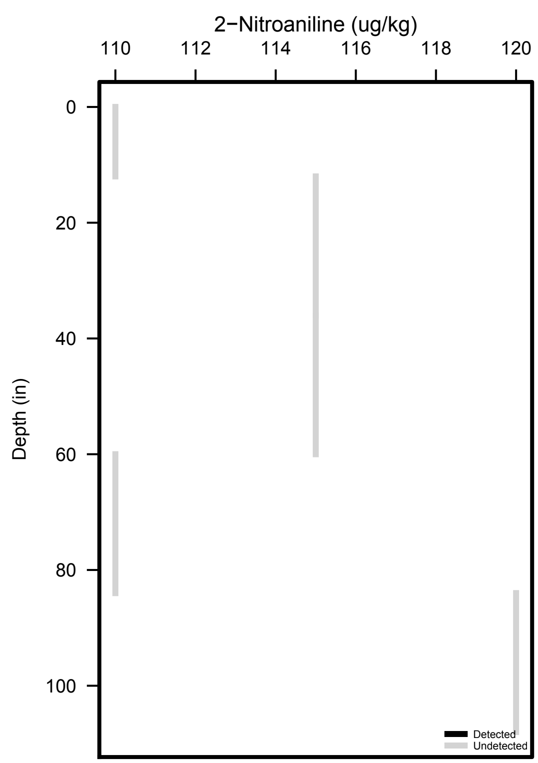

Figure 952. 2−Nitroaniline
at Core Location RM704C1.

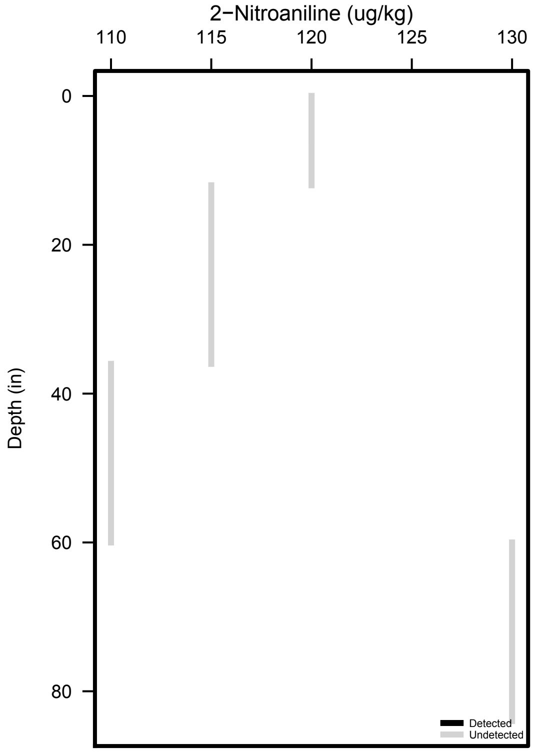

Figure 953. 2−Nitroaniline
at Core Location RM708C1.

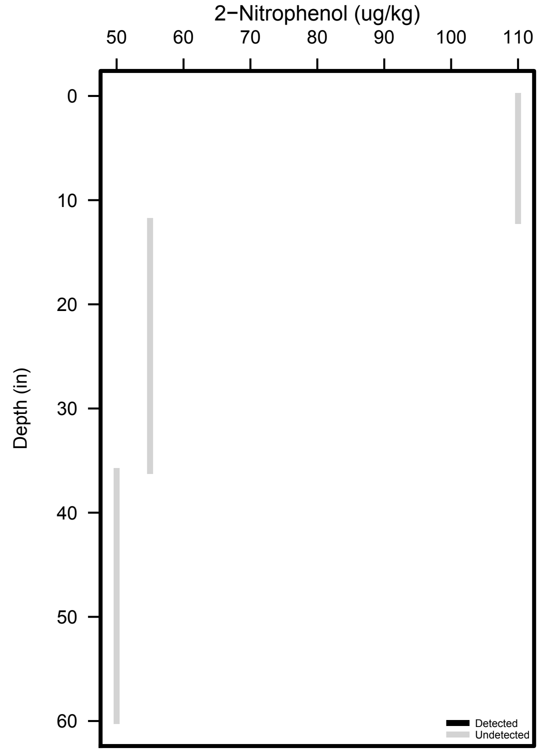

Figure 954. 2−Nitrophenol
at Core Location RM605C1.

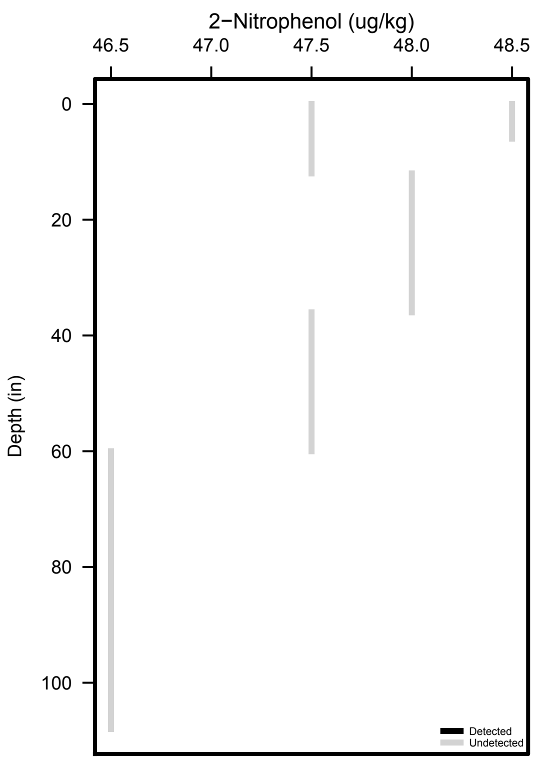

Figure 955. 2−Nitrophenol
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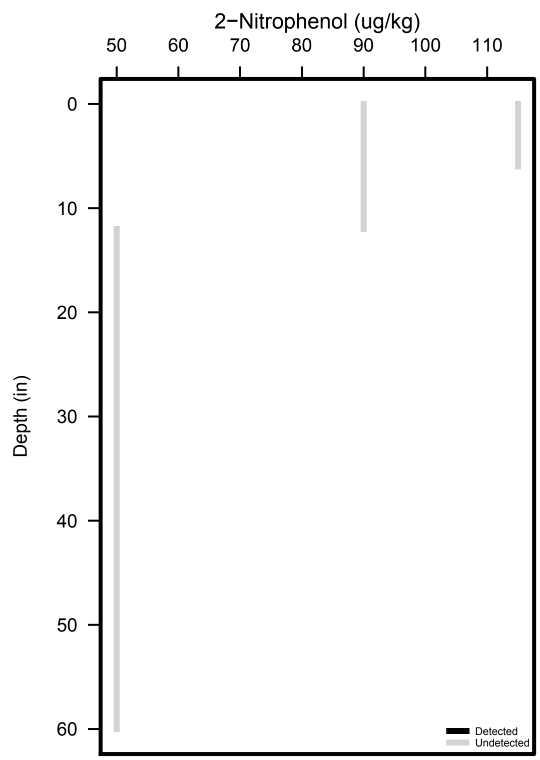

Figure 956. 2−Nitrophenol
at Core Location RM637C1.

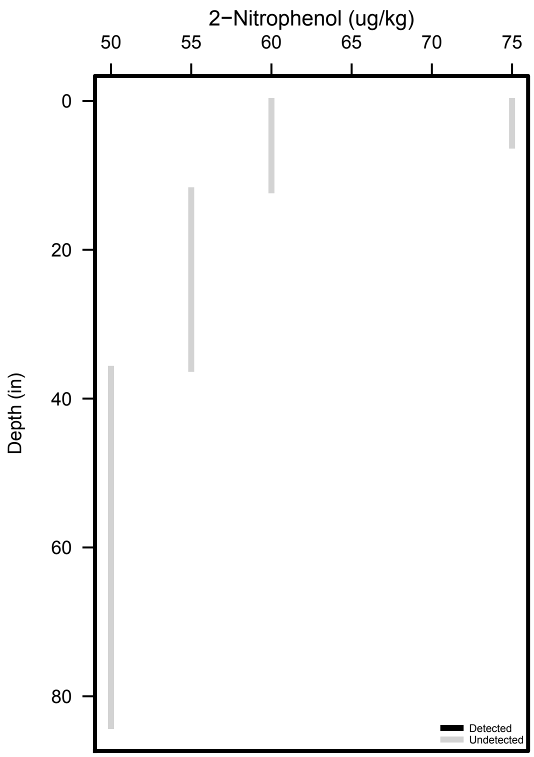

Figure 957. 2−Nitrophenol at Core Location RM644C1.

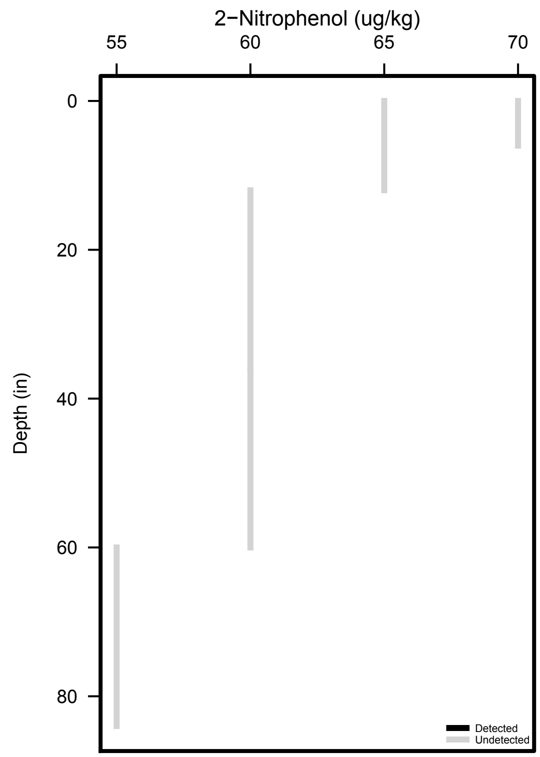

Figure 958. 2−Nitrophenol at Core Location RM661C1.

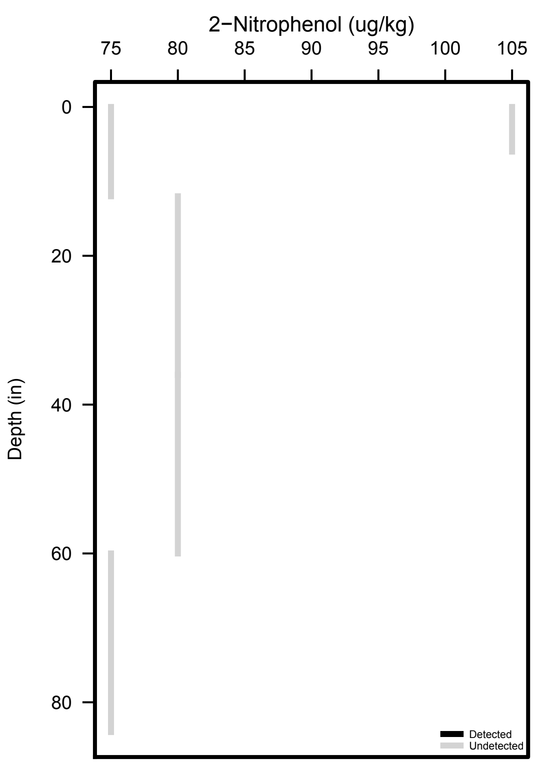

Figure 959. 2−Nitrophenol at Core Location RM676C1.

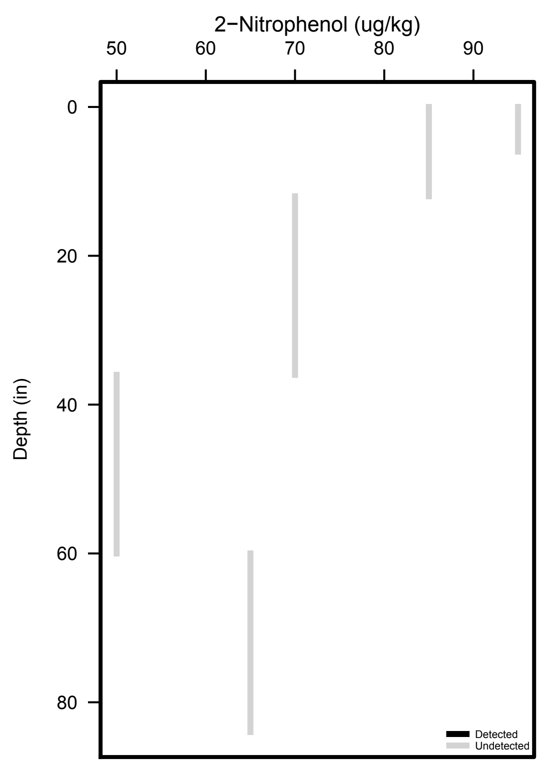

Figure 960. 2−Nitrophenol at Core Location RM692C1.

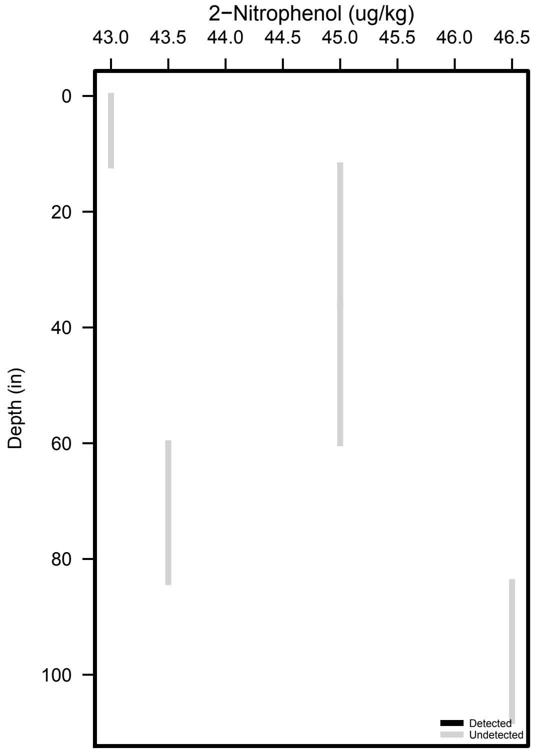

Figure 961. 2−Nitrophenol
at Core Location RM704C1.

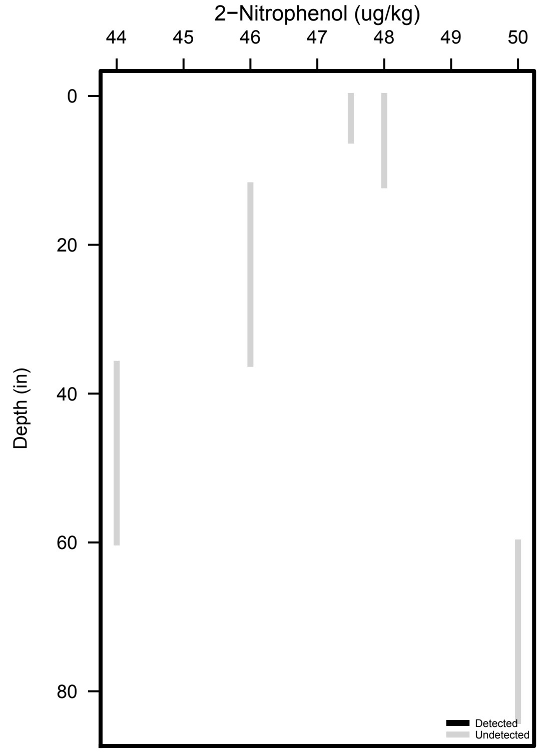

Figure 962. 2−Nitrophenol
at Core Location RM708C1.

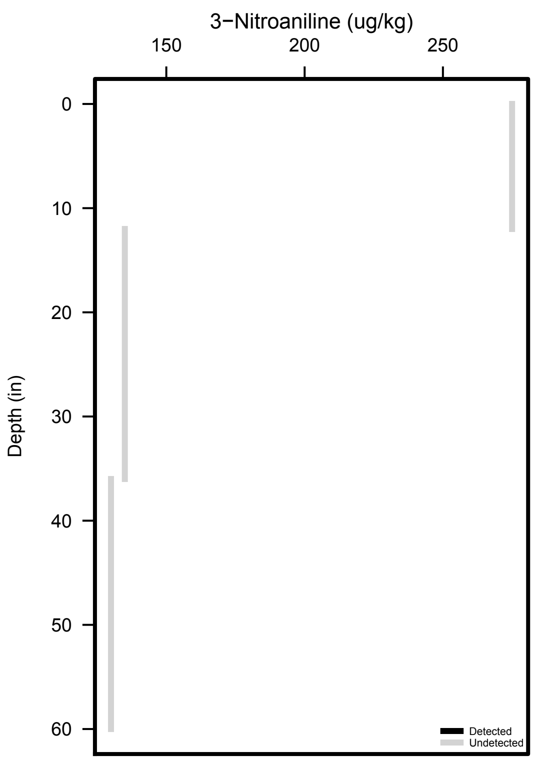

Figure 963. 3−Nitroaniline
at Core Location RM605C1.

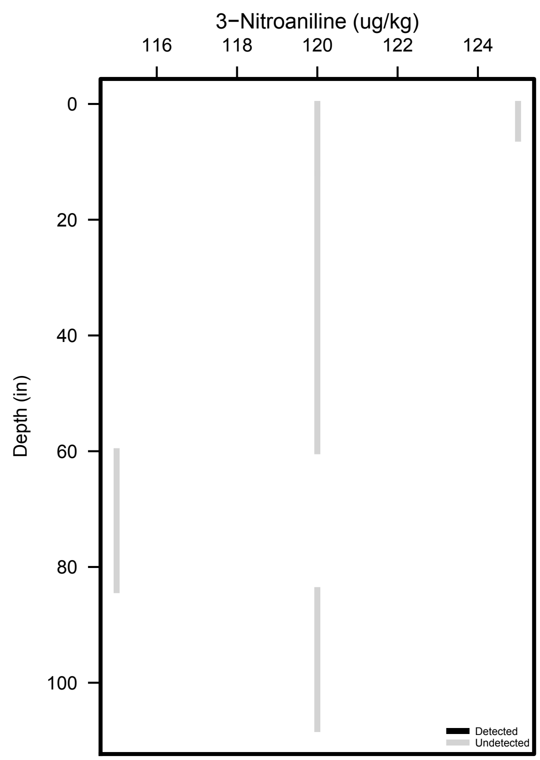

Figure 964. 3−Nitroaniline
at Core Location RM622C1.

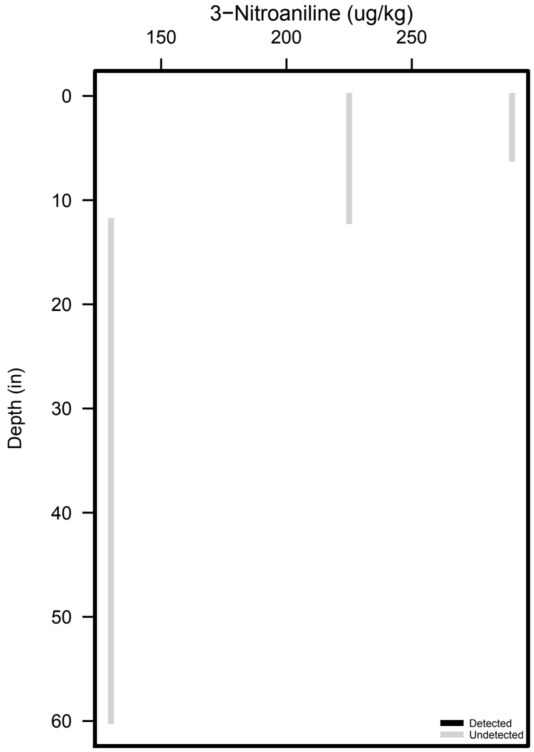

Figure 965. 3−Nitroaniline
at Core Location RM637C1.

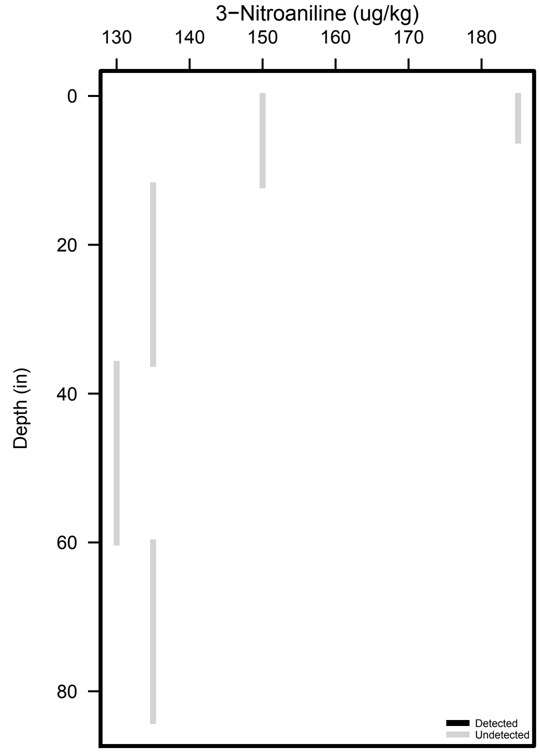

Figure 966. 3−Nitroaniline
at Core Location RM644C1.

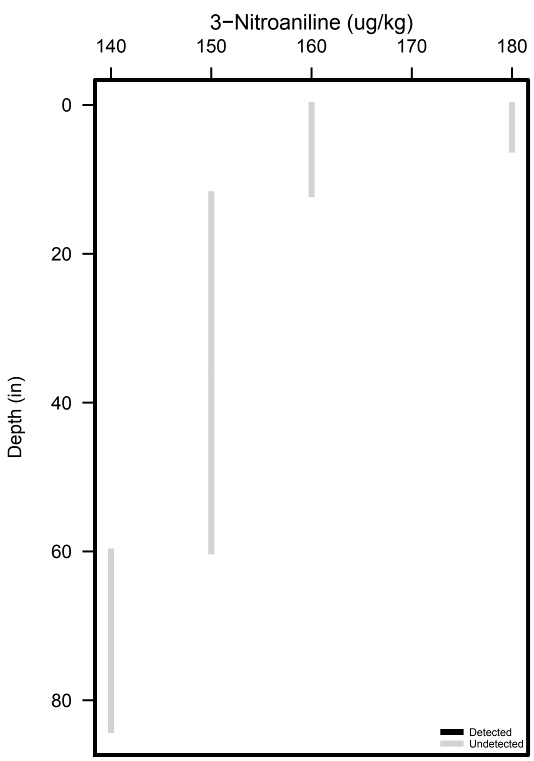

Figure 967. 3−Nitroaniline
at Core Location RM661C1.

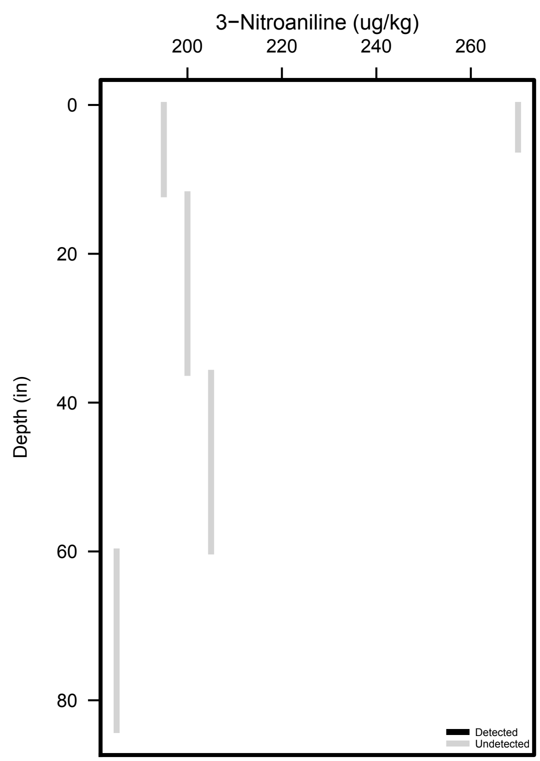

Figure 968. 3−Nitroaniline
at Core Location RM676C1.

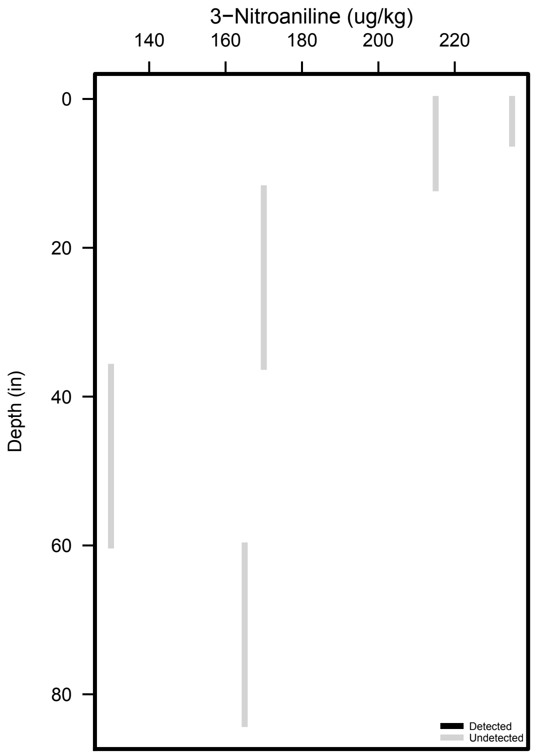

Figure 969. 3−Nitroaniline
at Core Location RM692C1.

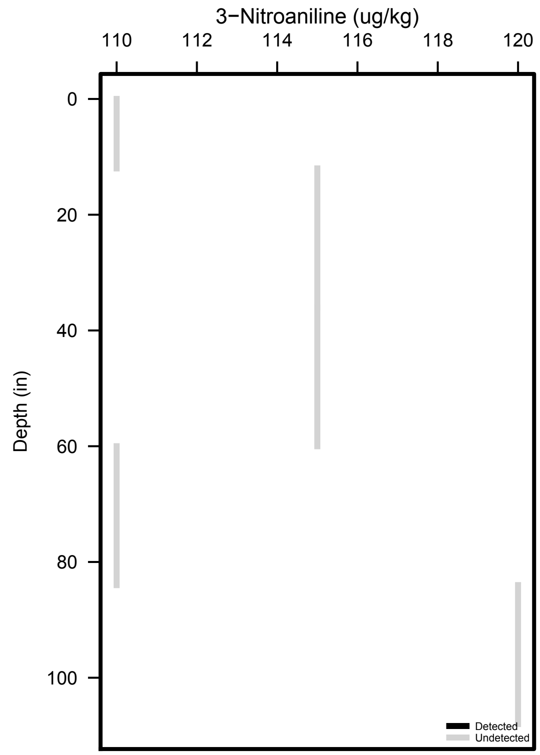

Figure 970. 3−Nitroaniline
at Core Location RM704C1.

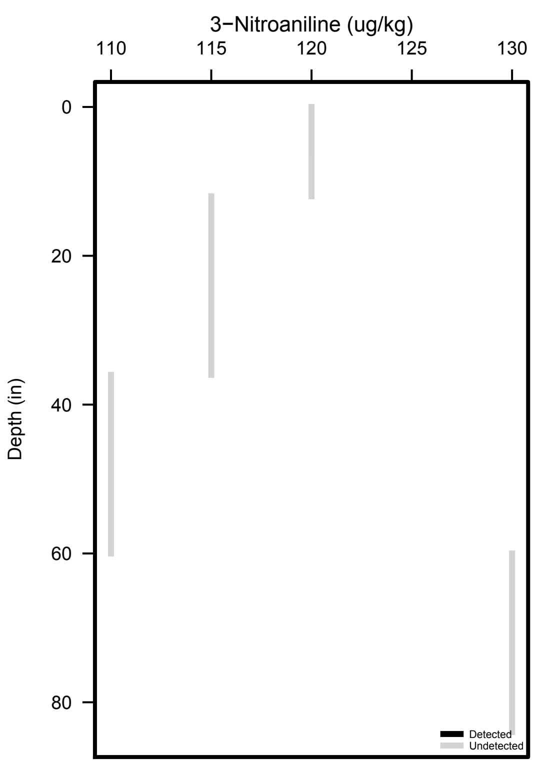

Figure 971. 3−Nitroaniline
at Core Location RM708C1.

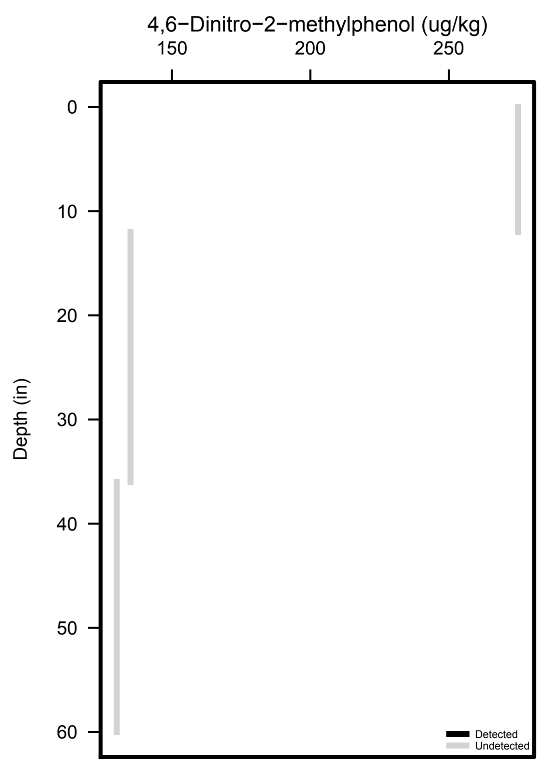

Figure 972. 4,6−Dinitro−2−methylphenol
at Core Location RM605C1.

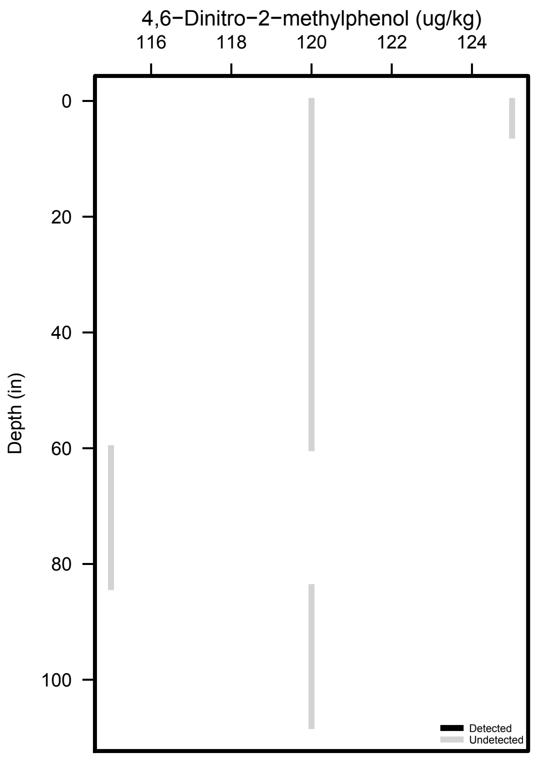

Figure 973. 4,6−Dinitro−2−methylphenol at Core Location RM622C1.

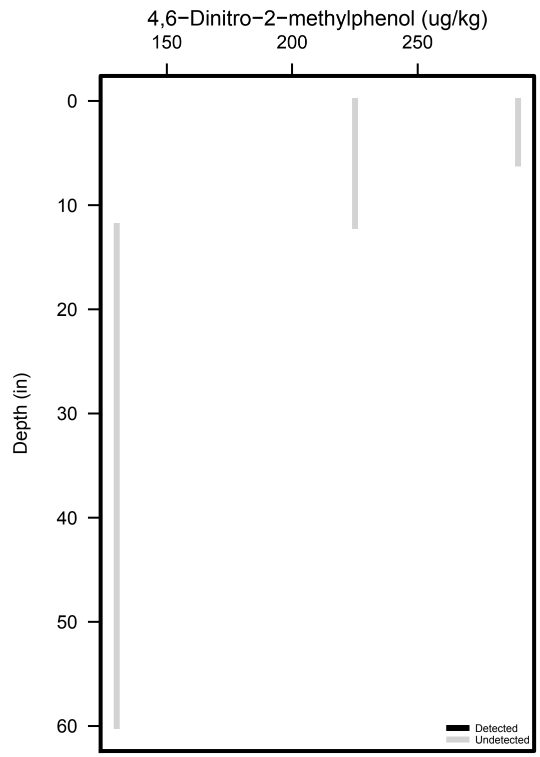

Figure 974. 4,6−Dinitro−2−methylphenol at Core Location RM637C1.

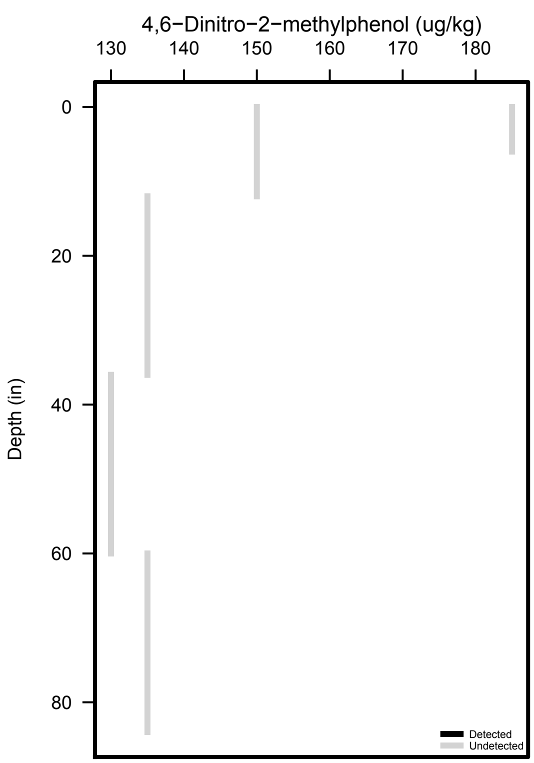

Figure 975. 4,6−Dinitro−2−methylphenol at Core Location RM644C1.

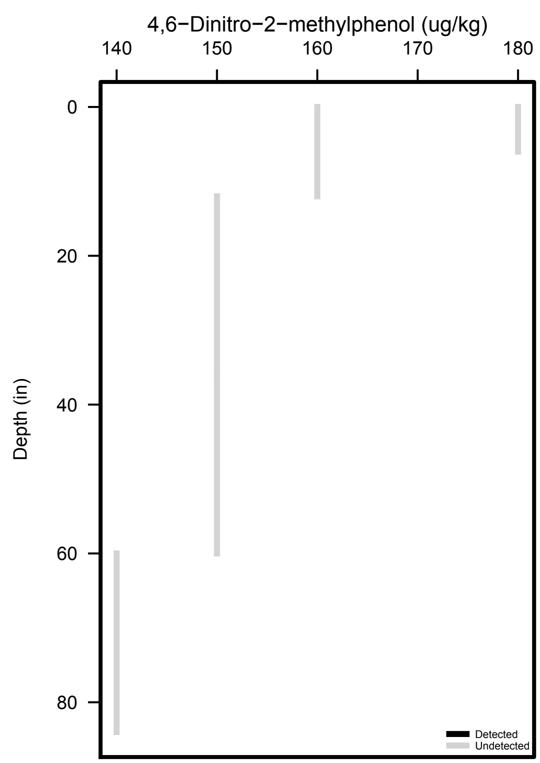

Figure 976. 4,6−Dinitro−2−methylphenol at Core Location RM661C1.

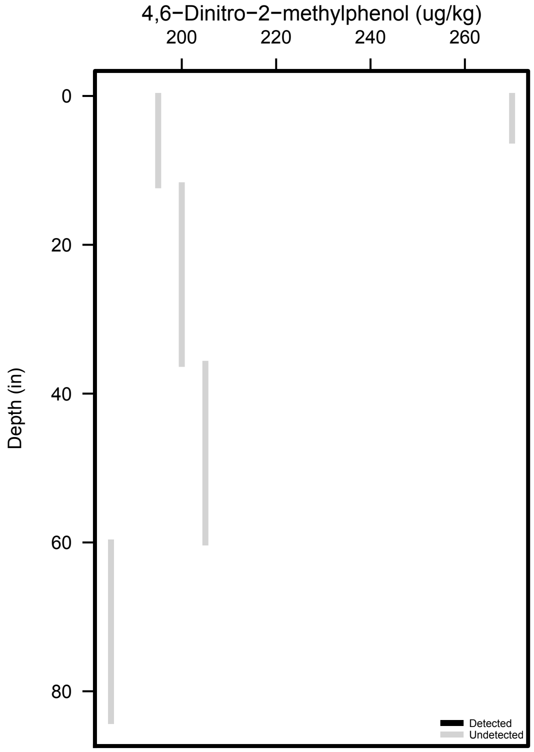

Figure 977. 4,6−Dinitro−2−methylphenol at Core Location RM676C1.

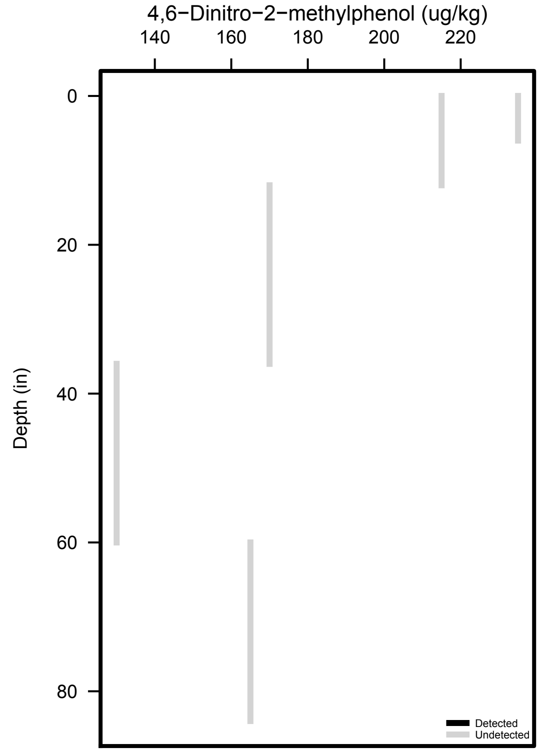

Figure 978. 4,6−Dinitro−2−methylphenol at Core Location RM692C1.

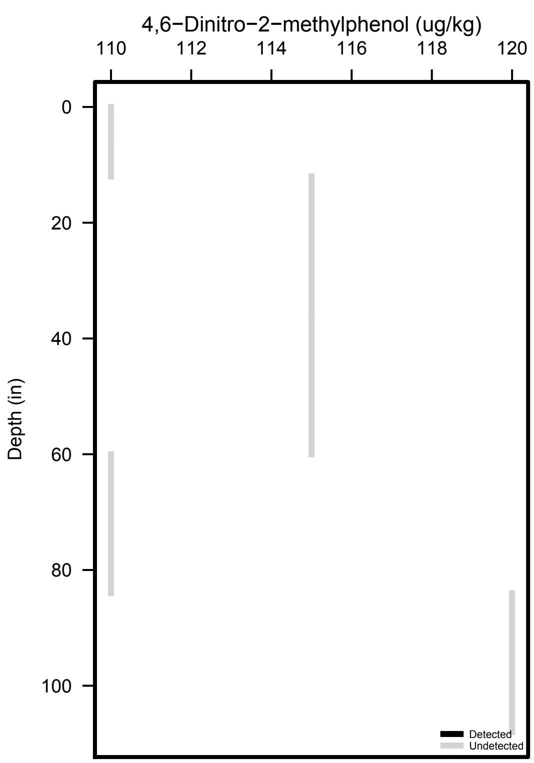

Figure 979. 4,6−Dinitro−2−methylphenol at Core Location RM704C1.

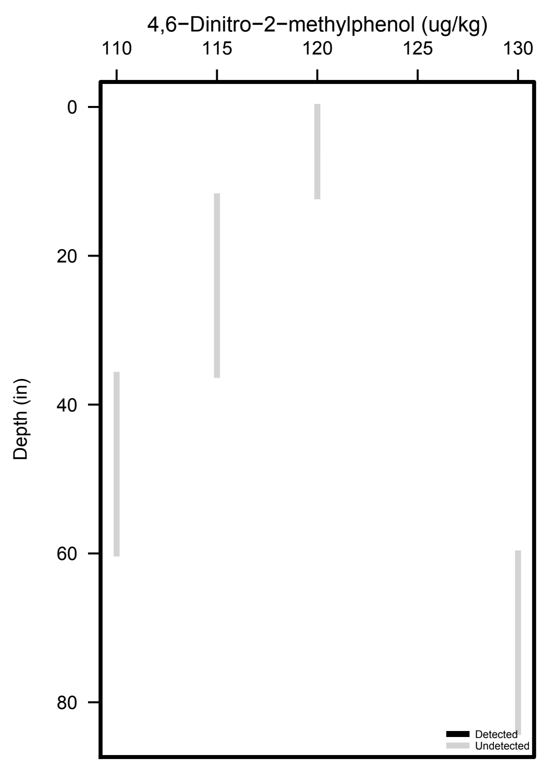

Figure 980. 4,6−Dinitro−2−methylphenol at Core Location RM708C1.

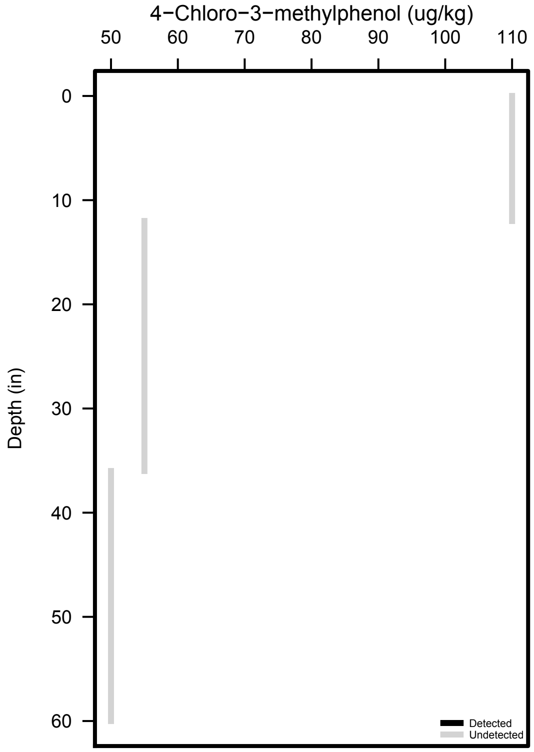

Figure 981. 4−Chloro−3−methylphenol
at Core Location RM605C1.

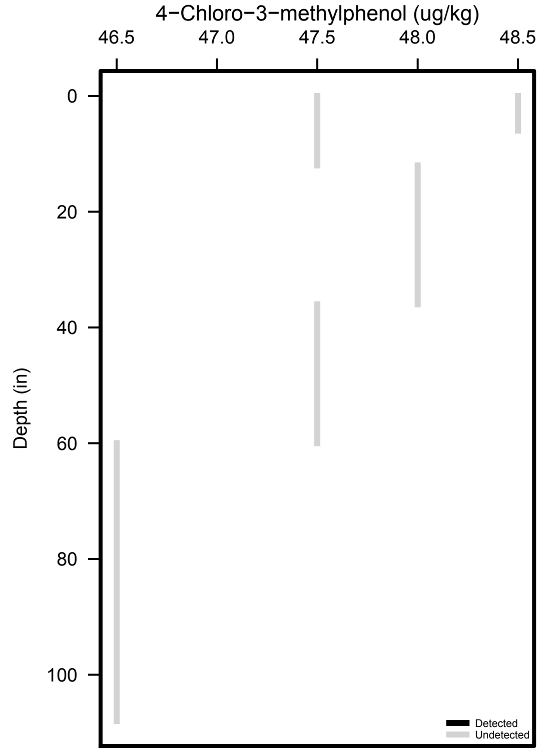

Figure 982. 4−Chloro−3−methylphenol
at Core Location RM622C1.

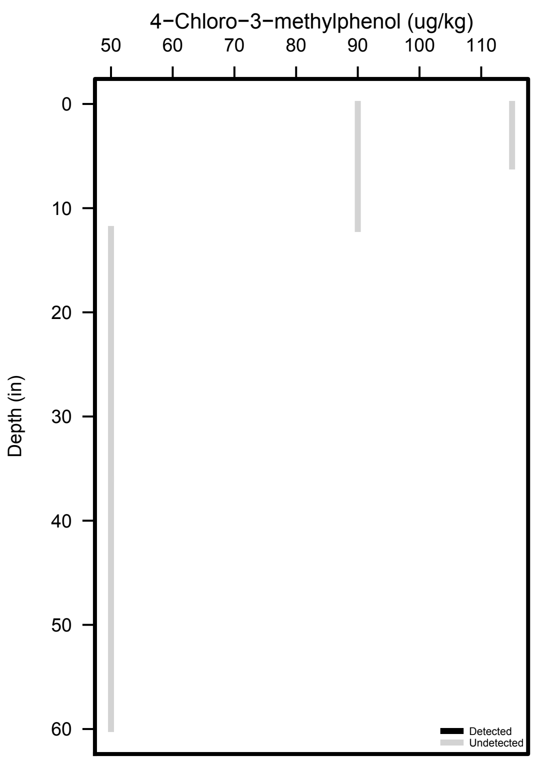

Figure 983. 4−Chloro−3−methylphenol
at Core Location RM637C1.

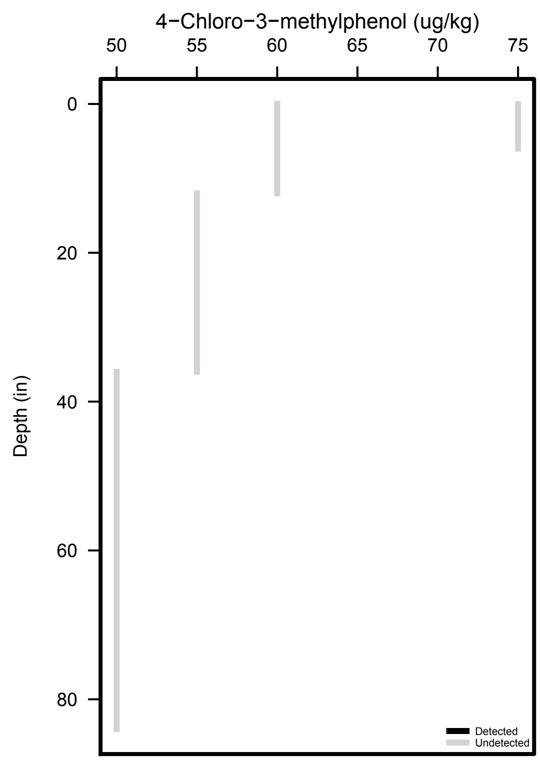

Figure 984. 4−Chloro−3−methylphenol
at Core Location RM644C1.

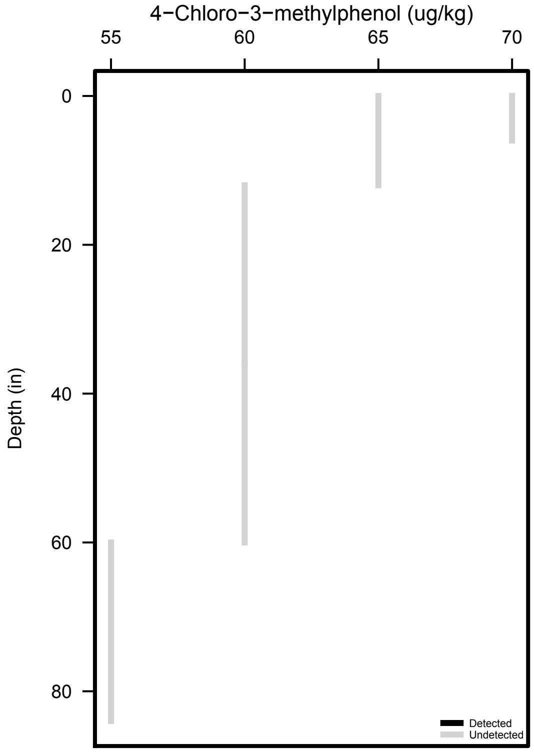

Figure 985. 4−Chloro−3−methylphenol at Core Location RM661C1.

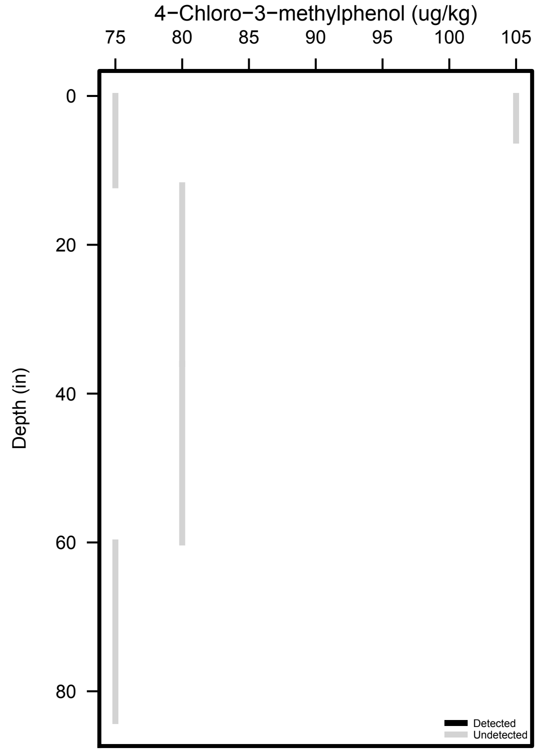

Figure 986. 4−Chloro−3−methylphenol at Core Location RM676C1.

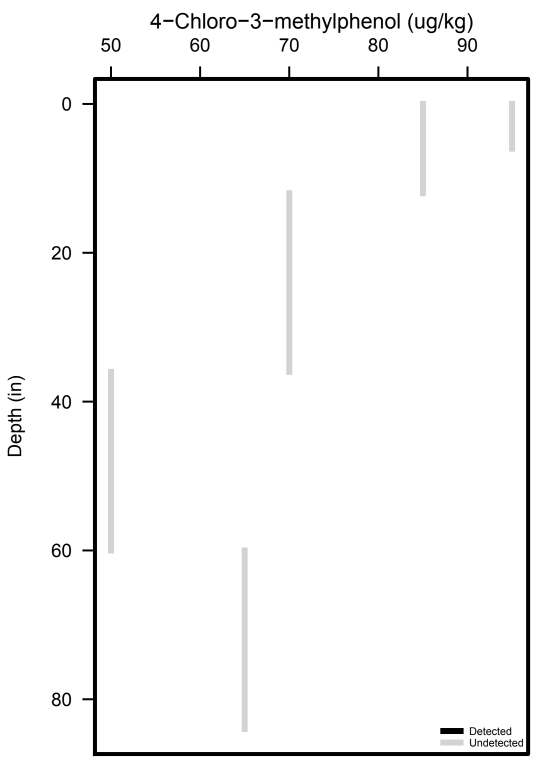

Figure 987. 4−Chloro−3−methylphenol at Core Location RM692C1.

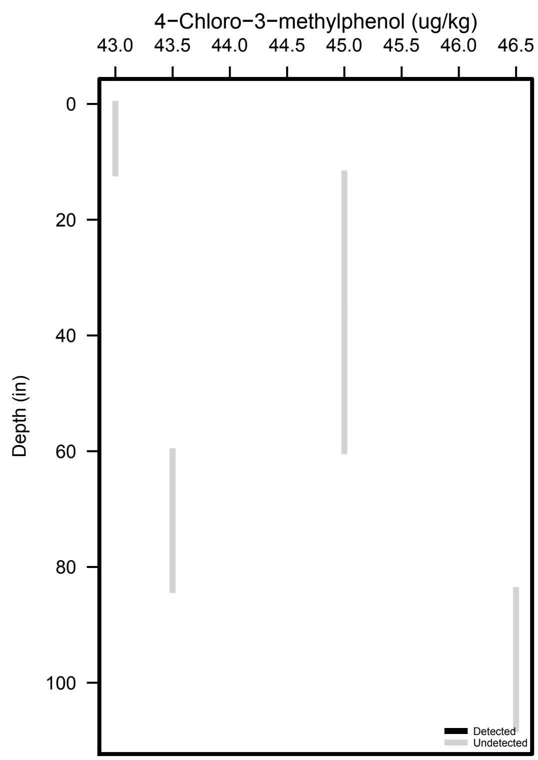

Figure 988. 4−Chloro−3−methylphenol at Core Location RM704C1.

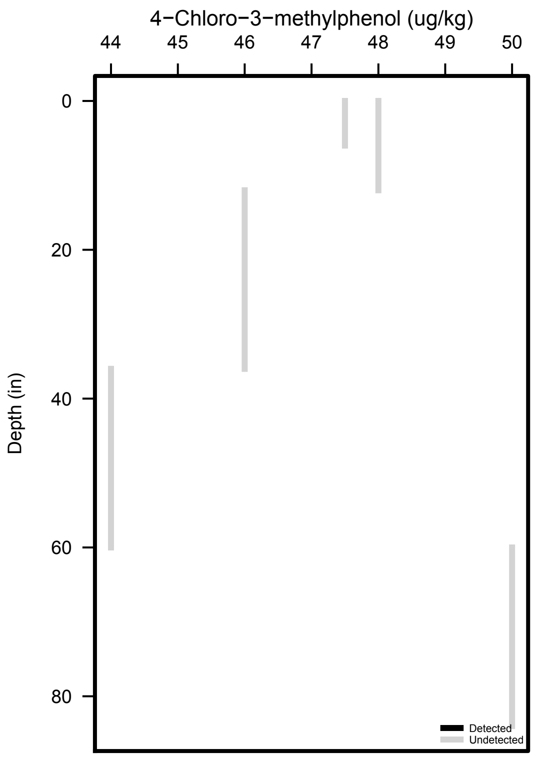

Figure 989. 4−Chloro−3−methylphenol
at Core Location RM708C1.

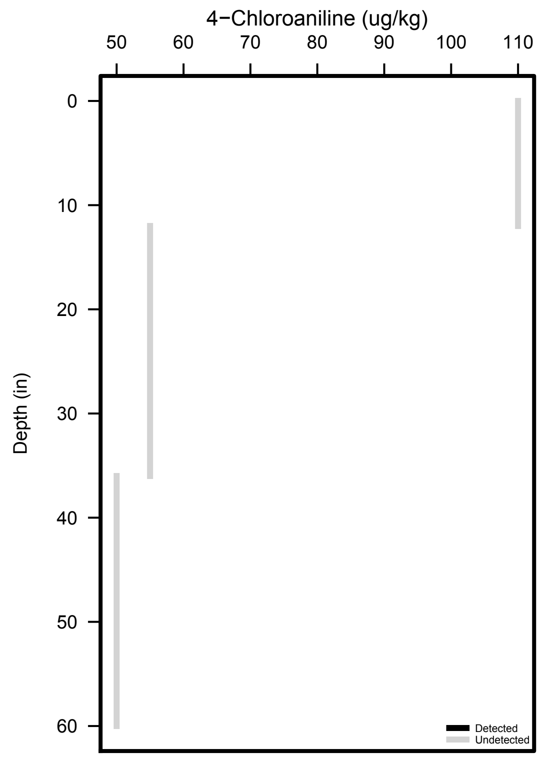

Figure 990. 4−Chloroaniline
at Core Location RM605C1.

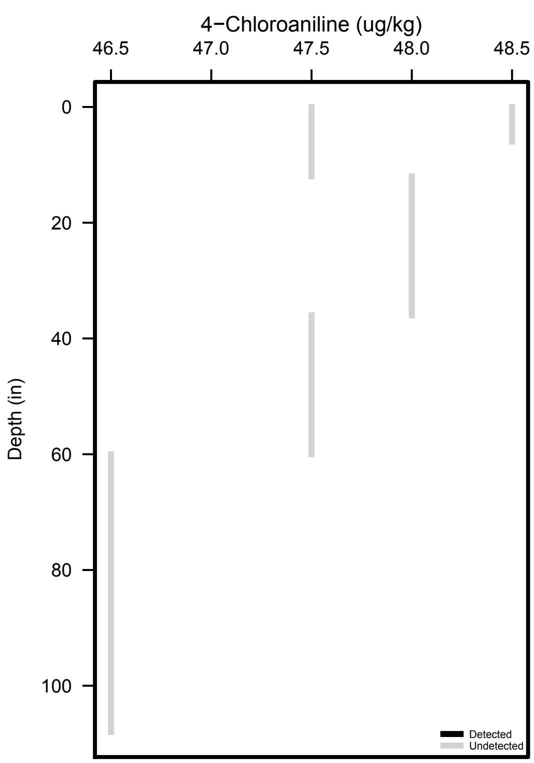

Figure 991. 4−Chloroaniline
at Core Location RM622C1.

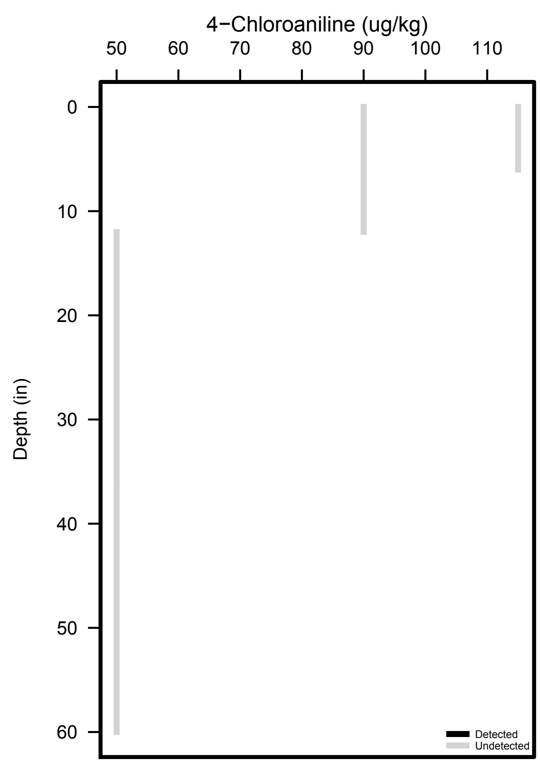

Figure 992. 4−Chloroaniline
at Core Location RM637C1.

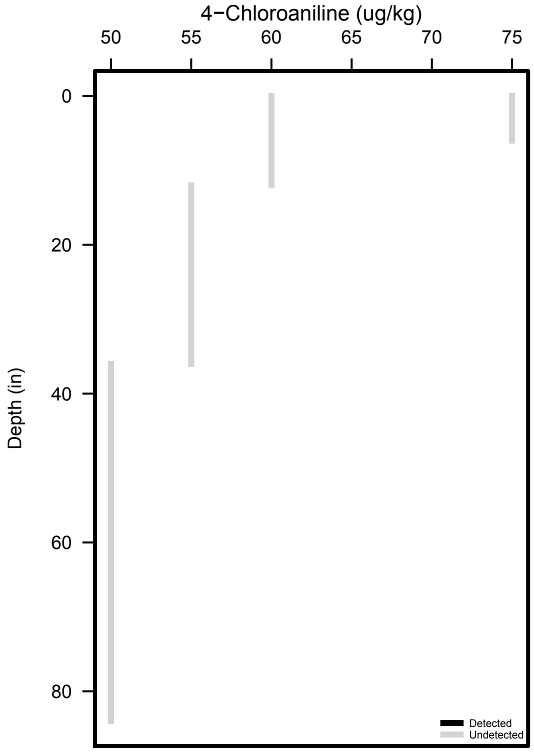

Figure 993. 4−Chloroaniline at Core Location RM644C1.

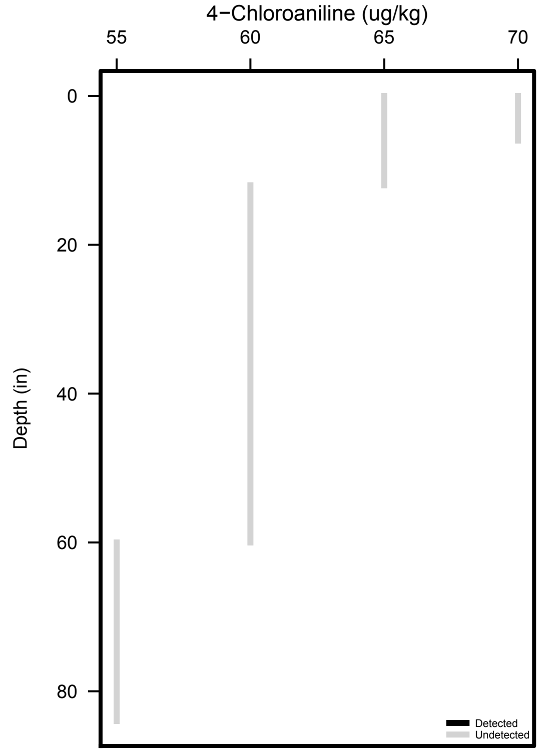

Figure 994. 4−Chloroaniline at Core Location RM661C1.

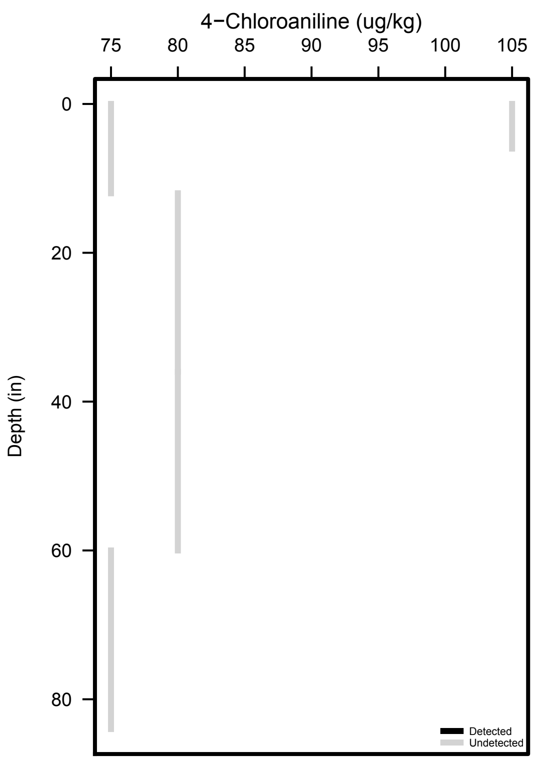

Figure 995. 4−Chloroaniline at Core Location RM676C1.

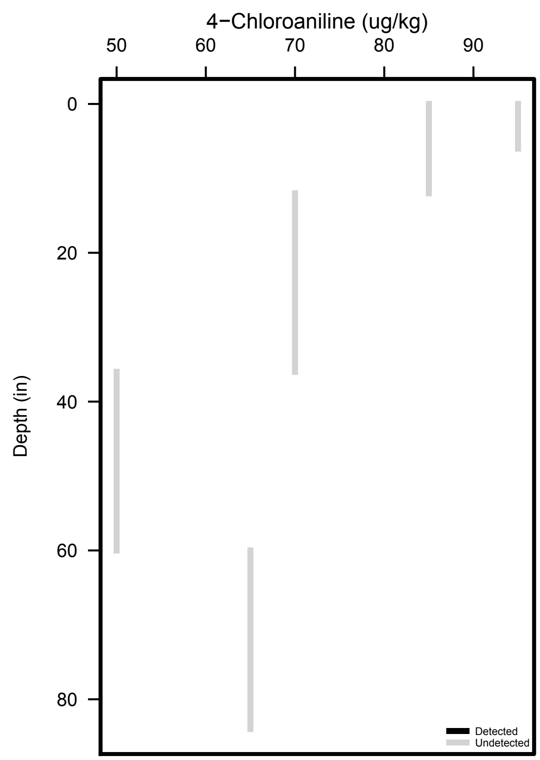

Figure 996. 4−Chloroaniline at Core Location RM692C1.

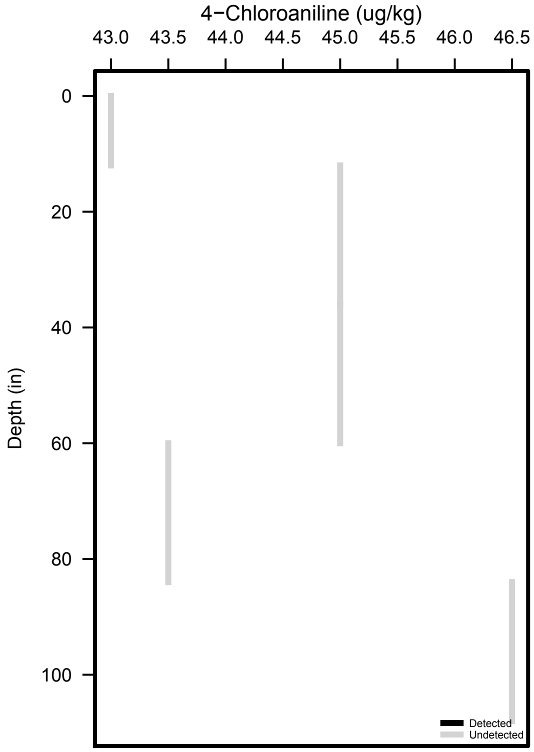

Figure 997. 4−Chloroaniline
at Core Location RM704C1.

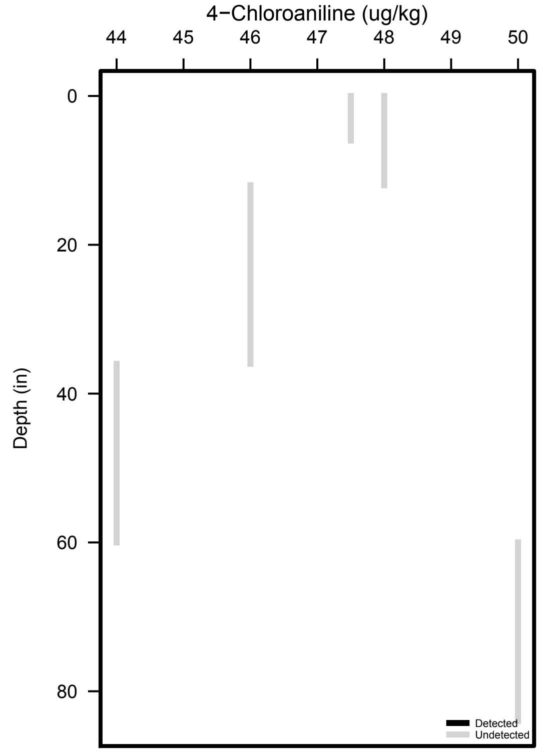

Figure 998. 4−Chloroaniline
at Core Location RM708C1.

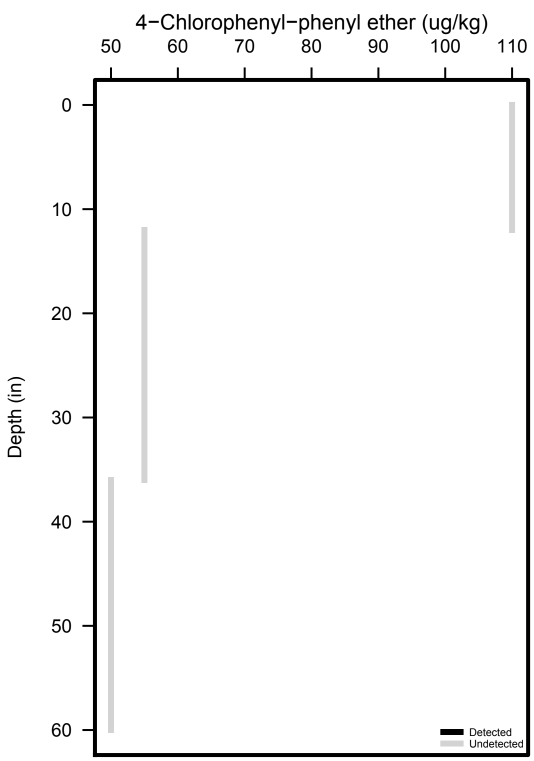

Figure 999. 4−Chlorophenyl−phenyl ether
at Core Location RM605C1.

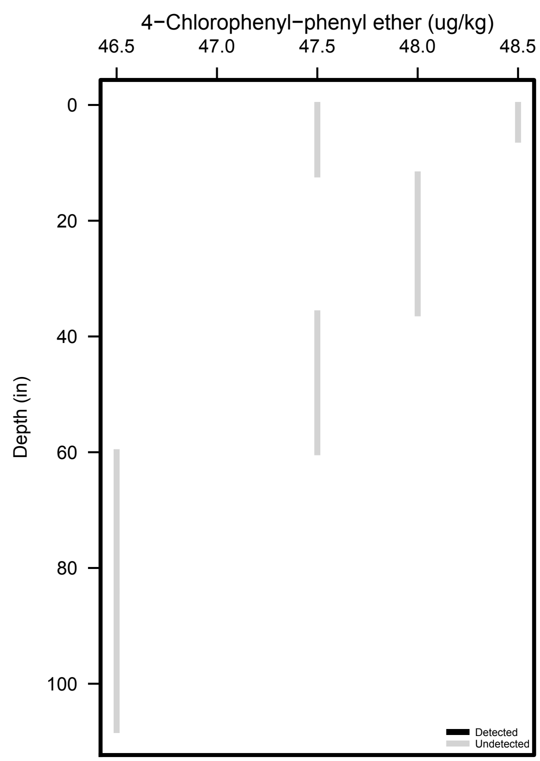

Figure 1000. 4−Chlorophenyl−phenyl ether
at Core Location RM622C1.

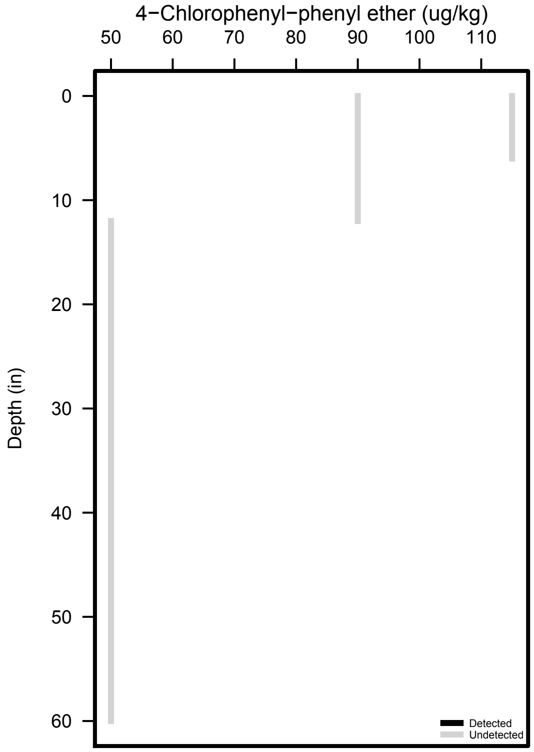

Figure 1001. 4−Chlorophenyl−phenyl ether at Core Location RM637C1.

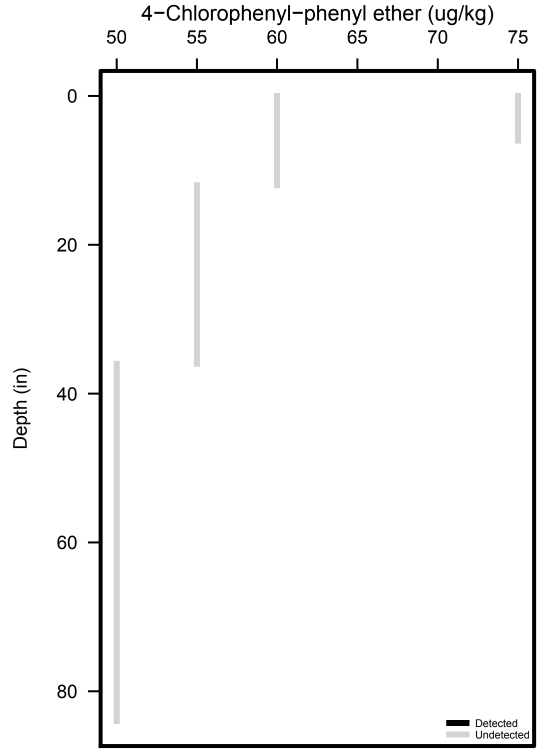

Figure 1002. 4−Chlorophenyl−phenyl ether at Core Location RM644C1.

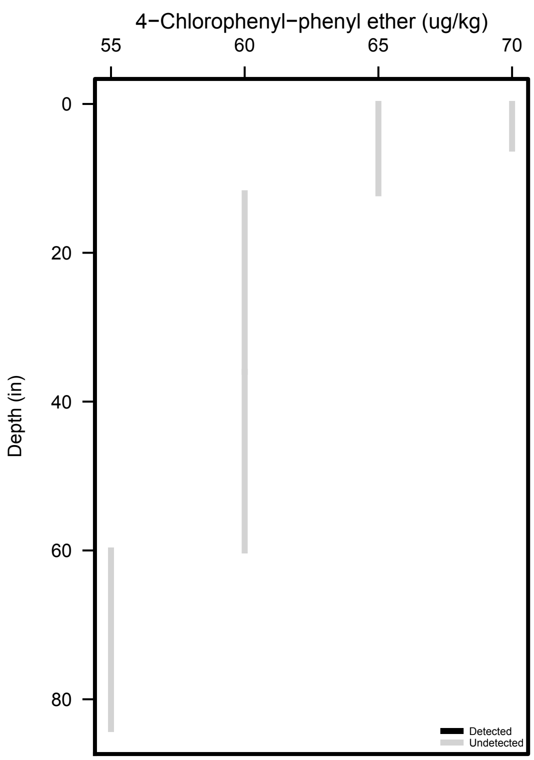

Figure 1003. 4−Chlorophenyl−phenyl ether at Core Location RM661C1.

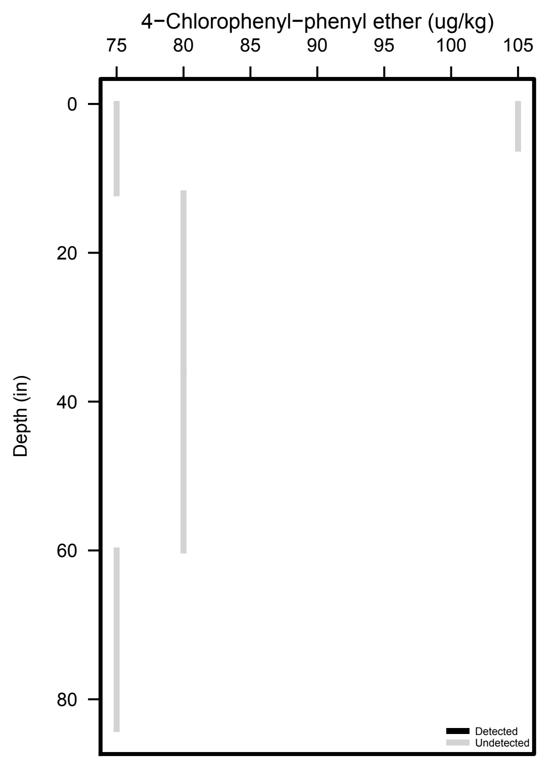

Figure 1004. 4−Chlorophenyl−phenyl ether at Core Location RM676C1.

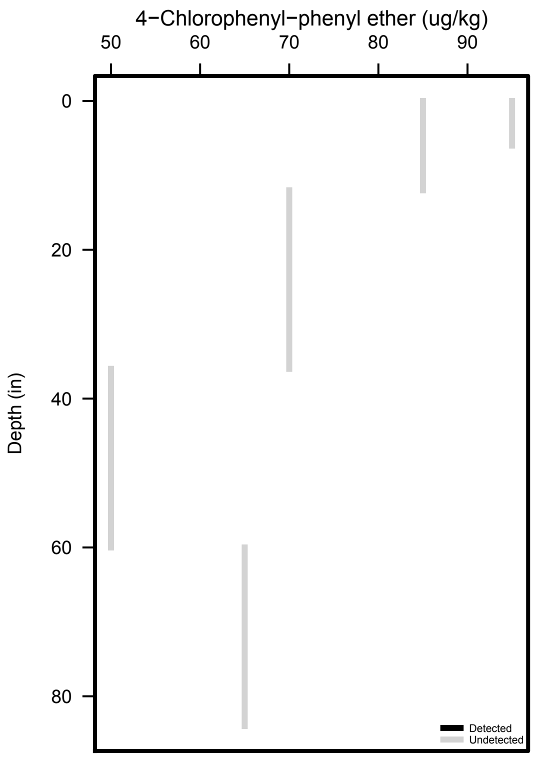

Figure 1005. 4−Chlorophenyl−phenyl ether at Core Location RM692C1.

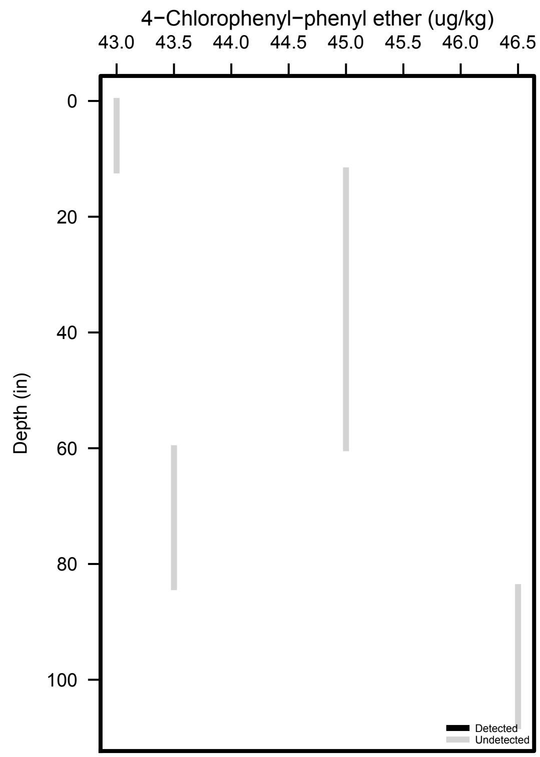

Figure 1006. 4−Chlorophenyl−phenyl ether at Core Location RM704C1.

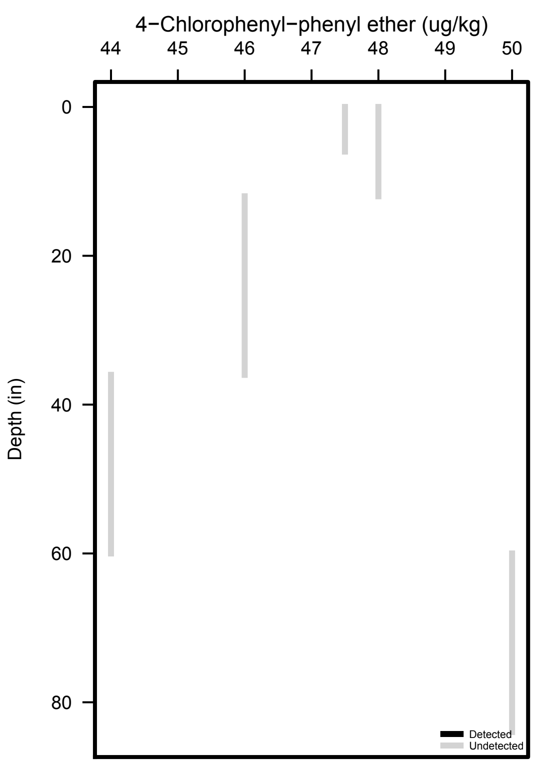

Figure 1007. 4−Chlorophenyl−phenyl ether at Core Location RM708C1.

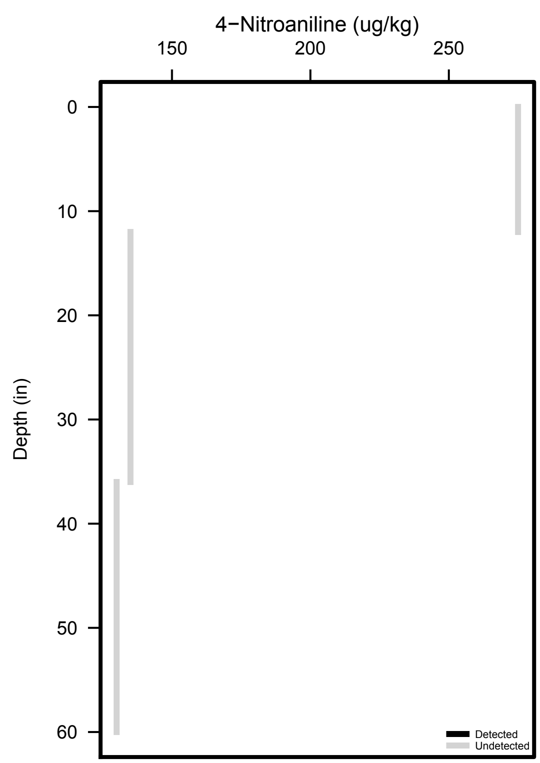

Figure 1008. 4−Nitroaniline at Core Location RM605C1.

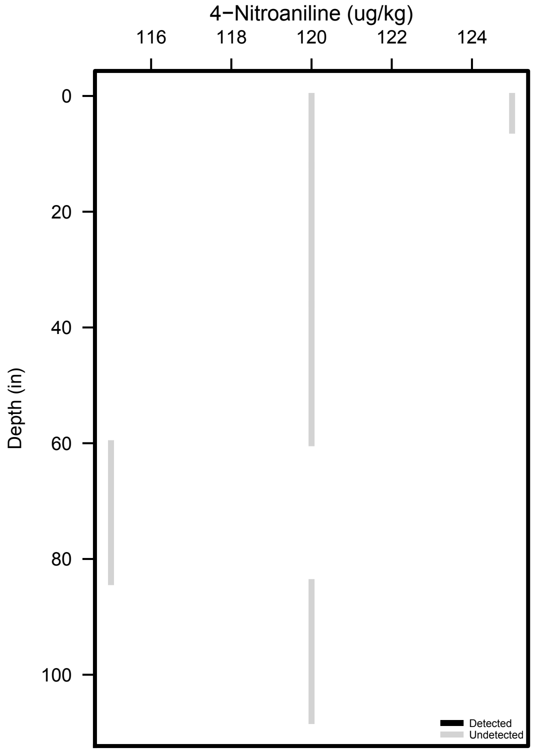

Figure 1009. 4−Nitroaniline
at Core Location RM622C1.

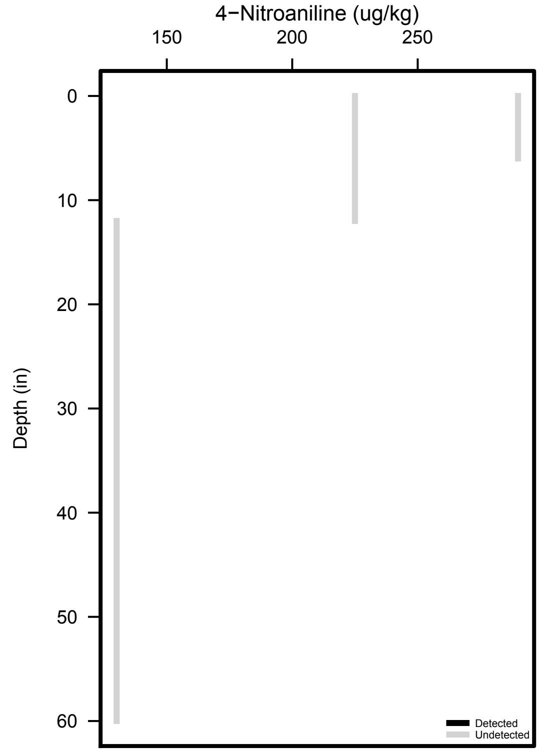

Figure 1010. 4−Nitroaniline
at Core Location RM637C1.

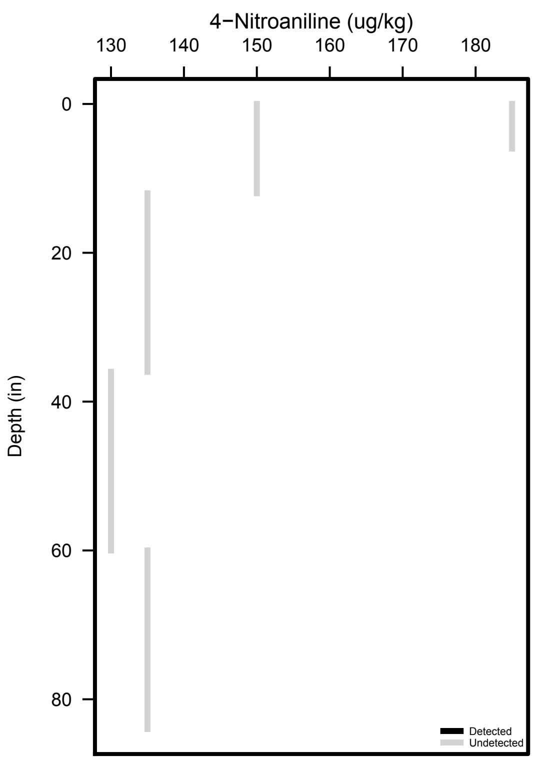

Figure 1011. 4−Nitroaniline
at Core Location RM644C1.

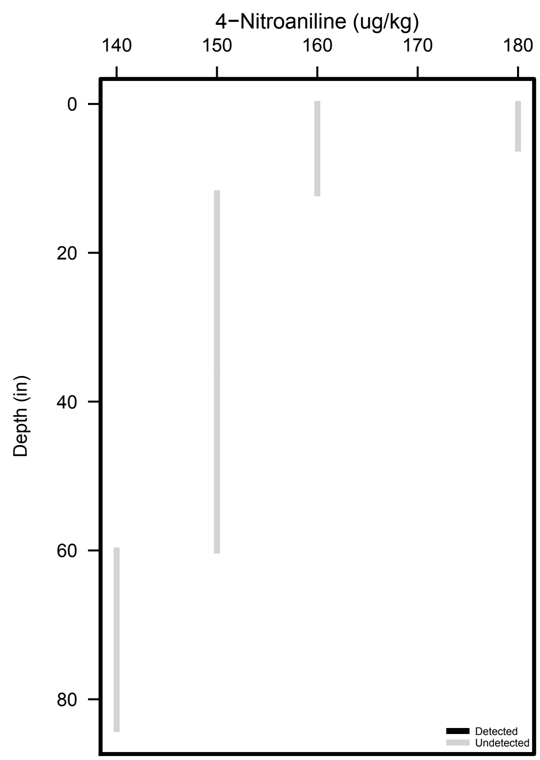

Figure 1012. 4−Nitroaniline
at Core Location RM661C1.

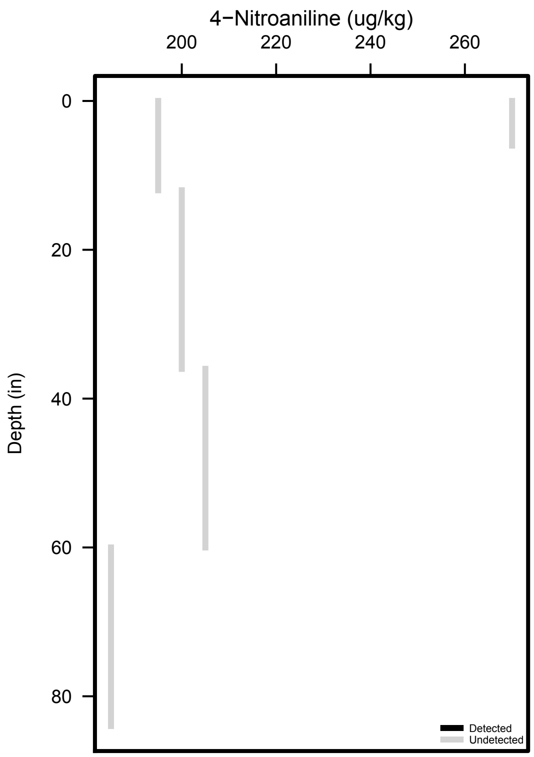

Figure 1013. 4−Nitroaniline
at Core Location RM676C1.

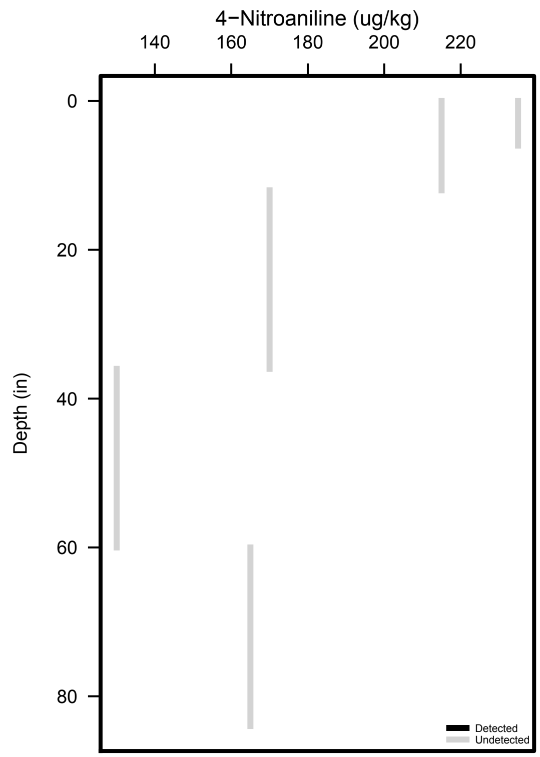

Figure 1014. 4−Nitroaniline
at Core Location RM692C1.

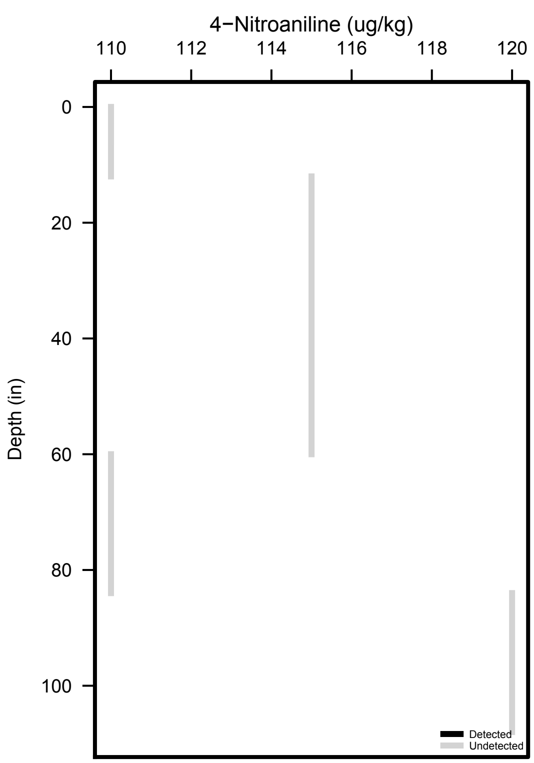

Figure 1015. 4−Nitroaniline
at Core Location RM704C1.

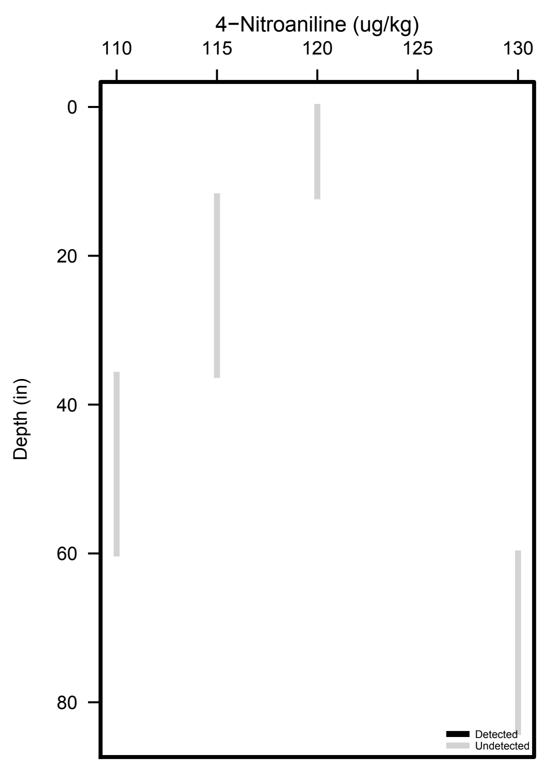

Figure 1016. 4−Nitroaniline
at Core Location RM708C1.

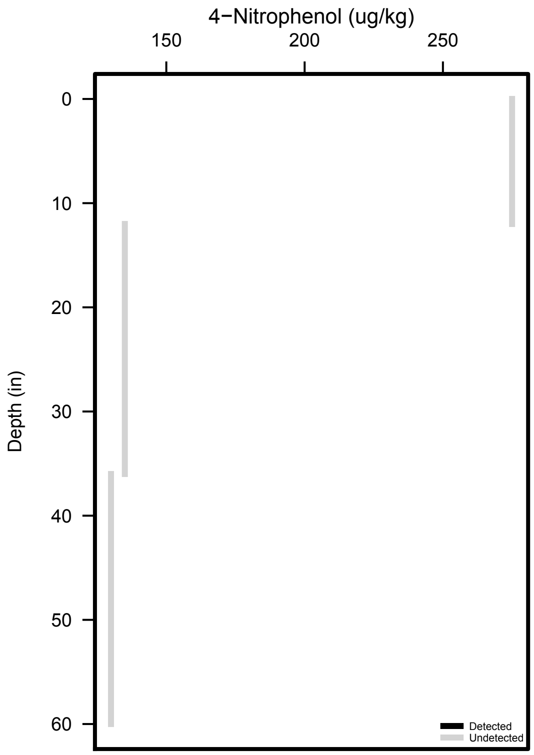

Figure 1017. 4−Nitrophenol at Core Location RM605C1.

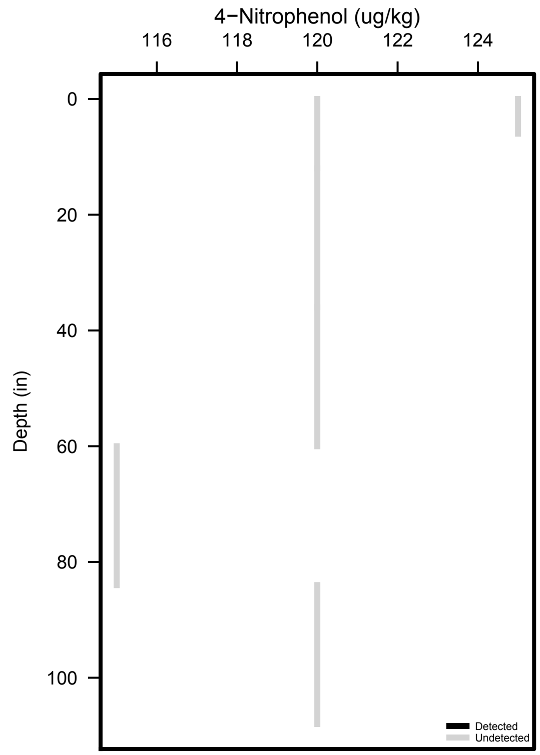

Figure 1018. 4−Nitrophenol at Core Location RM622C1.

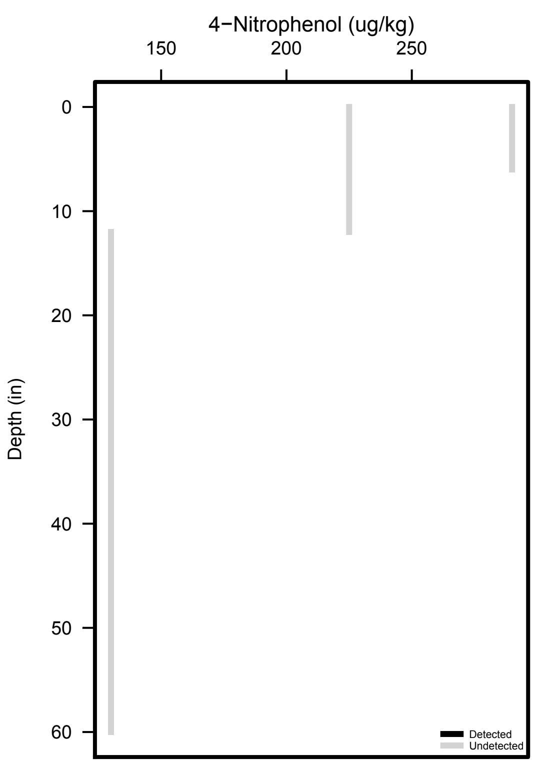

Figure 1019. 4−Nitrophenol at Core Location RM637C1.

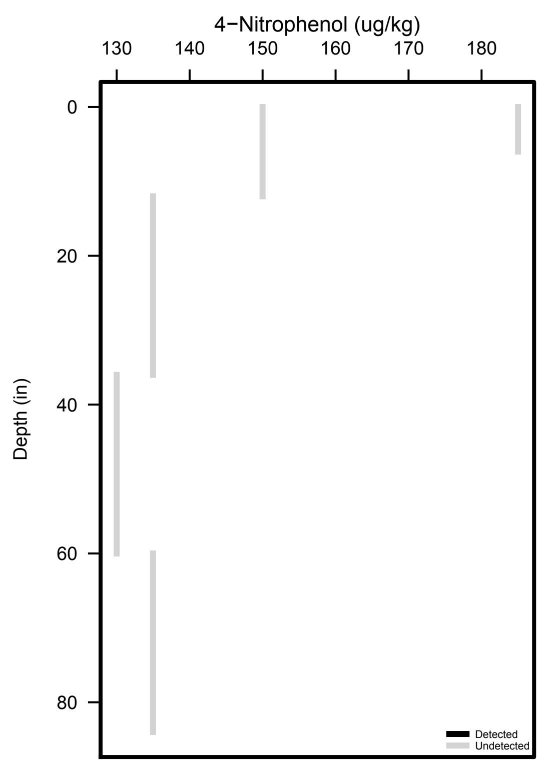

Figure 1020. 4−Nitrophenol at Core Location RM644C1.

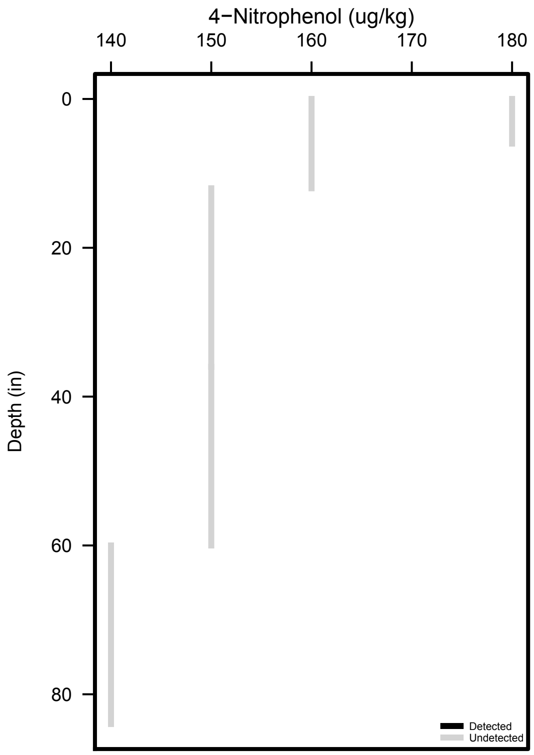

Figure 1021. 4−Nitrophenol
at Core Location RM661C1.

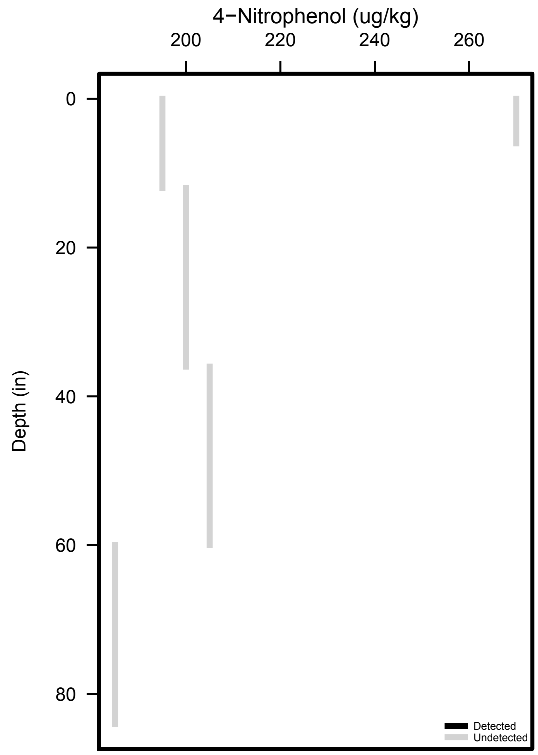

Figure 1022. 4−Nitrophenol
at Core Location RM676C1.

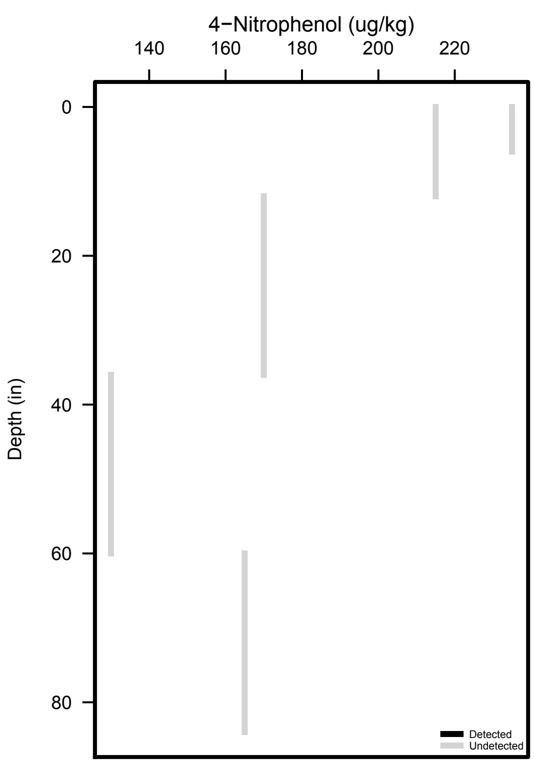

Figure 1023. 4−Nitrophenol
at Core Location RM692C1.

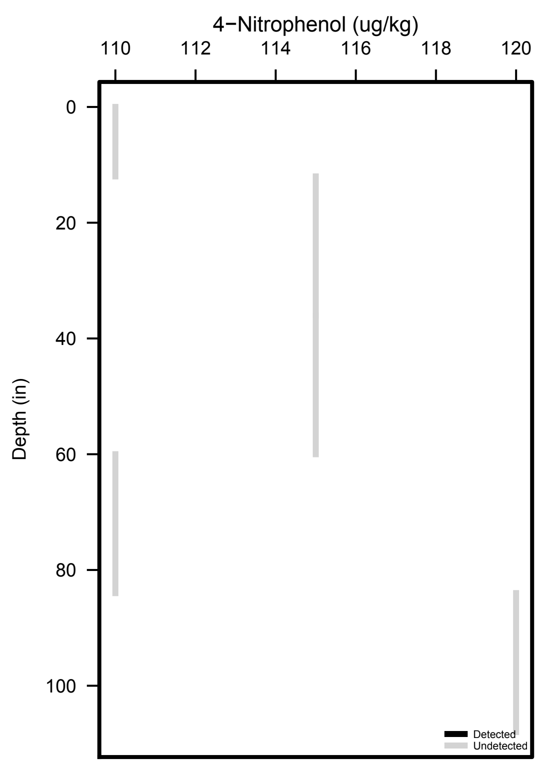

Figure 1024. 4−Nitrophenol
at Core Location RM704C1.

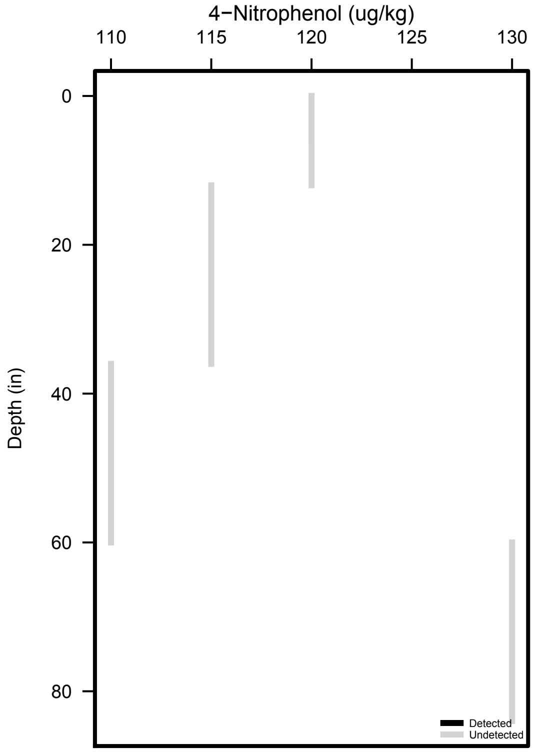

Figure 1025. 4−Nitrophenol
at Core Location RM708C1.

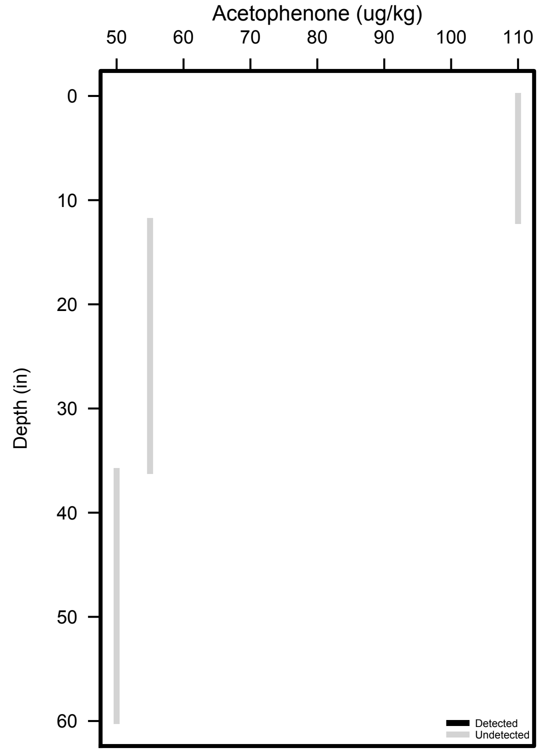

Figure 1026. Acetophenone
at Core Location RM605C1.

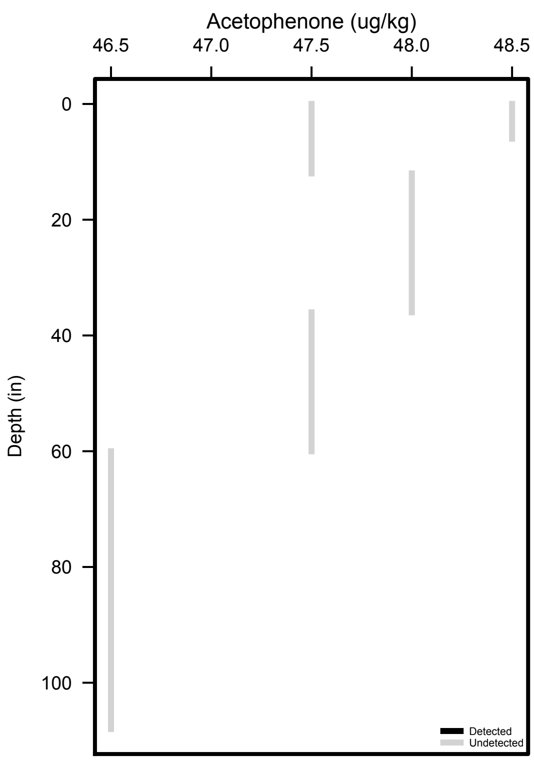

Figure 1027. Acetophenone
at Core Location RM622C1.

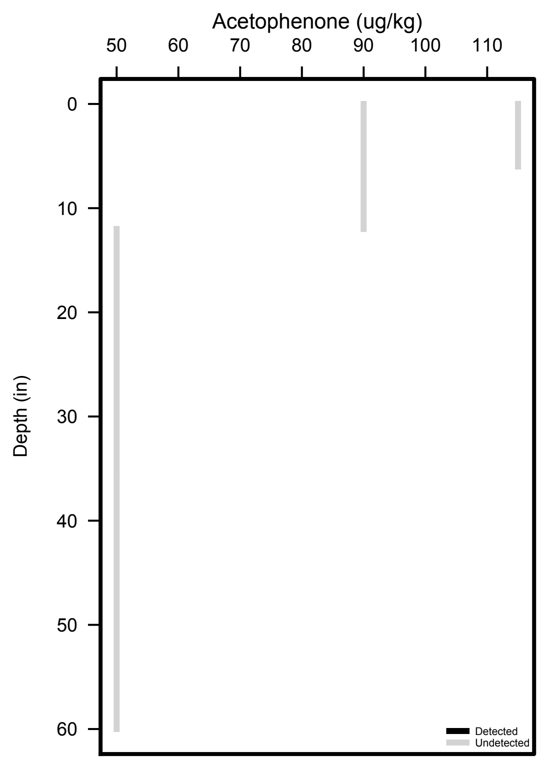

Figure 1028. Acetophenone
at Core Location RM637C1.

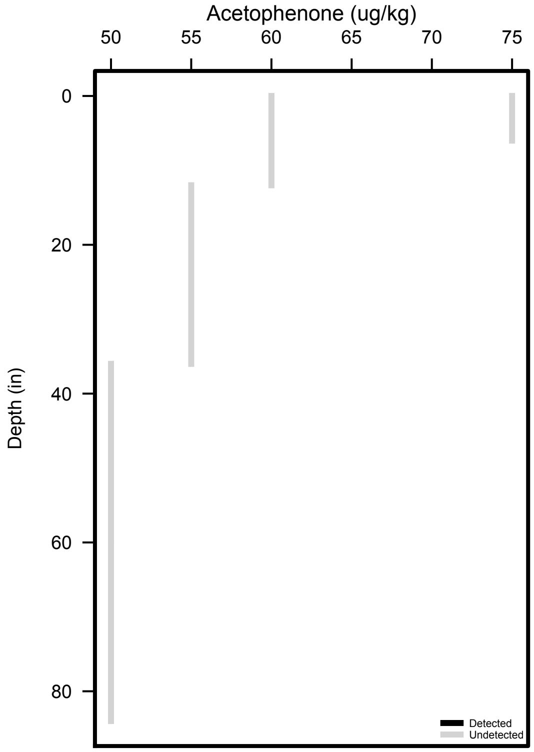

Figure 1029. Acetophenone at Core Location RM644C1.

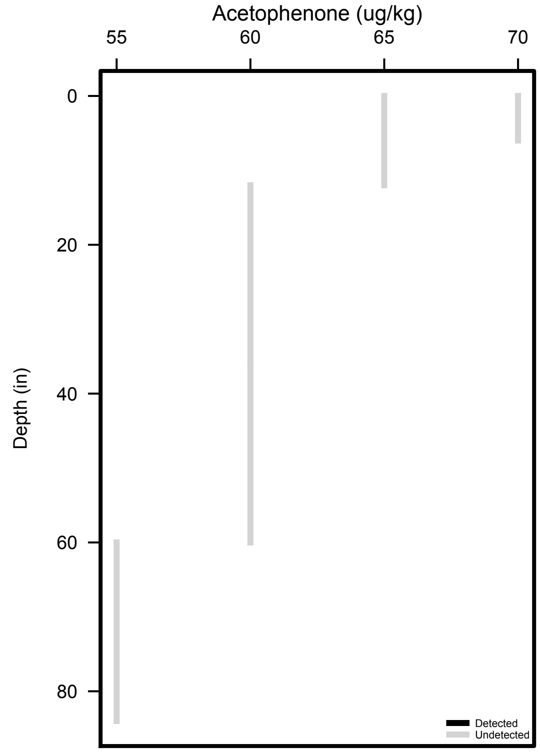

Figure 1030. Acetophenone at Core Location RM661C1.

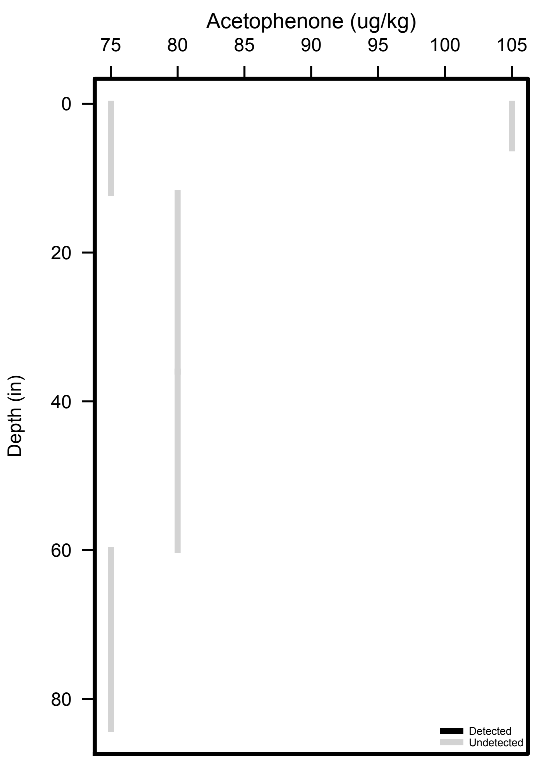

Figure 1031. Acetophenone at Core Location RM676C1.

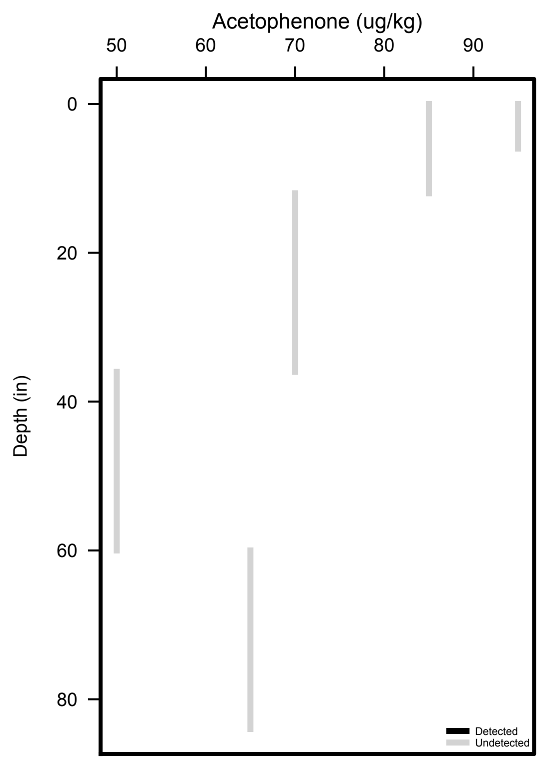

Figure 1032. Acetophenone at Core Location RM692C1.

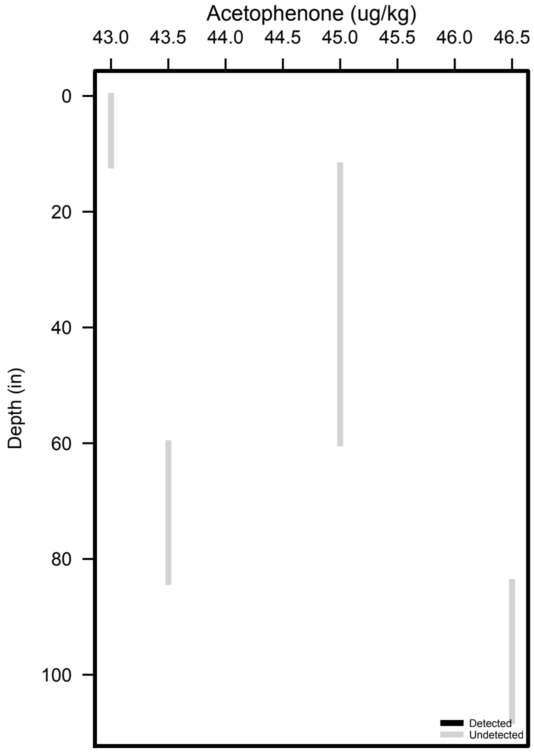

Figure 1033. Acetophenone at Core Location RM704C1.

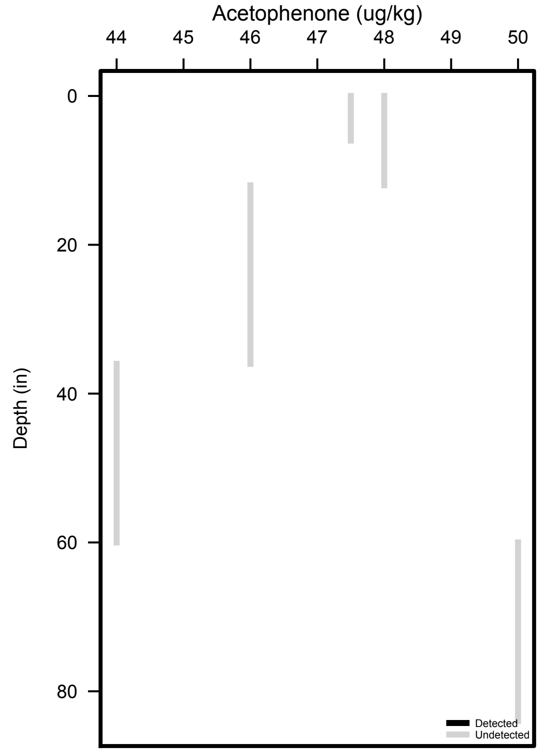

Figure 1034. Acetophenone at Core Location RM708C1.

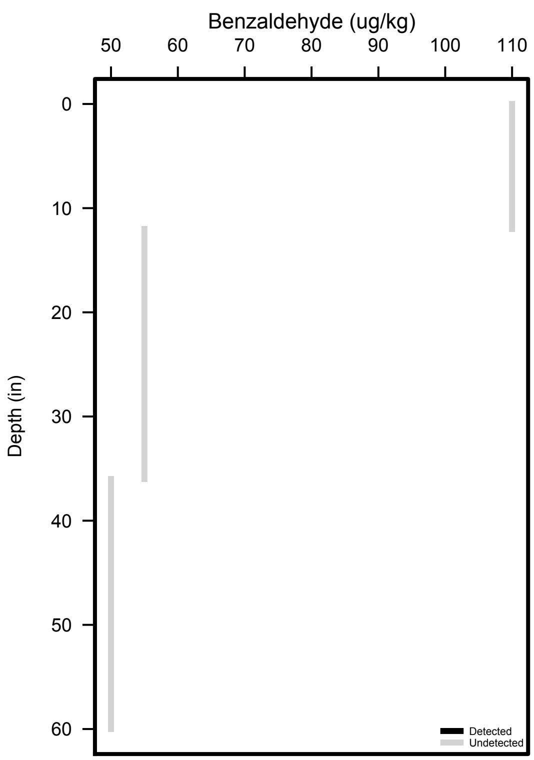

Figure 1035. Benzaldehyde at Core Location RM605C1.

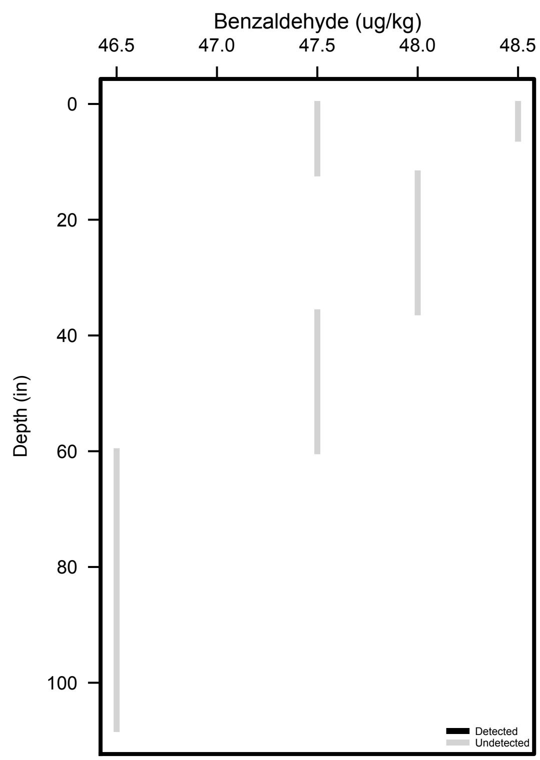

Figure 1036. Benzaldehyde at Core Location RM622C1.

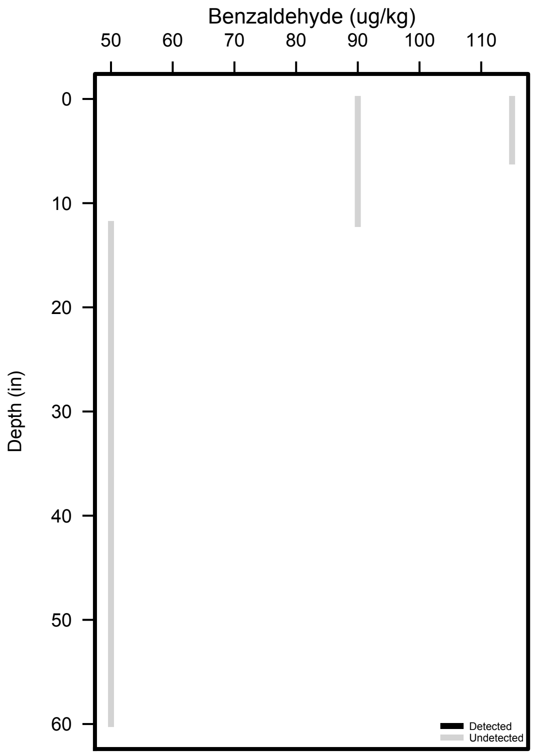

Figure 1037. Benzaldehyde
at Core Location RM637C1.

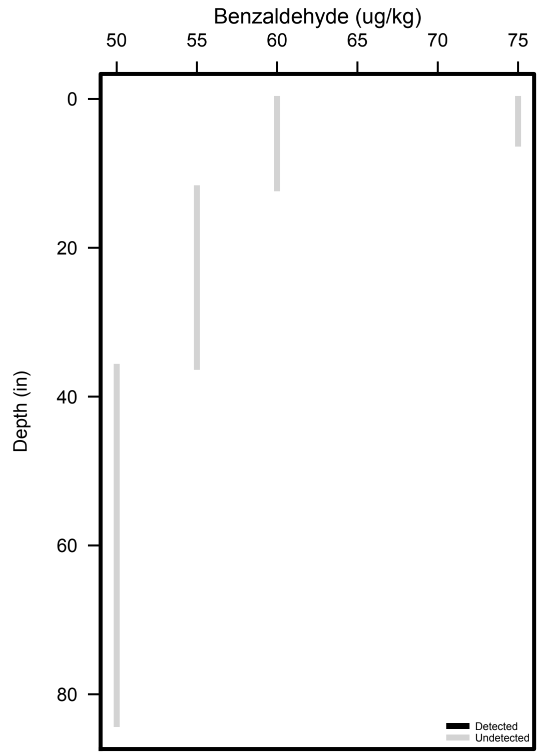

Figure 1038. Benzaldehyde
at Core Location RM644C1.

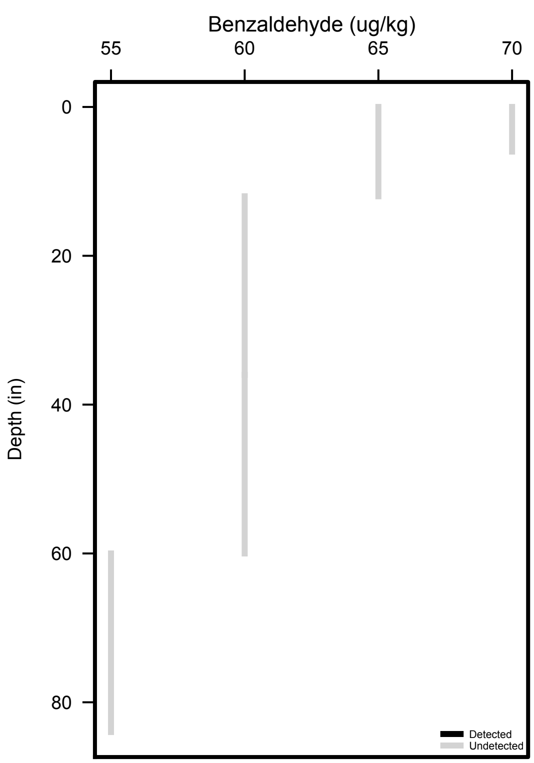

Figure 1039. Benzaldehyde
at Core Location RM661C1.

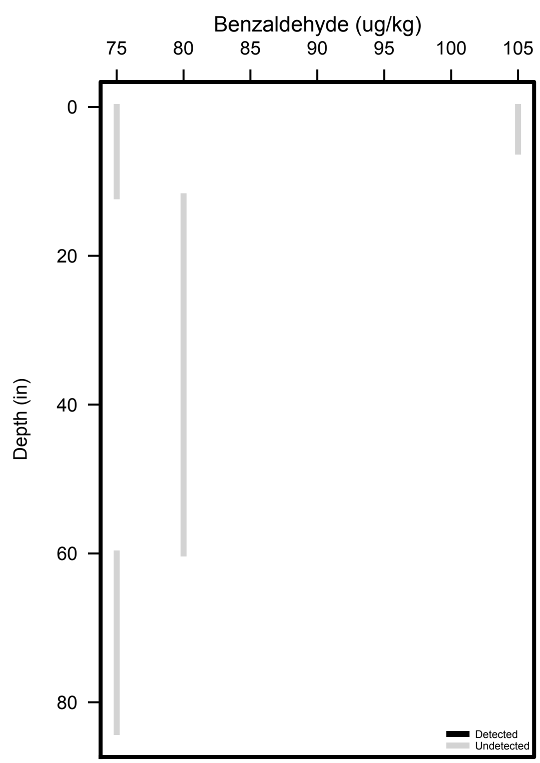

Figure 1040. Benzaldehyde
at Core Location RM676C1.

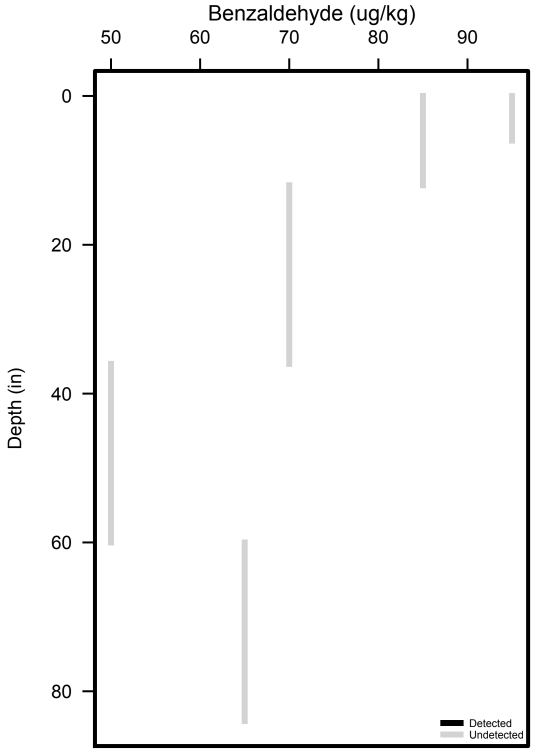

Figure 1041. Benzaldehyde
at Core Location RM692C1.

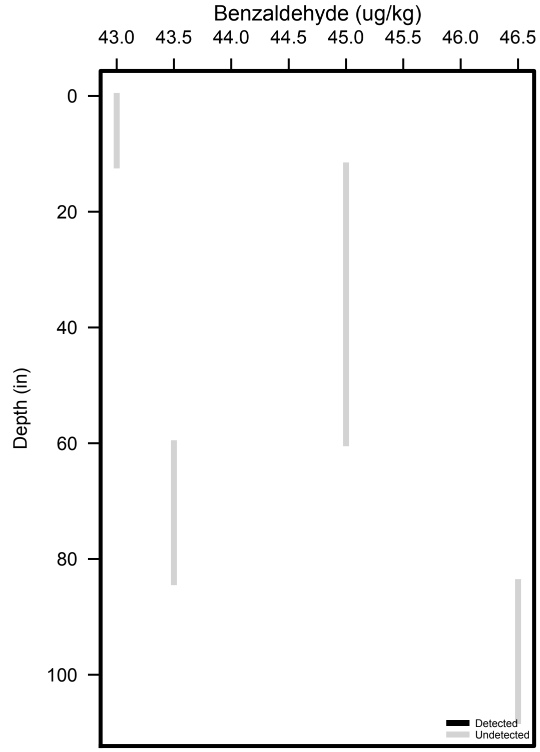

Figure 1042. Benzaldehyde
at Core Location RM704C1.

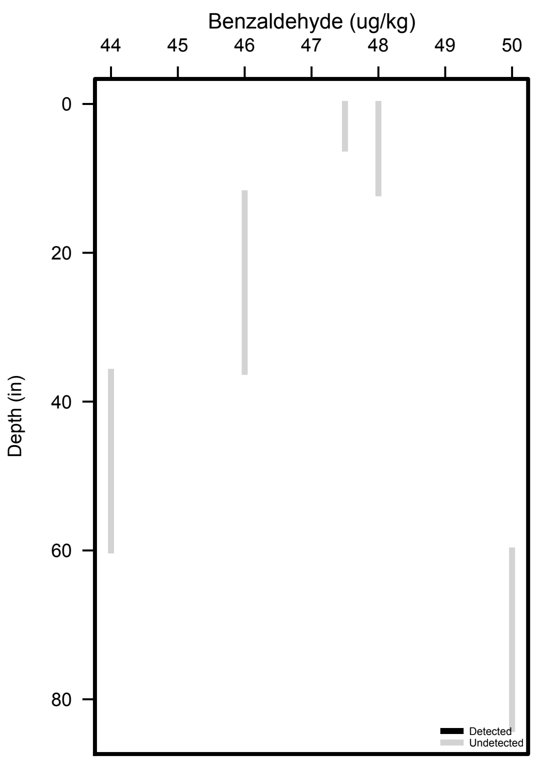

Figure 1043. Benzaldehyde
at Core Location RM708C1.

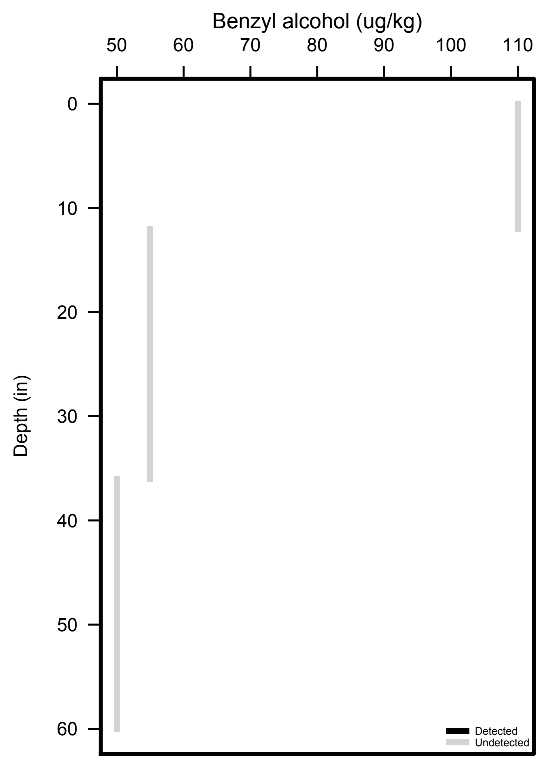

Figure 1044. Benzyl alcohol
at Core Location RM605C1.

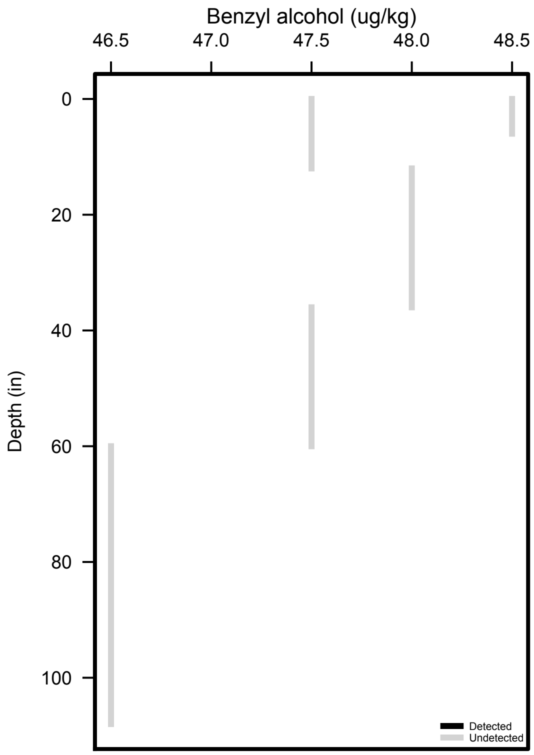

Figure 1045. Benzyl alcohol
at Core Location RM622C1.

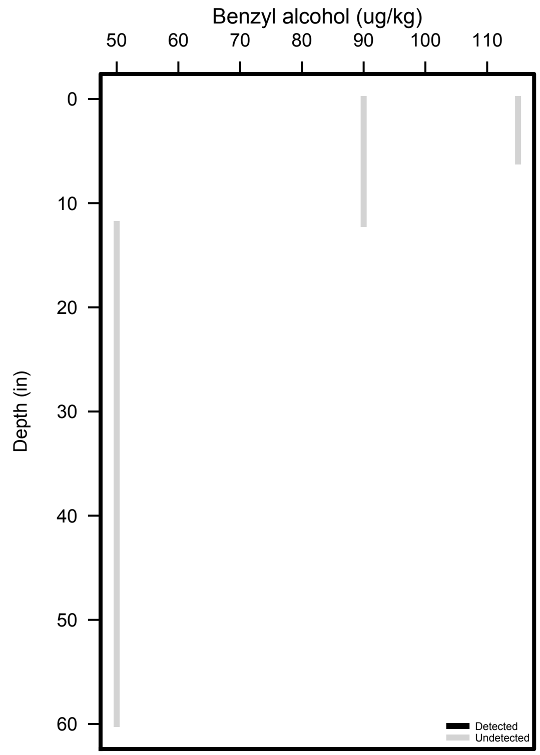

Figure 1046. Benzyl alcohol
at Core Location RM637C1.

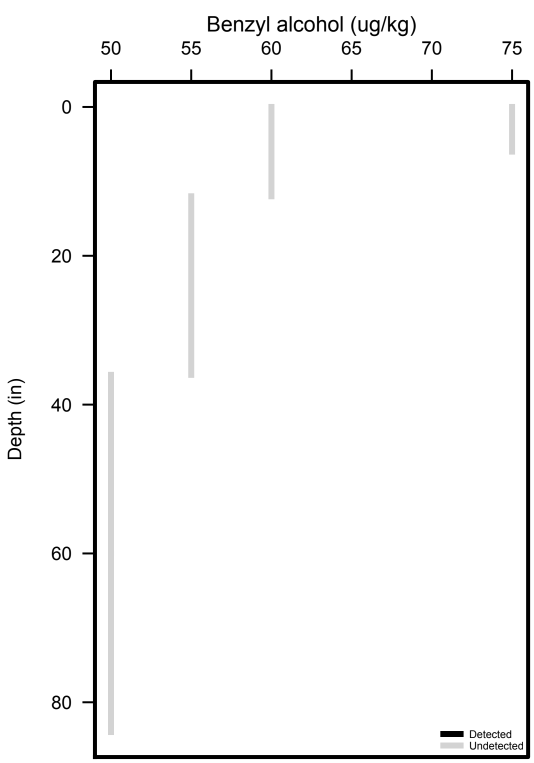

Figure 1047. Benzyl alcohol
at Core Location RM644C1.

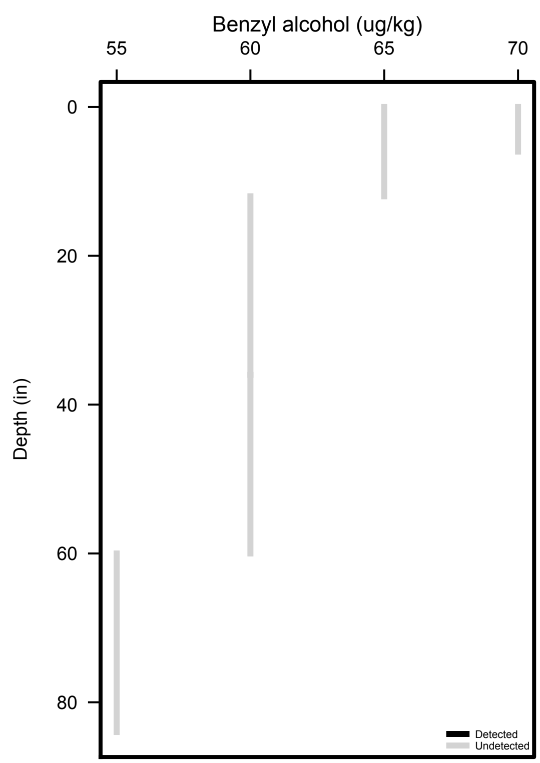

Figure 1048. Benzyl alcohol
at Core Location RM661C1.

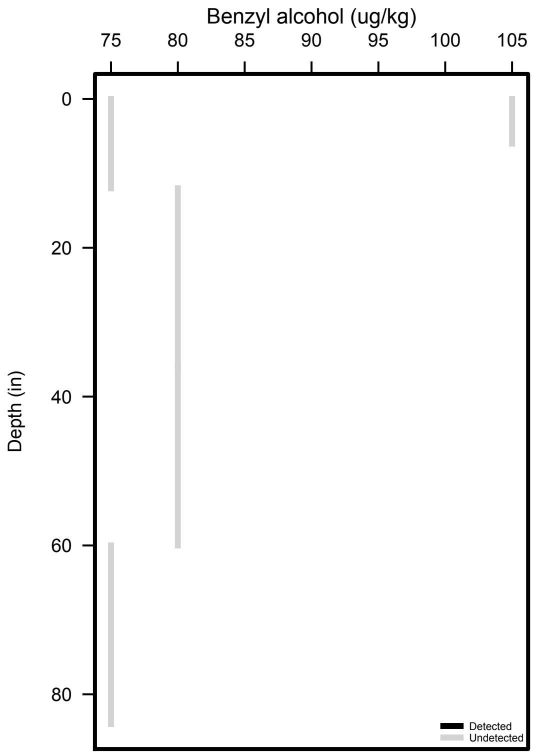

Figure 1049. Benzyl alcohol at Core Location RM676C1.

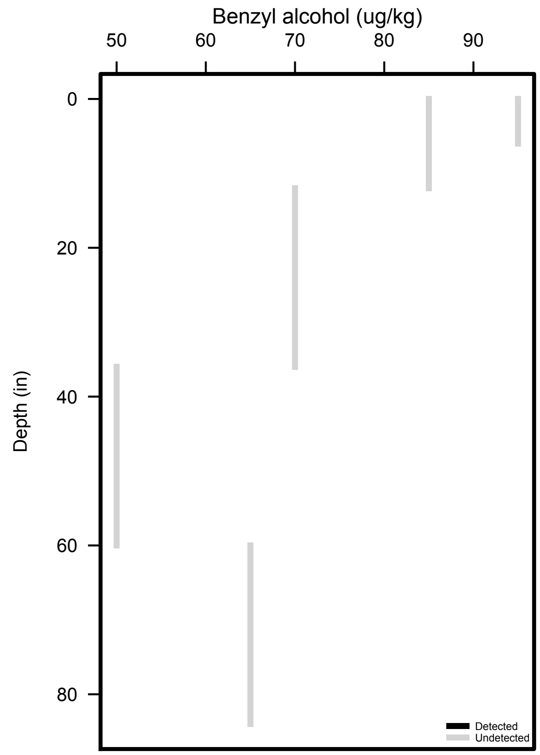

Figure 1050. Benzyl alcohol at Core Location RM692C1.

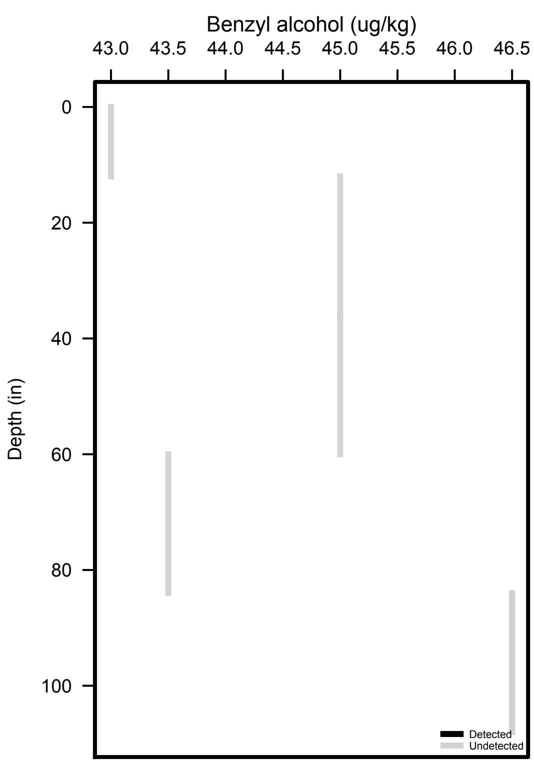

Figure 1051. Benzyl alcohol at Core Location RM704C1.

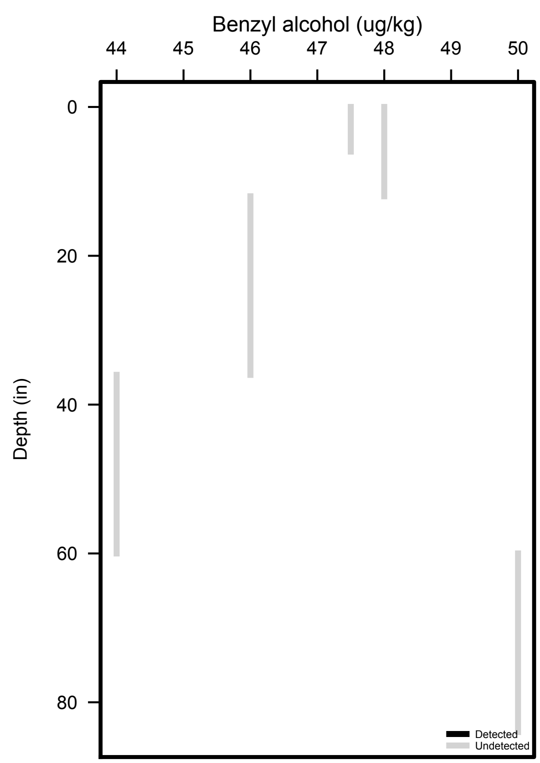

Figure 1052. Benzyl alcohol at Core Location RM708C1.

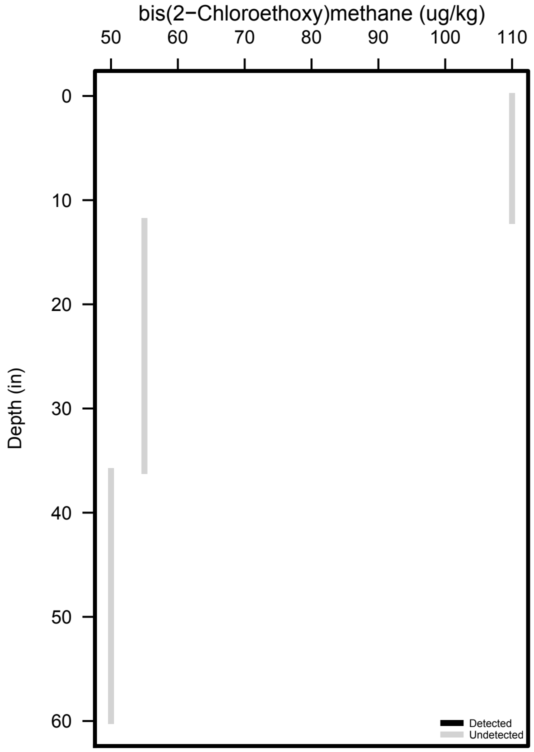

Figure 1053. bis(2−Chloroethoxy)methane at Core Location RM605C1.

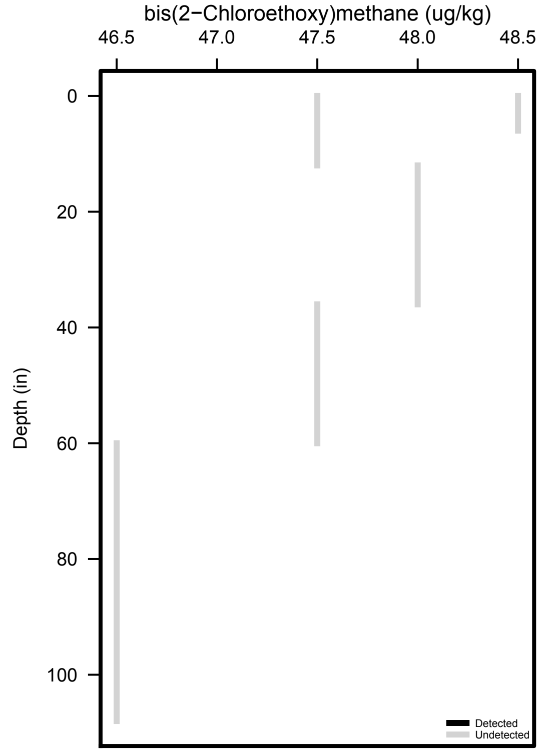

Figure 1054. bis(2−Chloroethoxy)methane at Core Location RM622C1.

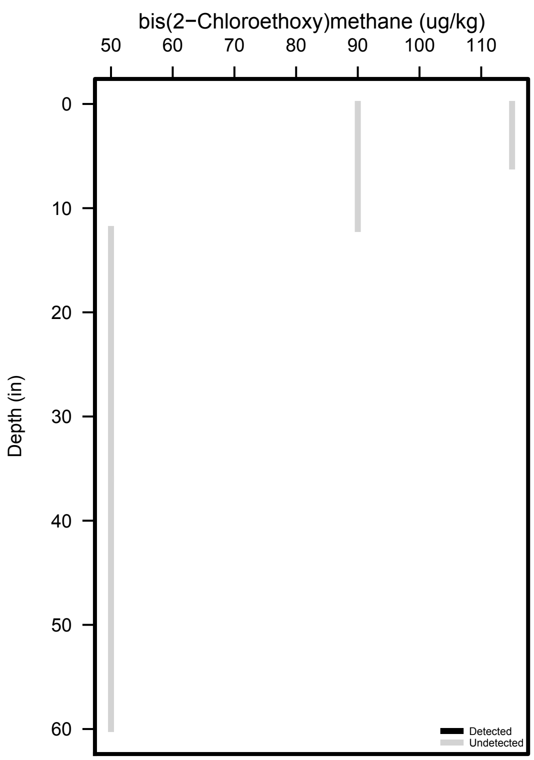

Figure 1055. bis(2−Chloroethoxy)methane at Core Location RM637C1.

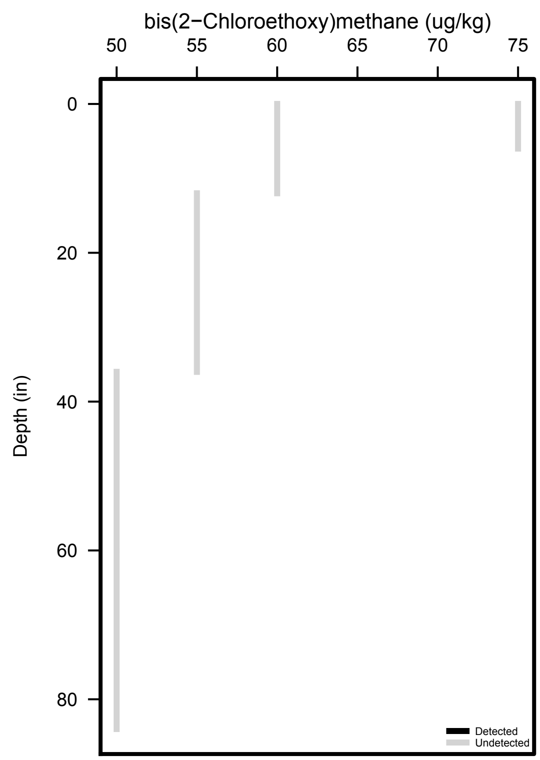

Figure 1056. bis(2−Chloroethoxy)methane at Core Location RM644C1.

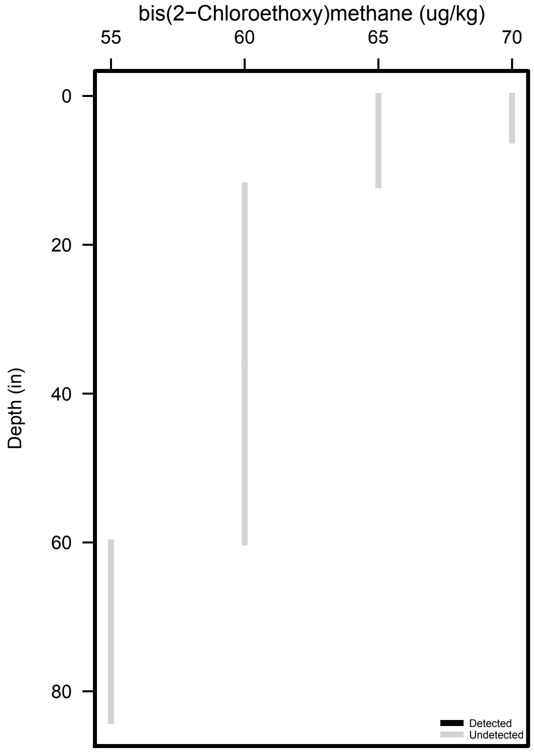

Figure 1057. bis(2−Chloroethoxy)methane at Core Location RM661C1.

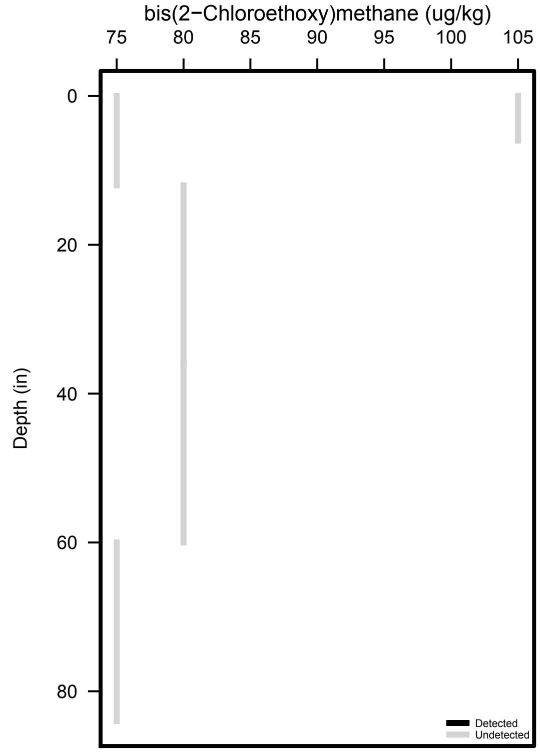

Figure 1058. bis(2−Chloroethoxy)methane at Core Location RM676C1.

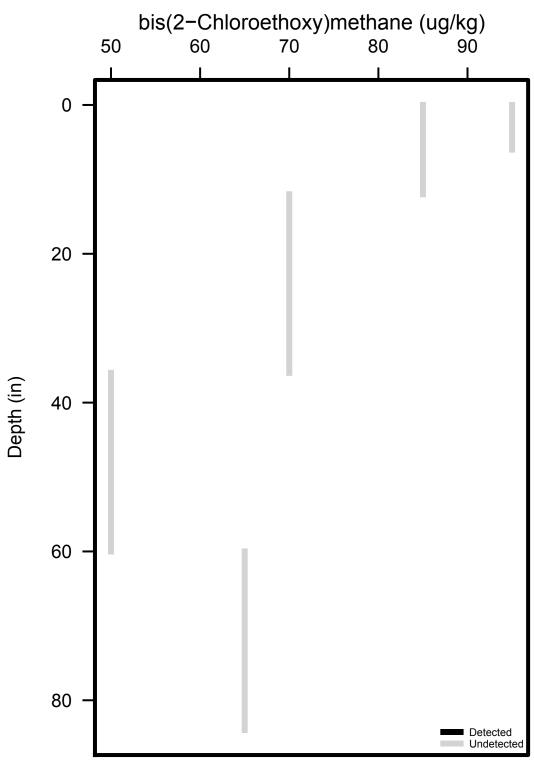

Figure 1059. bis(2−Chloroethoxy)methane at Core Location RM692C1.

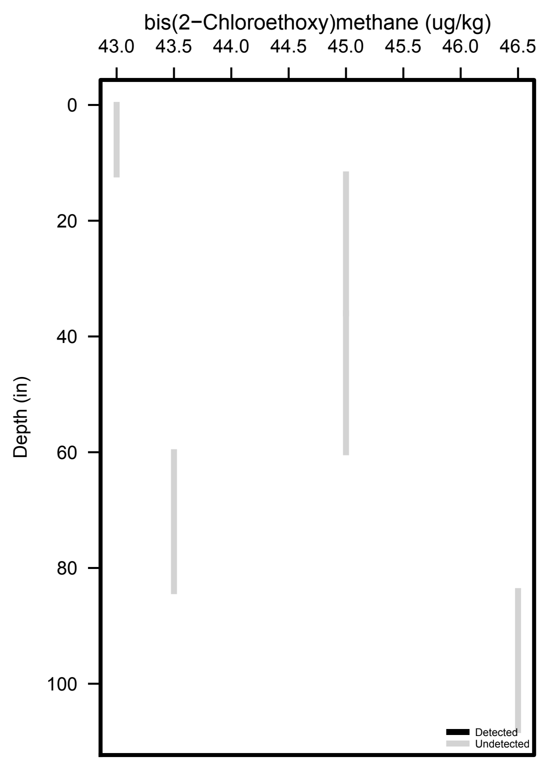

Figure 1060. bis(2−Chloroethoxy)methane at Core Location RM704C1.

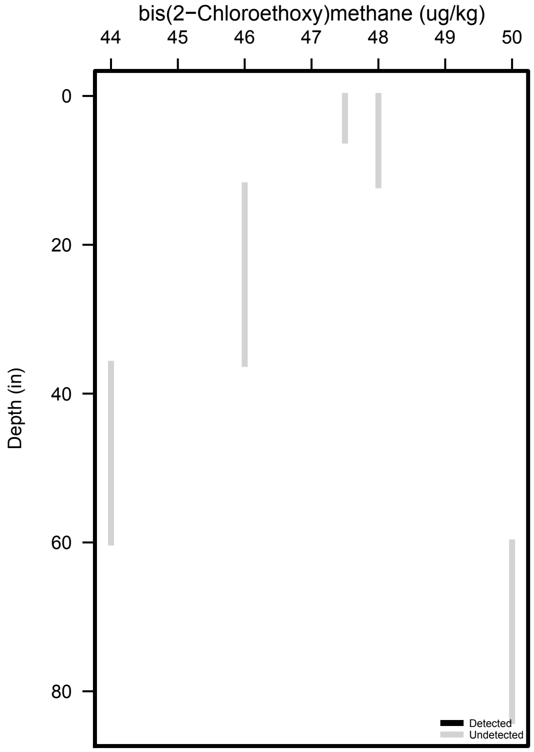

Figure 1061. bis(2−Chloroethoxy)methane
at Core Location RM708C1.

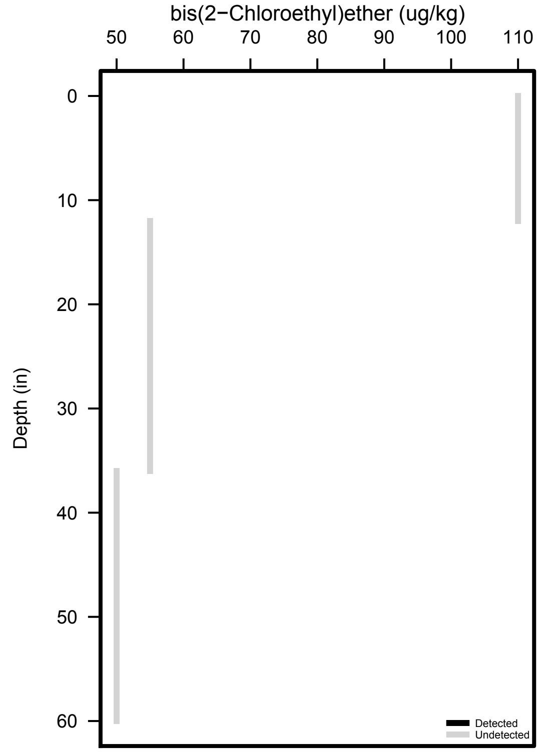

Figure 1062. bis(2−Chloroethyl)ether
at Core Location RM605C1.

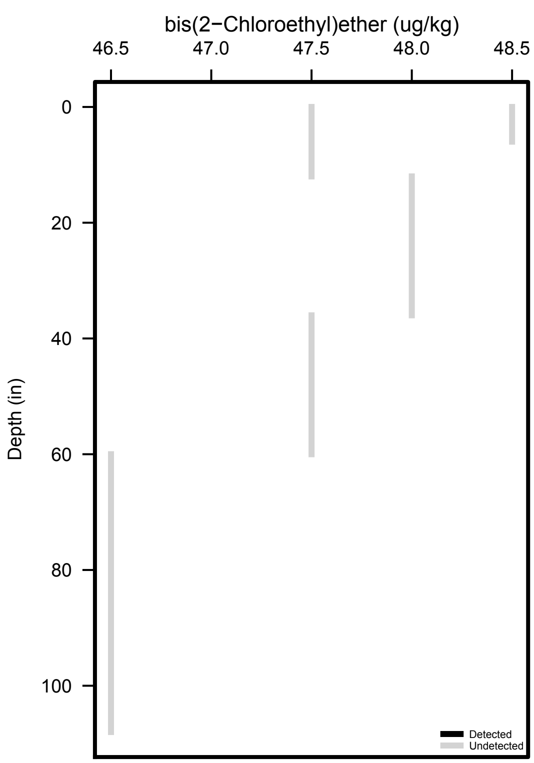

Figure 1063. bis(2−Chloroethyl)ether
at Core Location RM622C1.

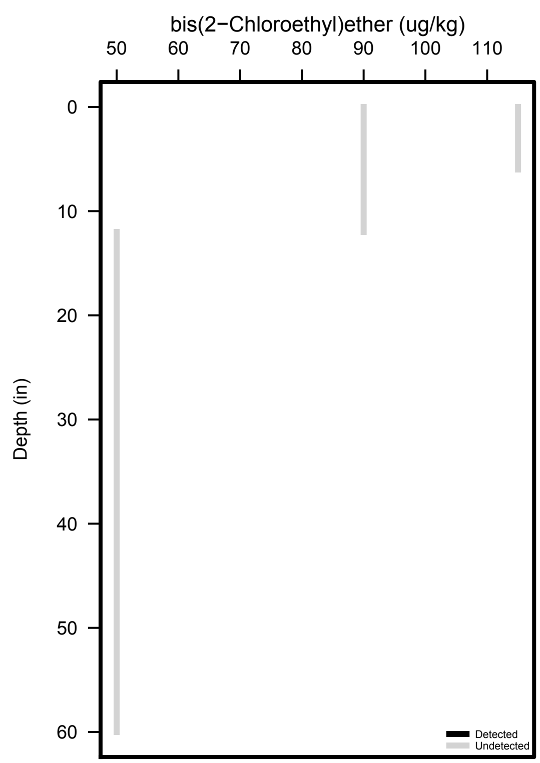

Figure 1064. bis(2−Chloroethyl)ether
at Core Location RM637C1.

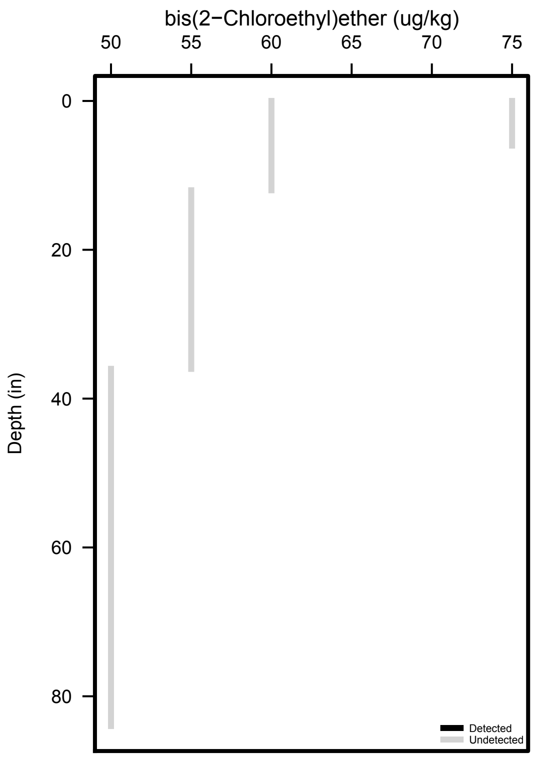

Figure 1065. bis(2−Chloroethyl)ether at Core Location RM644C1.

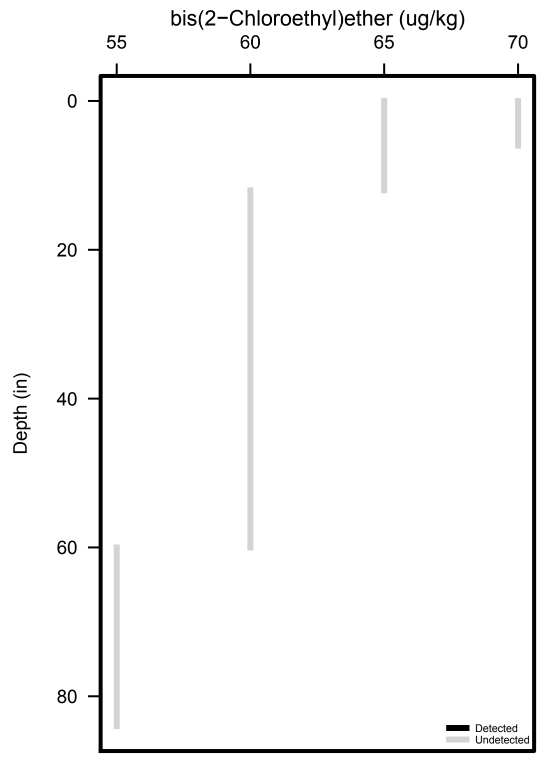

Figure 1066. bis(2−Chloroethyl)ether at Core Location RM661C1.

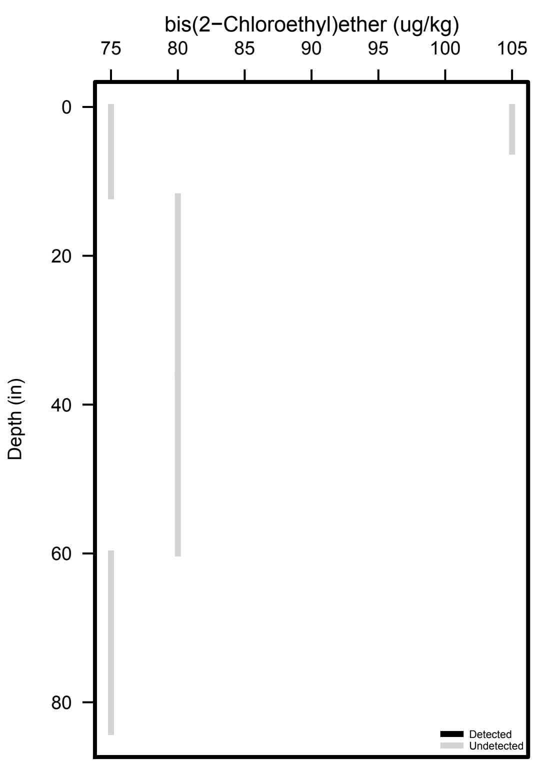

Figure 1067. bis(2−Chloroethyl)ether at Core Location RM676C1.

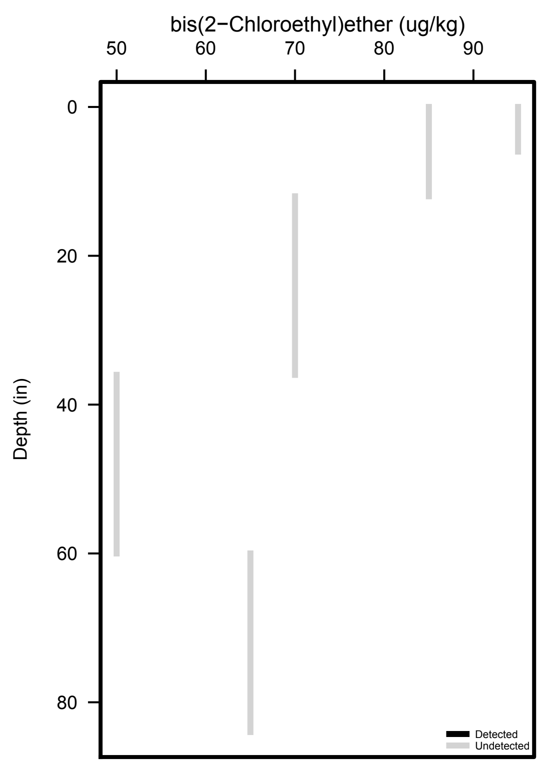

Figure 1068. bis(2−Chloroethyl)ether at Core Location RM692C1.

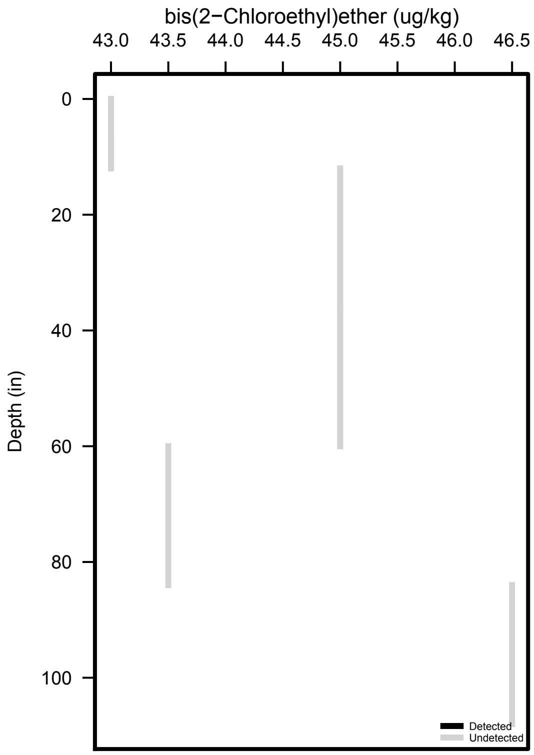

Figure 1069. bis(2−Chloroethyl)ether
at Core Location RM704C1.

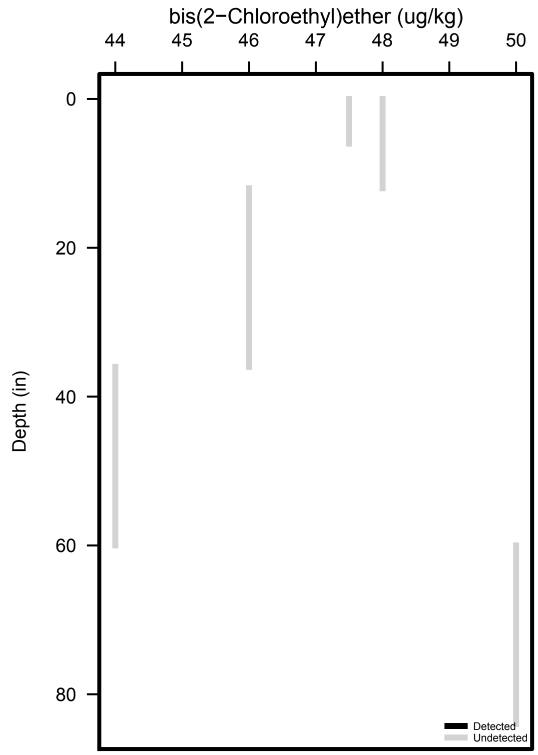

Figure 1070. bis(2−Chloroethyl)ether
at Core Location RM708C1.

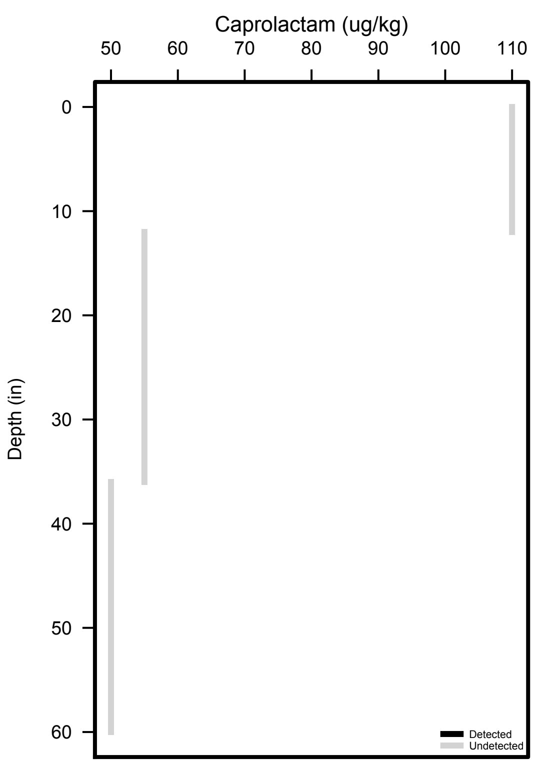

Figure 1071. Caprolactam
at Core Location RM605C1.

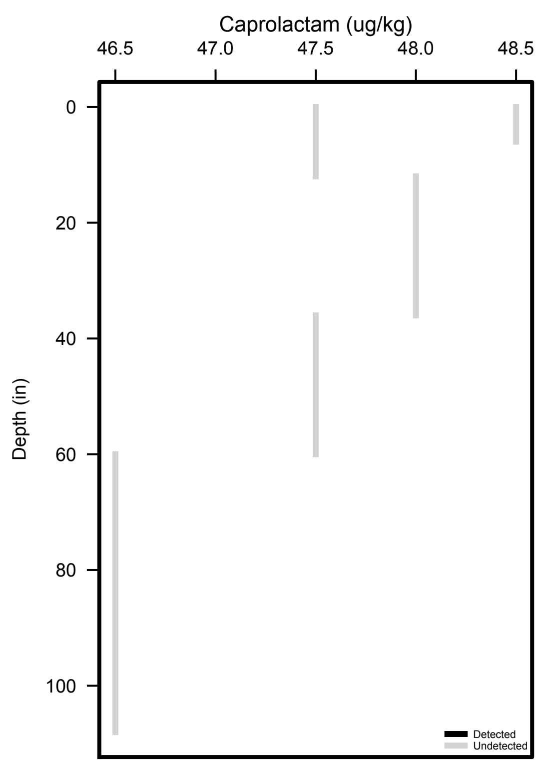

Figure 1072. Caprolactam
at Core Location RM622C1.

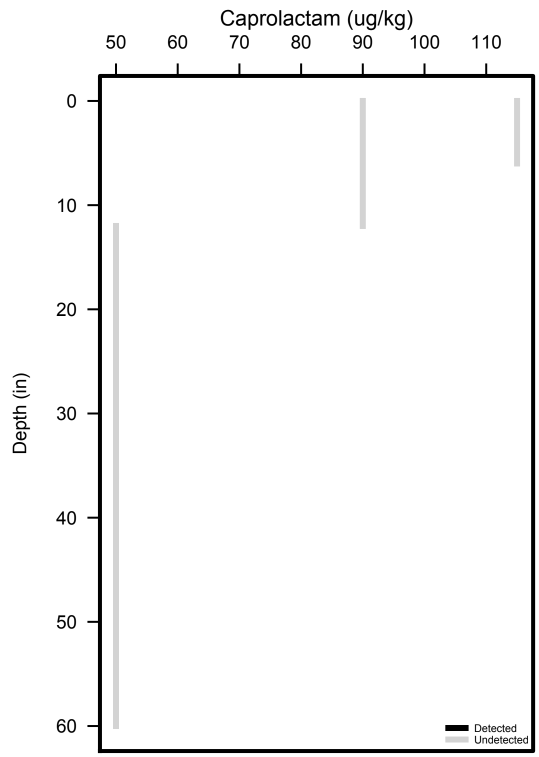

Figure 1073. Caprolactam
at Core Location RM637C1.

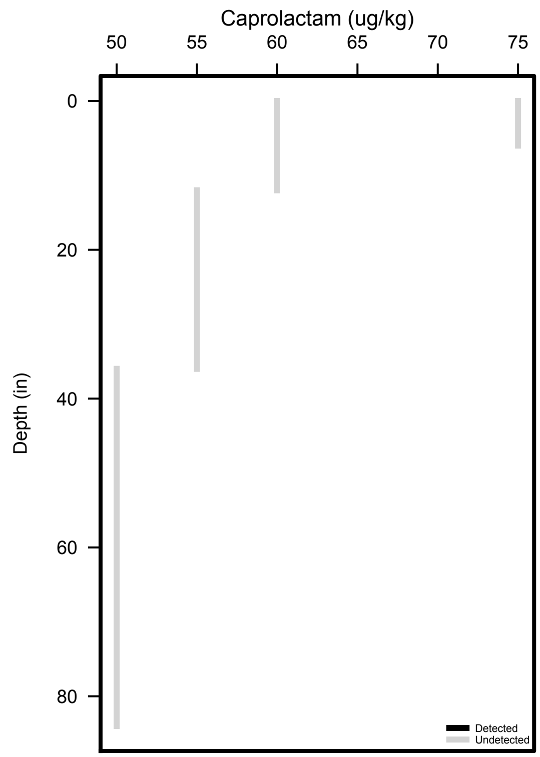

Figure 1074. Caprolactam
at Core Location RM644C1.

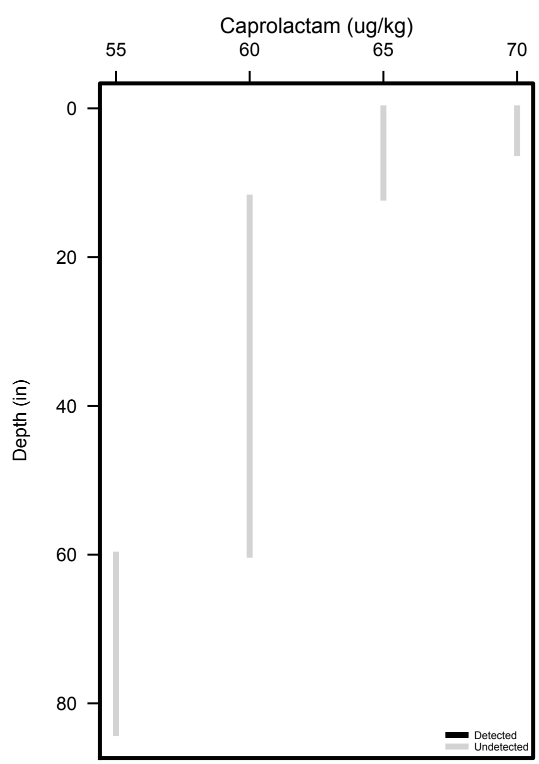

Figure 1075. Caprolactam
at Core Location RM661C1.

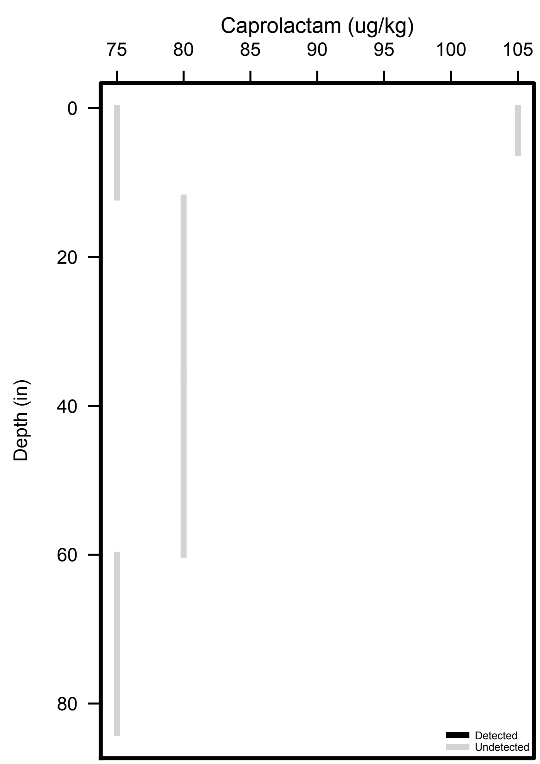

Figure 1076. Caprolactam
at Core Location RM676C1.

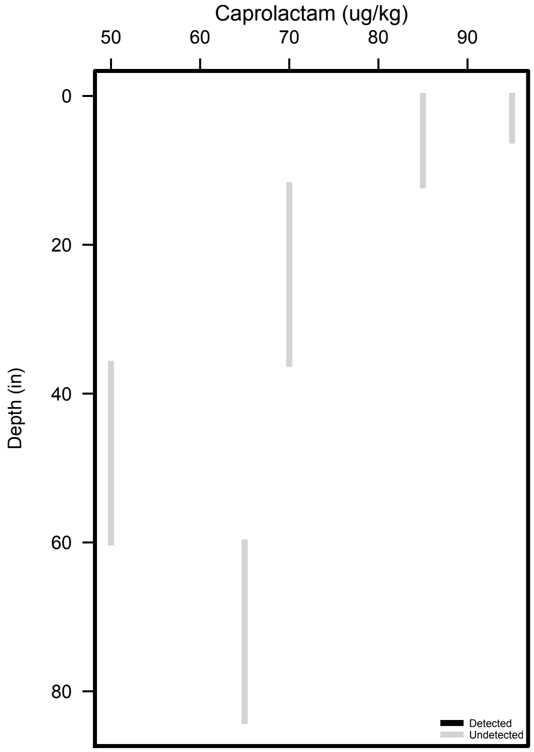

Figure 1077. Caprolactam
at Core Location RM692C1.

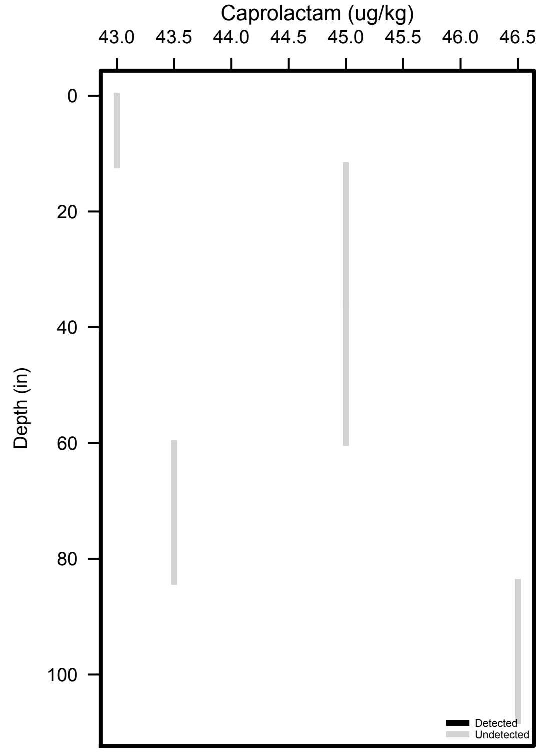

Figure 1078. Caprolactam
at Core Location RM704C1.

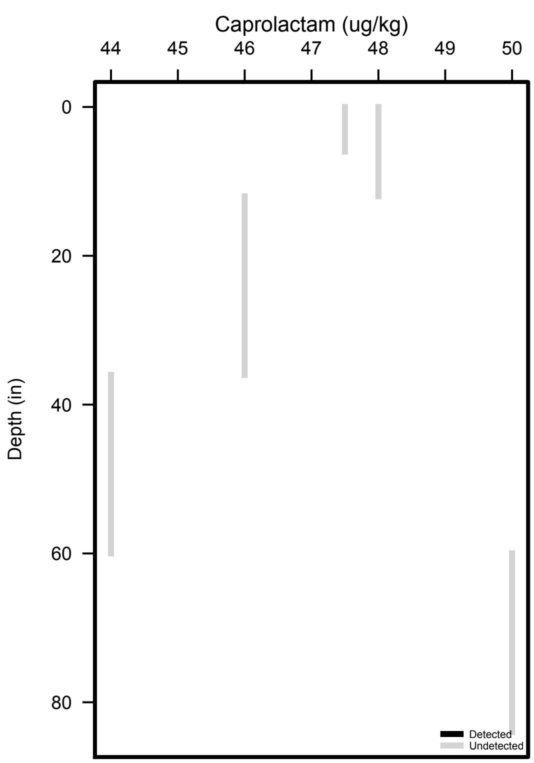

Figure 1079. Caprolactam
at Core Location RM708C1.

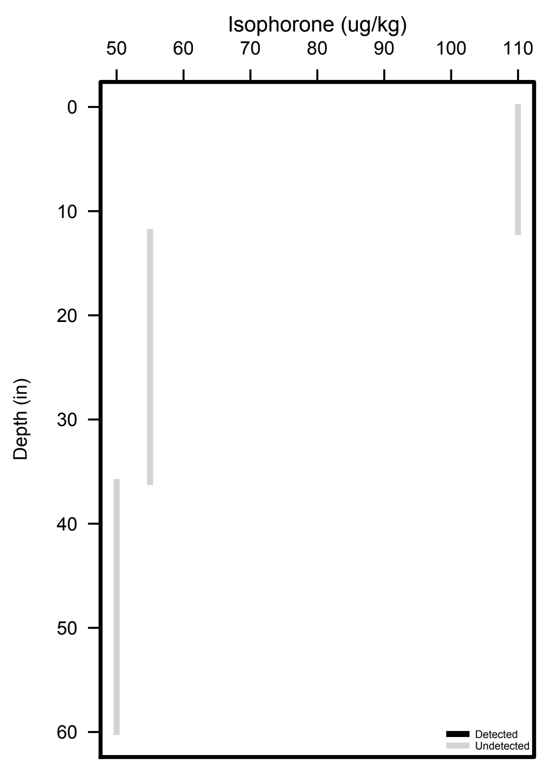

Figure 1080. Isophorone
at Core Location RM605C1.

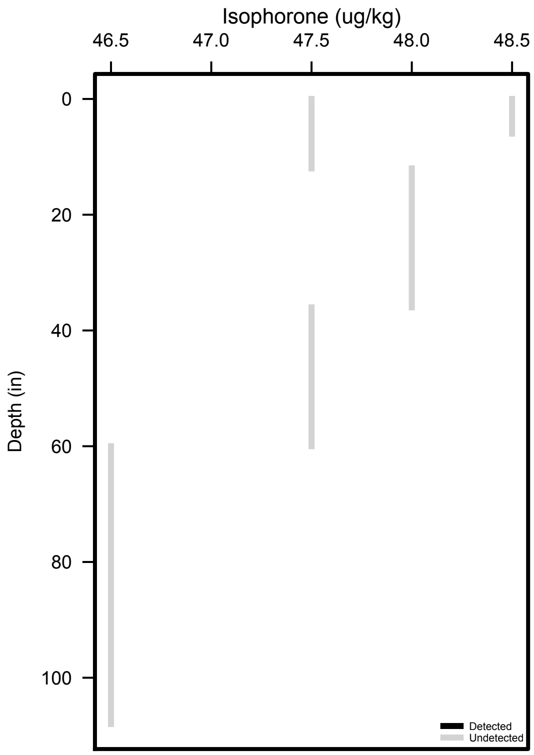

Figure 1081. Isophorone
at Core Location RM622C1.

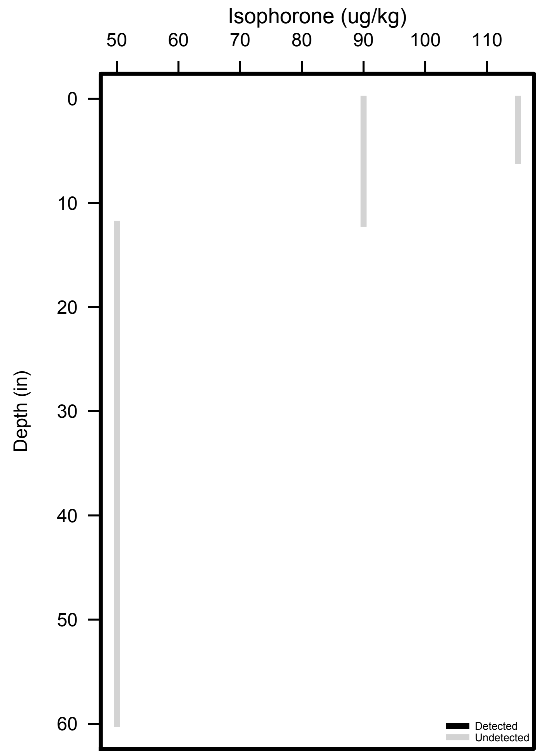

Figure 1082. Isophorone
at Core Location RM637C1.

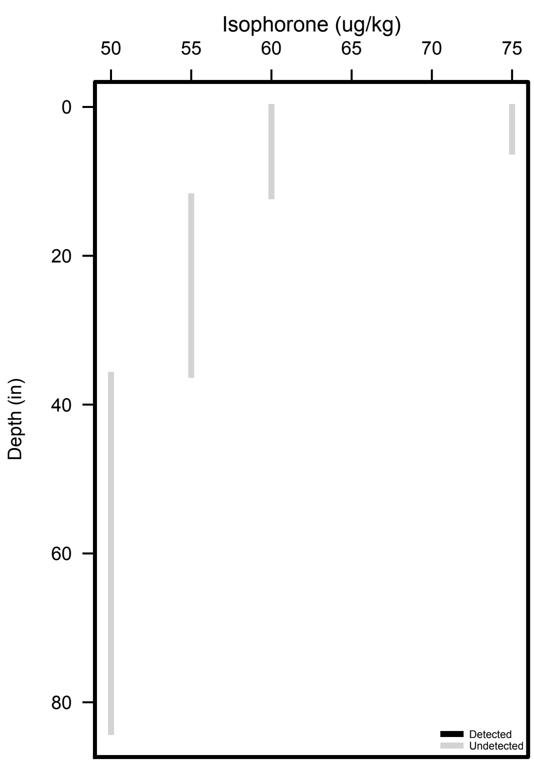

Figure 1083. Isophorone
at Core Location RM644C1.

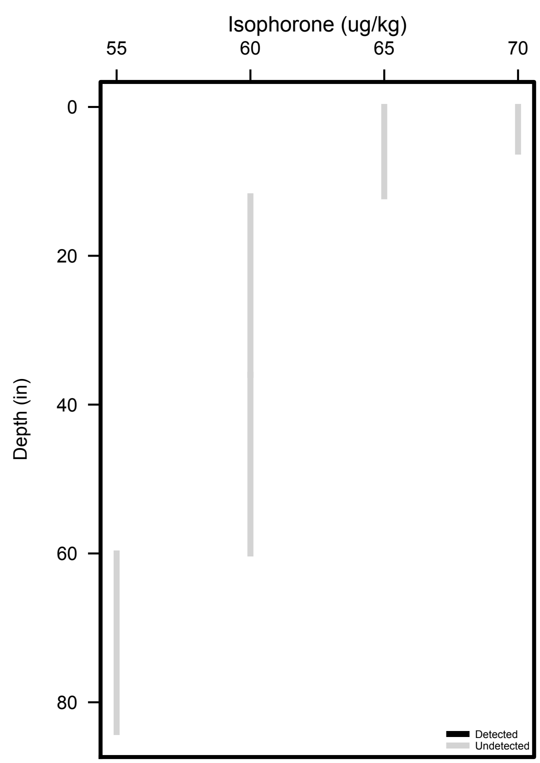

Figure 1084. Isophorone
at Core Location RM661C1.

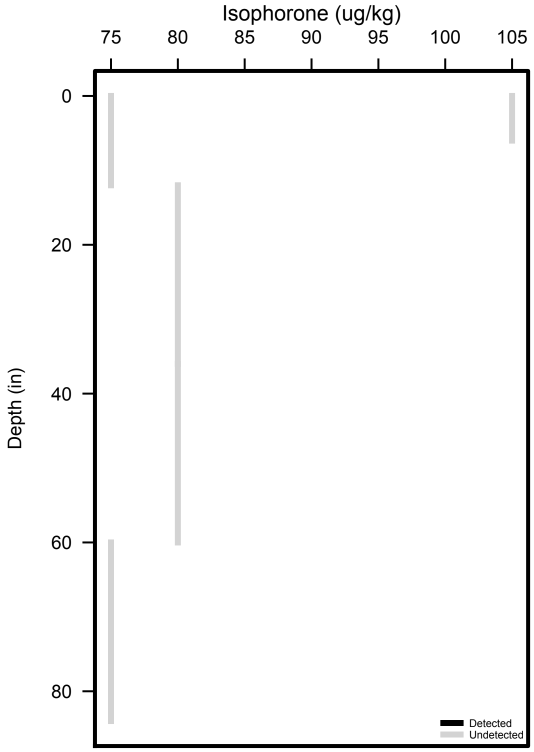

Figure 1085. Isophorone
at Core Location RM676C1.

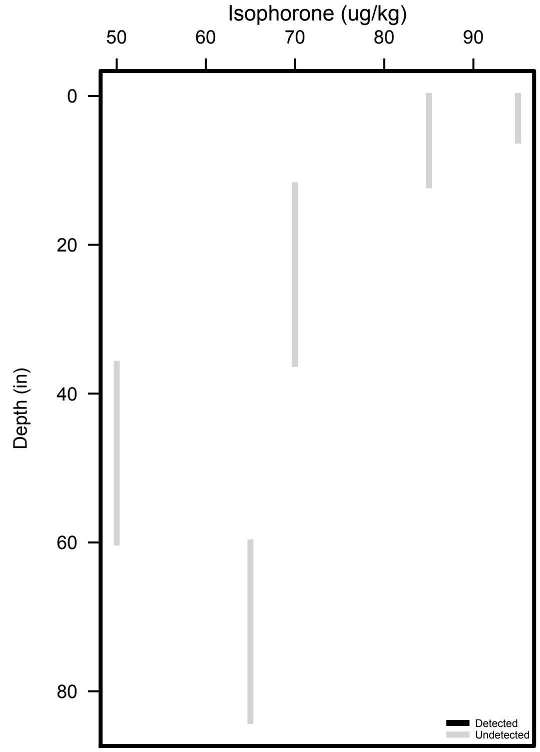

Figure 1086. Isophorone
at Core Location RM692C1.

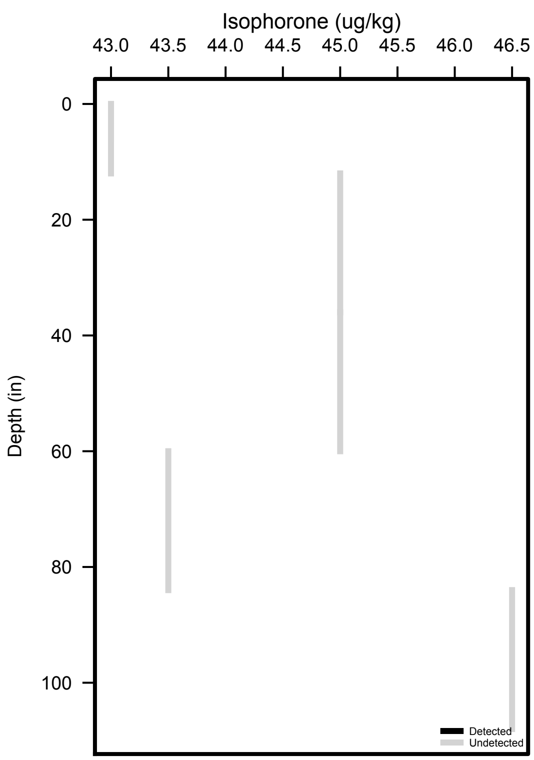

Figure 1087. Isophorone
at Core Location RM704C1.

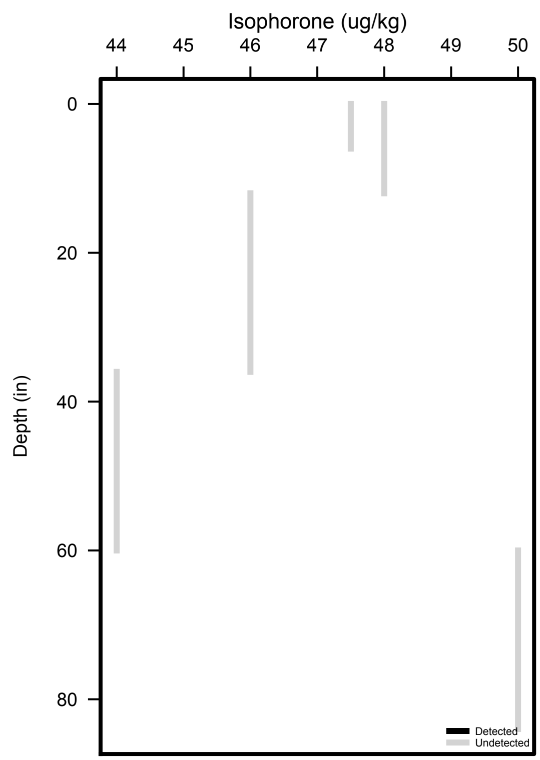

Figure 1088. Isophorone
at Core Location RM708C1.

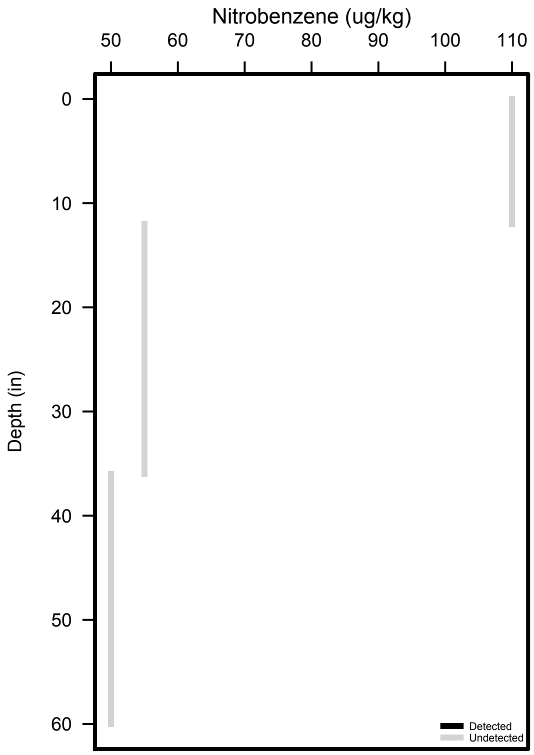

Figure 1089. Nitrobenzene
at Core Location RM605C1.

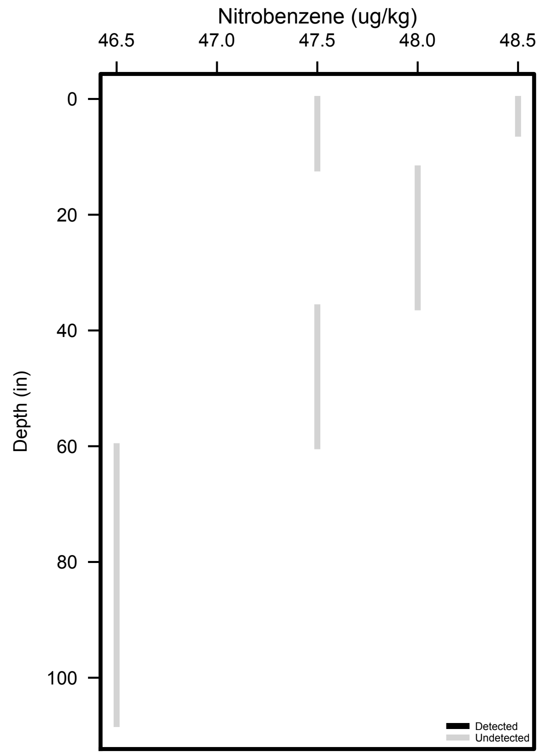

Figure 1090. Nitrobenzene
at Core Location RM622C1.

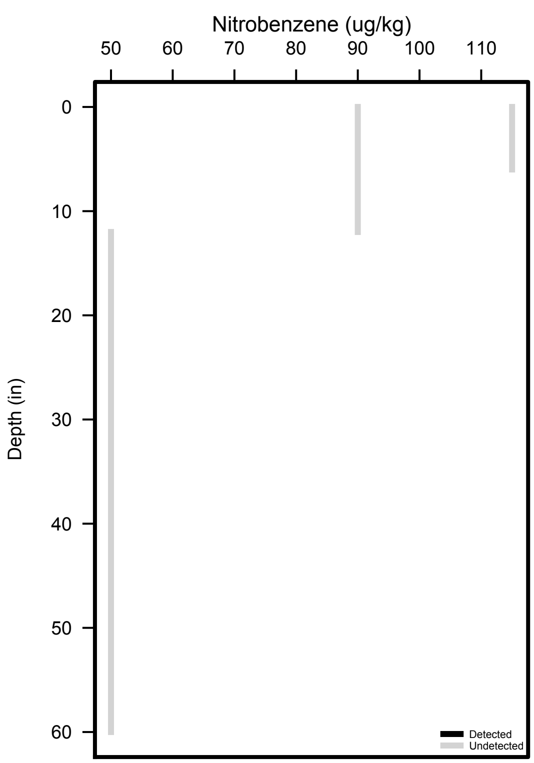

Figure 1091. Nitrobenzene
at Core Location RM637C1.

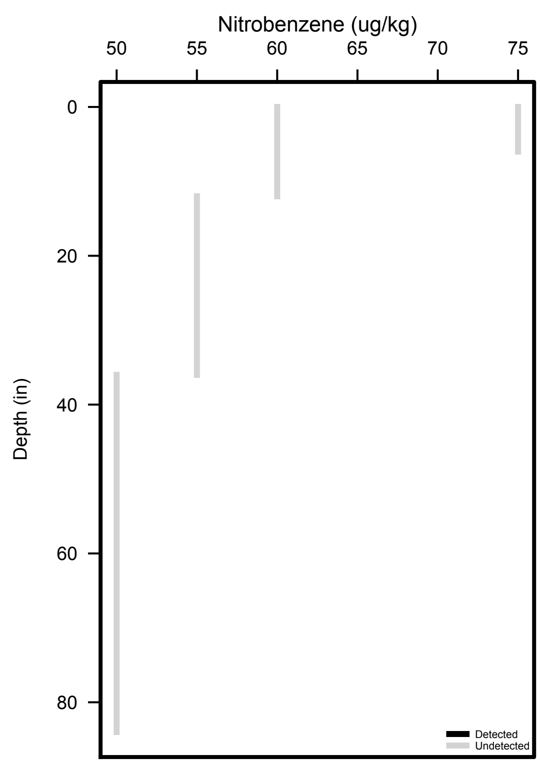

Figure 1092. Nitrobenzene
at Core Location RM644C1.

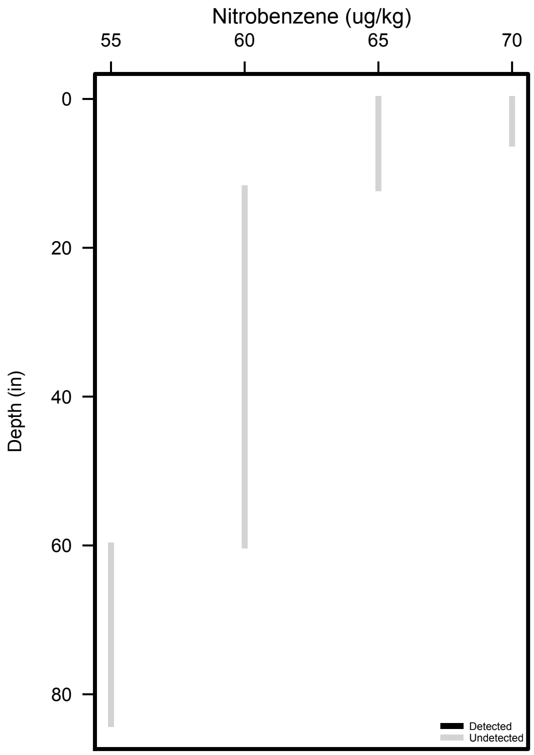

Figure 1093. Nitrobenzene
at Core Location RM661C1.

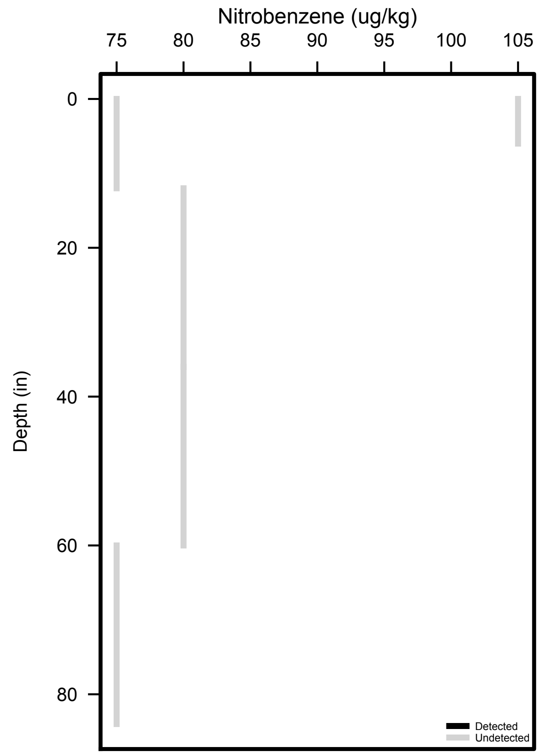

Figure 1094. Nitrobenzene
at Core Location RM676C1.

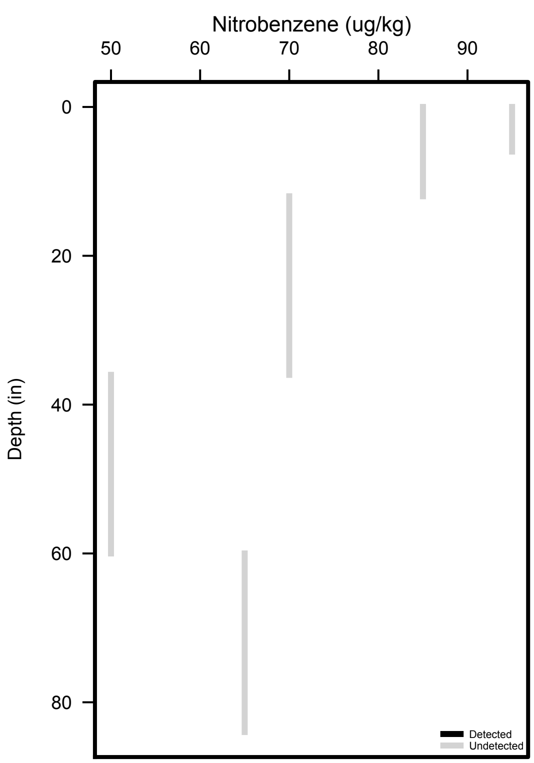

Figure 1095. Nitrobenzene
at Core Location RM692C1.

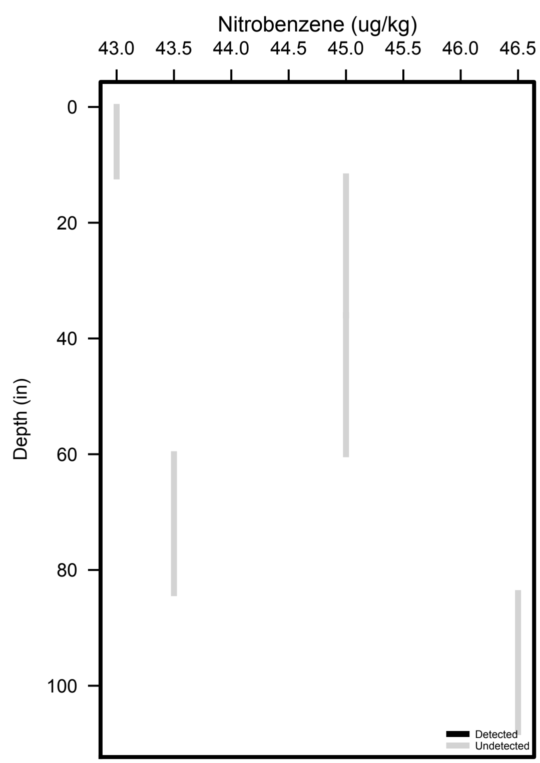

Figure 1096. Nitrobenzene
at Core Location RM704C1.

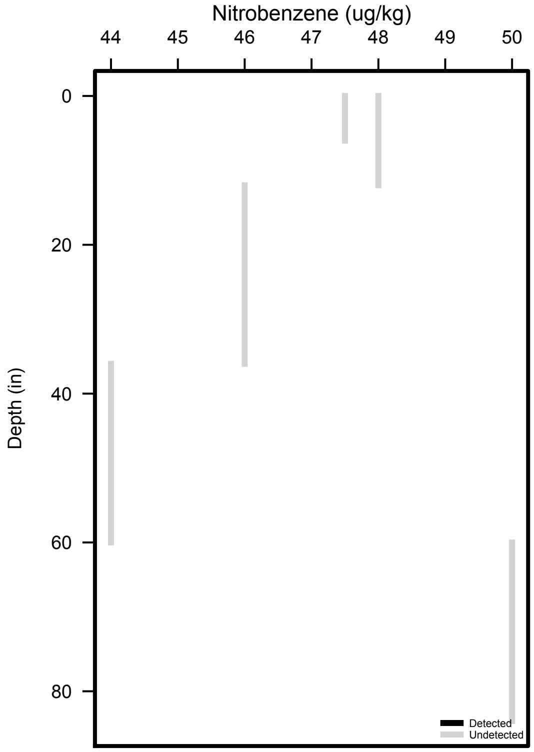

Figure 1097. Nitrobenzene
at Core Location RM708C1.

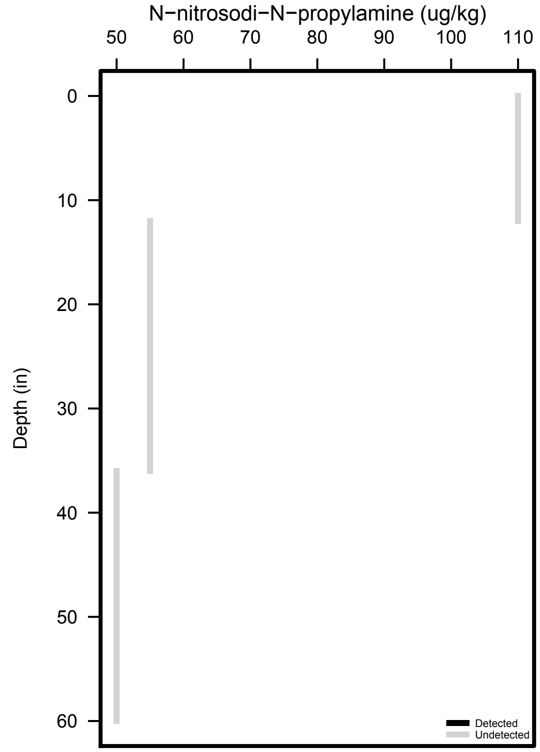

Figure 1098. N−nitrosodi−N−propylamine
at Core Location RM605C1.

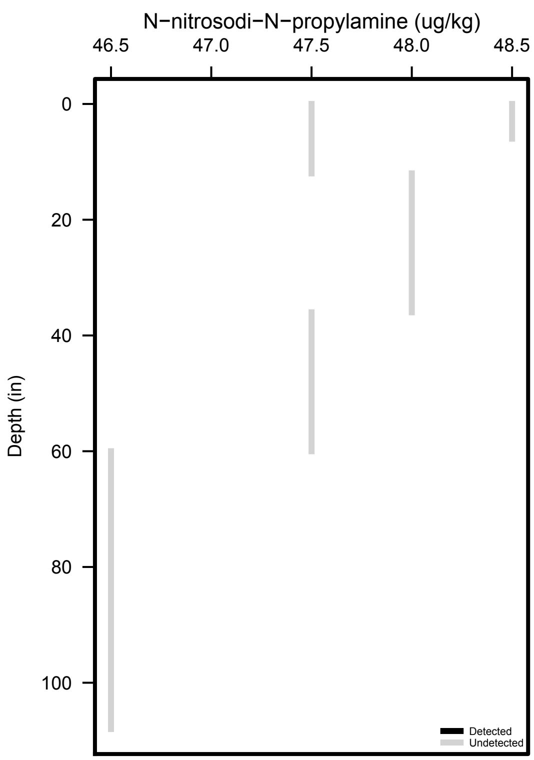

Figure 1099. N−nitrosodi−N−propylamine
at Core Location RM622C1.

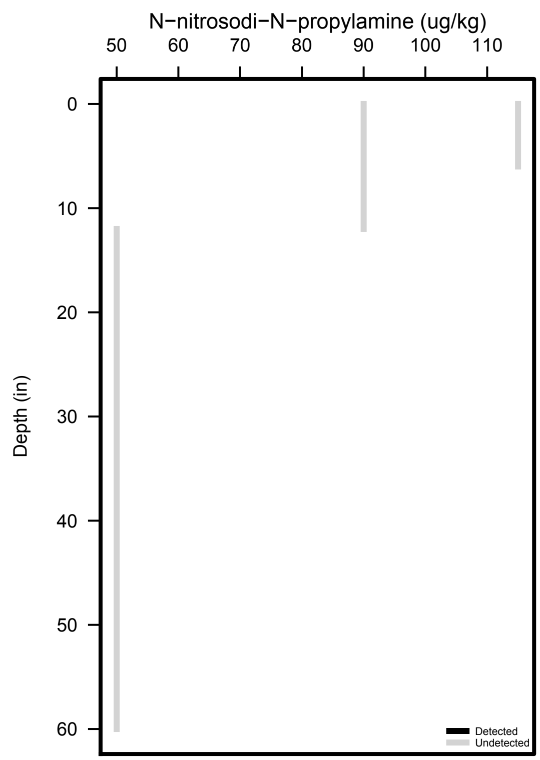

Figure 1100. N−nitrosodi−N−propylamine
at Core Location RM637C1.

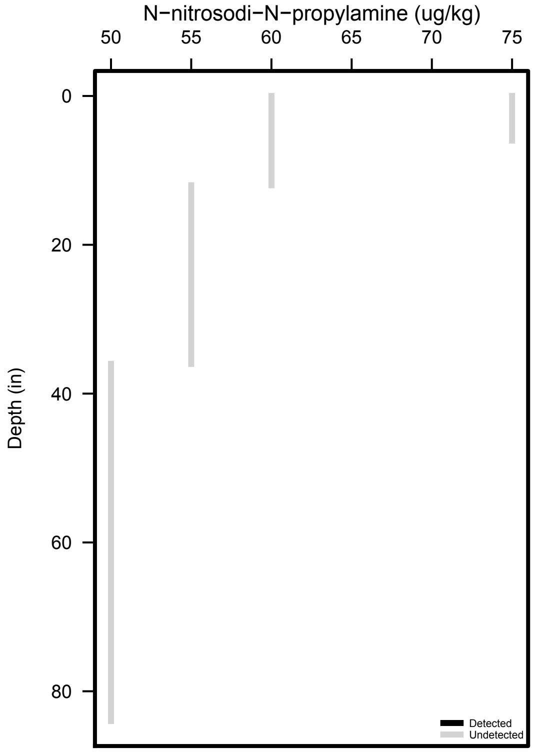

Figure 1101. N−nitrosodi−N−propylamine at Core Location RM644C1.

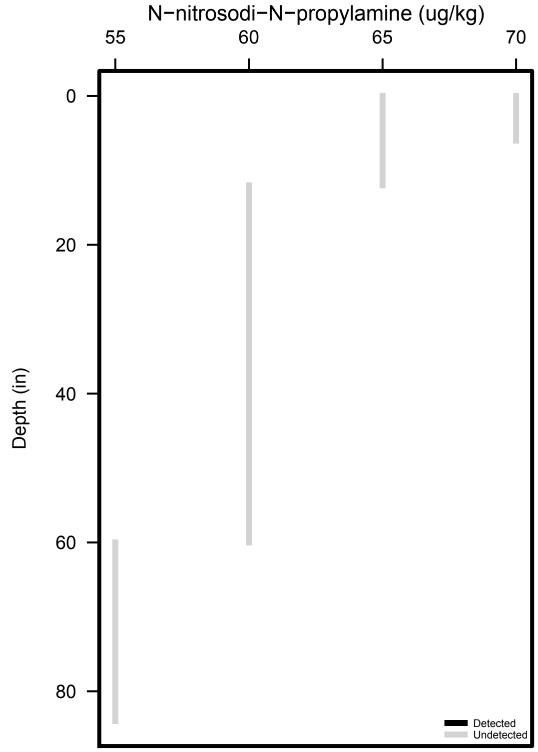

Figure 1102. N−nitrosodi−N−propylamine at Core Location RM661C1.

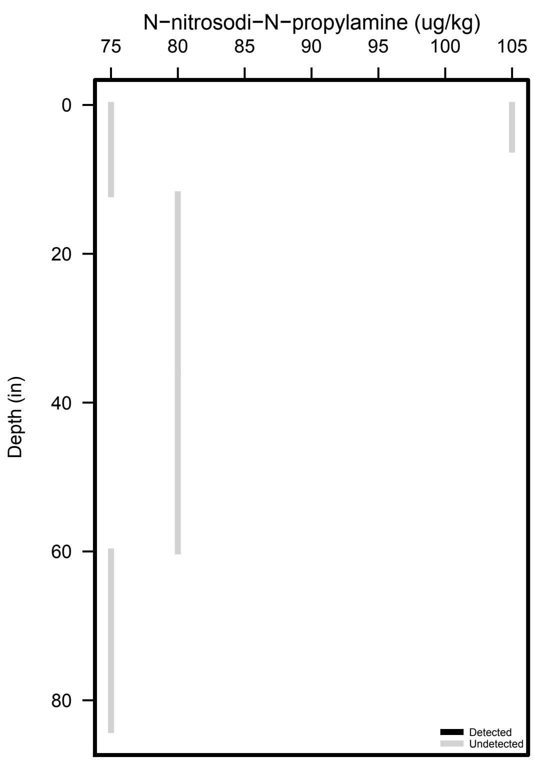

Figure 1103. N−nitrosodi−N−propylamine at Core Location RM676C1.

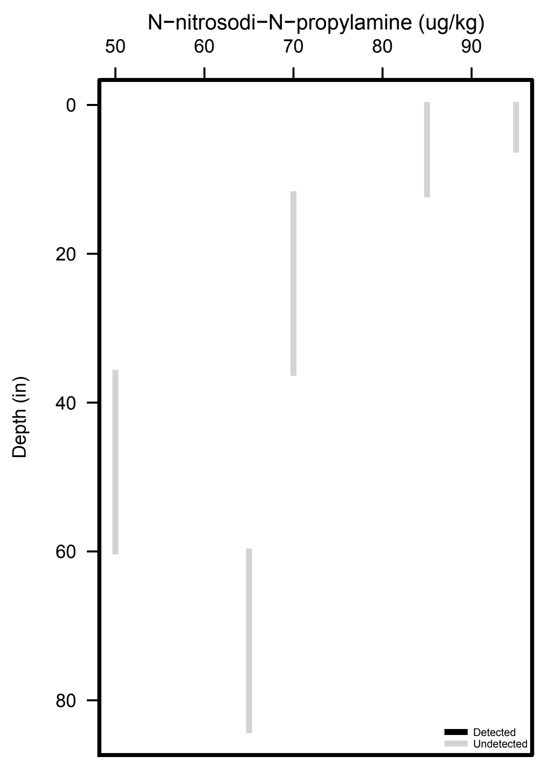

Figure 1104. N−nitrosodi−N−propylamine at Core Location RM692C1.

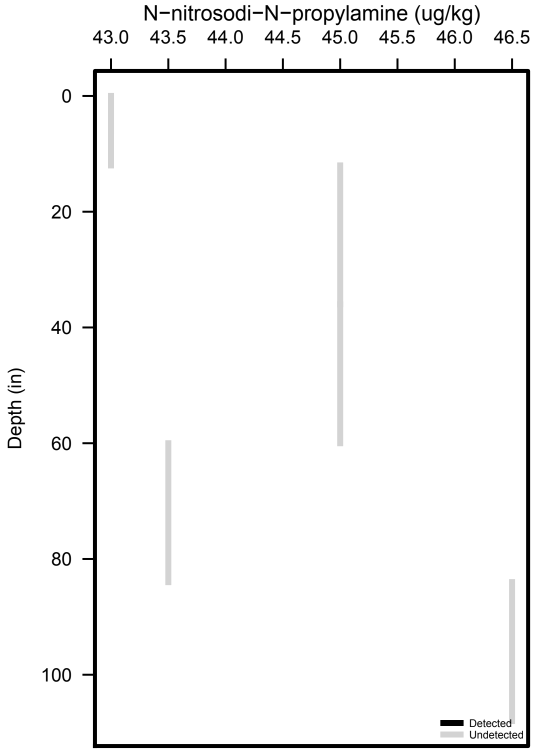

Figure 1105. N−nitrosodi−N−propylamine at Core Location RM704C1.

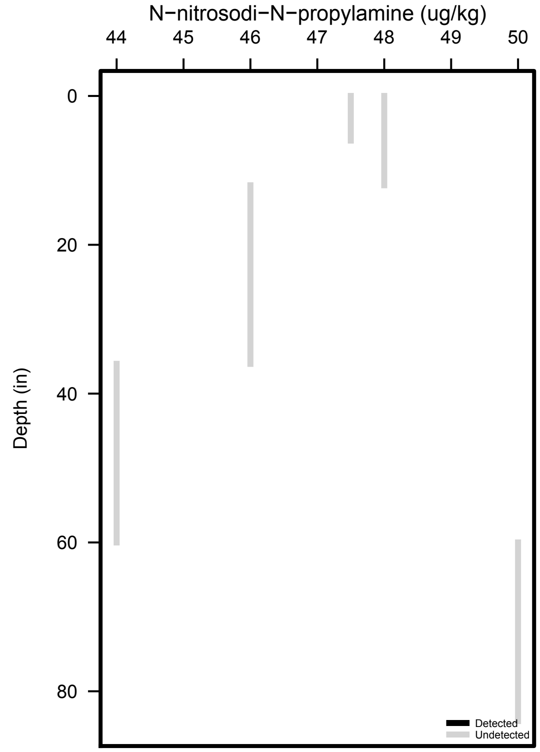

Figure 1106. N−nitrosodi−N−propylamine at Core Location RM708C1.

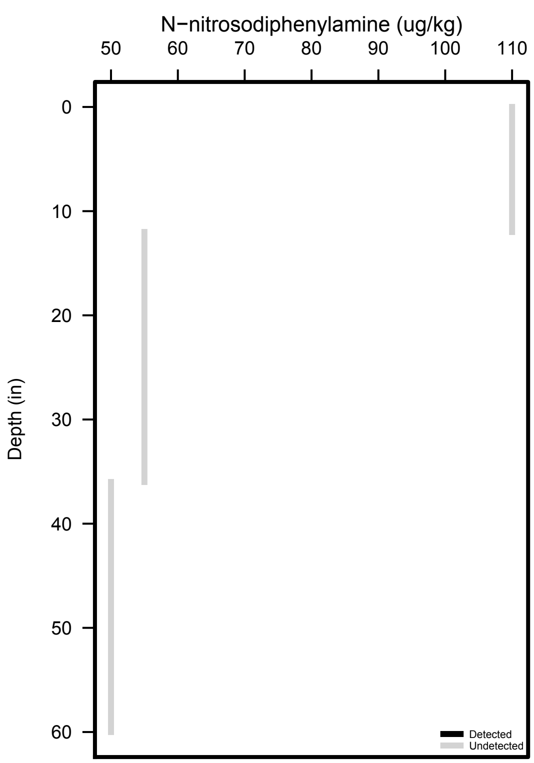

Figure 1107. N−nitrosodiphenylamine at Core Location RM605C1.

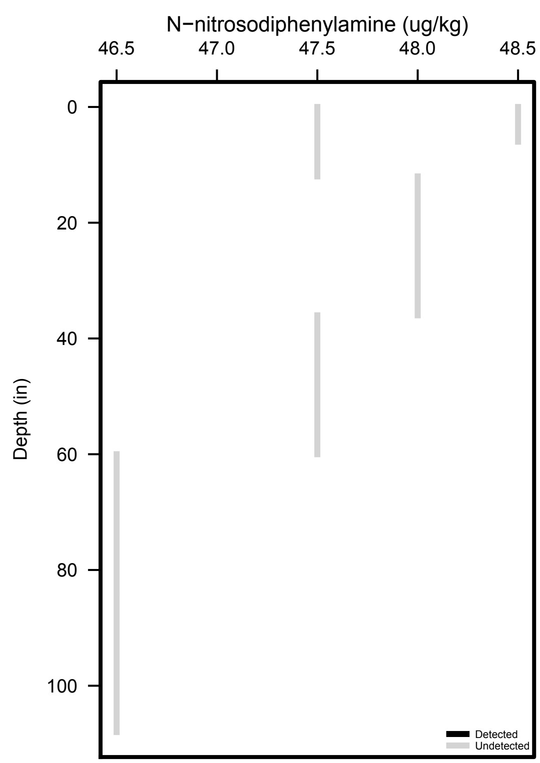

Figure 1108. N−nitrosodiphenylamine at Core Location RM622C1.

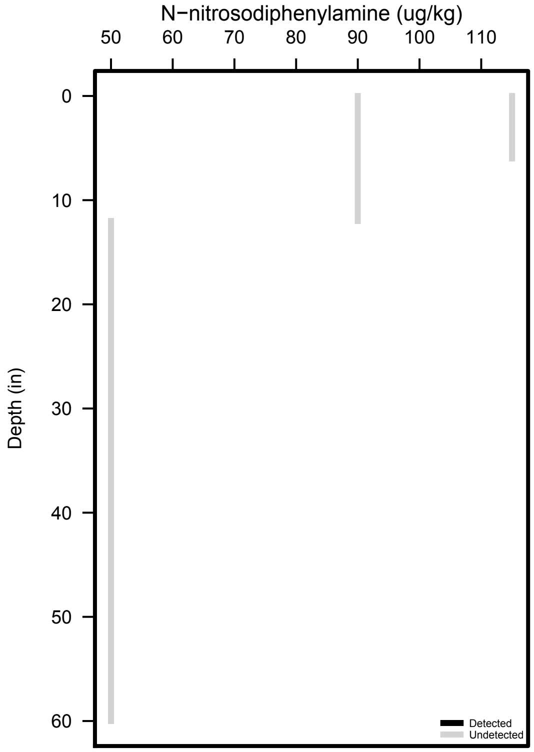

Figure 1109. N−nitrosodiphenylamine
at Core Location RM637C1.

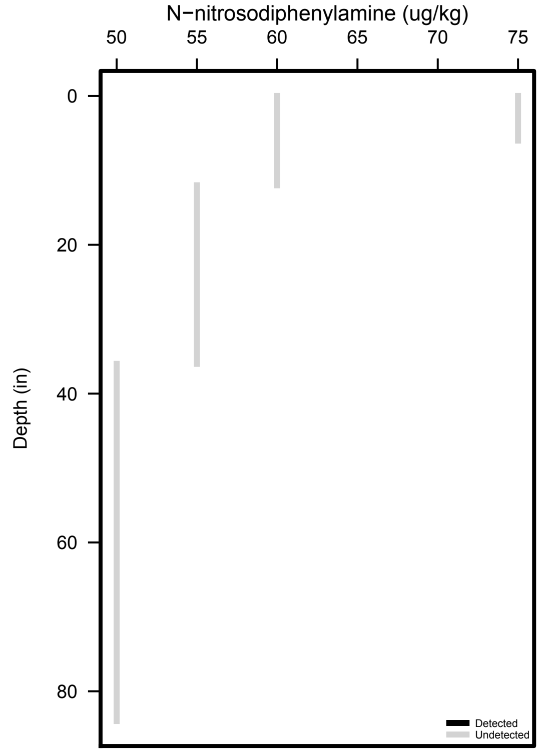

Figure 1110. N−nitrosodiphenylamine
at Core Location RM644C1.

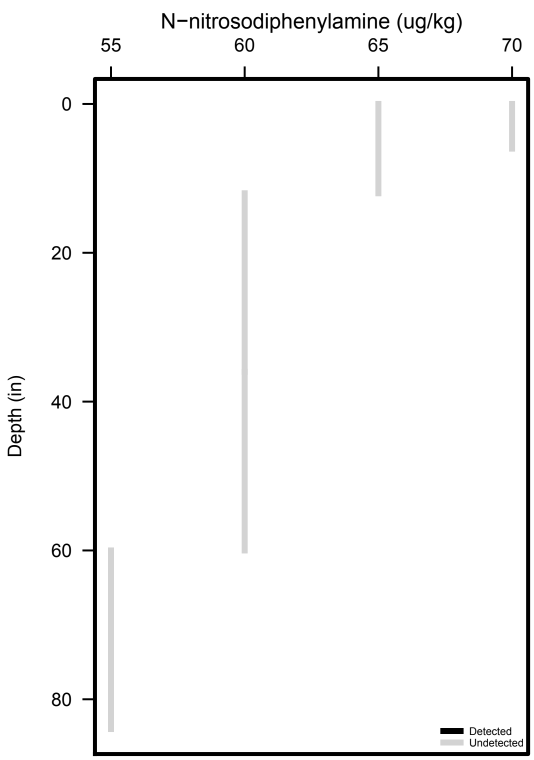

Figure 1111. N−nitrosodiphenylamine
at Core Location RM661C1.

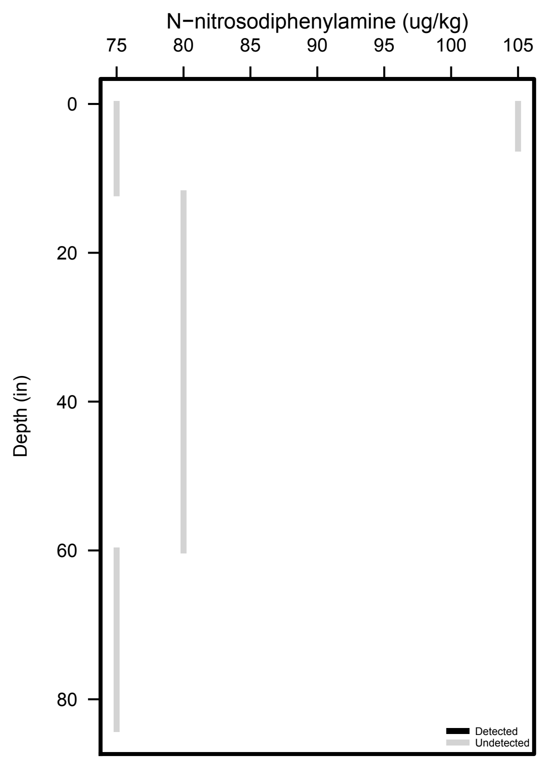

Figure 1112. N−nitrosodiphenylamine
at Core Location RM676C1.

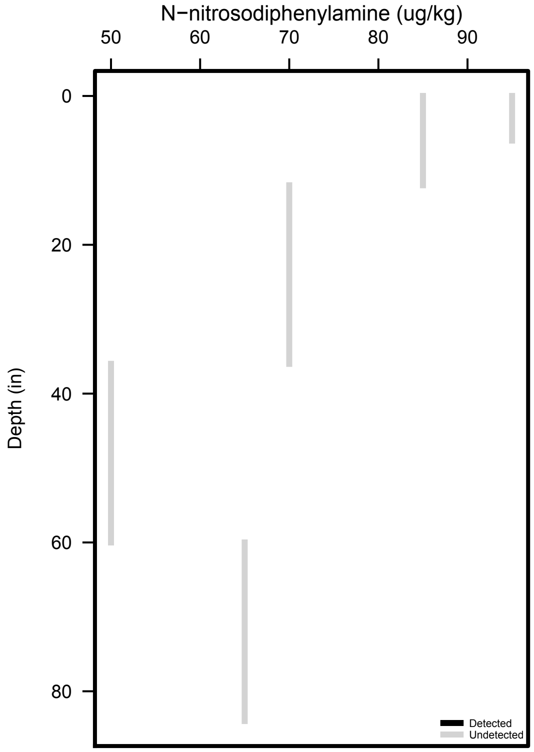

Figure 1113. N−nitrosodiphenylamine at Core Location RM692C1.

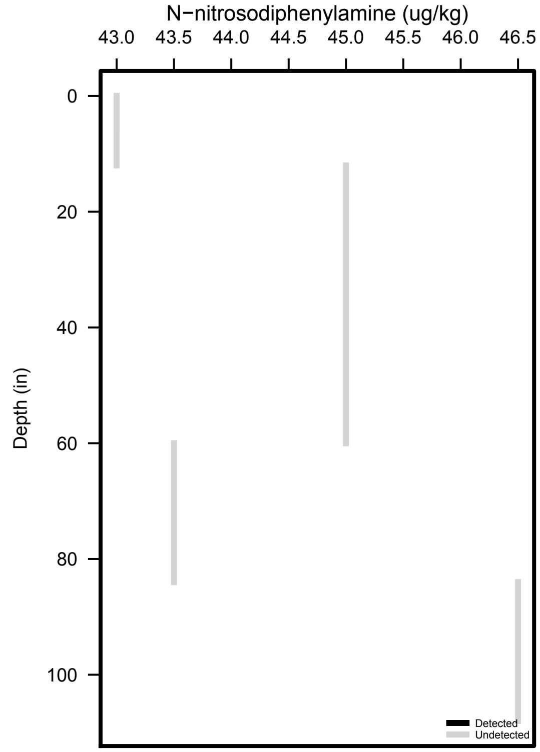

Figure 1114. N−nitrosodiphenylamine at Core Location RM704C1.

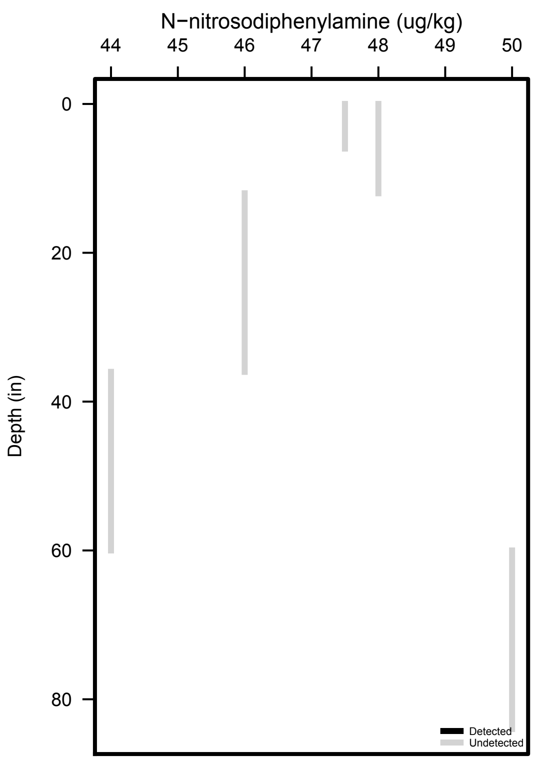

Figure 1115. N−nitrosodiphenylamine at Core Location RM708C1.

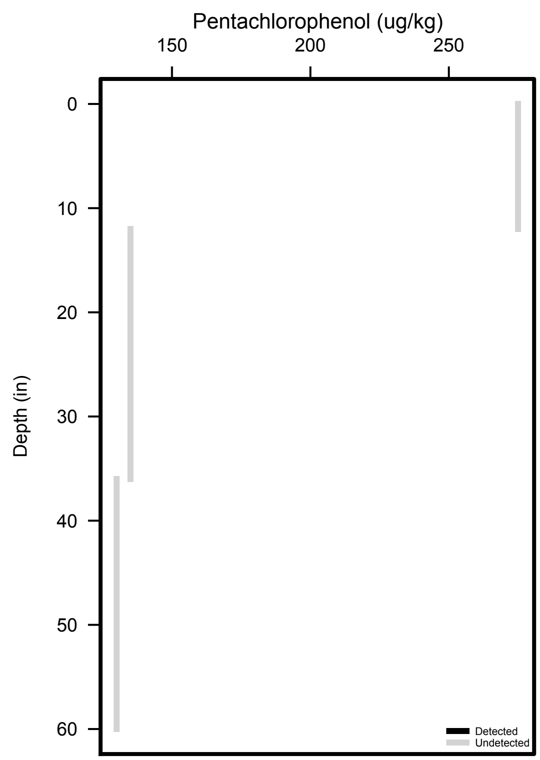

Figure 1116. Pentachlorophenol at Core Location RM605C1.

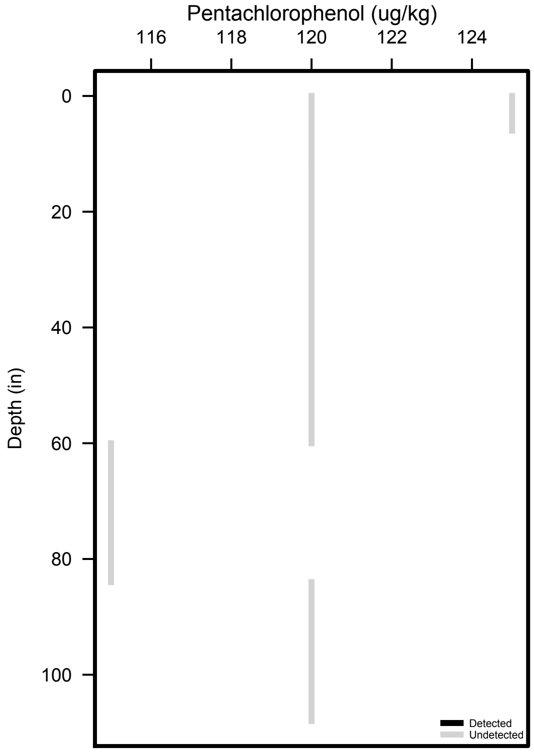

Figure 1117. Pentachlorophenol
at Core Location RM622C1.

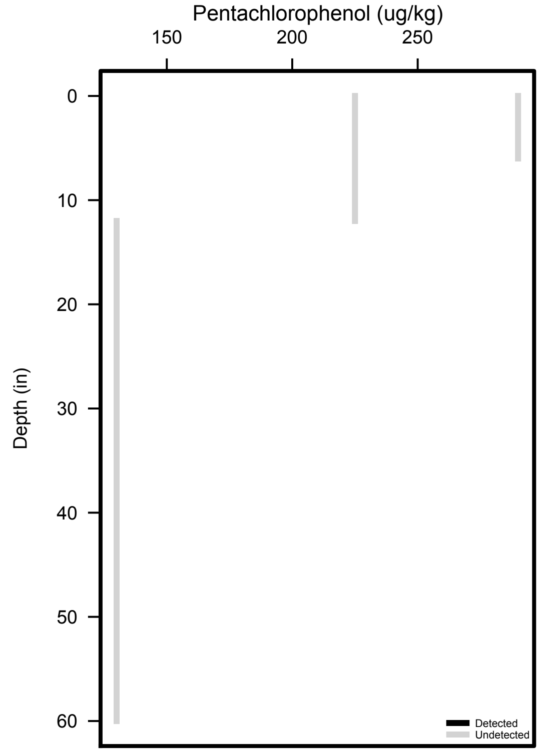

Figure 1118. Pentachlorophenol
at Core Location RM637C1.

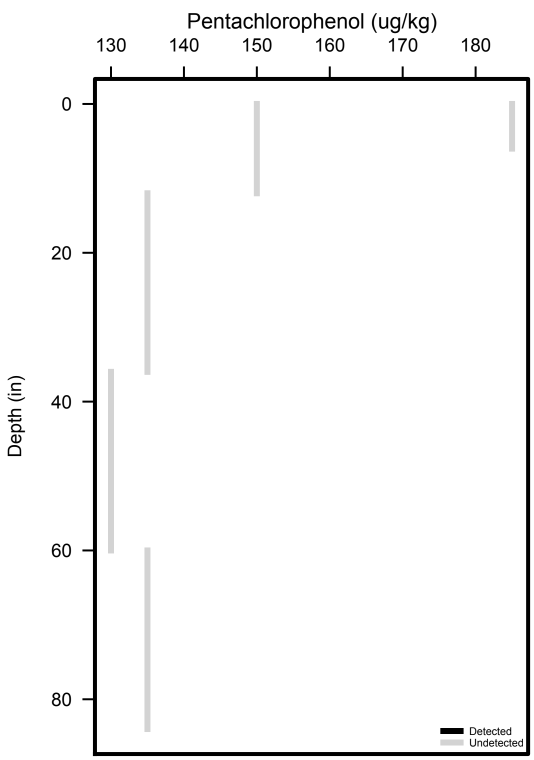

Figure 1119. Pentachlorophenol
at Core Location RM644C1.

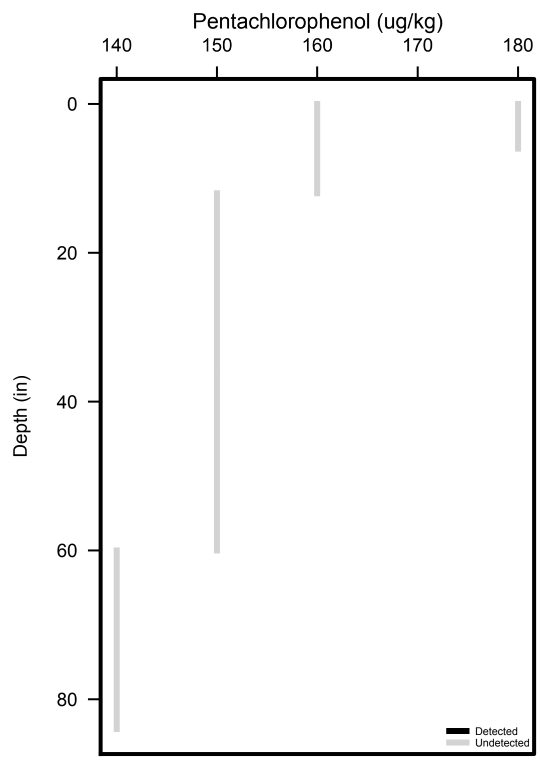

Figure 1120. Pentachlorophenol
at Core Location RM661C1.

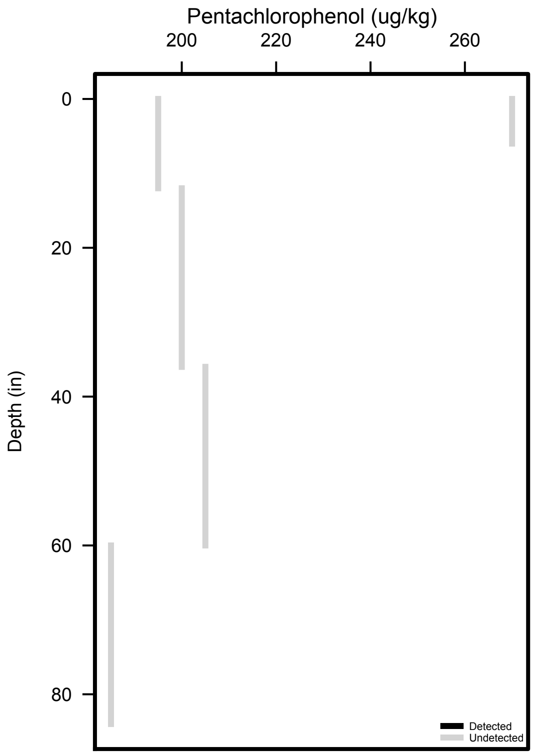

Figure 1121. Pentachlorophenol at Core Location RM676C1.

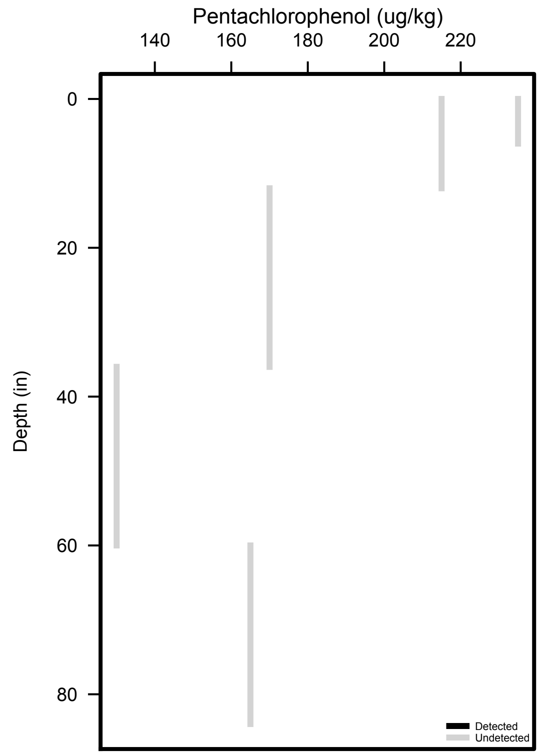

Figure 1122. Pentachlorophenol at Core Location RM692C1.

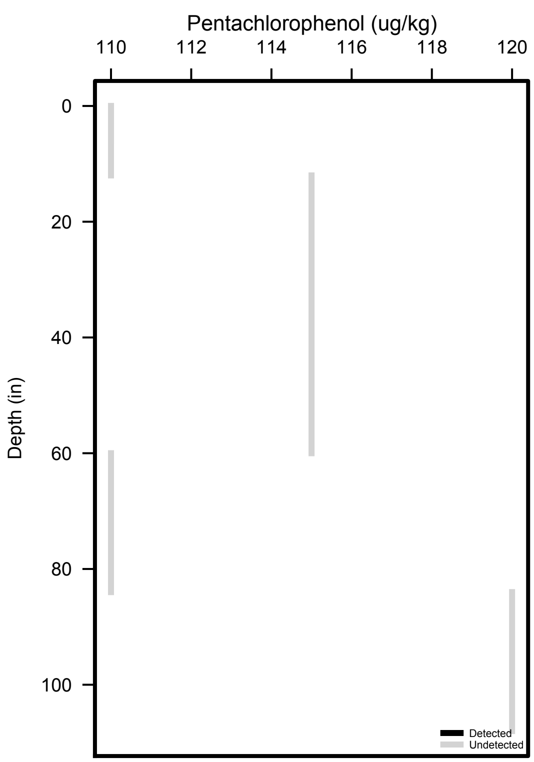

Figure 1123. Pentachlorophenol at Core Location RM704C1.

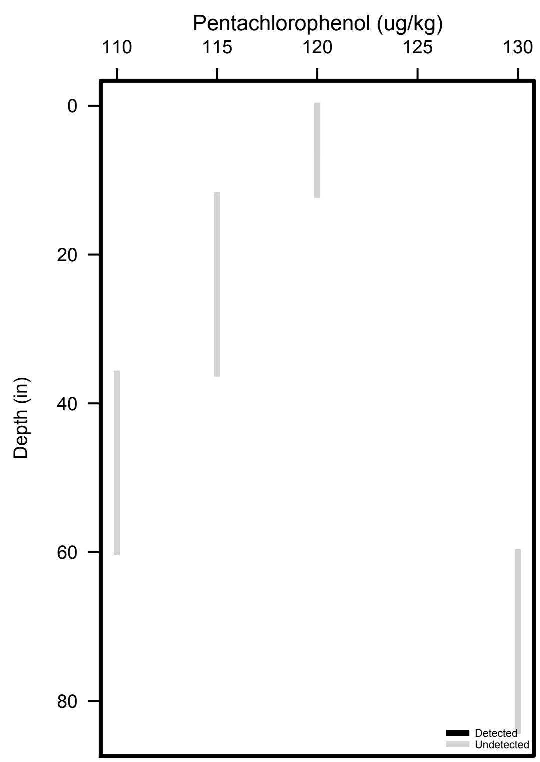

Figure 1124. Pentachlorophenol at Core Location RM708C1.

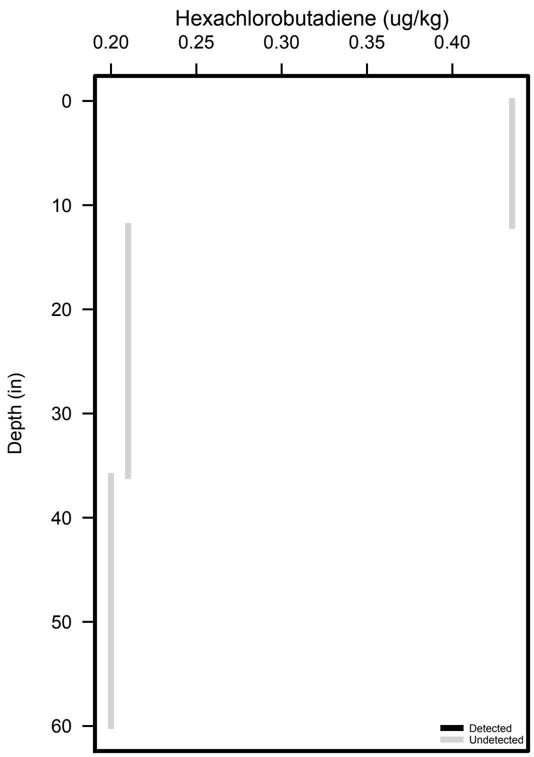

Figure 1125. Hexachlorobutadiene
at Core Location RM605C1.

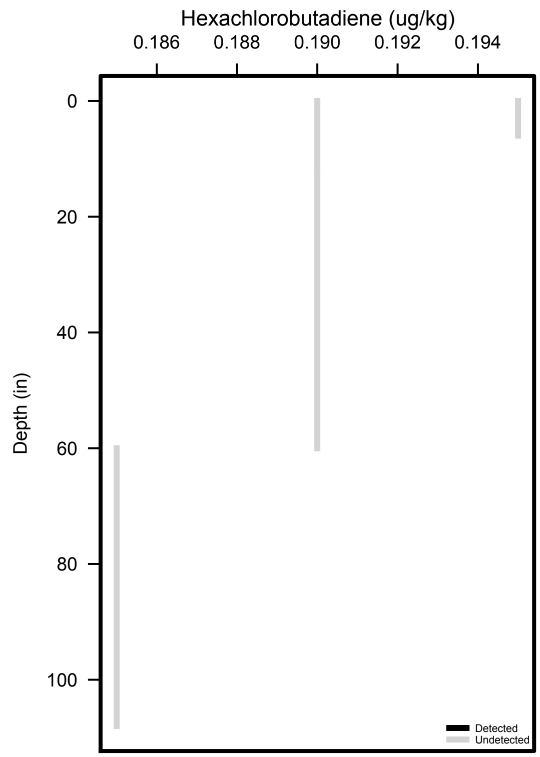

Figure 1126. Hexachlorobutadiene
at Core Location RM622C1.

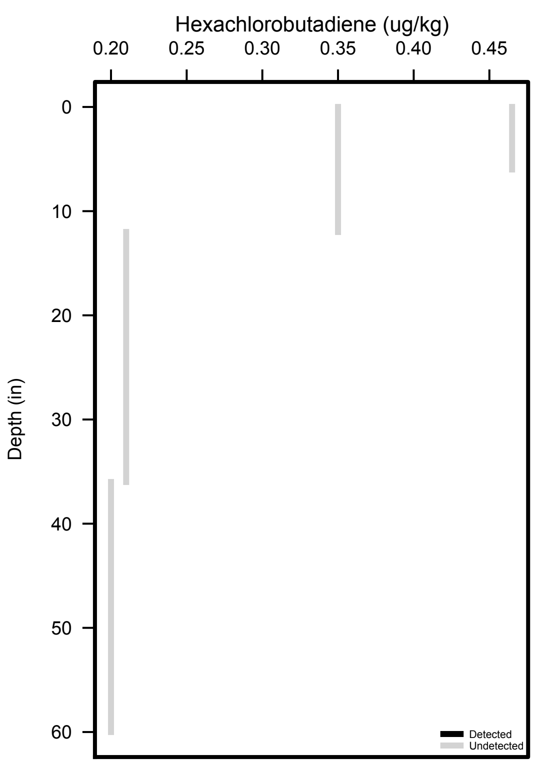

Figure 1127. Hexachlorobutadiene
at Core Location RM637C1.

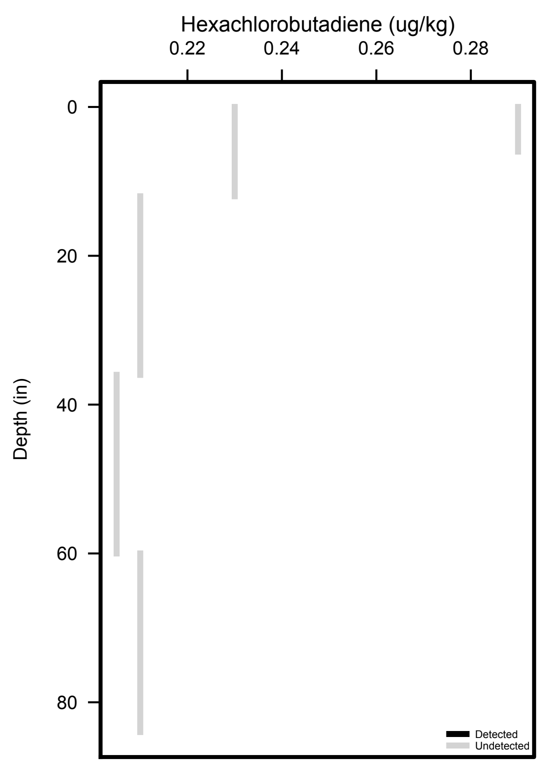

Figure 1128. Hexachlorobutadiene
at Core Location RM644C1.

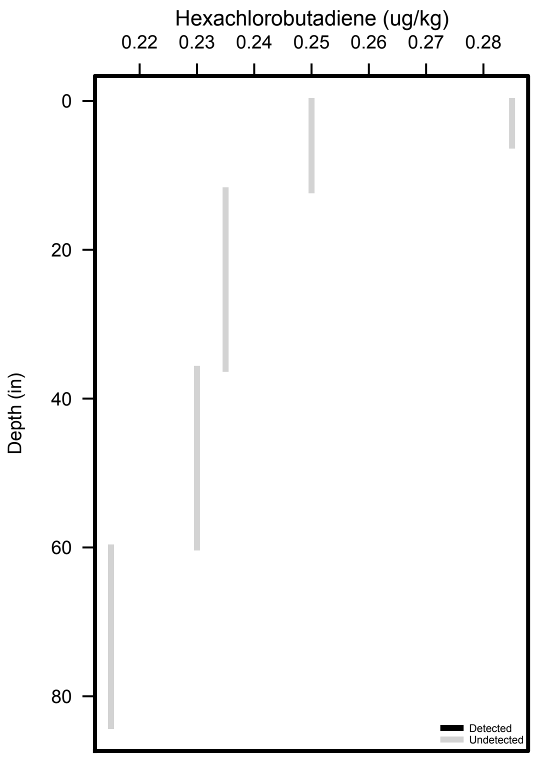

Figure 1129. Hexachlorobutadiene at Core Location RM661C1.

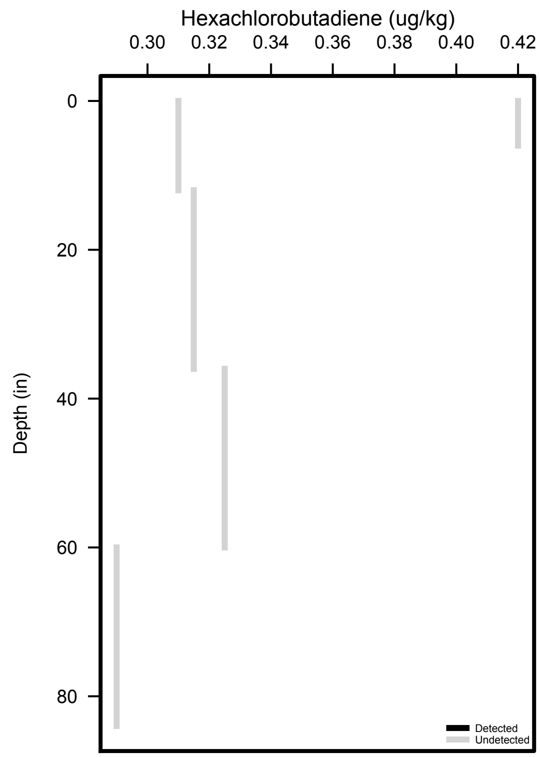

Figure 1130. Hexachlorobutadiene at Core Location RM676C1.

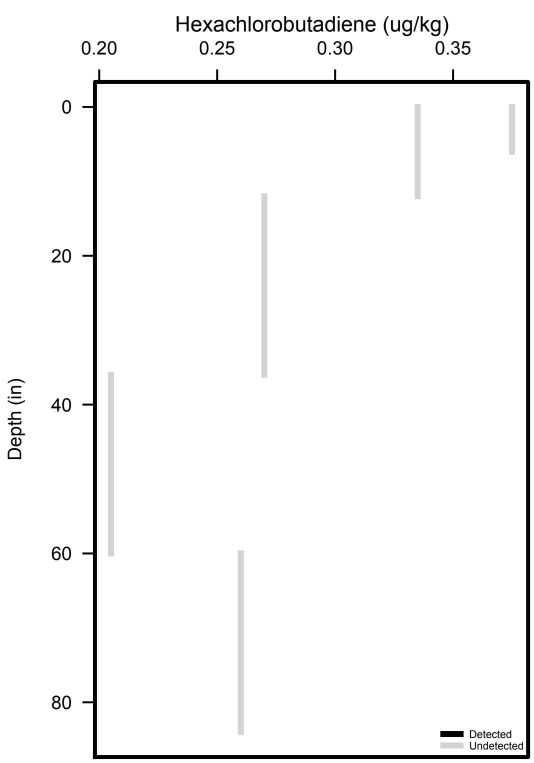

Figure 1131. Hexachlorobutadiene at Core Location RM692C1.

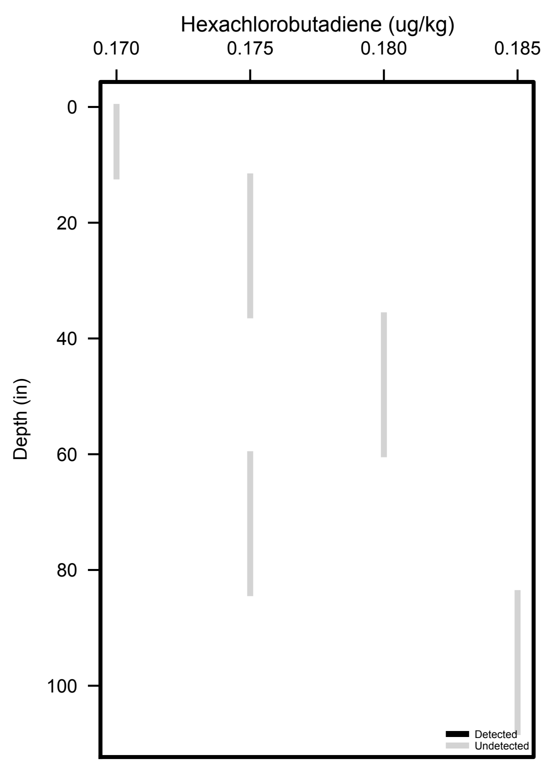

Figure 1132. Hexachlorobutadiene at Core Location RM704C1.

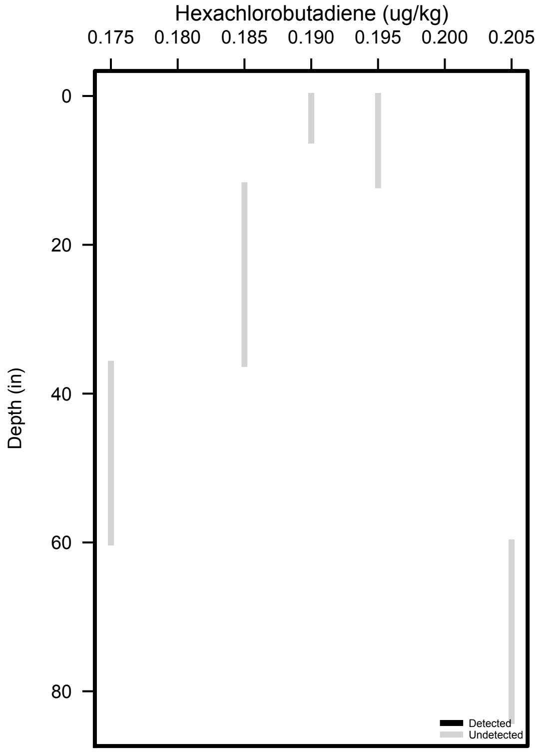

Figure 1133. Hexachlorobutadiene
at Core Location RM708C1.

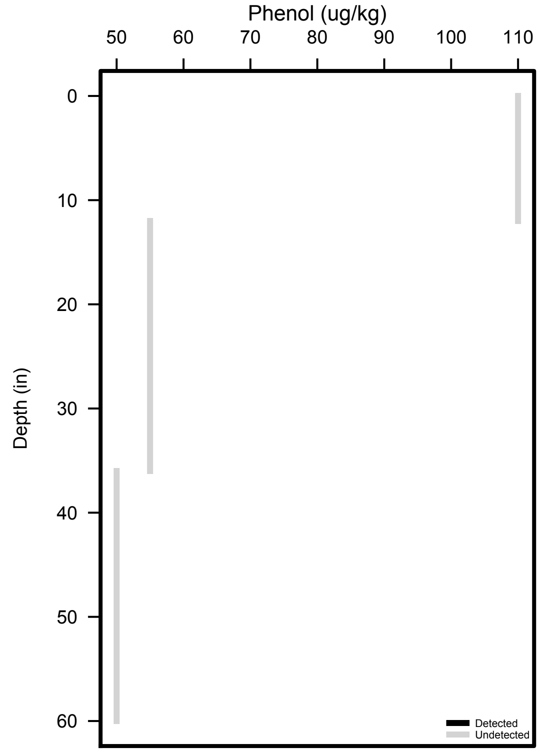

Figure 1134. Phenol
at Core Location RM605C1.

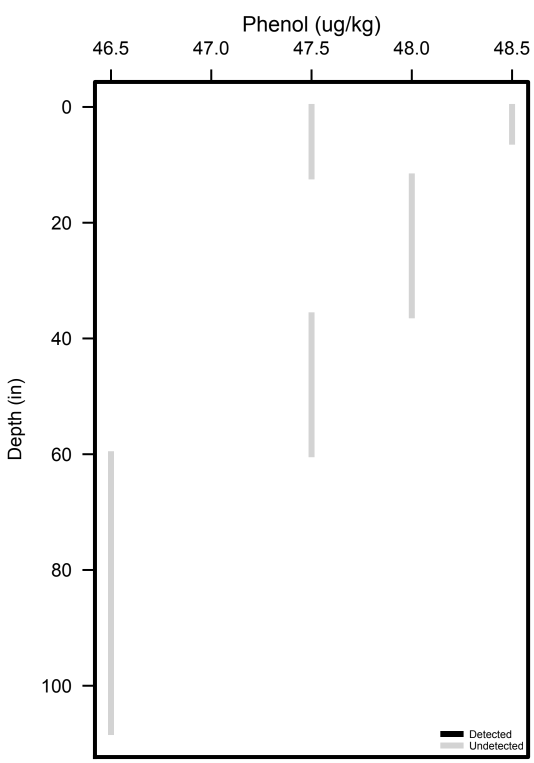

Figure 1135. Phenol
at Core Location RM622C1.

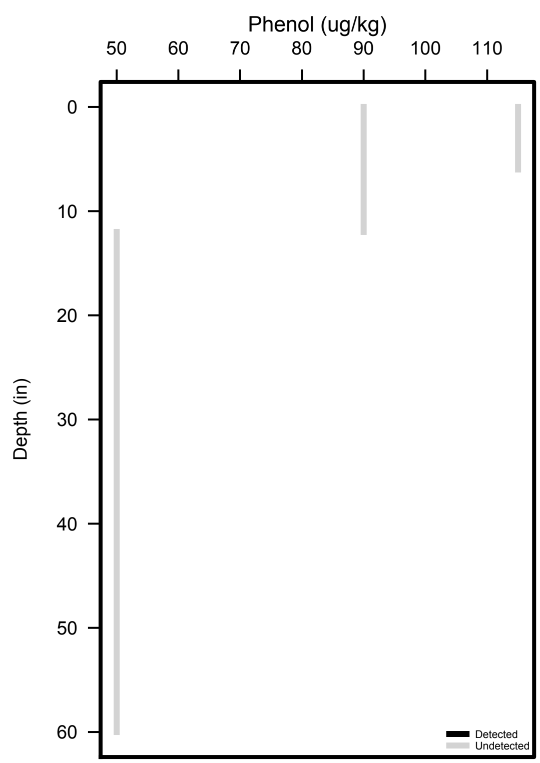

Figure 1136. Phenol
at Core Location RM637C1.

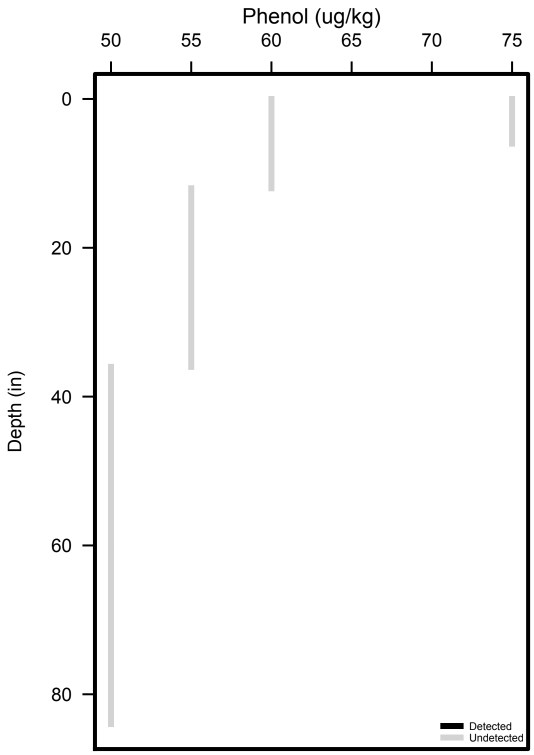

Figure 1137. Phenol
at Core Location RM644C1.

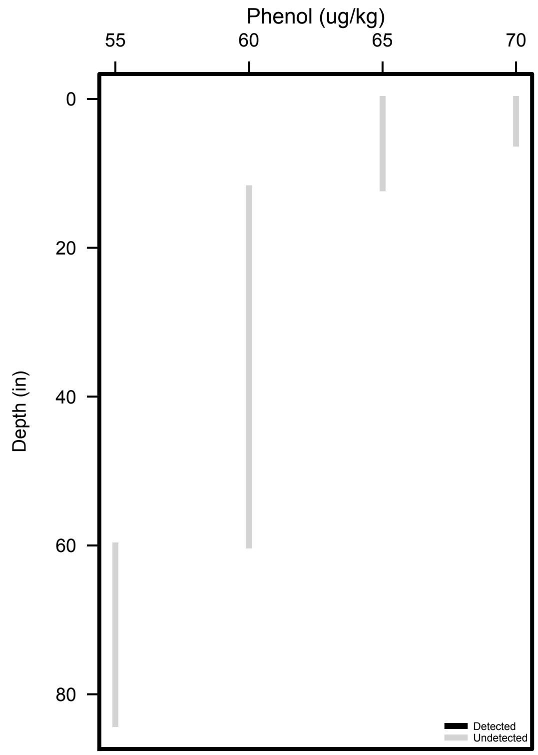

Figure 1138. Phenol
at Core Location RM661C1.

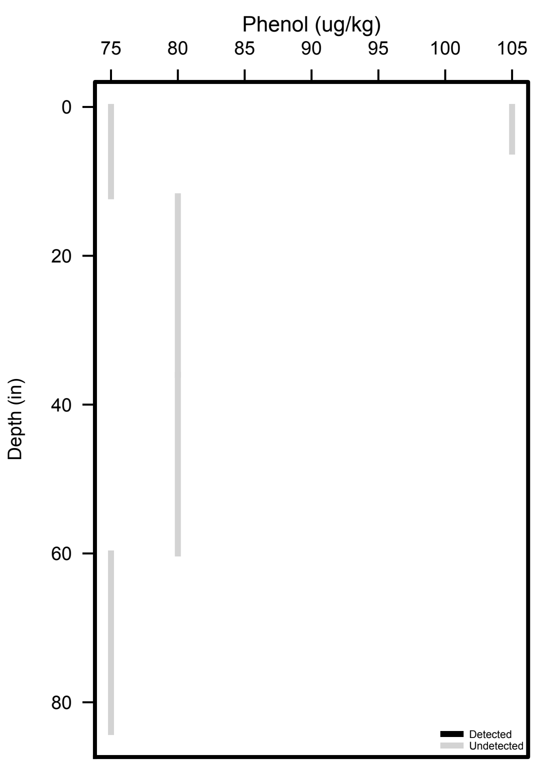

Figure 1139. Phenol
at Core Location RM676C1.

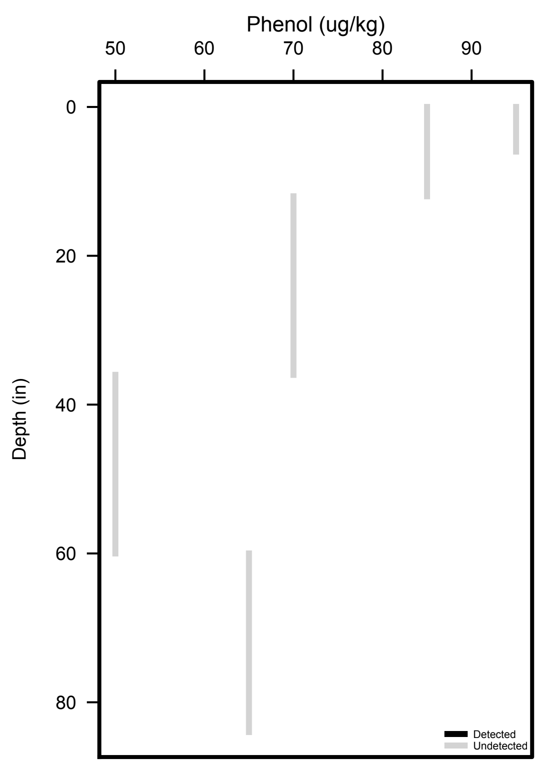

Figure 1140. Phenol
at Core Location RM692C1.

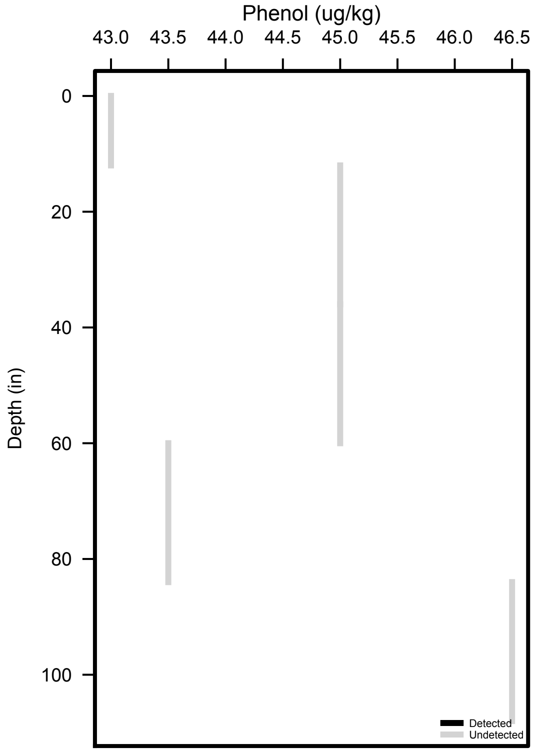

Figure 1141. Phenol
at Core Location RM704C1.

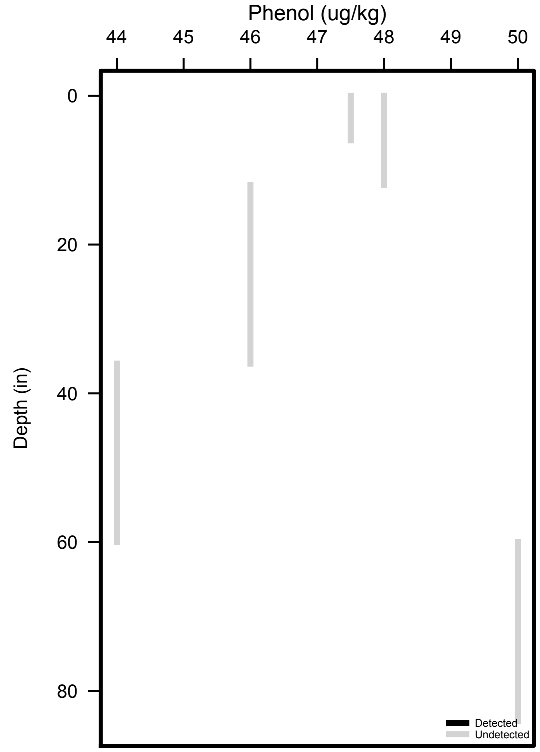

Figure 1142. Phenol
at Core Location RM708C1.

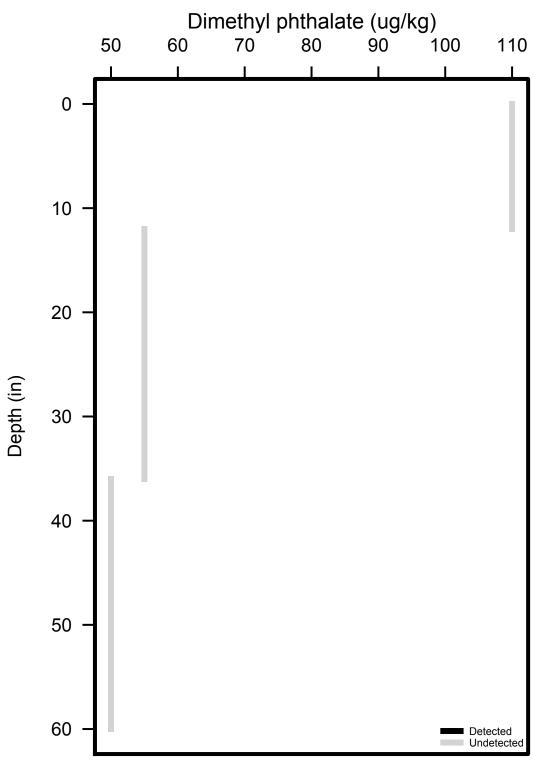

Figure 1143. Dimethyl phthalate
at Core Location RM605C1.

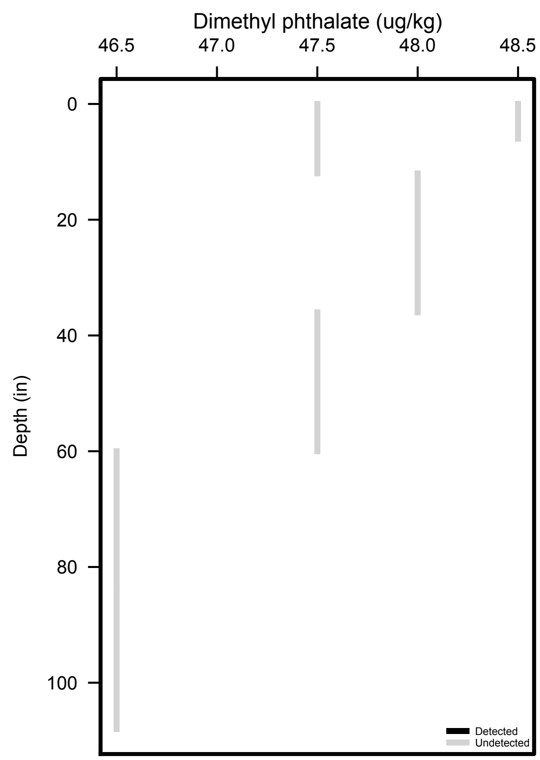

Figure 1144. Dimethyl phthalate
at Core Location RM622C1.

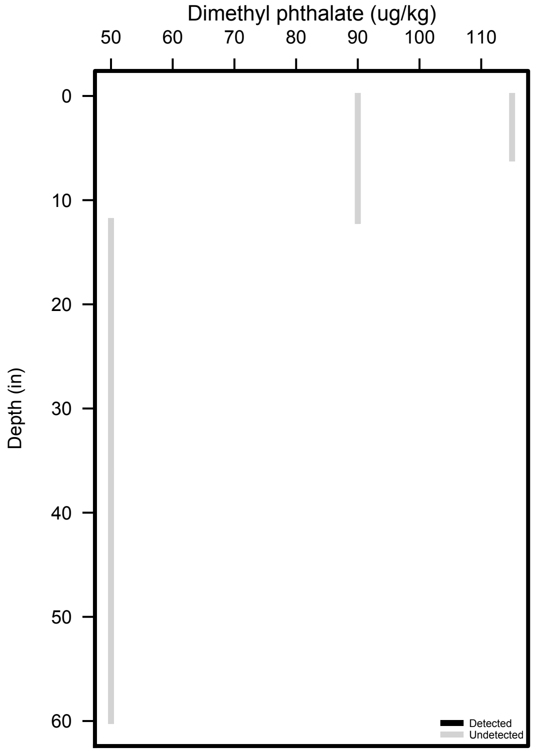

Figure 1145. Dimethyl phthalate
at Core Location RM637C1.

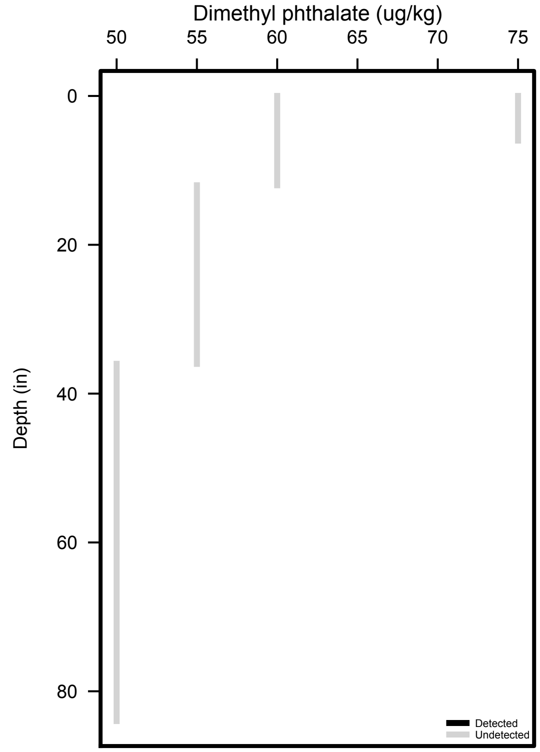

Figure 1146. Dimethyl phthalate
at Core Location RM644C1.

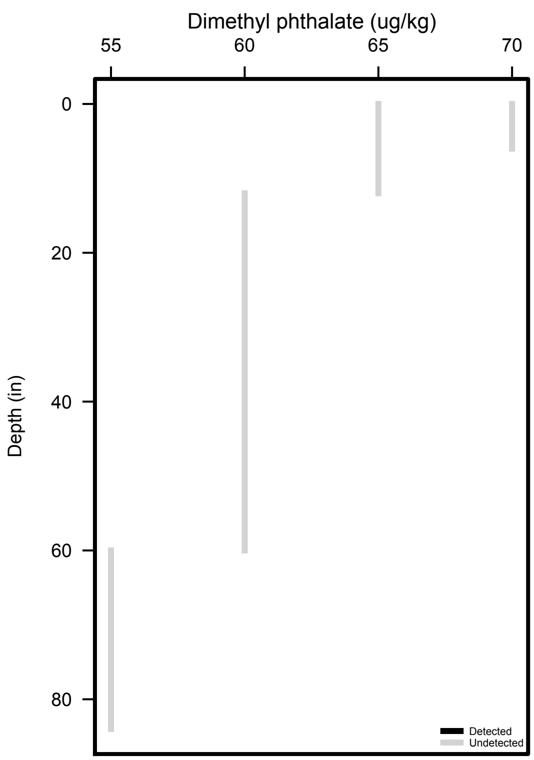

Figure 1147. Dimethyl phthalate
at Core Location RM661C1.

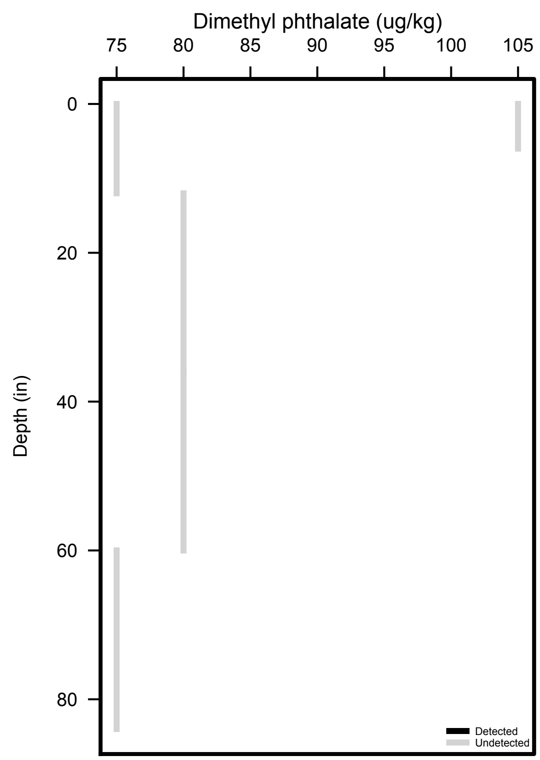

Figure 1148. Dimethyl phthalate
at Core Location RM676C1.

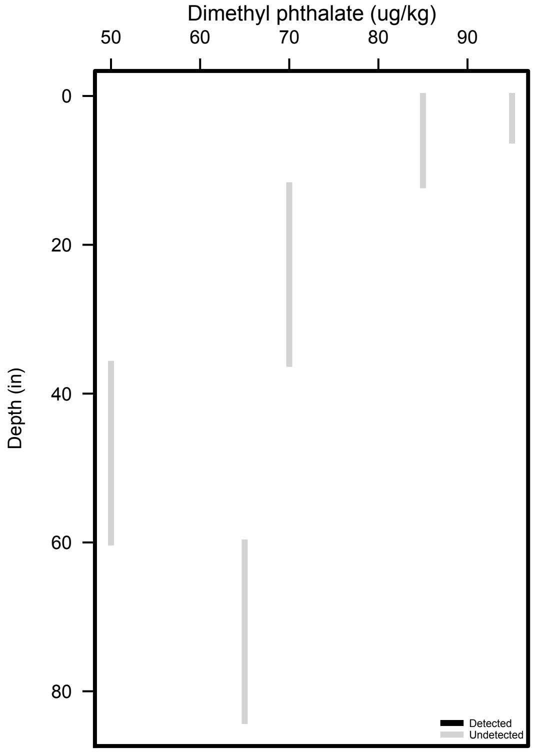

Figure 1149. Dimethyl phthalate at Core Location RM692C1.

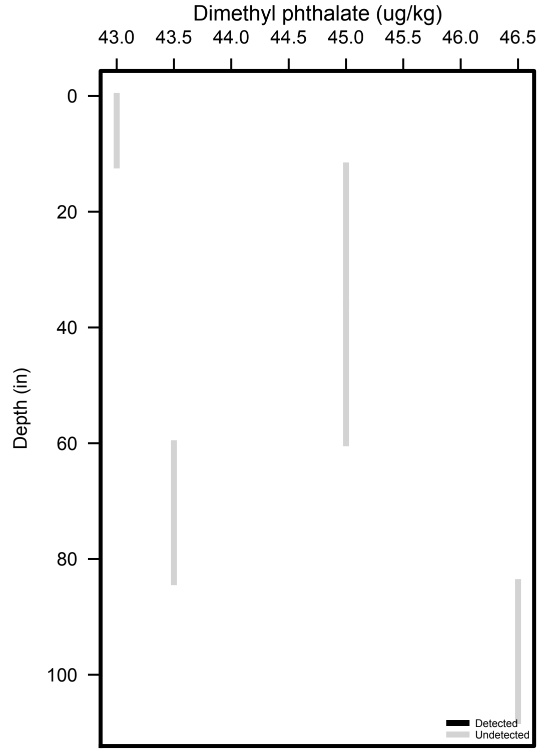

Figure 1150. Dimethyl phthalate at Core Location RM704C1.

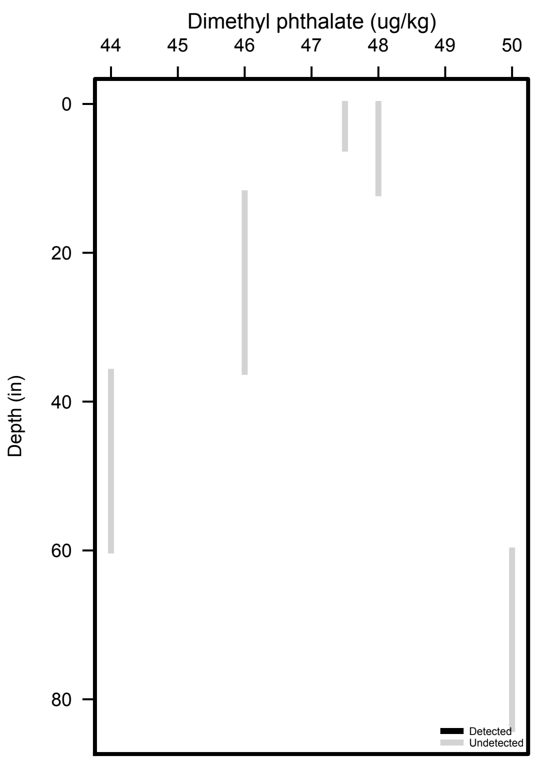

Figure 1151. Dimethyl phthalate at Core Location RM708C1.

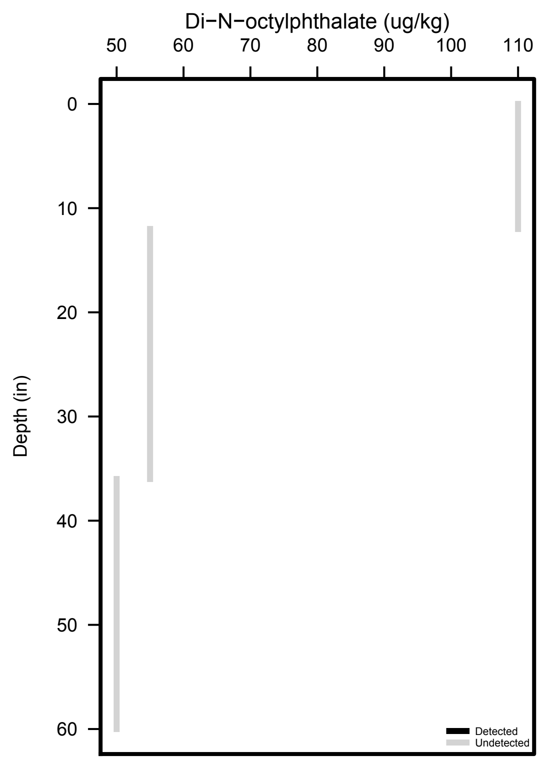

Figure 1152. Di−N−octylphthalate at Core Location RM605C1.

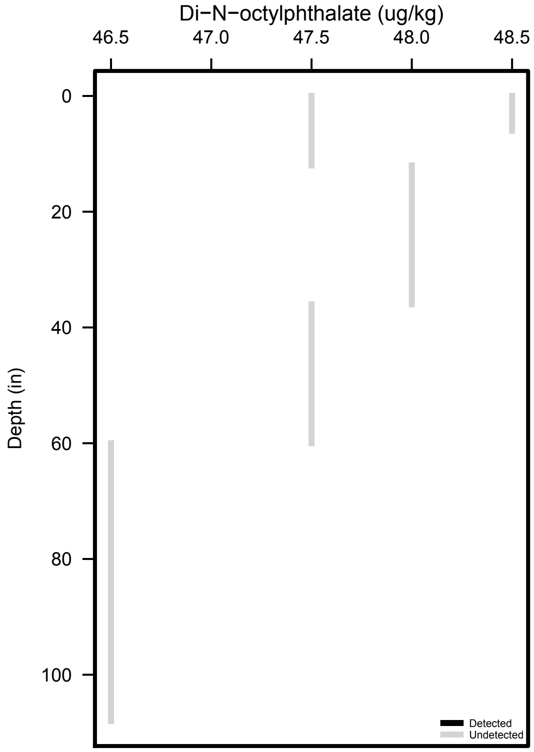

Figure 1153. Di−N−octylphthalate at Core Location RM622C1.

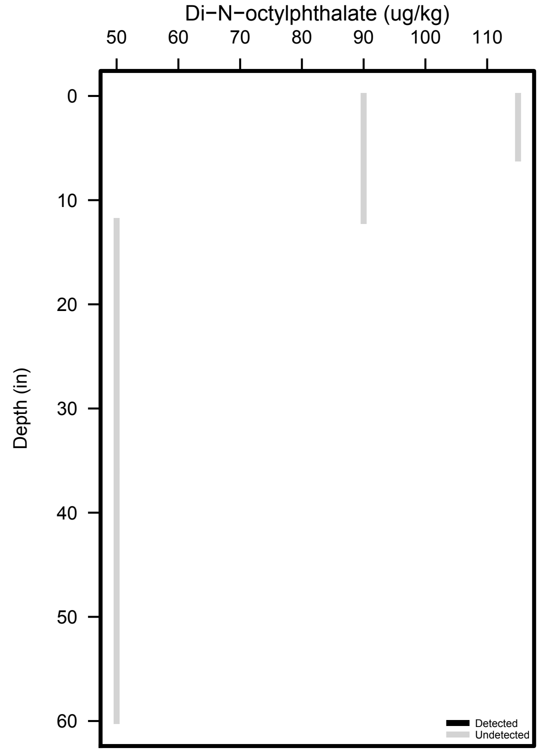

Figure 1154. Di−N−octylphthalate at Core Location RM637C1.

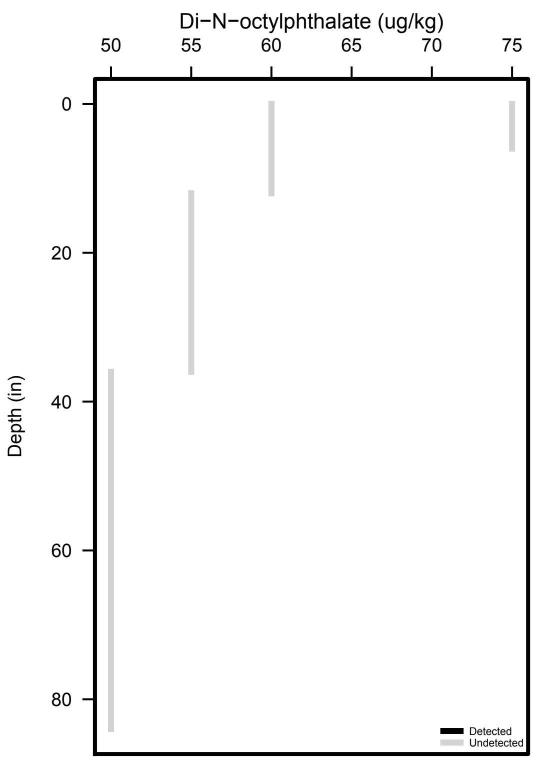

Figure 1155. Di−N−octylphthalate at Core Location RM644C1.

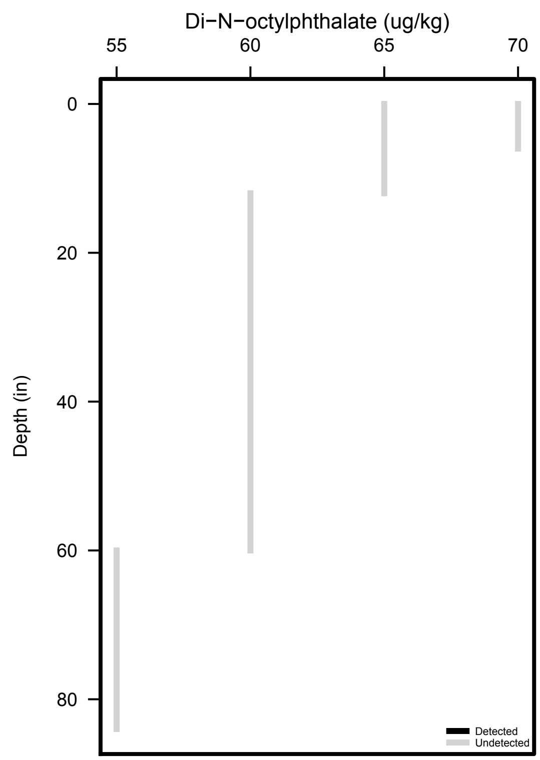

Figure 1156. Di−N−octylphthalate at Core Location RM661C1.

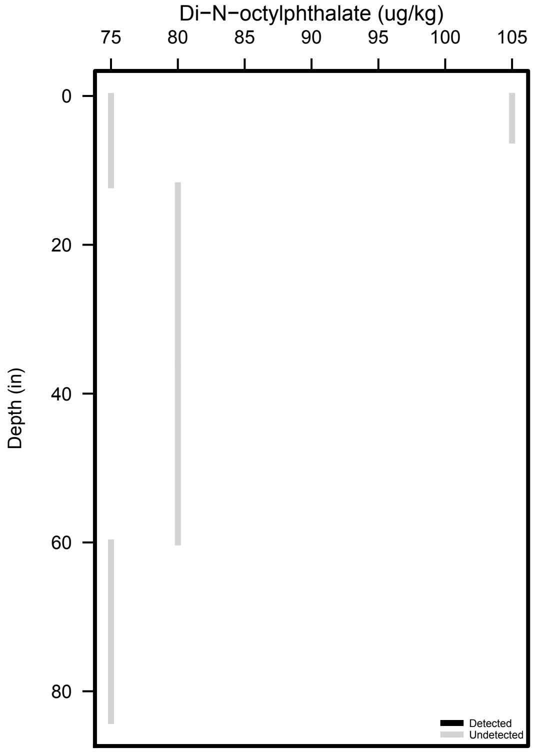

Figure 1157. Di−N−octylphthalate at Core Location RM676C1.

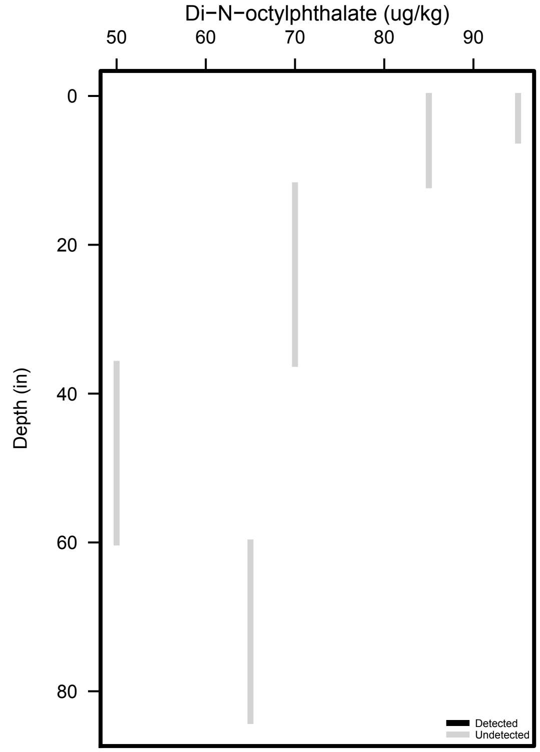

Figure 1158. Di−N−octylphthalate at Core Location RM692C1.

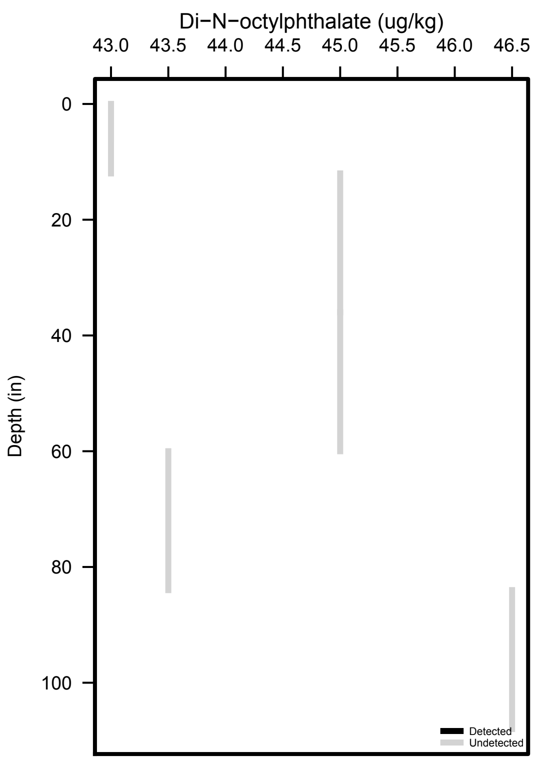

Figure 1159. Di−N−octylphthalate at Core Location RM704C1.

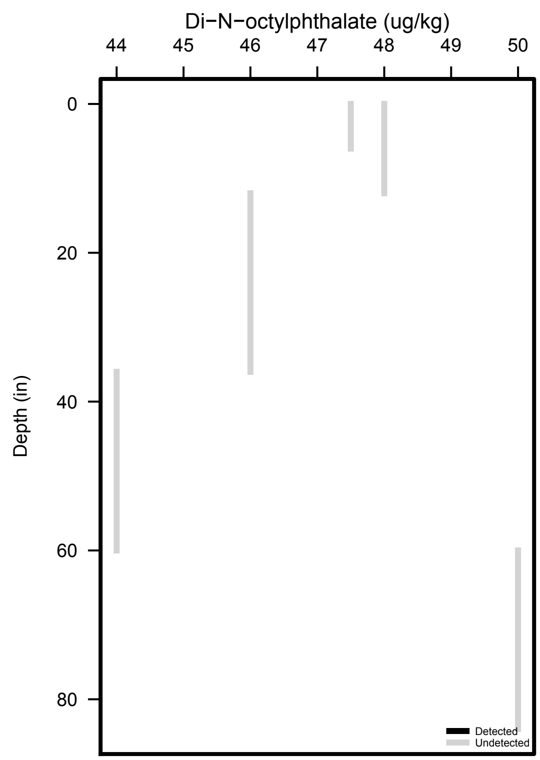

Figure 1160. Di−N−octylphthalate at Core Location RM708C1.

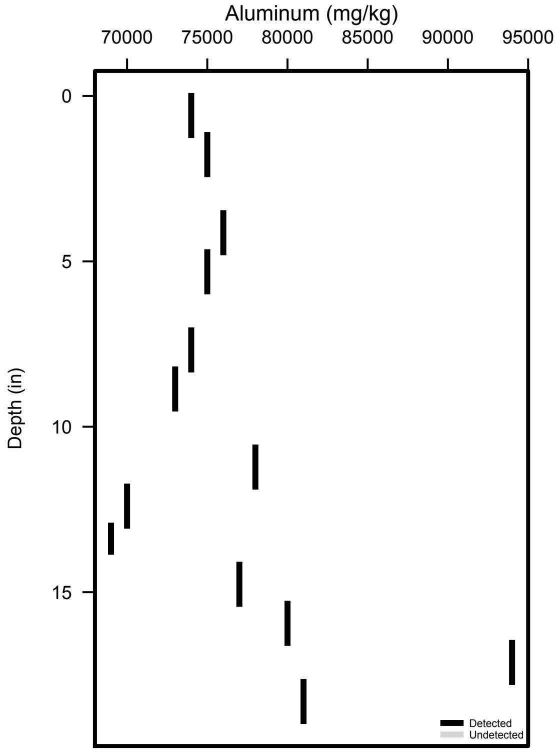

Figure 1161. Aluminum
at Cox Core Location CCR−624.

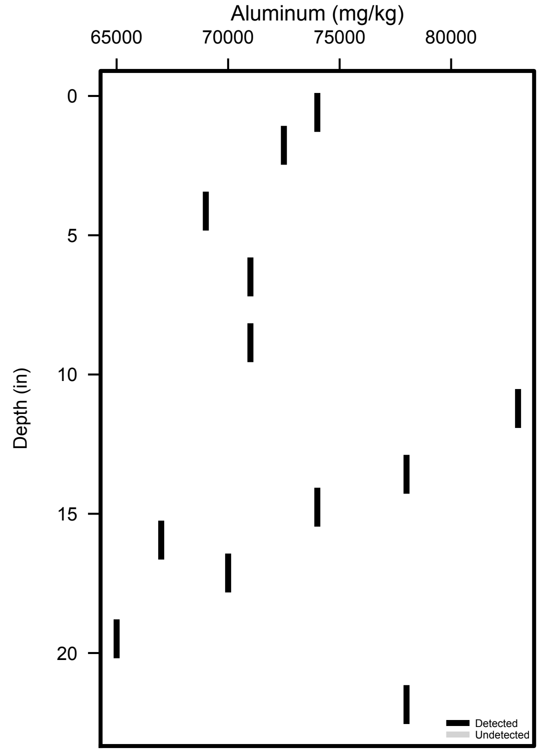

Figure 1162. Aluminum
at Cox Core Location CCR−643.

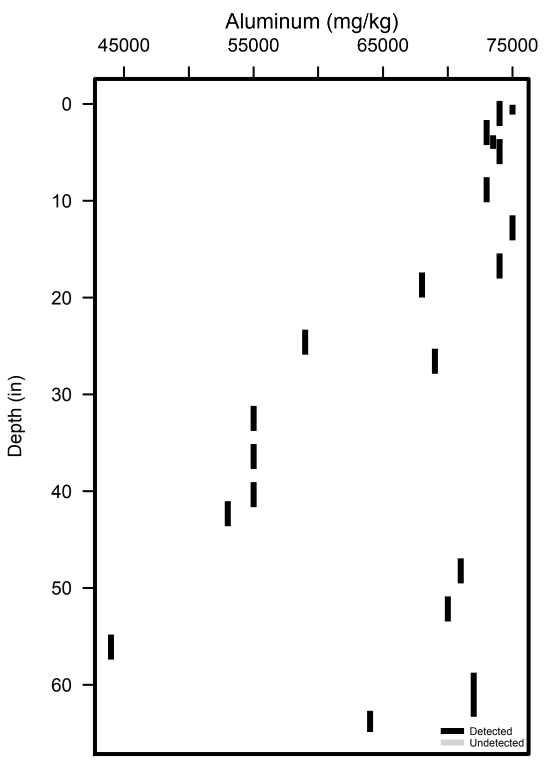

Figure 1163. Aluminum
at Cox Core Location CCR−668.

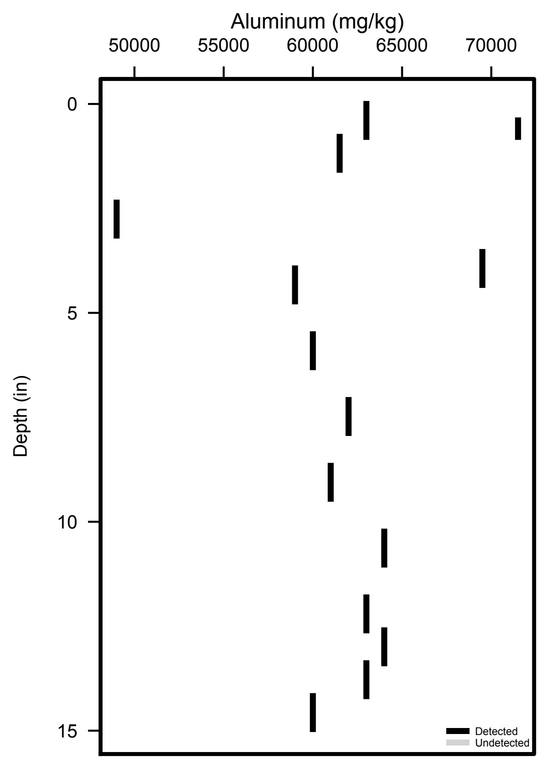

Figure 1164. Aluminum
at Cox Core Location CCR−692.

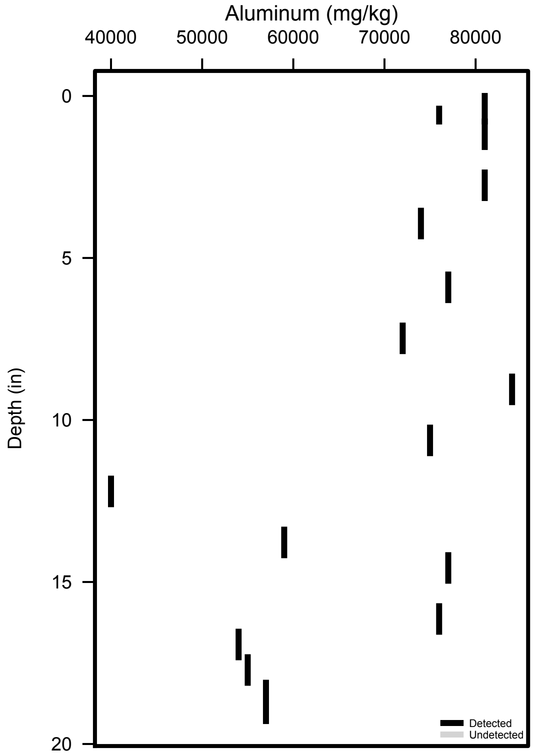

Figure 1165. Aluminum
at Cox Core Location CCR−705.

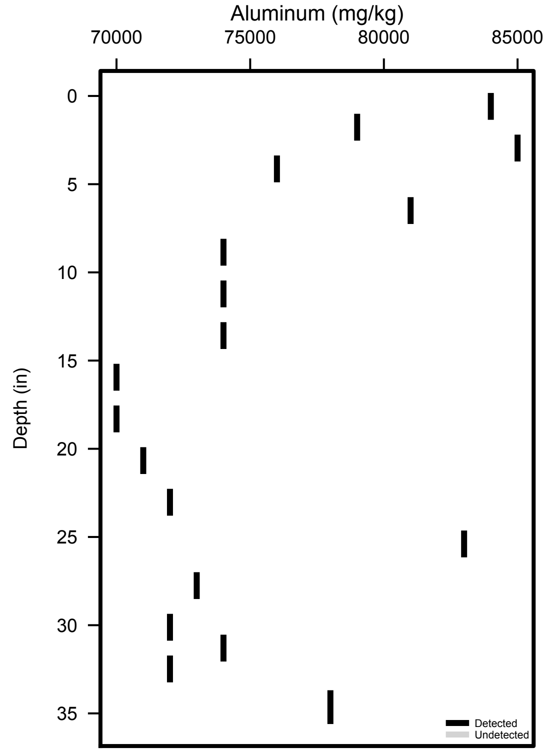

Figure 1166. Aluminum
at Cox Core Location CSA−8.

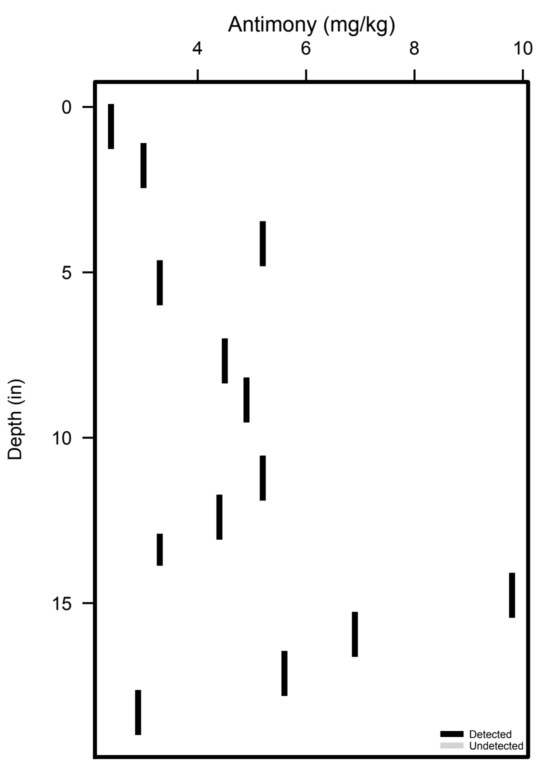

Figure 1167. Antimony
at Cox Core Location CCR−624.

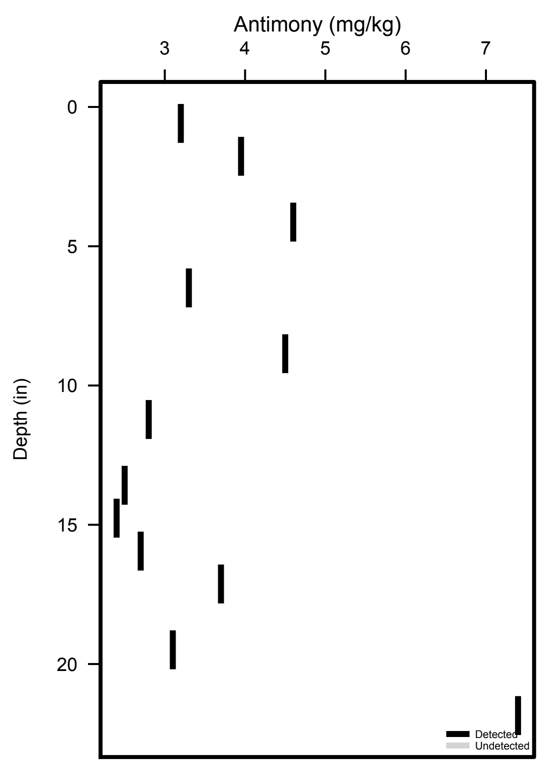

Figure 1168. Antimony
at Cox Core Location CCR−643.

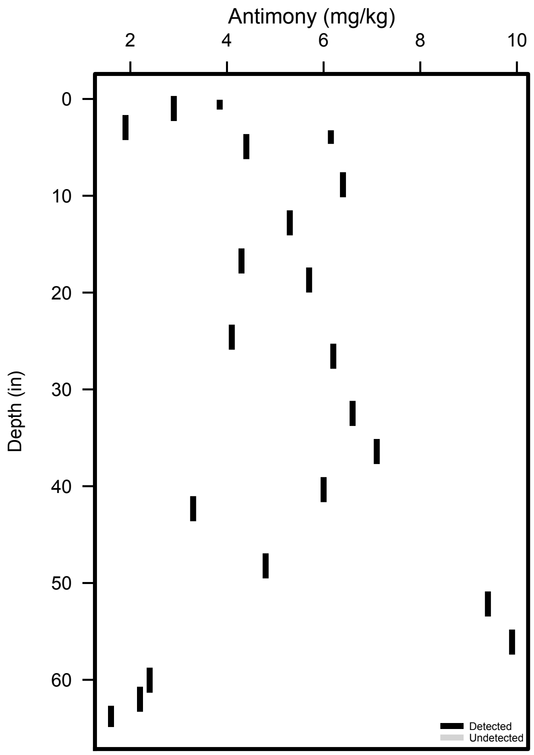

Figure 1169. Antimony
at Cox Core Location CCR−668.

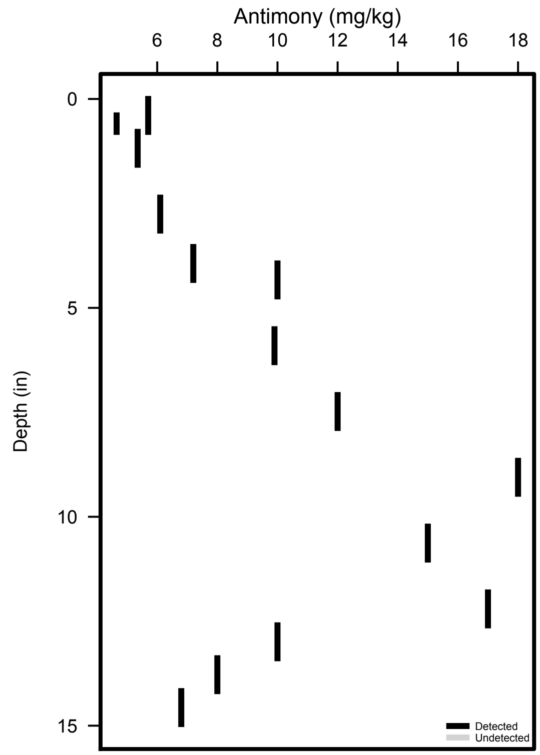

Figure 1170. Antimony
at Cox Core Location CCR−692.

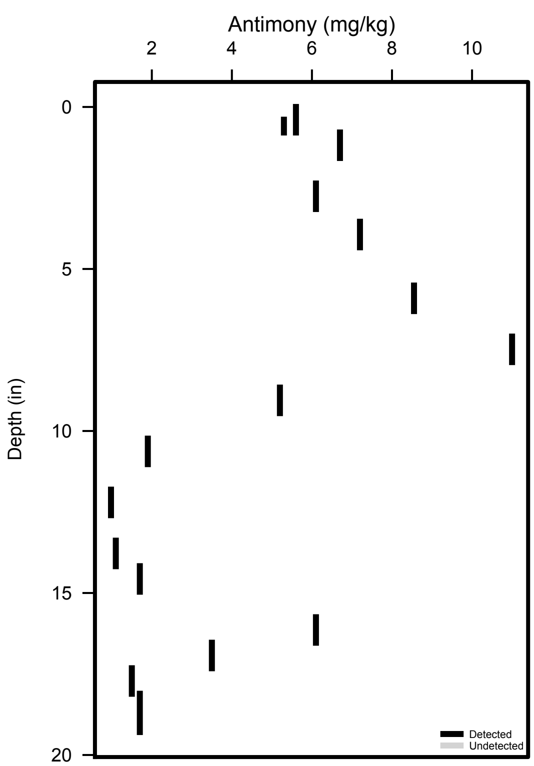

Figure 1171. Antimony
at Cox Core Location CCR−705.

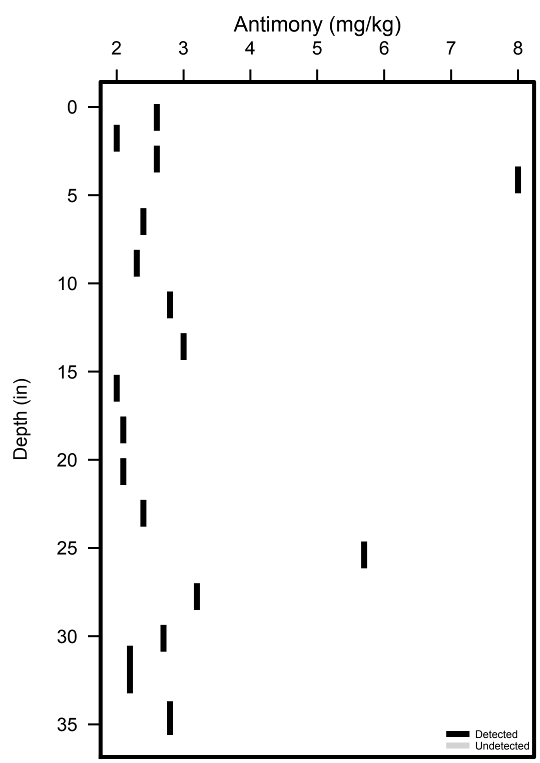

Figure 1172. Antimony
at Cox Core Location CSA−8.

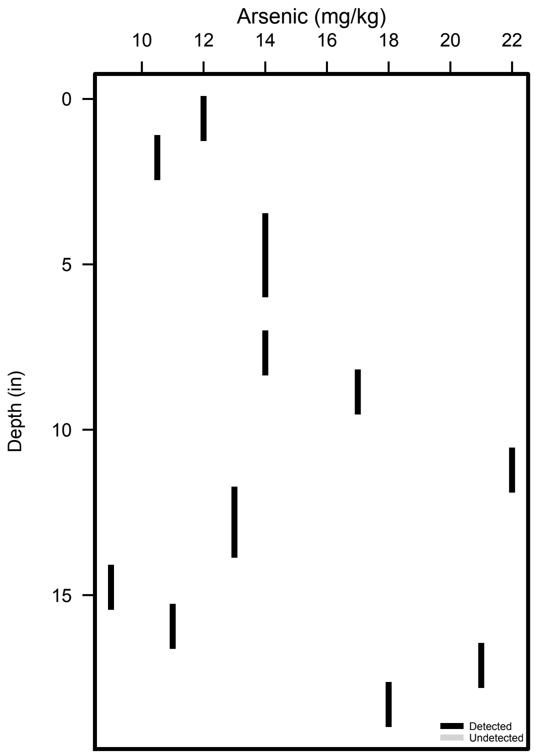

Figure 1173. Arsenic at Cox Core Location CCR−624.

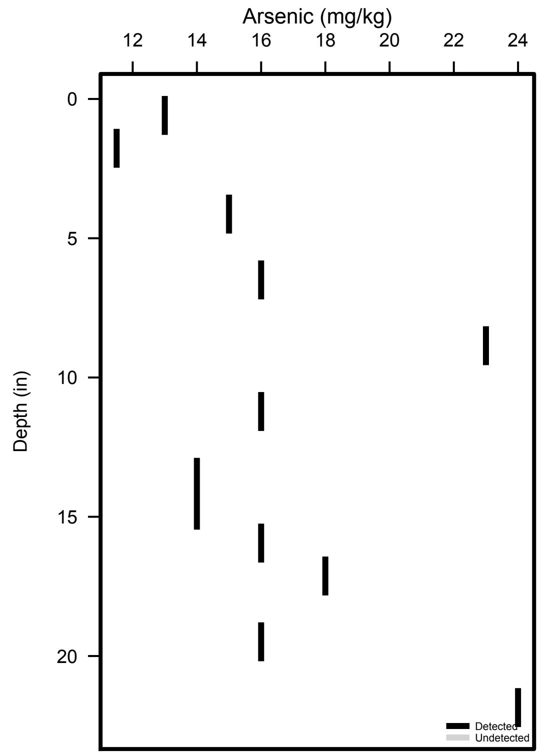

Figure 1174. Arsenic at Cox Core Location CCR−643.

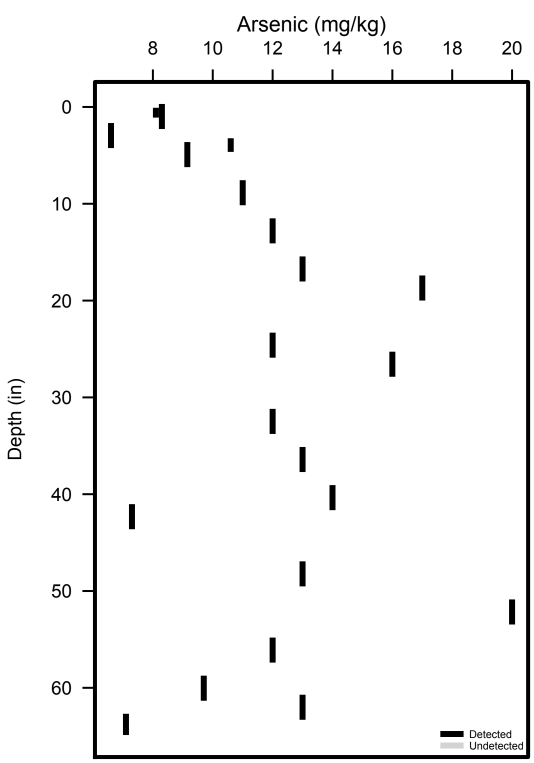

Figure 1175. Arsenic at Cox Core Location CCR−668.

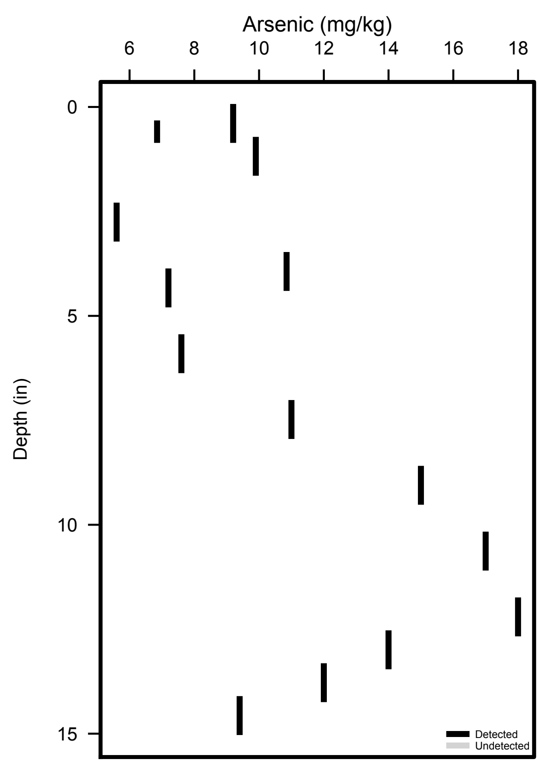

Figure 1176. Arsenic at Cox Core Location CCR−692.

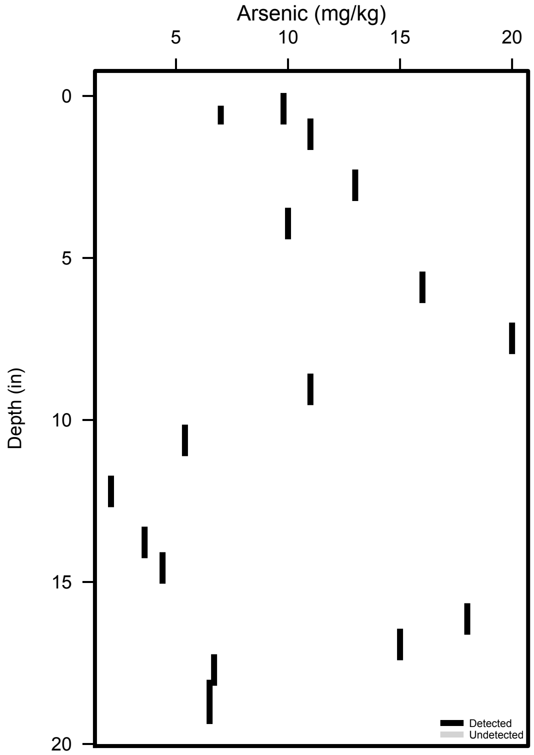

Figure 1177. Arsenic
at Cox Core Location CCR−705.

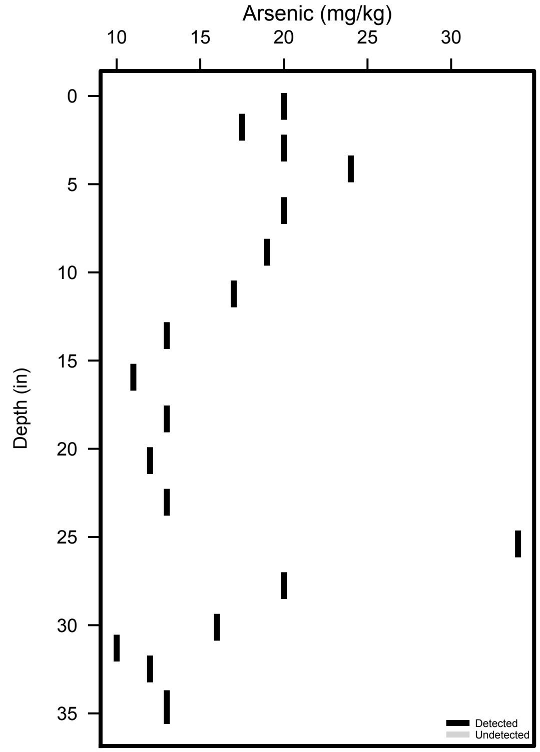

Figure 1178. Arsenic
at Cox Core Location CSA−8.

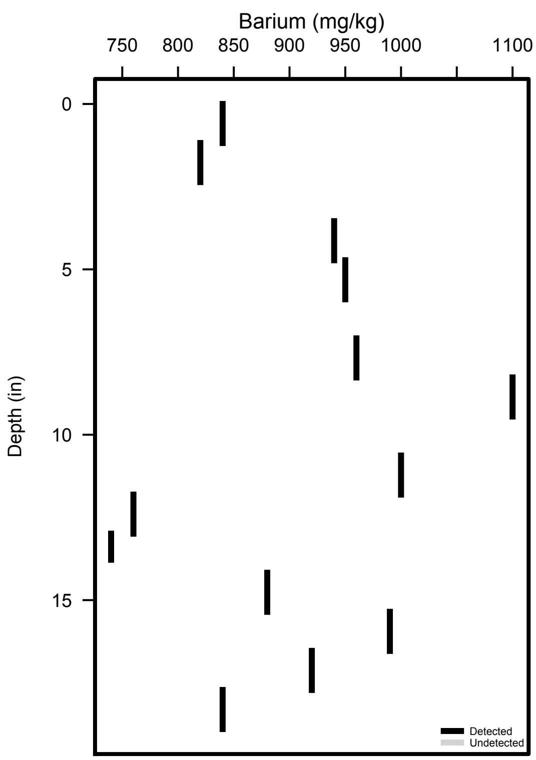

Figure 1179. Barium
at Cox Core Location CCR−624.

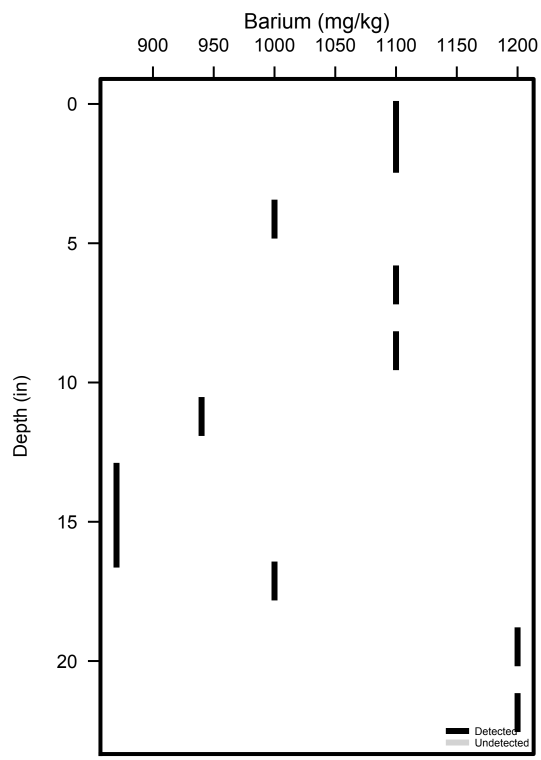

Figure 1180. Barium
at Cox Core Location CCR−643.

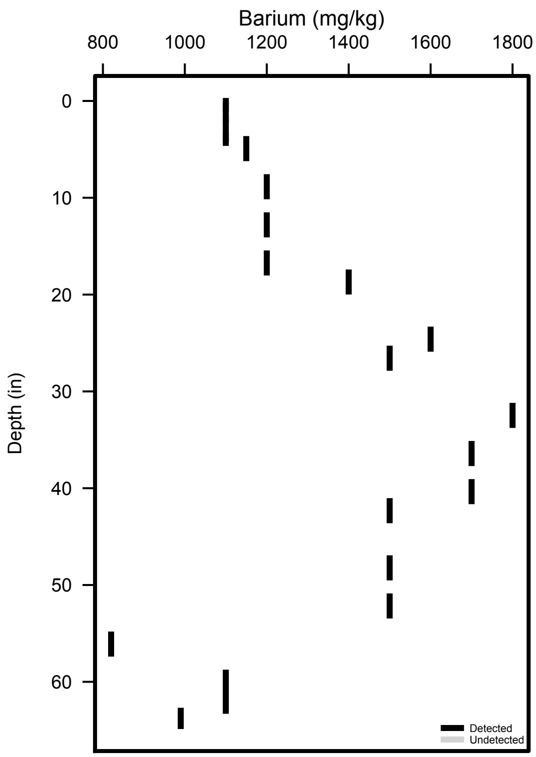

Figure 1181. Barium
at Cox Core Location CCR−668.

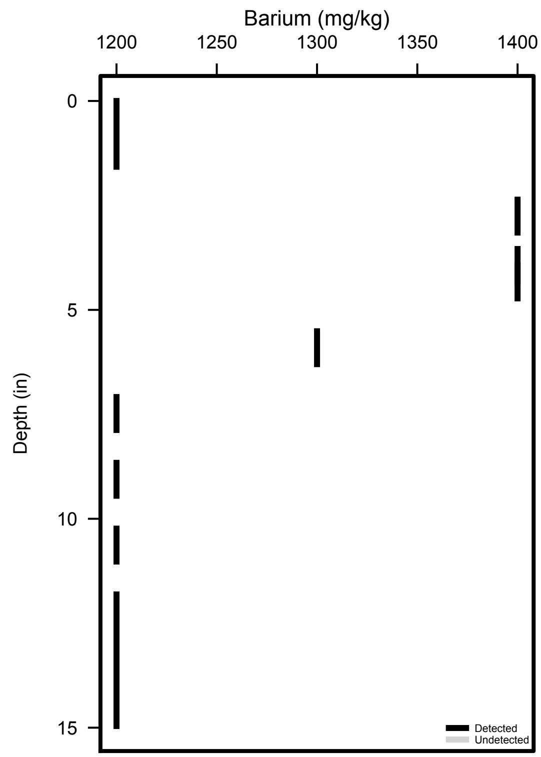

Figure 1182. Barium
at Cox Core Location CCR−692.

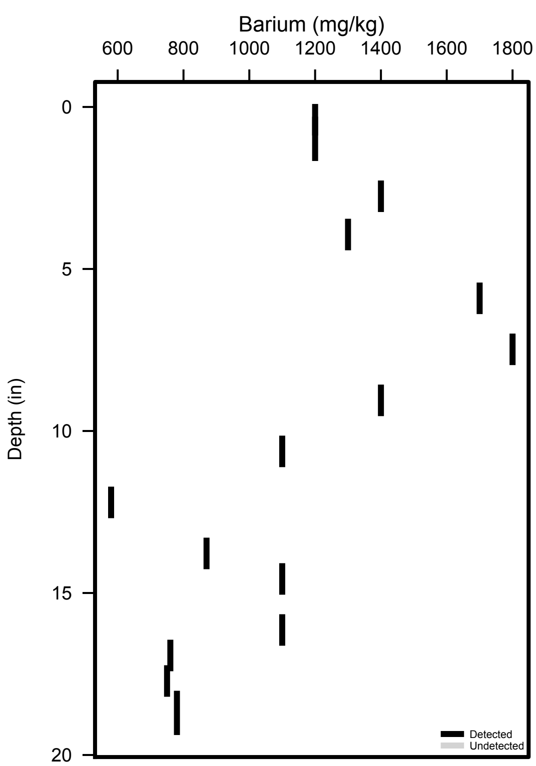

Figure 1183. Barium
at Cox Core Location CCR−705.

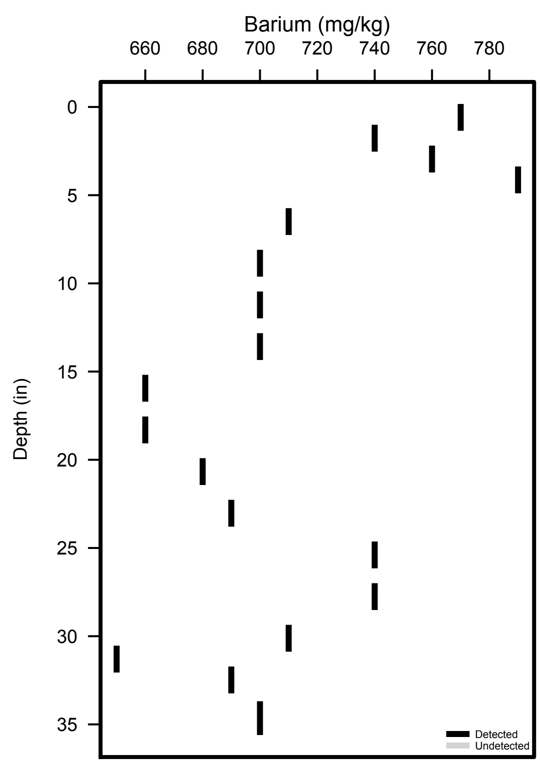

Figure 1184. Barium
at Cox Core Location CSA−8.

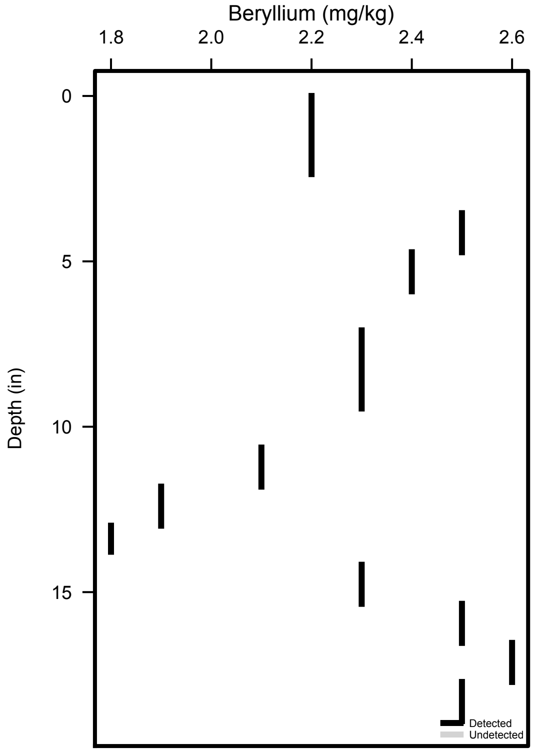

Figure 1185. Beryllium
at Cox Core Location CCR−624.

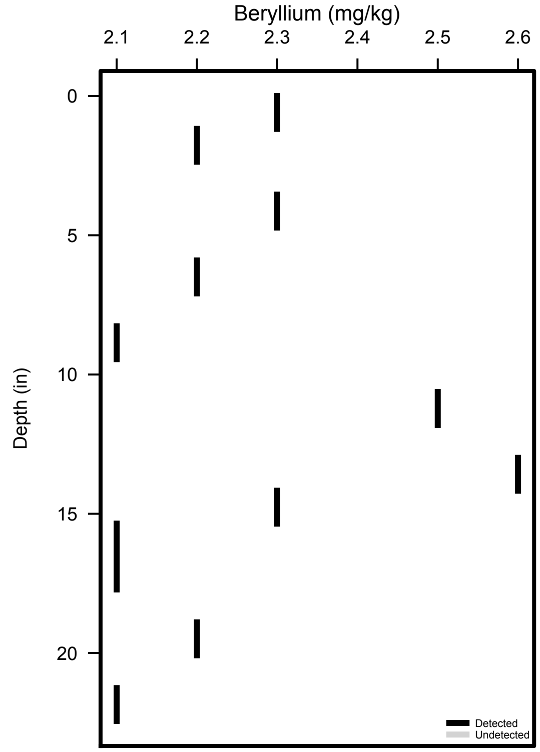

Figure 1186. Beryllium
at Cox Core Location CCR−643.

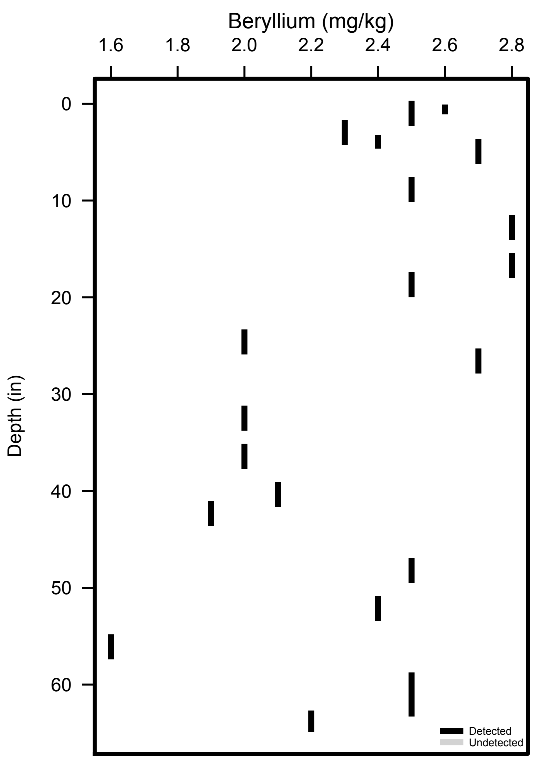

Figure 1187. Beryllium
at Cox Core Location CCR−668.

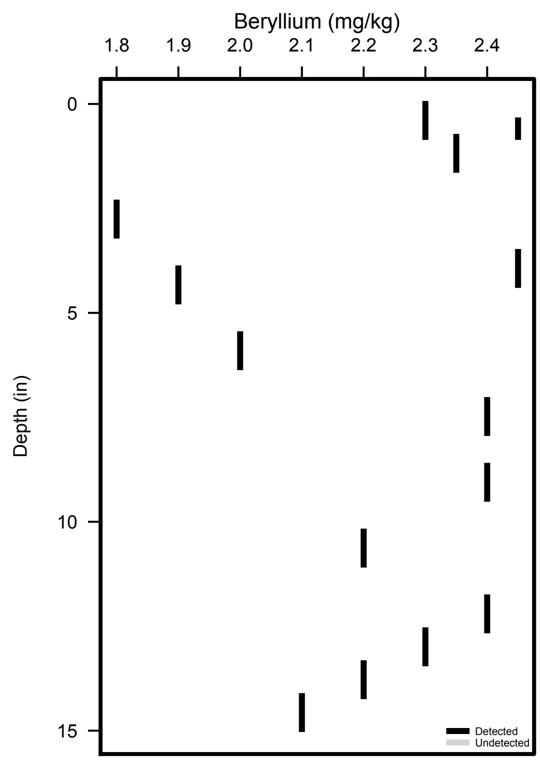

Figure 1188. Beryllium
at Cox Core Location CCR−692.

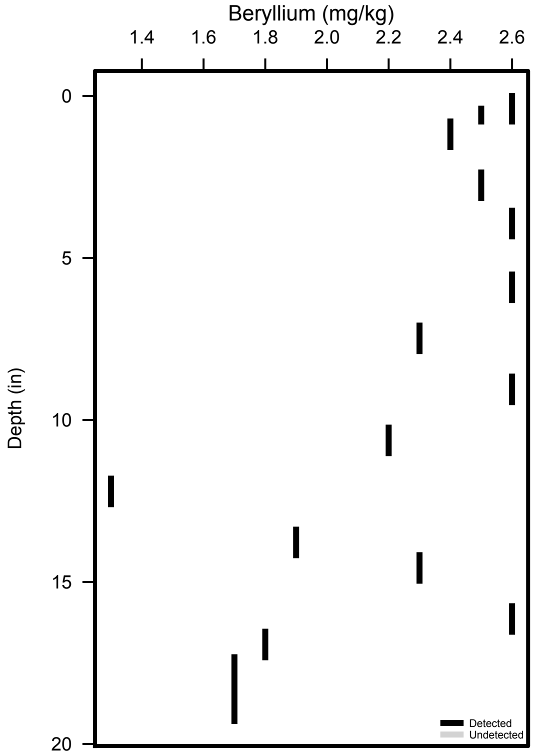

Figure 1189. Beryllium
at Cox Core Location CCR−705.

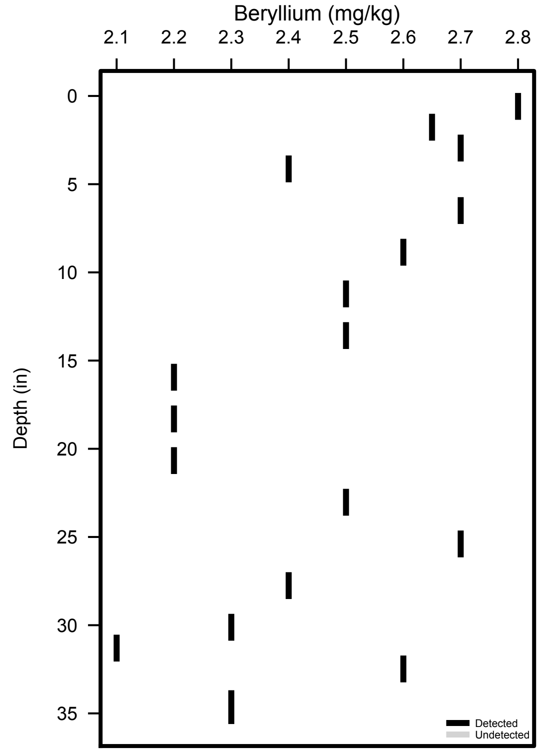

Figure 1190. Beryllium
at Cox Core Location CSA−8.

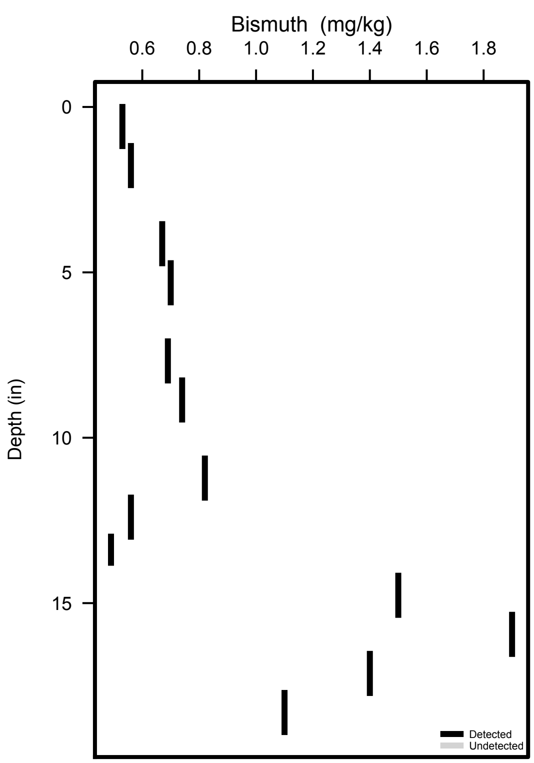

Figure 1191. Bismuth
at Cox Core Location CCR−624.

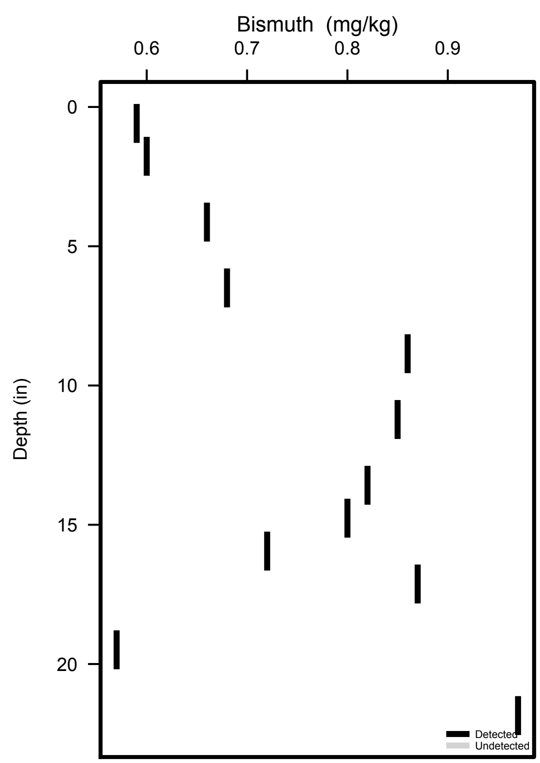

Figure 1192. Bismuth
at Cox Core Location CCR−643.

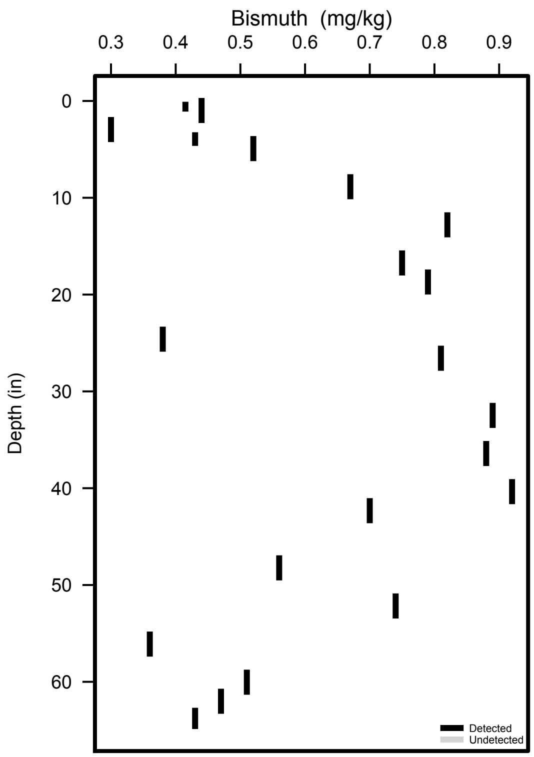

Figure 1193. Bismuth
at Cox Core Location CCR−668.

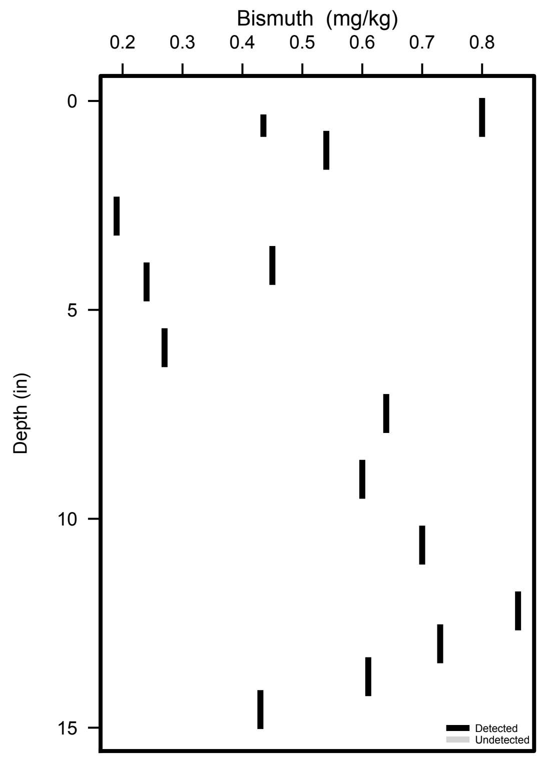

Figure 1194. Bismuth
at Cox Core Location CCR−692.

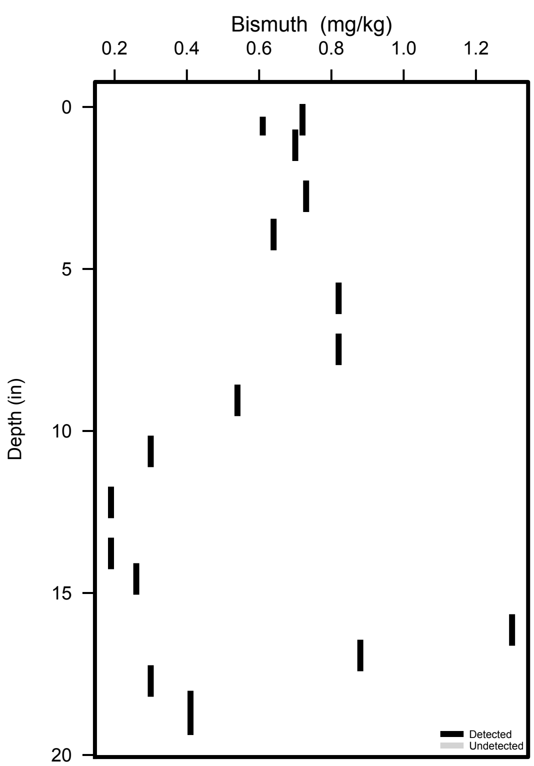

Figure 1195. Bismuth
at Cox Core Location CCR−705.

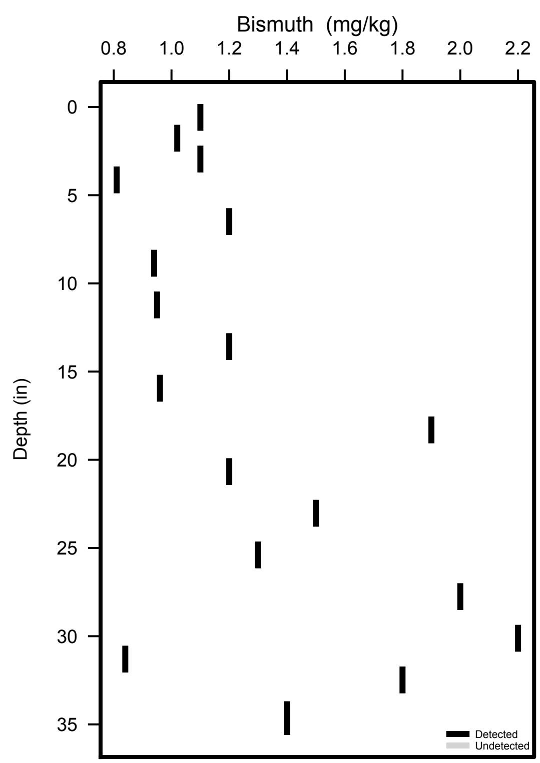

Figure 1196. Bismuth
at Cox Core Location CSA−8.

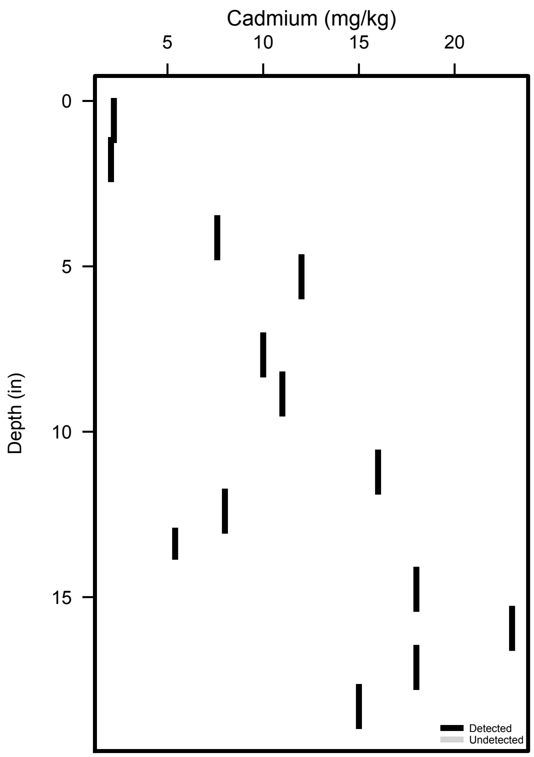

Figure 1197. Cadmium
at Cox Core Location CCR−624.

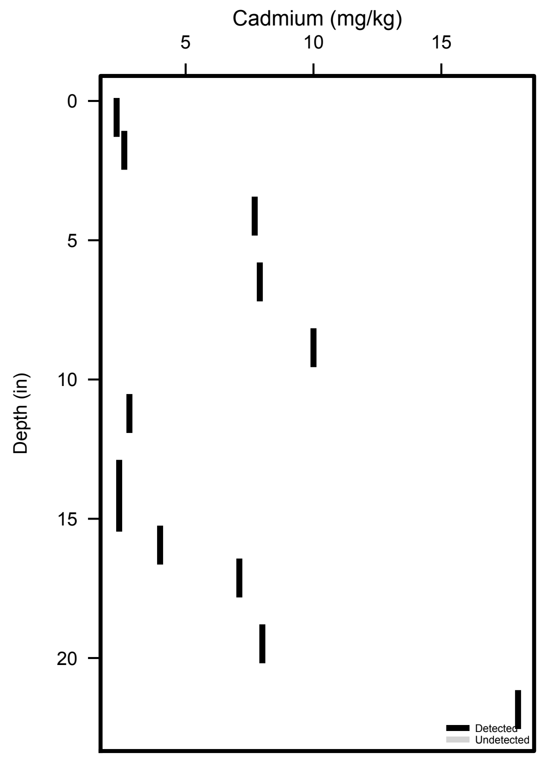

Figure 1198. Cadmium
at Cox Core Location CCR−643.

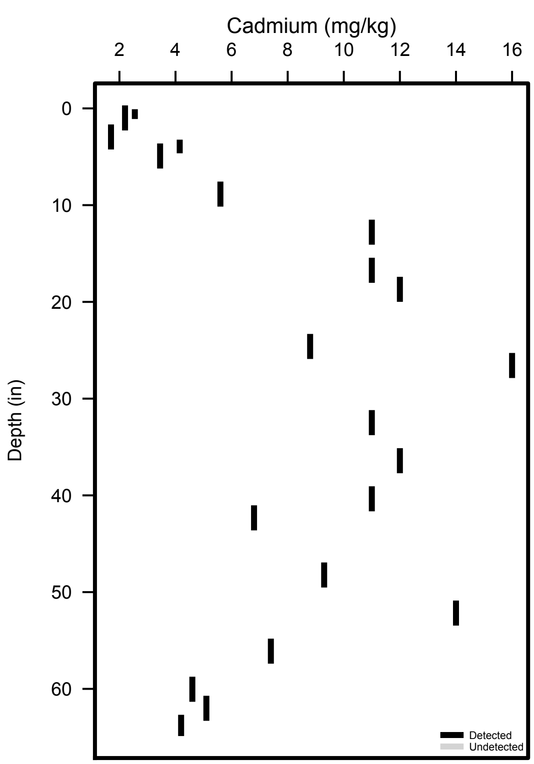

Figure 1199. Cadmium
at Cox Core Location CCR−668.

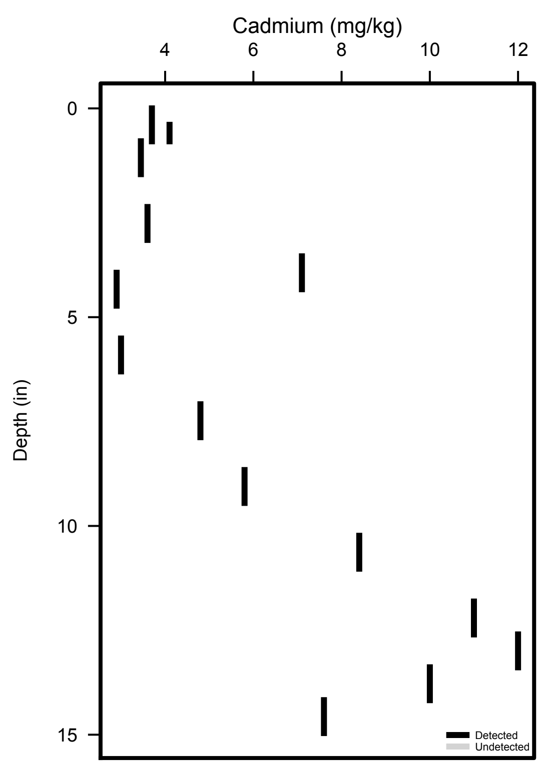

Figure 1200. Cadmium
at Cox Core Location CCR−692.

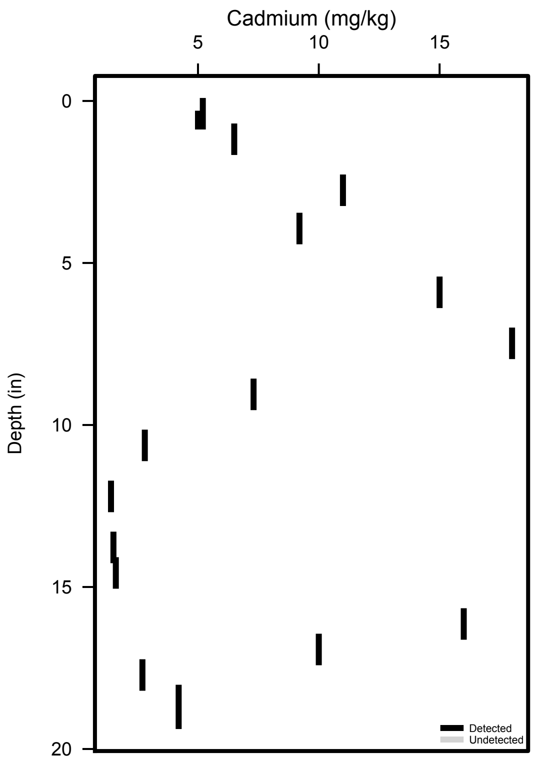

Figure 1201. Cadmium
at Cox Core Location CCR−705.

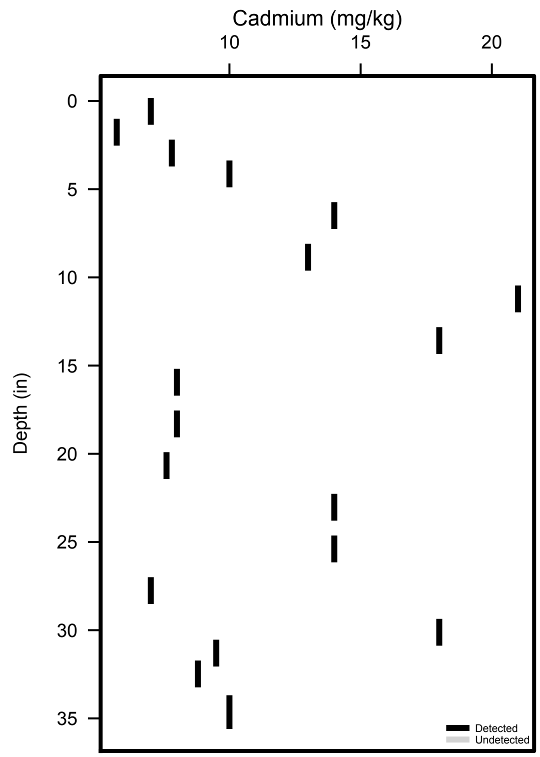

Figure 1202. Cadmium
at Cox Core Location CSA−8.

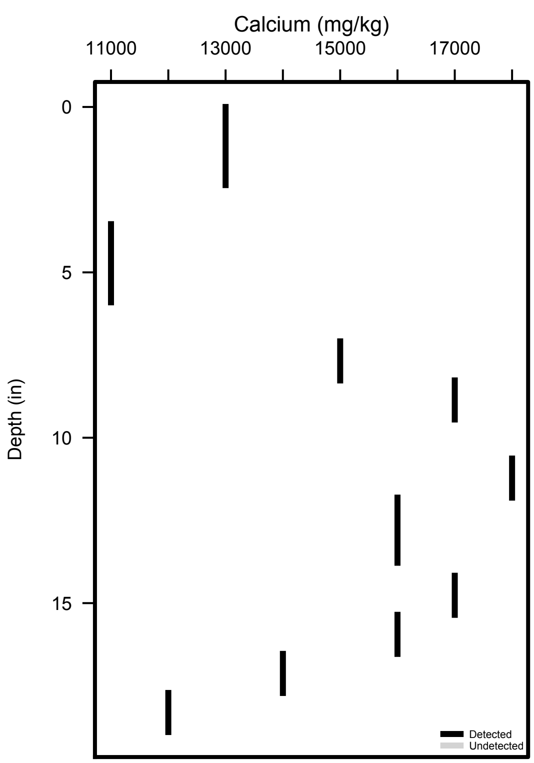

Figure 1203. Calcium
at Cox Core Location CCR−624.

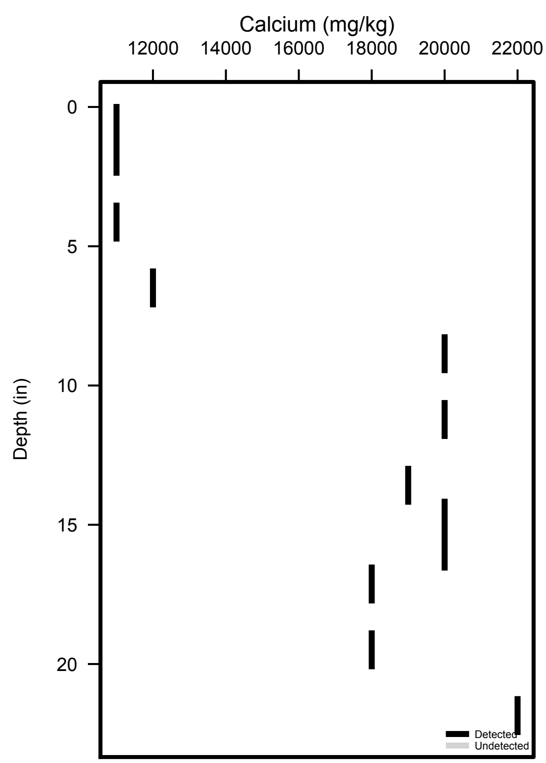

Figure 1204. Calcium
at Cox Core Location CCR−643.

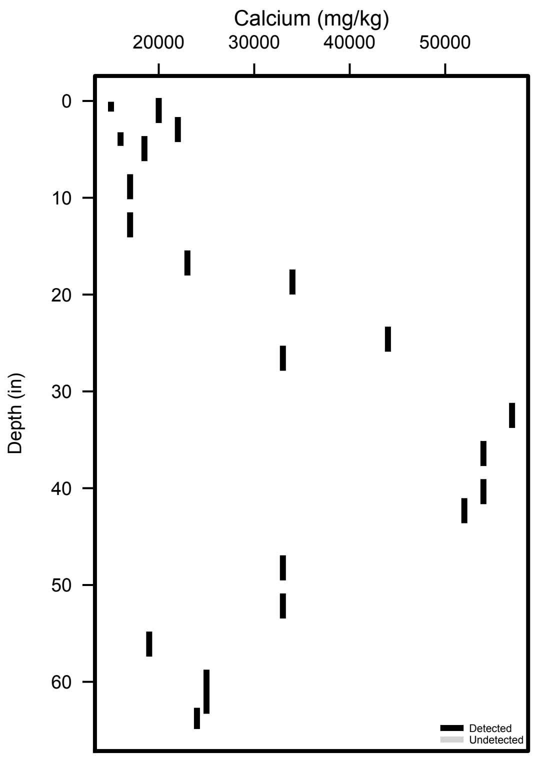

Figure 1205. Calcium
at Cox Core Location CCR−668.

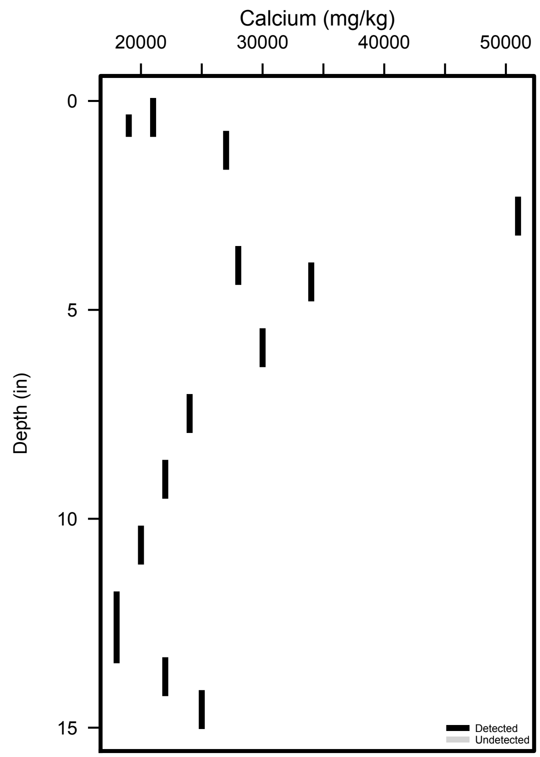

Figure 1206. Calcium
at Cox Core Location CCR−692.

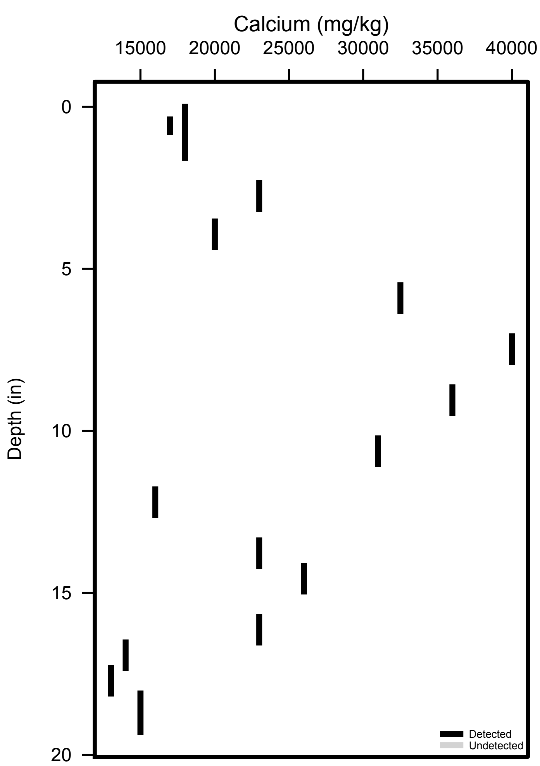

Figure 1207. Calcium
at Cox Core Location CCR−705.

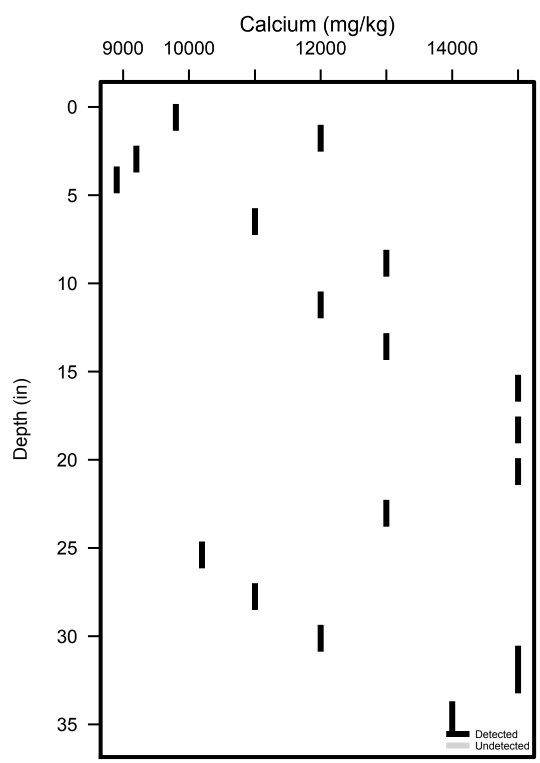

Figure 1208. Calcium
at Cox Core Location CSA−8.

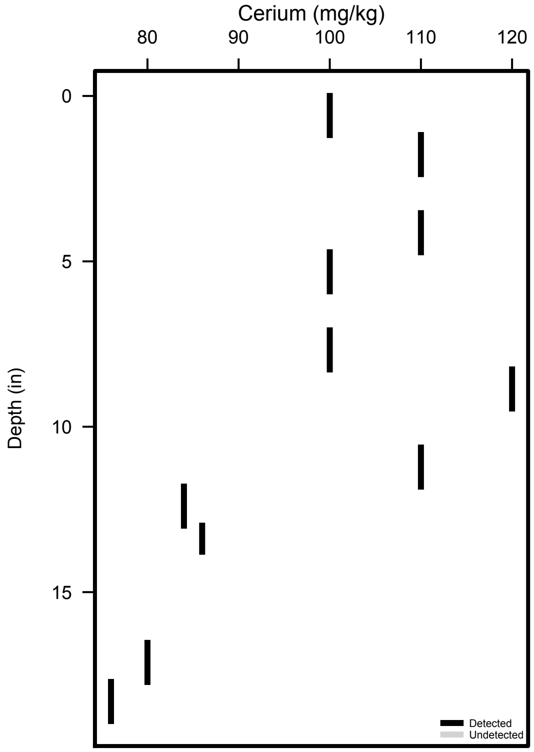

Figure 1209. Cerium
at Cox Core Location CCR−624.

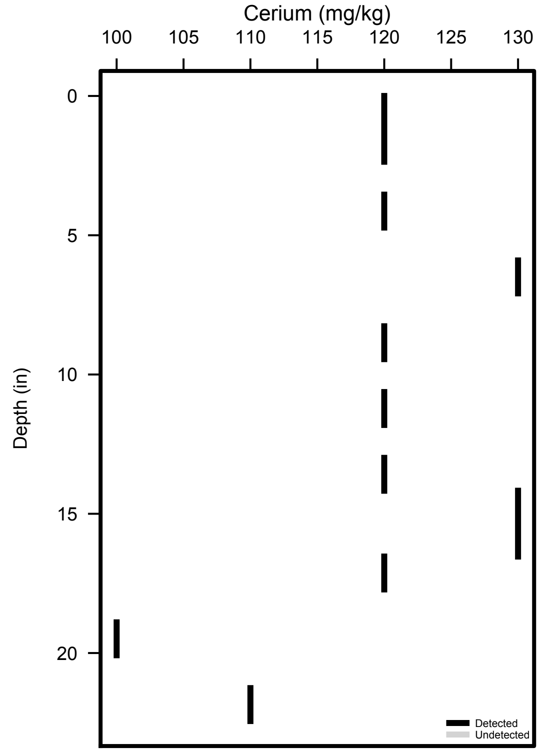

Figure 1210. Cerium
at Cox Core Location CCR−643.

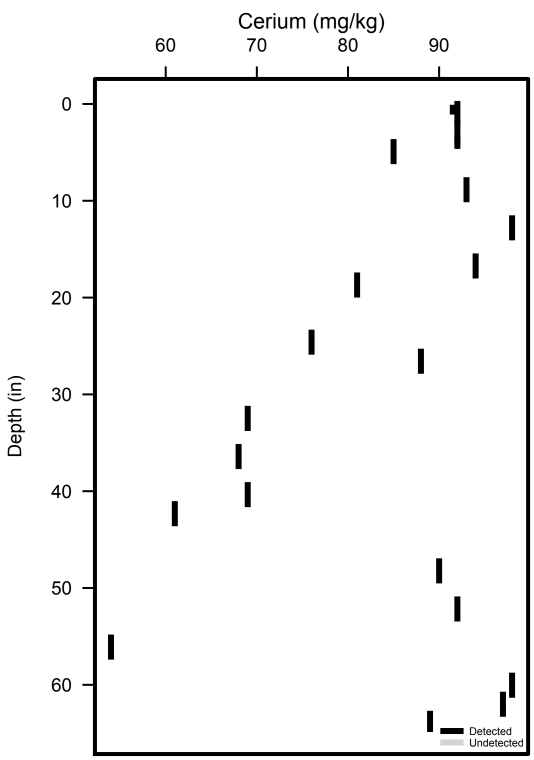

Figure 1211. Cerium
at Cox Core Location CCR−668.

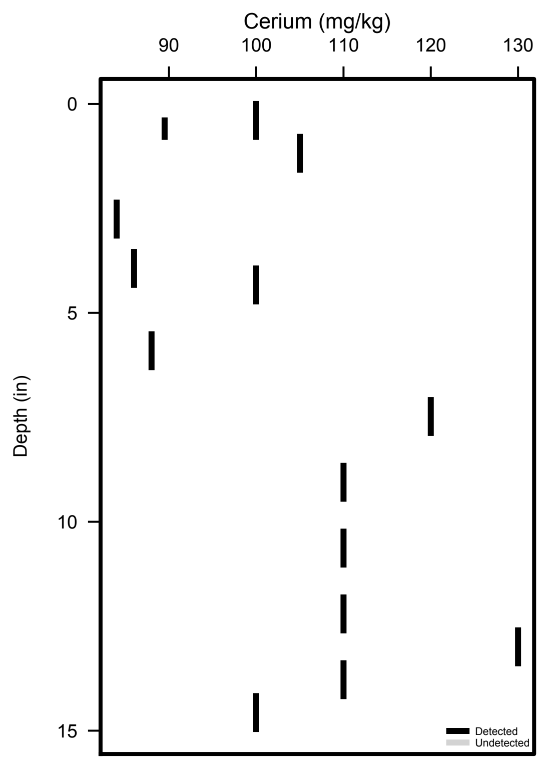

Figure 1212. Cerium
at Cox Core Location CCR−692.

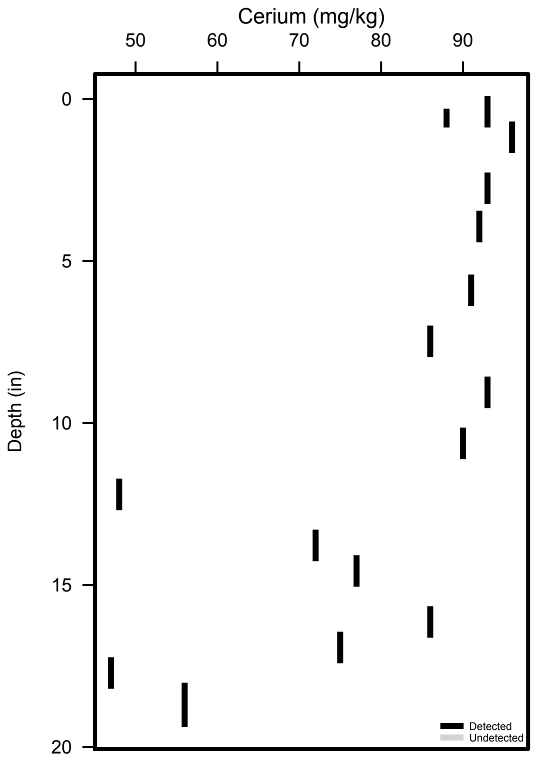

Figure 1213. Cerium
at Cox Core Location CCR−705.

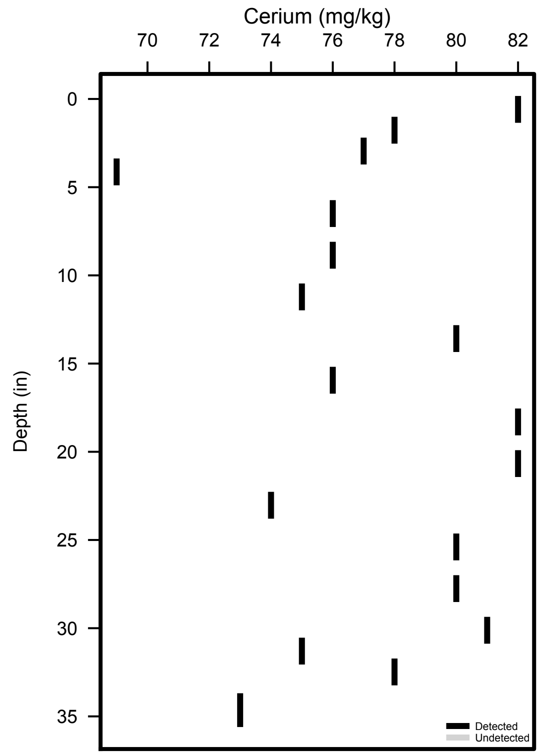

Figure 1214. Cerium
at Cox Core Location CSA−8.

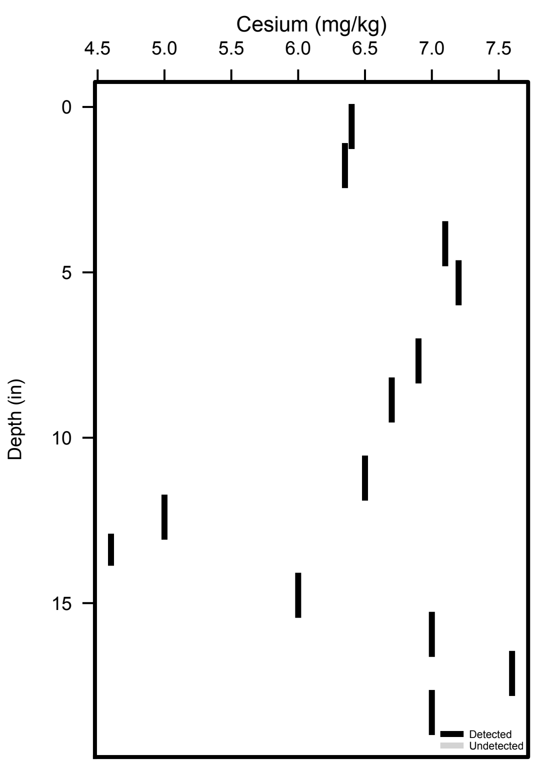

Figure 1215. Cesium
at Cox Core Location CCR−624.

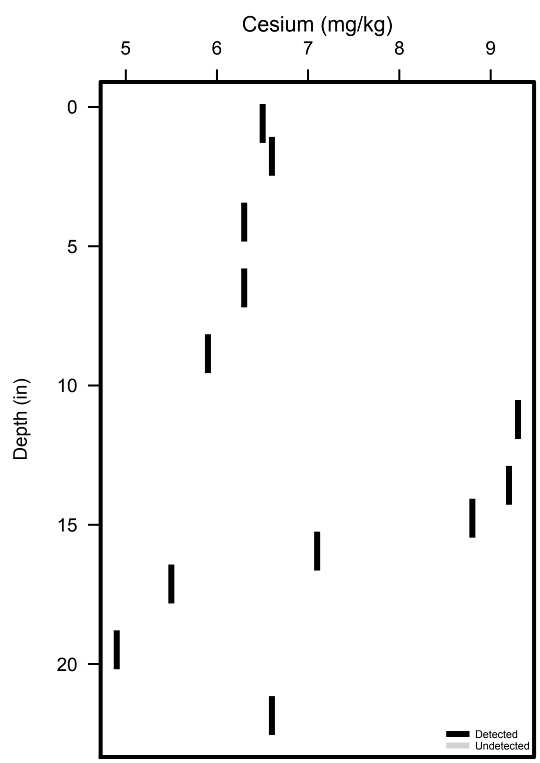

Figure 1216. Cesium
at Cox Core Location CCR−643.

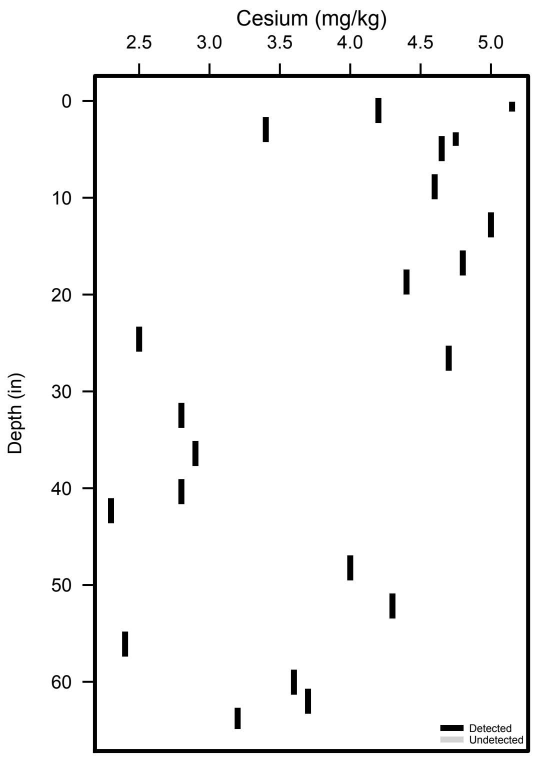

Figure 1217. Cesium
at Cox Core Location CCR−668.

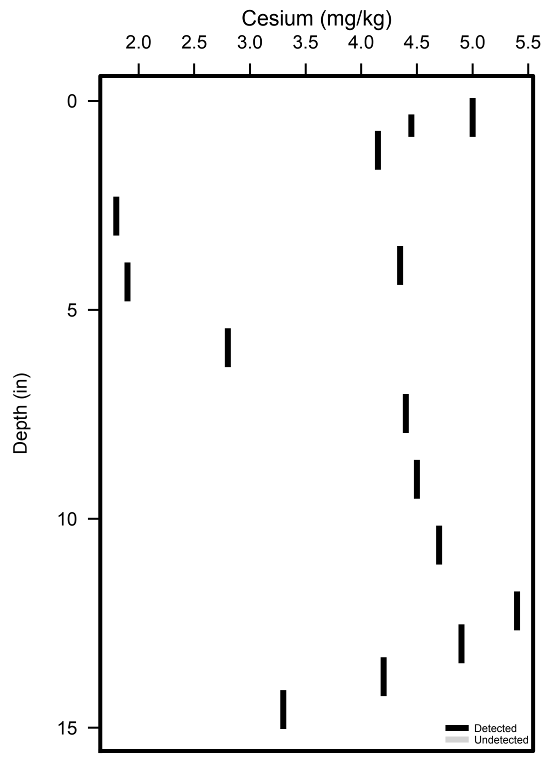

Figure 1218. Cesium
at Cox Core Location CCR−692.

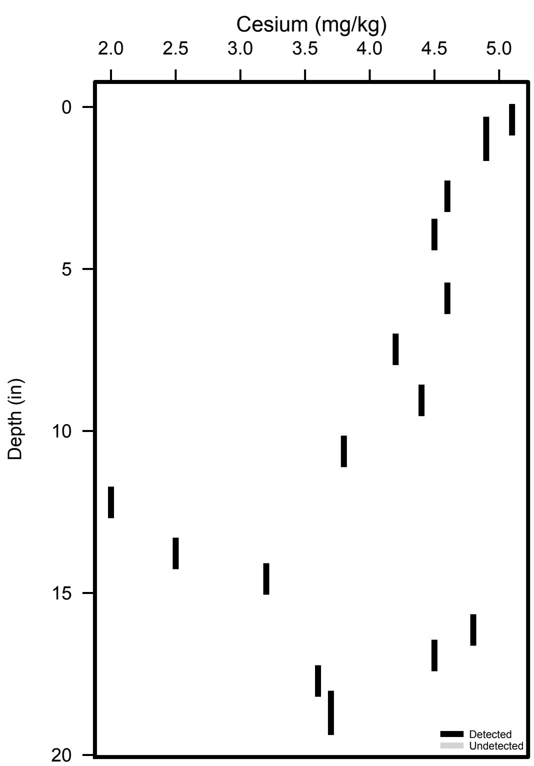

Figure 1219. Cesium
at Cox Core Location CCR−705.

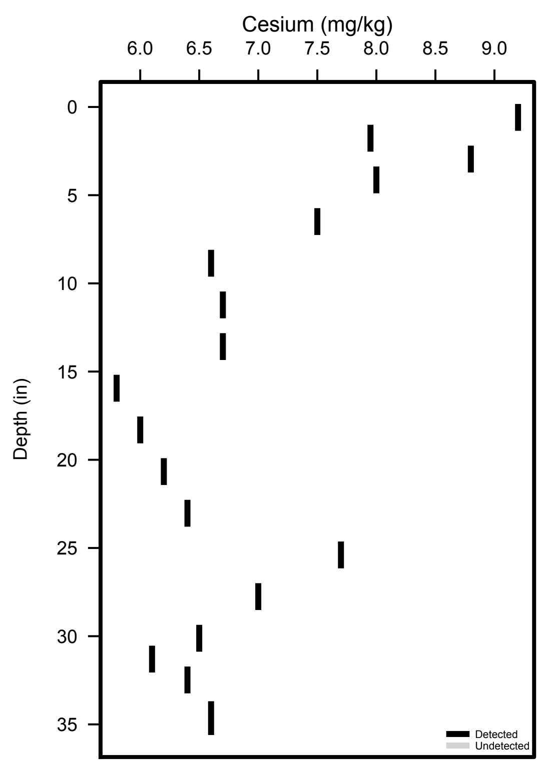

Figure 1220. Cesium
at Cox Core Location CSA−8.

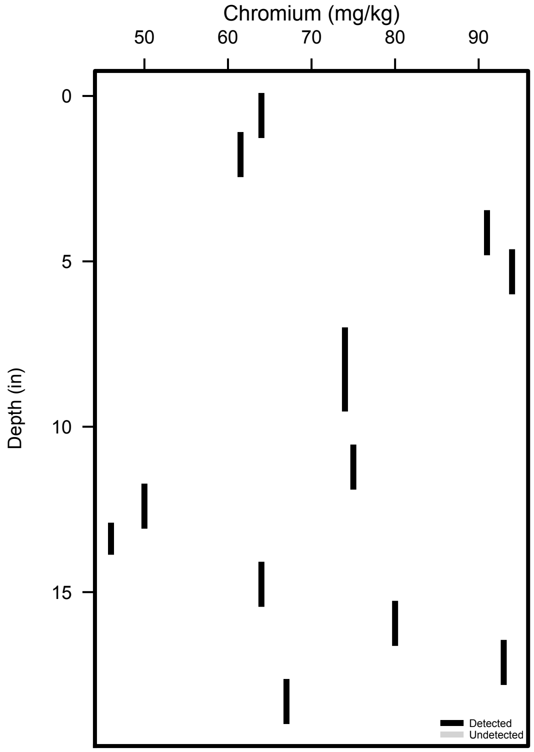

Figure 1221. Chromium at Cox Core Location CCR−624.

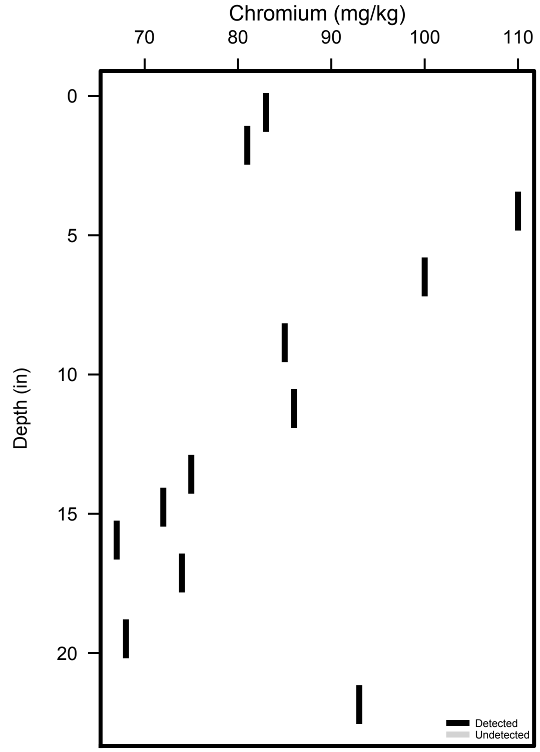

Figure 1222. Chromium at Cox Core Location CCR−643.

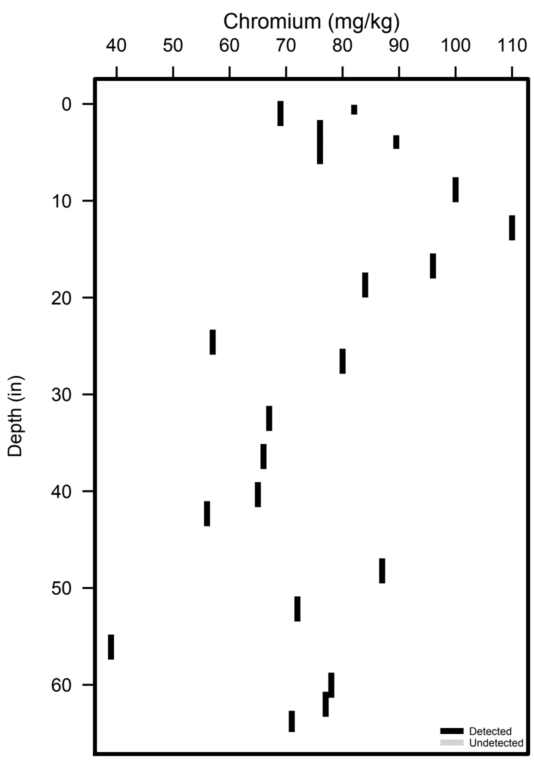

Figure 1223. Chromium at Cox Core Location CCR−668.

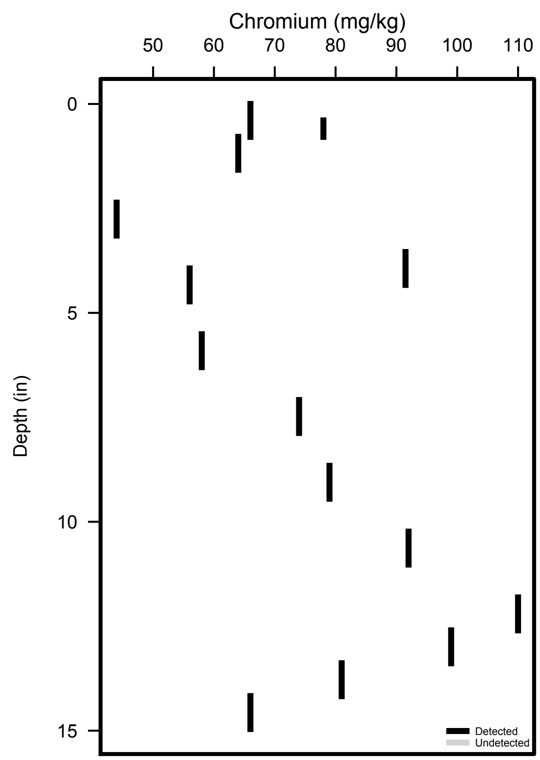

Figure 1224. Chromium at Cox Core Location CCR−692.

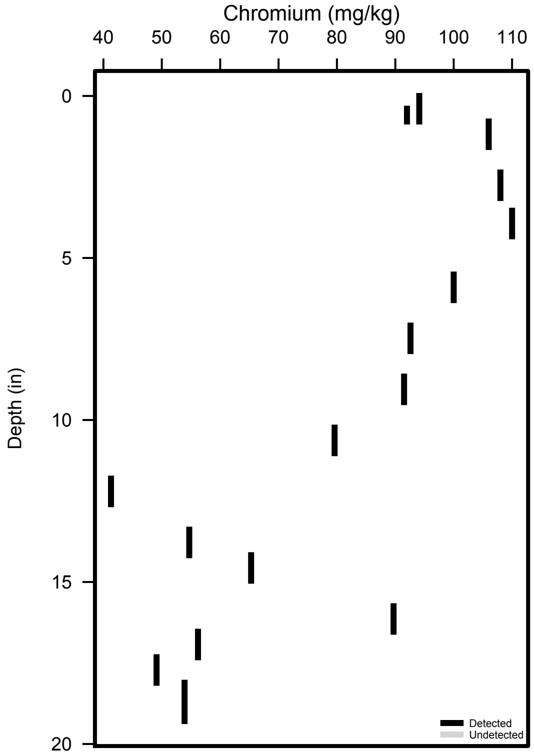

Figure 1225. Chromium
at Cox Core Location CCR−705.

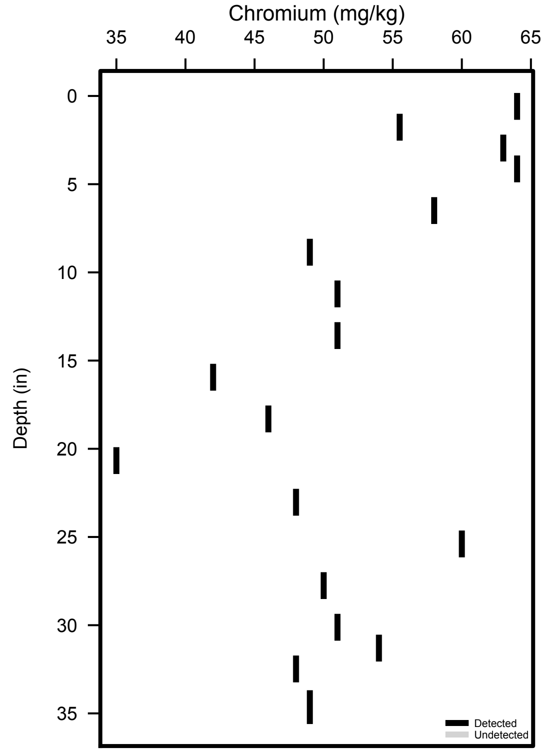

Figure 1226. Chromium
at Cox Core Location CSA−8.

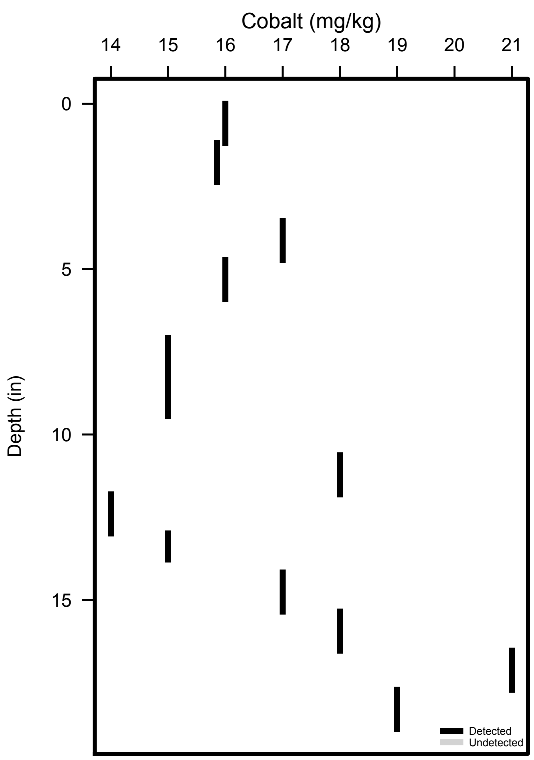

Figure 1227. Cobalt
at Cox Core Location CCR−624.

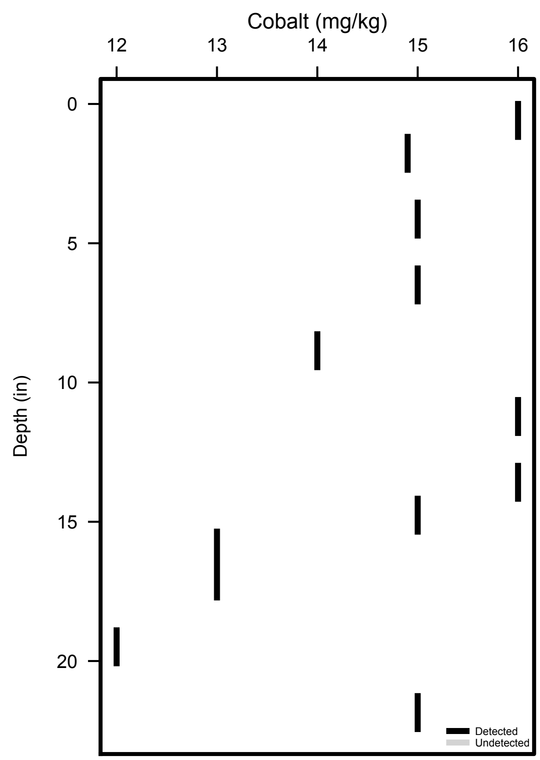

Figure 1228. Cobalt
at Cox Core Location CCR−643.

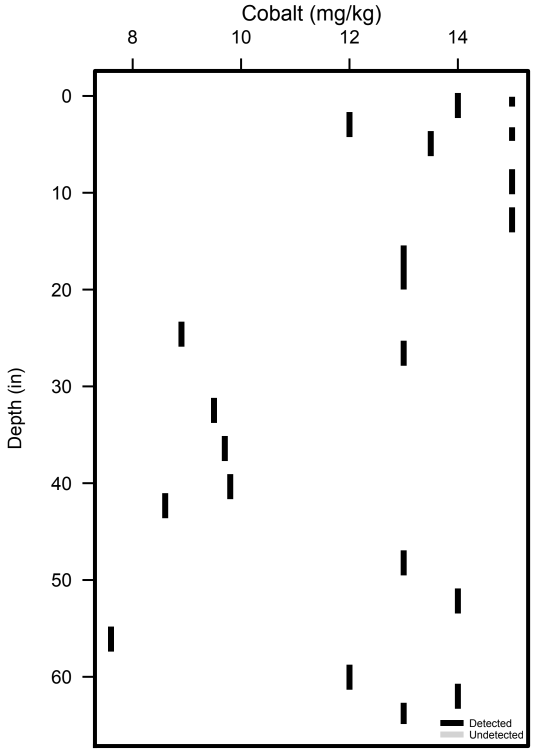

Figure 1229. Cobalt
at Cox Core Location CCR−668.

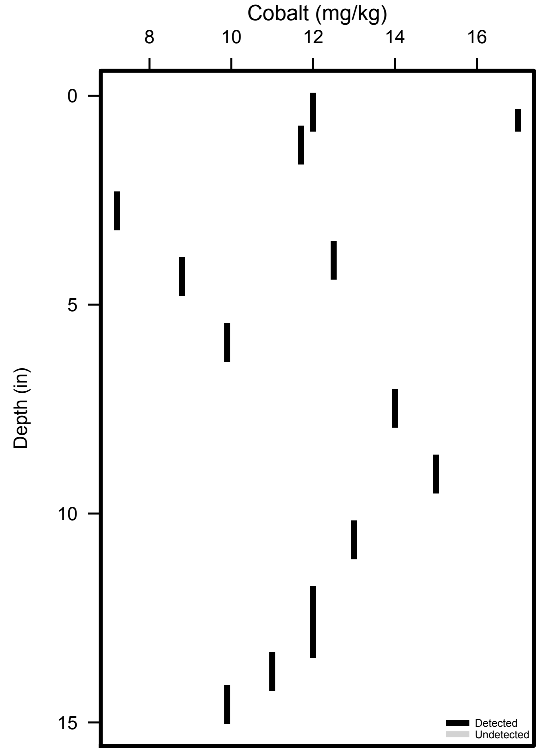

Figure 1230. Cobalt
at Cox Core Location CCR−692.

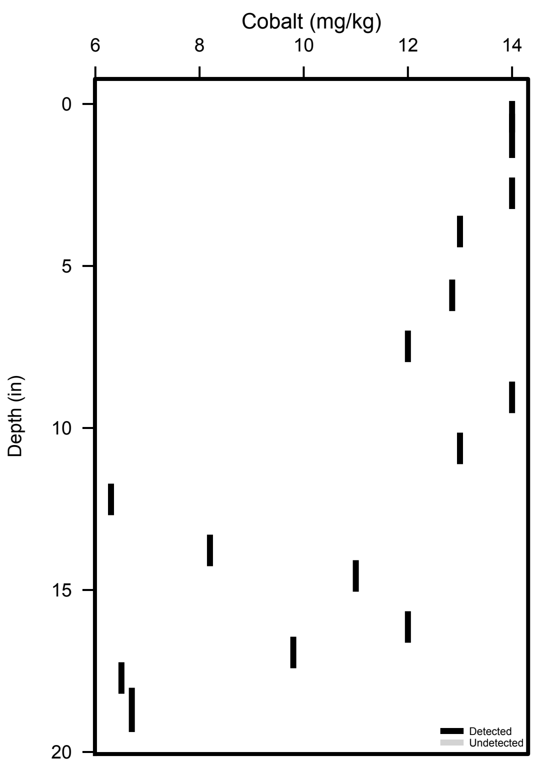

Figure 1231. Cobalt
at Cox Core Location CCR−705.

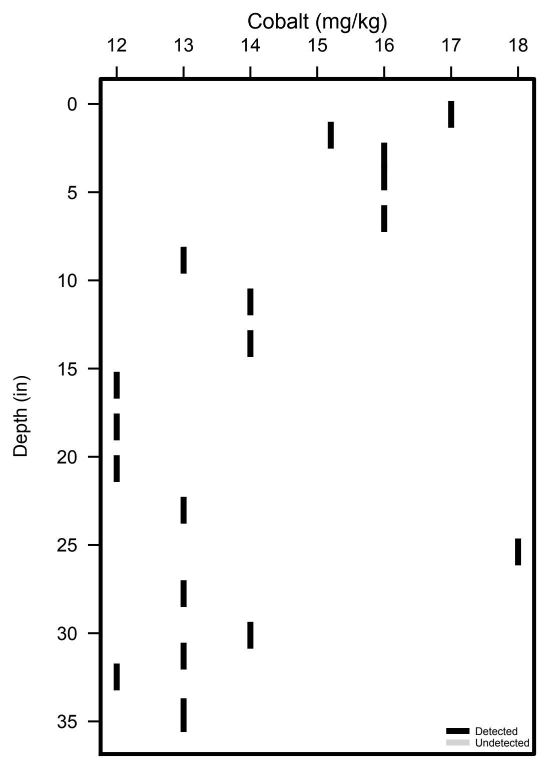

Figure 1232. Cobalt
at Cox Core Location CSA−8.

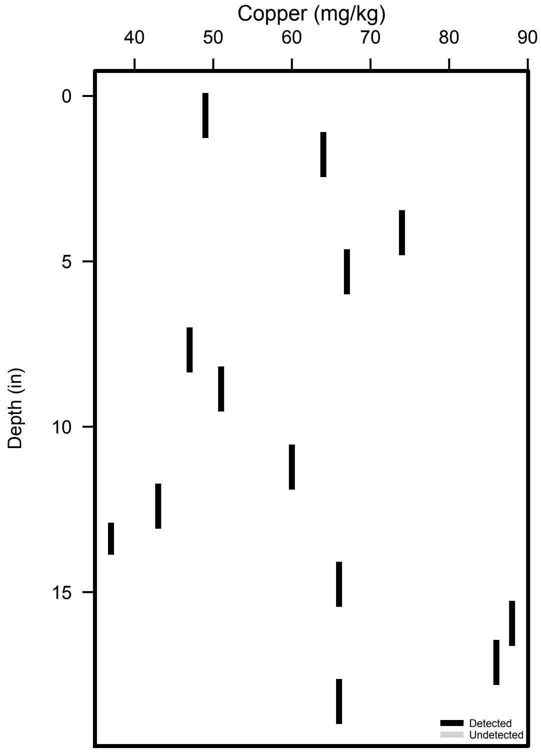

Figure 1233. Copper
at Cox Core Location CCR−624.

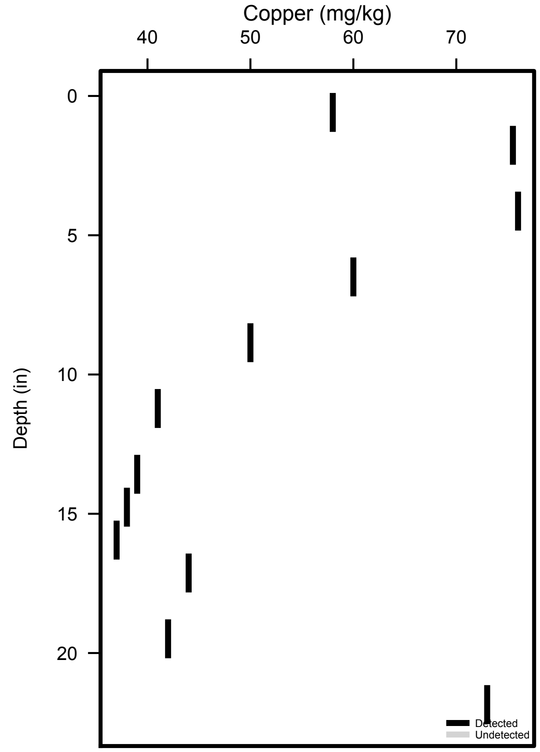

Figure 1234. Copper
at Cox Core Location CCR−643.

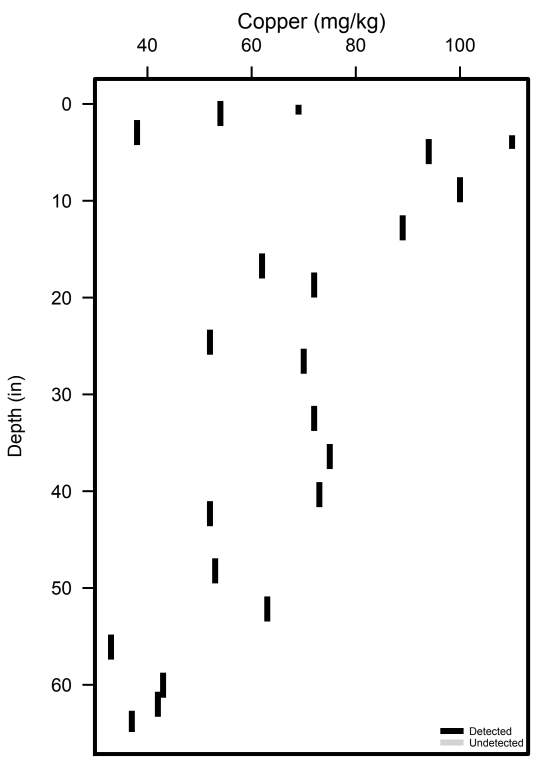

Figure 1235. Copper
at Cox Core Location CCR−668.

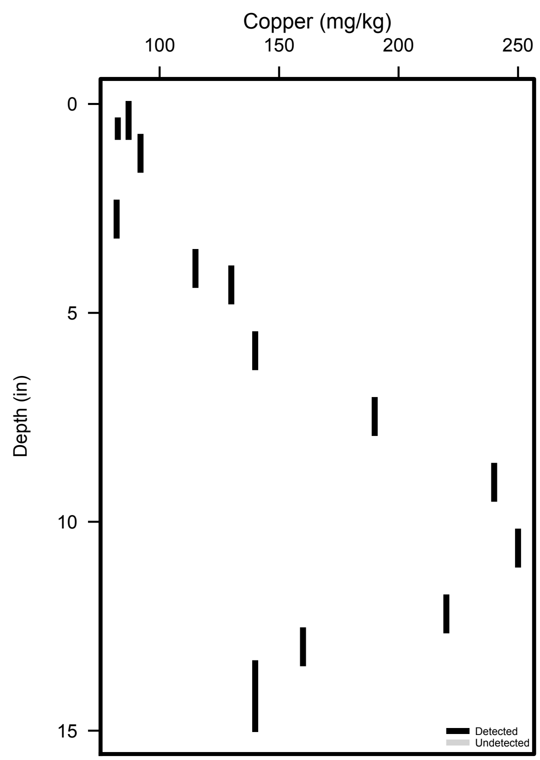

Figure 1236. Copper
at Cox Core Location CCR−692.

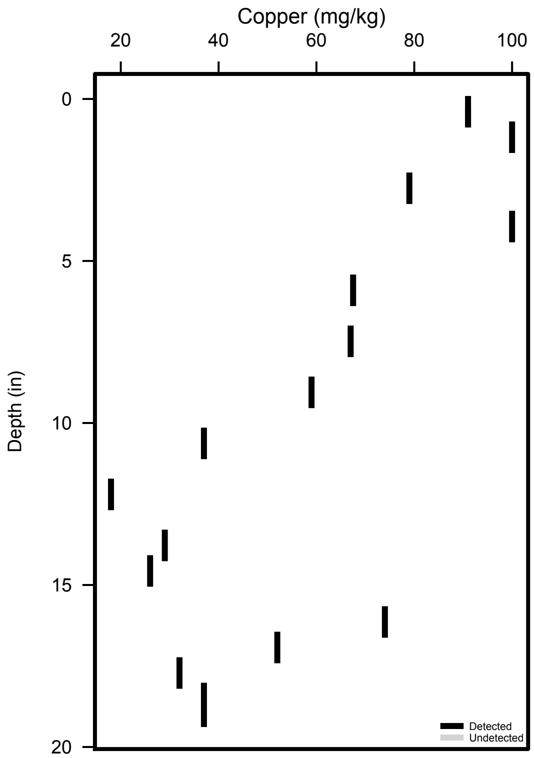

Figure 1237. Copper
at Cox Core Location CCR−705.

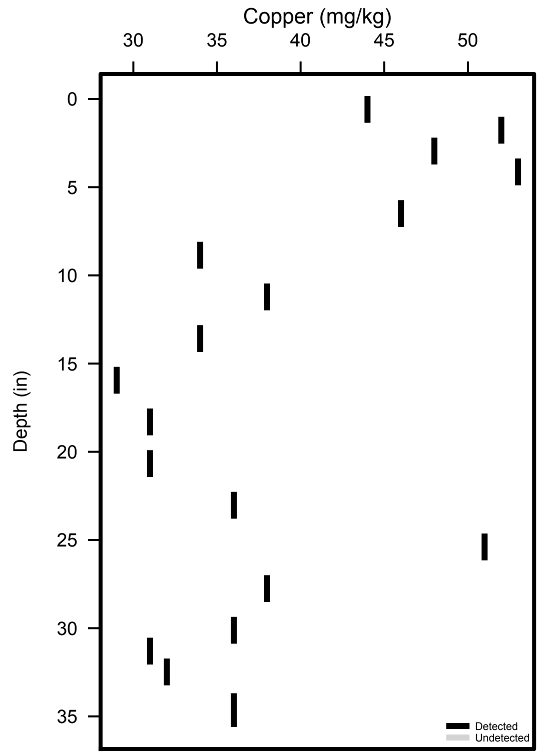

Figure 1238. Copper
at Cox Core Location CSA−8.

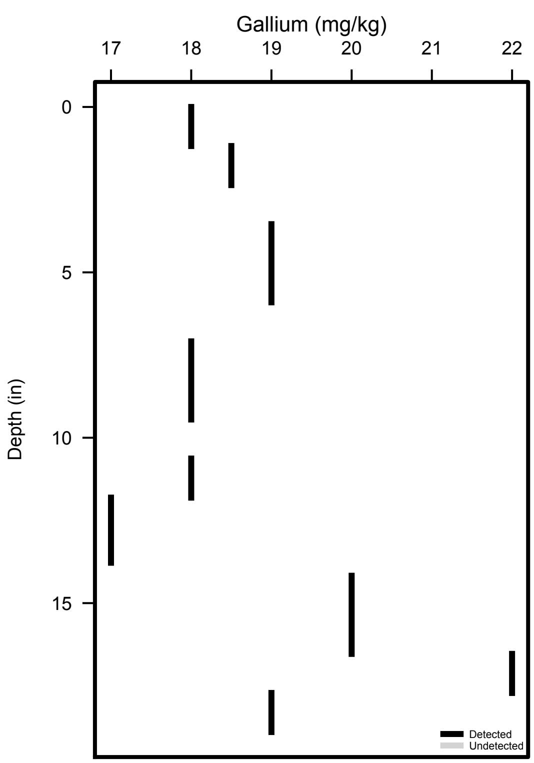

Figure 1239. Gallium
at Cox Core Location CCR−624.

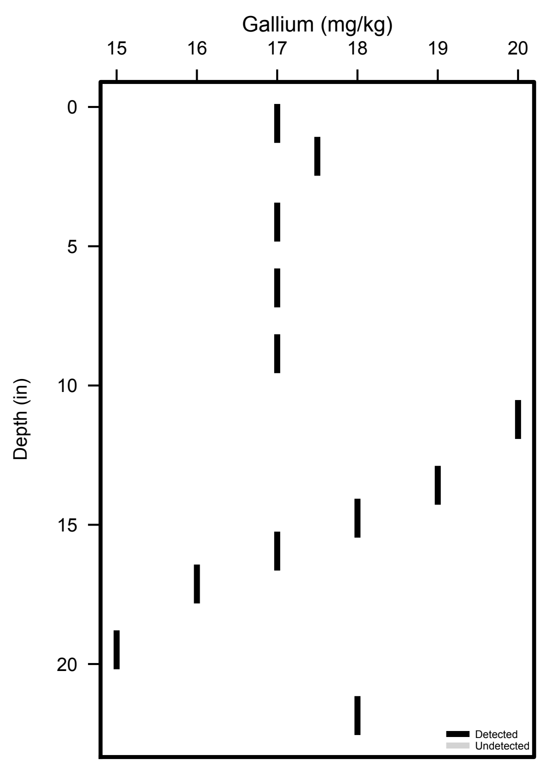

Figure 1240. Gallium
at Cox Core Location CCR−643.

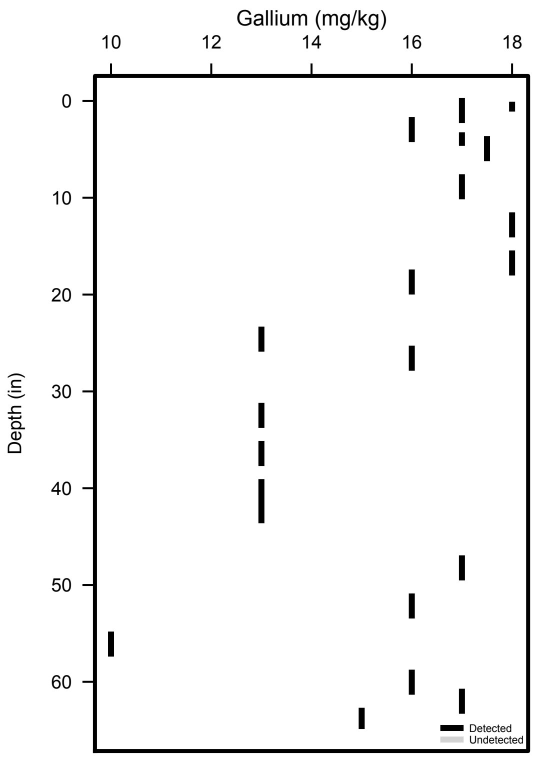

Figure 1241. Gallium
at Cox Core Location CCR−668.

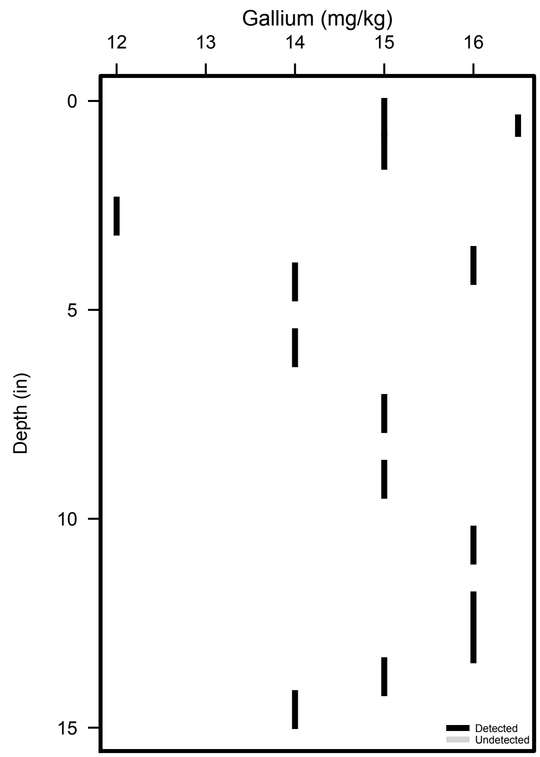

Figure 1242. Gallium
at Cox Core Location CCR−692.

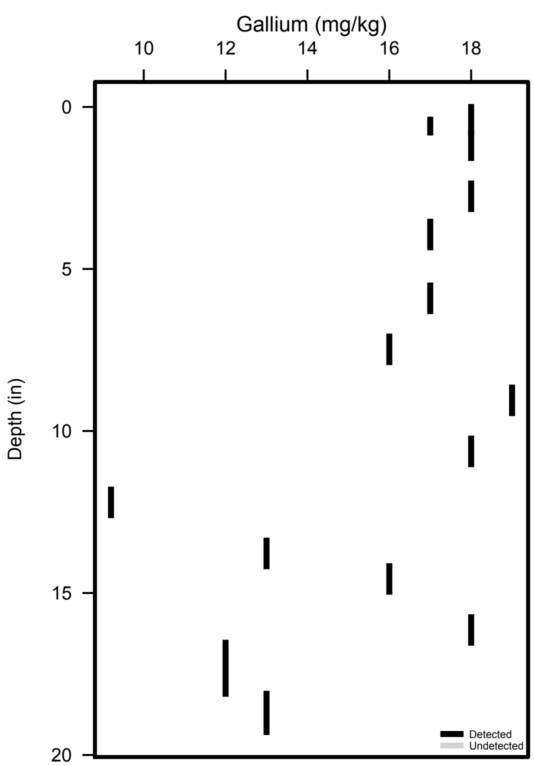

Figure 1243. Gallium
at Cox Core Location CCR−705.

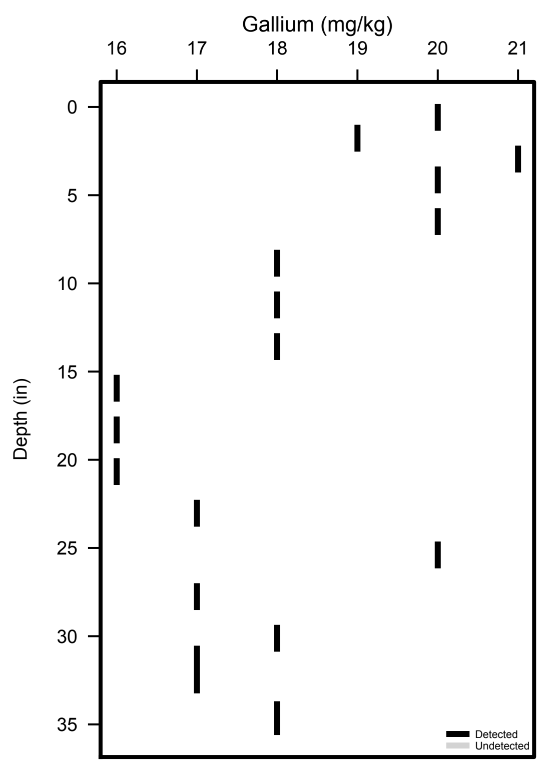

Figure 1244. Gallium
at Cox Core Location CSA−8.

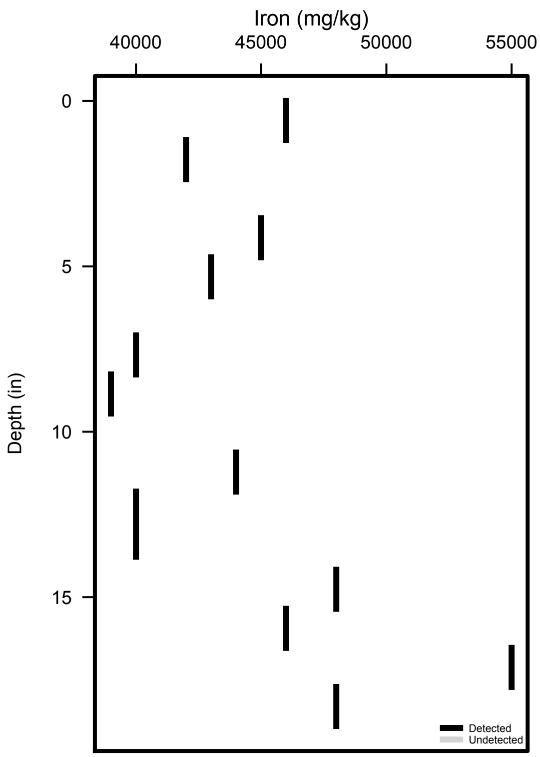

Figure 1245. Iron
at Cox Core Location CCR−624.

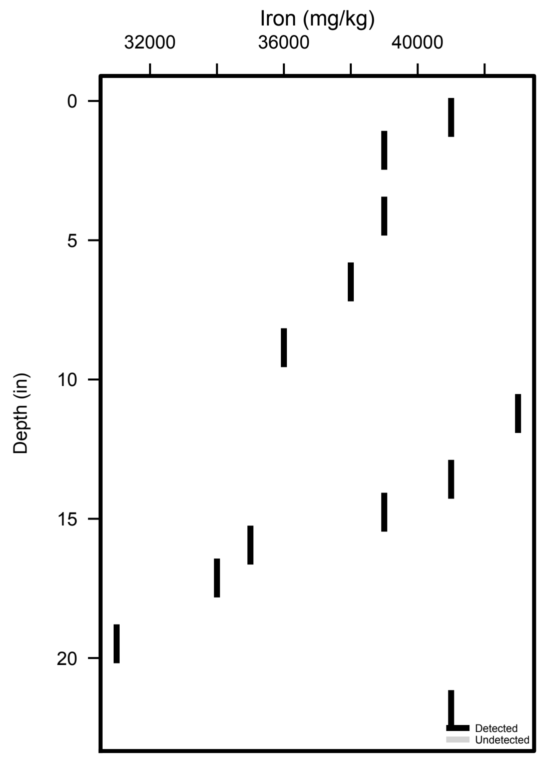

Figure 1246. Iron
at Cox Core Location CCR−643.

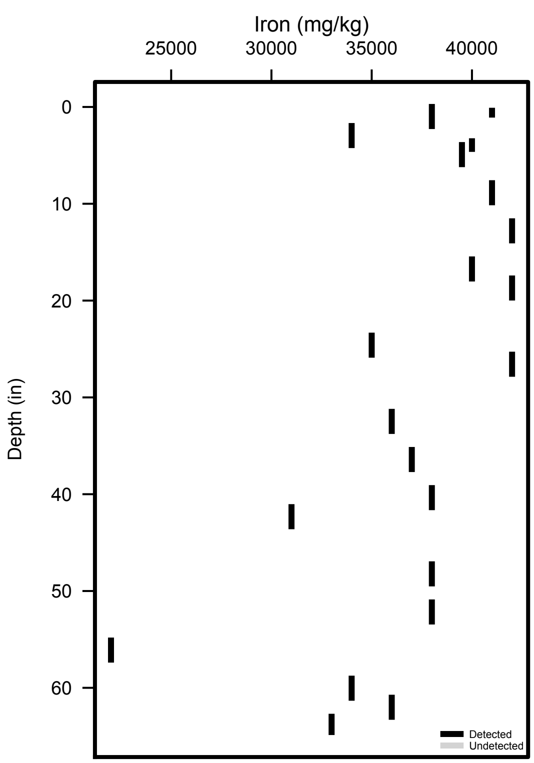

Figure 1247. Iron
at Cox Core Location CCR−668.

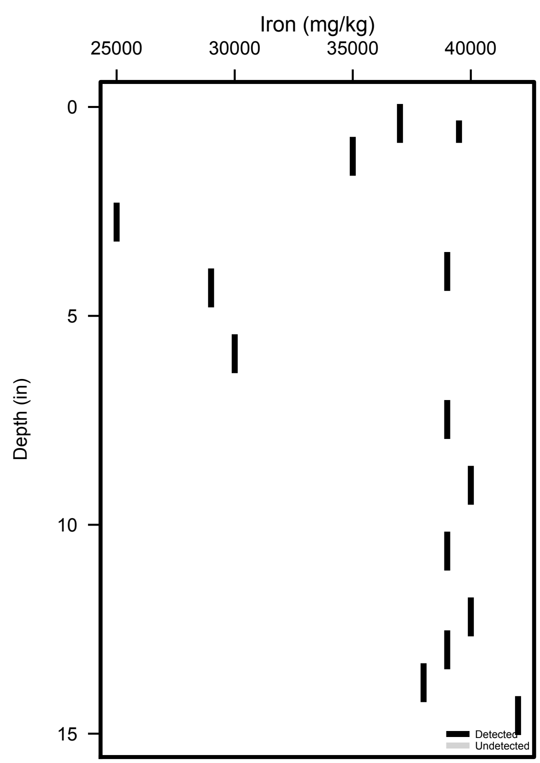

Figure 1248. Iron
at Cox Core Location CCR−692.

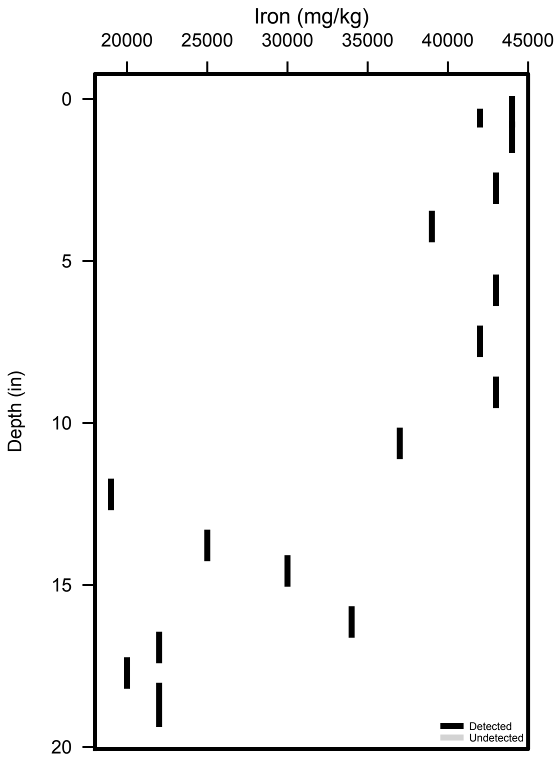

Figure 1249. Iron
at Cox Core Location CCR−705.

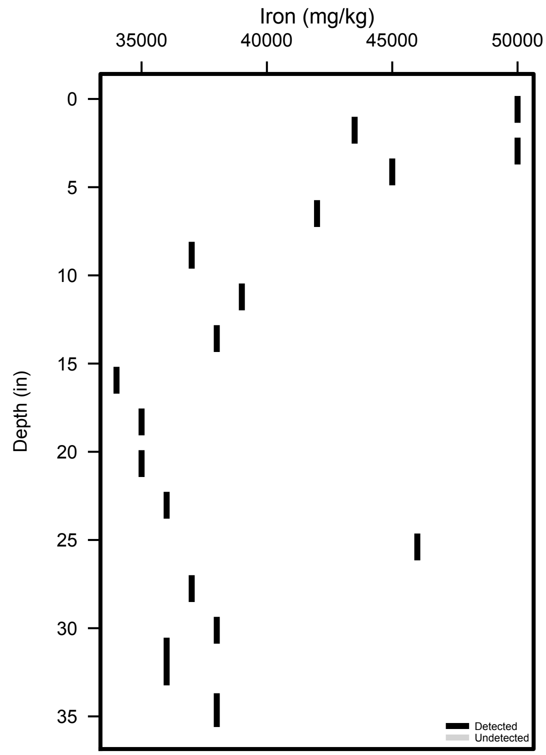

Figure 1250. Iron
at Cox Core Location CSA−8.

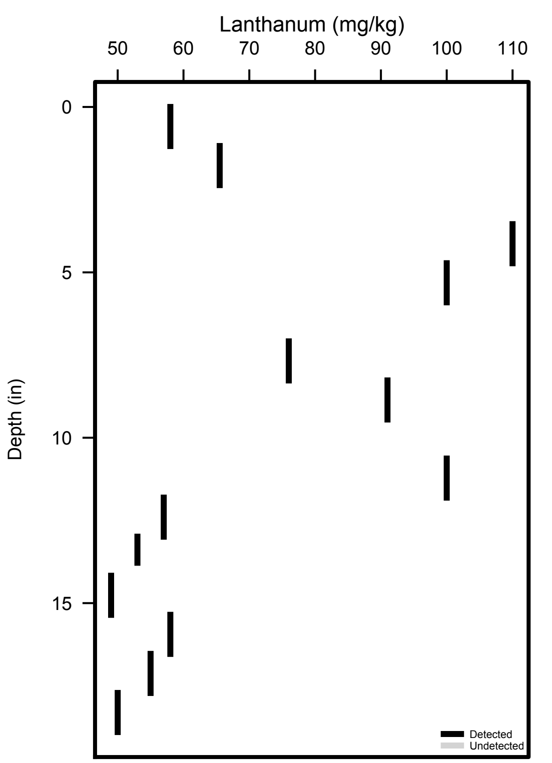

Figure 1251. Lanthanum
at Cox Core Location CCR−624.

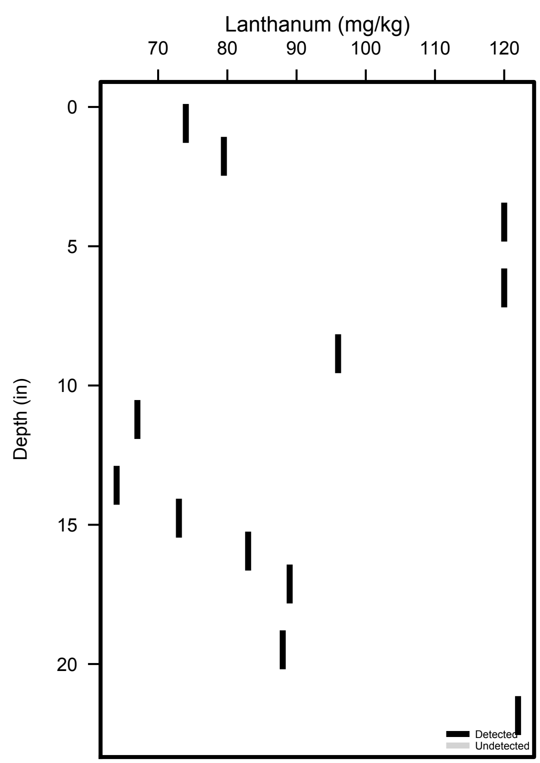

Figure 1252. Lanthanum
at Cox Core Location CCR−643.

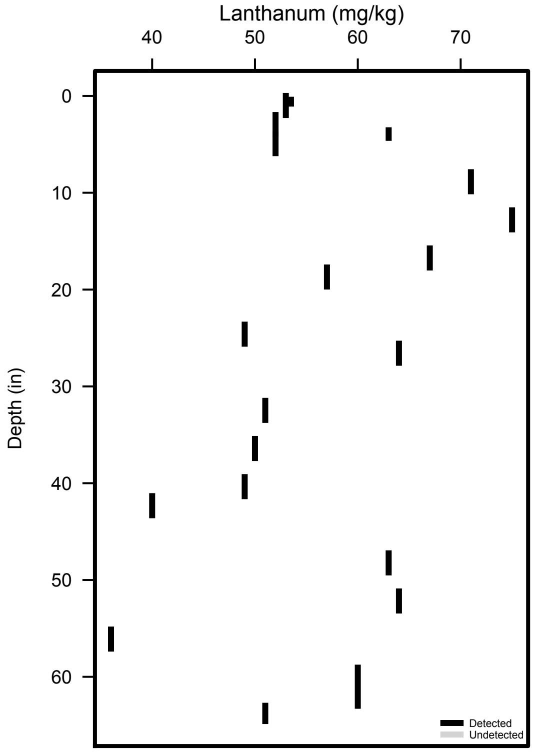

Figure 1253. Lanthanum
at Cox Core Location CCR−668.

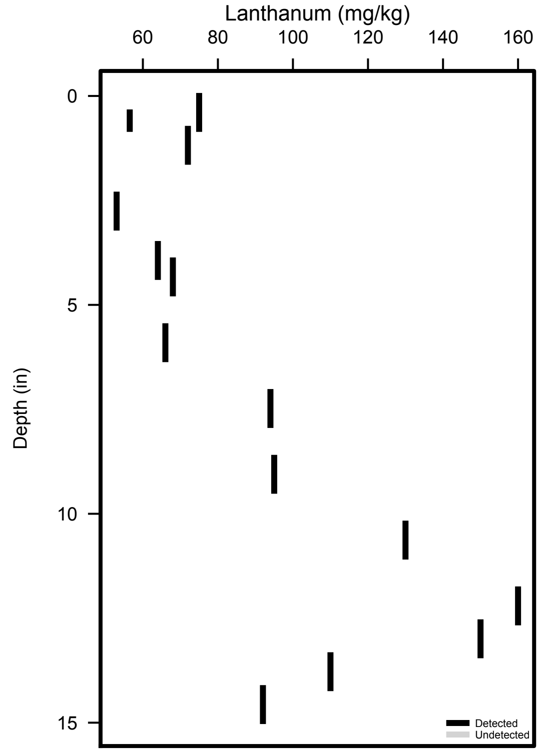

Figure 1254. Lanthanum
at Cox Core Location CCR−692.

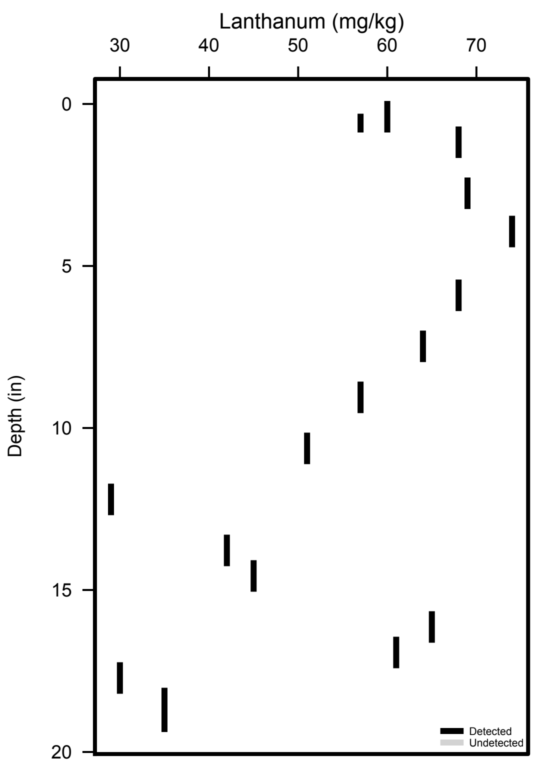

Figure 1255. Lanthanum
at Cox Core Location CCR−705.

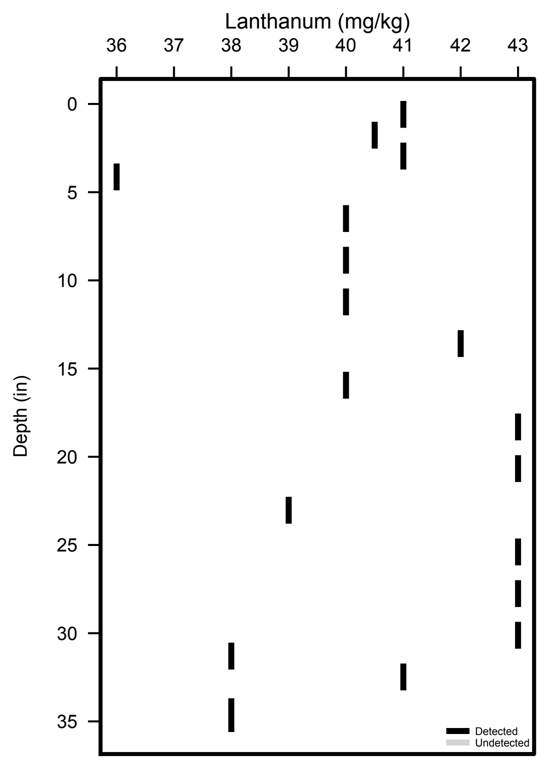

Figure 1256. Lanthanum
at Cox Core Location CSA−8.

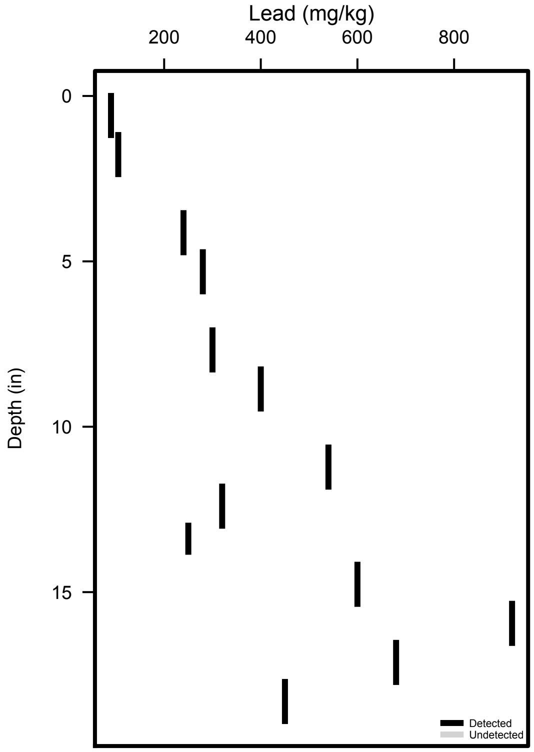

Figure 1257. Lead
at Cox Core Location CCR−624.

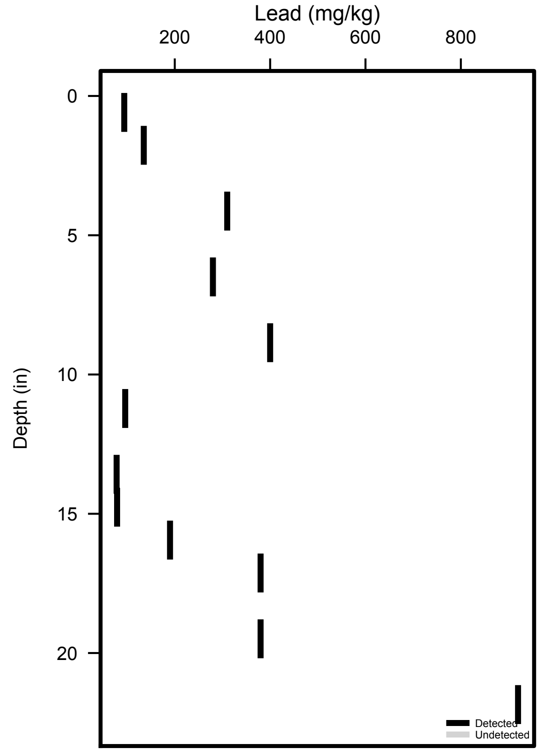

Figure 1258. Lead
at Cox Core Location CCR−643.

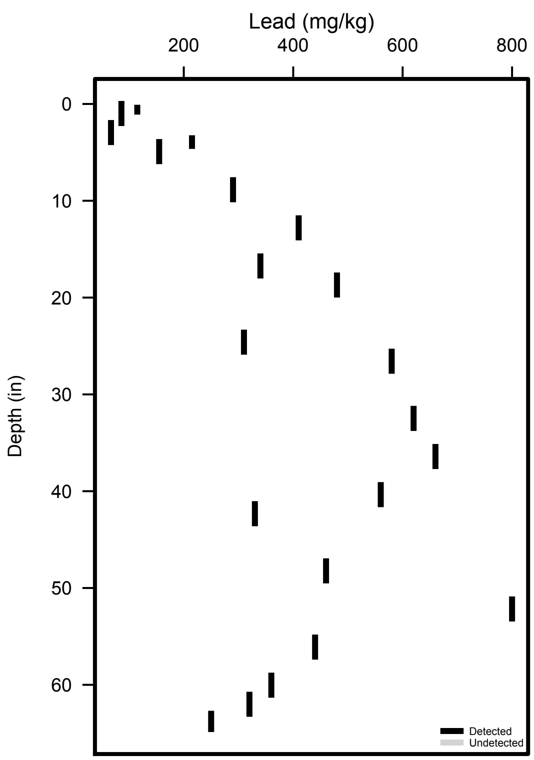

Figure 1259. Lead
at Cox Core Location CCR−668.

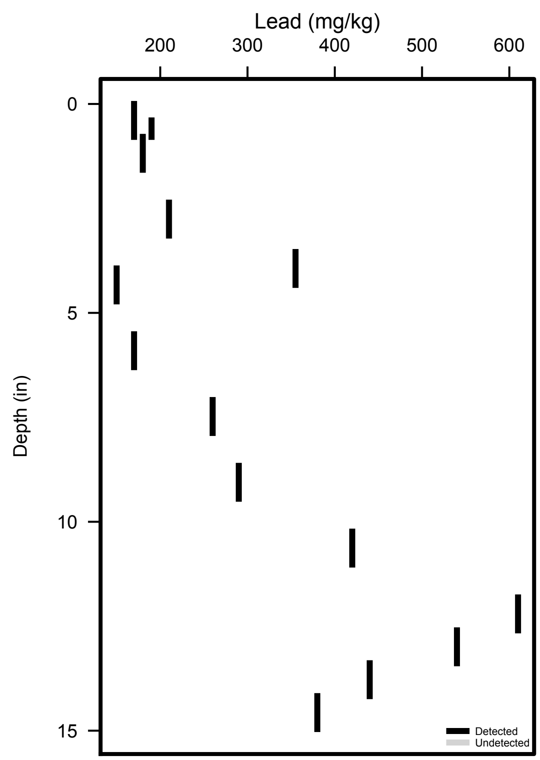

Figure 1260. Lead
at Cox Core Location CCR−692.

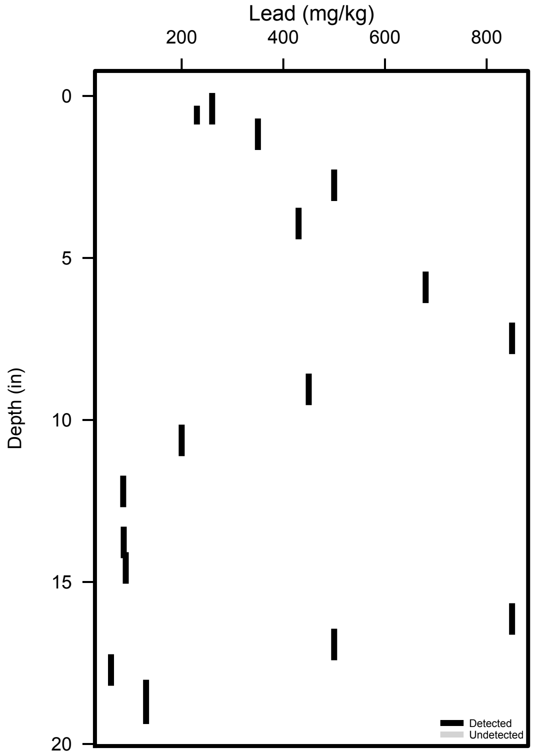

Figure 1261. Lead
at Cox Core Location CCR−705.

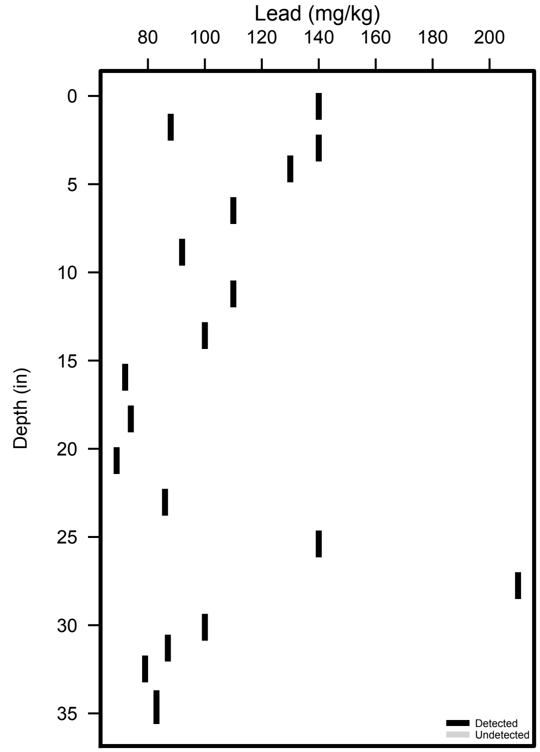

Figure 1262. Lead
at Cox Core Location CSA−8.

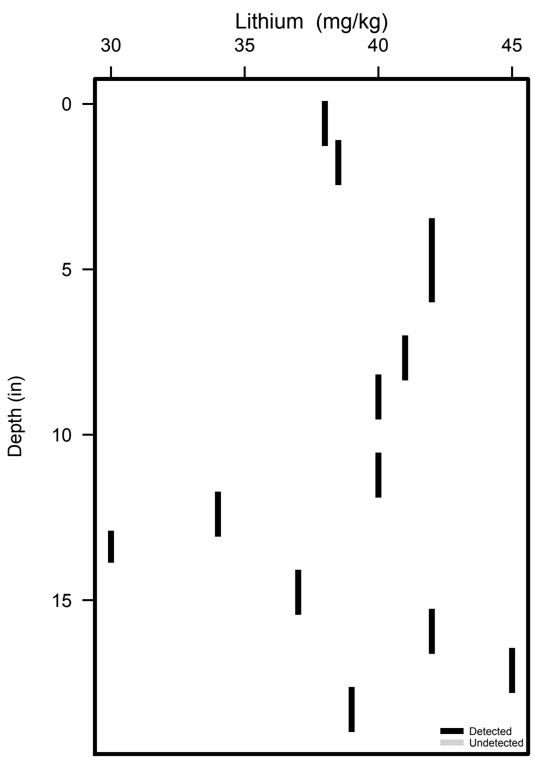

Figure 1263. Lithium
at Cox Core Location CCR−624.

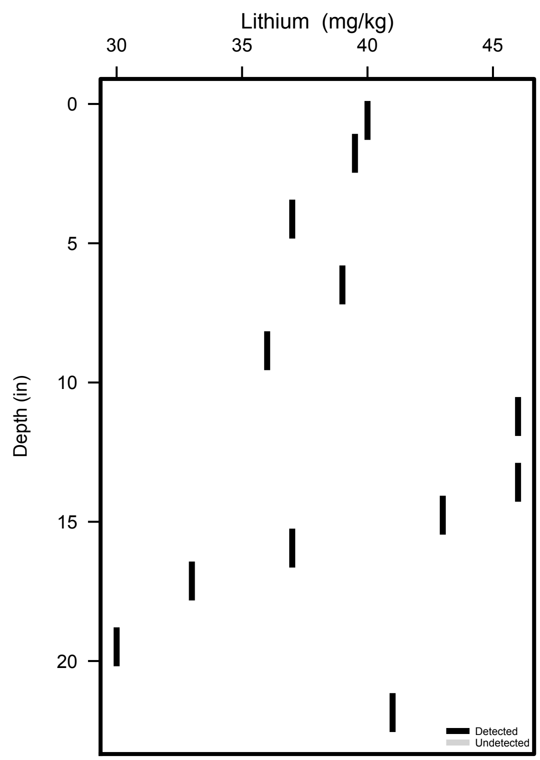

Figure 1264. Lithium
at Cox Core Location CCR−643.

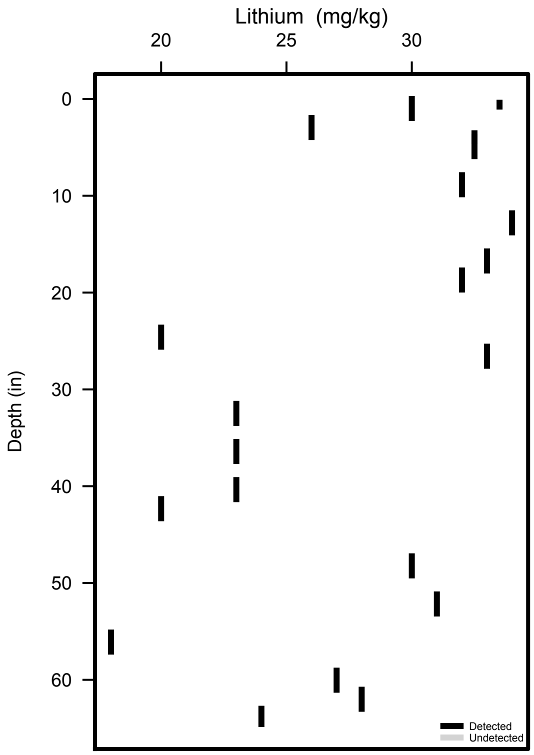

Figure 1265. Lithium
at Cox Core Location CCR−668.

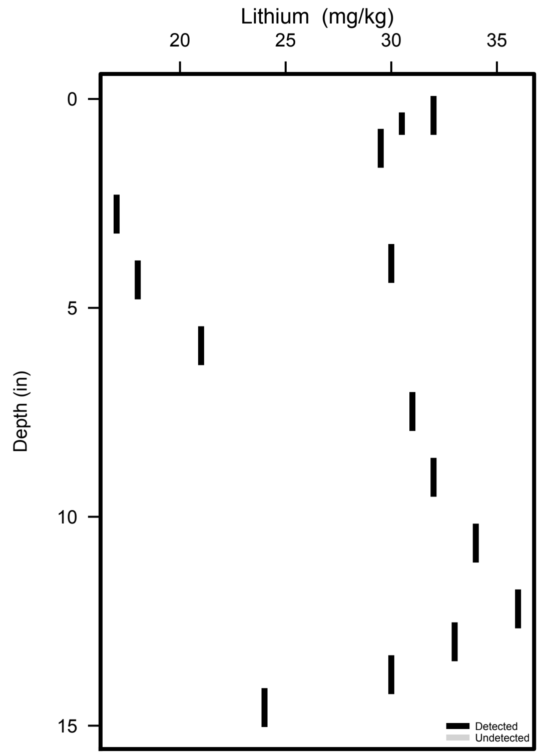

Figure 1266. Lithium
at Cox Core Location CCR−692.

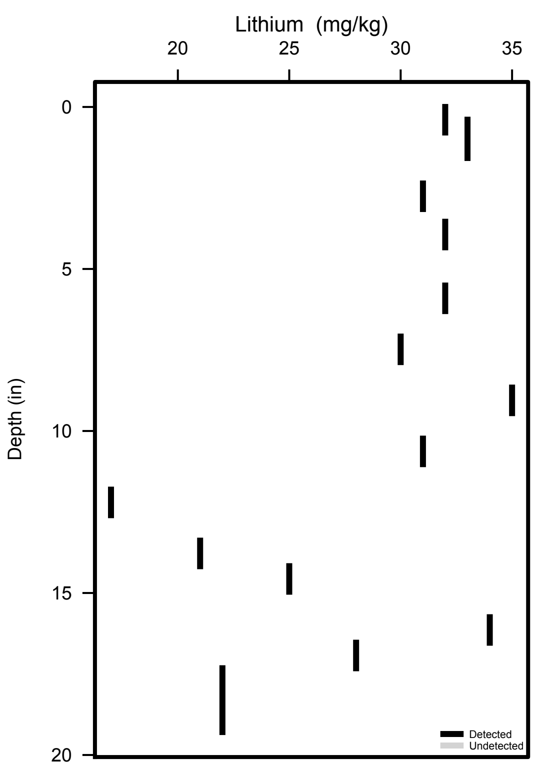

Figure 1267. Lithium
at Cox Core Location CCR−705.

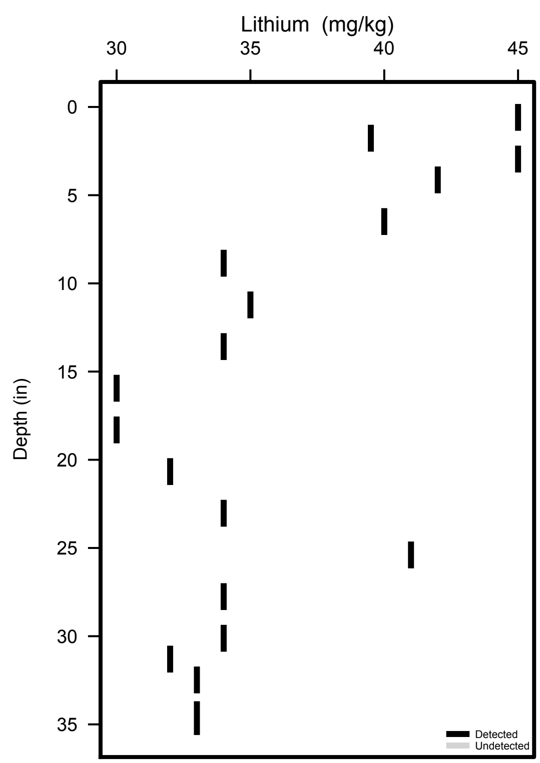

Figure 1268. Lithium
at Cox Core Location CSA−8.

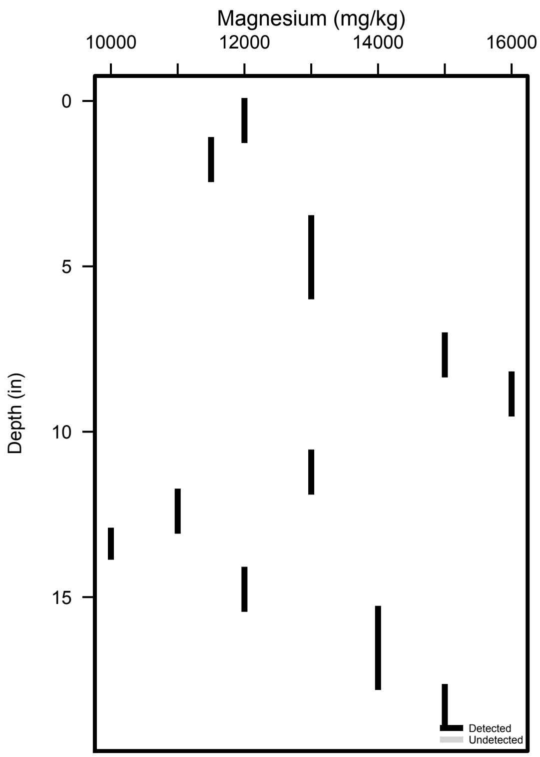

Figure 1269. Magnesium
at Cox Core Location CCR−624.

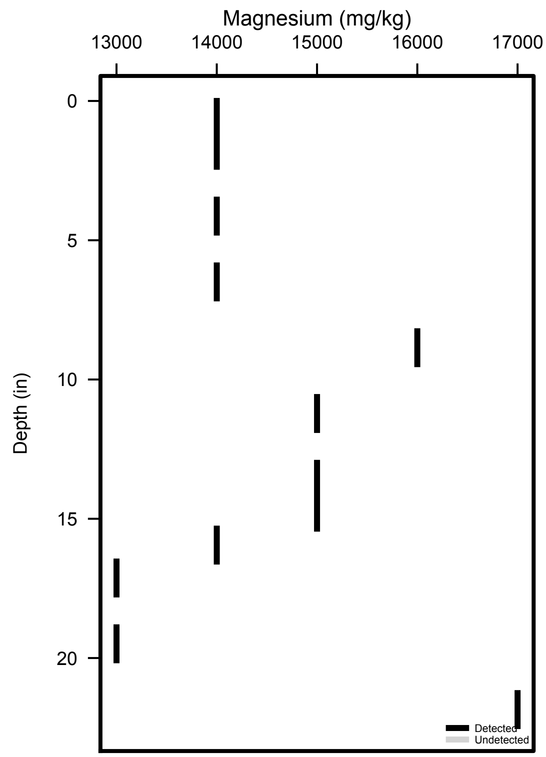

Figure 1270. Magnesium
at Cox Core Location CCR−643.

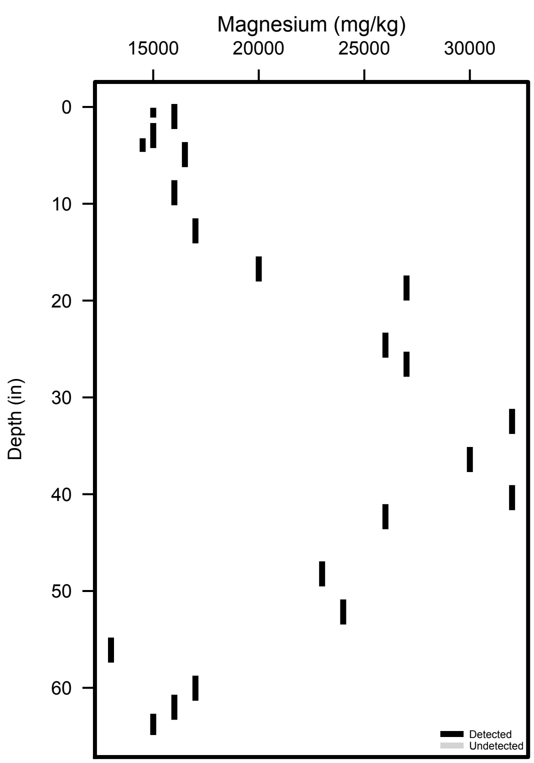

Figure 1271. Magnesium
at Cox Core Location CCR−668.

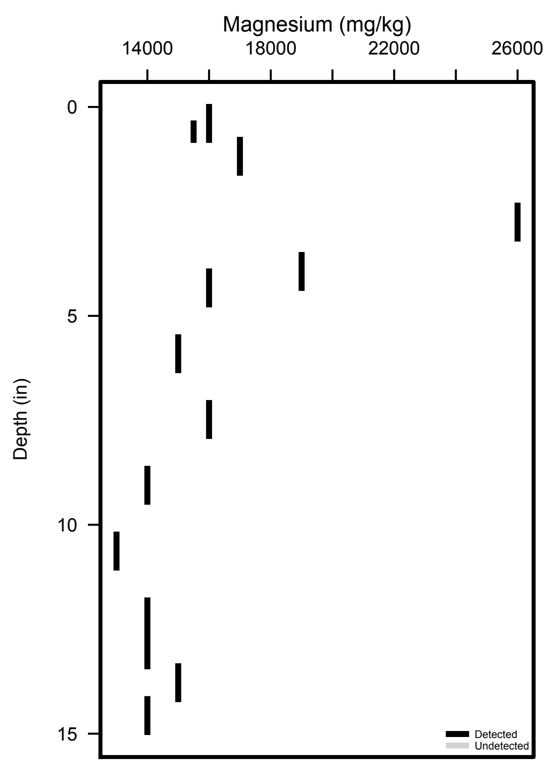

Figure 1272. Magnesium
at Cox Core Location CCR−692.

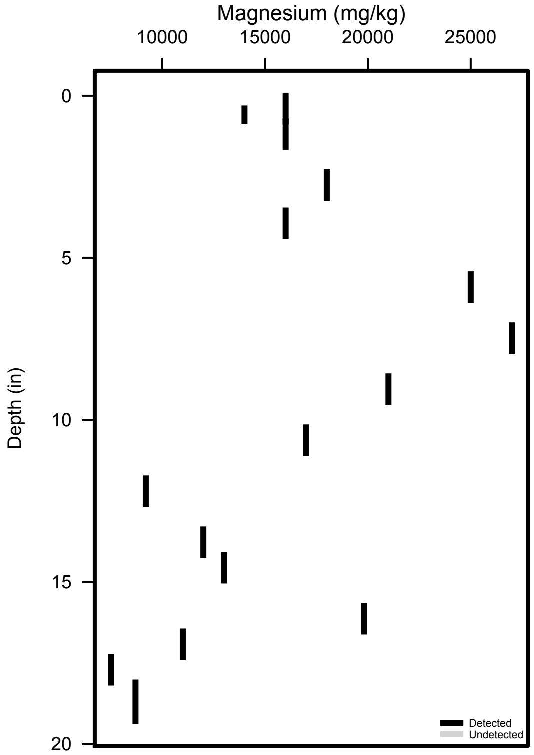

Figure 1273. Magnesium
at Cox Core Location CCR−705.

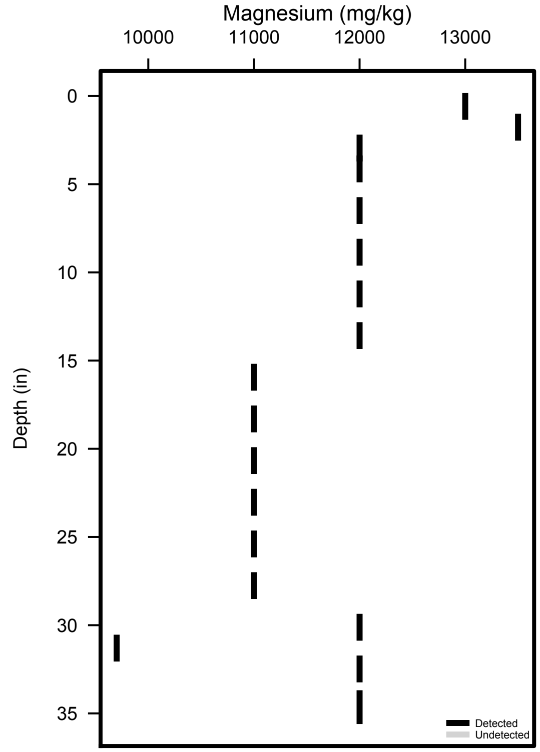

Figure 1274. Magnesium
at Cox Core Location CSA−8.

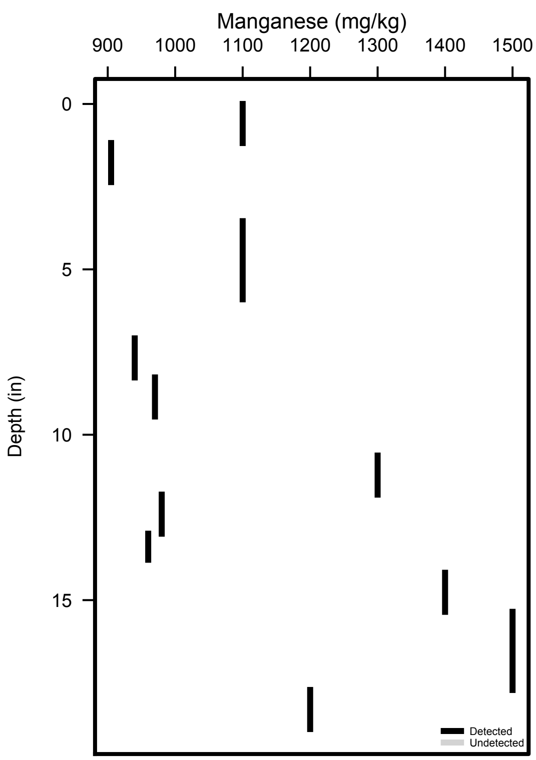

Figure 1275. Manganese
at Cox Core Location CCR−624.

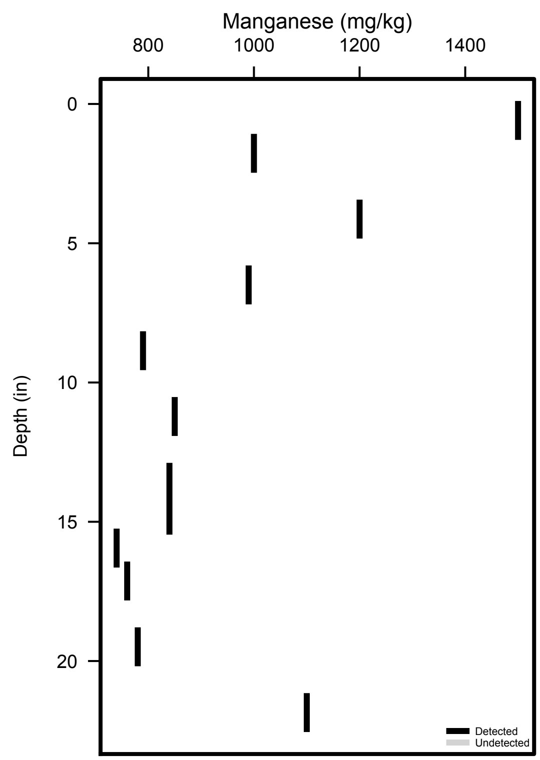

Figure 1276. Manganese
at Cox Core Location CCR−643.

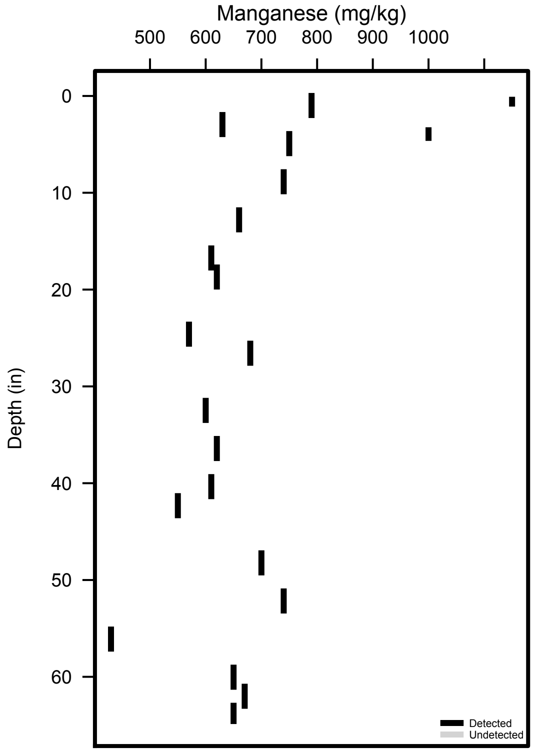

Figure 1277. Manganese
at Cox Core Location CCR−668.

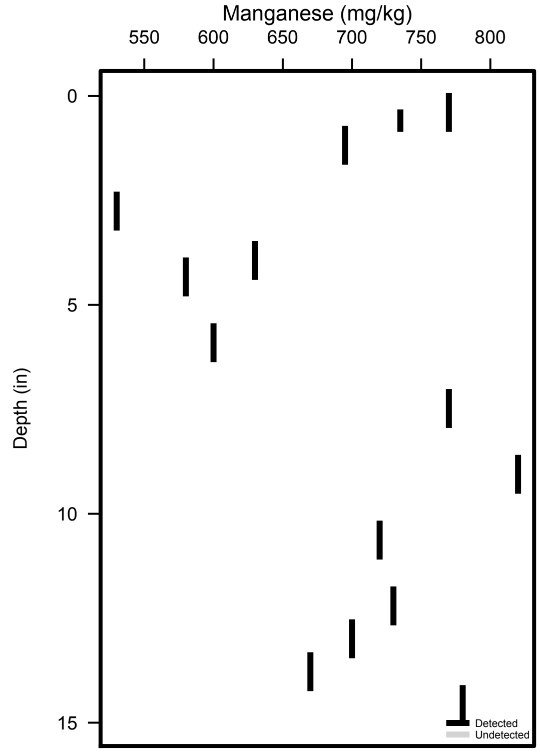

Figure 1278. Manganese
at Cox Core Location CCR−692.

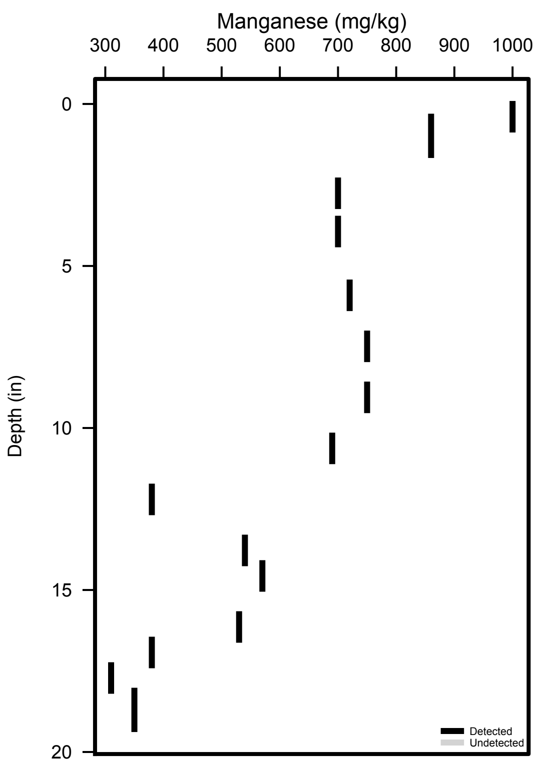

Figure 1279. Manganese
at Cox Core Location CCR−705.

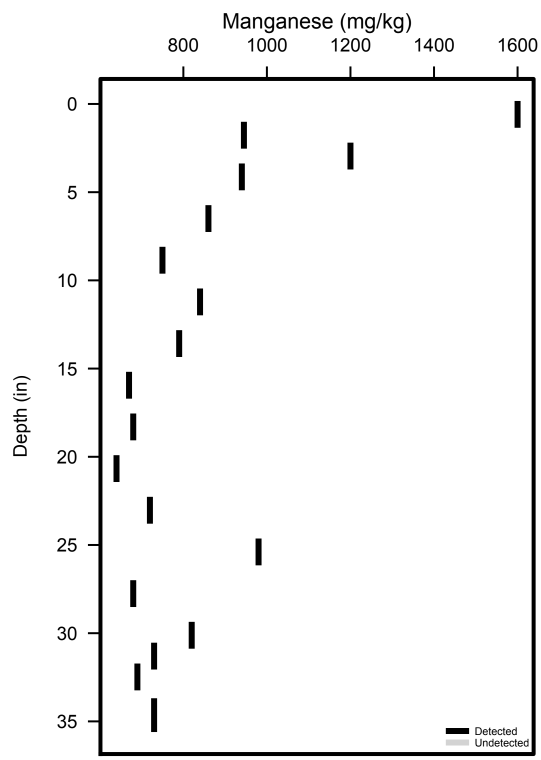

Figure 1280. Manganese
at Cox Core Location CSA−8.

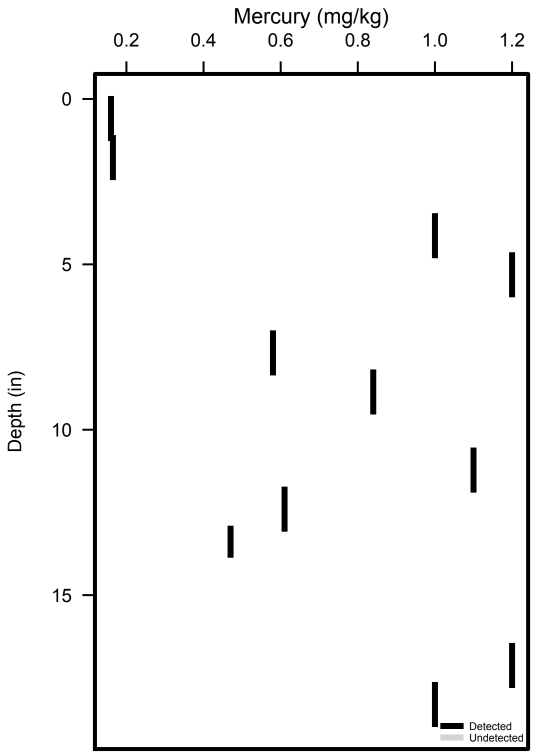

Figure 1281. Mercury at Cox Core Location CCR−624.

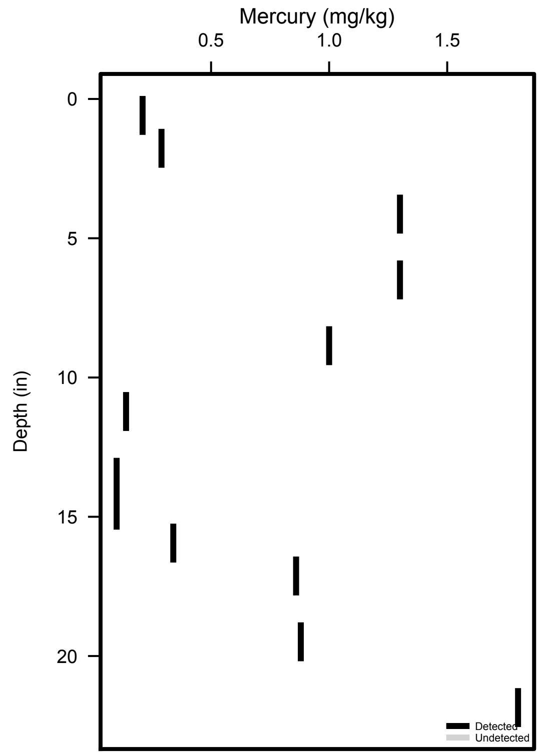

Figure 1282. Mercury at Cox Core Location CCR−643.

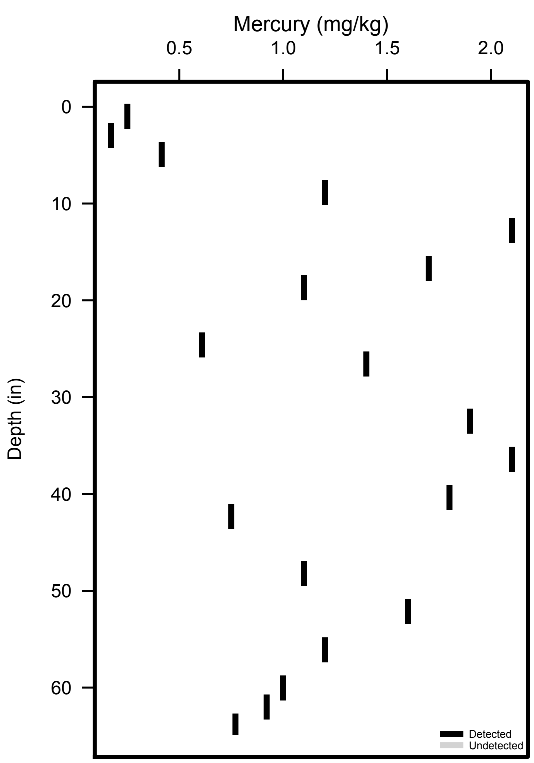

Figure 1283. Mercury at Cox Core Location CCR−668.

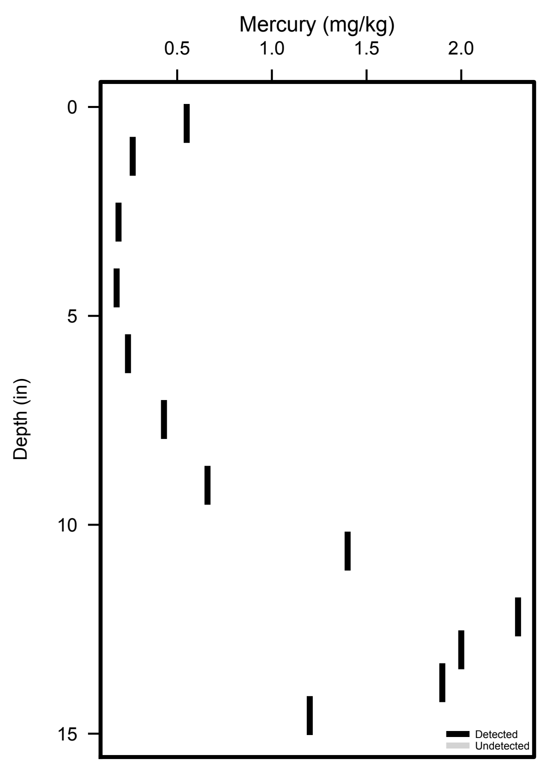

Figure 1284. Mercury at Cox Core Location CCR−692.

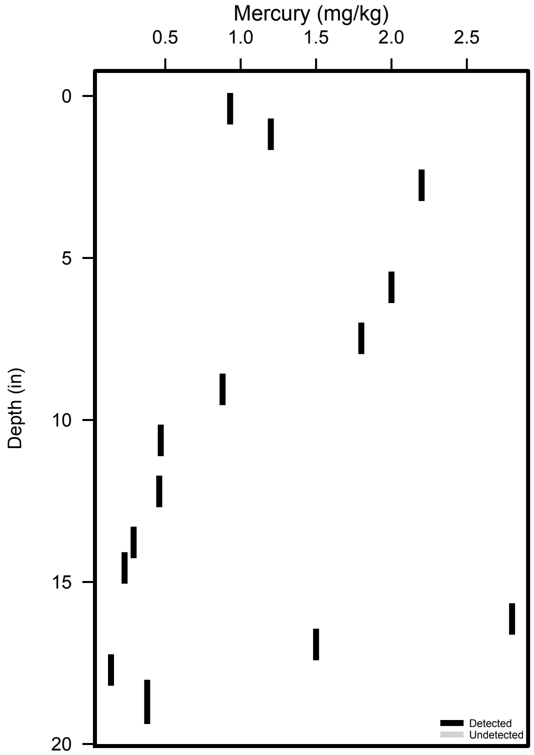

Figure 1285. Mercury
at Cox Core Location CCR−705.

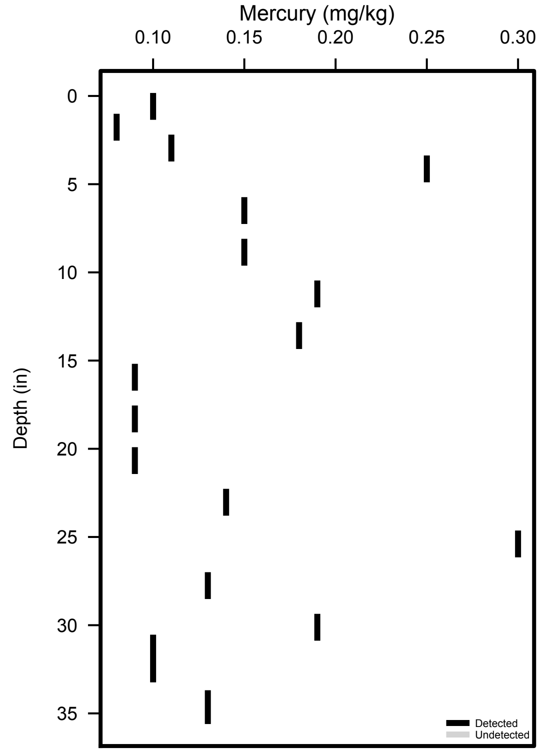

Figure 1286. Mercury
at Cox Core Location CSA−8.

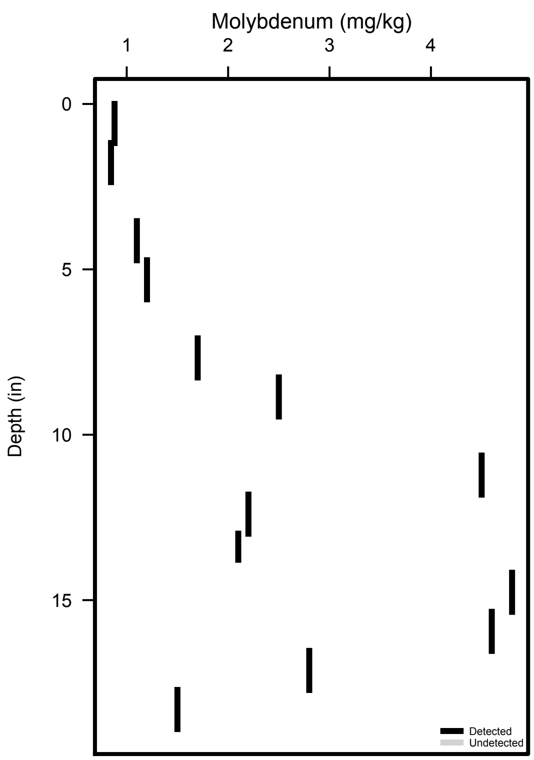

Figure 1287. Molybdenum
at Cox Core Location CCR−624.

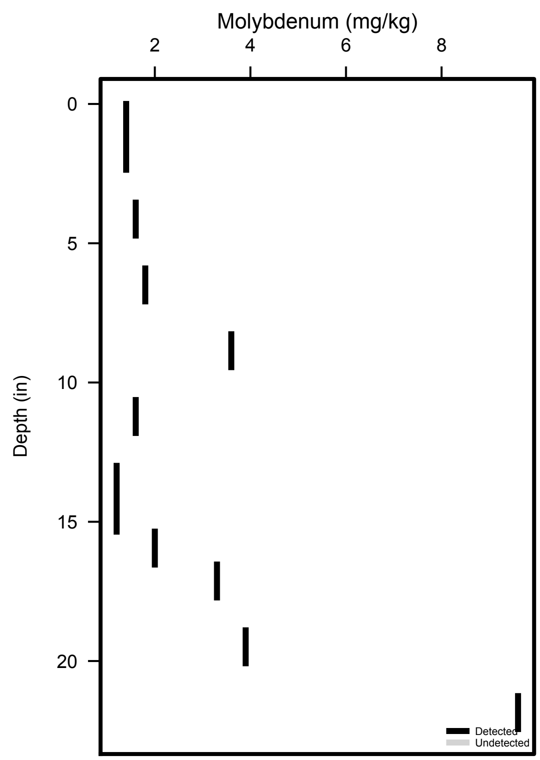

Figure 1288. Molybdenum
at Cox Core Location CCR−643.

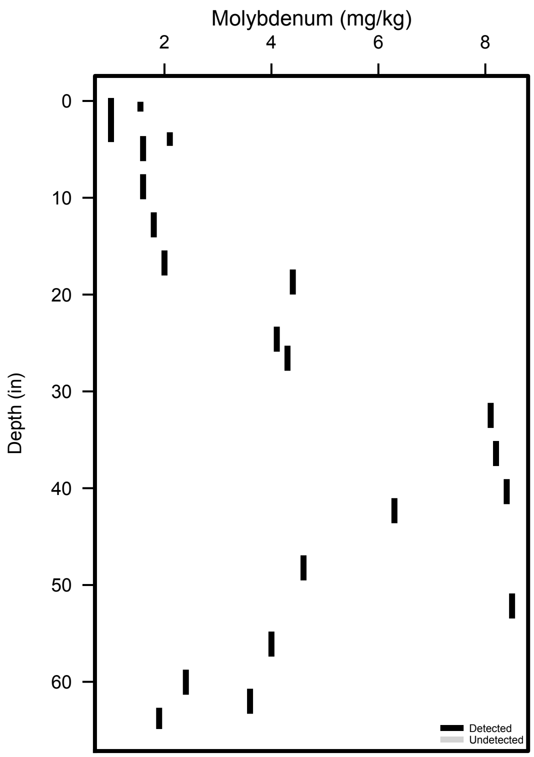

Figure 1289. Molybdenum
at Cox Core Location CCR−668.

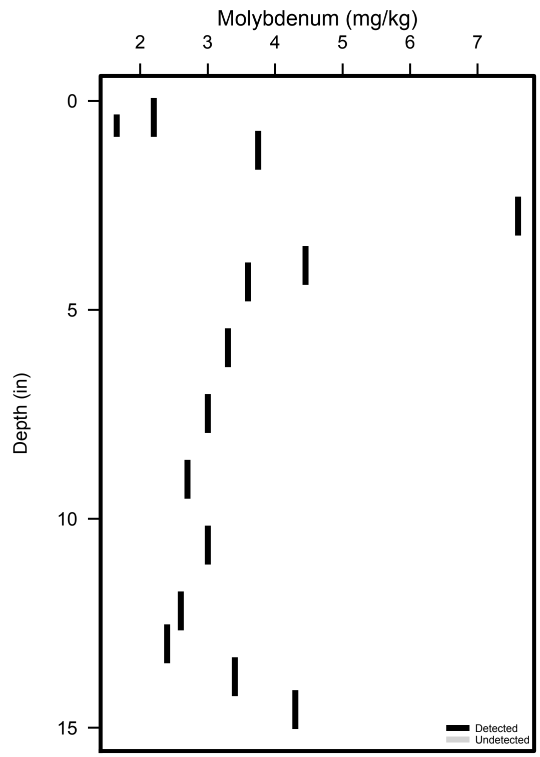

Figure 1290. Molybdenum
at Cox Core Location CCR−692.

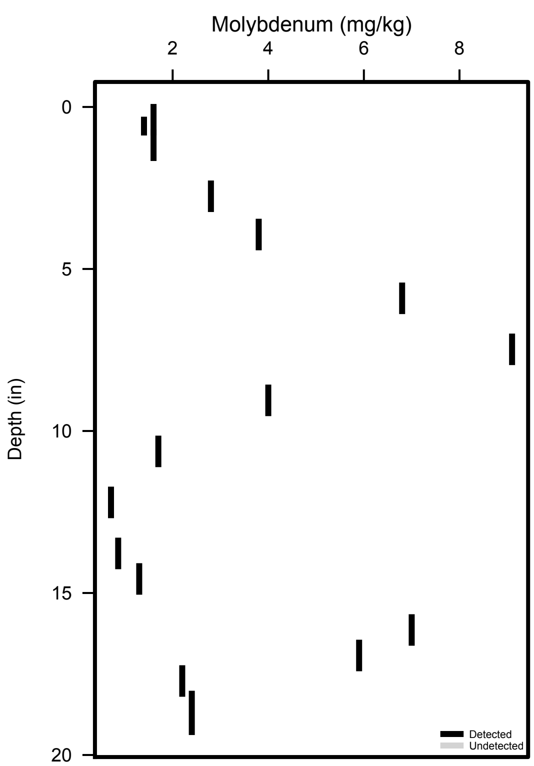

Figure 1291. Molybdenum
at Cox Core Location CCR−705.

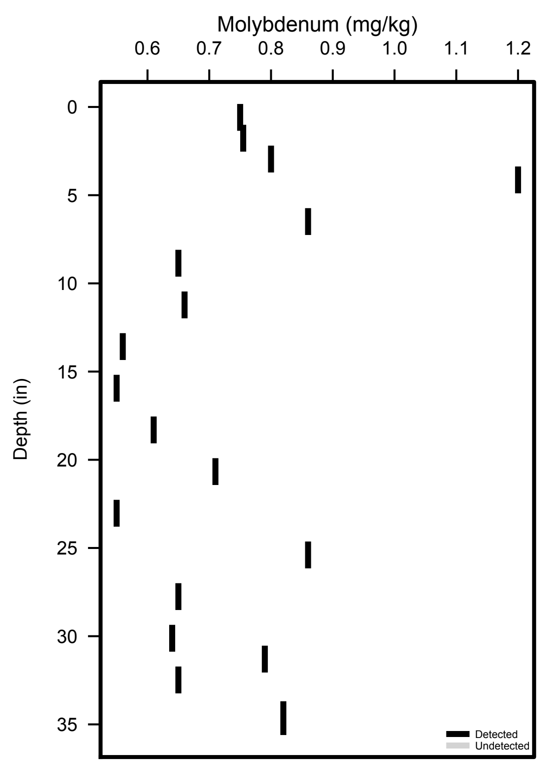

Figure 1292. Molybdenum
at Cox Core Location CSA−8.

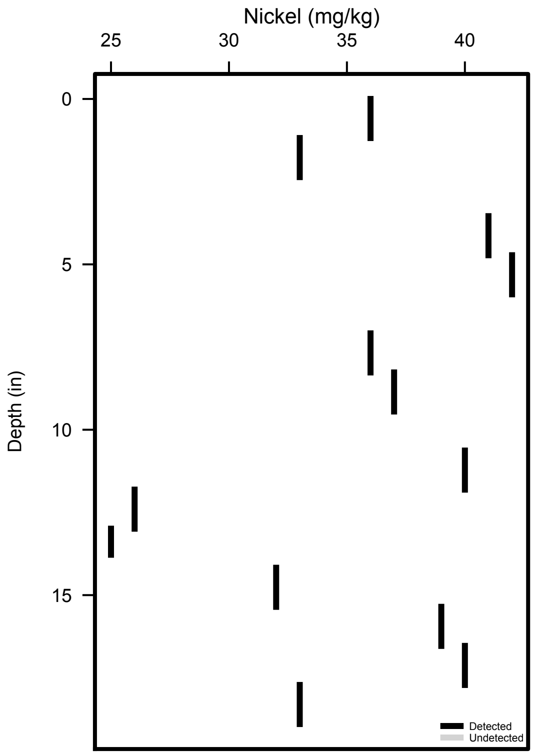

Figure 1293. Nickel
at Cox Core Location CCR−624.

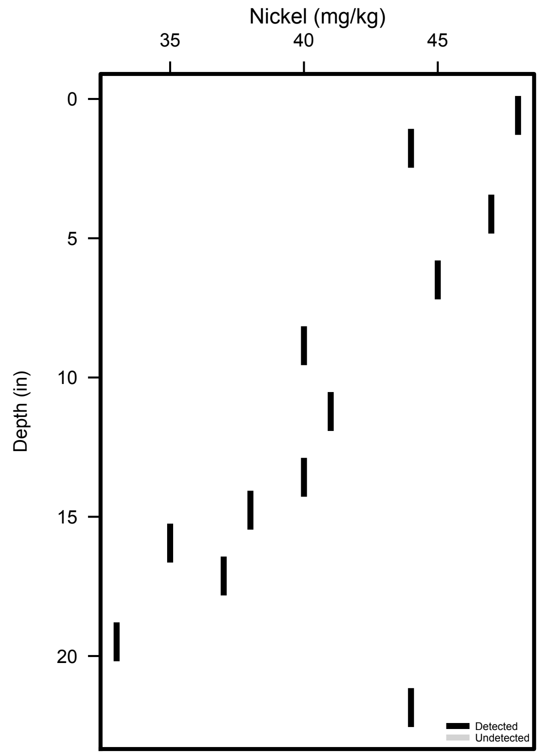

Figure 1294. Nickel
at Cox Core Location CCR−643.

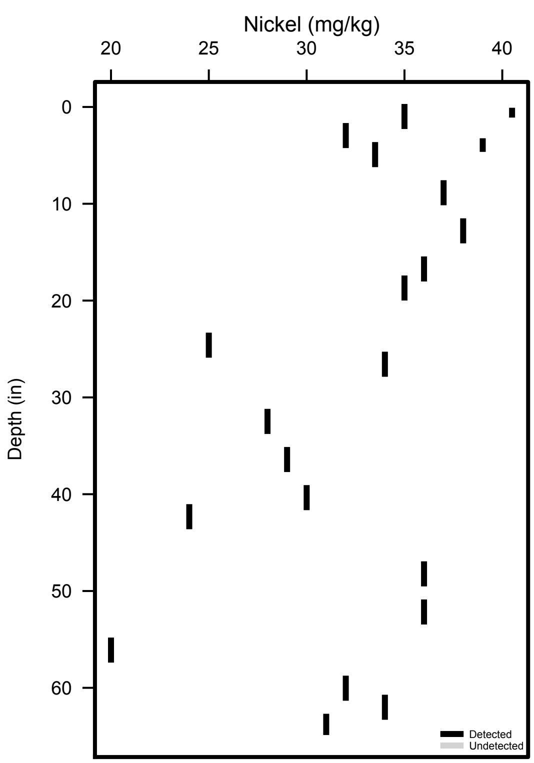

Figure 1295. Nickel
at Cox Core Location CCR−668.

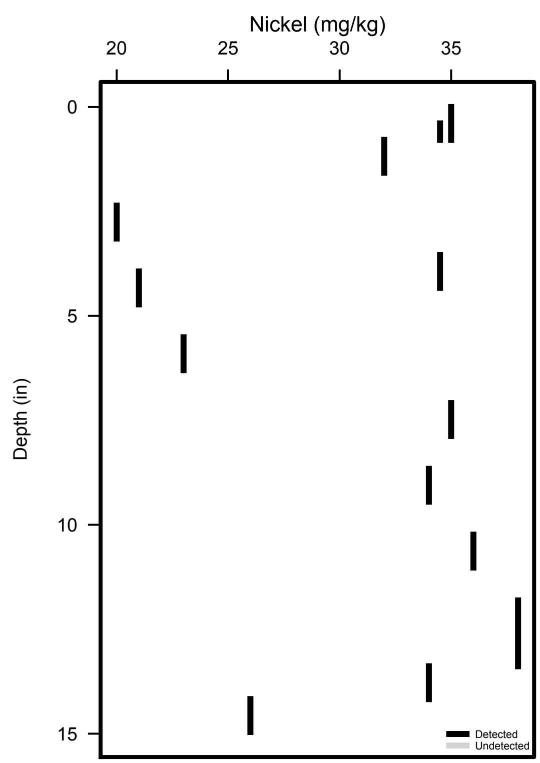

Figure 1296. Nickel
at Cox Core Location CCR−692.

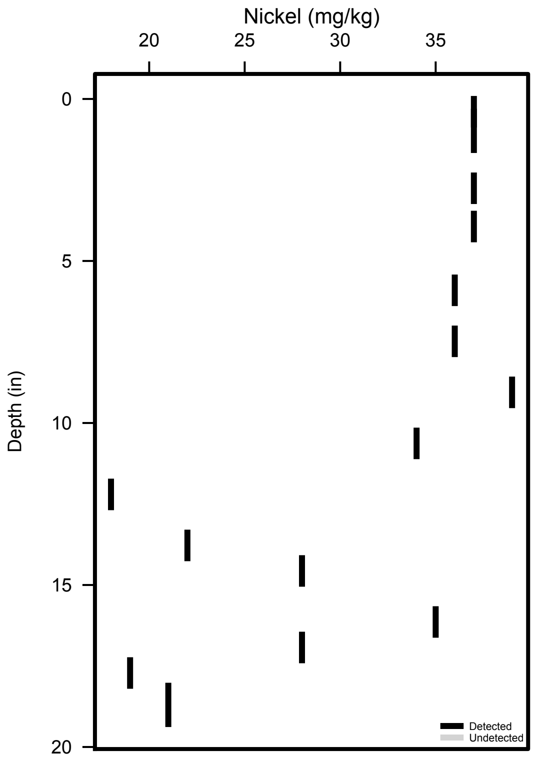

Figure 1297. Nickel
at Cox Core Location CCR−705.

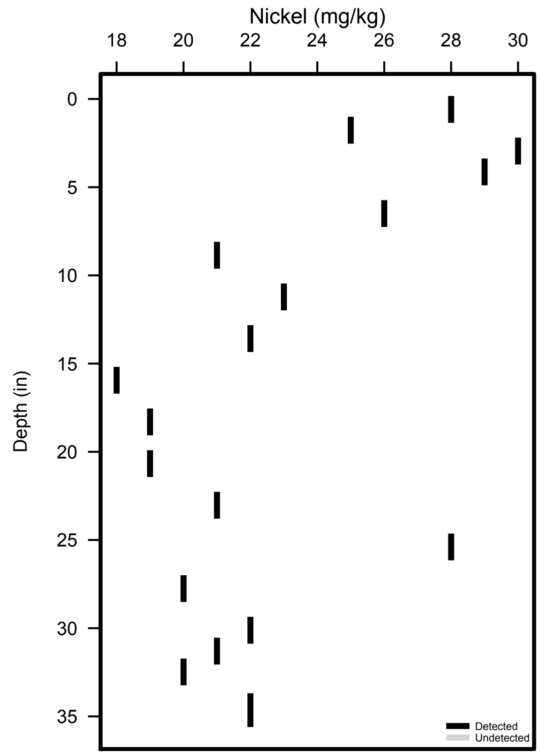

Figure 1298. Nickel
at Cox Core Location CSA−8.

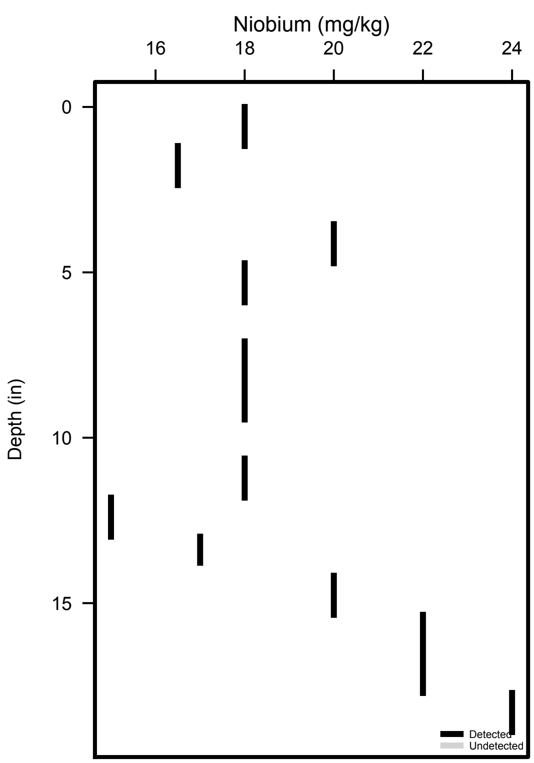

Figure 1299. Niobium
at Cox Core Location CCR−624.

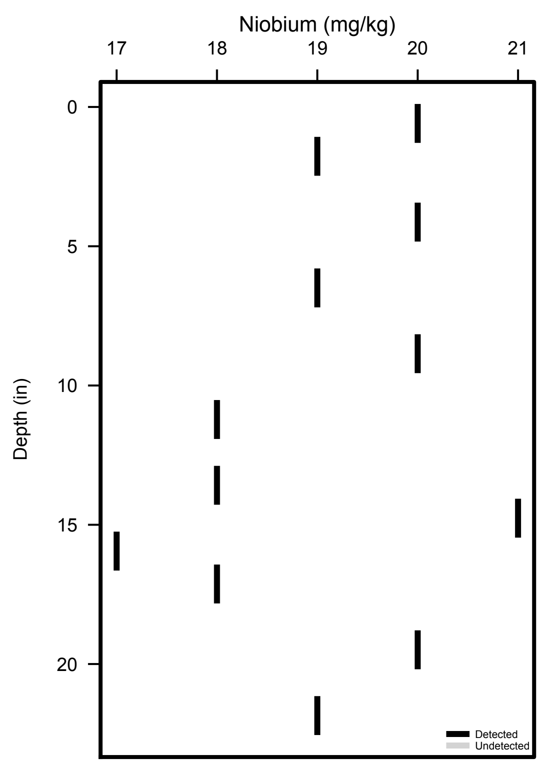

Figure 1300. Niobium
at Cox Core Location CCR−643.

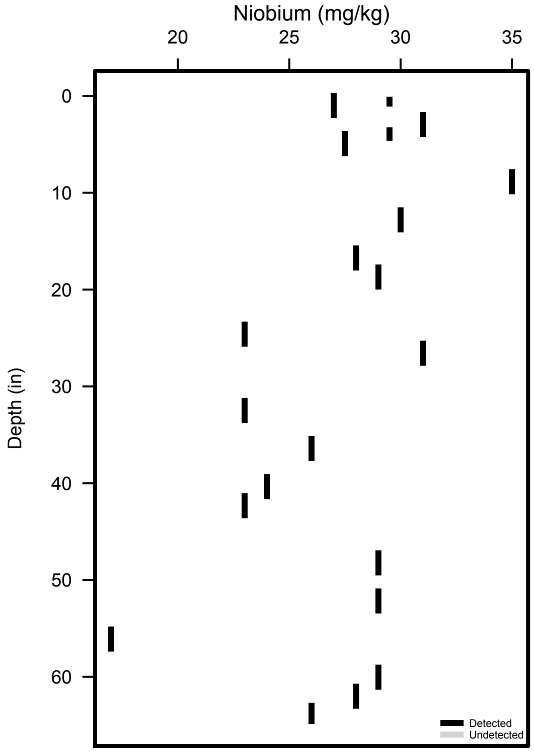

Figure 1301. Niobium
at Cox Core Location CCR−668.

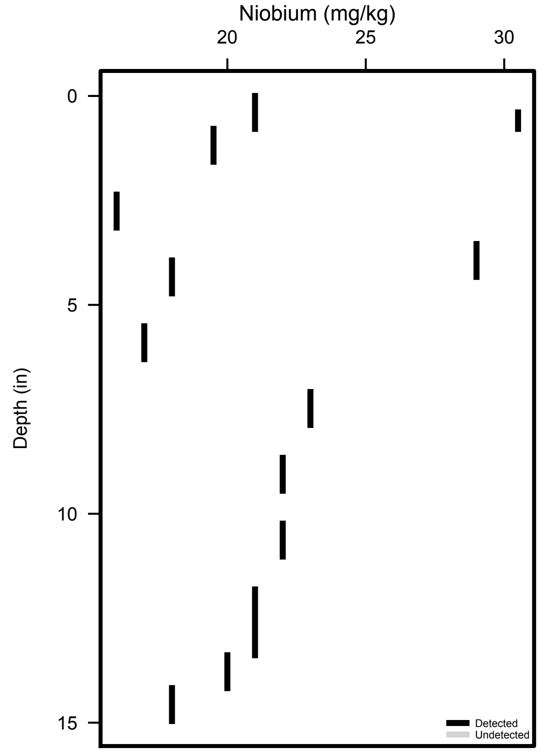

Figure 1302. Niobium
at Cox Core Location CCR−692.

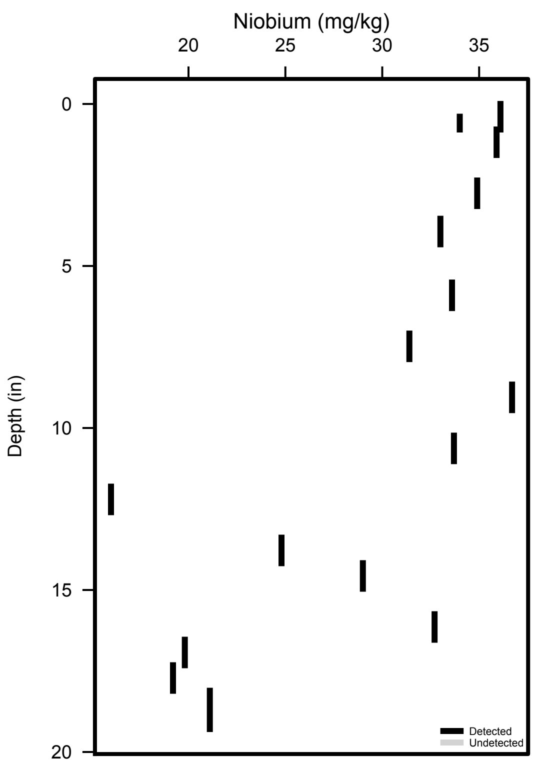

Figure 1303. Niobium
at Cox Core Location CCR−705.

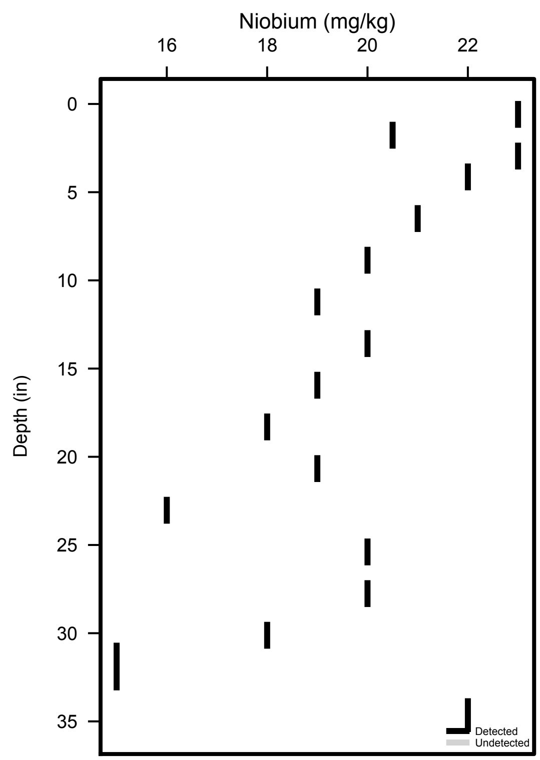

Figure 1304. Niobium
at Cox Core Location CSA−8.

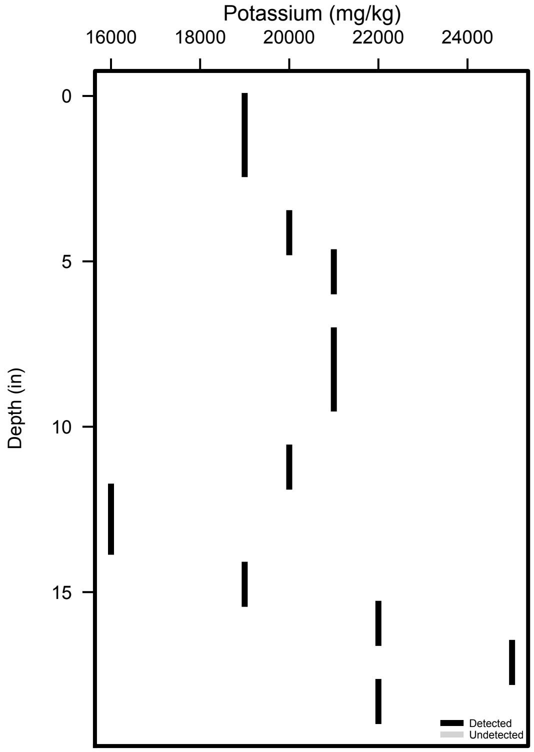

Figure 1305. Potassium
at Cox Core Location CCR−624.

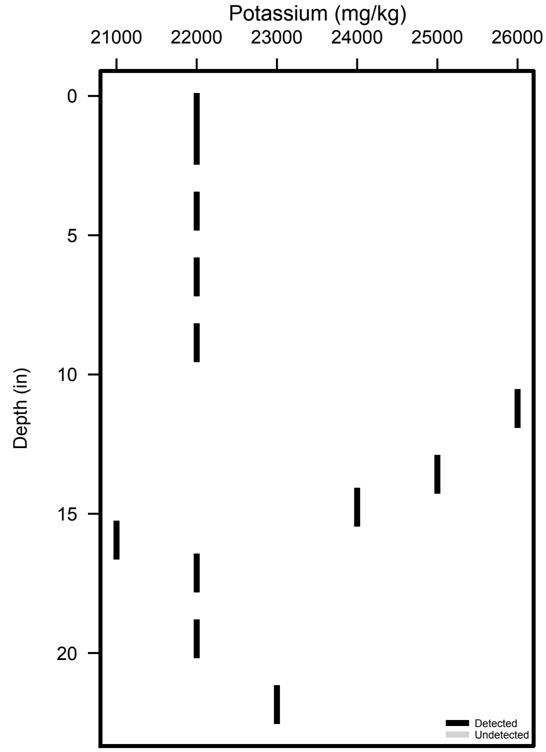

Figure 1306. Potassium
at Cox Core Location CCR−643.

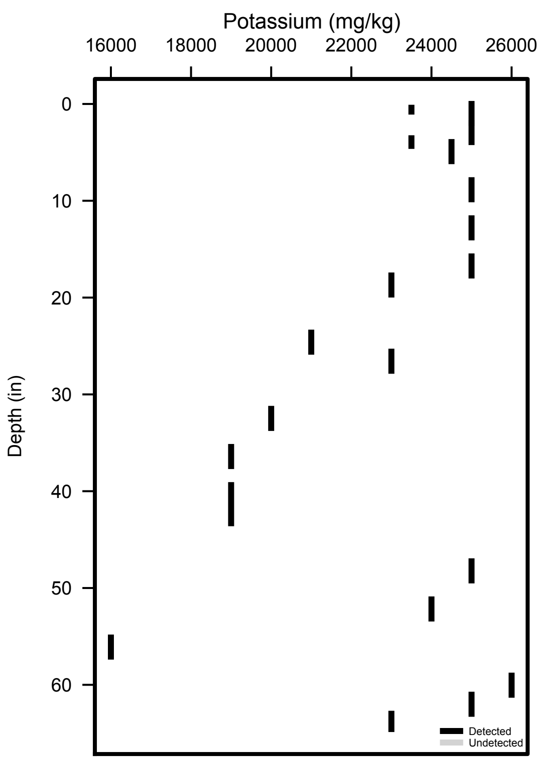

Figure 1307. Potassium
at Cox Core Location CCR−668.

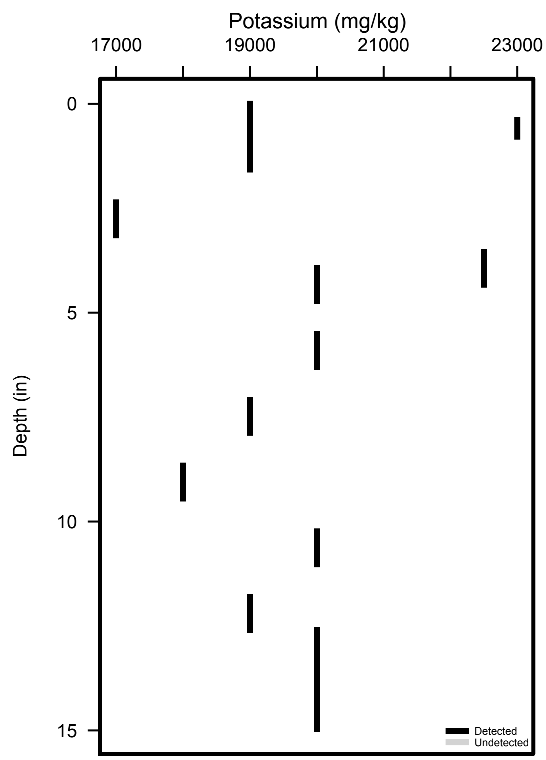

Figure 1308. Potassium
at Cox Core Location CCR−692.

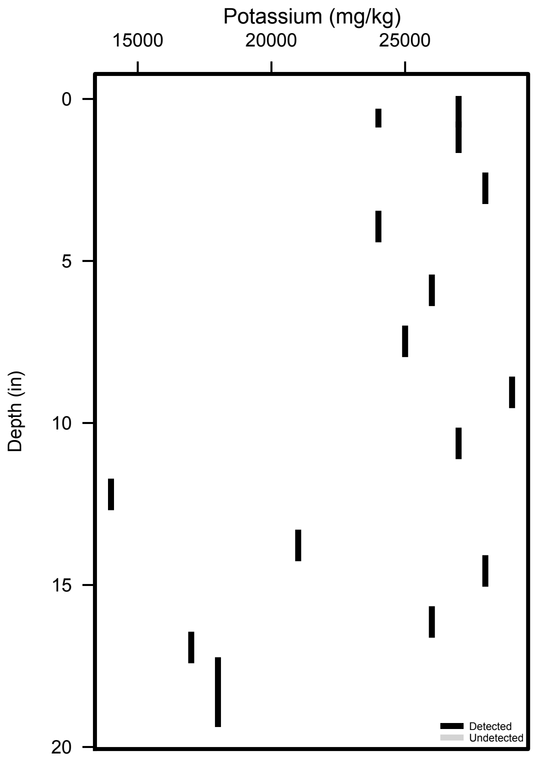

Figure 1309. Potassium
at Cox Core Location CCR−705.

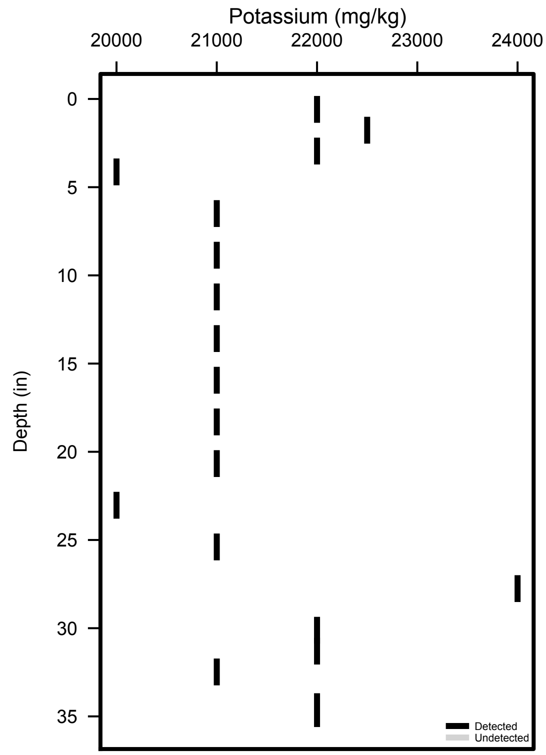

Figure 1310. Potassium
at Cox Core Location CSA−8.

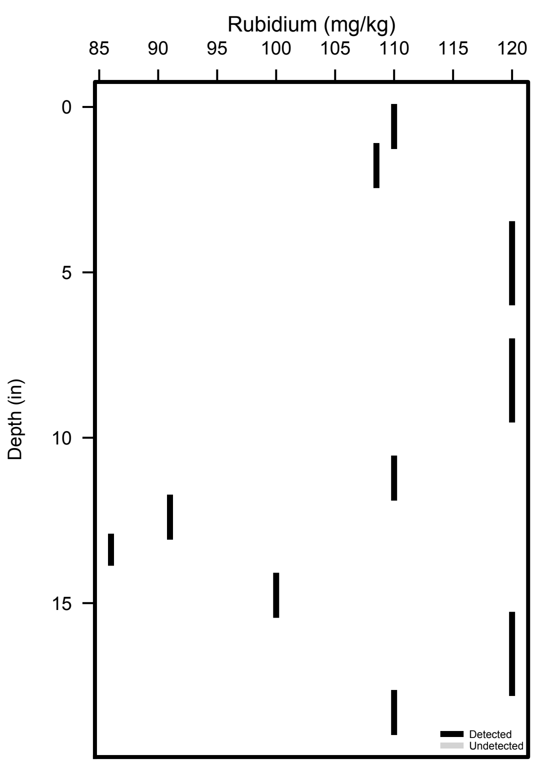

Figure 1311. Rubidium
at Cox Core Location CCR−624.

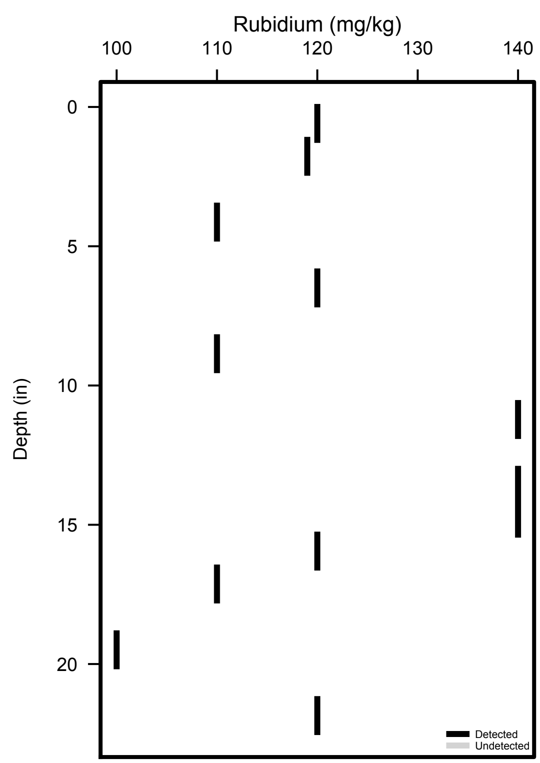

Figure 1312. Rubidium
at Cox Core Location CCR−643.

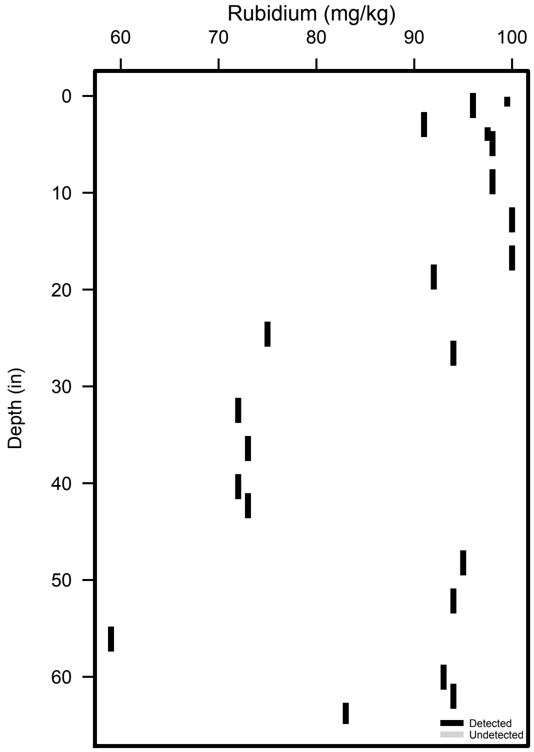

Figure 1313. Rubidium
at Cox Core Location CCR−668.

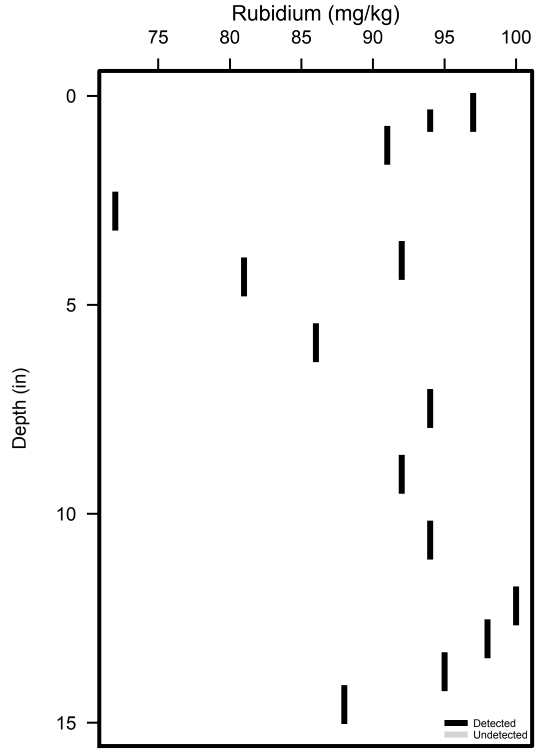

Figure 1314. Rubidium
at Cox Core Location CCR−692.

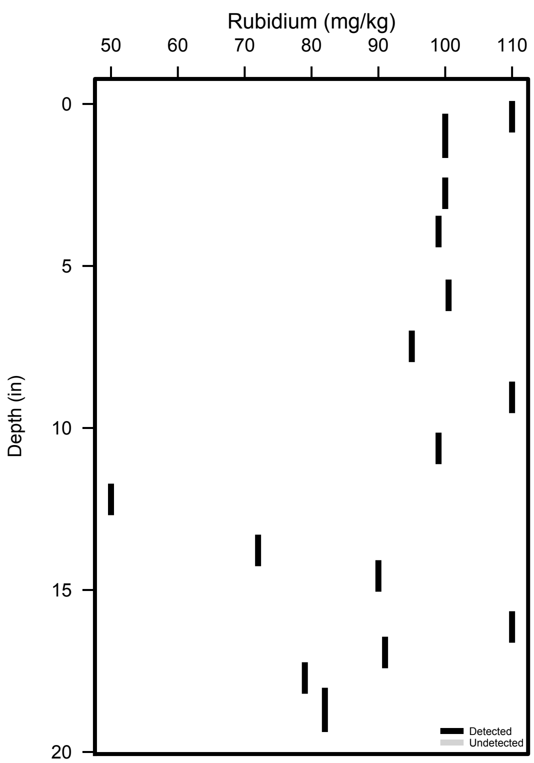

Figure 1315. Rubidium
at Cox Core Location CCR−705.

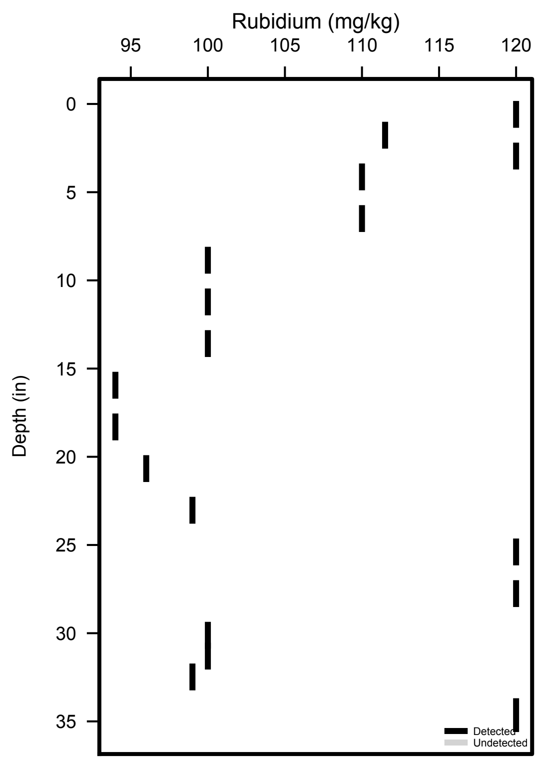

Figure 1316. Rubidium
at Cox Core Location CSA−8.

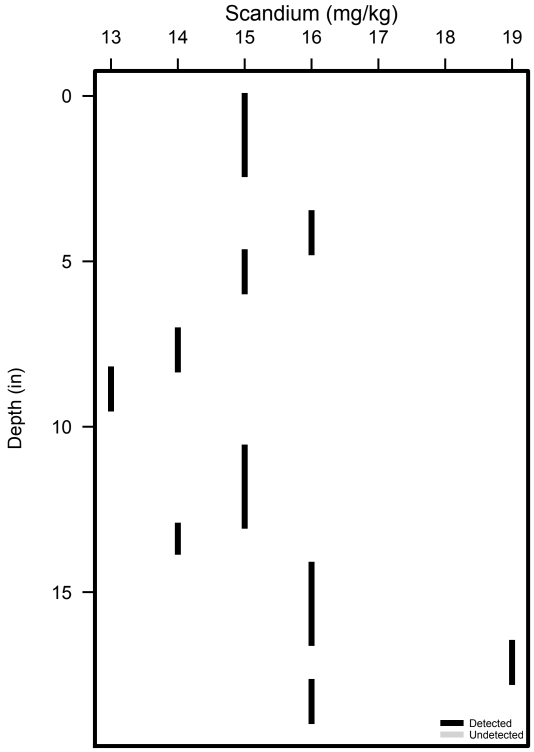

Figure 1317. Scandium at Cox Core Location CCR−624.

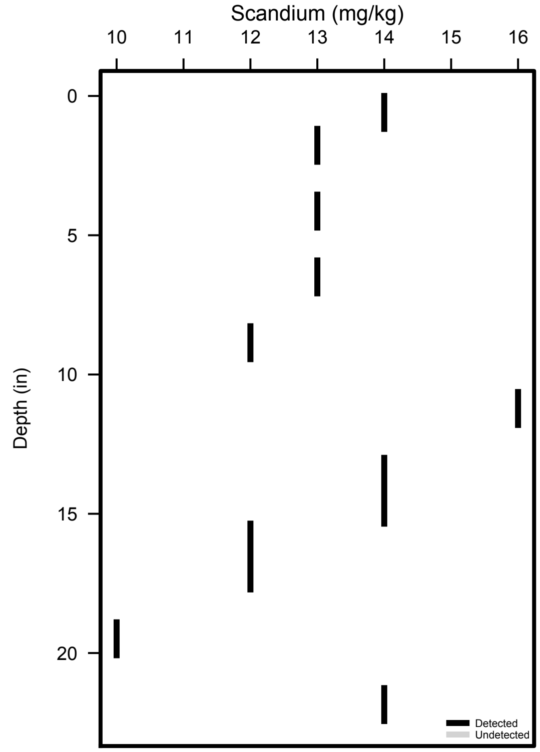

Figure 1318. Scandium at Cox Core Location CCR−643.

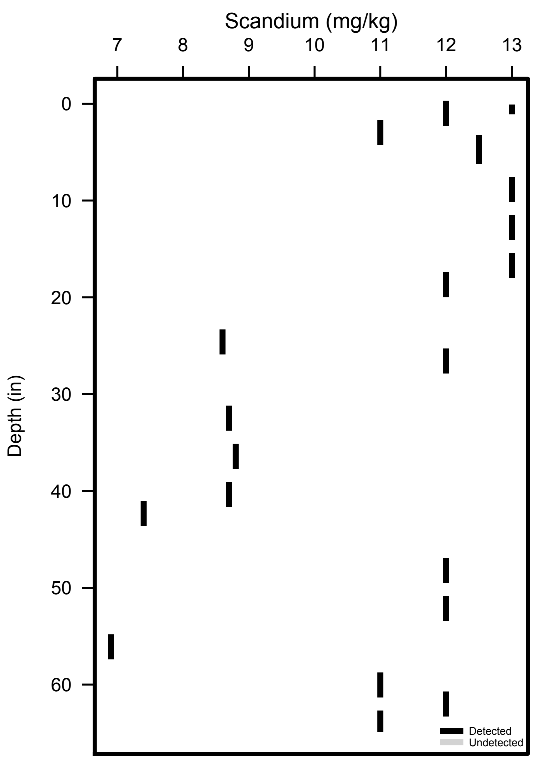

Figure 1319. Scandium at Cox Core Location CCR−668.

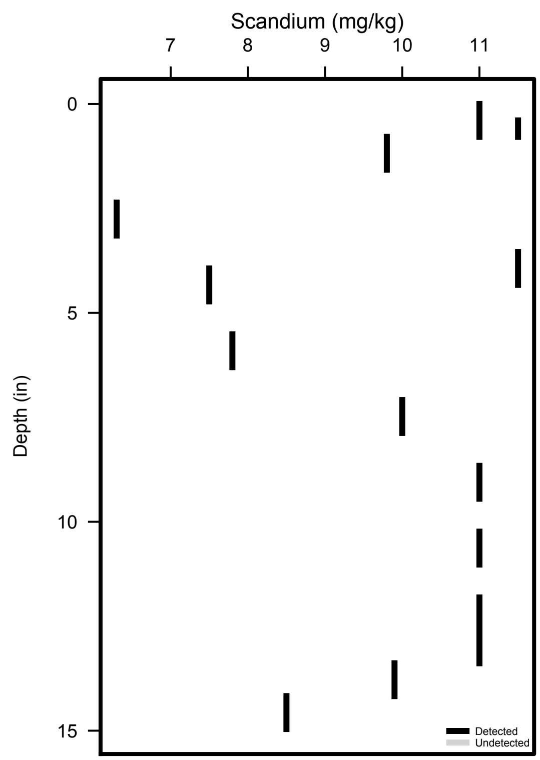

Figure 1320. Scandium at Cox Core Location CCR−692.

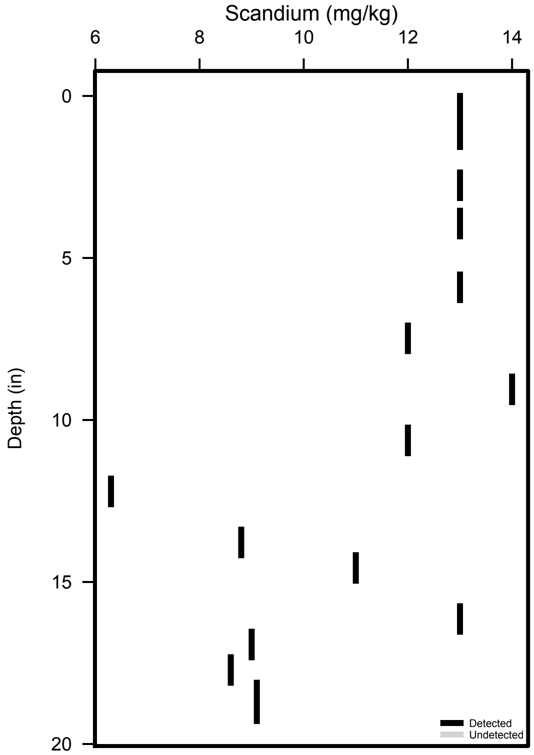

Figure 1321. Scandium
at Cox Core Location CCR−705.

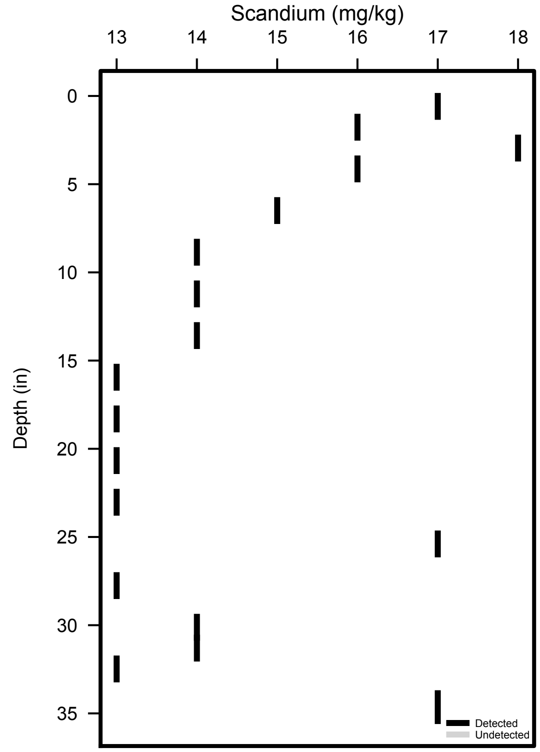

Figure 1322. Scandium
at Cox Core Location CSA−8.

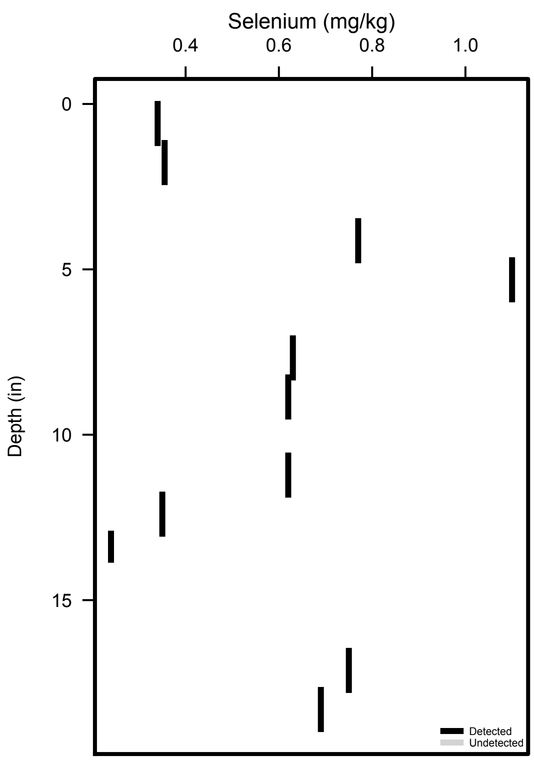

Figure 1323. Selenium
at Cox Core Location CCR−624.

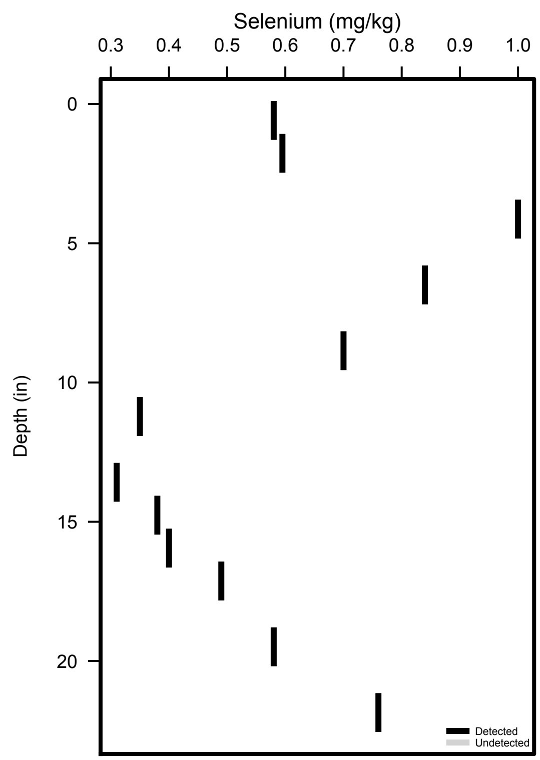

Figure 1324. Selenium
at Cox Core Location CCR−643.

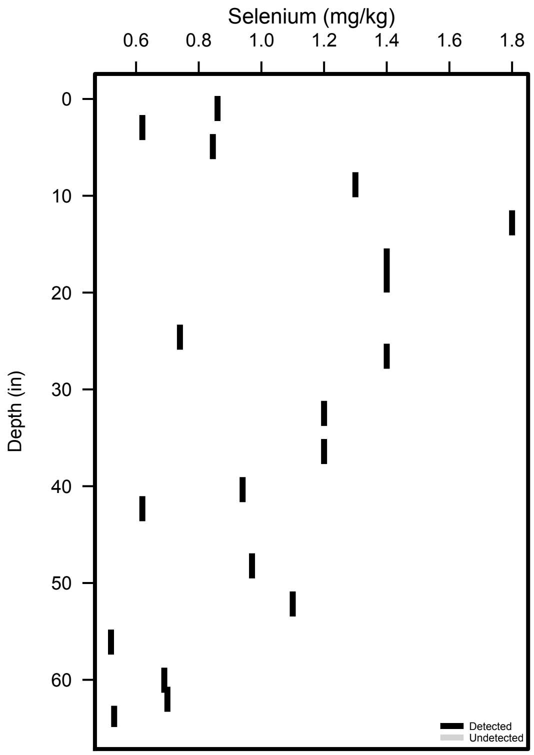

Figure 1325. Selenium
at Cox Core Location CCR−668.

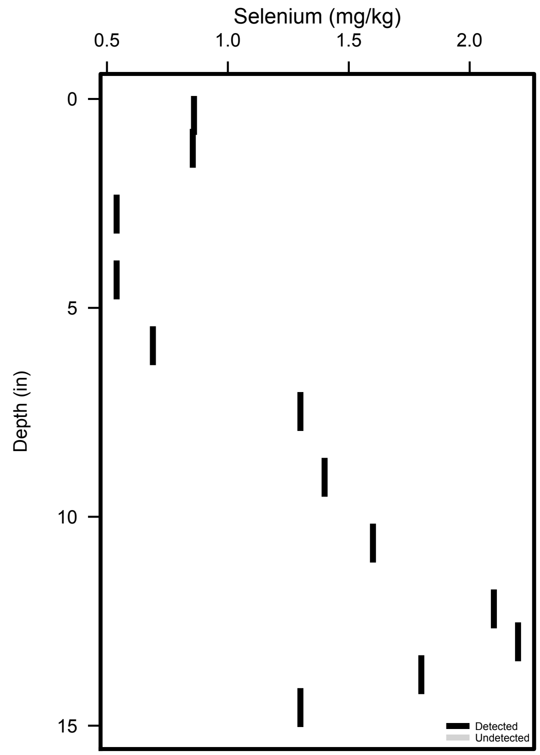

Figure 1326. Selenium
at Cox Core Location CCR−692.

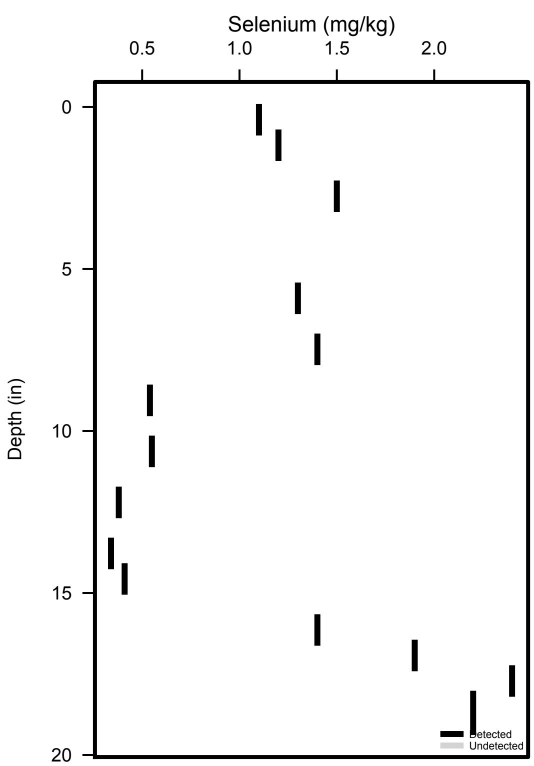

Figure 1327. Selenium
at Cox Core Location CCR−705.

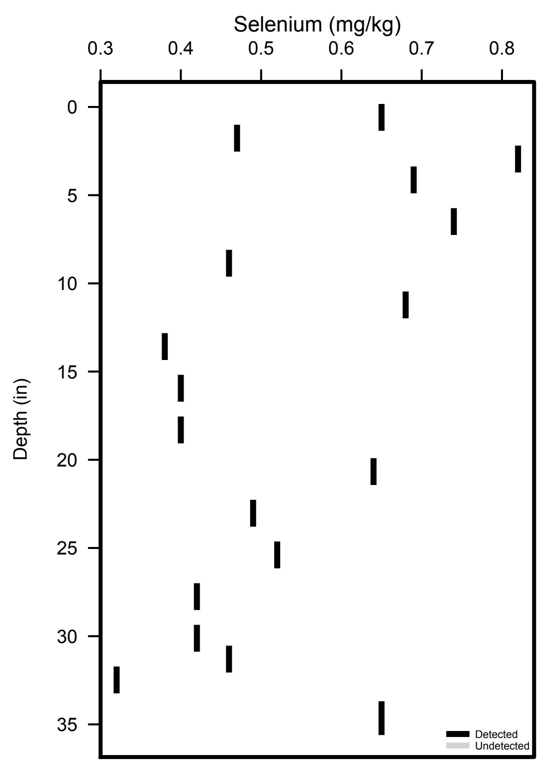

Figure 1328. Selenium
at Cox Core Location CSA−8.

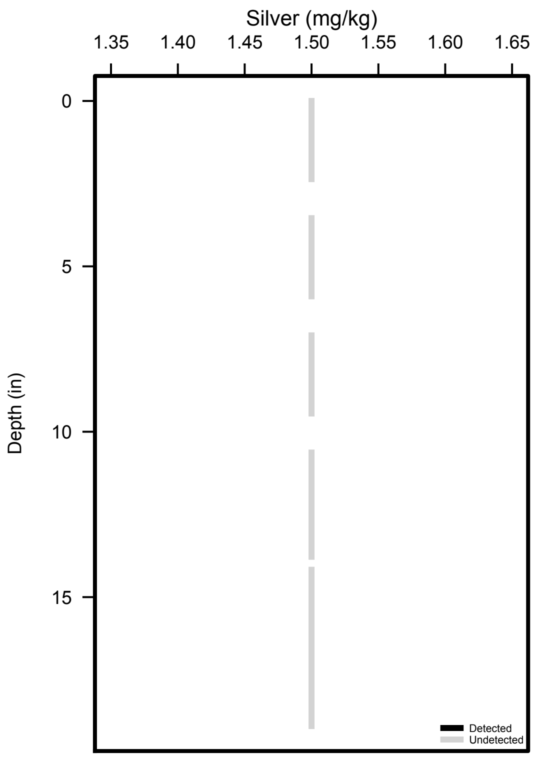

Figure 1329. Silver
at Cox Core Location CCR−624.

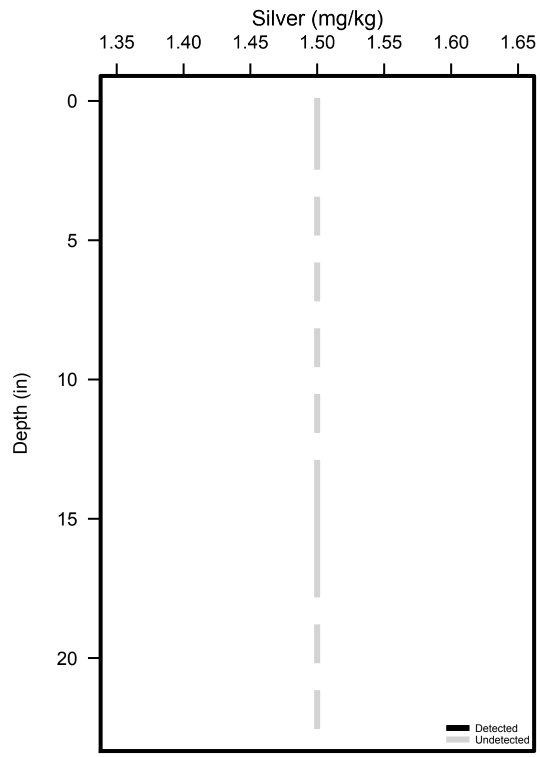

Figure 1330. Silver
at Cox Core Location CCR−643.

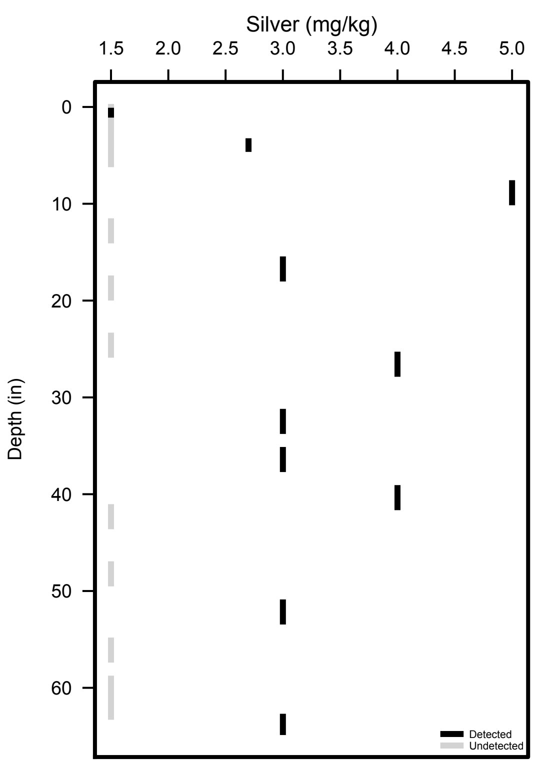

Figure 1331. Silver
at Cox Core Location CCR−668.

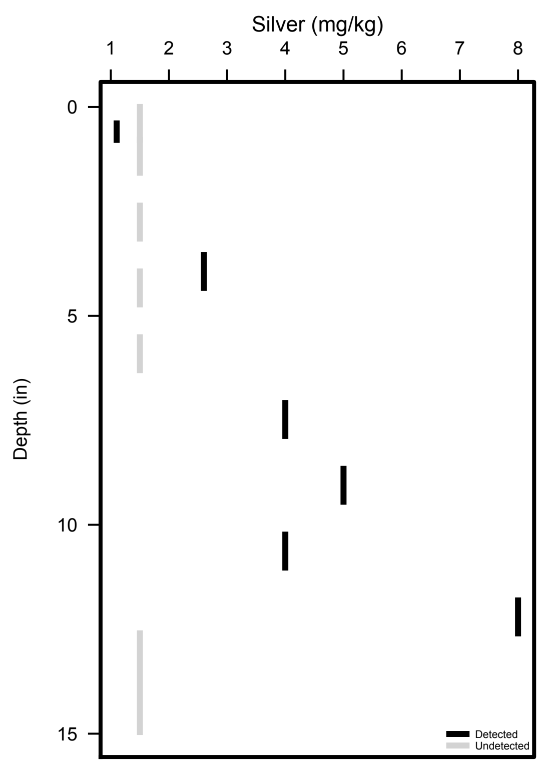

Figure 1332. Silver
at Cox Core Location CCR−692.

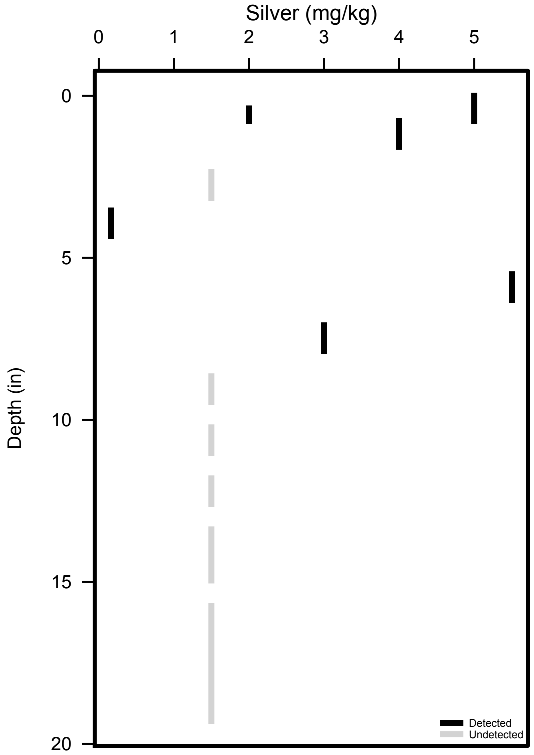

Figure 1333. Silver
at Cox Core Location CCR−705.

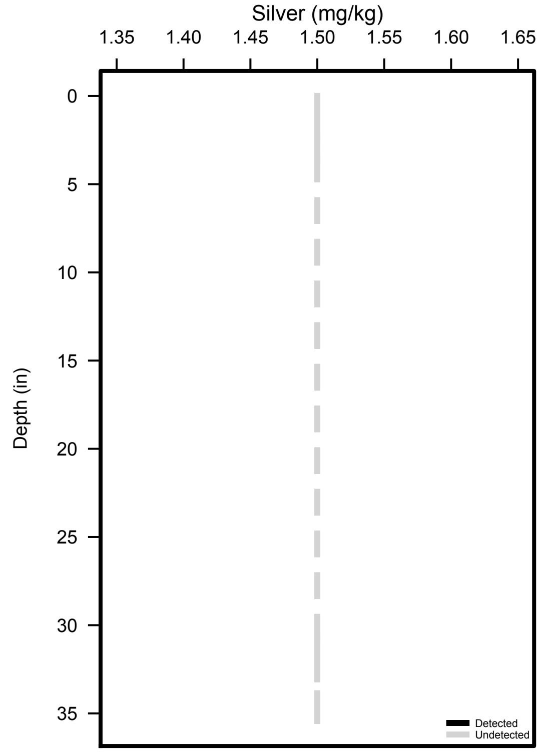

Figure 1334. Silver
at Cox Core Location CSA−8.

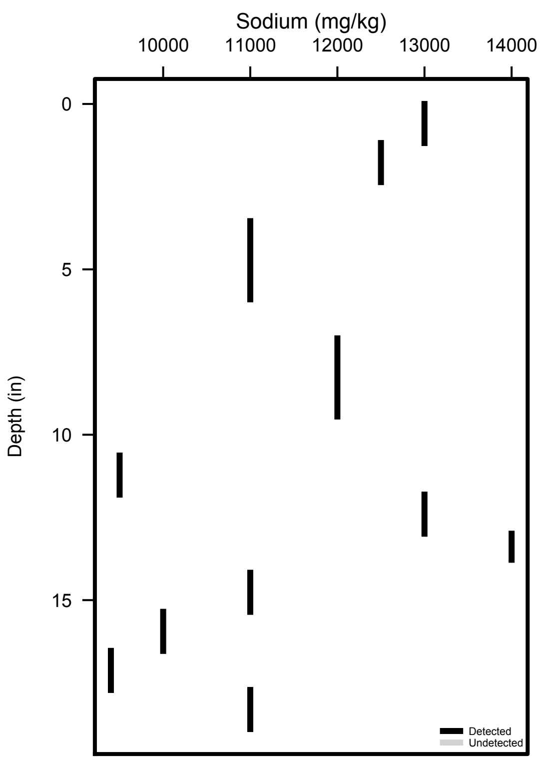

Figure 1335. Sodium
at Cox Core Location CCR−624.

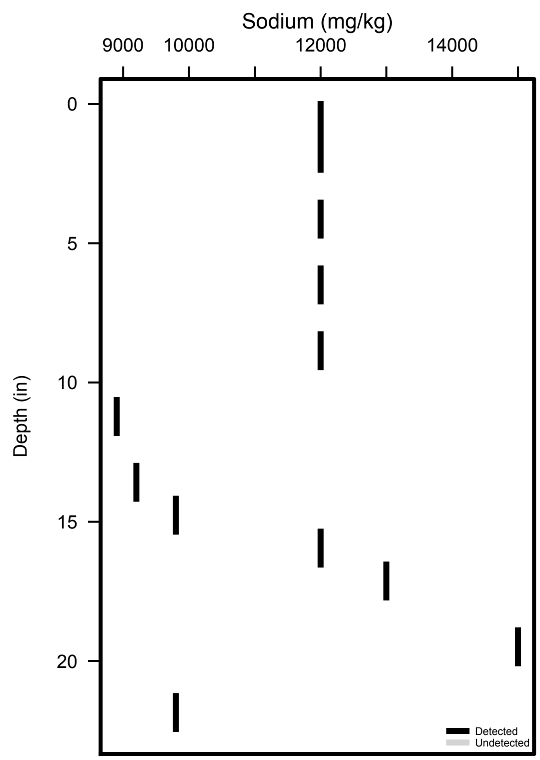

Figure 1336. Sodium
at Cox Core Location CCR−643.

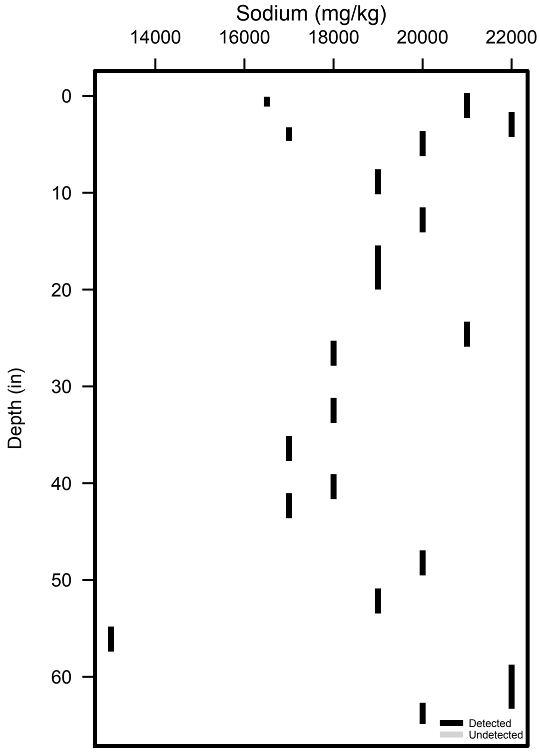

Figure 1337. Sodium
at Cox Core Location CCR−668.

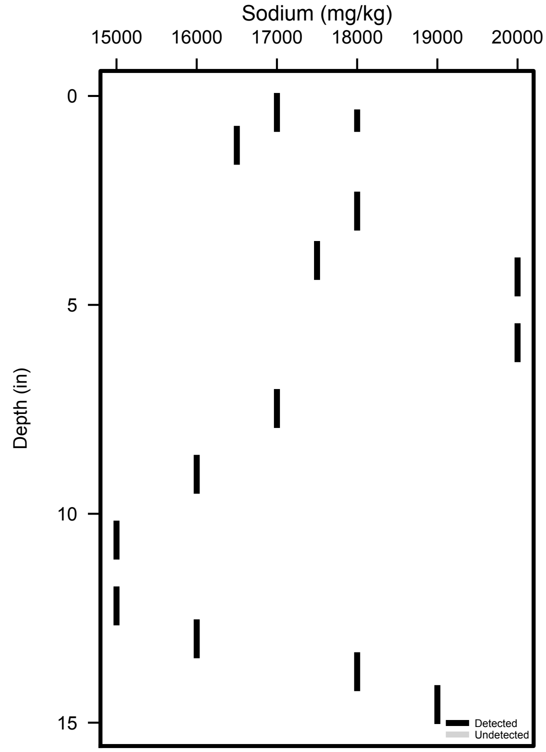

Figure 1338. Sodium
at Cox Core Location CCR−692.

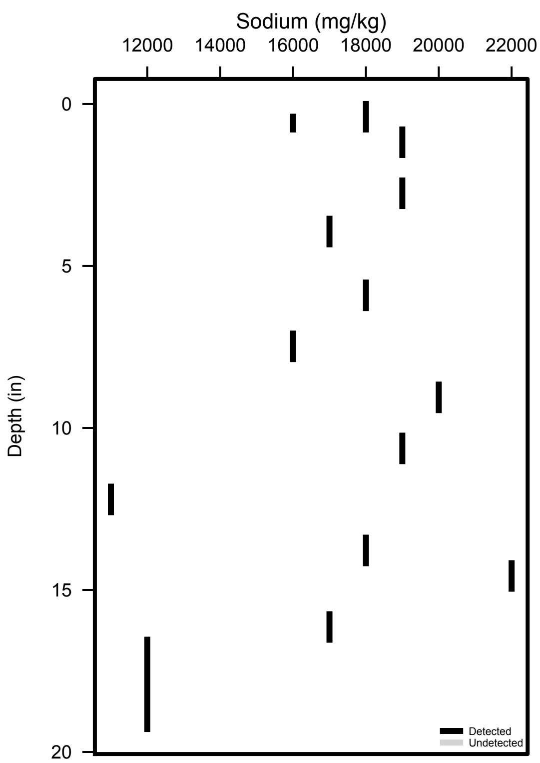

Figure 1339. Sodium
at Cox Core Location CCR−705.

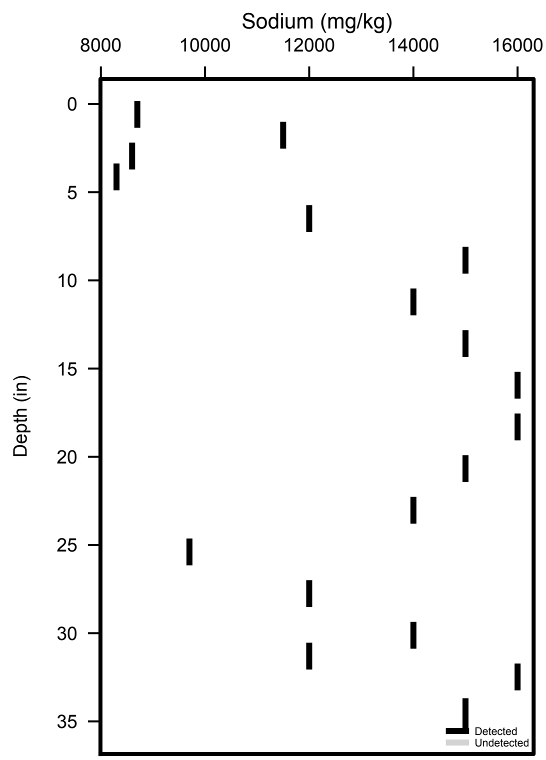

Figure 1340. Sodium
at Cox Core Location CSA−8.

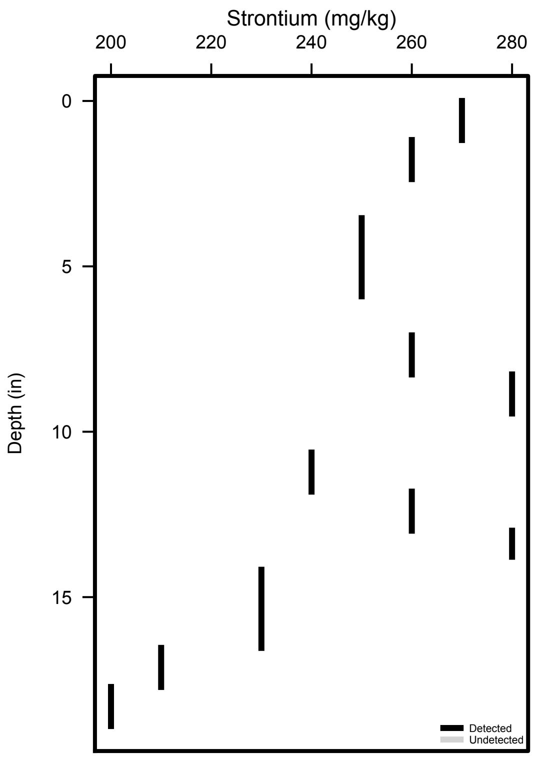

Figure 1341. Strontium
at Cox Core Location CCR−624.

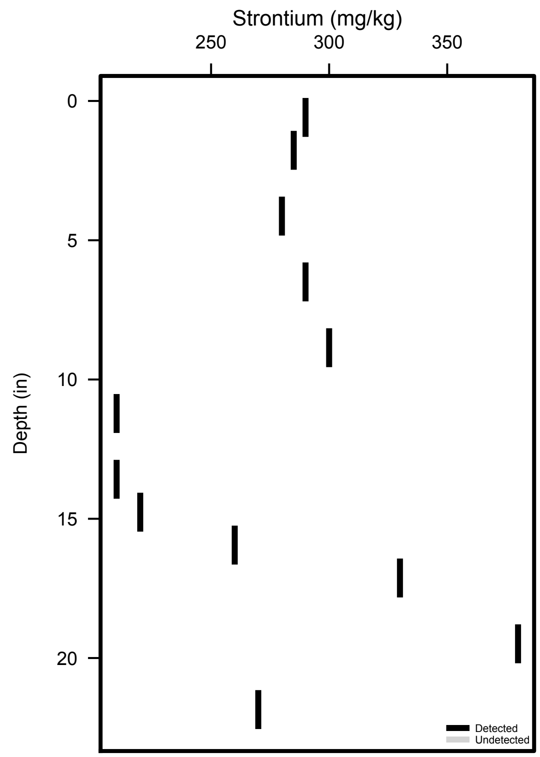

Figure 1342. Strontium
at Cox Core Location CCR−643.

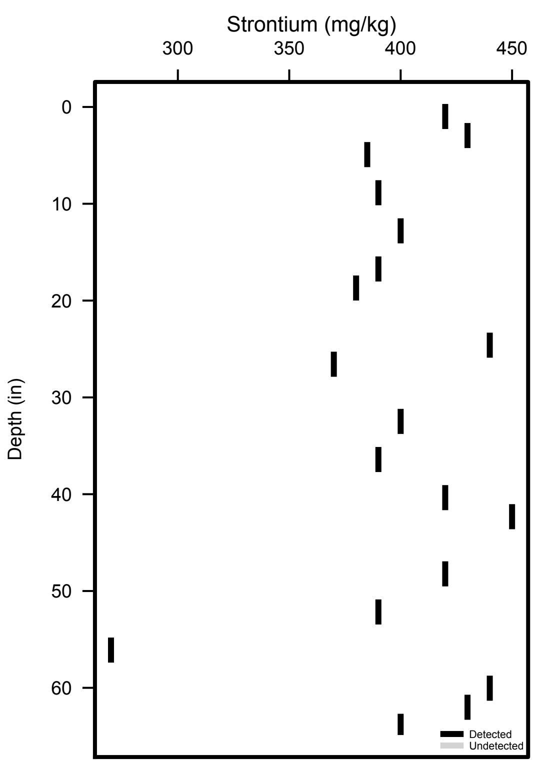

Figure 1343. Strontium
at Cox Core Location CCR−668.

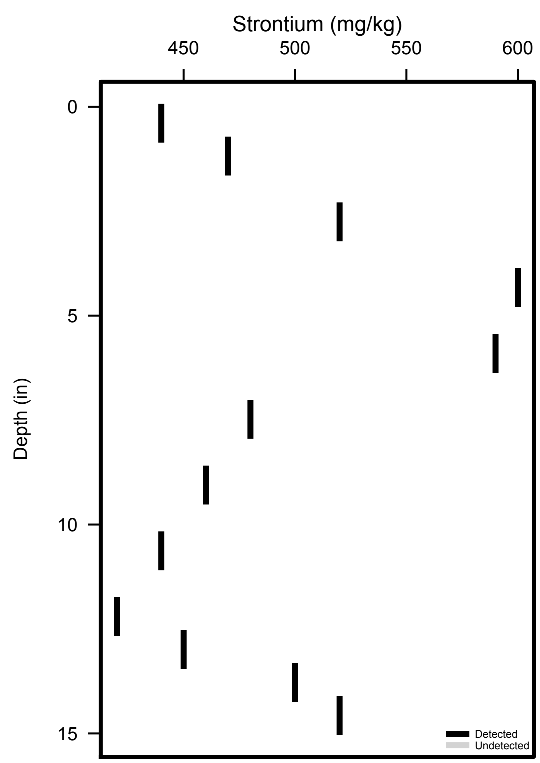

Figure 1344. Strontium
at Cox Core Location CCR−692.

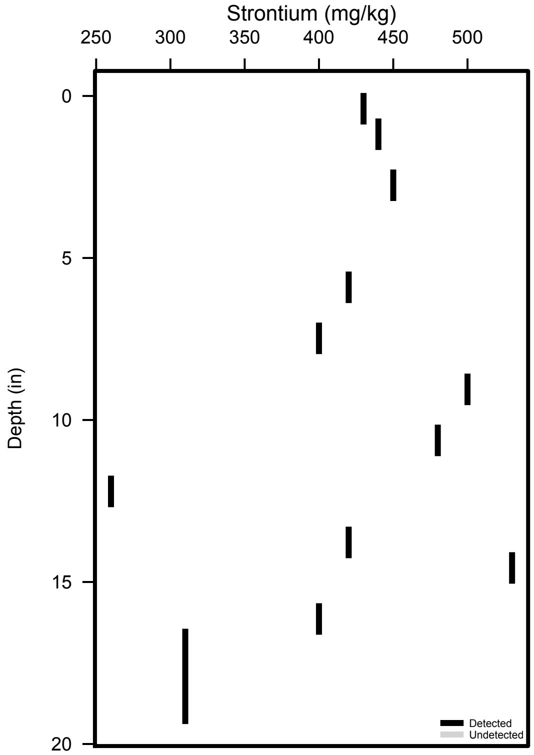

Figure 1345. Strontium
at Cox Core Location CCR−705.

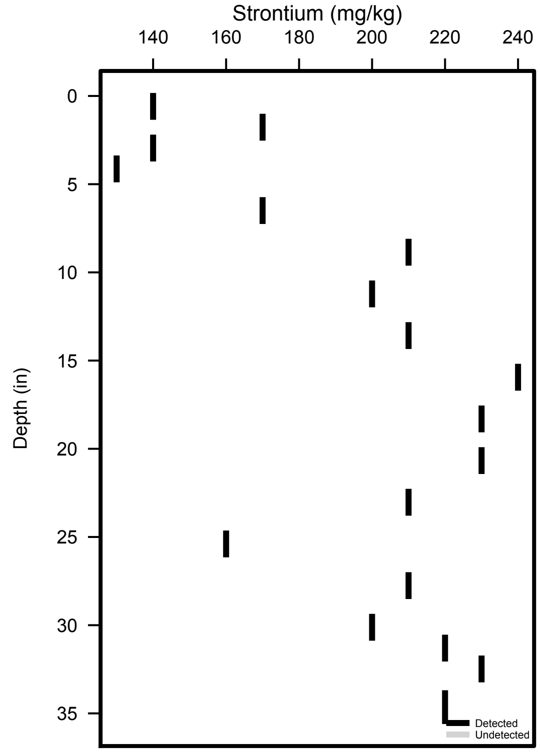

Figure 1346. Strontium
at Cox Core Location CSA−8.

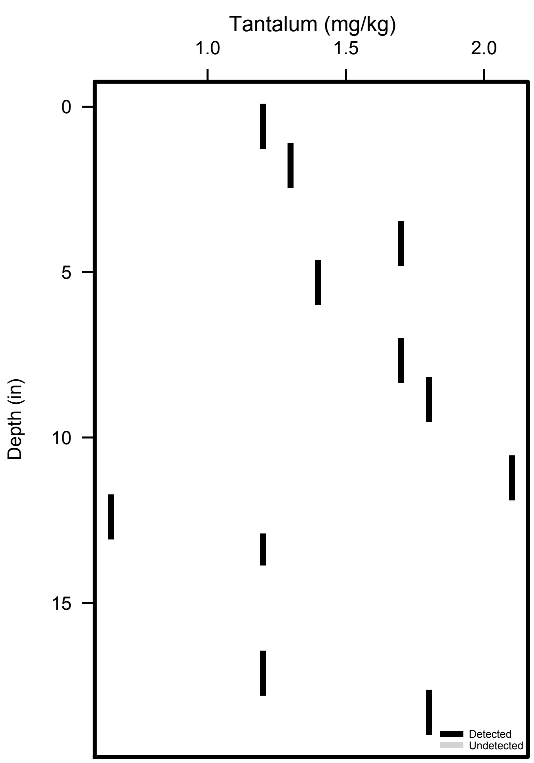

Figure 1347. Tantalum
at Cox Core Location CCR−624.

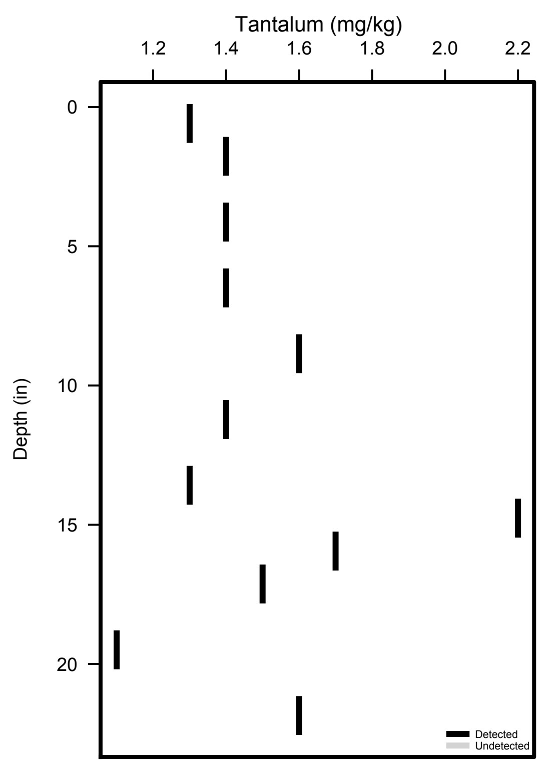

Figure 1348. Tantalum
at Cox Core Location CCR−643.

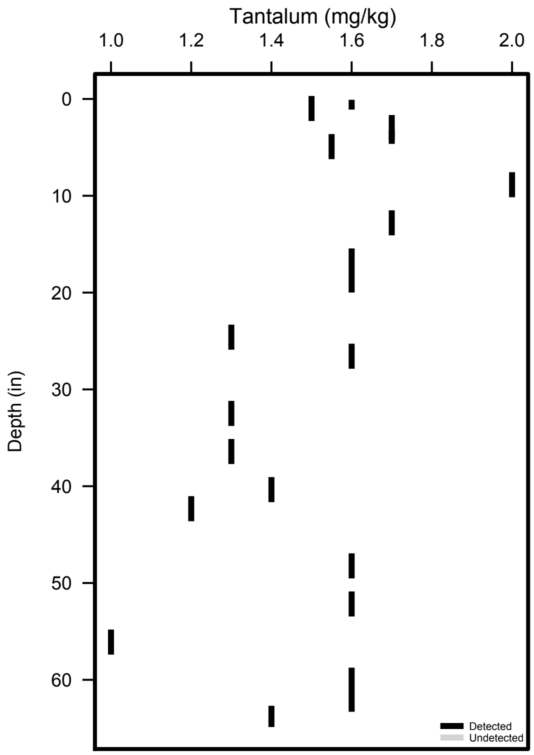

Figure 1349. Tantalum
at Cox Core Location CCR−668.

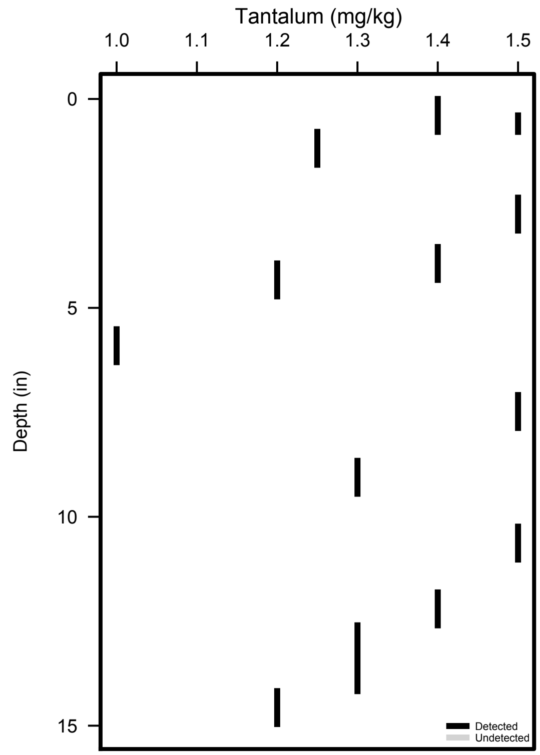

Figure 1350. Tantalum
at Cox Core Location CCR−692.

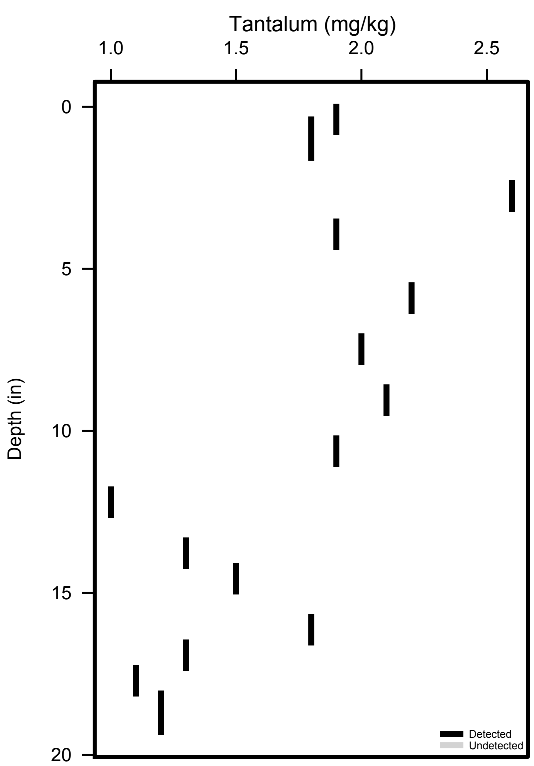

Figure 1351. Tantalum
at Cox Core Location CCR−705.

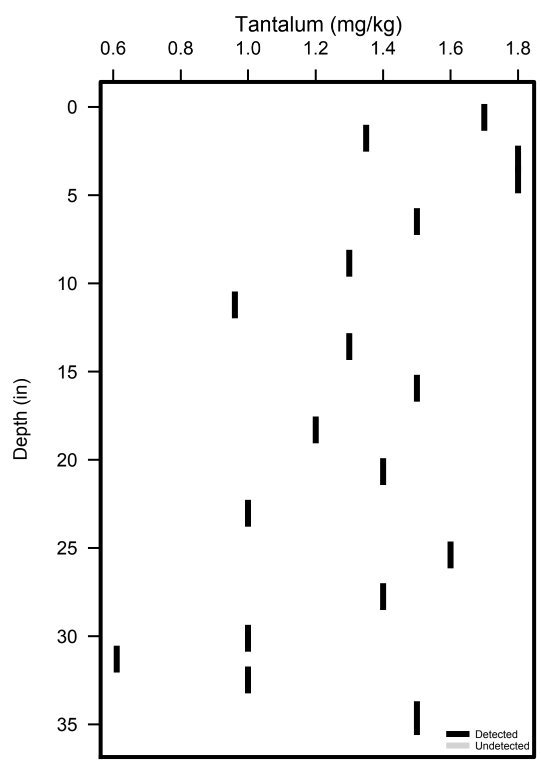

Figure 1352. Tantalum
at Cox Core Location CSA−8.

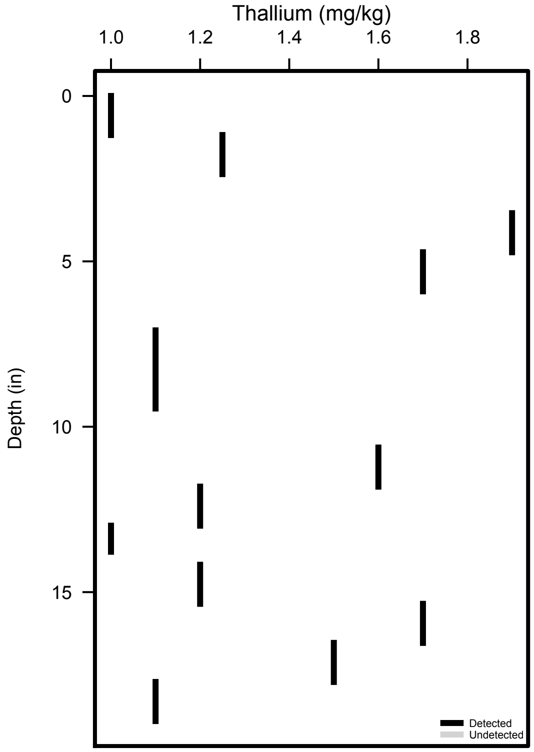

Figure 1353. Thallium
at Cox Core Location CCR−624.

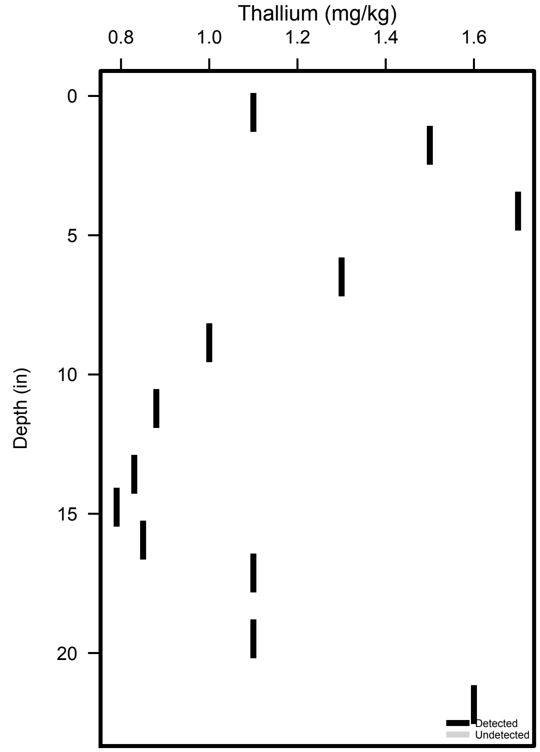

Figure 1354. Thallium
at Cox Core Location CCR−643.

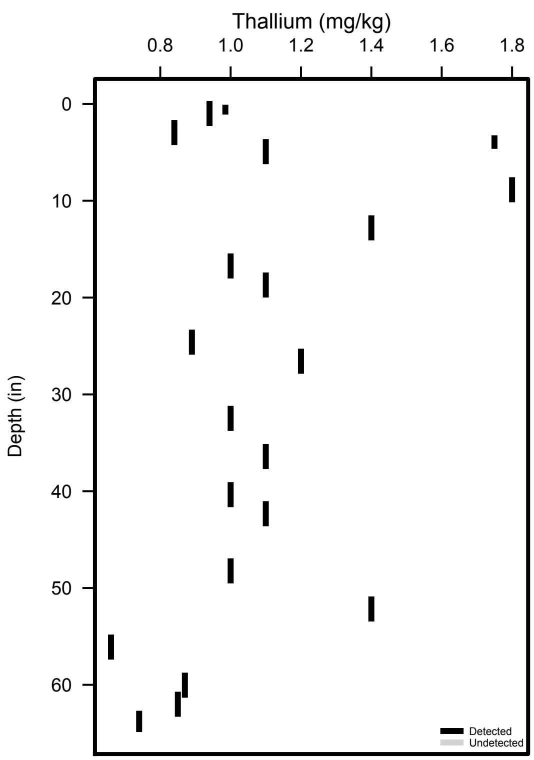

Figure 1355. Thallium
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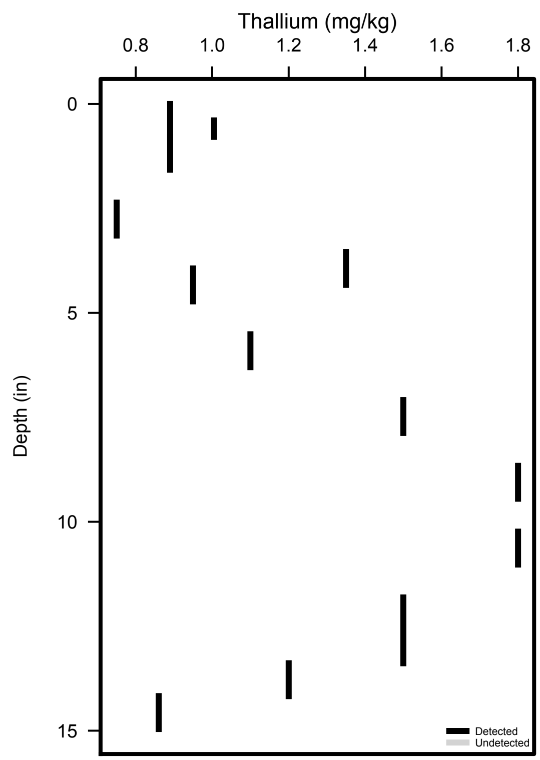

Figure 1356. Thallium
at Cox Core Location CCR−692.

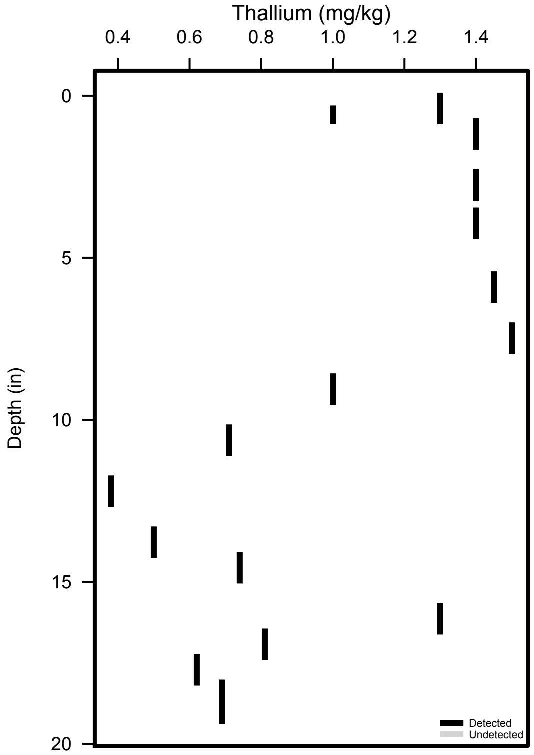

Figure 1357. Thallium
at Cox Core Location CCR−705.

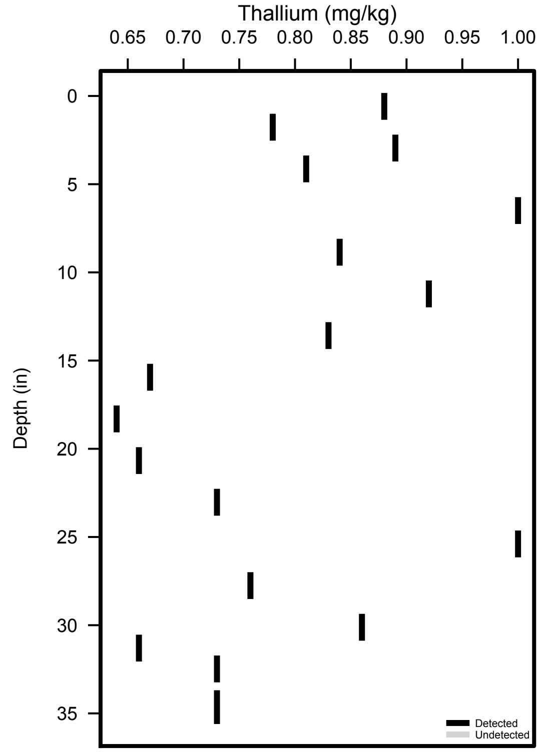

Figure 1358. Thallium
at Cox Core Location CSA−8.

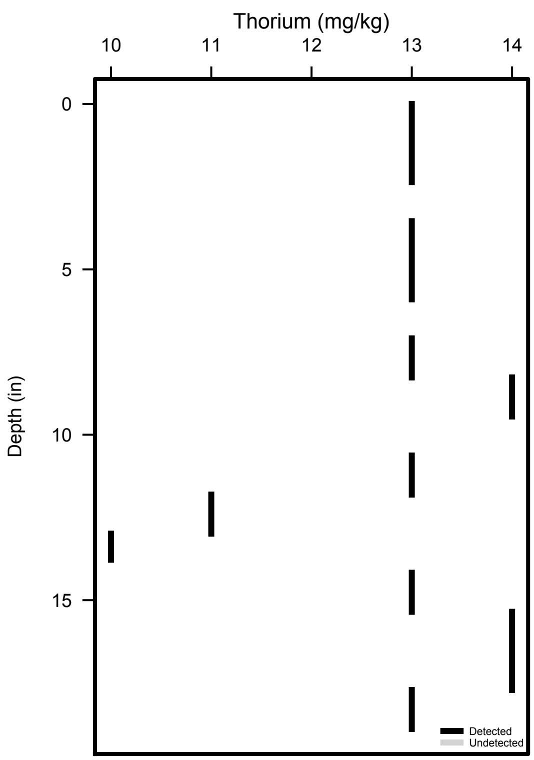

Figure 1359. Thorium
at Cox Core Location CCR−624.

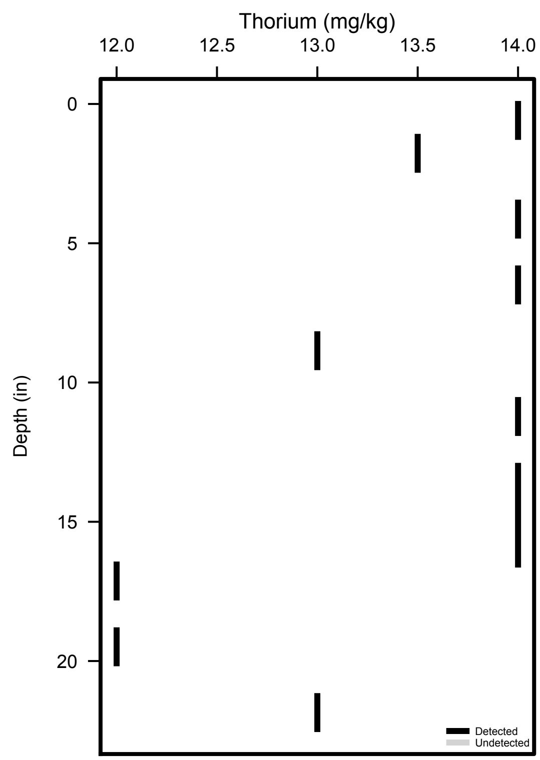

Figure 1360. Thorium
at Cox Core Location CCR−643.

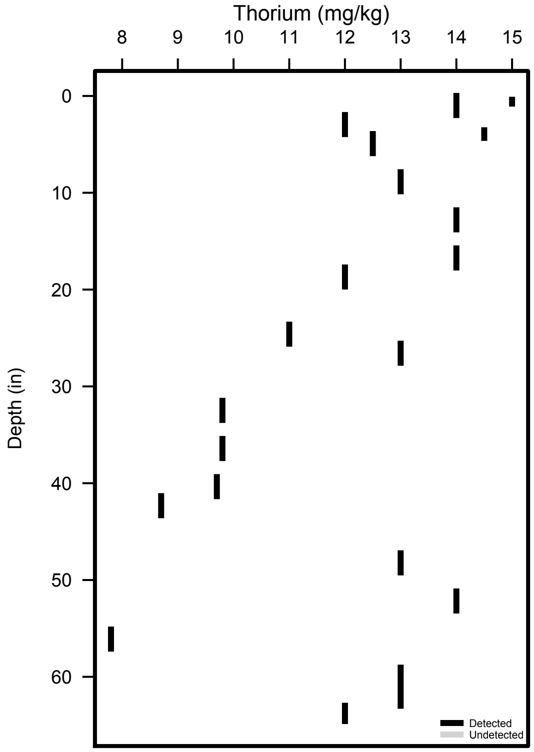

Figure 1361. Thorium
at Cox Core Location CCR−668.

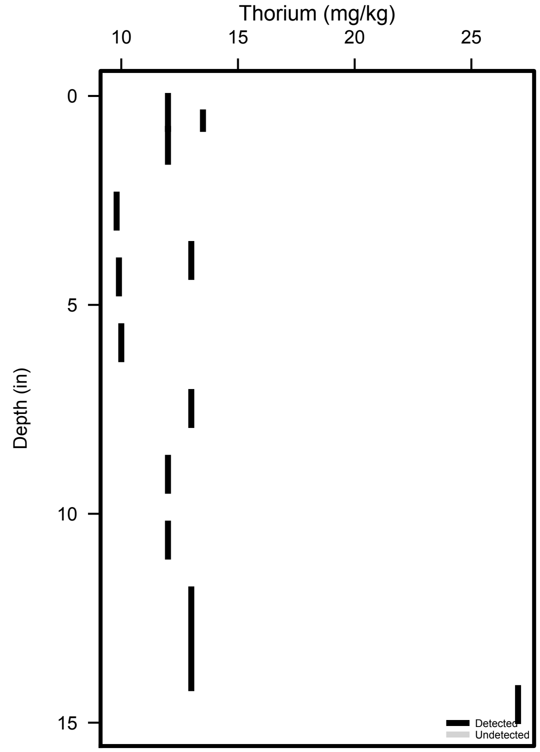

Figure 1362. Thorium
at Cox Core Location CCR−692.

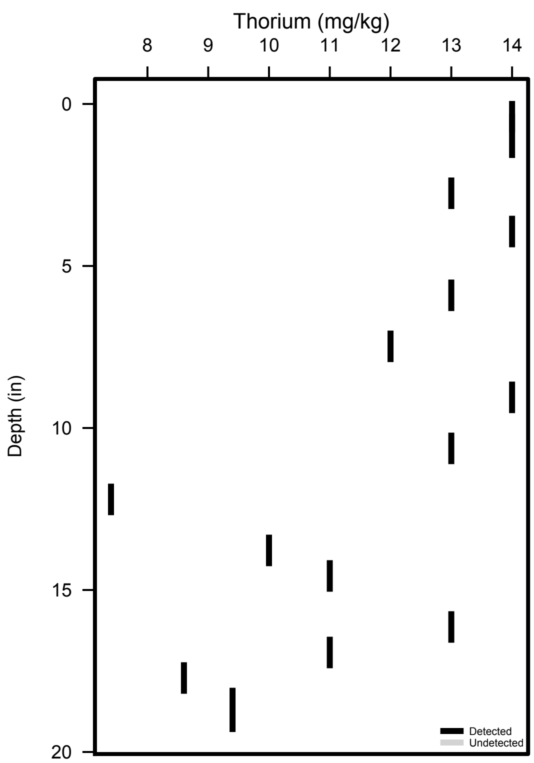

Figure 1363. Thorium
at Cox Core Location CCR−705.

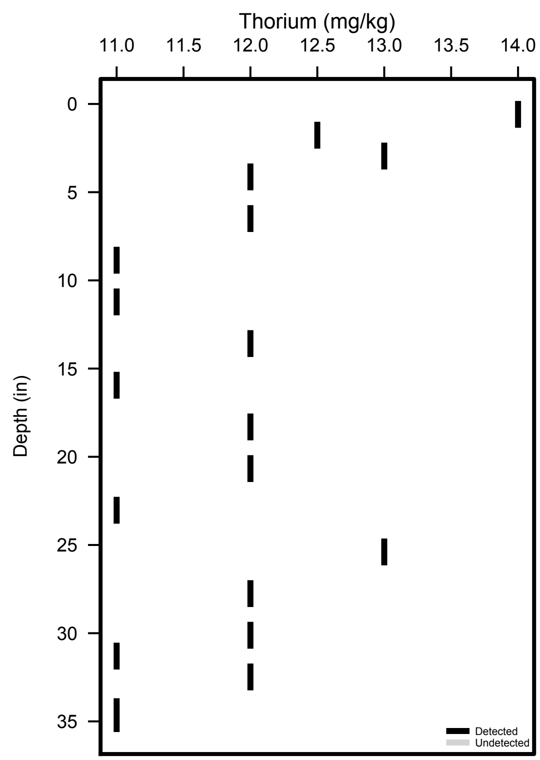

Figure 1364. Thorium
at Cox Core Location CSA−8.

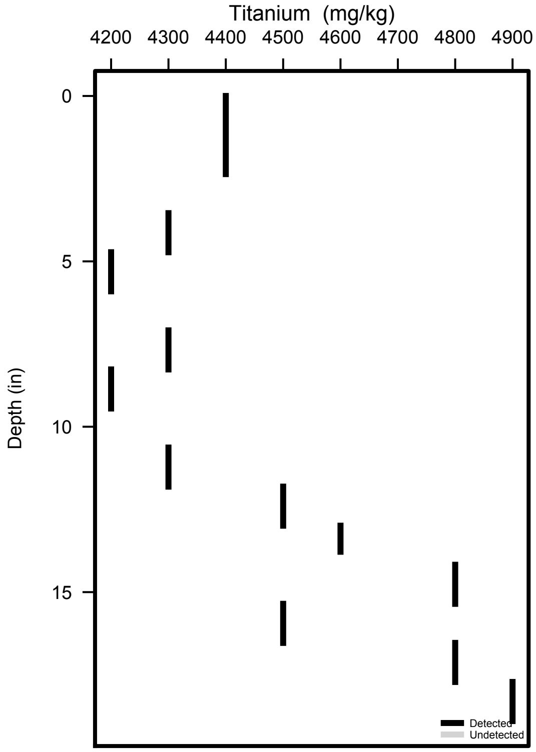

Figure 1365. Titanium
at Cox Core Location CCR−624.

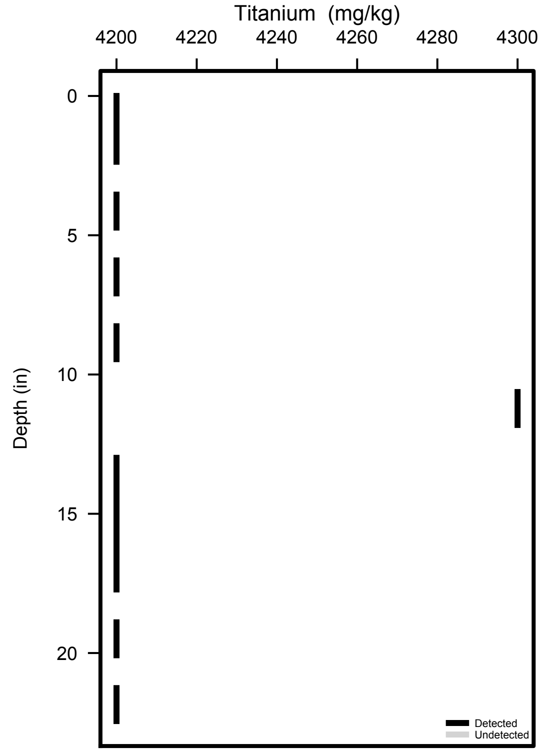

Figure 1366. Titanium
at Cox Core Location CCR−643.

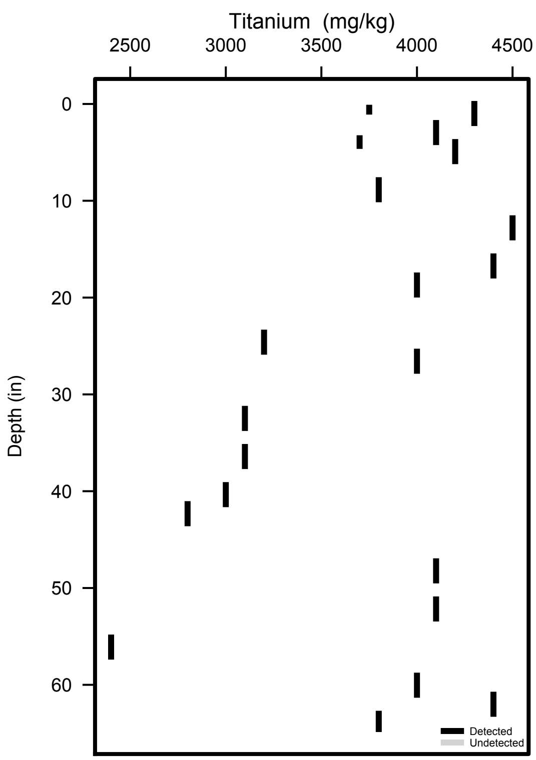

Figure 1367. Titanium
at Cox Core Location CCR−668.

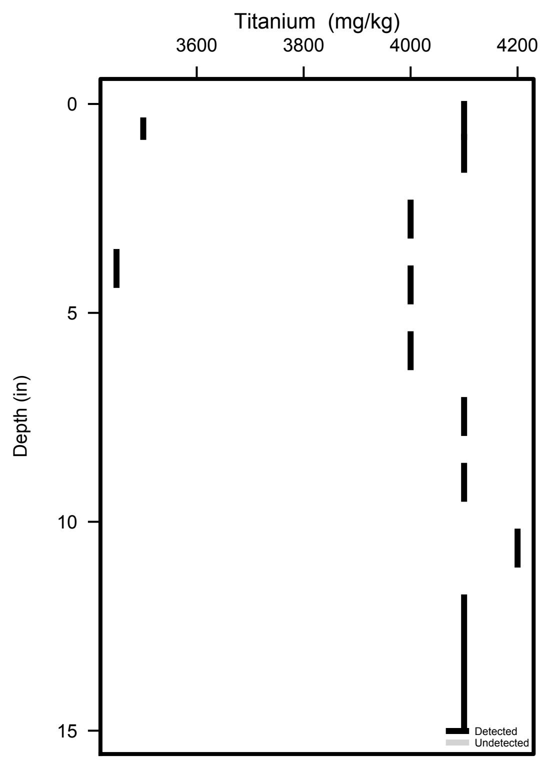

Figure 1368. Titanium
at Cox Core Location CCR−692.

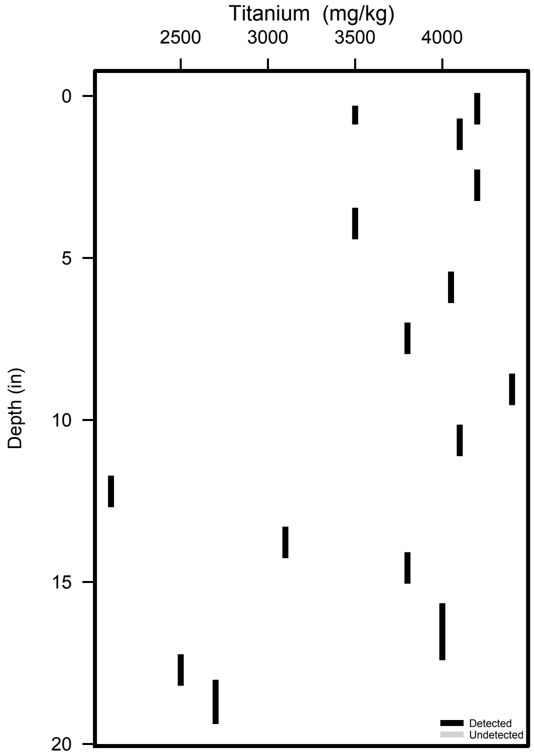

Figure 1369. Titanium
at Cox Core Location CCR−705.

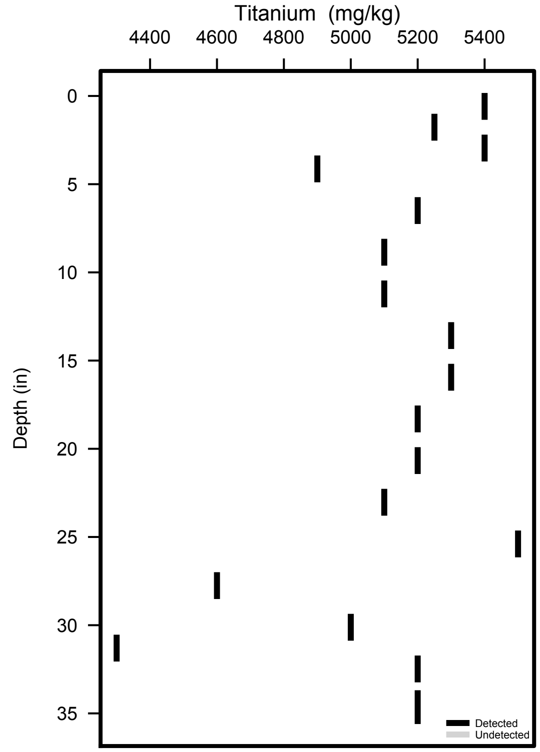

Figure 1370. Titanium
at Cox Core Location CSA−8.

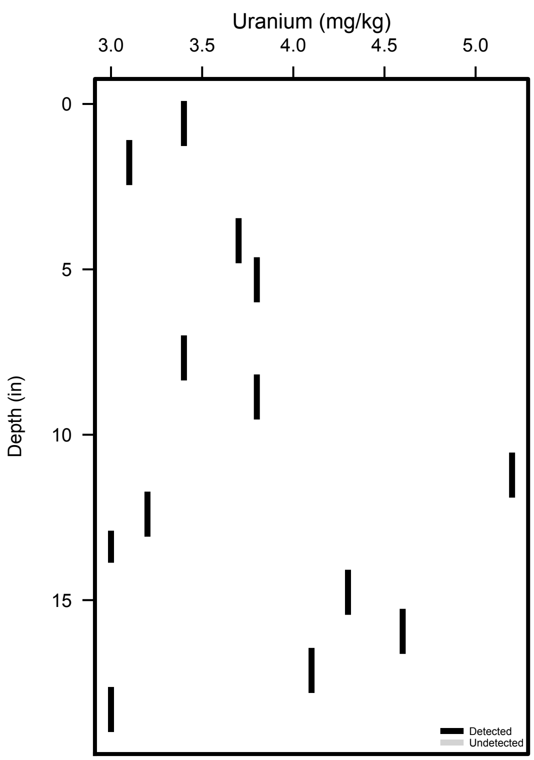

Figure 1371. Uranium
at Cox Core Location CCR−624.

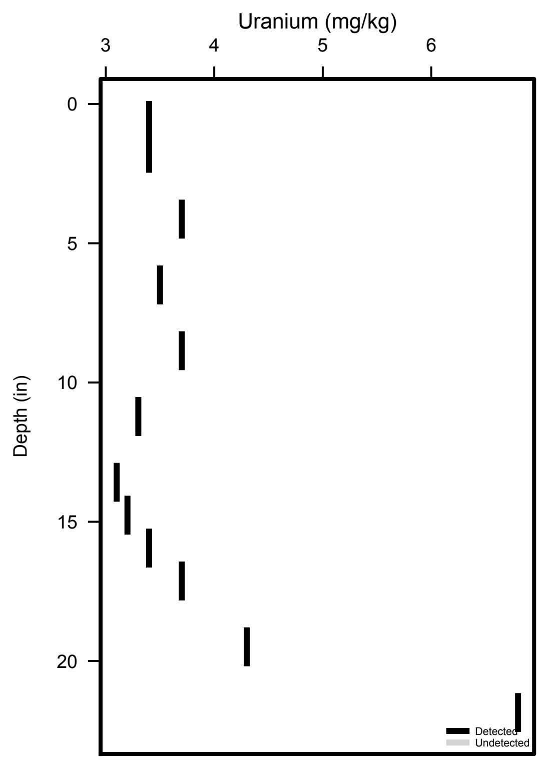

Figure 1372. Uranium
at Cox Core Location CCR−643.

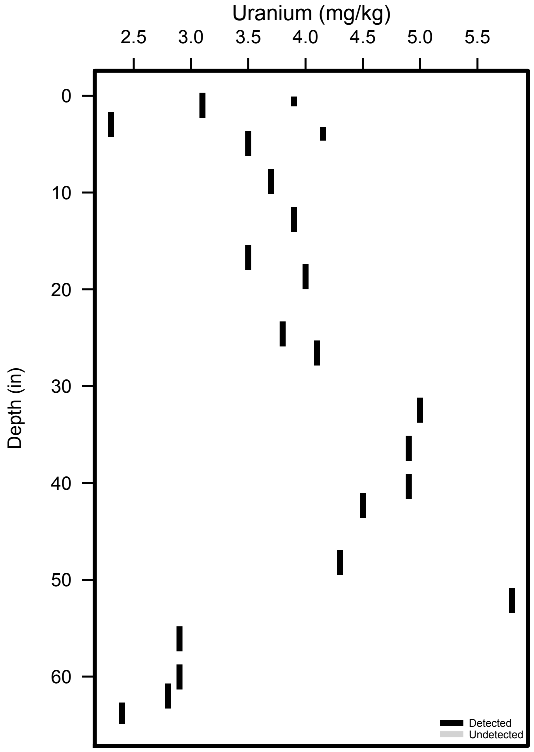

Figure 1373. Uranium
at Cox Core Location CCR−668.

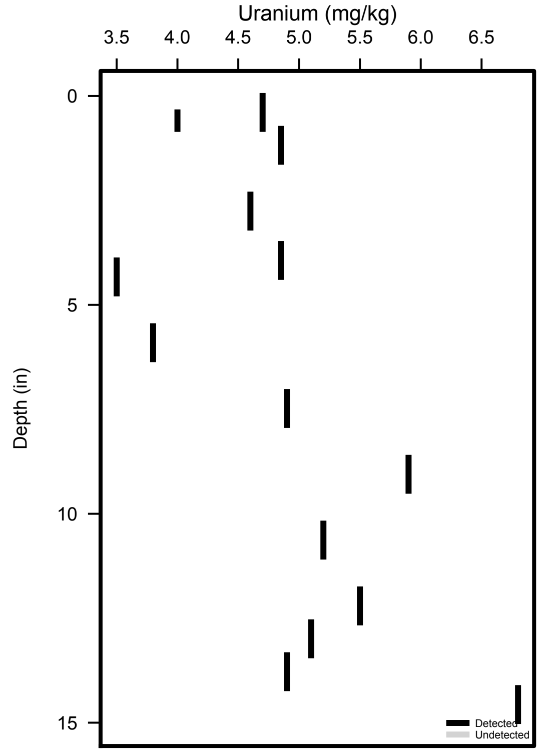

Figure 1374. Uranium
at Cox Core Location CCR−692.

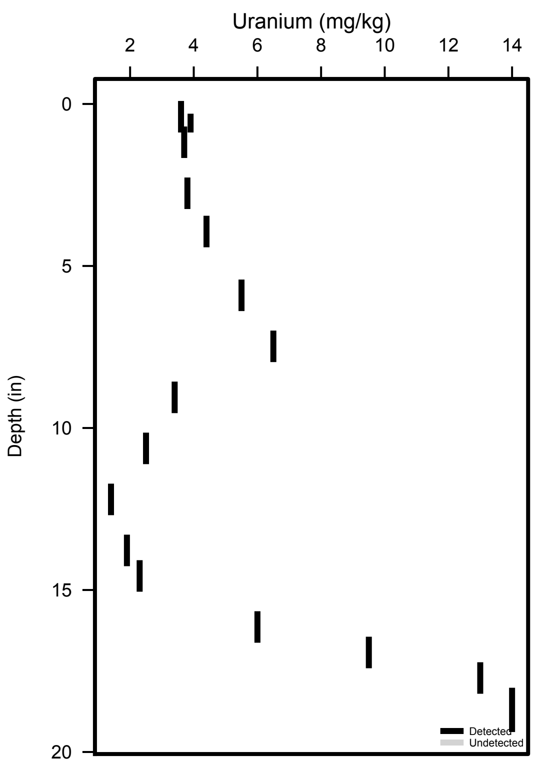

Figure 1375. Uranium
at Cox Core Location CCR−705.

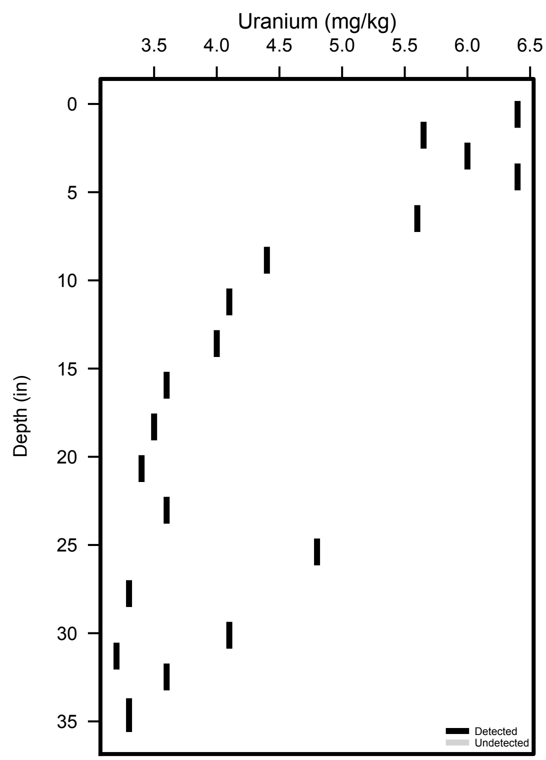

Figure 1376. Uranium
at Cox Core Location CSA−8.

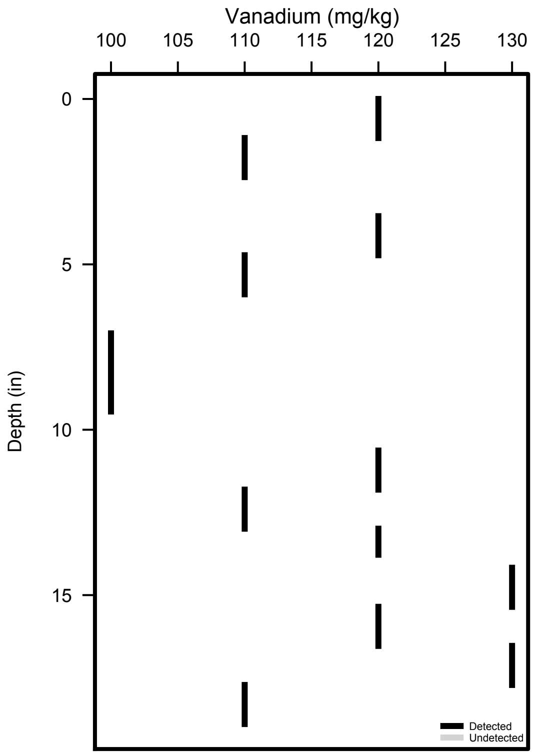

Figure 1377. Vanadium
at Cox Core Location CCR−624.

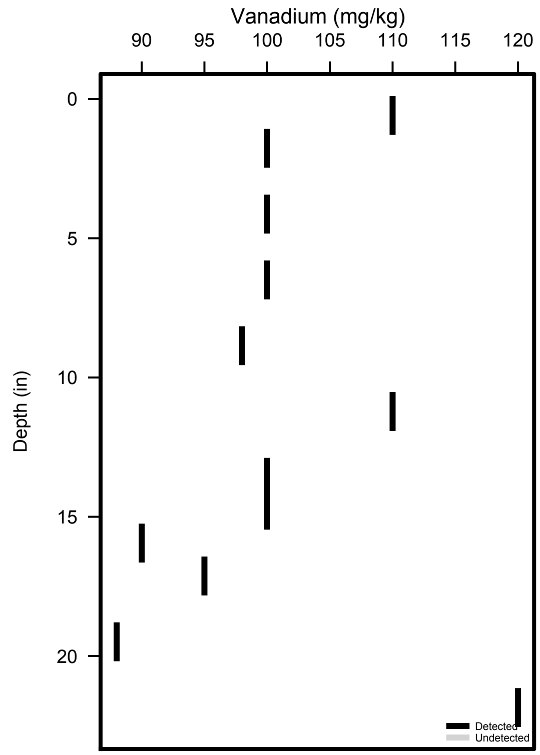

Figure 1378. Vanadium
at Cox Core Location CCR−643.

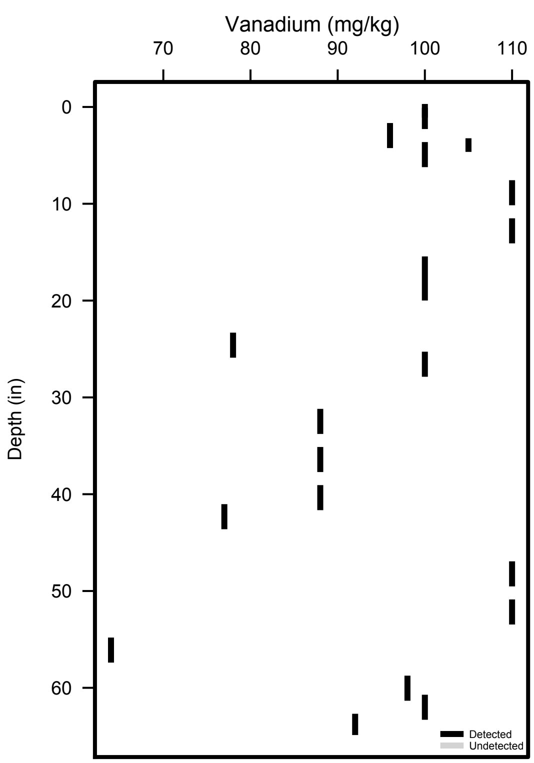

Figure 1379. Vanadium
at Cox Core Location CCR−668.

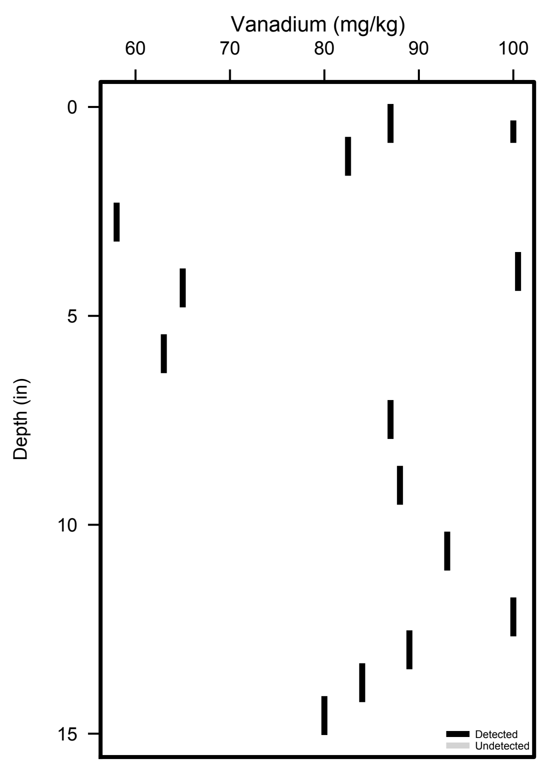

Figure 1380. Vanadium
at Cox Core Location CCR−692.

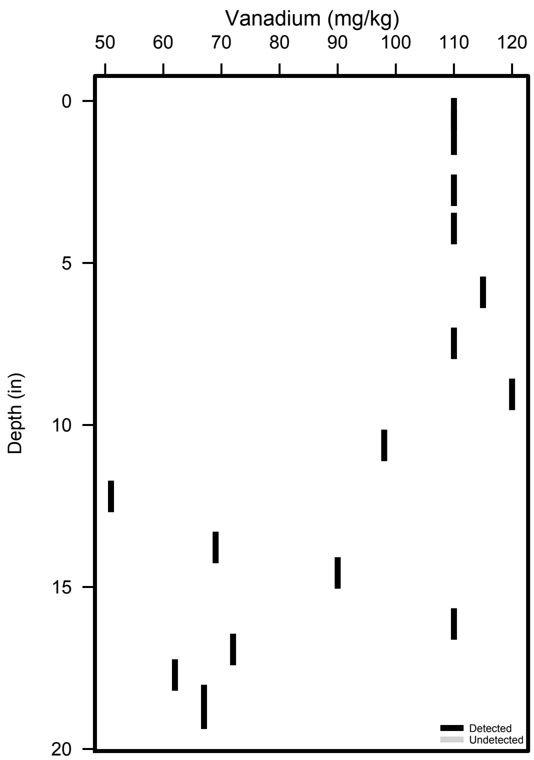

Figure 1381. Vanadium
at Cox Core Location CCR−705.

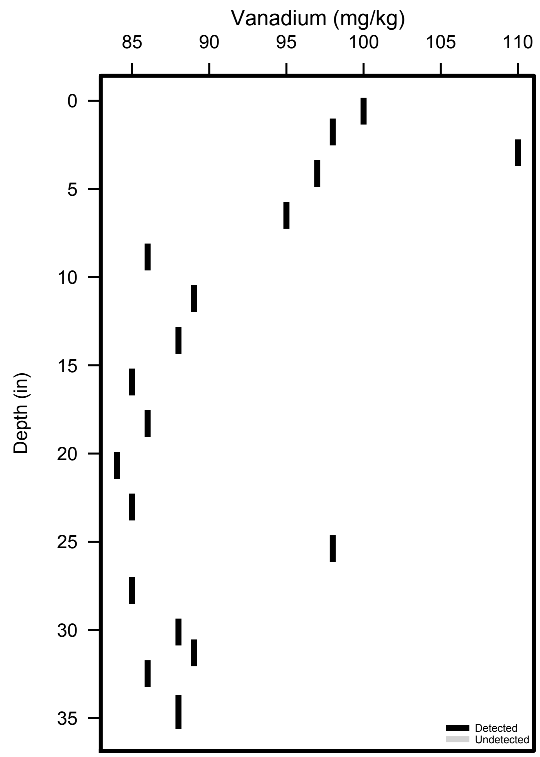

Figure 1382. Vanadium
at Cox Core Location CSA−8.

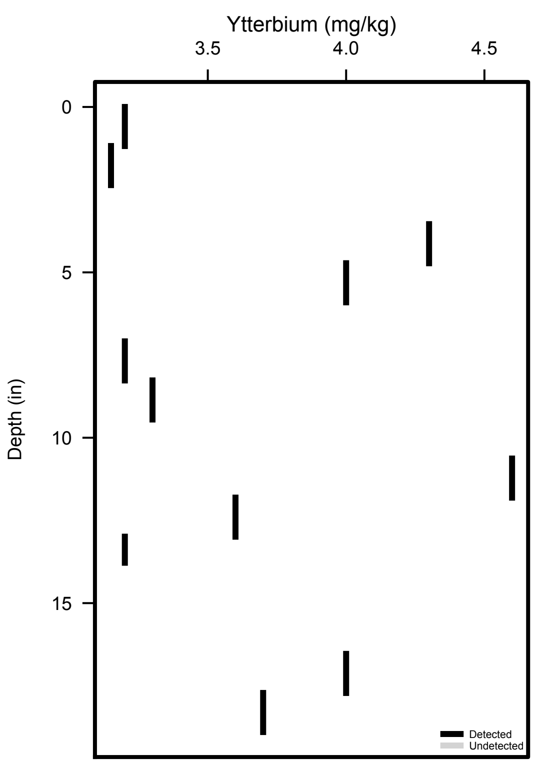

Figure 1383. Ytterbium
at Cox Core Location CCR−624.

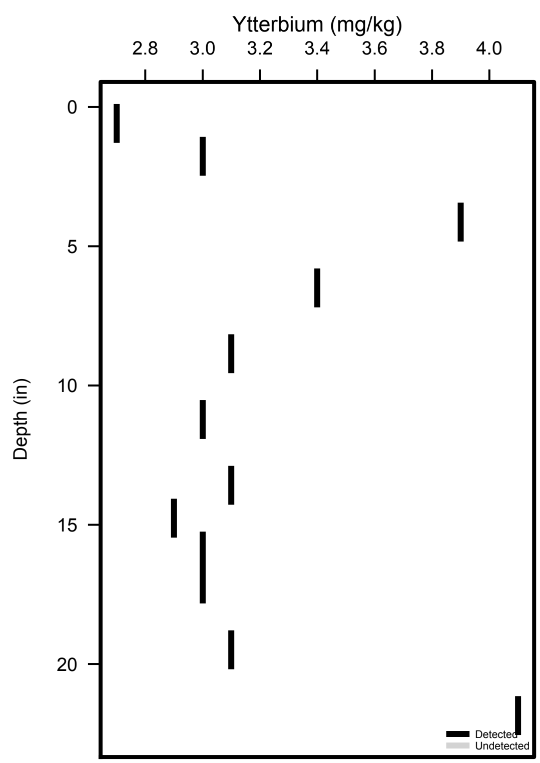

Figure 1384. Ytterbium
at Cox Core Location CCR−643.

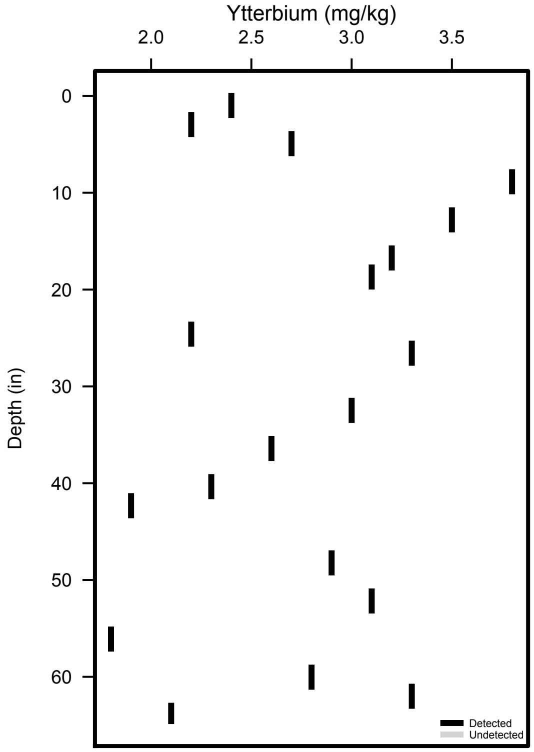

Figure 1385. Ytterbium
at Cox Core Location CCR−668.

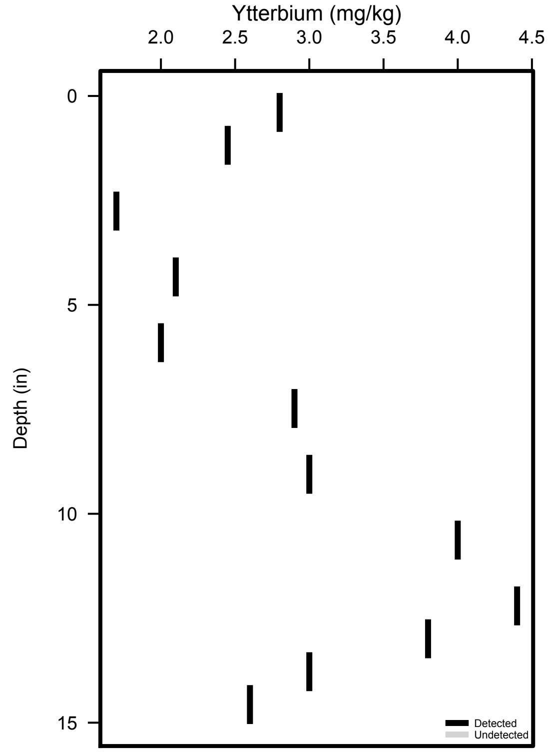

Figure 1386. Ytterbium
at Cox Core Location CCR−692.

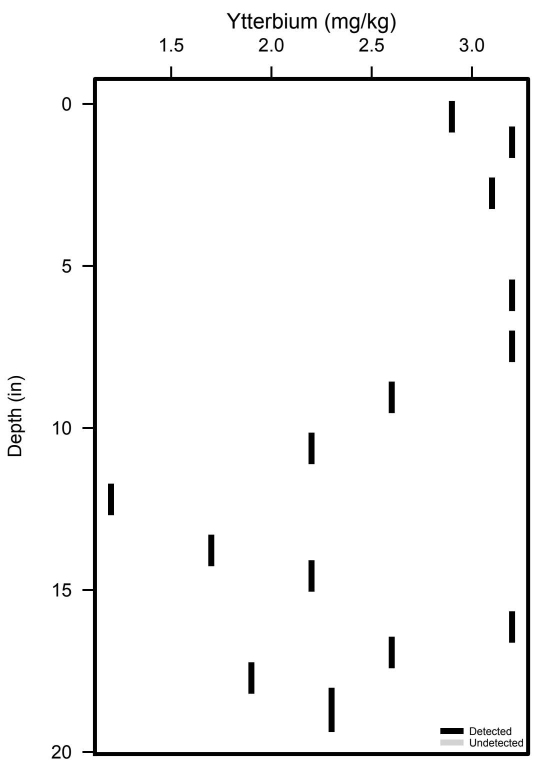

Figure 1387. Ytterbium
at Cox Core Location CCR−705.

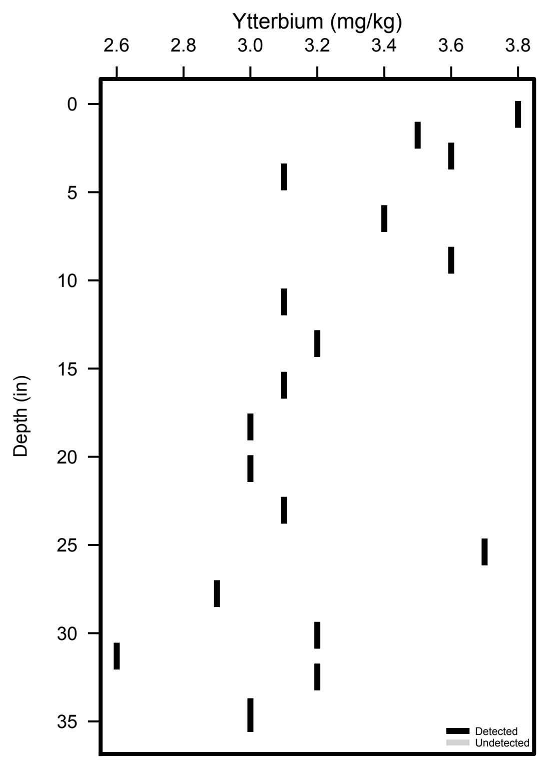

Figure 1388. Ytterbium
at Cox Core Location CSA−8.

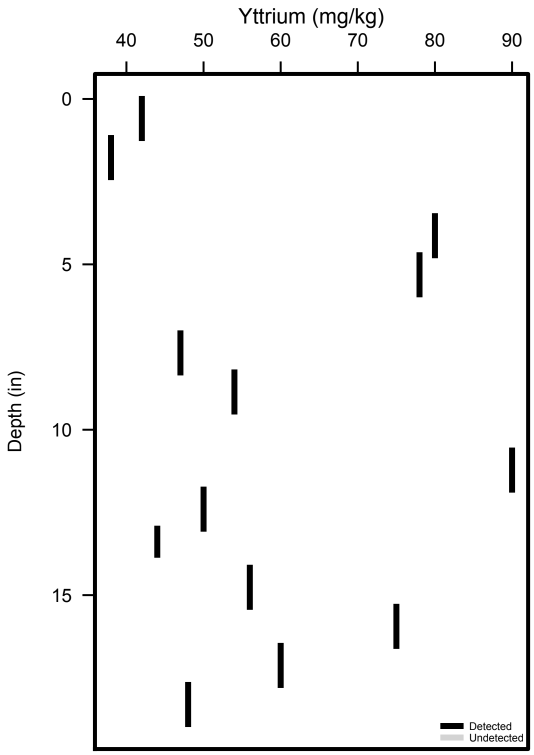

Figure 1389. Yttrium
at Cox Core Location CCR−624.

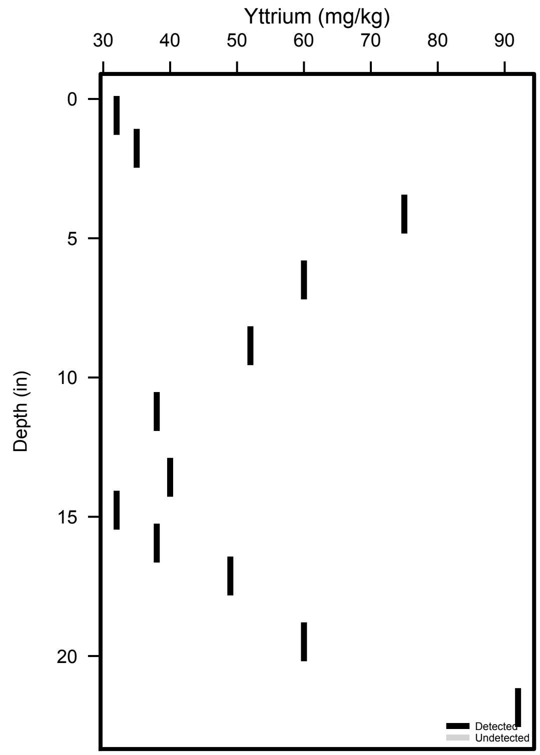

Figure 1390. Yttrium
at Cox Core Location CCR−643.

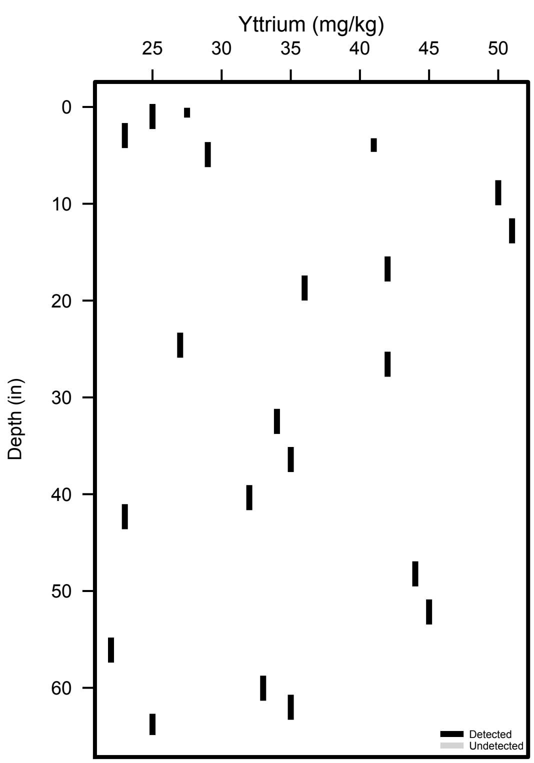

Figure 1391. Yttrium
at Cox Core Location CCR−668.

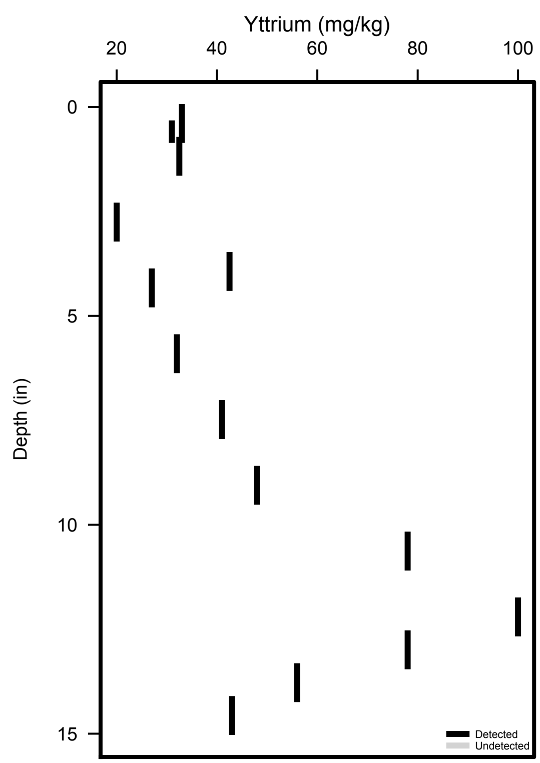

Figure 1392. Yttrium
at Cox Core Location CCR−692.

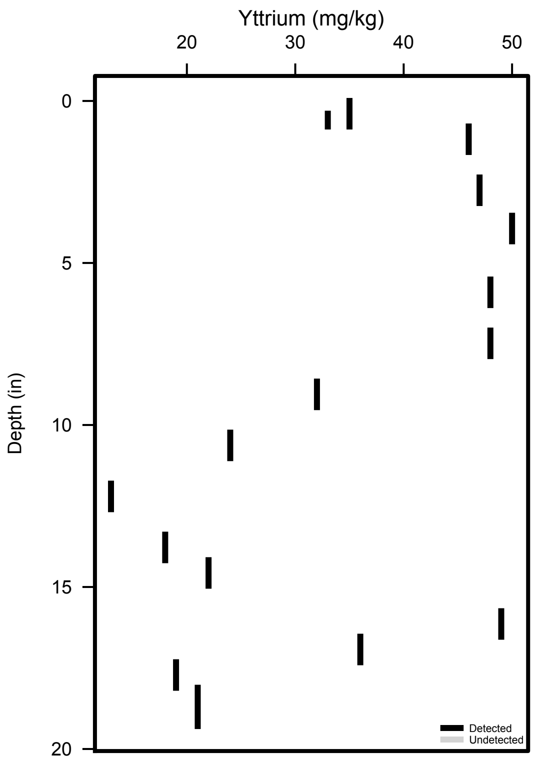

Figure 1393. Yttrium
at Cox Core Location CCR−705.

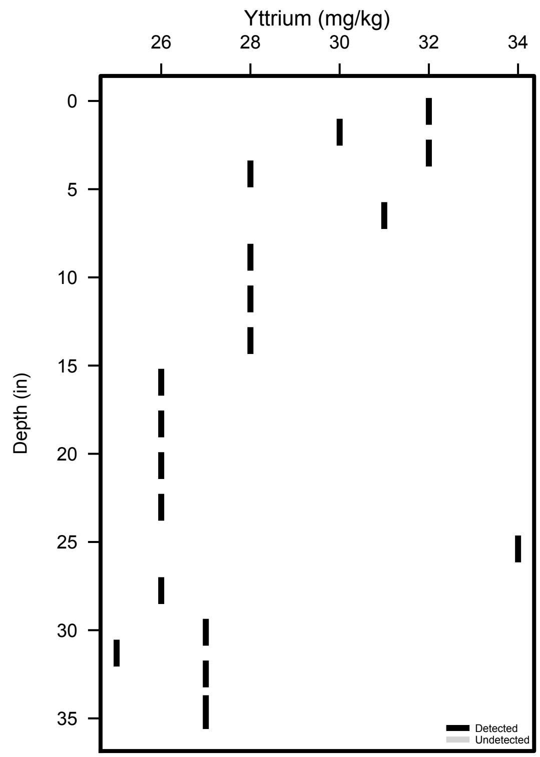

Figure 1394. Yttrium
at Cox Core Location CSA−8.

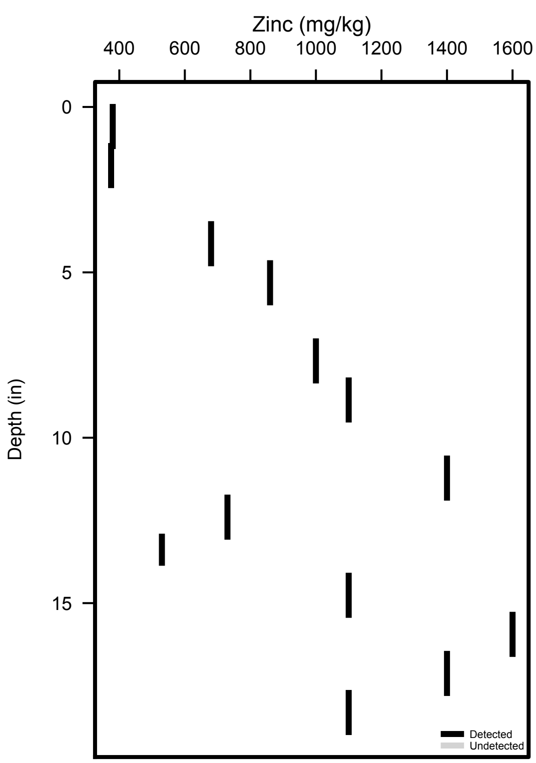

Figure 1395. Zinc
at Cox Core Location CCR−624.

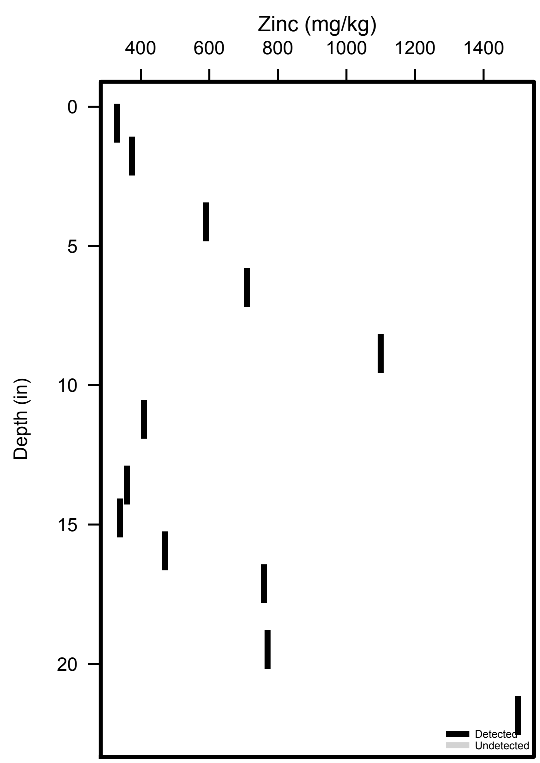

Figure 1396. Zinc
at Cox Core Location CCR−643.

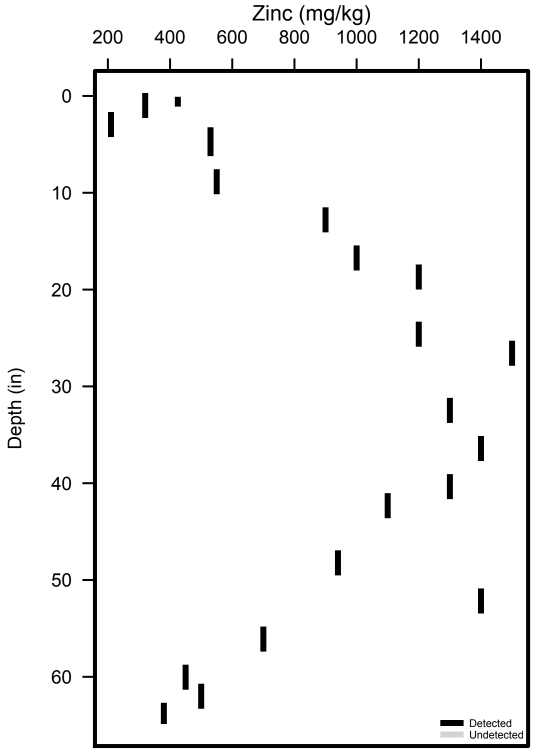

Figure 1397. Zinc
at Cox Core Location CCR−668.

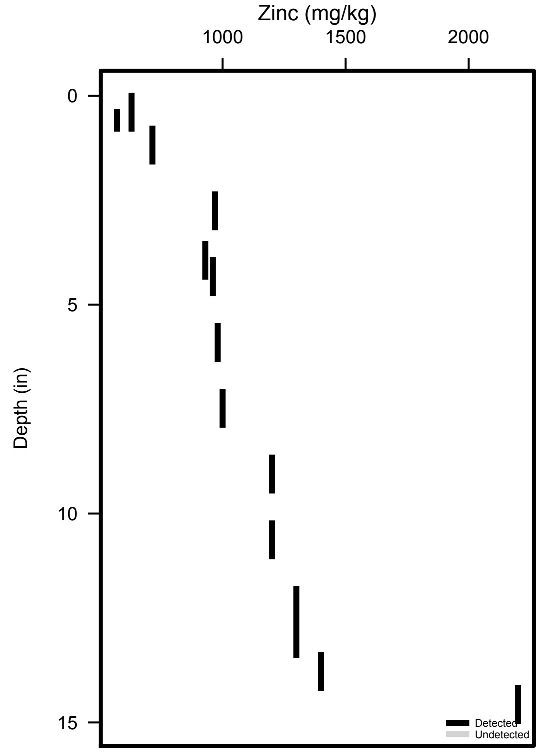

Figure 1398. Zinc
at Cox Core Location CCR−692.

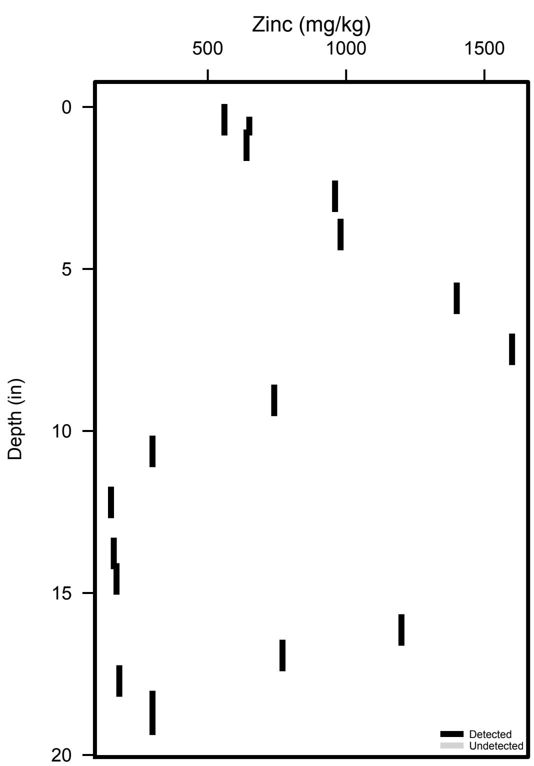

Figure 1399. Zinc
at Cox Core Location CCR−705.

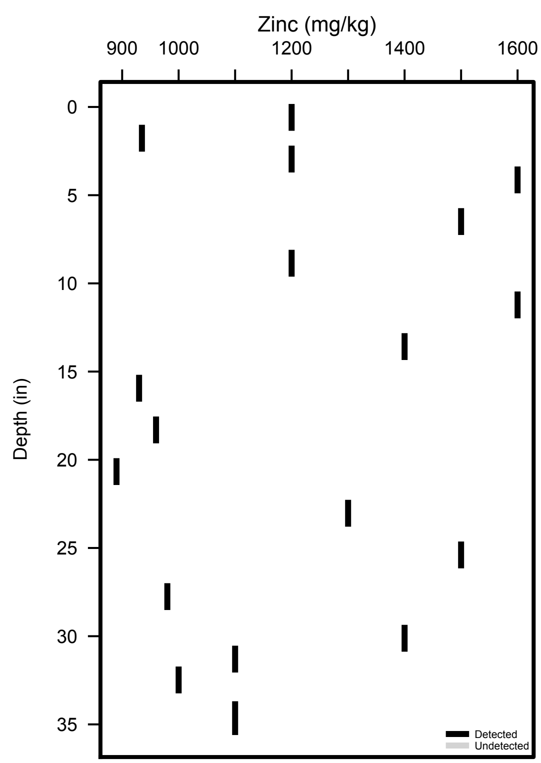

Figure 1400. Zinc
at Cox Core Location CSA−8.

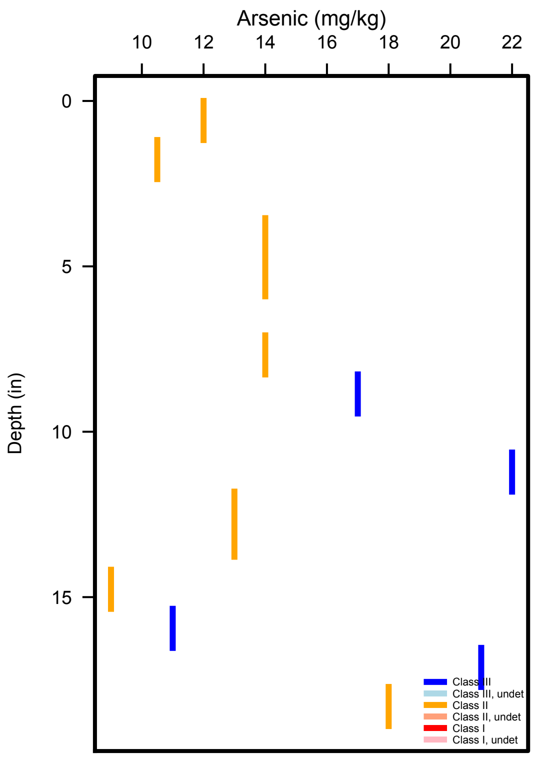

Figure 1401. Arsenic Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

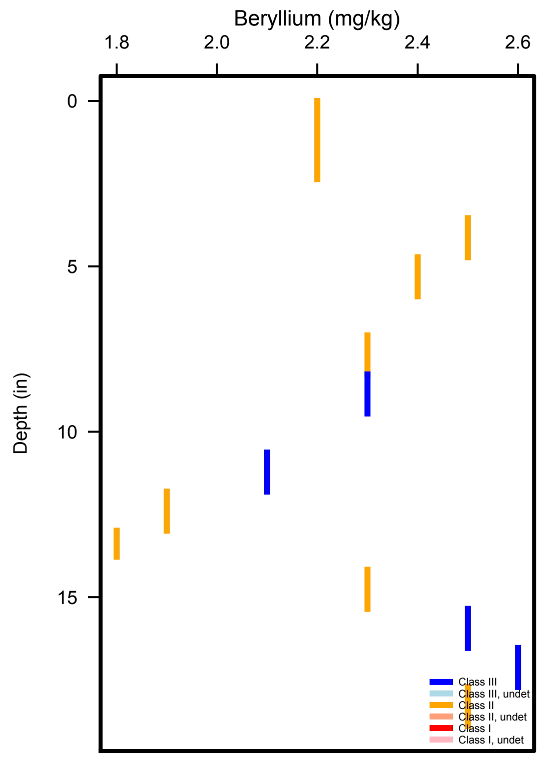

Figure 1402. Beryllium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

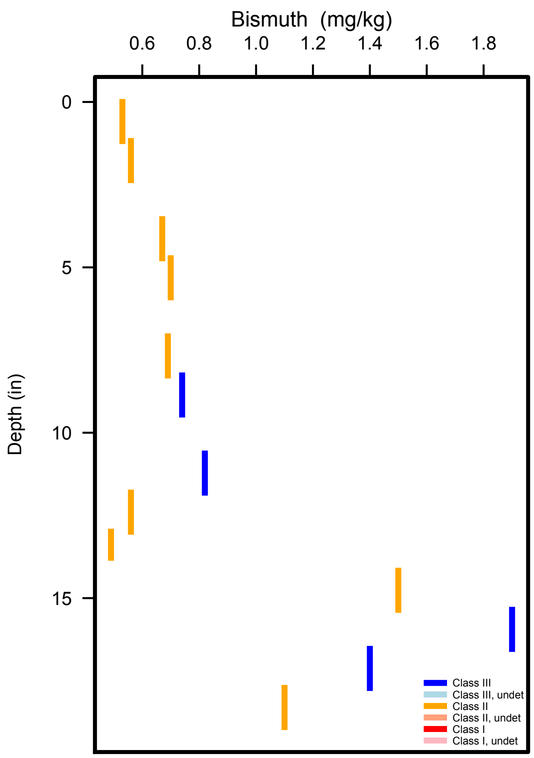

Figure 1403. Bismuth Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

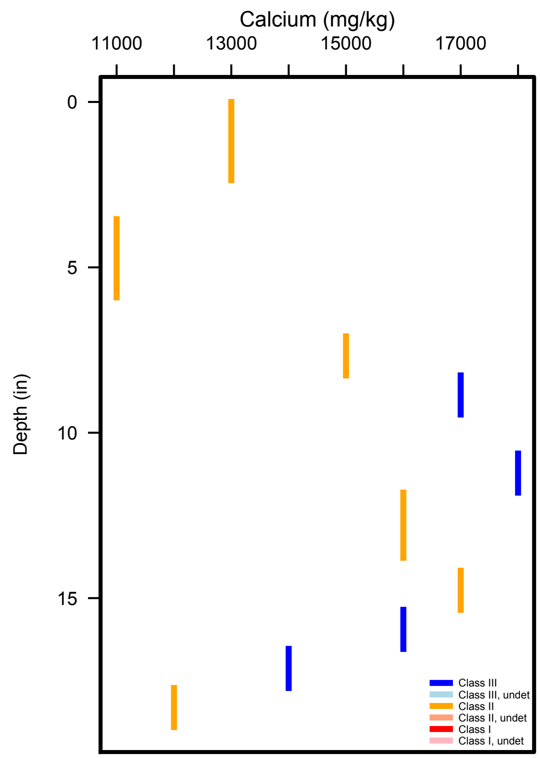

Figure 1404. Calcium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

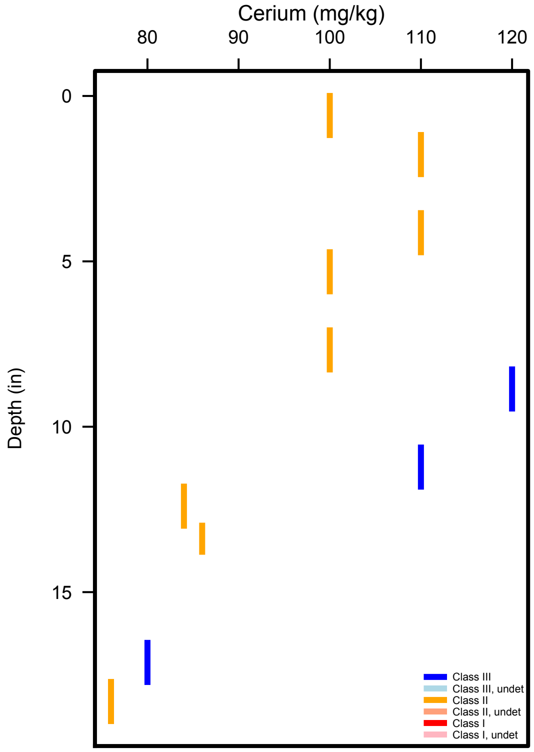

Figure 1405. Cerium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

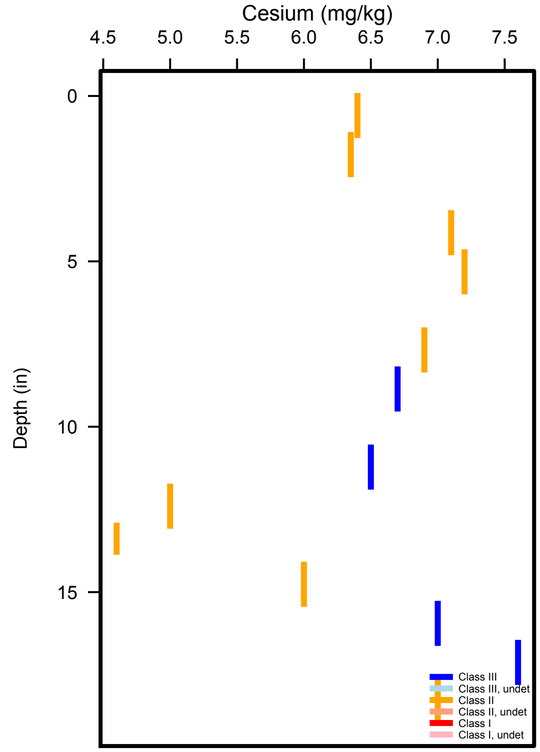

Figure 1406. Cesium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

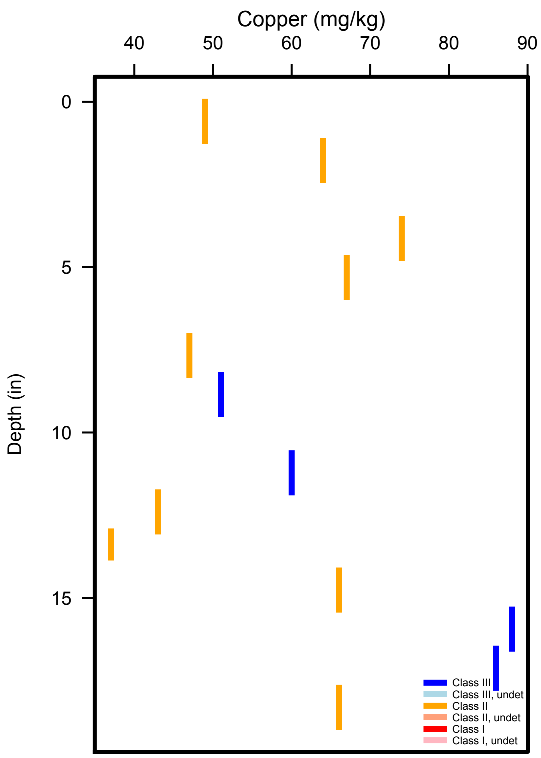

Figure 1407. Copper Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

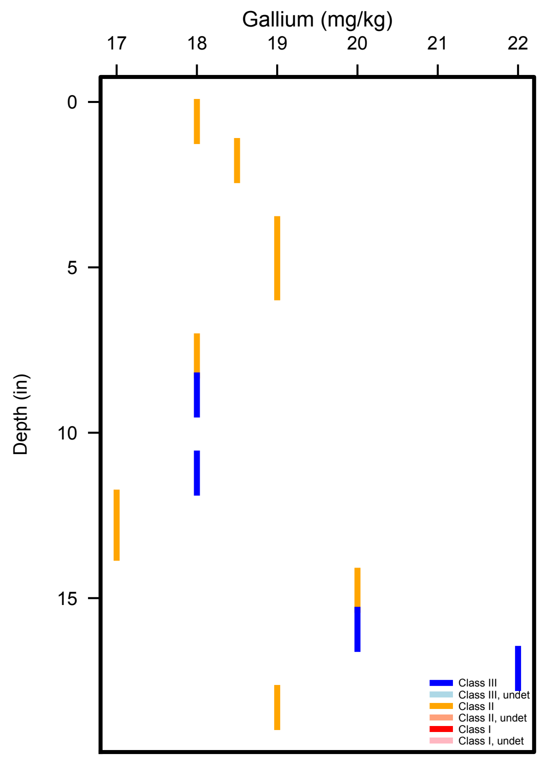

Figure 1408. Gallium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

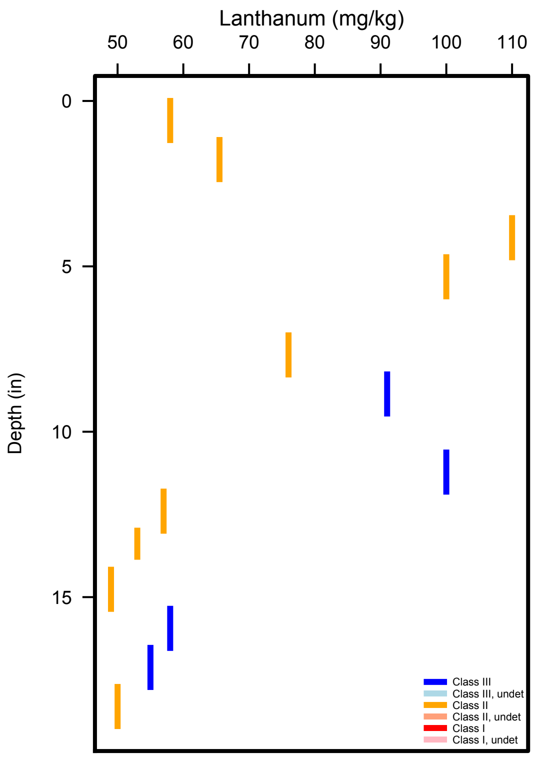

Figure 1409. Lanthanum Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

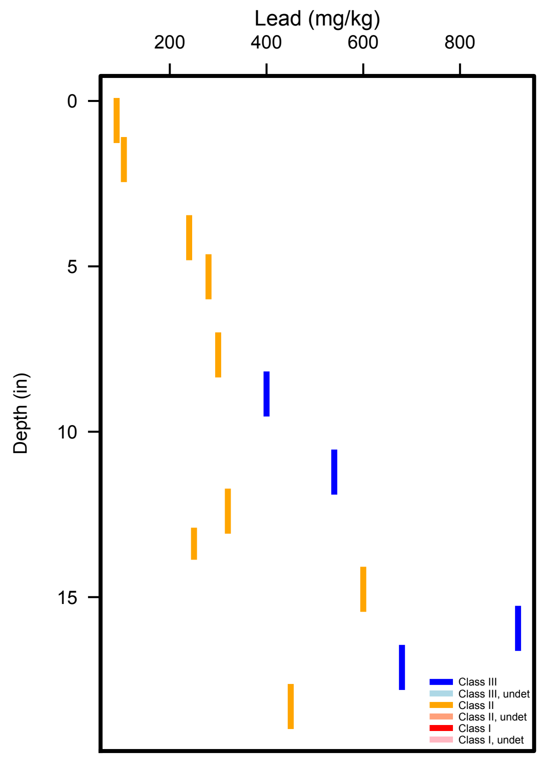

Figure 1410. Lead Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

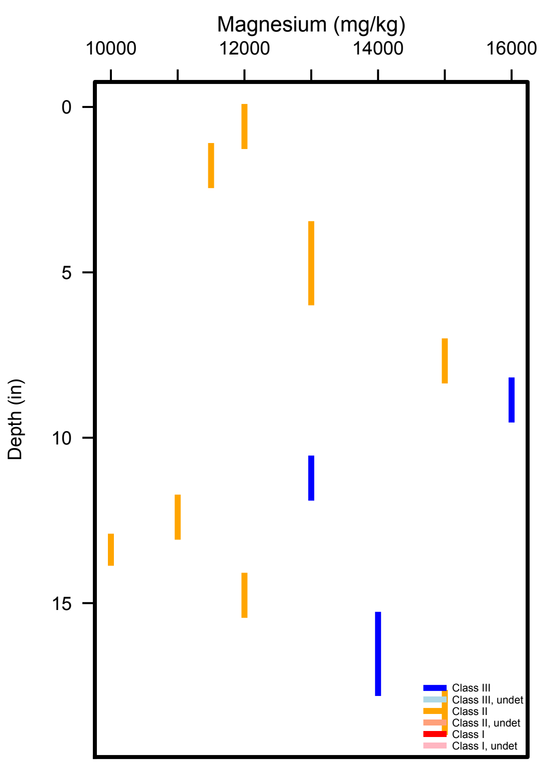

Figure 1411. Magnesium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

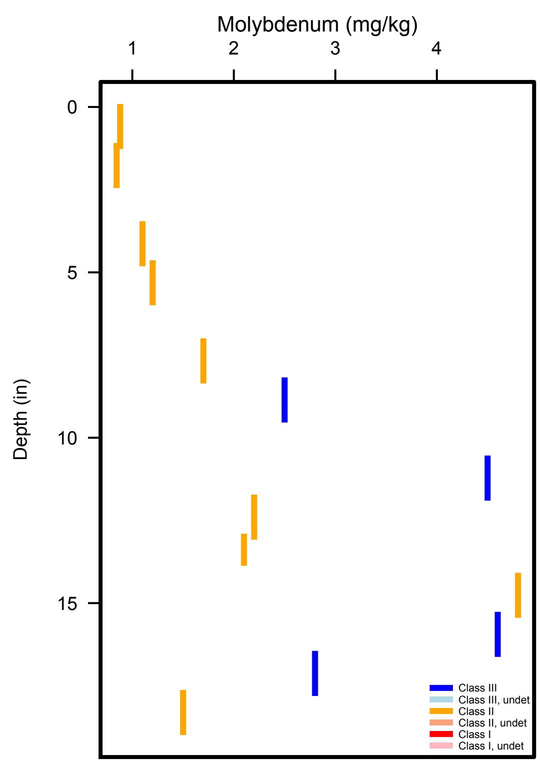

Figure 1412. Molybdenum Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

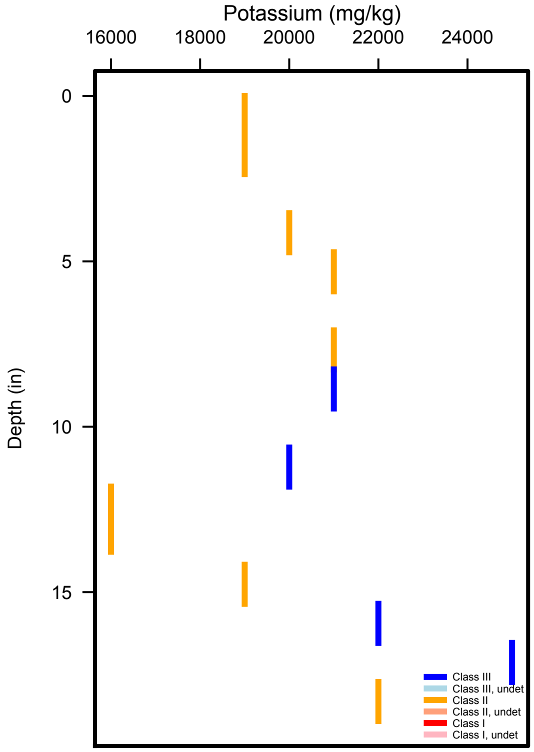

Figure 1413. Potassium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

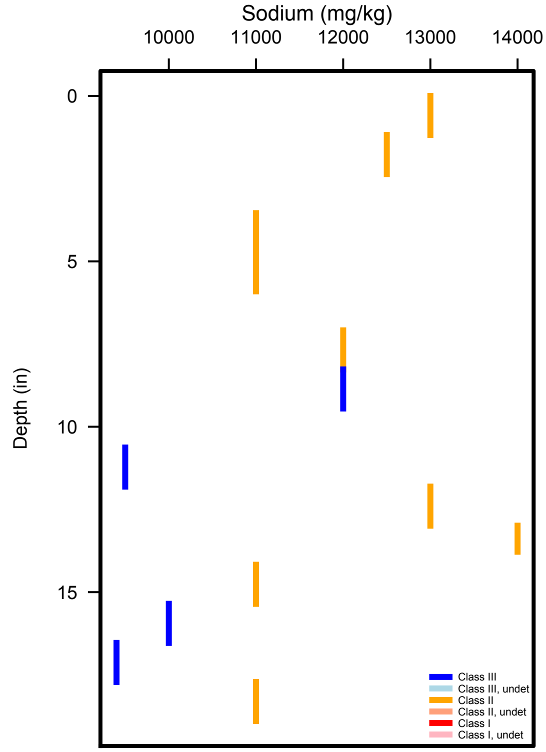

Figure 1414. Sodium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

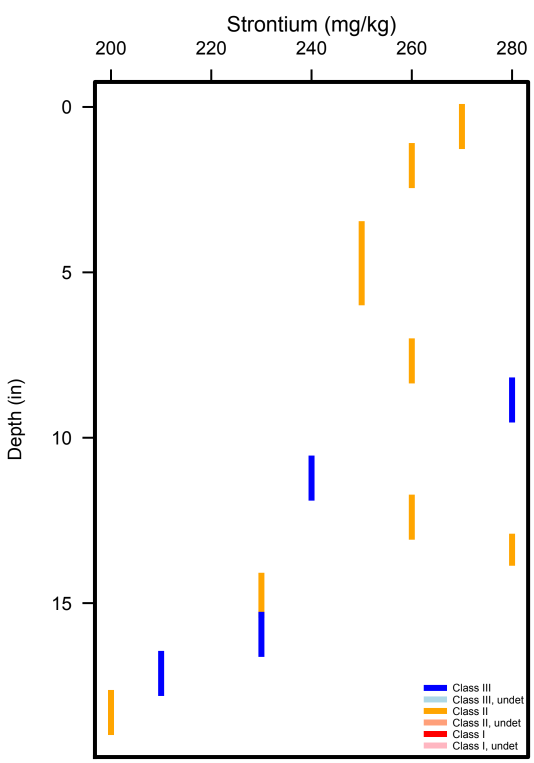

Figure 1415. Strontium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

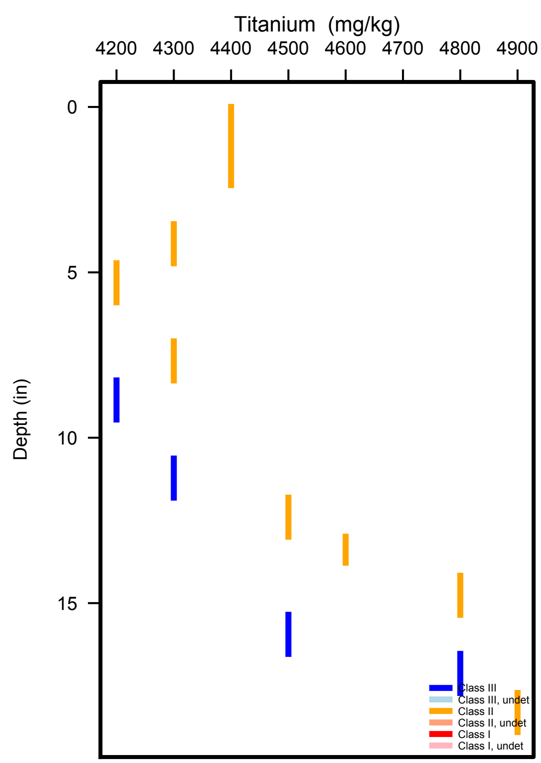

Figure 1416. Titanium Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

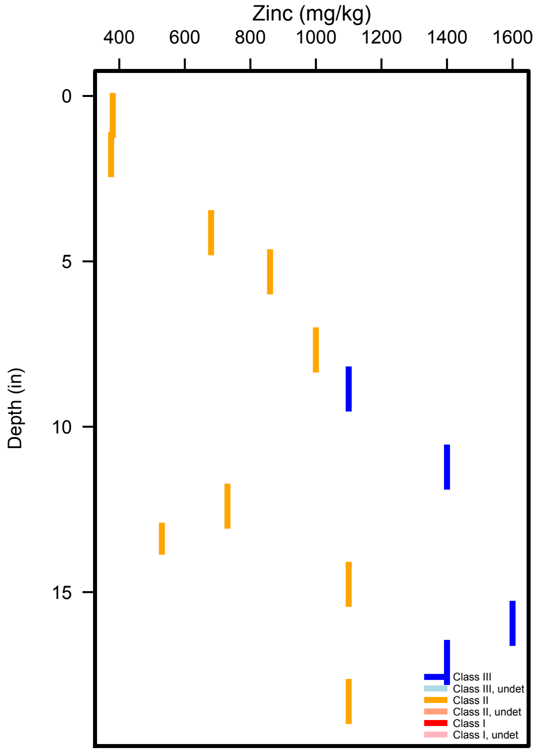

Figure 1417. Zinc Concentration and Sediment Class at Cox Core Location CCR−624 with a Significant Trend.

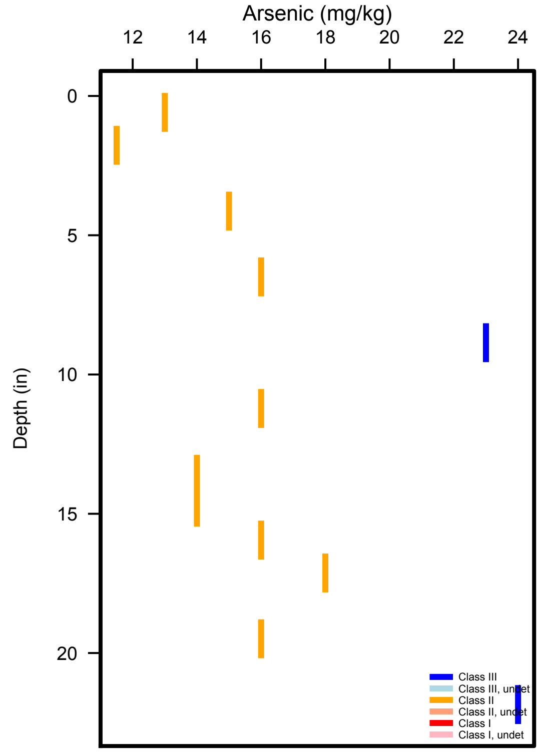

Figure 1418. Arsenic Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

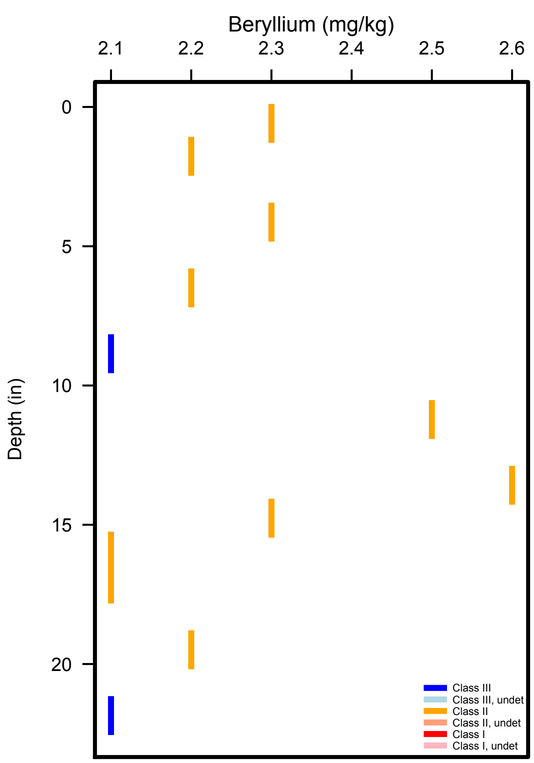

Figure 1419. Beryllium Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

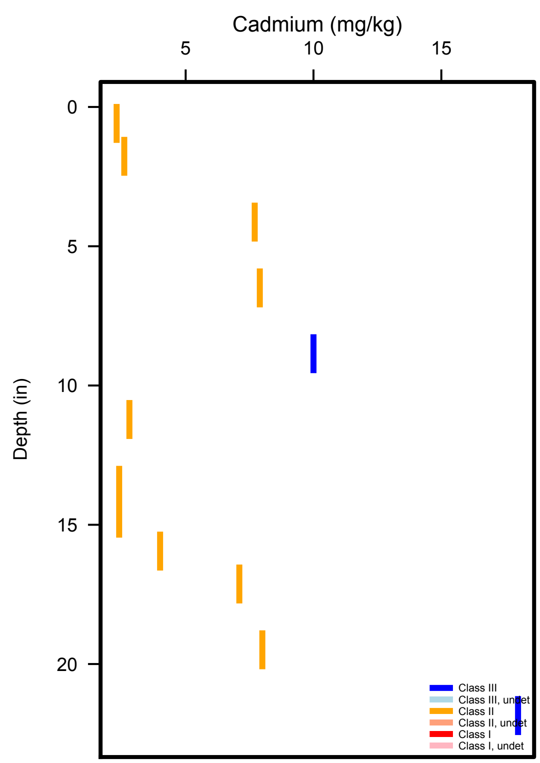

Figure 1420. Cadmium Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

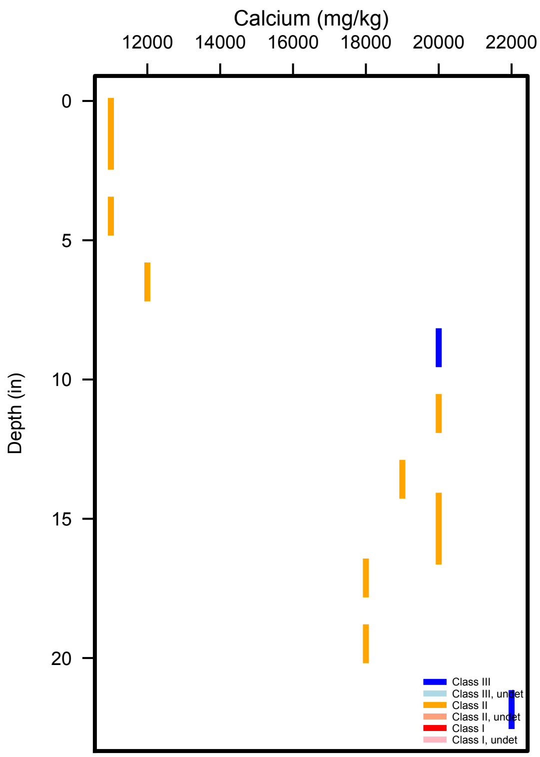

Figure 1421. Calcium Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

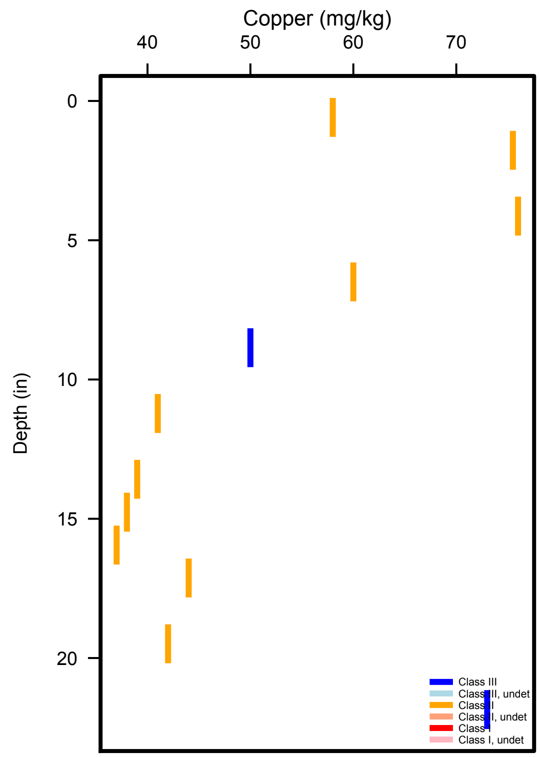

Figure 1422. Copper Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

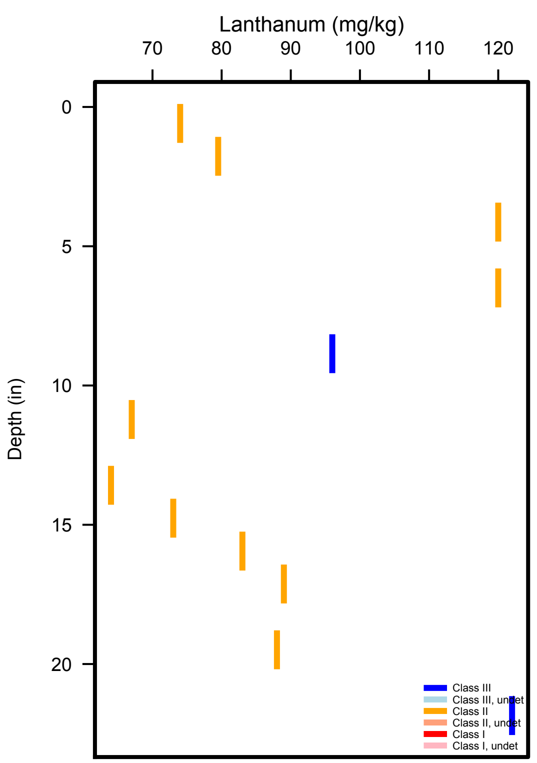

Figure 1423. Lanthanum Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

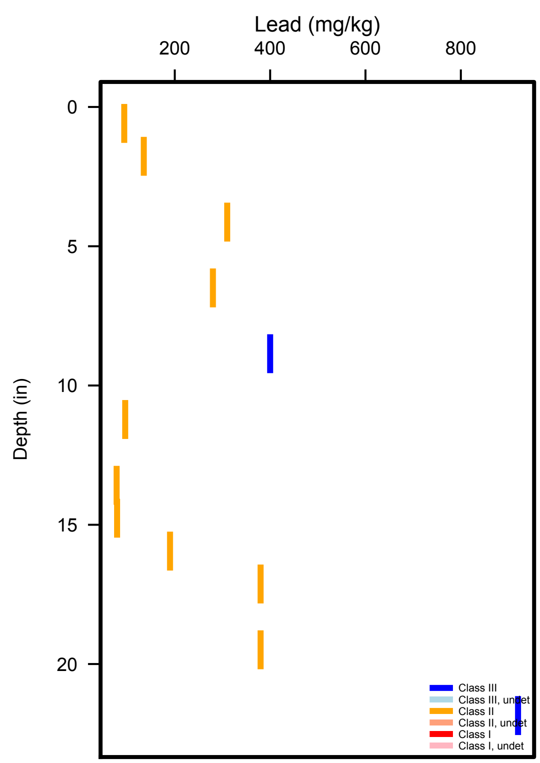

Figure 1424. Lead Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

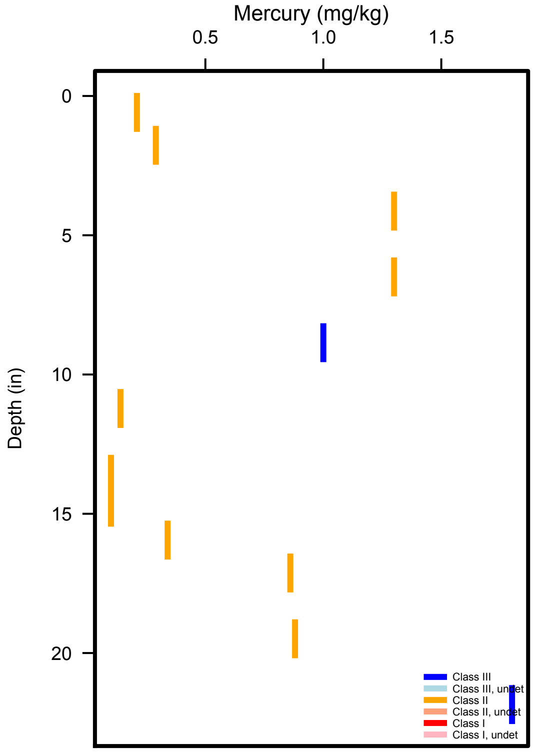

Figure 1425. Mercury Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

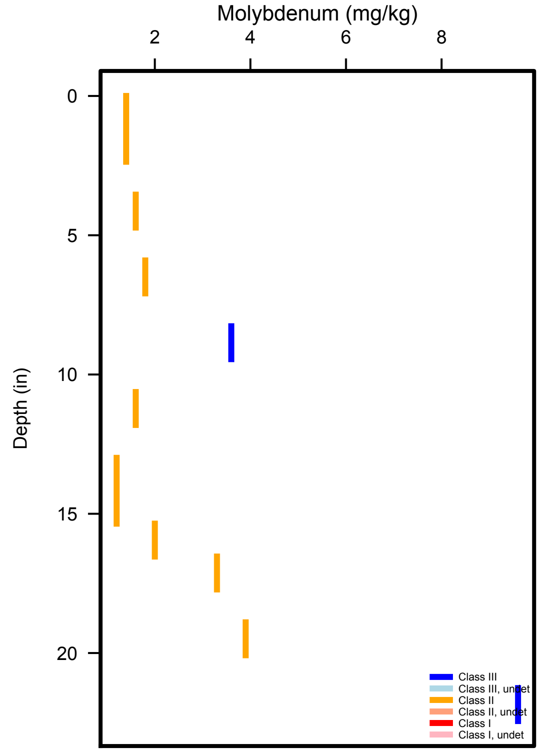

Figure 1426. Molybdenum Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

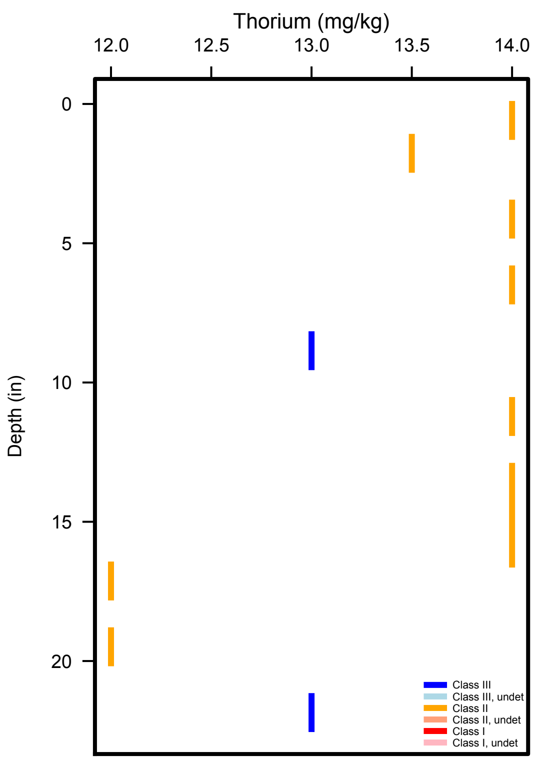

Figure 1427. Thorium Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

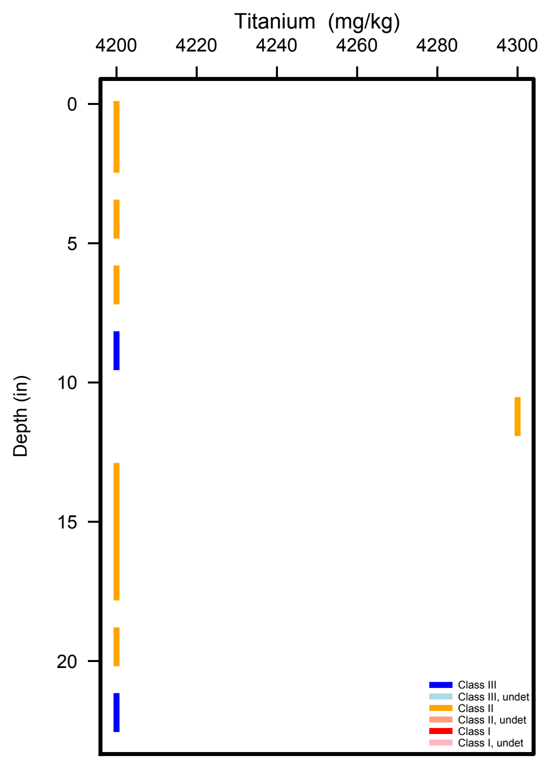

Figure 1428. Titanium Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

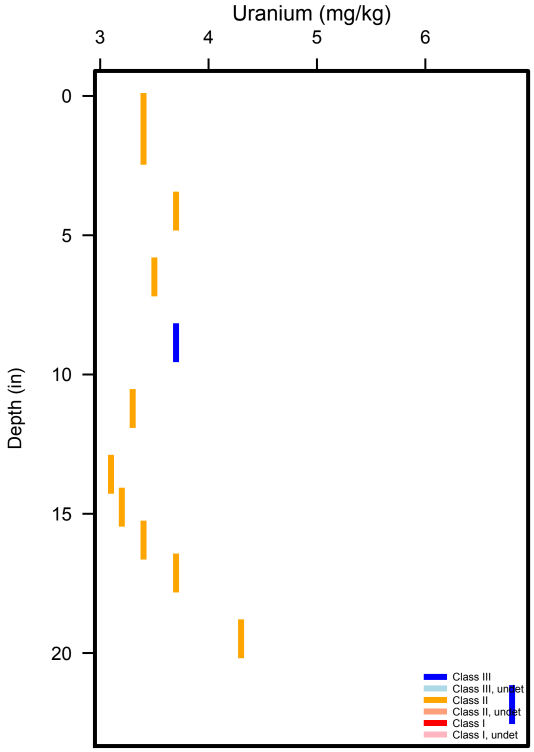

Figure 1429. Uranium Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

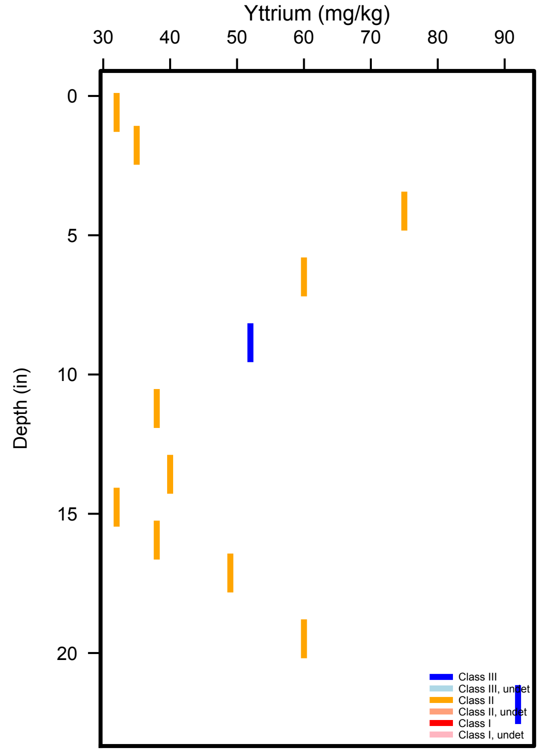

Figure 1430. Yttrium Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

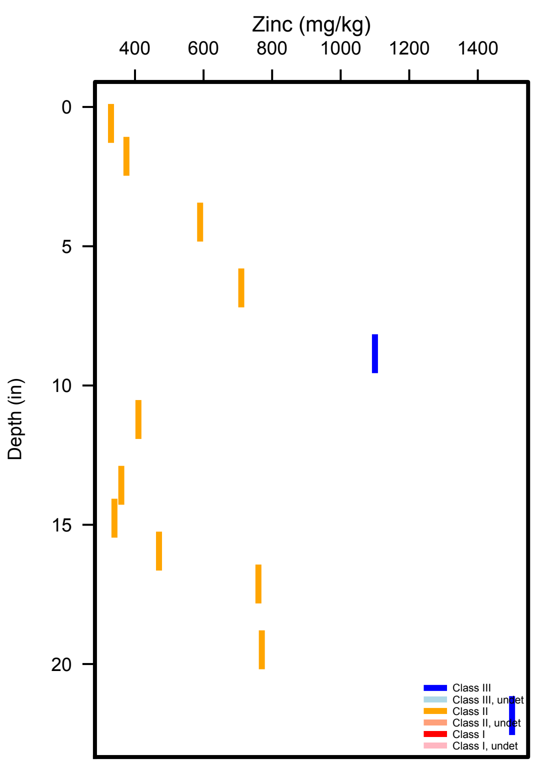

Figure 1431. Zinc Concentration and Sediment Class at Cox Core Location CCR−643 with a Significant Trend.

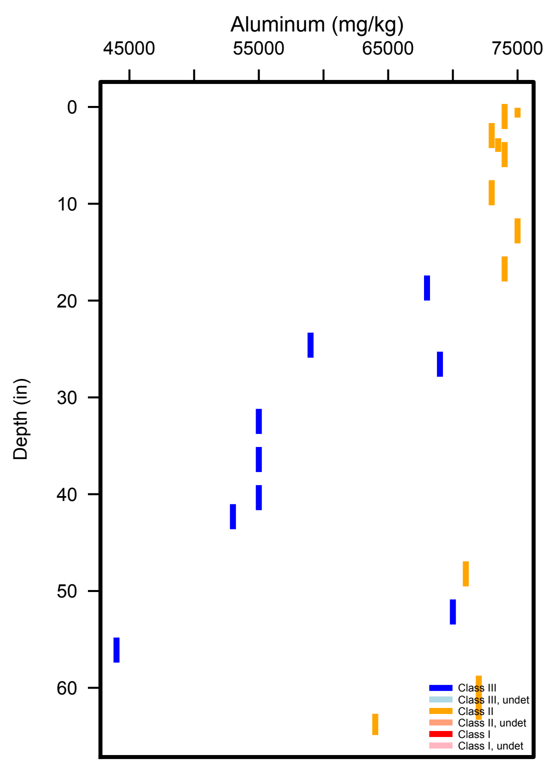

Figure 1432. Aluminum Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

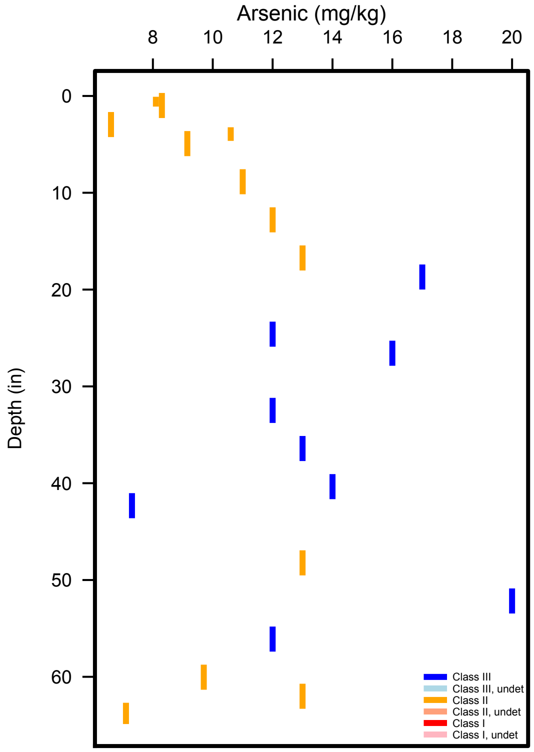

Figure 1433. Arsenic Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

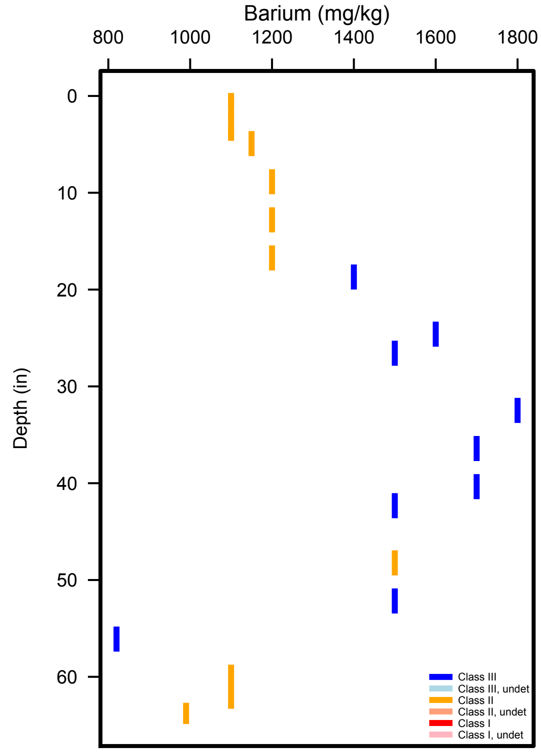

Figure 1434. Barium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

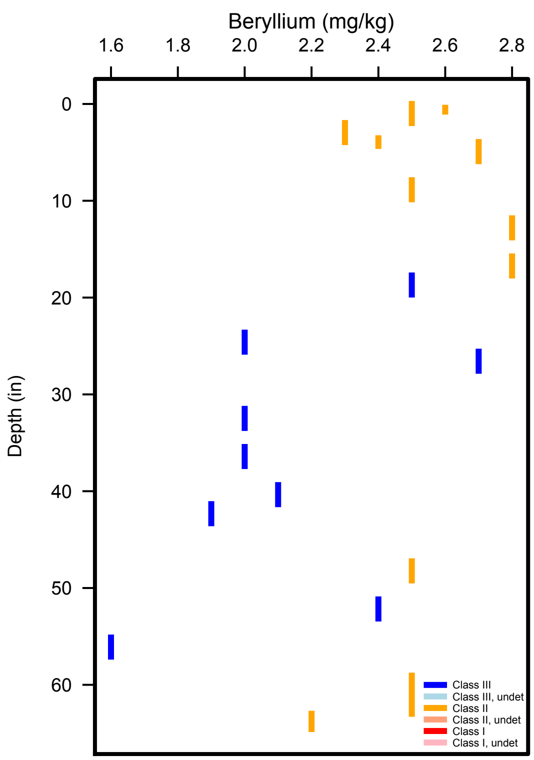

Figure 1435. Beryllium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

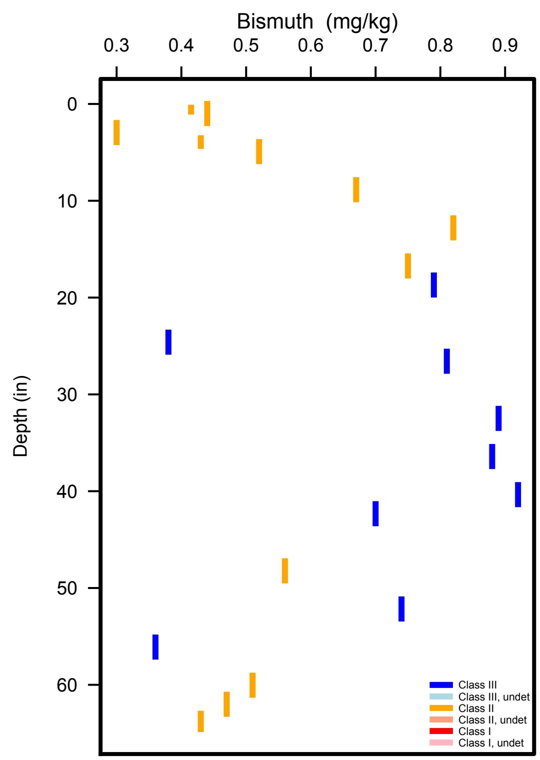

Figure 1436. Bismuth Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

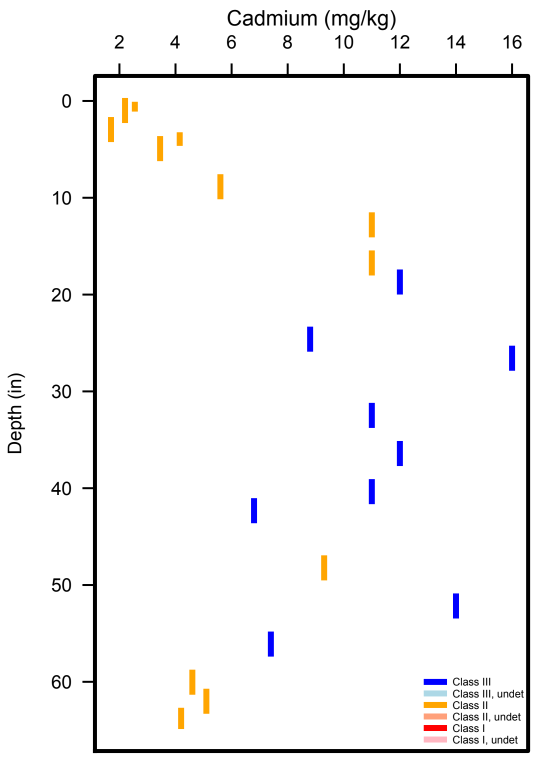

Figure 1437. Cadmium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

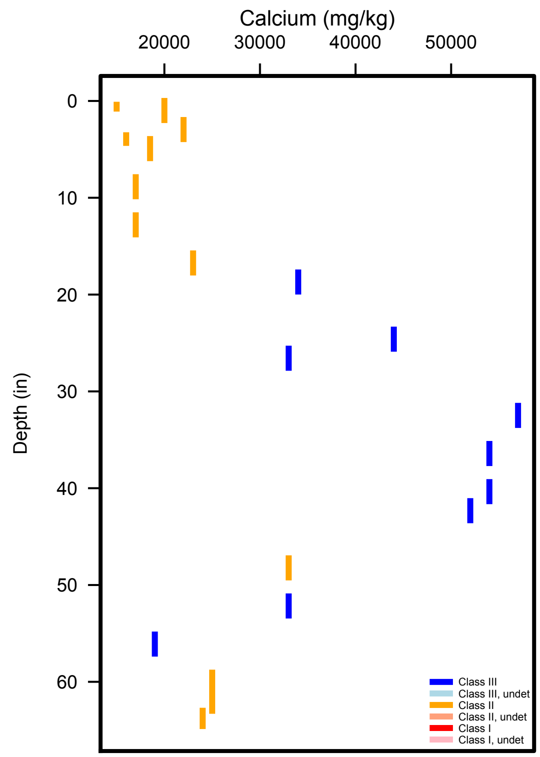

Figure 1438. Calcium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

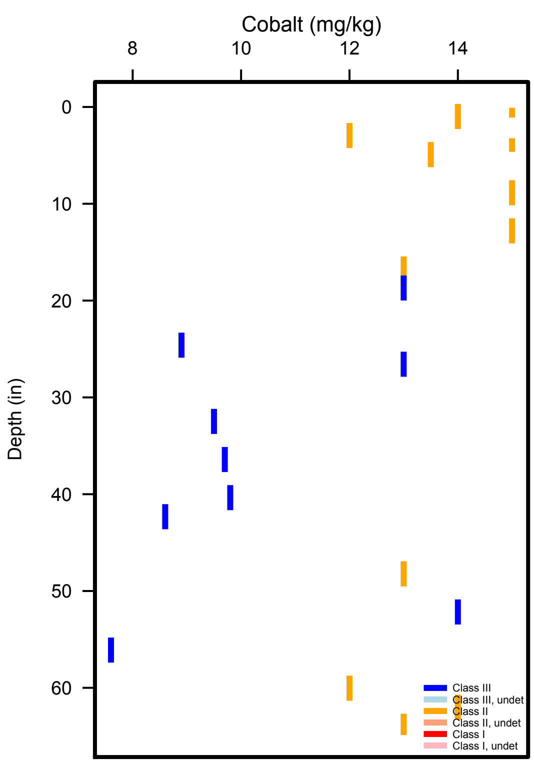

Figure 1439. Cobalt Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

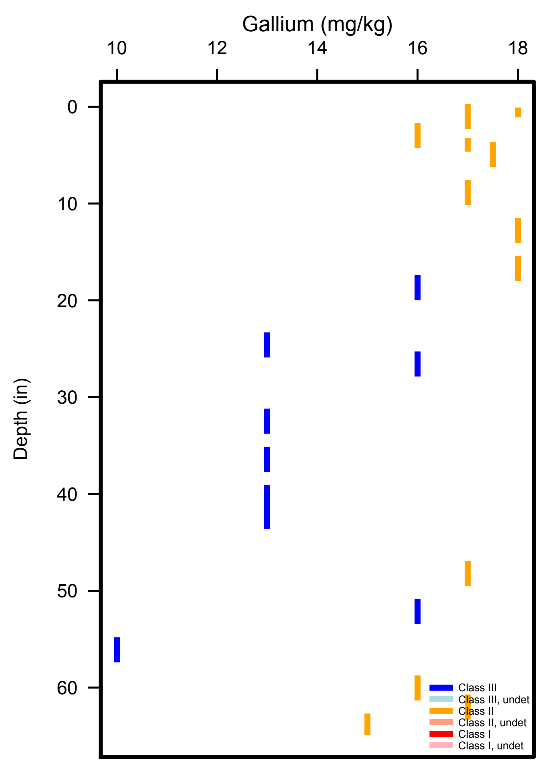

Figure 1440. Gallium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

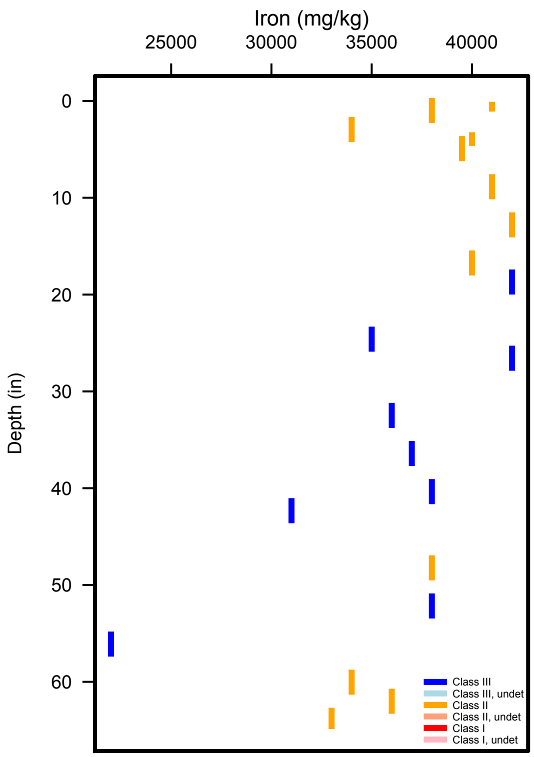

Figure 1441. Iron Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

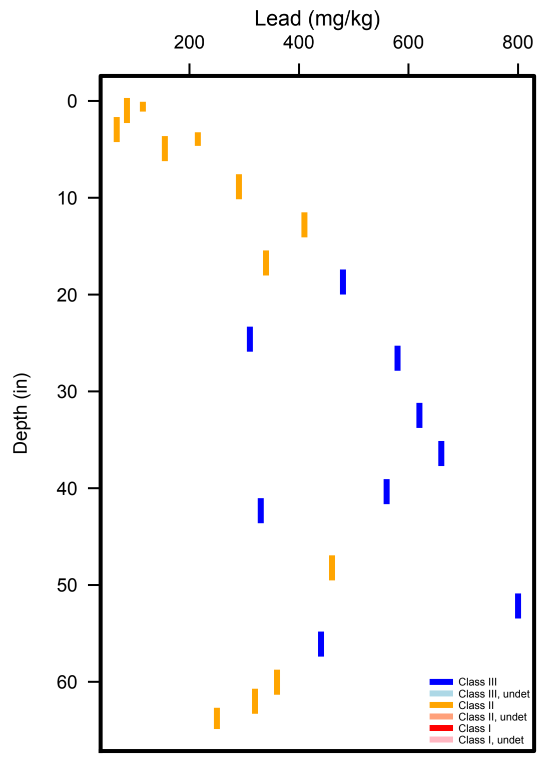

Figure 1442. Lead Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

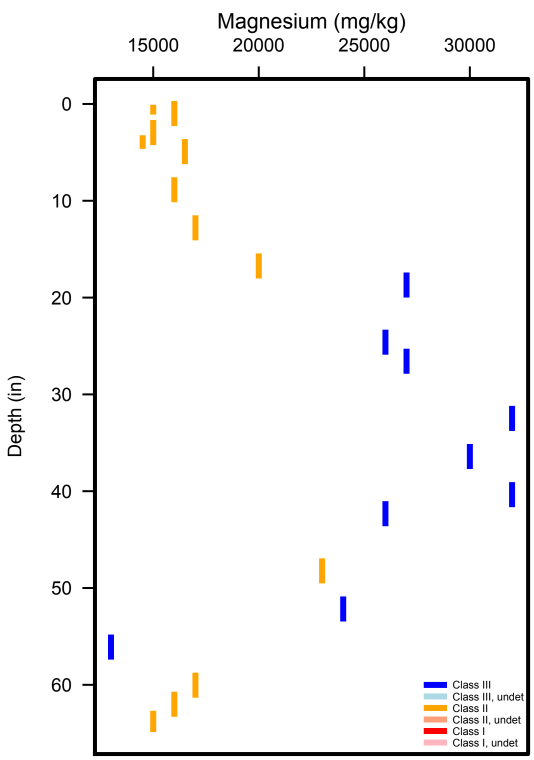

Figure 1443. Magnesium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

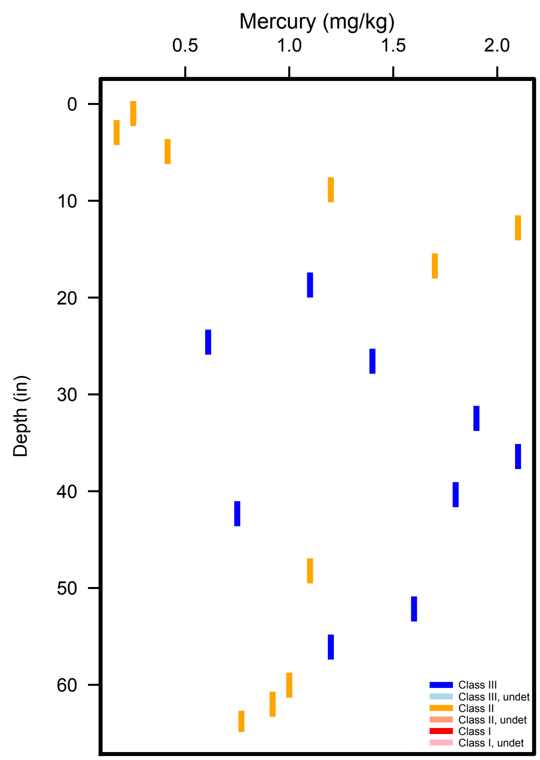

Figure 1444. Mercury Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

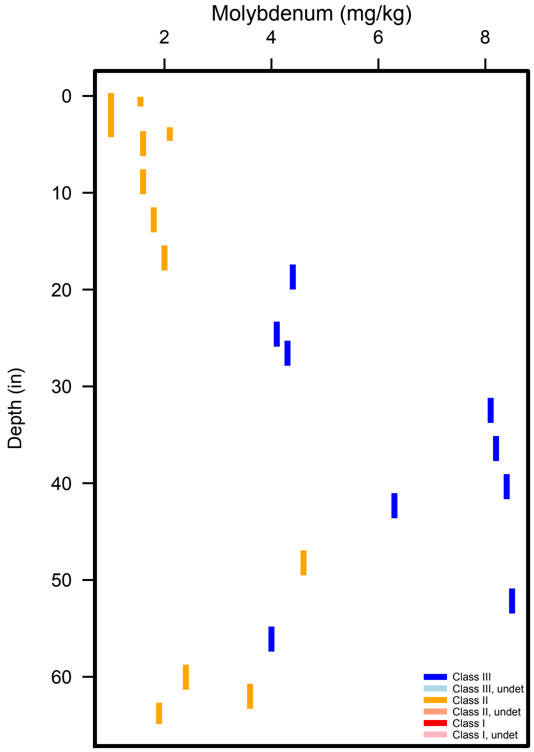

Figure 1445. Molybdenum Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

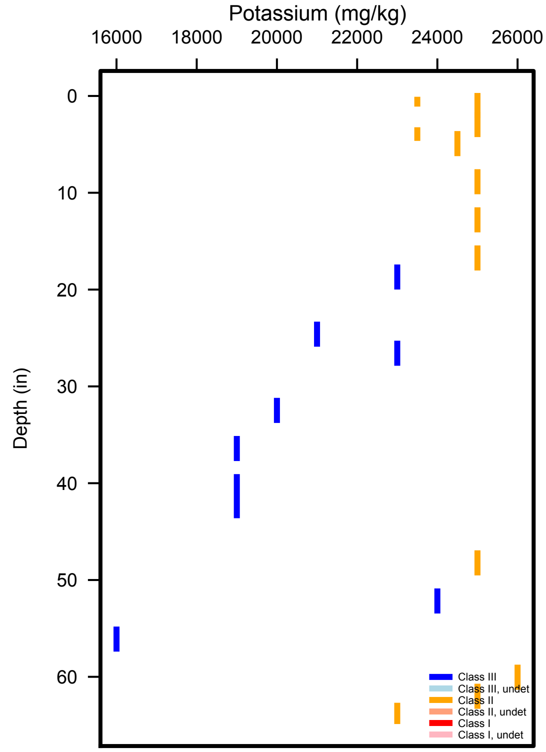

Figure 1446. Potassium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

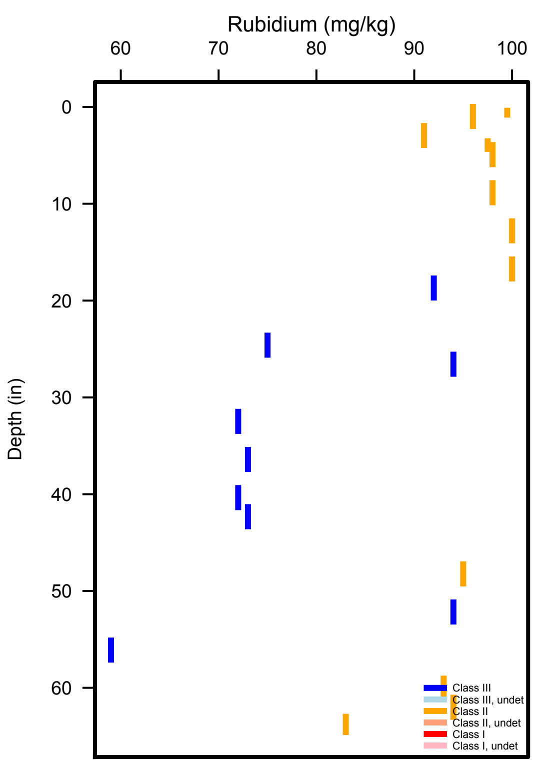

Figure 1447. Rubidium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

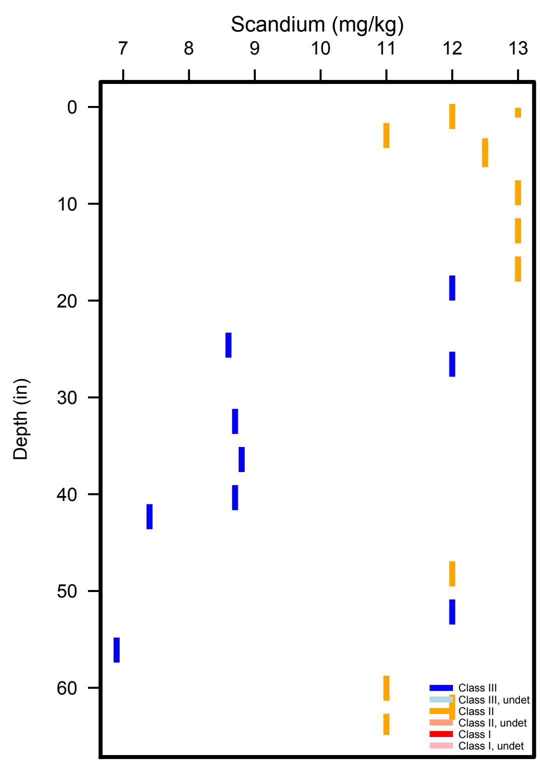

Figure 1448. Scandium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

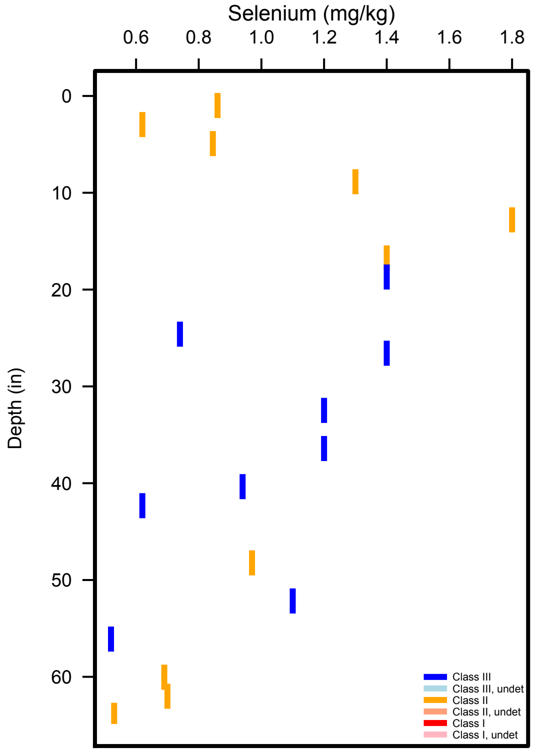

Figure 1449. Selenium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

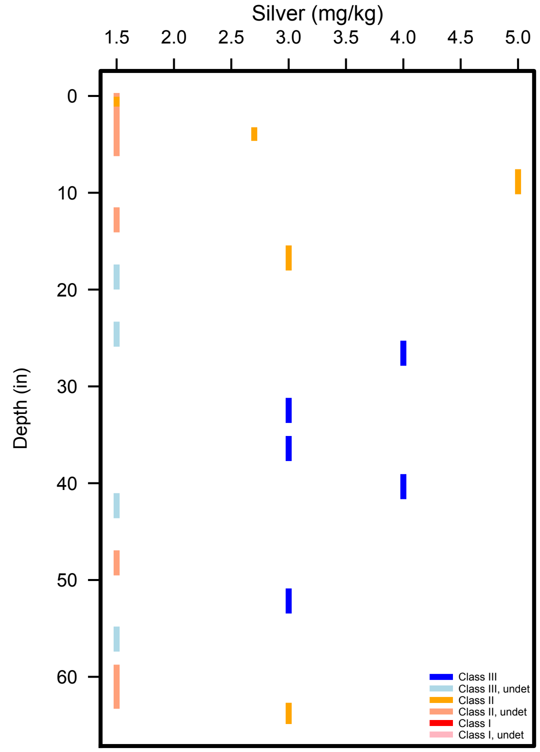

Figure 1450. Silver Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

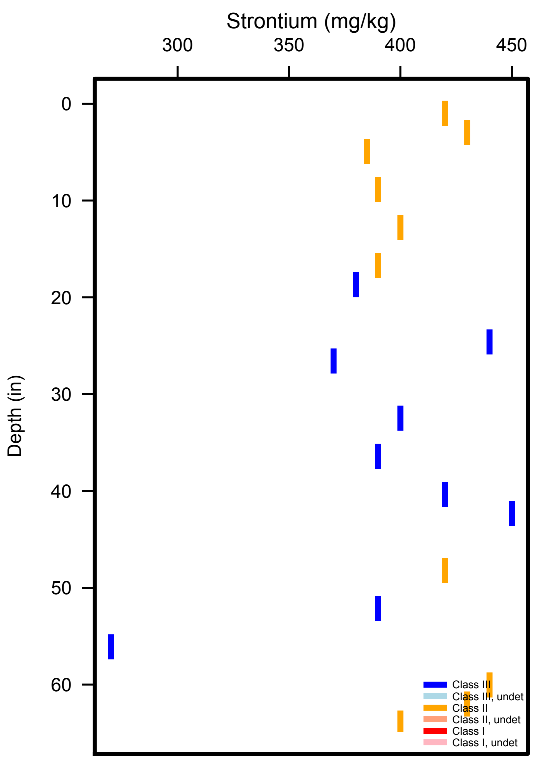

Figure 1451. Strontium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

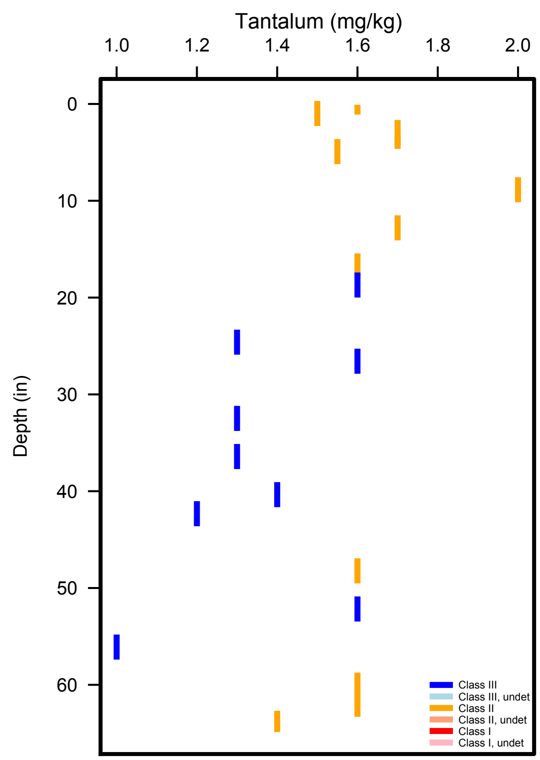

Figure 1452. Tantalum Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

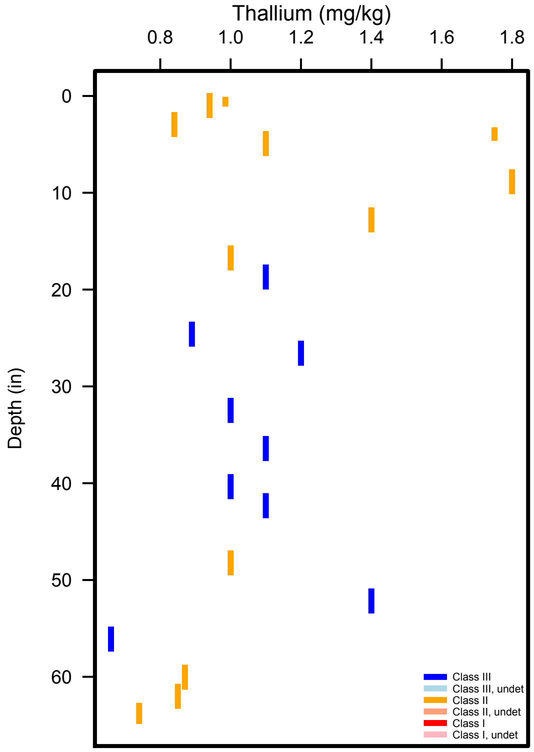

Figure 1453. Thallium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

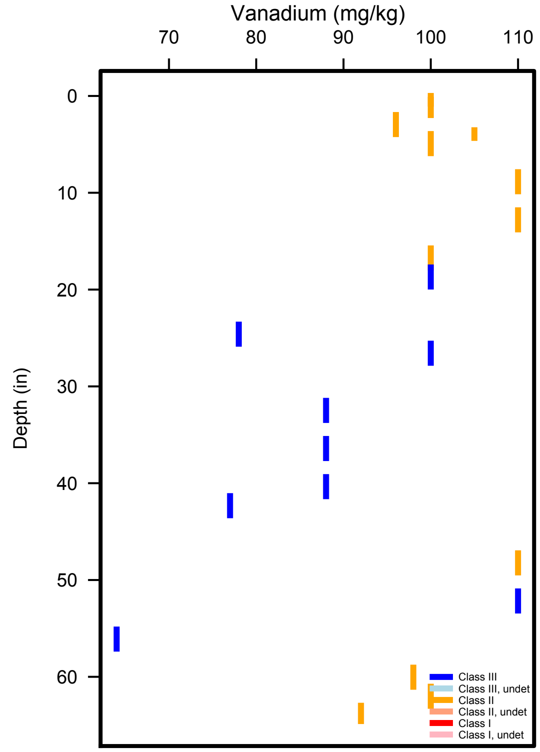

Figure 1454. Vanadium Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

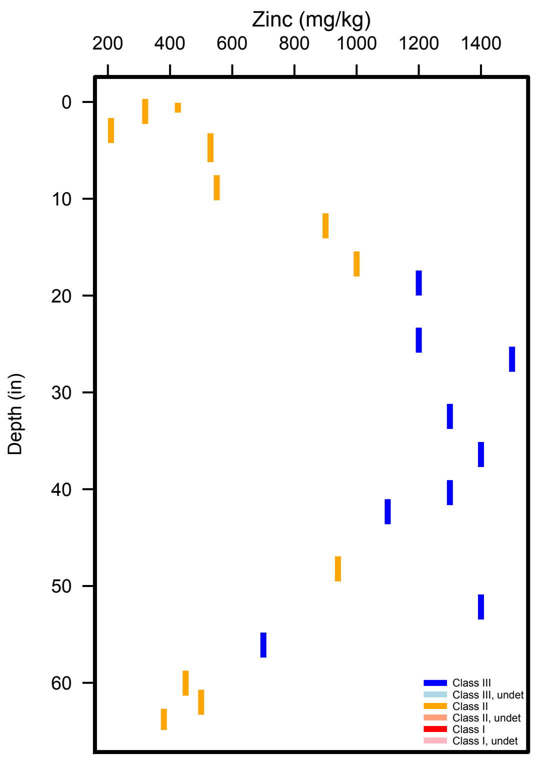

Figure 1455. Zinc Concentration and Sediment Class at Cox Core Location CCR−668 with a Significant Trend.

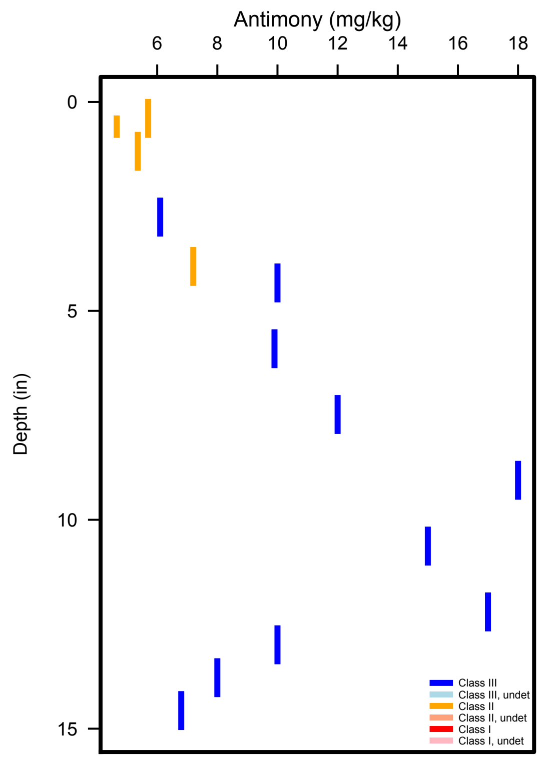

Figure 1456. Antimony Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

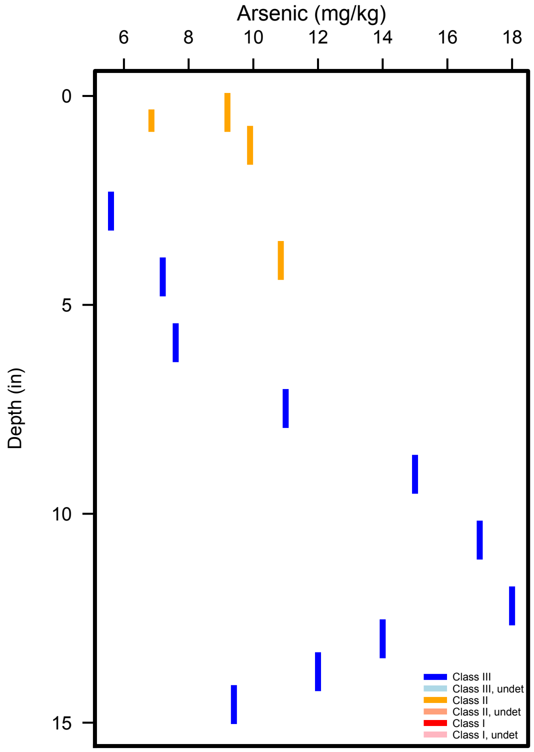

Figure 1457. Arsenic Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

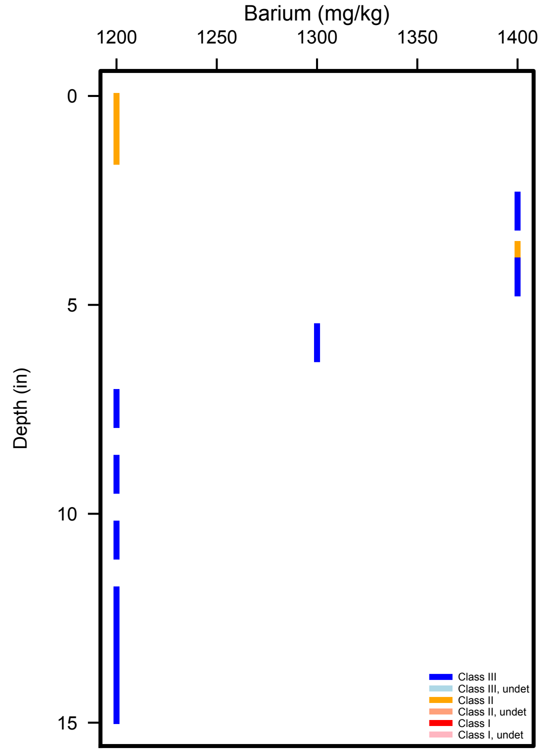

Figure 1458. Barium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

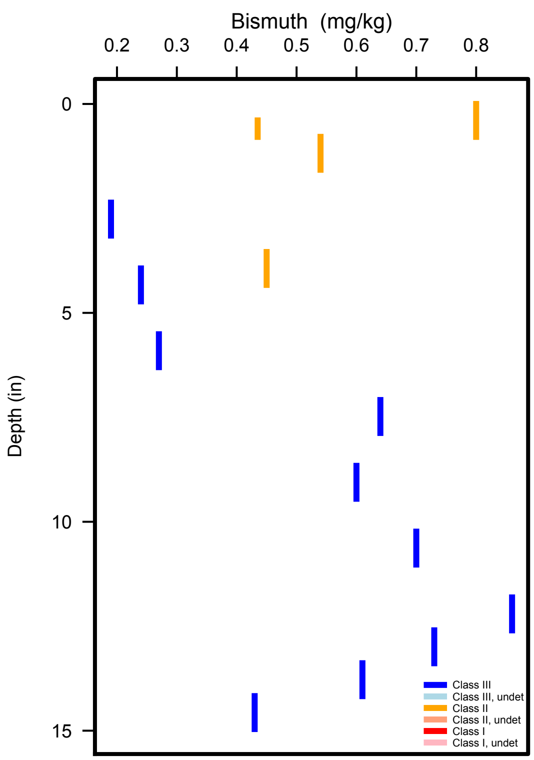

Figure 1459. Bismuth Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

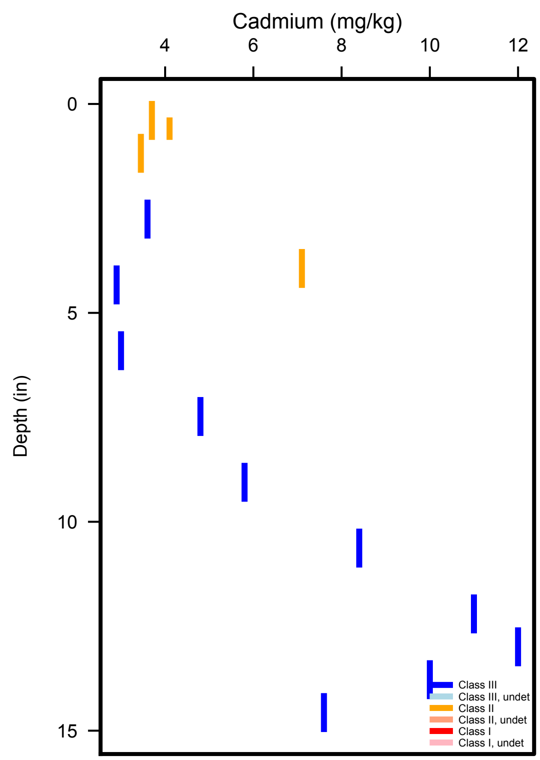

Figure 1460. Cadmium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

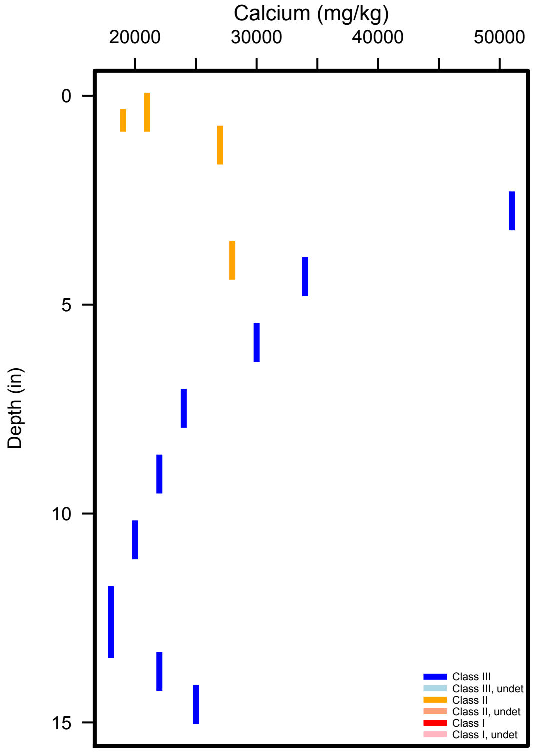

Figure 1461. Calcium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

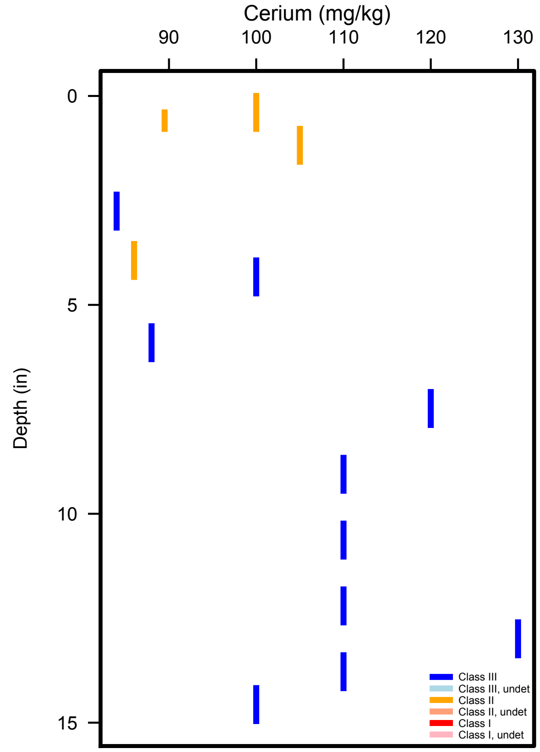

Figure 1462. Cerium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

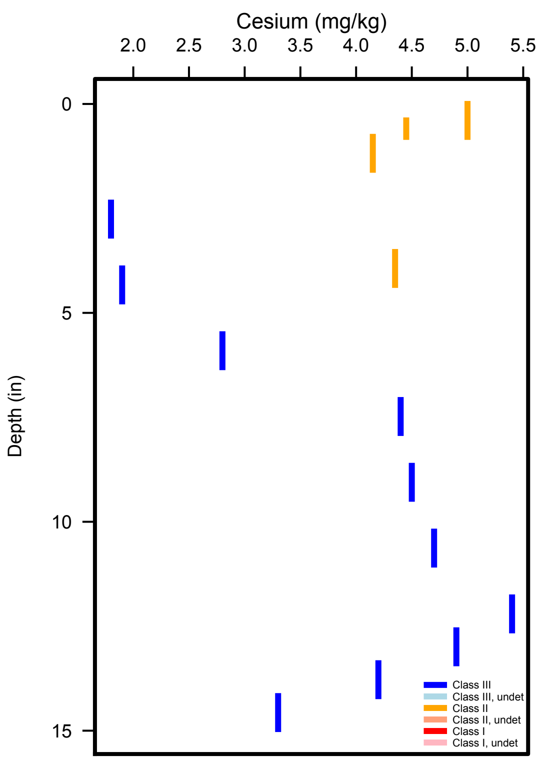

Figure 1463. Cesium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

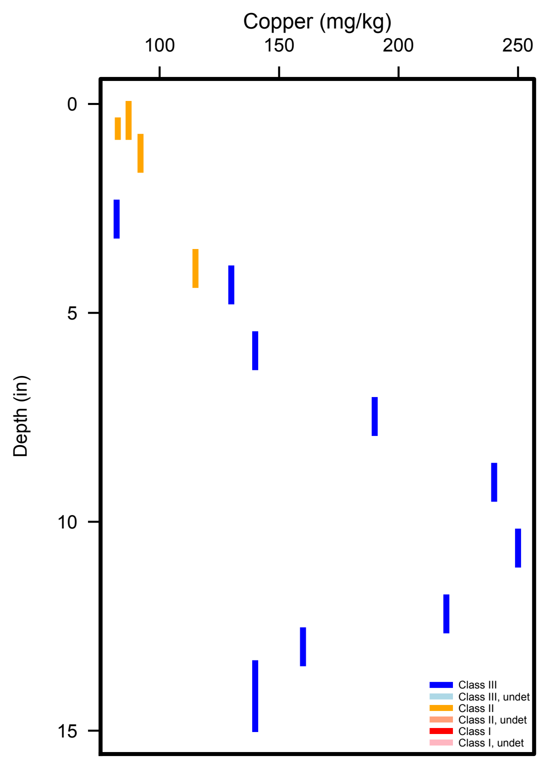

Figure 1464. Copper Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

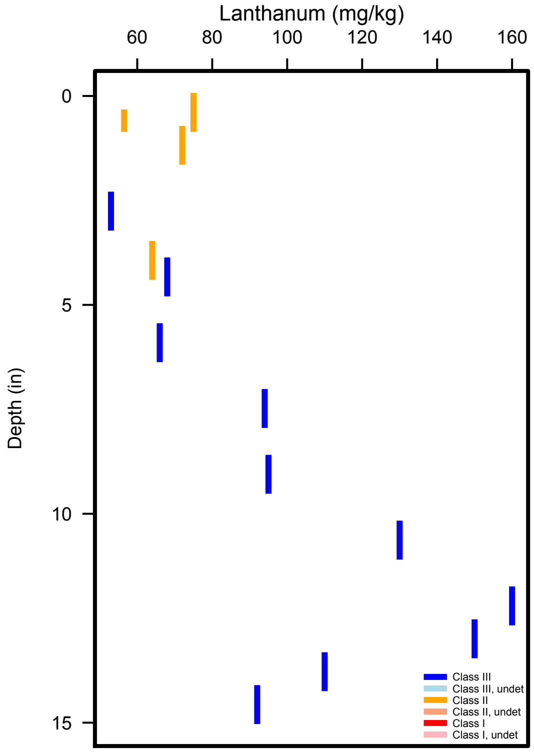

Figure 1465. Lanthanum Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

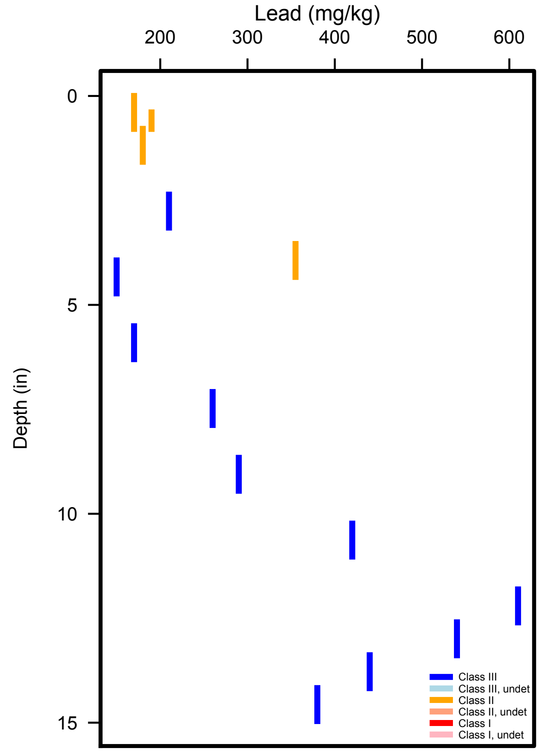

Figure 1466. Lead Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

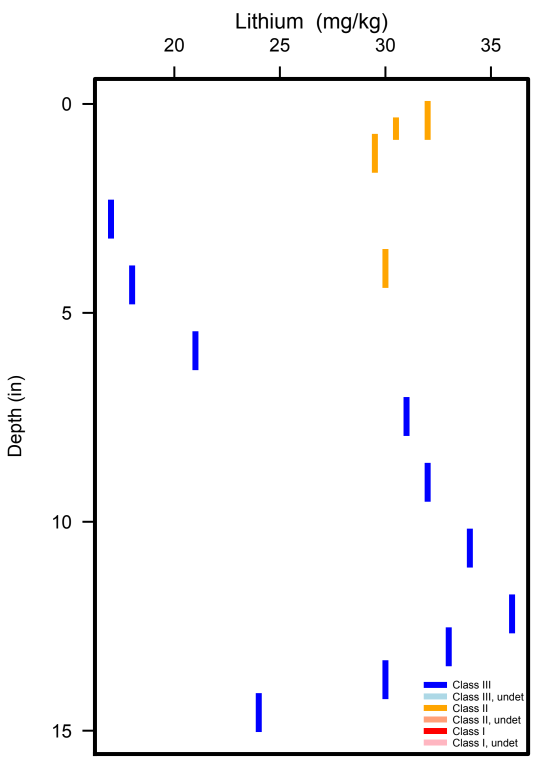

Figure 1467. Lithium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

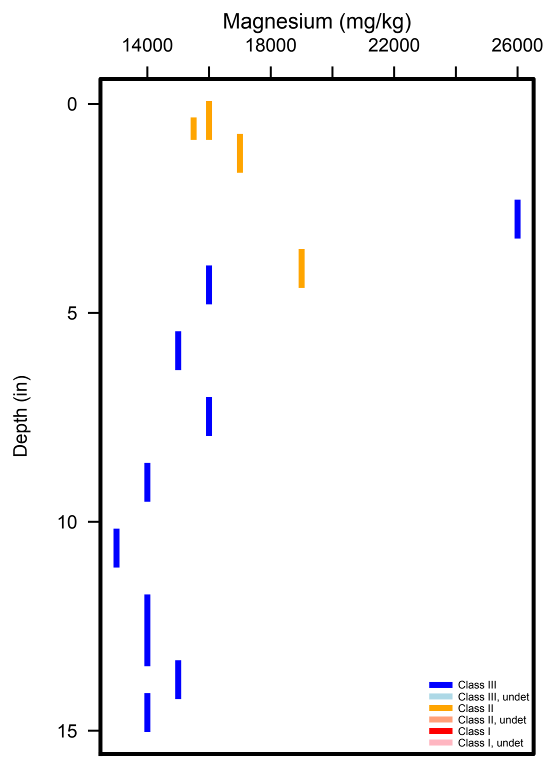

Figure 1468. Magnesium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

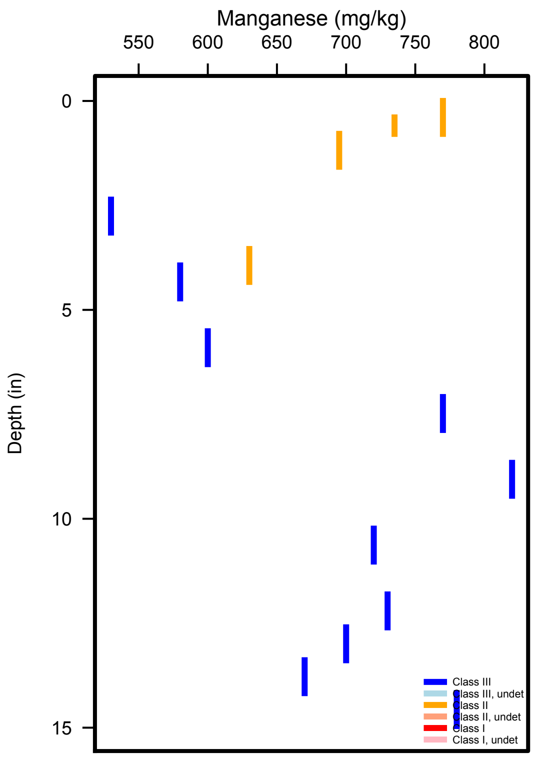

Figure 1469. Manganese Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

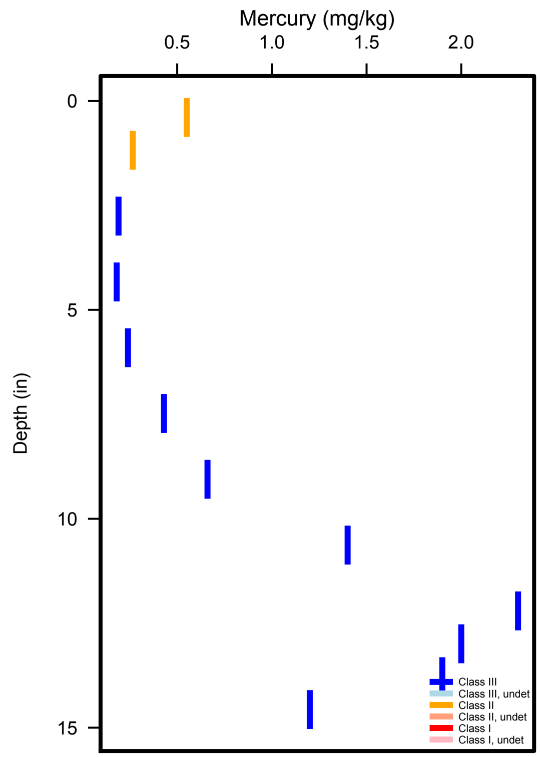

Figure 1470. Mercury Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

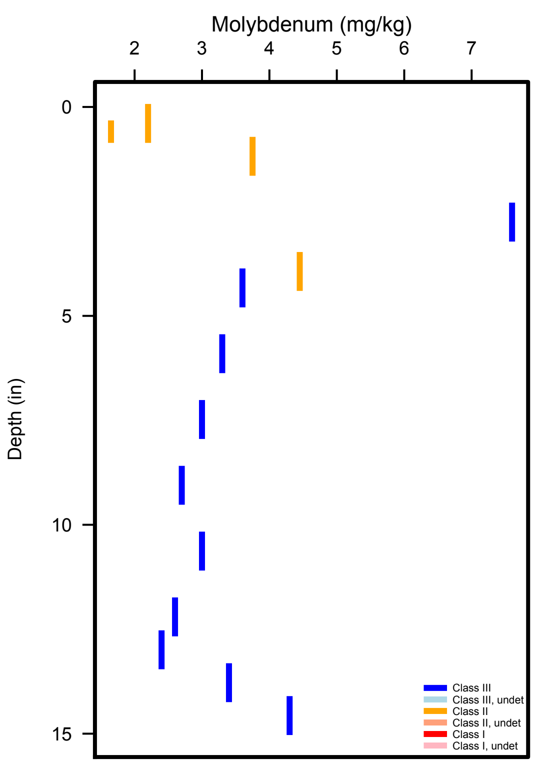

Figure 1471. Molybdenum Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

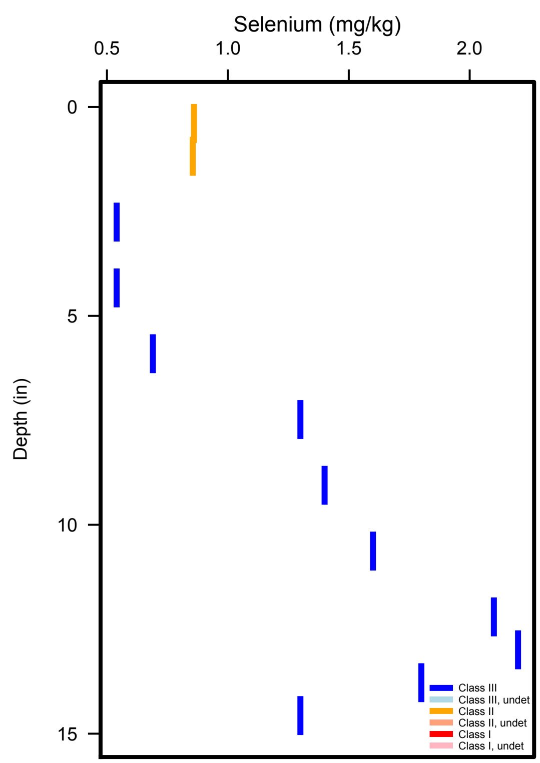

Figure 1472. Selenium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

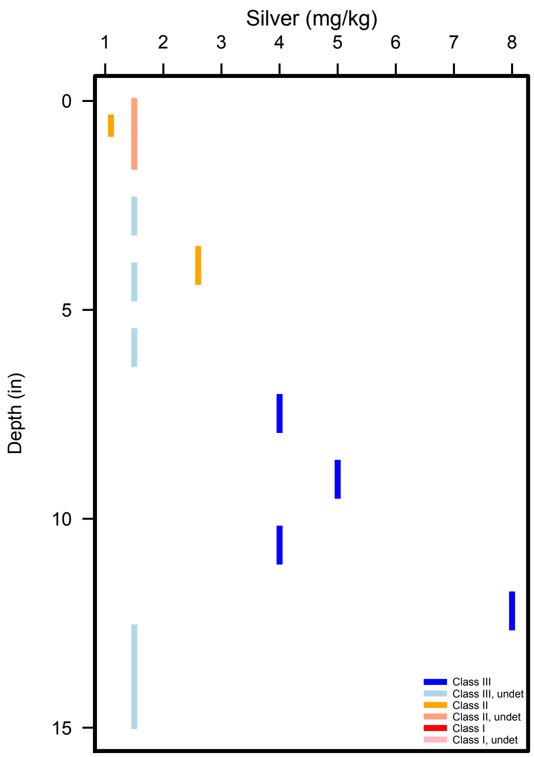

Figure 1473. Silver Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

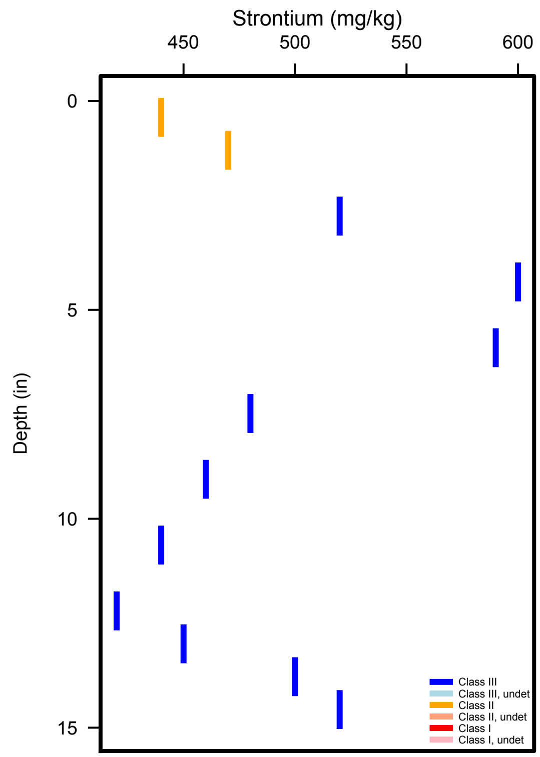

Figure 1474. Strontium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

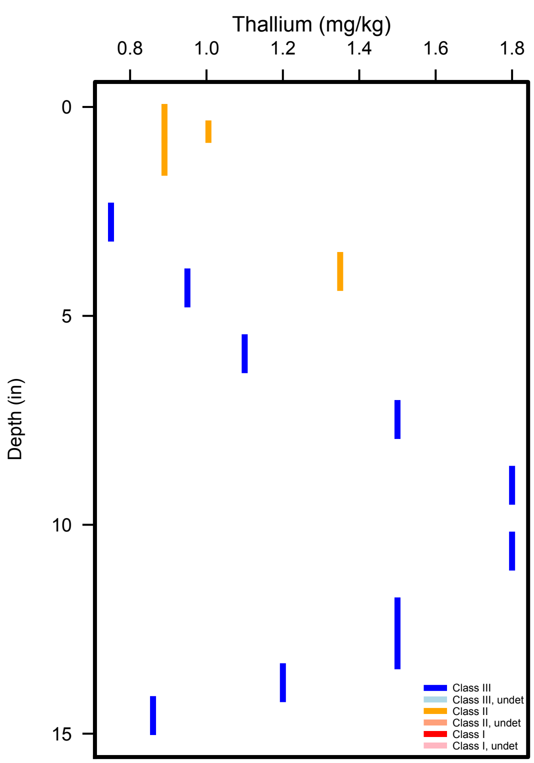

Figure 1475. Thallium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

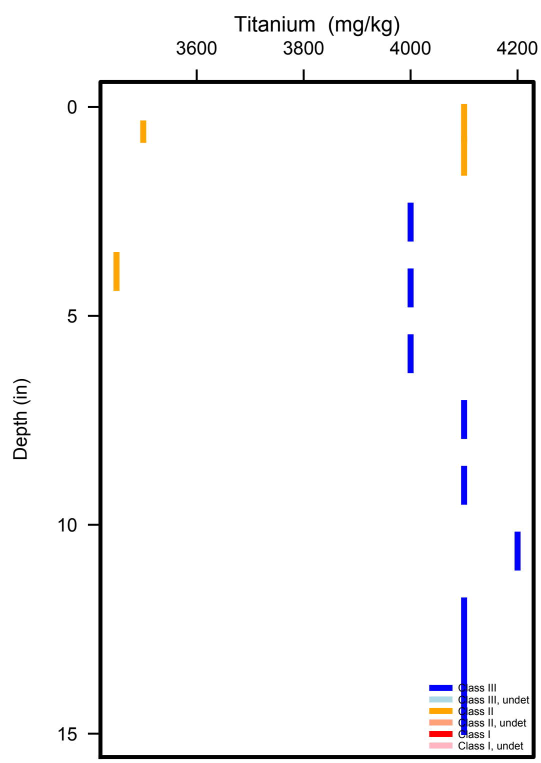

Figure 1476. Titanium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

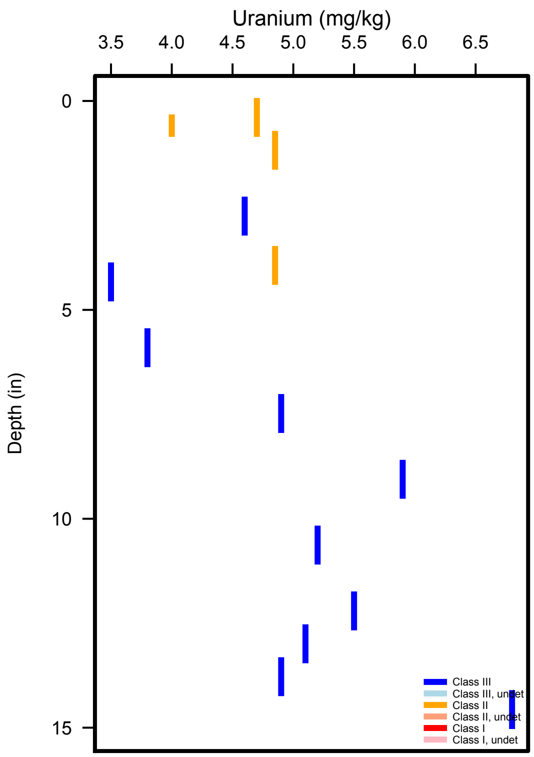

Figure 1477. Uranium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

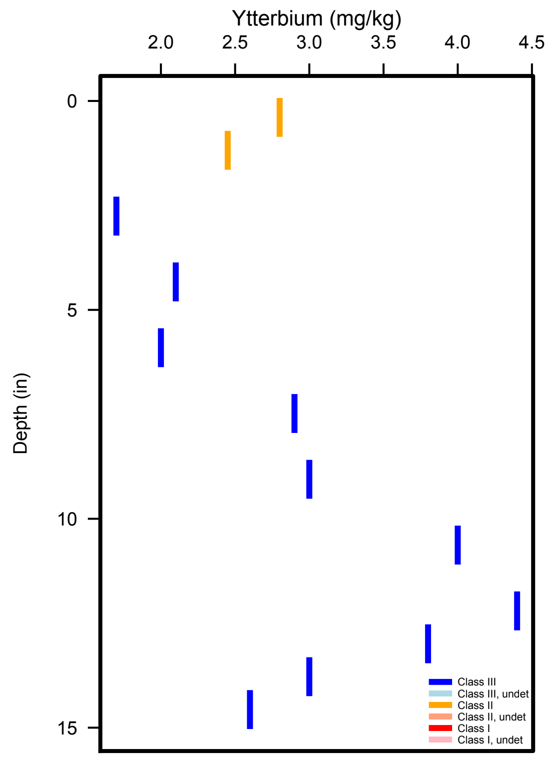

Figure 1478. Ytterbium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

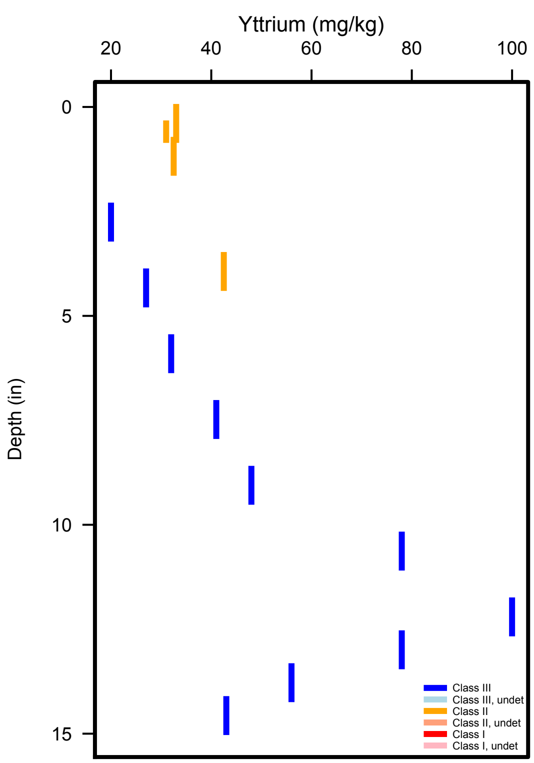

Figure 1479. Yttrium Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

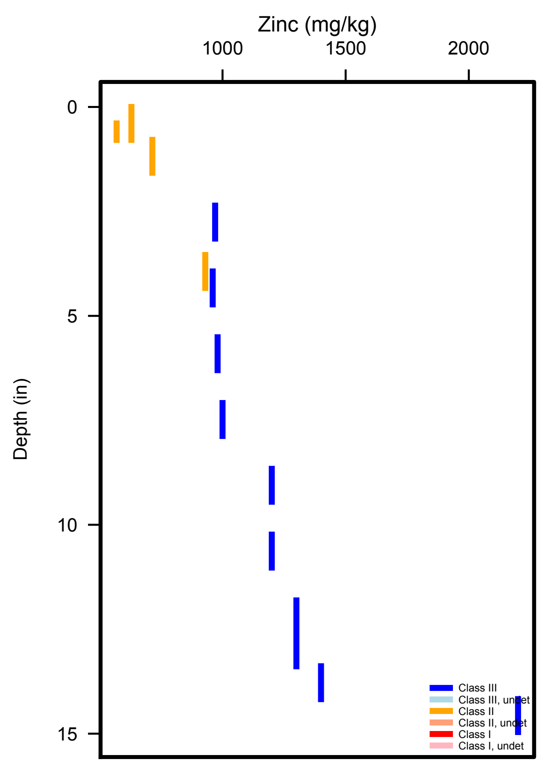

Figure 1480. Zinc Concentration and Sediment Class at Cox Core Location CCR−692 with a Significant Trend.

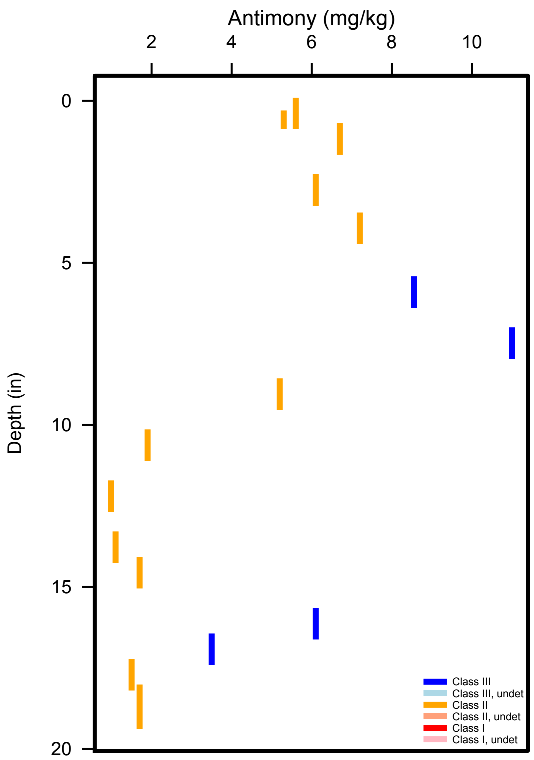

Figure 1481. Antimony Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

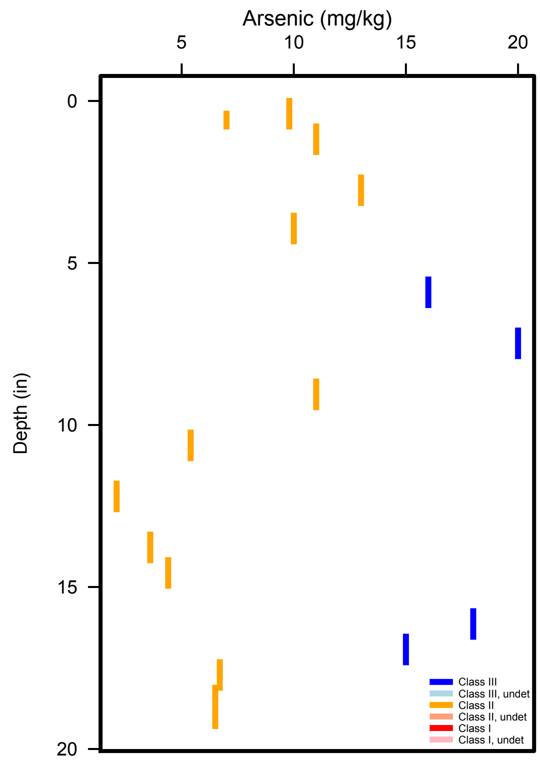

Figure 1482. Arsenic Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

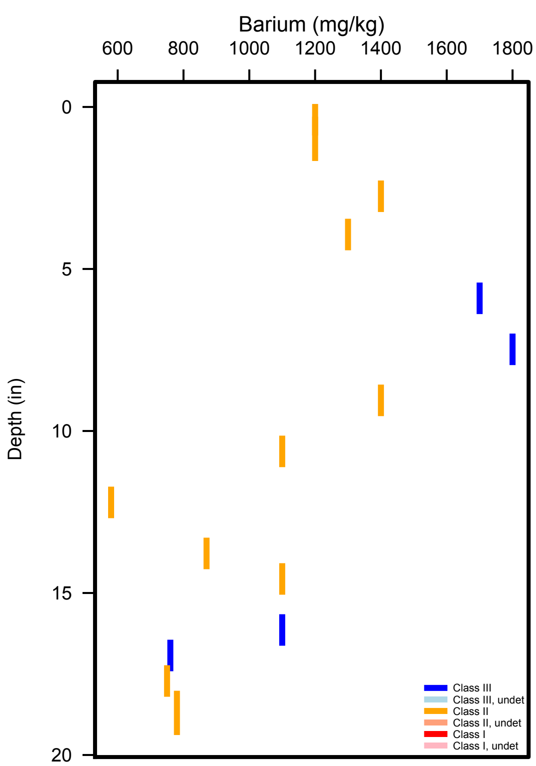

Figure 1483. Barium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

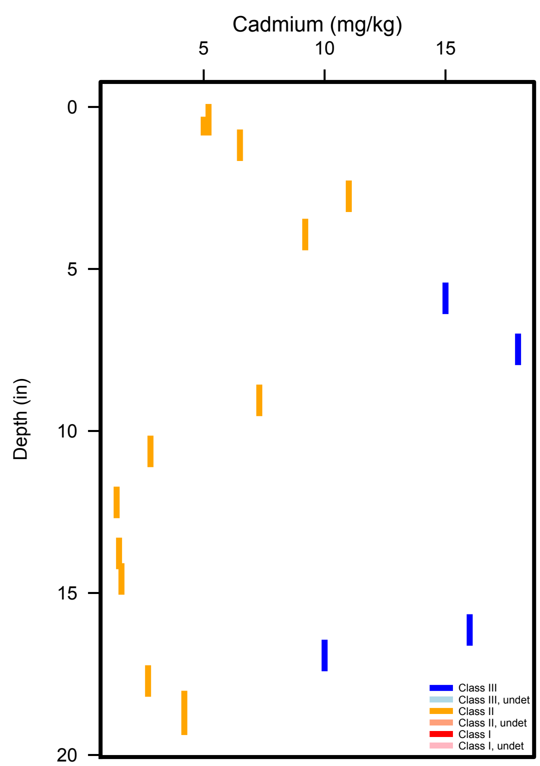

Figure 1484. Cadmium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

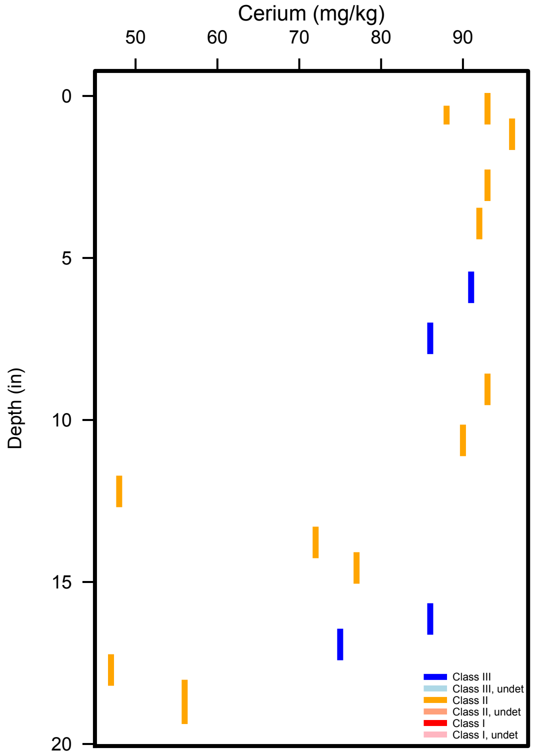

Figure 1485. Cerium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

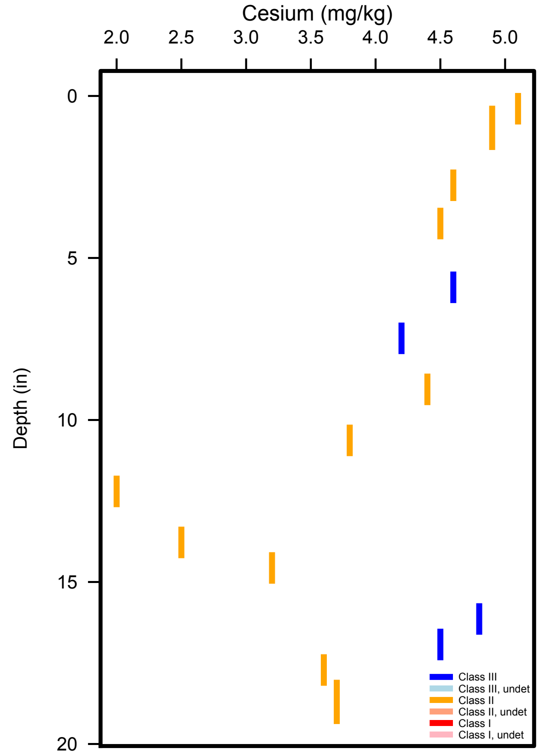

Figure 1486. Cesium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

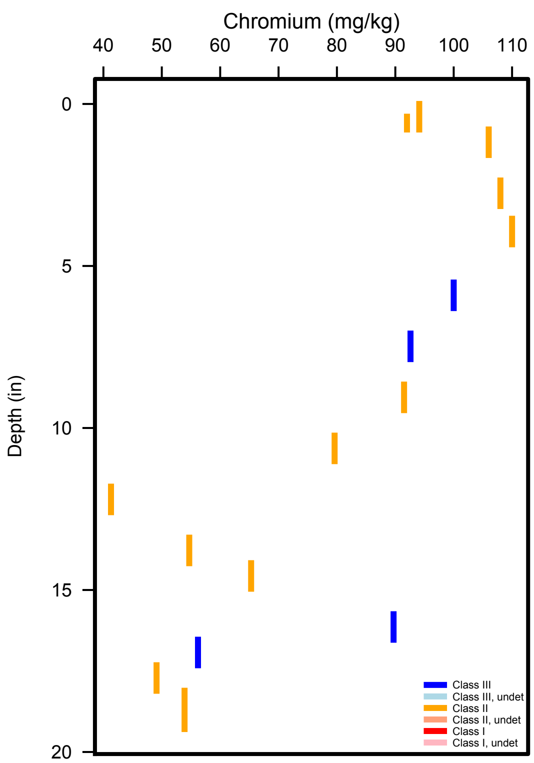

Figure 1487. Chromium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

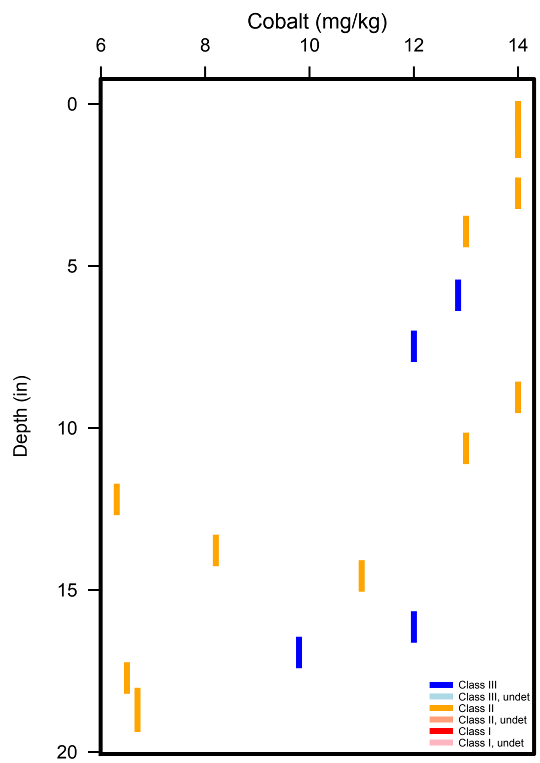

Figure 1488. Cobalt Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

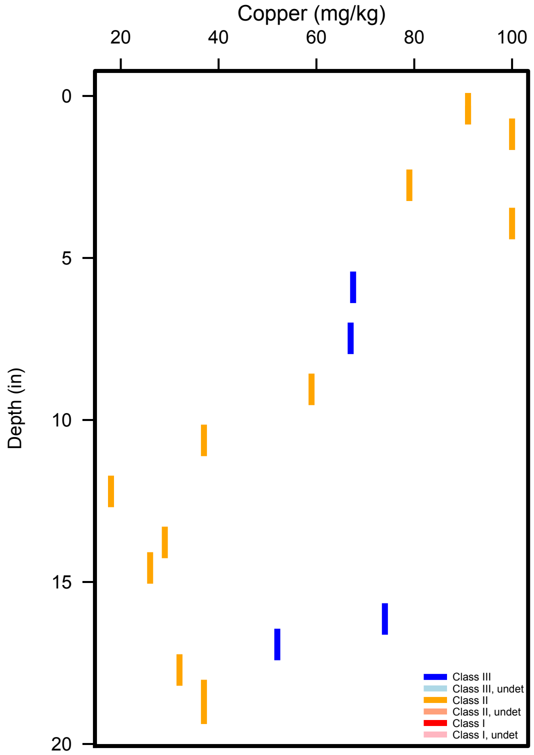

Figure 1489. Copper Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

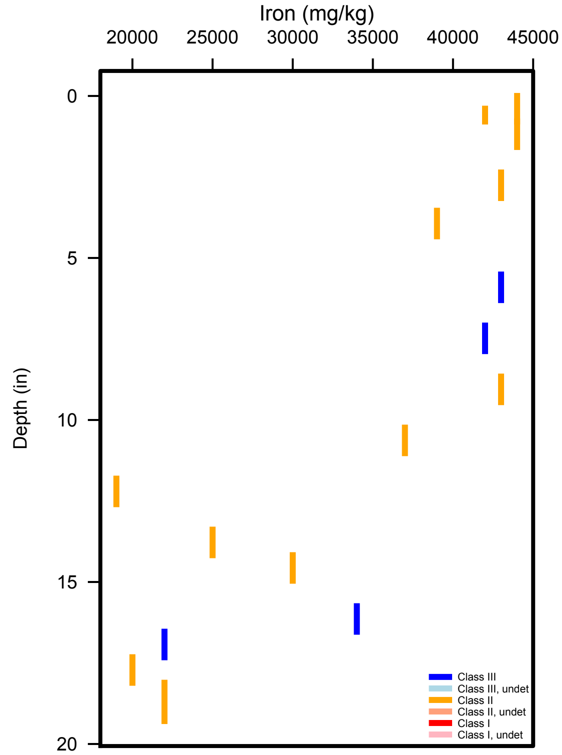

Figure 1490. Iron Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

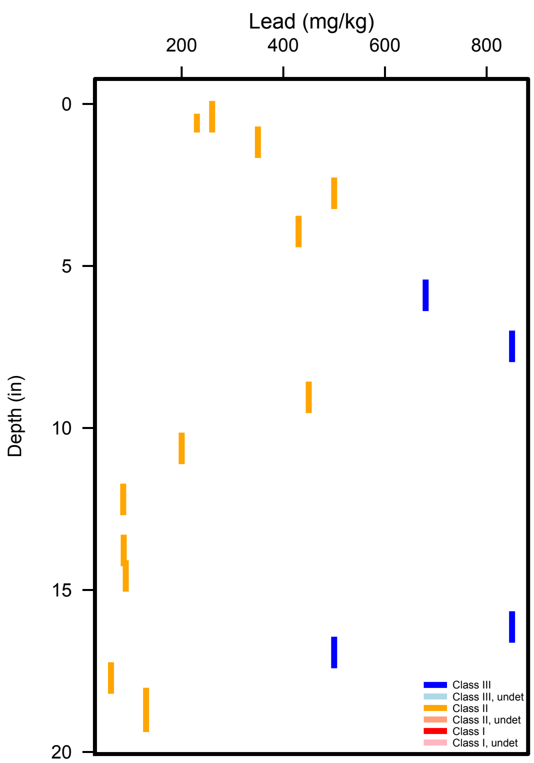

Figure 1491. Lead Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

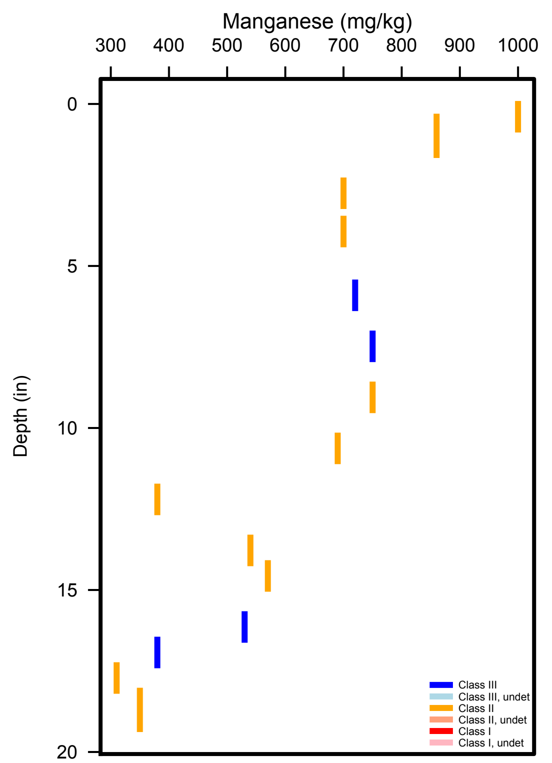

Figure 1492. Manganese Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

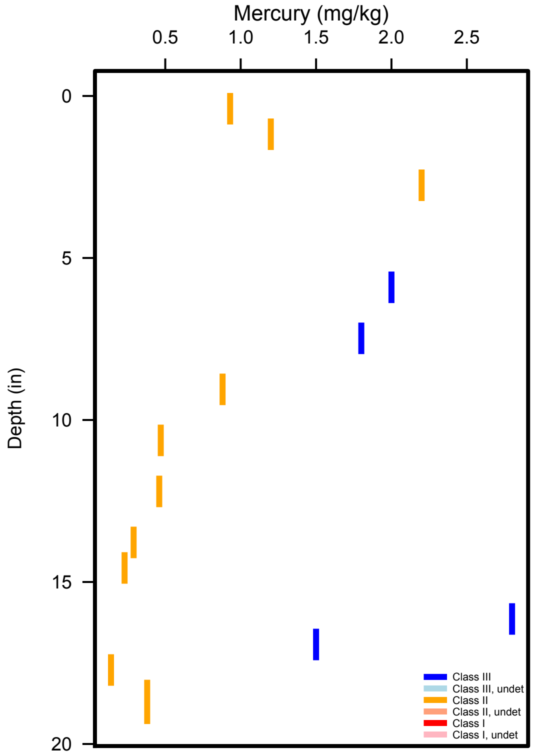

Figure 1493. Mercury Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

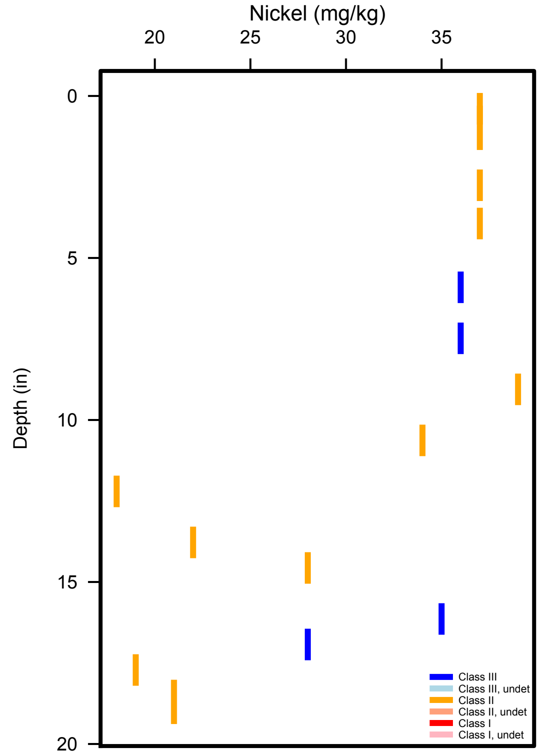

Figure 1494. Nickel Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

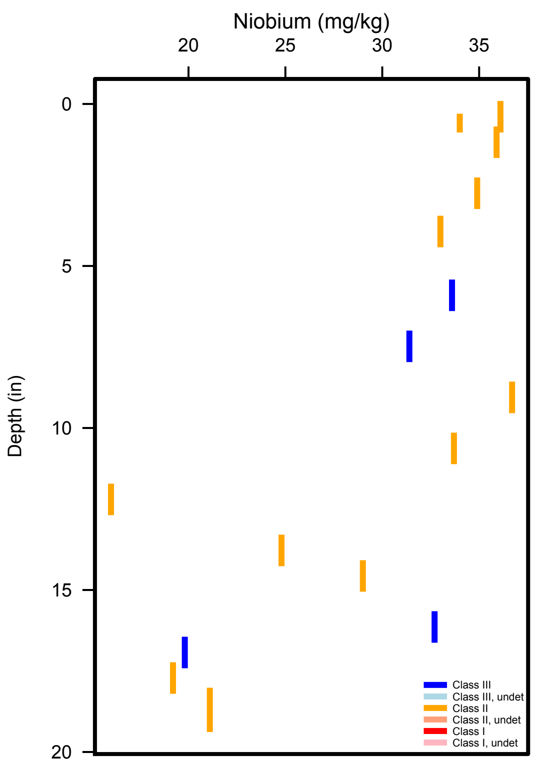

Figure 1495. Niobium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

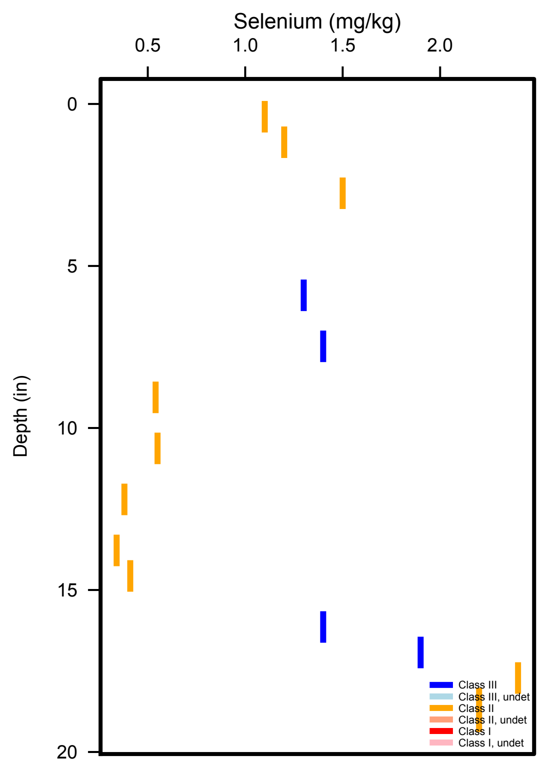

Figure 1496. Selenium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

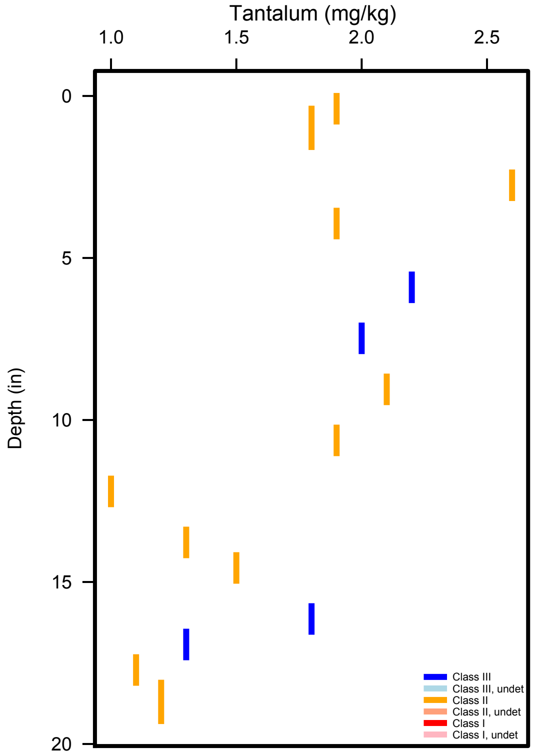

Figure 1497. Tantalum Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

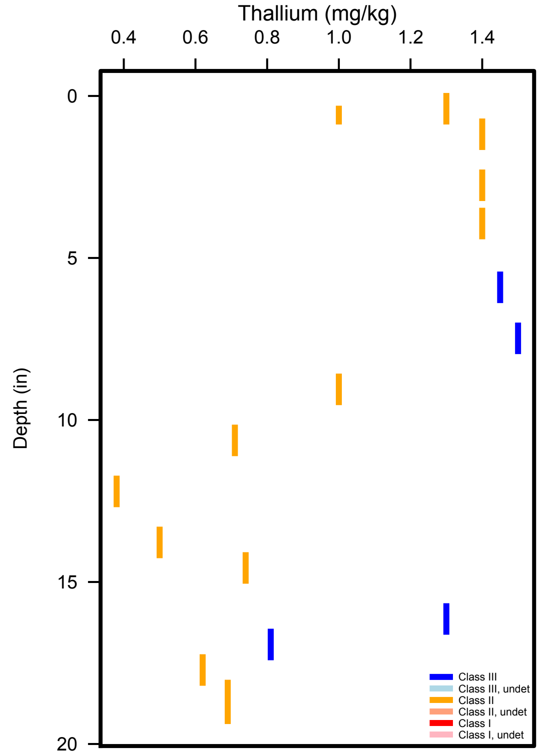

Figure 1498. Thallium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

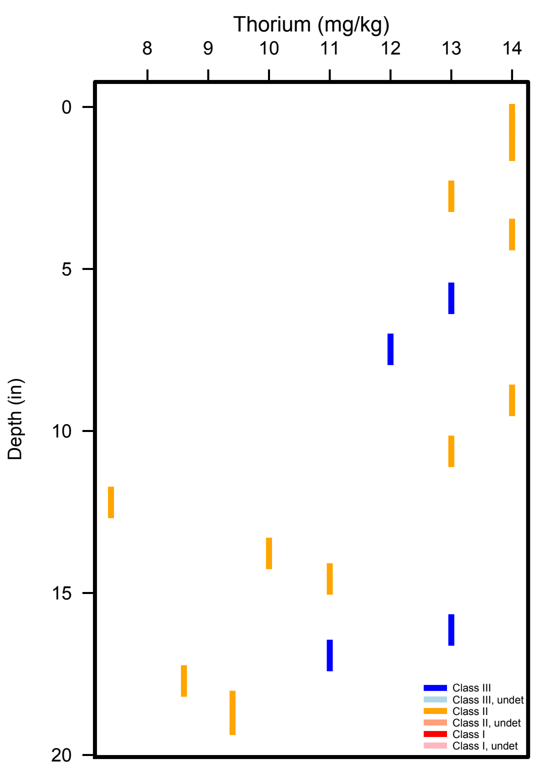

Figure 1499. Thorium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

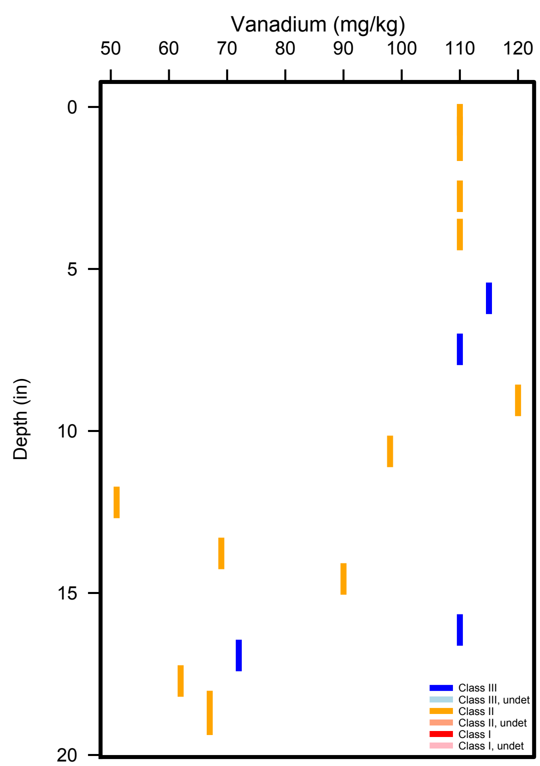

Figure 1500. Vanadium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

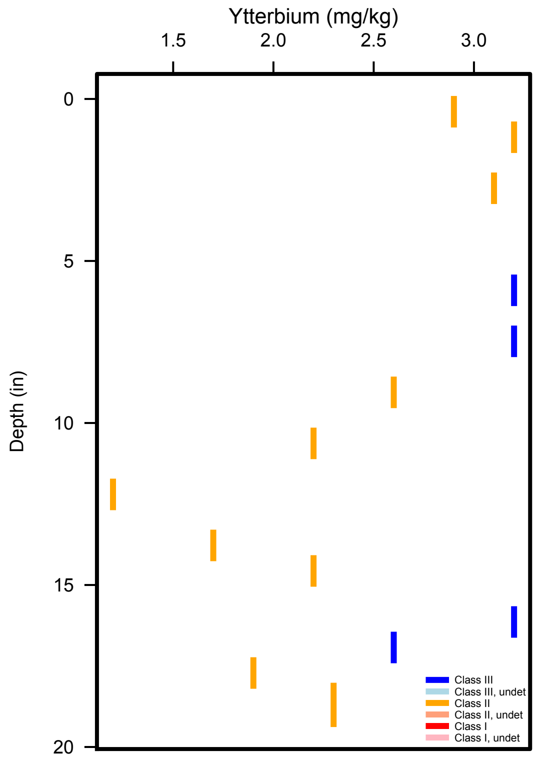

Figure 1501. Ytterbium Concentration and Sediment Class at Cox Core Location CCR−705 with a Significant Trend.

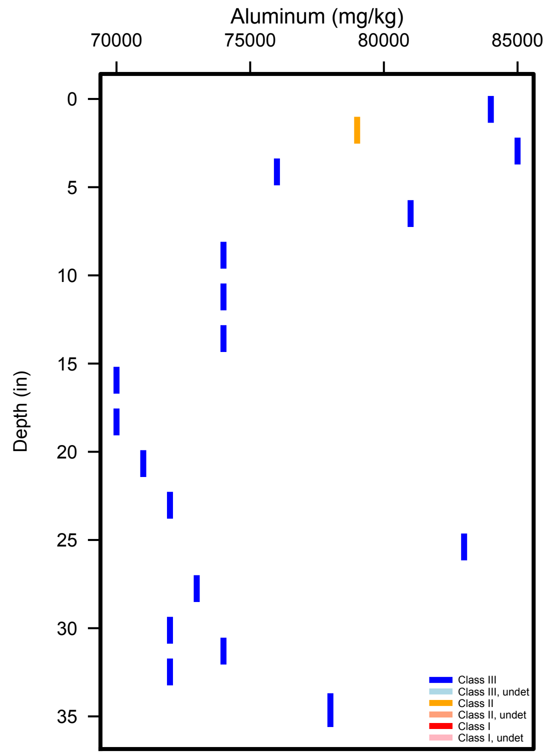

Figure 1502. Aluminum Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

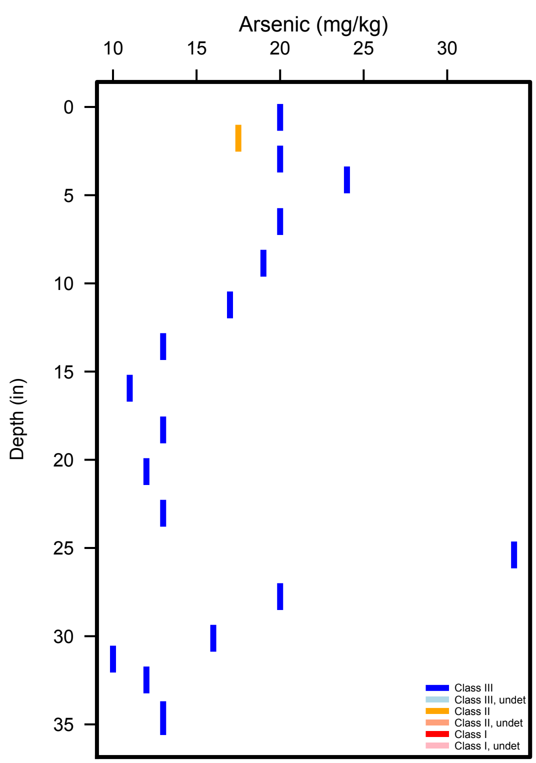

Figure 1503. Arsenic Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

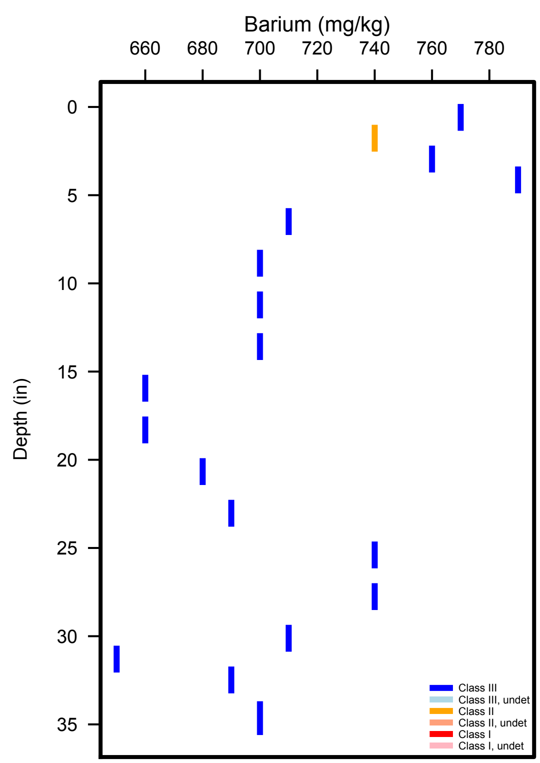

Figure 1504. Barium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

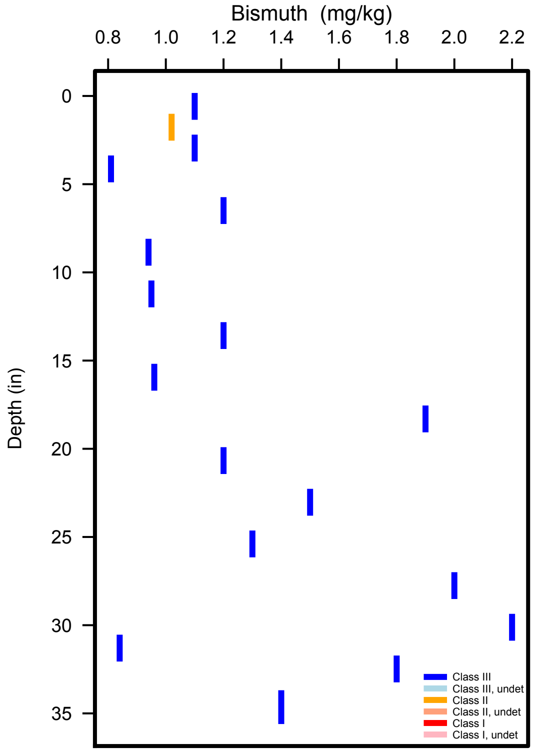

Figure 1505. Bismuth Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

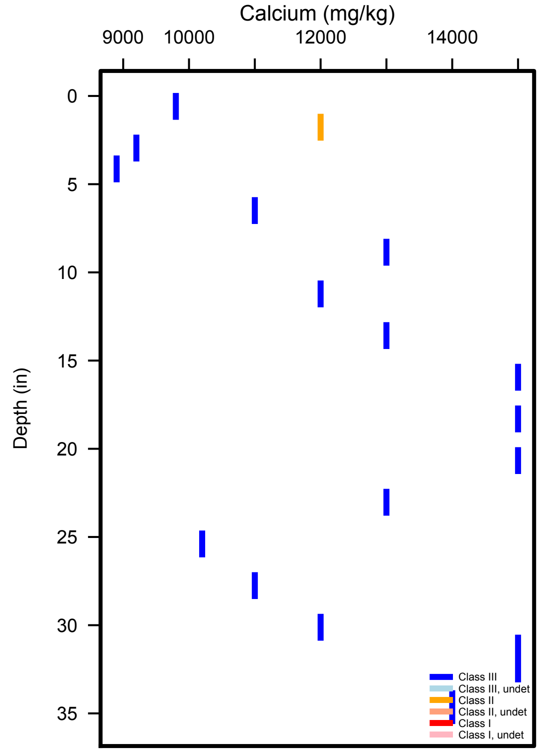

Figure 1506. Calcium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

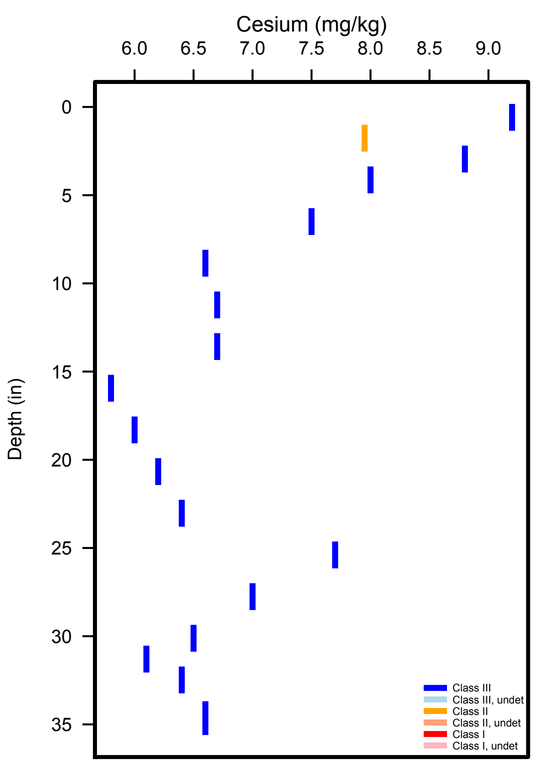

Figure 1507. Cesium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

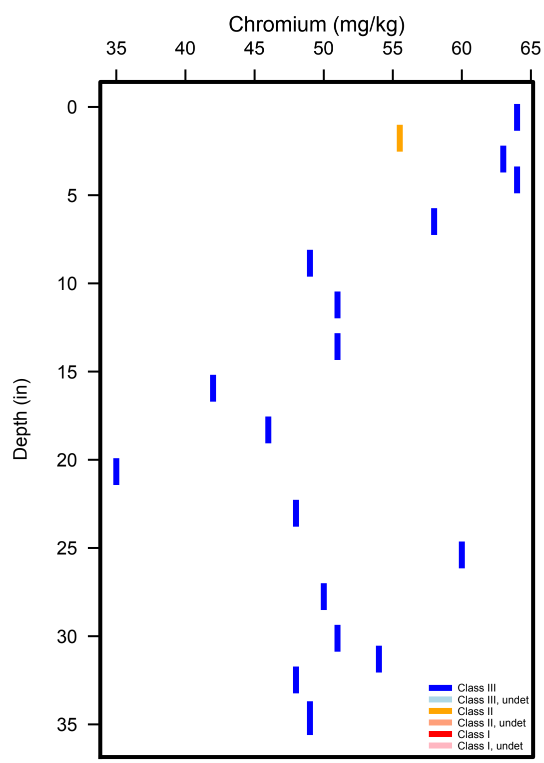

Figure 1508. Chromium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

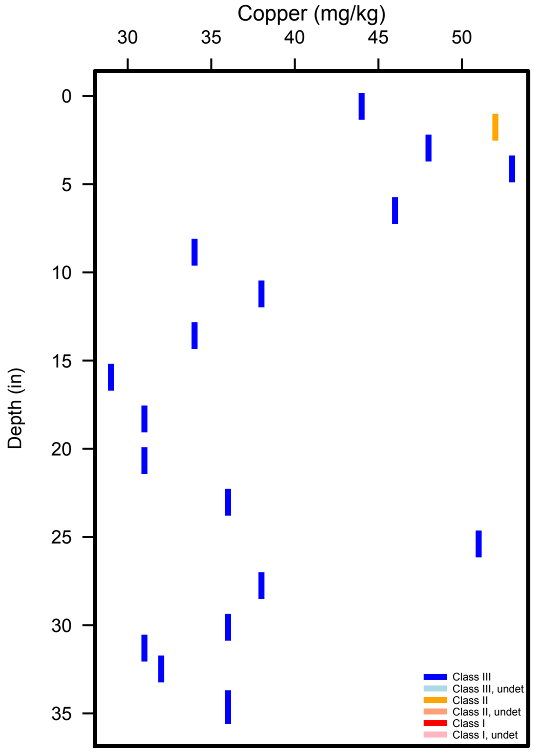

Figure 1509. Copper Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

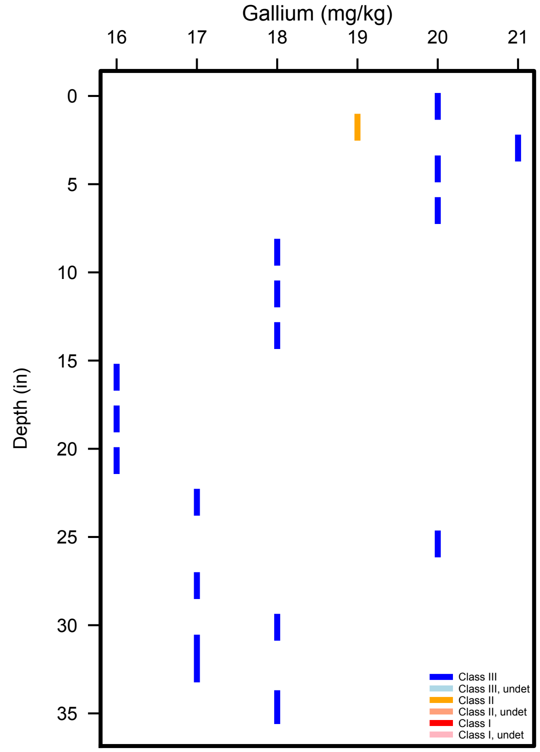

Figure 1510. Gallium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

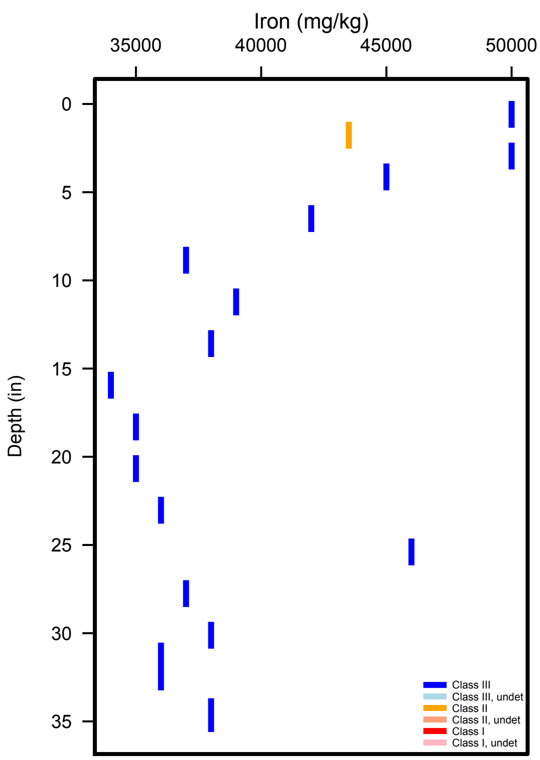

Figure 1511. Iron Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

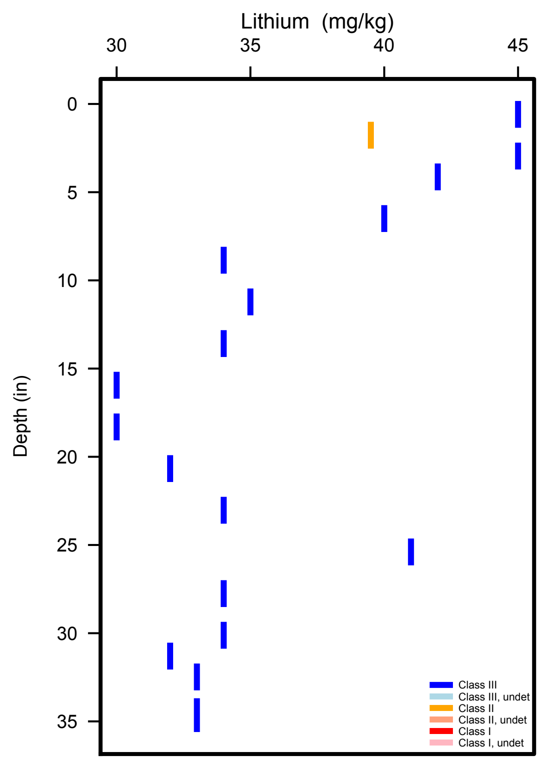

Figure 1512. Lithium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

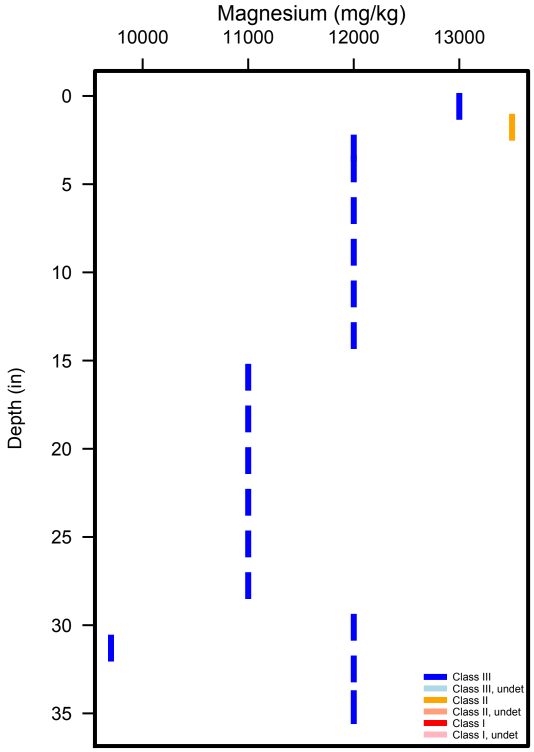

Figure 1513. Magnesium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

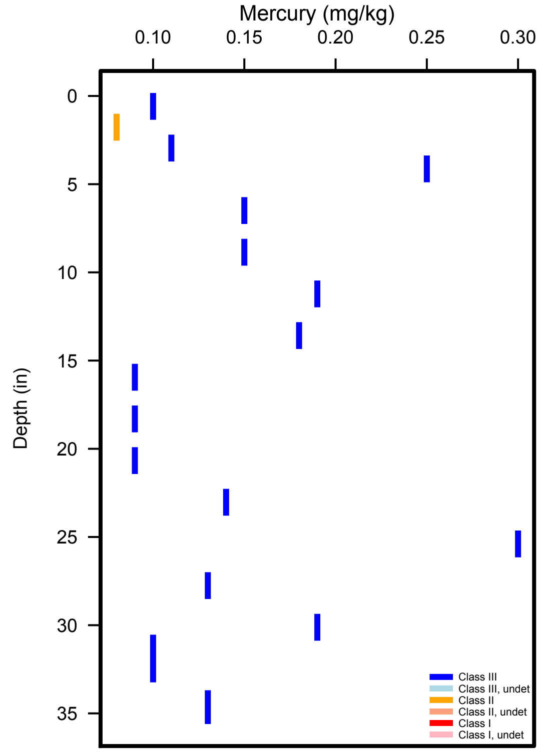

Figure 1514. Mercury Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

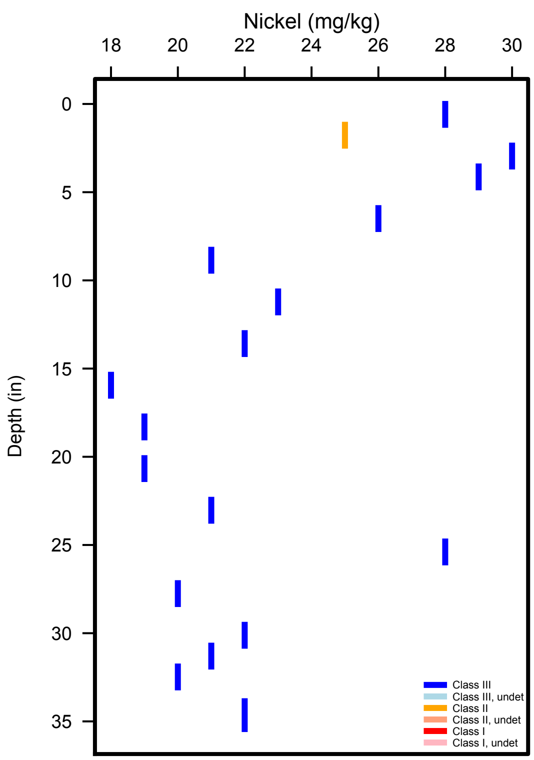

Figure 1515. Nickel Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

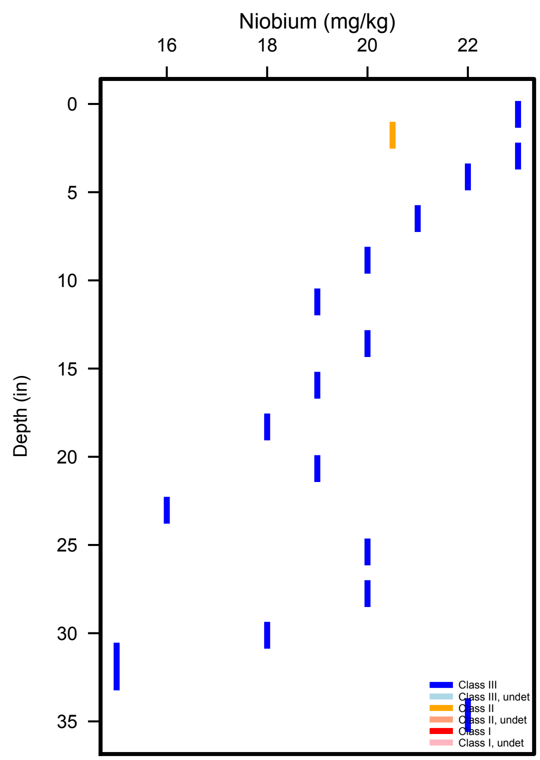

Figure 1516. Niobium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

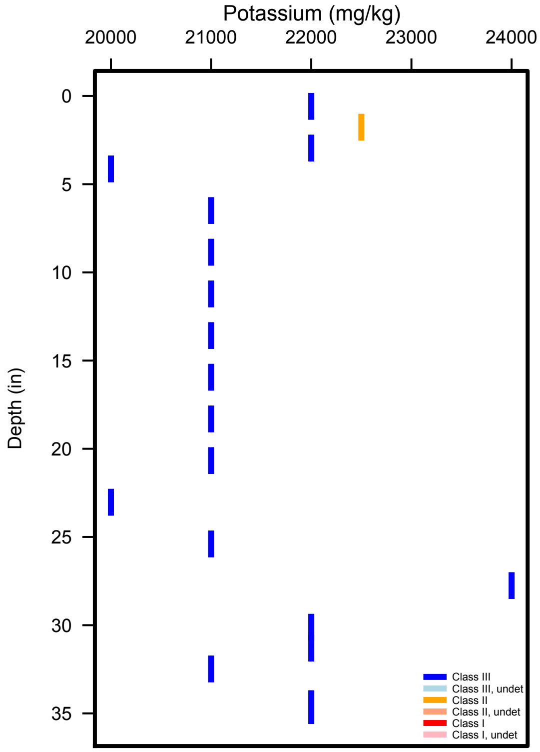

Figure 1517. Potassium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

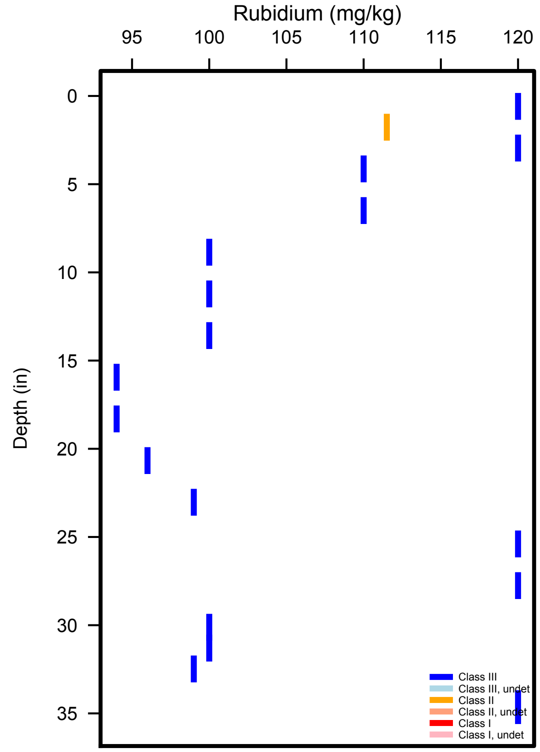

Figure 1518. Rubidium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

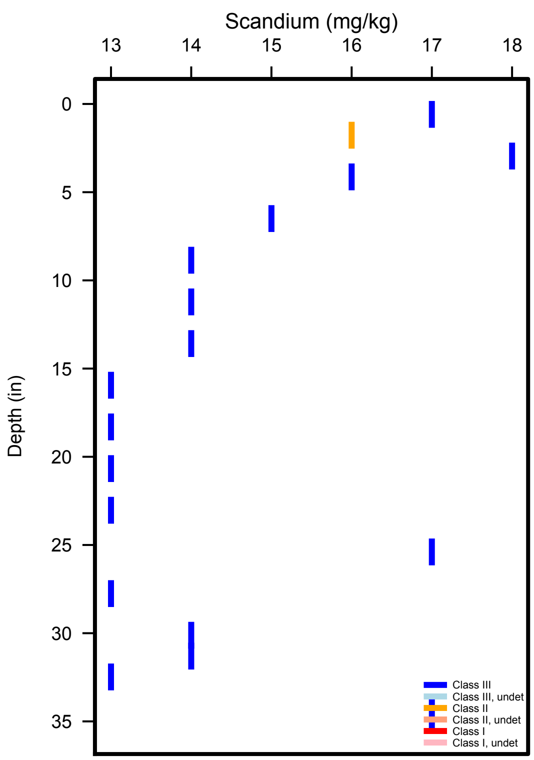

Figure 1519. Scandium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

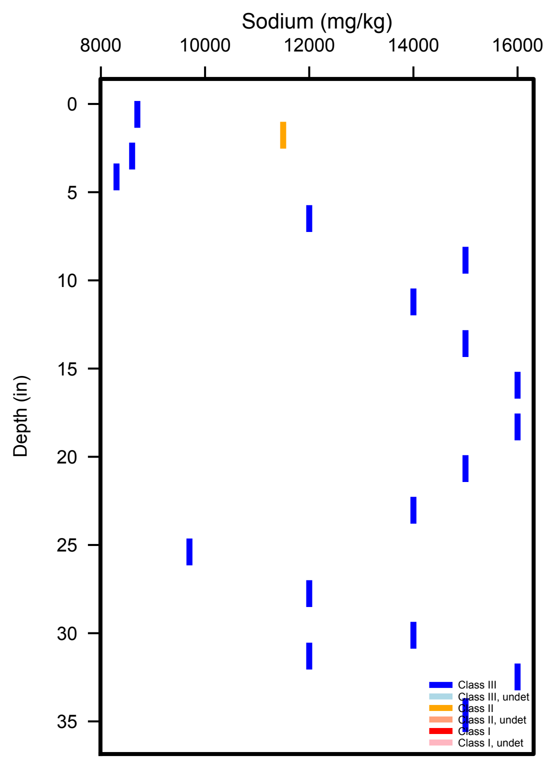

Figure 1520. Sodium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

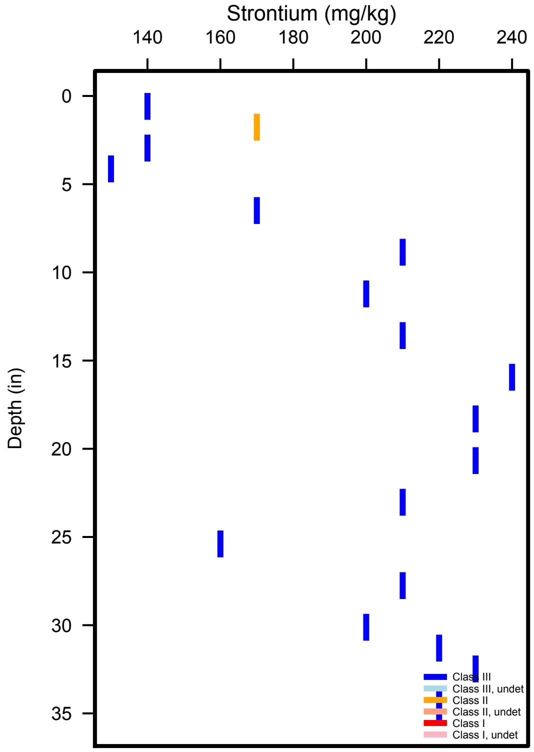

Figure 1521. Strontium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

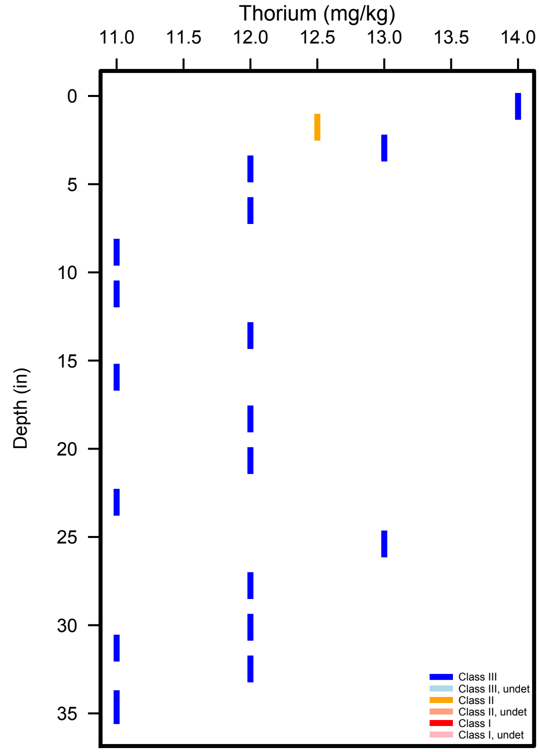

Figure 1522. Thorium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

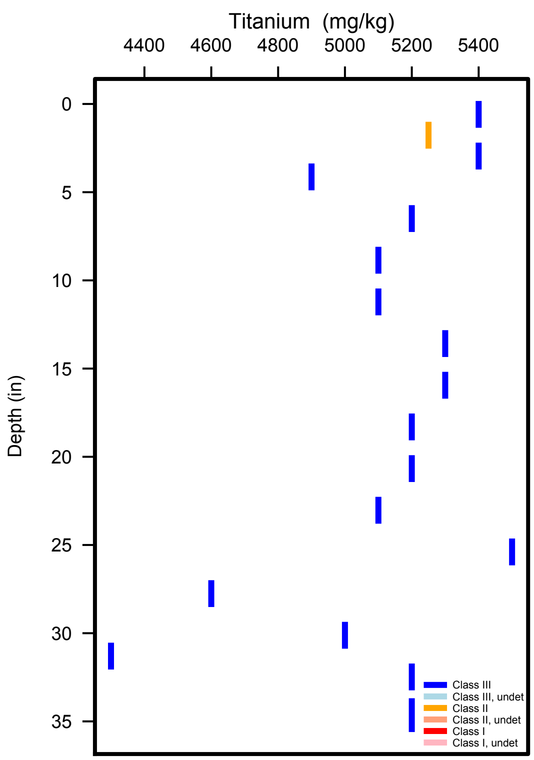

Figure 1523. Titanium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

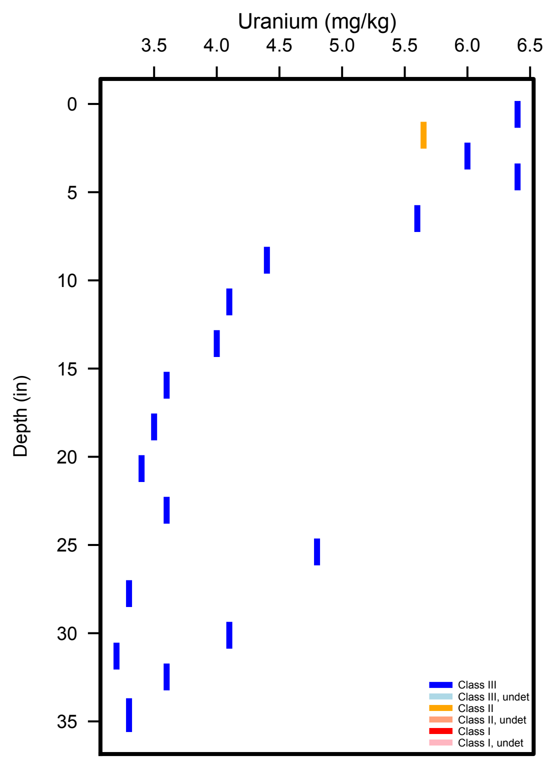

Figure 1524. Uranium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

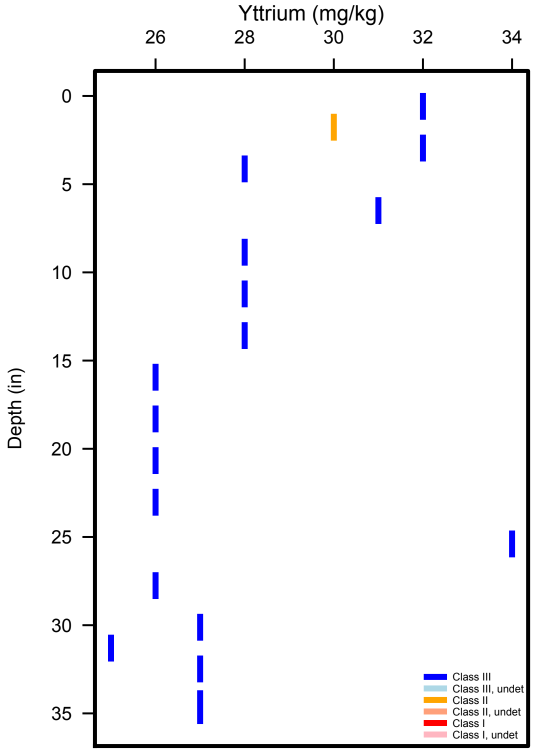

Figure 1525. Yttrium Concentration and Sediment Class at Cox Core Location CSA−8 with a Significant Trend.

MAPS

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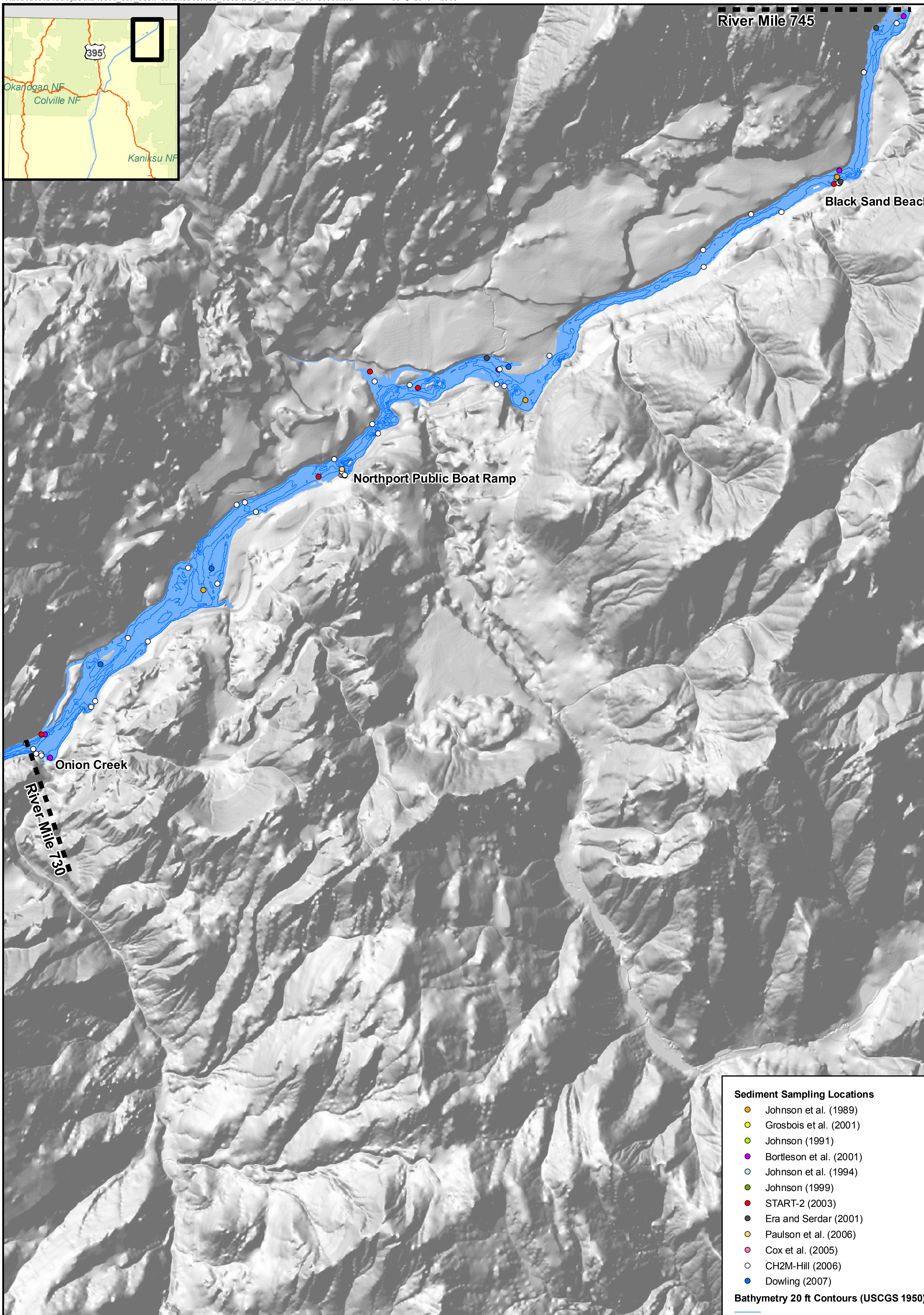

Integral Parametrix

0 0.5 1 Km

0 0.5 1 Miles

N

Map 1. **Sediment Sampling Locations by Study in Reach 1**

Upper Columbia River, WA

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Integral Parametrix

Km 0 0.5 1

Miles 0 0.5 1

N

Map 2. **Sediment Sampling Locations by Study in Reach 2**

Upper Columbia River, WA

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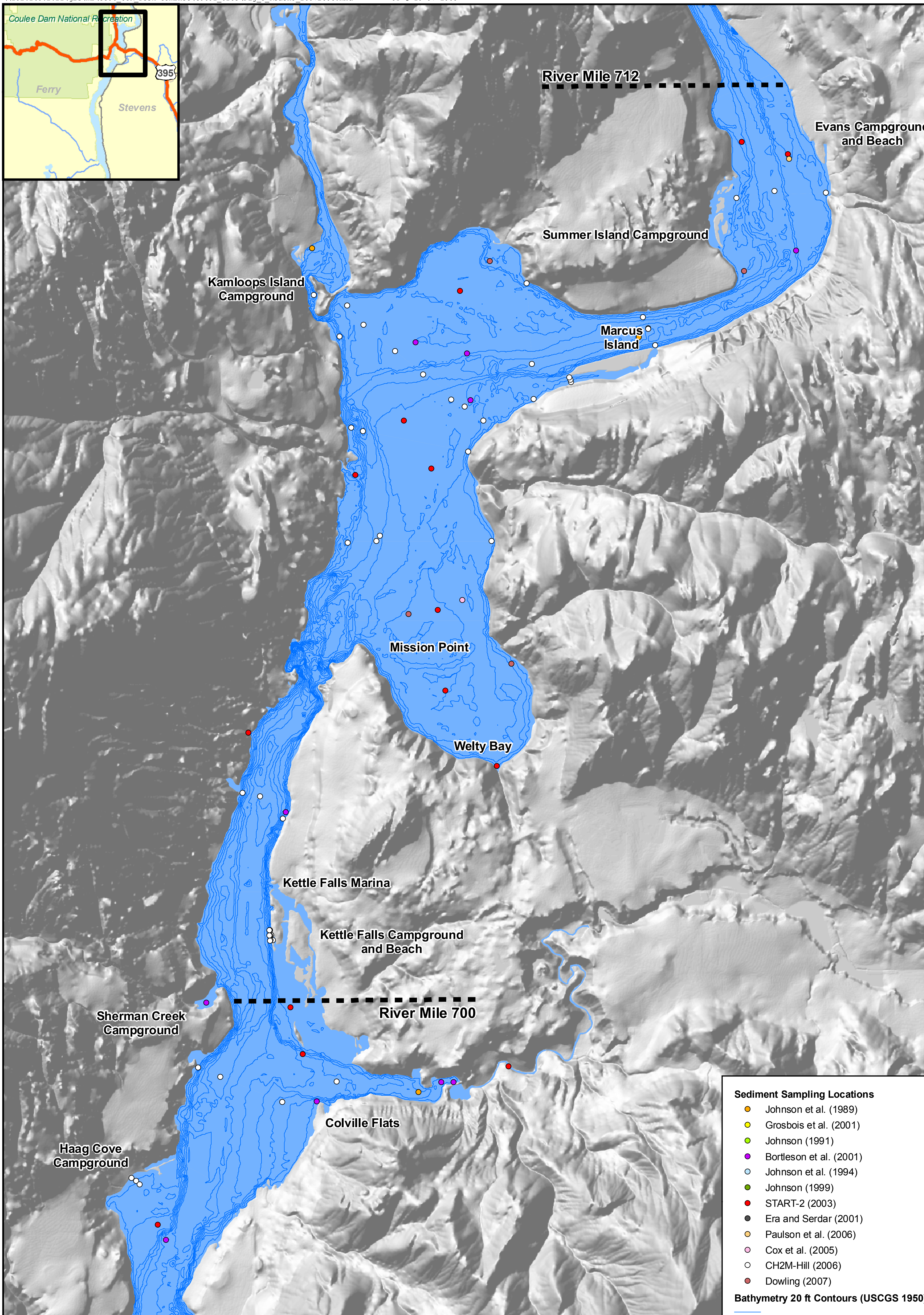


Integral Parametrix

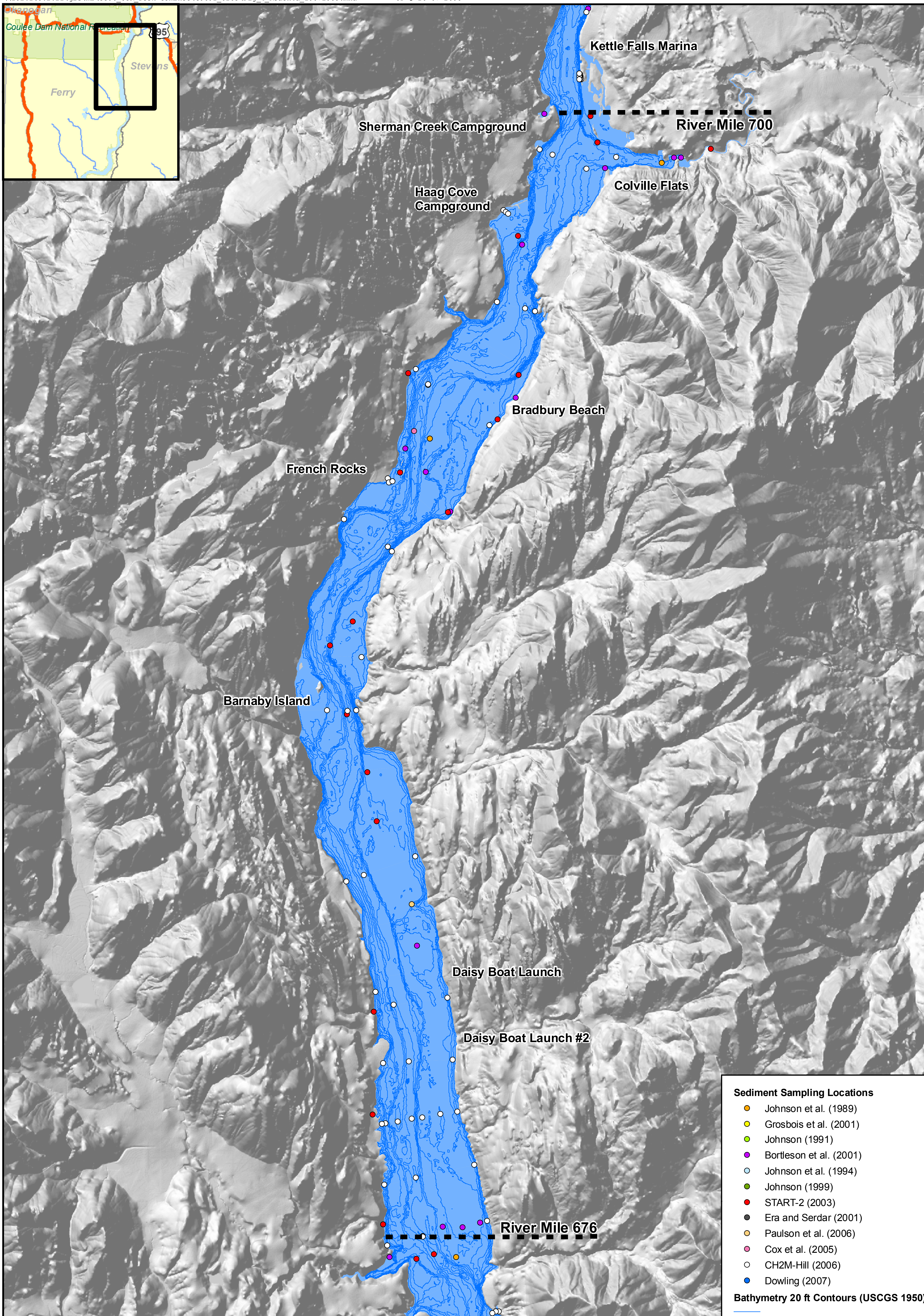
Km: 0 0.5 1

Miles: 0 0.5 1

N

Map 3. **Sediment Sampling Locations by Study in Reach 3**

Upper Columbia River, WA



Integral Parametrix

Map 4. **Sediment Sampling Locations by Study in Reach 4a**

Upper Columbia River, WA

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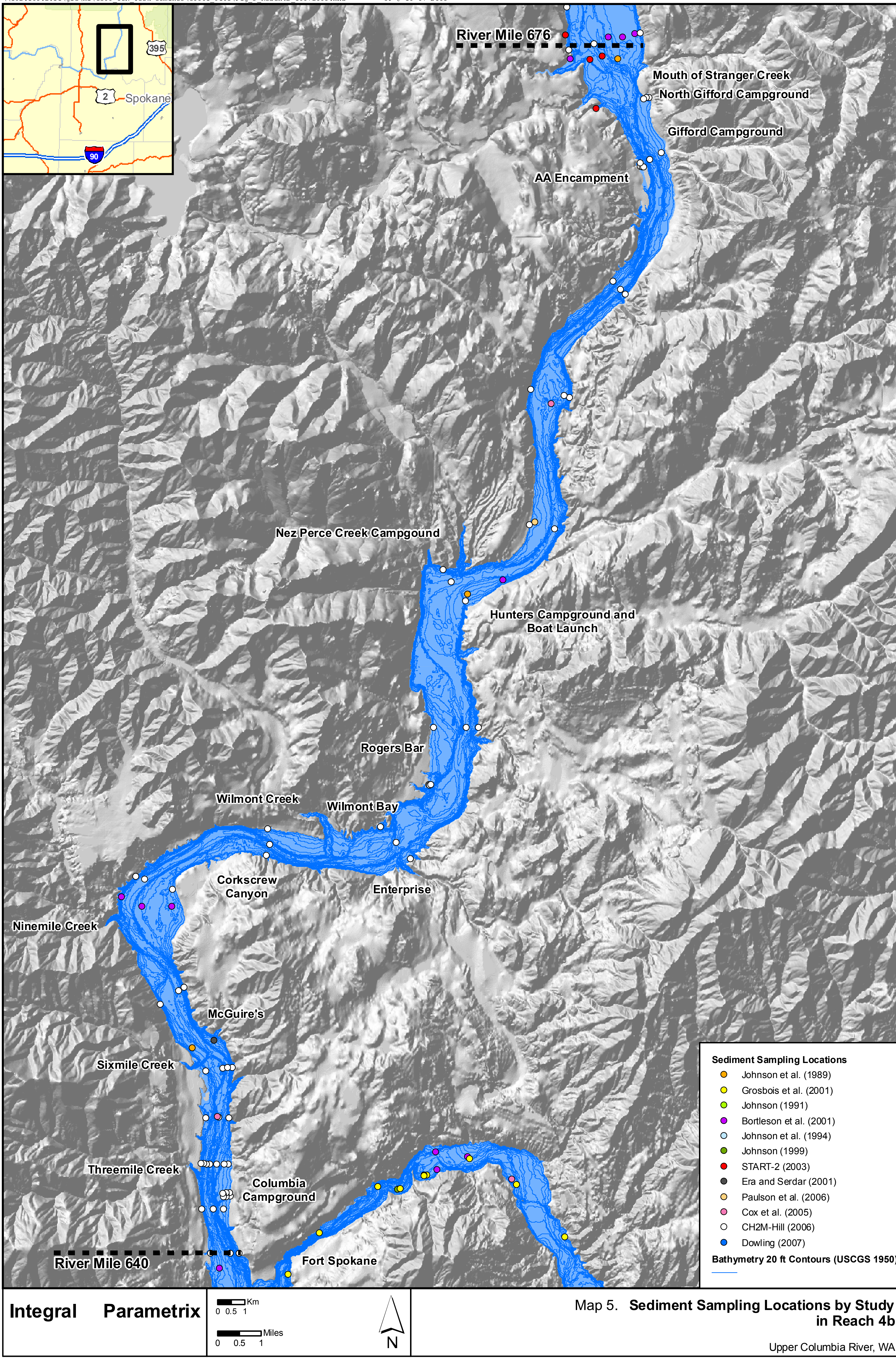
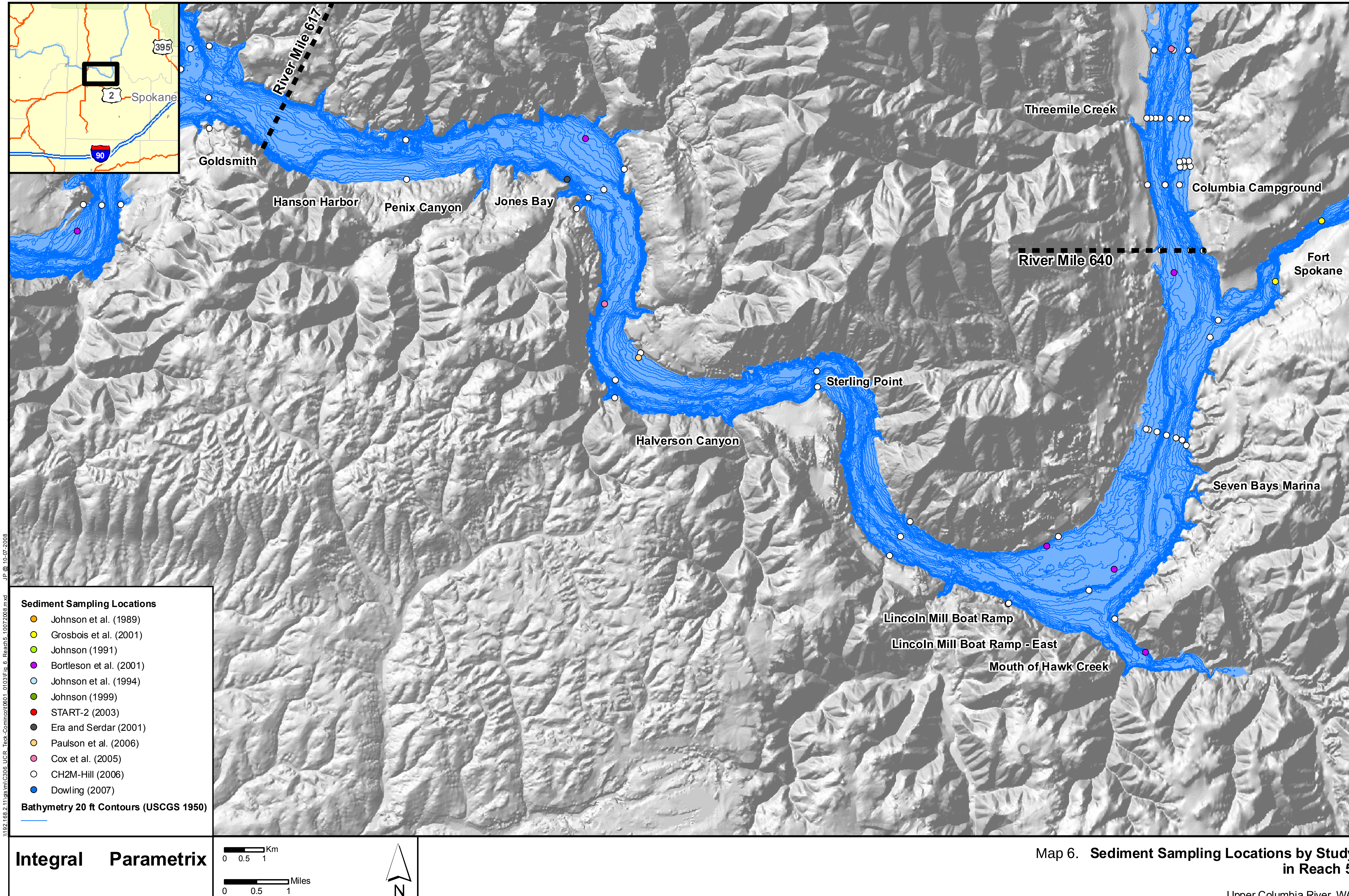


Integral Parametrix

Map 5. **Sediment Sampling Locations by Study in Reach 4b**

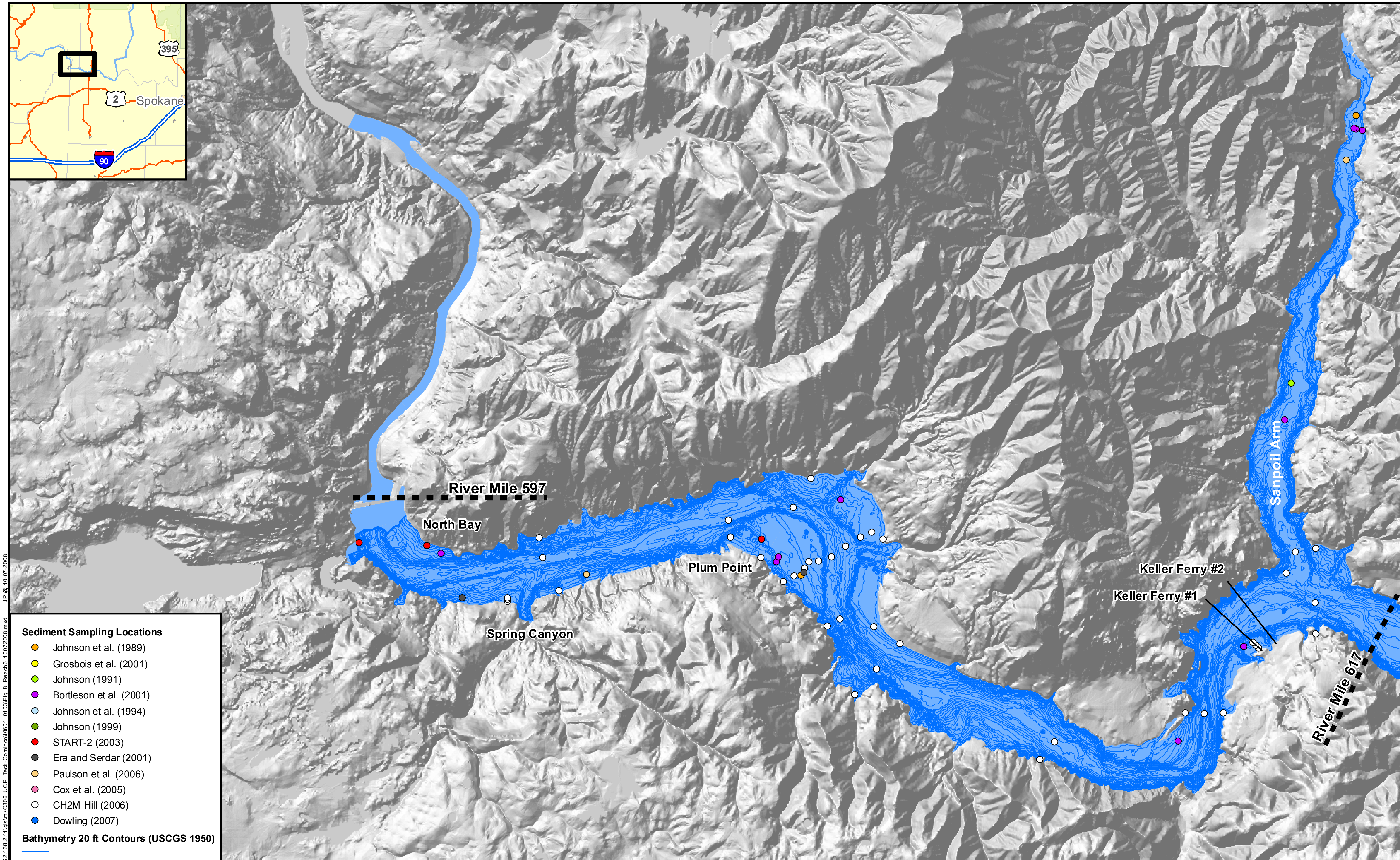
Upper Columbia River, WA



Integral Parametrix

Map 6. **Sediment Sampling Locations by Study in Reach 5**

Upper Columbia River, WA



Integral **Parametrix**

0 0.5 1 Km

0 0.5 1 Miles

N

Map 7. **Sediment Sampling Locations by Study in Reach 6**

Upper Columbia River, WA

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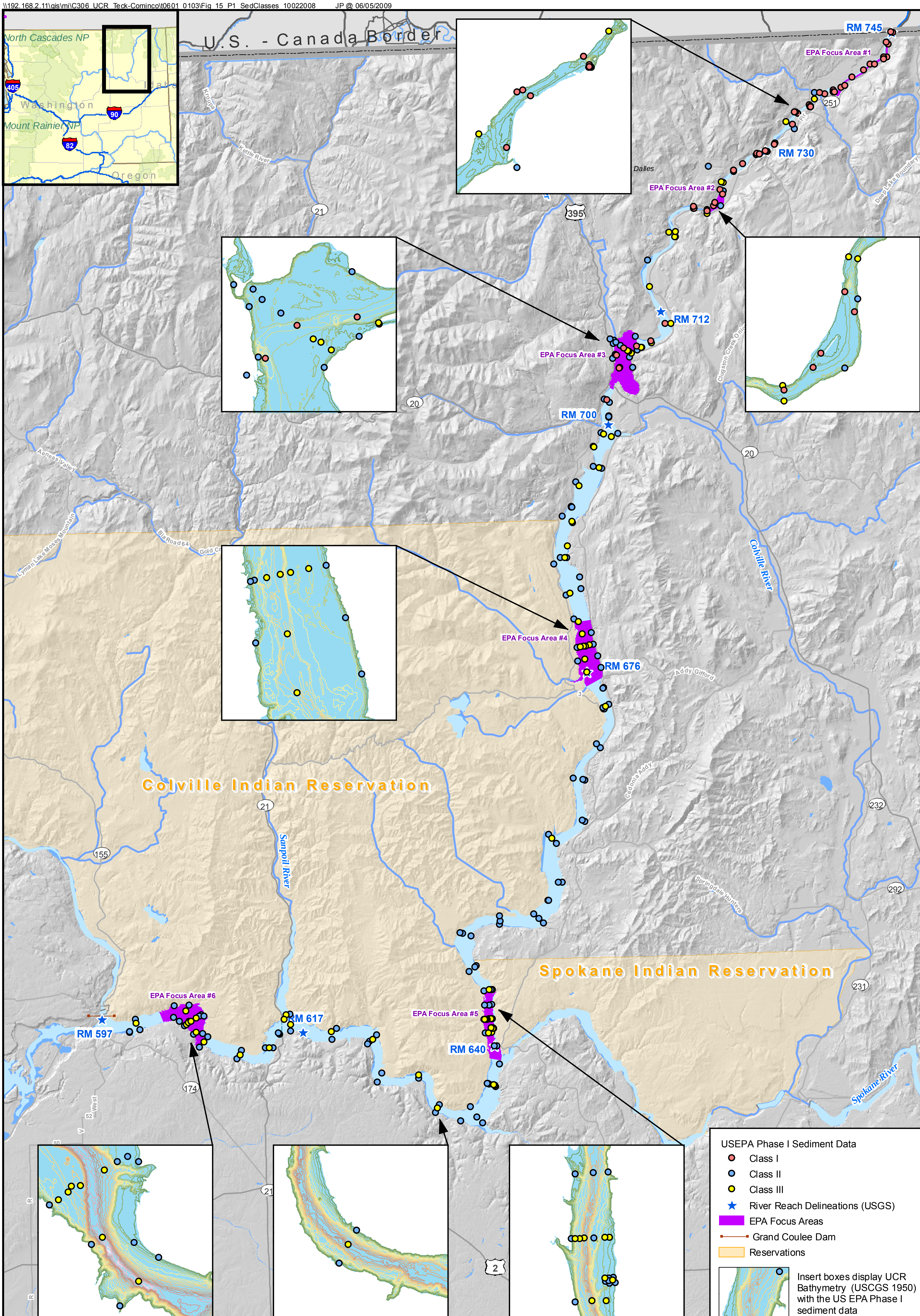

Integral Parametrix

0 5 10 Km

0 5 10 Miles

N

Map 8. Spatial Distribution of Sediment Classes in Phase I Data

Upper Columbia River, WA

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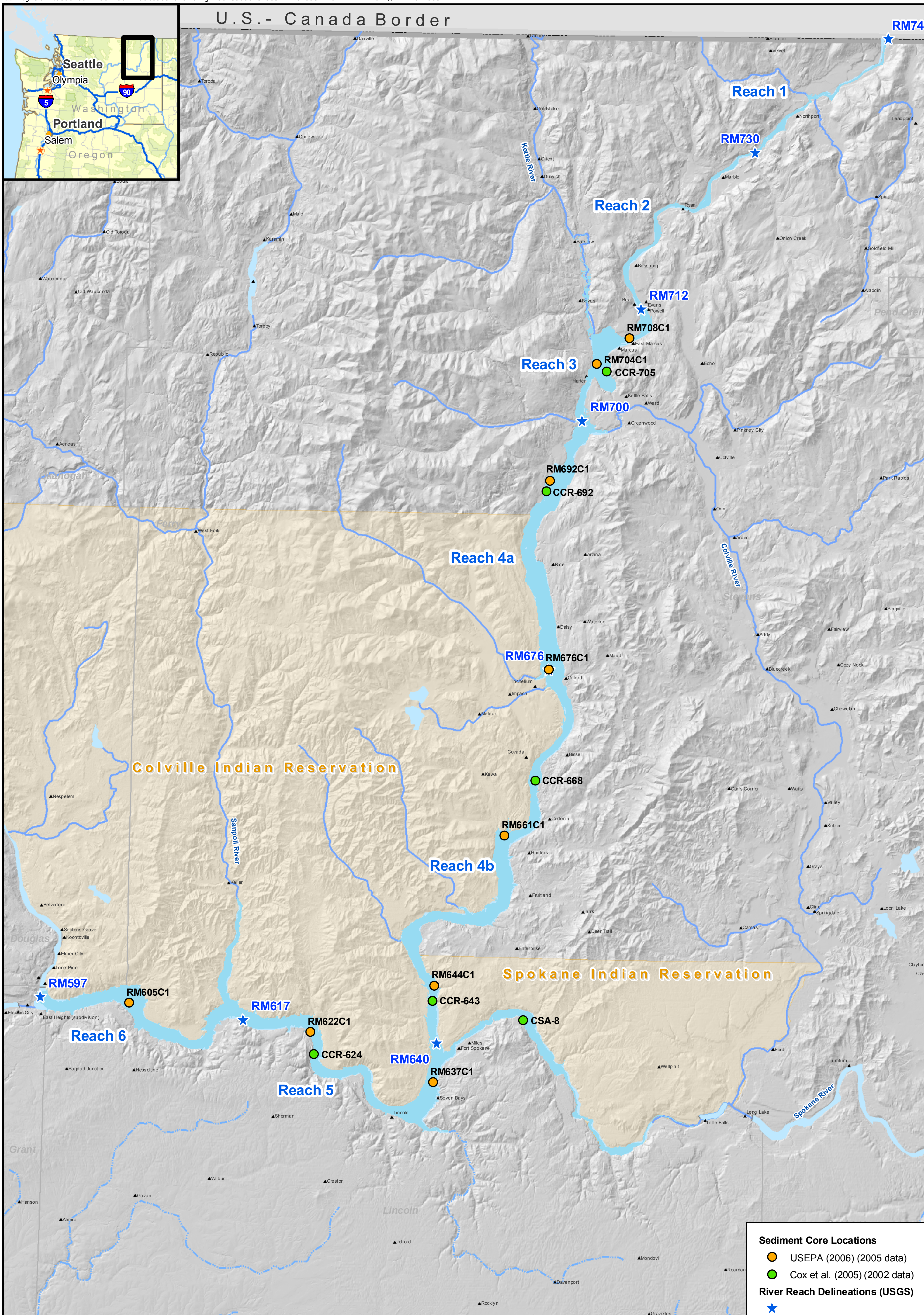

Integral Parametrix

Km 0 5 10

Miles 0 5 10

N

Map 9. **Sediment Core Locations in the Study Area**

Upper Columbia River, WA

TABLES

Table 1. Sediment Chemistry Data Sets Evaluated

Citation	Sampling Year	Analytes	Sponsoring Organization
Johnson et al. (1989)	1986	Metals	Ecology
Grosbois et al. (2001)	1999	Metals	Spokane Tribe
Johnson (1991)	1989	Metals	Ecology
Bortleson et al. (2001)	1992	Metals, semivolatiles	USGS
Johnson et al. (1994)	1993	Metals	Ecology
Johnson (1999)	1998	Metals	Ecology
START-2 (2003)	2001	Metals	EPA
Era and Serdar (2001)	2001	Metals	Ecology
Paulson et al. (2006)	2004	Metals, radionuclides	USGS
Cox et al. (2005)	2002	Metals, radionuclides	USGS
USEPA (2006)	2005	Metals, semivolatiles, pesticides, PCBs, dioxins	EPA
Dowling (2007)	2007	Metals	Ecology

Notes:
PCB = polychlorinated biphenyl
Ecology = Washington State Department of Ecology

Table 2. Number of Locations Sampled from Each Reach, by Study

	Reach						
Study	1	2	3	4a	4b	5	6
Bortleson et al. (2001)	5	3	8	10	7	8	10
USEPA (2006)	38	34	41	43	70	31	40
Cox et al. (2005)			1	1	2	1	
Dowling (2007)	2	1	4				
Era and Serdar (2001)	3		1		1	1	2
Grosbois et al. (2001)						15	
Johnson (1991)		1		1	1		2
Johnson (1999)						2	
Johnson et al. (1989)	3	1	2	2	3		2
Johnson et al. (1994)						1	
Paulson et al. (2006)	1	1	1	1	1	1	2
START-2 (2003)	5	3	10	17	3		3
Total =	57	44	68	75	88	60	61

Table 3. Summary of the Results of the Refined Data Quality Assessment

Study	Data Set Summary	Data Quality Category	Comments	Documents Reviewed
Johnson (1999)	Sediment samples collected from three locations in the Spokane Arm and additional locations in the Spokane River	Category 1	Sb and Tl results not reported due to low recoveries	Johnson (1999); Barton (2008)
Grosbois et al. (2001)	Sediment samples collected from 18 locations in the Spokane Arm and additional locations in the Spokane River	Category 1		Grosbois et al. (2001); Barton (2008)
Cox et al. (2005)	Surface and subsurface sediment from three locations in the main stem of the UCR	Category 1		Cox et al. (2005); Barton (2008)
Paulson et al. (2006)	Sediment samples collected from nine locations in the main stem of the UCR	Category 1 for all analytes but Mb and Tl; Category 2 for Mo and Tl	Mo estimates are biased low; Tl estimates are biased high. Lanthanides and actinides may have high variability.	Paulson et al. (2006); Barton (2008)
Dowling (2007)	Sediment samples collected from eight locations in Reaches 1, 2, and 3 of the UCR	Category 1	Data are acceptable, but spiking levels were too low to calculate recoveries for Cu, Pb, and Zn.	Dowling (2007)

Note:
RPD = relative percent difference

Table 4. Summary Statistics for the Partitions of the EPA Phase I Sediment Data Set and Granulated Slag (in mg/kg dry weight)

	Mean	SD	Min	Max	N
Zinc					
Class I	9836	6739	1110	26600	87
Class II	95	97	16	563	180
Class III	725	373	149	2370	92
Granulated slag	29300	7160	19900	48200	23
Vanadium					
Class I	31	8.5	11	49	87
Class II	24	11	7.7	71	180
Class III	39	12	14	69	92
Granulated slag	65	8	57	77	5.0
Zn/V Ratio					
Class I	285	141	51	629	87
Class II	3.7	2.2	1.2	10	180
Class III	19	8	10	40	92
Granulated slag	466	223	288	852	4.0

Table 5. Statistically Significant Differences among Sediment Metal Concentrations in Sediment Classes

	Class II	**Class III**
Class I	All metals, except Ni, Tl	All metals, except K, U
Class II		All metals

Table 6. Surface Sediment Samples by Reach, Class, and Channel Location

	Class I		Class II		Class III	
Reach	Number in Channel	Number Outside Channel	Number in Channel	Number Outside Channel	Number in Channel	Number Outside Channel
1	10	34		2	1	2
2	10	13		3	2	12
3	11			30		18
4a			2	39	12	14
4b			13	49	10	10
5			3	37	5	8
6				32	9	7

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
1	1,2,3,4,6,7,8-HpCDD	pg/g	6	2	33%	1.28	3.23	5.18
1	1,2,3,4,7,8,9-HpCDF	pg/g	6	0	0%			
1	1,2,3,4,7,8-HxCDD	pg/g	6	0	0%			
1	1,2,3,6,7,8-HxCDD	pg/g	6	0	0%			
1	1,2,3,7,8,9-HxCDD	pg/g	6	3	50%	0.0219	0.0342	0.0556
1	2,2'-Oxybis(1-chloropropane)	ug/kg	40	0	0%			
1	2,3,4,6,7,8-HxCDF	pg/g	6	0	0%			
1	2,4,5-Trichlorophenol	ug/kg	40	0	0%			
1	2,4,6-Trichlorophenol	ug/kg	40	0	0%			
1	2,4-DDD	ug/kg	40	0	0%			
1	2,4-DDE	ug/kg	40	0	0%			
1	2,4-DDT	ug/kg	40	4	10%	0.12	0.202	0.27
1	2,4-Dichlorophenol	ug/kg	40	0	0%			
1	2,4-Dimethylphenol	ug/kg	40	0	0%			
1	2,4-Dinitrophenol	ug/kg	29	0	0%			
1	2,4-Dinitrotoluene	ug/kg	40	0	0%			
1	2,6-Dinitrotoluene	ug/kg	40	0	0%			
1	2-Chloronaphthalene	ug/kg	40	0	0%			
1	2-Chlorophenol	ug/kg	40	0	0%			
1	2-Methylphenol (o-cresol)	ug/kg	40	0	0%			
1	2-Nitroaniline	ug/kg	40	0	0%			
1	2-Nitrophenol	ug/kg	40	0	0%			
1	3-Nitroaniline	ug/kg	40	0	0%			
1	4,4-DDD	ug/kg	40	0	0%			
1	4,4-DDE	ug/kg	40	4	10%	0.072	0.187	0.46
1	4,4-DDT	ug/kg	40	16	40%	0.2	0.442	1.5
1	4,6-Dinitro-2-methylphenol	ug/kg	40	0	0%			
1	4-Chloro-3-methylphenol	ug/kg	40	0	0%			
1	4-Chloroaniline	ug/kg	40	0	0%			
1	4-Chlorophenyl-phenyl ether	ug/kg	40	0	0%			
1	4-Nitroaniline	ug/kg	40	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
1	4-Nitrophenol	ug/kg	40	0	0%			
1	Acetophenone	ug/kg	40	1	3%	26	26	26
1	Aldrin	ug/kg	40	0	0%			
1	Alpha-BHC	ug/kg	40	0	0%			
1	Aluminum	mg/kg	47	47	100%	3080	12400	44000
1	Antimony	mg/kg	44	43	98%	5	32.8	168
1	Arsenic	mg/kg	50	46	92%	2	17.5	74.4
1	Atrazine	ug/kg	40	0	0%			
1	Barium	mg/kg	47	47	100%	94.6	906	2440
1	Benzaldehyde	ug/kg	40	0	0%			
1	Benzyl alcohol	ug/kg	40	0	0%			
1	Beryllium	mg/kg	47	47	100%	0.27	0.887	1.7
1	Beta-BHC	ug/kg	40	0	0%			
1	Bis(2-chloroethoxy)methane	ug/kg	40	0	0%			
1	Bis(2-chloroethyl)ether	ug/kg	40	0	0%			
1	Bismuth	mg/kg	2	2	100%	0.17	0.188	0.205
1	Cadmium	mg/kg	50	46	92%	0.27	2.79	18
1	Calcium	mg/kg	47	47	100%	5310	39800	85000
1	Caprolactam	ug/kg	40	0	0%			
1	Cerium	mg/kg	2	2	100%	49.7	50.5	51.2
1	Cesium	mg/kg	2	2	100%	1.8	1.95	2.1
1	Chromium	mg/kg	47	47	100%	0.165	61.4	170
1	Cobalt	mg/kg	47	47	100%	4.7	27.8	85.7
1	Copper	mg/kg	50	50	100%	21.4	1120	3300
1	Dimethyl phthalate	ug/kg	40	0	0%			
1	Di-N-octylphthalate	ug/kg	40	0	0%			
1	Endrin aldehyde	ug/kg	40	0	0%			
1	Endrin ketone	ug/kg	40	0	0%			
1	Gallium	mg/kg	2	2	100%	23	24.5	26
1	Heptachlor	ug/kg	40	0	0%			
1	Hexachlorobenzene	ug/kg	40	1	3%	0.11	0.11	0.11

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
1	Hexachlorobutadiene	ug/kg	40	0	0%			
1	Iron	mg/kg	47	47	100%	12000	100000	254000
1	Isophorone	ug/kg	40	0	0%			
1	Lanthanum	mg/kg	2	2	100%	31.4	32.1	32.8
1	Lead	mg/kg	50	50	100%	23.7	317	2760
1	Lithium	mg/kg	2	2	100%	19	19	19
1	Magnesium	mg/kg	47	47	100%	4360	8920	26600
1	Manganese	mg/kg	47	47	100%	163	1870	4920
1	Mercury	mg/kg	47	45	96%	0.005	0.123	0.68
1	Methoxychlor	ug/kg	40	3	8%	0.75	2.55	3.5
1	Molybdenum	mg/kg	2	2	100%	33.5	34.2	35
1	Nickel	mg/kg	47	47	100%	6.3	12.5	24.6
1	Nitrobenzene	ug/kg	40	0	0%			
1	N-nitrosodi-N-propylamine	ug/kg	40	0	0%			
1	N-nitrosodiphenylamine	ug/kg	40	0	0%			
1	Octachlorodibenzodioxin	pg/g	6	4	67%	10.9	21.2	32.6
1	Octachlorodibenzofuran	pg/g	6	4	67%	0.804	1.76	2.72
1	Pentachlorophenol	ug/kg	40	0	0%			
1	Phenol	ug/kg	40	0	0%			
1	Potassium	mg/kg	47	47	100%	611	2710	15000
1	Rubidium	mg/kg	2	2	100%	58.5	60	61.5
1	Scandium	mg/kg	2	2	100%	8.4	8.9	9.4
1	Selenium	mg/kg	23	8	35%	1.8	7.51	19.5
1	Silver	mg/kg	47	10	21%	0.69	5.45	12.6
1	Sodium	mg/kg	47	46	98%	102	1370	10300
1	Strontium	mg/kg	2	2	100%	432	454	478
1	Thallium	mg/kg	47	5	11%	0.2	0.844	1.5
1	Thorium	mg/kg	2	2	100%	6.6	6.98	7.35
1	Titanium	mg/kg	2	2	100%	2200	2300	2400
1	Uranium	mg/kg	42	19	45%	4.15	34.7	127
1	Vanadium	mg/kg	47	47	100%	11	32.8	95.5

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
1	Yttrium	mg/kg	2	2	100%	21	21.2	21.4
1	Zinc	mg/kg	50	50	100%	78.8	8440	26600
2	1,2,3,4,6,7,8-HpCDD	pg/g	5	3	60%	1.05	1.39	1.92
2	1,2,3,4,7,8,9-HpCDF	pg/g	5	0	0%			
2	1,2,3,4,7,8-HxCDD	pg/g	5	0	0%			
2	1,2,3,6,7,8-HxCDD	pg/g	5	0	0%			
2	1,2,3,7,8,9-HxCDD	pg/g	5	2	40%	0.0777	0.0968	0.116
2	2,2'-Oxybis(1-chloropropane)	ug/kg	34	0	0%			
2	2,3,4,6,7,8-HxCDF	pg/g	5	0	0%			
2	2,4,5-Trichlorophenol	ug/kg	34	0	0%			
2	2,4,6-Trichlorophenol	ug/kg	34	0	0%			
2	2,4-DDD	ug/kg	34	0	0%			
2	2,4-DDE	ug/kg	34	1	3%	0.17	0.17	0.17
2	2,4-DDT	ug/kg	34	1	3%	0.2	0.2	0.2
2	2,4-Dichlorophenol	ug/kg	34	0	0%			
2	2,4-Dimethylphenol	ug/kg	34	0	0%			
2	2,4-Dinitrophenol	ug/kg	33	0	0%			
2	2,4-Dinitrotoluene	ug/kg	34	0	0%			
2	2,6-Dinitrotoluene	ug/kg	34	0	0%			
2	2-Chloronaphthalene	ug/kg	34	0	0%			
2	2-Chlorophenol	ug/kg	34	0	0%			
2	2-Methylphenol (o-cresol)	ug/kg	34	0	0%			
2	2-Nitroaniline	ug/kg	34	0	0%			
2	2-Nitrophenol	ug/kg	34	0	0%			
2	3-Nitroaniline	ug/kg	34	0	0%			
2	4,4-DDD	ug/kg	34	0	0%			
2	4,4-DDE	ug/kg	34	5	15%	0.115	0.252	0.57
2	4,4-DDT	ug/kg	34	7	21%	0.28	0.459	0.665
2	4,6-Dinitro-2-methylphenol	ug/kg	34	0	0%			
2	4-Chloro-3-methylphenol	ug/kg	34	0	0%			
2	4-Chloroaniline	ug/kg	34	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
2	4-Chlorophenyl-phenyl ether	ug/kg	34	0	0%			
2	4-Nitroaniline	ug/kg	34	0	0%			
2	4-Nitrophenol	ug/kg	34	0	0%			
2	Acetophenone	ug/kg	34	0	0%			
2	Aldrin	ug/kg	34	1	3%	0.17	0.17	0.17
2	Alpha-BHC	ug/kg	34	0	0%			
2	Aluminum	mg/kg	40	40	100%	4070	12100	60400
2	Antimony	mg/kg	36	32	89%	1.3	16.4	53.9
2	Arsenic	mg/kg	40	38	95%	2.3	13.1	53.2
2	Atrazine	ug/kg	34	0	0%			
2	Barium	mg/kg	40	40	100%	80.5	655	2130
2	Benzaldehyde	ug/kg	34	0	0%			
2	Benzyl alcohol	ug/kg	34	0	0%			
2	Beryllium	mg/kg	40	40	100%	0.34	0.841	2.4
2	Beta-BHC	ug/kg	34	0	0%			
2	bis(2-Chloroethoxy)methane	ug/kg	34	0	0%			
2	bis(2-Chloroethyl)ether	ug/kg	34	0	0%			
2	Bismuth	mg/kg	2	2	100%	0.3	0.35	0.4
2	Cadmium	mg/kg	40	40	100%	0.12	2.73	6.9
2	Calcium	mg/kg	40	40	100%	4730	26500	75000
2	Caprolactam	ug/kg	34	1	3%	76	76	76
2	Cerium	mg/kg	2	2	100%	68.2	69.8	71.3
2	Cesium	mg/kg	2	2	100%	2	2.1	2.2
2	Chromium	mg/kg	40	40	100%	9.8	43.6	150
2	Cobalt	mg/kg	40	40	100%	4.2	17.7	66.9
2	Copper	mg/kg	40	40	100%	21	586	3030
2	Dimethyl phthalate	ug/kg	34	0	0%			
2	Di-N-octylphthalate	ug/kg	34	0	0%			
2	Endrin aldehyde	ug/kg	34	0	0%			
2	Endrin ketone	ug/kg	34	0	0%			
2	Gallium	mg/kg	2	2	100%	14	15	16

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
2	Heptachlor	ug/kg	34	0	0%			
2	Hexachlorobenzene	ug/kg	34	1	3%	0.3	0.3	0.3
2	Hexachlorobutadiene	ug/kg	34	0	0%			
2	Iron	mg/kg	40	40	100%	9880	59500	248000
2	Isophorone	ug/kg	34	0	0%			
2	Lanthanum	mg/kg	2	2	100%	41.8	42.3	42.8
2	Lead	mg/kg	40	40	100%	16	222	1590
2	Lithium	mg/kg	2	2	100%	17	18.2	19.3
2	Magnesium	mg/kg	40	40	100%	4450	9470	19800
2	Manganese	mg/kg	40	40	100%	147	1150	4860
2	Mercury	mg/kg	38	35	92%	0.0074	0.279	1.15
2	Methoxychlor	ug/kg	34	0	0%			
2	Molybdenum	mg/kg	2	2	100%	4.8	5.2	5.6
2	Nickel	mg/kg	40	40	100%	7.8	15	23
2	Nitrobenzene	ug/kg	34	0	0%			
2	N-nitrosodi-N-propylamine	ug/kg	34	0	0%			
2	N-nitrosodiphenylamine	ug/kg	34	0	0%			
2	Octachlorodibenzodioxin	pg/g	5	4	80%	4.15	33.5	77.2
2	Octachlorodibenzofuran	pg/g	5	3	60%	0.986	2.82	4.87
2	Pentachlorophenol	ug/kg	34	0	0%			
2	Phenol	ug/kg	34	0	0%			
2	Potassium	mg/kg	40	40	100%	664	2770	21300
2	Rubidium	mg/kg	2	2	100%	69	72.5	76
2	Scandium	mg/kg	2	2	100%	6.8	7.55	8.3
2	Selenium	mg/kg	15	8	53%	1.2	7.57	23.2
2	Silver	mg/kg	40	6	15%	1.2	4.1	7.7
2	Sodium	mg/kg	40	35	88%	124	1710	19300
2	Strontium	mg/kg	2	2	100%	482	506	530
2	Thallium	mg/kg	40	7	18%	0.6	1.32	4
2	Thorium	mg/kg	2	2	100%	10.3	11.1	11.9
2	Titanium	mg/kg	2	2	100%	2000	2350	2700

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
2	Uranium	mg/kg	36	15	42%	4.5	35.4	111
2	Vanadium	mg/kg	40	40	100%	15.2	30.6	80.4
2	Yttrium	mg/kg	2	2	100%	17.8	19.2	20.5
2	Zinc	mg/kg	40	40	100%	93.1	4570	24900
3	1,2,3,4,6,7,8-HpCDD	pg/g	9	4	44%	0.21	1.06	2.05
3	1,2,3,4,7,8,9-HpCDF	pg/g	9	0	0%			
3	1,2,3,4,7,8-HxCDD	pg/g	9	2	22%	0.0217	0.0342	0.0467
3	1,2,3,6,7,8-HxCDD	pg/g	9	3	33%	0.0384	0.0524	0.076
3	1,2,3,7,8,9-HxCDD	pg/g	9	3	33%	0.0244	0.0578	0.0766
3	2,2'-Oxybis(1-chloropropane)	ug/kg	44	0	0%			
3	2,3,4,6,7,8-HxCDF	pg/g	9	0	0%			
3	2,4,5-Trichlorophenol	ug/kg	44	0	0%			
3	2,4,6-Trichlorophenol	ug/kg	44	0	0%			
3	2,4-DDD	ug/kg	44	0	0%			
3	2,4-DDE	ug/kg	44	0	0%			
3	2,4-DDT	ug/kg	44	2	5%	0.28	0.49	0.7
3	2,4-Dichlorophenol	ug/kg	44	0	0%			
3	2,4-Dimethylphenol	ug/kg	44	0	0%			
3	2,4-Dinitrophenol	ug/kg	32	0	0%			
3	2,4-Dinitrotoluene	ug/kg	44	0	0%			
3	2,6-Dinitrotoluene	ug/kg	44	0	0%			
3	2-Chloronaphthalene	ug/kg	44	0	0%			
3	2-Chlorophenol	ug/kg	44	0	0%			
3	2-Methylphenol (o-cresol)	ug/kg	44	0	0%			
3	2-Nitroaniline	ug/kg	44	0	0%			
3	2-Nitrophenol	ug/kg	44	0	0%			
3	3-Nitroaniline	ug/kg	44	0	0%			
3	4,4-DDD	ug/kg	44	0	0%			
3	4,4-DDE	ug/kg	44	4	9%	0.16	0.312	0.43
3	4,4-DDT	ug/kg	44	8	18%	0.14	1.03	5.7
3	4,6-Dinitro-2-methylphenol	ug/kg	44	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
3	4-Chloro-3-methylphenol	ug/kg	44	0	0%			
3	4-Chloroaniline	ug/kg	44	0	0%			
3	4-Chlorophenyl-phenyl ether	ug/kg	44	0	0%			
3	4-Nitroaniline	ug/kg	44	0	0%			
3	4-Nitrophenol	ug/kg	44	0	0%			
3	Acetophenone	ug/kg	44	0	0%			
3	Aldrin	ug/kg	44	0	0%			
3	Alpha-BHC	ug/kg	44	0	0%			
3	Aluminum	mg/kg	57	57	100%	2530	14200	81000
3	Antimony	mg/kg	50	33	66%	0.52	9.04	42.5
3	Arsenic	mg/kg	58	53	91%	0.95	7.8	26.7
3	Atrazine	ug/kg	44	0	0%			
3	Barium	mg/kg	57	57	100%	29.6	409	1610
3	Benzaldehyde	ug/kg	44	0	0%			
3	Benzyl alcohol	ug/kg	44	0	0%			
3	Beryllium	mg/kg	57	57	100%	0.22	0.887	3
3	Beta-BHC	ug/kg	44	0	0%			
3	bis(2-Chloroethoxy)methane	ug/kg	44	0	0%			
3	bis(2-Chloroethyl)ether	ug/kg	44	1	2%	63	63	63
3	Bismuth	mg/kg	4	4	100%	0.38	0.588	0.75
3	Cadmium	mg/kg	58	54	93%	0.11	2.18	7.3
3	Calcium	mg/kg	57	57	100%	1900	17900	76500
3	Caprolactam	ug/kg	44	0	0%			
3	Cerium	mg/kg	4	4	100%	71.9	79.9	93
3	Cesium	mg/kg	4	4	100%	2.8	3.49	5.1
3	Chromium	mg/kg	57	57	100%	5.2	31.9	109
3	Cobalt	mg/kg	57	57	100%	2.6	10.5	41.6
3	Copper	mg/kg	58	58	100%	5.7	254	2240
3	Dimethyl phthalate	ug/kg	44	0	0%			
3	Di-N-octylphthalate	ug/kg	44	0	0%			
3	Endrin aldehyde	ug/kg	44	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
3	Endrin ketone	ug/kg	44	0	0%			
3	Gallium	mg/kg	4	4	100%	14.3	15.8	18
3	Heptachlor	ug/kg	44	0	0%			
3	Hexachlorobenzene	ug/kg	44	0	0%			
3	Hexachlorobutadiene	ug/kg	44	0	0%			
3	Iron	mg/kg	57	57	100%	5140	44000	266000
3	Isophorone	ug/kg	44	0	0%			
3	Lanthanum	mg/kg	4	4	100%	44.6	50.1	60
3	Lead	mg/kg	58	58	100%	3.9	202	1150
3	Lithium	mg/kg	4	4	100%	21.3	26.6	32
3	Magnesium	mg/kg	57	57	100%	1760	7730	21800
3	Manganese	mg/kg	57	57	100%	91.9	805	4690
3	Mercury	mg/kg	55	44	80%	0.004	0.254	1.2
3	Methoxychlor	ug/kg	44	3	7%	0.75	1.67	3.4
3	Molybdenum	mg/kg	4	4	100%	1.6	2.5	4.4
3	Nickel	mg/kg	57	57	100%	4.9	16.3	52.8
3	Niobium	mg/kg	1	1	100%	36.1	36.1	36.1
3	Nitrobenzene	ug/kg	44	0	0%			
3	N-nitrosodi-N-propylamine	ug/kg	44	0	0%			
3	N-nitrosodiphenylamine	ug/kg	44	0	0%			
3	Octachlorodibenzodioxin	pg/g	9	6	67%	4.97	32.5	87.1
3	Octachlorodibenzofuran	pg/g	9	6	67%	0.249	2	5.51
3	Pentachlorophenol	ug/kg	44	0	0%			
3	Phenol	ug/kg	44	0	0%			
3	Potassium	mg/kg	57	57	100%	523	3190	27000
3	Rubidium	mg/kg	4	4	100%	78	86.9	110
3	Scandium	mg/kg	4	4	100%	8.3	9.83	13
3	Selenium	mg/kg	25	11	44%	1.1	5.95	23.4
3	Silver	mg/kg	57	9	16%	0.34	1.99	5
3	Sodium	mg/kg	57	48	84%	19.5	1920	19200
3	Strontium	mg/kg	4	4	100%	406	450	486

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
3	Tantalum	mg/kg	1	1	100%	1.9	1.9	1.9
3	Thallium	mg/kg	57	6	11%	0.69	0.879	1.3
3	Thorium	mg/kg	4	4	100%	10.9	11.8	14
3	Titanium	mg/kg	4	4	100%	2530	3060	4200
3	Uranium	mg/kg	48	17	35%	3.6	27.5	78.4
3	Vanadium	mg/kg	57	57	100%	7.7	34	110
3	Ytterbium	mg/kg	1	1	100%	2.9	2.9	2.9
3	Yttrium	mg/kg	4	4	100%	21.4	26.9	35
3	Zinc	mg/kg	58	58	100%	22.4	2870	24800
5	1,2,3,4,6,7,8-HpCDD	pg/g	4	4	100%	0.161	4.37	12.2
5	1,2,3,4,7,8,9-HpCDF	pg/g	4	2	50%	0.215	0.36	0.506
5	1,2,3,4,7,8-HxCDD	pg/g	4	2	50%	0.449	0.69	0.93
5	1,2,3,6,7,8-HxCDD	pg/g	4	0	0%			
5	1,2,3,7,8,9-HxCDD	pg/g	4	1	25%	0.232	0.232	0.232
5	2,2'-Oxybis(1-chloropropane)	ug/kg	33	0	0%			
5	2,3,4,6,7,8-HxCDF	pg/g	4	2	50%	0.397	0.626	0.856
5	2,4,5-Trichlorophenol	ug/kg	33	0	0%			
5	2,4,6-Trichlorophenol	ug/kg	33	0	0%			
5	2,4-DDD	ug/kg	33	0	0%			
5	2,4-DDE	ug/kg	33	0	0%			
5	2,4-DDT	ug/kg	33	0	0%			
5	2,4-Dichlorophenol	ug/kg	33	0	0%			
5	2,4-Dimethylphenol	ug/kg	33	0	0%			
5	2,4-Dinitrophenol	ug/kg	31	0	0%			
5	2,4-Dinitrotoluene	ug/kg	33	0	0%			
5	2,6-Dinitrotoluene	ug/kg	33	0	0%			
5	2-Chloronaphthalene	ug/kg	33	0	0%			
5	2-Chlorophenol	ug/kg	33	0	0%			
5	2-Methylphenol (o-cresol)	ug/kg	33	0	0%			
5	2-Nitroaniline	ug/kg	33	0	0%			
5	2-Nitrophenol	ug/kg	33	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
5	3-Nitroaniline	ug/kg	33	0	0%			
5	4,4-DDD	ug/kg	33	1	3%	0.35	0.35	0.35
5	4,4-DDE	ug/kg	33	5	15%	0.37	0.421	0.46
5	4,4-DDT	ug/kg	33	7	21%	0.094	0.316	1.1
5	4,6-Dinitro-2-methylphenol	ug/kg	33	0	0%			
5	4-Chloro-3-methylphenol	ug/kg	33	0	0%			
5	4-Chloroaniline	ug/kg	33	0	0%			
5	4-Chlorophenyl-phenyl ether	ug/kg	33	0	0%			
5	4-Nitroaniline	ug/kg	33	0	0%			
5	4-Nitrophenol	ug/kg	33	0	0%			
5	Acetophenone	ug/kg	33	0	0%			
5	Aldrin	ug/kg	33	0	0%			
5	Alpha-BHC	ug/kg	33	1	3%	0.23	0.23	0.23
5	Aluminum	mg/kg	52	52	100%	5070	35000	91000
5	Antimony	mg/kg	26	20	77%	0.71	2.05	4.2
5	Arsenic	mg/kg	58	58	100%	2.7	10.8	22
5	Atrazine	ug/kg	33	0	0%			
5	Barium	mg/kg	52	52	100%	33.6	368	1080
5	Benzaldehyde	ug/kg	33	0	0%			
5	Benzyl alcohol	ug/kg	33	0	0%			
5	Beryllium	mg/kg	57	57	100%	0.32	1.42	2.9
5	Beta-BHC	ug/kg	33	0	0%			
5	bis(2-Chloroethoxy)methane	ug/kg	33	0	0%			
5	bis(2-Chloroethyl)ether	ug/kg	33	0	0%			
5	Bismuth	mg/kg	3	3	100%	0.53	0.683	0.81
5	Cadmium	mg/kg	58	49	84%	0.058	3.73	16.2
5	Calcium	mg/kg	36	36	100%	1590	8730	40800
5	Caprolactam	ug/kg	33	0	0%			
5	Cerium	mg/kg	3	3	100%	95.1	97.8	100
5	Cesium	mg/kg	3	3	100%	6.4	7.27	7.8
5	Chromium	mg/kg	57	57	100%	6.2	31.9	101

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
5	Cobalt	mg/kg	52	52	100%	3	10.9	21
5	Copper	mg/kg	58	57	98%	7.3	30.8	89.7
5	Dimethyl phthalate	ug/kg	33	0	0%			
5	Di-N-octylphthalate	ug/kg	33	0	0%			
5	Endrin aldehyde	ug/kg	33	1	3%	0.42	0.42	0.42
5	Endrin ketone	ug/kg	33	0	0%			
5	Gallium	mg/kg	3	3	100%	18	20.7	22
5	Heptachlor	ug/kg	33	0	0%			
5	Hexachlorobenzene	ug/kg	33	0	0%			
5	Hexachlorobutadiene	ug/kg	33	0	0%			
5	Iron	mg/kg	52	52	100%	10200	27800	53000
5	Isophorone	ug/kg	33	0	0%			
5	Lanthanum	mg/kg	3	3	100%	52.6	57.8	62.7
5	Lead	mg/kg	58	58	100%	4.4	86.7	583
5	Lithium	mg/kg	19	19	100%	29	38.8	59
5	Magnesium	mg/kg	36	36	100%	3280	7600	15700
5	Manganese	mg/kg	52	52	100%	189	791	3780
5	Mercury	mg/kg	56	47	84%	0.004	0.247	1.16
5	Methoxychlor	ug/kg	33	0	0%			
5	Molybdenum	mg/kg	5	3	60%	0.88	1.19	1.6
5	Nickel	mg/kg	57	57	100%	6.1	20.5	50.1
5	Niobium	mg/kg	1	1	100%	18	18	18
5	Nitrobenzene	ug/kg	33	0	0%			
5	N-nitrosodi-N-propylamine	ug/kg	33	0	0%			
5	N-nitrosodiphenylamine	ug/kg	33	0	0%			
5	Octachlorodibenzodioxin	pg/g	4	2	50%	138	238	338
5	Octachlorodibenzofuran	pg/g	4	3	75%	0.2	9.93	21.7
5	Pentachlorophenol	ug/kg	33	0	0%			
5	Phenol	ug/kg	33	0	0%			
5	Potassium	mg/kg	36	36	100%	881	3910	25800
5	Rubidium	mg/kg	3	3	100%	110	122	130

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
5	Scandium	mg/kg	3	3	100%	15	15.9	16.5
5	Selenium	mg/kg	53	41	77%	0.1	2.66	8.9
5	Silver	mg/kg	49	4	8%	0.5	0.6	0.8
5	Sodium	mg/kg	36	33	92%	57.2	1230	13000
5	Strontium	mg/kg	19	19	100%	130	205	300
5	Tantalum	mg/kg	1	1	100%	1.2	1.2	1.2
5	Thallium	mg/kg	37	3	8%	1	1.33	1.8
5	Thorium	mg/kg	3	3	100%	13	14.8	15.8
5	Titanium	mg/kg	19	19	100%	2300	3860	5100
5	Uranium	mg/kg	36	5	14%	3.4	5.32	6.4
5	Vanadium	mg/kg	52	52	100%	8.4	49.5	125
5	Ytterbium	mg/kg	1	1	100%	3.2	3.2	3.2
5	Yttrium	mg/kg	3	3	100%	30.3	39.4	45.8
5	Zinc	mg/kg	58	58	100%	26.5	451	1400
6	1,2,3,4,6,7,8-HpCDD	pg/g	7	6	86%	0.0764	1.65	9.19
6	1,2,3,4,7,8,9-HpCDF	pg/g	7	1	14%	0.555	0.555	0.555
6	1,2,3,4,7,8-HxCDD	pg/g	7	1	14%	0.936	0.936	0.936
6	1,2,3,6,7,8-HxCDD	pg/g	7	1	14%	0.658	0.658	0.658
6	1,2,3,7,8,9-HxCDD	pg/g	7	1	14%	0.34	0.34	0.34
6	2,2'-Oxybis(1-chloropropane)	ug/kg	40	0	0%			
6	2,3,4,6,7,8-HxCDF	pg/g	7	2	29%	0.0528	0.496	0.94
6	2,4,5-Trichlorophenol	ug/kg	40	0	0%			
6	2,4,6-Trichlorophenol	ug/kg	40	0	0%			
6	2,4-DDD	ug/kg	40	0	0%			
6	2,4-DDE	ug/kg	40	0	0%			
6	2,4-DDT	ug/kg	40	4	10%	0.09	1.84	6.5
6	2,4-Dichlorophenol	ug/kg	40	0	0%			
6	2,4-Dimethylphenol	ug/kg	40	0	0%			
6	2,4-Dinitrophenol	ug/kg	34	0	0%			
6	2,4-Dinitrotoluene	ug/kg	40	0	0%			
6	2,6-Dinitrotoluene	ug/kg	40	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
6	2-Chloronaphthalene	ug/kg	40	0	0%			
6	2-Chlorophenol	ug/kg	40	0	0%			
6	2-Methylphenol (o-cresol)	ug/kg	40	0	0%			
6	2-Nitroaniline	ug/kg	40	0	0%			
6	2-Nitrophenol	ug/kg	40	0	0%			
6	3-Nitroaniline	ug/kg	40	0	0%			
6	4,4-DDD	ug/kg	40	1	3%	2.1	2.1	2.1
6	4,4-DDE	ug/kg	40	1	3%	0.5	0.5	0.5
6	4,4-DDT	ug/kg	40	7	18%	0.08	3.38	20
6	4,6-Dinitro-2-methylphenol	ug/kg	40	0	0%			
6	4-Chloro-3-methylphenol	ug/kg	40	0	0%			
6	4-Chloroaniline	ug/kg	40	0	0%			
6	4-Chlorophenyl-phenyl ether	ug/kg	40	0	0%			
6	4-Nitroaniline	ug/kg	40	0	0%			
6	4-Nitrophenol	ug/kg	40	0	0%			
6	Acetophenone	ug/kg	40	0	0%			
6	Aldrin	ug/kg	40	0	0%			
6	Alpha-BHC	ug/kg	40	0	0%			
6	Aluminum	mg/kg	47	47	100%	4680	18300	77800
6	Antimony	mg/kg	14	6	43%	0.8	1.14	1.7
6	Arsenic	mg/kg	49	44	90%	1.8	8.1	15.5
6	Atrazine	ug/kg	40	0	0%			
6	Barium	mg/kg	47	47	100%	35.5	204	1030
6	Benzaldehyde	ug/kg	40	0	0%			
6	Benzyl alcohol	ug/kg	40	0	0%			
6	Beryllium	mg/kg	47	47	100%	0.35	1.24	2.5
6	Beta-BHC	ug/kg	40	0	0%			
6	bis(2-Chloroethoxy)methane	ug/kg	40	0	0%			
6	bis(2-Chloroethyl)ether	ug/kg	40	0	0%			
6	Bismuth	mg/kg	4	4	100%	0.27	0.33	0.42
6	Cadmium	mg/kg	49	33	67%	0.038	3.46	12.4

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
6	Calcium	mg/kg	47	47	100%	1430	6280	18800
6	Caprolactam	ug/kg	40	0	0%			
6	Cerium	mg/kg	4	4	100%	81.2	87.2	102
6	Cesium	mg/kg	4	4	100%	4.7	5.28	6.2
6	Chromium	mg/kg	47	47	100%	1.2	23.5	79
6	Cobalt	mg/kg	47	47	100%	2.7	8.89	18.4
6	Copper	mg/kg	49	46	94%	5.5	30.8	86.1
6	Dimethyl phthalate	ug/kg	40	0	0%			
6	Di-N-octylphthalate	ug/kg	40	0	0%			
6	Endrin aldehyde	ug/kg	40	0	0%			
6	Endrin ketone	ug/kg	40	0	0%			
6	Gallium	mg/kg	4	4	100%	16	18	20
6	Heptachlor	ug/kg	40	0	0%			
6	Hexachlorobenzene	ug/kg	40	0	0%			
6	Hexachlorobutadiene	ug/kg	40	0	0%			
6	Iron	mg/kg	47	47	100%	9830	23200	44200
6	Isophorone	ug/kg	40	0	0%			
6	Lanthanum	mg/kg	4	4	100%	44.6	47	51.6
6	Lead	mg/kg	49	49	100%	3.9	71.6	462
6	Lithium	mg/kg	4	4	100%	27	31	36.7
6	Magnesium	mg/kg	47	47	100%	3460	6960	14000
6	Manganese	mg/kg	47	47	100%	102	627	2220
6	Mercury	mg/kg	45	28	62%	0.004	0.474	1.8
6	Methoxychlor	ug/kg	40	0	0%			
6	Molybdenum	mg/kg	4	4	100%	0.31	0.506	0.78
6	Nickel	mg/kg	47	47	100%	0.68	16.8	37.2
6	Nitrobenzene	ug/kg	40	0	0%			
6	N-nitrosodi-N-propylamine	ug/kg	40	0	0%			
6	N-nitrosodiphenylamine	ug/kg	40	0	0%			
6	Octachlorodibenzodioxin	pg/g	7	5	71%	4.02	56.4	248
6	Octachlorodibenzofuran	pg/g	7	5	71%	0.155	3.65	17

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
6	Pentachlorophenol	ug/kg	40	0	0%			
6	Phenol	ug/kg	40	0	0%			
6	Potassium	mg/kg	47	47	100%	747	4200	27400
6	Rubidium	mg/kg	4	4	100%	104	114	125
6	Scandium	mg/kg	4	4	100%	9.6	11.3	13.2
6	Selenium	mg/kg	40	29	73%	1.3	4.35	8.6
6	Silver	mg/kg	38	3	8%	0.8	1	1.2
6	Sodium	mg/kg	47	44	94%	49.3	1590	17300
6	Strontium	mg/kg	4	4	100%	296	377	492
6	Thallium	mg/kg	47	4	9%	0.7	0.762	0.85
6	Thorium	mg/kg	4	4	100%	10.9	13.3	15.7
6	Titanium	mg/kg	4	4	100%	2500	3390	4300
6	Uranium	mg/kg	44	7	16%	2.65	4.16	5.4
6	Vanadium	mg/kg	47	47	100%	8.9	34	90
6	Yttrium	mg/kg	4	4	100%	18.7	21.9	26
6	Zinc	mg/kg	49	49	100%	27.9	286	1210
4a	1,2,3,4,6,7,8-HpCDD	pg/g	8	4	50%	0.987	2.31	3.85
4a	1,2,3,4,7,8,9-HpCDF	pg/g	8	4	50%	0.0618	0.154	0.224
4a	1,2,3,4,7,8-HxCDD	pg/g	8	4	50%	0.142	0.302	0.513
4a	1,2,3,6,7,8-HxCDD	pg/g	8	4	50%	0.102	0.226	0.364
4a	1,2,3,7,8,9-HxCDD	pg/g	8	2	25%	0.107	0.146	0.184
4a	2,2'-Oxybis(1-chloropropane)	ug/kg	44	0	0%			
4a	2,3,4,6,7,8-HxCDF	pg/g	8	4	50%	0.0453	0.237	0.45
4a	2,4,5-Trichlorophenol	ug/kg	44	0	0%			
4a	2,4,6-Trichlorophenol	ug/kg	44	0	0%			
4a	2,4-DDD	ug/kg	44	0	0%			
4a	2,4-DDE	ug/kg	44	0	0%			
4a	2,4-DDT	ug/kg	44	1	2%	0.51	0.51	0.51
4a	2,4-Dichlorophenol	ug/kg	44	0	0%			
4a	2,4-Dimethylphenol	ug/kg	44	0	0%			
4a	2,4-Dinitrophenol	ug/kg	36	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
4a	2,4-Dinitrotoluene	ug/kg	44	0	0%			
4a	2,6-Dinitrotoluene	ug/kg	44	0	0%			
4a	2-Chloronaphthalene	ug/kg	44	0	0%			
4a	2-Chlorophenol	ug/kg	44	0	0%			
4a	2-Methylphenol (o-cresol)	ug/kg	44	0	0%			
4a	2-Nitroaniline	ug/kg	44	0	0%			
4a	2-Nitrophenol	ug/kg	44	0	0%			
4a	3-Nitroaniline	ug/kg	44	0	0%			
4a	4,4-DDD	ug/kg	44	0	0%			
4a	4,4-DDE	ug/kg	44	4	9%	0.16	1.61	5.2
4a	4,4-DDT	ug/kg	44	4	9%	1	5.92	10
4a	4,6-Dinitro-2-methylphenol	ug/kg	44	0	0%			
4a	4-Chloro-3-methylphenol	ug/kg	44	0	0%			
4a	4-Chloroaniline	ug/kg	44	0	0%			
4a	4-Chlorophenyl-phenyl ether	ug/kg	44	0	0%			
4a	4-Nitroaniline	ug/kg	44	0	0%			
4a	4-Nitrophenol	ug/kg	44	0	0%			
4a	Acetophenone	ug/kg	44	0	0%			
4a	Aldrin	ug/kg	44	0	0%			
4a	Alpha-BHC	ug/kg	44	0	0%			
4a	Aluminum	mg/kg	66	66	100%	3000	14200	79900
4a	Antimony	mg/kg	56	32	57%	0.35	2.64	6.4
4a	Arsenic	mg/kg	66	63	95%	0.81	6.08	20.2
4a	Atrazine	ug/kg	44	0	0%			
4a	Barium	mg/kg	66	66	100%	29.2	287	1240
4a	Benzaldehyde	ug/kg	44	0	0%			
4a	Benzyl alcohol	ug/kg	44	0	0%			
4a	Beryllium	mg/kg	66	66	100%	0.21	0.92	3
4a	Beta-BHC	ug/kg	44	0	0%			
4a	bis(2-Chloroethoxy)methane	ug/kg	44	0	0%			
4a	bis(2-Chloroethyl)ether	ug/kg	44	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
4a	Bismuth	mg/kg	4	4	100%	0.1	0.381	0.8
4a	Cadmium	mg/kg	66	61	92%	0.057	2.82	11.1
4a	Calcium	mg/kg	66	66	100%	879	11300	34900
4a	Caprolactam	ug/kg	44	2	5%	50	100	150
4a	Cerium	mg/kg	4	4	100%	54.6	75	100
4a	Cesium	mg/kg	4	4	100%	1.8	3.41	5
4a	Chromium	mg/kg	66	66	100%	5.5	25.7	76.8
4a	Cobalt	mg/kg	66	66	100%	2.2	8.07	16.7
4a	Copper	mg/kg	66	66	100%	4.2	49.6	164
4a	Dimethyl phthalate	ug/kg	44	0	0%			
4a	Di-N-octylphthalate	ug/kg	44	0	0%			
4a	Endrin aldehyde	ug/kg	44	0	0%			
4a	Endrin ketone	ug/kg	44	0	0%			
4a	Gallium	mg/kg	4	4	100%	15	15.8	18
4a	Heptachlor	ug/kg	44	0	0%			
4a	Hexachlorobenzene	ug/kg	44	1	2%	0.092	0.092	0.092
4a	Hexachlorobutadiene	ug/kg	44	0	0%			
4a	Iron	mg/kg	66	66	100%	5180	20000	42000
4a	Isophorone	ug/kg	44	0	0%			
4a	Lanthanum	mg/kg	4	4	100%	32	47.6	75
4a	Lead	mg/kg	66	66	100%	2.6	130	841
4a	Lithium	mg/kg	4	4	100%	15.8	26.5	42.1
4a	Magnesium	mg/kg	66	66	100%	1390	7530	21400
4a	Manganese	mg/kg	66	66	100%	106	432	1150
4a	Mercury	mg/kg	63	40	63%	0.0063	0.637	2.4
4a	Methoxychlor	ug/kg	44	0	0%			
4a	Molybdenum	mg/kg	4	4	100%	0.36	1.04	2.2
4a	Nickel	mg/kg	66	66	100%	4.1	19.7	38
4a	Niobium	mg/kg	1	1	100%	21	21	21
4a	Nitrobenzene	ug/kg	44	0	0%			
4a	N-nitrosodi-N-propylamine	ug/kg	44	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
4a	N-nitrosodiphenylamine	ug/kg	44	0	0%			
4a	Octachlorodibenzodioxin	pg/g	8	5	63%	14.5	80	160
4a	Octachlorodibenzofuran	pg/g	8	5	63%	0.98	5.35	11.1
4a	Pentachlorophenol	ug/kg	44	0	0%			
4a	Phenol	ug/kg	44	0	0%			
4a	Potassium	mg/kg	66	66	100%	372	3080	26800
4a	Rubidium	mg/kg	4	4	100%	90.5	95.4	101
4a	Scandium	mg/kg	4	4	100%	7	9.16	11.6
4a	Selenium	mg/kg	40	9	23%	0.84	3.48	7.8
4a	Silver	mg/kg	66	19	29%	0.25	1.24	2.9
4a	Sodium	mg/kg	66	65	98%	42.1	1480	23500
4a	Strontium	mg/kg	4	4	100%	399	504	601
4a	Tantalum	mg/kg	1	1	100%	1.4	1.4	1.4
4a	Thallium	mg/kg	66	4	6%	0.6	0.748	0.9
4a	Thorium	mg/kg	4	4	100%	8.4	10.8	13.9
4a	Titanium	mg/kg	4	4	100%	1950	2890	4100
4a	Uranium	mg/kg	48	8	17%	1.45	6.06	11.5
4a	Vanadium	mg/kg	66	66	100%	9.1	33.6	103
4a	Ytterbium	mg/kg	1	1	100%	2.8	2.8	2.8
4a	Yttrium	mg/kg	4	4	100%	13.3	21.2	33
4a	Zinc	mg/kg	66	66	100%	16	365	1460
4b	1,2,3,4,6,7,8-HpCDD	pg/g	15	9	60%	0.274	0.792	2.02
4b	1,2,3,4,7,8,9-HpCDF	pg/g	15	2	13%	0.103	0.14	0.177
4b	1,2,3,4,7,8-HxCDD	pg/g	15	3	20%	0.035	0.147	0.312
4b	1,2,3,6,7,8-HxCDD	pg/g	15	4	27%	0.019	0.0367	0.0572
4b	1,2,3,7,8,9-HxCDD	pg/g	15	4	27%	0.0282	0.0641	0.1
4b	2,2'-Oxybis(1-chloropropane)	ug/kg	74	0	0%			
4b	2,3,4,6,7,8-HxCDF	pg/g	15	7	47%	0.0164	0.0919	0.211
4b	2,4,5-Trichlorophenol	ug/kg	74	0	0%			
4b	2,4,6-Trichlorophenol	ug/kg	74	0	0%			
4b	2,4-DDD	ug/kg	74	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
4b	2,4-DDE	ug/kg	74	6	8%	0.09	3.2	17
4b	2,4-DDT	ug/kg	74	11	15%	0.19	5.81	57
4b	2,4-Dichlorophenol	ug/kg	74	0	0%			
4b	2,4-Dimethylphenol	ug/kg	74	0	0%			
4b	2,4-Dinitrophenol	ug/kg	61	0	0%			
4b	2,4-Dinitrotoluene	ug/kg	74	0	0%			
4b	2,6-Dinitrotoluene	ug/kg	74	0	0%			
4b	2-Chloronaphthalene	ug/kg	74	0	0%			
4b	2-Chlorophenol	ug/kg	74	0	0%			
4b	2-Methylphenol (o-cresol)	ug/kg	74	0	0%			
4b	2-Nitroaniline	ug/kg	74	0	0%			
4b	2-Nitrophenol	ug/kg	74	0	0%			
4b	3-Nitroaniline	ug/kg	74	0	0%			
4b	4,4-DDD	ug/kg	74	1	1%	2.1	2.1	2.1
4b	4,4-DDE	ug/kg	74	14	19%	0.062	5.06	63
4b	4,4-DDT	ug/kg	74	29	39%	0.1	8.06	200
4b	4,6-Dinitro-2-methylphenol	ug/kg	74	0	0%			
4b	4-Chloro-3-methylphenol	ug/kg	74	0	0%			
4b	4-Chloroaniline	ug/kg	74	0	0%			
4b	4-Chlorophenyl-phenyl ether	ug/kg	74	0	0%			
4b	4-Nitroaniline	ug/kg	74	0	0%			
4b	4-Nitrophenol	ug/kg	74	0	0%			
4b	Acetophenone	ug/kg	74	0	0%			
4b	Aldrin	ug/kg	74	0	0%			
4b	Alpha-BHC	ug/kg	74	0	0%			
4b	Aluminum	mg/kg	82	82	100%	2760	14500	76200
4b	Antimony	mg/kg	42	25	60%	0.53	1.78	4.2
4b	Arsenic	mg/kg	83	75	90%	1.8	6.82	17.5
4b	Atrazine	ug/kg	74	0	0%			
4b	Barium	mg/kg	82	82	100%	20.6	194	1180
4b	Benzaldehyde	ug/kg	74	0	0%			

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
4b	Benzyl alcohol	ug/kg	74	0	0%			
4b	Beryllium	mg/kg	82	82	100%	0.21	1.03	2.7
4b	Beta-BHC	ug/kg	74	0	0%			
4b	bis(2-Chloroethoxy)methane	ug/kg	74	0	0%			
4b	bis(2-Chloroethyl)ether	ug/kg	74	0	0%			
4b	Bismuth	mg/kg	4	4	100%	0.44	0.558	0.66
4b	Cadmium	mg/kg	83	73	88%	0.052	2.34	14.2
4b	Calcium	mg/kg	82	82	100%	1320	6750	38200
4b	Caprolactam	ug/kg	74	2	3%	43	49	55
4b	Cerium	mg/kg	4	4	100%	87.9	100	120
4b	Cesium	mg/kg	4	4	100%	4.2	5.22	6.5
4b	Chromium	mg/kg	82	82	100%	4.6	27.2	101
4b	Cobalt	mg/kg	82	82	100%	2.1	9.32	18.4
4b	Copper	mg/kg	83	82	99%	3	33	98.5
4b	Dimethyl phthalate	ug/kg	74	0	0%			
4b	Di-N-octylphthalate	ug/kg	74	0	0%			
4b	Endrin aldehyde	ug/kg	74	0	0%			
4b	Endrin ketone	ug/kg	74	0	0%			
4b	Gallium	mg/kg	4	4	100%	17	17.8	19
4b	Heptachlor	ug/kg	74	0	0%			
4b	Hexachlorobenzene	ug/kg	74	4	5%	0.096	2.82	8.5
4b	Hexachlorobutadiene	ug/kg	74	0	0%			
4b	Iron	mg/kg	82	82	100%	4930	21700	42000
4b	Isophorone	ug/kg	74	0	0%			
4b	Lanthanum	mg/kg	4	4	100%	53	63.8	74
4b	Lead	mg/kg	83	83	100%	3	95.6	841
4b	Lithium	mg/kg	4	4	100%	30	33.8	40
4b	Magnesium	mg/kg	82	82	100%	1540	6650	22400
4b	Manganese	mg/kg	82	82	100%	95.3	486	3200
4b	Mercury	mg/kg	78	66	85%	0.005	0.395	2.4
4b	Methoxychlor	ug/kg	74	1	1%	2.4	2.4	2.4

Table 7. Concentration Ranges of COPCs in Surface Sediment, by Reach

Reach	Analyte	Units	Number of measurements	Number of detected values	Detection frequency (%)	Minimum detected value	Mean detected value	Maximum detected value
4b	Molybdenum	mg/kg	4	4	100%	1	1.35	1.7
4b	Nickel	mg/kg	82	82	100%	2.8	21.3	48
4b	Niobium	mg/kg	2	2	100%	20	23.5	27
4b	Nitrobenzene	ug/kg	74	0	0%			
4b	N-nitrosodi-N-propylamine	ug/kg	74	0	0%			
4b	N-nitrosodiphenylamine	ug/kg	74	0	0%			
4b	Octachlorodibenzodioxin	pg/g	15	9	60%	12.9	37.7	77.8
4b	Octachlorodibenzofuran	pg/g	15	9	60%	0.651	1.85	5.49
4b	Pentachlorophenol	ug/kg	74	0	0%			
4b	Phenol	ug/kg	74	0	0%			
4b	Potassium	mg/kg	82	82	100%	317	2930	25000
4b	Rubidium	mg/kg	4	4	100%	96	107	120
4b	Scandium	mg/kg	4	4	100%	12	13	14
4b	Selenium	mg/kg	44	25	57%	0.58	4.09	7.9
4b	Silver	mg/kg	70	4	6%	0.66	1.16	1.7
4b	Sodium	mg/kg	82	73	89%	56.3	1080	21000
4b	Strontium	mg/kg	4	4	100%	290	374	420
4b	Tantalum	mg/kg	2	2	100%	1.3	1.4	1.5
4b	Thallium	mg/kg	82	4	5%	0.94	1.31	1.8
4b	Thorium	mg/kg	4	4	100%	13.8	13.9	14
4b	Titanium	mg/kg	4	4	100%	3400	3850	4300
4b	Uranium	mg/kg	78	17	22%	3.1	9.04	21.7
4b	Vanadium	mg/kg	82	82	100%	8.7	34.1	112
4b	Ytterbium	mg/kg	2	2	100%	2.4	2.55	2.7
4b	Yttrium	mg/kg	4	4	100%	25	34.2	47
4b	Zinc	mg/kg	83	83	100%	21.3	271	1710

Table 8. Linear Regression Parameters between COPC and Sediment Particle Classes for Class III Samples in the EPA Phase I Data Set.

	Clay				Silt				Total Fines				Sand				Medium Sand			
	By Surface Area		By Weight		By Surface Area		By Weight		By Surface Area		By Weight		By Surface Area		By Weight		By Surface Area		By Weight	
Metals	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2	Slope $\times 10^3$	R^2
Aluminum	62.4	**0.826**	53200	**0.822**	0.43	0.027	2060	0.006	32.7	**0.829**	1370	**0.391**	-2300	**0.681**	-77000	**0.705**	-7000	**0.526**	-350000	**0.62**
Antimony	0.38	**0.512**	328	**0.518**	0	-0.01	1.39	-0.01	0.2	**0.508**	6.94	**0.159**	-13	**0.361**	-450	**0.39**	-50	**0.456**	-2300	**0.472**
Arsenic	0.24	**0.198**	208	**0.211**	0	-0.01	-2.7	-0.01	0.13	**0.208**	4.38	**0.059**	-8.5	**0.149**	-290	**0.165**	-34	**0.206**	-1600	**0.22**
Barium	1.6	**0.095**	1240	**0.076**	0.07	**0.195**	448	**0.18**	0.89	**0.11**	73.4	**0.216**	-61	**0.079**	-2100	**0.097**	-210	**0.08**	-11000	**0.119**
Beryllium	0.18	**0.794**	156	**0.806**	0	0.012	4.79	0	0.09	**0.793**	3.97	**0.374**	-6.8	**0.668**	-230	**0.696**	-20	**0.517**	-1000	**0.627**
Cadmium	0.23	**0.435**	189	**0.403**	0	0.039	12.7	0.017	0.12	**0.437**	5.02	**0.2**	-6.7	**0.212**	-230	**0.248**	-26	**0.282**	-1300	**0.314**
Calcium	-0.8	0.016	-810	0.026	0.03	0.039	250	**0.049**	-0.4	0.014	7.43	-0.01	31.4	0.011	936	0.008	71.9	0	3430	0
Chromium	1.81	**0.592**	1570	**0.612**	0.02	**0.052**	108	0.035	0.96	**0.609**	48.5	**0.42**	-74	**0.586**	-2400	**0.61**	-220	**0.424**	-11000	**0.51**
Cobalt	1.02	**0.77**	879	**0.78**	0.01	0.025	35.9	0.007	0.54	**0.774**	23.4	**0.396**	-39	**0.656**	-1300	**0.68**	-120	**0.516**	-5800	**0.612**
Copper	0.52	**0.078**	449	**0.079**	0.02	**0.085**	113	**0.083**	0.29	**0.089**	23.2	**0.168**	-23	**0.088**	-780	**0.102**	-69	**0.068**	-3700	**0.098**
Iron	126	**0.456**	110000	**0.476**	0.75	0.002	3360	-0.01	67.2	**0.473**	2870	**0.229**	-5100	**0.439**	-170000	**0.46**	-16000	**0.376**	-770000	**0.411**
Lead	1.08	**0.167**	887	**0.155**	0.02	0.044	110	0.029	0.58	**0.176**	29.6	**0.123**	-31	**0.077**	-1100	**0.099**	-120	**0.098**	-6100	**0.13**
Magnesium	33.5	**0.119**	26900	**0.104**	1.11	0.137	7170	**0.125**	18.3	**0.132**	1350	**0.203**	-1300	**0.105**	-45000	**0.124**	-4600	**0.116**	-240000	**0.155**
Manganese	3.02	**0.674**	2620	**0.699**	0.01	-0.01	-0.2	-0.01	1.57	**0.668**	58	**0.24**	-110	**0.567**	-3700	**0.588**	-380	**0.533**	-18000	**0.605**
Mercury	0.06	**0.44**	49	**0.433**	0	0.069	4.64	**0.052**	0.03	**0.446**	1.6	**0.332**	-2.2	**0.361**	-73	**0.398**	-6.5	**0.283**	-320	**0.325**
Nickel	1.92	**0.72**	1630	**0.714**	0.02	0.076	119	**0.05**	1.01	**0.73**	49.2	**0.469**	-75	**0.65**	-2500	**0.672**	-220	**0.471**	-11000	**0.564**
Potassium	30.9	**0.798**	26300	**0.795**	0.21	0.022	961	0.003	16.2	**0.799**	667	**0.365**	-1100	**0.633**	-37000	**0.655**	-3500	**0.511**	-170000	**0.601**
Selenium	0.26	**0.239**	217	**0.225**	0.01	0.142	41.9	**0.133**	0.14	**0.253**	9.7	**0.334**	-12	**0.29**	-370	**0.278**	-27	**0.121**	-1400	**0.165**
Silver	0.14	**0.719**	121	**0.726**	0	0.025	5.53	0.011	0.07	**0.72**	3.29	**0.388**	-5.3	**0.613**	-180	**0.646**	-17	**0.51**	-820	**0.602**
Sodium	4.77	**0.632**	4120	**0.647**	0.04	0.044	253	0.027	2.5	**0.635**	121	**0.405**	-180	**0.556**	-6100	**0.583**	-510	**0.358**	-26000	**0.467**
Thallium	0.28	**0.722**	240	**0.728**	0	0.027	11.2	0.012	0.15	**0.723**	6.56	**0.391**	-11	**0.612**	-350	**0.646**	-33	**0.521**	-1600	**0.613**
Uranium	1.74	**0.448**	1510	**0.466**	0	-0.01	-11	-0.01	0.91	**0.449**	32	**0.143**	-67	**0.394**	-2200	**0.421**	-230	**0.406**	-11000	**0.442**
Vanadium	1.78	**0.503**	1560	**0.534**	0.01	0.005	55.5	0	0.94	**0.516**	43.5	**0.295**	-74	**0.526**	-2500	**0.543**	-210	**0.36**	-11000	**0.434**
Zinc	1.24	**0.046**	1070	**0.047**	0.01	-0.01	65.5	-0.01	0.69	**0.053**	28.7	0.018	-34	0.012	-1300	0.024	-170	**0.045**	-7400	0.039

Note:
Bold values represent statistically significant models at $P \leq 0.05$. Values for R^2 were adjusted for each model with penalties for higher P.

Table 9. ANOVA Table for Mixed Effects Linear Model for Temporal Trends

	Fixed Effect DF	Total DF	F Value	p Value
Intercept	1	9259	7328.73	<.0001
Year	1	9259	1009.943	<.0001
Analyte	38	9259	4176.624	<.0001
Year × Analyte	38	9259	22.149	<.0001

Note:
DF = degrees of freedom

Table 10. Multiple Comparisons ANOVA Table for the Mixed Effects Linear Model for Temporal Trends

Analyte	Temporal Trend	Adjusted p-value				
		Overall	2002-2001	2003-2002	2004-2003	2005-2004
Aluminum	--[a]	0.38				
Antimony	--	1.00				
Arsenic	down	0.02	0.62	0.86	0.70	0.00
Barium	down	0.00	0.02	0.98	1.00	0.00
Beryllium	up	0.01	0.00	0.71	0.36	0.00
Bismuth	down	0.00		0.02	0.19	
Cadmium	down	0.00	0.27	0.24	1.00	0.02
Calcium	down	0.00	0.18	0.02	0.45	0.00
Cerium	--	0.97				
Cesium	--	1.00				
Chromium	--	1.00				
Cobalt	--	0.95				
Copper	down	0.00	0.10	0.47	0.42	0.00
Gallium	--	0.06				
Iron	down	0.00	0.60	0.87	0.52	0.00
Lanthanum	down	0.01		0.87	0.00	
Lead	down	0.00	0.90	0.26	0.07	0.00
Lithium	--	0.81				
Magnesium	--	1.00				
Manganese	down	0.00	0.25	0.07	0.88	0.00
Mercury	--	1.00				
Molybdenum	--	1.00				
Nickel	--	0.18				
Niobium	--	1.00				
Phosphorus	--	0.75				
Potassium	down	0.00	0.00	1.00	0.89	0.00
Rubidium	--	1.00				
Scandium	--	1.00				
Silver	--	0.60				
Sodium	down	0.00	0.00	1.00	0.45	0.00
Strontium	up	0.00		0.00		
Tantalum	--	1.00				
Thallium	down	0.02	0.12	0.18	0.01	0.22
Thorium	--	1.00				
Titanium	down	0.00		0.87	0.00	
Uranium	up	0.01		0.96	1.00	0.00
Vanadium	--	0.99				
Yttrium	down	0.00		0.94	0.00	
Zinc	down	0.00	0.97	0.73	0.36	0.00

Notes:

[a] No trend

Significance is recognized for Bonferroni-adjusted p-values ≤ 0.05.

Table 11. Results of a Runs Test on Sediment COPC Concentrations in Phase I Cores

Core Location	Analyte	Number of Samples	p Value
RM622C1	Aluminum	6	0.18
RM637C1	Aluminum	4	0.11
RM644C1	Aluminum	5	0.74
RM661C1	Aluminum	5	0.74
RM676C1	Aluminum	5	0.33
RM692C1	Aluminum	5	0.06
RM704C1	Aluminum	6	0.03
RM708C1	Aluminum	5	0.06
RM704C1	Antimony	6	0.18
RM708C1	Antimony	5	0.33
RM622C1	Arsenic	6	0.82
RM637C1	Arsenic	4	0.11
RM661C1	Arsenic	5	0.74
RM676C1	Arsenic	5	0.74
RM692C1	Arsenic	5	0.50
RM704C1	Arsenic	6	0.03
RM708C1	Arsenic	5	0.06
RM622C1	Barium	6	0.82
RM637C1	Barium	4	0.11
RM644C1	Barium	5	0.06
RM661C1	Barium	5	0.06
RM676C1	Barium	5	0.74
RM692C1	Barium	5	0.89
RM704C1	Barium	6	0.03
RM708C1	Barium	5	0.06
RM622C1	Beryllium	6	0.82
RM637C1	Beryllium	4	0.11
RM644C1	Beryllium	5	0.06
RM661C1	Beryllium	5	0.74
RM676C1	Beryllium	5	0.33
RM692C1	Beryllium	5	0.06
RM704C1	Beryllium	6	0.00
RM708C1	Beryllium	5	0.06
RM622C1	Cadmium	4	0.11
RM637C1	Cadmium	4	0.11
RM644C1	Cadmium	4	0.11
RM661C1	Cadmium	5	0.50
RM676C1	Cadmium	5	0.74
RM692C1	Cadmium	5	0.33
RM704C1	Cadmium	4	0.11
RM708C1	Cadmium	5	0.00
RM622C1	Calcium	6	0.18
RM637C1	Calcium	4	0.11
RM644C1	Calcium	5	0.06
RM661C1	Calcium	5	0.89
RM676C1	Calcium	5	0.74
RM692C1	Calcium	5	0.06
RM704C1	Calcium	6	0.03

Table 11. Results of a Runs Test on Sediment COPC Concentrations in Phase I Cores

Core Location	Analyte	Number of Samples	p Value
RM708C1	Calcium	5	0.06
RM622C1	Chromium	6	0.18
RM637C1	Chromium	4	0.11
RM644C1	Chromium	5	0.74
RM661C1	Chromium	5	0.74
RM676C1	Chromium	5	0.33
RM692C1	Chromium	5	0.06
RM704C1	Chromium	6	0.82
RM708C1	Chromium	5	0.06
RM622C1	Cobalt	6	0.18
RM637C1	Cobalt	4	0.11
RM644C1	Cobalt	5	0.74
RM661C1	Cobalt	5	0.74
RM676C1	Cobalt	5	0.74
RM692C1	Cobalt	5	0.74
RM704C1	Cobalt	6	0.08
RM708C1	Cobalt	5	0.06
RM622C1	Copper	6	0.50
RM637C1	Copper	4	0.11
RM644C1	Copper	5	0.06
RM661C1	Copper	5	0.06
RM676C1	Copper	5	0.33
RM692C1	Copper	5	0.33
RM704C1	Copper	6	0.03
RM708C1	Copper	5	0.06
RM622C1	Iron	6	0.18
RM637C1	Iron	4	0.11
RM644C1	Iron	5	0.74
RM661C1	Iron	5	0.74
RM676C1	Iron	5	0.50
RM692C1	Iron	5	0.50
RM704C1	Iron	6	0.18
RM708C1	Iron	5	0.06
RM622C1	Lead	6	0.50
RM637C1	Lead	4	0.11
RM644C1	Lead	5	0.06
RM661C1	Lead	5	0.50
RM676C1	Lead	5	0.06
RM692C1	Lead	5	0.50
RM704C1	Lead	6	0.03
RM708C1	Lead	5	0.06
RM622C1	Magnesium	6	0.18
RM637C1	Magnesium	4	0.11
RM644C1	Magnesium	5	0.33
RM661C1	Magnesium	5	0.06
RM676C1	Magnesium	5	0.74
RM692C1	Magnesium	5	0.89
RM704C1	Magnesium	6	0.03

Table 11. Results of a Runs Test on Sediment COPC Concentrations in Phase I Cores

Core Location	Analyte	Number of Samples	p Value
RM708C1	Magnesium	5	0.06
RM622C1	Manganese	6	0.18
RM637C1	Manganese	4	0.11
RM644C1	Manganese	5	0.06
RM661C1	Manganese	5	0.74
RM676C1	Manganese	5	0.06
RM692C1	Manganese	5	0.06
RM704C1	Manganese	6	0.03
RM708C1	Manganese	5	0.06
RM644C1	Mercury	5	0.06
RM661C1	Mercury	5	0.50
RM676C1	Mercury	5	0.33
RM692C1	Mercury	5	0.74
RM704C1	Mercury	6	0.50
RM708C1	Mercury	5	0.74
RM622C1	Nickel	6	0.82
RM637C1	Nickel	4	0.11
RM644C1	Nickel	5	0.33
RM661C1	Nickel	5	0.74
RM676C1	Nickel	5	0.33
RM692C1	Nickel	5	0.06
RM704C1	Nickel	6	0.79
RM708C1	Nickel	5	0.92
RM622C1	Potassium	6	0.82
RM637C1	Potassium	4	0.11
RM644C1	Potassium	5	0.06
RM661C1	Potassium	5	0.74
RM676C1	Potassium	5	0.50
RM692C1	Potassium	5	0.06
RM704C1	Potassium	6	0.18
RM708C1	Potassium	5	0.06
RM622C1	Selenium	6	0.97
RM637C1	Selenium	4	0.11
RM661C1	Selenium	5	0.06
RM676C1	Selenium	5	0.74
RM692C1	Selenium	5	0.33
RM708C1	Selenium	5	0.06
RM622C1	Sodium	6	0.82
RM637C1	Sodium	4	0.11
RM644C1	Sodium	5	0.74
RM661C1	Sodium	5	0.74
RM676C1	Sodium	5	0.33
RM704C1	Sodium	6	0.82
RM708C1	Sodium	5	0.06
RM704C1	Uranium	6	0.18
RM622C1	Vanadium	6	0.18
RM637C1	Vanadium	4	0.11
RM644C1	Vanadium	5	0.74

Table 11. Results of a Runs Test on Sediment COPC Concentrations in Phase I Cores

Core Location	Analyte	Number of Samples	p Value
RM661C1	Vanadium	5	0.74
RM676C1	Vanadium	5	0.33
RM692C1	Vanadium	5	0.06
RM704C1	Vanadium	6	0.82
RM708C1	Vanadium	5	0.06
RM622C1	Zinc	6	0.50
RM637C1	Zinc	4	0.11
RM644C1	Zinc	5	0.06
RM661C1	Zinc	5	0.06
RM676C1	Zinc	5	0.06
RM692C1	Zinc	5	0.06
RM704C1	Zinc	6	0.03
RM708C1	Zinc	5	0.06
RM637C1	1,2,3,4,6,7,8-HpCDD	4	0.11
RM661C1	1,2,3,4,6,7,8-HpCDD	5	0.06
RM692C1	1,2,3,4,6,7,8-HpCDD	5	0.33
RM637C1	1,2,3,4,6,7,8-HpCDD	4	0.11
RM661C1	1,2,3,4,6,7,8-HpCDD	5	0.06
RM692C1	1,2,3,4,6,7,8-HpCDD	5	0.33
RM661C1	1,2,3,4,7,8,9-HpCDF	5	0.50
RM692C1	1,2,3,4,7,8,9-HpCDF	5	0.33
RM692C1	1,2,3,4,7,8-HxCDD	5	0.33
RM692C1	1,2,3,4,7,8-HxCDD	5	0.33
RM692C1	1,2,3,6,7,8-HxCDD	5	0.33
RM692C1	1,2,3,4,7,8-HxCDD	5	0.33
RM661C1	1,2,3,7,8,9-HxCDD	4	0.11
RM692C1	1,2,3,7,8,9-HxCDD	5	0.33
RM661C1	1,2,3,7,8,9-HxCDD	4	0.11
RM692C1	1,2,3,7,8,9-HxCDD	5	0.33
RM661C1	1,2,3,7,8,9-HxCDD	4	0.11
RM692C1	1,2,3,7,8,9-HxCDD	5	0.33
RM661C1	1,2,3,7,8,9-HxCDD	4	0.11
RM692C1	1,2,3,7,8,9-HxCDD	5	0.33
RM637C1	2,3,4,6,7,8-HxCDF	4	0.11
RM661C1	2,3,4,6,7,8-HxCDF	5	0.06
RM692C1	2,3,4,6,7,8-HxCDF	5	0.33
RM637C1	Octachlorodibenzodioxin	4	0.11
RM661C1	Octachlorodibenzodioxin	5	0.06
RM692C1	Octachlorodibenzodioxin	5	0.33
RM637C1	Octachlorodibenzofuran	4	0.11
RM661C1	Octachlorodibenzofuran	5	0.06
RM692C1	Octachlorodibenzofuran	5	0.33

Table 12. Statistically Significant Results of a Runs Test on Sediment COPC Concentrations in Cox et al. (2005) Cores

Location	Analyte	N	Runs Test p Value
CCR-668	Aluminum	21	0.00
CSA-8	Aluminum	18	0.01
CCR-692	Antimony	14	0.00
CCR-705	Antimony	16	0.00
CCR-624	Arsenic	13	0.04
CCR-643	Arsenic	12	0.04
CCR-668	Arsenic	21	0.02
CCR-692	Arsenic	14	0.05
CCR-705	Arsenic	16	0.02
CSA-8	Arsenic	18	0.00
CCR-668	Barium	21	0.00
CCR-692	Barium	14	0.00
CCR-705	Barium	16	0.00
CSA-8	Barium	18	0.00
CCR-624	Beryllium	13	0.02
CCR-643	Beryllium	12	0.04
CCR-668	Beryllium	21	0.01
CCR-624	Bismuth	13	0.02
CCR-668	Bismuth	21	0.00
CCR-692	Bismuth	14	0.01
CSA-8	Bismuth	18	0.00
CCR-643	Cadmium	12	0.03
CCR-668	Cadmium	21	0.00
CCR-692	Cadmium	14	0.01
CCR-705	Cadmium	16	0.02
CCR-624	Calcium	13	0.00
CCR-643	Calcium	12	0.03
CCR-668	Calcium	21	0.00
CCR-692	Calcium	14	0.01
CSA-8	Calcium	18	0.03
CCR-624	Cerium	11	0.02
CCR-692	Cerium	14	0.05
CCR-705	Cerium	16	0.00
CCR-624	Cesium	13	0.02
CCR-692	Cesium	14	0.01
CCR-705	Cesium	16	0.00
CSA-8	Cesium	18	0.03
CCR-705	Chromium	16	0.00
CSA-8	Chromium	18	0.03
CCR-668	Cobalt	21	0.02
CCR-705	Cobalt	16	0.00
CCR-624	Copper	13	0.02
CCR-643	Copper	12	0.01
CCR-692	Copper	14	0.00
CCR-705	Copper	16	0.00

Table 12. Statistically Significant Results of a Runs Test on Sediment COPC Concentrations in Cox et al. (2005) Cores

Location	Analyte	N	Runs Test p Value
CSA-8	Copper	18	0.03
CCR-624	Gallium	13	0.02
CCR-668	Gallium	21	0.01
CSA-8	Gallium	18	0.00
CCR-668	Iron	21	0.01
CCR-705	Iron	16	0.00
CSA-8	Iron	18	0.03
CCR-624	Lanthanum	13	0.01
CCR-643	Lanthanum	12	0.03
CCR-692	Lanthanum	14	0.00
CCR-624	Lead	13	0.02
CCR-643	Lead	12	0.03
CCR-668	Lead	21	0.02
CCR-692	Lead	14	0.01
CCR-705	Lead	16	0.02
CCR-692	Lithium	14	0.01
CSA-8	Lithium	18	0.00
CCR-624	Magnesium	13	0.02
CCR-668	Magnesium	21	0.00
CCR-692	Magnesium	14	0.01
CSA-8	Magnesium	18	0.00
CCR-692	Manganese	14	0.05
CCR-705	Manganese	16	0.00
CCR-643	Mercury	12	0.03
CCR-668	Mercury	19	0.05
CCR-692	Mercury	12	0.00
CCR-705	Mercury	14	0.01
CSA-8	Mercury	18	0.01
CCR-624	Molybdenum	13	0.00
CCR-643	Molybdenum	12	0.03
CCR-668	Molybdenum	21	0.00
CCR-692	Molybdenum	14	0.01
CCR-705	Nickel	16	0.00
CSA-8	Nickel	18	0.03
CCR-705	Niobium	16	0.00
CSA-8	Niobium	18	0.00
CCR-624	Potassium	13	0.02
CCR-668	Potassium	21	0.04
CSA-8	Potassium	18	0.00
CCR-668	Rubidium	21	0.01
CSA-8	Rubidium	18	0.02
CCR-668	Scandium	21	0.00
CSA-8	Scandium	18	0.01
CCR-668	Selenium	19	0.05
CCR-692	Selenium	12	0.00

Table 12. Statistically Significant Results of a Runs Test on Sediment COPC Concentrations in Cox et al. (2005) Cores

Location	Analyte	N	Runs Test p Value
CCR-705	Selenium	14	0.01
CCR-668	Silver	10	0.01
CCR-692	Silver	6	0.03
CCR-624	Sodium	13	0.04
CSA-8	Sodium	18	0.00
CCR-624	Strontium	13	0.03
CCR-668	Strontium	19	0.05
CCR-692	Strontium	12	0.03
CSA-8	Strontium	18	0.00
CCR-668	Tantalum	21	0.03
CCR-705	Tantalum	16	0.00
CCR-668	Thallium	21	0.00
CCR-692	Thallium	14	0.05
CCR-705	Thallium	16	0.01
CCR-643	Thorium	12	0.00
CCR-705	Thorium	16	0.00
CSA-8	Thorium	18	0.00
CCR-624	Titanium	13	0.01
CCR-643	Titanium	12	0.00
CCR-692	Titanium	14	0.01
CSA-8	Titanium	18	0.03
CCR-643	Uranium	12	0.03
CCR-692	Uranium	14	0.00
CSA-8	Uranium	18	0.03
CCR-668	Vanadium	21	0.02
CCR-705	Vanadium	16	0.03
CCR-692	Ytterbium	12	0.01
CCR-705	Ytterbium	14	0.01
CCR-643	Yttrium	12	0.03
CCR-692	Yttrium	14	0.01
CSA-8	Yttrium	18	0.00
CCR-624	Zinc	13	0.02
CCR-643	Zinc	12	0.03
CCR-668	Zinc	21	0.00
CCR-692	Zinc	14	0.00

Table 13. Significant Trend Patterns in Sediment COPC Concentrations in Cox et al. (2005) Core CCR-705

Trend Pattern	Analyte
Decrease	Antimony
Decrease	Arsenic
Decrease	Cerium
Decrease	Chromium
Decrease	Cobalt
Decrease	Copper
Decrease	Manganese
Decrease	Nickel
Decrease	Niobium
Decrease	Thorium
Decrease, increase	Cesium
Decrease, increase	Ytterbium
Decrease, increase, decrease	Iron
Decrease, increase, decrease	Vanadium
Increase, decrease	Barium
Increase, decrease	Tantalum
Increase, decrease, increase	Selenium
Increase, decrease, increase, decrease	Cadmium
Increase, decrease, increase, decrease	Lead
Increase, decrease, increase, decrease	Mercury
Increase, decrease, increase, decrease	Thallium

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
3	1,2,3,4,6,7,8-HpCDD	pg/g	6	0	0%			
3	1,2,3,4,7,8,9-HpCDF	pg/g	6	0	0%			
3	1,2,3,4,7,8-HxCDD	pg/g	6	0	0%			
3	1,2,3,6,7,8-HxCDD	pg/g	6	0	0%			
3	1,2,3,7,8,9-HxCDD	pg/g	6	3	50%	0.0186	0.0273	0.034
3	2,2'-Oxybis(1-chloropropane)	ug/kg	11	0	0%			
3	2,3,4,6,7,8-HxCDF	pg/g	6	0	0%			
3	2,4,5-Trichlorophenol	ug/kg	11	0	0%			
3	2,4,6-Trichlorophenol	ug/kg	11	0	0%			
3	2,4-DDD	ug/kg	11	0	0%			
3	2,4-DDE	ug/kg	11	1	9%	0.32	0.32	0.32
3	2,4-DDT	ug/kg	11	0	0%			
3	2,4-Dichlorophenol	ug/kg	11	0	0%			
3	2,4-Dimethylphenol	ug/kg	11	0	0%			
3	2,4-Dinitrophenol	ug/kg	11	0	0%			
3	2,4-Dinitrotoluene	ug/kg	11	0	0%			
3	2,6-Dinitrotoluene	ug/kg	11	0	0%			
3	2-Chloronaphthalene	ug/kg	11	0	0%			
3	2-Chlorophenol	ug/kg	11	0	0%			
3	2-Methylphenol (o-cresol)	ug/kg	11	0	0%			
3	2-Nitroaniline	ug/kg	11	0	0%			
3	2-Nitrophenol	ug/kg	11	0	0%			
3	3-Nitroaniline	ug/kg	11	0	0%			
3	4,4-DDD	ug/kg	11	0	0%			
3	4,4-DDE	ug/kg	11	2	18%	0.16	0.485	0.81
3	4,4-DDT	ug/kg	11	1	9%	2.6	2.6	2.6
3	4,6-Dinitro-2-methylphenol	ug/kg	11	0	0%			
3	4-Chloro-3-methylphenol	ug/kg	11	0	0%			
3	4-Chloroaniline	ug/kg	11	0	0%			
3	4-Chlorophenyl-phenyl ether	ug/kg	11	0	0%			
3	4-Nitroaniline	ug/kg	11	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
3	4-Nitrophenol	ug/kg	11	0	0%			
3	Acetophenone	ug/kg	11	0	0%			
3	Aldrin	ug/kg	11	0	0%			
3	Alpha-BHC	ug/kg	11	0	0%			
3	Aluminum	mg/kg	27	27	100%	13900	48400	84000
3	Antimony	mg/kg	27	27	100%	0.98	11.6	42.5
3	Arsenic	mg/kg	27	27	100%	0.95	8.68	20
3	Atrazine	ug/kg	11	0	0%			
3	Barium	mg/kg	27	27	100%	580	1080	1800
3	Benzaldehyde	ug/kg	11	0	0%			
3	Benzyl alcohol	ug/kg	11	0	0%			
3	Beryllium	mg/kg	27	27	100%	1.1	1.88	2.6
3	Beta-BHC	ug/kg	11	0	0%			
3	Bis(2-chloroethoxy)methane	ug/kg	11	0	0%			
3	Bis(2-chloroethyl)ether	ug/kg	11	0	0%			
3	Bismuth	mg/kg	16	16	100%	0.19	0.588	1.3
3	Cadmium	mg/kg	27	25	93%	0.23	5.57	18
3	Calcium	mg/kg	27	27	100%	13000	32100	68700
3	Caprolactam	ug/kg	11	0	0%			
3	Cerium	mg/kg	16	16	100%	47	80.2	96
3	Cesium	mg/kg	16	16	100%	2	4.08	5.1
3	Chromium	mg/kg	27	27	100%	37.6	74.4	110
3	Cobalt	mg/kg	27	27	100%	6.3	17.3	41.6
3	Copper	mg/kg	27	27	100%	18	576	2240
3	Dimethyl phthalate	ug/kg	11	0	0%			
3	Di-N-octylphthalate	ug/kg	11	0	0%			
3	Endrin aldehyde	ug/kg	11	0	0%			
3	Endrin ketone	ug/kg	11	0	0%			
3	Gallium	mg/kg	16	16	100%	9.2	15.7	19
3	Heptachlor	ug/kg	11	0	0%			
3	Hexachlorobenzene	ug/kg	11	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
3	Hexachlorobutadiene	ug/kg	11	0	0%			
3	Iron	mg/kg	27	27	100%	19000	89900	266000
3	Isophorone	ug/kg	11	0	0%			
3	Lanthanum	mg/kg	16	16	100%	29	54.7	74
3	Lead	mg/kg	27	27	100%	61	457	1150
3	Lithium	mg/kg	16	16	100%	17	28.6	35
3	Magnesium	mg/kg	27	27	100%	4850	11900	27000
3	Manganese	mg/kg	27	27	100%	310	1620	4690
3	Mercury	mg/kg	25	25	100%	0.011	0.62	2.8
3	Methoxychlor	ug/kg	11	0	0%			
3	Molybdenum	mg/kg	16	16	100%	0.71	3.32	9.1
3	Nickel	mg/kg	27	27	100%	6.6	22.2	39
3	Niobium	mg/kg	16	16	100%	16	29.5	36.7
3	Nitrobenzene	ug/kg	11	0	0%			
3	N-nitrosodi-N-propylamine	ug/kg	11	0	0%			
3	N-nitrosodiphenylamine	ug/kg	11	0	0%			
3	Octachlorodibenzodioxin	pg/g	6	0	0%			
3	Octachlorodibenzofuran	pg/g	6	1	17%	0.249	0.249	0.249
3	Pentachlorophenol	ug/kg	11	0	0%			
3	Phenol	ug/kg	11	0	0%			
3	Potassium	mg/kg	27	27	100%	2790	15400	29000
3	Rubidium	mg/kg	16	16	100%	50	93	110
3	Scandium	mg/kg	16	16	100%	6.3	11.4	14
3	Selenium	mg/kg	25	19	76%	0.34	2.11	6.7
3	Silver	mg/kg	27	6	22%	0.16	3.28	5.5
3	Sodium	mg/kg	27	27	100%	922	10400	22000
3	Strontium	mg/kg	14	14	100%	260	404	530
3	Tantalum	mg/kg	16	16	100%	1	1.71	2.6
3	Thallium	mg/kg	27	17	63%	0.38	0.994	1.5
3	Thorium	mg/kg	16	16	100%	7.4	12	14
3	Titanium	mg/kg	16	16	100%	2100	3630	4400

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
3	Uranium	mg/kg	27	22	81%	1.4	20.6	89.6
3	Vanadium	mg/kg	27	27	100%	31	71.2	120
3	Ytterbium	mg/kg	14	14	100%	1.2	2.54	3.2
3	Yttrium	mg/kg	16	16	100%	13	33.8	50
3	Zinc	mg/kg	27	27	100%	150	6670	24800
5	1,2,3,4,6,7,8-HpCDD	pg/g	4	4	100%	0.0911	5.11	12.2
5	1,2,3,4,7,8,9-HpCDF	pg/g	4	3	75%	0.0381	0.253	0.506
5	1,2,3,4,7,8-HxCDD	pg/g	4	2	50%	0.449	0.69	0.93
5	1,2,3,6,7,8-HxCDD	pg/g	4	0	0%			
5	1,2,3,7,8,9-HxCDD	pg/g	4	1	25%	0.232	0.232	0.232
5	2,2'-Oxybis(1-chloropropane)	ug/kg	10	0	0%			
5	2,3,4,6,7,8-HxCDF	pg/g	4	4	100%	0.0205	0.338	0.856
5	2,4,5-Trichlorophenol	ug/kg	10	0	0%			
5	2,4,6-Trichlorophenol	ug/kg	10	0	0%			
5	2,4-DDD	ug/kg	10	0	0%			
5	2,4-DDE	ug/kg	10	0	0%			
5	2,4-DDT	ug/kg	10	0	0%			
5	2,4-Dichlorophenol	ug/kg	10	0	0%			
5	2,4-Dimethylphenol	ug/kg	10	0	0%			
5	2,4-Dinitrophenol	ug/kg	10	0	0%			
5	2,4-Dinitrotoluene	ug/kg	10	0	0%			
5	2,6-Dinitrotoluene	ug/kg	10	0	0%			
5	2-Chloronaphthalene	ug/kg	10	0	0%			
5	2-Chlorophenol	ug/kg	10	0	0%			
5	2-Methylphenol (o-cresol)	ug/kg	10	0	0%			
5	2-Nitroaniline	ug/kg	10	0	0%			
5	2-Nitrophenol	ug/kg	10	0	0%			
5	3-Nitroaniline	ug/kg	10	0	0%			
5	4,4-DDD	ug/kg	10	0	0%			
5	4,4-DDE	ug/kg	10	1	10%	0.43	0.43	0.43
5	4,4-DDT	ug/kg	10	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
5	4,6-Dinitro-2-methylphenol	ug/kg	10	0	0%			
5	4-Chloro-3-methylphenol	ug/kg	10	0	0%			
5	4-Chloroaniline	ug/kg	10	0	0%			
5	4-Chlorophenyl-phenyl ether	ug/kg	10	0	0%			
5	4-Nitroaniline	ug/kg	10	0	0%			
5	4-Nitrophenol	ug/kg	10	0	0%			
5	Acetophenone	ug/kg	10	0	0%			
5	Aldrin	ug/kg	10	0	0%			
5	Alpha-BHC	ug/kg	10	0	0%			
5	Aluminum	mg/kg	23	23	100%	6390	47600	94000
5	Antimony	mg/kg	22	14	64%	0.71	4.44	9.8
5	Arsenic	mg/kg	23	23	100%	2.45	11.1	22
5	Atrazine	ug/kg	10	0	0%			
5	Barium	mg/kg	23	23	100%	39.4	554	1100
5	Benzaldehyde	ug/kg	10	0	0%			
5	Benzyl alcohol	ug/kg	10	0	0%			
5	Beryllium	mg/kg	23	23	100%	0.49	1.66	2.6
5	Beta-BHC	ug/kg	10	0	0%			
5	Bis(2-chloroethoxy)methane	ug/kg	10	0	0%			
5	Bis(2-chloroethyl)ether	ug/kg	10	0	0%			
5	Bismuth	mg/kg	13	13	100%	0.49	0.897	1.9
5	Cadmium	mg/kg	23	21	91%	0.05	7.78	23
5	Calcium	mg/kg	23	23	100%	2060	10300	18000
5	Caprolactam	ug/kg	10	0	0%			
5	Cerium	mg/kg	11	11	100%	76	97.8	120
5	Cesium	mg/kg	13	13	100%	4.6	6.49	7.6
5	Chromium	mg/kg	23	23	100%	9	47.2	94
5	Cobalt	mg/kg	23	23	100%	4.1	12.3	21
5	Copper	mg/kg	23	23	100%	9.2	42.6	88
5	Dimethyl phthalate	ug/kg	10	0	0%			
5	Di-N-octylphthalate	ug/kg	10	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
5	Endrin aldehyde	ug/kg	10	1	10%	0.42	0.42	0.42
5	Endrin ketone	ug/kg	10	0	0%			
5	Gallium	mg/kg	13	13	100%	17	18.7	22
5	Heptachlor	ug/kg	10	0	0%			
5	Hexachlorobenzene	ug/kg	10	0	0%			
5	Hexachlorobutadiene	ug/kg	10	0	0%			
5	Iron	mg/kg	23	23	100%	13400	32600	55000
5	Isophorone	ug/kg	10	0	0%			
5	Lanthanum	mg/kg	13	13	100%	49	71	110
5	Lead	mg/kg	23	23	100%	5.2	247	920
5	Lithium	mg/kg	13	13	100%	30	39.1	45
5	Magnesium	mg/kg	23	23	100%	3500	9940	16000
5	Manganese	mg/kg	23	23	100%	201	802	1500
5	Mercury	mg/kg	21	14	67%	0.036	0.714	1.2
5	Methoxychlor	ug/kg	10	0	0%			
5	Molybdenum	mg/kg	13	13	100%	0.845	2.36	4.8
5	Nickel	mg/kg	23	23	100%	8.3	25.5	42
5	Niobium	mg/kg	13	13	100%	15	19	24
5	Nitrobenzene	ug/kg	10	0	0%			
5	N-nitrosodi-N-propylamine	ug/kg	10	0	0%			
5	N-nitrosodiphenylamine	ug/kg	10	0	0%			
5	Octachlorodibenzodioxin	pg/g	4	4	100%	1.45	120	338
5	Octachlorodibenzofuran	pg/g	4	4	100%	0.123	7.68	21.7
5	Pentachlorophenol	ug/kg	10	0	0%			
5	Phenol	ug/kg	10	0	0%			
5	Potassium	mg/kg	23	23	100%	1150	12100	25000
5	Rubidium	mg/kg	13	13	100%	86	110	120
5	Scandium	mg/kg	13	13	100%	13	15.3	19
5	Selenium	mg/kg	21	21	100%	0.24	1.58	4.9
5	Silver	mg/kg	23	0	0%			
5	Sodium	mg/kg	23	23	100%	62.2	6550	14000

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
5	Strontium	mg/kg	13	13	100%	200	248	280
5	Tantalum	mg/kg	11	11	100%	0.65	1.46	2.1
5	Thallium	mg/kg	23	13	57%	1	1.33	1.9
5	Thorium	mg/kg	13	13	100%	10	12.8	14
5	Titanium	mg/kg	13	13	100%	4200	4480	4900
5	Uranium	mg/kg	23	13	57%	3	3.74	5.2
5	Vanadium	mg/kg	23	23	100%	12.6	74.2	130
5	Ytterbium	mg/kg	11	11	100%	3.15	3.66	4.6
5	Yttrium	mg/kg	13	13	100%	38	58.6	90
5	Zinc	mg/kg	23	23	100%	30	614	1600
6	1,2,3,4,6,7,8-HpCDD	pg/g	3	3	100%	0.0756	3.16	9.19
6	1,2,3,4,7,8,9-HpCDF	pg/g	3	1	33%	0.555	0.555	0.555
6	1,2,3,4,7,8-HxCDD	pg/g	3	1	33%	0.936	0.936	0.936
6	1,2,3,6,7,8-HxCDD	pg/g	3	1	33%	0.658	0.658	0.658
6	1,2,3,7,8,9-HxCDD	pg/g	3	1	33%	0.34	0.34	0.34
6	2,2'-Oxybis(1-chloropropane)	ug/kg	3	0	0%			
6	2,3,4,6,7,8-HxCDF	pg/g	3	2	67%	0.0378	0.489	0.94
6	2,4,5-Trichlorophenol	ug/kg	3	0	0%			
6	2,4,6-Trichlorophenol	ug/kg	3	0	0%			
6	2,4-DDD	ug/kg	3	0	0%			
6	2,4-DDE	ug/kg	3	0	0%			
6	2,4-DDT	ug/kg	3	0	0%			
6	2,4-Dichlorophenol	ug/kg	3	0	0%			
6	2,4-Dimethylphenol	ug/kg	3	0	0%			
6	2,4-Dinitrophenol	ug/kg	3	0	0%			
6	2,4-Dinitrotoluene	ug/kg	3	0	0%			
6	2,6-Dinitrotoluene	ug/kg	3	0	0%			
6	2-Chloronaphthalene	ug/kg	3	0	0%			
6	2-Chlorophenol	ug/kg	3	0	0%			
6	2-Methylphenol (o-cresol)	ug/kg	3	0	0%			
6	2-Nitroaniline	ug/kg	3	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
6	2-Nitrophenol	ug/kg	3	0	0%			
6	3-Nitroaniline	ug/kg	3	0	0%			
6	4,4-DDD	ug/kg	3	0	0%			
6	4,4-DDE	ug/kg	3	0	0%			
6	4,4-DDT	ug/kg	3	0	0%			
6	4,6-Dinitro-2-methylphenol	ug/kg	3	0	0%			
6	4-Chloro-3-methylphenol	ug/kg	3	0	0%			
6	4-Chloroaniline	ug/kg	3	0	0%			
6	4-Chlorophenyl-phenyl ether	ug/kg	3	0	0%			
6	4-Nitroaniline	ug/kg	3	0	0%			
6	4-Nitrophenol	ug/kg	3	0	0%			
6	Acetophenone	ug/kg	3	0	0%			
6	Aldrin	ug/kg	3	0	0%			
6	Alpha-BHC	ug/kg	3	0	0%			
6	Aluminum	mg/kg	3	3	100%	11300	16200	21600
6	Antimony	mg/kg	3	0	0%			
6	Arsenic	mg/kg	3	3	100%	4.15	8.08	15.5
6	Atrazine	ug/kg	3	0	0%			
6	Barium	mg/kg	3	3	100%	98.8	196	325
6	Benzaldehyde	ug/kg	3	0	0%			
6	Benzyl alcohol	ug/kg	3	0	0%			
6	Beryllium	mg/kg	3	3	100%	0.98	1.36	1.9
6	Beta-BHC	ug/kg	3	0	0%			
6	Bis(2-chloroethoxy)methane	ug/kg	3	0	0%			
6	Bis(2-chloroethyl)ether	ug/kg	3	0	0%			
6	Cadmium	mg/kg	3	3	100%	0.11	3.94	11.3
6	Calcium	mg/kg	3	3	100%	2680	4910	8400
6	Caprolactam	ug/kg	3	0	0%			
6	Chromium	mg/kg	3	3	100%	15.1	22.4	35.4
6	Cobalt	mg/kg	3	3	100%	8.1	10.7	15.9
6	Copper	mg/kg	3	3	100%	15.4	31.9	60.8

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
6	Dimethyl phthalate	ug/kg	3	0	0%			
6	Di-N-octylphthalate	ug/kg	3	0	0%			
6	Endrin aldehyde	ug/kg	3	0	0%			
6	Endrin ketone	ug/kg	3	0	0%			
6	Heptachlor	ug/kg	3	0	0%			
6	Hexachlorobenzene	ug/kg	3	0	0%			
6	Hexachlorobutadiene	ug/kg	3	0	0%			
6	Iron	mg/kg	3	3	100%	17000	22800	34000
6	Isophorone	ug/kg	3	0	0%			
6	Lead	mg/kg	3	3	100%	8.9	163	462
6	Magnesium	mg/kg	3	3	100%	4790	6880	10500
6	Manganese	mg/kg	3	3	100%	344	579	953
6	Mercury	mg/kg	3	3	100%	0.009	0.35	1
6	Methoxychlor	ug/kg	3	0	0%			
6	Nickel	mg/kg	3	3	100%	13	19.3	30.5
6	Nitrobenzene	ug/kg	3	0	0%			
6	N-nitrosodi-N-propylamine	ug/kg	3	0	0%			
6	N-nitrosodiphenylamine	ug/kg	3	0	0%			
6	Octachlorodibenzodioxin	pg/g	3	3	100%	6.05	86.7	248
6	Octachlorodibenzofuran	pg/g	3	3	100%	0.305	5.88	17
6	Pentachlorophenol	ug/kg	3	0	0%			
6	Phenol	ug/kg	3	0	0%			
6	Potassium	mg/kg	3	3	100%	3060	3360	3650
6	Selenium	mg/kg	3	3	100%	1.95	3.08	4.7
6	Silver	mg/kg	2	0	0%			
6	Sodium	mg/kg	3	3	100%	319	459	534
6	Thallium	mg/kg	3	0	0%			
6	Uranium	mg/kg	3	0	0%			
6	Vanadium	mg/kg	3	3	100%	26.6	33.7	46
6	Zinc	mg/kg	3	3	100%	48.3	443	1210
4a	1,2,3,4,6,7,8-HpCDD	pg/g	5	5	100%	0.604	2.96	5.39

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
4a	1,2,3,4,7,8,9-HpCDF	pg/g	5	5	100%	0.0532	0.209	0.44
4a	1,2,3,4,7,8-HxCDD	pg/g	5	5	100%	0.0724	0.366	0.608
4a	1,2,3,6,7,8-HxCDD	pg/g	5	5	100%	0.0565	0.261	0.399
4a	1,2,3,7,8,9-HxCDD	pg/g	5	5	100%	0.0492	0.135	0.222
4a	2,2'-Oxybis(1-chloropropane)	ug/kg	5	0	0%			
4a	2,3,4,6,7,8-HxCDF	pg/g	5	5	100%	0.0566	0.297	0.455
4a	2,4,5-Trichlorophenol	ug/kg	5	0	0%			
4a	2,4,6-Trichlorophenol	ug/kg	5	0	0%			
4a	2,4-DDD	ug/kg	5	0	0%			
4a	2,4-DDE	ug/kg	5	0	0%			
4a	2,4-DDT	ug/kg	5	0	0%			
4a	2,4-Dichlorophenol	ug/kg	5	0	0%			
4a	2,4-Dimethylphenol	ug/kg	5	0	0%			
4a	2,4-Dinitrophenol	ug/kg	5	0	0%			
4a	2,4-Dinitrotoluene	ug/kg	5	0	0%			
4a	2,6-Dinitrotoluene	ug/kg	5	0	0%			
4a	2-Chloronaphthalene	ug/kg	5	0	0%			
4a	2-Chlorophenol	ug/kg	5	0	0%			
4a	2-Methylphenol (o-cresol)	ug/kg	5	0	0%			
4a	2-Nitroaniline	ug/kg	5	0	0%			
4a	2-Nitrophenol	ug/kg	5	0	0%			
4a	3-Nitroaniline	ug/kg	5	0	0%			
4a	4,4-DDD	ug/kg	5	0	0%			
4a	4,4-DDE	ug/kg	5	1	20%	0.16	0.16	0.16
4a	4,4-DDT	ug/kg	5	1	20%	1	1	1
4a	4,6-Dinitro-2-methylphenol	ug/kg	5	0	0%			
4a	4-Chloro-3-methylphenol	ug/kg	5	0	0%			
4a	4-Chloroaniline	ug/kg	5	0	0%			
4a	4-Chlorophenyl-phenyl ether	ug/kg	5	0	0%			
4a	4-Nitroaniline	ug/kg	5	0	0%			
4a	4-Nitrophenol	ug/kg	5	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
4a	Acetophenone	ug/kg	5	0	0%			
4a	Aldrin	ug/kg	5	0	0%			
4a	Alpha-BHC	ug/kg	5	0	0%			
4a	Aluminum	mg/kg	19	19	100%	7440	48500	71500
4a	Antimony	mg/kg	19	15	79%	3.75	9.3	18
4a	Arsenic	mg/kg	19	19	100%	2.9	9.62	18
4a	Atrazine	ug/kg	5	0	0%			
4a	Barium	mg/kg	19	19	100%	234	1020	1400
4a	Benzaldehyde	ug/kg	5	0	0%			
4a	Benzyl alcohol	ug/kg	5	0	0%			
4a	Beryllium	mg/kg	19	19	100%	0.71	1.92	2.45
4a	Beta-BHC	ug/kg	5	0	0%			
4a	Bis(2-chloroethoxy)methane	ug/kg	5	0	0%			
4a	Bis(2-chloroethyl)ether	ug/kg	5	0	0%			
4a	Bismuth	mg/kg	14	14	100%	0.19	0.535	0.86
4a	Cadmium	mg/kg	19	19	100%	2.9	6.26	12
4a	Calcium	mg/kg	19	19	100%	15100	26100	55700
4a	Caprolactam	ug/kg	5	0	0%			
4a	Cerium	mg/kg	14	14	100%	84	103	130
4a	Cesium	mg/kg	14	14	100%	1.8	3.99	5.4
4a	Chromium	mg/kg	19	19	100%	19	62.4	110
4a	Cobalt	mg/kg	19	19	100%	6.7	11.4	17
4a	Copper	mg/kg	19	19	100%	79.8	147	314
4a	Dimethyl phthalate	ug/kg	5	0	0%			
4a	Di-N-octylphthalate	ug/kg	5	0	0%			
4a	Endrin aldehyde	ug/kg	5	0	0%			
4a	Endrin ketone	ug/kg	5	0	0%			
4a	Gallium	mg/kg	14	14	100%	12	15	16.5
4a	Heptachlor	ug/kg	5	0	0%			
4a	Hexachlorobenzene	ug/kg	5	0	0%			
4a	Hexachlorobutadiene	ug/kg	5	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
4a	Iron	mg/kg	19	19	100%	22300	34800	42000
4a	Isophorone	ug/kg	5	0	0%			
4a	Lanthanum	mg/kg	14	14	100%	53	91.8	160
4a	Lead	mg/kg	19	19	100%	150	314	610
4a	Lithium	mg/kg	14	14	100%	17	28.4	36
4a	Magnesium	mg/kg	19	19	100%	7480	15200	26000
4a	Manganese	mg/kg	19	19	100%	391	654	822
4a	Mercury	mg/kg	17	17	100%	0.051	0.951	2.3
4a	Methoxychlor	ug/kg	5	0	0%			
4a	Molybdenum	mg/kg	14	14	100%	1.65	3.42	7.6
4a	Nickel	mg/kg	19	19	100%	10.2	28.2	38
4a	Niobium	mg/kg	14	14	100%	16	21.3	30.5
4a	Nitrobenzene	ug/kg	5	0	0%			
4a	N-nitrosodi-N-propylamine	ug/kg	5	0	0%			
4a	N-nitrosodiphenylamine	ug/kg	5	0	0%			
4a	Octachlorodibenzodioxin	pg/g	5	5	100%	23.6	123	201
4a	Octachlorodibenzofuran	pg/g	5	5	100%	1.76	8.66	16.2
4a	Pentachlorophenol	ug/kg	5	0	0%			
4a	Phenol	ug/kg	5	0	0%			
4a	Potassium	mg/kg	19	19	100%	1360	15100	23000
4a	Rubidium	mg/kg	14	14	100%	72	91	100
4a	Scandium	mg/kg	14	14	100%	6.3	9.84	11.5
4a	Selenium	mg/kg	17	17	100%	0.54	2.94	9.5
4a	Silver	mg/kg	19	6	32%	1.1	4.12	8
4a	Sodium	mg/kg	19	17	89%	292	14400	20000
4a	Strontium	mg/kg	12	12	100%	420	491	600
4a	Tantalum	mg/kg	14	14	100%	1	1.34	1.5
4a	Thallium	mg/kg	19	14	74%	0.75	1.22	1.8
4a	Thorium	mg/kg	14	14	100%	9.8	13.1	27
4a	Titanium	mg/kg	14	14	100%	3450	4000	4200
4a	Uranium	mg/kg	19	14	74%	3.5	4.9	6.8

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
4a	Vanadium	mg/kg	19	19	100%	26.8	71	100
4a	Ytterbium	mg/kg	12	12	100%	1.7	2.9	4.4
4a	Yttrium	mg/kg	14	14	100%	20	47.3	100
4a	Zinc	mg/kg	19	19	100%	570	1280	3800
4b	1,2,3,4,6,7,8-HpCDD	pg/g	5	5	100%	0.327	1.36	2.17
4b	1,2,3,4,7,8,9-HpCDF	pg/g	5	5	100%	0.0835	0.122	0.177
4b	1,2,3,4,7,8-HxCDD	pg/g	5	2	40%	0.304	0.308	0.312
4b	1,2,3,6,7,8-HxCDD	pg/g	5	0	0%			
4b	1,2,3,7,8,9-HxCDD	pg/g	5	4	80%	0.071	0.086	0.109
4b	2,2'-Oxybis(1-chloropropane)	ug/kg	15	0	0%			
4b	2,3,4,6,7,8-HxCDF	pg/g	5	5	100%	0.0686	0.14	0.211
4b	2,4,5-Trichlorophenol	ug/kg	15	0	0%			
4b	2,4,6-Trichlorophenol	ug/kg	15	0	0%			
4b	2,4-DDD	ug/kg	15	0	0%			
4b	2,4-DDE	ug/kg	15	0	0%			
4b	2,4-DDT	ug/kg	15	0	0%			
4b	2,4-Dichlorophenol	ug/kg	15	0	0%			
4b	2,4-Dimethylphenol	ug/kg	15	0	0%			
4b	2,4-Dinitrophenol	ug/kg	15	0	0%			
4b	2,4-Dinitrotoluene	ug/kg	15	0	0%			
4b	2,6-Dinitrotoluene	ug/kg	15	0	0%			
4b	2-Chloronaphthalene	ug/kg	15	0	0%			
4b	2-Chlorophenol	ug/kg	15	0	0%			
4b	2-Methylphenol (o-cresol)	ug/kg	15	0	0%			
4b	2-Nitroaniline	ug/kg	15	0	0%			
4b	2-Nitrophenol	ug/kg	15	0	0%			
4b	3-Nitroaniline	ug/kg	15	0	0%			
4b	4,4-DDD	ug/kg	15	0	0%			
4b	4,4-DDE	ug/kg	15	0	0%			
4b	4,4-DDT	ug/kg	15	0	0%			
4b	4,6-Dinitro-2-methylphenol	ug/kg	15	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
4b	4-Chloro-3-methylphenol	ug/kg	15	0	0%			
4b	4-Chloroaniline	ug/kg	15	0	0%			
4b	4-Chlorophenyl-phenyl ether	ug/kg	15	0	0%			
4b	4-Nitroaniline	ug/kg	15	0	0%			
4b	4-Nitrophenol	ug/kg	15	0	0%			
4b	Acetophenone	ug/kg	15	0	0%			
4b	Aldrin	ug/kg	15	0	0%			
4b	Alpha-BHC	ug/kg	15	0	0%			
4b	Aluminum	mg/kg	48	48	100%	6460	51100	83000
4b	Antimony	mg/kg	33	33	100%	1.6	4.5	9.9
4b	Arsenic	mg/kg	48	44	92%	6.6	13	24
4b	Atrazine	ug/kg	15	0	0%			
4b	Barium	mg/kg	48	48	100%	69.4	921	1800
4b	Benzaldehyde	ug/kg	15	0	0%			
4b	Benzyl alcohol	ug/kg	15	0	0%			
4b	Beryllium	mg/kg	48	48	100%	0.71	1.95	2.8
4b	Beta-BHC	ug/kg	15	0	0%			
4b	Bis(2-chloroethoxy)methane	ug/kg	15	0	0%			
4b	Bis(2-chloroethyl)ether	ug/kg	15	0	0%			
4b	Bismuth	mg/kg	33	33	100%	0.3	0.66	0.97
4b	Cadmium	mg/kg	48	47	98%	0.058	7.05	18
4b	Calcium	mg/kg	48	48	100%	2000	22400	57000
4b	Caprolactam	ug/kg	15	0	0%			
4b	Cerium	mg/kg	33	33	100%	54	97.3	130
4b	Cesium	mg/kg	33	33	100%	2.3	4.94	9.3
4b	Chromium	mg/kg	48	48	100%	13.9	62.6	110
4b	Cobalt	mg/kg	48	48	100%	6.2	12.1	16
4b	Copper	mg/kg	48	48	100%	11.3	56.9	120
4b	Dimethyl phthalate	ug/kg	15	0	0%			
4b	Di-N-octylphthalate	ug/kg	15	0	0%			
4b	Endrin aldehyde	ug/kg	15	0	0%			

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
4b	Endrin ketone	ug/kg	15	0	0%			
4b	Gallium	mg/kg	33	33	100%	10	16.2	20
4b	Heptachlor	ug/kg	15	0	0%			
4b	Hexachlorobenzene	ug/kg	15	0	0%			
4b	Hexachlorobutadiene	ug/kg	15	0	0%			
4b	Iron	mg/kg	48	48	100%	12500	33000	43000
4b	Isophorone	ug/kg	15	0	0%			
4b	Lanthanum	mg/kg	33	33	100%	36	68.4	122
4b	Lead	mg/kg	48	48	100%	4.4	355	1230
4b	Lithium	mg/kg	33	33	100%	18	31.9	46
4b	Magnesium	mg/kg	48	48	100%	2920	15900	32000
4b	Manganese	mg/kg	48	48	100%	189	678	1500
4b	Mercury	mg/kg	46	46	100%	0.005	1	3.2
4b	Methoxychlor	ug/kg	15	0	0%			
4b	Molybdenum	mg/kg	33	33	100%	1	3.46	9.6
4b	Nickel	mg/kg	48	48	100%	11.8	31.6	48
4b	Niobium	mg/kg	33	33	100%	17	24.3	35
4b	Nitrobenzene	ug/kg	15	0	0%			
4b	N-nitrosodi-N-propylamine	ug/kg	15	0	0%			
4b	N-nitrosodiphenylamine	ug/kg	15	0	0%			
4b	Octachlorodibenzodioxin	pg/g	5	5	100%	4.46	42.5	77.8
4b	Octachlorodibenzofuran	pg/g	5	5	100%	1.23	3.69	5.49
4b	Pentachlorophenol	ug/kg	15	0	0%			
4b	Phenol	ug/kg	15	0	0%			
4b	Potassium	mg/kg	48	48	100%	1410	16300	26000
4b	Rubidium	mg/kg	33	33	100%	59	99.9	140
4b	Scandium	mg/kg	33	33	100%	6.9	11.8	16
4b	Selenium	mg/kg	46	42	91%	0.31	1.94	7.5
4b	Silver	mg/kg	38	10	26%	1.5	3.22	5
4b	Sodium	mg/kg	48	48	100%	133	11300	22000
4b	Strontium	mg/kg	31	31	100%	210	353	450

Table 14. Concentration Ranges of COPCs in Sediment Cores, by Reach

Reach	Analyte	Units	Number of Measurements	Detected Values	Detection Frequency (%)	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
4b	Tantalum	mg/kg	33	33	100%	1	1.51	2.2
4b	Thallium	mg/kg	48	33	69%	0.66	1.11	1.8
4b	Thorium	mg/kg	33	33	100%	7.8	12.6	15
4b	Titanium	mg/kg	33	33	100%	2400	3920	4500
4b	Uranium	mg/kg	48	33	69%	2.3	3.81	6.8
4b	Vanadium	mg/kg	48	48	100%	21.3	78.2	120
4b	Ytterbium	mg/kg	31	31	100%	1.8	2.92	4.1
4b	Yttrium	mg/kg	33	33	100%	22	40.1	92
4b	Zinc	mg/kg	48	48	100%	30.9	779	2120

Note:
All measurements are in dry weight

Table 15. Comparison of Concentration Ranges in Surface Sediment and Cores

			Surface			Cores			
Reach	Analyte	Units	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Core/Surface Ratio of Means
3	Aluminum	mg/kg	2,530	14,200	81,000	13,900	48,400	84,000	3.4
3	Antimony	mg/kg	0.52	9	42.5	0.98	12	42.5	1.3
3	Arsenic	mg/kg	0.95	8	26.7	0.95	9	20	1.1
3	Barium	mg/kg	29.6	409	1,610	580	1,080	1,800	2.6
3	Beryllium	mg/kg	0.22	1	3	1.1	2	2.6	2.1
3	Bismuth	mg/kg	0.38	1	0.75	0.19	1	1.3	1.0
3	Cadmium	mg/kg	0.11	2	7.3	0.23	6	18	2.6
3	Calcium	mg/kg	1,900	17,900	76,500	13,000	32,100	68,700	1.8
3	Cerium	mg/kg	71.9	80	93	47	80	96	1.0
3	Cesium	mg/kg	2.8	3	5.1	2	4	5.1	1.2
3	Chromium	mg/kg	5.2	32	109	37.6	74	110	2.3
3	Cobalt	mg/kg	2.6	11	41.6	6.3	17	41.6	1.6
3	Copper	mg/kg	5.7	254	2240	18	576	2240	2.3
3	Gallium	mg/kg	14.3	16	18	9.2	16	19	1.0
3	Iron	mg/kg	5,140	44,000	266,000	19,000	89,900	266,000	2.0
3	Lanthanum	mg/kg	44.6	50	60	29	55	74	1.1
3	Lead	mg/kg	3.9	202	1150	61	457	1150	2.3
3	Lithium	mg/kg	21.3	27	32	17	29	35	1.1
3	Magnesium	mg/kg	1,760	7,730	21,800	4,850	11,900	27,000	1.5
3	Manganese	mg/kg	91.9	805	4,690	310	1,620	4,690	2.0
3	Mercury	mg/kg	0.004	0	1.2	0.011	1	2.8	2.4
3	Molybdenum	mg/kg	1.6	3	4.4	0.71	3	9.1	1.3
3	Nickel	mg/kg	4.9	16	52.8	6.6	22	39	1.4
3	Niobium	mg/kg	36.1	36	36.1	16	30	36.7	0.8
3	Potassium	mg/kg	523	3,190	27,000	2,790	15,400	29,000	4.8
3	Rubidium	mg/kg	78	87	110	50	93	110	1.1
3	Scandium	mg/kg	8.3	10	13	6.3	11	14	1.2
3	Selenium	mg/kg	1.1	6	23.4	0.34	2	6.7	0.4
3	Silver	mg/kg	0.34	2	5	0.16	3	5.5	1.6

Table 15. Comparison of Concentration Ranges in Surface Sediment and Cores

			Surface			Cores			
Reach	Analyte	Units	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Core/Surface Ratio of Means
3	Sodium	mg/kg	19.5	1,920	19,200	922	10,400	22,000	5.4
3	Strontium	mg/kg	406	450	486	260	404	530	0.9
3	Tantalum	mg/kg	1.9	2	1.9	1	2	2.6	0.9
3	Thallium	mg/kg	0.69	1	1.3	0.38	1	1.5	1.1
3	Thorium	mg/kg	10.9	12	14	7.4	12	14	1.0
3	Titanium	mg/kg	2,530	3,060	4,200	2,100	3,630	4,400	1.2
3	Uranium	mg/kg	3.6	28	78.4	1.4	21	89.6	0.7
3	Vanadium	mg/kg	7.7	34	110	31	71	120	2.1
3	Ytterbium	mg/kg	2.9	3	2.9	1.2	3	3.2	0.9
3	Yttrium	mg/kg	21.4	27	35	13	34	50	1.3
3	Zinc	mg/kg	22.4	2,870	24,800	150	6,670	24,800	2.3
4a	Aluminum	mg/kg	3,000	14,200	79,900	7,440	48,500	71,500	3.4
4a	Antimony	mg/kg	0.35	3	6.4	3.75	9	18	3.5
4a	Arsenic	mg/kg	0.81	6	20.2	2.9	10	18	1.6
4a	Barium	mg/kg	29.2	287	1,240	234	1,020	1,400	3.6
4a	Beryllium	mg/kg	0.21	1	3	0.71	2	2.45	2.1
4a	Bismuth	mg/kg	0.1	0	0.8	0.19	1	0.86	1.4
4a	Cadmium	mg/kg	0.057	3	11.1	2.9	6	12	2.2
4a	Calcium	mg/kg	879	11,300	34,900	15,100	26,100	55,700	2.3
4a	Cerium	mg/kg	54.6	75	100	84	103	130	1.4
4a	Cesium	mg/kg	1.8	3	5	1.8	4	5.4	1.2
4a	Chromium	mg/kg	5.5	26	76.8	19	62	110	2.4
4a	Cobalt	mg/kg	2.2	8	16.7	6.7	11	17	1.4
4a	Copper	mg/kg	4.2	50	164	79.8	147	314	3.0
4a	Gallium	mg/kg	15	16	18	12	15	16.5	0.9
4a	Iron	mg/kg	5,180	20,000	42,000	22,300	34,800	42,000	1.7
4a	Lanthanum	mg/kg	32	48	75	53	92	160	1.9
4a	Lead	mg/kg	2.6	130	841	150	314	610	2.4
4a	Lithium	mg/kg	15.8	27	42.1	17	28	36	1.1

Table 15. Comparison of Concentration Ranges in Surface Sediment and Cores

			Surface			Cores			
Reach	Analyte	Units	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Core/Surface Ratio of Means
4a	Magnesium	mg/kg	1,390	7,530	21,400	7,480	15,200	26,000	2.0
4a	Manganese	mg/kg	106	432	1,150	391	654	822	1.5
4a	Mercury	mg/kg	0.0063	1	2.4	0.051	1	2.3	1.5
4a	Molybdenum	mg/kg	0.36	1	2.2	1.65	3	7.6	3.3
4a	Nickel	mg/kg	4.1	20	38	10.2	28	38	1.4
4a	Niobium	mg/kg	21	21	21	16	21	30.5	1.0
4a	Potassium	mg/kg	372	3,080	26,800	1,360	15,100	23,000	4.9
4a	Rubidium	mg/kg	90.5	95	101	72	91	100	1.0
4a	Scandium	mg/kg	7	9	11.6	6.3	10	11.5	1.1
4a	Selenium	mg/kg	0.84	3	7.8	0.54	3	9.5	0.8
4a	Silver	mg/kg	0.25	1	2.9	1.1	4	8	3.3
4a	Sodium	mg/kg	42.1	1,480	23,500	292	14,400	20,000	9.7
4a	Strontium	mg/kg	399	504	601	420	491	600	1.0
4a	Tantalum	mg/kg	1.4	1	1.4	1	1	1.5	1.0
4a	Thallium	mg/kg	0.6	1	0.9	0.75	1	1.8	1.6
4a	Thorium	mg/kg	8.4	11	13.9	9.8	13	27	1.2
4a	Titanium	mg/kg	1,950	2,890	4,100	3,450	4,000	4,200	1.4
4a	Uranium	mg/kg	1.45	6	11.5	3.5	5	6.8	0.8
4a	Vanadium	mg/kg	9.1	34	103	26.8	71	100	2.1
4a	Ytterbium	mg/kg	2.8	3	2.8	1.7	3	4.4	1.0
4a	Yttrium	mg/kg	13.3	21	33	20	47	100	2.2
4a	Zinc	mg/kg	16	365	1,460	570	1,280	3,800	3.5
4b	Aluminum	mg/kg	2,760	14,500	76,200	6,460	51,100	83,000	3.5
4b	Antimony	mg/kg	0.53	2	4.2	1.6	5	9.9	2.5
4b	Arsenic	mg/kg	1.8	7	17.5	6.6	13	24	1.9
4b	Barium	mg/kg	20.6	194	1,180	69	921	1,800	4.7
4b	Beryllium	mg/kg	0.21	1	2.7	0.71	2	2.8	1.9
4b	Bismuth	mg/kg	0.44	1	0.66	0.3	1	0.97	1.2
4b	Cadmium	mg/kg	0.052	2	14.2	0.058	7	18	3.0

Table 15. Comparison of Concentration Ranges in Surface Sediment and Cores

			Surface			Cores			
Reach	Analyte	Units	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Core/Surface Ratio of Means
4b	Calcium	mg/kg	1,320	6,750	38,200	2,000	22,400	57,000	3.3
4b	Cerium	mg/kg	87.9	100	120	54	97	130	1.0
4b	Cesium	mg/kg	4.2	5	6.5	2.3	5	9.3	0.9
4b	Chromium	mg/kg	4.6	27	101	13.9	63	110	2.3
4b	Cobalt	mg/kg	2.1	9	18.4	6.2	12	16	1.3
4b	Copper	mg/kg	3	33	98.5	11.3	57	120	1.7
4b	Gallium	mg/kg	17	18	19	10	16	20	0.9
4b	Iron	mg/kg	4,930	21,700	42,000	12,500	33,000	43,000	1.5
4b	Lanthanum	mg/kg	53	64	74	36	68	122	1.1
4b	Lead	mg/kg	3	96	841	4.4	355	1,230	3.7
4b	Lithium	mg/kg	30	34	40	18	32	46	0.9
4b	Magnesium	mg/kg	1,540	6,650	22,400	2,920	15,900	32,000	2.4
4b	Manganese	mg/kg	95.3	486	3,200	189	678	1,500	1.4
4b	Mercury	mg/kg	0.005	0	2.4	0.005	1	3.2	2.5
4b	Molybdenum	mg/kg	1	1	1.7	1	3	9.6	2.6
4b	Nickel	mg/kg	2.8	21	48	11.8	32	48	1.5
4b	Niobium	mg/kg	20	24	27	17	24	35	1.0
4b	Potassium	mg/kg	317	2,930	25,000	1,410	16,300	26,000	5.6
4b	Rubidium	mg/kg	96	107	120	59	100	140	0.9
4b	Scandium	mg/kg	12	13	14	6.9	12	16	0.9
4b	Selenium	mg/kg	0.58	4	7.9	0.31	2	7.5	0.5
4b	Silver	mg/kg	0.66	1	1.7	1.5	3	5	2.8
4b	Sodium	mg/kg	56.3	1,080	21,000	133	11,300	22,000	10.5
4b	Strontium	mg/kg	290	374	420	210	353	450	0.9
4b	Tantalum	mg/kg	1.3	1	1.5	1	2	2.2	1.1
4b	Thallium	mg/kg	0.94	1	1.8	0.66	1	1.8	0.8
4b	Thorium	mg/kg	13.8	14	14	7.8	13	15	0.9
4b	Titanium	mg/kg	3,400	3,850	4,300	2,400	3,920	4,500	1.0
4b	Uranium	mg/kg	3.1	9	21.7	2.3	4	6.8	0.4

Table 15. Comparison of Concentration Ranges in Surface Sediment and Cores

			Surface			Cores			
Reach	Analyte	Units	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Core/Surface Ratio of Means
4b	Vanadium	mg/kg	8.7	34	112	21.3	78	120	2.3
4b	Ytterbium	mg/kg	2.4	3	2.7	1.8	3	4.1	1.1
4b	Yttrium	mg/kg	25	34	47	22	40	92	1.2
4b	Zinc	mg/kg	21.3	271	1710	30.9	779	2120	2.9
5	Aluminum	mg/kg	5,070	35,000	91,000	6,390	47,600	94,000	1.4
5	Antimony	mg/kg	0.71	2	4.2	0.71	4	9.8	2.2
5	Arsenic	mg/kg	2.7	11	22	2.45	11	22	1.0
5	Barium	mg/kg	33.6	368	1080	39.4	554	1100	1.5
5	Beryllium	mg/kg	0.32	1	2.9	0.49	2	2.6	1.2
5	Bismuth	mg/kg	0.53	1	0.81	0.49	1	1.9	1.3
5	Cadmium	mg/kg	0.058	4	16.2	0.05	8	23	2.1
5	Calcium	mg/kg	1,590	8,730	40,800	2,060	10,300	18,000	1.2
5	Cerium	mg/kg	95.1	98	100	76	98	120	1.0
5	Cesium	mg/kg	6.4	7	7.8	4.6	6	7.6	0.9
5	Chromium	mg/kg	6.2	32	101	9	47	94	1.5
5	Cobalt	mg/kg	3	11	21	4.1	12	21	1.1
5	Copper	mg/kg	7.3	31	89.7	9.2	43	88	1.4
5	Gallium	mg/kg	18	21	22	17	19	22	0.9
5	Iron	mg/kg	10,200	27,800	53,000	13,400	32,600	55,000	1.2
5	Lanthanum	mg/kg	52.6	58	62.7	49	71	110	1.2
5	Lead	mg/kg	4.4	87	583	5.2	247	920	2.8
5	Lithium	mg/kg	29	39	59	30	39	45	1.0
5	Magnesium	mg/kg	3,280	7,600	15,700	3,500	9,940	16,000	1.3
5	Manganese	mg/kg	189	791	3780	201	802	1500	1.0
5	Mercury	mg/kg	0.004	0	1.16	0.036	1	1.2	2.9
5	Molybdenum	mg/kg	0.88	1	1.6	0.845	2	4.8	2.0
5	Nickel	mg/kg	6.1	21	50.1	8.3	26	42	1.2
5	Niobium	mg/kg	18	18	18	15	19	24	1.1
5	Potassium	mg/kg	881	3,910	25,800	1,150	12,100	25,000	3.1

Table 15. Comparison of Concentration Ranges in Surface Sediment and Cores

			Surface			Cores			
Reach	Analyte	Units	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Core/Surface Ratio of Means
5	Rubidium	mg/kg	110	122	130	86	110	120	0.9
5	Scandium	mg/kg	15	16	16.5	13	15	19	1.0
5	Selenium	mg/kg	0.1	3	8.9	0.24	2	4.9	0.6
5	Silver	mg/kg	0.5	1	0.8	0	0	0	0.0
5	Sodium	mg/kg	57	1,230	13,000	62	6,550	14,000	5.3
5	Strontium	mg/kg	130	205	300	200	248	280	1.2
5	Tantalum	mg/kg	1.2	1	1.2	0.65	1	2.1	1.2
5	Thallium	mg/kg	1	1	1.8	1	1	1.9	1.0
5	Thorium	mg/kg	13	15	15.8	10	13	14	0.9
5	Titanium	mg/kg	2,300	3,860	5,100	4,200	4,480	4,900	1.2
5	Uranium	mg/kg	3.4	5	6.4	3	4	5.2	0.7
5	Vanadium	mg/kg	8.4	50	125	12.6	74	130	1.5
5	Ytterbium	mg/kg	3.2	3	3.2	3.15	4	4.6	1.1
5	Yttrium	mg/kg	30.3	39	45.8	38	59	90	1.5
5	Zinc	mg/kg	26.5	451	1400	30	614	1600	1.4
6	Aluminum	mg/kg	4,680	18,300	77,800	11,300	16,200	21,600	0.9
6	Antimony	mg/kg	0.8	1	1.7	0	0	0	0.0
6	Arsenic	mg/kg	1.8	8	15.5	4.15	8	15.5	1.0
6	Barium	mg/kg	35.5	204	1030	98.8	196	325	1.0
6	Beryllium	mg/kg	0.35	1	2.5	0.98	1	1.9	1.1
6	Bismuth	mg/kg	0.27	0	0.42				
6	Cadmium	mg/kg	0.038	3	12.4	0.11	4	11.3	1.1
6	Calcium	mg/kg	1,430	6,280	18,800	2,680	4,910	8,400	0.8
6	Cerium	mg/kg	81.2	87	102				
6	Cesium	mg/kg	4.7	5	6.2				
6	Chromium	mg/kg	1.2	24	79	15.1	22	35.4	1.0
6	Cobalt	mg/kg	2.7	9	18.4	8.1	11	15.9	1.2
6	Copper	mg/kg	5.5	31	86.1	15.4	32	60.8	1.0
6	Gallium	mg/kg	16	18	20				

Table 15. Comparison of Concentration Ranges in Surface Sediment and Cores

			Surface			Cores			
Reach	Analyte	Units	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Core/Surface Ratio of Means
6	Iron	mg/kg	9,830	23,200	44,200	17,000	22,800	34,000	1.0
6	Lanthanum	mg/kg	44.6	47	51.6				
6	Lead	mg/kg	3.9	72	462	8.9	163	462	2.3
6	Lithium	mg/kg	27	31	36.7				
6	Magnesium	mg/kg	3,460	6,960	14,000	4,790	6,880	10,500	1.0
6	Manganese	mg/kg	102	627	2,220	344	579	953	0.9
6	Mercury	mg/kg	0.004	0	1.8	0.009	0	1	0.7
6	Molybdenum	mg/kg	0.31	1	0.78				
6	Nickel	mg/kg	0.68	17	37.2	13	19	30.5	1.1
6	Potassium	mg/kg	747	4,200	27,400	3,060	3,360	3,650	0.8
6	Rubidium	mg/kg	104	114	125				
6	Scandium	mg/kg	9.6	11	13.2				
6	Selenium	mg/kg	1.3	4	8.6	1.95	3	4.7	0.7
6	Silver	mg/kg	0.8	1	1.2	0	0	0	0.0
6	Sodium	mg/kg	49.3	1,590	17,300	319	459	534	0.3
6	Strontium	mg/kg	296	377	492				
6	Thallium	mg/kg	0.7	1	0.85				
6	Thorium	mg/kg	10.9	13	15.7				
6	Titanium	mg/kg	2,500	3,390	4,300				
6	Uranium	mg/kg	2.65	4	5.4				
6	Vanadium	mg/kg	8.9	34	90	26.6	34	46	1.0
6	Yttrium	mg/kg	18.7	22	26				
6	Zinc	mg/kg	27.9	286	1210	48.3	443	1210	1.5

APPENDIX E

EVALUATION OF SEDIMENT TOXICITY

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ACRONYMS AND ABBREVIATIONS

AFDW	ash-free dry weight
AVS	acid-volatile sulfide
AWQC	ambient water quality criterion
B.C.	British Columbia
BERA	baseline ecological risk assessment
BLM	Biotic Ligand Model
$CaCO_3$	calcium carbonate
COPC	chemical of potential concern
DOC	dissolved organic carbon
Ecology	Washington State Department of Ecology
ECSMT	European Commission of Standards, Measurements, and Testing
EPA	U.S. Environmental Protection Agency
EqP	equilibrium partitioning
ERL	effects range low
ERM	effect range median
ESB	equilibrium partitioning sediment benchmark
FAV	final acute value
f_{oc}	fraction organic carbon
g_{oc}	grams organic carbon
IC25	25 percent inhibition concentration
KCl	potassium chloride
LC50	median lethal concentration
mPECQ	mean of the probable effect concentration quotient
NaCl	sodium chloride
PEC	probable effect concentration
PECQ	probable effect concentration quotient
QA/QC	quality assurance and quality control
RI/FS	remedial investigation and feasibility study
RM	river mile
RSET	Regional Sediment Evaluation Team
SAB	Science Advisory Board
SEM	simultaneously extracted metals
SSD	species sensitivity distribution

TEC	threshold effect concentration
TOC	total organic carbon
TU	toxicity unit
U.S.	United States
UCR	Upper Columbia River
USGS	U.S. Geological Survey
WQC	water quality criteria

UNITS OF MEASURE

°C	degrees Celsius
cm	centimeter(s)
g	gram(s)
g/L	gram(s) per liter
in.	inch(es)
kg	kilogram(s)
L	liter(s)
M	molar
m^2	square meter(s)
mg	milligram(s)
mg/kg	milligram(s) per kilogram
mL	milliliter(s)
mm	millimeter(s)
rpm	revolutions per minute
µg	microgram(s)
µg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
µm	micrometer(s)
µmol	micromole(s)
$\mu mol/g_{oc}$	micromole(s) per grams of organic carbon
µmol/g	micromole(s) per gram

1 INTRODUCTION

Several historical studies have evaluated sediment toxicity in the Upper Columbia River (UCR) at a total of 29 stations between 1986 and 2001. More recent information on sediment toxicity in the UCR has been collected at seven stations in 2004 by the U.S. Geological Survey (USGS) and at 50 stations in 2005. The 2005 data were collected by the U.S. Environmental Protection Agency (EPA) as part of Phase I of the remedial investigation and feasibility study (RI/FS).

The studies evaluated in this appendix are historical and were not necessarily conducted for the UCR RI/FS and baseline ecological risk assessment (BERA) and may not meet the current standards of practice and/or the data quality requirements necessary for completion of the BERA. However, for purposes of this BERA Work Plan, the data and analyses are assumed to be adequate to assist in identifying data gaps and describing general site characteristics, but may not be acceptable for use in future deliverables in their current form.

As the BERA progresses, the quality of the existing data, data analysis procedures, and suitability for inclusion in the BERA will be assessed according to procedures that will be reviewed and approved by the EPA. In addition, clear explanations of the data used in evaluations, evaluation methodology, and statistical analysis documentation will be provided in future documents.

Sediment toxicity data will be an important source of information with respect to evaluating potential risks of chemicals of potential concern (COPCs) in sediment and porewater to benthic macroinvertebrate communities in the UCR. The following appendix summarizes and analyzes historical and recent information (e.g., Phase I data) on sediment toxicity in the UCR. Primary objectives of this appendix are as follows:

1. Identify historical and recent sediment toxicity data sets for the UCR, evaluate the quality of those data, and recommend how those data should be used in the RI/FS
2. Summarize the statistical significance of the toxicity test responses found in the 2005 sediment toxicity study
3. Summarize the spatial and temporal patterns of the sediment toxicity test responses found in the historical and recent UCR studies
4. Compare the 2005 sediment toxicity responses with concentrations of total metals and physical characteristics of bulk sediments (i.e., water + solids)
5. Compare the 2005 sediment toxicity responses with sediment concentrations of simultaneously extracted metals (SEM), acid-volatile sulfide (AVS), and total organic carbon (TOC) content

6. Evaluate a quotient approach based on probable effect concentrations (PECs) to represent parameters related to SEM and AVS based on concentrations of the total metals in bulk sediment.

2 DATA QUALITY EVALUATION

In this section, the quality of the historical (1986 to 2001) and recent (2004 to 2005) sediment toxicity data for the UCR is evaluated. For each study, the following information is described:

- Study design and type of toxicity test (including test species)
- Field sampling methods
- Laboratory analytical methods
- Sediment holding time (i.e., whether holding time requirements were met)
- Water quality measurements during testing (i.e., whether parameters such as dissolved oxygen, temperature, ammonia, and pH were within the optimal ranges for the test organisms)
- Negative control results (i.e., whether these results met the performance standards)
- Positive control results (i.e., whether these results were within the control chart limits of the testing laboratories)
- A quality assurance and quality control (QA/QC) summary based on the information described above is provided for each study.

The information presented about data quality is presented for purposes of this analysis only. Final decisions about the quality and utility of existing data will depend on the specific uses proposed, and will be made in consultation with EPA as the BERA and overall remedial investigation progress.

2.1 HISTORICAL (1986–2001) SEDIMENT TOXICITY DATA

Four historical studies of the sediment toxicity of surface sediments in the UCR have been conducted by researchers at the Washington State Department of Ecology (Ecology) (Era and Serdar 2001; Johnson et al. 1989; Johnson 1991) and USGS (Bortleson et al. 2001). Given the age of these historical studies, they are considered too old to be representative of current conditions and as such, have limited applicability to the BERA. However, they are useful for qualitatively evaluating temporal trends in sediment toxicity since 1986.

2.1.1 Johnson et al. (1989)

This study is the earliest evaluation of sediment toxicity in the UCR.

2.1.1.1 Methods

Five stations were sampled between August 4 and 18, 1986. Four stations were sampled in the UCR between river mile (RM) 635 and 738 (Map 1). An additional station was sampled in a reference area located in Lower Arrow Lake, British Columbia (B.C.).

Two sediment toxicity tests were conducted:

- 10-day amphipod test using *Hyalella azteca* – Test endpoint is survival
- 48-hour daphnid test using *Daphnia pulex* – Test endpoint is survival.

Both toxicity tests were conducted using whole sediments and both test species are known to be sensitive to metals toxicity. *H. azteca* is commonly used to assess sediment toxicity and the ecological relevance of the test is high, as the test species lives in close contact with bottom sediment (USEPA 2000). The use of *D. pulex* to assess sediment toxicity is less common and the ecological relevance of this test is less certain because this species resides in the water column (i.e., they are planktonic; USEPA 2000).

Results of the 1986 sediment toxicity tests are presented in Table 1.

2.1.1.2 QA/QC Review

Field Collection Methods. Surface sediments (i.e., top 2 cm) in the UCR and Lower Arrow Lake were collected using a van Veen grab and an Ekman grab sampler, respectively. Both of these grab samplers are acceptable devices for collecting sediments for toxicity testing (USEPA 2001).

Sediments were transferred to a stainless steel container and homogenized using a stainless steel spoon. The homogenization devices were washed with LiquiNox detergent, 10 percent nitric acid, and deionized water between stations. Sediments for chemical analysis and toxicity testing were transferred to glass jars with Teflon-lined lids and transported to the laboratory on ice. These field procedures are acceptable for collecting sediments for toxicity testing (e.g., 2001).

Laboratory Analytical Methods. Both tests were conducted using protocols specified by Nebeker et al. (1984), and both methods are aerated static tests. These protocols have been replaced by those specified for the amphipod test (USEPA 2000) and ASTM (2000) for both tests. The amphipod protocol used by Johnson et al. (1989) has several elements that are inconsistent with the current protocol, which specifies an increased number of replicate test chambers per sample, use of a flow-through design, limited use of aeration, and smaller test chambers. These differences in protocols may limit the degree to which the results of the 1986 study can be compared directly to the results found for the more recent studies conducted in the UCR.

Sediment Holding Time. All toxicity testing was conducted within 14 days from sediment collection, which is considered an acceptable sediment holding time for sediment toxicity testing (USEPA 2001).

Water Quality Parameters. No data were provided by the authors.

Negative Control. Mean amphipod survival in the negative control was 92 percent, which is above the performance standard of 80 percent specified in the protocol, and is indicative of an acceptable test. Mean daphnid survival in the negative control was 70 percent, which is below the performance standard of 80 percent specified in the protocol, and is indicative of a potentially unacceptable test. The low survival for the daphnid test suggests that the test organisms were stressed during testing, and adds considerable uncertainty as to the validity of the test results.

Positive Control. No data were provided by the authors.

QA/QC Summary. Although the sediment collection procedures and laboratory analytical methods used during the 1986 study are considered acceptable, the latter methods are not comparable with current methods specified for these toxicity tests. This limits the degree to which the results of the 1986 sediment toxicity tests can be compared directly with results of current UCR studies.

For the daphnid test, the low survival in the negative control relative to the performance standard adds uncertainty as to the validity of the test results. Appendix III of Johnson et al. (1989) provides a summary of the sediment toxicity methods. They identify several irregularities that may have compromised the results for the daphnid test. Specifically, it was noted that the enumeration of survivors was hindered by the presence of particulate matter in the overlying water. They also had difficulty in locating test organisms on the sediment surface. It was also noted that aeration may have resulted in the relatively low survival in the negative control, as considerable "rolling" of the test organisms was observed in the control beakers during testing, potentially causing stress or damage to the organisms.

Because of the low survival in the negative control for the daphnid test, the results cannot be considered conclusive. In the 1989 study conducted by Johnson (1991), the authors stated that all of the 1986 sediment toxicity results "*are of questionable value due to technical problems encountered in conducting the tests.*"

In summary, the quality of the sediment toxicity data generated by Johnson et al. (1989) is considered questionable, and the data should therefore be used only in a qualitative manner for the UCR RI/FS.

2.1.2 Johnson (1991)

This study was a follow-up study of the initial UCR sediment toxicity conducted in 1986 by Johnson et al. (1989). It employed one test (Microtox®) that was not used in the 1986 study, as well as the two of the tests that were used in 1986.

2.1.2.1 Methods

Six stations were sampled between August 14 and 17, 1989. Four stations were sampled in the UCR between RM 605 and 728 (Map 1), one station was sampled near the head of the Sanpoil Arm, and one station was sampled in the Spokane Arm at RM 8 of that water body. No stations were sampled in a designated reference area.

Three sediment toxicity tests were conducted by Johnson (1991):

- 10-day amphipod test using *H. azteca* – Test endpoint is survival
- 7-day daphnid test using *Daphnia magna* – Test endpoint is survival
- 15-minute Microtox© test using the saltwater bacterium *V. fischeri* – Test endpoint is luminescence.

The amphipod test was conducted using whole sediments, the daphnid test was conducted using both whole sediments and sediment elutriates, and the Microtox© test was conducted using a sediment elutriate. For the 1986 study, the daphnid test was conducted using only whole sediments.

As stated above, *H. azteca* and *D. magna* are both known to be sensitive to metals toxicity and *H. azteca* is commonly used to assess sediment toxicity. By contrast, the Microtox© test is not commonly used to assess sediment toxicity and the ecological relevance of the test endpoint (i.e., reduced bacterial luminescence) is uncertain.

Results of the 1989 sediment toxicity tests are presented in Table 2.

2.1.2.2 QA/QC Review

Field collection methods—Surface sediments (i.e., top 2 cm) were collected using a 0.1-m^2 van Veen grab sampler, which is an acceptable device for collecting sediments for toxicity testing (e.g., USEPA 2001).

Sediments were transferred to a stainless steel container and homogenized using a stainless steel spoon. The homogenization devices were washed with LiquiNox detergent, 10 percent nitric acid, and deionized water between samples. Sediments for chemical analysis and toxicity testing were transferred to glass jars with Teflon-lined lids and transported to the laboratory on ice. These field procedures are acceptable for collecting sediments for toxicity testing (e.g., USEPA 2001).

Laboratory Analytical Methods. Both tests were conducted using the methods specified by Nebeker et al. (1984) and the Microtox© test was conducted using the methods specified by EPA (USEPA 1986). Protocols for both the amphipod and daphnid test have been replaced by those specified by EPA (USEPA 2000) for the amphipod test and ASTM (2000) for both tests. The amphipod protocol used by Johnson (1991) has several elements that are inconsistent with the current protocol, which specifies an increased number of replicate test chambers per sample, use of a flow-through design, limited use of aeration, and smaller test chambers. The daphnid protocol used by Johnson (1991) also has several elements that are inconsistent with the current protocol. These differences in protocols limit the degree to which the results of the 1986 study can be compared directly to the results found for the more recent studies conducted in the UCR.

Sediment Holding Time. No data were presented by the authors.

Water Quality Parameters. No data were presented by the authors.

Negative Control. No data were presented by the authors.

Positive Control. No data were presented by the authors.

QA/QC Summary. In summary, given the limited amount of information provided by the author, it was not possible to conduct a complete evaluation of the quality of the 1989 data set. Because the quality of the data cannot be determined with certainty, these data should be used only in a qualitative manner for the UCR RI/FS.

2.1.3 Bortleson et al. (2001)

This study represents the largest historical study of sediment toxicity in the UCR.

2.1.3.1 Methods

Sediment samples were collected in September and October of 1992 in the UCR from RM 596 to 745 (Map 1). Sediments were also collected in the Sanpoil and Spokane Arms, as well as the Kettle and Colville rivers. Lower Arrow Lake, B.C., was designated as the reference area for the study and two stations were sampled in that water body. Additional stations were sampled in the Kootenay and Pend Oreille rivers, which join the Columbia River above the United States (U.S.)-Canada border.

Three sediment toxicity tests were conducted by Bortleson et al. (2001):

- 7-day amphipod test using *H. azteca* – Test endpoint is survival
- 7-day daphnid test using *Ceriodaphnia dubia* – Test endpoint is survival and reproduction
- 15-minute Microtox© test using the saltwater bacterium *V. fischeri* – Test endpoint is luminescence.

Within the UCR, the amphipod and daphnid tests were conducted at a subset of 14 stations whereas the Microtox© test was conducted at all 27 stations. The amphipod and daphnid tests were conducted using whole sediments, whereas the Microtox© test was conducted using whole sediments and sediment porewater (obtained by centrifugation).

Results of the 1992 sediment toxicity tests are presented in Table 3.

2.1.3.2 QA/QC Review

Field Collection Methods. Surface sediments (i.e., top 1.3 to 2.5 cm) were collected using a stainless steel van Veen grab sampler, which is an acceptable device for collecting sediments for toxicity testing (e.g., USEPA 2001).

Sediments were transferred to a glass bowl and homogenized using Teflon blades and a stainless steel spoon. Sediments were then wet sieved through a 2- mm nylon screen, before shipment to the bioassay laboratories. Sediments for toxicity testing using the *H. azteca* and *C. dubia* tests were transferred to high-density polyethylene containers, whereas sediments for testing using Microtox© were transferred to glass jars. All sediments were maintained at or below 4 degrees °C prior to toxicity testing. These field procedures are generally acceptable for collecting sediments for toxicity testing (e.g., USEPA 2001), except that wet sieving is a non-standard procedure.

Laboratory Analytical Methods. Bortleson et al. (2001) briefly described the methods used for the amphipod and daphnid tests, but did not identify the specific testing protocols that were used. The Microtox© test was conducted using the procedures specified by Microbics Corporation (1992). The amphipod test was conducted using 10 test organisms per test chamber and three replicate chambers per sediment sample. Each chamber was aerated. The low number of replicates and 7-day exposure period were inconsistent with current methods (USEPA 2000 and (ASTM 2000). The daphnid test was conducted using protocols that were generally consistent with those specified by ASTM (2000).

Sediment Holding Time. All toxicity testing was conducted within 14 days from sediment collection, which is considered an acceptable sediment holding time for sediment toxicity testing (ASTM 2000; USEPA 2000).

Water Quality Parameters. No data were provided by the authors.

Negative Control. Mean amphipod survival in the three negative controls ranged from 87 to 97 percent, which are above the performance standard of 80 percent, and is indicative of an acceptable test. Mean daphnid survival was 90 percent in both negative controls, which is above the performance standard of 80 percent, and is indicative of an acceptable test. No negative controls were evaluated for the Microtox© test.

Positive Control. No data were provided by the authors.

QA/QC Summary. Although the sediment collection procedures and laboratory analytical methods are considered generally acceptable, the wet sieving of sediments before testing may have introduced artifacts[1] to the toxicity testing and is inconsistent with previous UCR sediment toxicity studies. In addition, the relatively short exposure period for the amphipod test and low number of replicates may limit their comparability to tests conducted using current protocols. Because of these limitations, the toxicity data should be used only in a qualitative manner for the UCR RI/FS.

2.1.4 Era and Serdar (2001)

This study of sediment toxicity in the UCR was conducted on sediments collected from May 7 to 9, 2001.

2.1.4.1 Methods

Ten stations were sampled between May 7 and 9, 2001. Seven stations were sampled in the upper and lower portions of the UCR, with four stations located between RM 596 and 645 and three stations located between RM 738 and 745 (Map 1). One additional station was sampled near the head of the Sanpoil Arm, and a second additional station was sampled in the Kettle River. The designated reference station was located in Lower Arrow Lake, B.C. Three sediment toxicity tests were conducted:

- 10-day amphipod test using *H. azteca* – Test endpoint is survival
- 20-day chironomid test using *Chironomus dilutus* – Test endpoint is survival and growth
- 15-minute Microtox© test using the saltwater bacterium *V. fischeri* – Test endpoint is luminescence.

The amphipod and chironomid tests were conducted with whole sediments, whereas the Microtox© test was conducted with porewater.

[1] Although intended to remove invertebrate predators and larger particles, wet sieving may have altered the sediment grain size of the sediments used for testing.

Results of the 2001 sediment toxicity tests are presented in Table 4.

2.1.4.2 QA/QC Review

Field Collection Methods. Surface sediments (i.e., top 10 cm) in the UCR were collected using a 0.1-m^2 stainless steel van Veen grab sampler, which is an acceptable device for collecting sediments for toxicity testing (e.g., USEPA 2001). Between stations, the grab sampler was brushed and rinsed with site water. The sample for the Kettle River was collected to a depth of 5 cm. Surface sediments in the Sanpoil Arm and Kettle River were collected by wading into the water and scooping sediments with a stainless steel spoon. This latter collection technique is not a standard procedure and as such, it is questionable whether sample integrity was maintained, or whether the sample may have been winnowed somewhat as it passed through the water column. This technique is not recommended by EPA (USEPA 2001).

Sediment processing, holding, and chain-of-custody procedures were consistent with established protocols (USEPA 2000, 2001). Sediments were transferred to a stainless steel container and homogenized using a stainless steel spoon. The homogenization devices were washed with LiquiNox detergent, tap water, 10 percent nitric acid, and deionized water between stations. The equipment was then air-dried and wrapped in aluminum foil. Sediments for chemical analysis and toxicity testing were transferred to pre-cleaned glass jars with Teflon-lined lids and transported to the laboratory on ice. These field procedures are acceptable for collecting sediments for toxicity testing (USEPA 2001).

Laboratory Analytical Methods. The amphipod and chironomid tests were conducted using EPA protocols (USEPA 2000) and the Microtox© test was conducted using the Ecology protocols (Adolfson 2000). Both protocols are considered acceptable. In addition, the methods used for the amphipod and chironomid tests are comparable to those used in the more recent UCR studies, with the exception that the chironomid test used in 2001 was initiated with 1-day old organisms (compared to 10-day old organisms used in the more recent studies) and the exposure period was 20 days (compared with the 10 to 12 day period used in the more recent studies). It is therefore possible that the former chironomid tests may have been more sensitive than the latter tests.

Sediment Holding Time. All toxicity testing was conducted within 14 days from sediment collection, which is considered an acceptable sediment holding time for sediment toxicity testing (ASTM 2000; USEPA 2000).

Water Quality Parameters—No data were provided by the authors.

Negative Control. Mean amphipod survival in the negative control was 90 percent, which is above the performance standard of 80 percent specified in the protocol, and is indicative of an acceptable test. Mean chironomid survival in the negative control was 69 percent, which is slightly below the performance standard of 70 percent specified in the protocol, and is indicative of a potentially unacceptable test. Mean chironomid biomass in the negative control was 1.52 mg/survivor, which is greater than the performance standard of 0.48 mg/survivor specified in the protocol, and is indicative of an acceptable test. No negative controls were evaluated for the Microtox© test.

Positive Control. No data were provided by the authors.

QA/QC Summary—In summary, the sediment collection procedures and laboratory analytical methods used by Era and Serdar (2001) are considered acceptable. However, the failure of the negative control for the chironomid tests adds uncertainty to the results for that test, although the magnitude of failure was relatively small. These results should therefore be used only in a qualitative manner for the UCR RI/FS.

2.2 RECENT (2004–2008) SEDIMENT TOXICITY DATA

In this section, the quality of the recent sediment toxicity data collected in the UCR in 2004 (Besser et. al. 2008) and 2005 (USEPA 2006) are reviewed. These two studies are the most recent studies of sediment toxicity conducted in the UCR, and are therefore considered most representative of current conditions in the UCR. They therefore have direct applicability to the BERA.

2.2.1 Besser et al. (2008)

Although only seven stations were sampled within this study, they were relatively evenly distributed from the Grand Coulee Dam to the vicinity of Northport, Washington, and were located in most of the major reaches of the UCR.

2.2.1.1 Methods

Sediment sampling was conducted in September of 2004. Seven stations were located in the UCR between approximately RM 735 and 601 (Map 2). One additional station was sampled near the head of the Sanpoil Arm, the designated reference area. Two sediment toxicity tests were conducted:

- 28-day amphipod test using *H. azteca* – Test endpoint is survival and growth
- 12-day chironomid test using *C. dilutus* – Test endpoint is survival and growth.

Results of the 2004 sediment toxicity tests are presented in Table 5.

2.2.1.2 QA/QC Review

Field Collection Methods. Surface sediments (i.e., top 4 to 10 cm) in the UCR were collected using a stainless steel box corer (20 cm diameter), which is an acceptable device for collecting sediments for toxicity testing (e.g., USEPA 2001). Sediments were homogenized using Teflon blades, placed in polyethylene containers, and refrigerated. Sediments were then stored in the dark at 4^{o}C prior to toxicity testing. These field procedures are acceptable for collecting sediments for toxicity testing (e.g., USEPA 2001).

Laboratory Analytical Methods. The amphipod and chironomid tests were conducted using approved protocols (USEPA 2000 and ASTM 2000), with the exception that the test duration for the latter test was 12 days, compared with the duration of 10 days specified in the protocol. Both protocols are considered acceptable.

Sediment Holding Time. All toxicity testing was conducted within 14 days from sediment collection, which is considered an acceptable sediment holding time for sediment toxicity testing (ASTM 2000; USEPA 2000).

Water Quality Parameters. No data were provided by the authors.

Negative Control. Mean amphipod survival in the negative control was 85 percent, which is above the performance standard of 80 percent specified in the protocol, and is indicative of an acceptable test. Mean chironomid survival in the negative control was 90 percent, which is above the performance standard of 70 percent specified in the protocol, and is indicative of an acceptable test. Mean chironomid biomass in the negative control was 1.92 mg/survivor, which is greater than the performance standard of 0.48 mg survivor specified in the protocol, and is indicative of an acceptable test.

Positive Control. No data were provided by the authors.

QA/QC Summary. The sediment collection procedures and laboratory analytical methods used during the 2004 UCR study are considered acceptable (e.g., USEPA 2001). However, the authors noted that highly variable survival was found for the amphipod test at three stations, with 0 percent survival occurring in some replicates, when 90 to 100 percent survival was found in most other replicates. The authors suggested that the high mortality may have been due to predation by indigenous organisms in the test sediment rather than highly variable toxicity or multiple technical errors. These unusual results add uncertainty to the results for the amphipod test at the three affected stations.

2.2.2 USEPA (2006) – Phase I Sediment Toxicity

This data set represents the most recent and most extensive evaluation of sediment toxicity in the UCR, was completed during Phase I RI/FS activities, and therefore has the greatest bearing on current conditions and the BERA.

2.2.2.1 Methods

Sediment sampling was conducted in April and May of 2005. Fifty stations were sampled for sediment toxicity testing between RM 603 and 745 (Map 3). Six additional stations were sampled in six tributaries to the UCR between RM 685 and 732, to represent reference areas. Three sediment toxicity tests were conducted:

- 28-day amphipod test using *H. azteca* – Test endpoint is survival and growth
- 10-day chironomid test using *C. dilutus* – Test endpoint is survival and growth
- 7-day daphnid test using *C. dubia* – Test endpoint is survival and reproduction.

All three toxicity tests were conducted using whole sediments.

With respect to the three sediment toxicity tests evaluated in Phase I, EPA provided a detailed ranking of these tests, along with other candidate tests, to select the preferred tests for development of standardized protocols for assessing sediment toxicity of freshwater sediments (USEPA 2000). Based on 10 selection criteria, EPA stated that the tests based on *H. azteca* and *C. dilutus* were the preferred tests for evaluating freshwater sediment toxicity (USEPA 2000). By contrast, tests based on cladocerans (i.e., *Daphnia* spp. and *Ceriodaphnia* spp.) were not selected in part because they ranked poorly with respect to two major selection criteria:

- The test organisms do not maintain direct contact with sediment
- There is no database for interlaboratory comparisons of test methods (i.e., round-robin studies) for whole-sediment exposures.

There were two additional selection criteria for which the cladoceran tests were weak:

- They do not have a niche similar to the organisms of concern (e.g., similar feeding guild or behavior to the indigenous organisms)
- Their responses (i.e., in whole-sediment exposures) have not been confirmed with responses of natural populations of benthic organisms.

Given the limitations of the cladoceran tests identified above for whole-sediment exposures, the 2005 results based on *C. dubia* should be interpreted with caution.

By contrast with the daphnid test, the 2005 results for the amphipod and chironomid tests should be given greater weight in evaluating potential sediment toxicity in the UCR, to the degree that the tests were conducted appropriately and achieved the data quality specifications. The amphipod test, in particular, has been shown to be a sensitive indicator of metals toxicity, and the sublethal growth endpoint has been shown to generally be a more sensitive indicator of sediment toxicity than the lethal endpoint (USEPA 2000).

H. azteca and *C. dilutus* are both known to be sensitive to metal toxicity and are commonly used to assess sediment toxicity. The ecological relevance of both tests is high, as the test species lives in close contact with bottom sediment. The use of *C. dubia* to assess sediment toxicity is less common and the ecological relevance of this test is less certain because the test species resides in the water column (i.e., it is planktonic).

Results of the 2005 sediment toxicity tests are presented in Table 6.

2.2.2.2 QA/QC Review

Field Collection Methods. Although the study design specified that the top 10 to 15 cm of sediment would be collected using a grab sampler, these specifications were not achieved at all stations (Figure 1). Surface sediments were collected using a van Veen grab sampler at most stations below RM 725, and generally the top 8 to 16 cm of the sediment column was sampled. Above RM 725, at several stations below that location, and at the six reference areas located in tributaries to the UCR, surface sediments were collected using hand tools, and generally the top 4 to 8 cm of the sediment column was sampled. The grab sampler is considered an acceptable device for collecting sediment for toxicity testing (e.g., USEPA 2001). The use of hand tools to collect submerged sediments is not considered an optimal method for collecting submerged sediments, and is not recommended by EPA (USEPA 2001).

Following collection, sediments were transferred to an aluminum-lined stainless steel bowl and homogenized using disposable hand tools. Any obvious abnormalities (e.g., wood/shell fragments, large organisms) and coarser-grained sediment (e.g., pebbles, gravel) were removed by hand or using the disposable hand tools prior to homogenization. Sediment subsamples were then distributed to pre-labeled sample containers and stored in a cooler at 4°C. These field procedures are acceptable for collecting sediments for toxicity testing (e.g., USEPA 2001).

Laboratory Analytical Methods. The amphipod and chironomid sediment toxicity tests were conducted using protocols specified by EPA (USEPA 2000) and ASTM (2000), and the daphnid test was conducted using the protocols specified by EPA (USEPA 2002). These protocols are considered acceptable for measuring sediment toxicity.

Sediments from the 50 stations sampled in the UCR were tested in two batches for each of the three toxicity tests. Each batch contained sediment samples from 25 different UCR stations, as well as sediment samples from all six candidate reference stations. That is, the candidate reference stations were tested twice on separate occasions, and each UCR station was tested once. Each batch also contained a negative control and an associated positive control. The negative control sediment was collected by personnel from the toxicity testing laboratory from Beaver Creek, Oregon, a site documented by the testing laboratory as being uncontaminated. The documentation was reviewed as part of this QA/QC assessment.

Sediment Holding Time—All toxicity testing was conducted within 14 days from sediment collection, which is considered an appropriate sediment holding time for sediment toxicity testing (ASTM 2000; USEPA 2000).

Water Quality Parameters. No significant departures from the test specifications were found for key water quality parameters (e.g., temperature, dissolved oxygen, and ammonia) for any of the three toxicity tests.

Negative Control. Mean amphipod survival in the negative control ranged from 96 to 98 percent, which is above the performance standard of 80 percent specified in the protocol, and is indicative of an acceptable test. Mean amphipod biomass in the negative controls ranged from 0.38 to 0.41 mg/survivor, which is above the performance standard of 0.15 mg/survivor specified in the protocol, and is indicative of an acceptable test.

Mean chironomid survival in the negative control ranged from 84 to 89 percent, which is above the performance standard of 70 percent specified in the protocol, and is indicative of an acceptable test. Mean chironomid biomass in the negative control ranged from 1.51 to 1.97 mg/survivor ash-free dry weight (AFDW), which is greater than the performance standard of 0.48 mg/survivor AFDW, and is indicative of an acceptable test.

Mean daphnid survival in the negative control ranged from 80 to 90 percent, which is at or above the performance standard of 80 percent specified in the protocol, and is indicative of an acceptable test. Mean number of young in the negative controls ranged from 23 to 24 individuals per female, which is above the performance standard of 15 individuals per female specified in the protocol, and is indicative of an acceptable test.

Positive Control. For the amphipod test, the 96-hour median lethal concentration (LC50) values for the reference toxicant (i.e., cadmium) ranged from 4.4 to 7.9 μg/L, which is within the control chart limits of the testing laboratory (i.e., 3.3 to 10.7 μg/L).

For the chironomid test, the 96-hour LC50 values for the reference toxicant (i.e., potassium chloride [KCl]) ranged from 5.1 to 6.6 g/L, which is within the control chart limits of the testing laboratory (i.e., 1.6 to 7.4 g/L).

For the daphnid test, the 25 percent inhibition concentration (IC25) values for the reference toxicant (i.e., sodium chloride [NaCl]) were 1.4 g/L for survival and 0.42 g/L for reproduction, which are within the control chart limits of the testing laboratory.

QA/QC Summary. In summary, there are no major concerns with respect to the laboratory methods used to conduct the 2005 tests based on the parameters commonly used to assess the quality of these sediment toxicity tests. DMR (2005a,b) conducted independent reviews of data quality for all three tests (including on-site laboratory audits while the tests were being conducted), and concluded that all of the data were of excellent quality and fully usable for any purpose. Although not necessarily a data quality concern unless the sediment samples were lost during sample collection, the use of hand tools (rather than grab samplers) to collect many of the sediment samples and the failure to achieve the target sampling depth of 10 to 15 cm indicate that the sampling methods were not optimal at many stations.

2.2.2.3 Phase I Sediment Toxicity Test Data - Limitations

Although Phase I sediment toxicity data collected in 2005 by EPA (USEPA 2006) met the standard criteria for data quality, a number of concerns were identified during review and analysis of the characteristics of the six reference areas, as well as the results of the amphipod and chironomid tests, that have implications with respect to the appropriateness of the reference areas. In addition, a number of additional concerns with the chironomid test were found. These various concerns are discussed below.

Concerns Related to the Reference Areas. As discussed previously, EPA (USEPA 2006) selected six reference areas in tributaries to the UCR between RM 685 and 732. EPA guidance for Superfund (USEPA 1994) specifies that, ideally, reference areas should be:

- Relatively uncontaminated
- Upgradient and in the same watershed as the test area
- Similar to the test area with respect to water depth and flow
- Similar to the test area with respect to sediment grain size distribution and TOC content.

Similarly, the Regional Sediment Evaluation Team (RSET) (USACE 2006) specifies that freshwater reference areas should be similar to their corresponding test areas with respect to sediment grain size distribution and TOC.

Although the six 2005 reference areas were located upgradient and in the same watershed as the UCR, inspection of site photographs and review of field log books indicated that they have no physical similarity to any parts of the UCR with respect to water depth and flow. All six areas are small, shallow streams surrounded by relatively dense vegetation. In most cases, sediments were collected in only 4 to 8 in. of water.

In addition to the physical characteristics of the six reference areas differing substantially from those of the UCR, the sediment TOC content of the reference areas was considerably greater than that for the UCR. The mean sediment TOC content of 2.5 percent for the six reference areas was significantly greater than the mean value of 0.5 percent for the 50 stations sampled in the UCR (Figure 2). Based on the data, sediment TOC of only 4 of the 50 UCR stations (8 percent) was within the range of values found for the reference areas (Figure 2).

Given the dissimilarities between the six 2005 reference areas and the UCR described above, their use to represent the conditions expected to be found in the UCR is questionable. In addition to these dissimilarities, selected results of the 2005 chironomid and amphipod toxicity tests described below cast additional doubt on the validity of the reference areas.

Concerns Related to the Chironomid Test. As discussed above, sediments from the 50 stations sampled in the UCR were tested in two batches, with each batch containing sediment samples from 25 different UCR stations, as well as all six reference stations. For the chironomid test, testing for Batch 1 was initiated on April 29, 2005, for sediments from 25 UCR stations located above RM 675 (near Inchelium). Testing for Batch 2 was initiated on May 6, 2005, for sediments collected from 10 stations above RM 675 and 15 stations below RM 675.

The one test condition that did not appear to meet the method specifications was age at test initiation. The method, as summarized within Table 12.1 of USEPA (2000), specifies that at least 50 percent of all test organisms must be at the third instar stage at test initiation. In addition, the developmental stage of the test organisms was not documented from a subset of 20 organisms by determining head capsule width, length, or dry weight (Section 12.3.4, USEPA 2000). Instead, the laboratory used the developmental stage estimated by the supplier of the test organisms based on time elapsed after oviposition. Based on that information, the test was started when most organisms were likely at the second instar stage. These results suggest that the test organisms were generally younger than the age at test initiation specified by EPA (USEPA 2000).

In addition to the above departure from the test protocols with respect to age at test initiation, a number of other irregularities were found with the data, including:

- Unusually high occurrence of pupation at test termination
- Inconsistent results for the candidate reference stations.

Each of these irregularities is described below.

Typically, pupation should occur in less than 1 percent of larvae at the end of testing (Section 15.3.8.3, USEPA 2000). However, for the 2005 tests, pupation occurred for approximately 9 and 26 percent of the surviving organisms for Batches 1 and 2, respectively. As a result, these organisms could not be used for biomass determinations, as specified by the test method (USEPA 2000). In addition, these results suggest that the test organisms either were generally older than the recommended age at test initiation, or they grew unusually fast during the 10-day exposure period. Because a review of the test conditions did not reveal any obvious departures from the method specifications that would lead to accelerated growth, it is most likely that the age of the organisms at test initiation was greater than the method specifications. However, this is contradictory to the estimated age at initiation of the test organisms based on oviposition date (described above), which was generally lower than the method specifications. Therefore, the actual age of the organisms used in the study remains an uncertainty.

Because sediments from the candidate reference stations were tested in both Batch 1 and 2, those sediments can be used as additional information on the sensitivity and consistency of testing between the two batches, in addition to the information on the negative and positive controls described above. Survival results for the reference areas differed significantly ($p \leq 0.05$) between the two batches, with the results for Batch 1 being lower than for those for Batch 2, regardless of whether the data were normalized to the negative controls (Figure 3). In addition, there was no overlap in the ranges of mean values for individual candidate reference stations between batches.

In contrast with survival, the grand mean of biomass was nearly identical between the two batches, and the ranges of mean values for individual candidate reference stations were very similar.

- Batch 1 – Mean = 2.00 mg AFDW, Range = 1.93 to 2.12 mg AFDW
- Batch 2 – Mean = 2.02 mg AFDW, Range = 1.91 to 2.20 mg AFDW.

Survival results for the candidate reference stations are considered highly unusual, as it would be expected that the grand mean would be similar between the two batches and that the individual values would overlap to a large degree. However, the large and consistent differences in survival between the two batches suggest that a systematic bias was present for one or both batches. The consistency of these differences is particularly striking because the candidate reference stations were sampled from six different streams distributed over 47 miles along the UCR, rather than from six locations in the same stream. In addition, the relatively low survival found for the candidate reference stations in Batch 1 are unusual, as sediment chemical concentrations were relatively low at all of those stations. For example, the values of survival in five of the six areas were at or below the minimum acceptable value of 70 percent specified for freshwater reference areas by RSET (USACE 2006).

Given the concerns identified above with respect to 1) the age of the test organisms at test initiation, 2) the unusually high occurrence of pupation at test termination, and 3) the consistently different results found between test batches for the six candidate reference stations, the results of the 2005 Phase I chironomid tests are considered questionable and should be interpreted with caution.

Concerns Related to the Amphipod Test. Although there were no data quality concerns with the conduct of the amphipod test, the biomass results for the six reference areas appeared to be influenced by the TOC content of the sediment. This apparent influence is important because, as described above, the TOC contents found for the six reference areas were considerably greater than those found for most of the 50 UCR stations.

Orr et al. (2004) found that sediment TOC can have a positive influence on biomass in the 28-day *H. azteca* test, and concluded that it can be a potentially confounding factor when comparing results for sediments with different organic contents. Based on the findings of Orr et al. (2004), the biomass results for the amphipod test conducted for the six UCR reference areas were evaluated to determine whether they were affected by sediment TOC, which could potentially confound comparisons with most results for the 50 UCR stations. These comparisons were made both with and without the results of a field split sample being included in the results for one of the reference stations.

Results of the amphipod biomass comparisons showed that, in general, biomass was greater for the stations with TOC concentrations greater than 2.0 percent, than for stations with TOC concentrations less than that value (Figure 4). These results suggest that it is questionable whether the former areas are valid reference areas for most of the 50 UCR stations, as sediment TOC content at only one of the UCR stations exceeded 2.5 percent (see Figure 2).

Summary. In summary, the concerns identified above with respect to the six 2005 reference areas and the results of the chironomid test cast uncertainty on the validity of the reference areas as representative of conditions expected in the UCR, as well as the validity of the results of the chironomid test as representative of sediment toxicity in the UCR. It therefore is recommended that the six reference areas sampled during the 2005 UCR study not be used to evaluate potential sediment toxicity in the UCR. However, should data evaluations be conducted using the reference areas, any observations related to patterns based on the reference areas or chironomid results should be qualified and viewed with caution and qualitatively only.

3 DETERMINATION OF SIGNIFICANT TOXICITY RESPONSES

Given the concerns identified in the previous section with respect to the appropriateness of the reference areas sampled in 2005, the reference areas were not used as the primary method to evaluate the statistical significance of the toxicity responses found at the 50 stations sampled in Phase I. Instead, comparisons were made with the batch-specific negative control results, in conjunction with criteria that identified two response levels:

- **Response Level 1.** The mean result for a UCR station was 1) significantly lower ($p \leq 0.05$) than the corresponding mean negative control value, and 2) between 70 and 80 percent of the mean value of the negative control value in magnitude.
- **Response Level 2.** The mean result for a UCR station was 1) significantly lower ($p \leq 0.05$) than the corresponding mean negative control value, and 2) less than 70 percent of the mean negative control value in magnitude.

The specification of two graduated response levels is useful for ranking stations with respect to unacceptable risks to benthic macroinvertebrate communities. In combination with the distinction between lethal and sublethal responses, there are at least four response categories that can be used to evaluate relative risks to those communities: lethal Level 1, lethal Level 2, sublethal Level 1, and sublethal Level 2. Lethal responses refer to direct mortality of the test organisms, whereas sublethal responses refer to responses such as growth and reproduction that do not result in direct mortality of the test organisms. Further distinctions can be made among the various responses, if desired, by considering characteristics of the sediment toxicity tests and test organisms, such as ecological relevance and degree of exposure to *in situ* bottom sediments.

Statistical significance was determined using the approach identified in SEDQUAL (Ecology 2004a). That is, each pair of test and negative control results were compared using a two-sample *t*-test (i.e., if the parametric assumptions of normality and homoscedasticity were achieved) or a Wilcoxon rank sum test (i.e., if the parametric assumptions were not achieved). Each comparison was made with a comparisonwise Type I error rate of 0.05. Throughout the remainder of this appendix, the term "significant response" will be used to refer to either a Level 1 or Level 2 response, as defined above.

Methods used to evaluate Phase I sediment toxicity results are similar to those selected to evaluate the sediment toxicity results within the Region (e.g., Portland Harbor). Similarly, the methods used for the UCR are similar to those used for evaluating freshwater sediment toxicity tests in Washington State by Ecology (2004b), in the Pacific Northwest by RSET (USACE 2006) and throughout the U.S. as part of the National Sediment Quality Survey (USEPA 2004). In addition, Chapman and Anderson (2005) considered a value of 80 percent of reference area response to be a threshold for toxic effects.

Results of the statistical evaluations of the UCR toxicity results are presented in Tables 7 and 8, and are plotted in Maps 4 and 5. Tables 7 and 8 illustrate the magnitudes of responses for the toxicity results that qualified as Level 1 and Level 2 responses. Although the evaluations described herein are based on comparisons with negative controls, the results of comparisons with the reference results are presented in Tables 9 and 10 for informational purposes only. Reference area comparisons were made using the methods specified above for comparisons with the negative controls.

Significant responses relative to the negative controls for one or more of the three sediment toxicity tests were found at approximately half (i.e., 26) of the 50 stations evaluated in 2005. The results can be summarized for each river reach as follows:

- **Reach 1 (RMs 744 to 730).** Level 1 or 2 responses were found at 8 of the 15 stations (53 percent) in this reach and for 17 of the 90 endpoints (19 percent) evaluated. Most of the significant responses (i.e., 76 percent) were sublethal, with significant lethal responses found only at one station; each for the amphipod and chironomid tests, and at two stations for the daphnid test. Approximately 60 percent of the significant responses were Level 2 responses. Concordance among all three toxicity tests was found at three stations.
- **Reach 2 (RMs 730 to 712).** Level 1 or 2 responses were found at 2 of the 7 stations (29 percent) in this reach and for 2 of the 42 endpoints (5 percent) evaluated. Both significant responses were lethal responses for the chironomid test with one being Level 1 and the other Level 2. No concordance among two or more of the three toxicity tests was found at any station.
- **Reach 3 (RMs 712 to 700).** Level 1 or 2 responses were found at 3 of the 4 stations (75 percent) in this reach and for 3 of the 24 endpoints (13 percent) evaluated. Two of the significant responses were lethal responses for the chironomid test, and the remaining significant response was a sublethal response for the amphipod test. Only one of the three significant responses was a Level 2 response. No concordance among two or more of the three toxicity tests was found at any station.
- **Reach 4 (RMs 700 to 640).** Level 1 or 2 responses were found at 10 of the 15 stations (67 percent) in this reach and for 14 of the 90 endpoints (16 percent) evaluated. Seven of the significant responses 44 percent were lethal responses. All of the lethal responses were found for the chironomid test, whereas the sublethal responses were found for both the amphipod and daphnid tests. Nine of the significant responses (64 percent) were Level 2 responses. Concordance among two of the three toxicity test was found at four stations.

- **Reach 5 (RMs 640 to 617).** Level 1 or 2 responses were found at 2 of the 4 stations (50 percent) in this reach and for 3 of the 24 endpoints (13 percent) evaluated. All three significant responses were found for the daphnid test and two of them were Level 2 responses found at the same station. No concordance among two or more of the three toxicity tests was found at any station.
- **Reach 6 (RMs 616 to 597).** Level 1 or 2 responses were found at 1 of the 5 stations (20 percent) in this reach and for 1 of the 30 endpoints (3 percent) evaluated. The significant response was a Level 2 sublethal response for the daphnid test. No concordance among two or more of the three toxicity tests was found at any station.

The reach-specific results described above indicate that, in general, most of the significant responses were found for sublethal endpoints, especially if the survival values for Batch 1 of the chironomid tests are qualified as uncertain (see Section 2.2.2.3). For example, 23 significant responses were found for the 150 sublethal responses evaluated in 2005 (i.e., three toxicity tests at 50 stations), whereas 17 lethal responses were found for the 150 lethal responses evaluated in 2005. The number of lethal responses would decline to 8 (i.e., one, three, and four for the amphipod, chironomid, and daphnid tests, respectively), if the chironomid survival results for Batch 1 were removed.

Although a number of significant responses were found for the three sediment toxicity tests, concordance among the tests was relatively low. For example, of the 26 stations that exhibited a significant response in one or more of the toxicity tests, all three tests exhibited significant responses at only three stations (12 percent), and two of the three tests exhibited significant responses at only four stations (15 percent). These patterns indicate that there was little corroboration among the three tests with respect to sediment toxicity, suggesting that the tests were responding relatively independently and casting doubt on whether most of the stations exhibiting significant toxicity tests were highly or even moderately toxic, as significant toxicity in the multiple tests would be expected under such conditions.

4 LONGITUDINAL PATTERNS IN SEDIMENT TOXICITY

In this section, the longitudinal patterns of the historical and recent sediment toxicity results are discussed and compared, to evaluate:

- If there are any consistent spatial patterns or trends that could potentially be related to chemical or physical sediment variables
- If there are substantial differences in the patterns or trends observed for the two generalized time periods.

These analyses were conducted independent of the statistical comparisons with negative controls, to focus on potential longitudinal patterns.

All of the longitudinal patterns were evaluated based on sediment toxicity results normalized to study-specific negative control values. By normalizing the data in such a manner, it was possible to compare results based on different test species, endpoints, exposure periods, and laboratory methods on the same scale. This kind of normalization also allowed the various kinds of data to be combined to provide a weight of evidence for the toxicity evaluations. To facilitate discussions of longitudinal patterns in toxicity responses, a control-normalized value of 80 percent was used as a point of reference, because this value was used in conjunction with statistical comparisons to identify Level 1 responses in Section 3 above. Also, as previously noted, Chapman and Anderson (2005) considered a value of 80 percent of reference area response to be a threshold for toxic effects.

The only data that were not included in the evaluation of the historical data were the data for the Microtox© test conducted during the 1991 and 2001 UCR studies. These data were not included because there were no data for negative controls for endpoint normalization and because, as discussed in Section 2, the ecological relevance of this bacterial test is uncertain. In addition, this test has not been used in the recent UCR studies. For the other species used in the historical studies (i.e., *H. azteca, C. dilutus*, and *D. pulex, D. magna, and C. dubia*), the recent studies have used the same species (i.e., *H. azteca, C. dilutus*, and *C. dubia)* or closely related species (i.e., *C. dubia* is cladoceran like *D. pulex and D. magna*).

4.1 LONGITUDINAL PATTERNS RELATED TO HISTORICAL UCR TOXICITY DATA

As described previously, the historical sediment toxicity data for the UCR are based on sediment samples from 27 stations that were evaluated in four studies between 1986 and 2001. The original data for those studies are presented earlier in Tables 1 through 4, whereas the control-normalized data used for the current evaluations are presented in Table 11.

The longitudinal patterns exhibited by the historical UCR toxicity data indicated that 26 of the 83 responses (31 percent) were less than 80 percent of their respective negative control values (Figure 5). Eighteen of those 27 responses (i.e., 66 percent) were found in Reach 1, where response values of 0 percent were found in four cases. The remaining nine responses lower than 80 percent were distributed across Reaches 3 to 6, with five of them occurring in Reaches 5 and 6. No responses less than 80 percent were found in Reach 2. In general, there was no clear response gradient of responses along the UCR in Reaches 2 to 6.

4.2 LONGITUDINAL PATTERNS RELATED TO CURRENT UCR TOXICITY DATA

As described previously, the current sediment toxicity data for the UCR is based on 7 stations sampled in 2004 (Besser et. al. 2008) and 50 stations sampled in 2005 (USEPA 2006). The original data for those studies are presented earlier in Tables 5 and 6, whereas the control-normalized data used for the current evaluations are presented in Tables 12 and 13.

Longitudinal patterns exhibited by the 2004 toxicity data indicated that 7 of the 28 responses (25 percent), all associated with the *C. dilutus* biomass endpoint, were less than 80 percent of their respective negative control values (Figure 6, Table 12). None of the other endpoints had any values less than 80 percent. In general and with the exception of the chironomid biomass value in Reach 1, which declined relative to the other values for that endpoint, there was no clear response gradient along the UCR. While the relatively consistent low values found for the chironomid biomass endpoints may have been due to site-related effects, they also may have been due, at least in part, to the large magnitude of the single negative control value to which they were compared. For example, the value of biomass found for the negative control (i.e., 1.92 mg/survivor) was approximately twice that found for the Sanpoil Arm reference location (i.e., 1.03 mg/survivor).

Evaluations of Phase I toxicity results were conducted separately for a) the two endpoints that were directly measured during the tests, and b) a combined endpoint for each test. The combined endpoint for each test incorporated the effects of both of the individual endpoints. For example, for the amphipod survival test, the individual endpoint for biomass is reported as the average biomass of each survivor (i.e., biomass/survivor) at the end of the test. By contrast, the combined endpoint is expressed as the total biomass of all survivors at the end of the test, thereby incorporating the effect of any mortality into the measurement of biomass. Whereas the individual endpoints represent either a lethal or sublethal effect, the combined endpoint represents the overall effect on biomass. Because the combined endpoint may be controlled by one of the individual endpoints (e.g., if there is no mortality, the combined endpoint reflects the growth endpoint), results for the individual endpoints and results for the combined endpoint are evaluated separately to avoid double counting of an effect.

Although the test protocols for the amphipod and chironomid tests identify survival and biomass as the two primary endpoints for these tests (ASTM 2000), a combined endpoint can be calculated. ASTM (2000) notes further that although a combined endpoint is recommended by EPA (USEPA 1993), this approach has not been routinely applied to sediment testing. By contrast, the combined endpoint is commonly used for the daphnid test. Determinations of significant toxicity described above were therefore made on endpoints most frequently used for the three toxicity tests (i.e., the individual endpoints for the amphipod and chironomid tests, and the combined endpoint for the daphnid test).

The longitudinal patterns exhibited by the Phase I toxicity data differed somewhat among the three toxicity tests. The results of each test can be summarized as follows:

- **Amphipod test.** Thirteen of the 100 individual responses (13 percent), and 14 of the 50 combined responses (28 percent) for this test were less than 80 percent of their respective negative control values (Figure 7, Table 13). Only one of the individual responses for survival was less than 80 percent (i.e., 78 percent at RM 744 in Reach 1). For the individual biomass endpoint (i.e., biomass/survivor), 12 values were less than 80 percent, with 7 and 3 of those values (58 and 25 percent) found in Reaches 1 and 4a, respectively. No values less than 80 percent were found in Reaches 2, 5, and 6. In general, the results for the total biomass endpoint controlled the results for the independent biomass endpoint.
- **Chironomid test.** Fifteen of the 100 individual responses (15 percent), and 15 of the 50 combined responses (30 percent) for this test were less than 80 percent of their respective negative control values (Figure 8, Table 13). Only three of the individual responses were for the biomass endpoint, and all three values were found in Reach 1. Responses less than 80 percent for the survival endpoint were found in Reaches 1 (1 response), 2 (2 responses), 3 (2 responses), 4a (4 responses), and 4b (3 responses). No responses less than 80 percent were found in Reaches 5 and 6. In general, results for the total biomass endpoint were primarily controlled by the results for the survival endpoint.
- **Daphnid test.** Seventeen of the 100 individual responses (17 percent), and 9 of the 50 combined responses (18 percent) for this test were less than 80 percent of their respective negative control values (Figure 9, Table 13). Only four of the 17 individual responses were for the survival endpoint, with two of these values found in Reach 1 and two in Reach 5. For the individual reproduction endpoint, 6 and 4 of the 13 responses less than 80 percent (46 and 31 percent, respectively) were found in Reaches 1 and 4b. The three remaining individual reproduction values less than 80 percent were found in Reaches 4a, 5, and 6. No values less than 80 percent were found in Reaches 2 or 3.

The results described above for the six individual endpoints and three combined endpoints from the three toxicity tests conducted in 2005 showed a number of similarities and differences. With respect to similarities, the following observations can be made:

- The greatest number of individual responses less than 80 percent were found in Reach 1 for all three tests (i.e., 8, 4 [tied with Reach 4a]), and 8 responses for the amphipod, chironomid, and daphnid tests, respectively.
- Relatively few individual responses, less than 80 percent, were found in Reaches 2 and 3 for all three tests (i.e., 0, 2, and 0 responses in Reach 2, and 0, 0, and 1 response in Reach 6).

With respect to dissimilarities, the following observations can be made:

- The amphipod test had more individual responses less than 80 percent than either of the other two tests only in Reach 1.
- The chironomid test had more individual responses less than 80 percent than either of the other two tests in Reaches 2, 3, and 4a.
- The daphnid test had more individual responses less than 80 percent than either of the other two tests in Reaches 4b and 6.
- Individual responses for the amphipod and daphnid tests were primarily sublethal responses, whereas the chironomid test showed primarily lethal responses.

Results of a correlation analysis among the nine toxicity endpoints using the Spearman rank correlation coefficient showed that there were few strong associations (i.e., $|\rho|$[2] ≥ 0.80) among the endpoints (Table 14). The only endpoint pairs that exhibited strong associations were amphipod biomass and total biomass ($|\rho| = 0.96$) and daphnid young/survivor and total young ($|\rho| = 0.82$). Neither pair represents two independent toxicity tests. The general lack of strong correlations among the independent toxicity endpoints is consistent with the dissimilarities among the tests identified above, and the general lack of concordance among significant responses identified in Section 2 above. Consistent with the results discussed in Section 2, the general lack of strong correlations among the nine toxicity endpoints suggests that the tests were responding relatively independently. This pattern casts doubt on whether most of the stations exhibiting significant toxicity were highly or even moderately toxic, as a greater degree of concordance among the toxicity endpoints would be expected in such situations.

[2] The absolute value of rho, the Spearman correlation coefficient.

4.3 EVALUATIONS BASED ON A WEIGHT-OF-EVIDENCE APPROACH

As described above, the control-normalization procedure applied to the historical and recent sediment toxicity data for the UCR was conducted, in part, to allow a variety of toxicity tests and endpoints to be compared on an 'equal' basis and considered collectively as part of a weight-of-evidence approach. In this section, these weight-of-evidence evaluations are conducted by averaging the control-normalized values or various combinations of UCR data sets. By averaging the various toxicity responses, each response that contributes to a mean value is given equal weight.

There are numerous methods for ranking or scoring various kinds of toxicity results. For example, lethal responses could be given greater weight than sublethal responses, acute responses could be given greater weight than chronic responses, or responses based on sediment-dwelling organisms could be given greater weight that those based on water-column organisms. As noted above, the method used in the present analysis gives equal weight to each kind of test and endpoint that has been evaluated in the UCR to date. Although the various toxicity tests and test endpoints provide independent information with results that sometimes differ (see Section 3), the purpose of the following evaluation is to describe overarching patterns described by all of the tests and endpoints considered together.

4.3.1 Longitudinal Patterns Based on the Recent UCR Data

Evaluations for the recent UCR toxicity data were conducted by first considering lethal and sublethal endpoints separately, and then by combining the endpoints by calculating the mean response across all tests. Figure 10 shows the weight of evidence provided by the mean values of the lethal (survival) endpoints measured in the 2004 and 2005 studies. A mean value less than 80 percent of the respective negative controls was found at only one location in Reach 1. In addition, the 2004 and 2005 data show similar patterns, and no obvious longitudinal gradient in the toxicity responses across the site.

Figure 11 shows the weight of evidence provided by the mean values of the various sublethal endpoints measured in the 2004 and 2005 UCR studies. For the 2004 data, a mean value less than 80 percent of the respective negative controls was found at six of the seven stations evaluated—in all reaches except Reach 4a—with the lowest value found in Reach 1. These low values were largely the result of the low values found for the chironomid biomass endpoint discussed previously, which may be an artifact of the high value found for the negative control rather than an indication of toxicity (i.e., a false positive). For the 2005 data, a mean sublethal response less than 80 percent was found at five stations, four of which were located in Reach 1 and one of which was located in Reach 6. Although the results for 2004 were generally lower than those for 2005, neither data set showed an obvious longitudinal gradient along the site, although as described previously, the lowest values for both data sets were consistently observed in Reach 1.

Figure 12 shows the combined weight of evidence provided by the mean values of the lethal and sublethal endpoints measured in the 2004 and 2005. For both the 2004 and 2005 data sets, a mean value less than 80 percent of the respective negative controls was found only in Reach 1, representing one station (2004) and two stations (2005) for the respective data sets. Despite these three stations in Reach 1, no obvious longitudinal gradient in toxicity responses across the site was observed.

Based on the above-described evaluations and with the exception that Reach 1 contained the greatest number of stations with mean toxicity responses less than 80 percent; no other apparent site-wide longitudinal gradient was observed.

4.3.2 Comparisons of the Historical and Recent UCR Data

A comparison between the mean overall responses of the combined lethal and sublethal endpoints measured in the historical (1986 to 2001) and recent (2004 to 2005) UCR sediment toxicity studies is presented in Figure 13. Longitudinal patterns shown by all data sets appear nearly identical, with most or all of the responses less than 80 percent with respect to the negative control observed in Reach 1, and few or no responses less than 80 percent observed downstream (i.e., Reaches 2 to 6). In Reach 1, the same number of responses lower than 80 percent (i.e., three) was found for both the historical and recent data. However, those responses represent 60 and 23 percent, respectively, of the total number of responses evaluated in the two data sets. In addition, two of the three responses for the historical data were considerably lower than the responses found for the recent data.

5 MEASURES OF METAL EXPOSURE IN SEDIMENTS AND THEIR RELATIONSHIP TO METAL BIOAVAILABILITY AND EFFECTS

Several alternative measures of the exposure of aquatic organisms to sediment metals exist. These measurements include 1) total metal concentrations (bulk chemistry), 2) sequential extracts of bulk sediments, including AVS and SEM; and 3) sediment porewater. These different types of metal measurements can be used in conjunction with results of toxicity tests to assess the potential for adverse effects on sediment dwelling organisms (i.e., lines-of-evidence). As a consequence of fundamental differences among these alternative measurements however, it is necessary to consider how these different estimates of exposure influence assessment of metal bioaccessibility, bioavailability and evaluation of potential effects. A brief review of the alternative measures of exposure, and how these different measurements are typically related to effects are presented below.

Metal concentrations in UCR sediment and porewater have been measured using a variety of methods. Given the availability of measurements collected using many of the above-mentioned methods, as well as associated bioaccumulation and toxicity test results, UCR sediment data sets from 2004 (Paulson et al. 2006; Besser et al. 2008) and 2005 (USEPA 2006) are further examined herein. Results of earlier investigations (e.g., Johnson et al. 1989; Johnson 1991; Era and Serdar 2001) are also considered qualitatively.

5.1 OVERVIEW OF ALTERNATIVE MEASURES OF EXPOSURE TO METALS IN SEDIMENTS

5.1.1 Bulk Sediment Metals

The simplest, and perhaps most commonly used measure of exposure to metals in sediments is the total metal concentration associated with a bulk sediment (water + solids) sample. This type of measurement involves a chemically rigorous digestion to extract metals from a sample, including metals bound to inorganic surfaces and organic matter; metals incorporated within the particle matrix; and metals within porewater. This type of measurement has served as the basis for the derivation of effects range lows (ERLs), effects range medians (ERMs), threshold effect concentrations (TECs), and PECs; all of which are used to assess the potential for effects on the basis of dry-weight normalized metal concentrations (Long et al. 1998; MacDonald et al. 2000). A potential limitation of total metal measurements is that they do not provide information about the phase distribution and chemical availability of a metal. The phase distribution and availability of metals within a sediment sample will vary as a function of the physicochemical characteristics of the sediment. Not all of the metal present in a sediment sample is necessarily accessible to organisms. Consequently, total metal concentrations may not always be good indicators of biotic exposures, as differences in sediment characteristics can cause a given dry-weight metal concentration to have a marked effect in one sediment, and limited or no effect in another.

5.1.2 Sequential Extractions

A less commonly used; but more informative, approach to measuring the forms and content of metals in sediments is to perform a series of extractions that selectively target different binding phases within the sediment matrix. Sequential extraction is a relatively involved analytical method that has the advantage of yielding information about the (operationally defined) distribution of metals within a sediment sample. The underlying rationale for use of sequential extractions is that metals have different affinities for different phases and, in contrast to total metals measurements, quantification of metal fractions associated with each of these phases provides an indication of the strength of metal binding, and related bioaccessibility.

Tessier et al. (1979) describe one of the earliest investigations where sequential extractions were used to chemically characterize associations between metals and some of the more important binding phases present in sediments. The basic approach used was directed at measuring metal concentrations associated with the following fractions 1) readily exchangeable metals (sensitive to the ionic composition of the water); 2) metals bound to carbonates (particularly sensitive to pH); 3) metals bound to easily reducible hydrous iron and manganese oxides (unstable under anoxic conditions); 4) metals bound to organic matter (releases soluble metals as it degrades under oxidizing conditions); and 5) a residual fraction (mainly mineral phases that incorporate metals within their crystalline structure). Since the work of Tessier et al. (1979), many variations on sequential extraction procedures have been proposed (see Tessier and Campbell 1987 for an early review; and Gleyzes et al. 2002 for a more recent review). Regardless of the exact details of the chemical extractions used, each sequential extraction is operationally defined. The reason is that sequential extraction 'operations' used to target metals associated with specific phases are not perfectly selective. That is, to varying degrees, less than 100 percent of the metal associated within a targeted phase may be extracted by a particular step in the extraction sequence. Further, and to varying degrees, metals associated with non-targeted phases may also be extracted during each step of the extraction procedure. Consequently, one potential limitation of metal concentrations determined by sequential extraction is that differences in extraction procedures, or other analytical artifacts, can confound interpretation of the pool of metals within a sample that are potentially bioaccessible.

It is worth noting that the sequential extraction procedure used by Paulson et al. (2006) was in general conformance with the method adopted for use by the European Commission of Standards, Measurements and Testing (ECSMT) (Rauret et al. 1999, 2001). This particular procedure has been tested as part of inter-laboratory investigations (SAIC/Black & Veatch 2005). The same or a very similar method was used by Bell (2004) to investigate UCR sediments, and by EPA to investigate Ocoee River sediments (SAIC/Black & Veatch 2005). While details of the ECSMT chemical extractions differ from those used by Tessier et al. (1979), the phases targeted by the four sequential extraction steps are similar 1) exchangeable and carbonate fractions; 2) an easily reducible fraction targeting iron and manganese oxides; 3) an oxidizable fraction that includes sulfides and organic matter; and 4) a residual, crystalline fraction.

5.1.3 AVS and SEM

Measurements of AVS and SEM involve a relatively simple, single-step extraction procedure. The results are used as a basis for assessing when levels of selected cationic metals in sediments are not expected to cause adverse effects on benthic organisms (USEPA 2005). The procedure involves a cold acid extraction of a sediment sample to measure a portion of the total sulfide in a sample (Allen et al. 1993). The extract is then analyzed to obtain a measure of co-extracted (or simultaneously extracted) metals. Metals extracted by this method include: copper, cadmium, nickel, lead, zinc, and silver (collectively termed "SEM metals"). As originally formulated, this approach was based on the ratio of SEM metals (expressed as a sum) to AVS (Di Toro et al. 1990, 1992). In samples where the sum of the molar concentrations of SEM metals (i.e., the sum of copper, cadmium, nickel, lead, zinc, and one-half silver concentrations, hereinafter termed ΣSEM) is less than the molar concentration of AVS (i.e., when ΣSEM-AVS < 1), there is sufficient sulfide to ensure that porewater concentrations of SEM would be low (because of the strong tendency of metals to form highly insoluble sulfide complexes). For all practical purposes, toxicity due to SEM is not observed when ΣSEM-AVS < 1 (USEPA 2005).

One limitation of this approach emerges when SEM exceeds AVS because a simple SEM to AVS ratio does not permit differentiation between samples where SEM and AVS concentrations are both low or are both high. Such differences are important because samples with similar SEM to AVS ratios may still have different potentials to exert toxicity on benthic organisms. To account for this limitation the AVS and SEM framework was subsequently refined such that the difference between SEM and AVS (i.e., ΣSEM-AVS) be used to indicate the potential for toxicity to occur. In particular, it is important to note that toxicity in sediments is not expected when ΣSEM-AVS < 0 (USEPA 2005).

However, this refinement does not directly address what happens when SEM exceeds AVS. When this situation occurs, excess SEM is available to distribute between porewater and other binding phases that may be present in the sediment (e.g., particulate organic matter and/or other inorganic mineral phases). The degree of increase in porewater metal concentrations is directly related to the magnitude of excess SEM, and inversely related to the complexation capacity of binding phases that are present. This led to a further refinement of the approach, the normalization of excess SEM by the organic carbon content of the sediment (i.e., carbon-normalized excess SEM = [ΣSEM-AVS]/f_{oc}) (Di Toro et al. 2005; USEPA 2005). Thus, for equivalent concentrations of excess SEM, this ratio will tend to be low when the organic carbon fraction (f_{oc}) of the sediment is high; and high when f_{oc} is low. This is important because the probability of toxic effects is low when carbon normalized excess SEM is low (less than 130 μmol/g_{oc}) (USEPA 2005). Further, use of carbon-normalized excess SEM reduces the uncertainty bounds associated with the assessment of the potential for effects when SEM exceeds AVS (USEPA 2005).

Based on the AVS and SEM framework, EPA (USEPA 2005) has published equilibrium partitioning sediment benchmarks (ESBs) for metals. The approach is considered applicable to sediments where AVS concentrations are greater than 0.1 μmol/g_d. The AVS-based ESB identifies that SEM metals should not cause direct toxicity to benthic organisms when ΣSEM-AVS < 0 (Figure 14, upper panel). When SEM exceeds AVS, consideration of carbon-normalized excess SEM will reduce uncertainty associated with assessing the potential for toxic effects (Figure 14, lower panel). With respect to sediment porewater, EPA (USEPA 2005) also provides guidance in the form of an interstitial water ESB, expressed in terms of toxic units (TUs). Specifically, cadmium, copper, nickel, lead and zinc should not cause toxicity to benthic organisms if the sum of the dissolved interstitial water concentrations for each of these metals, divided by their respective water quality criteria (WQC) final chronic values, is less than one.

Use of an interstitial water ESB is considered to be a conservative benchmark in the assessment of potential effects for several reasons. First, the interstitial water ESB is determined from dissolved[3] porewater metal concentrations rather than metal activities. In porewater, metal activities are typically expected to be much lower than the dissolved concentrations. Secondly, the ESB is based on the conservative assumption that toxicities of individual metals are additive. Additivity of TUs may not be strictly applicable given the different modes of action by which different SEM metals affect organisms, particularly under conditions of chronic exposure.

It is important to recognize that exceedance of either the sediment or interstitial water ESB does not indicate that adverse toxic effects will necessarily occur. Rather, and consistent with the EPA Science Advisory Board (SAB) recommendations, ESBs should not be used as stand-alone, pass-fail criteria. Instead, an ESB exceedance could serve as an indication that additional information is needed to complete an assessment (USEPA 2005).

[3] For porewater, the term "dissolved" includes not only the freely dissolved form of the element but also any and all dissolved salts and/or complexes.

5.1.4 Porewater

Several different approaches are commonly used to collect porewater from bulk sediments. Approaches include use of *in situ* (e.g., suction samplers and dialysis chambers, or peepers); or *ex situ* (e.g., centrifuge and sediment squeezers) devices. Numerous variations exist for each of these sampling approaches and each has its own advantages and disadvantages (Carr and Nipper 2003). Filtration is an additional processing step that may (or may not) occur at the time of collection (e.g., dialysis samplers exclude particulates from the sample); or as an additional sample processing step. Because methodological differences between sampling and analytical methods can affect the results obtained, measured porewater concentrations should be viewed as being operationally defined. As a result, it is reasonable to expect that there will be differences in porewater results obtained by different investigators.

As previously noted, porewater concentrations provide a useful measure for evaluating the potential for toxic effects in sediments. This is based on findings that the range of sensitivities of water column and sediment dwelling organisms are comparable; and that water only effect levels measured in lab waters provide an estimate of metal activities in porewater expected to cause an adverse response (Di Toro et al. 1991; USEPA 2000). Although metal activities would provide a better indication of the bioaccessible fraction of a metal, it is reasonable to use dissolved porewater concentration measurements because they are easier to measure, and will typically be higher than the metal activity (i.e., be conservative). Therefore, if benchmark effect levels are exceeded, further assessment is warranted. One option is to use a procedure that provides an improved estimate of exposure levels based on metal activity in the porewater. The Biotic Ligand Model (BLM) (Di Toro et al. 2001) is a tool than can be used to explicitly consider the activity of metals in porewater as a refinement to the conservative assessment based on dissolved metal concentrations, and a dissolved water quality criterion.

6 RELATIONSHIP OF TOTAL SEDIMENT AND EXTRACTION RESULTS TO ASSESSMENT OF BIOACCESSIBILITY, BIOAVAILABILITY AND EFFECTS

As described in Section 5, several alternative measures of the exposure of aquatic organisms to sediment metals exist. These measurements include 1) total metal concentrations (bulk chemistry); 2) sequential extracts of bulk sediments, including AVS and SEM; and 3) sediment porewater. These different types of metal measurements can be used in conjunction with results of toxicity tests to assess the potential for adverse effects on sediment dwelling organisms (e.g., benthic invertebrates). A refined analysis on each of the above-listed measurements and relationship to sediment toxicity is presented in the following sections.

6.1 PATTERNS RELATED TO METAL CONCENTRATIONS IN BULK SEDIMENTS

Concentrations of total metals in bulk sediments measured in 2005 sediment toxicity samples are presented in Table 15, along with the grain size distributions. With respect to correlations between the sediment toxicity responses and the chemical and physical variables for bulk sediments, no strong associations (i.e., $|\rho| \geq 0.80$) were found (Tables 16 through 18).

The concentrations of selected metals were compared to the PECs of MacDonald et al. (2000) to provide a conservative estimate of the potential for the metals to cause toxicity. MacDonald et al. (2000) defined the PEC for each metal as the concentration above which adverse biological effects are expected to occur frequently. PECs are available as dry-weight concentrations for eight metals, as follows:

- Arsenic—33 mg/ kg
- Cadmium—4.98 mg/kg
- Chromium—111 mg/kg
- Copper—149 mg/kg
- Lead—128 mg/kg
- Mercury—1.06 mg/kg
- Nickel—48.6 mg/kg
- Zinc—459 mg/kg.

The comparison of metals concentrations in UCR sediments to PECs is considered to be a conservative analysis because the PECs do not explicitly account for the bioavailability of metals.

The concentration of each metal at each station can be compared with its respective PEC value to provide a PEC quotient (PECQ), an index that expresses the relative magnitudes of the two values. In addition, the mean of the individual PECQs (i.e., mPECQ) for all eight metals at each sampling station can be calculated to provide an integrated index of metals concentrations that can then be compared with the sediment toxicity results (Long et al. 1998; MacDonald et al. 2000). In the following analyses, this mPECQ approach was applied to the matching bulk sediment chemistry and sediment toxicity data collected during Phase I.

The PECQs found for the 50 stations sampled in 2005 are presented in Table 19. In addition, the station where the PECQs for the various metals exceeded 1.0 are plotted on Map 6. PECQs for copper, lead, and zinc were the only ones that exceeded 1.0 at multiple stations (Table 19). In general, the highest PECQs were found for zinc and copper, for which the maximum values were 31 and 13, respectively. PECQs for arsenic, chromium, mercury, and nickel were not exceeded at any station, and the PECQ for cadmium was exceeded at only a single station.

The PECQ for one or more metals exceeded 1.0 at 24 of the 50 stations sampled in 2005, with all but two of those stations located in RMs 700 to 745 (Map 6). In Reaches 4 to 6(RMs 700 to 597), the PECQ for one or more metals exceeded 1.0 at only 2 of the 24 stations, with no exceedances found below RM 687.

The longitudinal distribution of mPECQs showed a gradient from Reaches 1 to 4a and then a relatively flat distribution from RMs 597 to 700 (Figure 15). Most values in Reaches 1 to 3 (RMs 744 to 700) (i.e., 88 percent) exceeded 0.2, whereas most values in Reaches 4 to 6 (RMs 700 to 597) (92 percent) were below 0.2. The longitudinal distribution of mPECQs was therefore consistent with the patterns discussed above for individual PECQs greater than 1.0.

The relative and absolute contributions of the various metals to the mPECQ at each of the 50 stations sampled in 2005 are shown in Figure 16. In general, zinc, copper, and lead were the primary contributors to mPECQ in Reaches 1 and 2 (RMs 744 to 712), and mercury and cadmium were the major contributors (in relative terms) in Reach 3 (RMs 712 to 700) at Marcus Flats. Downstream of Marcus Flats, nickel, chromium, and arsenic were contributors, although and as previously noted the mPECQ was low (i.e., < 0.2) at most of those stations (see Figures 15 and 16). With respect to correlations between the sediment toxicity responses and PECQs and mPEQC, no strong associations (i.e., $|\rho| \geq 0.80$) were found (Tables 20 through 22).

Besser et al. (2008) also used PECs to evaluate the sum of PECQs for copper, cadmium, lead, zinc, and arsenic (the notation used therein was PEQ rather than PECQ). The sum of PECQ values was then used to develop a linear relationship between amphipod growth and log [$\Sigma PECQ_i$]. When the control sediment is not considered, the ΣPECQ relationship exhibited good explanatory power (r^2 = 0.90). When (in an effort to extend the range of applicability of the results), this analysis is repeated with the control sample included, the explanatory power of the relationship is reduced (r^2 = 0.58).

Interestingly, PECQs for the sediment samples were as high as 85 at one of the stations (LR7 at RM 735) which potentially suggests a greater hazard than lesser PECQs. In this particular case, the PECQ for the individual metal concentrations for copper, lead, and zinc were considerably higher than their respective PECs (18.7-, 8.5- and 56.0-fold, respectively). Even so, reported effects were limited to a few endpoints: A non-lethal effect on growth of the midge, *C. dilutus* (40 percent of the Sanpoil River reference sediment) and marginally reduced survival of the amphipod *H. azteca* (70 percent, versus a commonly accepted control survival of 80 percent). If one assumes that one or more of the aforementioned metals was causally related to the observed responses, the presence of these relative elevated PEQs suggests that a considerable portion of the total metal concentrations was not accessible to the organism.

6.1.1 Relationship of Bulk Sediments to Sequential Extractions

Although sequential extractions were not measured during Phase I activities, such measurements in conjunction with total concentrations were reported by Besser et al. (2008) and Paulson et al. (2006), respectively. A plot of total metals (Besser et al. 2008), and the sum of sequentially extracted metal concentrations for copper, cadmium, zinc, lead, and arsenic (Paulson et al. 2006) is illustrated in Figure 17. Sampling stations are illustrated from upstream to downstream (left to right, LR7 at RM 735 to LR1 at RM 602), followed by the reference station (SA8, in the Sanpoil Arm) and a negative control sample. In general, the sum of metals determined by sequential extractions, are in close agreement with reported total metal concentrations. Although some variability exists, results are generally well within a factor of two; with total concentrations estimated as the sum of sequential extractions nearly always being less than measured total metal concentrations.

Overall, at most stations and for most metals (i.e., lead, cadmium, zinc, and copper), the sum of the metal concentrations associated with the individual extracts represents about 80 to 90 percent of the total metal measurement. Metal concentrations associated with each of the individual sediment extracts, expressed on a bulk sediment basis, are displayed on Figure 18. As previously mentioned, the sequential extraction procedures used by Paulson et al. (2006) targeted four phases 1) sorbed (exchangeable and carbonate fractions); 2) oxides (easily reduced iron and manganese oxides); 3) sulfide and organic matter; and 4) a residual (crystalline) fraction. Based on an inspection of results, no clear discernible and consistent spatial trend occurs in the distributions of sequentially extracted metal fractions. The lack of any systematic variation may reflect a relatively small sample size or as illustrated within Figure 18, samples were largely from the same class (Class II, refer to Appendix D). Copper and lead associated with sorbed and reducible oxide fractions (Extracts 1 and 2, respectively) at LR7 (RM 735) are relatively low compared to the sulfide/organic matter and residual fractions. This contrasts with results for zinc, which exhibit a somewhat more uniform distribution across the four extracts. Results for cadmium are more variable, with the sulfide/organic matter and residual fractions typically containing a comparatively small fraction (<30 percent) of the overall mass of metals.

Compared to sequential extraction procedures, measurements of AVS and SEM involve a relatively simple one-step extraction that provides a measure of both weakly bound metals (e.g., exchangeable and oxide-bound metals), as well as a portion of the metals associated with organic matter and sulfide (Allen et al. 1993). Comparison of the SEM results to total measurements for UCR sediments indicates that SEM recovers about 50 to 100 percent of total sediment lead, and progressively lesser amounts for cadmium, zinc and copper (e.g., 15 to 60 percent for copper). Recovery of lead, zinc, and copper from the 2004 data set (Paulson et al. 2006) were lowest at LR7 (RM 735), LR4 (RM 683), and LR1 (RM 602). Paulson et al. (2006) suggested that both LR1 and LR4 may reflect influences of landslide materials.

The observation that the recovery of SEM metals is considerably less than the recovery achieved by the four-step sequential extraction procedure is expected because the AVS extraction is not intended to achieve complete recovery of total sediment metals. Figures 19a and 19b illustrate alternative views of how SEM metal extracts compare to sequential extractions (i.e., Extraction [1]; Extractions [1+2], Extractions [1+2+3] and Extractions [1+2+3+4]). For Figure 19a, the cumulative sums of the concentrations in the extracts are plotted as a function of SEM concentration for each metal (copper, cadmium, lead, and zinc). Data points below, on, or above the diagonal line correspond to cases where the cumulative sums of sequentially extracted metal concentrations are less than, equal to, or greater than the SEM metal, respectively. Figure 19b shows the same results, but in this case they are displayed as ratios of the cumulative sums of the metal extractions to the measured SEM (i.e., a ratio of 1.0 indicates equality). As shown on the upper left panel of Figure 19b, Extraction 1 (exchangeable metals) yields an average of about 5 percent of SEM lead, 20 percent of SEM copper, 35 percent of SEM zinc and 50 percent of SEM cadmium. The sum of Extractions 1 and 2 approach SEM concentrations for most samples (about 80 percent, overall), with the notable exception for LR7 (RM 735), where recovery relative to SEM remains low (at most, about 50 percent of SEM zinc). The sums of Extractions 1, 2, and 3 exhibit the closest agreement to the SEM results (lower left panel), though the sum of extracts at LR7 (for lead, cadmium, and copper) and at LR6 (RM 722) in the case of lead, remain low. Finally, the sum of Extractions 1, 2, 3, and 4 (lower right panels of Figures 19a and 19b) leads to a higher concentration of metal relative to SEM. In short, these results indicate that SEM measurements are in reasonably good agreement with the sum of metal concentrations associated with sequential extractions 1, 2, and 3 (but not the complete digestion that includes extraction of metals in the residual fraction).

A notable difference between the sequential extraction procedures outlined above and the measurement of SEM is that the latter also yields a measure of AVS, an important metal-binding phase in sediments. This information, in combination with sediment TOC, has been shown to serve as a useful basis for evaluating the potential for effects due to sediment SEM (USEPA 2005).

Although the Phase I data did not evaluate sequentially extracted metals concentrations, SEM and AVS measurements were recorded and can be compared to the 2004 AVS and SEM results reported by Paulson et al. (2006) and Besser et al. (2008). As illustrated in Figure 20, the dry weight normalized AVS and SEM concentrations reported by Besser et al. (2008), EPA (USEPA 2006), and Paulson et al. (2006) tend to be somewhat higher than the Phase I results when expressed on a dry weight basis (which compares AVS and SEM probability distributions on the left and spatial profiles on the right). These results also show that AVS concentrations were less than the 0.1 $\mu mol/g_d$ lower limit of applicability for the AVS-based sediment ESB at several stations upstream of RM 705, and downstream of RM 705. The AVS-based sediment ESB is therefore limited in its applicability for those samples. It is relevant to note that the sediment samples used by Besser et al. (2008) were associated with relatively high sediment organic carbon levels. Thus, when the two data sets are compared on the basis of carbon normalized excess SEM (i.e., $[\Sigma SEM-AVS]/f_{oc}$), the results are actually quite similar (Figure 21). This is even more clearly the case in view of the fact that the lowest value shown for the 2004 data set (light blue triangle plotted at RM 615), is actually for a sample from the Sanpoil River reference station.

6.2 PATTERNS RELATED TO AVS, SEM, AND TOC CONCENTRATIONS IN SEDIMENT

In this section, analyses are conducted using SEM, AVS, and related parameters to evaluate the potential bioavailability of the SEM in sediments. Given that the Phase I data set is the most recent and comprehensive (i.e., spanning the entire Site), the following analyses are centered on this data, and supplemented when possible with data from 2004.

6.2.1 Overview of 2005 Sampling and Analysis Methods

In the field, sediment samples slated for SEM and AVS analysis were removed immediately from each sediment sample after decanting any overlying water (USEPA 2006). Each sediment subsample used for SEM and AVS analysis was collected directly into a jar using disposable hand tools. The jar was filled completely and capped quickly to minimize exposure to oxygen. The SEM and AVS aliquot was not homogenized prior to placement in the jar and was held at 4°C until analyzed. Separately, TOC was analyzed to support the AVS and SEM analysis. Sediment pH was not measured; although, pH can be important for interpreting sediment toxicity results (Di Toro et al. 2005). The sample used to measure TOC was obtained after transferring sediment to an aluminum foil-lined bowl and homogenized. The homogenate may have reflected multiple sediment samples, if they were required to obtain sufficient sediment to accommodate all planned analyses.

6.2.2 Longitudinal Patterns

Concentrations of AVS, SEM, and TOC observed during Phase I (USEPA 2006) are presented in Table 23. Concentrations of AVS were not reported by EPA (USEPA 2006) for 12 of the stations listed in Table 23, all of which were located between RM 706 and RM 603.

The longitudinal distribution of ΣSEM showed concentrations exceeding 5.0 µmol/g at all but 2 of the 26 stations in Reaches 1 to 3 (RMs 744 to 700), and concentrations less than that value at all but 3 of the 24 stations in Reaches 4 to 6 (RMs 700 to 597) (Figure 22). With respect to the relative contributions of the individual SEM to ΣSEM, Figure 23 shows that SEM zinc accounted for the greatest contribution at most stations, but that cadmium, nickel, and lead in combination account for relatively large contributions between RM 678 and 658 in Reaches 4a and 4b. Copper accounted for a relatively constant contribution at most stations.

The longitudinal distribution of AVS is generally similar to that described above for ΣSEM, with all but eight values being greater than 0.5 µmol/g in Reaches 1 to 3 (RMs 744 to 700), and all measured values being less than 0.1 µmol/g in Reaches 4 to 6 (RMs 700 to 597) (Figure 24). The longitudinal distribution of TOC did not show a pattern consistent with that found for ΣSEM and AVS (Figure 25). The concentrations of TOC generally increase from Reach 1 to Reach 3 (RMs 744 to 700) (i.e., Marcus Flats, where all four values were 0.8 percent or greater). In Reaches 4 to 6 (RMs 700 to 597), TOC varied markedly, ranging from 0.04 to 2.2 percent.

6.2.3 Comparisons to Generic Thresholds for Simultaneously Extracted Metals

EPA identified two sets of generic thresholds for AVS and SEM parameters that can be used to prioritize sediments of concern for further evaluation (USEPA 2005). According toEPA, these relationships apply only to sediments having AVS concentrations of 0.1 µmol/g or greater (USEPA 2005). As shown in Table 23 and Figure 24, the measured AVS values at numerous stations sampled in 2005 were less than 0.1 µmol/g, including three stations located upstream from RM 706 (i.e., at RM 744, 727, and 723), as well as all stations downstream from that location.

With respect to the difference between the sum of SEM and AVS (i.e., ΣSEM–AVS or excess SEM) in a sediment sample, the critical values are as follows:

- <1.7 µmol/g – toxicity unlikely
- >120 µmol/g – toxicity possible.

Between 1.7 and 120 µmol/g, the potential for toxicity is uncertain.

With respect to excess SEM normalized by the fraction of organic carbon in a sediment sample (i.e., [ΣSEM-AVS]/organic carbon fraction [f_{oc}]), the generic thresholds are as follows:

- <130 µmol/g_{oc} – toxicity unlikely
- >3,000 µmol/g_{oc} – toxicity possible.

Between 130 and 3,000 µmol/$g_{oc,}$ the potential for toxicity is uncertain.

In considering the preceding results, it is important to keep in mind that an exceedance of a threshold should not be viewed as an absolute indication that toxicity is expected. Rather, an exceedance should be viewed as an indication that additional assessment data are needed to evaluate the potential for toxicity. However, if the lower thresholds are not exceeded, toxicity can be considered unlikely with a reasonable degree of confidence.

Concentrations of (ΣSEM-AVS) in the UCR in 2005 are compared with the EPA thresholds (USEPA 2005) in Figure 26 (upper graph), and the results are plotted in Map 7. For this analysis, ΣSEM was used instead of (ΣSEM-AVS) for all 16 stations at which measured AVS concentrations were less than 0.1 µmol/g because, as noted above, the SEM and AVS relationships identified by EPA apply only to sediments having AVS concentrations of 0.1 µmol/g or greater (USEPA 2005). In addition, ΣSEM was used instead of (ΣSEM-AVS) for the 12 stations located downstream from RM 706 for which no AVS data were reported by EPA (USEPA 2006). Both of these methods are considered conservative with respect to assessing the potential bioavailability of the SEM, because they assume that AVS did not reduce the bioavailability of those metals.

Three stations in Reach 1 (i.e., at RM 737, 738, and 744) exceeded the upper generic threshold of 120 µmol/g and 27 additional stations exceeded the lower threshold of 1.7 µmol/g, indicating that additional evaluations would be required to confirm the potential presence of toxicity at those stations. Most of those 30 stations were located in Reaches 1 to 3 (RMs 744 to 700). By contrast, 20 stations were below the lower threshold of 1.7 µmol/g, indicating that toxicity was unlikely at those locations. That group of stations included 19 of the 24 stations sampled in Reaches 4 to 6 (RMs 700to 597) below Marcus Flats.

Concentrations of (ΣSEM-AVS)/foc for Phase I data are compared with the EPA thresholds (USEPA 2005) in Figure 26 (lower graph). For this analysis, organic-carbon normalization was used only for the 22 stations for which (ΣSEM-AVS) was calculated in the above analysis. All of the stations included in the analysis were located in Reaches 1 to 3 (RMs 744 to 700). Fourteen stations exceeded the upper critical value of 3,000 μmol/g_{oc} and an additional 7 stations exceeded the lower threshold of 130 μmol/g_{oc}, indicating that additional evaluations would be required to confirm the potential presence of toxicity at those stations. Only a single station (i.e., at RM 704 on Marcus Flats) was below the lower threshold of 130 μmol/g_{oc}, indicating that toxicity was unlikely at that location.

Results of the above analyses indicate that, in general, sediment toxicity is unlikely with respect to the SEM at most of the 2005 stations located downstream from Marcus Flats. By contrast, at most of the 2005 stations located at Marcus Flats and upstream from that area, additional evaluations would be needed to determine the potential for sediment toxicity.

Comparison of significant amphipod biomass responses for the 2005 data set with the evaluations described above with respect to (ΣSEM-AVS) showed relatively close relationships to the predictions of the lack of toxicity due to SEM and the actual toxicity results. For example, only one of the 20 stations (5 percent) with (ΣSEM-AVS) concentrations less than the lower threshold of 1.7 μmol/g exhibited a significant response (Figure 27). A similar evaluation for (ΣSEM-AVS)/f_{oc} was performed and is illustrated within Figure 28. With respect to correlations between the sediment toxicity responses and SEM, as well as (ΣSEM–AVS), no strong associations (i.e., $|\rho| \geq 0.80$) were found (Tables 24 through 26).

Besser et al. (2008) used the ESB for carbon-normalized, excess SEM to construct a linear relationship for amphipod growth versus log ([ΣSEM-AVS]/f_{oc}). The analysis yielded a $r^2 = 0.73$ without the Sanpoil River control sample (N = 8), and a $r^2 = 0.70$ with the control (N = 9). These results may be compared to an analogous relationships for amphipod growth as a function of log (ΣPECQ), which yielded $r^2 = 0.90$ (as reported by Besser et al. [2008] without the control) and $r^2 = 0.58$, which as previously mentioned was computed using the control. These results should not be interpreted to mean that the underlying relationships are in fact linear, but only that there may be some degree of explanatory power associated with the assumed form of the relationship when applied to this data set.

A notable difference in the regression analyses described above is that the PEC-based analysis employs a TU approach, while the ESB-based analysis does not. That is, use of total sediment concentrations assumes that responses to individual metals, normalized to their respective PECs, are additive. This is in contrast to the ESB approach which also uses the sum of SEM metals, but in a different way and for a different reason. In this case, the concentrations are not normalized by metal-specific effect levels. Rather, they are summed to appropriately account for the contribution of each of the metals to the utilization of the complexation capacity of AVS. Pursuant to EPA guidance (USEPA 2005), as long as the complexation capacity of AVS is not exceeded (i.e., SEM < AVS), then effects are not expected. If it is exceeded, then the possibility of adverse effects exists and additional information may be needed.

7 RELATIONSHIP OF POREWATER METALS TO ASSESSMENT OF BIOACCESSIBILITY, BIOAVAILABILITY AND EFFECTS

Concentrations of dissolved metals in porewater from 2004 (Paulson et al. 2006, and Besser et al. 2008) and 2005 (USEPA 2006) were measured to assist in the interpretation of the sediment toxicity results. The purpose was to evaluate which sediments may be toxic to benthic macroinvertebrates, based on porewater concentrations that were present under toxicity test conditions. These data sets also provide a relatively current view of conditions in the UCR relative to earlier investigations (Johnson et al. 1989; Johnson 1991; Era and Serdar 2001). The following analyses explore the use of porewater metals measurements to evaluate if there is a relationship between measured concentrations and observed toxicity and/or the potential for toxicity due to SEM metals.

7.1 OVERVIEW OF 2004 AND 2005 POREWATER ANALYSIS - METHODS

Porewater from 2004 (Besser et al. 2008) samples was extracted by centrifugation of whole sediments (30 minutes at 7,000 *g*) followed by filtration of the supernatant using 0.45 µm polypropylene cartridge filters. Porewater analytes included pH, conductivity, alkalinity, hardness, manganese, iron, ammonia, sulfide and metals (copper, zinc, arsenic, cadmium, and lead). Dissolved organic carbon (DOC) was measured on porewater obtained from a separate set of archived sediment cores that had been collected at the same time.

Separately, additional sediment samples from the same sampling locations were also collected and the porewater extracted at a field lab within 8 hours of sample collection (Paulson et al. 2006). Samples were obtained from the 0 to 2 cm slice of a 4.4 cm diameter core that was sub-sampled from a box core. Porewater was extracted by centrifuging the sample for 20 minutes at 2,000 rpm followed by filtration through a 0.22-µm pore size in-line filter. Paulson et al. (2006) reported that these samples were likely exposed to the atmosphere during sample collection and processing. A relatively extensive list of analytes was measured on this second set of porewater samples.

Phase I 2005 porewater samples were processed in the field at the time of sample collection (USEPA 2006). Sediment sample aliquots were loaded into centrifuge bottles and centrifuged for 30 minutes at 3,000 g, 10°C under oxic conditions. This step was repeated if the sample remained cloudy. Centrifuged supernatants (porewaters) that were recovered from the sequential centrifugations were combined until 200 mL was obtained. Twenty-four elements were measured by inductively coupled plasma with atomic emission spectrometry. Some elements, such as beryllium, silver, thallium, and uranium, were either undetected or detected at a very low frequency (i.e., <5 percent). A number of metals were measured with higher detection limits than their corresponding EPA chronic water quality criterion for aquatic life (i.e., aluminum, cadmium, copper, lead, and selenium), adding uncertainty to estimates of their concentration distributions. Correlations between sediment toxicity responses and porewater concentrations are presented in Tables 27 through 29. With respect to correlations between the sediment toxicity responses and porewater concentrations, no strong sitewide associations (i.e., $|\rho| \geq 0.80$) were found with the Phase I data (Table 27). Several significant associations were evident in Reaches 1 through 3 and 4 through 6 (Tables 28 and 29).

It is interesting to note that when one compares spatial profiles of copper, cadmium, lead, and zinc porewater concentrations recorded from several different data sets (Johnson 1991; Cox et al. 2005; USEPA 2005; Paulson et al. 2006; Besser et al. 2008) there is considerable spatial and temporal variability (see Figure 29). These differences may reflect a number of possibilities including, but not necessarily limited to, differences in sample collection methods and processing techniques, variations associated with sampling depth and time, and/or an inherent sediment heterogeneity.

7.1.1 Conservative Comparisons to Water Quality Criteria

The potential toxicity of porewater metal concentrations (i.e., arsenic, cadmium, copper, chromium, nickel, lead, mercury, selenium, and zinc) for Phase I sediment samples was evaluated by comparisons to EPA chronic ambient water quality criteria (AWQC) (USEPA 2002). For the metals that have hardness-dependent criteria (all of the above except arsenic and selenium), the AWQC was adjusted to the hardness of porewater found at each station using methods described by EPA (USEPA 2002). Comparisons to AWQC were conducted using the TU approach, where TUs were computed as the ratios of the metals concentrations to their respective AWQC (Figures 30 and 31). For example, a TU of 1.0 for a metal indicates that the measured concentration was equal to its AWQC, whereas a TU of 2.0 indicates that concentration was two times greater than the AWQC. Note that the BLM-based AWQC for copper was not used for this initial set of analyses; only the effects of hardness were considered. Other than adjustment for hardness-dependence, no attempt was made for this initial analysis to account for the potentially important effects of porewater quality on metal bioaccessibility, bioavailability and toxicity (i.e., an initial conservative evaluation).

Based on the above described approach, no TUs greater than 1.0 were found for arsenic and mercury, and only a single station exhibited a TU greater than 1.0 for chromium and nickel. The spatial distributions of TUs for individual metals are shown on Figure 30 for copper, zinc, lead and cadmium and on Figure 31 for selenium, chromium and nickel. The spatial distribution of TUs greater than 1.0 is presented in Map 8; while the results can be summarized as follows:

- **Copper (Cu).** TUs greater than 1.0 were found at 15 stations, with values ranging from 1.1 to 3.8 (Figure 30). Ten of the 15 stations (75 percent) were found in Reach 1 (RMs 744 to 730), which included the station with the maximum value. The remaining six stations were distributed across Reaches 2, 3, and 4a, between RM 729 and 687.
- **Zinc (Zn).** TUs greater than 1.0 were found at 5 stations, with values ranging from 1.1 to 1.6 (Figure 30). Four of the 5 stations (80 percent) were found in Reach 1, which included the station with the maximum value. The remaining station was found in Reach 3 at Marcus Flats (RM 704).
- **Lead (Pb).** TUs greater than 1.0 were found at 10 stations, with values ranging from 1.1 to 16 (Figure 30). Five of the 10 stations (50 percent) were found in Reach 4a (RMs 700 to 676), two stations were found in Reach 4b (RMs 676 to 640), and single stations were found in Reaches 1 and 3 (RMs 744 to 700). The maximum value was found in Reach 4b at RM 642 above the confluence with the Spokane River.
- **Cadmium (Cd).** TUs greater than 1.0 were found at 22 stations, with values ranging from 1.1 to 14 (Figure 30). The 22 stations were distributed across all six river reaches with 6, 4, 2, 6, 2, and 2 stations found in Reaches 1 to 6, respectively. The maximum value was found in Reach 4a at RM 687.
- **Selenium (Se).** TUs greater than 1.0 were found at seven stations, with values ranging from 1.9 to 4.1 (Figure 31). Selenium concentrations at all remaining stations were below the detection limit. Three of the 7 stations (43 percent) were found in Reach 2 (RMs 730 to 712), two stations were found in Reach 1 (RMS 744 to 730), and single stations were found in Reaches 4a (RMs 700 to 676) and 6 (RMs 616 to 597).
- **Chromium (Cr) and nickel (Ni).** The single TU greater than 1.0 for these two metals were both 1.1 and found at RM 742 (Figure 31).

The results described above indicate that most or all TUs greater than 1.0 for all metals except cadmium and lead were found in Reaches 1 to 3 (RMs 744 to 700).

Based on similar work completed by Paulson and Cox (2007), neither arsenic nor zinc concentrations in porewater yielded TUs >1; and only 1 of 7 stations had a copper TU >1 (i.e., 1.6 for sample LR7 [RM 735]). TUs >1 were reported for cadmium at LR3 [RM 665] (2.8) and LR1 [RM 602] (1.5); for lead at LR7 (1.6) and at three other reservoir sites (ranging from ~1.5 to 3.0). Overall, calculated porewater TUs tended to be lower than those evaluated on the basis of the Phase I data set and may reflect differences in sample handling.

Biomass responses for the amphipod test were compared with Phase I calculated porewater TUs to evaluate the degree to which TUs greater than 1.0 were associated with statistically significant responses (Figure 32). The comparisons showed that 11 of the 12 significant amphipod biomass responses were found at stations where the TU for copper or zinc exceeded 1.0, and/or the TUs for cadmium and lead exceeded 5.0. Exceedances of one TU for copper alone accounted for 10 of the 12 significant responses. The only station where a significant biomass response was not associated with one or more of the toxicity unit exceedances identified above was at RM 677 (Figure 32).

The patterns described above indicate that TU exceedances for the four metals were generally associated with significant amphipod biomass responses. The observation that the TUs for cadmium and lead were considerably greater than 1.0 (in several cases >10) suggests that *H. azteca* may be less sensitive to those metals than the test species that drive derivation of chronic AWQC for those metals, as suggested by the data of Suedel et al. (1996a,b). It is also possible that the hardness-based WQC does not provide a good indication of site-specific effect levels for porewaters that are relatively high in DOC, a constituent that would reduce metal availability to exposed organisms. Evidence that porewater metals are less available to benthic organisms than the preceding TUs suggest, is supported by the result that a significant response was not always observed when the critical TU value (1.0) for at least one of the metals was exceeded (i.e., 8 of 30 cases).

With respect to correlations between the sediment toxicity responses and TUs, the following strong associations (i.e., $|\rho| \geq 0.63$) were found (Tables 27 through 29)

- **Site-wide** (Table 27)**:**
  - Positive associations - daphnid survival and selenium
- **Reaches 1 to 3 (Table 28):**
  - Negative associations - amphipod biomass and nickel; amphipod total biomass and nickel; chironomid survival and arsenic; daphnid young/survivor and arsenic; and daphnid total young and nickel.
  - Positive associations - amphipod survival and arsenic; amphipod biomass and hardness; amphipod total biomass and hardness; chironomid biomass and arsenic and hardness; daphnid survival and arsenic and selenium; and daphnid total young and arsenic and hardness.
- **Reaches 4 to 6** (Table 29)**:**
  - Negative associations - amphipod biomass and copper; chironomid biomass and arsenic; chironomid total biomass and cadmium; and daphnid survival and arsenic.
  - Positive associations - amphipod biomass and arsenic; chironomid survival and arsenic; and chironomid total biomass and arsenic.

Based on the above results, it would appear all three Phase I sediment toxicity tests exhibited strong positive associations with porewater hardness (i.e., increasing hardness appears to have a beneficial effect) in Reaches 1 to 3, primarily for sub-lethal endpoints. Potential relationships between porewater hardness and significant toxicity responses for sub-lethal endpoints for all 50 stations were therefore further evaluated.

For amphipod biomass, all 12 stations where significant responses were found had porewater hardness values less than 200 mg/L (i.e., 78 to 192 mg/L) and the stations were distributed over multiple river reaches (i.e., 1, 3, 4a, and 4b) (Figure 33, upper left panel). For chironomid biomass, the three stations where significant responses were found had porewater hardness values less than 200 mg/L (i.e., 78 to 152 mg/L), and all three stations were located in Reach 1 (Figure 33, upper right panel). For daphnid young/survivor, 6 of the 8 stations where significant responses were found had porewater hardness values less than 200 mg/L (i.e., 78 to 181 mg/L), and the stations were distributed over multiple river reaches except Reach 2 (Figure 33, lower left panel). Two stations where significant responses were found for the daphnid test had hardness values greater than 200 mg/L (i.e., 210 and 330 mg/L at RM 739 and 740, respectively).

Nearly all stations where significant toxicity responses were observed had porewater hardness values less than 200 mg/L. This pattern is generally consistent with the strong positive correlations found between all three toxicity tests and porewater hardness in Reaches 1 to 3.

7.2 REFINED ASSESSMENT OF POREWATER METAL EFFECT LEVELS USING THE BLM

As discussed byEPA, an exceedance of an ESB such as the interstitial water ESB should not be viewed as a stand-alone pass-fail criterion with regard to assessments of the potential for adverse effects in sediments (USEPA 2005). Rather, it should serve as an indication that further assessment is needed. In the case of UCR porewaters, additional data are available for consideration. These data include measurements of several constituents known to influence bioavailability of metals (e.g., pH, DOC, hardness, cations, alkalinity, and sodium). This information can be used to further assess metal concentrations in sediment porewaters, while also considering the effect that other chemical constituents in sediments will have on the bioavailability and toxicity of metals. The effects of bioavailability on metal toxicity can be considered using the BLM. The BLM has been widely used to predict bioavailability trends in surface waters (Di Toro et al. 2001; Santore et al. 2001, 2002; Paquin et al. 2002); and has recently been used to assess sediment bioavailability in the context of the equilibrium partitioning framework (Di Toro et al. 2005).

7.2.1 Approach and Rationale

The approach used with the BLM is to evaluate WQC concentrations (in the case of copper) or other appropriate effects benchmarks for other metals (e.g., cadmium, lead or zinc) for sediment porewaters, and to compare those values with metal concentrations in the porewater. The theoretical basis for comparing sediment porewater concentrations to WQC values is consistent with the equilibrium partitioning (EqP) approach for assessing metal toxicity in sediments (Ankley et al. 1996). While in principle these porewater WQC concentrations can be converted to bulk sediment concentrations by considering partitioning to sediment surfaces and precipitation in sediment solid phases (such as AVS), this type of evaluation is not as readily accomplished for metals as it is for organic chemicals. Alternatively, since porewater metal concentrations in UCR sediments have been measured, they can be compared directly to WQC that are applied to porewater. As indicated by EqP, the comparison of sediment porewater concentrations to regulatory endpoints is relevant for assessing the absence of risk associated with sediments (USEPA 2005).

The most appropriate approaches available for copper, zinc, cadmium and lead were selected for BLM calculations. Copper calculations are based on the EPA copper criteria document finalized in 2007 (USEPA 2007). Consideration of the BLM in the development of criteria for other metals is still ongoing, but a number of alternative approaches are available. For zinc, a review of the all the toxicity data used in previous WQC as well as new studies that have become recently available was conducted to support the development of a BLM-based WQC for zinc. This review summarized the toxicity endpoints used in the criteria development process, and also the water quality conditions associated with the measurement of those endpoints so that BLM calculations for each toxicity endpoint could be made. By considering the toxicity endpoints and the chemistry of the exposure water, the BLM can normalize the toxicity database to remove variability associated with differences in bioavailability in the exposure waters. As a result, the BLM was used to develop a normalized species sensitivity distribution (SSD) for as many organisms as possible in the EPA WQC database for zinc. This normalized SSD was used to evaluate a 5th percentile zinc concentration that could be considered analogous to a final acute value (FAV). Acute and chronic benchmarks for zinc were then determined from the 5th percentile value, and these would be analogous to the acute WQC and chronic WQC. Parameters for predicting the acute and chronic benchmarks were defined to allow the BLM to predict acute and chronic benchmarks; while considering all of the modifying effects of water chemistry on metal bioavailability.

For cadmium and lead, criterion development efforts based on the BLM have net not yet been initiated. As an alternative, BLM versions calibrated to sensitive organisms for these metals could be used. The use of species-specific benchmarks, rather than WQC in porewater assessments is consistent with EPA guidance (USEPA 2005). The comparison of BLM-predicted effect levels to metal concentrations in sediment porewater allows for the consideration of bioavailability, however, the 5th percentile value from a normalized distribution considering all aquatic species may be somewhat lower or higher than the predicted effect levels for these sensitive organisms. As a result, these estimates of the BLM predicted toxicity for cadmium and lead would provide a bioavailability-corrected benchmark that can be compared with sediment porewater metal concentrations. Use of the rainbow trout BLM was particularly appropriate in the case of cadmium, because the GMAV for rainbow trout is equivalent to the FAV that the cadmium water quality criteria are based on. Since the predicted toxicity levels for lead are not equivalent to a FAV (that is the 5th percentile for the normalized species sensitivity distribution), Pb concentrations near the BLM-predicted toxicity levels are not necessarily protective of other sensitive organisms.

7.2.2 Sediment Porewater Chemistry - Refinement

The BLM can be used to evaluate expected metal bioavailability based on existing sediment porewater chemistry. As previously noted, it is important to remember that different sampling methods, sample storage protocols, and porewater extraction methods were used in each of the 2004 and 2005 data sets. Therefore, the differences in sample collection and processing may affect the concentrations that are measured in sediment porewaters.

For the Besser et al. (2008) and Paulson et al. (2006) data sets, measurements of porewater chemistry were sufficiently complete to directly develop BLM inputs. For the Phase I 2005 data set however, several parameters (i.e., pH, alkalinity, sulfate, chloride, and DOC) were not measured and as such, need to be estimated for the following evaluation. Estimated BLM parameters should always be evaluated with care, especially for parameters that can strongly affect metal toxicity. Therefore, evaluations of the data using the BLM should be considered preliminary in nature until site-specific data are available for all the required input parameters. For this analysis, the need to estimate pH, DOC, and alkalinity are of particular concern because they are among the most important factors controlling metal bioavailability. Fortunately, the spatial patterns in porewater pH (Figure 34) are consistent enough that values near pH 7.7 could be used throughout the UCR (dashed line in Figure 34).

DOC concentrations measured in sediment porewaters are shown in Figure 35. Spatial variability in DOC concentrations is suggested, depending on whether a single high value of 120 mg/L at RM 711 is considered in the analysis. Because six of the seven measured DOC values from Besser et al. (2008) range from 15 to 44 mg/L, the single value of 120 mg/L appears to be an outlier. With the exception of the aforementioned outlier, the remaining data are in the vicinity of the median value of 27 mg/L, with a range from 15 to 44 mg/L. Given the scarcity of porewater DOC values it is not known whether the high DOC concentration at RM 711 is representative of other samples in the area or not. For the analysis presented herein, all data were considered by conservatively developing separate geometric mean values for samples upstream and downstream of RM 705, as illustrated by the dashed lines in Figure 35. These reach-specific mean DOC values were assigned to the Phase I samples in accordance with their respective sample locations.

Hardness concentrations had been measured in two of the three data sets. In the third data set (Paulson et al. 2006), hardness concentrations were calculated from reported calcium and magnesium concentrations (as $CaCO_3$). Hardness concentrations from each source are compared in Figure 36. There are some striking differences in concentrations and spatial patterns suggested by the three data sets. The Phase I data are the most variable and range from 78 to 578 mg/L as $CaCO_3$. Values from Besser et al. (2008) are less variable and range from 120 to 160 mg/L as $CaCO_3$; while values reported by Paulson et al. (2006) are lower than either of the other two data sources ranging from 60 to 140 mg/L as $CaCO_3$. These differences are notable, not only because hardness cations affect metal bioavailability, but also because systematic differences in values of water quality parameters such as hardness cations suggest that differences in sampling strategy, sample handling, and processing methods used to collect these three data sets may also be significant. In addition to differences in hardness, there were differences in porewater metals concentrations between the data sets with the Paulson et al. (2006) data set consistently observing lower metal concentrations than those by Besser et al. (2008), see Figure 37. As previously mentioned, these differences may reflect differences in sample collection, storage, and extraction techniques.

7.2.3 Bioavailability Calculations

The BLM was used to estimate the effect levels for metals in porewater that consider bioavailability (the BLM-based WQC, or an analogous benchmark for copper, cadmium and zinc; an effect level for a metal-sensitive invertebrate in the case of lead). These effect levels were then compared to metal concentrations reported by Besser et al. (2008) using the previously described TU approach. One approach uses the sum of TUs for copper, cadmium, nickel, lead, and zinc calculated as the ratio of dissolved metal concentration in sediment porewater to the hardness-based chronic WQC for each metal. When the sum of TUs for these metals is < 1, it is assumed that toxicity is not expected for that sediment sample. If the sum of TUs exceeds 1, then additional consideration should be made to evaluate toxicity for that sample. The sum of TUs as described in the sediment guidelines is intentionally designed to be conservative. Elements of conservatism include 1) the use of dissolved metals, 2) the assumption that TUs for each metal are additive; and 3) the use of hardness-based WQC only. Since the approach was designed to be conservative, it is very useful for screening samples where toxicity is unlikely, but for samples where the approach results in a summed TU value greater than 1, it does not indicate that toxicity due to these metals should necessarily be expected.

The BLM can be used to refine the preceding approach and is intended to reduce the degree of uncertainty (i.e., conservatism) that is built into the preceding procedure, thereby providing more realistic information. The primary refinement incorporated is consideration of chemical factors associated with the sediment porewaters that are known to modify metal bioavailability such as pH, DOC, cation concentrations, and alkalinity (Chapman et al. 1998; Di Toro et al. 2005;

Koretsky et al. 2006). Given the uncertainty related to whether TU values for individual metals are additive; the TU values for each of the four individual metals will be discussed separately. This same approach, but based on the hardness-based WQC, was used by Paulson and Cox (2007). Nickel concentrations in these sediments are generally very low so calculations for nickel (the remaining SEM metal) have not been performed.

TUs in this case are defined as the ratio of observed dissolved metal concentrations in sediment porewaters to BLM predicted acute and chronic WQC for copper, or BLM-predicted benchmarks for cadmium, lead and zinc. The TU results for copper, using porewater concentrations reported by Besser et al. (2008) are shown in Figure 38. TU values on an acute basis are shown on the left panel of this figure by river mile beginning with (from left to right) samples from LR7 (RM 735) and proceeding downstream to LR1 (RM 602). The vertical line drawn near RM 590 separates samples in the UCR from the Sanpoil River reference sample (blue square), and the negative control sample from Florissant, MO (white triangle). TU values for copper in the Besser et al. (2008) data set are < 1 upstream of RM 680, but samples taken at LR3 (RM 665) and LR2 (RM 626) are > 1. At LR1, near the Grand Coulee Dam, the TU value is again < 1. The pattern for TUs on a chronic basis (Figure 38, right panel) is very similar, although the values are slightly higher overall. This is due to use of the lower chronic WQC in place of the acute WQC in the evaluation of TUs.

The TU analysis originally proposed in the sediment quality guidelines was expected to be conservative in part because of the use of hardness-based WQC values, which do not take into account some of the factors that are known to modify metal bioavailability. The BLM provides a more complete evaluation of how water quality affects metal toxicity, and can be used to calculate WQC values that more appropriately reflect a wide range of water chemistry effects on metal toxicity. Although the WQC obtained by the BLM may be higher or lower than that obtained with the hardness-equation, the chemistry expected in sediment porewaters will include elevated DOC, and pH values above 7, and in these conditions the BLM typically results in higher WQC values than the hardness equation.

Comparison of TU values developed with either the BLM or the hardness equation is shown in Figure 39, where the TU values based on the BLM are shown on the vertical axis, and those based on the hardness equation are shown on the horizontal axis. Values based on the BLM-WQC tend to be much lower on either an acute (left panel) or chronic (right panel) basis. Only two of the TU values exceed a value of 1 when using the BLM, but using the hardness-based WQC results in 4 samples (on an acute basis) or 5 samples (on a chronic basis) with TUs > 1.

This overall pattern of BLM-calculated TU values suggest that toxicity due to copper may be more likely near stations LR2 (RM 626) and LR3 (RM 665) than elsewhere in the UCR. A different picture results from performing the same analysis on the 2005 Phase I data. As indicated within Figure 40, calculated TUs are consistently less than 1 throughout the UCR on both an acute (Figure 40. left panel) and chronic (Figure 40, right panel). The differences in these results compared with those using the Besser et al. (2008) data (refer to Figure 38) are likely the result of previously acknowledged differences in porewater chemistry.

Comparison of TU values from the BLM-WQC and the hardness equation WQC indicate that, for the Phase I data, the BLM calculates much lower TU values than the hardness equation (Figure 41). The TU values based on the BLM-WQC are all < 1, while a significant portion were > 1 using the hardness equation only. Many of the samples with TUs > 1 based on the hardness equation are Class I sediments (refer to Appendix D). As previously discussed within Section 4 of this appendix, sediment toxicity test results (historical and current) indicate potential effects within this portion of the Site (i.e., Reach 1). Based on the TU values using BLM-calculated WQCs however, it does not appear that copper is resulting in the apparent affects.

TU results for zinc can also be developed, using both the BLM and the hardness-based WQC for zinc. As previously detailed, EPA has not yet updated the zinc WQC based on the BLM. As an alternative, the BLM will be used to derive acute and chronic benchmarks for zinc. These benchmarks were derived with the intent that they be analogous to acute and chronic WQC and, as such, be applied in a similar manner. TU values based on chemistry reported by Besser et al. (2008) show a similar pattern to that seen for copper, with values of about 1 to 5 for samples taken at LR3 (RM 665) and LR2 (RM 626), see Figure 42. The pattern is consistent for both acute and chronic benchmarks. TU values for zinc based on BLM-benchmarks are lower than TU values based on hardness-equation WQC (Figure 43).

Values of TU > 1 are not seen using the acute BLM-based benchmark that is evaluated with Phase I porewater chemistry (Figure 44). TU values based on BLM benchmarks are lower overall than those based on hardness-dependent WQC (Figure 45). However, it is of interest to point out that one sample did have a higher TU value when it was evaluated with the BLM-based rather than the hardness-based chronic WQC (see Figure 45, right panel).

The lack of a BLM-based WQC or analogous benchmark for cadmium and lead required that a different approach be used for these metals. BLM-based TU calculations were based on effect levels that were evaluated for sensitive organisms for which the BLM had previously been applied. Use of the BLM in this way still provides insight to the ways that porewater chemistry is anticipated to affect metal bioaccessibility and bioavailability. A similar approach was used in testing the ability of the sediment BLM to explain and predict metal toxicity to benthic organisms with good results (Di Toro et al. 2005). For cadmium (Figure 46, left panel) and lead (Figure 46, right panel), BLM-based TU values using the Besser et al. (2008) data resulted in a very similar pattern as that seen for copper and zinc, with TU > 1 in samples from stations LR2 and LR3. This pattern was not reproduced in similar TU calculations performed using the Phase I porewater data (Figure 47).

EPA guidance (USEPA 2005) suggests use of a sum of TU approach for the SEM metals copper, cadmium, nickel, lead and zinc. As previously noted given the low nickel concentrations, it was not explicitly considered in the analyses presented herein. Summing the TUs for the other four metals in the Phase I data set results in only one TU value > 1 (TU = 1.09 at RM 741; which includes a zinc TU = 0.96). A second sample also had a sum of TU (0.96 at RM 743) that approached a value of 1. These observations are limited to the riverine reach where as previously discussed the more notable instances of toxicity have historically been observed. Otherwise, in all other areas of the Site, TU sums were < 0.73. Based on the Besser et al. (2008) data set, elevated TU sums were calculated at LR3 (TU = 24.8), LR2 (TU = 9.5), and LR6 (TU = 1.24).

7.3 SUMMARY OF POREWATER REFINEMENT AND ANALYSES

The results presented and discussed above highlight the difficulty of obtaining highly reproducible measurements of metals in porewater. When these results were used in the evaluations based on the hardness WQC they suggested that the sediment metals, particularly copper, but also perhaps lead and zinc, might be contributing to the toxicity observed in some areas, particularly the riverine reach. A refined analysis was then completed using a BLM-based approach and compared to the more traditional hardness-based WQC approach. Benchmarks evaluated with both approaches were used in combination with the sediment porewater ESB to assess whether or not metals were likely causing toxicity to benthic organisms. Each of these approaches was applied to data sets where sediment porewater chemistry was reported. In comparing the two approaches, the BLM generally resulted in much lower TU values than the hardness equation based approach. This is consistent with the fact that sediment porewaters are expected to have elevated DOC concentrations, as was observed in on-site measurements. The effect of DOC in sediment porewater is to reduce metal bioavailability, and is considered by the BLM, but not by the hardness-based approach.

Differences in porewater concentrations between studies have been discussed and, in particular, the data from Besser et al. (2008) included much higher porewater metal concentrations than were reported for the Phase I dataset. Several factors have been suggested as the reason for these differences including different sampling methods, different sample storage and processing techniques, and different extraction methods. As a result of the different porewater chemistries, the TUs calculated from these two data sources were markedly different. Results based on measurements reported by Besser et al. (2008) might suggest that toxicity would be expected near stations LR2 (RM 626) and LR3 (RM 665) from each of the metals. In contrast, results based on the much larger Phase I data set suggest that no toxicity would be expected. The overall BLM-based results were not markedly altered by the summing of TUs. When this conservative variation is applied to the Phase I data, maximum TU sums of 1.09 and 0.96 were respectively determined for samples at RM 741 and RM 743. Generally, BLM-based sum TU values for Phase I data were calculated to be < 0.73.

The preceding hardness-based results suggested that the observed sediment toxicity in the UCR, particularly the toxicity observed at upstream riverine stations, was associated with elevated exposure levels of copper, lead, and zinc in porewaters. The hardness-based TU results of Besser et al. (2008) were highest at LR2 and LR3. These results differed somewhat from the hardness-based evaluations of Paulson and Cox (2006) for the same stations where these authors reported a TU >1 for more than one metal at LR7 in Reach 1 (copper and lead), and at LR3 in Reach 4B (cadmium and lead). Values of TU > 1 were also evaluated for lead at sampling stations LR4A and LR6. However, when factors affecting bioavailability are considered, a much different view of the situation emerged suggesting that copper, lead, and zinc are not necessarily contributing to the effects that were reported (refer to Figures 40, 45, and 47).

8 SUMMARY

The major findings of the evaluations conducted in this technical memorandum can be summarized as follows:

- It is recommended that the historical UCR sediment toxicity data collected between 1986 and 2001 should be used only in a qualitative manner in the UCR RI/FS, as insufficient information was available to conduct complete data quality reviews for most data sets, many of the sediment toxicity tests were conducted using protocols that are not currently used for sediment quality assessments, suboptimal toxicity responses were found in some cases for negative controls and reference-area sediments, and many of the tests were conducted at a time when the testing laboratories had much less experience in conducting freshwater sediment toxicity tests than they do today.
- The most recent UCR sediment toxicity data collected in 2004 and 2005 are considered most representative of current conditions, are generally well documented such that data quality can be determined with a reasonable degree of confidence, were generated using the most recent standardized protocols, and passed all negative control performance criteria. Those data are therefore considered of sufficient quality for use in the UCR RI/FS, with the exception of the 2005 chironomid test for which several data quality concerns were identified in this appendix. Those data should therefore be used with caution as they have uncertainties associated with them.
- Significant toxicity responses for the 2005 study were determined relative to negative control responses, because the six reference areas sampled in that study were considered sufficiently dissimilar to the UCR with respect to general physical characteristics (e.g., grain size, water depth, flow) and sediment characteristics (primarily TOC content) to be questionable representations of the conditions expected to be found in the UCR.
- Significant toxicity responses were found in all six UCR reaches in the 2005 study, but were found at the greatest percentage of stations in Reaches 1, 3, and 4. In Reach 2, significant responses were found only for the chironomid test, and in Reaches 5 and 6, significant responses were found only for the daphnid test.
- Most of the significant toxicity responses in the 2005 study were found for sublethal endpoints, especially if the survival values for the chironomid test are considered uncertain. For example, 23 significant responses were found for the 150 sublethal responses evaluated in 2005 (i.e., three toxicity tests at 50 stations), whereas 17 lethal responses were found for the 150 lethal responses. The number of lethal responses would decline to 8 (i.e., one, three, and four for the amphipod, chironomid, and daphnid tests, respectively), if the questionable chironomid survival results were removed.
- Concordance among the 2005 sediment toxicity tests was relatively low. For example, of the 26 stations that exhibited a significant response in one or more of the toxicity tests,

all three tests exhibited significant responses at only three stations, all located in Reach 1, and two of the three tests exhibited significant responses at only four stations, all located in Reach 4. No concordance among the three toxicity tests was found at any station in Reaches 2, 3, 5, and 6. These patterns indicate that there was little corroboration among the three tests with respect to sediment toxicity, suggesting that the tests were responding relatively independently. These patterns cast doubt on whether most of the stations exhibiting significant toxicity responses were highly or even moderately toxic, as significant toxicity in multiple tests would generally be expected under such conditions.

- Evaluations of longitudinal patterns in sediment toxicity responses using a weight-of-evidence approach for the 2005 toxicity study showed that the greatest number of stations with toxicity responses less than a benchmark value of 80 percent of negative control values was found in Reach 1. In addition, no apparent site-wide longitudinal gradient in sediment toxicity responses was found.

- Comparisons of the historical (1986 to 2001) and recent (2004 to 2005) sediment toxicity data for the UCR using a weight-of-evidence approach showed that the longitudinal patterns of both groups of data appeared nearly identical, with most or all of the toxicity responses less than 80 percent of negative control values observed in Reach 1, and few or no responses less than 80 percent observed in Reaches 2 to 6. However, in Reach 1, several of the responses for the historical data were considerably lower than the responses found for the recent data.

- The PECQs for one or more of the eight metals having PECs exceeded 1.0 at 24 of the 50 stations sampled for sediment toxicity in 2005, with all but two of those stations located in Reaches 1 to 3. In Reaches 4 to 6 below Marcus Flats, the PECQs for one or more metals exceeded 1.0 at only 2 of the 24 stations, with no exceedances found below RM 687.

- The longitudinal distribution of mPECQs showed a decreasing gradient from Reaches 1 to 4a and then a relatively flat distribution from Reaches 4a to 6. The longitudinal distribution of mPECQs was therefore generally consistent with the patterns discussed above for PECQs greater than 1.0 for individual metals.

- In general, zinc, copper, and lead were the primary contributors (in relative terms) to the mPECQs in Reaches 1 to 3. Below Marcus Flats, other metals made increasing contributions, although it should be noted that the absolute values of the mPECQs were low at most of those stations.

- The longitudinal distribution of ΣSEM showed concentrations exceeding 5.0 μmol/g at all but 2 of the 26 stations in Reaches 1 to 3, and concentrations less than that value at all but 3 of the 24 stations in Reaches 4 to 6. With respect to the relative contributions of the individual SEM to ΣSEM, zinc accounted for the greatest contribution at most stations, but cadmium, nickel, and lead combined to account for relatively large contributions between RMs 678 and 658 in Reaches 4a and 4b. Copper accounted for a relatively constant contribution at most stations.

- The longitudinal distribution of AVS was generally similar to that for ΣSEM, with all but eight values being greater than 0.5 µmol/g in Reaches 1 to 3, and all measured values being less than 0.1 µmol/g in Reaches 4 to 6.
- The longitudinal distribution of TOC did not show a pattern consistent with that found for ΣSEM and AVS. The concentrations of TOC generally increased from Reach 1 to Reach 3 (i.e., Marcus Flats, where all four values were 0.8 percent or greater). In Reaches 4 to 6, TOC varied markedly, ranging from 0.04 to 2.2 percent.
- Concentrations of (ΣSEM–AVS) measured in the sediments sampled for toxicity testing in 2005 were compared with generic EPA thresholds (USEPA 2005), developed to prioritize sediments of concern for potential further evaluation (i.e., 1.7 and 120 µmol/g). For this analysis, ΣSEM was used instead of (ΣSEM–AVS) for 16 of the 50 toxicity stations for which measured AVS concentrations were less than 0.1 µmol/g (i.e., the limit of the applicability of the SEM and AVS methodology), and for 12 of the 50 stations for which no AVS data were reported (USEPA 2006). The results of the analysis showed that three stations in Reach 1 exceeded the upper generic threshold of 120 µmol/g and 27 additional stations exceeded the lower threshold of 1.7 µmol/g, indicating that additional evaluations would be required to confirm the potential presence of toxicity at those stations. Most of those 30 stations were located in Reaches 1 to 3. By contrast, 20 stations were below the lower threshold of 1.7 µmol/g, indicating that toxicity was unlikely at those locations. That group of stations included 19 of the 24 stations sampled in Reaches 4 to 6 below Marcus Flats.
- Comparison of measured AVS–SEM concentrations in sediments with generic no effects thresholds suggested they are a reasonably good indicator for assessing conditions where toxicity is not expected as a consequence of SEM metals.
- Comparison of dissolved metals concentrations in porewater with hardness-based water quality criteria suggested that sediment toxicity reported at some locations in the UCR, particularly at upstream riverine stations, may be associated with elevated exposure levels of some metals in porewater. However, when factors affecting bioavailability are considered, the cause of the observed effects is much less well defined. In this case, the fact that the sum of toxic units is nearly always < 1.0 suggests that levels of copper, lead and zinc are not sufficient to be the cause of the reported effects..

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FIGURES

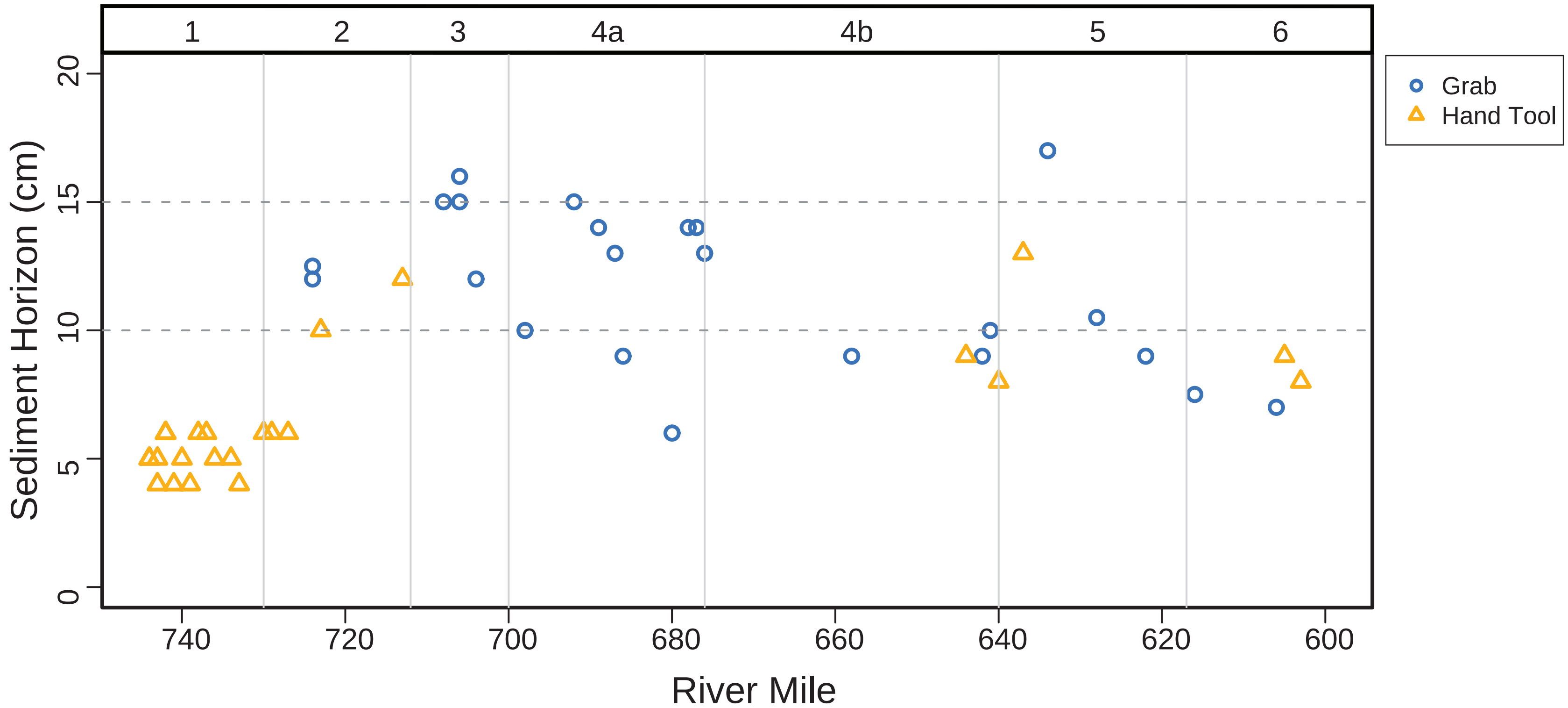


Figure 1. Longitudinal Distribution of Sediment Horizons
Sampled During the 2005 Sediment Toxicity Study

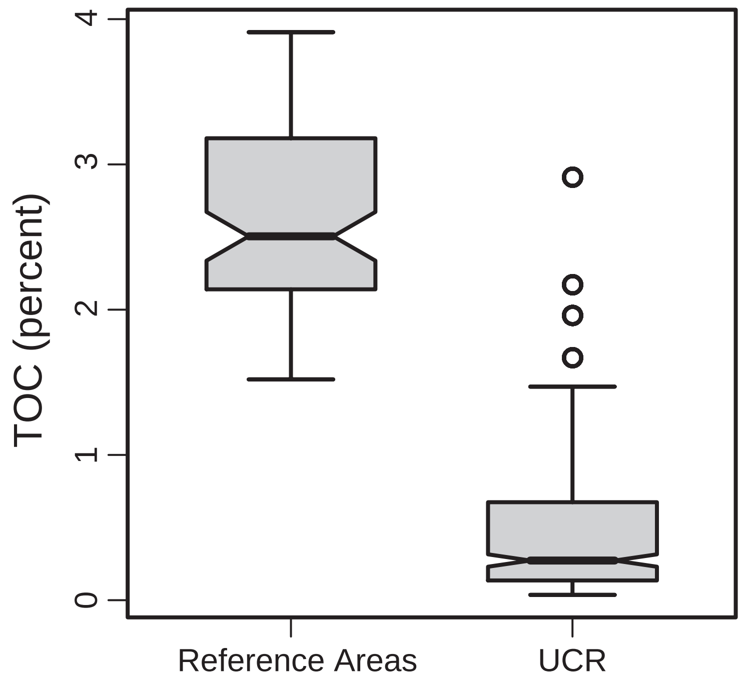


Figure 2. Comparison of Total Organic Carbon Concentrations
between the Six Reference Areas and 50 UCR Stations Sampled
during the 2005 Sediment Toxicity Study

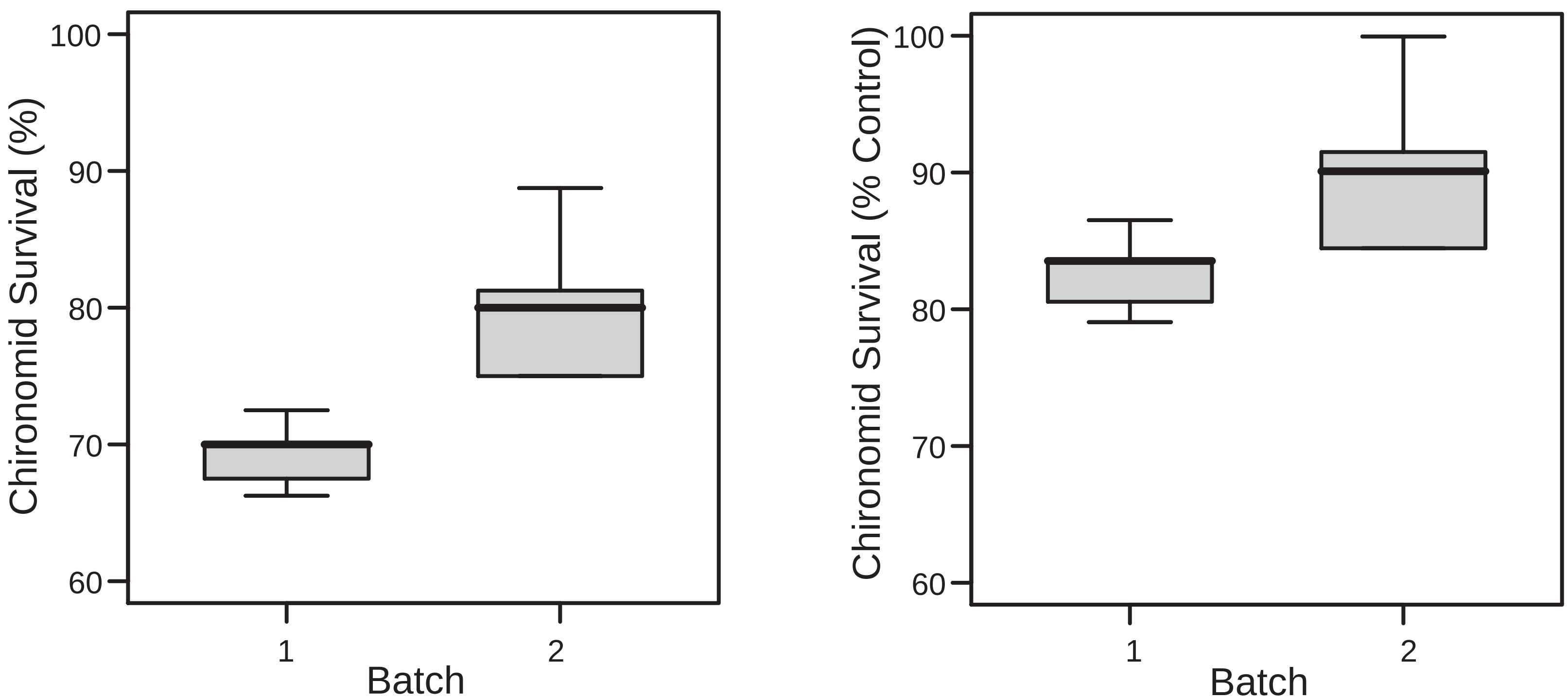
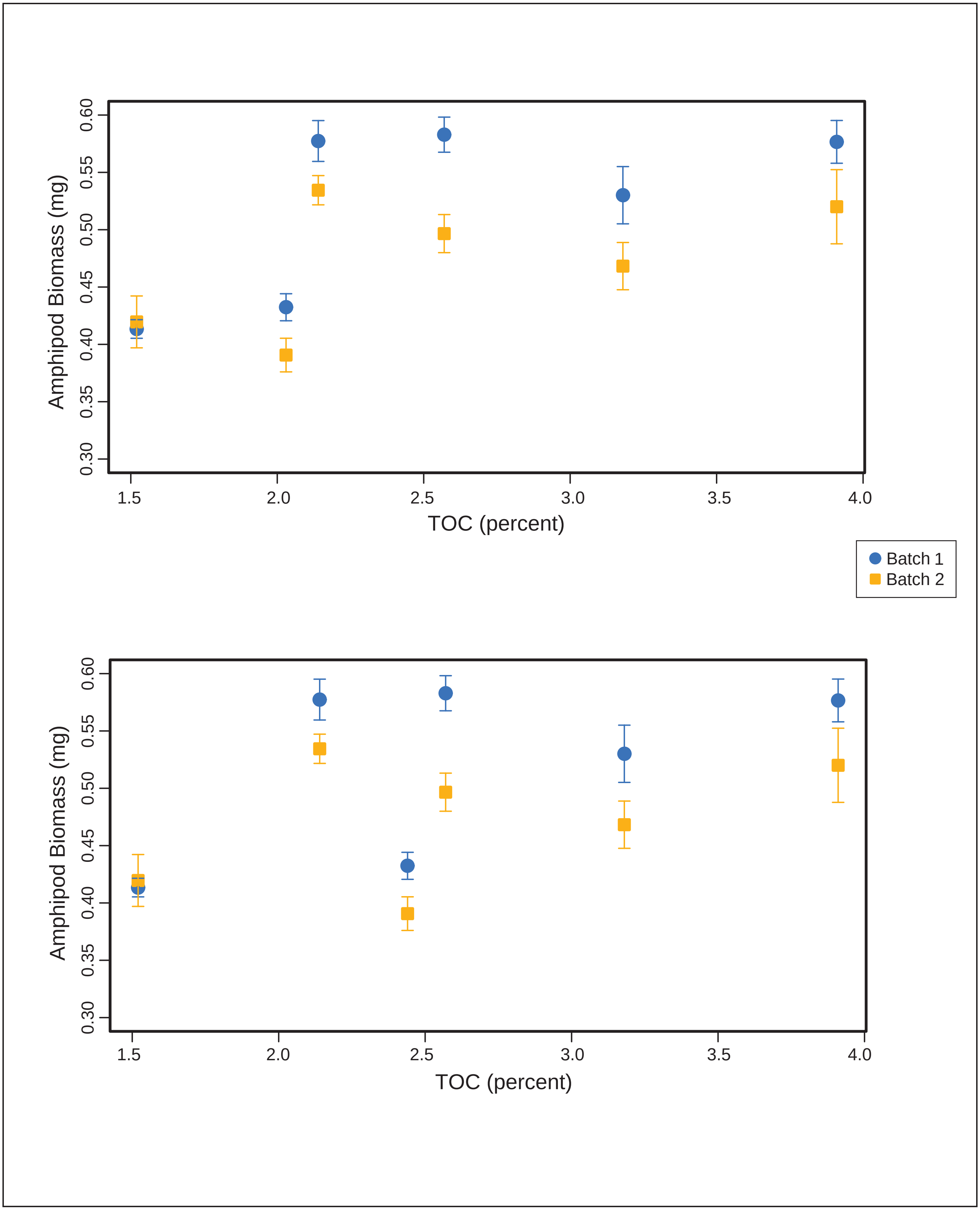


Figure 3. Comparison of Chironomid Survival between Test Batches for the Six Reference Areas Sampled during the 2005 Sediment Toxicity Study



Note: Bottom panel includes field duplicate for the sample with approximately 2 percent TOC in the top panel.

Figure 4. Comparison of Amphipod Biomass and Total Organic Carbon Concentration of Sediment for the Six Reference Areas Sampled during the 2005 Sediment Toxicity Study

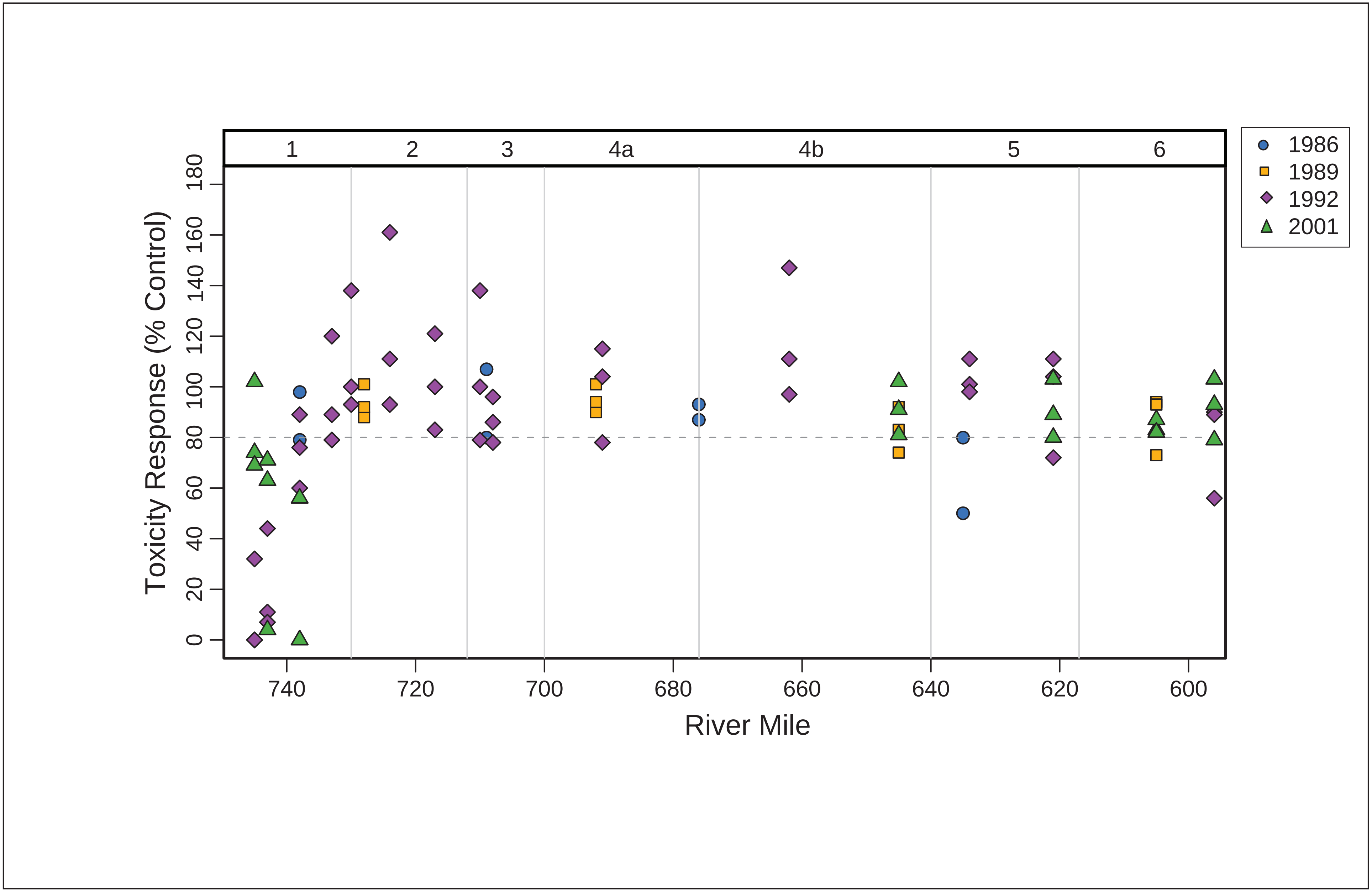


Figure 5. Longitudinal Distribution of Sediment Toxicity Responses for Historical (1986–2001) UCR Studies

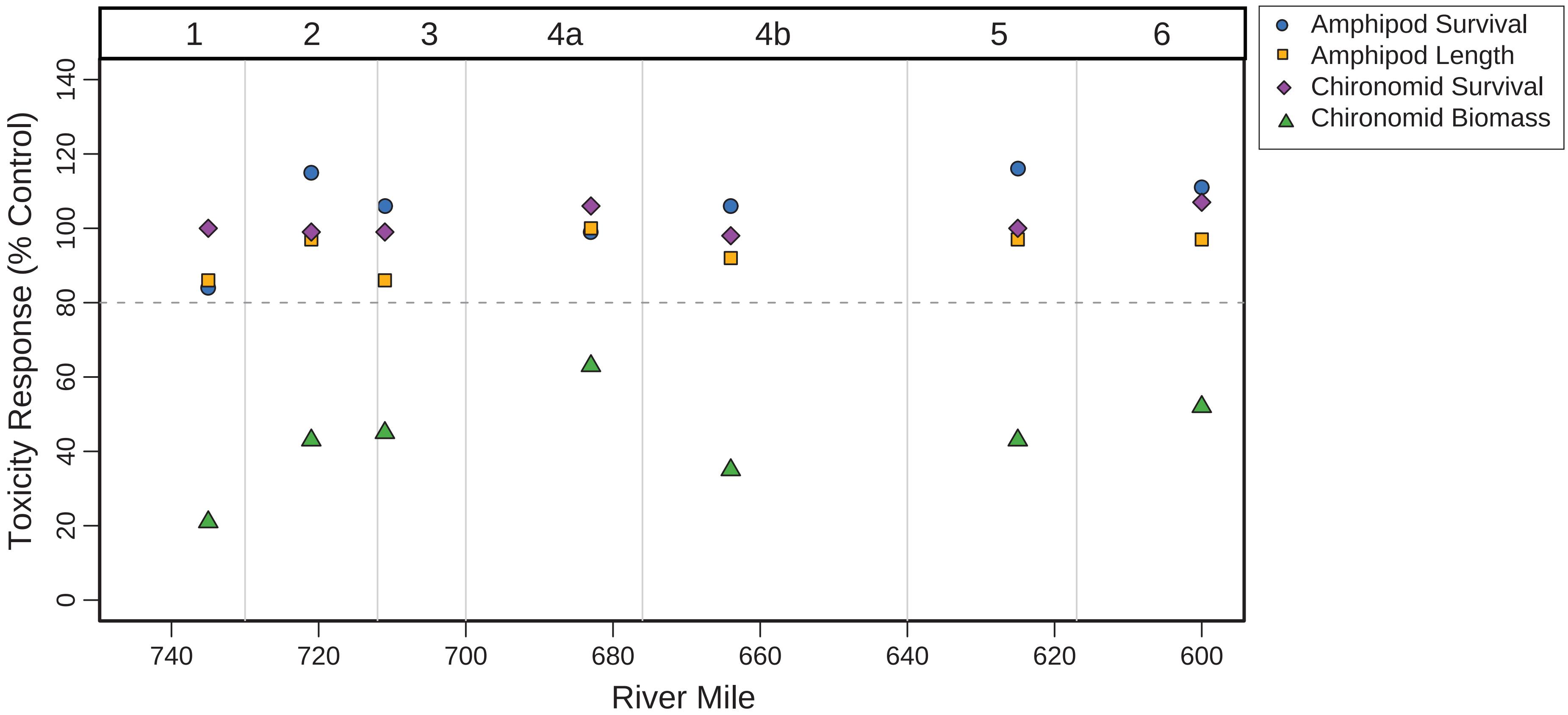


Figure 6. Longitudinal Distribution of Sediment Toxicity Responses for the 2004 UCR Study

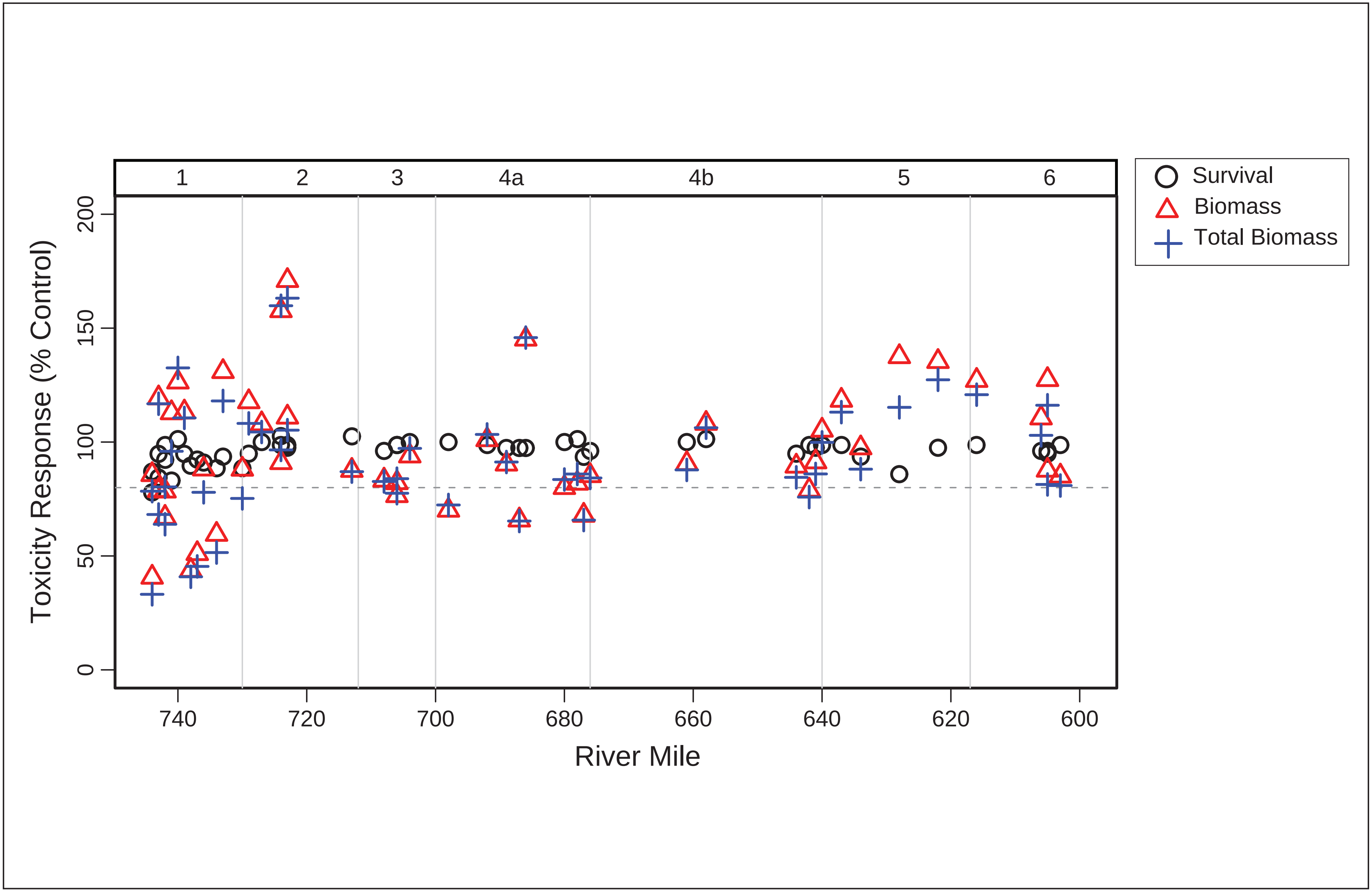


Figure 7. Longitudinal Distribution of Sediment Toxicity
Responses for the Amphipod Test in the 2005 UCR Study

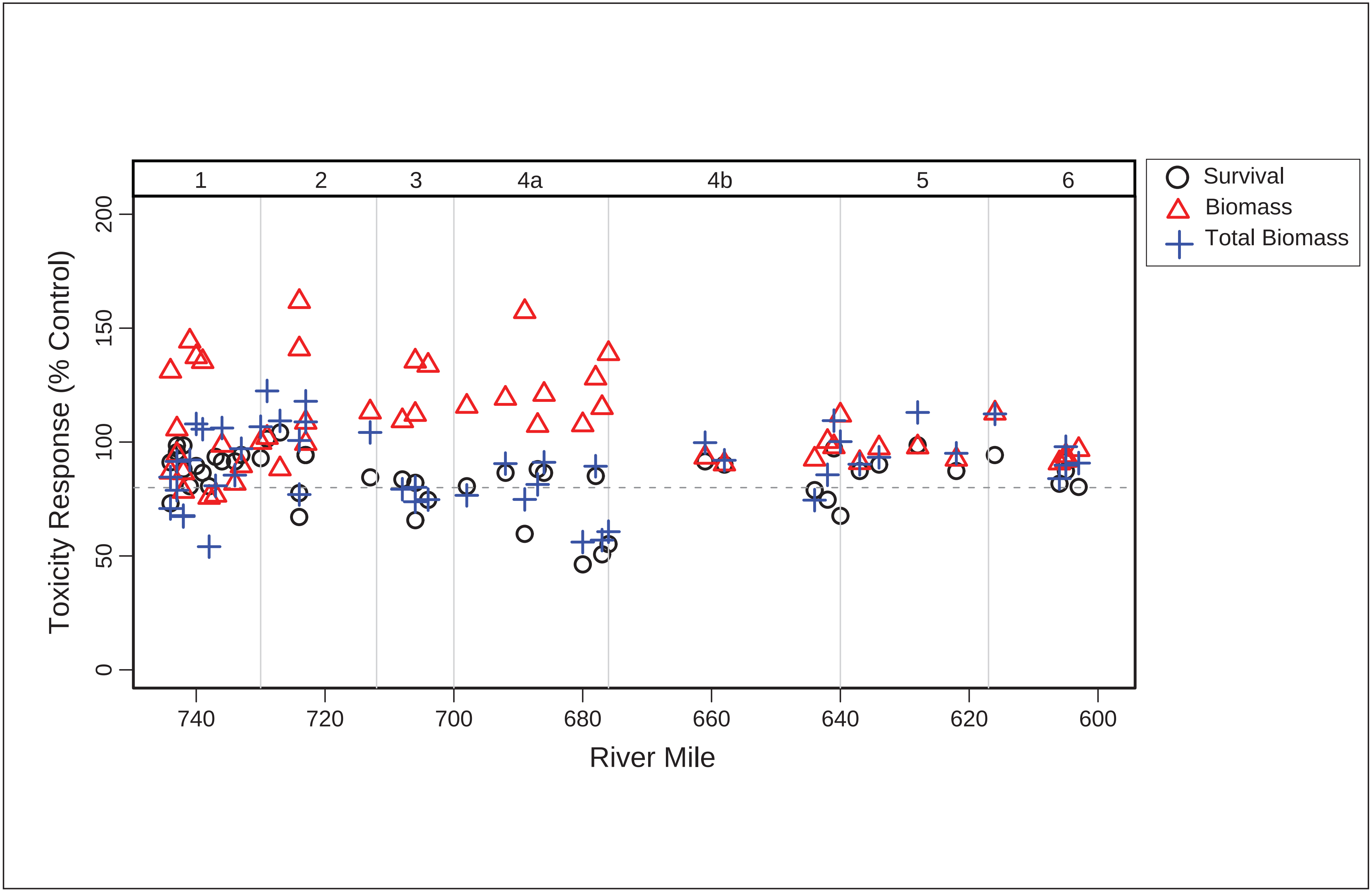


Figure 8. Longitudinal Distribution of Sediment Toxicity
Responses for the Chironomid Test in the 2005 UCR Study

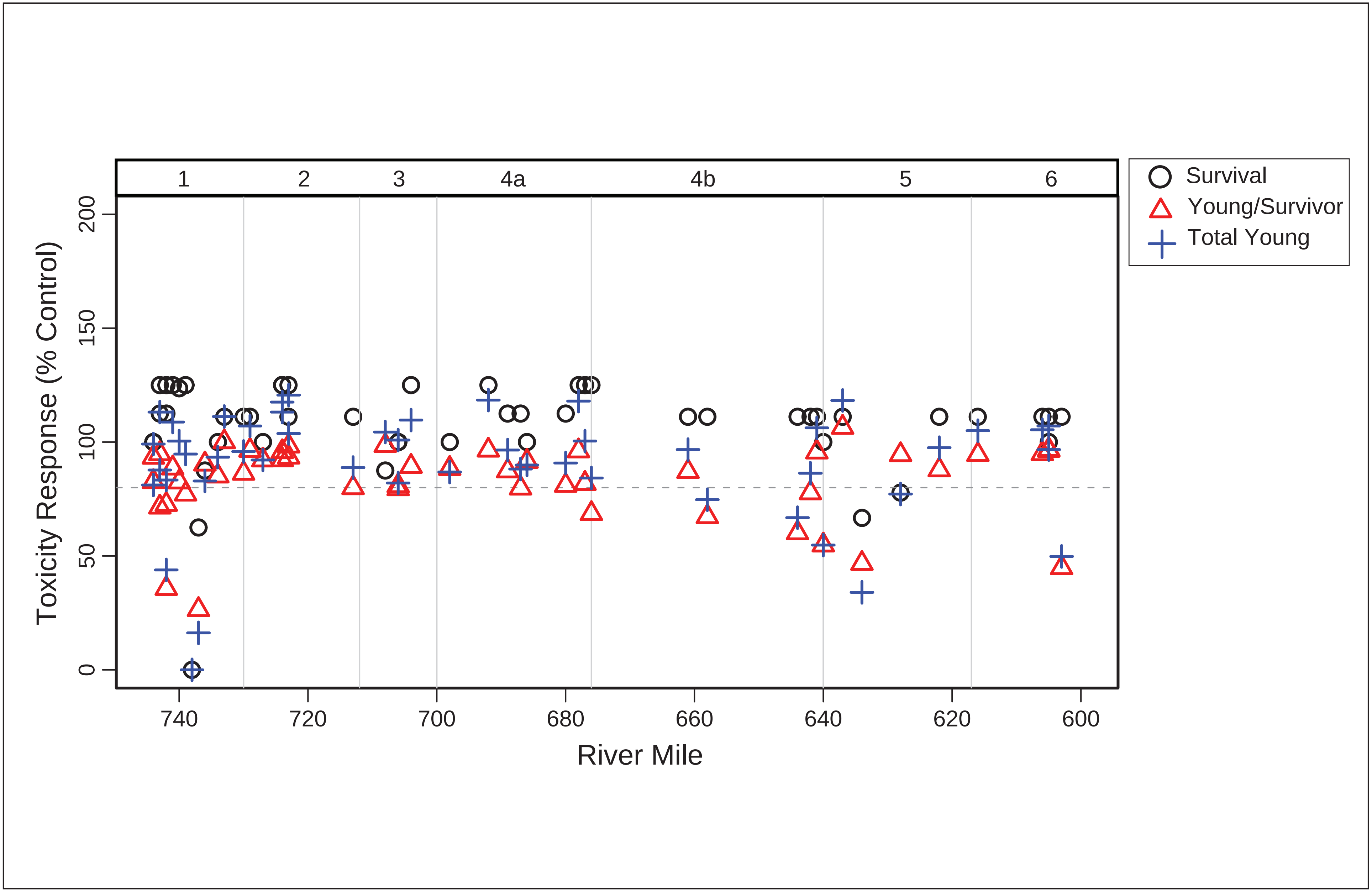


Figure 9. Longitudinal Distribution of Sediment Toxicity Responses for the Daphnid Test in the 2005 UCR Study

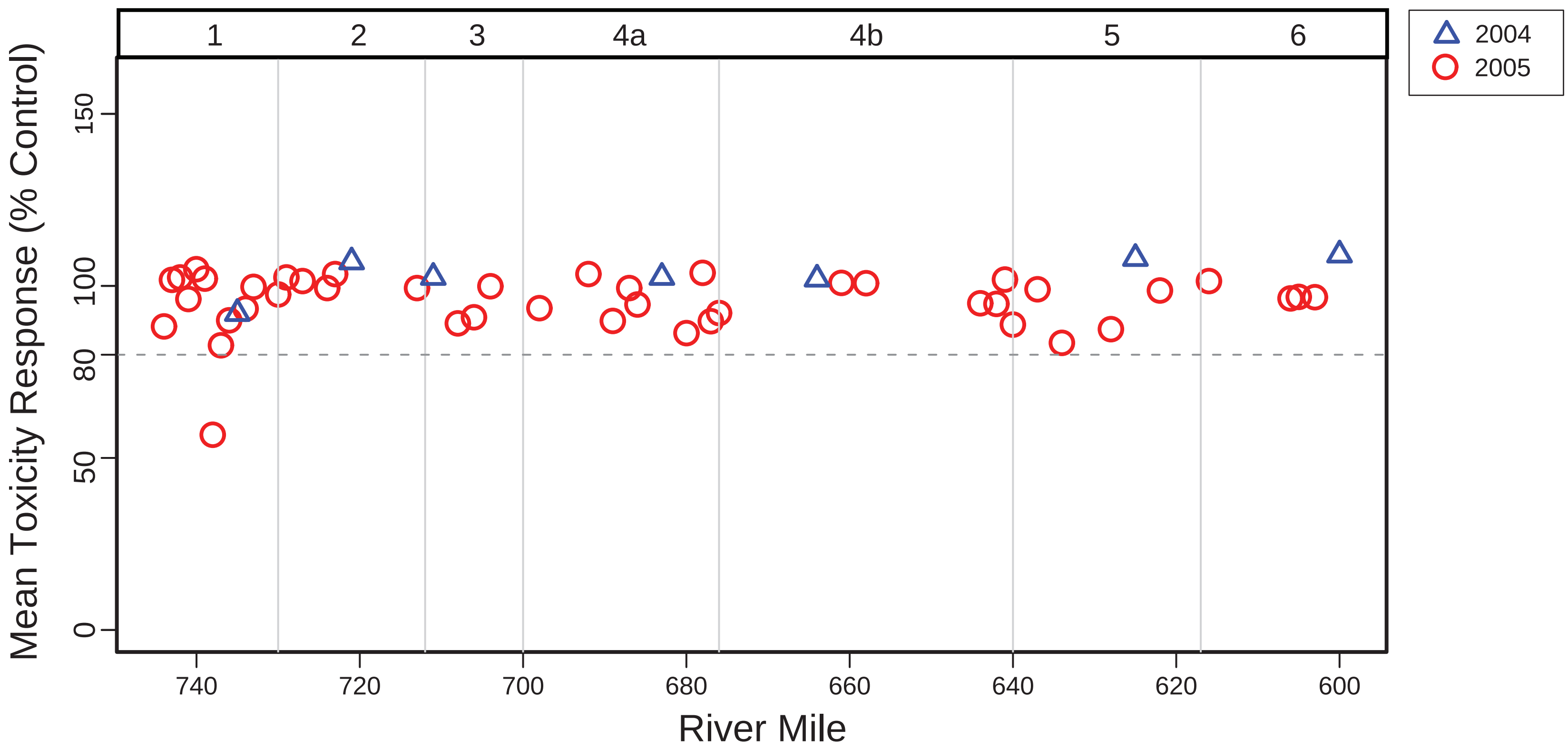


Figure 10. Longitudinal Distribution of Lethal Sediment Toxicity Responses for the 2004 and 2005 UCR Studies

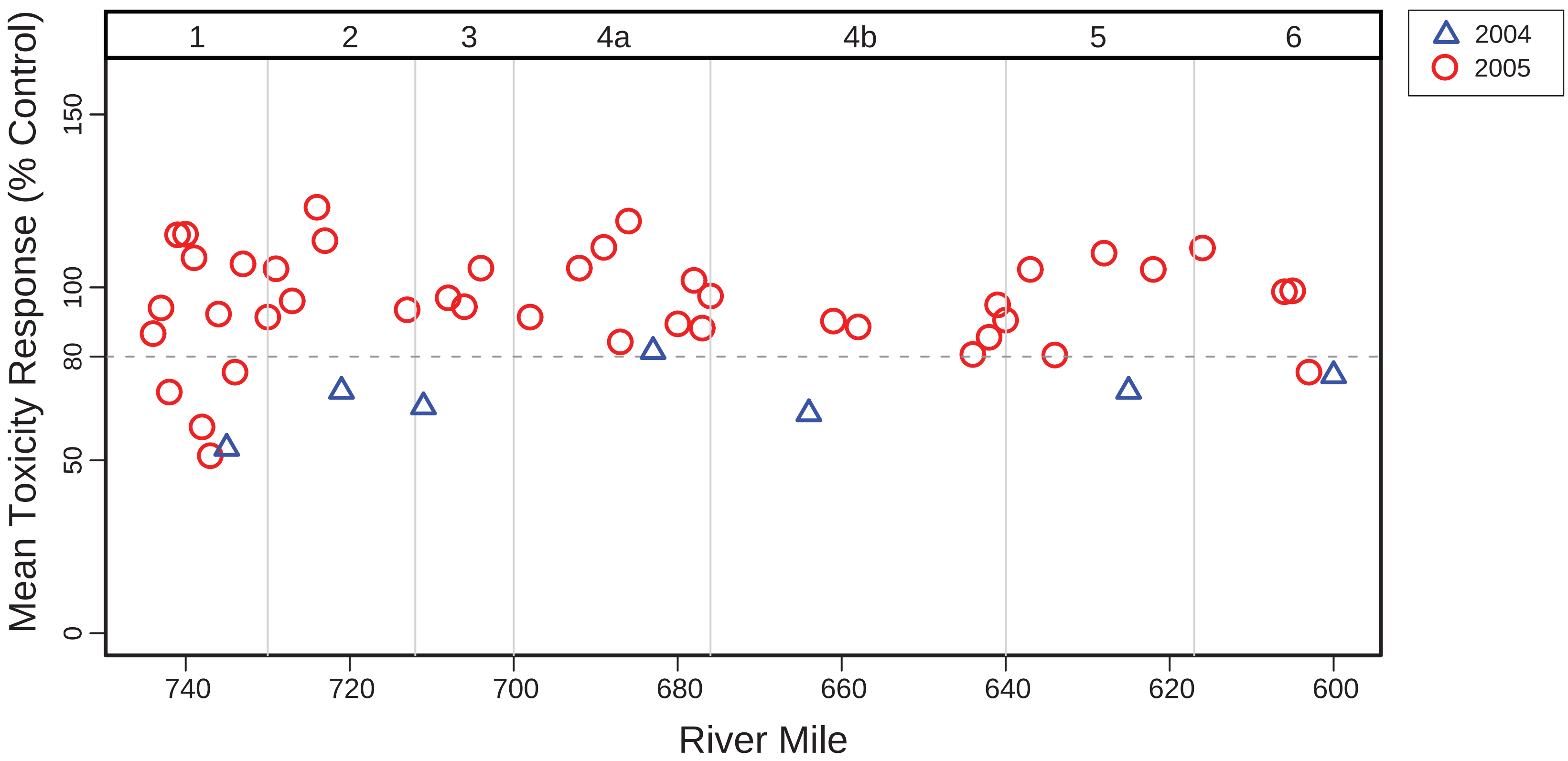


Figure 11. Longitudinal Distribution of Sublethal Sediment Toxicity Responses for the 2004 and 2005 UCR Studies

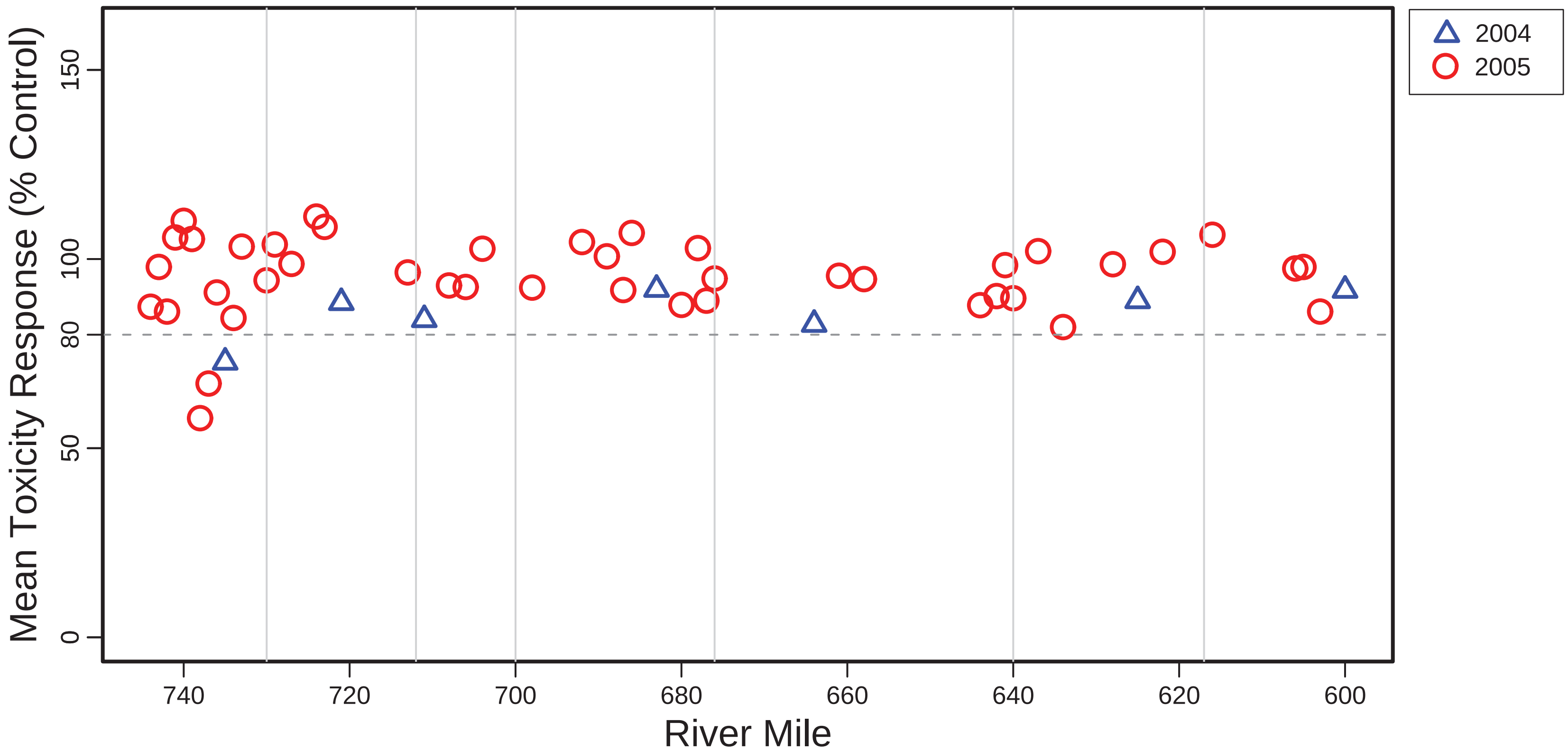


Figure 12. Longitudinal Distribution of Overall Sediment Toxicity Responses for the 2004 and 2005 UCR Studies

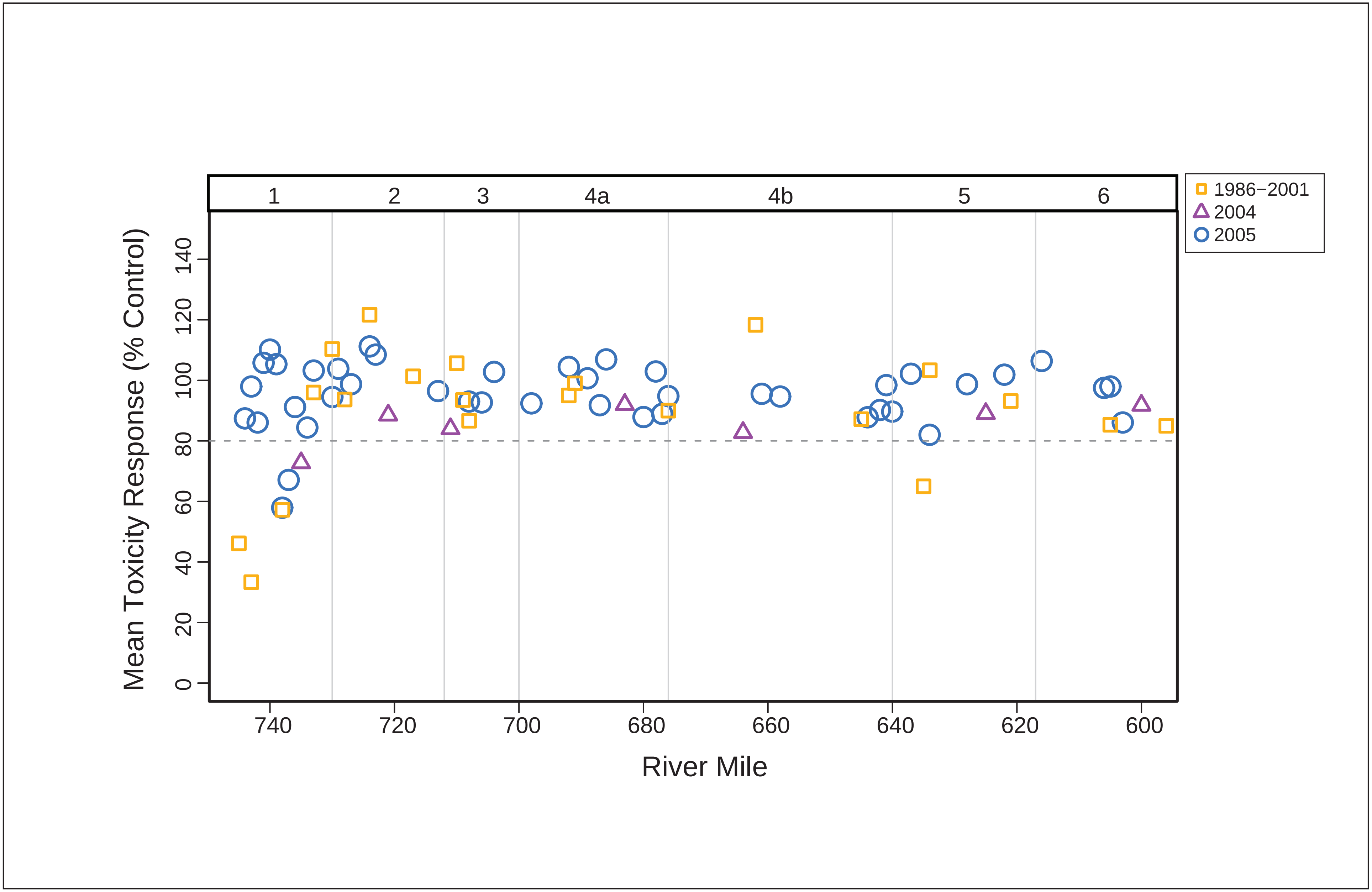
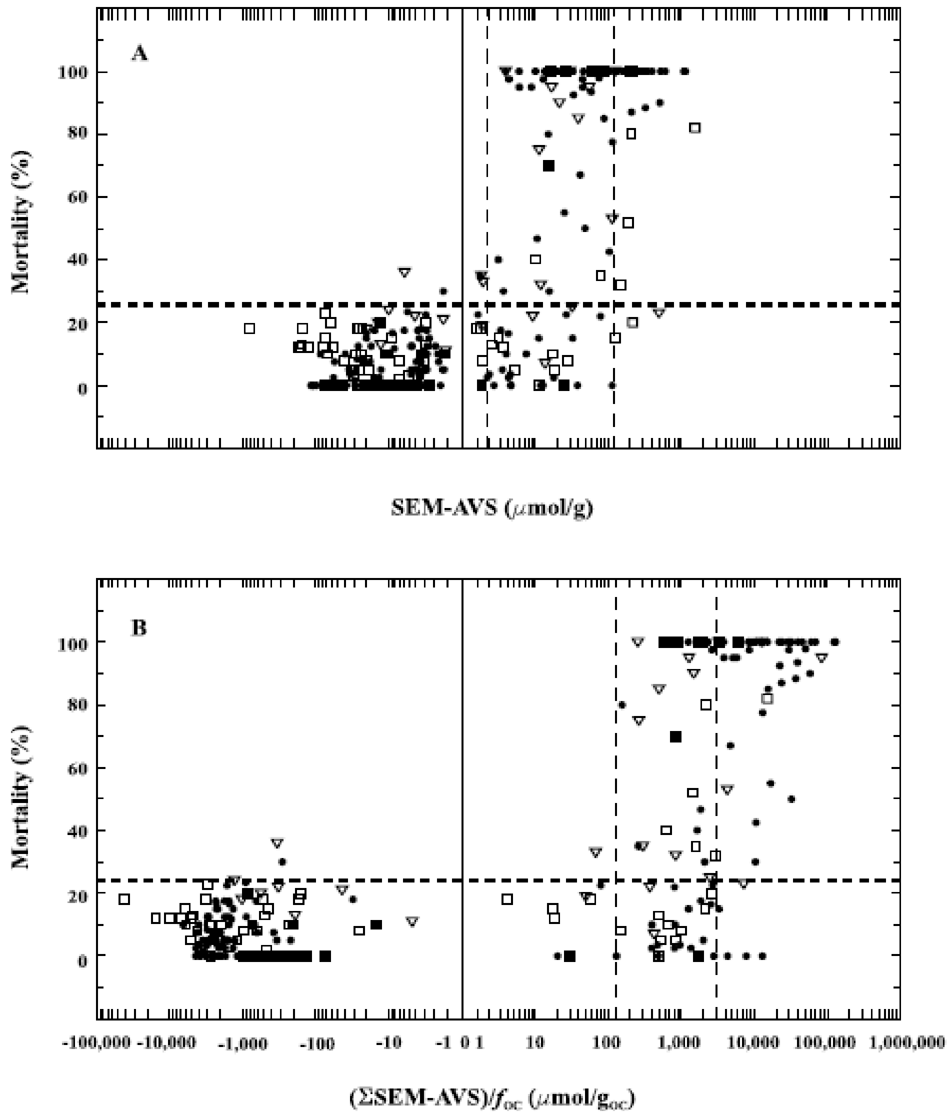


Figure 13. Comparison of Longitudinal Distributions of Overall Sediment Toxicity Responses for the Historical (1986 to 2001) and Recent (2004 and 2005) UCR Studies



Percent mortality versus SEM-AVS (A) and (ΣSEM-AVS)/f_{oc} (B) for saltwater field data without Bear Creek and Jinzhou Bay (□), freshwater field data (▽), freshwater spiked data (■), and saltwater spiked data (●); silver data excluded. Vertical dashed lines are the 90% uncertainty bound limits (figure from Di Toro et al., 2000).

Figure 14. Percent Mortality versus SEM – AVS and (Sum SEM-AVS)/f_{oc} for Saltwater and Freshwater Field Data and Spiked Sediment Data
Source: USEPA (2006).

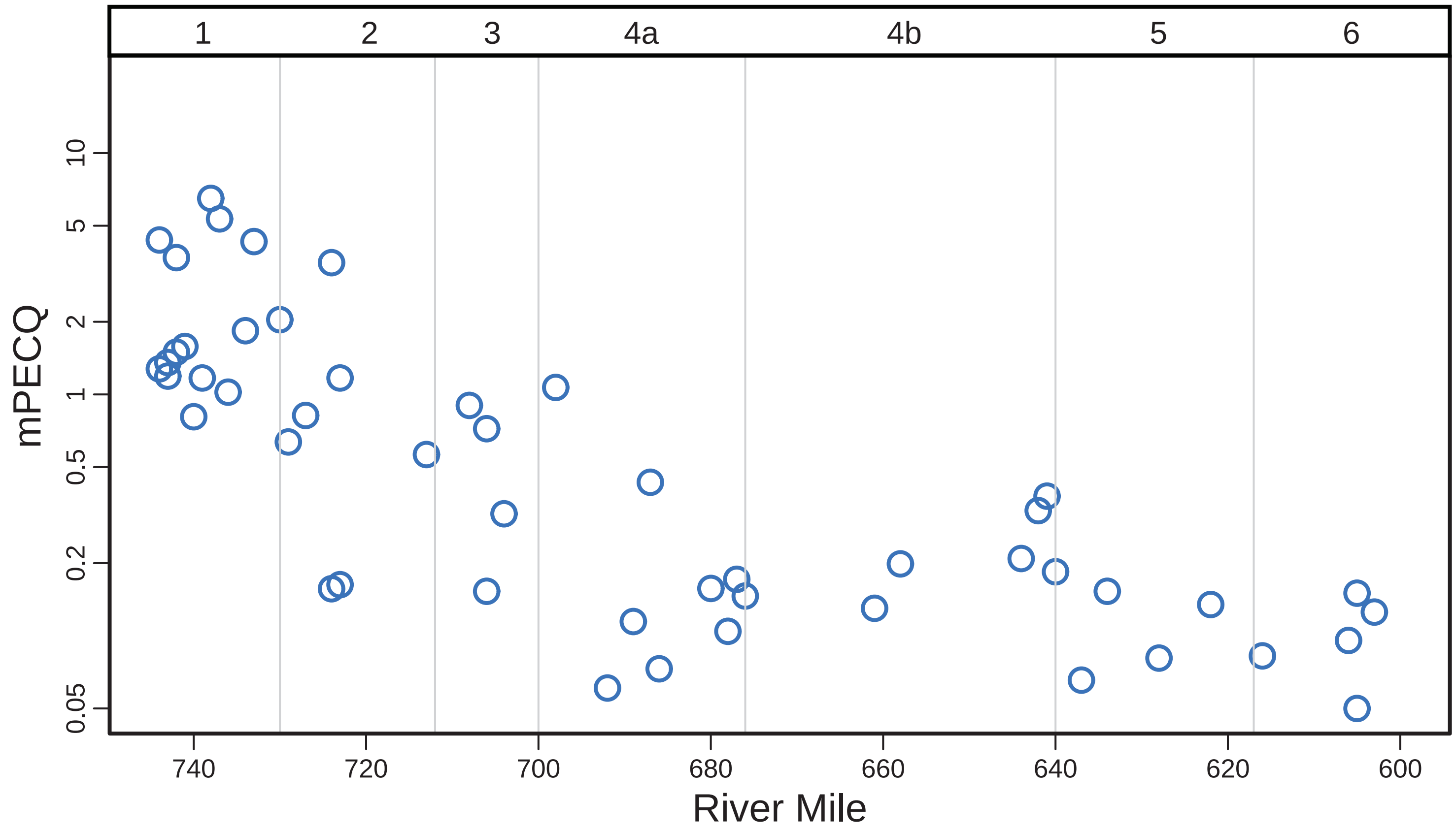


Figure 15. Longitudinal Distribution of mPECQ in Surface Sediments at Sediment Toxicity Stations in the 2005 UCR Study

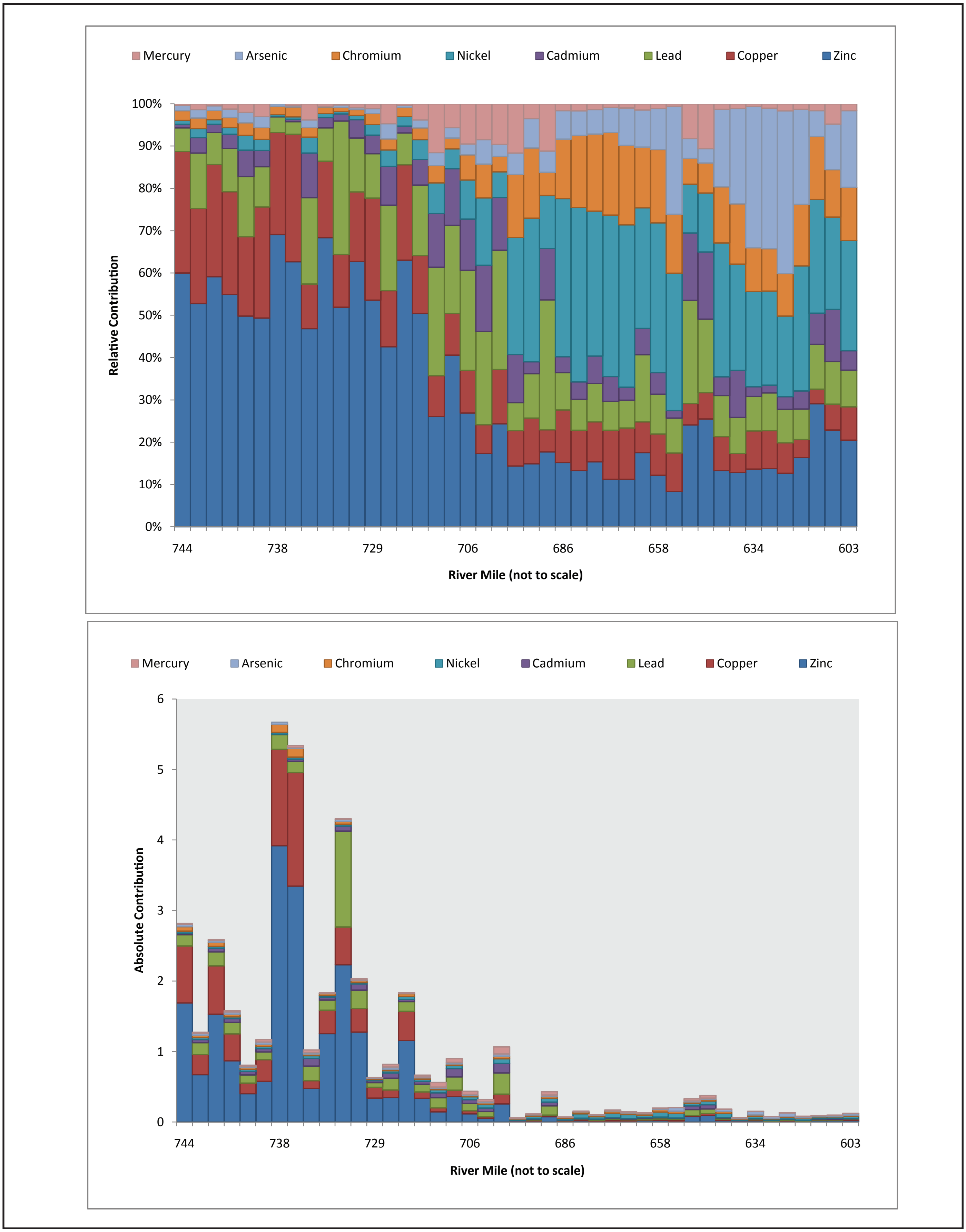


Figure 16. Longitudinal Distribution of Relative and Absolute Contributions to mPECQ by Individual Metals at Sediment Toxicity Stations in the 2005 UCR Study

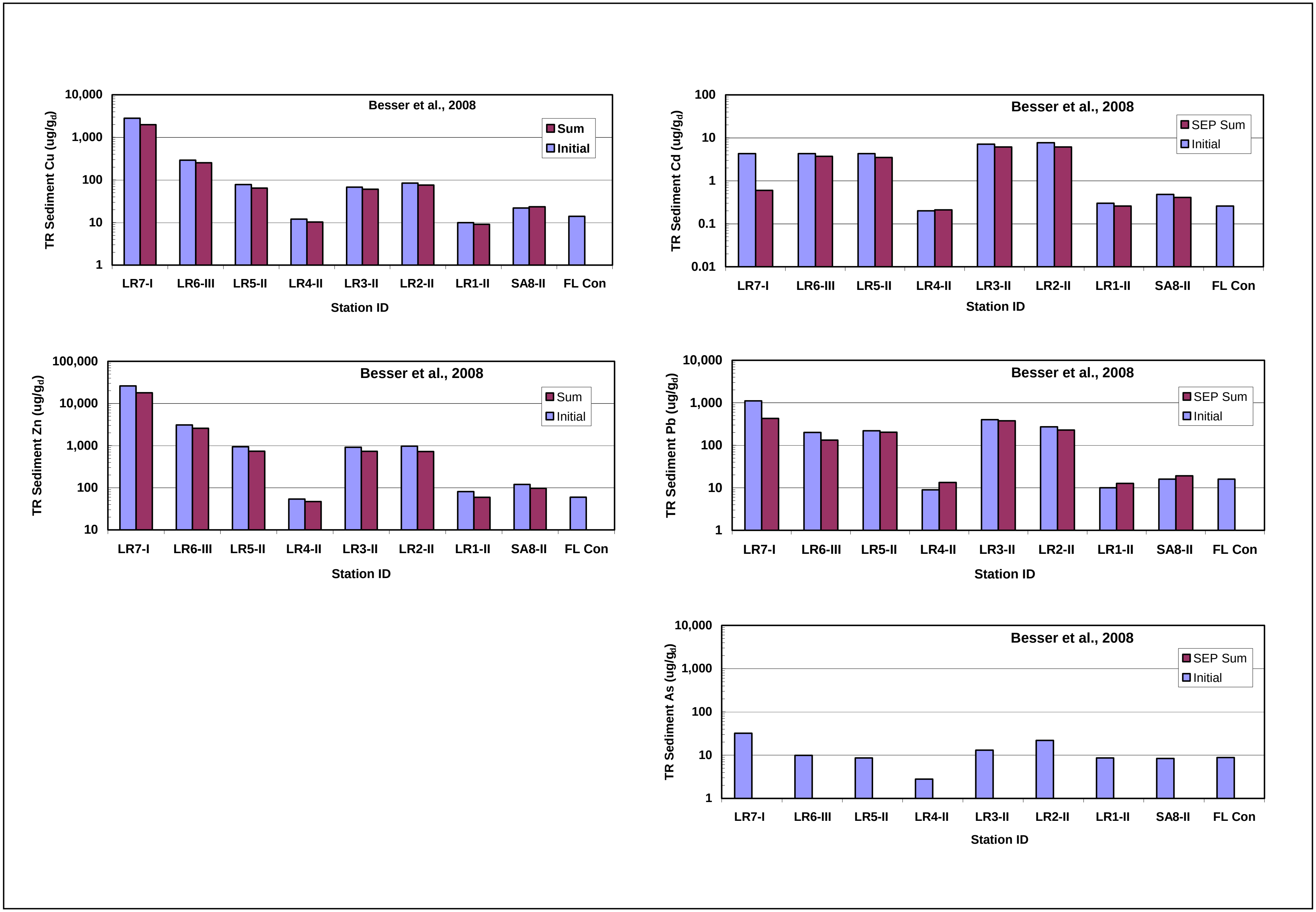


Figure 17. Total Recoverable Metals reported by Paulson et al. (2006) and Besser et al. (2008).

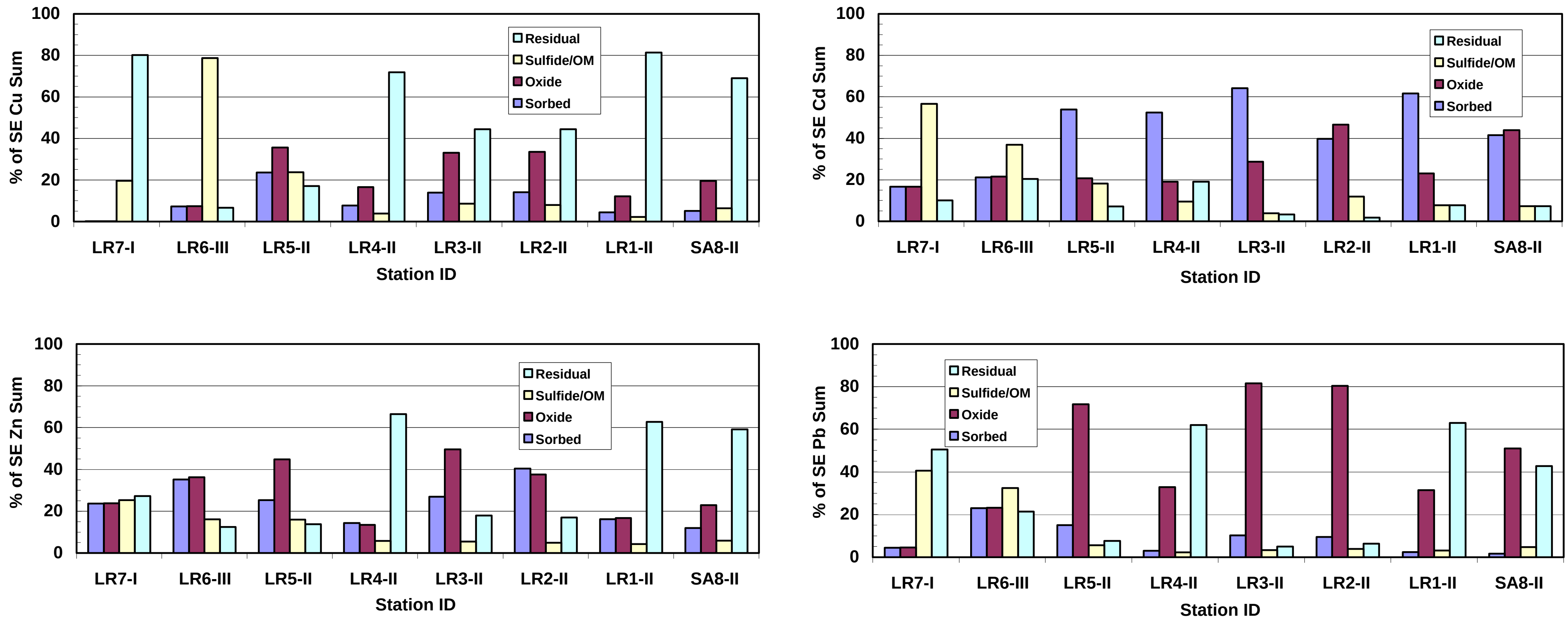


Figure 18. Sequential Extraction Sediment Metal Concentrations
Data Source: Paulson et al. (2006).

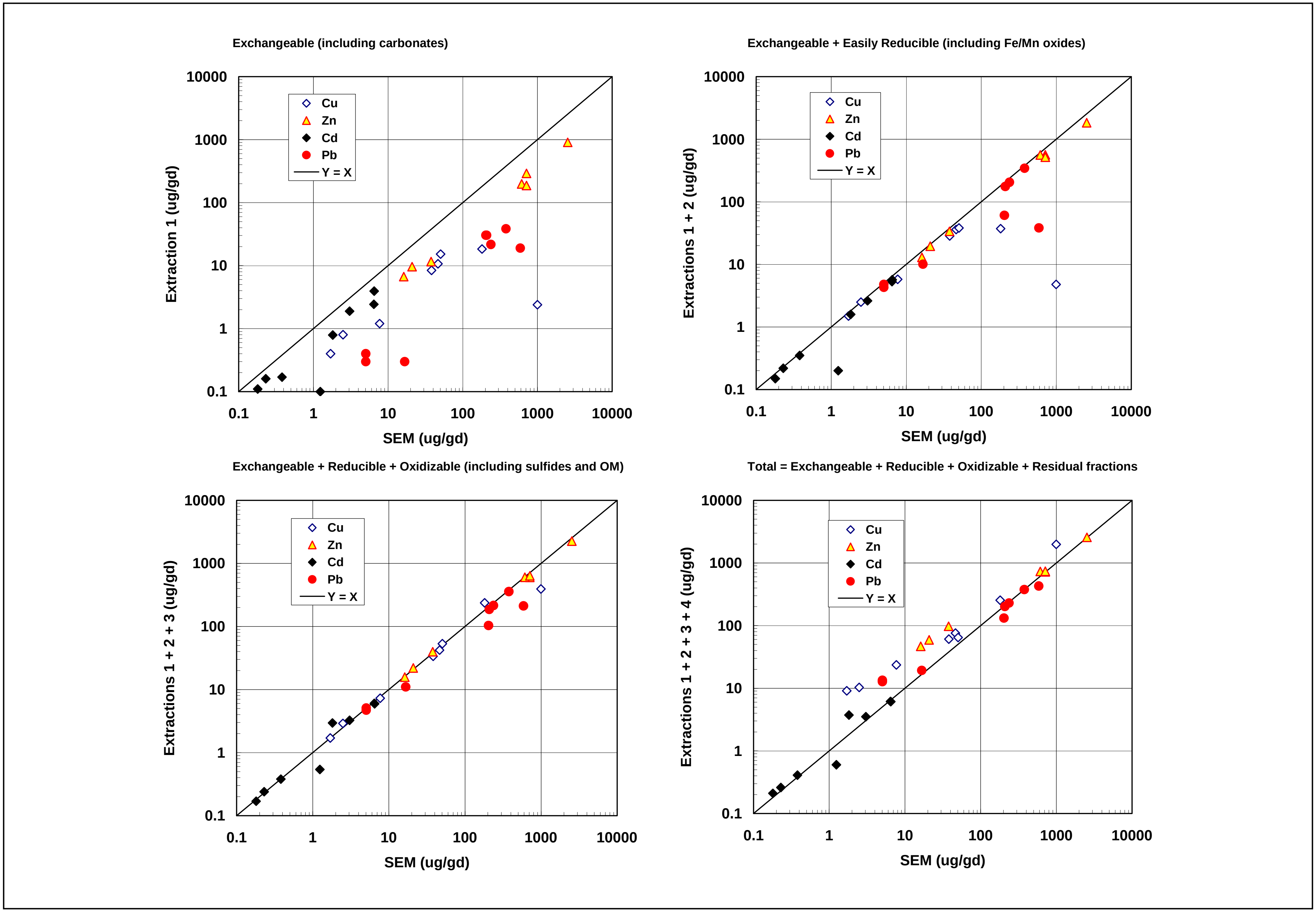


Figure 19a. Comparison of Sequential Extractions to SEM
Data Source: Paulson et al. (2006).

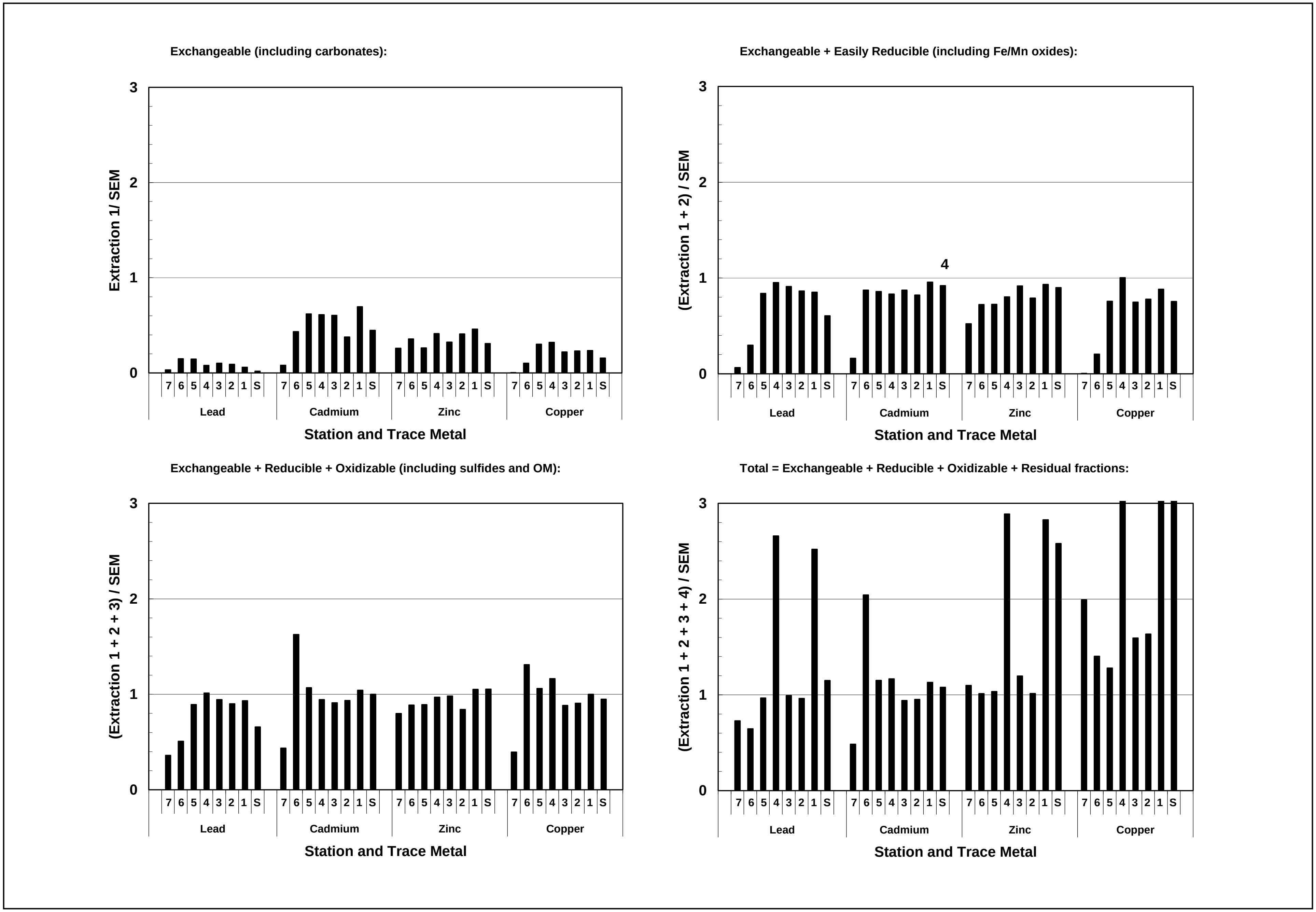


Figure 19b. Comparison of Sequential Extractions to SEM
Data Source: Paulson et al. (2006).

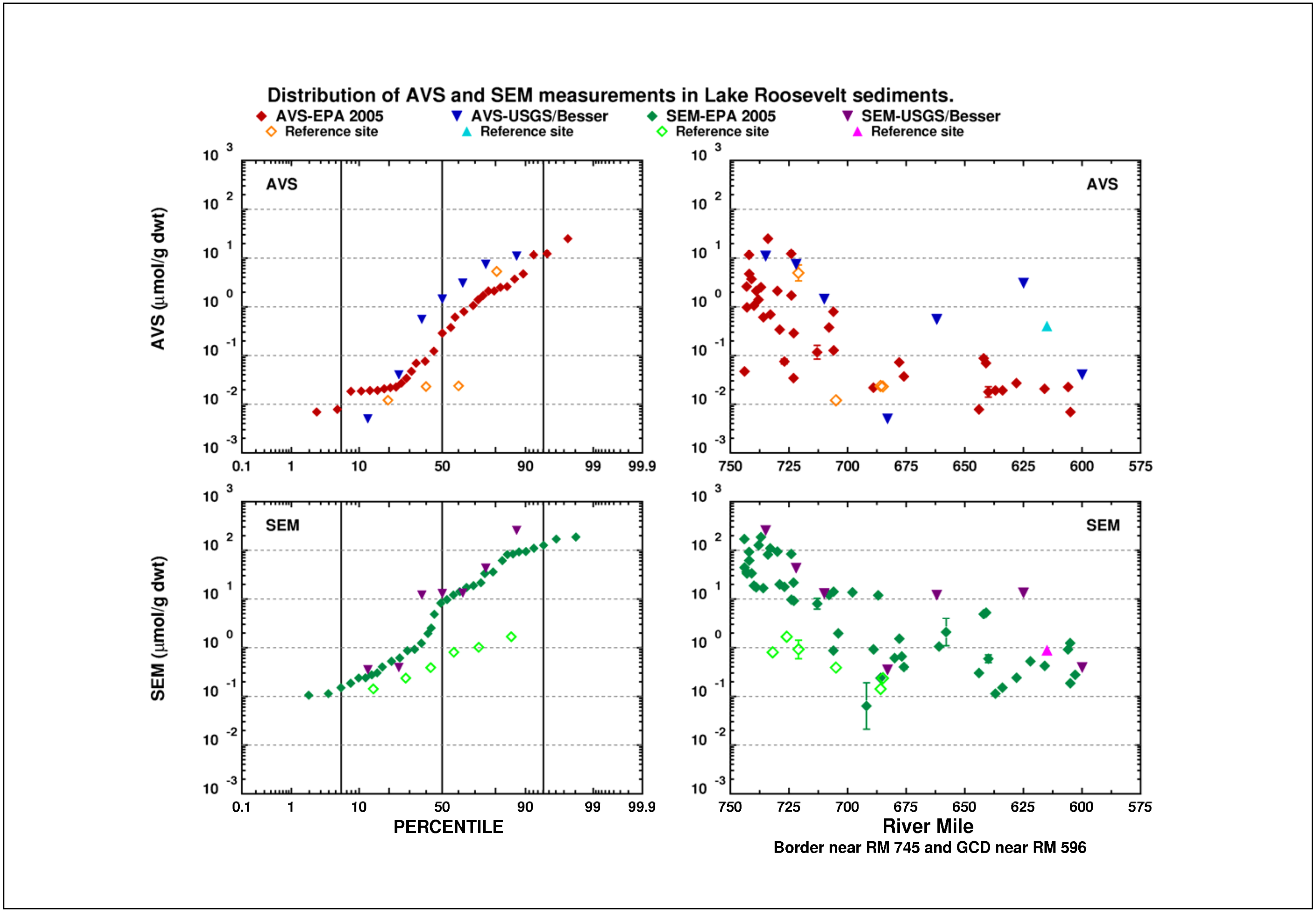


Figure 20. AVS and SEM in UCR Sediments
Data Source: USEPA (2006) and Paulson et al. (2006).

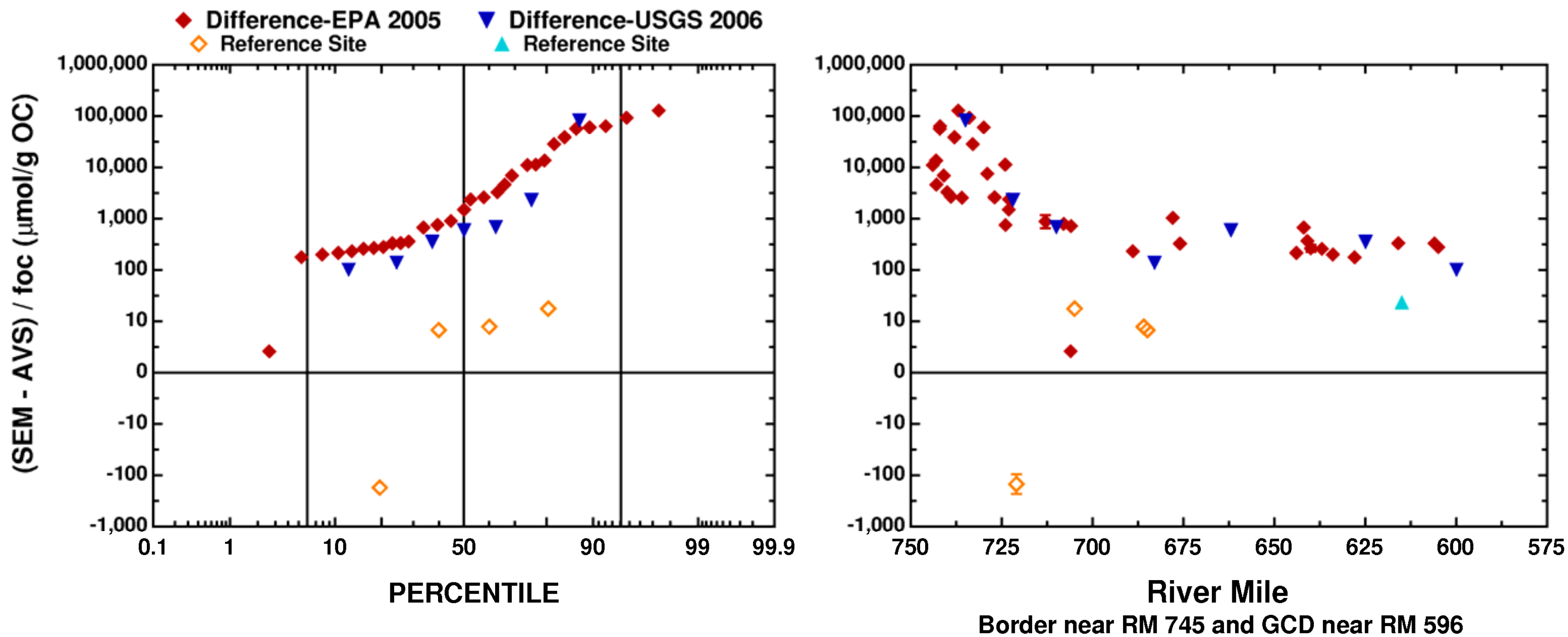


Figure 21. Comparison of 2004 and 2005 C-Normalized Excess SEM Data
Data Source: USEPA (2006) and Paulson et al. (2006).

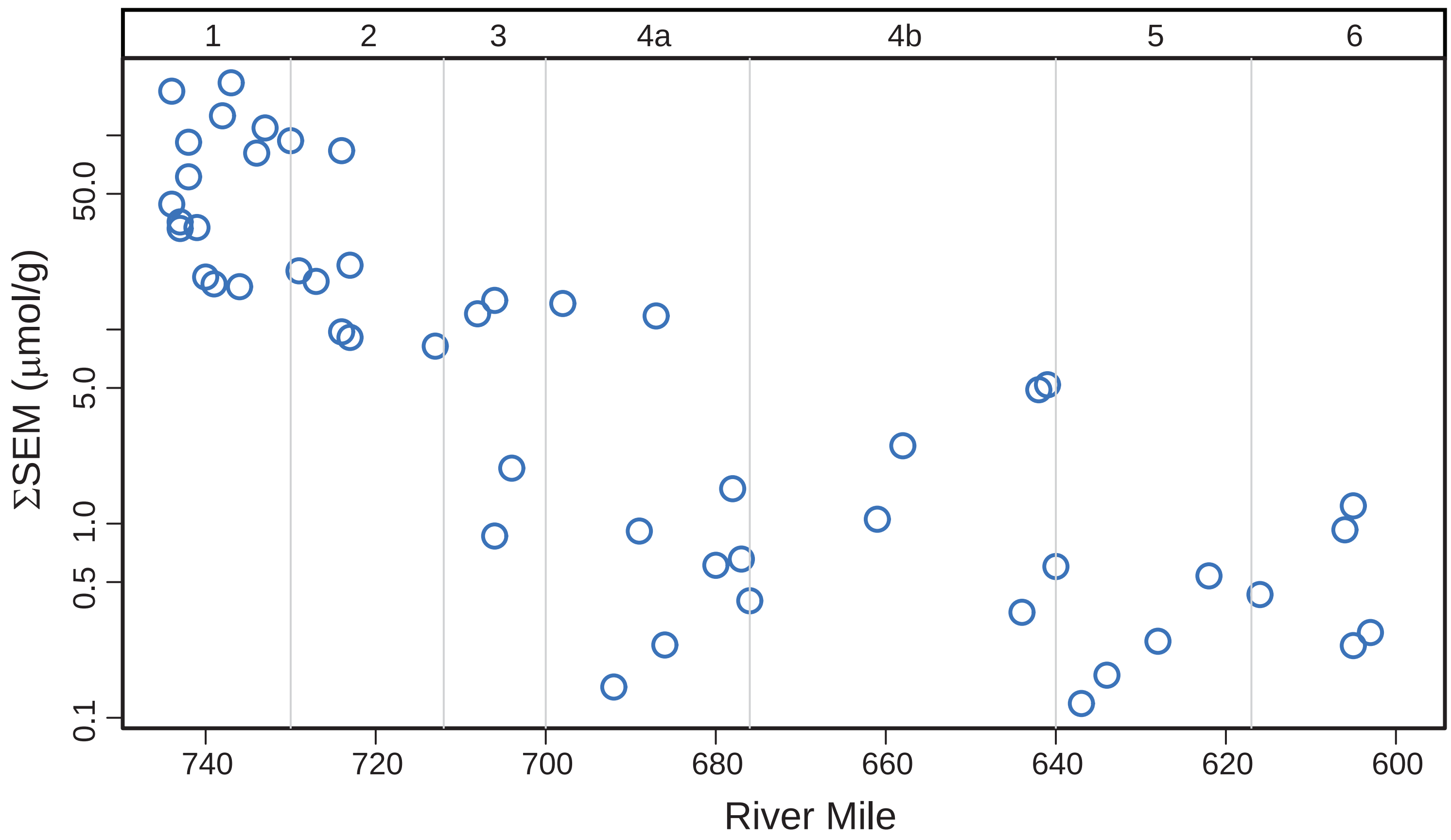


Figure 22. Longitudinal Distribution of ΣSEM Concentrations in Surface Sediments at Sediment Toxicity Stations in the 2005 UCR Study

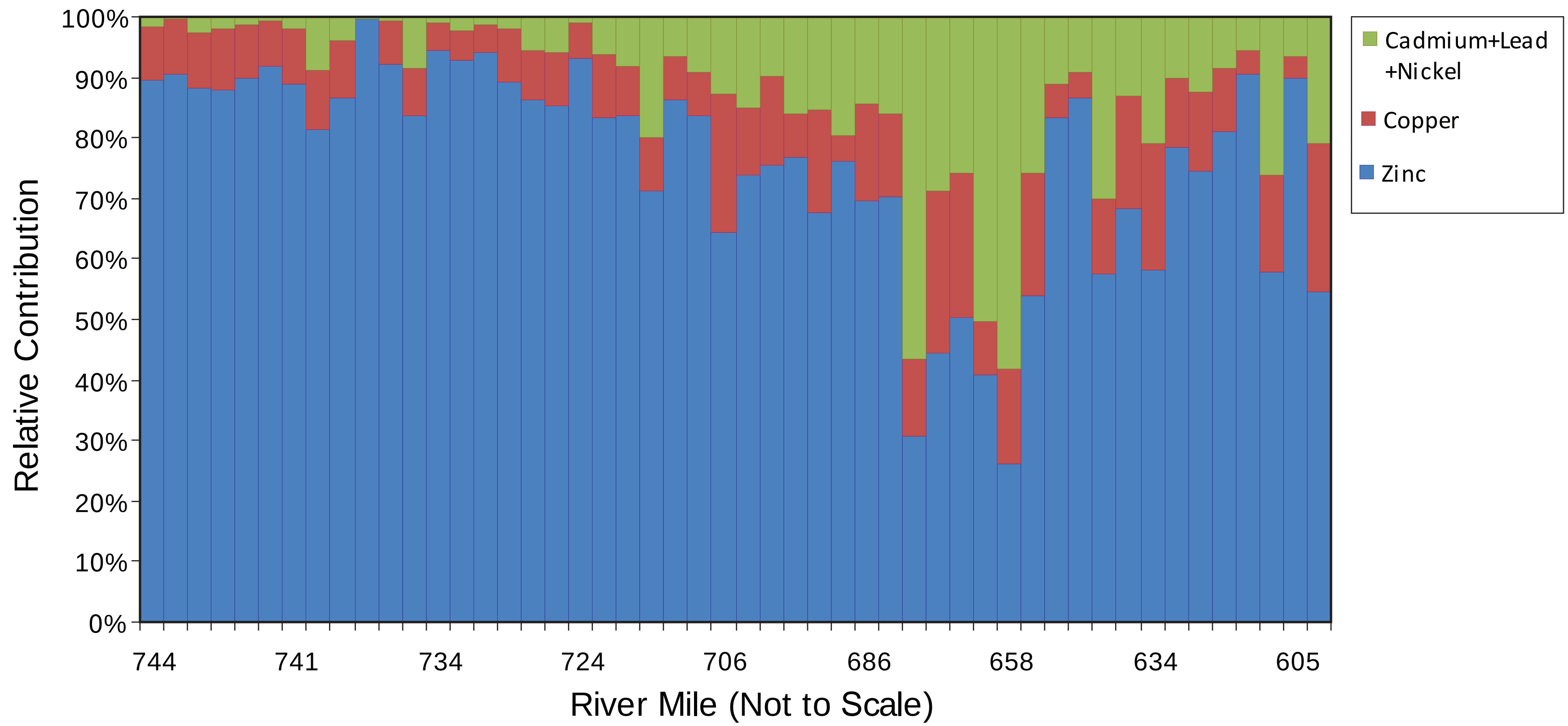
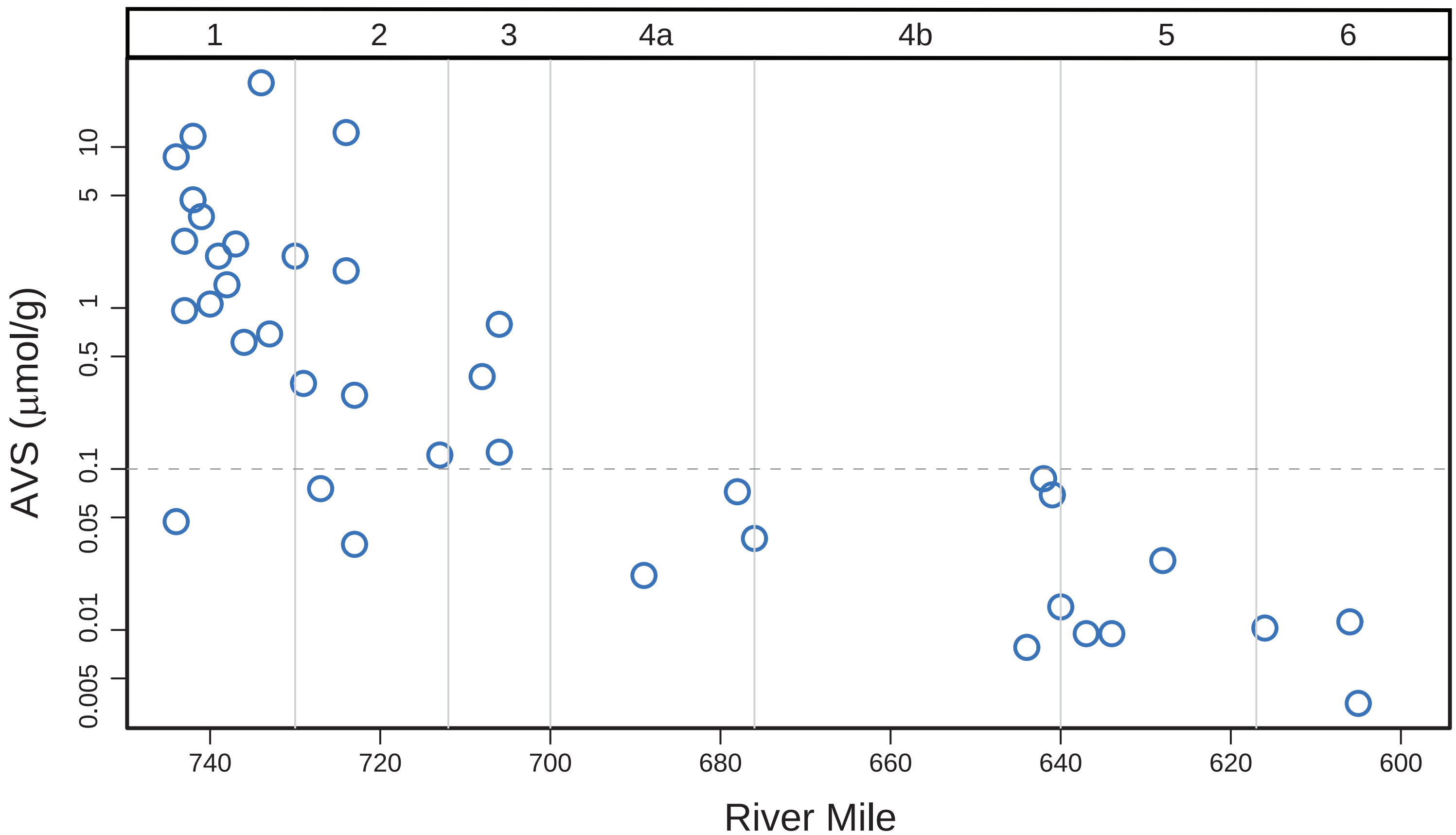


Figure 23. Longitudinal Distribution of Relative Contributions to ΣSEM by Individual Metals at Sediment Toxicity Stations in the 2005 UCR Study



Note: AVS and SEM methodologies apply only to AVS concentrations ≥ 0.1 µmol/g

Figure 24. Longitudinal Distribution of AVS Concentrations in Surface Sediments at Sediment Toxicity Stations in the 2005 UCR Study

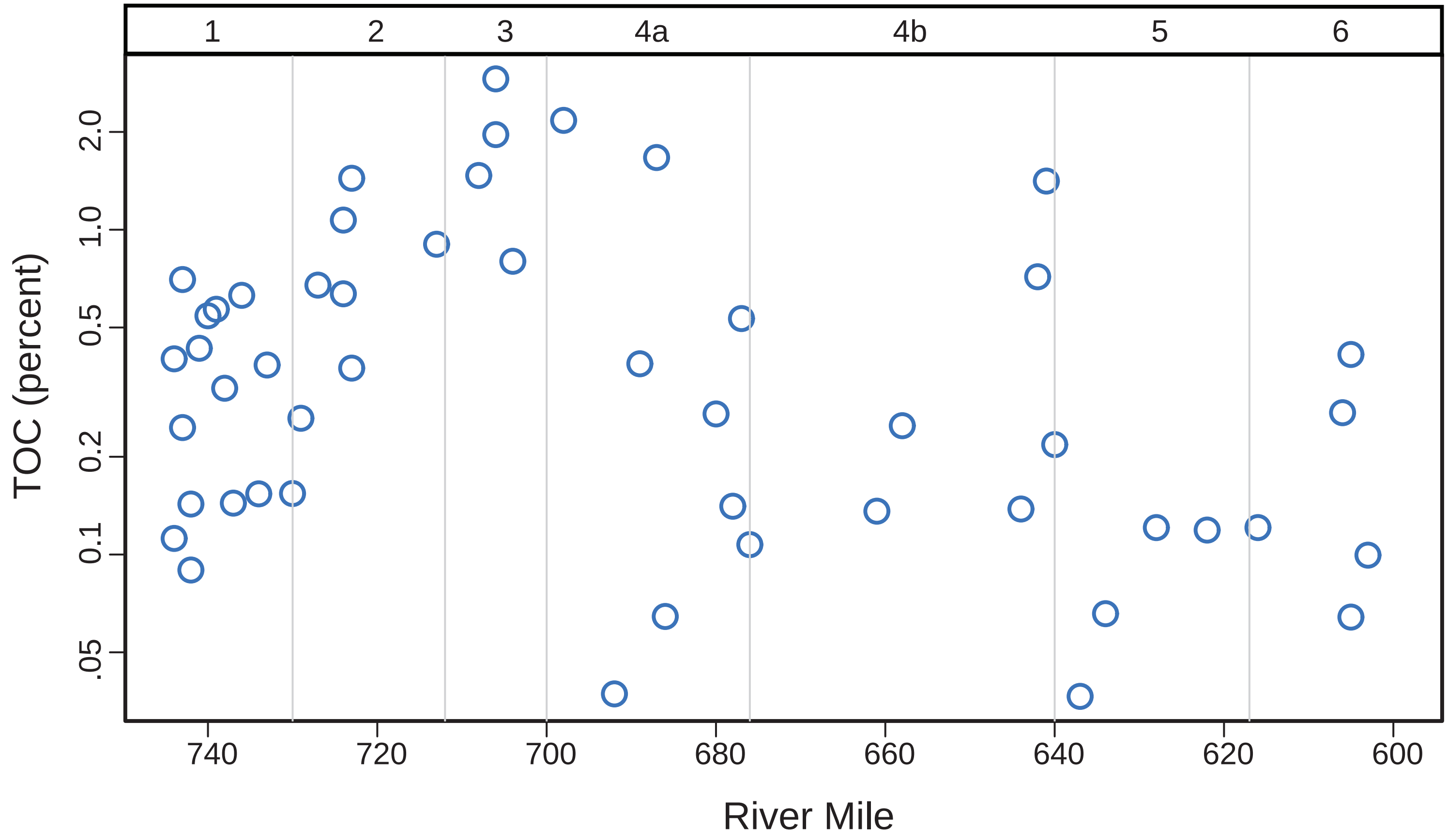


Figure 25. Longitudinal Distribution of TOC Concentrations in Surface Sediments at Sediment Toxicity Stations in the 2005 UCR Study

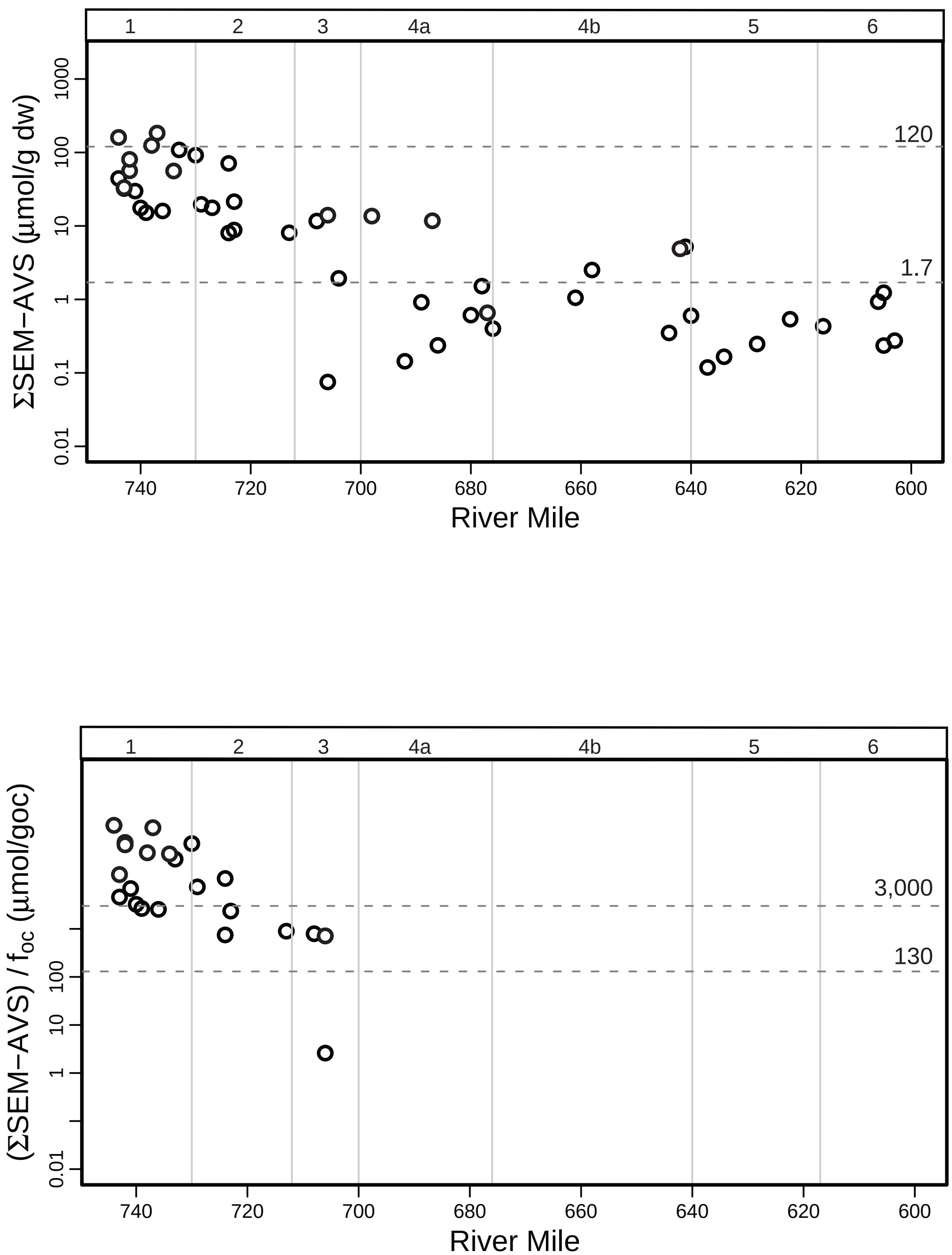


Figure 26. Comparison of ΣSEM-AVS and (ΣSEM-AVS)/foc Concentrations in Sediment for the 2005 UCR Study with USEPA (2006) Thresholds (dashed lines)

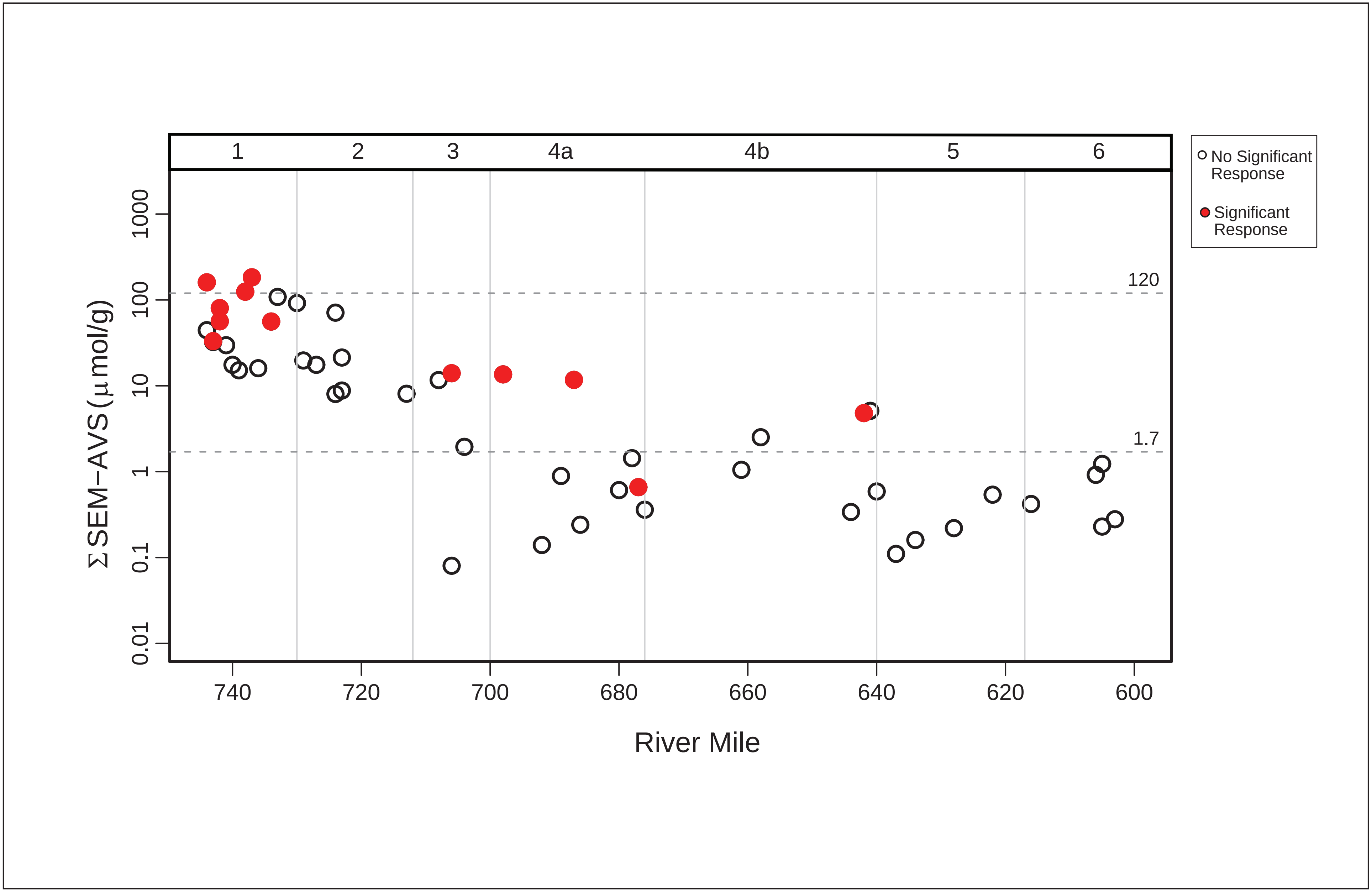


Figure 27. Comparison of Significant Biomass Responses for the Amphipod Test for the 2005 UCR Study with USEPA (2006) Thresholds for ΣSEM-AVS Concentrations (dashed lines)

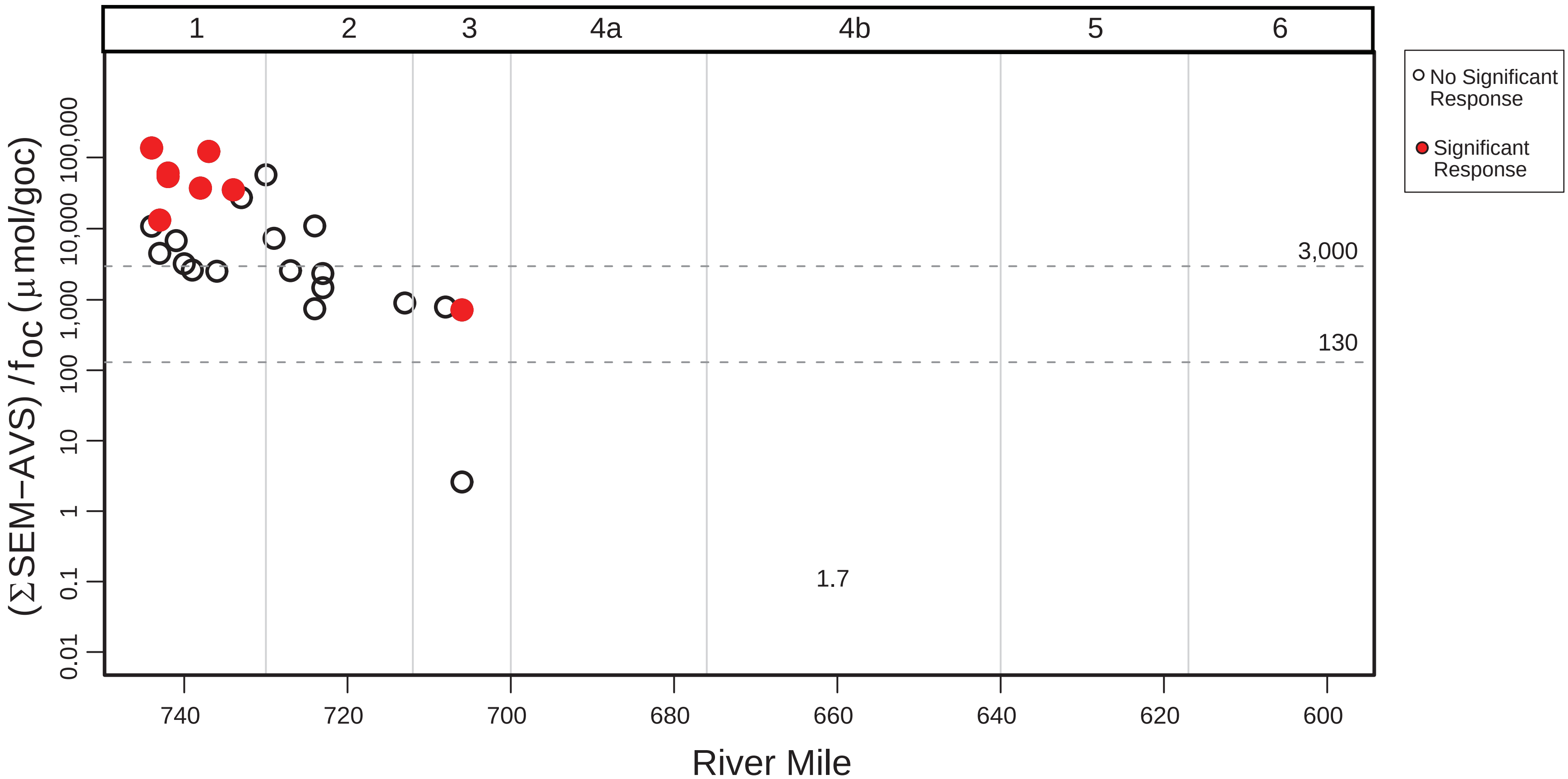


Figure 28. Comparison of Significant Biomass Responses for the Amphipod Test for the 2005 UCR Study with USEPA (2006) Thresholds for (ΣSEM-AVS)/foc Concentrations (dashed lines)

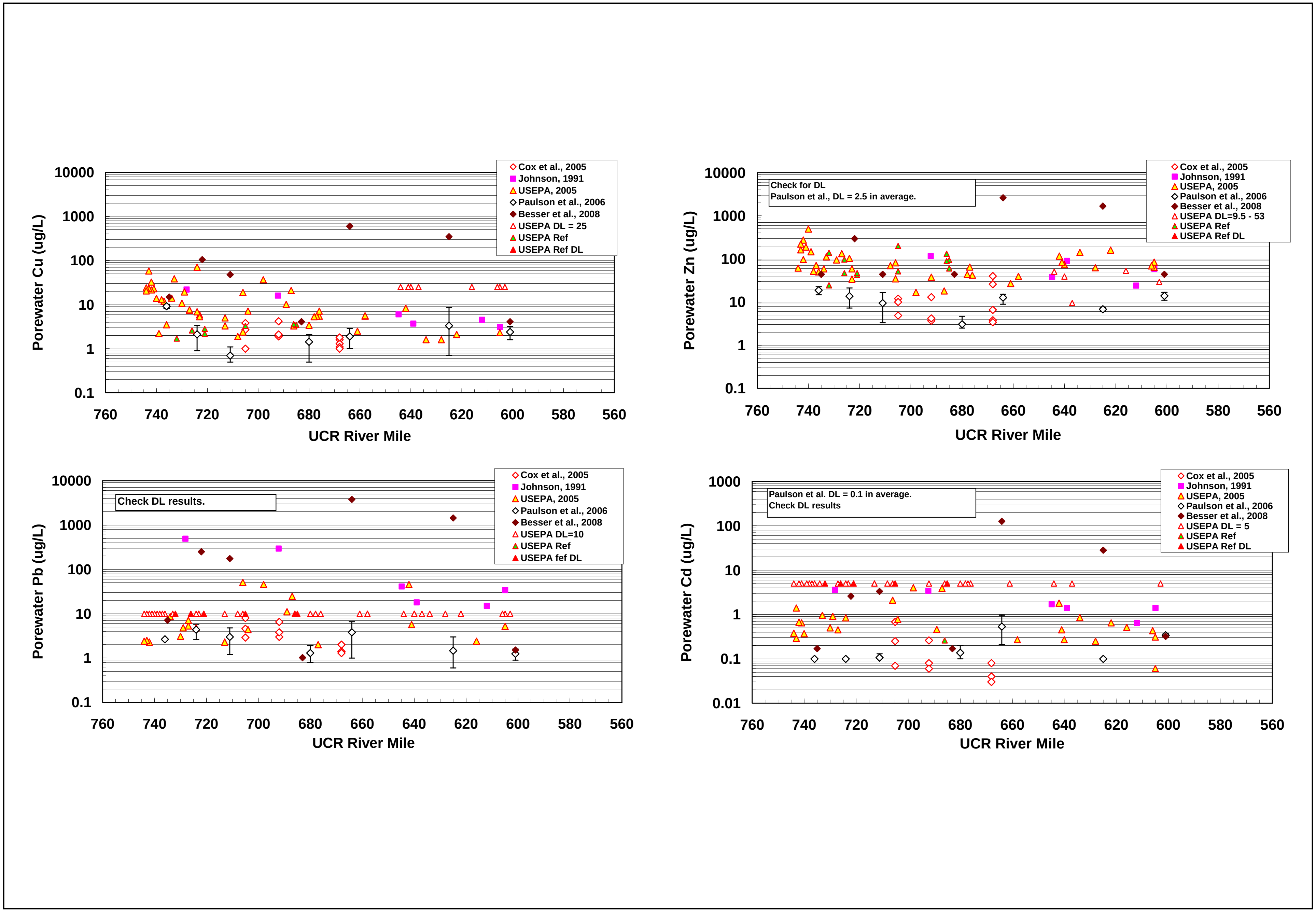


Figure 29. Comparison of Spatial Profiles of Porewater Cu, Cd, Pb and Zn in UCR Sediments

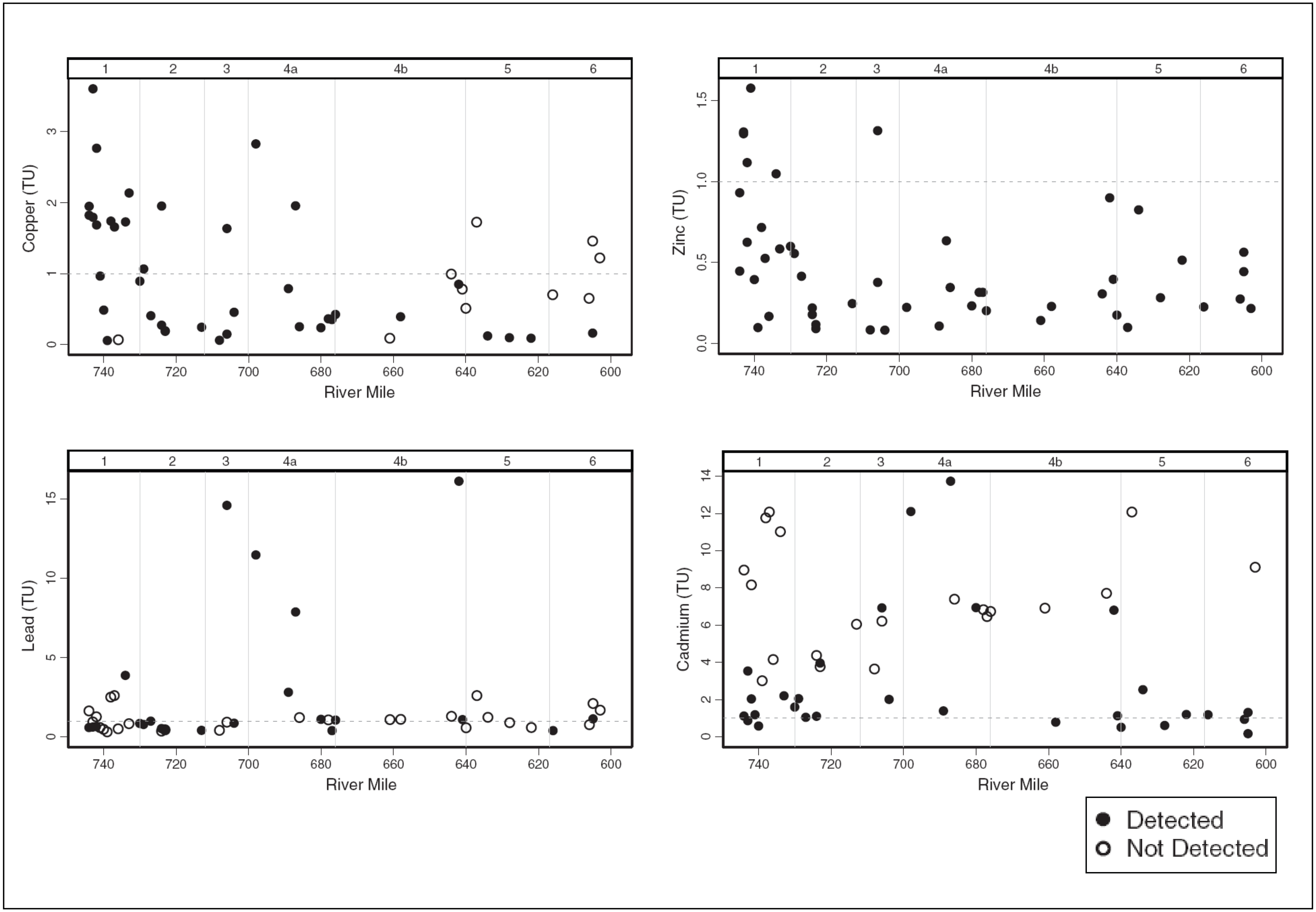


Figure 30. Porewater TU: Cu, Zn, Cd, and Pb
(based on total dissolved metal)

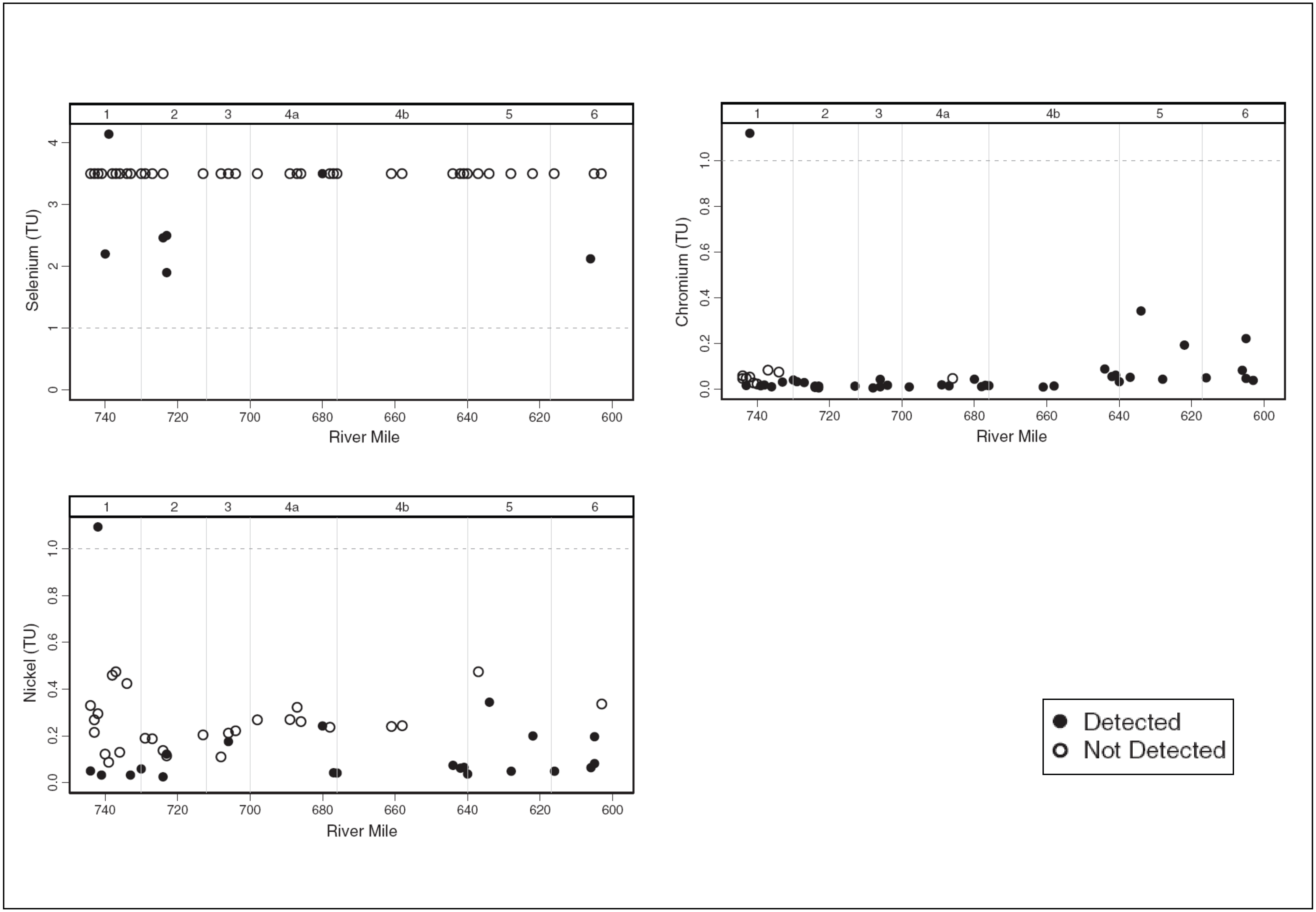


Figure 31. Porewater TU: Se, Cr, and Ni
(based on total dissolved metal)

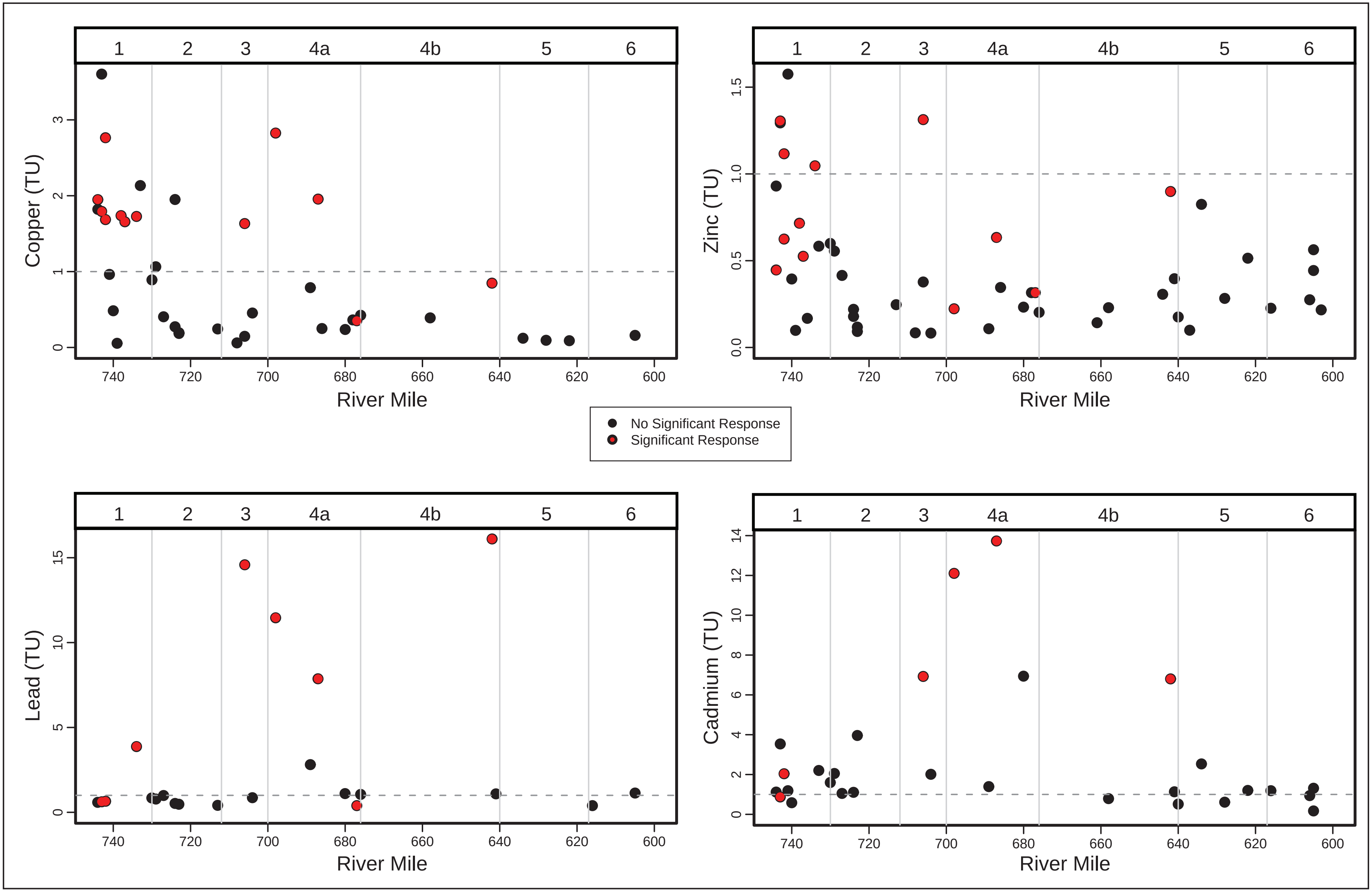


Figure 32. Comparisons of Significant Amphipod Biomass Toxicity Response with the TUs of Selected Metals in the 2005 UCR Study

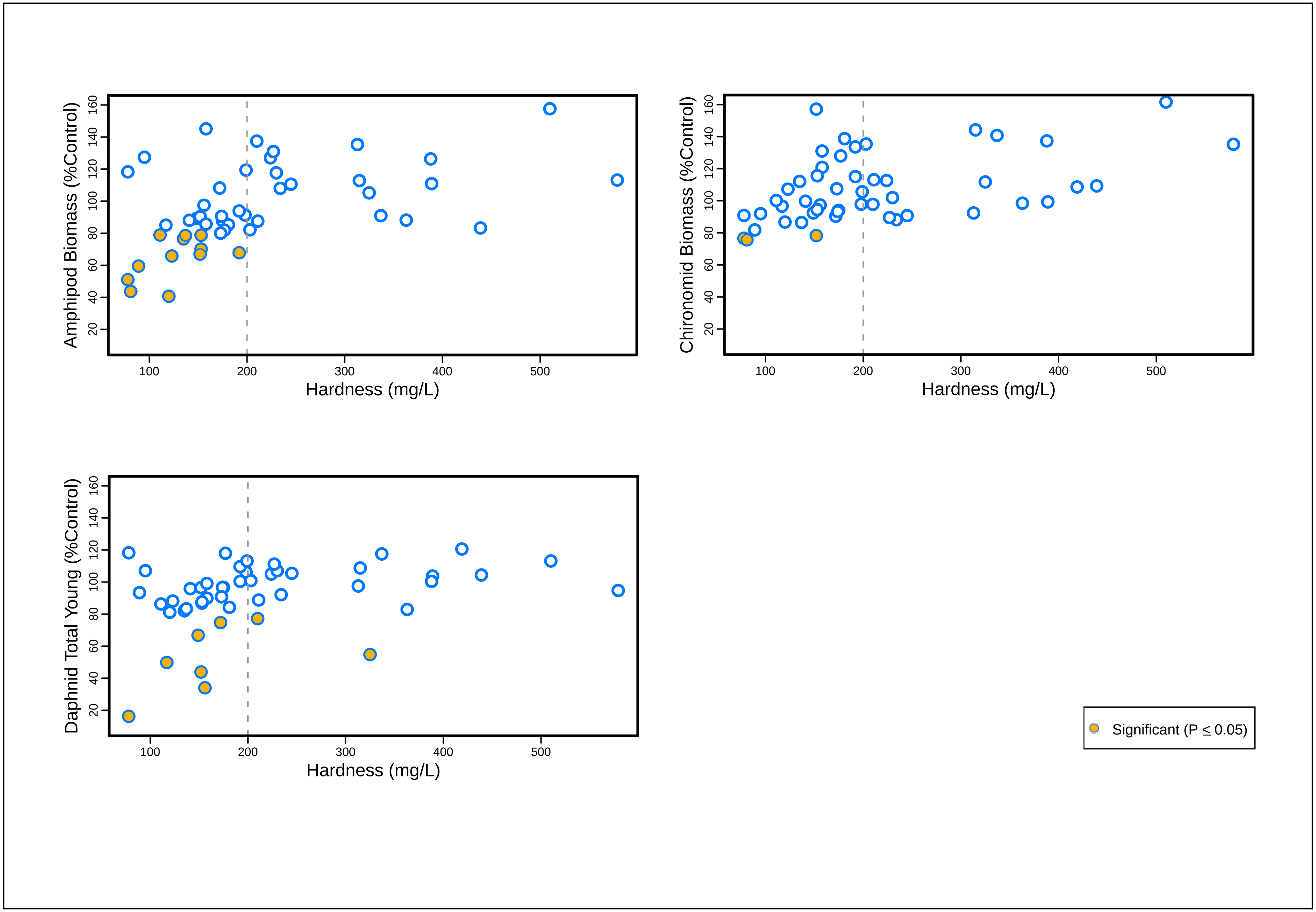


Figure 33. Comparisons of Amphipod and Chironomid Biomass Responses and Daphnid Reproduction to Porewater Hardness
Data Source: USEPA (2006).

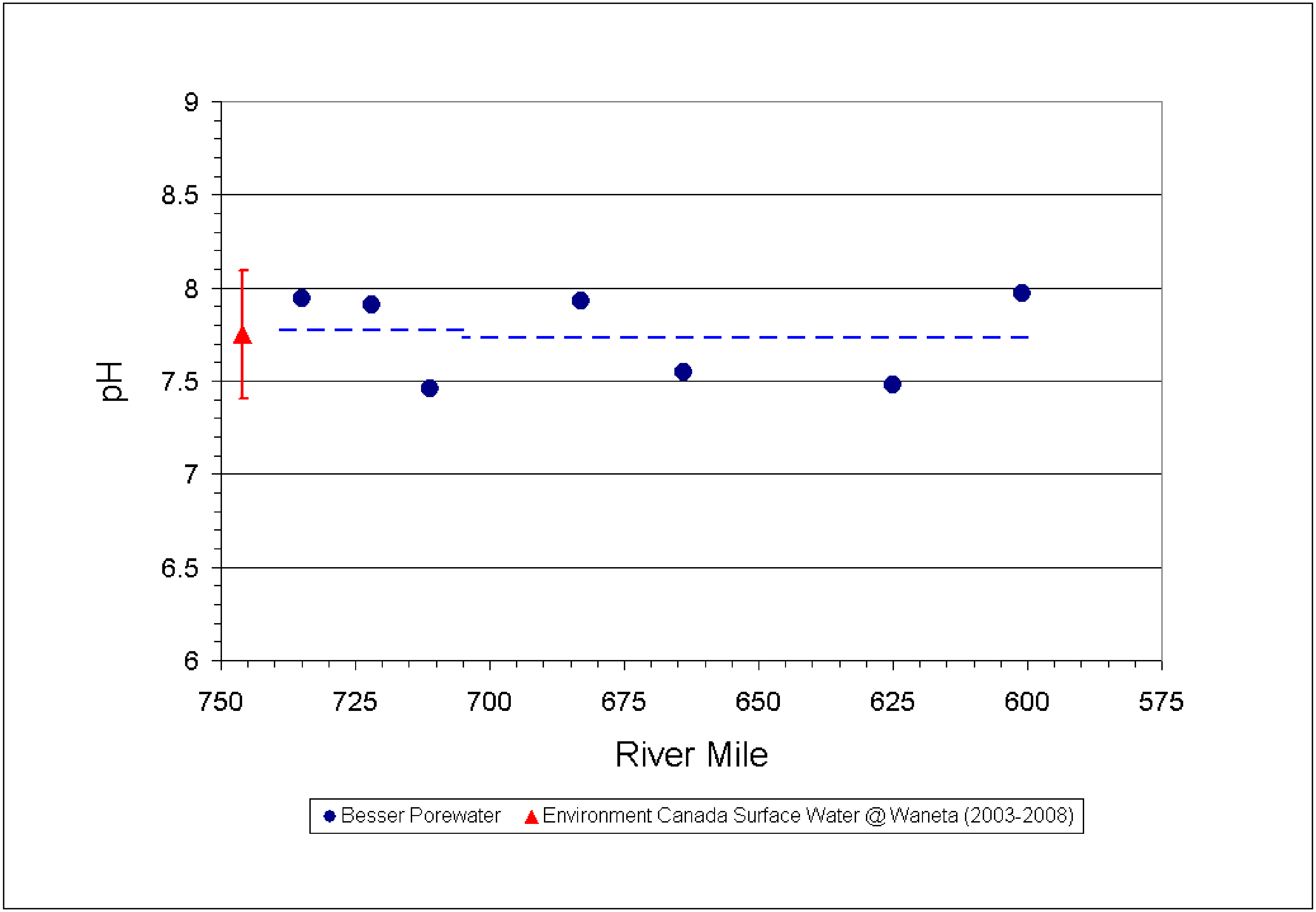


Figure 34. Measured porewater pH Values from Besser et al. (2008)
Note: pH values shown as filled circles, were used to estimate values throughout the UCR for use in BLM calculations with other data sets (dashed lines).

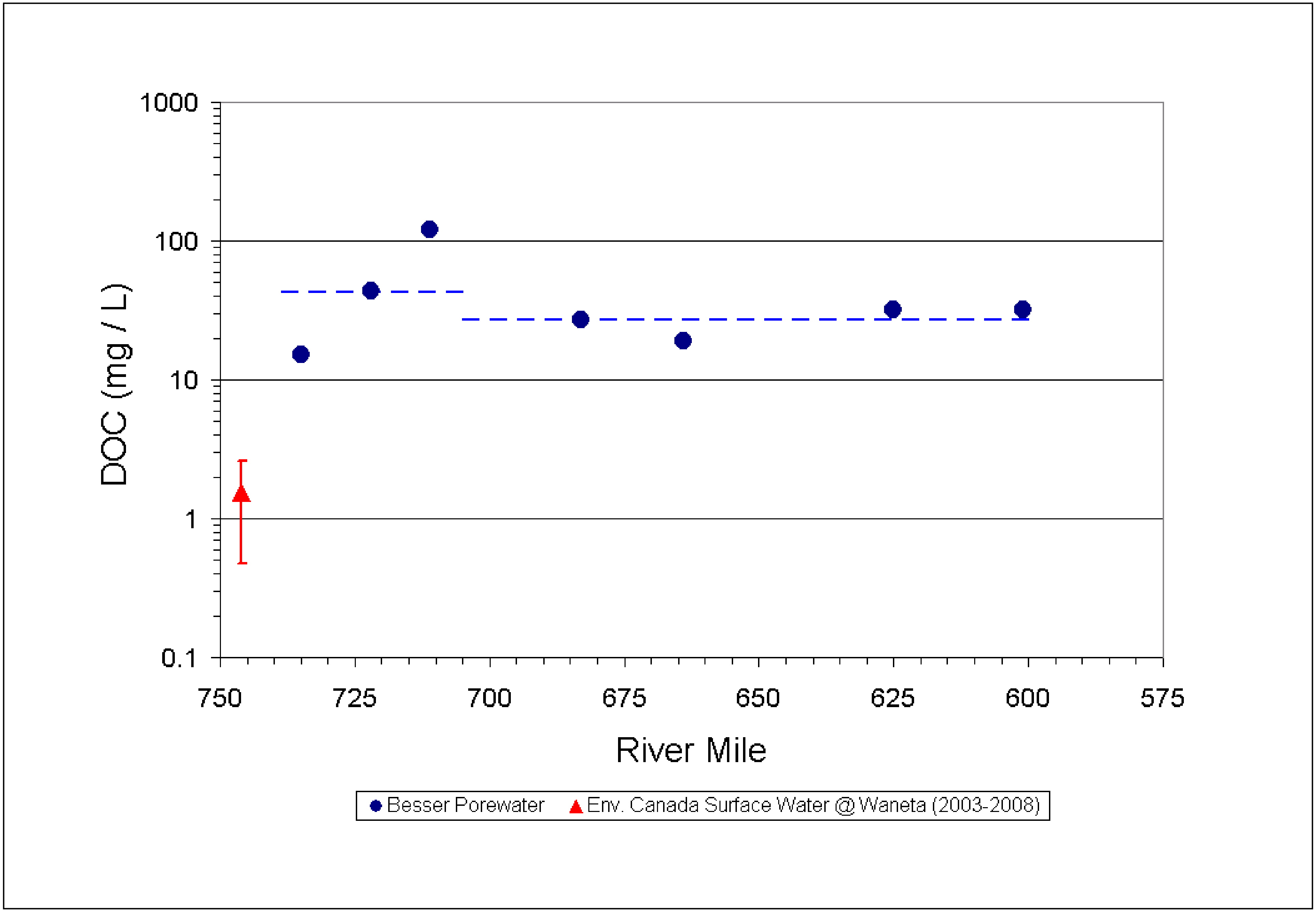


Figure 35. Measured porewater DOC Values from Besser et al. (2008)
Note: DOC values shown as filled circles, were used to estimate DOC values throughout the UCR for use in BLM calculations with other data sets (dashed lines).

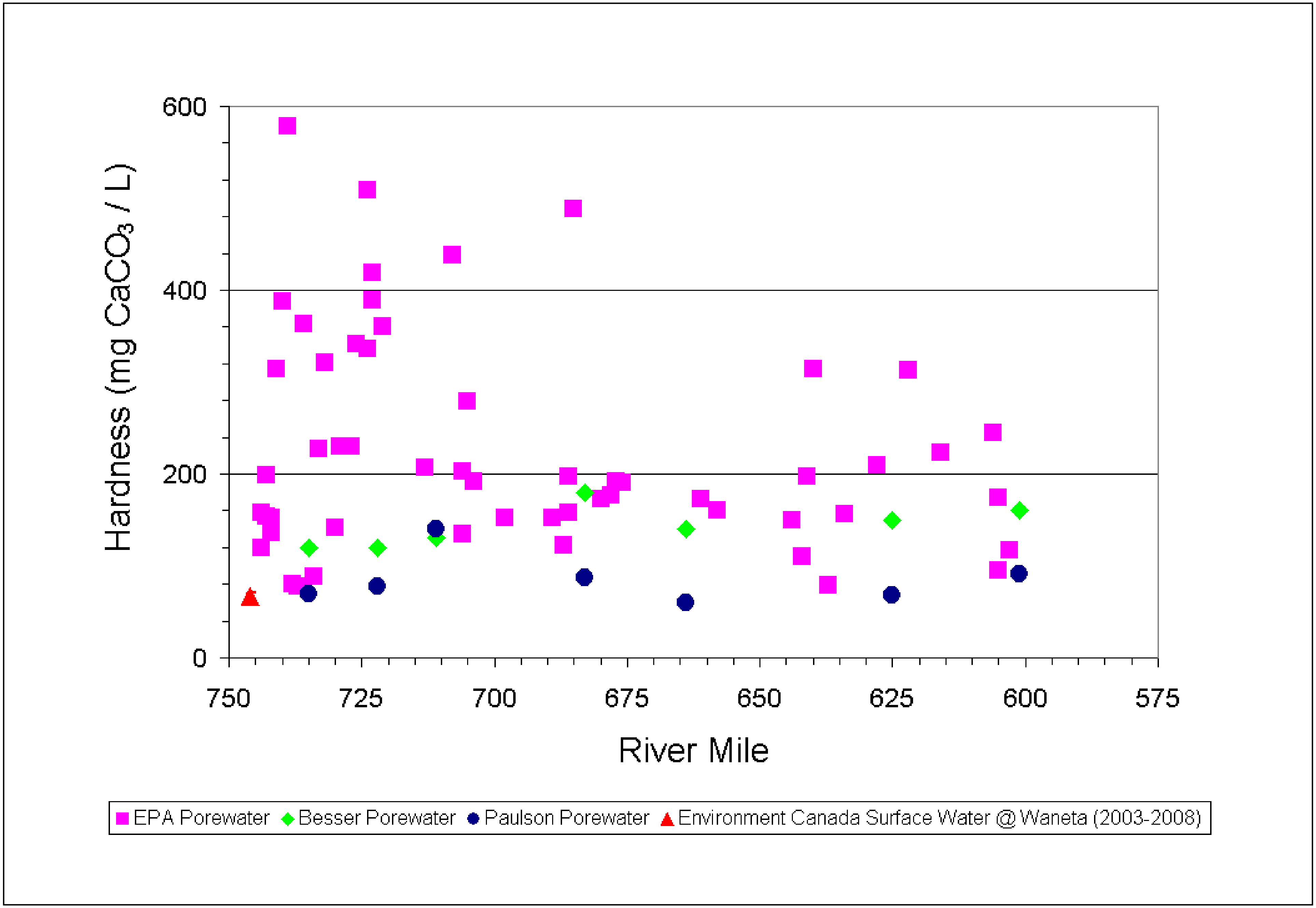


Figure 36. Measured Hardness Concentrations in Sediment Porewater from USEPA (2006), and Besser et al. (2008) in Sediment Samples Collected throughout the UCR

Note: The hardness values shown for the Paulson data set were summed from individual measured Ca and Mg concentrations (Paulson et al. 2006).

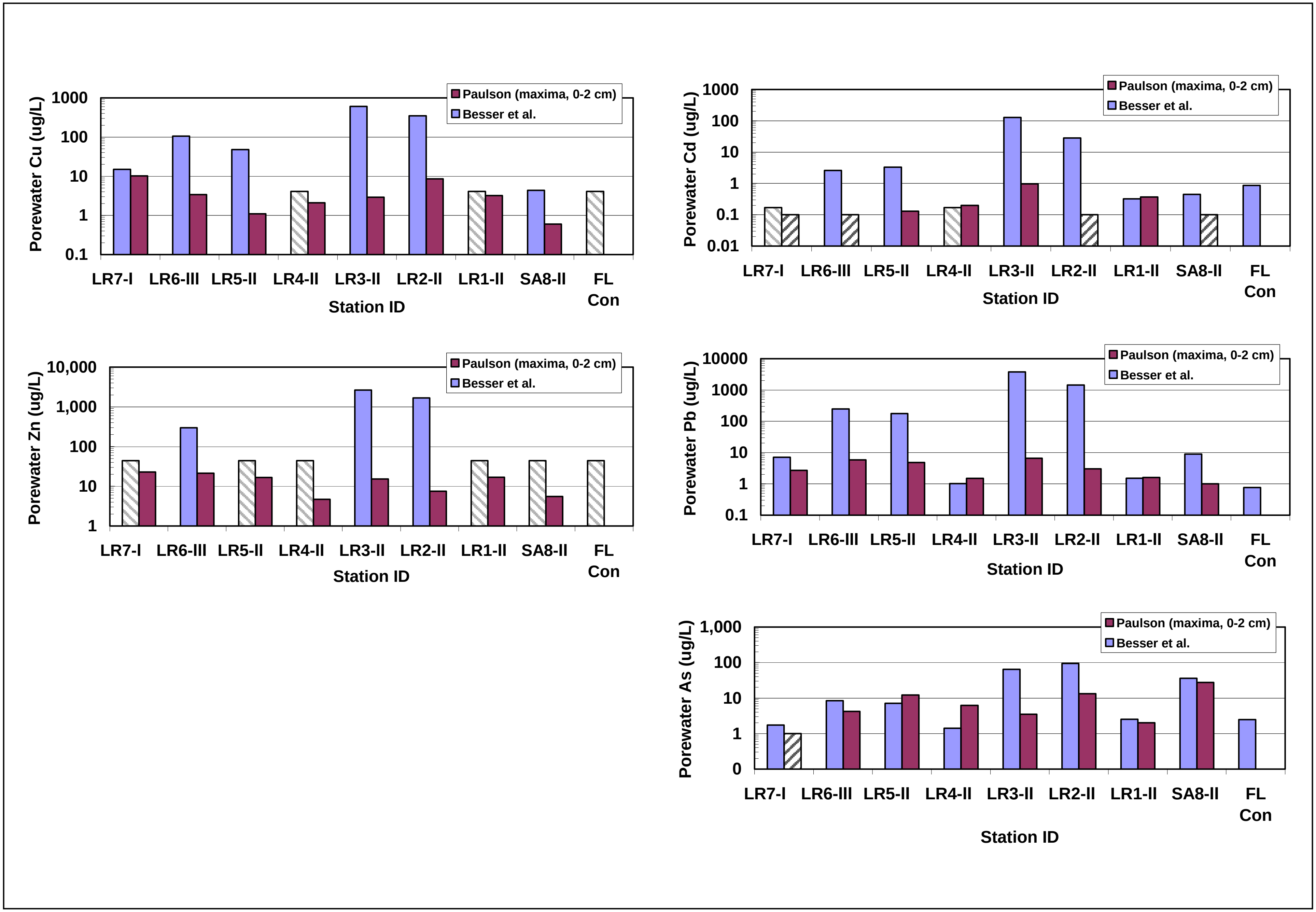


Figure 37. Measured Metal Concentrations in Sediment Porewater from Paulson et al. (2006), and Besser et al. (2008) in Sediment Samples Collected throughout the UCR

Note: Bars shown with a hatched pattern indicated values below detection limits and are plotted at the detection limit. Sample location is indicated by station name (1st three letters) followed by sediment classification type (either I, II, or III).

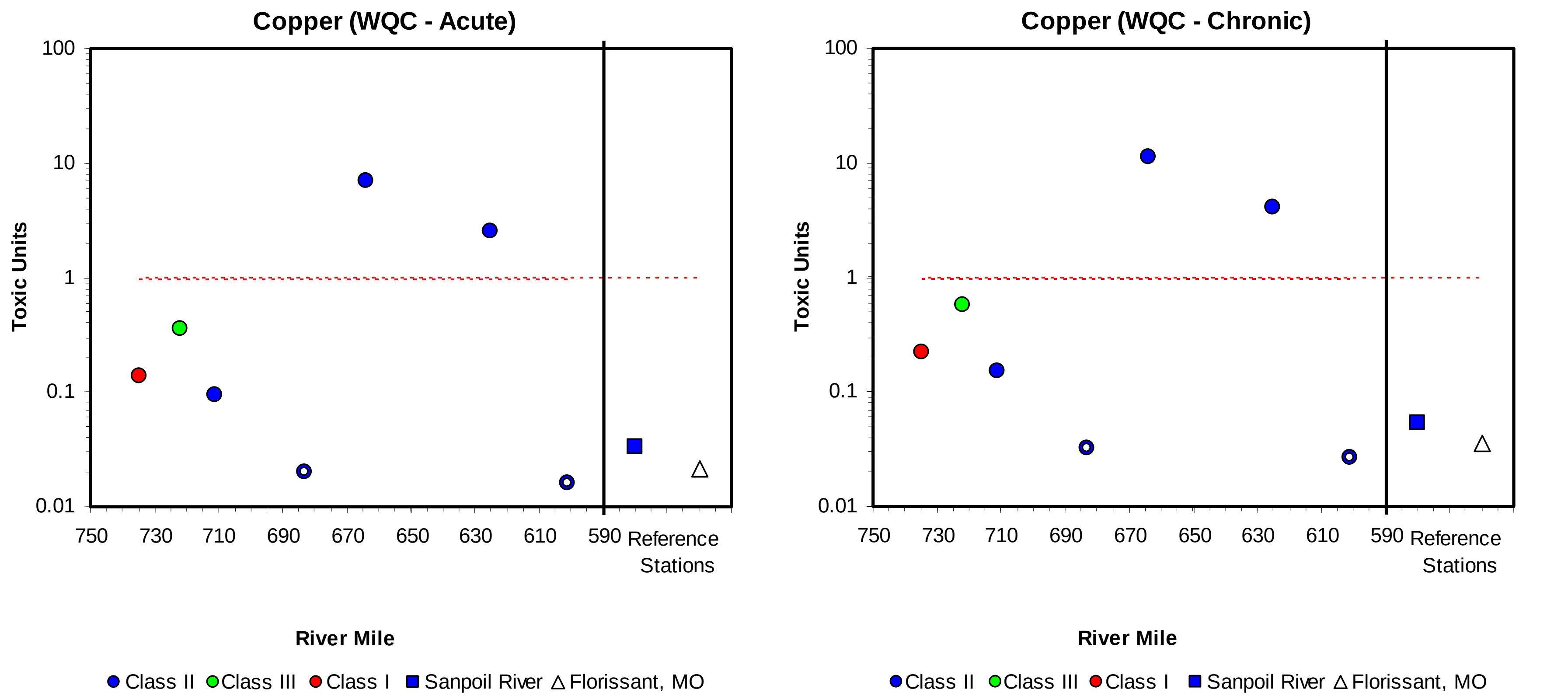


Figure 38. Acute and Chronic Toxic Units for Copper based on Preliminary BLM Calculations for Sediment Porewater Samples Characterized by Besser et al. (2008)

Note: Toxic units are defined as the ratio of BLM-predicted WQC to observed metal concentration. Values greater than 1 indicate that the metal exceeds regulatory guidelines. When metal concentrations were reported as below a detection limit, the TU was calculated using the detection limit value, and these cases are indicated using un-filled symbols.

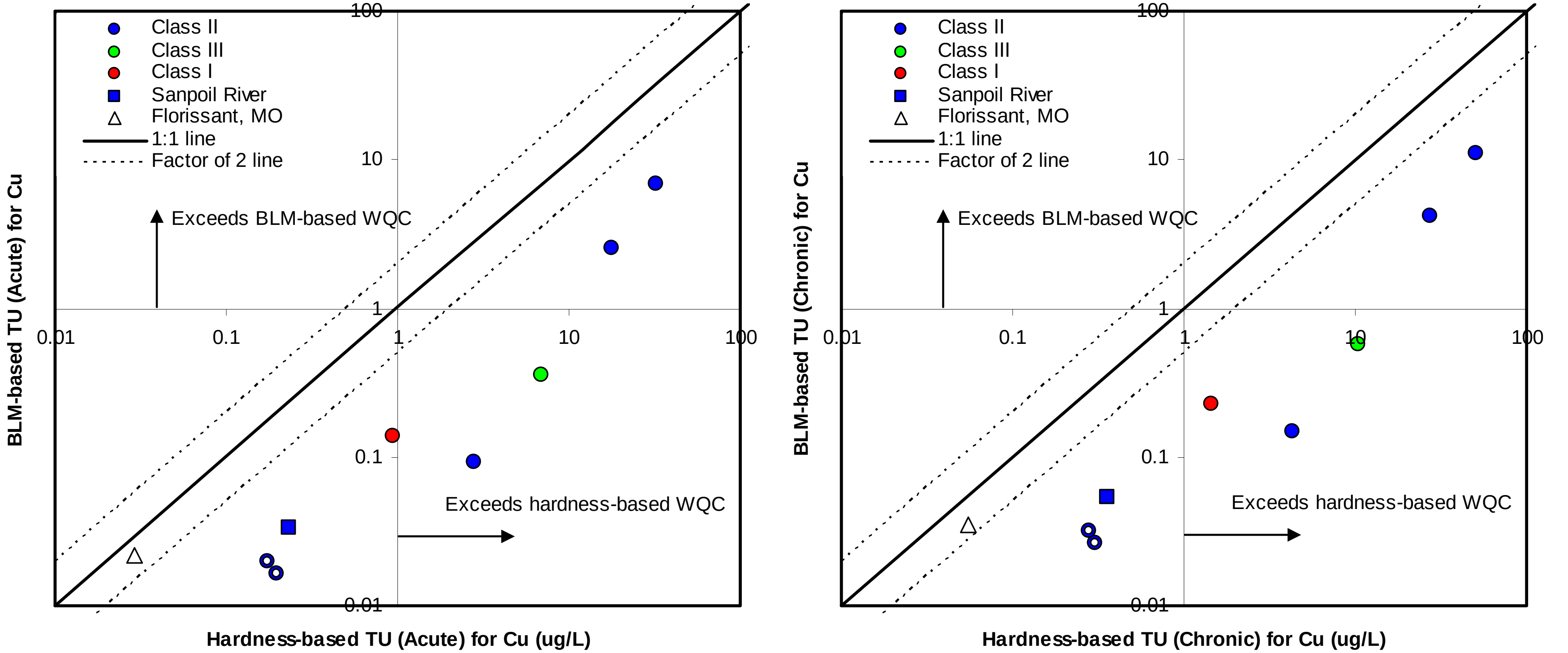


Figure 39. Comparison of Acute and Chronic Toxic Units for Copper using Chemical Characterization of Sediment Porewater Reported by Besser et al. (2008) as Determined by the Preliminary BLM (vertical axis) with that Determined by the Hardness Equation (horizontal axis)

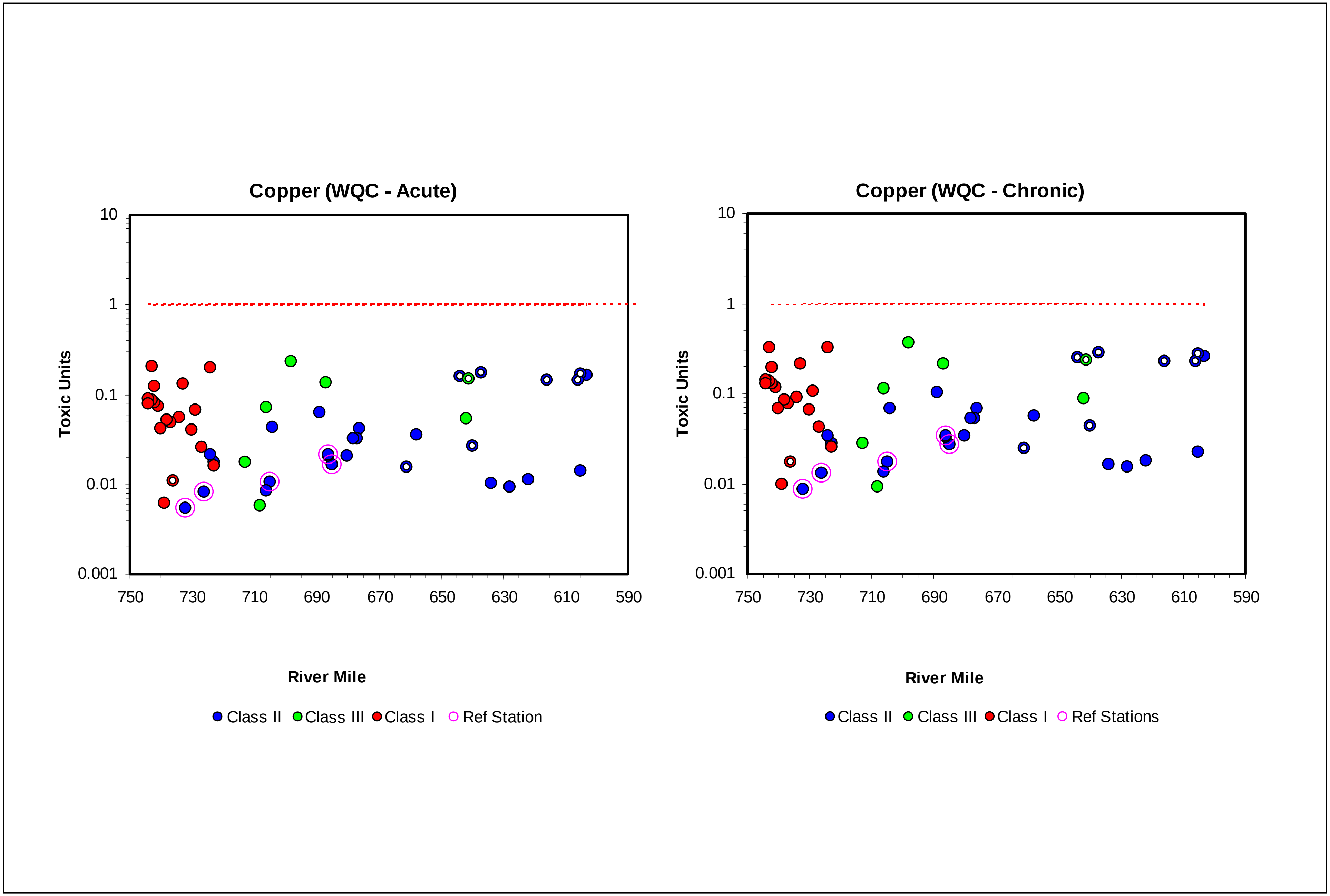


Figure 40. Acute and Chronic Toxic Units for Copper based on Preliminary BLM Calculations for Sediment Porewater Samples Characterized by USEPA (2006)

Note: Toxic units are defined as the ratio of BLM-predicted WQC to observed metal concentration. Values greater than 1 indicate that the metal exceeds regulatory guidelines. When metal concentrations were reported as below a detection limit, the TU was calculated using the detection limit value, and these cases are indicated using un-filled symbols.

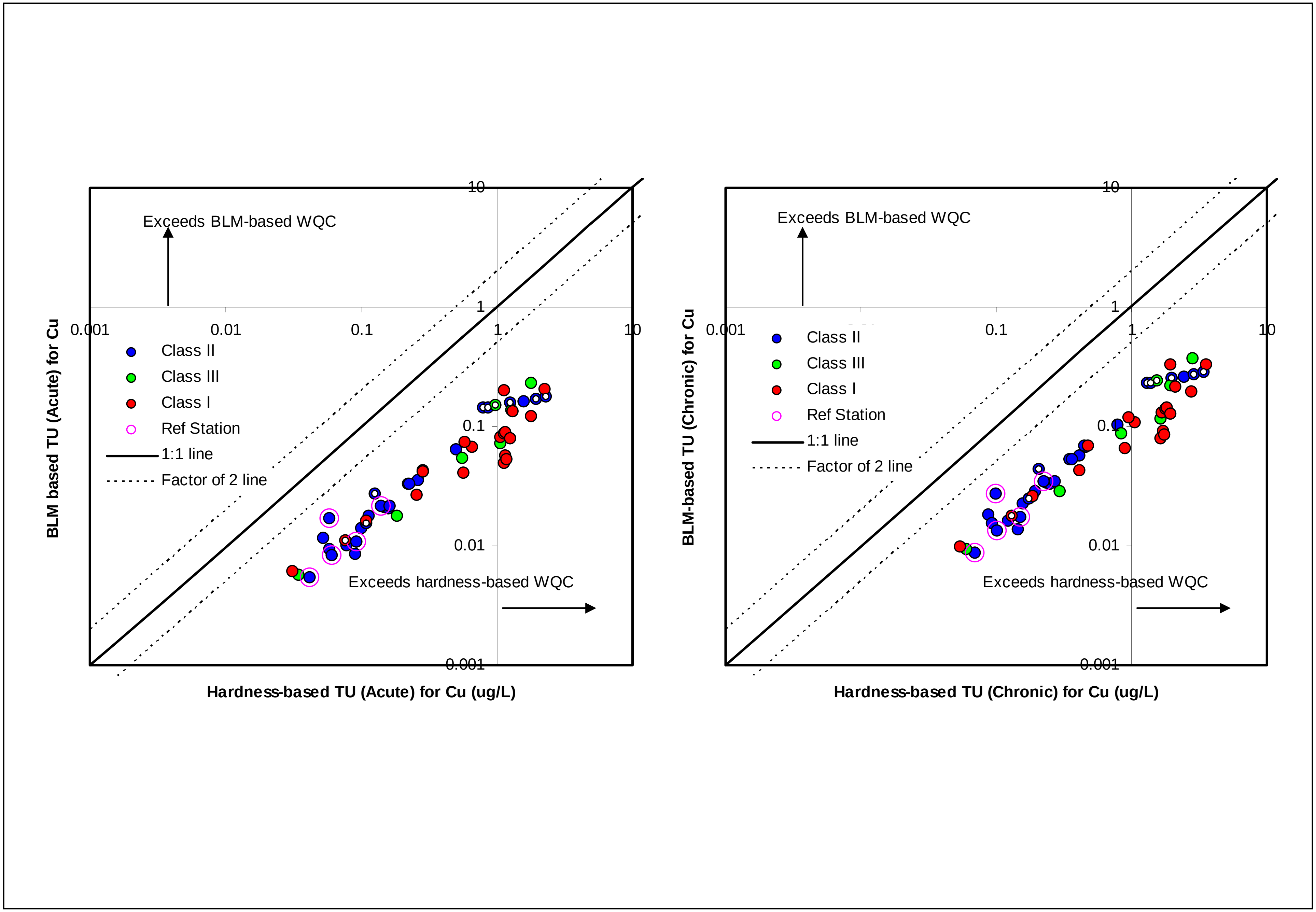


Figure 41. Comparison of Acute and Chronic Toxic Units for Copper using Chemical Characterization of Sediment Porewater Reported by USEPA (2006) as Determined by the Preliminary BLM (vertical axis) with that Determined by the Hardness Equation (horizontal axis)

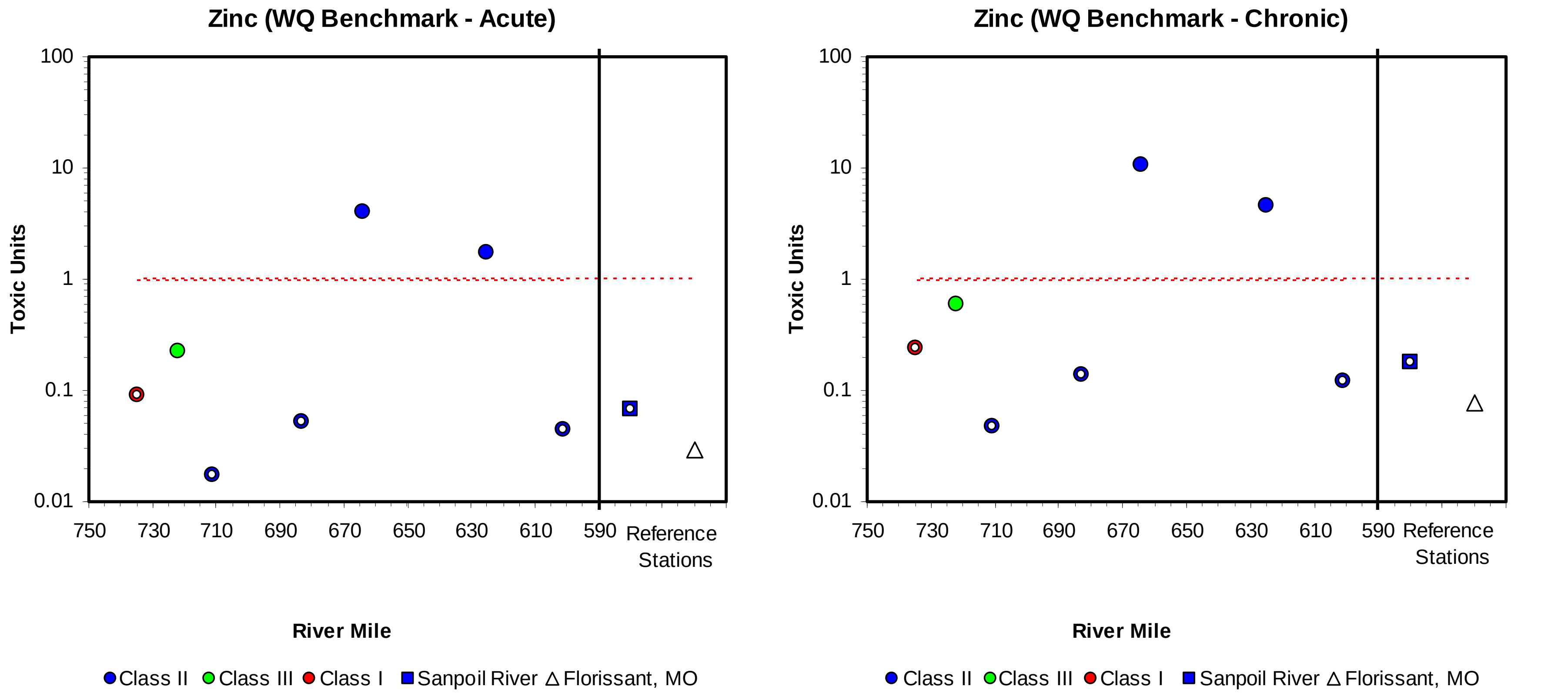


Figure 42. Acute and Chronic Toxic Units for Zinc based on Preliminary BLM Calculations for Sediment Porewater Samples Characterized by Besser et al. (2008)
Note: Toxic units are defined as the ratio of BLM predicted WQC to observed metal concentration. Values greater than 1 indicate that the metal concentrations are expected to exceed regulatory guidelines. When metal concentrations were reported as below a detection limit, the TU was calculated using the detection limit value, and these cases are indicated using un-filled symbols.

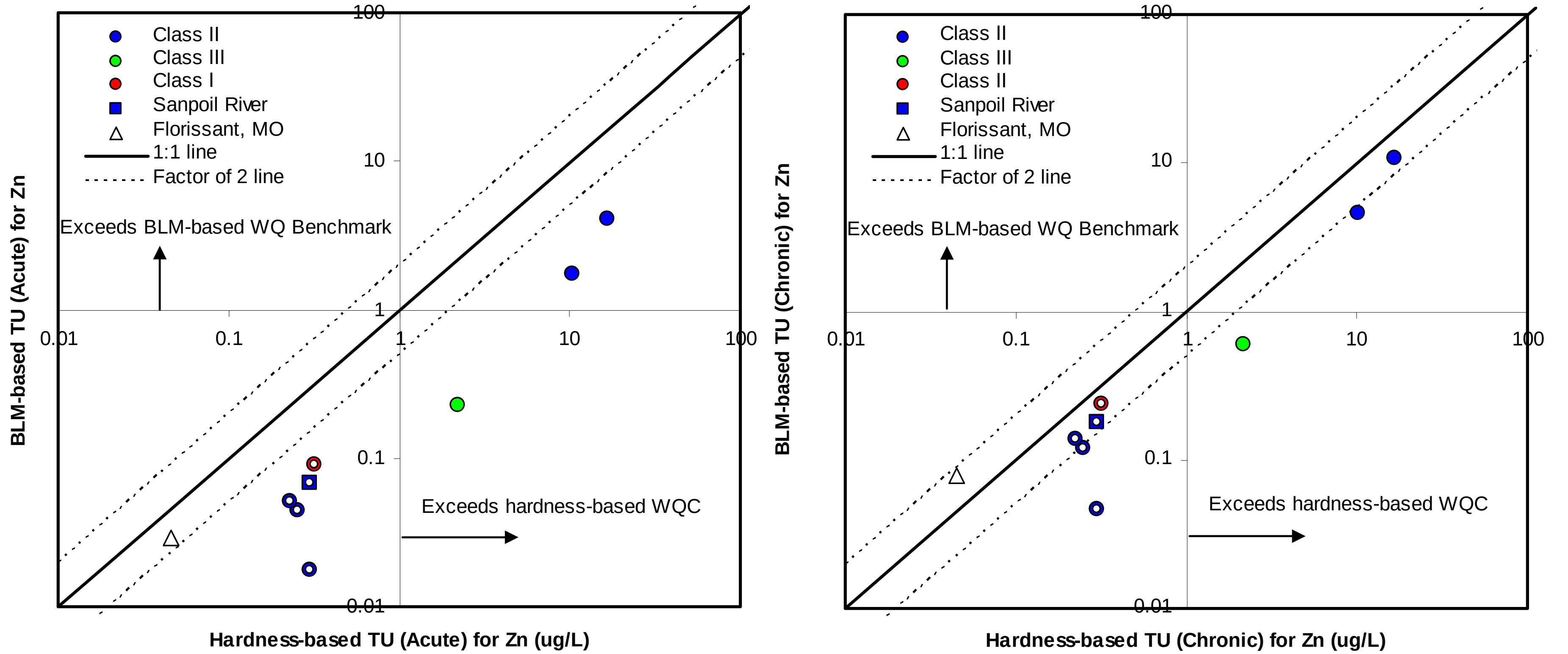


Figure 43. Comparison of Acute and Chronic Toxic Units for Zinc as Determined by the Preliminary BLM (vertical axis) with that Determined by the Hardness Equation (horizontal axis)

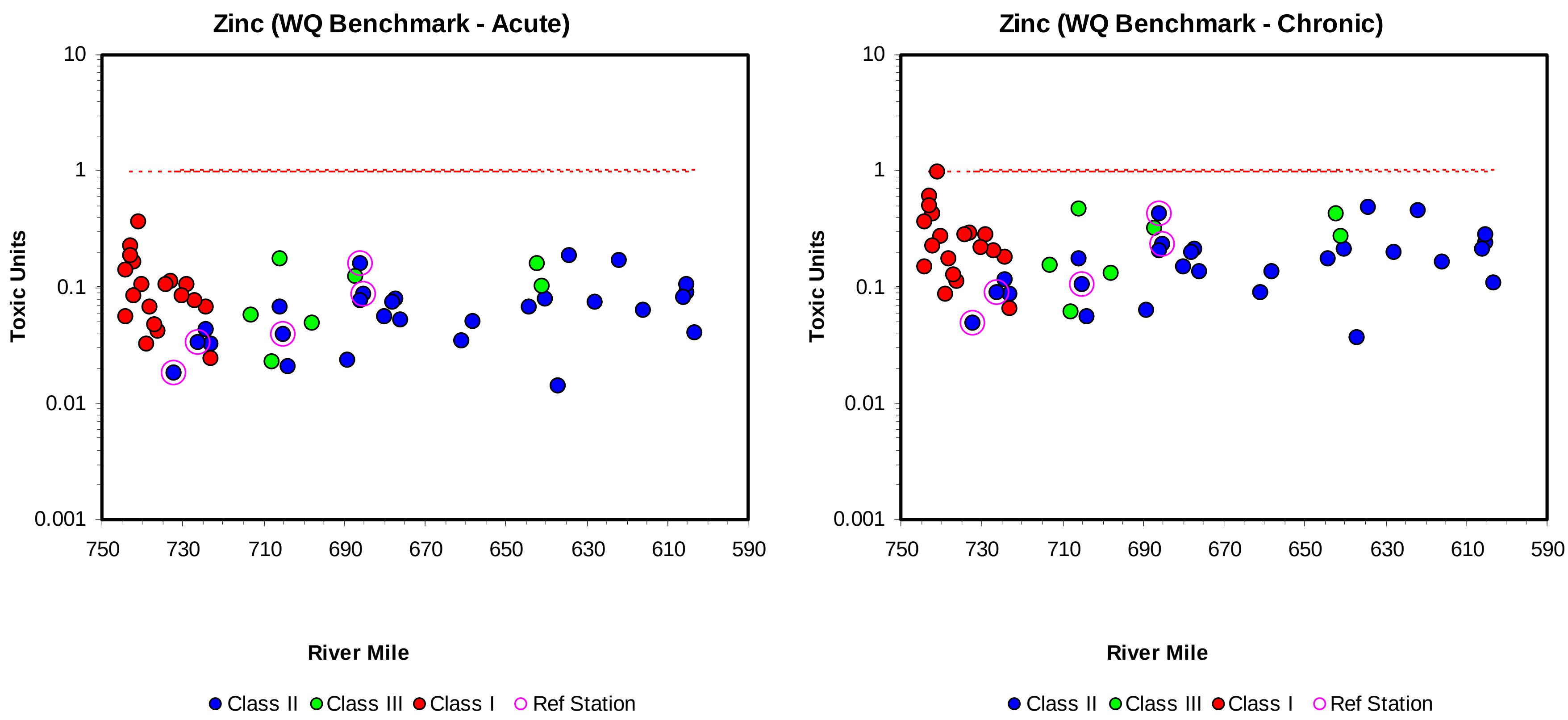


Figure 44. Acute and Chronic Toxic Units for Zinc based on Preliminary BLM Calculations for Sediment Porewater Samples Characterized by USEPA (2006)
Note: Toxic units are defined as the ratio of BLM predicted WQC to observed metal concentration. Values greater than 1 indicate that the metal concentrations are expected to exceed regulatory guidelines. When metal concentrations were reported as below a detection limit, the TU was calculated using the detection limit value, and these cases are indicated using un-filled symbols.

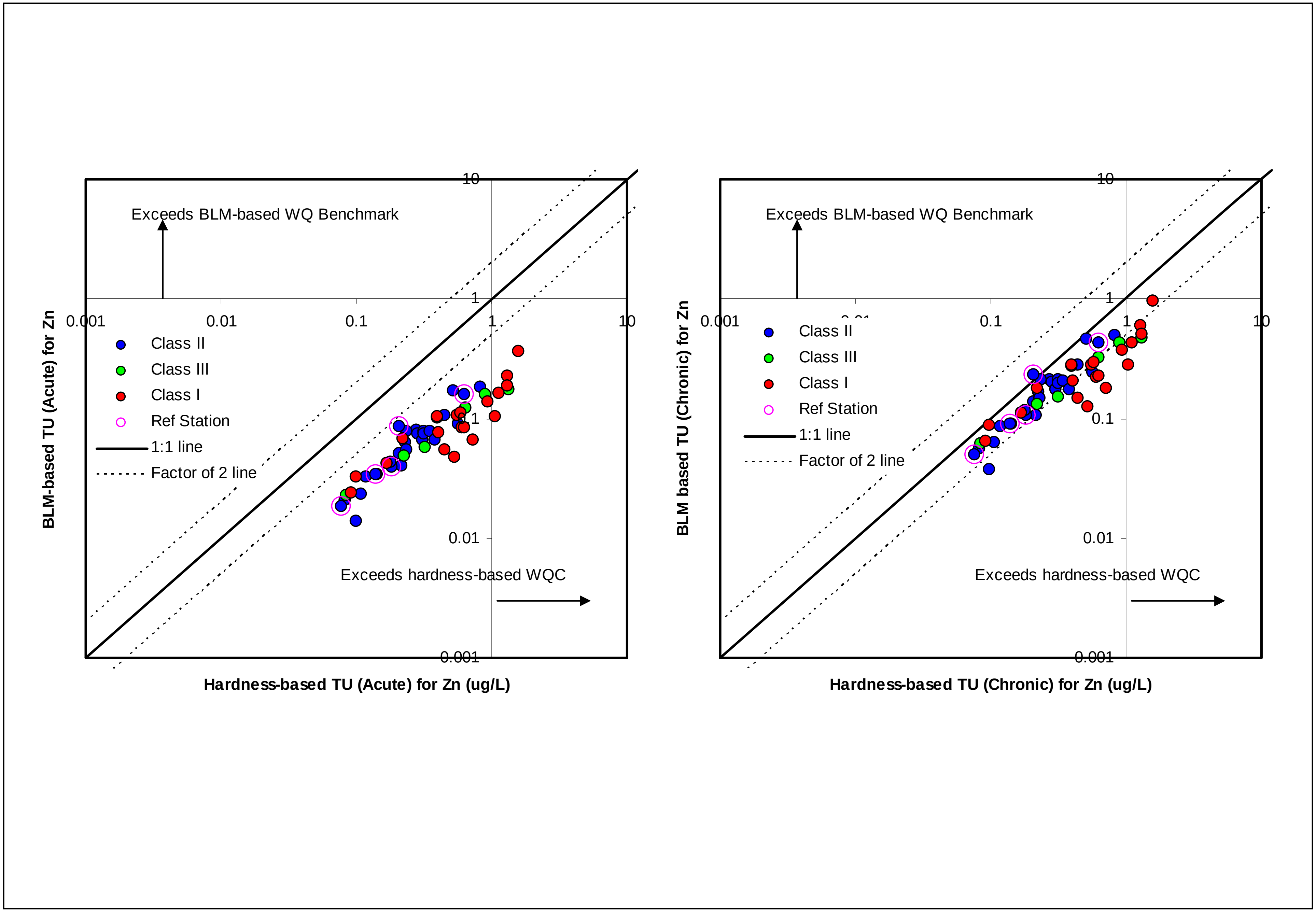


Figure 45. Comparison of Acute and Chronic Toxic Units for Zinc using Chemical Characterization of Sediment Porewater Reported by USEPA (2006) as Determined by the Preliminary BLM (vertical axis) with that Determined by the Hardness Equation (horizontal axis)

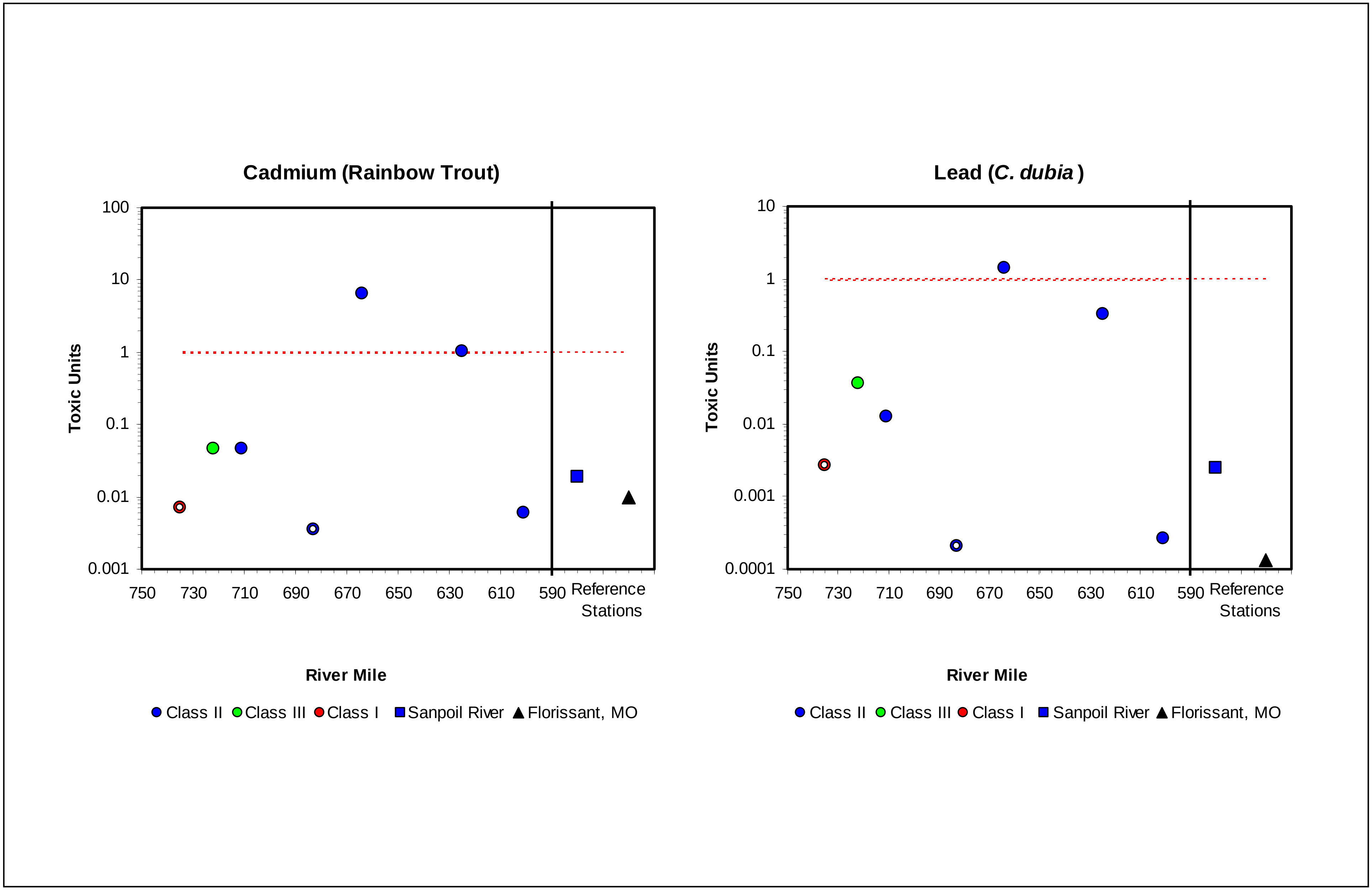


Figure 46. Acute Toxic Units for Cadmium and Lead based on Preliminary BLM Calculations for Sediment Porewater Samples Characterized by Besser et al. (2008)
Note: Toxic units are defined as the ratio of BLM-predicted acute LC50 to observed metal concentration. Values greater than 1 indicate that toxicity would be expected from the metal to sensitive organisms. When metal concentrations were reported as below a detection limit, the TU was calculated using the detection limit value, and these cases are indicated using un-filled symbols.

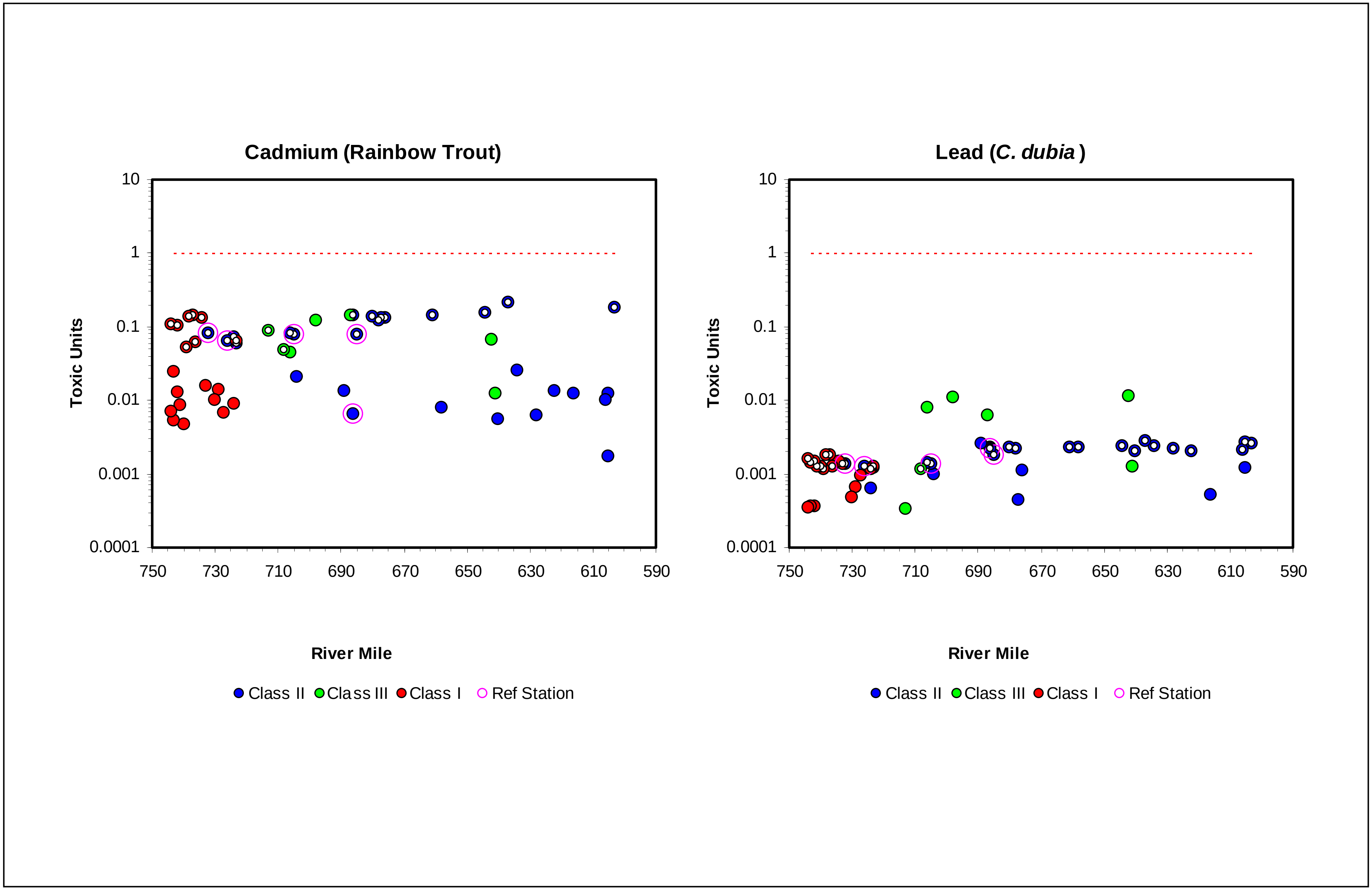
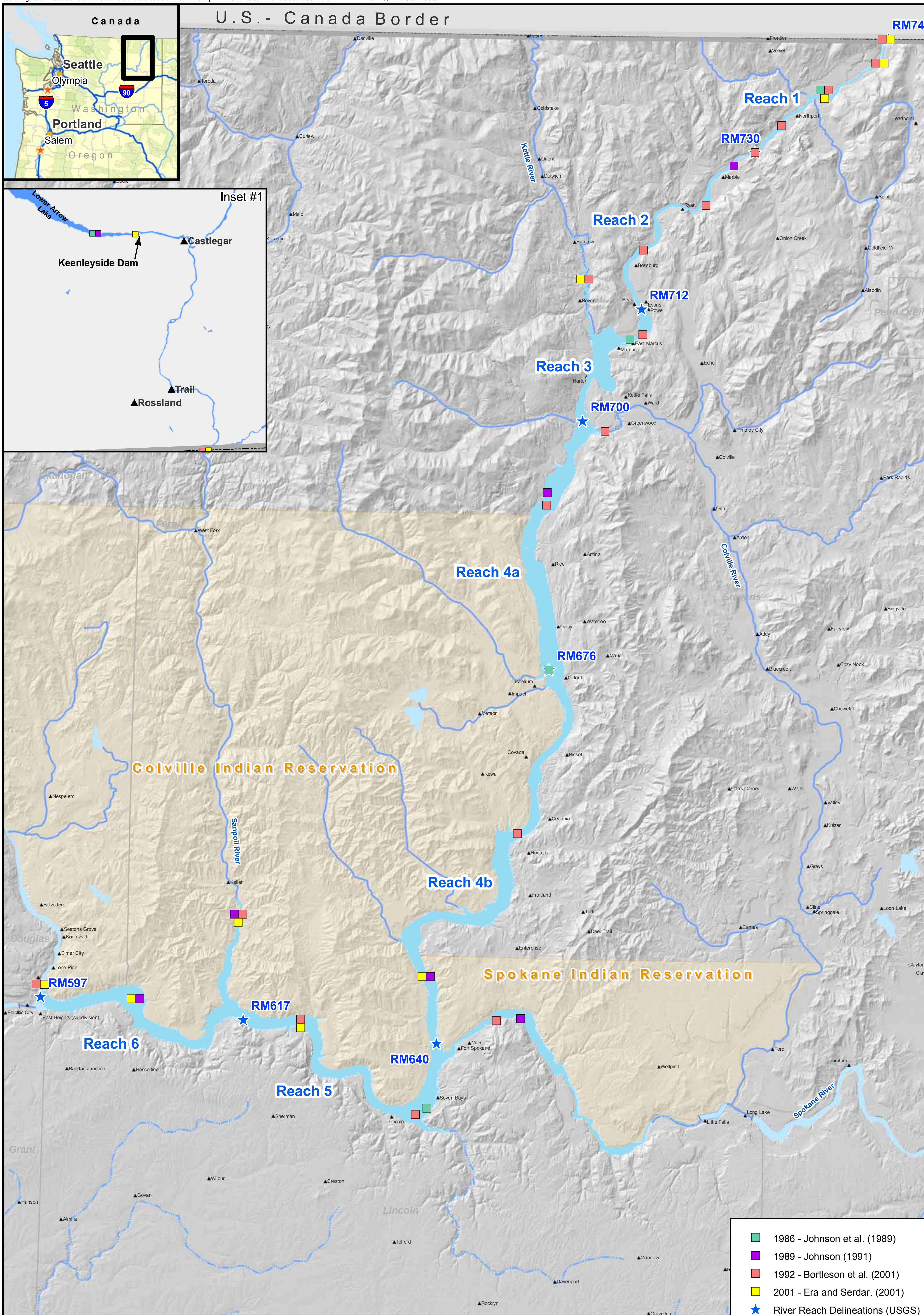


Figure 47. Acute Toxic Units for Cadmium and Lead based on Preliminary BLM Calculations for Sediment Porewater Samples Characterized by USEPA (2006)
Note: Toxic units are defined as the ratio of BLM-predicted acute LC50 to observed metal concentration. Values greater than 1 indicate that toxicity would be expected from the metal to sensitive organisms. When metal concentrations were reported as below a detection limit, the TU was calculated using the detection limit value, and these cases are indicated using un-filled symbols.

MAPS

\\Mi\gis\mi\C306_UCR_Teck-Cominco\t0601_0102\Map_2_ToxHistoric_06052008.mxd JP @ 11-05-2008



Integral Parametrix

Km 0 5 10

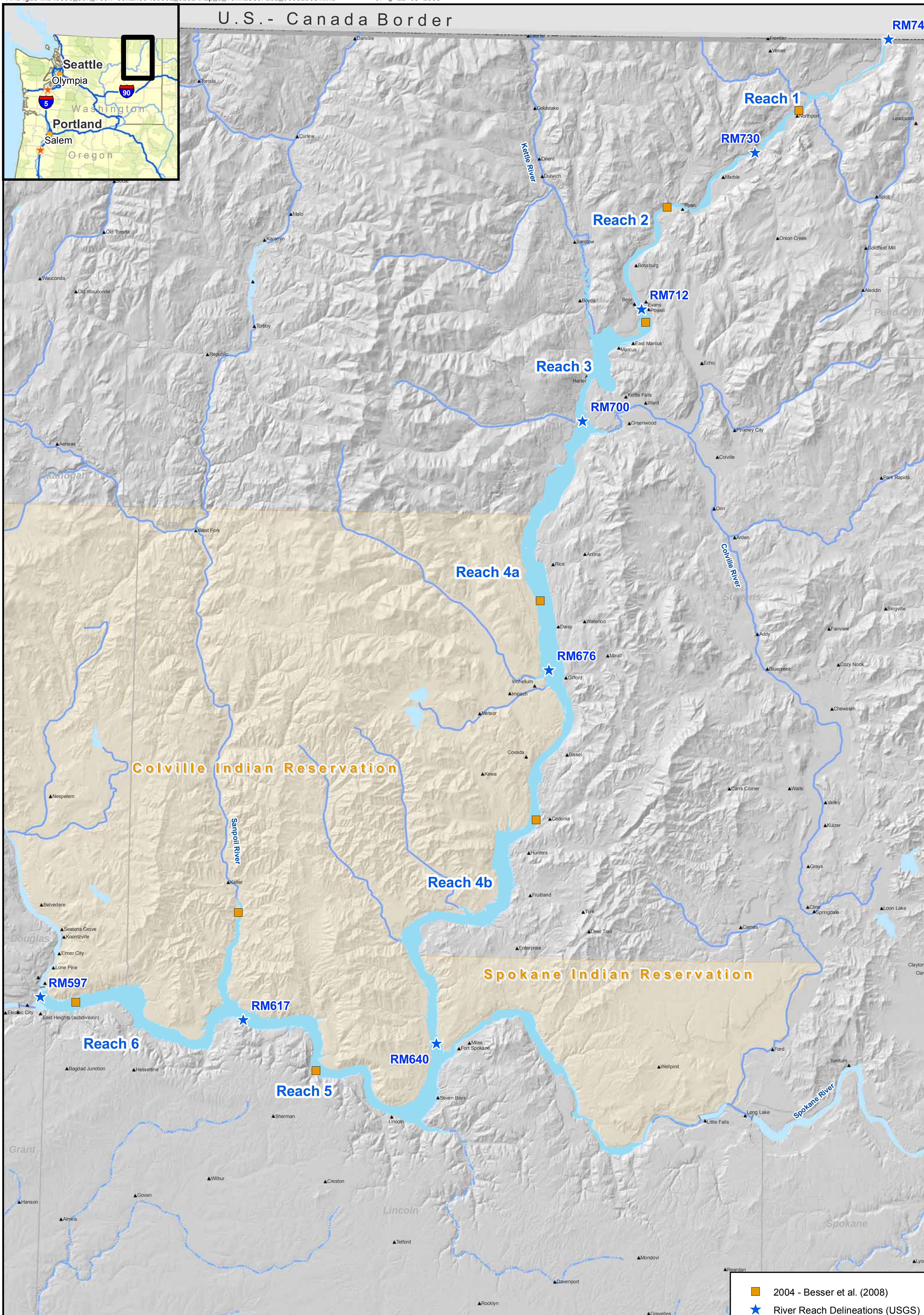
Miles 0 5 10

N

Map 1. **Locations of Historical (1986-2001) Sediment Toxicity Stations in the UCR**

Upper Columbia River, WA

\\Mi\gis\mi\C306_UCR_Teck-Cominco\t0601_0102\Map_3_ToxHistoric2_06052008.mxd JP @ 11-05-2008



Integral Parametrix

Km 0 5 10

Miles 0 5 10

N

Map 2. **Locations of 2004 Sediment Toxicity Stations in the UCR**

Upper Columbia River, WA

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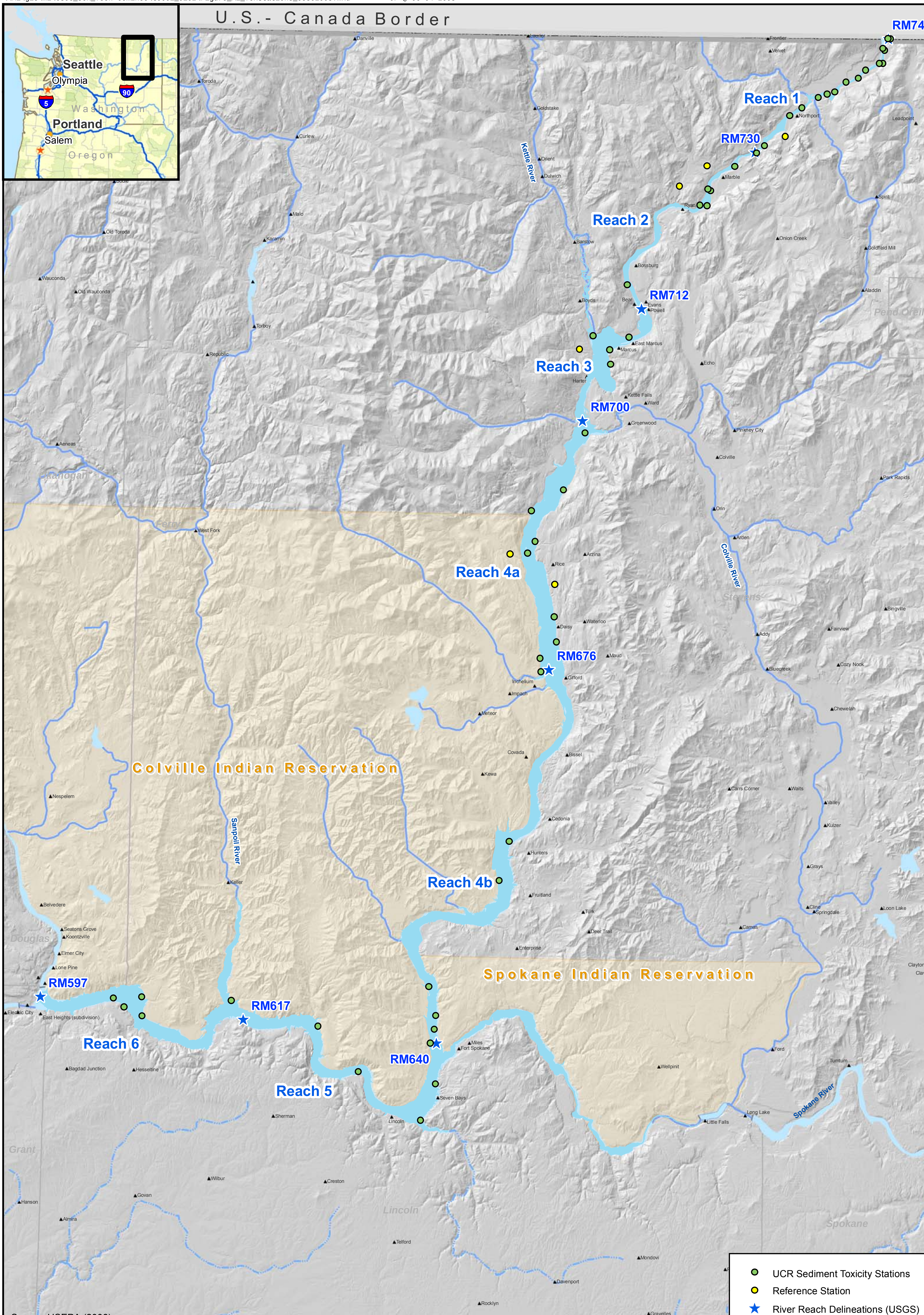

Integral Parametrix

Map 3. **Locations of 2005 Sediment Toxicity Stations in the UCR**

Upper Columbia River, WA

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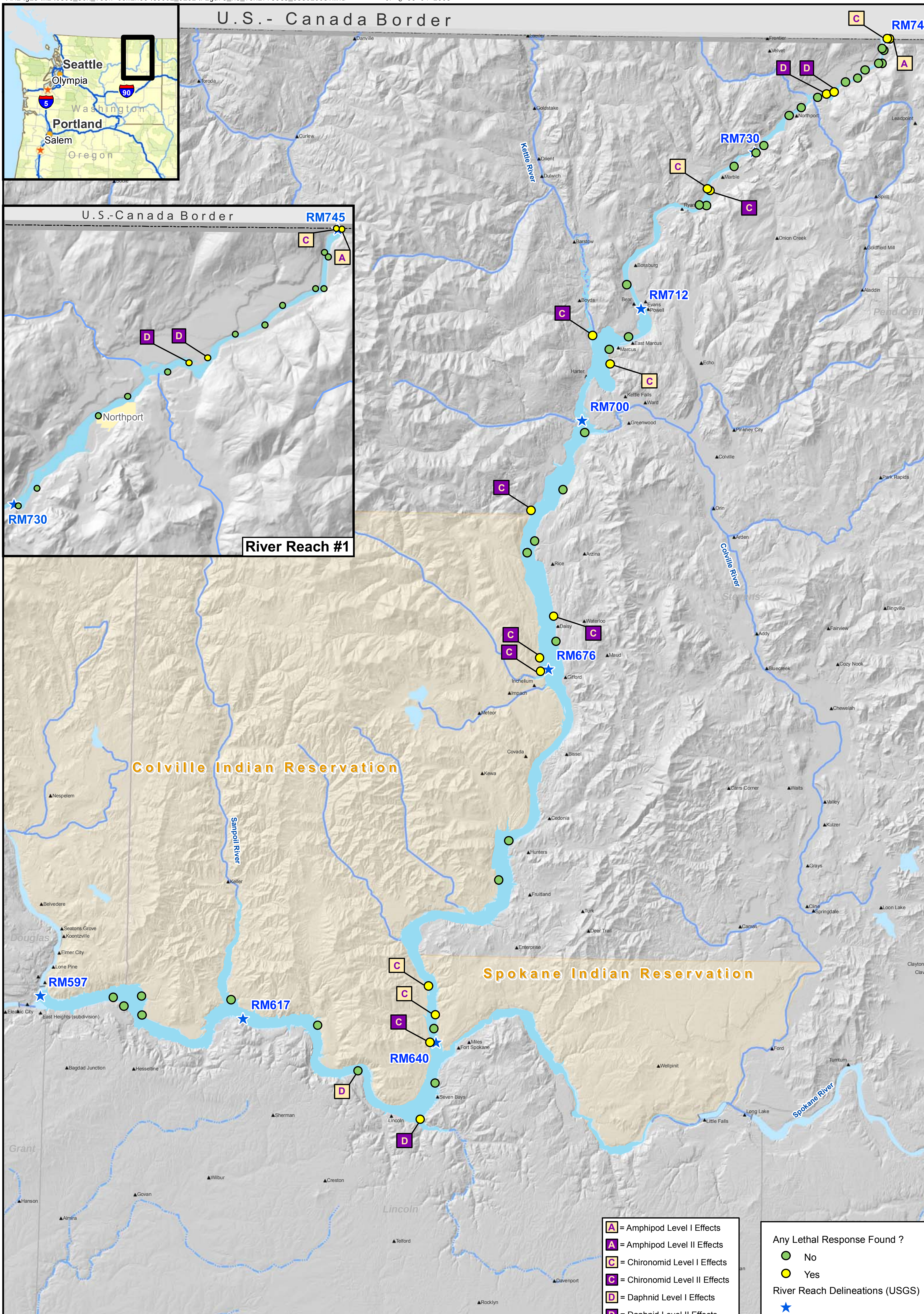

Integral Parametrix

Km 0 5 10

Miles 0 5 10

N

Map 4. **Summary of Significant Lethal Responses in the Sediment Toxicity Tests for the 2005 Study**

Upper Columbia River, WA

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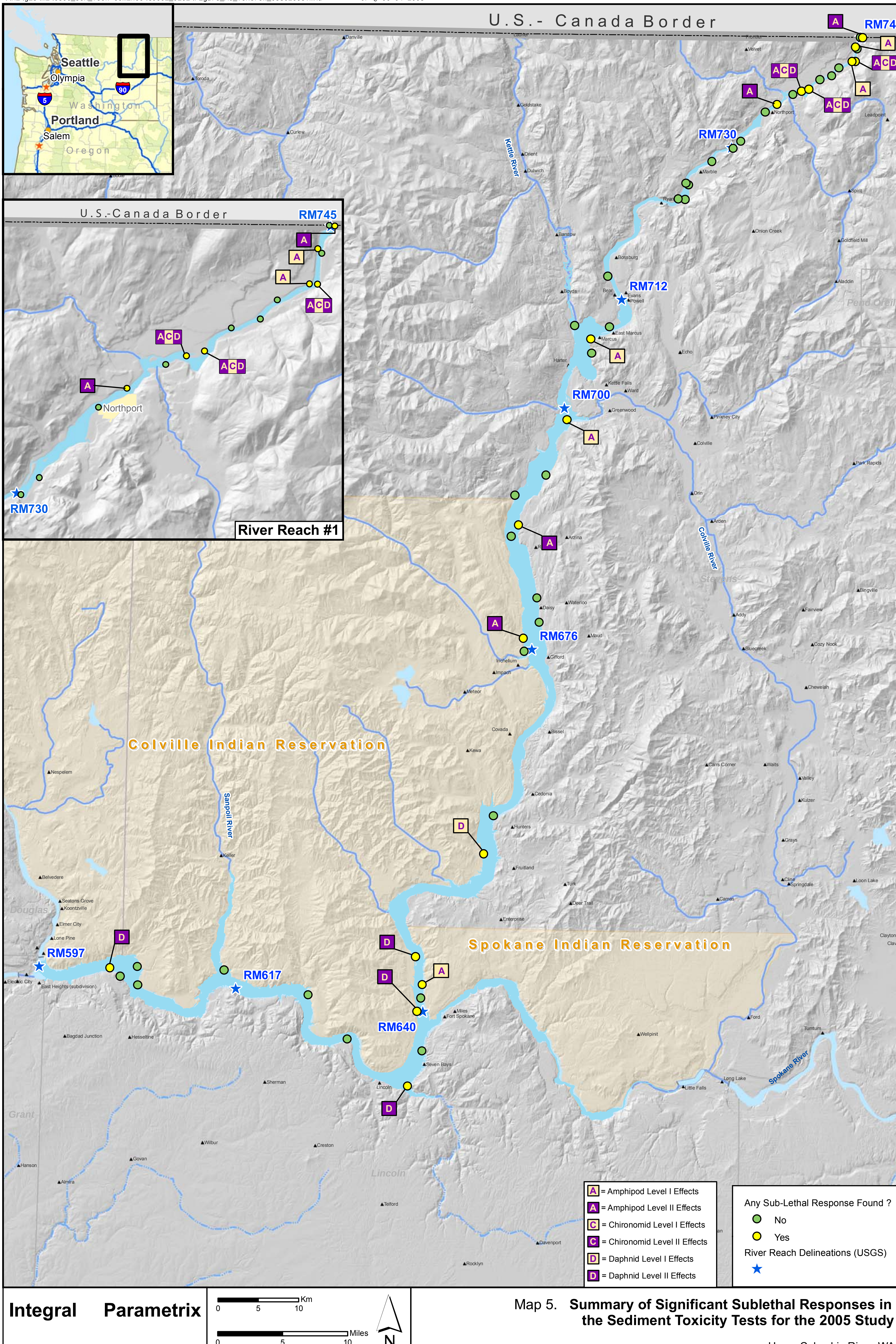

Integral Parametrix

Map 5. **Summary of Significant Sublethal Responses in the Sediment Toxicity Tests for the 2005 Study**

Upper Columbia River, WA

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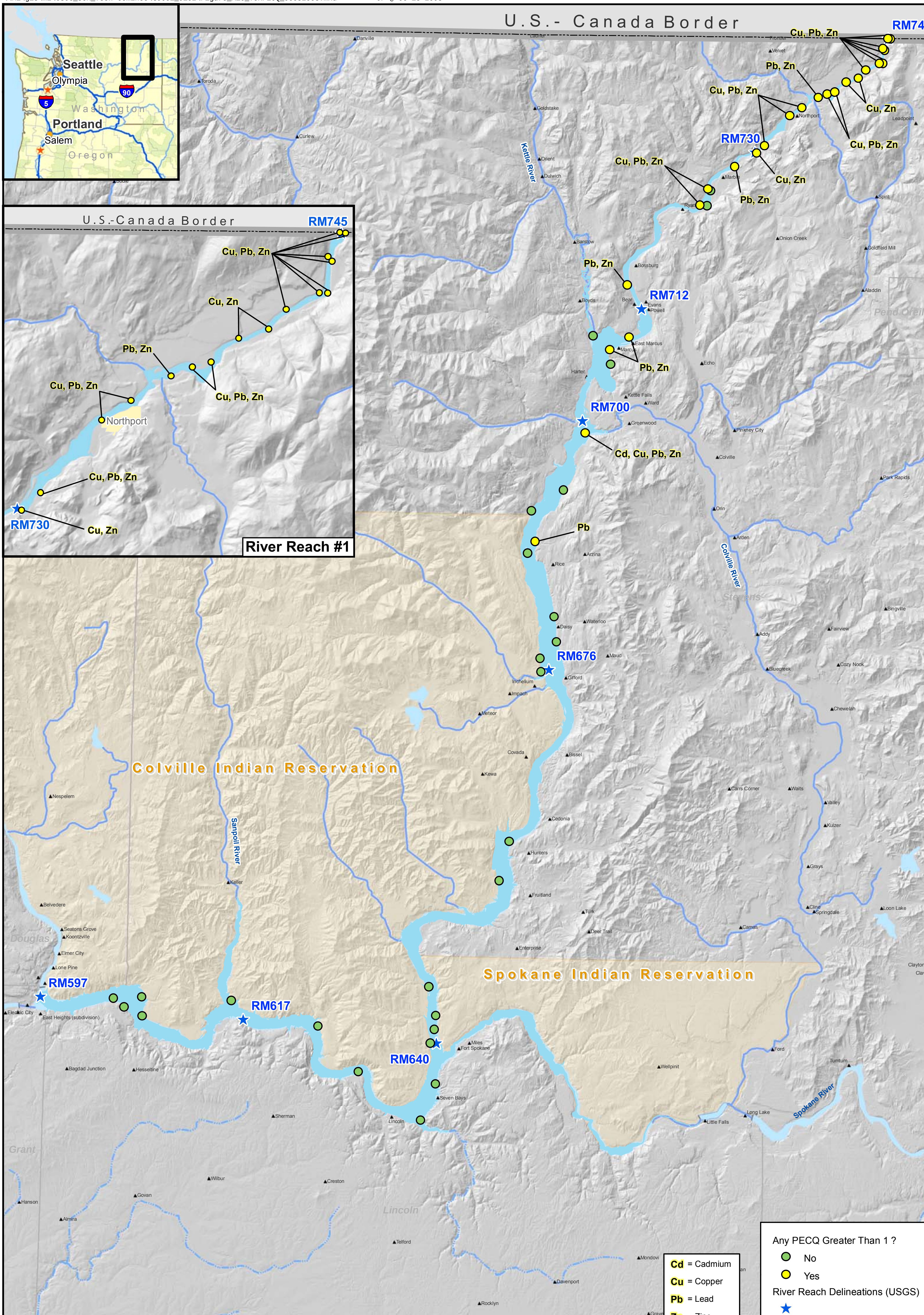

Integral Parametrix

Km 0 5 10

Miles 0 5 10

N

Map 6. **Summary of PECQs Greater Than 1.0 for Sediment in the 2005 Sediment Toxicity Study**

Upper Columbia River, WA

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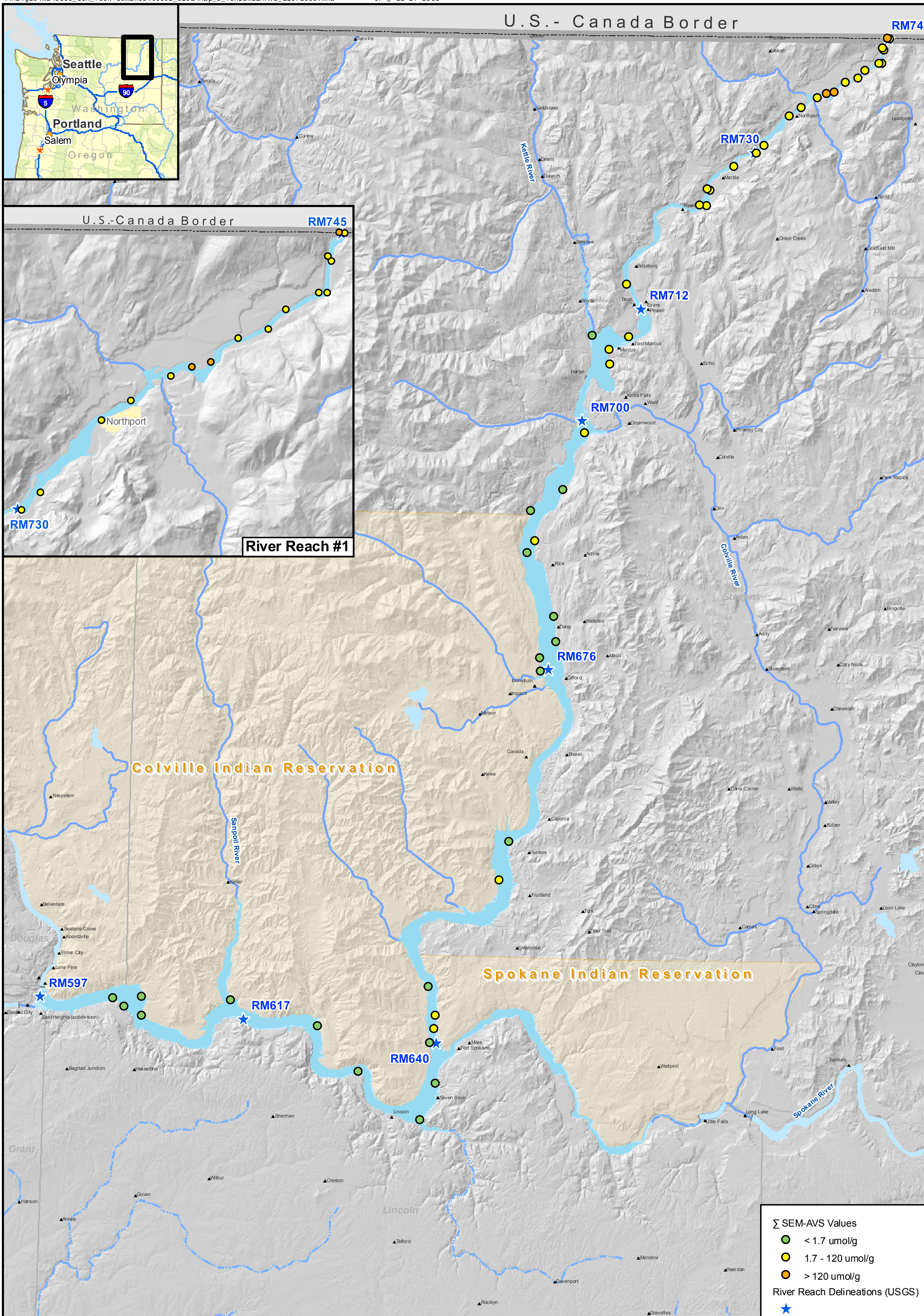


Integral Parametrix

Km 0 5 10

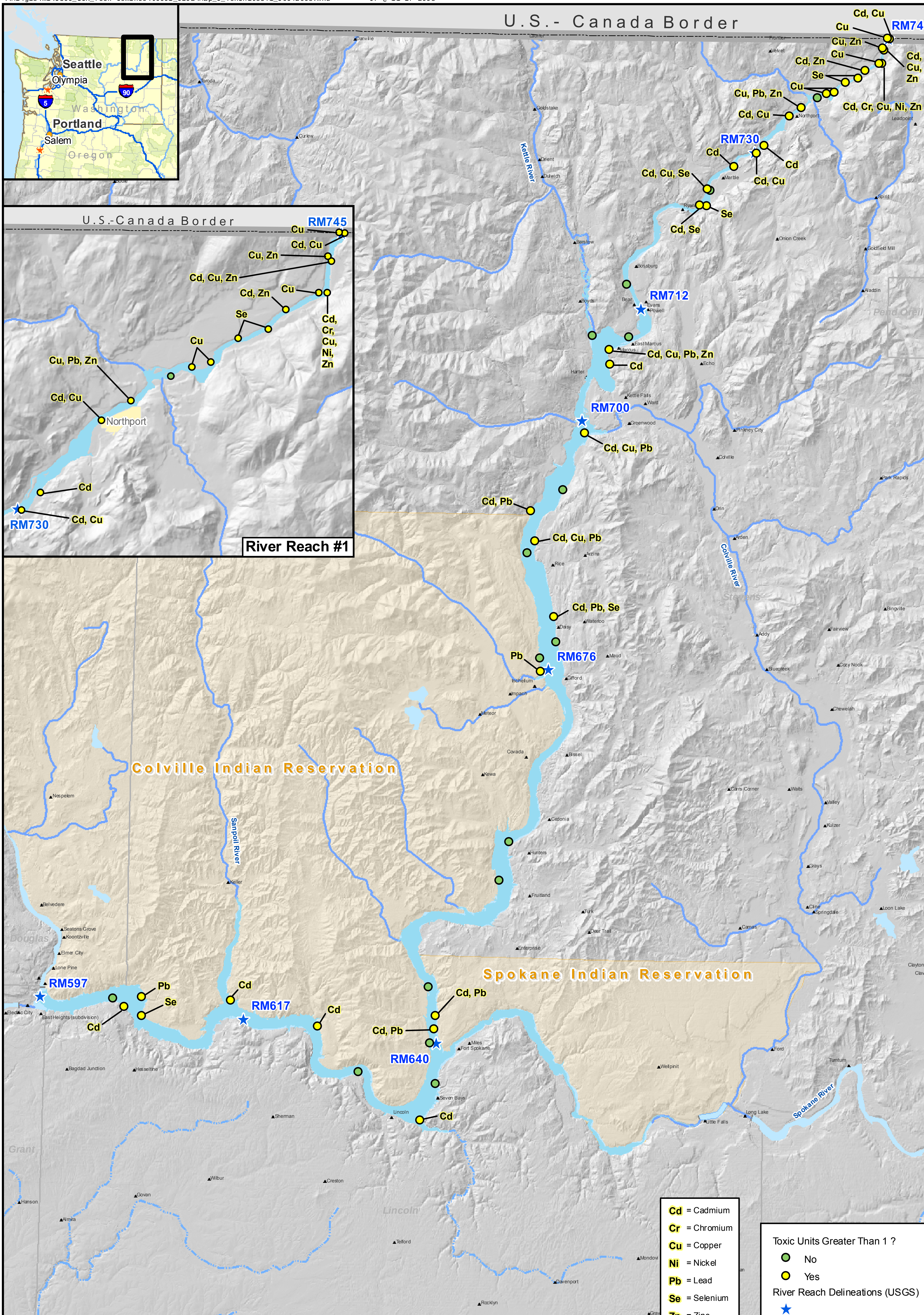
Miles 0 5 10

N

Map 7. **Summary of (∑SEM-AVS) Concentrations in Sediment for the 2005 Sediment Toxicity Study**

Upper Columbia River, WA

\\Mi\gis\mi\C306_UCR_Teck-Cominco\t0601_0102\Map_9_ToxUnitsGT1_06042008.mxd JP @ 11-17-2008



Integral Parametrix

Km 0 5 10
Miles 0 5 10
N

Map 8. **Summary of Toxic Units Greater Than 1.0 for Porewater in the 2005 Sediment Toxicity Study**

Upper Columbia River, WA

TABLES

Table 1. Summary of Sediment Toxicity Responses for the 1986 UCR Study

		10-Day *Hyalella azteca* Test		48-Hour *Daphnia pulex* Test	
		Survival (percent)		Survival (percent)	
Station	River Mile	Mean	SD	Mean	SD
Deadman's Eddy	738	90	7	55	19
Marcus Island	709	74	20	75	10
Gifford	676	80	14	65	19
Seven Bays	635	74	18	35	25
Lower Arrow Lake		78	4	45	19
Negative Control		92	11	70	38

Notes:
Source: Johnson et al. (1989)
SD = standard deviation

Table 2. Summary of Sediment Toxicity Responses for the 1989 UCR Study[a]

		10-Day *Hyalella azteca* Test	7-Day *Daphnia magna* Test	
		Survival (percent)	Survival (percent)	
Station	River Mile	Mean	Elutriate Mean	Whole Sediment Mean
Little Dalles	728	88	84	100
French Pt. Rocks	692	90	86	100
Castle Rock	645	80	88	73
Swawilla Basin	605	70	90	92
Spokane Arm		86	98	99
Sanpoil Arm		90	78	96
Negative Control		96	96	99

Notes:
Source: Johnson (1991)
Standard deviations were not reported by the authors

[a] Results of the Microtox test are not presented because they were not used in this technical memorandum.

Table 3. Summary of Sediment Toxicity Responses for the 1992 UCR Study[a]

		7-Day *Hyalella azteca* Test		7-Day *Ceriodaphnia dubia* Test			
		Survival (percent)		Survival (percent)		No. Young per Female	
Station	River Mile	Mean	SD	Mean	SD	Mean	SD
Boundary	745	30	10.0	0		0	0
Auxiliary Gage	738	10	10.0	40		1.8	3.0
Goodeve Creek	738	56	11.6	80		18.4	8.7
Fivemile Creek	733	73	25.2	80		29.0	10.2
Onion Creek	730	87	5.8	90		33.3	16.9
China Bend	724	87	5.8	100		38.7	2.8
Bossborg	717	77	5.8	90		29.2	4.8
Summer Island	710	73	20.8	90		33.2	5.0
Marcus Island	708	80	10.0	70		23.2	18.2
French Pt. Rocks	691	97	5.8	70		27.7	15.5
Hunters	662	90	10.0	100		35.6	7.0
Seven Bays	634	93	11.6	100		23.6	6.2
Whitestone Creek	621	97	5.8	100		17.3	6.9
Grand Coulee Dam	596	83	5.8	80		13.6	10.7
Kettle River		87	5.8	50		19.4	19
Colville River		80	17.3	70		31.9	12.6
Spokane Arm		100	0	100		22.1	3.1
Sanpoil Arm		60	26.5	90		22.3	9.7
Lower Arrow Lake 1		90	10.0	100		31.2	5.5
Lower Arrow Lake 2		87	5.8	90		30.8	14.2
Negative Control[b]		93		90		24.1	

Notes:
Source: Bortleson et al. (2001)
SD = standard deviation

[a] Results for the Microtox test are not presented because they were not used in this technical memorandum.
[b] Negative control values are means of three negative controls for *H. azteca* and two negative controls for *C. dubia*.

Table 4. Summary of Sediment Toxicity Responses for the 2001 UCR Study[a]

		10-Day *Hyalella azteca* Test		20-Day *Chironomus dilutus* Test			
		Survival (percent)		Survival (percent)		Biomass (mg)	
Station	River Mile	Mean	SD	Mean	SD	Mean	SD
Boundary	745	66	21.3	70	12.0	1.05	0.19
Auxiliary Gage	743	56	15.1	3	4.6	1.08	1.36
Goodeve Creek	738	50	15.1	0	0	NA	NA
Castle Rock	645	73	12.8	63	10.4	1.55	0.34
Whitestone Creek	621	93	11.6	55	20.0	1.36	0.18
Swawilla Basin	605	75	16.0	60	16.0	1.25	0.28
Grand Coulee Dam	596	71	17.3	64	23.3	1.57	0.52
Kettle River		69	28.0	51	36.4	2.55	0.77
Sanpoil Arm		70	19.3	54	27.7	1.08	0.18
Lower Arrow Lake		71	22.3	76	10.6	1.18	0.14
Negative Control		90	13.1	69	13.6	1.52	0.24

Notes:
Source: Era and Serdar (2001)
NA = not applicable because survival was 0 percent
SD = standard deviation

[a] Results for the Microtox test are not presented because they were not used in this technical memorandum.

Table 5. Summary of Sediment Toxicity Resources for the 2004 UCR Study

		28-Day *Hyalella azteca* Test				12-Day *Chironomus dilutus* Test			
		Survival (percent)		Length (mm)		Survival (percent)		Biomass (mg)	
Station	River Mile	Mean	SE	Mean	SE	Mean	SE	Mean	SE
LR7	735	71	5	3.2	0.10	90	3	0.41	0.08
LR6	722	98	2	3.6	0.05	89	7	0.82	0.05
LR5	711	90	6	3.2	0.10	89	2	0.87	0.05
LR4	683	84	16	3.7	0.22	95	4	1.21	0.07
LR3	664	90	2	3.4	0.06	88	5	0.67	0.05
LR2	625	98	2	3.6	0.11	90	3	0.82	0.04
LR1	601	94	3	3.6	0.09	96	3	0.99	0.07
SA8[a]		98	2	3.2	0.08	81	6	1.03	0.05
Negative Control		85	3	3.7	0.05	90	4	1.92	0.08

Notes:
Source: Besser et al. (2008)
SE = standard error

[a] This station was located in the Sanpoil Arm.

Table 6. Summary of Sediment Toxicity Responses for the 2005 UCR Study

		28-Day *Hyalella azteca* Test				10-Day *Chironomus dilutus* Test				7-Day *Ceriodaphnia dubia* Test			
		Survival (percent)		Biomass (mg)		Survival (percent)		Biomass (mg)		Survival (percent)		Young/Female	
Location ID	River Mile	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RM744A1(X1)	744	84	13	0.35	0.04	61	14	1.98	0.35	80	42	22.60	8.24
RM744A2(X3)	744	75	9	0.17	0.05	76	12	1.31	0.31	80	42	18.50	10.67
RM743A1(X1)	743	91	8	0.49	0.07	83	15	1.60	0.32	90	32	25.80	3.58
RM743A2(X3)	743	81	8	0.32	0.08	80	18	1.43	0.29	100	0	20.00	4.42
RM742A1(X1)	742	89	11	0.27	0.07	83	16	1.18	0.28	100	0	10.00	8.86
RM742A2(X5)	742	95	5	0.32	0.04	74	20	1.31	0.37	90	32	19.00	9.10
RM741A1(X3)	741	80	12	0.46	0.06	68	26	2.18	0.82	100	0	24.80	2.82
RM740A1(X1)	740	98	5	0.51	0.10	75	11	2.08	0.35	100	0	23.00	5.73
RM739A1(X3)	739	91	6	0.46	0.06	73	13	2.04	0.22	100	0	21.60	4.27
RM738A1(X3)	738	86	13	0.18	0.03	68	15	1.14	0.27	0	0	0.00	0.00
RM737A1(X3)	737	90	13	0.19	0.04	83	18	1.47	0.26	50	53	3.70	7.56
RM736A1(X1)	736	89	11	0.34	0.04	81	11	1.94	0.29	70	48	18.90	11.10
RM734A1	734	86	11	0.23	0.06	81	8	1.61	0.29	90	32	22.50	8.42
RM733A1(X1)	733	91	11	0.50	0.09	84	13	1.76	0.24	100	0	26.80	4.37
RM730A1	730	86	11	0.34	0.05	83	15	1.96	0.24	100	0	23.10	6.08
RM729A1(X1)	729	93	7	0.45	0.06	90	8	2.01	0.27	100	0	25.80	5.12
RM727A1(X1)	727	98	5	0.41	0.03	93	12	1.74	0.20	90	32	22.20	8.35
RM724A1(X1)	724	99	4	0.37	0.05	56	19	2.13	0.79	100	0	26.80	2.74
RM724A2(X3)	724	95	8	0.64	0.10	65	23	2.44	0.69	100	0	25.80	3.39
RM723A1(X1)	723	96	5	0.65	0.04	84	12	2.14	0.36	100	0	27.50	5.38
RM723A2(X3)	723	95	8	0.42	0.07	84	11	1.96	0.41	100	0	25.00	4.69
RM713A1(X3)	713	100	0	0.33	0.05	75	21	2.23	0.70	100	0	21.40	6.11
RM708A1(X3)	708	93	7	0.34	0.05	70	23	1.65	0.33	70	48	23.80	9.33
RM706A1(X1)	706	95	8	0.31	0.05	69	22	1.69	0.24	80	42	18.70	8.82
RM706A2(X7)	706	95	5	0.33	0.05	55	26	2.05	0.53	80	42	23.00	5.64
RM704A1(X1)	704	96	5	0.38	0.06	63	27	2.02	1.01	100	0	25.00	2.79
RM698A1(X1)	698	96	7	0.29	0.04	68	24	1.75	0.56	80	42	19.80	10.77
RM692A1(X1)	692	95	5	0.41	0.08	73	17	1.80	0.29	100	0	27.00	2.16
RM689A1(X3)	689	94	5	0.37	0.06	50	27	2.37	0.79	90	32	22.00	8.49
RM687A1	687	94	11	0.27	0.06	74	18	1.62	0.36	90	32	20.10	7.52
RM686A1(X3)	686	94	9	0.59	0.14	73	20	1.83	0.29	80	42	20.50	11.67
RM680A1(X1)	680	96	7	0.33	0.09	39	26	1.62	1.09	90	32	20.70	6.38
RM678A1(X1)	678	98	5	0.33	0.07	71	19	1.93	0.57	100	0	26.90	4.58
RM677A1(X3)	677	90	14	0.28	0.09	43	24	1.74	0.77	100	0	22.90	4.38

Table 6. Summary of Sediment Toxicity Responses for the 2005 UCR Study

		28-Day *Hyalella azteca* Test				10-Day *Chironomus dilutus* Test				7-Day *Ceriodaphnia dubia* Test			
		Survival (percent)		Biomass (mg)		Survival (percent)		Biomass (mg)		Survival (percent)		Young/Female	
Location ID	River Mile	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RM676A1(X3)	676	93	12	0.35	0.03	46	27	2.10	0.62	100	0	19.20	5.14
RM661A1(X1)	661	98	5	0.35	0.03	81	8	1.84	0.23	100	0	23.30	4.85
RM658A1(X3)	658	99	4	0.41	0.04	80	14	1.78	0.43	100	0	18.00	4.67
RM644A1(X3)	644	93	18	0.34	0.06	70	24	1.82	0.57	100	0	16.10	3.25
RM642A1(X1)	642	96	7	0.30	0.06	66	30	1.97	0.28	100	0	20.80	8.18
RM641A1(X1)	641	95	8	0.35	0.06	86	15	1.93	0.30	100	0	25.60	4.99
RM640A1(X3)	640	96	7	0.40	0.07	60	24	2.20	1.02	90	32	13.20	5.31
RM637A1(X1)	637	96	5	0.45	0.05	78	10	1.79	0.38	100	0	28.50	3.31
RM634A1(X1)	634	91	8	0.37	0.05	80	15	1.92	0.62	60	52	8.20	8.20
RM628A1(X1)	628	84	26	0.52	0.05	88	12	1.93	0.44	70	48	18.60	11.19
RM622A1(X3)	622	95	11	0.52	0.09	78	14	1.82	0.28	100	0	23.50	3.37
RM616A1(X3)	616	96	7	0.48	0.07	84	9	2.22	0.80	100	0	25.30	3.50
RM606A1(X3)	606	94	7	0.42	0.07	73	28	1.79	1.13	100	0	25.40	3.60
RM605A1(X1)	605	93	9	0.49	0.07	78	18	1.81	0.70	100	0	25.80	3.55
RM605A2(X8)	605	94	7	0.33	0.05	81	10	1.85	0.24	90	32	23.30	9.31
RM603A1(X1)	603	96	7	0.32	0.05	71	10	1.90	0.25	100	0	12.00	3.02

Notes:
SD - standard deviation

Table 7. Summary of Significant Toxicity Responses Found in Reaches 1 through 3 for the 2005 Study Based on Comparisons with Negative Control Responses[a]

	Amphipod Test		Chironomid Test		Daphnid Test	
River Mile	Survival (percent)	Biomass (percent)	Survival (percent)	Biomass (percent)	Survival (percent)	No. of Young (percent)
Reach 1						
744	--	--	73*	--	--	--
744	78*	41**	--	--	--	--
743	--	79*	--	--	--	--
743	--	--	--	--	--	--
742	--	79*	--	--	--	--
742[b]	--	67**	--	78*	--	44**
741	--	--	--	--	--	--
740	--	--	--	--	--	--
739	--	--	--	--	--	--
738[b]	--	44**	--	76*	0**	0**
737[b]	--	51**	--	77*	63**	16**
736	--	--	--	--	--	--
734	--	60**	--	--	--	--
733	--	--	--	--	--	--
730	--	--	--	--	--	--
Reach 2						
729	--	--	--	--	--	--
727	--	--	--	--	--	--
724	--	--	78*	--	--	--
724	--	--	67**	--	--	--
723	--	--	--	--	--	--
723	--	--	--	--	--	--
713	--	--	--	--	--	--
Reach 3						
708	--	--	--	--	--	--
706	--	--	66**	--	--	--
706	--	77*	--	--	--	--
704	--	--	75*	--	--	--

Notes:
-- = significant response was not found
* Level 1 response
** Level 2 response

[a] Values are percent of negative control (i.e., responses are control-adjusted)
[b] More than one toxicity test exhibited a significant response at this station.

Table 8. Summary of Significant Toxicity Responses Found in Reaches 4 through 6 for the 2005 Study Based on Comparisons with Negative Control Responses[a]

	Amphipod Test		Chironomid Test		Daphnid Test	
River Mile	Survival (percent)	Biomass (percent)	Survival (percent)	Biomass (percent)	Survival (percent)	No. of Young (percent)
Reach 4a						
698	--	70*	--	--	--	--
692	--	--	--	--	--	--
689	--	--	60**	--	--	--
687	--	66**	--	--	--	--
686	--	--	--	--	--	--
680	--	--	46**	--	--	--
678	--	--	--	--	--	--
677[b]	--	68**	51**	--	--	--
676	--	--	55**	--	--	--
Reach 4b						
661	--	--	--	--	--	--
658	--	--	--	--	--	75*
644[b]	--	--	79*	--	--	67**
642[b]	--	79*	75*	--	--	--
641	--	--	--	--	--	--
640[b]	--	--	68**	--	--	55**
Reach 5						
637	--	--	--	--	--	--
634	--	--	--	--	67**	34**
628	--	--	--	--	74*	--
622	--	--	--	--	--	--
Reach 6						
616	--	--	--	--	--	--
606	--	--	--	--	--	--
605	--	--	--	--	--	--
605	--	--	--	--	--	--
603	--	--	--	--	--	50**

Notes:
-- denotes significant response was not found
* Level 1 response
** Level 2 response

[a] Values are percent of negative control (i.e., responses are control-adjusted)
[b] More than one toxicity test exhibited a significant response at this station.

Table 9. Summary of Significant Toxicity Responses Found in Reaches 1 through 3 for the 2005 Study Based on Comparisons with Reference Area Responses[a]

	Amphipod Test		Chironomid Test		Daphnid Test	
River Mile	Survival (percent)	Biomass (percent)	Survival (percent)	Biomass (percent)	Survival (percent)	No. of Young (percent)
Reach 1						
744	--	67**	--	--	--	--
744	77*	32**	--	66**	--	--
743	--	62**	--	--	--	--
743	--	--	--	72*	--	--
742	--	62**	--	66**	--	--
742	--	53**	--	59**	--	44**
741	--	--	--	--	--	--
740	--	--	--	--	--	--
739	--	--	--	--	--	--
738	--	34**	--	57**	0**	0**
737	--	41**	--	75**	52**	16**
736	--	71*	--	--	73*	--
734	--	48**	--	--	--	--
733	--	--	--	--	--	--
730	--	--	--	--	--	--
Reach 2						
729	--	--	--	--	--	--
727	--	--	--	--	--	--
724	--	--	--	--	--	--
724	--	--	--	--	--	--
723	--	--	--	--	--	--
723	--	--	--	--	--	--
713	--	71*	--	--	--	--
Reach 3						
708	--	65**	--	--	--	--
706	--	65**	--	--	--	--
706	--	60**	--	--	--	--
704	--	74*	--	--	--	--

Notes:
-- = significant response was not found
* Level 1 response
** Level 2 response

[a] Values are percent of batch-specific mean reference-area value

Table 10. Summary of Significant Toxicity Responses Found in Reaches 4 through 6 for the 2005 Study Based on Comparisons with Reference Area Responses[a]

	Amphipod Test		Chironomid Test		Daphnid Test	
River Mile	Survival (percent)	Biomass (percent)	Survival (percent)	Biomass (percent)	Survival (percent)	No. of Young (percent)
Reach 4a						
698	--	55**	--	--	--	--
692	--	79*	--	--	--	--
689	--	71*	72*	--	--	--
687	--	52**	--	--	--	--
686	--	--	--	--	--	--
680	--	63**	56**	--	--	--
678	--	64**	--	--	--	--
677	--	53**	61**	--	--	--
676	--	67**	67**	--	--	--
Reach 4b						
661	--	73*	--	--	--	--
658	--	--	--	--	--	79*
644	--	72*	--	--	--	71*
642	--	64**	--	--	--	--
641	--	74*	--	--	--	--
640	--	--	75*	--	--	58**
Reach 5						
637	--	79*	--	--	--	--
634	--	--	--	--	67**	36**
628	--	--	--	--	76*	--
622	--	--	--	--	--	--
Reach 6						
616	--	--	--	--	--	--
606	--	--	--	--	--	--
605	--	71*	--	--	--	--
605	--	--	--	--	--	--
603	--	69**	--	--	--	53**

Notes:
-- denotes significant response was not found
* Level 1 response
** Level 2 response

[a] Values are percent of batch-specific mean reference area value

Table 11. Summary of Control-Normalized Sediment Toxicity Responses for Historical (1986-2001) UCR Studies[a,b]

	1986		1989			1992			2001		
			Daphnia magna Survival				*Ceriodaphnia dubia*			*Chironomus dilutus*	
River Mile	*Hyalella azteca* Survival	*Daphnia pulex* Survival	Elutriate	Whole Sediment	*Hyalella azteca* Survival	*Hyalella azteca* Survival	Survival	Neonates per Female	*Hyalella azteca* Survival	Survival	Biomass
745						32	0	0	74	102	69
743						11	44	7	63	4	71
738	98	79				60	89	76	56	0	0
733						79	89	120			
730						93	100	138			
728			88	101	92						
724						93	111	161			
717						83	100	121			
710						79	100	138			
709	80	107									
708						86	78	96			
692			90	101	94						
691						104	78	115			
676	87	93									
662						97	111	147			
645			92	74	83				81	91	102
635	80	50									
634						101	111	98			
621						104	111	72	103	80	89
605			94	93	73				83	87	82
596						90	89	56	79	93	103

Notes:

[a] See Tables 1 through 4 for additional details of the studies

[b] Values are percent of negative control

Table 12. Summary of Control-Normalized Sediment Toxicity Responses for the 2004 UCR Study[a,b]

River Mile	*Hyalella azteca*		*Chironomus dilutus*	
	Survival	Length	Survival	Biomass
735	84	86	100	21
721	115	97	99	43
711	106	86	99	45
683	99	100	106	63
664	106	92	98	35
625	116	97	100	43
600	111	97	107	52

Notes:
[a] See Table 5 for additional details of this study
[b] Values are percent of negative control

Table 13. Summary of Control-Normalized Sediment Toxicity Responses for the 2005 UCR Study[a,b]

		Hyalella azteca			*Chironomus dilutus*			*Ceriodaphnia dubia*		
Location ID	RM	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
RM744A1(X1)	744	87	86	78	73	131	85	100	93	99
RM744A2(X3)	744	78	41	33	91	87	71	100	83	81
RM743A1(X1)	743	95	119	117	99	106	92	113	95	113
RM743A2(X3)	743	84	79	68	96	95	79	125	71	88
RM742A1(X1)	742	92	67	64	99	78	68	125	36	44
RM742A2(X5)	742	99	79	80	88	87	67	113	73	83
RM741A1(X3)	741	83	113	96	81	144	92	125	89	109
RM740A1(X1)	740	101	126	133	90	137	108	124	83	100
RM739A1(X3)	739	95	113	111	87	135	106	125	77	95
RM738A1(X3)	738	90	44	41	81	76	54	0	0	0
RM737A1(X3)	737	92	51	45	94	77	81	63	26	16
RM736A1(X1)	736	91	88	78	92	99	106	88	90	83
RM734A1	734	89	60	52	92	82	86	100	85	93
RM733A1(X1)	733	94	131	118	94	90	97	111	100	111
RM730A1	730	89	88	75	93	100	107	111	86	96
RM729A1(X1)	729	95	118	108	101	102	122	111	96	107
RM727A1(X1)	727	100	108	104	104	88	109	100	92	92
RM724A1(X1)	724	103	91	97	67	141	77	125	96	118
RM724A2(X3)	724	99	158	160	78	162	101	125	92	113
RM723A1(X1)	723	99	171	163	94	109	118	125	98	121
RM723A2(X3)	723	97	111	105	94	99	109	111	93	104
RM713A1(X3)	713	103	88	87	85	113	104	111	80	89
RM708A1(X3)	708	96	83	83	84	109	79	88	99	104
RM706A1(X1)	706	99	77	78	82	112	80	100	80	82
RM706A2(X7)	706	99	82	84	66	135	74	100	81	101
RM704A1(X1)	704	100	94	97	75	134	75	125	89	110
RM698A1(X1)	698	100	70	72	81	116	77	100	88	87
RM692A1(X1)	692	99	101	103	87	119	91	125	96	118
RM689A1(X3)	689	97	90	91	60	157	75	113	87	97
RM687A1	687	97	66	65	88	107	81	113	80	88
RM686A1(X3)	686	97	145	146	87	121	91	100	92	90
RM680A1(X1)	680	100	80	84	46	108	56	113	81	91
RM678A1(X1)	678	101	82	86	85	128	89	125	96	118
RM677A1(X3)	677	94	68	66	51	115	57	125	82	100
RM676A1(X3)	676	96	85	84	55	139	61	125	69	84
RM661A1(X1)	661	100	91	88	92	93	100	111	87	97
RM658A1(X3)	658	101	108	106	90	90	92	111	67	75
RM644A1(X3)	644	95	89	85	79	92	75	111	60	67
RM642A1(X1)	642	99	79	76	75	100	86	111	78	86
RM641A1(X1)	641	97	91	86	97	98	109	111	96	106

Table 13. Summary of Control-Normalized Sediment Toxicity Responses for the 2005 UCR Study[a,b]

		Hyalella azteca			*Chironomus dilutus*			*Ceriodaphnia dubia*		
Location ID	RM	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
RM640A1(X3)	640	99	105	100	68	112	100	100	55	55
RM637A1(X1)	637	99	118	113	87	91	90	111	106	118
RM634A1(X1)	634	94	97	88	90	97	93	67	47	34
RM628A1(X1)	628	86	137	115	99	98	113	78	94	77
RM622A1(X3)	622	97	135	127	87	92	95	111	88	98
RM616A1(X3)	616	99	127	121	94	113	112	111	95	105
RM606A1(X3)	606	96	111	103	82	91	84	111	95	105
RM605A1(X1)	605	95	127	116	87	92	90	111	96	107
RM605A2(X8)	605	96	88	81	92	94	98	100	97	97
RM603A1(X1)	603	99	85	81	80	97	91	111	45	50

Notes:
[a] See Table 6 for additional details of this study
[b] Values are percent of negative control

Table 14. Correlations between Sediment Toxicity Responses for the 2005 UCR Study

		Amphipod Test			Chironomid Test			Daphnid Test		
		Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Amphipod Test	Survival		0.13	0.31	-0.28	0.26	0.08	0.20	0.07	0.20
	Biomass	0.13		0.96	0.23	0.16	0.67	0.11	0.51	0.48
	Total Biomass	0.31	0.96		0.15	0.23	0.58	0.19	0.49	0.52
Chironomid Test	Survival	-0.28	0.23	0.15		-0.58	0.58	-0.20	0.22	-0.01
	Biomass	0.26	0.16	0.23	-0.58		-0.02	0.39	0.12	0.37
	Total Biomass	0.08	0.67	0.58	0.58	-0.02		-0.17	0.37	0.22
Daphnid Test	Survival	0.20	0.11	0.19	-0.20	0.39	-0.17		0.02	0.45
	Young/Survivor	0.07	0.51	0.49	0.22	0.12	0.37	0.02		0.82
	Total Young	0.20	0.48	0.52	-0.01	0.37	0.22	0.45	0.82	

Table 15. Summary of Metals Concentrations (mg/kg dry weight) and Sediment Grain Size Distribution for Bulk Sediments for the 2005 UCR Study

Location ID	RM	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Uranium	Vanadium	Zinc	Clay (%)	Coarse Sand (%)	Fine Sand (%)	Gravel (%)	Medium Sand (%)	Sand (%)	Silt (%)	Total Fines (%)
RM744A1(X1)	744	5310	21.2	6.9	415	0.54	1.5	20000	26.4	13.6	390	35800	141	7440	718	0.15	9.7	1010	2.05	0.6	368	1.1	11.4	20.1	2480	0.1245	0.2	84	0	7.5	91.7	8.0	8.09
RM744A2(X3)	744	12300	29.6	10.7	1200	1.2	0.31	38400	89.3	50.1	1540	124000	183	3960	2410	0.048	11.2	2400	2.15	0.71	1390	1.55	54.7	28.3	9940	0.054	0.1	61.8	0	34.5	96.4	3.5	3.58
RM743A1(X1)	743	7370	20.7	8.7	406	0.72	2	18800	28.5	10.1	356	42500	201	7950	616	0.17	11.1	1060	7	0.65	386	1.6	12.95	24.2	2560	0.168	0.7	84.7	0.6	5.6	91	8.0	8.19
RM743A2(X3)	743	5560	14.1	4.7	398	0.71	1.7	18100	28.6	11.8	325	34200	142	8140	613	0.12	9.9	1210	2.35	0.65	251	1.65	16.4	20.6	2380	0.1365	0	90	0.1	0.8	90.8	8.6	8.78
RM742A1(X1)	742	6080	19	6.3	516	0.6	3.4	41700	29.6	14.3	399	39200	182	17700	745	0.16	10.6	1050	9.2	0.65	534	1.6	12.65	23.1	2920	0.046	0	92.8	0	2.6	95.4	4.5	4.51
RM742A2(X5)	742	12100	41.7	8.2	966	0.99	0.65	34500	72.3	34.9	1240	99700	221	4630	2080	0.052	10.9	2130	11.4	0.6	1220	1.55	12.2	28.1	8330	0.059	0	82.1	0.1	11.9	94	5.7	5.75
RM741A1(X3)	741	6590	24.1	8.2	437	0.61	2.1	21900	33.1	14.3	458	44600	166	8340	819	0.17	9.9	1120	7.4	0.6	438	1.55	12.4	21.5	3190	0.242	0.3	85.7	0	1.9	87.9	11.6	11.9
RM740A1(X1)	740	5740	6.2	5.2	268	0.73	2	17800	21.5	8.3	181	25200	118	8440	429	0.14	11	1190	2.5	0.7	226	1.5	9.4	21.4	1480	0.226	4.7	68	9.3	6.7	79.4	10.8	11.1
RM739A1(X3)	739	7030	25.4	7.9	327	0.7	1.8	18000	29.1	12.2	367	35700	114	8130	570	0.3	12	1180	4.8	0.75	390	1.85	14.95	22.6	2120	0.74	1.6	75.5	4.8	3.3	80.4	13.9	14.7
RM738A1(X3)	738	21100	25.2	8.5	1140	1.5	0.27	58300	100	38.1	1630	207000	215	6810	3410	[a]	9.3	4020	19.5	0.6	1770	1.5	11.9	41.3	14400	0.1085	0	45.1	0	51.8	96.9	3.0	3.08
RM737A1(X3)	737	14600	62.5	3.6	1490	1.3	1.2	47100	111	59.4	1920	172000	163	5270	3050	0.22	11.6	3200	13	0.6	1630	1.5	11.9	35.1	12300	0.0805	0	39.9	0	57.8	97.7	2.2	2.29
RM736A1(X1)	736	6390	5.1	4.8	540	0.71	4.3	35300	20.7	7.5	129	27400	214	20700	378	0.33	15.1	1330	9.8	0.7	98.5	1.75	14.15	27	1760	0.78	1.3	56.4	20.6	2.2	59.9	18.5	19.3
RM734A1	734	7280	11.6	0.65	318	0.67	1.8	21200	25.9	10.1	396	57600	148	5470	1140	0.09	6.6	1500	6.4	0.65	460	1.65	13.35	20	4610	0.1715	0.3	92.6	0.4	1.8	94.7	4.7	4.90
RM733A1(X1)	733	9510	17.4	6.6	489	0.88	2.9	29700	38.6	20	641	88400	1390	5860	2490	0.083	9.5	2480	3.7	0.49	957	1.2	9.8	28	8200	0.086	1.2	61.1	3.1	26	88.3	8.4	8.51
RM730A1	730	6250	14.9	2.4	424	0.61	3.5	23600	25.4	10.3	400	46400	266	7880	1030	0.16	7.7	1220	4.4	0.55	394	1.35	10.65	20	4690	0.07	0.2	88	0	4.8	93	6.8	6.90
RM729A1(X1)	729	3080	9.9	2	172	0.32	1.1	11100	14.5	6.1	183	16200	68.4	5090	371	0.06	6.3	611	3.9	0.6	78.5	1.5	12.05	11	1250	0.057	8.2	51.6	6.5	28	87.8	5.6	5.67
RM727A1(X1)	727	5900	5.7	7.85	337.5	0.59	3	25150	18.85	7.3	130	24000	169.5	13250	366	0.325	12.35	1012.5	6.35	0.6	109	1.55	12.25	23.6	1280	0.91625	0.75	78.05	0.45	1.45	80.25	18.1	19.1
RM724A1(X1)	724	9990	1.3	3.1	99.4	1	0.14	4730	22.1	9.4	21	19300	16	5770	358	0.017	21.7	1690	2.55	0.7	154	1.8	14.5	28.2	93.1	0.48	0	79.7	0	1.1	80.8	17.8	18.2
RM724A2(X3)	724	12300	24.6	1.05	769	1.1	2.2	34300	49	20.7	969	114000	267	7940	1980	0.11	10.6	2520	10.6	0.6	933	1.5	12.2	30	8410	0.639	0	37.9	0	47.9	85.8	13.4	14.1
RM723A1(X1)	723	5030	0.75	2.3	109	0.44	0.53	6940	12.6	4.8	22.2	13600	24.5	4530	195	0.038	12	890	1.8	0.55	56	1.35	10.7	19.1	179	0.835	0.5	39.2	0	43.6	83.3	15.8	16.6
RM723A2(X3)	723	6410	7	4.4	368	0.69	2.7	18200	20.3	9.1	195	34900	203	10600	558	0.39	12.2	1250	7.7	0.8	121.5	2	16.1	22.5	2290	2.79	0.2	58.6	0	10.2	69	27.6	30.4
RM713A1(X3)	713	6890	4.85	4.6	267	0.825	2.85	8675	20.35	7.25	64.95	17600	148	7010	273.5	0.55	16	1275	5.8	0.8	124	2.05	16.2	28.05	538.5	1.525	1.6	60.5	1.7	2.2	64.3	31.8	33.3
RM708A1(X3)	708	7960	1.4	5.8	526	0.8	4.8	37600	20.7	7.3	106	26300	192	21800	380	0.43	16.4	1330	9.6	0.8	172	2	16.2	28.8	1340	3.472	0	56.2	0	0.4	56.6	36.5	39.9
RM706A1(X1)	706	7390	1.9	4.5	445	0.97	3.8	15000	21.3	6.7	78.8	18800	197	10400	317	0.66	15.5	1600	3.85	1.1	137	2.75	9.6	26.3	764	9.288	0.2	21.8	0	0.6	22.6	62.7	72.0
RM706A2(X7)	706	10700	7	1.4	102	1.3	0.42	5300	24.9	7.7	26.2	19500	14.7	5130	276	0.044	15.9	1180	4.1	1.15	229	2.9	23.35	36.9	97.5	7.084	0.6	32.4	0.4	2.2	35.2	52.2	59.2
RM704A1(X1)	704	10000	0.7	4.9	141	1.1	2	5470	22.8	8.2	25.9	18900	72.4	5800	433	0.23	19.8	1950	2.3	0.65	215	1.65	5.6	31.2	204	7.14	0	48.2	0	0.8	49	40.3	47.4
RM698A1(X1)	698	14000	3.5	7.9	546	1.5	5.3	16000	34.9	11.6	164	29800	309	11600	417	0.87	25.3	2110	3.55	1	249	2.55	11.5	40	954	15.334	0.2	9.2	0	0.4	9.8	64.9	80.3
RM692A1(X1)	692	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
RM689A1(X3)	689	7540	3.7	2.1	78.3	0.8	0.13	4870	16.9	6.7	14.7	15000	12.3	4020	319	0.034	15.1	1370	2.15	0.6	165	1.55	12.4	25.9	62.6	6.556	0	40	0	0.4	40.4	48.9	55.4
RM687A1	687	11000	0.7	5.7	160	0.91	2.1	4170	21.2	8.4	27	19600	136	4480	291	0.41	21	1870	2.2	0.6	120	1.55	5.1	27.6	281	3	3.2	18.6	9.2	9	30.8	57.0	60.0
RM686A1(X3)	686	5470	3.45	1.3	49.6	0.46	0.11	2390	9.1	3.6	10.8	10400	6.6	3300	161	0.01	10.6	714	1.4	0.6	172	1.45	11.55	18.2	40.7	0.132	6.8	45.4	4.9	36.3	88.5	6.3	6.47
RM680A1(X1)	680	9870	3.8	2.4	83.5	0.78	0.26	8360	23.8	9.3	17.9	21700	11.7	5730	343	0.022	25.2	1300	3.6	0.65	167	1.6	12.65	27	76.6	1.792	7.2	47	3.8	16.4	70.6	22.0	23.8
RM678A1(X1)	678	6660	0.35	1.6	60.1	0.67	0.27	4280	16.9	5.6	11.8	13500	9.7	4030	268	0.012	13.9	1040	2.4	0.65	150	1.55	12.6	22.9	58.7	0.884	3	60.9	0.9	13.1	77	20.6	21.4
RM677A1(X3)	677	11800	4.3	2.7	139	1.2	0.4	14800	29.7	10.9	23.7	21200	12	8570	466	0.012	25.4	2370	5	0.7	270	1.8	14.25	38.8	70.4	12.09	0	6.6	0	0.4	7	67.9	80.0
RM676A1(X3)	676	9890	1.3	3.4	115	0.98	0.18	11350	24.4	9.7	21.1	21200	9.85	6490	477.5	0.012	21.8	1920	4	0.65	271	1.6	12.7	34.1	60.05	4.248	0.3	37.2	0	2.2	39.7	50.7	54.9
RM661A1(X1)	661	7830	0.5	3	76.6	0.77	0.32	2430	16.6	7.3	11.3	13700	21.1	3280	162	0.016	14.4	1490	1.15	0.6	76.5	1.5	12.1	22	83.5	0.93	1.6	56.6	8.6	2.2	60.4	29.5	30.4
RM658A1(X3)	658	13500	[a]	5.1	148	1.2	0.405	5085	30.55	12.3	23.1	23500	19.1	7090	568	0.018	27.35	2565	1.7	[a]	296.5	1.5	11.9	38.5	88.75	9.69	1.2	40.7	0.3	6.8	48.7	37.2	46.9
RM644A1(X3)	644	14000	[a]	14.1	162	1.2	0.15	10200	25.9	15	22.6	25900	17.7	7260	641	0.01	26.4	2310	1.75	[a]	197	1.5	12	34.4	64	6.272	2.6	45.2	0.6	6.8	54.6	33.2	39.4
RM642A1(X1)	642	10100	[a]	4.1	94.9	0.91	2.1	2620	17.9	7.7	19.9	16900	82.4	4010	314	0.23	14.8	1800	1.55	[a]	171	1.5	12.15	22.8	292	7.028	0	48.4	0	1.4	49.8	39.2	46.2
RM641A1(X1)	641	13500	[a]	3.4	128	1.3	2.4	3770	24.1	10.3	28	20500	67.7	5230	379	0.34	20.5	2430	4.8	[a]	254	2.35	18.85	29.6	355	15.48	0	12.8	0.2	1	13.8	61.9	77.4
RM640A1(X3)	640	11350	[a]	8.95	120	1	0.325	4120	21.7	13.95	17.6	20950	18.35	5320	498.5	0.02	22.7	2240	1.55	[a]	168	1.45	11.65	29.95	90.15	2.832	0.8	56	1.2	2.4	59.2	32.2	35.1
RM637A1(X1)	637	5620	[a]	3.9	41.1	0.57	0.29	11300	8.3	4.4	3.5	12400	5.7	4700	214	0.006	6.4	1180	1.3	[a]	55.5	1.45	11.65	14.5	30.9	0.0405	6	33.8	14.7	42.8	82.6	2.6	2.69
RM634A1(X1)	634	10400	[a]	13.5	97.2	0.99	0.14	19400	14	9.7	16.5	24800	12.7	7330	458	0.008	13.4	1860	1.95	[a]	68	1.3	10.45	28.1	76.4	0.657	2.2	22	0	61.2	85.4	13.7	14.3
RM628A1(X1)	628	5870	[a]	7.1	38.7	0.46	0.058	8050	7.2	3.6	8.7	12400	7.4	4890	257	0.007	7	1020	3.6	0.6	46	1.45	11.55	9	40.7	0.0585	6.3	6.9	0.2	82.7	95.9	3.8	3.88
RM622A1(X3)	622	9630	[a]	13.7	68.7	0.77	0.16	15300	12	5.7	11.6	17800	10.9	9140	413	0.019	10	1810	1.35	0.5	137	1.25	10.1	17.8	62.5	0.711	1.7	55.8	1.4	25.3	82.8	14.7	15.4
RM616A1(X3)	616	6140	[a]	4.9	47.8	0.51	0.14	4510	10.7	4.5	4.25	12100	6.1	4240	225	0.009	9.5	1120	1.4	[a]	56	1.5	12.2	14.3	49.5	0.411	2.6	63.8	1.7	18.2	84.6	13.2	13.6
RM606A1(X3)	606	8020	[a]	1.55	56.8	0.73	0.28	2290	12.6	5.4	3.95	15300	10.4	4110	217	0.013	10	1400	1.55	[a]	159	1.65	13.4	20.1	102	0.78	2	44.6	3.1	30.8	77.4	18.4	19.2
RM605A1(X1)	605	4680	[a]	1.5	35.5	0.35	0.31	5370	6.4	2.7	3	9830	3.9	4000	138	0.006	5.7	747	1.5	[a]	49.5	1.55	12.4	8.9	27.9	0.022	12.9	5.6	19.5	59.8	78.3	2.2	2.19
RM605A2(X8)	605	10500	[a]	4.2	74.2	0.86	0.67	2690	13.5	6.3	11.5	17800	16.8	5940	243	0.075	11.3	1740	0.85	0.5	184	1.25	10	21.1	140	1.776	0	42.2	0	28.2	70.4	26.0	27.8
RM603A1(X1)	603	12000	[a]	6	125	1.3	0.23	8370	14	11	11.8	24900	11.1	8090	457	0.017	12.7	2430	1.15	0.465	320	1.15	9.3	33.4	94.2	9.0465	4.4	32.3	4	10.4	47.1	36.9	46.0

Note:
[a] Data not reported by USEPA (2005)

Table 16. Correlations between Sediment Toxicity Responses, Metals Concentrations, Sediment Grain Size Distribution, and TOC for Bulk Sediments for the 2005 UCR Study on a Sitewide Basis

	Amphipod Test			Chironomid Test			Daphnid Test		
Analyte	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Aluminum	0.11	-0.45	-0.40	-0.38	-0.14	-0.45	-0.14	-0.42	-0.38
Antimony	-0.61	-0.11	-0.19	0.26	-0.34	0.00	-0.18	-0.22	-0.27
Arsenic	-0.19	-0.05	-0.08	0.12	-0.23	-0.03	-0.20	-0.29	-0.43
Barium	-0.35	-0.41	-0.45	0.14	-0.14	-0.18	-0.10	-0.25	-0.27
Beryllium	0.17	-0.48	-0.42	-0.44	-0.02	-0.48	-0.12	-0.46	-0.37
Cadmium	-0.05	-0.19	-0.24	0.26	0.00	0.18	-0.01	0.04	0.08
Calcium	-0.52	-0.24	-0.30	0.23	-0.28	-0.14	-0.15	-0.15	-0.22
Chromium	-0.30	-0.47	-0.46	-0.13	-0.06	-0.44	0.13	-0.40	-0.23
Cobalt	-0.33	-0.42	-0.45	-0.11	-0.17	-0.35	0.06	-0.52	-0.39
Copper	-0.42	-0.35	-0.38	0.20	-0.12	-0.12	0.01	-0.20	-0.14
Iron	-0.46	-0.38	-0.43	0.08	-0.23	-0.24	-0.06	-0.34	-0.30
Lead	-0.24	-0.29	-0.34	0.25	-0.14	0.00	-0.11	-0.08	-0.13
Magnesium	-0.14	-0.08	-0.13	0.04	0.08	0.03	0.01	-0.18	-0.15
Manganese	-0.49	-0.31	-0.36	0.03	-0.22	-0.25	0.02	-0.41	-0.31
Mercury	-0.02	-0.32	-0.34	0.15	0.11	0.08	-0.06	-0.07	-0.05
Nickel	0.47	-0.32	-0.22	-0.47	0.33	-0.31	0.11	-0.38	-0.22
Potassium	0.04	-0.38	-0.36	-0.29	-0.24	-0.35	-0.12	-0.40	-0.38
Selenium	-0.30	-0.28	-0.29	0.13	0.01	-0.11	0.02	-0.08	-0.06
Silver	0.16	-0.32	-0.20	-0.25	0.32	-0.28	0.01	-0.20	-0.03
Sodium	-0.37	-0.40	-0.41	-0.13	-0.11	-0.41	0.10	-0.36	-0.22
Thallium	0.10	-0.36	-0.28	-0.16	0.24	-0.31	0.18	-0.06	0.09
Uranium	-0.15	-0.20	-0.16	-0.02	0.05	-0.18	0.15	0.04	0.14
Vanadium	0.15	-0.49	-0.41	-0.45	0.06	-0.51	-0.05	-0.46	-0.37
Zinc	-0.39	-0.32	-0.38	0.27	-0.21	-0.03	-0.07	-0.11	-0.11
TOC	0.21	-0.14	-0.12	-0.16	0.38	0.03	0.01	0.10	0.18
Clay	0.48	-0.20	-0.13	-0.45	0.36	-0.13	0.07	-0.23	-0.08
Silt	0.47	-0.20	-0.13	-0.46	0.43	-0.15	0.15	-0.20	-0.02
Sand	-0.51	0.12	0.05	0.47	-0.39	0.12	-0.12	0.12	-0.04
Fines[a]	0.47	-0.20	-0.13	-0.46	0.43	-0.14	0.14	-0.19	-0.02
Coarse Sand	0.18	0.46	0.48	0.12	-0.02	0.37	-0.08	0.11	0.06
Fine Sand	-0.15	-0.03	-0.04	0.27	-0.07	0.09	0.21	0.00	0.11
Medium Sand	-0.17	0.36	0.33	0.27	-0.37	0.24	-0.22	0.19	-0.02
Gravel	0.22	0.35	0.38	0.18	-0.13	0.33	0.00	0.12	0.12

Note:
[a] Fines = silt + clay
TOC - total organic carbon

Table 17. Correlations between Sediment Toxicity Responses, Metals Concentrations, Sediment Grain Size Distribution, and TOC for Bulk Sediments for the 2005 UCR Study for Reaches 1 through 3

	Amphipod Test			Chironomid Test			Daphnid Test		
Analyte	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Aluminum	0.04	-0.38	-0.27	-0.48	-0.11	-0.63	-0.26	-0.17	-0.16
Antimony	-0.60	-0.27	-0.30	0.07	-0.34	-0.27	-0.08	-0.38	-0.38
Arsenic	-0.29	-0.12	-0.12	0.05	-0.21	-0.31	-0.05	-0.08	-0.26
Barium	-0.53	-0.43	-0.49	0.07	-0.50	-0.35	-0.41	-0.23	-0.54
Beryllium	0.17	-0.37	-0.24	-0.52	0.00	-0.62	-0.24	-0.27	-0.20
Cadmium	0.02	0.17	0.09	0.23	0.04	0.33	-0.08	0.08	-0.04
Calcium	-0.55	-0.42	-0.49	0.23	-0.64	-0.27	-0.44	-0.16	-0.54
Chromium	-0.53	-0.38	-0.40	-0.18	-0.29	-0.61	0.00	-0.43	-0.34
Cobalt	-0.55	-0.33	-0.38	-0.10	-0.34	-0.49	0.01	-0.34	-0.32
Copper	-0.65	-0.30	-0.38	0.15	-0.50	-0.25	-0.17	-0.29	-0.41
Iron	-0.62	-0.34	-0.41	0.01	-0.46	-0.37	-0.22	-0.23	-0.34
Lead	-0.29	-0.08	-0.16	0.19	-0.39	-0.06	-0.27	0.07	-0.24
Magnesium	-0.03	0.12	0.06	0.14	0.12	0.20	-0.01	0.00	-0.12
Manganese	-0.63	-0.31	-0.39	0.06	-0.49	-0.37	-0.13	-0.20	-0.31
Mercury	0.04	-0.08	-0.10	0.04	0.01	0.20	-0.29	-0.15	-0.31
Nickel	0.63	0.02	0.16	-0.33	0.36	-0.09	0.00	0.01	0.11
Potassium	-0.01	-0.38	-0.34	-0.35	-0.24	-0.48	-0.28	-0.16	-0.26
Selenium	-0.10	-0.23	-0.22	0.06	-0.34	-0.14	-0.31	-0.20	-0.34
Silver	0.25	-0.26	-0.13	-0.31	0.27	-0.20	-0.13	-0.26	-0.18
Sodium	-0.52	-0.42	-0.43	-0.14	-0.36	-0.58	-0.08	-0.41	-0.35
Thallium	0.29	-0.25	-0.12	-0.24	0.20	-0.22	-0.04	-0.25	-0.12
Uranium	-0.17	-0.28	-0.23	0.00	-0.03	-0.19	-0.07	-0.13	-0.14
Vanadium	0.23	-0.34	-0.20	-0.49	-0.03	-0.61	-0.30	-0.14	-0.19
Zinc	-0.66	-0.31	-0.41	0.16	-0.53	-0.26	-0.21	-0.24	-0.40
TOC	0.59	0.33	0.43	-0.42	0.64	0.16	-0.03	0.33	0.42
Clay	0.56	0.25	0.35	-0.39	0.53	0.19	-0.01	0.18	0.30
Silt	0.60	0.33	0.42	-0.35	0.61	0.20	0.12	0.21	0.37
Sand	-0.63	-0.38	-0.46	0.30	-0.62	-0.29	-0.07	-0.22	-0.35
Fines[a]	0.60	0.33	0.42	-0.35	0.61	0.20	0.12	0.21	0.37
Coarse Sand	0.15	0.51	0.47	0.28	0.22	0.71	-0.04	0.20	0.19
Fine Sand	-0.42	-0.10	-0.21	0.31	-0.20	-0.06	0.31	-0.19	-0.09
Medium Sand	-0.16	0.13	0.11	0.19	-0.28	0.14	-0.10	0.09	-0.05
Gravel	0.16	0.33	0.33	0.33	0.01	0.42	-0.03	-0.01	0.00

Note:

[a] Fines = silt + clay

TOC - total organic carbon

Table 18. Correlations between Sediment Toxicity Responses, Metals Concentrations, Sediment Grain Size Distribution, and TOC for Bulk Sediments for the 2005 UCR Study for Reaches 4 through 6

	Amphipod Test			Chironomid Test			Daphnid Test		
Analyte	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Aluminum	0.09	-0.57	-0.64	-0.19	-0.04	-0.19	-0.02	-0.56	-0.50
Antimony	-0.47	-0.25	-0.22	-0.77	0.08	-0.77	-0.01	-0.20	-0.05
Arsenic	-0.05	-0.04	-0.12	0.18	-0.22	0.28	-0.44	-0.49	-0.62
Barium	0.12	-0.67	-0.70	-0.32	0.15	-0.37	0.15	-0.66	-0.53
Beryllium	0.11	-0.60	-0.65	-0.28	0.08	-0.23	0.03	-0.60	-0.51
Cadmium	0.34	-0.52	-0.56	0.02	-0.15	-0.09	0.09	0.08	0.17
Calcium	-0.20	-0.13	-0.12	-0.23	0.02	-0.30	0.06	-0.28	-0.24
Chromium	0.25	-0.69	-0.66	-0.45	0.29	-0.48	0.35	-0.51	-0.34
Cobalt	0.17	-0.55	-0.58	-0.37	0.08	-0.26	0.07	-0.73	-0.60
Copper	0.12	-0.69	-0.69	-0.31	0.34	-0.39	0.25	-0.52	-0.40
Iron	0.06	-0.56	-0.61	-0.37	0.00	-0.36	0.01	-0.69	-0.62
Lead	0.24	-0.58	-0.62	-0.04	0.03	-0.08	-0.08	-0.44	-0.40
Magnesium	-0.11	-0.27	-0.33	-0.18	-0.08	-0.15	-0.10	-0.40	-0.41
Manganese	-0.02	-0.38	-0.39	-0.41	0.12	-0.26	0.11	-0.74	-0.63
Mercury	0.39	-0.57	-0.57	-0.17	0.22	-0.15	0.12	-0.18	-0.13
Nickel	0.21	-0.64	-0.60	-0.48	0.29	-0.48	0.31	-0.60	-0.43
Potassium	0.06	-0.45	-0.52	-0.18	-0.12	-0.12	0.08	-0.61	-0.47
Selenium	-0.21	-0.40	-0.37	-0.29	0.50	-0.42	0.37	-0.14	-0.08
Silver	0.11	-0.52	-0.30	-0.51	0.60	-0.65	0.42	-0.03	0.14
Sodium	0.14	-0.46	-0.50	-0.43	0.19	-0.33	0.19	-0.42	-0.35
Thallium	0.05	-0.43	-0.36	-0.31	0.34	-0.55	0.53	0.17	0.35
Uranium	-0.01	-0.08	0.01	-0.31	0.21	-0.32	0.56	0.22	0.47
Vanadium	0.13	-0.65	-0.65	-0.46	0.26	-0.44	0.21	-0.65	-0.51
Zinc	0.26	-0.58	-0.65	-0.05	-0.04	-0.06	-0.10	-0.30	-0.28
TOC	0.13	-0.63	-0.65	-0.15	0.15	-0.25	0.08	-0.13	-0.11
Clay	0.22	-0.69	-0.69	-0.37	0.25	-0.35	0.29	-0.45	-0.31
Silt	0.12	-0.76	-0.76	-0.38	0.37	-0.42	0.39	-0.42	-0.25
Sand	-0.14	0.76	0.75	0.41	-0.28	0.48	-0.47	0.33	0.13
Fines[a]	0.15	-0.75	-0.74	-0.36	0.36	-0.41	0.37	-0.41	-0.26
Coarse Sand	-0.01	0.37	0.39	0.14	-0.22	0.03	-0.08	0.12	0.05
Fine Sand	0.54	0.12	0.24	-0.07	0.08	0.19	0.08	-0.06	0.06
Medium Sand	-0.29	0.64	0.58	0.45	-0.44	0.37	-0.44	0.33	0.11
Gravel	0.24	0.34	0.37	0.18	-0.38	0.13	0.07	0.21	0.32

Note:
[a] Fines = silt + clay
TOC - total organic carbon

Table 19. Summary of PECQs and mPECQs for the 2005 Sediment Toxicity Study

Location ID	RM	Mean PECQ	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
RM744A1(X1)	744	1.28	0.21	0.30	0.24	2.62	1.10	0.14	0.20	5.40
RM744A2(X3)	744	4.36	0.32	*0.06U*	0.81	10.30	1.43	0.05	0.23	21.70
RM743A1(X1)	743	1.36	0.26	0.40	0.26	2.39	1.57	0.16	0.23	5.58
RM743A2(X3)	743	1.19	0.14	0.34	0.26	2.18	1.11	0.11	0.20	5.19
RM742A1(X1)	742	1.50	0.19	0.68	0.27	2.68	1.42	0.15	0.22	6.36
RM742A2(X5)	742	3.69	0.25	0.13	0.65	8.32	1.73	0.05	0.22	18.10
RM741A1(X3)	741	1.58	0.25	0.42	0.30	3.07	1.30	0.16	0.20	6.95
RM740A1(X1)	740	0.81	0.16	0.40	0.19	1.21	0.92	0.13	0.23	3.22
RM739A1(X3)	739	1.17	0.24	0.36	0.26	2.46	0.89	0.28	0.25	4.62
RM738A1(X3)	738	6.49	0.26	0.05	0.90	10.90	1.68	[a]	0.19	31.40
RM737A1(X3)	737	5.34	0.11	0.24	1.00	12.90	1.27	0.21	0.24	26.80
RM736A1(X1)	736	1.02	0.15	0.86	0.19	0.87	1.67	0.31	0.31	3.83
RM734A1	734	1.84	*0.02U*	0.36	0.23	2.66	1.16	0.08	0.14	10.00
RM733A1(X1)	733	4.30	0.20	0.58	0.35	4.30	10.90	0.08	0.20	17.90
RM730A1	730	2.04	0.07	0.70	0.23	2.68	2.08	0.15	0.16	10.20
RM729A1(X1)	729	0.64	0.06	0.22	0.13	1.23	0.53	0.06	0.13	2.72
RM727A1(X1)	727	0.82	0.24	0.60	0.17	0.87	1.32	0.31	0.25	2.79
RM724A1(X1)	724	0.16	0.09	0.03	0.20	0.14	0.13	0.02	0.45	0.20
RM724A2(X3)	724	3.52	*0.03U*	0.44	0.44	6.50	2.09	0.10	0.22	18.30
RM723A1(X1)	723	0.16	0.07	0.11	0.11	0.15	0.19	0.04	0.25	0.39
RM723A2(X3)	723	1.17	0.13	0.54	0.18	1.31	1.59	0.37	0.25	4.99
RM713A1(X3)	713	0.56	0.14	0.57	0.18	0.44	1.16	0.52	0.33	1.17
RM708A1(X3)	708	0.90	0.18	0.96	0.19	0.71	1.50	0.41	0.34	2.92
RM706A1(X1)	706	0.72	0.14	0.76	0.19	0.53	1.54	0.62	0.32	1.66
RM706A2(X7)	706	0.15	0.04	0.08	0.22	0.18	0.12	0.04	0.33	0.21
RM704A1(X1)	704	0.32	0.15	0.40	0.21	0.17	0.57	0.22	0.41	0.44
RM698A1(X1)	698	1.07	0.24	1.06	0.31	1.10	2.41	0.82	0.52	2.08
RM692A1(X1)	692	0.06	0.02	*0.06U*	0.07	0.04	0.03	*0.06U*	0.14	0.07
RM689A1(X3)	689	0.11	0.06	0.03	0.15	0.10	0.10	0.03	0.31	0.14
RM687A1	687	0.43	0.17	0.42	0.19	0.18	1.06	0.39	0.43	0.61
RM686A1(X3)	686	0.07	0.04	0.02	0.08	0.07	0.05	0.01	0.22	0.09
RM680A1(X1)	680	0.16	0.07	0.05	0.21	0.12	0.09	0.02	0.52	0.17
RM678A1(X1)	678	0.10	0.05	0.05	0.15	0.08	0.08	0.01	0.29	0.13
RM677A1(X3)	677	0.17	0.08	0.08	0.27	0.16	0.09	0.01	0.52	0.15
RM676A1(X3)	676	0.15	0.10	0.04	0.22	0.14	0.08	0.01	0.45	0.13
RM661A1(X1)	661	0.13	0.09	0.06	0.15	0.08	0.17	0.02	0.30	0.18
RM658A1(X3)	658	0.20	0.16	0.08	0.28	0.16	0.15	0.02	0.56	0.19
RM644A1(X3)	644	0.21	0.43	0.03	0.23	0.15	0.14	0.01	0.54	0.14
RM642A1(X1)	642	0.33	0.12	0.42	0.16	0.13	0.64	0.22	0.31	0.64
RM641A1(X1)	641	0.38	0.10	0.48	0.22	0.19	0.53	0.32	0.42	0.77
RM640A1(X3)	640	0.18	0.27	0.07	0.20	0.12	0.14	0.02	0.47	0.20
RM637A1(X1)	637	0.07	0.12	*0.06U*	0.07	*0.02U*	0.04	0.01	0.13	0.07
RM634A1(X1)	634	0.15	0.41	0.03	0.13	0.11	0.10	0.01	0.28	0.17
RM628A1(X1)	628	0.08	0.22	0.01	0.06	0.06	0.06	0.01	0.14	0.09
RM622A1(X3)	622	0.14	0.42	0.03	0.11	0.08	0.09	0.02	0.21	0.14
RM616A1(X3)	616	0.08	0.15	0.03	0.10	*0.03U*	0.05	0.01	0.20	0.11
RM606A1(X3)	606	0.10	*0.05U*	0.06	0.11	*0.03U*	0.08	0.01	0.21	0.22
RM605A1(X1)	605	0.05	*0.05U*	*0.06U*	0.06	*0.02U*	0.03	0.01	0.12	0.06
RM605A2(X8)	605	0.15	0.13	0.14	0.12	0.08	0.13	0.07	0.23	0.31
RM603A1(X1)	603	0.13	0.18	0.05	0.13	0.08	0.09	0.02	0.26	0.21

Notes:
MPECQ - mean probable effect concentration quotient
PECQ - probable effect concentration quotient
U = unidentified
[a] Data not reported by USEPA (2006)

Table 20. Correlations between Sediment Toxicity Responses and PECQs and mPECQs for Bulk Sediments for the 2005 UCR Study on a Sitewide Basis

	Amphipod Test			Chironomid Test			Daphnid Test		
PECQ	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Arsenic	-0.20	-0.06	-0.10	0.12	-0.25	-0.03	-0.23	-0.32	-0.46
Cadmium	-0.06	-0.19	-0.24	0.26	-0.02	0.17	-0.03	0.02	0.06
Chromium	-0.30	-0.47	-0.47	-0.12	-0.07	-0.43	0.09	-0.42	-0.27
Copper	-0.42	-0.35	-0.38	0.20	-0.13	-0.12	-0.03	-0.24	-0.19
Lead	-0.24	-0.29	-0.34	0.24	-0.16	0.00	-0.14	-0.13	-0.18
Mercury	-0.03	-0.31	-0.33	0.15	0.10	0.09	-0.06	-0.06	-0.05
Nickel	0.44	-0.33	-0.24	-0.46	0.29	-0.30	0.07	-0.40	-0.26
Zinc	-0.39	-0.32	-0.38	0.27	-0.23	-0.03	-0.10	-0.15	-0.16
Mean PECQ	-0.41	-0.36	-0.41	0.22	-0.22	-0.10	-0.09	-0.24	-0.23

Notes:

MPECQ - mean probable effect concentration quotient

PECQ - probable effect concentration quotient

Table 21. Correlations between Sediment Toxicity Responses and PECQs and mPECQs for Bulk Sediments for the 2005 UCR Study for Reaches 1 through 3

	Amphipod Test			Chironomid Test			Daphnid Test		
PECQ	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Arsenic	-0.29	-0.12	-0.12	0.05	-0.21	-0.31	-0.05	-0.08	-0.26
Cadmium	0.02	0.17	0.09	0.23	0.04	0.33	-0.08	0.08	-0.04
Chromium	-0.53	-0.38	-0.40	-0.18	-0.29	-0.61	0.00	-0.43	-0.34
Copper	-0.65	-0.30	-0.38	0.15	-0.50	-0.25	-0.17	-0.29	-0.41
Lead	-0.29	-0.08	-0.16	0.19	-0.39	-0.06	-0.27	0.07	-0.24
Mercury	0.04	-0.08	-0.10	0.04	0.01	0.20	-0.29	-0.15	-0.31
Nickel	0.63	0.02	0.16	-0.33	0.36	-0.09	0.00	0.01	0.11
Zinc	-0.66	-0.31	-0.41	0.16	-0.53	-0.26	-0.21	-0.24	-0.40
Mean PECQ	-0.67	-0.33	-0.43	0.17	-0.56	-0.28	-0.23	-0.23	-0.41

Notes:
MPECQ - mean probable effect concentration quotient
PECQ - probable effect concentration quotient

Table 22. Correlations between Sediment Toxicity Responses and PECQs and mPECQs for Bulk Sediments for the 2005 UCR Study for Reaches 4 through 6

	Amphipod Test			Chironomid Test			Daphnid Test		
PECQ	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Arsenic	-0.05	-0.06	-0.15	0.17	-0.30	0.26	-0.50	-0.53	-0.66
Cadmium	0.33	-0.49	-0.53	0.03	-0.18	-0.08	0.07	0.09	0.16
Chromium	0.23	-0.68	-0.67	-0.44	0.20	-0.45	0.23	-0.56	-0.40
Copper	0.10	-0.69	-0.69	-0.31	0.26	-0.36	0.15	-0.56	-0.46
Lead	0.22	-0.58	-0.64	-0.04	-0.05	-0.07	-0.17	-0.49	-0.47
Mercury	0.37	-0.55	-0.54	-0.16	0.24	-0.13	0.15	-0.09	-0.05
Nickel	0.18	-0.63	-0.62	-0.46	0.21	-0.44	0.19	-0.64	-0.50
Zinc	0.23	-0.58	-0.67	-0.06	-0.11	-0.05	-0.18	-0.37	-0.36
Mean PECQ	0.14	-0.65	-0.69	-0.18	0.02	-0.22	-0.05	-0.55	-0.49

Notes:
MPECQ - mean probable effect concentration quotient
PECQ - probable effect concentration quotient

Table 23. Summary of SEM, AVS, TOC, and Related Parameters for the 2005 Sediment Toxicity Study

Location ID	RM	Cadmium	Copper	Lead	Nickel	Zinc	∑SEM	AVS	TOC	∑SEM- AVS	(∑SEM- AVS)/foc
RM744A1(X1)	744	0.00480	3.98	0.632	0.0477	39.6	44.3	0.0470	0.40	[b]	[b]
RM744A2(X3)	744	0.000100	15.4	0.710	0.0784	153	169	8.70	0.11	160	143000
RM743A1(X1)	743	0.0125	2.97	0.806	0.0630	29.4	33.2	0.965	0.70	32.3	4600
RM743A2(X3)	743	0.00810	3.64	0.618	0.0443	31.5	35.8	2.60	0.25	33.2	13500
RM742A1(X1)	742	0.00840	5.27	0.792	0.0477	54.9	61.0	4.70	0.09	56.3	62900
RM742A2(X5)	742	0.000100	6.85	0.618	0.0409	84.6	92.1	11.6	0.14	80.5	56300
RM741A1(X3)	741	0.00660	3.05	0.579	0.0443	29.8	33.5	3.70	0.43	29.8	6920
RM740A1(X1)	740	0.00810	1.86	0.408	1.22	15.2	18.7	1.06	0.54	17.6	3240
RM739A1(X3)	739	0.0160	1.59	0.454	0.227	14.9	17.2	2.10	0.57	15.1	2660
RM738A1(X3)	738	0.0133	0.000200	0.0555	0.448	126	126	1.39	0.33	125	38400
RM737A1(X3)	737	0.0222	13.8	0.642	0.366	171	186	2.50	0.14	184	128000
RM736A1(X1)	736	0.0151	1.33	0.787	0.600	13.9	16.6	0.610	0.63	16.0	2550
RM734A1	734	0.0196	3.90	0.681	0.0221	76.3	81.0	25.0	0.15	56.0	36300
RM733A1(X1)	733	0.0205	5.30	2.51	0.0213	101	109	0.690	0.38	108	28300
RM730A1	730	0.0240	4.14	1.25	0.0153	88.5	93.9	2.10	0.15	91.8	59600
RM729A1(X1)	729	0.00390	1.76	0.349	0.0204	17.9	20.0	0.340	0.26	19.7	7490
RM727A1(X1)	727	0.0173	1.46	0.888	0.0698	15.2	17.7	0.0755	0.68	[b]	[b]
RM724A1(X1)	724	0.00810	0.848	0.354	0.213	8.29	9.71	1.70	1.07	8.01	749
RM724A2(X3)	724	0.0160	5.00	0.787	0.0477	77.5	83.4	12.3	0.64	71.1	11200
RM723A1(X1)	723	0.0178	0.966	0.478	0.0647	7.57	9.10	0.287	0.38	8.81	2350
RM723A2(X3)	723	0.0214	1.78	0.936	0.777	17.9	21.4	0.0340	1.44	[b]	[b]
RM713A1(X3)	713	0.0147	0.729	0.707	0.915	5.83	8.19	0.122	0.90	8.07	896
RM708A1(X3)	708	0.0160	0.870	0.695	0.0681	10.4	12.0	0.375	1.47	11.7	793
RM706A1(X1)	706	0.0302	1.02	1.17	0.104	11.8	14.1	0.127	1.96	14.0	715
RM706A2(X7)	706	0.00200	0.197	0.0569	0.0511	0.558	0.865	0.790	2.91	0.0800	2.60
RM704A1(X1)	704	0.00980	0.217	0.204	0.0766	1.43	1.94	[a]	0.80	[b]	[b]
RM698A1(X1)	698	0.0356	2.01	1.17	0.119	10.3	13.6	[a]	2.17	[b]	[b]
RM692A1(X1)	692	0.000800	0.0102	0.0138	0.00870	0.111	0.144	[a]	0.04	[b]	[b]
RM689A1(X3)	689	0.00380	0.156	0.0714	0.0647	0.618	0.914	0.0218	0.39	[b]	[b]
RM687A1	687	0.0391	0.505	2.17	0.0937	8.95	11.8	[a]	1.67	[b]	[b]
RM686A1(X3)	686	0.00110	0.0378	0.0208	0.0123	0.165	0.237	[a]	0.06	[b]	[b]
RM680A1(X1)	680	0.00240	0.0834	0.0449	0.0511	0.430	0.612	[a]	0.27	[b]	[b]
RM678A1(X1)	678	0.00230	0.192	0.0454	0.809	0.468	1.52	0.0720	0.14	[b]	[b]
RM677A1(X3)	677	0.00470	0.176	0.0560	0.128	0.292	0.657	[a]	0.53	[b]	[b]

Table 23. Summary of SEM, AVS, TOC, and Related Parameters for the 2005 Sediment Toxicity Study

Location ID	RM	Cadmium	Copper	Lead	Nickel	Zinc	∑SEM	AVS	TOC	∑SEM- AVS	(∑SEM- AVS)/foc
RM676A1(X3)	676	0.00130	0.0960	0.0311	0.0707	0.201	0.400	0.0370	0.11	[b]	[b]
RM661A1(X1)	661	0.00110	0.0928	0.0767	0.451	0.431	1.05	[a]	0.14	[b]	[b]
RM658A1(X3)	658	0.00640	0.389	0.0827	1.38	0.659	2.51	[a]	0.25	[b]	[b]
RM644A1(X3)	644	0.00180	0.0710	0.0410	0.0477	0.188	0.350	0.00780	0.14	[b]	[b]
RM642A1(X1)	642	0.0302	0.274	0.476	0.0358	4.07	4.89	0.0870	0.72	[b]	[b]
RM641A1(X1)	641	0.0214	0.220	0.341	0.121	4.50	5.20	0.0690	1.41	[b]	[b]
RM640A1(X3)	640	0.00130	0.0747	0.0630	0.116	0.346	0.601	0.0139	0.22	[b]	[b]
RM637A1(X1)	637	0.000200	0.0220	0.0101	0.00500	0.0811	0.119	0.00950	0.04	[b]	[b]
RM634A1(X1)	634	0.000700	0.0346	0.0188	0.0153	0.0964	0.166	0.00950	0.07	[b]	[b]
RM628A1(X1)	628	0.000800	0.0283	0.0179	0.00620	0.194	0.248	0.0270	0.12	[b]	[b]
RM622A1(X3)	622	0.00250	0.0708	0.0473	0.0162	0.401	0.538	[a]	0.12	[b]	[b]
RM616A1(X3)	616	0.00180	0.0441	0.0251	0.0102	0.350	0.432	0.0103	0.12	[b]	[b]
RM606A1(X3)	606	0.00140	0.0362	0.0405	0.0102	0.841	0.930	0.0112	0.27	[b]	[b]
RM605A1(X1)	605	0.00100	0.0378	0.00970	0.0511	0.136	0.236	0.00350	0.06	[b]	[b]
RM605A2(X8)	605	0.00560	0.0456	0.0550	0.0204	1.11	1.23	[a]	0.41	[b]	[b]
RM603A1(X1)	603	0.00210	0.0677	0.0212	0.0341	0.150	0.275	[a]	0.10	[b]	[b]

Notes:

AVS - acid volatile sulfide

SEM - simultaneously extracted metals

foc - fraction organic carbon

TOC - total organic carbon

Concentrations are in μmol/g, except TOC, which is in percent.

[a] Data not reported by USEPA (2006)

[b] Paramerter was not calculated because AVS concentration was less than 0.1 μmol/g or AVS concentration was not reported. See text for detailed explanation

Table 24. Correlations between SEM, (∑SEM-AVS), and Sediment Toxicity Responses for the 2005 Study on a Sitewide Basis

Analyte	Amphipod Test			Chironomid Test			Daphnid Test		
	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
SEM Cadmium	0.00	-0.20	-0.23	0.17	0.05	0.15	-0.01	-0.01	0.02
SEM Copper	-0.24	-0.23	-0.25	0.28	-0.03	0.00	0.14	-0.16	0.00
SEM Lead	-0.14	-0.27	-0.30	0.28	-0.04	0.07	-0.01	-0.08	-0.05
SEM Nickel	0.30	-0.29	-0.20	-0.14	0.16	-0.09	0.07	-0.24	-0.15
SEM Zinc	-0.37	-0.29	-0.33	0.32	-0.20	-0.02	-0.04	-0.04	-0.06
∑SEM - AVS	-0.36	-0.29	-0.34	0.34	-0.23	-0.01	0.00	-0.06	-0.09

Notes:

AVS - acid volatile sulfide

SEM - simultaneously extracted metals

Table 25. Correlations between SEM, (∑SEM-AVS), and Sediment Toxicity Responses for the 2005 Study in Reaches 1 through 3

	Amphipod Test			Chironomid Test			Daphnid Test		
Analyte	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
SEM Cadmium	0.08	0.12	0.06	0.26	-0.19	0.40	-0.21	0.11	-0.02
SEM Copper	-0.51	-0.11	-0.20	0.37	-0.37	-0.04	0.08	-0.25	-0.20
SEM Lead	-0.16	0.04	-0.04	0.45	-0.27	0.25	-0.17	0.10	-0.11
SEM Nickel	0.39	-0.07	0.02	-0.21	0.11	0.04	-0.21	-0.16	-0.25
SEM Zinc	-0.65	-0.32	-0.42	0.28	-0.60	-0.21	-0.21	-0.18	-0.39
∑SEM - AVS	-0.65	-0.32	-0.42	0.31	-0.62	-0.20	-0.22	-0.19	-0.41

Notes:

AVS - acid volatile sulfide

SEM - simultaneously extracted metals

Table 26. Correlations between SEM, (∑SEM-AVS), and Sediment Toxicity Responses for the 2005 Study in Reaches 4 through 6

	Amphipod Test			Chironomid Test			Daphnid Test		
Analyte	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
SEM Cadmium	0.27	-0.62	-0.60	-0.15	0.13	-0.27	0.20	-0.17	-0.09
SEM Copper	0.39	-0.68	-0.62	-0.26	0.26	-0.34	0.30	-0.36	-0.20
SEM Lead	0.36	-0.58	-0.56	-0.10	0.13	-0.13	0.10	-0.29	-0.19
SEM Nickel	0.35	-0.54	-0.47	-0.21	0.18	-0.23	0.32	-0.32	-0.12
SEM Zinc	0.33	-0.45	-0.45	0.05	0.08	-0.08	0.06	0.03	0.02
∑SEM - AVS	0.40	-0.57	-0.55	-0.02	0.09	-0.15	0.13	-0.07	-0.01

Notes:
AVS - acid volatile sulfide
SEM - simultaneously extracted metals

Table 27. Summary of Correlations between Sediment Toxicity Responses and Toxic Units for Porewater for the 2005 Sediment Toxicity Study on a Sitewide Basis

	Amphipod Test			Chironomid Test			Daphnid Test		
Analyte	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Arsenic	0.22	0.50	0.44	0.48	-0.41	0.54	-0.28	0.37	0.43
Cadmium	0.03	-0.37	-0.34	-0.12	0.13	-0.41	0.09	-0.14	-0.02
Chromium	-0.31	0.13	0.05	0.15	-0.51	-0.01	-0.13	-0.15	-0.23
Copper	-0.24	-0.36	-0.36	0.11	-0.19	-0.28	0.06	-0.10	-0.12
Lead	0.05	-0.41	-0.39	-0.10	-0.13	-0.12	-0.34	-0.23	-0.49
Mercury	0.10	-0.13	-0.11	-0.19	0.14	-0.16	-0.02	0.08	0.05
Nickel	0.14	-0.32	-0.25	0.23	-0.54	-0.27	-0.21	-0.23	-0.42
Selenium	0.00	0.11	0.11	-0.36	0.39	-0.21	0.69	-0.57	-0.36
Zinc	-0.48	-0.29	-0.35	0.27	-0.33	-0.15	-0.13	-0.20	-0.22
Hardness	0.20	0.58	0.59	0.06	0.47	0.51	0.25	0.37	0.47

Note:

Shaded cells highlight relationships with |ρ| ≥ 0.63

Table 28. Summary of Correlations between Sediment Toxicity Responses and Toxic Units for Porewater for the 2005 Sediment Toxicity Study in Reaches 1 through 3

	Amphipod Test			Chironomid Test			Daphnid Test		
Analyte	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Arsenic	0.74	0.21	0.21	-0.95	0.95	-0.63	0.78	-0.74	0.95
Cadmium	-0.01	-0.09	-0.03	0.14	-0.21	-0.09	-0.30	0.35	0.13
Chromium	-0.36	-0.12	-0.21	0.43	-0.46	0.01	0.07	-0.34	-0.36
Copper	-0.46	-0.18	-0.24	0.18	-0.39	-0.33	-0.05	-0.09	-0.19
Lead	-0.13	-0.29	-0.28	0.18	-0.33	0.01	-0.41	-0.22	-0.26
Mercury	0.04	0.10	0.14	-0.06	0.06	0.01	0.03	0.42	0.38
Nickel	0.05	-0.90	-0.81	0.53	-0.57	-0.40	-0.24	-0.62	-0.93
Selenium	-0.30	0.40	0.40	-0.36	0.20	-0.20	0.89	-0.30	-0.10
Zinc	-0.54	-0.34	-0.42	0.20	-0.31	-0.27	-0.05	-0.33	-0.34
Hardness	0.43	0.79	0.79	-0.05	0.63	0.58	0.40	0.52	0.64

Note:
Shaded cells highlight relationships with |ρ| ≥ 0.63

Table 29. Summary of Correlations between Sediment Toxicity Responses and Toxic Units for Porewater for the 2005 Sediment Toxicity Study in Reaches 4 through 6

	Amphipod Test			Chironomid Test			Daphnid Test		
Analyte	Survival	Biomass	Total Biomass	Survival	Biomass	Total Biomass	Survival	Young / Survivor	Total Young
Arsenic	0.21	0.67	0.62	0.81	-0.83	0.91	-0.87	0.54	0.38
Cadmium	0.20	-0.58	-0.49	-0.43	0.41	-0.71	0.44	-0.31	-0.04
Chromium	-0.48	0.49	0.41	0.14	-0.47	0.17	-0.34	0.12	0.10
Copper	0.37	-0.64	-0.57	-0.39	0.48	-0.57	0.38	-0.25	-0.10
Lead	0.45	-0.35	-0.36	0.09	-0.16	0.10	-0.48	-0.16	-0.55
Mercury	0.14	-0.51	-0.48	-0.24	0.14	-0.37	-0.10	-0.10	-0.30
Nickel	0.04	0.11	0.13	0.18	-0.61	-0.13	-0.19	0.13	0.10
Selenium									
Zinc	-0.35	-0.06	-0.11	0.24	-0.13	0.05	-0.14	0.07	0.03
Hardness	-0.05	0.27	0.27	0.14	0.13	0.39	-0.06	0.10	0.12

Note:

Empty cells correspond to metals that had fewer than five detected values.

Shaded cells highlight relationships with |ρ| ≥ 0.63

APPENDIX F

EVALUATION OF EXISTING FISH TISSUE DATA

CONTENTS

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ACRONYMS AND ABBREVIATIONS

AFDW	ash-free dry weight
ANOVA	analysis of variance
AWQC	ambient water quality criteria
B.C. MoE	British Columbia Ministry of Environment
BCF	bioconcentration factor
BERA	baseline ecological risk assessment
CBR	critical body residue
CCME	Canadian Council of Ministers of the Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRIEMP	Columbia River Integrated Environmental Monitoring Program
CV	coefficient of variation
DDD	dichloro-diphenyl-dichloroethane
DDE	dichloro-diphenyl-dichloroethene
DDT	dichloro-diphenyl-trichloroethane
DL	detection limit
DMA	dimethylarsenic acid
DOH	U.S. Department of Health
dw	dry weight
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
EVS	EVS Environmental Consultants, Inc.
FSCA	fish sample collection area
NCBP	National Contaminant Biomonitoring Program
NOAEC	no-observed-adverse-effects-concentration
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
QA/QC	quality assurance and quality control
QAPP	Quality Assurance Project Plan
RESET	Regression Equation Specification Error test
rho	Spearman rank coefficient
RI/FS	remedial investigation and feasibility study
RM	River Mile
SLERA	Screening Level Ecological Risk Assessment
SSD	species sensitivity distribution
TCAI	Teck Cominco American Incorporated

TCDD	tetrachlorodibenzo-*p*-dioxin
TCDF	tetrachlorodibenzofuran
TEF	toxic equivalency factor
TEQ	toxic equivalent
TRA	tissue residue approach
TRV	toxicity reference value
UCR	Upper Columbia River
USGS	U.S. Geological Survey
ww	wet weight

UNITS OF MEASURE

in.	inche(s)
mg/kg	milligrams per kilogram
μg/kg	micrograms per kilogram

1 INTRODUCTION

One or more species and size classes of fish will be considered ecological receptors in the baseline ecological risk assessment (BERA), and several species and size classes will be sampled for chemical analysis to assess risks to piscivorous fish and wildlife, and to people. This appendix is intended to address fish tissue chemistry data collected to date for the Upper Columbia River (UCR), specifically to

- Determine the usefulness of historical (i.e., pre-2005) fish tissue data and the 2005 U.S. Environmental Protection Agency (EPA) (USEPA 2007) fish tissue data fish tissue data for planning and scoping future fish tissue sampling programs and the BERA.
- Analyze the historical and 2005 data to identify potential spatial and temporal patterns in residues of chemicals in fish from the UCR.
- Evaluate fish tissue data interpretations by authors of historical reports, and by EPA (USEPA 2007).
- Describe potential reference conditions by compiling available tissue data from area lakes previously sampled in Eastern Washington.
- Gather and evaluate information on polybrominated diphenyl ethers (PBDEs) in fish tissue.

The studies evaluated in this appendix are historical and were not necessarily conducted for the UCR RI/FS and BERA and may not meet the current standards of practice and/or the data quality requirements necessary for completion of the BERA. However, for purposes of this BERA Work Plan, the data and analyses are assumed to be adequate to assist in identifying data gaps and describing general site characteristics, but may not be acceptable for use in future deliverables in their current form.

As the BERA progresses, the quality of the existing data, data analysis procedures, and suitability for inclusion in the BERA will be assessed according to procedures that will be reviewed and approved by the EPA. In addition, clear explanations of the data used in evaluations, evaluation methodology, and statistical analysis documentation will be provided in future documents.

2 USEFULNESS OF EXISTING UCR FISH TISSUE DATA FOR ECOLOGICAL RISK ASSESSMENT

Several studies involving the collection and chemical analyses of fish tissue have been conducted in the UCR since the early 1970s. Target chemical analytes have included metals[1], polychlorinated biphenyls (PCBs), dioxins and furans, and pesticides (Hopkins et al. 1985; Johnson 1991; Johnson et al. 1988, 1989, 1990, 1991a,b; Johnson and Yake 1989; Serdar et al. 1991, 1994; Johnson and Serdar 1991; Serdar et al. 1994; Munn et al. 1995; EVS 1998; Hinck et al. 2004, 2006; USGS 2006). More recently, EPA collected and analyzed fish tissue from six locations across the UCR site in 2005 (USEPA 2007) and is refreed herein as Phase 1 data.

2.1 EVALUATION OF HISTORICAL UCR FISH TISSUE DATA

As noted previously, several studies involving the collection and chemical analyses of fish tissue have been conducted in the UCR since the early 1970s (Table 1). Target chemical analytes have included metals, PCBs, dioxins and furans, and pesticides. This section evaluates the applicability of historical UCR fish tissue data (those data preceding EPA's 2005 investigation) to the ecological risk assessment, within the framework outlined in Section 2.1.

The set of historical reports preceding EPA's 2005 study, ranges in subject matter and focus, sample numbers, extent of sampling, tissue types, analytes, and the degree to which data analysis was presented (Hopkins et al. 1985; Johnson et al. 1988, 1989, 1990, 1991a,b; Serdar et al. 1991, 1994; Johnson and Yake 1989; Munn et al. 1995; EVS 1998; Hinck et al. 2004; USGS 2006). EPA has conducted a systematic review of some of these historical fish tissue reports to ensure that the data were of acceptable quality for the remedial investigation process. EPA's data evaluation, which included QA/QC review by an EPA chemist, is documented by EPA (USEPA 2004a,b). EPA's analysis classified several of the reports providing historical fish tissue data for the UCR as either Category 2 (containing data of partially known quality) or Category 3 (containing data of unknown quality). None of those reports reviewed by EPA were in Category 1 (known quality). All of the historical documents containing fish tissue data have been individually summarized by EPA (USEPA 2005a).

The historical data (i.e., preceding Phase 1 data) are considered to have limited applicability to ecological risk assessment for the following reasons:

- Much of the data are for fillet tissue. For assessment of risks to piscivorous fish and wildlife, and for assessing exposures and toxicity of some chemicals to fish, whole body tissue residues are more relevant than fillet residues.

[1] Metals include metalloids.

- Whole body samples in the pre-2005 historical data are primarily for largescale sucker *(Catastomus macrocheilus)*, with the most recent data from 1997, and therefore do not describe current conditions in the UCR.
- Historical data for whole body sucker do not differentiate gut contents from other tissues. This may confound interpretation of exposure and risk to some wildlife consumers of largescale sucker (i.e., those that do not consume whole fish), and the inclusion of sediment in a whole body sample does confound understanding exposures of the fish to the potentially biologically active fraction of chemicals.
- Species sampled tended to be those targeted by anglers, and the samples represented relatively large size classes within those species. Although some of the species represented prey of piscivorous fish and wildlife, other species (e.g. sculpins, dace) that are more likely to be prey are not represented in the historical data set.
- Spatial representation in the UCR is uneven, and sample sizes of each species and tissue type vary. There is a mixture of individual fish and composite samples for both fillet and whole body samples. These differences between data sets make it difficult to generalize about exposures or risks using the pre-2005 historical data.

In spite of the limitations identified above, the pre-2005 historical data do provide insights into patterns of exposure among fish species (Table 2).

2.2 EVALUATION OF PHASE 1 DATA

EPA collected samples of the following fish species:

- Burbot (*Lota lota*)
- Largescale sucker (*Catastomus macrocheilus*)
- Rainbow trout (*Oncorhynchus mykiss*, including wild and hatchery-reared fish)
- Lake whitefish (*Coregonus clupeaformis*)
- Mountain whitefish (*Prosopium williamsoni*)
- Walleye (*Sander vitreum*).

Fish were collected from six fish sample collection areas (FSCAs) distributed throughout the UCR site (Map 1), with FSCAs selected to correspond to the general locations of Phase 1 sediment focus areas (USEPA 2006). Individual fish were sexed, aged, and their lengths and weights measured. Walleye and rainbow trout from FSCAs 1, 3 and 6 were sectioned, and fillet and non-fillet (i.e., offal) tissues analyzed separately; mass-weighted concentrations of individual tissue classes were used to estimate whole body concentrations. Samples of fillet tissues and whole body fish for all species, other than largescale sucker, were submitted as composites for chemical analyses. Composites generally consisted of tissues from five fish, with a few exceptions noted by EPA (Section 2.2.4 in USEPA 2007).

Largescale suckers were analyzed whole, or as paired gut samples and gutless whole body samples. To estimate concentrations of chemicals in the sucker gut contents, the full stomach and tissues from the stomach, the esophagus, and the intestines were excised from the fish, and each was analyzed as an individual sample, separate from the remaining fish tissue. These samples are referred to as "gut/gut contents" samples to acknowledge the presence of the fish stomach tissue in the sample. Analytical results for these samples were used by EPA (USEPA 2007) to evaluate the contribution of sediment in sucker stomachs to whole-body chemical concentrations.

While EPA's original sampling design could not be achieved because some target species were not available in some areas, the final sampling design was relatively systematic and balanced (Table 3), allowing for spatial and interspecific statistical comparisons of tissue chemistry. Note that mountain whitefish was only collected in FSCA 1 (where no lake whitefish were available), and that among rainbow trout, those considered wild rainbow dominated the sample upstream (FSCAs 1 and 2), while hatchery-reared rainbow were more abundant in samples in more downstream areas (FSCAs 3, 4, 5 and 6).

The text below examines whether the Phase 1 data reported by EPA (USEPA 2007) can be used for the ecological risk assessment. Section 3.2 describes spatial and interspecific patterns that can be derived using Phase 1 data (USEPA 2007).

In describing their data quality objectives for fish tissue collection, EPA (USEPA 2007) provided the following Problem Statements:

- "Contaminants are likely present in edible fish at concentrations that pose unacceptable risk to some people who consume fish from the UCR."
- "Determine whether measures are needed to prevent exposure of fish or bioaccumulation of site contaminants from the UCR to contaminant concentrations that pose unacceptable risk to fish."
- "Contaminants may be present in fish and invertebrates at concentrations that pose unacceptable risk to wildlife (birds and mammals) in the UCR site."

Although the Phase 1 data can be used for some aspects of the UCR BERA, they are considered insufficient to fully characterize risks to fish and wildlife. For assessment of risks to piscivorous fish and wildlife, EPA's data (USEPA 2007) have the following limitations:

- All fish represented in the Phase 1 data set were relatively large, ranging in size from 35 to 60 cm (14 to 24 in.). These sizes are greater than the preferred sizes of many piscivorous fish and wildlife found at the UCR site.
- Species sampled do not necessarily represent those that are most likely to be the prey of piscivorous fish and wildlife, such as sculpins (*Cottus* spp.).
- For assessment of risks to fish resulting from metals exposures, both fillet and whole body concentrations of metals are considered to be unreliable indicators or predictors of

toxic effects (Section 5.1.2), unless a specific exposure-response relationship can be derived (Meador 2006). Therefore, while the Phase 1 data may be of use in characterizing the degree of exposure of fish to metals, they may not (if necessary) be as useful for assessment of risks to fish. However, whole body concentrations of organic compounds, such as PCBs, dioxins, and furans can be used to assess potential toxicity to fish.

- Assessment of exposures of fish to all chemicals included by EPA (USEPA 2007) may be confounded for some species when a composite sample was created with individuals that have widely varying ages. This issue affects longer-lived species (i.e., for which individuals of similar size may differ greatly in age), particularly the largescale sucker, but may be a confounding factor for other species as well. It will affect both the comparability of samples in space and time, and the interpretation of the importance of the exposure relative to other species and to toxicity benchmarks.

Despite these limitations, the Phase 1 fish tissue chemistry data have value in both the exposure and risk assessments for piscivorous fish and wildlife, and in characterizing spatial and species-specific patterns of exposure. However, the overall 2005 data set is considered insufficient for a complete evaluation of risks to piscivorous fish and wildlife.

3 ANALYSIS OF EXISTING UCR FISH TISSUE DATA

The available data to describe fish tissue chemistry in the UCR consist of the pre-2005 historical data generated for a variety of purposes, as well as the 2005 (Phase 1) data generated by EPA (USEPA 2007). Although it was concluded in Section 2 that both the pre-2005 and 2005 fish tissue data have limitations for use in assessing baseline risks to fish, both are helpful in understanding temporal trends and other patterns in fish exposures. Among the various datasets that are available to describe chemical concentrations in fish tissues within the UCR (Table 1), the Phase 1 fish tissue dataset (USEPA 2007) represents the most comprehensively designed and systematically collected dataset. It also provides relatively uniform spatial coverage within the study area. Therefore, providing significant fish exposure information relevant to the BERA.

This section uses data provided by the pre-2005 historical studies and the 2005 data set to address Objectives 2 and 3 of this appendix. Independent analyses of the data are conducted, and temporal, spatial and interspecific patterns are evaluated using statistical comparisons among chemical concentrations in fish tissues. In these types of comparisons, uncertainties resulting from the influence of differing food habits, fish sizes, patterns of bioaccumulation, or lipid contents (for nonmetabolizable organic chemicals) (Bryan 1979; Gobas and Mackay 1987; Michaels and Flegal 1990) are unavoidable.

Since the pre-2005 reports and EPA (USEPA 2007) provide similar analyses to some extent, relevant sections of these reports are critically reviewed. The data from key historical studies are also compared to results of recent EPA analyses of the 2005 dataset (USEPA 2007). Tissue concentrations are expressed in wet weight (ww) unless otherwise noted.

3.1 SUMMARY OF PRE-2005 HISTORICAL UCR FISH TISSUE DATA

A summary of the chemical concentrations reported for fish tissue samples in pre-2005 studies is provided in Table 2. Historical fish tissue studies have focused primarily on seven metals (i.e., arsenic, cadmium, copper, lead, mercury, selenium, and zinc), but some data for pesticides, dioxins, furans, and PCBs are also included. Historical patterns for metals and organic compounds are reviewed briefly below.

3.1.1 Metals

On the basis of data collected in the 1980s and 1990s, copper, lead, and zinc concentrations in fish tissue generally decline with increasing distance downstream from Northport (Johnson et al. 1989; Serdar et al. 1994). For example, mean lead concentrations in whole body largescale suckers measured at River Mile (RM) 732 below Northport, RM 680 above Gifford, and RM 635 near Seven Bays were 6.09, 2.00, and 0.39 mg/kg ww, respectively (Johnson et al. 1988). However, it should be noted that these concentrations may have been influenced to an unknown degree by sediment in the sucker guts, as the guts were not removed from the fish prior to chemical analysis. Mercury concentrations did not follow the spatial pattern observed for copper, lead, and zinc. Cadmium, copper, lead, and zinc concentrations in fish were greater than national averages in the historical data set (Serdar et al. 1994). Historical concentrations of mercury were generally higher in walleye, carp, and largescale sucker relative to other species (Table 2). Mercury in walleye generally declined from 1994 through 1998 (Munn et al. 1995; Munn 2000).

Upstream of the U.S.-Canada border, several metals in fish tissue were stable over time or declined from 1995 to 1999 (Aquatic Resources Ltd. 2001; Teck Cominco 2001), including arsenic, cadmium, copper, lead, mercury, thallium, and zinc.

3.1.2 Organic Compounds

Washington State Department of Ecology (Ecology), USGS, and EPA studied dioxin/furan concentrations during the 1990s, and a summary of their data is presented in Table 2. Dioxins and furans were detected in several fish species, including kokanee *(Oncorhynchus nerka)*, lake whitefish, mountain whitefish, rainbow trout, walleye, and white sturgeon (*Acipenser transmontanus*). 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF) was the predominant form among dioxins/furans found in UCR fish (EVS 1998; Johnson et al. 1991a,b; Munn 2000). Historically, the ranges of 2,3,7,8-TCDF wet weight concentrations found in lake whitefish and white sturgeon were broader than the range in other fish species within the UCR (Table 2).

Tissue concentrations of dioxins and furans measured in the mid-1990s were found to substantially decrease following improvements in the Zellstoff Celgar Ltd. bleached kraft pulp mill (EVS 1998; Munn 2000; Serdar et al. 1994). For example, EVS (1998) found that mean concentrations of 2,3,7,8-TCDF in lake whitefish declined either 7-fold (on a wet-weight basis) or 34-fold (when normalized for lipid content) from 1990 to 1994. These differences were highly significant ($p \leq 0.01$; Spearman's rank correlation coefficient). Similarly, EVS (1998) reported substantial declines in tetrachlorodibenzo-*p*-dioxin (TCDD) and 2,3,7,8-TCDF concentrations in kokanee, rainbow trout, walleye, and white sturgeon. Hinck et al. (2004) found dioxin-like potency of extracts of whole fish collected in 1997 from the UCR to be similar to, or lower, than those measured in fish from the middle or lower Columbia River. Decreasing concentrations of dioxins and furans have also been observed above the U.S.-Canada border since 1992 (Antcliffe et al. 1997a,b; B.C. MoE 2000, 2001).

PCBs Aroclors 1254 and 1260 were the primary PCBs measured in a variety of fish species from the UCR since the early 1970s. In 1984 and 1990, Ecology found PCB concentrations in fish from the UCR to be less than national averages, and lower than in the nearby Spokane River (Hopkins et al. 1985; Johnson 1991).

Tissue concentrations of PCBs in fish from the Spokane River (Ecology 1995; Jack and Roose 2002; Serdar et al. 1994; Johnson 2000) have typically been higher than those found in fish from the UCR. For example, Serdar et al. (1994) measured concentrations of PCBs in fillet tissues of walleye, smallmouth bass (*Micropterus dolomieu*), kokanee, rainbow trout, largemouth bass (*Micropterus salmoides*), mountain whitefish, and yellow perch (*Perca flavescens*); and whole body tissues of largescale suckers from the Spokane Arm of Lake Roosevelt and the Spokane River (i.e., Long Lake, above Nine Mile Dam, and above Upriver Dam). The authors found that total PCBs in fillets and whole body tissues from the Spokane Arm ranged from 15 to 92 μg/kg ww and 630 μg/kg ww, respectively, while concentrations from the Spokane River ranged from 9.4 to 1,124 μg/kg ww and 450 to 2,775 μg/kg ww, respectively. The majority of fish tissue samples collected from the UCR during that time had concentrations of Aroclors 1254 and 1260 lower than 500 μg/kg ww, although the maximum concentrations of these Aroclors in samples of sucker species, carp (*Cyprinus carpio*), and walleye from the UCR were 4,800, 1,900 and 3,600 μg/kg, respectively (Table 2).

EPA and USGS studied PCB concentrations in fish from Lake Roosevelt in the 1990s (EVS 1998; Munn 2000)[2]. These studies evaluated tissues from kokanee, lake whitefish, rainbow trout, smallmouth bass, walleye, and white sturgeon (Table 2). EVS (1998) found PCB concentrations in wild rainbow trout fillets to be higher in the upper reach of the UCR, near Northport (mean total PCB concentration = 88 μg/kg ww) than in parts of the lower reservoir that included a sampling reach just downstream of the Spokane Arm, waters within the Sanpoil Arm, and a region just above the Grand Coulee Dam (mean total PCB concentration = 22 μg/kg ww). PCB concentrations in wild rainbow trout fillets were higher than the concentrations in hatchery-raised rainbow trout. This trend was not found in other fish species. Concentrations of PCBs in the lower reach of Lake Roosevelt were shown to have substantially decreased in wild rainbow trout from 1994 to 1998 (Munn 2000) and in largescale suckers from 1976 to 1997 (Hinck et al. 2004).

Pesticide residues have been monitored infrequently in fish tissues collected from the UCR. USGS (2006) monitored pesticide residues at Grand Coulee Dam from 1969 to 1986 through the National Contaminant Biomonitoring Program (NCBP). Whole body composite samples for several species (including yellow perch, walleye, largescale sucker, northern pikeminnow [*Ptychocheilus oregonensis*], carp, channel catfish [*Ictalurus punctatus*], and others) were analyzed for select pesticides (varying by year). Pesticides detected at least once by the NCBP were chlordane (alpha and gamma), Dacthal™,[3] dieldrin, *p,p′*-DDD (dichloro-diphenyl-

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[2] Definitions of "upper," "middle," and "lower" differ for EVS (1998) and Munn (2000). EVS (1998) does not specify the river miles sampled, but data provided are from a reach near Northport, centered approximately at RM 730 (upper); a reach at the mouths of the Colville River and Sherman Creek and centered approximately at RM 700 (middle); and a three separate sampling areas consisting of waters just upstream of the Grand Coulee Dam, the mouth of the Sanpoil Arm, and the Seven Bays area (lower). Munn's (2000) data are from the "upper" UCR, consisting of the reach between Northport and Kettle Falls, and the "lower" reach, between the Spokane River and Grand Coulee Dam. For locations established for the UCR RI/FS see Map 1.

[3] Dacthal™ is a pre-emergent herbicide also known as DCPA, DAC, and dimethyl ester 2,3,5,6-tetracholoroterephthalic acid.

dichloroethane), *p,p′*-DDE (dichloro-diphenyl-dichloroethene), *p,p′*-DDT (dichloro-diphenyl-trichloroethane), endrin, hexachlorobenzene, heptachlor epoxide, lindane (alpha and gamma), nonachlor (*cis* and *trans*), pyrazon, and toxaphene. Since the completion of the NCBP, the only pesticides evaluated and detected in subsequent investigations of fish tissues in the UCR were *p,p′*-DDE, and other DDT metabolites (Johnson 1991; Hinck et al. 2004).

Concentrations of *p,p′*-DDE measured in a variety of fish species by the NCBP (1969 to 1986) ranged from ≤10 to 3,000 µg/kg ww. Hinck et al. (2004) found that 1997 concentrations of DDT and its metabolites were significantly lower ($p \leq 0.05$) than historical concentrations in the UCR (i.e., NCBP data) and significantly ($p \leq 0.05$) lower than concentrations from tissues collected from the Middle and Lower Columbia River (i.e., below Grand Coulee Dam).

Other pesticides analyzed in fish tissue from the UCR by the USGS in 1997 but never detected included chlordane (alpha, gamma, and oxy), dieldrin, DDT and metabolites, endrin, hexachlorobenzene, heptachlor epoxide, lindane (alpha, beta, delta, and gamma), mirex, nonachlor (*cis* and *trans*), and toxaphene. In summary, review of the historical data for pesticides in fish tissues indicates that concentrations of *p,p′*-DDE have been decreasing over time, DDT metabolite concentrations are lower than they are in other portions of the Columbia River, and other pesticides are infrequently detected in the UCR.

3.2 ANALYSIS OF PHASE 1 FISH TISSUE DATA

Because of the more comprehensive nature and balanced design of the 2005 fish tissue data set, analysis of those data allows for greater insights into patterns of fish exposure than does analysis of the pre-2005 data sets. This section describes patterns in the distribution of chemicals among the species sampled, as well as the spatial distribution of chemicals in fish tissue.

To analyze the data for spatial and interspecific patterns the following methods were applied:

- Concentrations of non-detected (*U*-qualified data) chemicals were conservatively assumed to equal the detection limit. *J*- (estimated) or *K*- (biased) qualified data were analyzed at the value reported.
- Age was found to correlate positively with length and weight, so length was used to evaluate the potential for size- or age-related differences within species.
- Whole body concentrations were calculated from concentrations in fillet and offal samples that had been analyzed separately.
- Tests for normality and homogeneity of variance for data sets pooled across the sampling area within species were conducted, and data were transformed appropriately before conducting statistical tests.

- One-way analysis of variance (ANOVA) was used for normal data sets, although the Kruskal-Wallis test was used for the non-parametric data sets. Comparisons among species within FSCAs were conducted using the Kruskal-Wallis test.
- Patterns in PCB concentrations were evaluated using only data for Aroclor 1254 or Aroclor 1260, because all other Aroclors (except Aroclor 1016, frequency of detection = 2 percent) were not detected in UCR fish tissue, and PCB congeners were not analyzed. Data analyses are conducted for the sum of these two Aroclors, referred to as "Aroclor 1254/1260" herein.
- Among the dioxins and furans, only 2,3,7,8-TCDF was consistently detected, so only concentrations of this chemical were considered in spatial and interspecific comparisons.

3.2.1 Metals

Spatial variation of metal concentrations among FSCAs in the UCR was common, but the magnitude of variation differed among the fish species evaluated. To determine which of the metals in each species and in each tissue type were at concentrations that differed significantly in different areas of the UCR, concentrations of each metal in each tissue type (whole fish, fillets, gutless whole bodies or gut/gut contents for suckers) within each species were compared among FSCAs using ANOVA on non-transformed (normal) or log-transformed data; or using the Kruskal-Wallis test for non parametric datasets. For each species, all composite sample data available for any tissue analyzed were used. Whole body estimates based on fillet and offal concentrations were also used where available (FSCAs 1, 3, and 6). Mean concentrations of several metals differed significantly for various species, and for fillet and whole body tissues, but not for all metals in any one species or tissue type, nor for all species for any given metal. Results of all such comparisons (presented as the level of significance [*p*-values] for spatial comparisons of tissue concentrations among FSCAs for each tissue type and each species) indicating existence of significant differences within a species and tissue type, and among FSCAs for selected metals. Table 4 summarizes the information for burbot, walleye, and largescale sucker. Largescale suckers, burbot, and walleye tended to have the highest whole body metals concentrations among the fish when averaged across the UCR (with the exception of selenium in mountain whitefish) (Figures 1 through 10), so spatial patterns evident in these species are highlighted.

3.2.1.1 Largescale Sucker

The greatest spatial variation occurred in whole body metals concentrations in largescale suckers (Table 4). Spatial differences resulted primarily from relatively greater metals concentrations measured at FSCAs l, 2 and/or 3 (plotted as RM738, 728, and 706, respectively), with the exceptions of mercury and selenium (Figure 11). Arsenic was significantly different ($p \leq 0.5$) among FSCAs in whole bodies and in gut/gut contents samples, but not in gutless whole bodies. This could indicate that the non-gut fish tissues were not necessarily as impacted by elevated metal concentrations in the system as might appear to be the case on the basis of whole body (including gut contents) measurements. Rather, the gut/gut contents were the reason for the spatial variation observed for arsenic, as well as for mercury and selenium (Table 4). Mean concentrations of copper in whole body tissue differed by almost an order of magnitude between the most upstream collection area (FSCA 1; plotted as RM 738) and the one at Marcus Flats (FSCA 3; plotted as RM 706). Other metals, such as lead and zinc, differed by a factor 3 to 5 over the length of the river, with the greatest mean concentrations measured upstream. Mercury concentrations differed by a factor of 3 between FSCAs 1 (plotted as RM 738) and FSCA 3 (plotted as RM 706), but in this case, the greatest measured concentration was in whole body tissue from FSCA 3. In many cases, however, spatial variation in tissue concentrations resulted in significant differences among FSCAs even when the magnitude of differences was not large.

3.2.1.2 Burbot

The least spatial variation in metal concentrations was found in burbot; mean concentrations of most metals in whole burbot were not significantly different among FSCAs (Table 4). However, although mean arsenic concentrations only ranged from 0.64 and 0.87 mg/kg ww (FSCAs 3 and 6, respectively), the differences were statistically significant (ANOVA, $p=0.033$). Selenium in burbot was also significantly different among stations (ANOVA, $p = 0.005$), and tended to decline with distance from the border (USEPA 2007).

3.2.1.3 Walleye

Whole body concentrations of most metals in walleye differed by less than 50 percent across the entire study area, but concentrations of chromium, copper, lead and selenium (and several other metals) were greatest or nearly greatest at FSCA 4, near Inchelium (RM 675) (Figure 12). Mercury concentrations tended to increase in whole body, fillet, and offal of walleye moving downstream, and were greatest in FSCAs 5 and 6 (plotted as RMs 636 and 606, respectively).

3.2.2 Organic Compounds

Results of statistical comparisons of tissue concentrations among FSCAs for each tissue type and each species (both normal and lipid-normalized concentrations) were evaluated for spatial differences. A summary of observed statistical differences among FSCAs is provided below.

3.2.2.1 2,3,7,8-TCDF

Lipid-normalized concentrations of 2,3,7,8-TCDF in whole bodies of largescale sucker, lake whitefish or rainbow trout did not differ significantly ($p>0.05$) among FSCAs. Lipid-normalized 2,3,7,8-TCDF concentrations in burbot, walleye fillet and whole walleye differed significantly ($p\leq0.05$) among stations. The maximum lipid-normalized 2,3,7,8-TCDF concentration for burbot was from near Inchelium (RM 675), and was higher than at any other location (Figure 13). Both wet-weight and lipid normalized 2,3,7,8-TCDF concentrations in whole body and fillet tissues of walleye were significantly different ($p \leq 0.05$) among FSCAs. Lipid-normalized concentrations in whole bodies of walleye from FSCAs 1 and 6 (plotted as RMs 738 and 606, respectively) were higher than other collection areas (Figure 13).

3.2.2.2 Aroclor 1254/1260

Concentrations of Aroclor 1254/1260 in whole bodies of largescale suckers and burbot did not show a significant pattern among FSCAs. Concentrations of Aroclor 1254/1260 in whole bodies and fillets of walleye (wet-weight and lipid normalized) from FSCAs 3 and 4 (plotted as RMs 706 and 680, respectively) were lower than at all other FSCAs, and lipid-normalized Aroclor 1254/1260 concentrations were highest in whole walleye from FSCAs 1 and 2 (RMs 738 and 728, respectively) (Figure 13). Walleye fillets from FSCAs 1, 3, and 6 (RMs 738, 706, and 606, respectively) showed a general decrease from north to south. Lipid-normalized Aroclor 1254/1260 concentrations in whole lake whitefish appear to decline with distance from Northport, while whole wild rainbow trout generally followed the same pattern as whole walleye, with lowest concentration at FSCAs 3 and 5 (RMs 706 and 636, respectively). The differences between FSCAs in whole wild rainbow and lake whitefish were not significant.

3.2.3 Interspecific Differences

3.2.3.1 Metals

Because many data were neither normally nor lognormally distributed, and because variances differed among species, comparisons of metal concentrations among species at each FSCA were made using the Kruskal-Wallis non-parametric test. In nearly every case, differences among species were significant ($p \leq 0.05$). Because the concentrations of each metal in largescale sucker whole body tissues were often much greater than concentrations in all other species, the Kruskal-Wallis procedure was repeated with largescale suckers removed from the data set. From 84 tests (14 trace elements at 6 collection areas), only 9 were non-significant, with $p > 0.05$ (data not shown). However, as with the spatial comparisons, in many cases, the differences were not large (Figures 1 through 10).

Mean tissue concentrations of lead in whole body samples of largescale suckers were more than 10 times greater than those of rainbow, walleye and whitefish in each FSCA (Figure 14). In addition to lead, whole body largescale suckers had the greatest mean concentrations of cadmium, chromium, cobalt, manganese, and nickel at each FSCA. Tables showing mean concentrations are provided in Attachment 1.

Mean tissue concentrations of total arsenic in burbot were 2 to 3 times greater than for all other species in each FSCA (Figure 15). Mean total arsenic concentration was greatest at FSCA 6, near the Grand Coulee Dam (at 0.87 mg/kg ww). The arsenic speciation results indicated that accumulation of the organic arsenic species, dimethylarsenic acid (DMA), in burbot tissue explains the difference. DMA in burbot whole body tissue ranged from 0.50 mg/kg ww in

FSCA 3 (plotted as RM 706)) to 0.78 mg/kg in FSCA 6 (RM 606). All other fish species had whole body concentrations of DMA less than 0.02 mg/kg ww.

The spatial pattern of mercury accumulation in fish tissue appeared to be related primarily to the trophic position of each fish species (Figure 16). For example, the mean concentration in the two piscivorous species (i.e., walleye and burbot) followed a similar pattern among FSCAs, as did the mean concentration of the invertivorous/planktivorous species (i.e., rainbow trout and whitefish). By contrast, the benthivorous largescale sucker exhibited a pattern distinct from the piscivores and invertivores/planktivores.

3.2.3.2 Organic Compounds

Nearly all comparisons of organic compounds among species at FSCA's indicated significant differences among species ($p \leq 0.05$, Kruskal-Wallis). Major patterns, based on lipid-normalized concentrations of Aroclors 1254/1260 and 2,3,7,8-TCDF, were as follows:

- Lipid-normalized 2,3,7,8-TCDF concentrations were highest in burbot, compared to other species (Figure 17). Whole burbot had the lowest mean lipid content at 1.7 percent, while mean lipid contents for the other species' whole body samples ranged from 3 to 12 percent.
- Both Aroclor 1254/1260 and 2,3,7,8-TCDF concentrations were higher in rainbow trout fillets than walleye fillets, but this was reversed when fillet concentrations were lipid-normalized; the mean lipid content in walleye fillet was 0.4 percent, while in rainbow fillets it was 3.6 percent. Concentrations of 2,3,7,8-TCDF in hatchery and wild rainbow trout fillets were comparable, as were lipid contents.
- Whole burbot, walleye, and largescale suckers had the highest median lipid-normalized Aroclor 1254/1260 concentrations among fish species (Figure 17).

3.2.4 Other Tissue Chemistry Patterns, and Occurrence of External Anomalies in Fish

3.2.4.1 Differences in Size and Age within Species

Highly significant differences ($p \leq 0.001$) in the sizes of fish among FSCAs for all species except for wild rainbow trout exist for the Phase 1 data. In particular, largescale suckers were much smaller in FSCA 1 than in other FSCAs. This was due to a shift by EPA in sampling strategy when they found that smaller suckers, which were targeted by the sampling design, were less abundant (more difficult to catch) than larger in FSCA 1, and they changed the design to target larger suckers. Largescale suckers also had the widest age range (≤10 to 40 years). Wild rainbow trout were larger than hatchery rainbow; and walleye were larger in downstream FSCAs than in upstream FSCAs. Since composites were created on the basis of consistency in fish size, these factors add uncertainty to the spatial patterns described above, because size (length) correlates with age and age may affect concentrations of chemicals in fillet or whole body tissue.

3.2.4.2 Temporal Patterns in Fish Tissue Chemistry

Temporal trends can be qualitatively evaluated in cases where the same species and tissues have been analyzed within a particular part of the river over time (in the pre-2005 and 2005 datasets). EPA (USEPA 2007) provides a summary of data from key historical studies (USGS 1995; EVS 1998) compared to the 2005 data set for metals in fillets of walleye, wild rainbow trout, and hatchery rainbow trout; and for 2,3,7,8,-TCDF and total PCBs in walleye and rainbow trout fillets. These comparisons were made on the basis of general areas or reaches (i.e., upper, middle, and lower)[4], and are summarized in Figures 18 through 25. Although the sizes of the fish and the locations of capture are not perfectly matched among these datasets, the comparisons provide some insights into temporal trends in some tissues. The results of this comparison are as follows:

- Temporal patterns for arsenic and cadmium were difficult to discern as the result of elevated detection limits for the 1995 data (Figures 18 and 19).
- Concentrations of copper, lead, and mercury have generally declined in walleye, wild rainbow trout and hatchery rainbow trout between 1995 and 2005 (Figures 20 to 22). However, because lead in walleye was undetected in 1995 in fish from the middle and lower reaches, the presence of a declining trend is less certain for that species (Figure 21).
- Concentrations of selenium in walleye, hatchery rainbow, and wild rainbow trout tended to vary, and increased in all parts of the river between 1995 and 2005.
- Wet-weight concentrations of 2,3,7,8-TCDF have generally declined in walleye and rainbow trout between 1994 and 2005, but this pattern is not observed when 2,3,7,8-TCDF is lipid-normalized.
- Lipid-normalized concentrations of total PCBs have declined somewhat in rainbow trout in the upper and lowest reaches, and in walleye in the middle and lowest reaches. PCB concentrations have increased in walleye in the upper reach of the study area.

3.2.4.3 Whole Body and Fillet Tissue Concentrations

Concentrations of metals in composite fillet and composite offal samples were measured in walleye and rainbow trout from FSCAs 1, 3, and 6. As described above, these two measurements were later combined mathematically to estimate composite whole body

[4] USGS (1995) defines lower, middle, and upper reaches of the UCR system as follows: “the Sanpoil River embayment, the middle reach of Lake Roosevelt and Lower Spokane River, and Columbia River and Lake Roosevelt near Kettle Falls.” Fish sampling areas established for the RI/FS by USEPA (2007) are shown in Map 1.

concentrations. In nearly all cases, metals concentrations in fillets were lower than in whole body samples from the same location. The exception was for mercury, for which concentrations in fillets were generally greater than concentrations in whole bodies.

To determine whether concentrations in fillet can be predicted from concentrations in whole fish, correlations between metal concentrations in whole body samples and fillets for walleye and rainbow trout were evaluated using Spearman's rho. When a significant relationship was found (experiment-wise $p \leq 0.05$), whether a linear or non-linear relationship provided a better fit to the data was tested using Ramsey Regression Equation Specification Error tests (RESET). The results were metal- and tissue-specific showing some metals can be predicted in fillet from data on whole body concentrations, and some cannot (Tables 5 and 6). For both species, whole body concentrations can be used to predict fillet concentrations of arsenic, beryllium, and mercury. In addition to these metals, concentrations of antimony, chromium, selenium and silver in rainbow trout fillets can be predicted from concentrations in whole rainbow. Where significant correlations do occur, the relationship is not always linear, and none are proportional. Therefore fillet concentrations cannot always be predicted from whole body fish samples, and any predictions should be based on a regression equation that is both metal- and species-specific.

3.2.4.4 Largescale Sucker Gut Analysis

Because largescale suckers ingest sediment during feeding, sediment ingestion may be an important exposure pathway for this species. In addition, sediment and metals in the gut of fishes may contribute to the estimate of whole body concentration. Inclusion of gut that contains sediment in estimates of whole body concentrations has the potential to overestimate exposure to consumers that do not eat gut contents of fish, and may overestimate risk to consumers or to the fish themselves if the metals in the gut are not bioavailable, or are excreted by the fish. More refined understanding of these relationships can be used to reduce uncertainties in assessment of exposure to both suckers and their predators.

The strength of correlations and the types of statistical relationships between concentrations in paired gut/gut contents and gutless whole body samples provide insights into patterns of uptake and retention of metals from ingested sediment by largescale sucker (Table 7). Using a Spearman's rank correlation coefficient, the concentrations of aluminum, cadmium, cobalt, copper, iron, lead, manganese, and zinc in gutless whole bodies were found to correlate significantly (experiment-wise $p<0.05$) and positively with those in gut/gut contents samples (Table 7). Two-sided, non-parametric regressions were fitted for each of the metals with significant correlations. Ramsey's RESET was used as a proxy for estimating the nature of significant correlations between gutless whole body and gut/gut contents samples, and both linear and non linear relationships were identified (Table 7). Scatter plots for arsenic, cadmium, lead and zinc illustrate the three patterns observed (Figure 26). Concentrations of arsenic in gut/gut contents and gutless whole bodies do not correlate (as for antimony, barium, beryllium, calcium, chromium, magnesium, nickel, selenium and silver); concentrations of cadmium show a significant linear relationship (as for cobalt); and lead and zinc in the two media show significant non-linear relationships (as for copper, iron and manganese). For those metals with non-linear relationships between gutless whole bodies and gut/gut contents, the upper limit on the uptake of the metal by sucker may indicate a limit on the bioavailability of the metal from the gut contents, or an increased tendency to excrete the metal as concentrations of the gut contents increase. Those metals with linear relationships may also ultimately show non-linear relationships if the range of the concentrations in gut/gut contents were expanded.

The percent of the gut contents consisting of organic matter, or the ash-free dry weight (AFDW) of the gut/gut contents sample, was lowest in FSCA 1 , but the median AFDWs for FSCAs 1a[5], 3 and 6 were greater, ranging from 79 to 92 percent (Figure 27). Effects of the variation in percent AFDW on the relationships between metals concentrations in gut/gut contents and gutless whole bodies were not investigated with multivariate methods because the gut/gut contents samples contained variable amounts of stomach and other intestinal tissue, which could not be distinguished from ingested food with the available data.

Detailed results of the chemical analyses for all largescale sucker tissues analyzed are presented with the whole body results, see Attachment 1.

3.2.4.5 Sediment-Fish Tissue Relationships

Statistical correlations between concentrations of chemicals in fish tissue and in sediment collected from the same areas can provide insights into fish exposure pathways. For this purpose, and in response to comments on EPA (USEPA 2007), correlations between metals in whole body or fillet tissue samples and concentrations of metals in sediment were evaluated. Although there was not perfect spatial concordance between sediment collection areas and FSCAs, multiple sediment samples were collected for analysis of metals within each of the FSCAs, facilitating the comparison of fish tissue metal concentrations to those of the sediments. Only data for those sediment samples collected during Phase 1 sampling activities (USEPA 2007) from within the boundaries of the FSCAs were used.

Sediment data were aggregated in two ways. First, sediment samples from locations within the boundaries of the FSCAs were identified, and these were sorted into two groups–samples occurring within deep water areas of the UCR (i.e., deep water sediments) and those in shallow water areas (shallow water sediments). Two sediment datasets were created–a set of all stations within the boundaries of the FSCA (including deep water samples); and a set excluding deep water samples. The resulting number of sediment stations within each group varied among the FSCAs; mean concentrations of metals calculated using each of these two datasets are provided

[5] For the purposes of sampling gut/gut contents in largescale sucker, EPA sampled suckers in a portion of the UCR that was somewhat downstream of FSCA 1, from RM 735.5 just upstream of the Northport public boat ramp (Map 1). This station was termed FSCA 1a. Only largescale suckers were sampled there, and only for evaluation of stomach contents of individuals and individual gutless whole body samples.

in Table 8 (with deep water sediment data) and Table 9 (without deep water sediment data). Neither the raw values, nor the transformed concentrations of metals in sediment accurately fit the assumption of normality (Shapiro-Wilk tests). Various logarithm bases, square root and Box-Cox transformations were attempted without positive result. Because of the non-normal distribution of the data, parametric statistics and linear models were not considered appropriate for data analysis. Concentrations of metals were compared between the two groups (with and without deep water sediment data) using pair-wise Mann-Whitney-Wilcoxon rank-sum tests. With the exception of nickel, metal concentrations in the group that included the deep water area were significantly greater than those of samples collected from outside of the deep water area. Therefore, correlations between sediment and tissue were conducted separately using each of the two sediment data sets.

The arithmetic mean concentration of each metal in sediment was calculated for each FSCA for the dataset inclusive of the deep water sediment data and the one not including deep water sediment data. Correlations between this mean and the individual tissue concentrations were computed for both whole body fish and fillet tissue using Spearman’s rank correlation coefficient (rho). Rho is a measure of how well these pairs of values all exhibit the same ratio. It is a nonparametric statistic, so it not dependent upon normally distributed data. Each mean was paired with the concentration of metal in each fish within that FSCA. All these pairs of sediment (mean)-fish tissue concentration were used to calculate rho. A positive rho means the fish tissue concentrations tend to increase as mean sediment concentration increases, while a negative correlation means fish tissue concentrations decrease with increasing sediment concentration. Those metals with detection frequencies of less than 50 percent in the fish tissue samples (vanadium in whole body samples of some fish species; aluminum, barium, cadmium, lead, nickel and vanadium in fillets of walleye and rainbow) were excluded from the analysis. Statistical significance was recognized at an experiment-wise $p \leq 0.05$.

Results of the correlation analyses using whole body fish samples are presented in Tables 10 and 11; results of correlation analyses using fillet tissue, including a result with all rainbow trout fillet tissue combined are presented in Tables 12 and 13. There are few general patterns, except that among the sediment-whole body correlations, cobalt and nickel are the only metals for which none are significant; for the sediment-fillet correlations, arsenic, cobalt, iron and vanadium are never significant. Otherwise, significant correlations occur for one to three metals per fish species, and for one to three fish species per metal, except for the combined dataset of rainbow trout fillets. Aggregating the rainbow trout fillets across the wild and hatchery groups resulted in a greater number of significant correlations (Tables 12 and 13) regardless of the sediment dataset. However, when deep water area data are excluded, uranium does not correlate significantly with the combined rainbow trout fillet data, and lead does, in contrast to the result when deep water area data are included.

The relationship of fish tissue metal concentrations to those in sediments may be complicated by a number of factors, such as the bioavailability of metals in sediments, fish migration, and the numerous exposure pathways and processes that can link metal concentrations in fish tissue to those in sediment.

3.2.4.6 Occurrence of Lesions and Other Anomalies in Fish

The occurrence and types of external lesions observed on fish collected by EPA in 2005 (USEPA 2007) were recorded prior to processing fish for chemical analysis. The examination protocol and data collection form for external examination described by Smith et al. (2002) were used. Tissue anomalies recorded included lesions, deformities, abnormalities, fin erosion, and visible external parasites (Table 14). In recommending assessment of these lesions, Smith et al. (2002) does not provide any information on their etiology. Internal examinations and analysis of histopathology were not performed.

A summary of the frequency of anomalies for each species collected by EPA (USEPA 2007), by FSCA, is provided in Table 15. EPA recorded results of examinations of individual fish for all fish that were used in the composite samples plus a random selection of additional fish that were available; selection of fish was not dependent upon whether or not external anomalies were apparent. Anomalies were counted individually, but in many cases more than one anomaly occurred on a single fish (Table 15)[6]. The percent of all fish examined in each FSCA that had external anomalies was highest in FSCA 5 at 81 percent (Figure 28). When the percent of anomalies is considered by species, the maximum for each species is also in FSCA 5, with the exceptions of lake whitefish (Figure 29) and burbot, although the 100 percent incidence for burbot in FSCA 1 is based on only one fish. For all species combined, the average number of lesions per fish examined (within species) generally increased moving downstream (Figure 30).

Hinck et al. (2006) monitored fish throughout the Columbia River Basin for both internal and external lesions, abnormalities, and histopathology in 1997 and 1998. Two of their monitoring stations were in the UCR–(Northport and Grand Coulee Dam). A total of 74 percent of all fish sampled throughout the Columbia River Basin had some type of external anomaly, and 50 percent or more of fish had external anomalies at any given station. EPA's 2005 results (Table 15) indicate that the percent of all fish with external anomalies in the UCR overall was 66 percent in 2005, and that the percentages of all fish with anomalies in FSCAs 2 and 3 were close to the lower end of the range observed by Hinck et al. (2006) across the Columbia River Basin. Seventy-eight percent of all largescale sucker (N=160) throughout the Columbia River Basin had one or more lesions (Hinck et al. 2006); in the UCR (Phase 1), 88 percent of suckers had external anomalies, with the highest rates in FSCAs 3, 4, 5 and 6. Histopathological examinations by Hinck et al. (2006) indicated that the majority of external lesions observed (and several types of lesions on internal organs) were the result of inflammatory responses to parasitic or bacterial infections.

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[6] Counts of anomalies reported in Table 15 do not include anomalies that were recorded in the "notes" sections of the field forms.

An investigation by Peters (1995) within the UCR linked parasites to a number of fish abnormalities (gross and histopathological) and lesions. Peters (1995) used gill nets to sample 598 fish from three areas within Lake Roosevelt.These were near Kettle Falls (~RM 700), Gifford (~RM 675) and Hunters (~RM 660). The nematode *Eustrongylides* spp. occurred in at least seven species of fish in Lake Roosevelt (Peters 1995). It infects oligochaetes, fish, and birds. More importantly, *Eustrongylides* can cause lesions in fish and illness and death in birds and mammals. The highest frequency of infestation (18 to 19 percent) occurred in lake whitefish and mountain whitefish, but also in walleye (8 percent), kokanee (5.5 percent), and rainbow trout (0.7 percent). A higher infestation (66 percent) was observed in burbot, but only three fish were sampled. Lake whitefish had the greatest number of nematodes (7.2 ± 16.2) per fish, but infestations could reach 100 per fish. Most infected fish came from the station sampled farthest upriver (Kettle Falls).

The Canadian government sponsored a major study in the early 1990s of fish health in relation to organic and metal concentrations in fish tissues and upgrades in wastewater treatment at the pulp mill in Celgar, B.C. and smelter at Trail, B.C (Boyle et al. 1992; Nener et al. 1995a,b; Antcliffe et al. 1997a). They also documented parasites of fish as being associated with many of the morphological, histological, and biochemical abnormalities found in at least seven fish species in the Columbia River upstream to Hugh Keenleyside Dam in British Columbia. The Canadian government comprehensively examined the causes of abnormalities by investigating chemicals in fish tissues, viruses, bacteria, and parasites. The most important biological stressor was identified as the blood fluke (*Sanguinicola* sp.), which was associated with multiple external and internal lesions and other pathologies in the whitefish (Antcliffe et al. 1997b). The evidence indicated that the blood fluke infestations were a natural occurrence.

Although the Phase 1 data do not allow for the determination of the etiology of fish lesions. A number of studies have identified lesions as being common in fish throughout the Columbia River Basin, and the majority appear to be the result of bacterial or parasitic infections.

3.3 SUMMARY OF PATTERNS IN UCR FISH TISSUE DATA

Evaluation of the pre-2005 historical and the 2005 fish tissue data identified several spatial and interspecific patterns in fish tissue chemistry that may be useful for the BERA are summarized below

- Pre-2005 historical data were primarily for fillet tissue and for species and sizes considered edible by people. A few studies provided data for whole largescale sucker, but were published in 1997. As such, the data are not believed to be sufficiently systematic, current, or representative of fish and tissues eaten by piscivorous fish and wildlife to have substantial value for the BERA.
- EPA (USEPA 2007) provides the most systematic and robust data set for fish tissue for the UCR, and the data are useful for ecological risk assessment.

- Pre-2005 historical data are primarily of value in understanding temporal and interspecific contaminant trends, although these conclusions should be considered preliminary as they are based on a small amount of available data and differences in ages and species of fish across studies adds uncertainty. Regardless, the following general patterns are observed in the historical data:
  - Concentrations of copper, lead, and zinc in whole largescale sucker declined significantly ($p \leq 0.05$) with increasing distance downstream from Northport. However, arsenic, cadmium and mercury concentrations did not decrease significantly with distance from Northport.
  - Concentrations of mercury were generally higher in walleye and largescale sucker than in other species. Mercury in walleye tissues declined from 1994 to 1998.
  - Several metals, including arsenic, cadmium, copper, lead, mercury, and zinc declined in fish tissue upstream of the U.S.-Canada border between 1995 and 1999.
  - Simple, qualitative comparisons between pre-2005 historical data sets and recent samples (USEPA 2007) suggest that tissue concentrations of copper, mercury, lead, and 2,3,7,8 TCDF have been declining from the mid- to late-1990s to 2005; while data for arsenic and cadmium are equivocal due to high detection limits. PCBs may have increased in some species in the middle and lower portions of the UCR between 1994 and 2005.
- Phase 1 data (USEPA 2007) describe fish species and size classes primarily of interest for human consumption risk; the data are sufficient to illuminate patterns in the spatial distribution of fish exposures, and other species-specific fish exposure patterns relevant to the BERA. These include
  - The highest concentrations of most metals occurred in largescale sucker, burbot and walleye. Consistent with historical trends, the highest mercury concentrations were in walleye and largescale sucker; relatively high concentrations were also detected in burbot, which were not sampled historically.
  - As in the historical data, concentrations of copper, lead, and zinc declined with distance downstream from the U.S.-Canada border, but only for largescale sucker. This pattern was not observed for other species.
  - Differences among species in the locations and magnitude of peak concentrations of both metals and organic compounds suggest different pathways and mechanisms of exposure among the species. This is consistent with the different life histories, feeding habits, migration patterns, and other species-specific variables that control chemical uptake, retention and elimination processes in fish. Benthic fish (largescale suckers) and top predators (walleye, burbot and to some degree rainbow trout) consistently show the most pronounced spatial patterns (i.e., high spatial variability) and highest body burdens.

- Understanding patterns of exposure may be confounded by the effect of length (as a surrogate for size and age) on tissue concentrations, but no consistent patter among species or metals was observed. Understanding historical patterns in whole largescale sucker may be confounded by the presence of sediment in the fish guts.
- Statistically significant relationships between metals concentrations in sediments and whole fish tissue occurred in several species-sediment combinations. Strong associations between mean concentrations of metals in sediment and individual fillet samples of rainbow trout occurred for several metals when all rainbow trout fillet samples were considered as a group, and were rare in walleye.

4 SELECTION AND DESCRIPTION OF POTENTIAL REFERENCE LOCATIONS

Several studies and databases provide concentrations of chemicals in fish tissue from rivers and lakes in Washington and elsewhere in the Pacific Northwest. However, the definitions of "reference locations" or "reference conditions" are often subjective. The data and statistical methods used to define reference conditions generally depend on the specific questions to be addressed regarding comparisons with site conditions. The purpose of this section is to identify and describe available fish tissue data, for the purpose of characterizing potential reference conditions, which, if required during the ERA process, and per EPA guidance (USEPA 1989, 1997), will facilitate comparisons of individual fish tissue chemical measurements from within the Site and help inform risk-based management decisions.

4.1 DEVELOPMENT OF THE REFERENCE LOCATION DATA SET

To begin the evaluation of potential reference conditions for fish tissue chemistry, general criteria for reference locations potentially representative of the UCR were defined. Fish tissue data were included if they were from water bodies (lakes and rivers) that

- Are in the state of Washington
- Are monitored by Ecology or are among sites in EPA's National Study of Chemical Residues in Lake Fish Tissue
- Are not directly adjacent to or clearly influenced by large municipal and industrial areas
- Are east of the Cascade crest.

Fish tissue chemistry data meeting these criteria were compiled from various sources, including several reports by Ecology (Johnson et al. 2006; Seiders et al. 2006, 2007, 2008), and results of the EPA fish study (USEPA 2005b). Each data source included a list of locations where samples had been acquired. These locations were cross-referenced with maps to determine which of the sampling sites were in eastern Washington. All sites monitored by Ecology or in the EPA databases and within this geographic region were included, with the exceptions of any reach of the Spokane River and Moses Lake (Table 16). Fish from those two water bodies may be impacted by municipal or other sources and were excluded.

Data for all years, for any fish species represented in the pre-2005 or 2005 data sets for the UCR, and for any analyte in these data sets (Tables 1 and 2) were compiled for the selected water bodies (Table 16). Analytes of concern included metals, PCBs, PBDEs, selected pesticides, and conventional variables such as percent lipid and percent moisture.

4.2 SUMMARY OF POTENTIAL REFERENCE CONDITIONS

The available potential reference locations identified using this approach were found to be very limited and did not provide a consistent or coherent picture of conditions outside the UCR. All of the important parameters for providing a consistent data set to which site conditions can be compared varied considerably, such as species sampled, tissue types analyzed, analytes, and years sampled. Furthermore, previous collections targeted larger fish for human consumption and are not appropriate for risk evaluations for ecological receptors. However, the data that were generally comparable to data reported by EPA (USEPA 2007) are summarized in Table 17. For qualitative comparison with the 2005 UCR data, only data from 2000 and later were included, and summary statistics calculated. Only walleye and rainbow trout fillet, and whole largescale sucker sampled from both the candidate reference locations and the UCR in 2005 were included in this summary, because the most robust data sets for the site are for these sample types, and only for mercury and PCBs. Concentrations of PBDEs in fish from these (and other) locations are summarized in Section 5.

A relatively large data set for both largemouth and smallmouth bass tissue samples from waterbodies other than the UCR in Washington by EPA and Ecology has been collected. If bass were collected from the UCR, these potential reference location data may be sufficiently numerous and recent for comparison to bass collected from the UCR. Among recent Ecology and EPA reports, there are approximately 20 recent smallmouth and largemouth bass samples (collected since 2000) each from sites that meet the criteria for reference locations defined above. Nearly all of these bass tissue samples were skin-on fillets analyzed for total mercury; more than half were analyzed for PCBs and chlorinated pesticides, with a subset analyzed for PBDEs, dioxins and furans. Ecology continues to generate new data on mercury and other chemicals in bass, prompted in part by the U.S. Department of Health (DOH)'s statewide advisory for mercury in smallmouth and largemouth bass. Both species are favorable for regional-scale monitoring because they're ubiquitous, and both are found in the UCR (e.g., Scofield et al. 2007).

5 POLYBROMINATED DIPHENYL ETHERS IN FISH

PBDEs are a class of compounds structurally similar to PCBs, consisting of two carbon rings linked by an oxygen bond. The carbon rings have various degrees of bromination, giving rise to 209 individual BDE compounds, or congeners. Manufactured for use as flame retardants and textile coatings, PBDEs have recently gained widespread scientific and public attention because of apparent increases in concentrations in human tissue and environmental media in recent decades. PBDEs have been measured in fish tissue in the UCR and in nearby areas, and are among the chemical groups potentially of interest to the BERA.

This section describes the available information on PBDE concentrations in tissue of fish collected from the UCR basin, and considers additional collection of tissue and analysis for PBDEs.

PBDEs bioaccumulate in fish, and tri- to hepta-BDEs biomagnify, with the maximum biomagnification in a community of pike, perch, and roach observed to be by the penta-brominated group by Burreau et al. (2004). These authors reported that biomagnification by the hexa- and hepta-brominated groups was inversely proportional to the degree of bromination; and that octa-, nona- and deca-brominated BDEs did not biomagnify, but did occur in fish tissue sampled during their study (i.e., they bioaccumulated). Fish size, but not fish sex, affected concentrations of PBDEs in this study when trophic position was accounted for. Differences in the apparent rates of bioaccumulation by different fish species have been attributed to the ability of some fish to debrominate some of the congeners, and interspecific differences in metabolism (Rayne et al. 2003).

Data describing concentrations of total PBDEs in fillet tissue of fish from the UCR are available from three studies (Rayne et al. 2003; Johnson et al. 2006; Hatfield Consultants 2008) (Table 18). Rayne et al. (2003) analyzed fillets of mountain whitefish collected from the confluence of Beaver Creek and the Columbia River, 9 kilometers (~6 miles) downstream from Trail, British Columbia in 1992 and 2000; and from a site near the town of Genelle, British Columbia 13 kilometers downstream of the City of Castlegar, British Columbia; and upstream from Trail in 1992, 1996, and 2000. Rayne et al. (2003) compared concentrations in individual mountain whitefish skinless fillet tissue from the 1990s with concentrations found in 2000, and reported that, while tissue concentrations at both sites generally increased from 1992 to 2000, the rate of increase in PBDEs in mountain whitefish fillets downstream of Trail (a factor of 6.5 increase) was less than the rate of increase at Genelle (a factor of 11.8 increase). In 2000, the mean PBDE concentration in whitefish fillets below Trail (29.2 μg/kg ww) was significantly less than at Genelle (71.8 μg/kg ww).

PBDEs analyzed in mountain whitefish from the Genelle and Beaver Creek reaches during 2002 and 2004 indicate that concentrations may have continued to increase in the UCR (Hatfield Consultants 2008). Skin-on fillets of mountain whitefish from Genelle analyzed for the Columbia River Integrated Environmental Monitoring Program (CRIEMP) during 2002 and

2004 had mean total PBDE concentrations of 107 μg/kg ww and 130 μg/kg ww, respectively. Lower mean total PBDE concentrations were reported in specimens from Beaver Creek in 2002 and 2004 (90.8 μg/kg ww and 85.5 μg/kg ww, respectively), but the differences between sites were not as pronounced as those reported earlier by Rayne et al. (2003). The larger sample sizes analyzed during 2004 demonstrate the wide range of concentrations from the same reach. However, the absence of lipid data in the Hatfield Consultants (2008) report precludes the examination of this variable as an influencing factor.

Skin-on rainbow trout fillets were also analyzed for PBDEs as part of the CRIEMP sampling during 2003 (Hatfield Consultants 2008). Mean total PBDEs from Genelle and Beaver Creek specimens were 18.4 μg/kg ww and 17.3 μg/kg ww, respectively, much lower than concentrations in mountain whitefish. Hatfield Consultants (2008) attributed the differences in PBDE concentrations to dissimilarity in feeding behavior between rainbow trout, a surface-feeder, and mountain whitefish, a near bottom-feeder. While variables accounting for differences between species have yet to be thoroughly examined, much lower PBDE concentrations in rainbow trout compared to mountain whitefish has also been reported elsewhere, most notably at two locations in the Spokane River (Table 18).

All mountain whitefish data analyzed in the Columbia River upstream of the U.S.-Canada border since 2000 had greater mean concentrations than the 18 μg/kg ww total PBDEs found in one composite of lake whitefish fillets (with skin) from the UCR near Kettle Falls by Johnson et al. (2006). Other species tested at this location by Johnson et al. (2006) had lower total PBDE concentrations (Table 18).

Information on PBDE concentrations in fish is available for elsewhere in eastern Washington state (Johnson and Olson 2001; Serdar and Johnson 2006; Johnson et al. 2006; Seiders et al. 2006). A summary of the data for PBDEs in various fish species from among the reference location data set described in Section 4.1 was compiled (Table 18). Concentrations of total PBDEs in reference location lakes are generally comparable to those downstream of Trail (Rayne et al. 2003) and from Kettle Falls (Johnson et al. 2006). Figure 31 shows lipid-normalized concentrations of total PBDEs in the mountain whitefish samples from the Methow, Wenatchee, Middle Columbia, and Spokane rivers, and the two sites in the Rayne et al. (2003) study and the CRIEMP (Hatfield Consultants 2008) study, as well as for the lake whitefish fillet without skin from the UCR.[7] This limited comparison suggests that the near-urban areas of Upper and Lower Long lakes (downstream of Spokane, Washington) and Genelle tend to have higher concentrations of total PBDEs than fish from the reference locations. On the basis of lipid-normalized concentrations, the value for the lake whitefish sample from the UCR near

[7] Rayne et al. (2003) did not report lipid content. Lipids were estimated using the percent lipid for a skin-off fillet sample from the Methow River (3.9 percent), because it was the only available lipid measurement for a mountain whitefish skinless fillet. Lipid was estimated for samples for the Upper and Lower Long Lake samples as the mean of lipids in three skin-on fillets from reference locations. That estimated lipid value was 4.6 percent.

Kettle Falls was more comparable to the values for mountain whitefish from the reference locations than to the values for mountain whitefish from rivers near urban areas (e.g., Upper Long Lake and Lower Long Lake). However, because mountain whitefish tended to have higher wet-weight concentrations of total PBDEs than lake whitefish, it is important to note that the UCR sample is a different species than that collected by Rayne et al. (2003) and Hatfield Consultants (2008), with a different life history, and likely different prey and habitats. Figure 31 also illustrates the difference between the mean PBDE concentrations in whitefish at Genelle, upstream of Trail, and at Beaver Creek downstream.

Rayne et al. (2003) evaluated the potential sources of PBDEs, and discussed spatial patterns of their data, which include largescale sucker samples from the more rural area downstream of Nelson, British Columbia and multiple sediment samples. They concluded that relatively elevated concentrations of PBDEs were likely attributable to releases of domestic wastewaters and septic systems from diffuse communities that reside along the waterways they examined. PBDE sampling by Serdar and Johnson (2006) from the Spokane River (Table 18; Figure 31) support this finding.

6 SUMMARY

This appendix provided an overview of information on the concentrations of chemicals in fish tissue from the UCR; evaluated the value of historical (pre-2005) and recent (2005) fish tissue data for ecological risk assessment purposes; explored spatial, temporal and interspecific patterns in fish tissue chemistry; and interpreted information on exposures of fish to chemical contaminants. The results can be used to guide development of the BERA and future sampling plans, both for risk assessment to fish and to piscivorous wildlife. This section provides a summary and synthesis of the information presented, and identifies potential data needs and recommendations for future evaluations to more effectively evaluate potential risks to fish in the UCR.

Several important findings resulted from the evaluation of existing information on fish tissue chemistry in the UCR

- The data on chemical concentrations in fish tissue collected in the UCR prior to 2005 were primarily for fillet tissue and for species and sizes considered edible by people. Few studies provided data for whole bodies of largescale sucker, but the most recent data of this kind were published in 1997. The pre-2005 data are not considered to be highly useful for the BERA, because they vary substantially with respect to target species, fish size, and sampling locations. In addition, the data generally are not representative of the tissue (i.e., whole body) and size ranges commonly consumed by piscivorous fish and wildlife, and are not considered representative of current conditions in the UCR.
- Although the historical data have limitations for the ERA, they have value in qualitatively evaluating general spatial and temporal trends in historical fish tissue concentrations in the UCR, and the following generalizations can be made:
    - Concentrations of copper, lead, and zinc in whole largescale sucker declined considerably with increasing distance downstream from Northport. However, arsenic, cadmium and mercury concentrations did not decrease with distance from Northport. Results for whole bodies of suckers were likely affected to an unknown degree by sediment in their guts.
    - Tissue concentrations of mercury were generally higher in walleye and largescale sucker than in other species.
    - Mercury concentrations in walleye tissues generally declined in the middle and lower reaches of the UCR between 1995 and 2005.
    - Several metals, including cadmium, copper, lead, and mercury declined in tissue of whitefish, rainbow trout and walleye collected upstream of the U.S.-Canada border between 1995 and 1999.

- The Phase 1 data set on fish tissue concentrations by EPA (USEPA 2007) in 2005 provides the most systematic and robust data set for fish tissue at the Site. This data set is considered useful for the ERA, and representative of baseline conditions. However, it is incomplete with respect to smaller fish species and life stages that are important for understanding risks to piscivorous fish and wildlife.
- Qualitative comparisons between the pre-2005 and 2005 data for chemical concentrations in UCR fish suggest that tissue concentrations of copper, lead, and mercury have declined in fillet of walleye and rainbow trout from the mid- to late-1990s to 2005; whereas patterns for arsenic, cadmium and 2,3,7,8-TCDF are equivocal, partly due to the high metals detection limits for the pre-2005 data. Concentrations of PCBs appear to have decreased in walleye and trout fillets from the middle and lower portions of the site over that time period.
- Although the 2005 fish tissue data were primarily for fish species and size classes of interest to human consumption, the data are useful for evaluating patterns in the spatial distribution of fish exposures, and other species-specific fish exposure patterns that are relevant to the BERA. These include
    - The highest concentrations of most metals occurred in largescale sucker, burbot and walleye. Consistent with trends identified for the pre-2005 data, the highest mercury concentrations were found in walleye and sucker. In 2005, mercury concentrations in burbot were also among the highest for the species evaluated. Mercury was not measured in this species in the pre-2005 data set. The elevated concentrations in walleye and burbot likely reflect their high trophic level as piscivores. The relatively long lifespan of the benthivorous largescale sucker may affect concentrations of mercury in that species.
    - As found for the pre-2005 data, tissue concentrations of copper, lead and zinc in largescale sucker declined with distance downstream from the U.S.-Canada border. However, clear patterns of declining concentrations from north to south were not observed for other fish species.
    - Differences among species in the locations and magnitude of peak tissue concentrations of both metals and organic compounds suggest different pathways and mechanisms of exposure. Benthic fish (i.e., largescale suckers) and top predators (i.e., walleye, burbot and to some degree rainbow trout) consistently showed the most pronounced spatial patterns (i.e., high spatial variability). However, some of these spatial differences, while statistically significant ($p \leq 0.05$), were not large. Whether these differences reflect such factors as variations in age, life history, and diet of each species across the UCR is uncertain.
    - Understanding the spatial patterns of exposure for each fish species may be confounded to some degree by the effect of length (i.e., as a surrogate for size and age) on tissue concentrations. In addition, understanding the spatial patterns for

whole bodies of largescale sucker may be confounded by the presence of sediment in the fish stomachs.

- Statistically significant correlations between whole body concentrations and fillet concentrations in rainbow trout and walleye occur in both species for arsenic, beryllium and mercury, and only in rainbow trout for antimony, chromium, selenium and silver. Therefore, if it is necessary to predict fillet concentrations from whole body concentrations, this should only be performed where a statistically significant relationship can be demonstrated and described.

- Correlations between concentrations of metals in the gut/gut contents samples of largescale sucker and the gutless whole body samples were conducted. The analysis identifies three different patterns–no relationship between gut/gut contents and gutless whole body concentrations (antimony, arsenic, barium, beryllium, calcium, chromium, magnesium, nickel, potassium, selenium, silver), a significant linear relationship (aluminum, cadmium, cobalt) and a significant non-linear relationship (copper, iron, lead, manganese zinc). The differences suggest that the uptake, retention, and excretion rates of metals from the guts, which contained large amounts of sediment, are variable.

- Statistically significant correlations ($p \leq 0.05$) between chemical concentrations in whole fish and sediments were apparent for several species, and several metals. When wild and hatchery rainbow trout data were combined, the largest number of significant correlations between sediment and tissue occurred. The absence of a consistent pattern of sediment-tissue correlations suggests that exposure pathways vary across the UCR or among species, or the confounding effect of fish movements within the site. It may also be an indication of the limits of this analysis resulting from the use of mean sediment concentrations for each of only three locations.

- A variety of external abnormalities including skin lesions, hemorrhagic abnormalities, fin erosion, external parasites and other anomalies were observed and recorded by EPA biologists during Phase 1 activities (USEPA 2007). The data illustrate that the greatest percentage of fish examined with external anomalies was in FSCA 5, and that the overall percent of fish affected with anomalies in the UCR (66 percent) was less than the percent of fish affected across the Columbia River Basin (74 percent from Hinck et al. [2006]). Although histopathological examinations were not perfoemed, Hinck et al. (2006) concluded that the majority of anomalies (including lesions) observed throughout the Columbia River Basin (including the UCR) are inflammatory responses to parasitic or bacterial infections. Peters (1995) and studies sponsored by the Canadian government also equated most fish lesions with parasitic infections.

- The information on reference conditions for fish tissue concentrations in eastern Washington was found to be limited. Data are lacking for many chemicals, and have been intermittently collected for many others. In addition, most of the tissue data collected in candidate reference locations were for fillet tissue, rather than whole bodies. It was therefore concluded that quantitative comparisons of these small data sets with data for the UCR was limited at this time. However, both smallmouth and largemouth bass fillet samples have been analyzed in many potential reference locations in eastern Washington. Data for these species from the UCR could allow for direct comparison with available reference locations, if necessary.
- Although PBDEs have been detected in fish from the UCR, as well as other water bodies in the UCR drainage basin, they appear to be associated primarily with domestic wastewaters, and are typically lower in fish tissue from stations downstream from Trail, British Columbia, than from locations upstream of that location. In addition, PBDE concentrations in fish tissue from the UCR were generally comparable to concentrations in fish from reference locations in eastern Washington.

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ATTACHMENT F1

SUMMARY OF ANALYTICAL DATA FOR EPA 2005 FISH COMPOSITE SAMPLES

Note: This is a copy of material from Appendix B of the Upper Columbia River Quality Assurance Project Plan for the 2009 Fish Tissue Study - September 2009

CONTENTS

Table B1-1. Summary of Analytical Data for Burbot

Burbot	Collection Area	2		3		4		5		6	
	River Mile	723		706		678		635		605	
	Fish per composite	3		5		5		5		5	
	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Aluminum											
	1	5.0		4.7		5.5		5.3		11	
	2	5.5		8.1		5.0		20		6.0	
	3	3.7		14		4.9		7.5		8.6	
	4			3.8		6.2		8.5		8.6	
	5			4.8				11.1		6.8	
	median	*5.0*		*4.8*		*5.2*		*8.5*		*8.6*	
	mean	*4.7*		*7.0*		*5.4*		10		*8.3*	
	se	*0.5*		*2.2*		*0.3*		*3.2*		*1.1*	
Arsenic											
	1	0.78		0.62		0.88		0.80		0.71	
	2	0.67		0.68		0.64		0.68		0.94	
	3	0.73		0.65		0.76		0.96		0.73	
	4			0.72		0.94		0.85		0.96	
	5			0.52				0.87		0.86	
	median	0.70		0.66		0.76		0.86		0.90	
	mean	0.70		0.64		0.78		0.84		0.87	
	se	*0.03*		*0.03*		*0.07*		*0.05*		*0.05*	
Barium											
	1	5.4		5.3		6.6		5.1		6.2	
	2	3.9		6.1		5.9		5.9		7.3	
	3	5.6		6.0		5.0		8.1		6.3	
	4			5.2		6.2		5.6		5.8	
	5			3.2				8.5		7.1	
	median	*5.4*		*5.3*		*6.1*		*5.9*		*6.3*	
	mean	*5.0*		*5.2*		*5.9*		*6.6*		*6.5*	
	se	*1.3*		*1.1*		*1.2*		*1.3*		*1.3*	
Cadmium											
	1	0.030		0.021		0.032		0.088		0.037	
	2	0.025		0.048		0.046		0.023		0.038	
	3	0.020		0.039		0.043		0.047		0.065	
	4			0.024		0.043		0.042		0.044	
	5			0.032				0.040		0.053	
	median	*0.025*		*0.032*		*0.043*		*0.042*		*0.044*	
	mean	*0.025*		*0.033*		*0.041*		*0.048*		*0.047*	
	se	*0.003*		*0.006*		*0.003*		*0.014*		*0.006*	
Calcium											
	1	8390	J	9120	J	9700	J	7080	J	10100	
	2	7710	J	7990	J	7260	J	10300	J	10400	
	3	9240	J	8610	J	6690	J	10300	J	7780	
	4			7840	J	8180	J	8350		7390	
	5			4900	J			11600		8830	
	median	*8390*		*7990*		*7720*		*10300*		*8830*	
	mean	*8450*		*7690*		*7958*		*9530*		*8900*	
	se	*443*		*295*		*657*		*790*		*776*	

Table B1-1. Summary of Analytical Data for Burbot

Burbot	Collection Area	2		3		4		5		6	
	River Mile	723		706		678		635		605	
	Fish per composite	3		5		5		5		5	
	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Chromium											
	1	0.39		0.30		0.44		0.29		0.45	
	2	0.50		0.37		0.26		1.49		0.34	
	3	0.41		0.42		0.31		0.27		0.26	
	4			0.33		0.29		0.40		0.48	
	5			0.34				0.34		0.27	
	median	0.41		0.34		0.30		0.34		0.34	
	mean	0.43		0.35		0.33		0.56		0.36	
	se	*0.03*		*0.03*		*0.04*		*0.29*		*0.05*	
Cobalt											
	1	0.041		0.028		0.038		0.035		0.029	
	2	0.027		0.042		0.038		0.037		0.030	
	3	0.028		0.044		0.037		0.039		0.040	
	4			0.033		0.035		0.032		0.035	
	5			0.029				0.036		0.033	
	median	*0.028*		*0.033*		*0.037*		*0.036*		*0.033*	
	mean	*0.032*		*0.035*		*0.037*		*0.036*		*0.033*	
	se	*0.004*		*0.004*		*0.001*		*0.002*		*0.003*	
Copper											
	1	1.2		0.9		1.2		1.3		1.0	
	2	1.1		1.4		1.4		0.8		0.9	
	3	1.0		1.4		1.0		1.2		1.5	
	4			1.0		1.0		1.0		1.0	
	5			1.3				0.9		1.1	
	median	*1.1*		*1.3*		*1.1*		*1.0*		*1.0*	
	mean	*1.1*		*1.2*		*1.1*		*1.0*		*1.1*	
	se	*0.0*		*0.1*		*0.1*		*0.1*		*0.1*	
Iron											
	1	22		18		21		30		26	
	2	18		34		24		36		24	
	3	17		37		23		28		28	
	4			22		23		26		32	
	5			21				29		26	
	median	*18*		*22*		*23*		*29*		*26*	
	mean	*19*		*27*		*23*		*30*		*27*	
	se	*1*		*5*		*1*		*2*		*2*	
Lead											
	1	0.073		0.066		0.082		0.092		0.078	
	2	0.064		0.13		0.084		0.056		0.089	
	3	0.065		0.17		0.10		0.12		0.091	
	4			0.087		0.11		0.062		0.083	
	5			0.070				0.11		0.084	
	median	*0.065*		*0.087*		*0.094*		*0.092*		*0.084*	
	mean	*0.067*		*0.10*		*0.095*		*0.088*		*0.085*	
	se	*0.003*		*0.023*		*0.007*		*0.015*		*0.003*	

Table B1-1. Summary of Analytical Data for Burbot

Burbot	Collection Area	2		3		4		5		6	
	River Mile	723		706		678		635		605	
	Fish per composite	3		5		5		5		5	
	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Magnesium											
	1	350	J	350	J	365	J	341	J	332	
	2	347	J	335	J	322	J	364	J	354	
	3	358	J	348	J	310	J	363	J	305	
	4			353	J	334	J	320		300	
	5			294	J			370		324	
	median	*350*		*348*		*328*		*363*		*324*	
	mean	*352*		*336*		*333*		*352*		*323*	
	se	*3.3*		*4.0*		*12*		*10*		*13*	
Manganese											
	1	2.1		1.9		3.2		2.1		2.4	
	2	2.2		2.1		2.4		2.8		2.8	
	3	2.1		2.9		2.1		3.0		1.9	
	4			1.9		2.5		1.8		2.5	
	5			1.3				2.8		2.6	
	median	*2.1*		*1.9*		*2.4*		*2.8*		*2.5*	
	mean	*2.1*		*2.0*		*2.6*		*2.5*		*2.4*	
	se	*0.0*		*0.2*		*0.2*		*0.3*		*0.2*	
Mercury											
	1	0.18		0.14		0.17		0.24		0.21	
	2	0.11		0.20		0.23		0.13		0.15	
	3	0.12		0.18		0.18		0.18		0.23	
	4			0.12		0.18		0.18		0.18	
	5			0.16				0.22		0.24	
	median	*0.12*		*0.16*		*0.18*		*0.18*		*0.21*	
	mean	*0.14*		*0.16*		*0.19*		*0.19*		*0.20*	
	se	*0.02*		*0.02*		*0.01*		*0.02*		*0.02*	
Nickel											
	1	0.30		0.32		0.38		0.27		0.35	
	2	0.32		0.31		0.26		0.42		0.32	
	3	0.30		0.33		0.25		0.37		0.26	
	4			0.24		0.29		0.28		0.25	
	5			0.18				0.36		0.31	
	median	*0.30*		*0.31*		*0.27*		*0.36*		*0.31*	
	mean	*0.31*		*0.28*		*0.29*		*0.34*		*0.30*	
	se	*0.01*		*0.02*		*0.03*		*0.04*		*0.02*	
Potassium											
	1	3140		2900		2960		3160		2640	
	2	3120		2950		3060		2700		2600	
	3	2990		2950		2990		2720		2870	
	4			3170		3170		2880		2860	
	5			3160				2810		2710	
	median	*3120*		*2950*		*3025*		*2810*		*2710*	
	mean	*3080*		*3030*		*3045*		*2850*		*2740*	
	se	*47*		*60*		*47*		*106*		*71*	

Table B1-1. Summary of Analytical Data for Burbot

Burbot	Collection Area	2		3		4		5		6	
	River Mile	723		706		678		635		605	
	Fish per composite	3		5		5		5		5	
	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Selenium											
	1	0.58		0.59		0.59		0.52		0.41	
	2	0.71		0.58		0.56		0.42		0.49	
	3	0.77		0.83		0.63		0.43		0.42	
	4			0.71		0.58		0.51		0.46	
	5			0.57				0.52		0.39	
	median	0.71		0.59		0.59		0.51		0.42	
	mean	0.68		0.66		0.59		0.48		0.43	
	se	*0.06*		*0.06*		*0.02*		*0.03*		*0.02*	
Sodium											
	1	1360		1360		1340		1640		1300	
	2	1330		1360		1330		1400		1460	
	3	1540		1550		1300		1560		1490	
	4			1420		1470		1460		1490	
	5			1220				1510		1370	
	median	*1360*		*1360*		*1335*		*1510*		*1460*	
	mean	*1410*		*1380*		*1360*		*1510*		*1420*	
	se	*66*		*45*		*38*		*53*		*46*	
Uranium											
	1	0.0046		0.0042		0.0054		0.0052		0.0051	
	2	0.0045		0.0053		0.0038		0.0045		0.0070	
	3	0.0031		0.011		0.0039		0.0063		0.0045	
	4			0.0044		0.0048		0.0043		0.0037	
	5			0.0030				0.0051		0.0051	
	median	*0.0045*		*0.0044*		*0.0043*		*0.0051*		*0.0051*	
	mean	*0.0041*		*0.0057*		*0.0045*		*0.0051*		*0.0051*	
	se	*0.0005*		*0.0017*		*0.0004*		*0.0005*		*0.0007*	
Vanadium											
	1	0.084	U	0.085		0.099		0.086		0.08	U
	2	0.11		0.11		0.076	U	0.079	U	0.097	
	3	0.13		0.17		0.080		0.10		0.091	
	4			0.093		0.080	U	0.10		0.089	U
	5			0.09	U			0.10		0.084	U
	median	*0.11*		*0.09*		*0.08*		*0.10*		*0.09*	
	mean	*0.11*		*0.11*		*0.08*		*0.09*		*0.09*	
	se	*0.01*		*0.02*		*0.01*		*0.01*		*0.00*	
Zinc											
	1	12		12		13		14		12	J
	2	12		13		13		11		12	J
	3	12		14		11		13		13	J
	4			13		12		13	J	12	J
	5			11				13	J	14	J
	median	*12*		*13*		*12*		*13*		*12*	
	mean	*12*		*12*		*12*		*13*		*12*	
	se	*0.2*		*0.4*		*0.4*		*0.5*		*0.3*	

Table B1-1. Summary of Analytical Data for Burbot

Burbot	Collection Area	2		3		4		5		6	
	River Mile	723		706		678		635		605	
	Fish per composite	3		5		5		5		5	
	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Moisture %	1	79		79		79		80		80	
	2	77		79		80		79		79	
	3	78		79		81		80		80	
	4			78		79		79		79	
	5			77				79		80	
	median	*78*		*79*		*80*		*79*		*80*	
	mean	*78*		*79*		*80*		*79*		*79*	
	se	*0.4*		*0.3*		*0.3*		*0.3*		*0.2*	
Lipids %	1	1.3		6.3		1.1		0.8		1.6	
	2	2.4		1.3		0.6		1.4		2.0	
	3	2.2		1.2		0.9		0.9		1.3	
	4			2.3		1.3		1.9		1.6	
	5			2.5				1.4		1.0	
	median	*2.2*		*2.3*		*1.0*		*1.4*		*1.6*	
	mean	*2.0*		*2.7*		*1.0*		*1.3*		*1.5*	
	se	*0.3*		*1.2*		*0.1*		*0.3*		*0.1*	
Age years	1	3.7		4.0		3.8		8.0		4.6	
	2	3.3		7.2		5.2		3.8		5.4	
	3	3.7		6.6		5.0		7.0		6.8	
	4			4.2		5.2		8.2		5.2	
	5			4.8				7.2		7.2	
	median	*3.7*		*4.8*		*5.1*		*7.2*		*5.4*	
	mean	*3.6*		*5.4*		*4.8*		*6.8*		*5.8*	
	se	*0.1*		*0.8*		*0.3*		*1.0*		*0.5*	
Length mm	1	597		734		490		872		621	
	2	781		650		492		758		593	
	3	602		714		584		781		637	
	4			735		619		796		659	
	5			1042				706		616	
	median	602		734		538		781		621	
	mean	660		775		546		783		625	
	se	*60*		*20*		*33*		*25*		*14*	
Weight g	1	484		515		471		573		496	
	2	536		523		493		527		495	
	3	490		541		498		569		507	
	4			513		540		557		510	
	5			553				550		503	
	median	*490*		*523*		*495*		*557*		*503*	
	mean	*503*		*529*		*501*		*556*		*502*	
	se	*16*		*6.2*		*14*		*10*		*3.7*	

Notes: Q = Laboratory qualifier
U = reported value is at or below the limit of detection

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Aluminum	whole body composite														
	1	138	J	64	J	12	J	51	J	46	J	22	J	40	J
	2	81	J			24	J	48	J	79	J	79	J	88	J
	3					19	J	13	J	86	J	23	J	50	J
	4					42	J	20	J	86	J	13	J	47	J
	5									89	J	9	J		
	median	109		64		21		34		86		22		49	
	mean	109		64		24		33		77		29		56	
	se	29				6		10		8		13		11	
	gutless individual														
	1	20	J	3.7	U			4.3	J					4.8	U
	2	7.1	J	5.1				3.6	J					3.7	U
	3	113	J	4.5				15	J					14	
	4	6.8	J	5.2				5.8	J					3.9	U
	5	8.2	J	3.8				4.5	J					4.0	U
	median	8.2		4.5				4.5						4.0	
	mean	31		4.5				6.7						6.0	
	se	21		0.3				2.2						2.0	
	gut														
	1	2860		213				609						56	
	2	1870		450				346						29	
	3	744		246				183						1180	
	4	1410		424				324						117	
	5	6490		297				65						150	
	median	1870		297				324						117	
	mean	2670		326				305						307	
	se	1000		47				91						220	
	reconstructed whole body														
	1	232		20				38						8	
	2	150		39				23						5	
	3	138		27				27						107	
	4	94.5		32				31						13	
	5	401		32				8.3						11	
	median	150		32				27						11	
	mean	203		30				26						29	
	se	54		3				5						20	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Arsenic	whole body composite														
	1	0.33		0.16		0.16		0.16		0.18		0.17		0.18	
	2	0.28				0.15		0.19		0.19		0.23		0.22	
	3					0.14		0.16		0.18		0.20		0.18	
	4					0.20		0.13		0.22		0.19		0.21	
	5									0.20		0.13			
	median	0.31		0.16		0.16		0.16		0.19		0.19		0.20	
	mean	0.31		0.16		0.16		0.16		0.19		0.18		0.20	
	se	0.03				0.01		0.01		0.01		0.02		0.01	
	gutless individual														
	1	0.15		0.10				0.19						0.21	
	2	0.20		0.18				0.21						0.20	
	3	0.12		0.18				0.21						0.15	
	4	0.18		0.10				0.12						0.14	
	5	0.15		0.19				0.14						0.15	
	median	0.15		0.18				0.19						0.15	
	mean	0.16		0.15				0.18						0.17	
	se	0.01		0.02				0.02						0.02	
	gut														
	1	2.4		0.61				0.67						0.47	
	2	1.7		0.73				0.39						0.25	
	3	1.1		0.81				0.63						1.6	
	4	1.5		1.0				0.50						0.38	
	5	5.0		0.083				0.26						0.35	
	median	1.7		0.73				0.50						0.38	
	mean	2.3		0.65				0.49						0.62	
	se	0.7		0.16				0.08						0.26	
	reconstructed whole body														
	1	0.31		0.14				0.22						0.23	
	2	0.31		0.22				0.22						0.20	
	3	0.16		0.24				0.24						0.27	
	4	0.26		0.16				0.15						0.16	
	5	0.44		0.25				0.15						0.16	
	median	0.31		0.22				0.22						0.20	
	mean	0.30		0.20				0.20						0.20	
	se	0.04		0.02				0.02						0.02	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale	Collection Area	1		1(A)		2		3		4		5		6	
Sucker	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Barium	whole body composite														
	1	12		5.1	J	2.0		2.6		4.0	J	3.3	J	2.8	J
	2	7.7				2.8		3.1		4.3	J	4.1	J	3.7	J
	3					2.5		1.6		2.6	J	3.7	J	3.8	J
	4					3.5		1.9		3.4	J	2.3	J	3.5	J
	5									4.2	J	3.3	J		
	median	9.7		5.1		2.7		2.2		4.0		3.3		3.6	
	mean	9.7		5.1		2.7		2.3		3.7		3.3		3.5	
	se	1.9				0.3		0.3		0.3		0.3		0.2	
	gutless individual														
	1	2.6		1.1				4.1						2.0	
	2	1.7		2.3				2.2						1.7	
	3	3.2		1.2				1.5						2.5	
	4	3.0		1.8				0.97						3.3	
	5	2.2		1.9				2.3						2.6	
	median	2.6		1.8				2.2						2.5	
	mean	2.6		1.7				2.2						2.4	
	se	0.3		0.2				0.5						0.3	
	gut														
	1	2.4		0.61				0.67						0.47	
	2	1.7		0.73				0.39						0.25	
	3	1.1		0.81				0.63						1.6	
	4	1.5		1.0				0.50						0.38	
	5	5.0		0.83				0.26						0.35	
	median	1.7		0.81				0.50						0.38	
	mean	2.3		0.80				0.49						0.62	
	se	0.7		0.068				0.075						0.26	
	reconstructed whole body														
	1	21		2.1				4.4						2.0	
	2	11		3.4				2.9						1.6	
	3	4.9		2.0				1.8						3.7	
	4	7.0		3.2				1.2						3.3	
	5	39		3.5				2.2						2.7	
	median	11		3.2				2.2						2.7	
	mean	16		2.9				2.5						2.7	
	se	6		0.3				0.6						0.4	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Cadmium	whole body composite														
	1	0.20		0.31		0.29		0.29		0.28		0.28		0.29	
	2	0.27				0.45		0.30		0.30		0.29		0.30	
	3					0.37		0.31		0.37		0.29		0.26	
	4					0.34		0.39		0.27		0.28		0.26	
	5									0.33		0.26			
	median	0.24		0.31		0.35		0.31		0.30		0.28		0.275	
	mean	0.24		0.31		0.36		0.32		0.31		0.28		0.277	
	se	0.04				0.03		0.02		0.02		0.01		0.01	
	gutless individual														
	1	0.27		0.29				0.20						0.30	
	2	0.41		0.26				0.27						0.15	
	3	0.34		0.25				0.11						0.33	
	4	0.41		0.35				0.03						0.17	
	5	0.038		0.24				0.10						0.15	
	median	0.34		0.26				0.11						0.17	
	mean	0.30		0.28				0.14						0.22	
	se	0.07		0.02				0.04						0.04	
	gut														
	1	1.6		1.4				1.1						2.0	
	2	2.1		1.7				1.2						0.97	
	3	2.3		1.0				0.89						0.69	
	4	1.6		2.0				0.21						0.78	
	5	2.5		1.3				0.44						1.0	
	median	2.1		1.4				0.89						0.97	
	mean	2.0		1.5				0.77						1.1	
	se	0.2		0.2				0.19						0.23	
	reconstructed whole body														
	1	0.37		0.37				0.25						0.41	
	2	0.54		0.36				0.32						0.19	
	3	0.42		0.33				0.17						0.36	
	4	0.49		0.45				0.043						0.22	
	5	0.51		0.35				0.13						0.19	
	median	0.49		0.36				0.17						0.22	
	mean	0.47		0.37				0.18						0.27	
	se	0.03		0.02				0.05						0.05	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Calcium	whole body composite														
	1	8650		13200	J	9810		10600		15700	J	11700	J	6830	J
	2	8120				11300		12800		13000	J	13600	J	9890	J
	3					11400		9810		8010	J	10900	J	10700	J
	4					10300		8830		8200	J	9300	J	12700	J
	5									12000	J	14100	J		
	median	8390		13200		10800		10200		12000		11700		10300	
	mean	8390		13200		10700		10500		11400		11900		10000	
	se	270				390		840		1500		880		1200	
	gutless individual														
	1	9660		7730				11100						7840	
	2	8910		8110				10600						11700	
	3	14000		10500				12400						7730	
	4	10600		9410				9520						12600	
	5	8240		9890				10600						10300	
	median	9660		9410				10600						10300	
	mean	10300		9130				10800						10000	
	se	1000		530				470						990	
	gut														
	1	7740		17800				3070						2560	
	2	6350		8930				8320						167	
	3	8990		18800				10900						2250	
	4	5360		27800				407						1700	
	5	21100		14100				514						735	
	median	7740		17800				3070						1700	
	mean	9910		17500				4640						1480	
	se	2900		3100				2100						450	
	reconstructed whole body														
	1	9510		8490				10500						7510	
	2	8710		8170				10500						11100	
	3	13800		11200				12300						7290	
	4	10300		10600				8810						11700	
	5	9020		10300				10000						9840	
	median	9510		10300				10500						9840	
	mean	10300		9750				10400						9490	
	se	920		600				560						900	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Chromium	whole body composite														
	1	3.1	J	1.3		0.67	J	1.0	J	0.71		1.1		1.8	
	2	1.7	J			1.6	J	0.86	J	1.2		1.5		1.8	
	3					1.1	J	0.65	J	1.3		0.95		1.3	
	4					1.0	J	0.60	J	1.6		0.51		1.7	
	5									2.1		0.47			
	median	2.4		1.3		1.1		0.76		1.3		0.95		1.8	
	mean	2.4		1.3		1.1		0.79		1.4		0.89		1.7	
	se	0.7				0.2		0.10		0.2		0.18		0.1	
	gutless individual														
	1	0.64	J	0.47				0.50	J					0.81	
	2	0.66	J	0.68				0.43	J					0.76	
	3	0.75	J	0.59				0.36						1.5	
	4	0.63	J	0.33				0.50						0.46	
	5	0.55	J	0.61				0.37						0.95	
	median	0.64		0.59				0.43						0.81	
	mean	0.64		0.53				0.44						0.89	
	se	0.03		0.06				0.03						0.16	
	gut														
	1	54		3.2				46						1.3	
	2	99		8.6				4.7						2.0	
	3	54		3.5				3.5						21	
	4	38		4.6				24						6.8	
	5	102		3.3				1.9						5.6	
	median	54		3.5				4.7						5.6	
	mean	69		4.6				16						7.3	
	se	13		1.0				8.4						3.5	
	reconstructed whole body														
	1	4.6		0.68				3.0						0.84	
	2	8.2		1.3				0.68						0.82	
	3	2.9		0.86				0.58						3.0	
	4	3.0		0.60				2.3						0.99	
	5	6.7		0.87				0.47						1.2	
	median	4.6		0.86				0.68						0.99	
	mean	5.1		0.86				1.4						1.4	
	se	1.1		0.12				0.52						0.41	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Cobalt	whole body composite														
	1	0.36		0.12		0.040		0.065		0.063		0.054		0.061	
	2	0.18				0.056		0.067		0.081		0.099		0.080	
	3					0.045		0.034		0.086		0.061		0.058	
	4					0.064		0.039		0.11		0.036		0.063	
	5									0.11		0.050			
	median	0.27		0.12		0.050		0.052		0.086		0.054		0.062	
	mean	0.27		0.12		0.051		0.051		0.091		0.060		0.065	
	se	0.09				0.006		0.009		0.009		0.011		0.005	
	gutless individual														
	1	0.052		0.03				0.050						0.035	
	2	0.036		0.03				0.027						0.023	
	3	0.058		0.05				0.029						0.069	
	4	0.041		0.04				0.016						0.046	
	5	0.035		0.04				0.034						0.027	
	median	0.041		0.037				0.029						0.035	
	mean	0.044		0.038				0.031						0.040	
	se	0.005		0.005				0.006						0.008	
	gut														
	1	8.7		0.44				0.86						0.10	
	2	5.0		0.45				0.24						0.06	
	3	1.9		0.36				0.17						0.80	
	4	2.5		0.58				0.39						0.15	
	5	18.8		0.33				0.06						0.16	
	median	5.000		0.440				0.240						0.150	
	mean	7.380		0.432				0.344						0.255	
	se	3.096		0.044				0.140						0.137	
	reconstructed whole body														
	1	0.70		0.057				0.096						0.039	
	2	0.42		0.065				0.039						0.025	
	3	0.13		0.083				0.039						0.128	
	4	0.19		0.074				0.045						0.055	
	5	1.18		0.066				0.036						0.033	
	median	0.416		0.066				0.039						0.039	
	mean	0.524		0.069				0.051						0.056	
	se	0.191		0.004				0.011						0.019	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Copper	whole body composite														
	1	13	J	3.1		0.91	J	0.95	J	0.71		0.77		1.2	
	2	8.1	J			1.4	J	0.91	J	0.83		0.81		1.0	
	3					1.2	J	0.72	J	0.86		0.67		0.79	
	4					1.5	J	0.79	J	0.83		0.60		0.96	
	5									0.82		0.71			
	median	10		3.1		1.3		0.85		0.83		0.71		1.0	
	mean	10		3.1		1.3		0.84		0.81		0.72		0.99	
	se	2.3				0.1		0.05		0.03		0.04		0.08	
	gutless individual														
	1	1.9	J	0.61				0.50	J					0.61	
	2	0.92	J	0.59				0.65	J					0.37	
	3	1.2	J	0.81				0.49						0.94	
	4	0.77	J	0.74				0.40						0.54	
	5	1.0	J	0.70				0.45						0.35	
	median	1.0		0.70				0.49						0.54	
	mean	1.2		0.69				0.50						0.56	
	se	0.2		0.04				0.04						0.11	
	gut														
	1	307		25				13						3.9	
	2	164		14				7.5						7.4	
	3	71		14				6.9						4.2	
	4	83		26				6.0						2.7	
	5	785		7.4				5.7						5.9	
	median	164		14				6.9						4.2	
	mean	282		17				7.8						4.8	
	se	130		4				1.3						0.8	
	reconstructed whole body														
	1	25		2.4				1.2						0.81	
	2	13		1.6				1.0						0.72	
	3	3.9		2.0				0.95						1.2	
	4	5.9		2.3				0.83						0.72	
	5	49		1.4				0.78						0.62	
	median	13		2.0				0.95						0.72	
	mean	19		2.0				0.96						0.81	
	se	8		0.2				0.07						0.10	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Iron	whole body composite														
	1	1060		301		44		89		67		38		86	
	2	585				69		93		93		120		151	
	3					56		29		122		46		91	
	4					92		46		130		25		90	
	5									131		19			
	median	823		301		63		67		122		38		90	
	mean	823		301		65		64		109		49		104	
	se	240				10		16		12		18		16	
	gutless individual														
	1	139		14	J			11						11	J
	2	30		23	J			26						10	J
	3	70		22	J			11						28	J
	4	34		44	J			9.7						11	J
	5	62		15	J			16						12	J
	median	62		22				11						11	
	mean	67		24				15						15	
	se	20		5				3						4	
	gut														
	1	25000		833				1080						96	
	2	14100		1210				677						102	
	3	4980		728				304						2030	
	4	7770		1390				617						259	
	5	66700		665				146						352	
	median	14100		833				617						259	
	mean	23700		965				565						568	
	se	11000		140				160						370	
	reconstructed whole body														
	1	1990		76				71						16	
	2	1100		113				63						15	
	3	265		88				32						188	
	4	517		129				57						32	
	5	4100		79				24						28	
	median	1100		88				57						28	
	mean	1590		97				49						56	
	se	690		10				9						33	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Lead	whole body composite														
	1	6.4	J	6.5	J	3.6	J	3.3	J	2.1	J	0.72	J	0.43	J
	2	3.2	J			4.1	J	3.0	J	1.4	J	0.74	J	0.55	J
	3					4.3	J	2.0	J	1.1	J	0.72	J	0.81	0
	4					3.7	J	3.5	J	1.1	0	0.45	J	0.95	J
	5									1.5	J	0.63	J		
	median	4.8		6.5		3.9		3.2		1.4		0.72		0.68	
	mean	4.8		6.5		3.9		3.0		1.5		0.65		0.69	
	se	1.6				0.2		0.3		0.2		0.05		0.12	
	gutless individual														
	1	5.0	J	3.2				0.71	J					0.35	
	2	7.3	J	6.8				4.3	J					0.29	
	3	14	J	4.1				2.0	J					0.52	
	4	6.3	J	7.8				0.12	J					0.52	
	5	7.8	J	3.5				1.7	J					0.27	
	median	7.3		4.1				1.7						0.35	
	mean	8.0		5.1				1.8						0.39	
	se	1.5		0.93				0.72						0.05	
	gut														
	1	35		2.4				0.80						0.14	
	2	22		5.0				1.9						0.070	
	3	12		2.1				1.4						1.0	
	4	14		4.8				0.66						0.17	
	5	116		2.2				0.29						0.20	
	median	22		2.4				0.80						0.17	
	mean	40		3.3				1.0						0.32	
	se	19		0.66				0.29						0.18	
	reconstructed whole body														
	1	7.3		3.1				0.72						0.34	
	2	8.4		6.6				4.2						0.28	
	3	13		3.9				2.0						0.56	
	4	6.8		7.6				0.16						0.49	
	5	14		3.4				1.7						0.27	
	median	8.4		3.9				1.7						0.34	
	mean	10		4.9				1.7						0.39	
	se	1.6		0.9				0.7						0.06	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Magnesium	whole body composite														
	1	367		383		337		370		394		339		305	
	2	353				356		398		382		397		364	
	3					356		337		346		327		351	
	4					338		324		343		289		369	
	5									398		369			
	median	360		383		347		354		382		339		358	
	mean	360		383		347		357		373		344		347	
	se	7				5		17		12		18		15	
	gutless individual														
	1	357		305				334						289	
	2	332		319				362						307	
	3	412		347				385						291	
	4	369		319				389						318	
	5	328		321				374						340	
	median	357		319				374						307	
	mean	359		322				369						309	
	se	15		7				10						9	
	gut														
	1	1200		363				505						173	
	2	885		536				348						129	
	3	498		417				295						887	
	4	854		595				262						174	
	5	2020		422				146						214	
	median	885		422				295						174	
	mean	1090		467				311						316	
	se	260		43				59						140	
	reconstructed whole body														
	1	420		310				343						282	
	2	374		335				361						299	
	3	415		353				378						339	
	4	399		336				379						306	
	5	430		331				360						334	
	median	415		335				361						306	
	mean	408		333				364						312	
	se	9.8		7				7						11	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Manganese	whole body composite														
	1	28		14	J	6.7		7.6		8.9	J	6.3	J	4.4	J
	2	23				7.5		8.3		9.3	J	9.3	J	6.5	J
	3					6.9		4.3		6.6	J	7.7	J	6.3	J
	4					7.5		5.3		7.3	J	4.3	J	8.2	J
	5									9.1	J	6.1	J		
	median	25		14		7.2		6.5		8.9		6.3		6.4	
	mean	25		14		7.1		6.4		8.2		6.7		6.3	
	se	2				0.2		0.9		0.5		0.8		0.8	
	gutless individual														
	1	8.7		4.5	J			4.5						2.4	J
	2	12		11	J			5.8						2.6	J
	3	15		5.4	J			6.8	J					7.5	J
	4	12		9.9	J			2.0	J					4.6	J
	5	10		5.1	J			5.9	J					2.4	J
	median	12		5.4				5.8						2.6	
	mean	12		7.1				5.0						3.9	
	se	1.1		1.3				0.8						1.0	
	gut														
	1	504	J	26	J			47	J					11	J
	2	284	J	28	J			22	J					1.7	J
	3	100	J	22	J			19	J					47	
	4	166	J	43	J			13						12	J
	5	1250	J	17	J			3.1	J					8.8	J
	median	284		26				19						10.6	
	mean	461		27				21						16.0	
	se	210		5				7						7.9	
	reconstructed whole body														
	1	46		6.1				6.9						2.9	
	2	33		12				6.7						2.6	
	3	19		6.9				7.6						11	
	4	22		12				2.9						5.2	
	5	85		6.2				5.7						2.8	
	median	33		6.9				6.8						2.9	
	mean	41		8.7				6.0						4.8	
	se	12		1.4				0.8						1.5	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Mercury	whole body composite														
	1	0.077		0.19		0.22		0.28		0.30		0.24		0.21	
	2	0.093				0.21		0.23		0.26		0.23		0.25	
	3					0.17		0.28		0.25		0.21		0.23	
	4					0.17		0.29		0.22		0.20		0.21	
	5									0.26		0.26			
	median	0.085		0.19		0.19		0.28		0.26		0.23		0.22	
	mean	0.085		0.19		0.19		0.27		0.26		0.23		0.23	
	se	0.008				0.01		0.01		0.01		0.01		0.01	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Nickel	whole body composite														
	1	0.89		0.60		0.35		0.57		0.58		0.54		0.61	
	2	0.40				0.84		0.54		0.54		0.73		0.58	
	3					0.63		0.39		0.49		0.50		0.57	
	4					0.53		0.37		0.58		0.30		0.60	
	5									0.89		0.41			
	median	0.65		0.60		0.58		0.46		0.58		0.50		0.59	
	mean	0.65		0.60		0.59		0.47		0.62		0.50		0.59	
	se	0.24				0.10		0.05		0.07		0.07		0.01	
	gutless individual														
	1	0.29		0.24				0.38						0.21	
	2	0.30		0.31				0.36						0.25	
	3	0.42		0.34				0.34						0.63	
	4	0.35		0.29				0.34						0.30	
	5	0.09		0.11				0.09						0.12	
	median	0.30		0.29				0.34						0.25	
	mean	0.29		0.26				0.30						0.30	
	se	0.06		0.04				0.05						0.09	
	gut														
	1	20	J	1.8	J			30	J					0.47	J
	2	64	J	4.7	J			2.6	J					0.70	J
	3	33	J	2.0	J			2.1	J					10	J
	4	20	J	2.3	J			17	J					3.8	J
	5	39	J	1.8	J			0.70	J					3.1	J
	median	33		2.0				2.7						3.1	
	mean	35		2.5				11						3.7	
	se	8		0.6				5.8						1.8	
	reconstructed whole body														
	1	1.7		0.36				2.0						0.23	
	2	5.2		0.64				0.49						0.27	
	3	1.7		0.49				0.46						1.4	
	4	1.6		0.41				1.7						0.59	
	5	2.6		0.47				0.34						0.36	
	median	1.7		0.47				0.49						0.36	
	mean	2.6		0.48				1.0						0.57	
	se	0.7		0.05				0.36						0.22	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Potassium	whole body composite														
	1	3280		2700		3210		3420		2910		2880		3110	
	2	3420				3160		3070		3040		2890		3180	
	3					3250		3180		3310		2880		2800	
	4					3240		3150		3210		2810		2730	
	5									3200		2670			
	median	3350		2700		3230		3170		3200		2880		2960	
	mean	3350		2700		3220		3210		3130		2830		2960	
	se	70				20		75		71		42		110	
	gutless individual														
	1	3480		3367				3389						2922	
	2	3206		3596				3736						3207	
	3	3353		2961				3458						3020	
	4	3440		3418				3551						2712	
	5	3767		2932				3498						3400	
	median	3440		3370				3500						3020	
	mean	3450		3250				3530						3050	
	se	92		130				59						120	
	gut														
	1	20	J	1.8	J			30	J					0.47	J
	2	64	J	4.7	J			2.6	J					0.70	J
	3	33	J	2.0	J			2.1	J					10	J
	4	20	J	2.3	J			17	J					3.8	J
	5	39	J	1.8	J			0.70	J					3.1	J
	median	33		2.0				2.7						3.1	
	mean	35		2.5				11						3.7	
	se	8		0.6				5.8						1.8	
	reconstructed whole body														
	1	3424		3272				3348						2868	
	2	3154		3501				3673						3162	
	3	3331		2863				3370						2919	
	4	3399		3357				3397						2641	
	5	3716		2850				3422						3339	
	median	3400		3270				3400						2920	
	mean	3400		3170				3440						2990	
	se	91		130				59						120	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Selenium	whole body composite														
	1	0.36		0.57		0.58		0.73		0.45		0.44		0.49	
	2	0.60				0.61		0.68		0.57		0.50		0.52	
	3					0.58		0.73		0.46		0.47		0.54	
	4					0.64		0.59		0.55		0.48		0.63	
	5									0.62		0.36			
	median	0.48		0.57		0.60		0.70		0.55		0.47		0.53	
	mean	0.48		0.57		0.60		0.68		0.53		0.45		0.54	
	se	0.12				0.01		0.03		0.03		0.03		0.03	
	gutless individual														
	1	0.55		0.50				0.58						0.61	
	2	0.52		0.59				0.77						0.48	
	3	0.68		0.68				0.49						0.44	
	4	0.66		0.47				0.42						0.54	
	5	0.52		0.70				0.56						0.30	
	median	0.55		0.59				0.56						0.48	
	mean	0.59		0.59				0.56						0.47	
	se	0.04		0.05				0.06						0.05	
	gut														
	1	1.1		1.2				1.06						0.93	
	2	0.81		1.5				0.94						0.95	
	3	1.0		1.2				0.83						0.93	
	4	0.84		1.0				0.82						0.87	
	5	1.5		1.5				0.94						1.2	
	median	1.1		1.2				0.94						0.93	
	mean	1.1		1.3				0.92						0.97	
	se	0.1		0.1				0.04						0.05	
	reconstructed whole body														
	1	0.59		0.55				0.60						0.63	
	2	0.54		0.65				0.78						0.50	
	3	0.70		0.73				0.52						0.48	
	4	0.67		0.51				0.45						0.57	
	5	0.58		0.78				0.58						0.34	
	median	0.59		0.65				0.58						0.50	
	mean	0.62		0.64				0.59						0.50	
	se	0.03		0.05				0.06						0.05	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1	Q	1(A)	Q	2	Q	3	Q	4	Q	5	Q	6	Q
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Sodium	whole body composite														
	1	1020		1300		1050		1360		1290		1340		1180	
	2	1050				1360		1350		1270		1290		1300	
	3					1380		1410		1170		1240		1310	
	4					1320		1380		1150		1210		1290	
	5									1300		1430			
	median	1040		1300		1340		1370		1270		1290		1300	
	mean	1040		1300		1280		1380		1240		1300		1270	
	se	15				77		13		32		39		30	
	gutless individual														
	1	1020		987				1230						1070	
	2	1120		1060				1370						1180	
	3	1390		122				1080						985	
	4	1230		1280				836						1490	
	5	1200		1230				1040						1290	
	median	1200		1060				1080						1180	
	mean	1190		936				1110						1200	
	se	61		210				90						88	
	gut														
	1	1310		1610				1380						1650	
	2	1500		1420				1750						1680	
	3	1450		1560				1390						943	
	4	1590		1750				961						1680	
	5	1860		1650				1250						1450	
	median	1500		1610				1380						1650	
	mean	1540		1600				1350						1480	
	se	92		54				130						140	
	reconstructed whole body														
	1	1040		1030				1240						1110	
	2	1150		1090				1390						1200	
	3	1400		1250				1110						982	
	4	1340		1300				846						1500	
	5	1240		1270				1050						1300	
	median	1240		1250				1110						1200	
	mean	1230		1190				1130						1220	
	se	65		54				91						88	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Uranium	whole body composite														
	1	0.033		0.028		0.018		0.018		0.018		0.016		0.013	
	2	0.024				0.018		0.026		0.021		0.019		0.018	
	3					0.014		0.016		0.015		0.014		0.014	
	4					0.016		0.015		0.014		0.015		0.017	
	5									0.020		0.0092			
	median	0.028		0.028		0.017		0.017		0.018		0.015		0.015	
	mean	0.028		0.028		0.017		0.019		0.017		0.015		0.015	
	se	0.004				0.001		0.002		0.001		0.002		0.001	
	gutless individual														
	1	0.015		0.0078				0.019						0.011	
	2	0.027		0.010				0.019						0.0068	
	3	0.030		0.011				0.024						0.015	
	4	0.018		0.024				0.0028						0.010	
	5	0.011		0.011				0.022						0.0066	
	median	0.018		0.011				0.019						0.010	
	mean	0.020		0.013				0.018						0.010	
	se	0.004		0.003				0.004						0.002	
	gut														
	1	0.66		0.10				0.058						0.010	
	2	0.39		0.11				0.12						0.0059	
	3	0.20		0.14				0.050						0.096	
	4	0.31		0.16				0.024						0.016	
	5	1.4		0.11				0.0097						0.019	
	median	0.39		0.12				0.050						0.016	
	mean	0.60		0.13				0.053						0.030	
	se	0.22		0.01				0.020						0.017	
	reconstructed whole body														
	1	0.063		0.015				0.021						0.011	
	2	0.055		0.018				0.025						0.007	
	3	0.036		0.023				0.026						0.022	
	4	0.036		0.033				0.004						0.011	
	5	0.098		0.021				0.022						0.007	
	median	0.055		0.021				0.022						0.011	
	mean	0.058		0.022				0.020						0.012	
	se	0.011		0.003				0.004						0.003	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Vanadium	whole body composite														
	1	0.33		0.18		0.10	U	0.21		0.17		0.12		0.16	
	2	0.27				0.13		0.21		0.20		0.25		0.33	
	3					0.12		0.14		0.29		0.11	U	0.15	J
	4					0.18		0.14		0.28		0.12	U	0.20	
	5									0.30		0.11	U		
	median	0.30		0.18		0.13		0.18		0.28		0.12		0.18	
	mean	0.30		0.18		0.14		0.18		0.25		0.14		0.21	
	se	0.03				0.02		0.02		0.03		0.03		0.04	
	gutless individual														
	1	0.11	U	0.10	U			0.12						0.12	U
	2	0.11	U	0.10	U			0.12						0.10	U
	3	0.11	U	0.11	U			0.10	U					0.17	U
	4	0.11	U	0.10				0.11	U					0.10	U
	5	0.11	U	0.10	U			0.10	U					0.11	U
	median	0.11		0.10				0.11						0.11	
	mean	0.11		0.10				0.11						0.12	
	se	0.00		0.00				0.00						0.01	
	gut														
	1	6.9		0.77				2.1						0.15	
	2	5.3		1.5				1.1						0.13	
	3	2.8		1.1				0.51						3.0	
	4	4.5		1.4				1.2						0.35	
	5	11.5		1.1				0.25						0.44	
	median	5.3		1.1				1.1						0.35	
	mean	6.2		1.2				1.0						0.81	
	se	1.5		0.1				0.3						0.54	
	reconstructed whole body														
	1	0.62		0.15				0.23						0.13	
	2	0.50		0.20				0.17						0.10	
	3	0.21		0.20				0.13						0.39	
	4	0.38		0.19				0.19						0.12	
	5	0.80		0.20				0.11						0.12	
	median	0.50		0.20				0.17						0.12	
	mean	0.50		0.19				0.17						0.17	
	se	0.10		0.01				0.02						0.06	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Zinc	whole body composite														
	1	126	J	45		23	J	21	J	24		18		19	
	2	68	J			28	J	21	J	22		22		20	
	3					27	J	18	J	21		21		17	
	4					25	J	21	J	23		18		19	
	5									21		18			
	median	97		45		26		21		22		18		19	
	mean	97		45		26		20		22		19		19	
	se	29				1.0		0.84		0.67		0.94		0.53	
	gutless individual														
	1	40	J	23				22	J					18	
	2	51	J	40				24	J					19	
	3	55	J	21				23						17	
	4	37	J	29				13						18	
	5	49	J	21				24						18	
	median	49		23				23						18	
	mean	46		27				21						18	
	se	3		4				2						0	
	gut														
	1	1950		58				28						15	
	2	1040		60				26						17	
	3	331		39				26						21	
	4	460		74				16						13	
	5	5170		32				17						17	
	median	1040		58				26						17	
	mean	1790		53				23						17	
	se	890		8				3						1	
	reconstructed whole body														
	1	183		26				22						18	
	2	126		41				24						19	
	3	66		23				23						18	
	4	64		32				13						18	
	5	360		22				24						18	
	median	126		26				23						18	
	mean	160		29				21						18	
	se	55		4				2						0	

Table B1-2. Summary of Analytical Data for Largescale Sucker

Largescale Sucker	Collection Area	1		1(A)		2		3		4		5		6	
	River Mile	741		735		723		706		678		635		605	
	Fish per composite	5		5		5		5		5		5		5	
		mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Lipids	whole body composite														
%	1	5.8		4.0		3.5		5.7		4.1		4.6		8.3	
	2	2.7				2.8		11		5.1		7.7		6.4	
	3					3.6		4.3		7.5		8.1		6.6	
	4					5.3		3.1		6.4		11		8.3	
	5									5.2		6.7			
	median	4.3		4.0		3.6		5.0		5.2		7.7		7.5	
	mean	4.3		4.0		3.8		6.0		5.7		7.5		7.4	
	se	1.6				0.5		1.7		0.6		1.0		0.5	
Age	whole body composite														
years	1	12		30		24		28		26		27		32	
	2	14				27		31		30		29		30	
	3					25		23		24		31		23	
	4					29		30		26		27		29	
	5									28		31			
	median	13		30		26		29		26		29		29	
	mean	13		30		26		28		27		29		29	
	se	1				1		2		1		1		2	
Length	whole body composite														
mm	1	453		553		518		548		500		550		533	
	2	444				592		579		521		532		521	
	3					537		522		508		541		559	
	4					575		566		518		523		521	
	5									533		573			
	median	449		553		556		557		518		541		527	
	mean	449		553		556		554		516		544		534	
	se	5				17		12		6		9		9	
Weight	whole body composite														
g	1	1078		1854		1414		1684		1301		1732		1921	
	2	1088				1918		1893		1602		1603		1487	
	3					1664		1628		1324		1781		1745	
	4					2029		1674		1619		1566		1546	
	5									28		31			
	median	1083		1854		1666		1789		1451		1667		1704	
	mean	1083		1854		1666		1789		1451		1667		1704	
	se	5				252		105		151		65		217	

Notes: Q = Laboratory qualifier
U = reported value is at or below the limit of detection

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Aluminum															
	Wild	WB	1	4.7	2u	4.4	U	8.8	1u			5.1		5.7	1u
	Wild	WB	2	6.6	1u	4.8	U	6.5	1u						
	Wild	WB	3	5.7	2u	4.8	U								
	Wild	WB	4	4.4	2u	4.8									
	Wild	WB	5	5.5	1u	9.3									
			median	*5.5*		*4.8*		*7.7*				*5.1*		*5.7*	
			mean	*5.4*		*5.6*		*7.7*				*5.1*		*5.7*	
			se	*0.4*		*0.9*		*1.1*							
	Wild	F	1	4.2	U			3.6	U					3.1	U
	Wild	F	2	3.8	U			3.8	U						
	Wild	F	3	3.9	U										
	Wild	F	4	4.1	U										
	Wild	F	5	4	U										
			median	*4.0*				*3.7*						*3.1*	
			mean	*4.0*				*3.7*						*3.1*	
			se	*0.1*				*0.1*							
	Wild	O	1	5.2	U			*14*						8.2	
	Wild	O	2	9.3				8.9							
	Wild	O	3	7.5	U										
	Wild	O	4	4.8	U										
	Wild	O	5	7.2											
			median	*7.2*				*11*						*8.2*	
			mean	*6.8*				*11*						*8.2*	
			se	*0.8*				*2*							
	Hatchery	WB	1					29	1u	4.5		11		6.2	1u
	Hatchery	WB	2					13	1u	18		4.8		6.1	1u
	Hatchery	WB	3					34	1u	8.2		24		5.6	1u
	Hatchery	WB	4							5.4		4.7		5.5	1u
	Hatchery	WB	5							8.9		6.5			
			median					*29*		*8.2*		*6.5*		*5.9*	
			mean					*25*		*9.0*		*10*		*5.9*	
			se					*6.5*		*2.4*		*3.5*		*0.18*	
	Hatchery	F	1					3.8	U					3.7	U
	Hatchery	F	2					3.7	U					3.7	U
	Hatchery	F	3					3.7	U					3.7	U
	Hatchery	F	4											3.7	U
	Hatchery	F	5												
			median					*3.7*						*3.7*	
			mean					*3.7*						*3.7*	
			se					*0.0*						*0.0*	
	Hatchery	O	1					55						9.5	
	Hatchery	O	2					23						8.8	
	Hatchery	O	3					61						7.6	
	Hatchery	O	4											7.5	
	Hatchery	O	5												
			median					*55*						*8.2*	
			mean					*46*						*8.4*	
			se					12						*0.48*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Zinc															
	Wild	WB	1	24		20		22				21.8		28.1	
	Wild	WB	2	30		22		23							
	Wild	WB	3	26		21									
	Wild	WB	4	24		23									
	Wild	WB	5	24		22									
			median	*24*		*22*		*23*				*21.800*		*28.100*	
			mean	*26*		*22*		*23*				*21.800*		*28.100*	
			se	*1*		*0*		*0*							
	Wild	F	1	8.5				6.5						6.33	
	Wild	F	2	7.9				6.3							
	Wild	F	3	8.0											
	Wild	F	4	8.4											
	Wild	F	5	8.6											
			median	*8.4*				*6.4*						*6.330*	
			mean	*8.3*				*6.4*						*6.330*	
			se	*0.1*				*0.1*							
	Wild	O	1	40				37						49.7	
	Wild	O	2	51				37							
	Wild	O	3	45											
	Wild	O	4	41											
	Wild	O	5	41											
			median	*41*				*37*						*49.700*	
			mean	*44*				*37*						*49.700*	
			se	*2*				*0*							
	Hatchery	WB	1					25		21.2		24.5		21.7	
	Hatchery	WB	2					20		24.4		23.5		25.4	
	Hatchery	WB	3					23		24.5		26.2		25.5	
	Hatchery	WB	4							22.2		22.9		24.8	
	Hatchery	WB	5							22.8		22			
			median					*23*		*22.800*		*23.500*		*25.100*	
			mean					*23*		*23.000*		*23.800*		*24.400*	
			se					*1*		*0.637*		*0.721*		*0.897*	
	Hatchery	F	1					7.7						6.52	
	Hatchery	F	2					6.5						7.92	
	Hatchery	F	3					8.0						7.05	
	Hatchery	F	4											6.4	
	Hatchery	F	5												
			median					*7.7*						*6.790*	
			mean					*7.4*						*6.970*	
			se					*0*						*0.346*	
	Hatchery	O	1					41						41.6	
	Hatchery	O	2					36						44.2	
	Hatchery	O	3					37						44.5	
	Hatchery	O	4											45.7	
	Hatchery	O	5												
			median					*37*						*44.400*	
			mean					*38*						*44.000*	
			se					*2*						*0.863*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Vanadium															
	Wild	WB	1	0.12	2u	0.12	U	0.12	1u			0.12	U	0.12	1u
	Wild	WB	2	0.12	1u	0.13	U	0.11	1u						
	Wild	WB	3	0.12	2u	0.13	U								
	Wild	WB	4	0.12	2u	0.12	U								
	Wild	WB	5	0.12	2u	0.11	U								
			median	*0.12*		*0.12*		*0.11*				*0.12*		*0.12*	
			mean	*0.12*		*0.12*		*0.11*				*0.12*		*0.12*	
			se	*0.00*		*0.00*		*0.00*							
	Wild	F	1	0.11	U			0.10	U					0.08	U
	Wild	F	2	0.10	U			0.10	U						
	Wild	F	3	0.10	U										
	Wild	F	4	0.11	U										
	Wild	F	5	0.11	U										
			median	*0.11*				*0.10*						*0.08*	
			mean	*0.11*				*0.10*						*0.08*	
			se	*0.00*				*0.00*							
	Wild	O	1	0.14	U			0.14	0					0.15	0
	Wild	O	2	0.14				0.12	0						
	Wild	O	3	0.13	U										
	Wild	O	4	0.13	U										
	Wild	O	5	0.13	U										
			median	*0.13*				*0.13*						*0.15*	
			mean	*0.13*				*0.13*						*0.15*	
			se	*0.00*				*0.01*							
	Hatchery	WB	1					0.13	1u	0.11	U	0.11	U	0.11	2u
	Hatchery	WB	2					0.10	2u	0.12	U	0.11	U	0.11	2u
	Hatchery	WB	3					0.13	1u	0.11	U	0.11	U	0.11	2u
	Hatchery	WB	4							0.11	U	0.11	U	0.11	2u
	Hatchery	WB	5							0.11	U	0.12	U		
			median					*0.13*		*0.11*		*0.11*		*0.11*	
			mean					*0.12*		*0.11*		*0.11*		*0.11*	
			se					*0.01*		*0.00*		*0.00*		*0.00*	
	Hatchery	F	1					0.10	U					0.10	U
	Hatchery	F	2					0.10	U					0.10	U
	Hatchery	F	3					0.10	U					0.10	U
	Hatchery	F	4											0.10	U
	Hatchery	F	5												
			median					*0.10*						*0.10*	
			mean					*0.10*						*0.10*	
			se					*0.00*						*0.00*	
	Hatchery	O	1					0.16						0.12	U
	Hatchery	O	2					0.11	U					0.12	U
	Hatchery	O	3					0.16						0.11	U
	Hatchery	O	4											0.12	U
	Hatchery	O	5												
			median					*0.16*						*0.12*	
			mean					*0.15*						*0.12*	
			se					*0.02*						*0.00*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout		Collection	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Uranium															
Wild	WB	1	0.0028	1u	0.0015		0.0023	1u			0.0016	U	0.0019	1u
Wild	WB	2	0.0039	1u	0.0032		0.0020	1u						
Wild	WB	3	0.0030	1u	0.0018									
Wild	WB	4	0.0022	1u	0.0035									
Wild	WB	5	0.0027	1u	0.0042									
		median	*0.0028*		*0.0032*		*0.0022*				*0.0016*		*0.0019*	
		mean	*0.0030*		*0.0028*		*0.0022*				*0.0016*		*0.0019*	
		se	*0.0003*		*0.0005*		*0.0001*							
Wild	F	1	0.0014	U			0.0012	U					0.0011	U
Wild	F	2	0.0013	U			0.0013	U						
Wild	F	3	0.0013	U										
Wild	F	4	0.0014	U										
Wild	F	5	0.0013	U										
		median	*0.0013*				*0.0012*						*0.0011*	
		mean	*0.0013*				*0.0012*						*0.0011*	
		se	*0.0000*				*0.0000*							
Wild	O	1	0.0044				0.0033						0.0027	
Wild	O	2	0.0064				0.0027							
Wild	O	3	0.0049											
Wild	O	4	0.0032											
Wild	O	5	0.0042											
		median	*0.0044*				*0.0030*						*0.0027*	
		mean	*0.0046*				*0.0030*						*0.0027*	
		se	*0.0005*				*0.0003*							
Hatchery	WB	1					0.0084	1u	0.0014	U	0.0014		0.0016	1u
Hatchery	WB	2					0.0027	1u	0.0014	U	0.0014	U	0.0018	2u
Hatchery	WB	3					0.0087	1u	0.0014	U	0.0020		0.0013	2u
Hatchery	WB	4							0.0014	U	0.0014	U	0.0014	2u
Hatchery	WB	5							0.0014	U	0.0016	U		
		median					*0.0084*		*0.0014*		*0.0014*		*0.0015*	
		mean					*0.0066*		*0.0014*		*0.0016*		*0.0015*	
		se					*0.0019*		*0.0000*		*0.0001*		*0.0001*	
Hatchery	F	1					0.0013	U					0.0012	U
Hatchery	F	2					0.0012	U					0.0012	U
Hatchery	F	3					0.0012	U					0.0012	U
Hatchery	F	4											0.0012	U
Hatchery	F	5												
		median					*0.0012*						*0.0012*	
		mean					*0.0012*						*0.0012*	
		se					*0.0000*						*0.0000*	
Hatchery	O	1					0.0155						0.0021	
Hatchery	O	2					0.0044						0.0025	U
Hatchery	O	3					0.0152						0.0014	U
Hatchery	O	4											0.0015	U
Hatchery	O	5												
		median					*0.0152*						*0.0018*	
		mean					*0.0117*						*0.0019*	
		se					*0.0036*						*0.0003*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Sodium															
	Wild	WB	1	807		811		877				808		1040	
	Wild	WB	2	920		819		921							
	Wild	WB	3	831		781									
	Wild	WB	4	840		786									
	Wild	WB	5	787		858									
			median	*831.000*		*811.000*		*899.000*				*808.000*		*1040.000*	
			mean	*837.000*		*811.000*		*899.000*				*808.000*		*1040.000*	
			se	*22.731*		*13.780*		*22.000*							
	Wild	F	1	382				407						497	
	Wild	F	2	434				431							
	Wild	F	3	390											
	Wild	F	4	424											
	Wild	F	5	397											
			median	*397.000*				*419.000*						*497.000*	
			mean	*405.000*				*419.000*						*497.000*	
			se	*10.048*				*12.000*							
	Wild	O	1	1260				1320						1570	
	Wild	O	2	1380				1330							
	Wild	O	3	1300											
	Wild	O	4	1280											
	Wild	O	5	1210											
			median	*1280.000*				*1330.000*						*1570.000*	
			mean	*1290.000*				*1330.000*						*1570.000*	
			se	*27.857*				*5.000*							
	Hatchery	WB	1					898		811		976		857	
	Hatchery	WB	2					763		841		868		1040	
	Hatchery	WB	3					879		837		924		934	
	Hatchery	WB	4							906		868		876	
	Hatchery	WB	5							917		844			
			median					*879.000*		*841.000*		*868.000*		*905.000*	
			mean					*847.000*		*862.000*		*896.000*		*927.000*	
			se					*42.191*		*20.769*		*23.933*		*41.149*	
	Hatchery	F	1					414						409	
	Hatchery	F	2					350						486	
	Hatchery	F	3					373						454	
	Hatchery	F	4											412	
	Hatchery	F	5												
			median					*373.000*						*433.000*	
			mean					*379.000*						*440.000*	
			se					*18.717*						*18.386*	
	Hatchery	O	1					1380	0					1440	
	Hatchery	O	2					1230	0					1630	
	Hatchery	O	3					1320						1430	
	Hatchery	O	4											1400	
	Hatchery	O	5												
			median					*1320.000*						*1440.000*	
			mean					*1310.000*						*1480.000*	
			se					*43.589*						*52.361*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Selenium															
	Wild	WB	1	0.82		0.62		0.71				0.53		0.54	
	Wild	WB	2	0.76		0.58		0.68							
	Wild	WB	3	0.75		0.64									
	Wild	WB	4	0.69		0.64									
	Wild	WB	5	0.75		0.60									
			median	*0.75*		*0.62*		*0.69*				*0.53*		*0.54*	
			mean	*0.75*		*0.61*		*0.69*				*0.53*		*0.54*	
			se	*0.02*		*0.01*		*0.02*							
	Wild	F	1	0.61				0.46						0.38	
	Wild	F	2	0.43				0.40							
	Wild	F	3	0.45											
	Wild	F	4	0.49											
	Wild	F	5	0.49											
			median	*0.49*				*0.43*						*0.38*	
			mean	*0.49*				*0.43*						*0.38*	
			se	*0.03*				*0.03*							
	Wild	O	1	1.0				0.95						0.70	
	Wild	O	2	1.1				0.91							
	Wild	O	3	1.1											
	Wild	O	4	0.91											
	Wild	O	5	1.0											
			median	*1.0*				*0.93*						*0.70*	
			mean	*1.0*				*0.93*						*0.70*	
			se	*0.03*				*0.02*							
	Hatchery	WB	1					0.56		0.41		0.40		0.32	
	Hatchery	WB	2					0.46		0.46		0.31		0.28	
	Hatchery	WB	3					0.50		0.50		0.39		0.31	
	Hatchery	WB	4							0.41		0.44		0.27	
	Hatchery	WB	5							0.54		0.37			
			median					*0.50*		*0.46*		*0.39*		*0.29*	
			mean					*0.51*		*0.46*		*0.38*		*0.29*	
			se					*0.03*		*0.03*		*0.02*		*0.01*	
	Hatchery	F	1					0.43						0.29	
	Hatchery	F	2					0.34						0.22	
	Hatchery	F	3					0.32						0.24	
	Hatchery	F	4											0.22	
	Hatchery	F	5												
			median					*0.34*						*0.23*	
			mean					*0.36*						*0.24*	
			se					*0.03*						*0.02*	
	Hatchery	O	1					0.68						0.36	
	Hatchery	O	2					0.60						0.36	
	Hatchery	O	3					0.66						0.37	
	Hatchery	O	4											0.33	
	Hatchery	O	5												
			median					*0.66*						*0.36*	
			mean					*0.65*						*0.35*	
			se					*0.02*						*0.01*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Potassium															
	Wild	WB	1	3410		3540		3730				3410	0	3540	
	Wild	WB	2	3320		3360		3570							
	Wild	WB	3	3420		3350									
	Wild	WB	4	3380		3390									
	Wild	WB	5	3290		3460									
			median	*3380*		*3390*		*3650*				*3410*		*3540*	
			mean	*3360*		*3420*		*3650*				*3410*		*3540*	
			se	*25*		*36*		*80*							
	Wild	F	1	4100				4570						4530	
	Wild	F	2	4170				4440							
	Wild	F	3	4300											
	Wild	F	4	4270											
	Wild	F	5	4160											
			median	*4170*				*4510*						*4530*	
			mean	*4200*				*4510*						*4530*	
			se	*37*				*65*							
	Wild	O	1	2680				2940						2560	
	Wild	O	2	2530				2840							
	Wild	O	3	2500											
	Wild	O	4	2450											
	Wild	O	5	2360											
			median	*2500*				*2890*						*2560*	
			mean	*2500*				*2890*						*2560*	
			se	*53*				*50*							
	Hatchery	WB	1					3830		3550		3780		3500	
	Hatchery	WB	2					3620		3820		3610		3480	
	Hatchery	WB	3					3690		3470		3660		3570	
	Hatchery	WB	4							3810		3740		3450	
	Hatchery	WB	5							3530		3530			
			median					*3690*		*3550*		*3660*		*3490*	
			mean					*3710*		*3640*		*3660*		*3500*	
			se					*62*		*74*		*45*		*25*	
	Hatchery	F	1					4870						4260	
	Hatchery	F	2					4330						4350	
	Hatchery	F	3					4590						4400	
	Hatchery	F	4											4300	
	Hatchery	F	5												
			median					*4590*						*4330*	
			mean					*4600*						*4330*	
			se					*156*						*30*	
	Hatchery	O	1					2780						2500	
	Hatchery	O	2					2820						2560	
	Hatchery	O	3					2900						2730	
	Hatchery	O	4											2490	
	Hatchery	O	5												
			median					*2820*						*2530*	
			mean					*2830*						*2570*	
			se					*35*						*56*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Nickel															
	Wild	WB	1	0.21	1u	0.16		0.19				0.14		0.24	
	Wild	WB	2	0.28		0.21		0.21	1u						
	Wild	WB	3	0.23	1u	0.17									
	Wild	WB	4	0.17	1u	0.21									
	Wild	WB	5	0.20	1u	0.37									
			median	*0.21*		*0.21*		*0.20*				*0.14*		*0.24*	
			mean	*0.22*		*0.22*		*0.20*				*0.14*		*0.24*	
			se	*0.02*		*0.04*		*0.01*							
	Wild	F	1	0.042	U			0.039						0.033	
	Wild	F	2	0.053				0.038	U						
	Wild	F	3	0.039	U										
	Wild	F	4	0.041	U										
	Wild	F	5	0.040	U										
			median	*0.041*				*0.038*						*0.033*	
			mean	*0.043*				*0.038*						*0.033*	
			se	*0.003*				*0.000*							
	Wild	O	1	0.38				0.34						0.44	
	Wild	O	2	0.49				0.35							
	Wild	O	3	0.43											
	Wild	O	4	0.31											
	Wild	O	5	0.37											
			median	*0.38*				*0.34*						*0.44*	
			mean	*0.40*				*0.34*						*0.44*	
			se	*0.03*				*0.00*							
	Hatchery	WB	1					0.37		0.15		0.18		0.16	1u
	Hatchery	WB	2					0.22		0.18		0.21		0.21	1u
	Hatchery	WB	3					0.39	1u	0.14		0.24		0.16	1u
	Hatchery	WB	4							0.12		0.15		0.19	1u
	Hatchery	WB	5							0.19		0.15			
			median					*0.37*		*0.15*		*0.18*		*0.17*	
			mean					*0.33*		*0.16*		*0.19*		*0.18*	
			se					*0.05*		*0.01*		*0.02*		*0.01*	
	Hatchery	F	1					0.13						0.037	U
	Hatchery	F	2					0.06						0.041	U
	Hatchery	F	3					0.04	U					0.037	U
	Hatchery	F	4											0.037	U
	Hatchery	F	5												
			median					*0.06*						*0.037*	
			mean					*0.08*						*0.038*	
			se					*0.03*						*0.001*	
	Hatchery	O	1					0.60						0.33	
	Hatchery	O	2					0.41						0.38	
	Hatchery	O	3					0.70						0.29	
	Hatchery	O	4											0.35	
	Hatchery	O	5												
			median					*0.60*						*0.34*	
			mean					*0.57*						*0.34*	
			se					*0.08*						*0.02*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Manganese															
	Wild	WB	1	1.4		1.2		1.3				1.3		2.4	
	Wild	WB	2	1.4		1.7		1.1							
	Wild	WB	3	1.7		1.2									
	Wild	WB	4	1.0		2.1									
	Wild	WB	5	1.2		2.2									
			median	*1.4*		*1.7*		*1.2*				*1.3*		*2.4*	
			mean	*1.3*		*1.7*		*1.2*				*1.3*		*2.4*	
			se	*0.1*		*0.2*		*0.1*							
	Wild	F	1	0.14				0.14						0.17	
	Wild	F	2	0.13				0.12							
	Wild	F	3	0.12											
	Wild	F	4	0.15											
	Wild	F	5	0.13											
			median	*0.13*				*0.13*						*0.17*	
			mean	*0.13*				*0.13*						*0.17*	
			se	*0.00*				*0.01*							
	Wild	O	1	2.6				2.3						4.5	
	Wild	O	2	2.6				1.9							
	Wild	O	3	3.3											
	Wild	O	4	1.8											
	Wild	O	5	2.3											
			median	*2.6*				*2.1*						*4.5*	
			mean	*2.5*				*2.1*						*4.5*	
			se	*0.2*				*0.2*							
	Hatchery	WB	1					2.4		1.0		1.8		1.2	
	Hatchery	WB	2					1.4		1.6		1.3		1.4	
	Hatchery	WB	3					2.9		1.0		1.8		1.1	
	Hatchery	WB	4							0.9		1.5		1.4	
	Hatchery	WB	5							1.1		1.6			
			median					*2.4*		*1.0*		*1.6*		*1.3*	
			mean					*2.2*		*1.1*		*1.6*		*1.3*	
			se					*0.5*		*0.1*		*0.1*		*0.1*	
	Hatchery	F	1					0.16						0.14	
	Hatchery	F	2					0.11						0.14	
	Hatchery	F	3					0.18						0.13	
	Hatchery	F	4											0.19	
	Hatchery	F	5												
			median					*0.16*						*0.14*	
			mean					*0.15*						*0.15*	
			se					*0.02*						*0.01*	
	Hatchery	O	1					4.7						2.7	
	Hatchery	O	2					2.8						2.7	
	Hatchery	O	3					5.3						2.1	
	Hatchery	O	4											2.9	
	Hatchery	O	5												
			median					*4.7*						*2.7*	
			mean					*4.3*						*2.6*	
			se					*0.8*						*0.2*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Magnesium															
	Wild	WB	1	303		289		303	1J			304	J	336	2J
	Wild	WB	2	296		309		308	1J						
	Wild	WB	3	312		296									
	Wild	WB	4	287		293									
	Wild	WB	5	270		310									
			median	*296*		*296*		*306*				*304*		*336*	
			mean	*294*		*299*		*306*				*304*		*336*	
			se	*7*		*4*		*3*							
	Wild	F	1	265				283	J					273	J
	Wild	F	2	262				267	J						
	Wild	F	3	272											
	Wild	F	4	275											
	Wild	F	5	258											
			median	*265*				*275*						*273*	
			mean	*266*				*275*						*273*	
			se	*3*				*8*							
	Wild	O	1	343				323	J					397	J
	Wild	O	2	328				342	J						
	Wild	O	3	353											
	Wild	O	4	299											
	Wild	O	5	283											
			median	*328*				*333*						*397*	
			mean	*321*				*333*						*397*	
			se	*13*				*10*							
	Hatchery	WB	1					355		303		307		287	
	Hatchery	WB	2					305		324		319		304	
	Hatchery	WB	3					332		302		303		290	
	Hatchery	WB	4							286		292		306	
	Hatchery	WB	5							307		291			
			median					*332*		*303*		*303*		*297*	
			mean					*331*		*304*		*302*		*297*	
			se					*14*		*6*		*5*		*5*	
	Hatchery	F	1					306						257	
	Hatchery	F	2					272						259	
	Hatchery	F	3					283						265	
	Hatchery	F	4											262	
	Hatchery	F	5												
			median					*283*						*261*	
			mean					*287*						*261*	
			se					*10*						*2*	
	Hatchery	O	1					404						326	
	Hatchery	O	2					343						353	
	Hatchery	O	3					375						316	
	Hatchery	O	4											357	
	Hatchery	O	5												
			median					*375*						*340*	
			mean					*374*						*338*	
			se					*18*						*10*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Lead															
	Wild	WB	1	0.12		0.06		0.032	1u			0.015	U	0.025	1u
	Wild	WB	2	0.16		0.12		0.034	1u						
	Wild	WB	3	0.18	1u	0.08									
	Wild	WB	4	0.11		0.11									
	Wild	WB	5	0.13		0.11									
			median	*0.13*		*0.11*		*0.033*				*0.015*		*0.025*	
			mean	*0.14*		*0.10*		*0.033*				*0.015*		*0.025*	
			se	*0.01*		*0.01*		*0.001*							
	Wild	F	1	0.018				0.012	U					0.011	U
	Wild	F	2	0.016				0.013	U						
	Wild	F	3	0.013	U										
	Wild	F	4	0.018											
	Wild	F	5	0.016											
			median	*0.016*				*0.012*						*0.011*	
			mean	*0.016*				*0.012*						*0.011*	
			se	*0.00*				*0.000*							
	Wild	O	1	0.22				0.051						0.039	
	Wild	O	2	0.30				0.052							
	Wild	O	3	0.37											
	Wild	O	4	0.20											
	Wild	O	5	0.26											
			median	*0.26*				*0.052*						*0.039*	
			mean	*0.27*				*0.052*						*0.039*	
			se	*0.03*				*0.001*							
	Hatchery	WB	1					0.21	1u	0.014	U	0.014	U	0.014	1u
	Hatchery	WB	2					0.07	1u	0.017		0.014	U	0.020	1u
	Hatchery	WB	3					0.21	1u	0.015		0.022		0.014	1u
	Hatchery	WB	4							0.014		0.014	U	0.016	1u
	Hatchery	WB	5							0.014	U	0.015	U		
			median					*0.21*		*0.014*		*0.014*		*0.015*	
			mean					*0.16*		*0.015*		*0.016*		*0.016*	
			se					*0.05*		*0.001*		*0.002*		*0.002*	
	Hatchery	F	1					0.013	U					0.012	U
	Hatchery	F	2					0.012	U					0.012	U
	Hatchery	F	3					0.012	U					0.012	U
	Hatchery	F	4											0.012	U
	Hatchery	F	5												
			median					*0.012*						*0.012*	
			mean					*0.012*						*0.012*	
			se					*0.000*						*0.000*	
	Hatchery	O	1					0.41						0.016	
	Hatchery	O	2					0.13						0.029	
	Hatchery	O	3					0.38						0.015	
	Hatchery	O	4											0.021	
	Hatchery	O	5												
			median					*0.38*						*0.018*	
			mean					*0.31*						*0.020*	
			se					*0.09*						*0.003*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Iron															
	Wild	WB	1	20		19		25				17		22	
	Wild	WB	2	29		19		20							
	Wild	WB	3	38		18									
	Wild	WB	4	21		24									
	Wild	WB	5	30		30									
			median	*29*		*19*		*22*				*17*		*22*	
			mean	*28*		*22*		*22*				*17*		*22*	
			se	*3*		*2*		*3*							
	Wild	F	1	4.1				3.8						5.2	
	Wild	F	2	6.3				4.1							
	Wild	F	3	5.2											
	Wild	F	4	5.5											
	Wild	F	5	4.9											
			median	*5.2*				*3.9*						*5.2*	
			mean	*5.2*				*3.9*						*5.2*	
			se	*0.4*				*0.1*							
	Wild	O	1	37				46						38	
	Wild	O	2	51				33							
	Wild	O	3	72											
	Wild	O	4	37											
	Wild	O	5	58											
			median	*51*				*39*						*38*	
			mean	*51*				*39*						*38*	
			se	*7*				*7*							
	Hatchery	WB	1					43		15		19		15	
	Hatchery	WB	2					21		28		15		18	
	Hatchery	WB	3					45		18		34		17	
	Hatchery	WB	4							15		16		15	
	Hatchery	WB	5							16		17			
			median					*43*		*16*		*17*		*16*	
			mean					*37*		*18*		*20*		*16*	
			se					*8*		*2*		*3*		*1*	
	Hatchery	F	1					5.0						3.3	
	Hatchery	F	2					3.4						4.5	
	Hatchery	F	3					4.0						3.9	
	Hatchery	F	4											3.6	
	Hatchery	F	5												
			median					*4.0*						*3.8*	
			mean					*4.1*						*3.8*	
			se					*0.5*						*0.3*	
	Hatchery	O	1					81						30	
	Hatchery	O	2					42						33	
	Hatchery	O	3					81						31	
	Hatchery	O	4											27	
	Hatchery	O	5												
			median					*81*						*30*	
			mean					*68*						*30*	
			se					*13*						*1*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Copper															
	Wild	WB	1	1.2		1.3		1.3				0.56		0.42	
	Wild	WB	2	1.9		1.3		1.0							
	Wild	WB	3	1.4		1.5									
	Wild	WB	4	1.1		1.8									
	Wild	WB	5	1.3		1.9									
			median	*1.3*		*1.5*		*1.2*				*0.56*		*0.42*	
			mean	*1.4*		*1.6*		*1.2*				*0.56*		*0.42*	
			se	*0.2*		*0.1*		*0.1*							
	Wild	F	1	0.36				0.34						0.27	
	Wild	F	2	0.33				0.33							
	Wild	F	3	0.34											
	Wild	F	4	0.35											
	Wild	F	5	0.32											
			median	*0.34*				*0.33*						*0.27*	
			mean	*0.34*				*0.33*						*0.27*	
			se	*0.01*				*0.01*							
	Wild	O	1	2.0				2.2						0.58	
	Wild	O	2	3.5				1.6							
	Wild	O	3	2.5											
	Wild	O	4	1.8											
	Wild	O	5	2.3											
			median	*2.3*				*1.9*						*0.58*	
			mean	*2.4*				*1.9*						*0.58*	
			se	*0.3*				*0.3*							
	Hatchery	WB	1					2.5		0.61		0.56		0.41	
	Hatchery	WB	2					1.6		0.90		0.45		0.39	
	Hatchery	WB	3					2.6		0.71		0.86		0.42	
	Hatchery	WB	4							0.54		0.55		0.42	
	Hatchery	WB	5							0.56		0.58			
			median					*2.5*		*0.61*		*0.56*		*0.42*	
			mean					*2.2*		*0.66*		*0.60*		*0.41*	
			se					*0.3*		*0.06*		*0.07*		*0.01*	
	Hatchery	F	1					0.40						0.27	
	Hatchery	F	2					0.32						0.27	
	Hatchery	F	3					0.32						0.27	
	Hatchery	F	4											0.27	
	Hatchery	F	5												
			median					*0.32*						*0.27*	
			mean					*0.35*						*0.27*	
			se					*0.03*						*0.00*	
	Hatchery	O	1					4.61						0.60	
	Hatchery	O	2					2.99						0.52	
	Hatchery	O	3					4.55						0.57	
	Hatchery	O	4											0.59	
	Hatchery	O	5												
			median					*4.55*						*0.58*	
			mean					*4.05*						*0.57*	
			se					*0.53*						*0.02*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Cobalt															
	Wild	WB	1	0.026	1u	0.015	U	0.019	1u			0.018		0.025	
	Wild	WB	2	0.032	1u	0.016	U	0.018	1u						
	Wild	WB	3	0.030	1u	0.011	U								
	Wild	WB	4	0.018	1u	0.017	U								
	Wild	WB	5	0.023	1u	0.022									
			median	*0.026*		*0.016*		*0.018*				*0.018*		*0.025*	
			mean	*0.026*		*0.016*		*0.018*				*0.018*		*0.025*	
			se	*0.002*		*0.002*		*0.001*							
	Wild	F	1	0.008	U			0.004	U					0.005	
	Wild	F	2	0.010	U			0.004	U						
	Wild	F	3	0.007	U										
	Wild	F	4	0.007	U										
	Wild	F	5	0.008	U										
			median	*0.008*				*0.004*						*0.005*	
			mean	*0.008*				*0.004*						*0.005*	
			se	*0.001*				*0.000*							
	Wild	O	1	0.045				0.034						0.044	
	Wild	O	2	0.052				0.029							
	Wild	O	3	0.053											
	Wild	O	4	0.030											
	Wild	O	5	0.040											
			median	*0.045*				*0.032*						*0.044*	
			mean	*0.044*				*0.032*						*0.044*	
			se	*0.004*				*0.003*							
	Hatchery	WB	1					0.034		0.017		0.025		0.022	
	Hatchery	WB	2					0.021		0.022		0.018		0.021	
	Hatchery	WB	3					0.034		0.018		0.033		0.018	
	Hatchery	WB	4							0.014		0.021		0.025	
	Hatchery	WB	5							0.017		0.021			
			median					*0.034*		*0.017*		*0.021*		*0.021*	
			mean					*0.030*		*0.018*		*0.023*		*0.022*	
			se					*0.004*		*0.001*		*0.003*		*0.001*	
	Hatchery	F	1					0.009						0.006	
	Hatchery	F	2					0.006						0.006	
	Hatchery	F	3					0.006						0.006	
	Hatchery	F	4											0.008	
	Hatchery	F	5												
			median					*0.006*						*0.006*	
			mean					*0.007*						*0.007*	
			se					*0.001*						*0.001*	
	Hatchery	O	1					0.060						0.042	
	Hatchery	O	2					0.038						0.037	
	Hatchery	O	3					0.058						0.031	
	Hatchery	O	4											0.044	
	Hatchery	O	5												
			median					*0.058*						*0.039*	
			mean					*0.052*						*0.039*	
			se					*0.007*						*0.003*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Chromium															
	Wild	WB	1	0.81		0.62		0.68				0.69		0.48	
	Wild	WB	2	0.81		0.58		0.62							
	Wild	WB	3	0.86		0.81									
	Wild	WB	4	0.73		0.73									
	Wild	WB	5	0.98		0.91									
			median	*0.81*		*0.73*		*0.65*				*0.69*		*0.48*	
			mean	*0.84*		*0.73*		*0.65*				*0.69*		*0.48*	
			se	*0.04*		*0.06*		*0.03*							
	Wild	F	1	0.53				0.41						0.44	
	Wild	F	2	0.51				0.40							
	Wild	F	3	0.58											
	Wild	F	4	0.54											
	Wild	F	5	0.72											
			median	*0.54*				*0.41*						*0.44*	
			mean	*0.57*				*0.41*						*0.44*	
			se	*0.04*				*0.00*							
	Wild	O	1	1.1				0.92						0.52	0
	Wild	O	2	1.1				0.80							
	Wild	O	3	1.2											
	Wild	O	4	0.9											
	Wild	O	5	1.3											
			median	*1.1*				*0.86*						*0.52*	
			mean	*1.1*				*0.86*						*0.52*	
			se	*0.05*				*0.06*							
	Hatchery	WB	1					0.77		0.50		0.40		0.38	
	Hatchery	WB	2					0.42		0.52		0.53		0.36	
	Hatchery	WB	3					0.72		0.53		0.63		0.35	
	Hatchery	WB	4							0.41		0.55		0.31	
	Hatchery	WB	5							0.51		0.57			
			median					*0.72*		*0.51*		*0.55*		*0.35*	
			mean					*0.64*		*0.49*		*0.54*		*0.35*	
			se					*0.11*		*0.02*		*0.04*		*0.01*	
	Hatchery	F	1					0.53						0.37	
	Hatchery	F	2					0.27						0.33	
	Hatchery	F	3					0.27						0.37	
	Hatchery	F	4											0.30	
	Hatchery	F	5												
			median					*0.27*						*0.35*	
			mean					*0.35*						*0.34*	
			se					*0.09*						*0.02*	
	Hatchery	O	1					1.0						0.39	
	Hatchery	O	2					0.6						0.38	
	Hatchery	O	3					1.1						0.34	
	Hatchery	O	4											0.33	
	Hatchery	O	5												
			median					*1.0*						*0.36*	
			mean					*0.9*						*0.36*	
			se					*0.16*						*0.02*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Calcium															
	Wild	WB	1	5310	2j	3810	J	4620				4190		6970	
	Wild	WB	2	6200	2j	5600	J	5540							
	Wild	WB	3	5910	2j	4340	J								
	Wild	WB	4	4630	2j	5050	J								
	Wild	WB	5	4630	2j	8610	J								
			median	*5310*		*5050*		*5080*				*4190*		*6970*	
			mean	*5340*		*5480*		*5080*				*4190*		*6970*	
			se	*322*		*839*		*460*							
	Wild	F	1	296	J			341						249	
	Wild	F	2	340	J			196							
	Wild	F	3	272	J										
	Wild	F	4	370	J										
	Wild	F	5	380	J										
			median	*340*				*269*						*249*	
			mean	*332*				*269*						*249*	
			se	*21*				*73*							
	Wild	O	1	10700	J			8630						13600	
	Wild	O	2	11800	J			10000							
	Wild	O	3	11800	J										
	Wild	O	4	9120	J										
	Wild	O	5	9220	J										
			median	*10700*				*9320*						*13600*	
			mean	*10500*				*9320*						*13600*	
			se	*590*				*685*							
	Hatchery	WB	1					7520	1j	3930	J	5250		4490	
	Hatchery	WB	2					4800	1j	4330	J	5850		5460	
	Hatchery	WB	3					6770	1j	3610	J	4950		4410	
	Hatchery	WB	4							3430		4010		5510	
	Hatchery	WB	5							5580		4340			
			median					*6770*		*3930*		*4950*		*4980*	
			mean					*6360*		*4180*		*4880*		*4970*	
			se					*811*		*383*		*326*		*299*	
	Hatchery	F	1					341	J					243	
	Hatchery	F	2					250	J					299	
	Hatchery	F	3					442	J					311	
	Hatchery	F	4											311	
	Hatchery	F	5												
			median					*341*						*305*	
			mean					*344*						*291*	
			se					*55*						*16*	
	Hatchery	O	1					14700	J					10000	
	Hatchery	O	2					9970	J					11000	
	Hatchery	O	3					12300	J					8610	
	Hatchery	O	4											11400	
	Hatchery	O	5												
			median					*12300*						*10500*	
			mean					*12300*						*10300*	
			se					*1365*						*622*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Cadmium															
	Wild	WB	1	0.023	1u	0.033		0.053	1u			0.066	0	0.048	1u
	Wild	WB	2	0.054	1u	0.035		0.045	1u						
	Wild	WB	3	0.024	1u	0.039									
	Wild	WB	4	0.020	1u	0.035									
	Wild	WB	5	0.022	1u	0.048									
			median	*0.023*		*0.035*		*0.049*				*0.066*		*0.048*	
			mean	*0.029*		*0.038*		*0.049*				*0.066*		*0.048*	
			se	*0.006*		*0.003*		*0.004*							
	Wild	F	1	0.014	U			0.012	U					0.011	U
	Wild	F	2	0.064	U			0.013	U						
	Wild	F	3	0.013	U										
	Wild	F	4	0.014	U										
	Wild	F	5	0.013	U										
			median	*0.014*				*0.012*						*0.011*	
			mean	*0.023*				*0.012*						*0.011*	
			se	*0.010*				*0.000*							
	Wild	O	1	0.034				0.091						0.086	
	Wild	O	2	0.046				0.073							
	Wild	O	3	0.035											
	Wild	O	4	0.028											
	Wild	O	5	0.032											
			median	*0.034*				*0.082*						*0.086*	
			mean	*0.035*				*0.082*						*0.086*	
			se	*0.003*				*0.009*							
	Hatchery	WB	1					0.068	1u	0.061		0.051		0.052	1u
	Hatchery	WB	2					0.063	1u	0.055		0.022		0.057	1u
	Hatchery	WB	3					0.060	1u	0.059		0.047		0.039	1u
	Hatchery	WB	4							0.038		0.041		0.043	1u
	Hatchery	WB	5							0.040		0.036			
			median					*0.063*		*0.055*		*0.041*		*0.047*	
			mean					*0.063*		*0.050*		*0.039*		*0.048*	
			se					*0.002*		*0.005*		*0.005*		*0.004*	
	Hatchery	F	1					0.013	U					0.012	U
	Hatchery	F	2					0.012	U					0.012	U
	Hatchery	F	3					0.012	U					0.012	U
	Hatchery	F	4											0.012	U
	Hatchery	F	5												
			median					*0.012*						*0.012*	
			mean					*0.012*						*0.012*	
			se					*0.000*						*0.000*	
	Hatchery	O	1					0.123						0.105	
	Hatchery	O	2					0.121						0.105	
	Hatchery	O	3					0.101						0.066	
	Hatchery	O	4											0.077	
	Hatchery	O	5												
			median					*0.121*						*0.091*	
			mean					*0.115*						*0.088*	
			se					*0.007*						*0.010*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Barium															
	Wild	WB	1	0.73	1u	0.61		0.57	1u			0.38	0	0.76	1u
	Wild	WB	2	0.97	1u	0.69		0.47	1u						
	Wild	WB	3	1.01	1u	0.50									
	Wild	WB	4	0.59	1u	1.20									
	Wild	WB	5	0.70	1u	1.74									
			median	*0.73*		*0.69*		*0.52*				*0.38*		*0.76*	
			mean	*0.80*		*0.95*		*0.52*				*0.38*		*0.76*	
			se	*0.08*		*0.23*		*0.05*							
	Wild	F	1	0.14	U			0.12	U					0.11	U
	Wild	F	2	0.13	U			0.13	U						
	Wild	F	3	0.13	U										
	Wild	F	4	0.14	U										
	Wild	F	5	0.13	U										
			median	*0.13*				*0.12*						*0.11*	
			mean	*0.13*				*0.12*						*0.11*	
			se	*0.00*				*0.00*							
	Wild	O	1	1.37	0			0.99						1.42	
	Wild	O	2	1.78	0			0.76							
	Wild	O	3	1.94	0										
	Wild	O	4	1.07	0										
	Wild	O	5	1.32	0										
			median	*1.37*				*0.87*						*1.42*	
			mean	*1.50*				*0.87*						*1.42*	
			se	*0.16*				*0.11*							
	Hatchery	WB	1					1.6	1u	0.35		0.69		0.46	1u
	Hatchery	WB	2					0.6	1u	0.62		0.40		0.52	1u
	Hatchery	WB	3					1.6	1u	0.34		0.88		0.41	1u
	Hatchery	WB	4							0.28		0.36		0.42	1u
	Hatchery	WB	5							0.47		0.43			
			median					*1.6*		*0.35*		*0.43*		*0.44*	
			mean					*1.3*		*0.41*		*0.55*		*0.45*	
			se					*0.3*		*0.06*		*0.10*		*0.02*	
	Hatchery	F	1					0.13	U					0.12	U
	Hatchery	F	2					0.12	U					0.12	U
	Hatchery	F	3					0.12	U					0.12	U
	Hatchery	F	4											0.12	U
	Hatchery	F	5												
			median					*0.12*						*0.12*	
			mean					*0.12*						*0.12*	
			se					*0.00*						*0.00*	
	Hatchery	O	1					3.0	0					0.91	0
	Hatchery	O	2					1.2	0					0.95	0
	Hatchery	O	3					2.9						0.70	0
	Hatchery	O	4											0.76	0
	Hatchery	O	5												
			median					*2.9*						*0.83*	
			mean					*2.4*						*0.83*	
			se					*0.6*						*0.06*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Arsenic															
	Wild	WB	1	0.15		0.10		0.16				0.18		0.14	
	Wild	WB	2	0.14		0.11		0.15							
	Wild	WB	3	0.14		0.13									
	Wild	WB	4	0.13		0.11									
	Wild	WB	5	0.15		0.16									
			median	*0.14*		*0.11*		*0.15*				*0.18*		*0.14*	
			mean	*0.14*		*0.12*		*0.15*				*0.18*		*0.14*	
			se	*0.01*		*0.01*		*0.00*							
	Wild	F	1	0.10				0.08						0.08	
	Wild	F	2	0.07				0.07							
	Wild	F	3	0.07											
	Wild	F	4	0.10											
	Wild	F	5	0.10											
			median	*0.10*				*0.07*						*0.08*	
			mean	*0.09*				*0.07*						*0.08*	
			se	*0.01*				*0.01*							
	Wild	O	1	0.22				0.23						0.20	
	Wild	O	2	0.21				0.22							
	Wild	O	3	0.20											
	Wild	O	4	0.16											
	Wild	O	5	0.21											
			median	*0.21*				*0.22*						*0.20*	
			mean	*0.20*				*0.22*						*0.20*	
			se	*0.01*				*0.01*							
	Hatchery	WB	1					0.10	1u	0.09		0.14		0.12	0
	Hatchery	WB	2					0.09	1u	0.09		0.11		0.09	1u
	Hatchery	WB	3					0.11	1u	0.13		0.14		0.08	1u
	Hatchery	WB	4							0.09		0.14		0.10	1u
	Hatchery	WB	5							0.13		0.16			
			median					*0.10*		*0.09*		*0.14*		*0.10*	
			mean					*0.10*		*0.10*		*0.14*		*0.10*	
			se					*0.00*		*0.01*		*0.01*		*0.01*	
	Hatchery	F	1					0.063	U					0.081	0
	Hatchery	F	2					0.061	U					0.061	U
	Hatchery	F	3					0.061	U					0.061	U
	Hatchery	F	4											0.062	U
	Hatchery	F	5												
			median					*0.061*						*0.061*	
			mean					*0.062*						*0.066*	
			se					*0.001*						*0.005*	
	Hatchery	O	1					0.15						0.16	
	Hatchery	O	2					0.13						0.13	
	Hatchery	O	3					0.15						0.11	
	Hatchery	O	4											0.15	
	Hatchery	O	5												
			median					*0.15*						*0.14*	
			mean					*0.14*						*0.14*	
			se					*0.00*						*0.01*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Mercury															
	Wild	WB	1	0.057		0.051		0.056				0.070		0.098	
	Wild	WB	2	0.086		0.041		0.070							
	Wild	WB	3	0.066		0.038									
	Wild	WB	4	0.073		0.048									
	Wild	WB	5	0.073		0.036									
			median	*0.073*		*0.041*		*0.063*				*0.070*		*0.098*	
			mean	*0.071*		*0.043*		*0.063*				*0.070*		*0.098*	
			se	*0.005*		*0.003*		*0.007*							
	Wild	F	1	0.065				0.068						0.120	
	Wild	F	2	0.108				0.084							
	Wild	F	3	0.080											
	Wild	F	4	0.087											
	Wild	F	5	0.089											
			median	*0.087*				*0.076*						*0.120*	
			mean	*0.086*				*0.076*						*0.120*	
			se	*0.007*				*0.008*							
	Wild	O	1	0.048				0.044						0.076	
	Wild	O	2	0.064				0.058							
	Wild	O	3	0.050											
	Wild	O	4	0.058											
	Wild	O	5	0.055											
			median	*0.055*				*0.051*						*0.076*	
			mean	*0.055*				*0.051*						*0.076*	
			se	*0.003*				*0.007*							
	Hatchery	WB	1					0.054		0.072		0.071		0.068	
	Hatchery	WB	2					0.061		0.075		0.067		0.103	
	Hatchery	WB	3					0.053		0.057		0.059		0.085	
	Hatchery	WB	4							0.058		0.060		0.069	
	Hatchery	WB	5							0.065		0.062			
			median					*0.054*		*0.065*		*0.062*		*0.077*	
			mean					*0.056*		*0.065*		*0.064*		*0.081*	
			se					*0.002*		*0.004*		*0.002*		*0.008*	
	Hatchery	F	1					0.063						0.080	
	Hatchery	F	2					0.074						0.122	
	Hatchery	F	3					0.063						0.104	
	Hatchery	F	4											0.081	
	Hatchery	F	5												
			median					*0.063*						*0.093*	
			mean					*0.067*						*0.097*	
			se					*0.004*						*0.010*	
	Hatchery	O	1					0.045						0.054	
	Hatchery	O	2					0.046						0.083	
	Hatchery	O	3					0.045						0.066	
	Hatchery	O	4											0.054	
	Hatchery	O	5												
			median					*0.045*						*0.060*	
			mean					*0.045*						*0.064*	
			se					*0.000*						*0.007*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Age															
	Wild	WB	1	2.2		1.2		2.0				2.8		5.0	
	Wild	WB	2	2.8		1.0		2.3							
	Wild	WB	3	3.2		1.4									
	Wild	WB	4	3.0		1.2									
	Wild	WB	5	3.0		1.0									
			median	*3.0*		*1.2*		*2.2*				*2.8*		*5.0*	
			mean	*2.8*		*1.2*		*2.2*				*2.8*		*5.0*	
			se	*0.2*		*0.1*		*0.2*							
	Wild	F	1	2.2				2.0						5.0	
	Wild	F	2	2.8				2.3							
	Wild	F	3	3.2											
	Wild	F	4	3.0											
	Wild	F	5	3.0											
			median	*3.0*				*2.2*						*5.0*	
			mean	*2.8*				*2.2*						*5.0*	
			se	*0.2*				*0.2*							
	Wild	O	1	2.2				2.0						5.0	
	Wild	O	2	2.8				2.3							
	Wild	O	3	3.2											
	Wild	O	4	3.0											
	Wild	O	5	3.0											
			median	*3.0*				*2.2*						*5.0*	
			mean	*2.8*				*2.2*						*5.0*	
			se	*0.2*				*0.2*							
	Hatchery	WB	1					1.2		1.4		1.2		1.3	
	Hatchery	WB	2					1.0		1.2		1.2		1.8	
	Hatchery	WB	3							1.0		1.4		1.6	
	Hatchery	WB	4							1.0		1.0		1.2	
	Hatchery	WB	5							1.0		1.3			
			median					*1.1*		*1.0*		*1.2*		*1.5*	
			mean					*1.1*		*1.1*		*1.2*		*1.5*	
			se					*0.1*		*0.1*		*0.1*		*0.1*	
	Hatchery	F	1					1.2						1.3	
	Hatchery	F	2					1.0						1.8	
	Hatchery	F	3											1.6	
	Hatchery	F	4											1.2	
	Hatchery	F	5												
			median					*1.1*						*1.5*	
			mean					*1.1*						*1.5*	
			se					*0.1*						*0.1*	
	Hatchery	O	1					1.2						1.3	
	Hatchery	O	2					1.0						1.8	
	Hatchery	O	3											1.6	
	Hatchery	O	4											1.2	
	Hatchery	O	5												
			median					*1.1*						*1.5*	
			mean					*1.1*						*1.5*	
			se					*0.1*						*0.1*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Length															
	Wild	WB	1	913		662		496				860		572	
	Wild	WB	2	1024		600		595							
	Wild	WB	3	907		689									
	Wild	WB	4	969		662									
	Wild	WB	5	1018		600									
			median	*969*		*662*		*546*				*860*		*572*	
			mean	*966*		*642*		*546*				*860*		*572*	
			se	*25*		*18*		*49*							
	Wild	F	1	913				496						572	
	Wild	F	2	1024				595							
	Wild	F	3	907											
	Wild	F	4	969											
	Wild	F	5	1018											
			median	*969*				*546*						*572*	
			mean	*966*				*546*						*572*	
			se	*25*				*49*							
	Wild	O	1	913				496						572	
	Wild	O	2	1024				595							
	Wild	O	3	907											
	Wild	O	4	969											
	Wild	O	5	1018											
			median	*969*				*546*						*572*	
			mean	*966*				*546*						*572*	
			se	*25*				*49*							
	Hatchery	WB	1					662		966		710		652	
	Hatchery	WB	2					600		867		748		772	
	Hatchery	WB	3							700		838		852	
	Hatchery	WB	4							658		598		607	
	Hatchery	WB	5							770		747			
			median					*631*		*770*		*747*		*712*	
			mean					*631*		*792*		*728*		*721*	
			se					*31*		*56*		*39*		*56*	
	Hatchery	F	1					662						652	
	Hatchery	F	2					600						772	
	Hatchery	F	3											852	
	Hatchery	F	4											607	
	Hatchery	F	5												
			median					*631*						*721*	
			mean					*631*						*721*	
			se					*31*						*56*	
	Hatchery	O	1					662						652	
	Hatchery	O	2					600						772	
	Hatchery	O	3											852	
	Hatchery	O	4											607	
	Hatchery	O	5												
			median					*631*						*721*	
			mean					*631*						*721*	
			se					*31*						*56*	

Table B1-3. Summary of Analytical Data for Rainbow Trout

Rainbow Trout			Collection	1		2		3		4		5		6	
			River Mile	741		723		706		678		635		605	
	Origin	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Weight															
	Wild	WB	1	440		380		462				410		370	
	Wild	WB	2	459		480		429							
	Wild	WB	3	438		394									
	Wild	WB	4	446		380									
	Wild	WB	5	458		480									
			median	*446*		*394*		*445*				*410*		*370*	
			mean	*448*		*422*		*445*				*410*		*370*	
			se	*4*		*23*		*17*							
	Wild	F	1	440				462						370	
	Wild	F	2	459				429							
	Wild	F	3	438											
	Wild	F	4	446											
	Wild	F	5	458											
			median	*446*				*445*						*370*	
			mean	*448*				*445*						*370*	
			se	*4*				*17*							
	Wild	O	1	440				462						370	
	Wild	O	2	459				429							
	Wild	O	3	438											
	Wild	O	4	446											
	Wild	O	5	458											
			median	*446*				*445*						*370*	
			mean	*448*				*445*						*370*	
			se	*4*				*17*							
	Hatchery	WB	1					380		412		391		378	
	Hatchery	WB	2					480		399		397		426	
	Hatchery	WB	3							384		410		423	
	Hatchery	WB	4							374		364		381	
	Hatchery	WB	5							397		390			
			median					*430*		*397*		*391*		*402*	
			mean					*430*		*393*		*390*		*402*	
			se					*50*		*7*		*8*		*13*	
	Hatchery	F	1					380						378	
	Hatchery	F	2					480						426	
	Hatchery	F	3											423	
	Hatchery	F	4											381	
	Hatchery	F	5												
			median					*430*						*402*	
			mean					*430*						*402*	
			se					*50*						*13*	
	Hatchery	O	1					380						378	
	Hatchery	O	2					480						426	
	Hatchery	O	3											423	
	Hatchery	O	4											381	
	Hatchery	O	5												
			median					*430*						*402*	
			mean					*430*						*402*	
			se					*50*						*13*	

Notes: Q = Laboratory qualifier
U = reported value is at or below the limit of detection

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Aluminum														
	WB	1	126	1u	5.1		3.2	2u	3.3	U	3.1	U	3.0	1u
	WB	2	3.1	2u	5.7		2.9	2u	6.5		25.9		5.5	1u
	WB	3	2.9	2u	3.1	U	4.1	1u	5.0		3.0	U	4.3	1u
	WB	4	3.2	2u	3.1	U	4.5	1u	6.8		3.0	U	4.5	1u
	WB	5	2.9	2u	3.1	U	3.8	1u	5.2		5.5		3.6	1u
	WB	6											7.5	
	WB	7											3.2	U
	WB	*median*	*3.1*		*3.1*		*3.8*		*5.2*		*3.1*		*4.3*	
	WB	*mean*	*27.6*		*4.0*		*3.7*		*5.4*		*8.1*		*4.5*	
	WB	*se*	*25*		*0.6*		*0.3*		*0.6*		*4.5*		*0.6*	
	F	1	280				2.6	U					2.5	U
	F	2	2.6	U			2.4	U					2.5	U
	F	3	2.5	U			2.5	U					2.5	U
	F	4	2.6	U			2.5	U					2.6	U
	F	5	2.4	U			2.5	U					2.5	U
	F	*median*	*2.6*				*2.5*						*2.5*	
	F	*mean*	*58.0*				*2.5*						*2.5*	
	F	*se*	*55.5*				*0.0*						*0.0*	
	O	1	3.6	U			3.6	U					3.5	
	O	2	3.6	U			3.4	U					8.3	
	O	3	3.3	U			5.6						5.7	
	O	4	3.7	U			6.0						6.0	
	O	5	3.3	U			4.9						4.5	
	O	*median*	*3.6*				*4.9*						*5.7*	
	O	*mean*	*3.5*				*4.7*						*5.6*	
	O	*se*	*0.1*				*0.5*						*0.8*	
Zinc														
	WB	1	13		14		11		14		12		12	
	WB	2	13		14		11		16		14		13	
	WB	3	13		12		12		14		12		12	
	WB	4	13		13		11		12		12		12	
	WB	5	13		13		13		12		13		11	
	WB	6											11	
	WB	7											12	
	WB	*median*	*13*		*13*		*11*		*14*		*12*		*12*	
	WB	*mean*	*13*		*13*		*12*		*14*		*13*		*12*	
	WB	*se*	*0.1*		*0.4*		*0.3*		*0.7*		*0.4*		*0.2*	
	F	1	7.7				6.3						6.4	
	F	2	7.7				5.7						6.6	
	F	3	6.7				6.4						6.4	
	F	4	7.3				5.2						6.2	
	F	5	7.0				6.7						6.5	
	F	*median*	*7.3*				*6.3*						*6.4*	
	F	*mean*	*7.3*				*6.1*						*6.4*	
	F	*se*	*0.2*				*0.3*						*0.1*	
	O	1	18				15						18	
	O	2	17				16						18	
	O	3	18				18						17	
	O	4	18				16						17	
	O	5	18				18						16	
	O	*median*	*18*				*16*						*17*	
	O	*mean*	*18*				*16*						*17*	
	O	*se*	*0.2*				*0.6*						*0.5*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Uranium														
	WB	1	0.0009	1u	0.0008		0.0008	1u	0.0010		0.0008		0.0008	1u
	WB	2	0.0008	1u	0.0007		0.0009	1u	0.0012		0.0012		0.0009	1u
	WB	3	0.0008	1u	0.0006	U	0.0010	1u	0.0009		0.0007		0.0008	1u
	WB	4	0.0008	1u	0.0006	U	0.0012	1u	0.0010		0.0008		0.0013	1u
	WB	5	0.0012	1u	0.0007	U	0.0015	1u	0.0007		0.0009		0.0009	1u
	WB	6											0.0020	
	WB	7											0.0013	
	WB	*median*	*0.0008*		*0.0007*		*0.0010*		*0.0010*		*0.0008*		*0.0009*	
	WB	*mean*	*0.0009*		*0.0007*		*0.0011*		*0.0010*		*0.0009*		*0.0011*	
	WB	*se*	*0.0001*		*0.0000*		*0.0001*		*0.0001*		*0.0001*		*0.0002*	
	F	1	0.0005	U			0.0005	U					0.0005	U
	F	2	0.0005	U			0.0005	U					0.0005	U
	F	3	0.0005	U			0.0005	U					0.0005	U
	F	4	0.0005	U			0.0005	U					0.0005	U
	F	5	0.0005	U			0.0005	U					0.0005	U
	F	*median*	*0.0005*				*0.0005*						*0.0005*	
	F	*mean*	*0.0005*				*0.0005*						*0.0005*	
	F	*se*	*0.0000*				*0.0000*						*0.0000*	
	O	1	0.0013				0.0010						0.0011	
	O	2	0.0010				0.0013						0.0012	
	O	3	0.0011				0.0014						0.0009	
	O	4	0.0010				0.0017						0.0019	
	O	5	0.0017				0.0023						0.0012	
	O	*median*	*0.0011*				*0.0014*						*0.0012*	
	O	*mean*	*0.0012*				*0.0015*						*0.0013*	
	O	*se*	*0.0001*				*0.0002*						*0.0002*	
Sodium														
	WB	1	968		1100		982		1010		1090		967	
	WB	2	917		1000		902		936		1020		945	
	WB	3	911		1040		944		913		937		983	
	WB	4	892		979		890		949		967		1030	
	WB	5	948		971		962		974		945		932	
	WB	6											919	
	WB	7											1010	
	WB	*median*	*917*		*1000*		*944*		*949*		*967*		*967*	
	WB	*mean*	*927*		*1020*		*936*		*956*		*992*		*969*	
	WB	*se*	*14*		*24*		*18*		*17*		*29*		*15*	
	F	1	411				430						460	
	F	2	392				434						428	
	F	3	377				479						500	
	F	4	388				375						529	
	F	5	390				485						477	
	F	*median*	*390*				*434*						*477*	
	F	*mean*	*392*				*441*						*479*	
	F	*se*	*5.5*				*20*						*17*	
	O	1	1410				1370						1400	
	O	2	1350				1360						1410	
	O	3	1360				1370						1370	
	O	4	1330				1280						1420	
	O	5	1400				1350						1310	
	O	*median*	*1360*				*1360*						*1400*	
	O	*mean*	*1370*				*1350*						*1380*	
	O	*se*	*15*				*17*						*20*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Selenium														
	WB	1	0.42		0.51		0.43		0.72		0.55		0.50	
	WB	2	0.39		0.47		0.41		0.75		0.37		0.50	
	WB	3	0.42		0.52		0.51		0.80		0.58		0.52	
	WB	4	0.42		0.44		0.66		0.54		0.50		0.40	
	WB	5	0.43		0.48		0.59		0.80		0.50		0.33	
	WB	6											0.62	
	WB	7											0.51	
	WB	*median*	*0.42*		*0.48*		*0.51*		*0.75*		*0.50*		*0.50*	
	WB	*mean*	*0.41*		*0.48*		*0.52*		*0.72*		*0.50*		*0.48*	
	WB	*se*	*0.01*		*0.01*		*0.05*		*0.05*		*0.04*		*0.04*	
	F	1	0.39				0.37						0.57	
	F	2	0.32				0.39						0.42	
	F	3	0.37				0.42						0.38	
	F	4	0.37				0.43						0.30	
	F	5	0.38				0.44						0.30	
	F	*median*	*0.37*				*0.42*						*0.38*	
	F	*mean*	*0.37*				*0.41*						*0.39*	
	F	*se*	*0.01*				*0.01*						*0.05*	
	O	1	0.45				0.48						0.44	
	O	2	0.45				0.43						0.56	
	O	3	0.47				0.59						0.63	
	O	4	0.46				0.82						0.48	
	O	5	0.46				0.70						0.36	
	O	*median*	*0.46*				*0.59*						*0.48*	
	O	*mean*	*0.46*				*0.60*						*0.49*	
	O	*se*	*0.00*				*0.07*						*0.05*	
Potassium														
	WB	1	3300		3690		3320		3300		3290		3370	
	WB	2	3290		3240		3360		3200		3180		3250	
	WB	3	3190		3370		3540		3220		3230		3340	
	WB	4	3350		3320		3290		3320		3370		3210	
	WB	5	3300		3330		3270		3250		3250		3200	
	WB	6											3320	
	WB	7											3310	
	WB	*median*	*3300*		*3330*		*3320*		*3250*		*3250*		*3310*	
	WB	*mean*	*3290*		*3390*		*3360*		*3260*		*3260*		*3290*	
	WB	*se*	*26*		*78*		*48*		*23*		*32*		*25*	
	F	1	4390				4360						4330	
	F	2	4390				4340						4240	
	F	3	4160				4430						4280	
	F	4	4470				4220						4300	
	F	5	4460				4300						4240	
	F	*median*	*4390*				*4340*						*4280*	
	F	*mean*	*4370*				*4330*						*4280*	
	F	*se*	*56*				*35*						*17*	
	O	1	2430				2590						2550	
	O	2	2380				2380						2350	
	O	3	2360				2710						2600	
	O	4	2370				2590						2370	
	O	5	2360				2420						2340	
	O	*median*	*2370*				*2590*						*2370*	
	O	*mean*	*2380*				*2540*						*2440*	
	O	*se*	*13*				*61*						*55*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Nickel														
	WB	1	0.46		0.41		0.38		0.36		0.34		0.36	
	WB	2	0.47		0.44		0.35		0.39		0.37		0.38	
	WB	3	0.44		0.34		0.31		0.42		0.35		0.48	
	WB	4	0.37		0.36		0.42		0.40		0.36		0.47	
	WB	5	0.42		0.33		0.45		0.44		0.38		0.43	
	WB	6											0.34	
	WB	7											0.35	
	WB	*median*	*0.44*		*0.36*		*0.38*		*0.40*		*0.36*		*0.38*	
	WB	*mean*	*0.43*		*0.38*		*0.38*		*0.40*		*0.36*		*0.40*	
	WB	*se*	*0.02*		*0.02*		*0.02*		*0.01*		*0.01*		*0.02*	
	F	1	0.17				0.16						0.06	
	F	2	0.10				0.07						0.06	
	F	3	0.15				0.08						0.13	
	F	4	0.10				0.14						0.10	
	F	5	0.16				0.10						0.13	
	F	*median*	*0.15*				*0.10*						*0.10*	
	F	*mean*	*0.14*				*0.11*						*0.10*	
	F	*se*	*0.01*				*0.02*						*0.02*	
	O	1	0.68				0.54						0.61	
	O	2	0.78				0.63						0.66	
	O	3	0.69				0.53						0.75	
	O	4	0.61				0.63						0.75	
	O	5	0.63				0.73						0.69	
	O	*median*	*0.68*				*0.63*						*0.69*	
	O	*mean*	*0.68*				*0.61*						*0.69*	
	O	*se*	*0.03*				*0.04*						*0.03*	
Manganese														
	WB	1	1.5		1.5		1.0		1.9		1.4		1.2	
	WB	2	1.3		1.1		1.2		2.3		1.4		1.3	
	WB	3	1.1		1.0		1.0		1.9		1.4		1.5	
	WB	4	0.9		1.2		1.3		1.6		1.2		1.7	
	WB	5	1.1		1.1		1.2		1.5		1.3		1.2	
	WB	6											1.1	
	WB	7											1.2	
	WB	*median*	*1.1*		*1.1*		*1.2*		*1.9*		*1.4*		*1.2*	
	WB	*mean*	*1.2*		*1.2*		*1.1*		*1.8*		*1.3*		*1.3*	
	WB	*se*	*0.1*		*0.1*		*0.1*		*0.1*		*0.0*		*0.1*	
	F	1	0.20				0.15						0.13	
	F	2	0.16				0.12						0.14	
	F	3	0.16				0.15						0.15	
	F	4	0.19				0.47						0.15	
	F	5	0.20				0.15						0.17	
	F	*median*	*0.19*				*0.15*						*0.15*	
	F	*mean*	*0.18*				*0.21*						*0.15*	
	F	*se*	*0.01*				*0.07*						*0.01*	
	O	1	2.5				1.6						2.1	
	O	2	2.2				2.2						2.4	
	O	3	1.9				1.8						2.5	
	O	4	1.6				1.9						2.8	
	O	5	1.8				2.0						2.0	
	O	*median*	*1.9*				*1.9*						*2.4*	
	O	*mean*	*2.0*				*1.9*						*2.4*	
	O	*se*	*0.2*				*0.1*						*0.1*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye	Collection Area	1		2		3		4		5		6	
	River Mile	741		723		706		678		635		605	
Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Magnesium													
Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	
WB	1	372		394		352		388		363		360	
WB	2	368		383		371		356		368		342	
WB	3	368		352		342		370		360		349	
WB	4	350		373		344		364		360		375	
WB	5	361		364		364		369		342		360	
WB	6											344	
WB	7											368	
WB	*median*	*368*		*373*		*352*		*369*		*360*		*360*	
WB	*mean*	*364*		*373*		*355*		*369*		*359*		*357*	
WB	*se*	*3.9*		*7.3*		*5.6*		*5.3*		*4.4*		*4.7*	
F	1	280				280						266	
F	2	281				264						260	
F	3	269				281						265	
F	4	282				268						272	
F	5	277				274						270	
F	*median*	*280*				*274*						*266*	
F	*mean*	*278*				*273*						*267*	
F	*se*	*2.4*				*3.3*						*2.1*	
O	1	446				402						441	
O	2	440				478						416	
O	3	452				398						416	
O	4	409				402						454	
O	5	429				436						435	
O	*median*	*440*				*402*						*435*	
O	*mean*	*435*				*423*						*432*	
O	*se*	*7.6*				*15*						*7.4*	
Lead													
WB	1	0.030	1u	0.033		0.032		0.072		0.16		0.051	
WB	2	0.029	1u	0.023		0.045		0.107		0.013		0.024	1u
WB	3	0.039	1u	0.036		0.038		0.085		0.048		0.036	
WB	4	0.038	1u	0.047		0.053	1u	0.12		0.051		0.020	1u
WB	5	0.041	1u	0.055		0.054	1u	0.22		0.024		0.016	1u
WB	6											0.015	
WB	7											0.015	
WB	*median*	*0.038*		*0.036*		*0.045*		*0.11*		*0.048*		*0.020*	
WB	*mean*	*0.035*		*0.039*		*0.044*		*0.12*		*0.060*		*0.025*	
WB	*se*	*0.002*		*0.005*		*0.004*		*0.027*		*0.027*		*0.005*	
F	1	0.011	U			0.022						0.062	
F	2	0.011	U			0.053						0.011	U
F	3	0.010	U			0.012						0.040	
F	4	0.011	U			0.010	U					0.011	U
F	5	0.010	U			0.011	U					0.011	U
F	*median*	*0.011*				*0.012*						*0.011*	
F	*mean*	*0.011*				*0.021*						*0.027*	
F	*se*	*0.000*				*0.008*						*0.011*	
O	1	0.045				0.039						0.041	
O	2	0.045				0.037						0.036	
O	3	0.063				0.062						0.033	
O	4	0.061				0.085						0.028	
O	5	0.066				0.089						0.021	
O	*median*	*0.061*				*0.062*						*0.033*	
O	*mean*	*0.056*				*0.062*						*0.032*	
O	*se*	*0.005*				*0.011*						*0.003*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Iron														
	WB	1	11		9.2		9.2		9.7		8.6		12	
	WB	2	9.6		9.1		7.1		13		8.7		10	
	WB	3	9.4		12		11		10		7.1		9.8	
	WB	4	10		9.1		12		10		12		10	
	WB	5	11		8.2		10		9.4		10		8.4	
	WB	6											11.2	
	WB	7											9.1	
	WB	*median*	*10*		*9.1*		*10*		*10*		*8.7*		*10*	
	WB	*mean*	*10*		*9.4*		*9.8*		*11*		*9.3*		*10*	
	WB	*se*	*0.4*		*0.6*		*0.8*		*0.7*		*0.8*		*0.4*	
	F	1	4.7				3.4						2.3	
	F	2	2.3				2.6						2.1	
	F	3	3.3				2.5						2.9	
	F	4	3.7				5.6						3.0	
	F	5	3.4				2.5						3.0	
	F	*median*	*3.4*				*2.6*						*2.9*	
	F	*mean*	*3.5*				*3.3*						*2.7*	
	F	*se*	*0.4*				*0.6*						*0.2*	
	O	1	16				13						20	
	O	2	16				12						17	
	O	3	15				19						15	
	O	4	16				17						15	
	O	5	18				16						13	
	O	*median*	*16*				*16*						*15*	
	O	*mean*	*16*				*15*						*16*	
	O	*se*	*1*				*1*						*1*	
Copper														
	WB	1	0.34		0.38		0.32		0.36		0.34		0.35	
	WB	2	0.34		0.34		0.26		0.57		0.40		0.36	
	WB	3	0.30		0.29		0.35		0.45		0.30		0.39	
	WB	4	0.32		0.36		0.42		0.48		0.35		0.40	
	WB	5	0.33		0.29		0.38		0.44		0.36		0.36	
	WB	6											0.31	
	WB	7											0.37	
	WB	*median*	*0.33*		*0.34*		*0.35*		*0.45*		*0.35*		*0.36*	
	WB	*mean*	*0.33*		*0.33*		*0.35*		*0.46*		*0.35*		*0.36*	
	WB	*se*	*0.01*		*0.02*		*0.03*		*0.03*		*0.02*		*0.01*	
	F	1	0.24				0.18						0.20	
	F	2	0.21				0.18						0.21	
	F	3	0.20				0.19						0.23	
	F	4	0.24				0.25						0.21	
	F	5	0.24				0.20						0.21	
	F	*median*	*0.24*				*0.19*						*0.21*	
	F	*mean*	*0.23*				*0.20*						*0.21*	
	F	*se*	*0.01*				*0.01*						*0.00*	
	O	1	0.42				0.42						0.47	
	O	2	0.45				0.34						0.50	
	O	3	0.38				0.50						0.51	
	O	4	0.40				0.54						0.54	
	O	5	0.41				0.52						0.48	
	O	*median*	*0.41*				*0.50*						*0.50*	
	O	*mean*	*0.41*				*0.46*						*0.50*	
	O	*se*	*0.01*				*0.04*						*0.01*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Cobalt														
	WB	1	0.021		0.026		0.020		0.025		0.020		0.023	
	WB	2	0.020		0.023		0.021		0.039		0.020		0.021	
	WB	3	0.020		0.021		0.022		0.029		0.020		0.022	
	WB	4	0.020		0.023		0.029		0.028		0.023		0.024	
	WB	5	0.021		0.020		0.025		0.030		0.021		0.022	
	WB	6											0.020	
	WB	7											0.021	
	WB	*median*	*0.020*		*0.023*		*0.022*		*0.029*		*0.020*		*0.022*	
	WB	*mean*	*0.020*		*0.023*		*0.023*		*0.030*		*0.021*		*0.022*	
	WB	*se*	*0.000*		*0.001*		*0.002*		*0.002*		*0.001*		*0.000*	
	F	1	0.0060				0.0056						0.0044	
	F	2	0.0051				0.0037						0.0040	
	F	3	0.0051				0.0044						0.0052	
	F	4	0.0048				0.0074						0.0048	
	F	5	0.0060				0.0038						0.0057	
	F	*median*	*0.0051*				*0.0044*						*0.0048*	
	F	*mean*	*0.0054*				*0.0050*						*0.0048*	
	F	*se*	*0.0003*				*0.0007*						*0.0003*	
	O	1	0.033				0.030						0.038	
	O	2	0.033				0.037						0.036	
	O	3	0.033				0.038						0.036	
	O	4	0.034				0.045						0.039	
	O	5	0.033				0.043						0.036	
	O	*median*	*0.033*				*0.038*						*0.036*	
	O	*mean*	*0.033*				*0.039*						*0.037*	
	O	*se*	*0.000*				*0.003*						*0.001*	
Chromium														
	WB	1	0.56		0.41		0.53		0.53		0.47		0.84	
	WB	2	0.56		0.44		0.38		0.47		0.45		0.55	
	WB	3	0.49		0.97		0.47		0.53		0.48		0.68	
	WB	4	0.55		0.41		0.80		0.63		0.84		0.47	
	WB	5	0.49		0.38		0.55		0.63		0.55		0.42	
	WB	6											0.47	
	WB	7											0.40	
	WB	*median*	*0.55*		*0.41*		*0.53*		*0.53*		*0.48*		*0.47*	
	WB	*mean*	*0.53*		*0.52*		*0.55*		*0.56*		*0.56*		*0.55*	
	WB	*se*	*0.02*		*0.11*		*0.07*		*0.03*		*0.07*		*0.06*	
	F	1	0.51				0.57						0.46	
	F	2	0.26				0.39						0.42	
	F	3	0.45				0.40						0.54	
	F	4	0.52				0.90						0.39	
	F	5	0.52				0.40						0.46	
	F	*median*	*0.51*				*0.40*						*0.46*	
	F	*mean*	*0.45*				*0.53*						*0.45*	
	F	*se*	*0.05*				*0.10*						*0.02*	
	O	1	0.59				0.51						1.17	
	O	2	0.81				0.37						0.66	
	O	3	0.52				0.53						0.79	
	O	4	0.58				0.73						0.54	
	O	5	0.46				0.67						0.39	
	O	*median*	*0.58*				*0.53*						*0.66*	
	O	*mean*	*0.59*				*0.56*						*0.71*	
	O	*se*	*0.06*				*0.06*						*0.13*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Calcium														
	WB	1	11600		12400		10100		13600		12200		11200	
	WB	2	11200		13200		11500		11700		11900		10500	
	WB	3	11500		10800		8930		11800		12000		10600	
	WB	4	10100		12100		10100		11700		11200		12800	
	WB	5	11100		11400		11800		12400		10500		11800	
	WB	6											10500	
	WB	7											12200	
	WB	*median*	*11200*		*12100*		*10100*		*11800*		*11900*		*11200*	
	WB	*mean*	*11100*		*12000*		*10500*		*12200*		*11600*		*11400*	
	WB	*se*	*266*		*413*		*523*		*364*		*314*		*347*	
	F	1	847				516						468	
	F	2	547				264						397	
	F	3	502				559						393	
	F	4	393				424						540	
	F	5	456				551						874	
	F	*median*	*502*				*516*						*468*	
	F	*mean*	*549*				*463*						*534*	
	F	*se*	*79*				*55*						*89*	
	O	1	20100				16800						20300	
	O	2	20100				22600						19600	
	O	3	20900				16600						18700	
	O	4	18500				17400						22300	
	O	5	19800				21000						21000	
	O	*median*	*20100*				*17400*						*20300*	
	O	*mean*	*19900*				*18900*						*20400*	
	O	*se*	*390*				*1226*						*613*	
Cadmium														
	WB	1	0.026	1u	0.038		0.019	1u	0.022		0.022		0.021	1u
	WB	2	0.021	1u	0.017		0.018	1u	0.042		0.020		0.021	1u
	WB	3	0.019	1u	0.018		0.026	1u	0.032		0.014		0.025	1u
	WB	4	0.026	1u	0.026		0.036	1u	0.028		0.021		0.025	1u
	WB	5	0.024	1u	0.019		0.023	1u	0.026		0.021		0.024	1u
	WB	6											0.017	
	WB	7											0.017	
	WB	*median*	*0.024*		*0.019*		*0.023*		*0.028*		*0.021*		*0.021*	
	WB	*mean*	*0.023*		*0.024*		*0.024*		*0.030*		*0.019*		*0.021*	
	WB	*se*	*0.001*		*0.004*		*0.003*		*0.003*		*0.001*		*0.001*	
	F	1	0.011	U			0.011	U					0.010	U
	F	2	0.011	U			0.010	U					0.011	U
	F	3	0.010	U			0.011	U					0.011	U
	F	4	0.011	U			0.010	U					0.011	U
	F	5	0.010	U			0.011	U					0.011	U
	F	*median*	*0.011*				*0.011*						*0.011*	
	F	*mean*	*0.011*				*0.011*						*0.011*	
	F	*se*	*0.000*				*0.000*						*0.000*	
	O	1	0.039				0.024						0.029	
	O	2	0.030				0.025						0.031	
	O	3	0.026				0.041						0.036	
	O	4	0.040				0.054						0.036	
	O	5	0.036				0.034						0.036	
	O	*median*	*0.036*				*0.034*						*0.036*	
	O	*mean*	*0.034*				*0.036*						*0.034*	
	O	*se*	*0.003*				*0.006*						*0.001*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Barium														
	WB	1	0.91	1u	0.96		0.78	1u	1.06		1.02		0.80	1u
	WB	2	0.82	1u	0.88		0.81	1u	1.03		0.82		0.83	1u
	WB	3	0.85	1u	0.80		0.74	1u	0.97		0.79		0.83	1u
	WB	4	0.73	1u	0.88		0.86	1u	0.95		0.80		1.03	1u
	WB	5	0.86	1u	0.79		0.91	1u	0.88		0.83		0.85	1u
	WB	6											0.78	
	WB	7											0.90	
	WB	*median*	*0.85*		*0.88*		*0.81*		*0.97*		*0.82*		*0.83*	
	WB	*mean*	*0.83*		*0.86*		*0.82*		*0.98*		*0.85*		*0.86*	
	WB	*se*	*0.03*		*0.03*		*0.03*		*0.03*		*0.04*		*0.03*	
	F	1	0.086	U			0.086	U					0.083	U
	F	2	0.085	U			0.081	U					0.084	U
	F	3	0.082	U			0.084	U					0.084	U
	F	4	0.087	U			0.082	U					0.086	U
	F	5	0.080	U			0.084	U					0.084	U
	F	*median*	*0.085*				*0.084*						*0.084*	
	F	*mean*	*0.084*				*0.084*						*0.084*	
	F	*se*	*0.001*				*0.001*						*0.001*	
	O	1	1.6				1.3						1.4	
	O	2	1.4				1.5						1.5	
	O	3	1.5				1.4						1.4	
	O	4	1.3				1.5						1.8	
	O	5	1.5				1.6						1.5	
	O	*median*	*1.5*				*1.5*						*1.5*	
	O	*mean*	*1.5*				*1.4*						*1.5*	
	O	*se*	*0.0*				*0.1*						*0.1*	
Arsenic														
	WB	1	0.11		0.15		0.12		0.21		0.16		0.16	
	WB	2	0.10		0.09		0.14		0.31		0.12		0.16	
	WB	3	0.11		0.13		0.14		0.23		0.19		0.16	
	WB	4	0.07		0.11		0.19		0.20		0.16		0.12	
	WB	5	0.07		0.09		0.15		0.25		0.16		0.13	
	WB	6											0.20	
	WB	7											0.16	
	WB	*median*	*0.10*		*0.11*		*0.14*		*0.23*		*0.16*		*0.16*	
	WB	*mean*	*0.09*		*0.12*		*0.15*		*0.24*		*0.16*		*0.16*	
	WB	*se*	*0.01*		*0.01*		*0.01*		*0.02*		*0.01*		*0.01*	
	F	1	0.11				0.11						0.18	
	F	2	0.10				0.13						0.14	
	F	3	0.10				0.11						0.12	
	F	4	0.07				0.10						0.10	
	F	5	0.06				0.12						0.12	
	F	*median*	*0.10*				*0.11*						*0.12*	
	F	*mean*	*0.09*				*0.11*						*0.13*	
	F	*se*	*0.01*				*0.01*						*0.01*	
	O	1	0.12				0.12						0.14	
	O	2	0.10				0.15						0.19	
	O	3	0.12				0.18						0.19	
	O	4	0.08				0.25						0.14	
	O	5	0.07	U			0.18						0.13	
	O	*median*	*0.10*				*0.18*						*0.14*	
	O	*mean*	*0.10*				*0.18*						*0.16*	
	O	*se*	*0.01*				*0.02*						*0.01*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Age														
	WB	1	3.3		3		3.8		3.8		3.2		3.2	
	WB	2	3.6		3.4		2.5		4		2.5		3.5	
	WB	3	3.8		3.4		3.8		3.3		2.2		3.2	
	WB	4	4		2.6		3.4		4		3.2		3.6	
	WB	5	3.6		3.6		3.8		3.2		3.5		3.3	
	WB	6											3	
	WB	7											3.6	
	WB	*median*	*3.6*		*3.4*		*3.8*		*3.8*		*3.2*		*3.3*	
	WB	*mean*	*3.7*		*3.2*		*3.5*		*3.7*		*2.9*		*3.3*	
	WB	*se*	*0.1*		*0.2*		*0.3*		*0.2*		*0.2*		*0.1*	
	F	1	3.3				3.8						3.2	
	F	2	3.6				2.5						3.5	
	F	3	3.8				3.8						3.2	
	F	4	4				3.4						3.6	
	F	5	3.6				3.8						3.3	
	F	*median*	*3.6*				*3.8*						*3.3*	
	F	*mean*	*3.7*				*3.5*						*3.4*	
	F	*se*	*0.1*				*0.3*						*0.1*	
	O	1	3.3				3.8						3.2	
	O	2	3.6				2.5						3.5	
	O	3	3.8				3.8						3.2	
	O	4	4				3.4						3.6	
	O	5	3.6				3.8						3.3	
	O	*median*	*3.6*				*3.8*						*3.3*	
	O	*mean*	*3.7*				*3.5*						*3.4*	
	O	*se*	*0.1*				*0.3*						*0.1*	
Length														
	WB	1	499		435		538		555		508		547	
	WB	2	512		404		512		502		598		559	
	WB	3	431		409		514		536		430		558	
	WB	4	539		344		448		553		547		585	
	WB	5	394		477		482		510		559		566	
	WB	6											574	
	WB	7											623	
	WB	*median*	*499*		*409*		*512*		*536*		*547*		*566*	
	WB	*mean*	*475*		*414*		*499*		*531*		*528*		*573*	
	WB	*se*	*27*		*22*		*16*		*11*		*29*		*9.5*	
	F	1	499				538						547	
	F	2	512				512						559	
	F	3	431				514						558	
	F	4	539				448						585	
	F	5	394				482						566	
	F	*median*	*499*				*512*						*559*	
	F	*mean*	*475*				*499*						*563*	
	F	*se*	*27*				*16*						*6.3*	
	O	1	499				538						547	
	O	2	512				512						559	
	O	3	431				514						558	
	O	4	539				448						585	
	O	5	394				482						566	
	O	*median*	*499*				*512*						*559*	
	O	*mean*	*475*				*499*						*563*	
	O	*se*	*27*				*16*						*6.3*	

Table B1-4. Summary of Analytical Data for Walleye

Walleye		Collection Area	1		2		3		4		5		6	
		River Mile	741		723		706		678		635		605	
	Tissue	comp	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Weight														
	WB	1	382		384		405		405		392		412	
	WB	2	396		365		400		399		420		409	
	WB	3	376		367		391		399		373		409	
	WB	4	397		355		377		397		412		419	
	WB	5	362		388		391		392		409		411	
	WB	6											401	
	WB	7											418	
	WB	*median*	*382*		*367*		*391*		*399*		*409*		*411*	
	WB	*mean*	*382*		*372*		*393*		*398*		*401*		*411*	
	WB	*se*	*6.5*		*6.2*		*4.8*		*2.0*		*8.4*		*2.2*	
	F	1	382				405						412	
	F	2	396				400						409	
	F	3	376				391						409	
	F	4	397				377						419	
	F	5	362				391						411	
	F	*median*	*382*				*391*						*411*	
	F	*mean*	*382*				*393*						*412*	
	F	*se*	*6.5*				*4.8*						*1.8*	
	O	1	382				405						412	
	O	2	396				400						409	
	O	3	376				391						409	
	O	4	397				377						419	
	O	5	362				391						411	
	O	*median*	*382*				*391*						*411*	
	O	*mean*	*382*				*393*						*412*	
	O	*se*	*6.5*				*4.8*						*1.8*	

Notes:

U = result not detected, reported at detection limit converted from dry weight to wet weight using sample-specific moisture content

1U = one sample used to estimate value was below detection limit

2U = both samples used to estimate value were below detection limit

Table B1-5. Summary of Analytical Data for Whitefish Species

		Mountain		Lake		Lake		Lake		Lake		Lake	
Whitefish	Collection Area	1		2		3		4		5		6	
species	River Mile	741		723		706		678		635		605	
	composite	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Aluminum													
	1	19		4.8		3.8	U	7.1		5.2		3.9	U
	2	13		3.9	U	3.8	U	5.9		3.7	U	4.0	U
	3	4.9		3.8	U	3.9		4.8		6.0			
	4	20		4.1	U	3.5	U	5.2		4.5			
	5	17		3.9	U	5.8		7.8		4.2	U		
	median	*17*		*3.9*		*3.8*		*5.9*		*4.5*		*4.0*	
	mean	*15*		*4.1*		*4.2*		*6.2*		*4.7*		*4.0*	
	se	*2.6*		*0.18*		*0.42*		*0.56*		*0.40*		*0.1*	
Arsenic													
	1	*0.17*		*0.27*		*0.27*		*0.29*		*0.30*		*0.19*	
	2	*0.16*		*0.20*		*0.28*		*0.26*		*0.30*		*0.31*	
	3	*0.14*		*0.26*		*0.24*		*0.22*		0.23			
	4	*0.15*		*0.26*		*0.28*		*0.25*		*0.30*			
	5	0.12		*0.19*		*0.24*		*0.23*		*0.29*			
	median	*0.15*		*0.26*		*0.27*		*0.25*		*0.30*		*0.25*	
	mean	*0.15*		*0.24*		*0.26*		*0.25*		*0.28*		*0.25*	
	se	*0.01*		*0.02*		*0.01*		*0.01*		*0.01*		*0.06*	
Barium													
	1	1.0		*0.51*		*0.51*		*0.70*		*0.55*		*0.35*	
	2	1.8		*0.55*		*0.53*		*0.62*		*0.63*		*0.32*	
	3	0.46		*0.41*		*0.52*		*0.55*		*0.67*			
	4	1.3		*0.54*		*0.58*		*0.85*		*0.58*			
	5	2.8		*0.45*		*0.62*		0.7		*0.56*			
	median	*1.3*		*0.51*		*0.53*		*0.7*		*0.58*		*0.33*	
	mean	*1.5*		*0.49*		*0.55*		*0.68*		*0.60*		*0.33*	
	se	*0.39*		*0.03*		*0.02*		*0.05*		*0.02*		*0.01*	
Cadmium													
	1	0.13		0.024		0.019		0.02		0.018		0.017	
	2	0.11		0.016	U	0.018	J	0.029		0.016	U	0.024	
	3	0.092		0.016	U	0.020		0.022		0.017	U		
	4	0.13		0.017	U	0.016		0.024		0.015	U		
	5	0.092		0.020		0.017		0.032		0.017	U		
	median	*0.11*		*0.017*		*0.018*		*0.024*		*0.017*		*0.020*	
	mean	*0.11*		*0.019*		*0.018*		*0.025*		*0.017*		*0.020*	
	se	*0.01*		*0.002*		*0.001*		*0.002*		*0.000*		*0.003*	
Calcium													
	1	*6070*		*4550*	J	*5690*		*5070*		*5570*		*4860*	
	2	*4870*		*5150*	J	*5470*		*4760*		*7410*		*6000*	J
	3	*4120*		*4650*	J	*4840*		*4650*		*6280*			
	4	*6290*		*4610*	J	*4980*		*6490*		*4420*			
	5	*5490*		*4960*	J	*4600*		*4500*		*7500*			
	median	*5490*		*4650*		*4980*		*4760*		*6280*		*5430*	
	mean	*5370*		*4780*		*5120*		*5090*		*6240*		*5430*	
	se	*398*		*116*		*202*		*361*		*580*		*570*	
Chromium													
	1	1.2		0.72		0.66		0.88		0.92		0.91	
	2	0.95		0.52		0.69		0.84		0.82		0.64	
	3	1.0		0.66		0.65		0.86		0.80			
	4	1.1		0.64		0.70		0.82		0.90			
	5	1.1		0.55		0.94		0.75		0.92			
	median	*1.1*		*0.64*		*0.69*		*0.84*		*0.90*		*0.78*	
	mean	*1.1*		*0.62*		*0.73*		*0.83*		*0.87*		*0.78*	
	se	*0.0*		*0.04*		*0.05*		*0.02*		*0.02*		*0.14*	
Cobalt													
	1	0.059		0.029	JK	0.025	JK	0.025	JK	0.030	JK	0.020	JK
	2	0.062		0.025	JK	0.023	JK	0.029	JK	0.037	JK	0.026	JK
	3	0.028		0.024	JK	0.019	JK	0.024	JK	0.032	JK		
	4	0.072		0.022	JK	0.024	JK	0.028	JK	0.027	JK		
	5	0.067		0.023	JK	0.033	JK	0.029	JK	0.031	J		
	median	*0.062*		*0.024*		*0.024*		*0.028*		*0.031*		*0.023*	
	mean	*0.058*		*0.025*		*0.025*		*0.027*		*0.032*		*0.023*	
	se	*0.008*		*0.001*		*0.002*		*0.001*		*0.002*		*0.003*	

Table B1-5. Summary of Analytical Data for Whitefish Species

		Mountain		Lake		Lake		Lake		Lake		Lake	
Whitefish species	Collection Area	1		2		3		4		5		6	
	River Mile	741		723		706		678		635		605	
	composite	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Copper													
	1	1.2	J	0.82		0.44		0.68		0.73		0.45	
	2	1.5	J	0.65		0.53		0.72		0.54		0.57	
	3	0.56	J	0.54		0.65		0.72		0.67			
	4	2.0	J	0.64		0.51		0.65		0.67			
	5	1.3	J	0.75		0.85		0.65		0.56			
	median	*1.3*		*0.65*		*0.53*		*0.68*		*0.67*		*0.51*	
	mean	*1.3*		*0.68*		*0.60*		*0.68*		*0.63*		*0.51*	
	se	*0.23*		*0.05*		*0.07*		*0.02*		*0.04*		*0.06*	
Iron													
	1	112	J	17		11		18		17		11	
	2	113	J	12		12		17		13		18	
	3	30	J	11		15		15		16			
	4	147	J	15		12		17		19			
	5	109	J	15		22		19		11			
	median	*112*		*15*		*12*		*17*		*16*		*15*	
	mean	*102*		*14*		*15*		*17*		*15*		*15*	
	se	*19*		*1*		*2*		*1*		*2*		*4*	
Lead													
	1	0.45		0.075		0.089		0.068		0.048		0.071	
	2	0.40		0.058		0.057		0.049		0.047		0.040	
	3	0.18		0.06		0.049		0.041		0.053			
	4	0.34		0.081		0.067		0.062		0.038			
	5	0.30		0.062		0.12		0.11		0.053			
	median	*0.34*		*0.062*		*0.067*		*0.062*		*0.048*		*0.056*	
	mean	*0.34*		*0.067*		*0.077*		*0.067*		*0.048*		*0.056*	
	se	*0.047*		*0.0046*		*0.013*		*0.013*		*0.0027*		*0.016*	
Magnesium													
	1	314		277		297		286		279		258	
	2	344		284		276		289		282		268	
	3	296		269		278		267		280			
	4	336		274		276		296		265			
	5	322		271		271		270		297			
	median	*322*		*274*		*276*		*286*		*280*		*263*	
	mean	*322*		*275*		*280*		*282*		*281*		*263*	
	se	*8*		*3*		*5*		*6*		*5*		*5*	
Manganese													
	1	4		*1.1*		0.81	J	1.7	J	2.0	J	1.0	J
	2	*4.9*		0.68		0.90	J	2.0	J	1.7	J	*0.99*	
	3	*1.6*		0.63		0.87	J	1.2	J	1.7	J		
	4	*4.3*		0.85		0.67	J	3.8	J	2.4	J		
	5	*3.7*		0.81		1.6	J	2.1	J	1.3	J		
	median	*4.0*		*0.81*		*0.87*		*2.0*		*1.7*		*0.99*	
	mean	*3.7*		*0.81*		*0.97*		*2.2*		*1.8*		*0.99*	
	se	*0.6*		*0.08*		*0.17*		*0.4*		*0.2*		*0.01*	
Mercury													
	1	0.082		0.065		0.051		0.045		0.080		0.094	
	2	0.083		0.069		0.056		0.058		0.067		0.095	
	3	0.063		0.052		0.054		0.070		0.065			
	4	0.080		0.055		0.051		0.066		0.069			
	5	0.075		0.058		0.050		0.057		0.066			
	median	*0.080*		*0.058*		*0.051*		*0.058*		*0.067*		*0.094*	
	mean	*0.077*		*0.060*		*0.052*		*0.059*		*0.069*		*0.094*	
	se	*0.004*		*0.003*		*0.001*		*0.004*		*0.003*		*0.000*	
Nickel													
	1	0.27		0.17		0.24		0.23		0.21		0.24	
	2	0.21		0.18		0.21		0.19		0.27		0.21	
	3	0.17		0.17		0.16		0.19		0.26			
	4	0.29		0.16		0.17		0.25		0.18			
	5	0.27		0.17		0.30		0.17		0.25			
	median	*0.27*		*0.17*		*0.21*		*0.19*		*0.25*		*0.23*	
	mean	*0.24*		*0.17*		*0.22*		*0.20*		*0.23*		*0.23*	
	se	*0.02*		*0.00*		*0.03*		*0.01*		*0.02*		*0.01*	

Table B1-5. Summary of Analytical Data for Whitefish Species

		Mountain		Lake		Lake		Lake		Lake		Lake	
Whitefish species	Collection Area	1		2		3		4		5		6	
	River Mile	741		723		706		678		635		605	
	composite	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Potassium													
	1	3020		2980		3160		3000		3040		2970	
	2	3430		3170		2990		3110		2750		2790	
	3	3050		3110		3020		2900		2910			
	4	3040		3120		3070		3010		3010			
	5	3220		2990		3070		3000		2810			
	median	*3050*		*3110*		*3070*		*3000*		*2910*		*2880*	
	mean	*3150*		*3070*		*3060*		*3000*		*2900*		*2880*	
	se	*78*		*38*		*29*		*33*		*56*		*90*	
Selenium													
	1	1.0		0.86		0.78		0.87		0.59		0.49	
	2	1.1		0.71		0.65		0.78		0.64		0.44	
	3	1.0		0.70		0.59		0.75		0.67			
	4	1.2		0.75		0.80		0.86		0.84			
	5	0.85		0.62		0.88		0.78		0.70			
	median	*1.0*		*0.71*		*0.78*		*0.78*		*0.67*		*0.46*	
	mean	*1.0*		*0.73*		*0.74*		*0.81*		*0.69*		*0.46*	
	se	*0.1*		*0.04*		*0.05*		*0.02*		*0.04*		*0.03*	
Silver													
	1	0.052	U	0.092	U	0.076	U	0.081	U	0.080	U	0.081	U
	2	0.055	U	0.081	U	0.077	U	0.078	U	0.078	U	0.084	U
	3	0.053	U	0.079	U	0.079	U	0.086	U	0.084	U		
	4	0.052	U	0.085	U	0.073	U	0.082	U	0.077	U		
	5	0.053	U	0.081	U	0.079	U	0.081	U	0.085	U		
	median	*0.053*		*0.081*		*0.077*		*0.081*		*0.080*		*0.082*	
	mean	*0.053*		*0.084*		*0.077*		*0.081*		*0.080*		*0.082*	
	se	*0.001*		*0.002*		*0.001*		*0.001*		*0.002*		*0.001*	
Sodium													
	1	742	J	677		762	JK	665	JK	720		791	JK
	2	732	J	687		692	JK	688	JK	809		690	
	3	648	J	657		674		657	JK	698			
	4	751	J	658		729		737	JK	707			
	5	722	J	690		700		642	JK	753	JK		
	median	*732*		*677*		*700*		*665*		*720*		*741*	
	mean	*719*		*674*		*711*		*678*		*737*		*741*	
	se	*18*		*7*		*15*		*17*		*20*		*51*	
Thallium													
	1	0.086	U	0.092	U	0.076	U	0.081	U	0.080	U	0.081	U
	2	0.092	U	0.081	U	0.077	U	0.078	U	0.078	U	0.084	U
	3	0.088	U	0.079	U	0.079	U	0.086	U	0.084	U		0
	4	0.087	U	0.085	U	0.073	U	0.082	U	0.077	U		0
	5	0.088	U	0.081	U	0.079	U	0.081	U	0.085	U		0
	median	*0.088*		*0.081*		*0.077*		*0.081*		*0.080*		*0.082*	
	mean	*0.088*		*0.084*		*0.077*		*0.081*		*0.080*		*0.082*	
	se	*0.001*		*0.002*		*0.001*		*0.001*		*0.002*		*0.001*	
Uranium													
	1	0.0096	0	0.0025	0	0.0047	0	0.0019	0	0.0025	0	0.0016	U
	2	0.012	0	0.0024	0	0.0023	0	0.0016	U	0.0031	0	0.0017	U
	3	0.0046	0	0.0022	0	0.0017	0	0.0017	U	0.0025	0		0
	4	0.0104	0	0.0022	0	0.0014	U	0.0021	0	0.0021	0		0
	5	0.0075	0	0.0018	0	0.0038	0	0.0017	0	0.0018	U		0
	median	*0.0096*		*0.0022*		*0.00227*		*0.00172*		*0.0025*		*0.0017*	
	mean	*0.0089*		*0.0022*		*0.0028*		*0.0018*		*0.0024*		*0.0017*	
	se	*0.0013*		*0.0001*		*0.0006*		*0.0001*		*0.0002*		*0.0000*	
Vanadium													
	1	0.14	U	0.15	U	0.12	U	0.13	U	0.14		0.13	U
	2	0.15	U	0.13	U	0.12	U	0.13	U	0.16		0.13	U
	3	0.14	U	0.13	U	0.12	U	0.14	U	0.14			
	4	0.14	U	0.14	U	0.11	U	0.13	U	0.12	U		
	5	0.14	U	0.13	U	0.13	U	0.13	U	0.14	U		
	median	*0.14*		*0.13*		*0.12*		*0.13*		*0.14*		*0.13*	
	mean	*0.14*		*0.13*		*0.12*		*0.13*		*0.14*		*0.13*	
	se	*0.00*		*0.00*		*0.00*		*0.00*		*0.01*		*0.00*	

Table B1-5. Summary of Analytical Data for Whitefish Species

		Mountain		Lake		Lake		Lake		Lake		Lake	
Whitefish	Collection Area	1		2		3		4		5		6	
species	River Mile	741		723		706		678		635		605	
	composite	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q	mg/kg ww	Q
Zinc													
	1	29	J	14	0	14	0	14	0	14	0	13	0
	2	32	J	12	0	13	0	12	0	14	0	12	0
	3	20	J	12	0	13	0	11	0	13	0		0
	4	28	J	12	0	14	0	12	0	12	0		0
	5	40	J	13	0	14	0	11	0	13	0		0
	median	*29*		*12*		*14*		*12*		*13*		*12*	
	mean	*30*		*13*		*14*		*12*		*13*		*12*	
	se	*3*		*0*		*0*		*1*		*0*		*0*	
Lipids													
%	1	7.6	0	13	0	7.8	0	11	0	10	0	13	0
	2	8.3	0	12	0	11	0	12	0	13	0	14	0
	3	8.9	0	11	0	12	0	15	0	14	0		0
	4	7.8	0	14	0	11	0	13	0	12	0		0
	5	10	0	1.4	0	6	0	12	0	16	0		0
	median	*8.3*		*12*		*11*		*12*		*13*		*13*	
	mean	*8.6*		*10*		*9.6*		*12*		*13*		*13*	
	se	*0.5*		*2*		*1*		*1*		*1*		*1*	
Age													
years	1	6.5		2.8		1.6		1.4		2.6		2	
	2	6.3		2.4		2		1.4		2.6		3.7	
	3	ND		2.8		2		2		2			
	4	ND		2.2		1.6		1.2		1.8			
	5	ND		2.4		2		1.6		2.4			
	median	*6.4*		*2.4*		*2*		*1.4*		*2.4*		*2.9*	
	mean	*6.4*		*2.5*		*1.8*		*1.5*		*2.3*		*2.9*	
	se	*0.1*		*0.1*		*0.1*		*0.1*		*0.2*		*0.9*	
Length													
mm	1	928		499		427		401		469		462	
	2	923		473		438		406		487		505	
	3	834		492		464		448		468			
	4	978		483		435		423		431			
	5	978		484		448		410		484			
	median	*928*		*484*		*438*		*410*		*469*		*483*	
	mean	*928*		*486*		*442*		*418*		*468*		*483*	
	se	*26*		*4*		*6*		*8*		*10*		*22*	
Weight													
g	1	422		1500		892		772		1170		1139	
	2	416		1106		970		800		1194		1523	
	3	407		1232		1144		1032		1108			
	4	423		1234		957		897		921			
	5	417		1342		1044		804		1253			
	median	*417*		*1234*		*970*		*804*		*1170*		*1331*	
	mean	*417*		*1280*		*1000*		*861*		*1130*		*1330*	
	se	*2.9*		*66*		*43*		*48*		*57*		*192*	

Table B1-6. Summary Statistics for 2,3,7,8-TCDF, Aroclor 1254/1260, and Total PCB Congeners in Fish Tissues Collected by EPA in 2005

	Collection Area =	1		2	3		4	5	6	
	River Mile =	738		728	706		680	635	606	
Analyte	Composite									
Burbot (whole body)										
Lipids (%)	1	-		1.30	6.30		1.10	0.80	1.60	
	2	-		2.40	1.30		0.60	1.40	2.00	
	3	-		2.20	1.20		1.30	0.90	1.30	
	4	-		-	2.30		0.90	1.90	1.60	
	5	-		-	2.50		-	1.40	1.00	
2,3,7,8-TCDF	1	-		3.97	2.71		5.71	1.59	4.93	
(ng/kg-ww)	2	-		5.11	3.65		4.12	3.90	3.96	
	3	-		5.48	3.03		4.78	2.19	3.26	
	4	-		-	4.03		3.14	3.89	4.67	
	5	-		-	3.67		-	3.41	3.92	
2,3,7,8-TCDF	1	-		305.38	43.02		519.09	198.75	308.13	
(ng/kg lipid)	2	-		212.92	280.77		686.67	278.57	198.00	
	3	-		249.09	252.50		531.11	243.33	250.77	
	4	-		-	175.22		241.54	204.74	291.88	
	5	-		-	146.80		-	243.57	392.00	
Aroclor 1254/1260	1	-		20.00	18.00		28.00	20.00	20.00	
(ug/kg-ww)	2	-		43.00	32.00		21.00	26.00	19.00	
	3	-		27.00	35.33		11.00	20.00	21.00	
	4	-		-	21.00		33.00	58.00	27.00	
	5	-		-	28.00		-	28.00	27.00	
Aroclor 1254/1260	1	-		1538.46	285.71		2545.45	2500.00	1250.00	
(ug/kg lipid)	2	-		1791.67	2461.54		3500.00	1857.14	950.00	
	3	-		1227.27	2944.44		846.15	2222.22	1615.38	
	4	-		-	913.04		3666.67	3052.63	1687.50	
	5	-		-	1120.00		-	2000.00	2700.00	
Total PCB Congeners	1	-		27.89	26.68		14.87	22.96	24.78	
(ug/kg-ww)	2	-		-	-		-	-	-	
Total PCB Congeners	1	-		1267.67	2223.07		2478.74	1640.14	2477.58	
(ug/kg lipid)	2	-		-	-		-	-	-	
Walleye (whole body)										
Lipids (%)	1	2.94	E	2.10	3.68	E	2.70	3.10	3.30	
	2	2.54	E	2.20	2.51	E	3.00	3.60	3.50	
	3	1.29	E	2.60	3.11	E	3.50	3.00	2.27	E
	4	2.94	E	2.10	2.36	E	5.10	-	5.37	E
	5	1.21	E	2.27	3.65	E	4.00	-	3.53	E
	6	-		-	-		-	-	3.94	E
	7	-		-	-		-	-	3.07	E
2,3,7,8-TCDF	1	1.15	E	1.13	1.38	E	2.62	1.57	2.05	
(ng/kg-ww)	2	1.31	E	0.89	1.12	E	2.35	1.56	2.06	
	3	0.92	E	1.36	1.13	E	1.59	1.98	1.39	E
	4	1.01	E	1.27	1.37	E	2.37	-	2.79	E
	5	0.67	E	1.14	1.10	E	1.29	-	2.37	E
	6	-		-	-		-	-	2.06	E
	7	-		-	-		-	-	1.49	E
2,3,7,8-TCDF	1	168.86	E	53.81	50.78	E	97.04	50.65	62.12	
(ng/kg lipid)	2	106.15	E	40.45	63.03	E	78.33	43.33	58.86	
	3	171.28	E	52.31	54.02	E	45.43	66.00	70.21	E
	4	72.58	E	60.48	88.52	E	46.47	-	79.15	E
	5	110.62	E	50.29	48.75	E	32.25	-	108.62	E
	6	-		-			-	-	74.24	E
	7	-		-			-	-	77.25	E
Aroclor 1254/1260	1	34.79	E	33.00	13.55	E	18.30	21.00	22.00	
(ug/kg-ww)	2	24.80	E	22.00	8.89	E	20.90	33.00	33.00	
	3	18.81	E	26.00	6.46	E	16.40	28.00	20.13	E

Table B1-6. Summary Statistics for 2,3,7,8-TCDF, Aroclor 1254/1260, and Total PCB Congeners in Fish Tissues Collected by EPA in 2005

	Collection Area =	1		2	3		4	5	6	
	River Mile =	738		728	706		680	635	606	
Analyte	Composite									
	4	27.42	E	27.00	10.63	E	20.80	-	54.81	E
	5	19.17	E	47.67	11.59	E	16.50	-	27.53	E
	6	-		-	-		-	-	35.32	E
	7	-		-	-		-	-	27.69	E
Aroclor 1254/1260	1	2058.93	E	1571.43	380.03	E	677.78	677.42	666.67	
(ug/kg lipid)	2	1615.66	E	1000.00	499.36	E	696.67	916.67	942.86	
	3	2887.51	E	1000.00	343.75	E	468.57	933.33	653.56	E
	4	1622.93	E	1285.71	2120.70	E	407.84	-	803.55	E
	5	2956.06	E	2102.94	446.76	E	412.50	-	891.86	E
	6	-		-	-		-	-	839.18	E
	7	-		-	-		-	-	869.01	E
Total PCB Congeners	1	246.05	E	38.39	37.46	E	37.03	35.65	37.82	E
(ug/kg-ww)	2	3.70	E	-	-		-	-	-	
Total PCB Congeners	1	6545.75	E	1693.89	1464.19	E	726.11	990.41	1248.49	E
(ug/kg lipid)	2	3366.36	E	-	-		-	-	-	
Walleye (fillet)										
Lipids (%)	1	0.10		-	0.50		-	-	0.60	
	2	0.20		-	0.40		-	-	0.70	
	3	0.11		-	0.50		-	-	0.40	
	4	0.23		-	0.30		-	-	0.60	
	5	0.11		-	0.40		-	-	0.40	
2,3,7,8-TCDF	1	0.34	U	-	0.36		-	-	0.51	
(ng/kg-ww)	2	0.36	U	-	0.34	U	-	-	0.80	
	3	0.33	U	-	0.39		-	-	0.67	
	4	0.28	U	-	0.40		-	-	0.65	
	5	0.20	U	-	0.30	U	-	-	0.47	U
2,3,7,8-TCDF	1	338.00		-	72.80		-	-	84.67	
(ng/kg lipid)	2	177.50		-	85.50		-	-	113.71	
	3	300.00		-	77.00		-	-	167.50	
	4	120.00		-	134.67		-	-	108.00	
	5	185.45		-	74.50		-	-	117.00	
Aroclor 1254/1260	1	3.20		-	2.00		-	-	1.70	
(ug/kg-ww)	2	4.90		-	2.70		-	-	3.70	
	3	5.20		-	2.60		-	-	4.20	
	4	5.70		-	14.00		-	-	4.50	
	5	5.30		-	2.50		-	-	3.30	
Aroclor 1254/1260	1	3200.00		-	400.00		-	-	283.33	
(ug/kg lipid)	2	2450.00		-	675.00		-	-	528.57	
	3	4727.27		-	520.00		-	-	1050.00	
	4	2478.26		-	4666.67		-	-	750.00	
	5	4818.18		-	625.00		-	-	825.00	
Total PCB Congeners	1	9.81		-	5.73		-	-	6.00	
(ug/kg-ww)	2	8.27		-	-		-	-	-	
Total PCB Congeners	1	4266.61		-	1433.13		-	-	1498.87	
(ug/kg lipid)	2	7522.04		-	-		-	-	-	
Walleye (offal)										
Lipids (%)	1	5.20		-	5.90		-	-	3.70	
	2	4.50		-	4.60		-	-	9.60	
	3	2.30		-	5.50		-	-	6.00	
	4	5.30		-	3.90		-	-	6.50	
	5	2.10		-	6.30		-	-	5.30	
2,3,7,8-TCDF	1	1.79		-	2.09		-	-	2.14	
(ng/kg-ww)	2	2.10		-	1.88		-	-	4.60	
	3	1.42		-	1.81		-	-	3.72	
	4	1.65		-	2.10		-	-	3.14	

Table B1-6. Summary Statistics for 2,3,7,8-TCDF, Aroclor 1254/1260, and Total PCB Congeners in Fish Tissues Collected by EPA in 2005

Analyte	Collection Area = River Mile = Composite	1 738		2 728	3 706		4 680	5 635	6 606	
	5	1.05		-	1.75		-	-	2.34	
2,3,7,8-TCDF	1	34.42			35.42				57.84	
(ng/kg lipid)	2	46.67			40.87				47.92	
	3	61.74			32.91				62.00	
	4	31.13			53.85				48.31	
	5	50.00			27.78				44.15	
Aroclor 1254/1260	1	59.90			21.60				35.90	
(ug/kg-ww)	2	41.40			15.00				101.00	
	3	30.40			10.00				46.00	
	4	46.40			8.10				59.00	
	5	30.40			19.00				48.00	
Aroclor 1254/1260	1	1151.92			366.10				970.27	
(ug/kg lipid)	2	920.00			326.09				1052.08	
	3	1321.74			181.82				766.67	
	4	875.47			207.69				907.69	
	5	1447.62			301.59				905.66	
Total PCB Congeners	1	452.49		-	68.76		-	-	63.02	
(ug/kg-ww)	2	-		-	-		-	-	-	
Total PCB Congeners	1	8537.46		-	1494.82		-	-	1050.26	
(ug/kg lipid)	2	-		-	-		-	-	-	
Wild Rainbow Trout (whole body)										
Lipids (%)	1	8.86	E	7.60	4.16	E	-	8.20	3.86	E
	2	6.58	E	10.70	5.24	E	-	-	-	
	3	6.54	E	9.87	-		-	-	-	
	4	5.76	E	6.70	-		-	-	-	
	5	7.69	E	4.80	-		-	-	-	
2,3,7,8-TCDF	1	3.39	E	2.25	1.03	E	-	1.84	0.97	E
(ng/kg-ww)	2	1.01	E	1.54	1.17	E	-	-	-	
	3	1.02	E	3.28	-		-	-	-	
	4	0.93	E	3.95	-		-	-	-	
	5	1.15	E	4.67	-		-	-	-	
2,3,7,8-TCDF	1	38.79	E	29.61	27.27	E	-	22.44	30.79	E
(ng/kg lipid)	2	16.10	E	14.39	24.55	E	-	-	-	
	3	15.72	E	33.21	-		-	-	-	
	4	15.34	E	58.96	-		-	-	-	
	5	14.73	E	97.29	-		-	-	-	
Aroclor 1254/1260	1	59.27	E	25.50	12.22	E	-	16.00	10.37	E
(ug/kg-ww)	2	35.15	E	27.90	12.17	E	-	-	-	
	3	25.82	E	30.37	-		-	-	-	
	4	22.56	E	34.30	-		-	-	-	
	5	27.39	E	24.00	-		-	-	-	
Aroclor 1254/1260	1	654.00	E	335.53	324.37	E	-	195.12	322.22	E
(ug/kg lipid)	2	603.45	E	260.75	255.23	E	-	-	-	
	3	425.92	E	307.77	-		-	-	-	
	4	406.87	E	511.94	-		-	-	-	
	5	387.75	E	500.00	-		-	-	-	
Total PCB Congeners	1	39.21	E	63.80	8.94	E	-	13.14	-	
(ug/kg-ww)	2	-		-	-		-	-	-	
Total PCB Congeners	1	646.12	E	952.24	227.05	E	-	160.25	-	
(ug/kg lipid)	2	-		-	-		-	-	-	
Wild Rainbow Trout (fillet)										
Lipids (%)	1	6.00		-	2.10		-	-	1.40	
	2	3.10		-	2.80		-	-	-	
	3	4.10		-	-		-	-	-	
	4	4.50		-	-		-	-	-	

Table B1-6. Summary Statistics for 2,3,7,8-TCDF, Aroclor 1254/1260, and Total PCB Congeners in Fish Tissues Collected by EPA in 2005

Analyte	Collection Area = River Mile = Composite	1 738	2 728	3 706	4 680	5 635	6 606
	5	4.45	-	-	-	-	-
2,3,7,8-TCDF (ng/kg-ww)	1	2.42	-	0.68	-	-	0.56
	2	0.54	-	0.84	-	-	-
	3	0.66	-	-	-	-	-
	4	0.53	-	-	-	-	-
	5	0.63	-	-	-	-	-
2,3,7,8-TCDF (ng/kg lipid)	1	40.33	-	32.57	-	-	39.93
	2	17.52	-	30.11	-	-	-
	3	16.15	-	-	-	-	-
	4	11.87	-	-	-	-	-
	5	14.19	-	-	-	-	-
Aroclor 1254/1260 (ug/kg-ww)	1	36.60	-	8.20	-	-	5.70
	2	23.00	-	8.80	-	-	-
	3	20.70	-	-	-	-	-
	4	21.30	-	-	-	-	-
	5	20.35	-	-	-	-	-
Aroclor 1254/1260 (ug/kg lipid)	1	610.00	-	390.48	-	-	407.14
	2	741.94	-	314.29	-	-	-
	3	504.88	-	-	-	-	-
	4	473.33	-	-	-	-	-
	5	457.30	-	-	-	-	-
Total PCB Congeners (ug/kg-ww)	1	23.15	-	5.32	-	-	-
	2	-	-	-	-	-	-
Total PCB Congeners (ug/kg lipid)	1	746.63	-	253.51	-	-	-
	2	-	-	-	-	-	-
Wild Rainbow Trout (offal)							
Lipids (%)	1	11.90	-	6.10	-	-	6.30
	2	9.90	-	7.30	-	-	-
	3	9.10	-	-	-	-	-
	4	7.10	-	-	-	-	-
	5	11.20	-	-	-	-	-
2,3,7,8-TCDF (ng/kg-ww)	1	4.42	-	1.36	-	-	1.37
	2	1.46	-	1.45	-	-	-
	3	1.39	-	-	-	-	-
	4	1.35	-	-	-	-	-
	5	1.72	-	-	-	-	-
2,3,7,8-TCDF (ng/kg lipid)	1	37.14	-	22.30	-	-	21.75
	2	14.75	-	19.86	-	-	-
	3	15.27	-	-	-	-	-
	4	19.01	-	-	-	-	-
	5	15.31	-	-	-	-	-
Aroclor 1254/1260 (ug/kg-ww)	1	83.40	-	16.00	-	-	15.00
	2	46.70	-	15.00	-	-	-
	3	31.20	-	-	-	-	-
	4	23.90	-	-	-	-	-
	5	35.00	-	-	-	-	-
Aroclor 1254/1260 (ug/kg lipid)	1	700.84	-	262.30	-	-	238.10
	2	471.72	-	205.48	-	-	-
	3	342.86	-	-	-	-	-
	4	336.62	-	-	-	-	-
	5	312.50	-	-	-	-	-
Total PCB Congeners (ug/kg-ww)	1	54.50	-	12.33	-	-	-
	2	-	-	-	-	-	-
Total PCB Congeners (ug/kg lipid)	1	550.51	-	202.20	-	-	-
	2	-	-	-	-	-	-

Table B1-6. Summary Statistics for 2,3,7,8-TCDF, Aroclor 1254/1260, and Total PCB Congeners in Fish Tissues Collected by EPA in 2005

Analyte	Collection Area = River Mile = Composite	1 738	2 728	3 706		4 680		5 635	6 606	
Hatchery Rainbow Trout (whole body)										
Lipids (%)	1	-	-	7.70	E	5.20		6.30	5.57	E
	2	-	-	3.40	E	5.20		6.50	5.45	E
	3	-	-	3.66	E	5.20		5.30	5.17	E
	4	-	-	-		4.90		5.20	5.34	E
	5	-	-	-		6.20		9.37	-	
2,3,7,8-TCDF (ng/kg-ww)	1	-	-	1.16	E	1.24	U	1.55	1.52	E
	2	-	-	0.97	E	1.41		1.40	1.36	E
	3	-	-	1.71	E	0.91		1.54	1.82	E
	4	-	-	-		1.25		0.97	0.97	E
	5	-	-	-		1.25		1.50	-	
2,3,7,8-TCDF (ng/kg lipid)	1	-	-	21.38	E	23.85		24.60	29.90	E
	2	-	-	29.91	E	27.12		21.54	26.04	E
	3	-	-	51.07	E	17.42		29.06	42.18	E
	4	-	-	-		25.51		18.65	17.67	E
	5	-	-	-		20.16		15.98	-	
Aroclor 1254/1260 (ug/kg-ww)	1	-	-	10.50	E	12.00		7.30	9.36	E
	2	-	-	7.20	E	7.60		9.20	13.51	E
	3	-	-	7.70	E	6.70		17.10	15.84	E
	4	-	-	-		7.40		6.30	10.66	E
	5	-	-	-		7.50		10.30	-	
Aroclor 1254/1260 (ug/kg lipid)	1	-	-	170.47	E	230.77		115.87	197.43	E
	2	-	-	223.79	E	146.15		141.54	294.89	E
	3	-	-	243.30	E	128.85		322.64	374.79	E
	4	-	-	-		151.02		121.15	223.52	E
	5	-	-	-		120.97		109.96	-	
Total PCB Congeners (ug/kg-ww)	1	-	-	15.60	E	11.26		9.10	17.29	E
	2	-	-	-		-		-	-	
Total PCB Congeners (ug/kg lipid)	1	-	-	429.29	E	229.89		97.18	354.45	E
	2	-	-	-		-		-	-	
Hatchery Rainbow Trout (fillet)										
Lipids (%)	1	-	-	11.00		-		-	2.75	
	2	-	-	2.00		-		-	2.50	
	3	-	-	1.90		-		-	2.20	
	4	-	-	-		-		-	2.20	
	5	-	-	-		-		-	-	
2,3,7,8-TCDF (ng/kg-ww)	1	-	-	0.73	U	-		-	0.93	U
	2	-	-	0.65		-		-	0.70	
	3	-	-	1.16		-		-	1.19	
	4	-	-	-		-		-	0.37	U
	5	-	-	-		-		-	-	
2,3,7,8-TCDF (ng/kg lipid)	1	-	-	6.61		-		-	33.96	
	2	-	-	32.65		-		-	27.88	
	3	-	-	61.05		-		-	54.09	
	4	-	-	-		-		-	16.91	
	5	-	-	-		-		-	-	
Aroclor 1254/1260 (ug/kg-ww)	1	-	-	10.00		-		-	6.65	
	2	-	-	5.00		-		-	9.40	
	3	-	-	6.10		-		-	10.80	
	4	-	-	-		-		-	5.70	
	5	-	-	-		-		-	-	
Aroclor 1254/1260 (ug/kg lipid)	1	-	-	90.91		-		-	241.82	
	2	-	-	250.00		-		-	376.00	
	3	-	-	321.05		-		-	490.91	
	4	-	-	-		-		-	259.09	

Table B1-6. Summary Statistics for 2,3,7,8-TCDF, Aroclor 1254/1260, and Total PCB Congeners in Fish Tissues Collected by EPA in 2005

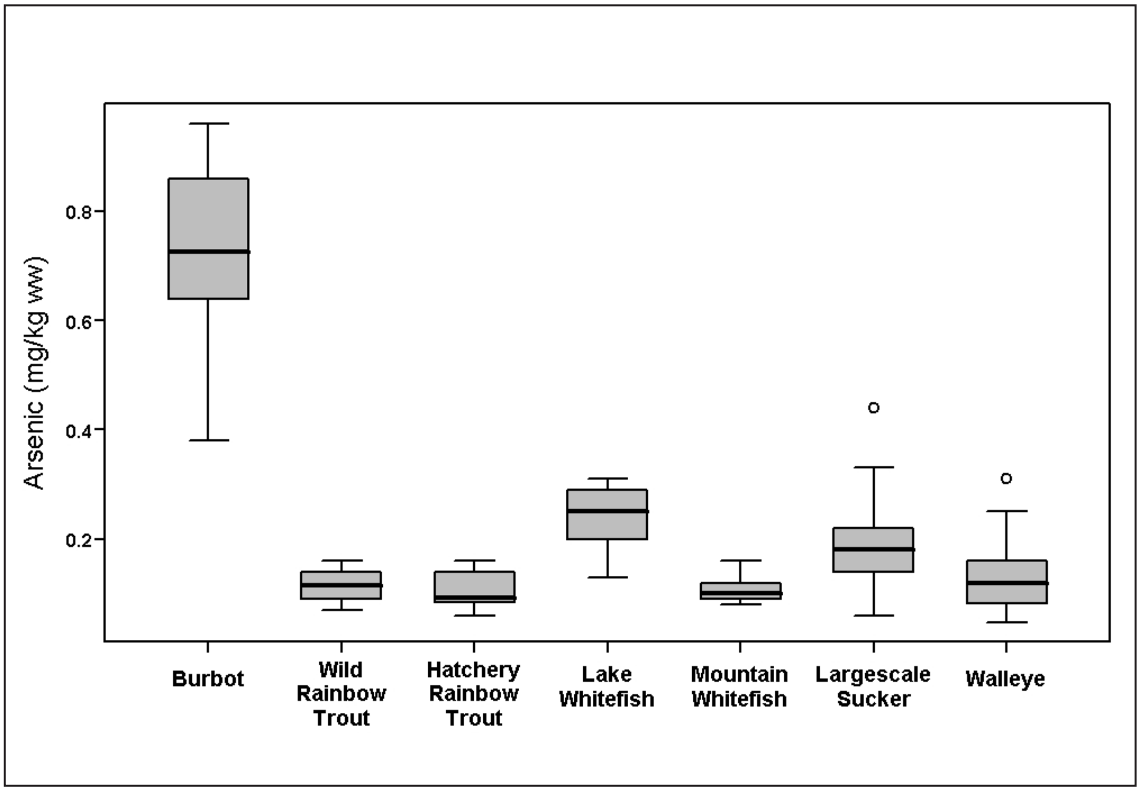
	Collection Area =	1	2	3	4	5	6
	River Mile =	738	728	706	680	635	606
Analyte	Composite						
	5	-	-	-	-	-	-
Total PCB Congeners	1	-	-	8.28	-	-	8.54
(ug/kg-ww)	2	-	-	-	-	-	-
Total PCB Congeners	1	-	-	435.55	-	-	388.28
(ug/kg lipid)	2	-	-	-	-	-	-
Hatchery Rainbow Trout (offal)							
Lipids (%)	1	-	-	4.40	-	-	9.25
	2	-	-	5.00	-	-	8.60
	3	-	-	5.20	-	-	8.20
	4	-	-	-	-	-	8.90
	5	-	-	-	-	-	-
2,3,7,8-TCDF	1	-	-	1.59 U	-	-	2.28
(ng/kg-ww)	2	-	-	1.34	-	-	2.07
	3	-	-	2.20 U	-	-	2.46
	4	-	-	-	-	-	1.65
	5	-	-	-	-	-	-
2,3,7,8-TCDF	1	-	-	36.14	-	-	24.59
(ng/kg lipid)	2	-	-	26.80	-	-	24.07
	3	-	-	42.31	-	-	30.00
	4	-	-	-	-	-	18.54
	5	-	-	-	-	-	-
Aroclor 1254/1260	1	-	-	4.40	-	-	9.25
(ug/kg-ww)	2	-	-	5.00	-	-	8.60
	3	-	-	5.20	-	-	8.20
	4	-	-	-	-	-	8.90
	5	-	-	-	-	-	-
Aroclor 1254/1260	1	-	-	11.00	-	-	12.90
(ug/kg lipid)	2	-	-	9.70	-	-	17.90
	3	-	-	9.10	-	-	21.00
	4	-	-	-	-	-	16.30
	5	-	-	-	-	-	-
Total PCB Congeners	1	-	-	22.04	-	-	26.23
(ug/kg-ww)	2	-	-	-	-	-	-
Total PCB Congeners	1	-	-	423.79	-	-	319.87
(ug/kg lipid)	2	-	-	-	-	-	-
Whitefish (whole body)							
Lipids (%)	1	7.60	13.00	7.80	11.30	13.00	12.80
	2	8.30	12.00	11.33	11.70	13.50	14.00
	3	8.90	11.00	12.00	14.70	11.50	-
	4	7.83	14.00	10.90	12.80	15.80	-
	5	10.20	1.40	6.00	11.60	-	-
2,3,7,8-TCDF	1	4.28	4.93	2.12	5.26	7.76	7.35
(ng/kg-ww)	2	3.32	4.92	3.40	6.79	8.19	8.35
	3	6.00	4.55	3.46	7.45	7.02	-
	4	3.48	4.67	4.15	4.80	5.30	-
	5	2.58	3.56	3.04	6.87	6.96	-
2,3,7,8-TCDF	1	56.32	37.92	27.18	46.55	77.60	57.42
(ng/kg lipid)	2	40.00	41.00	29.97	58.03	63.00	59.64
	3	67.42	41.36	28.83	50.68	52.00	-
	4	44.43	33.36	38.07	37.50	46.09	-
	5	25.29	254.29	50.67	59.22	44.05	-
Aroclor 1254/1260	1	57.30	31.00	15.00	20.60	26.90	30.50
(ug/kg-ww)	2	49.00	14.90	20.95	13.70	48.00	38.00
	3	55.70	15.00	13.40	17.30	28.40	-
	4	45.35	15.00	9.50	11.00	21.80	-

Table B1-6. Summary Statistics for 2,3,7,8-TCDF, Aroclor 1254/1260, and Total PCB Congeners in Fish Tissues Collected by EPA in 2005

Analyte	Collection Area = River Mile = Composite	1 738	2 728	3 706	4 680	5 635	6 606
	5	58.20	5.50	21.30	18.90	28.10	-
Aroclor 1254/1260	1	753.95	238.46	192.31	182.30	269.00	238.28
(ug/kg lipid)	2	590.36	124.17	184.85	117.09	369.23	271.43
	3	625.84	136.36	111.67	117.69	210.37	-
	4	578.94	107.14	87.16	85.94	189.57	-
	5	570.59	392.86	355.00	162.93	177.85	-
Total PCB Congeners	1	97.35	25.97	24.80	22.24	37.07	47.28
(ug/kg-ww)	2	-	-	-	-	-	-
Total PCB Congeners	1	1280.97	1854.83	218.82	190.12	322.38	369.34
(ug/kg lipid)	2	-	-	-	-	-	-
Largescale Sucker (whole body)							
Lipids (%)	1	5.80	3.50	5.70	4.10	4.60	8.30
	2	2.70	2.83	11.00	5.10	7.70	6.40
	3	4.00	3.60	4.30	7.50	8.10	6.60
	4	-	5.30	3.10	6.40	10.50	8.30
	5	-	-	-	5.20	6.70	-
2,3,7,8-TCDF	1	0.92	1.60	1.90	2.57	3.83	6.52
(ng/kg-ww)	2	1.53	6.39	3.12	3.73	3.72	5.63
	3	1.22	11.50	1.57	4.28	3.45	3.71
	4	-	2.33	1.93	3.92	5.44	4.70
	5	-	-	-	3.35	3.54	-
2,3,7,8-TCDF	1	15.79	45.71	33.33	62.68	83.26	78.55
(ng/kg lipid)	2	56.67	225.41	28.36	73.14	48.31	87.97
	3	30.50	319.44	36.51	57.07	42.59	56.21
	4	-	43.96	62.26	61.25	51.81	56.63
	5	-	-	-	64.42	52.84	-
Aroclor 1254/1260	1	55.00	40.00	31.00	126.00	102.00	103.00
(ug/kg-ww)	2	89.00	80.00	56.00	73.00	123.00	146.00
	3	58.00	419.00	61.00	142.00	154.00	79.33
	4	-	74.00	68.00	76.00	164.00	87.00
	5	-	-	-	154.00	93.00	-
Aroclor 1254/1260	1	948.28	1142.86	543.86	3073.17	2217.39	1240.96
(ug/kg lipid)	2	3296.30	2823.53	509.09	1431.37	1597.40	2281.25
	3	1450.00	11638.89	1418.60	1893.33	1901.23	1202.02
	4	-	1396.23	2193.55	1187.50	1561.90	1048.19
	5	-	-	-	2961.54	1388.06	-
Total PCB Congeners	1	104.96	126.86	108.81	152.31	133.85	172.39
(ug/kg-ww)	2	-	-	-	-	-	-
Total PCB Congeners	1	3887.52	2393.65	989.16	2929.10	1738.31	2693.54
(ug/kg lipid)	2	-	-	-	-	-	-

" - " = No data collected
E = Estimated from fillet and offal tissues.
U = Not-detected

FIGURES



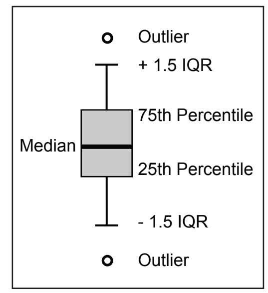


Figure 1. Comparison of Arsenic Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

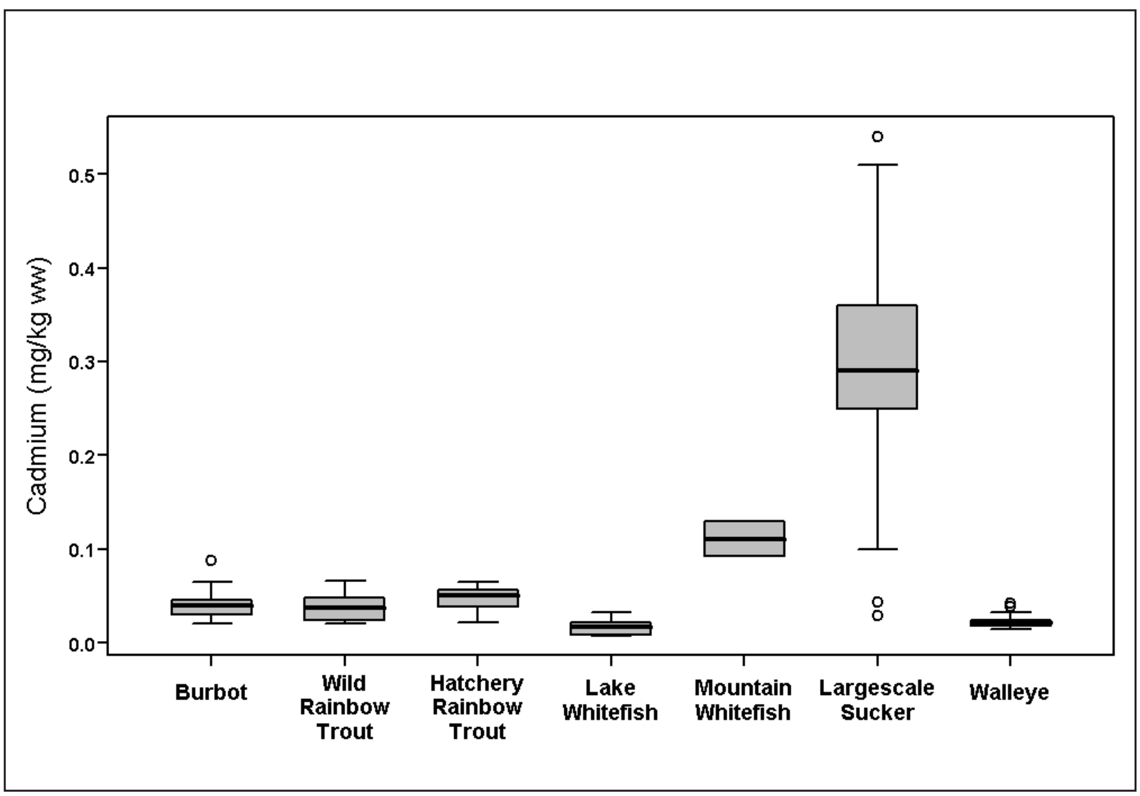


Figure 2. Comparison of Cadmium Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

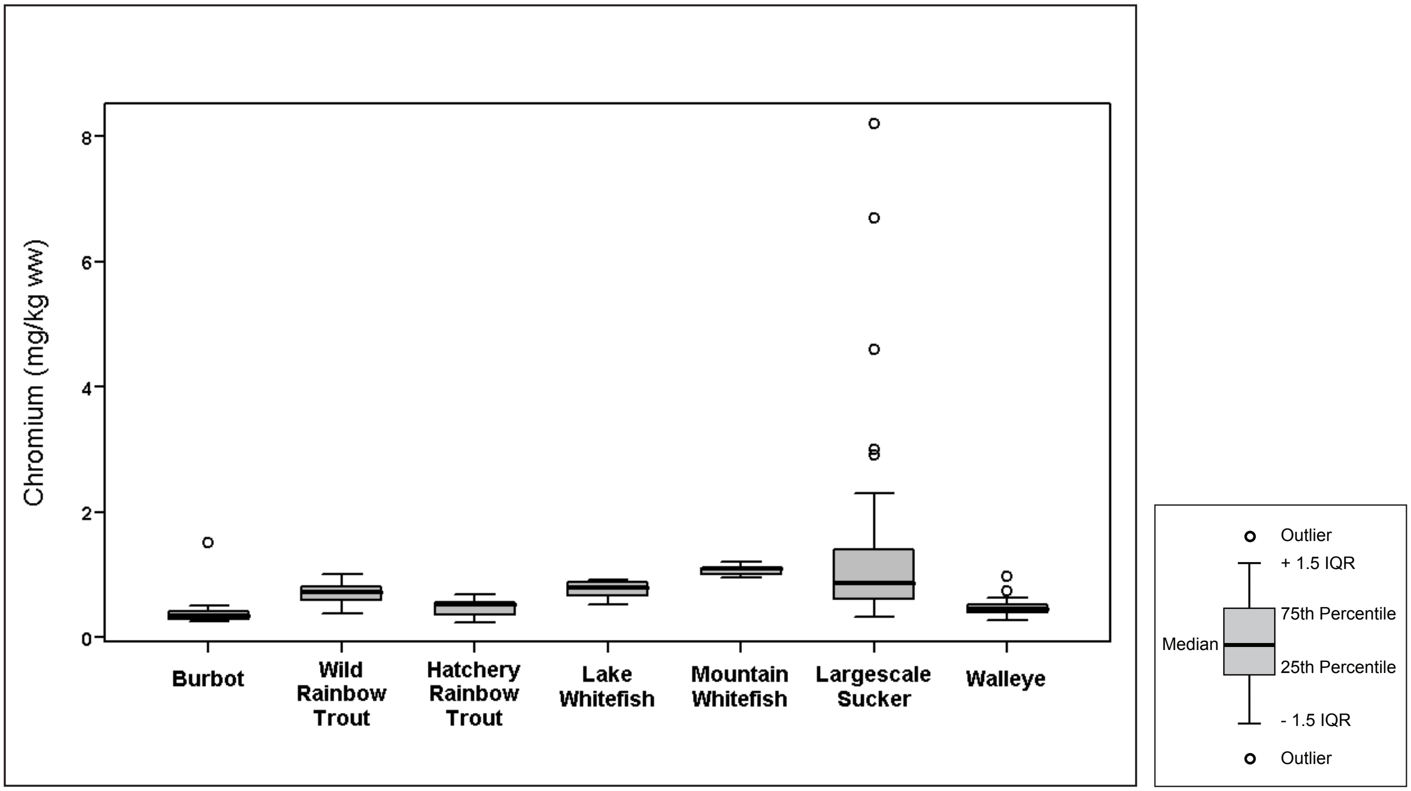


Figure 3. Comparison of Chromium Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

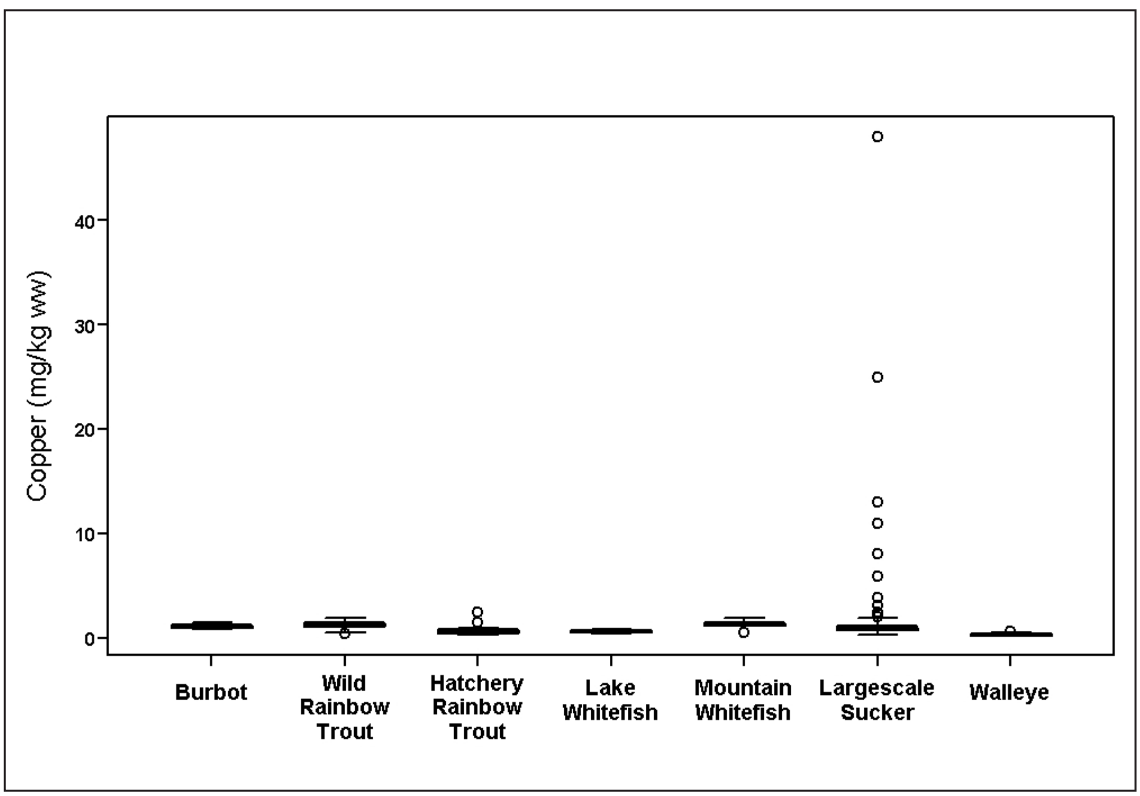


Figure 4. Comparison of Copper Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

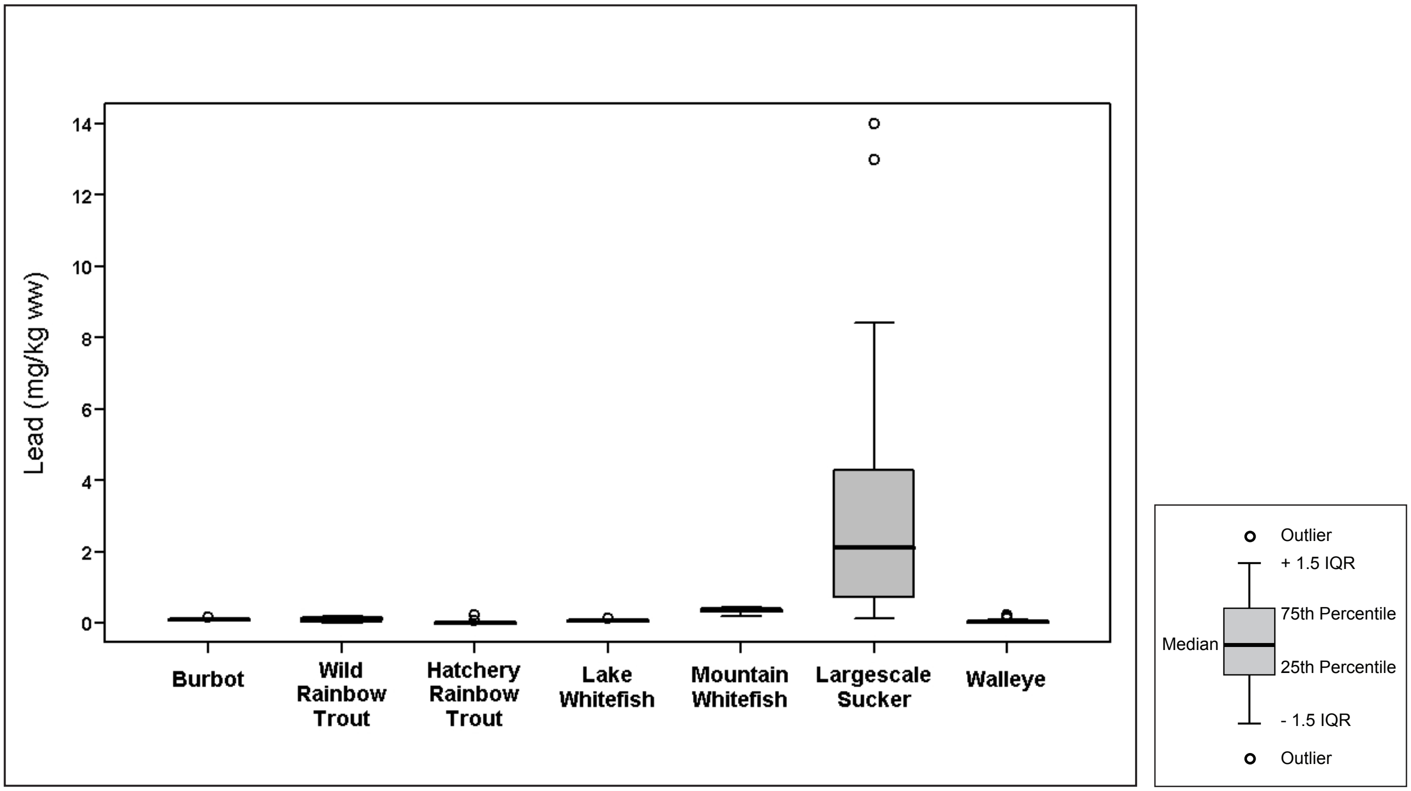


Figure 5. Comparison of Lead Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

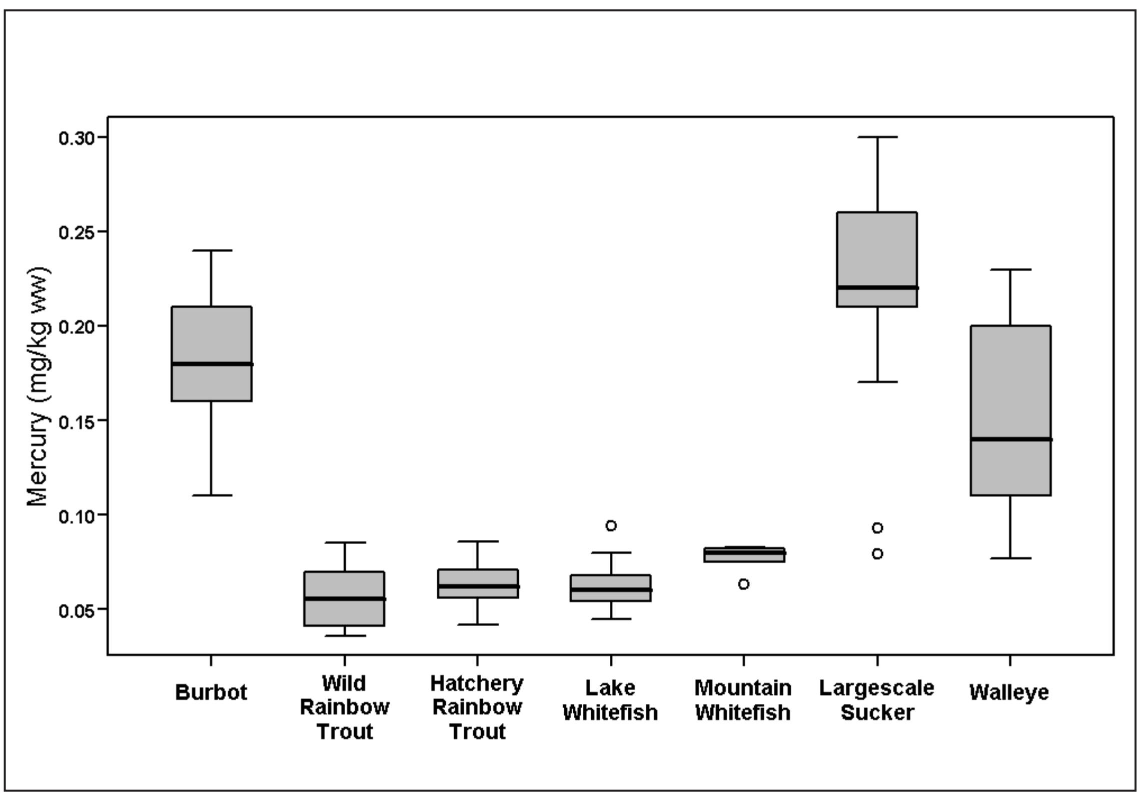


Figure 6. Comparison of Mercury Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

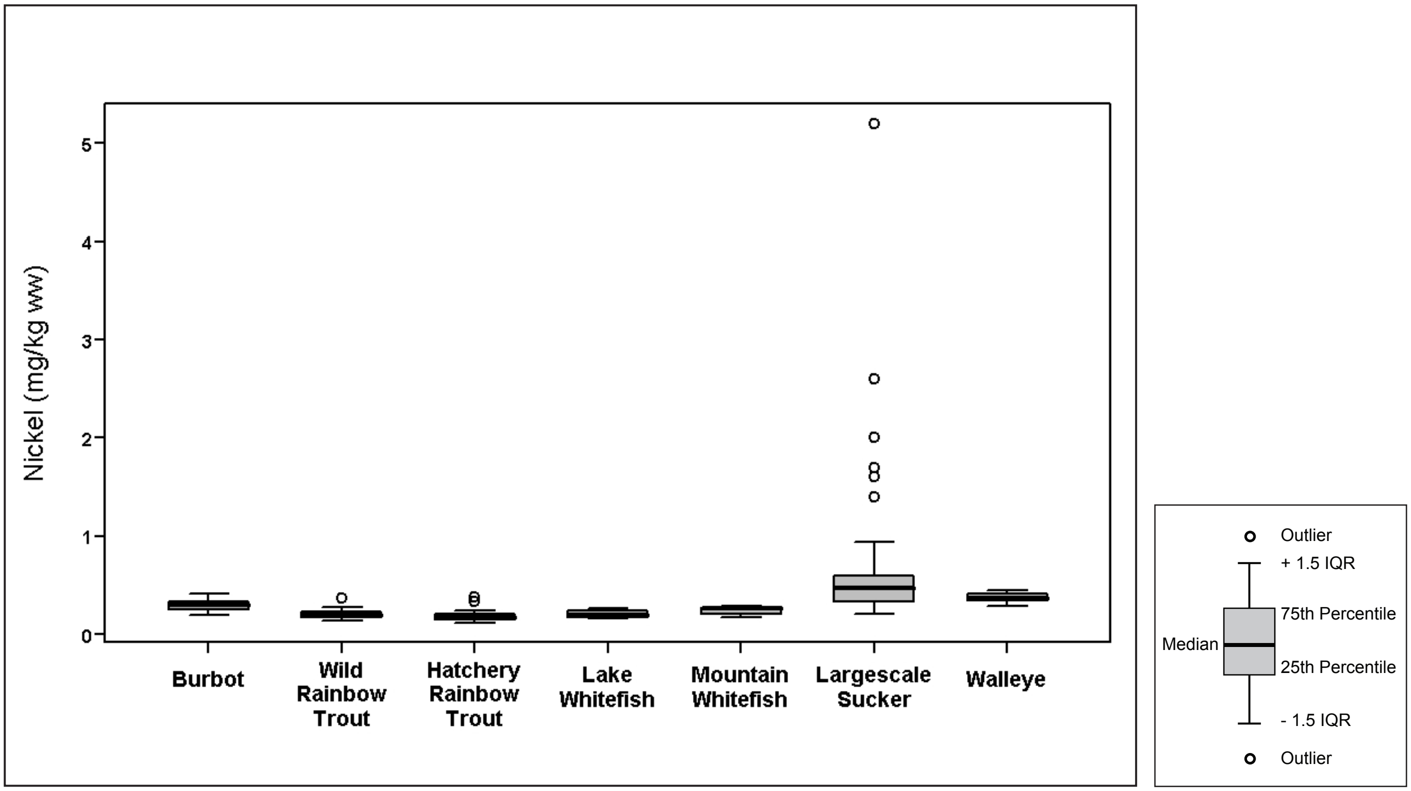


Figure 7. Comparison of Nickel Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

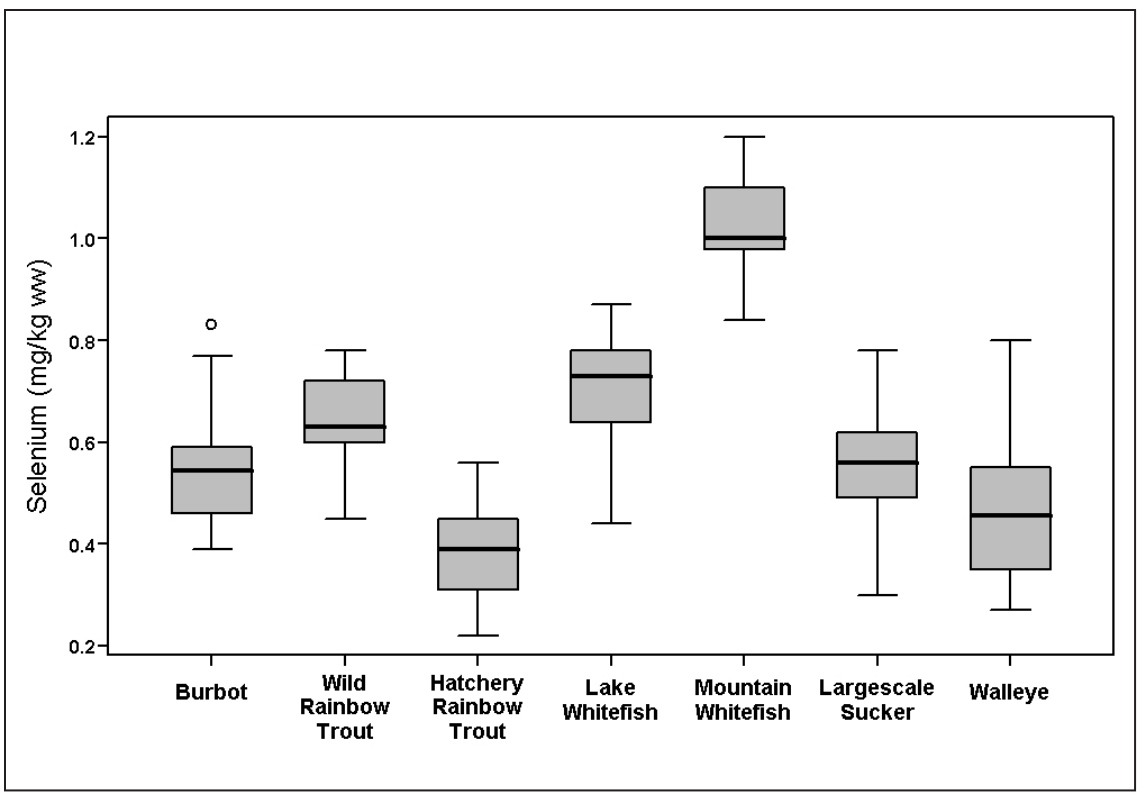


Figure 8. Comparison of Selenium Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

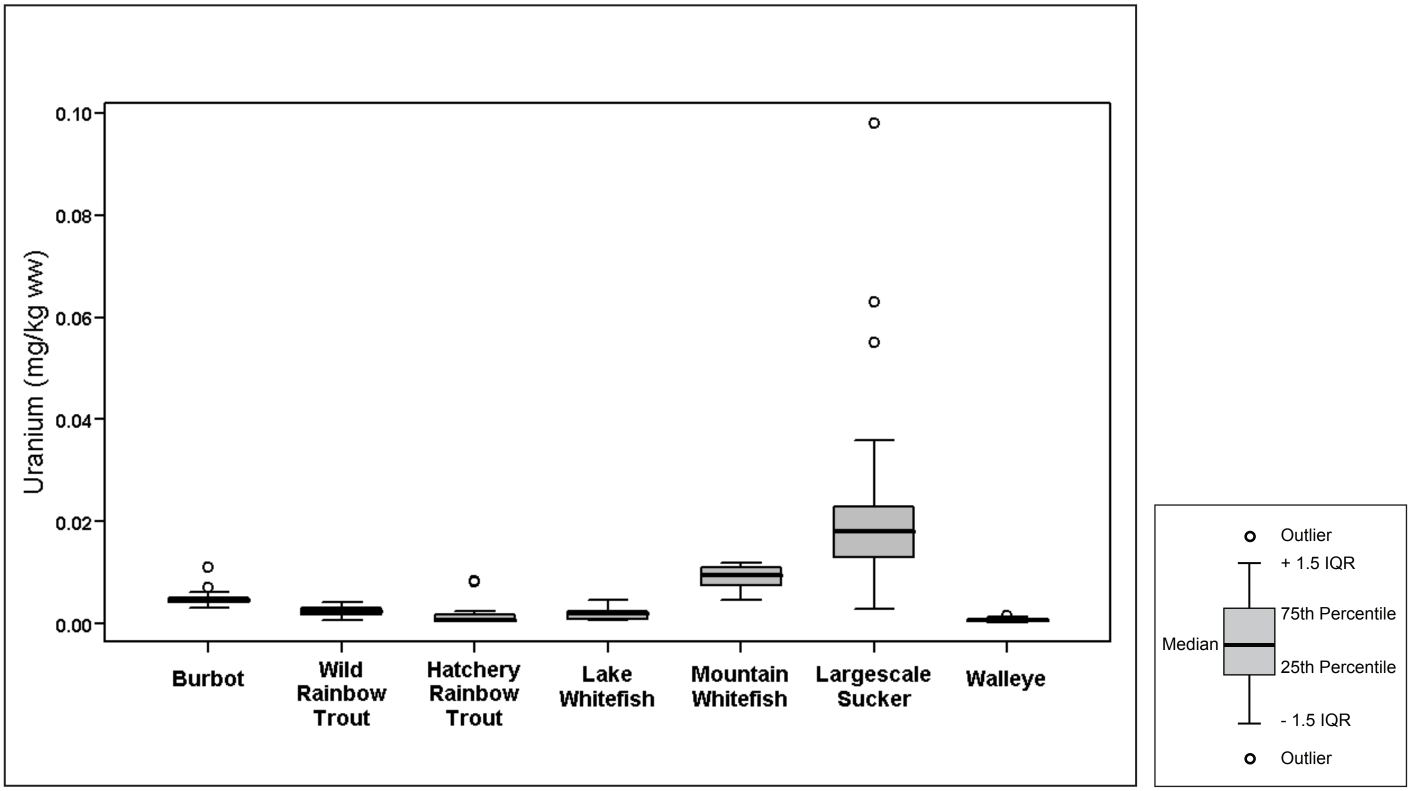


Figure 9. Comparison of Uranium Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.

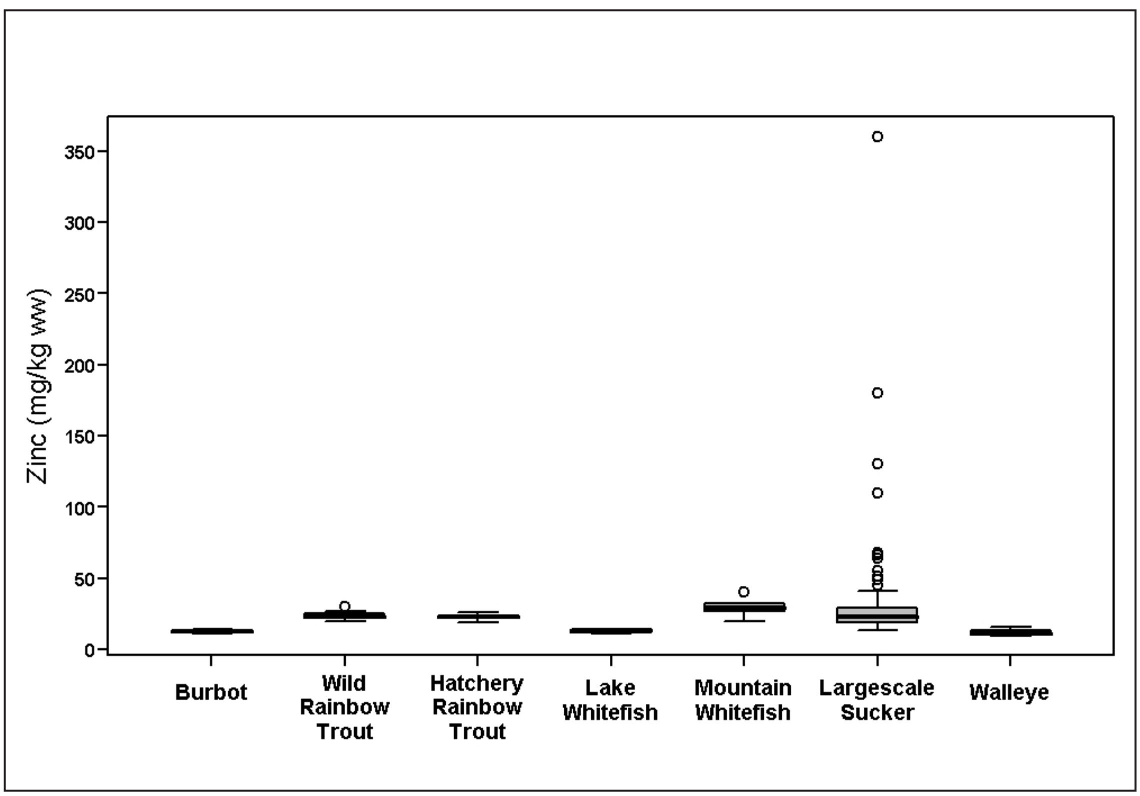
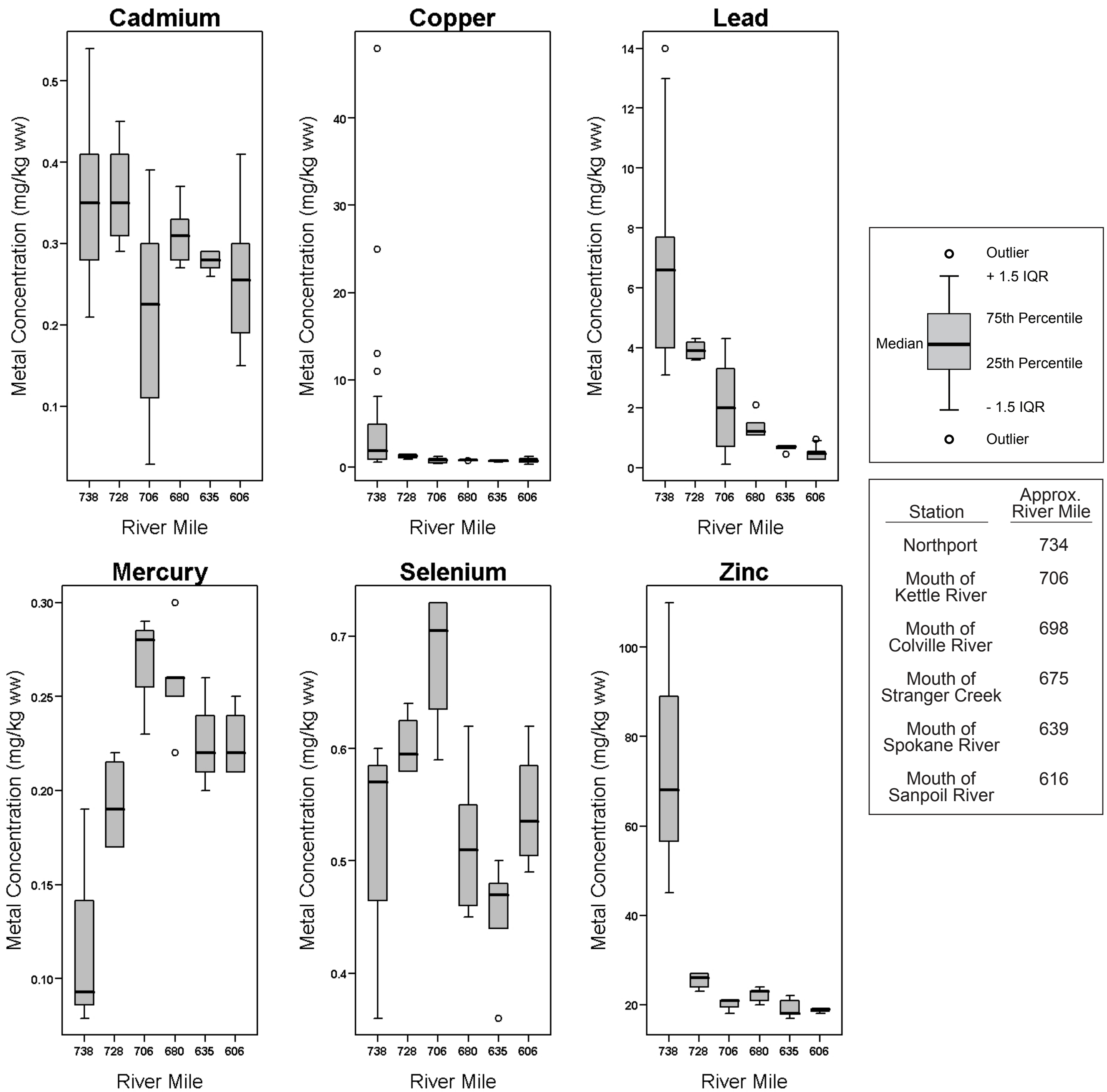


Figure 10. Comparison of Zinc Concentrations in Whole Body Samples of Target Species across all FSCAs (USEPA 2007)
Note: IQR - Interquartile Range.



Station	Approx. River Mile
Northport	734
Mouth of Kettle River	706
Mouth of Colville River	698
Mouth of Stranger Creek	675
Mouth of Spokane River	639
Mouth of Sanpoil River	616

Figure 11. Concentrations of Cadmium, Copper, Lead, Mercury, Selenium, and Zinc in Whole Largescale Sucker Composites (USEPA 2007)
Note: IQR - Interquartile Range.

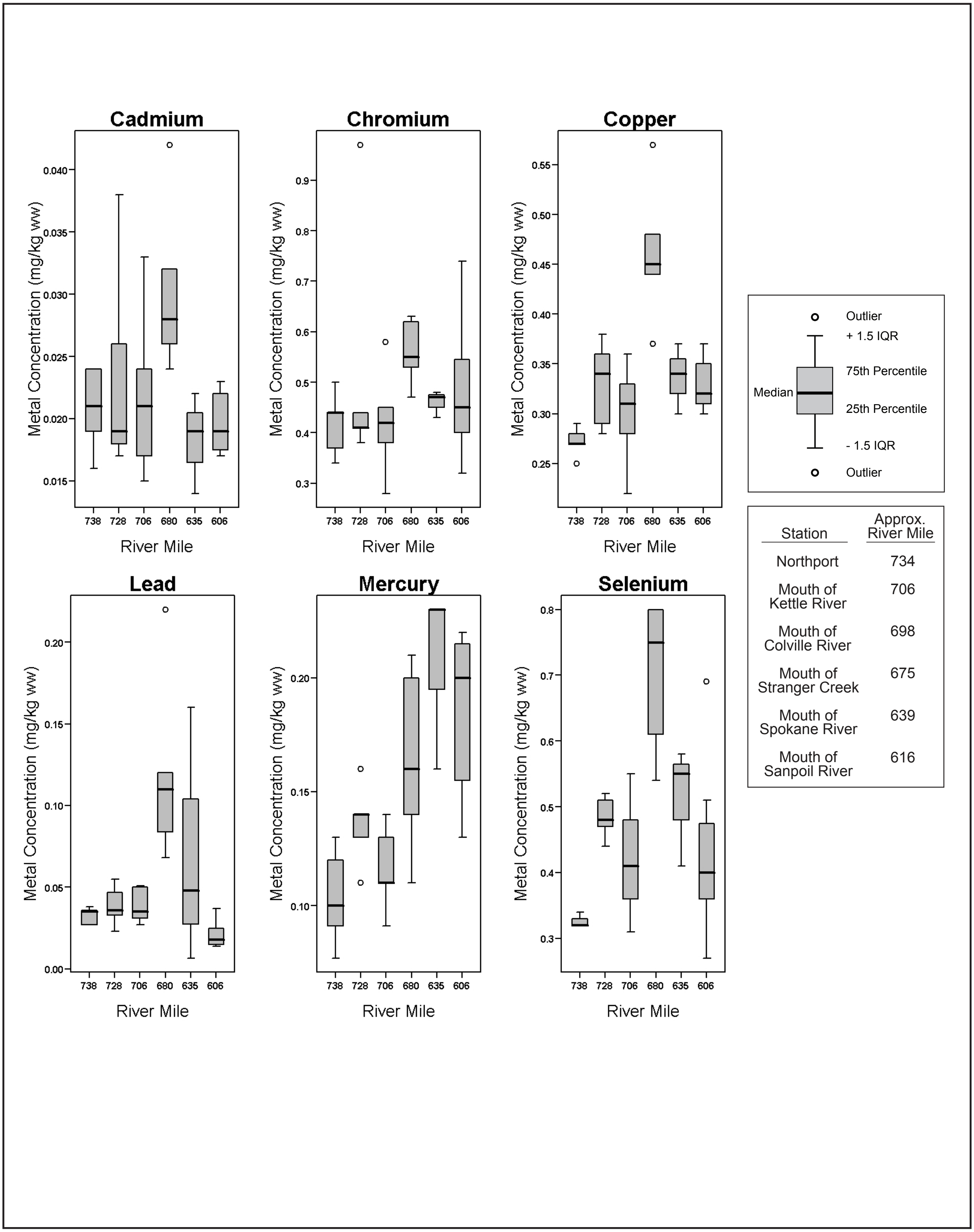


Figure 12. Concentrations of Cadmium, Chromium, Copper, Lead, Mercury, and Selenium in Whole Walleye Composites (USEPA 2007)
Note: IQR - Interquartile Range.

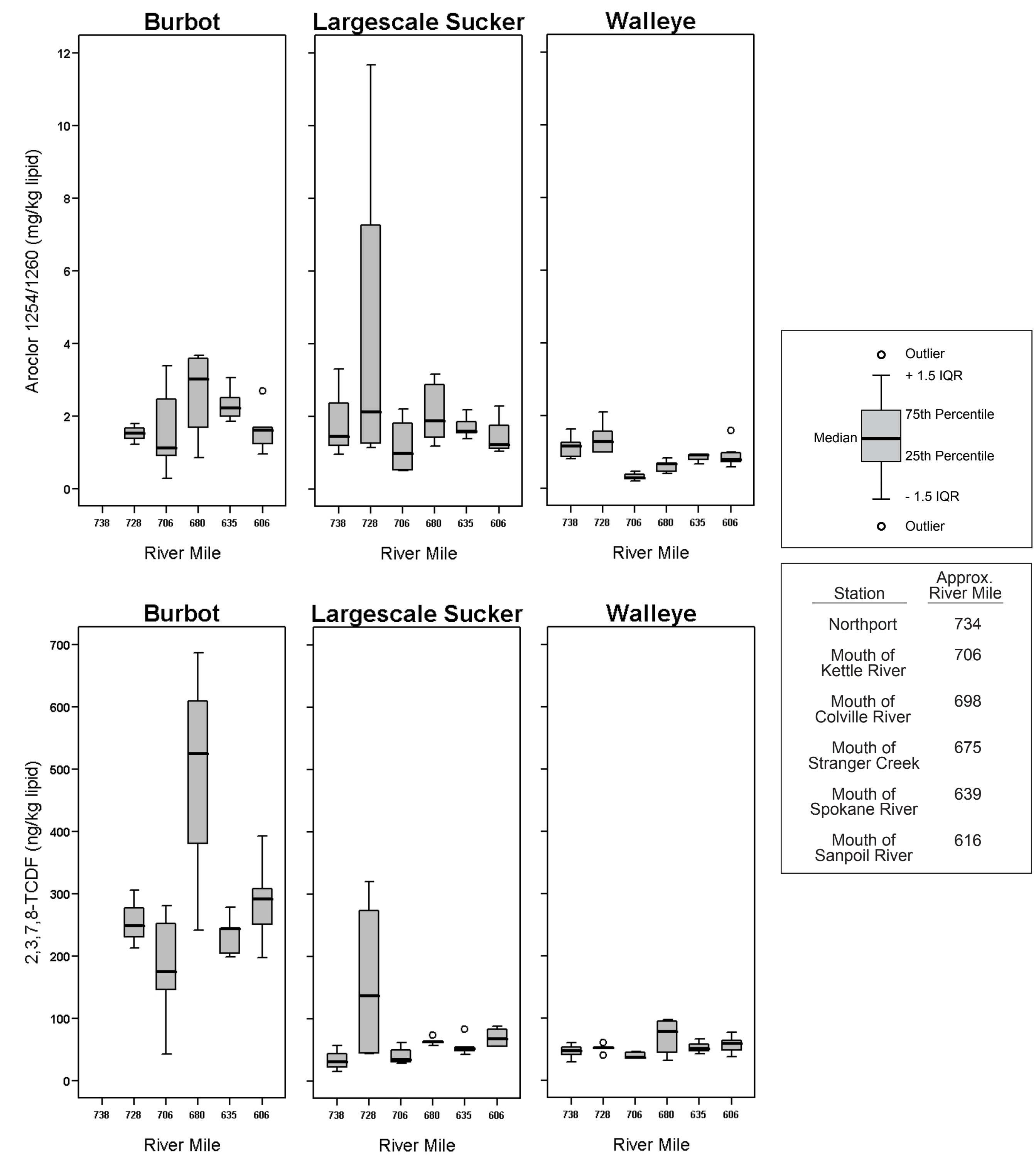


Figure 13. Lipid-Normalized Concentrations of Aroclor 1254/1260 and 2,3,7,8-TCDF in Whole Burbot, Largescale Sucker, and Walleye by River Mile (USEPA 2007)
Note: IQR - Interquartile Range.

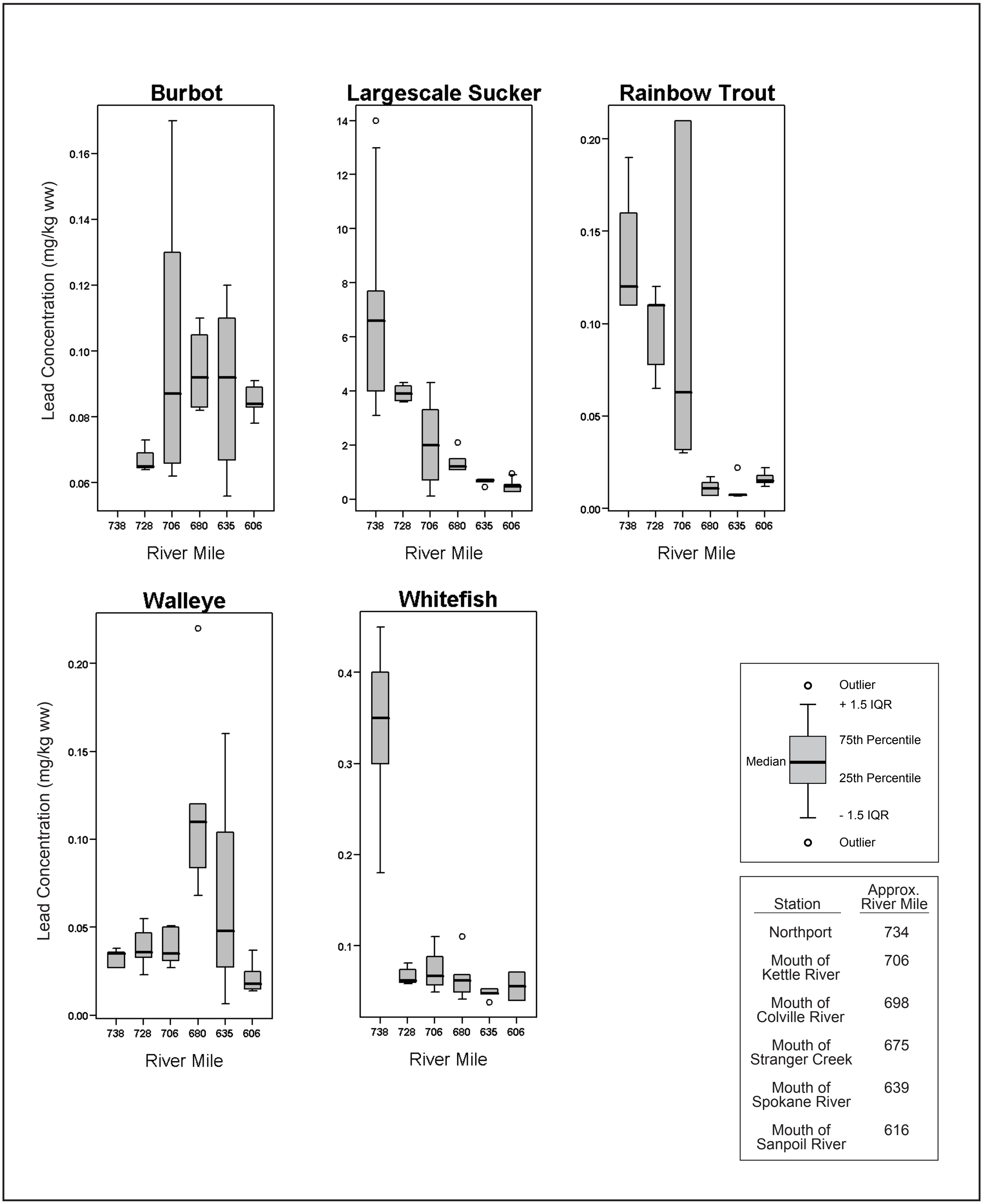


Figure 14. Lead Concentrations in Composite Samples of Whole Burbot, Largescale Sucker, Rainbow Trout, Walleye, and Whitefish by River Mile (USEPA 2007)
Note: IQR - Interquartile Range.
Only Mountain Whitefish Were Collected from FSCA1, and Only Lake Whitefish Were Collected from Other FSCAs.

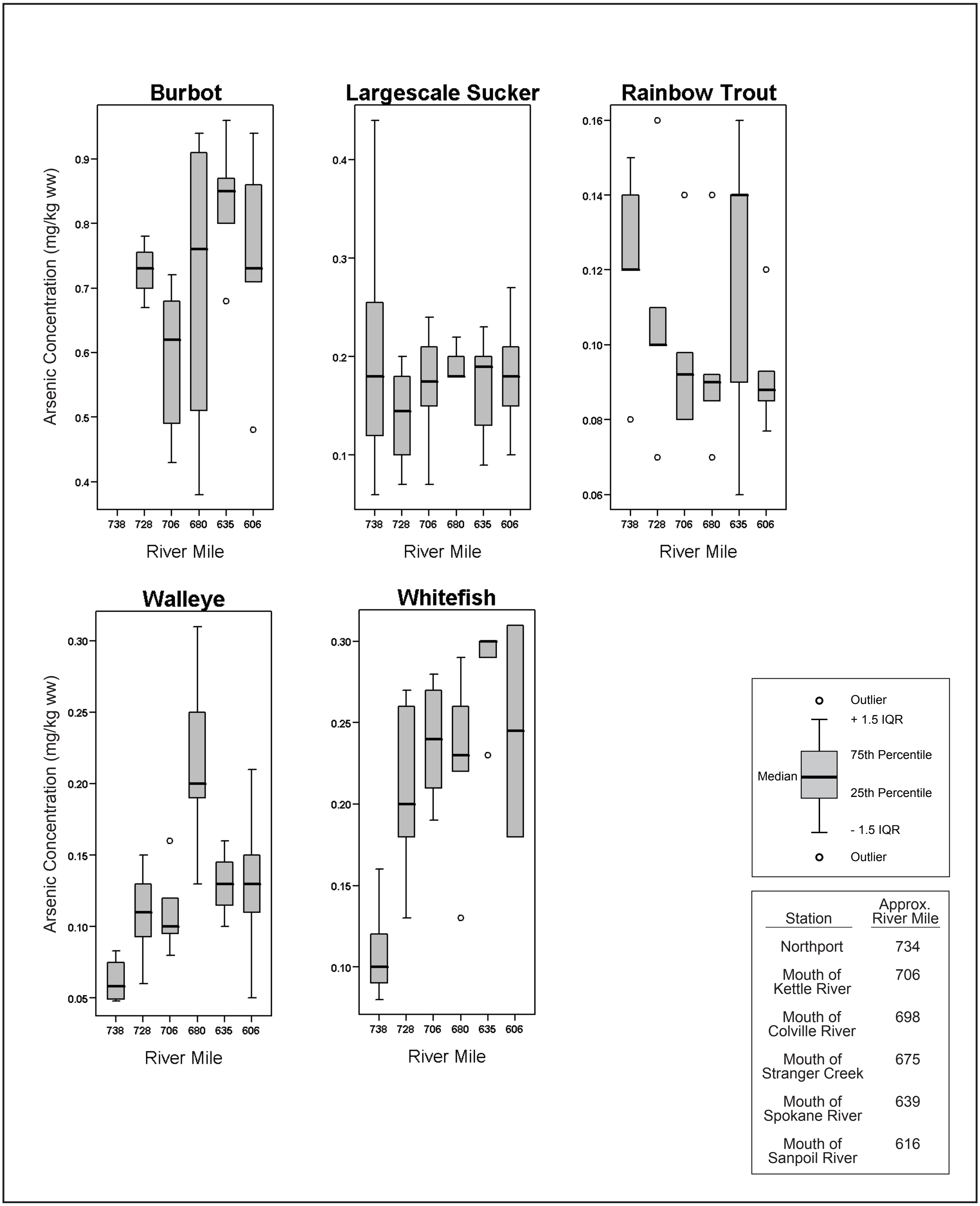
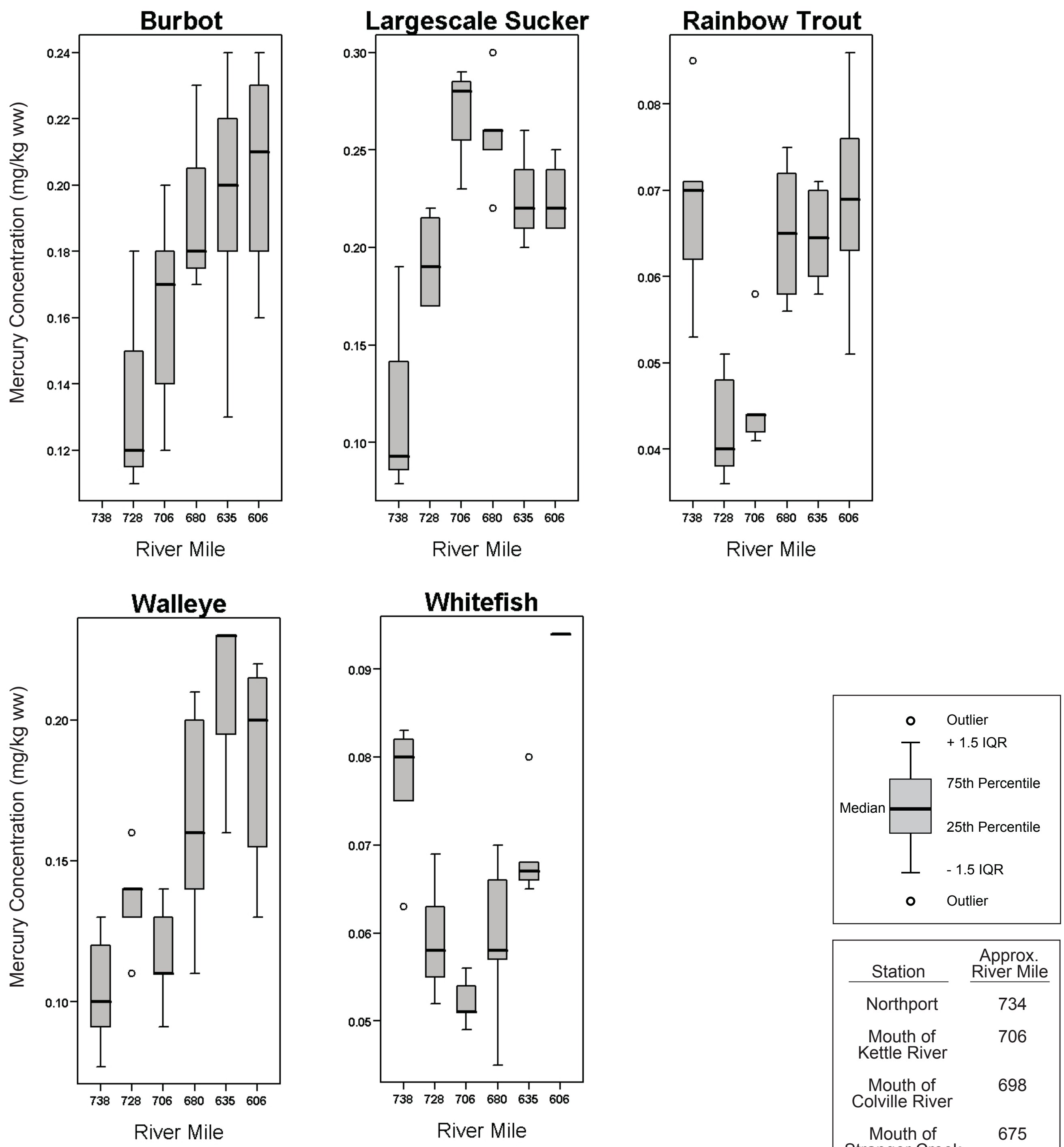


Figure 15. Arsenic Concentrations in Composite Samples of Whole Burbot, Largescale Sucker, Rainbow Trout, Walleye, and Whitefish by River Mile (USEPA 2007)
Note: IQR - Interquartile Range.
Only Mountain Whitefish Were Collected from FSCA1,
and Only Lake Whitefish Were Collected from All Other FSCAs.



Station	Approx. River Mile
Northport	734
Mouth of Kettle River	706
Mouth of Colville River	698
Mouth of Stranger Creek	675
Mouth of Spokane River	639
Mouth of Sanpoil River	616

Figure 16. Mercury Concentrations in Composite Samples of Whole Burbot, Largescale Sucker, Rainbow Trout, Walleye, and Whitefish by River Mile (USEPA 2007)
Note: IQR - Interquartile Range.
Only Mountain Whitefish Were Collected from FSCA1,
and Only Lake Whitefish Were Collected from All Other FSCAs.

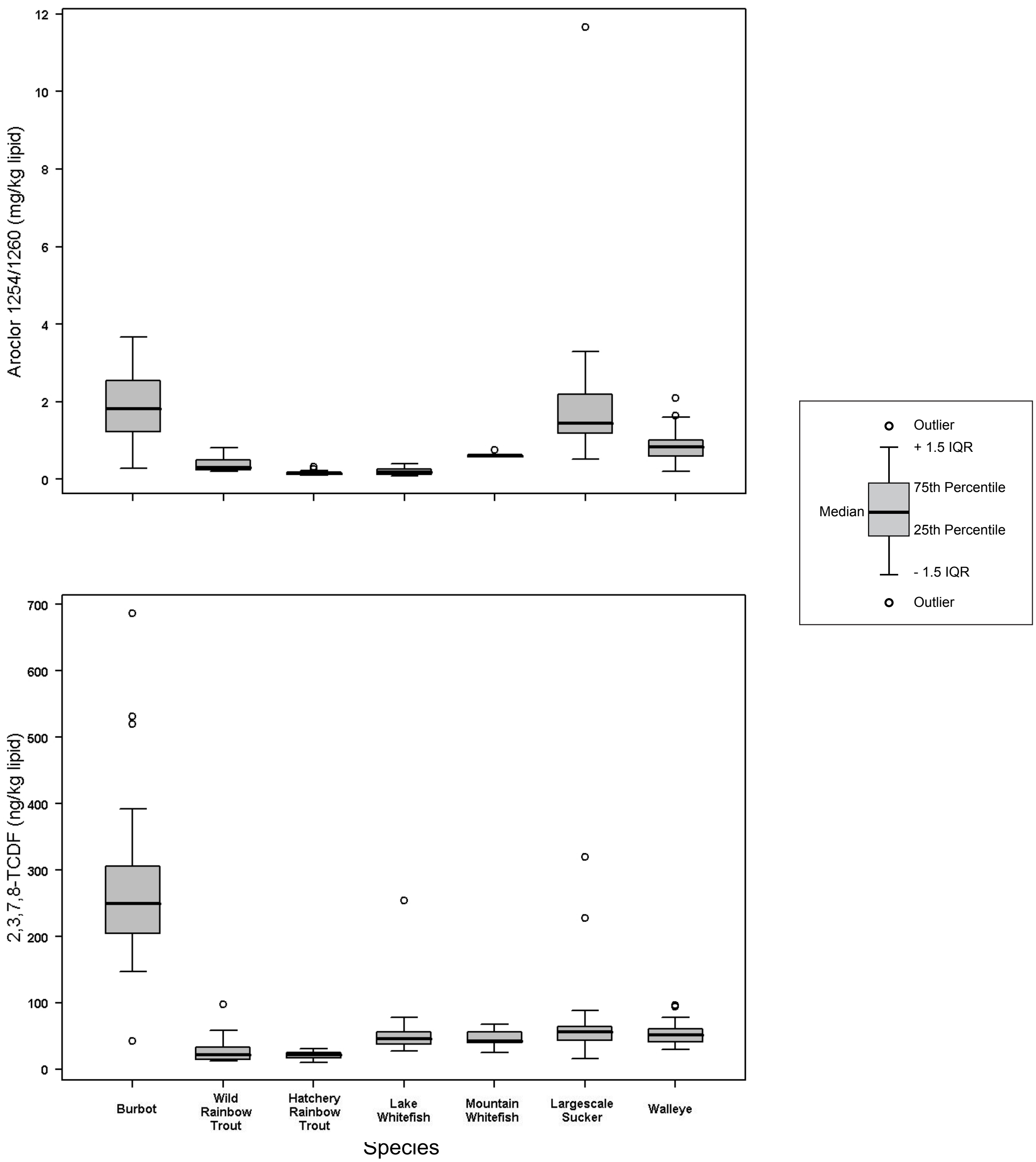


Figure 17. Lipid-Normalized Concentrations of Aroclor 1254/1260 and 2,3,7,8-TCDF in Whole Bodies of All Fish Collected for USEPA (2007)

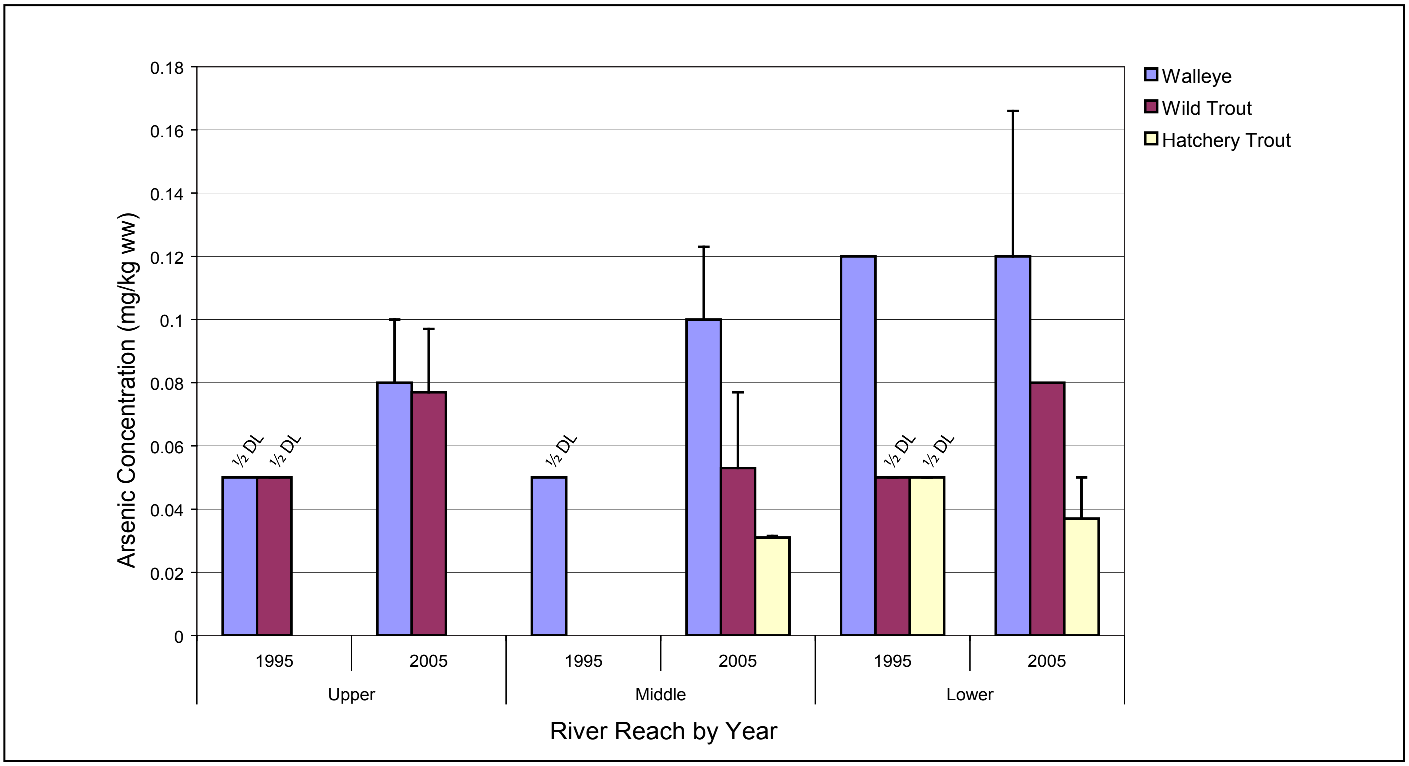


Figure 18. Historical (USGS 1995) and 2005 (USEPA 2007) Mean Arsenic Concentrations in Fillet of Wild and Hatchery Rainbow Trout and Walleye in Three Reaches of the UCR

Notes: Error Bars Represent +1SD, where available.
DL - Detection Limit.

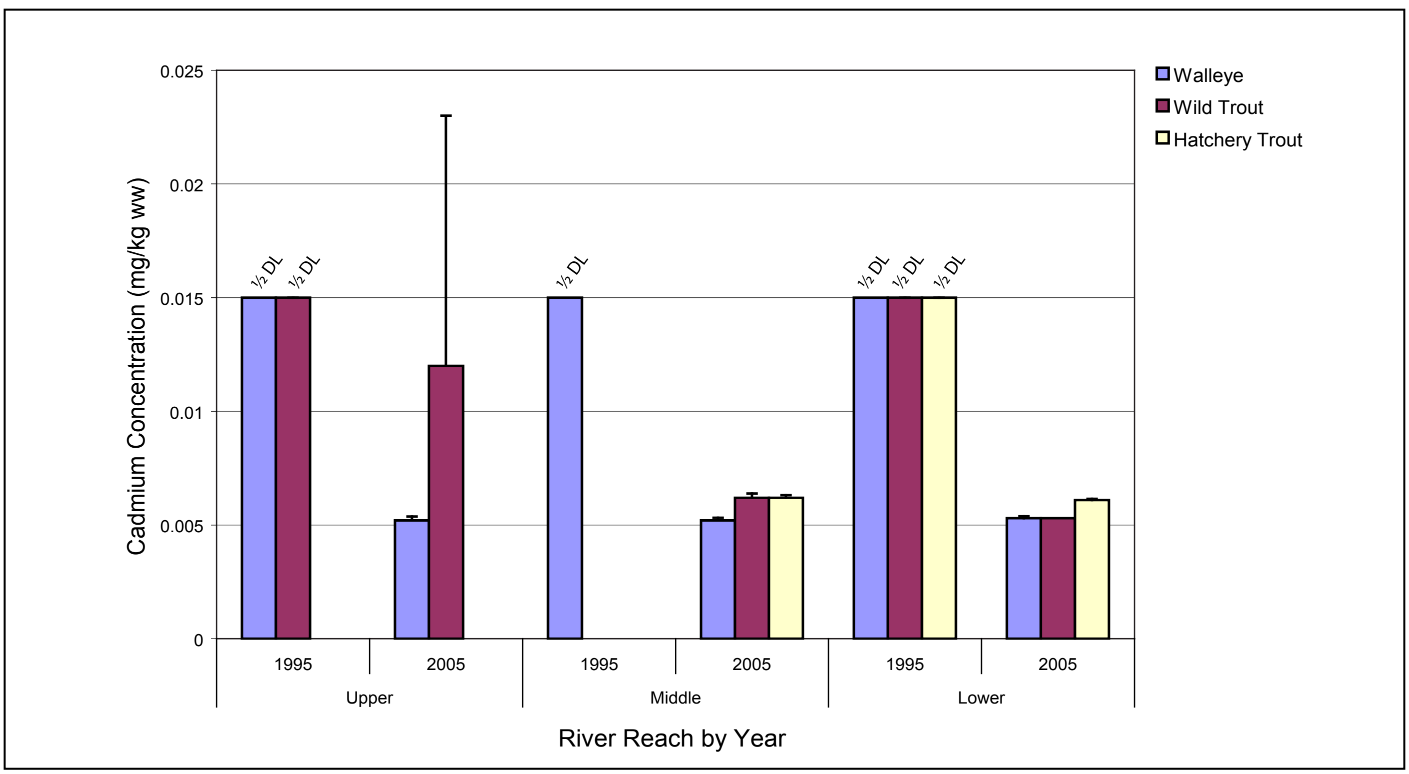


Figure 19. Historical (USGS 1995) and 2005 (USEPA 2007) Mean Cadmium Concentrations in Fillet of Wild and Hatchery Rainbow Trout and Walleye in Three Reaches of the UCR

Notes: Error Bars Represent +1SD, where available.
DL - Detection Limit.

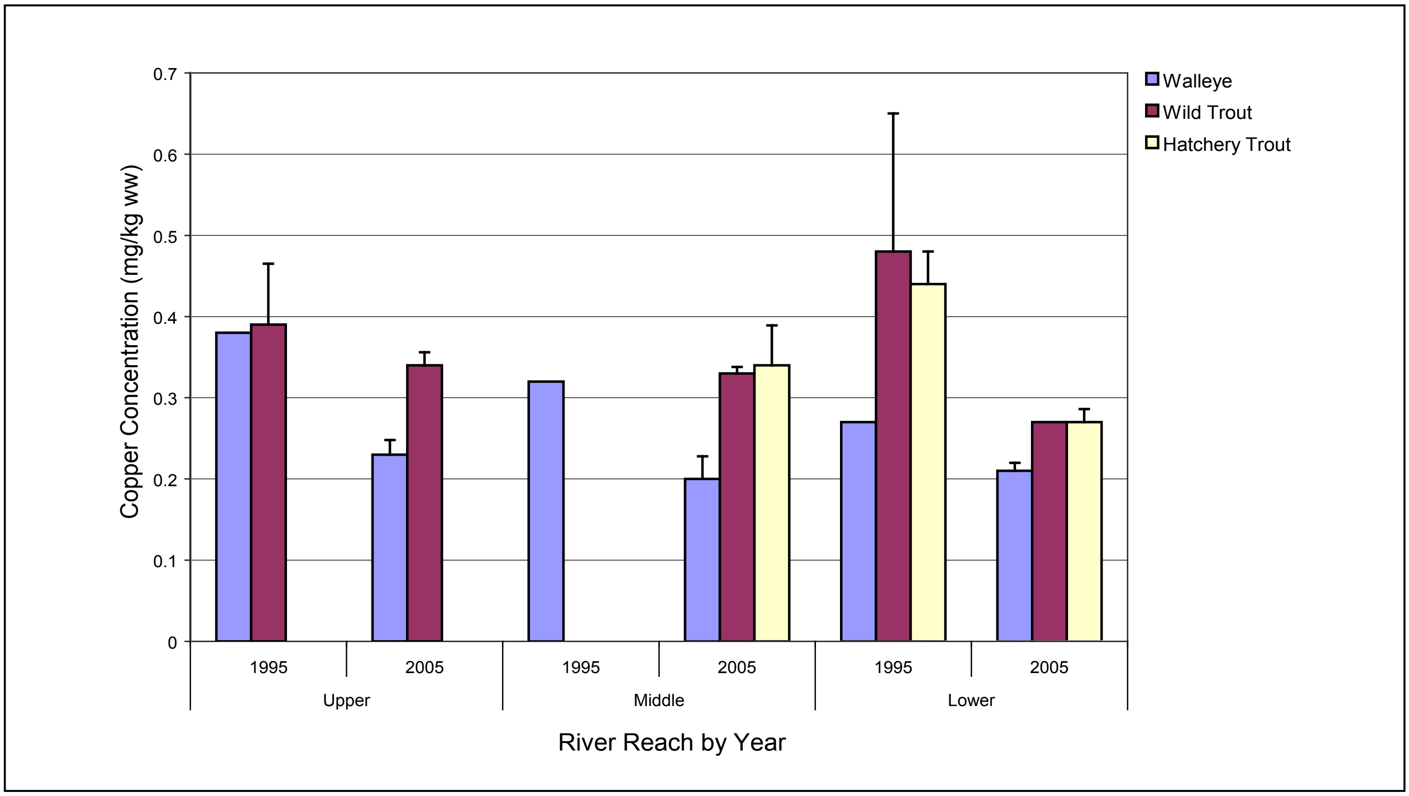


Figure 20. Historical (USGS 1995) and 2005 (USEPA 2007) Mean Copper Concentrations in Fillet of Wild and Hatchery Rainbow Trout and Walleye in Three Reaches of the UCR
Notes: Error Bars Represent +1SD, where available.

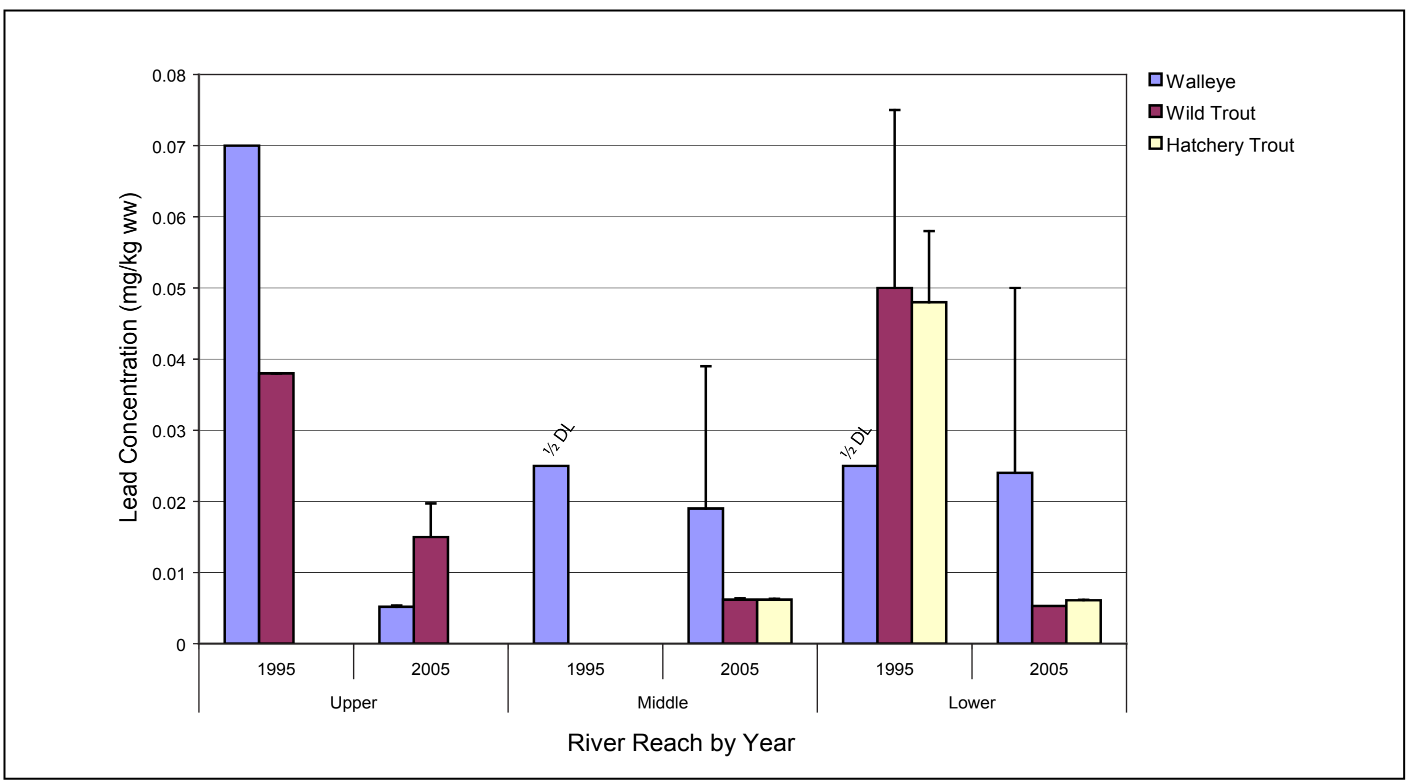


Figure 21. Historical (USGS 1995) and 2005 (USEPA 2007) Mean Lead Concentrations in Fillet of Wild and Hatchery Rainbow Trout and Walleye in Three Reaches of the UCR
Notes: Error Bars Represent +1SD, where available. DL - Detection Limit.

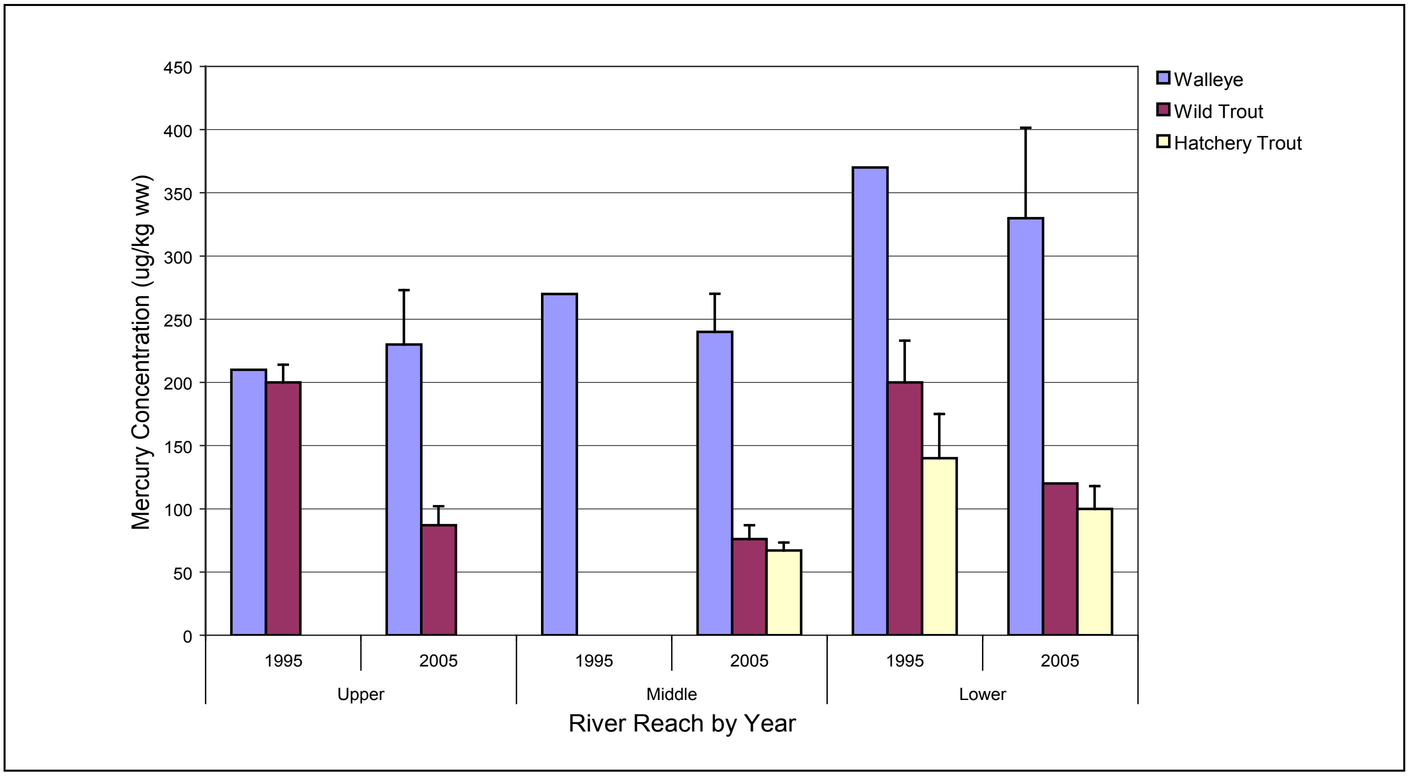


Figure 22. Historical (USGS 1995) and 2005 (USEPA 2007) Mean Mercury Concentrations in Fillet of Wild and Hatchery Rainbow Trout and Walleye in Three Reaches of the UCR
Notes: Error Bars Represent +1SD, where available.

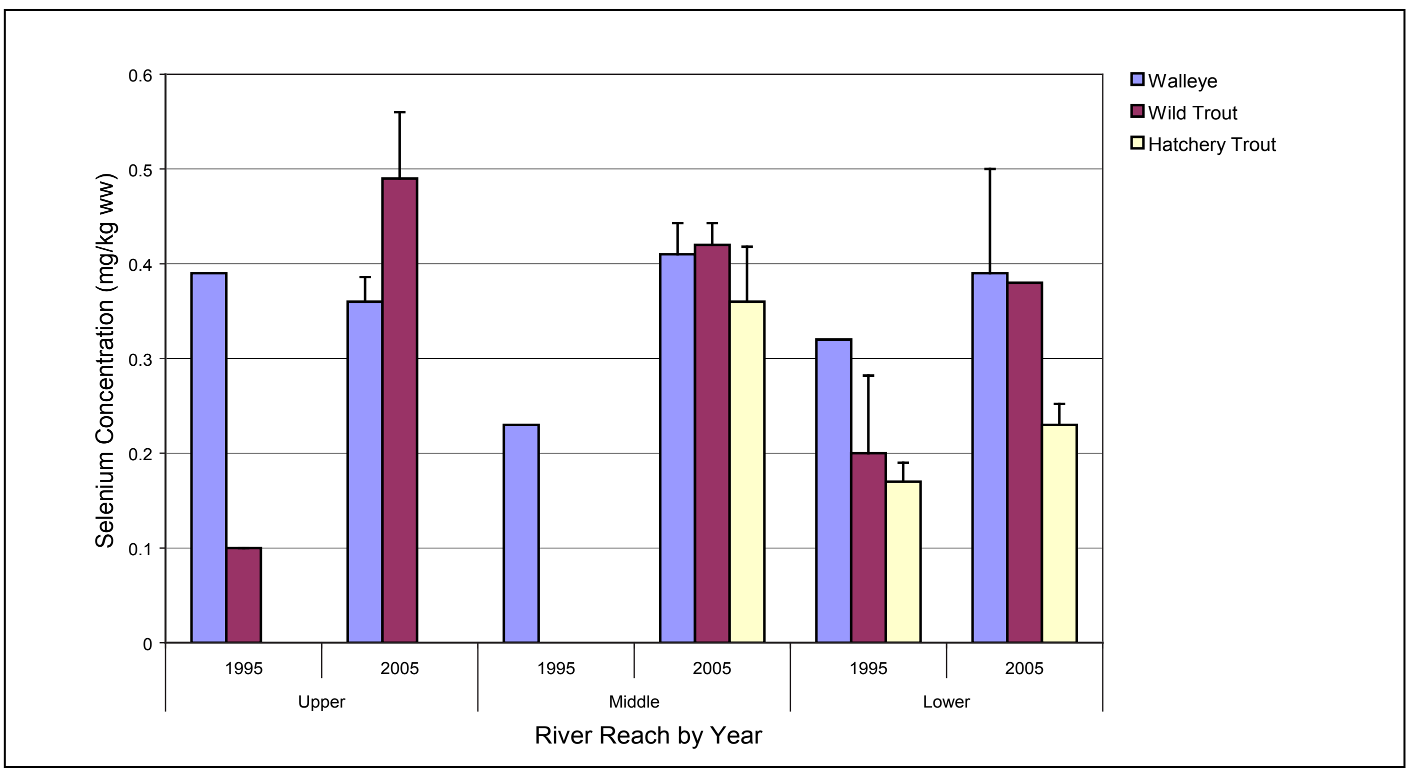


Figure 23. Historical (USGS 1995) and 2005 (USEPA 2007) Mean Selenium Concentrations in Fillet of Wild and Hatchery Rainbow Trout and Walleye in Three Reaches of the UCR
Notes: Error Bars Represent +1SD, where available.

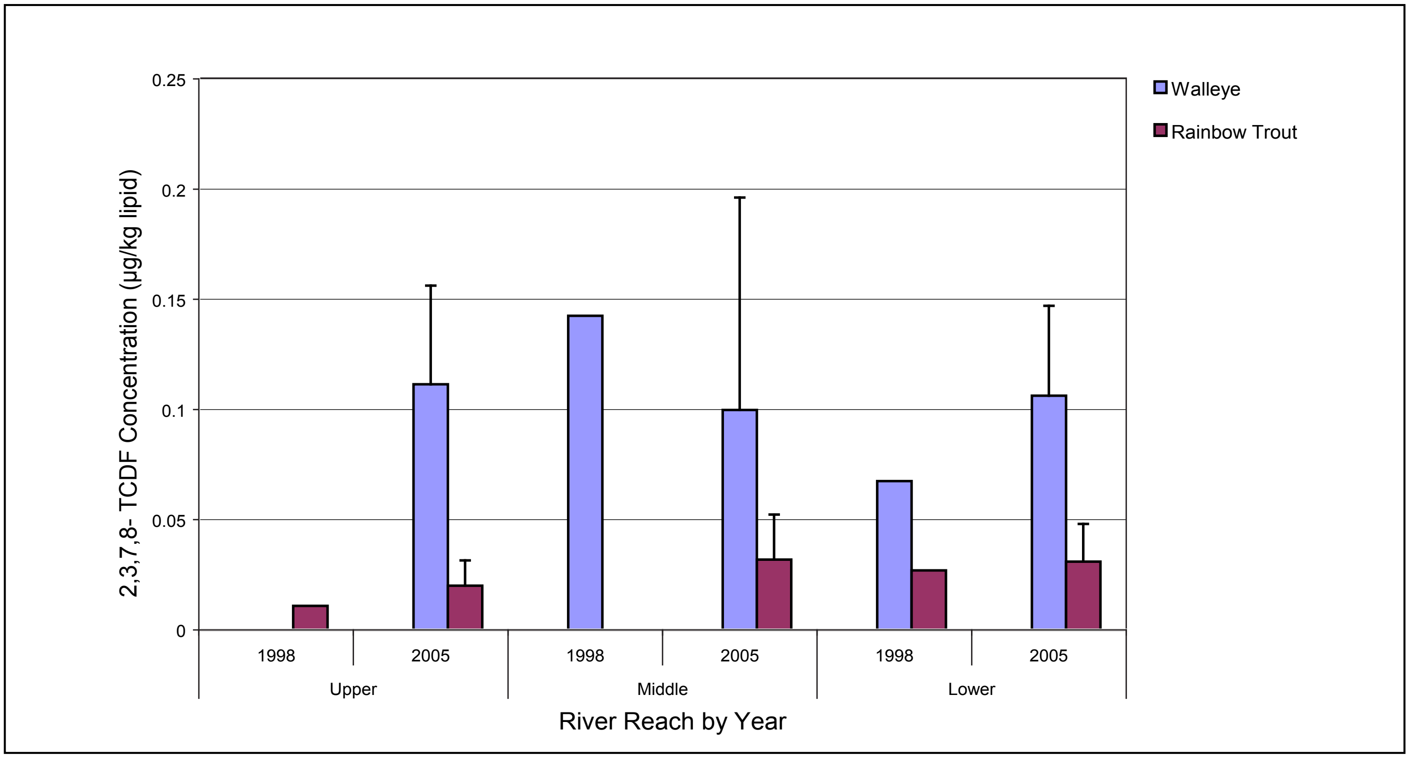


Figure 24. Historical (EVS 1998) and 2005 (USEPA 2007) Mean Lipid-Normalized 2,3,7,8-TCDF Concentrations in Fillet of Wild and Hatchery Rainbow Trout and Walleye in Three Reaches of the UCR
Note: Error Bars Represent +1SD, where available.

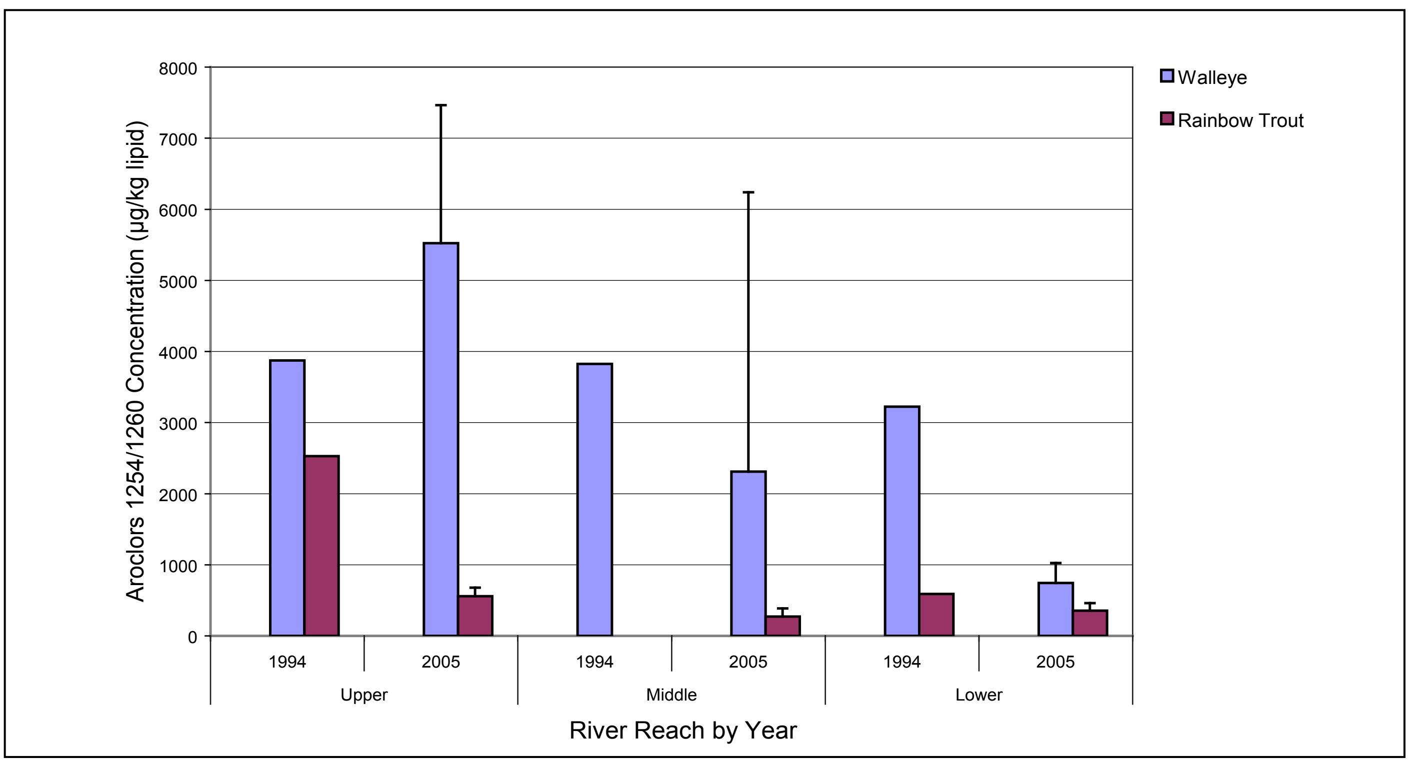


Figure 25. Historical (EVS 1998) and 2005 (USEPA 2007) Mean Lipid-Normalized Total PCB Concentrations in Fillet of Wild and Hatchery Rainbow Trout and Walleye in Three Reaches of the UCR
Note: Error Bars Represent +1SD, where available.
Aroclor 1256/1260 = Total PCBs as the Sum of Aroclors 1256 and 1260.

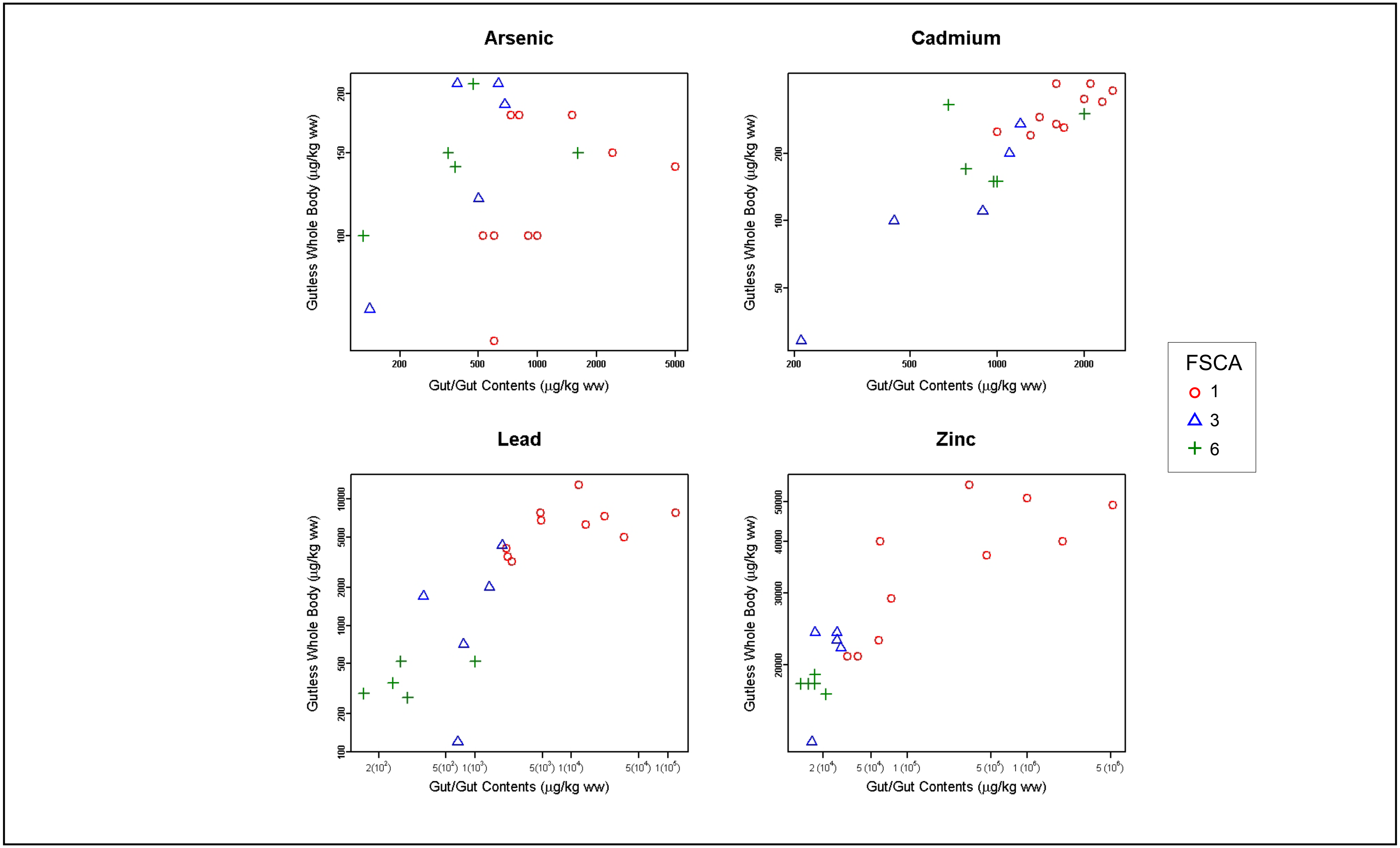


Figure 26. Illustration of the Three Types of Relationships between Gut/Gut Contents and Gutless Whole Body Concentrations of Metals in Largescale Sucker
Notes: Gut/Gut Contents - A Sample That Included Both Stomach Contents and Portions of the Fish Digestive Tract. FSCA - Fish Sample Collection Area.

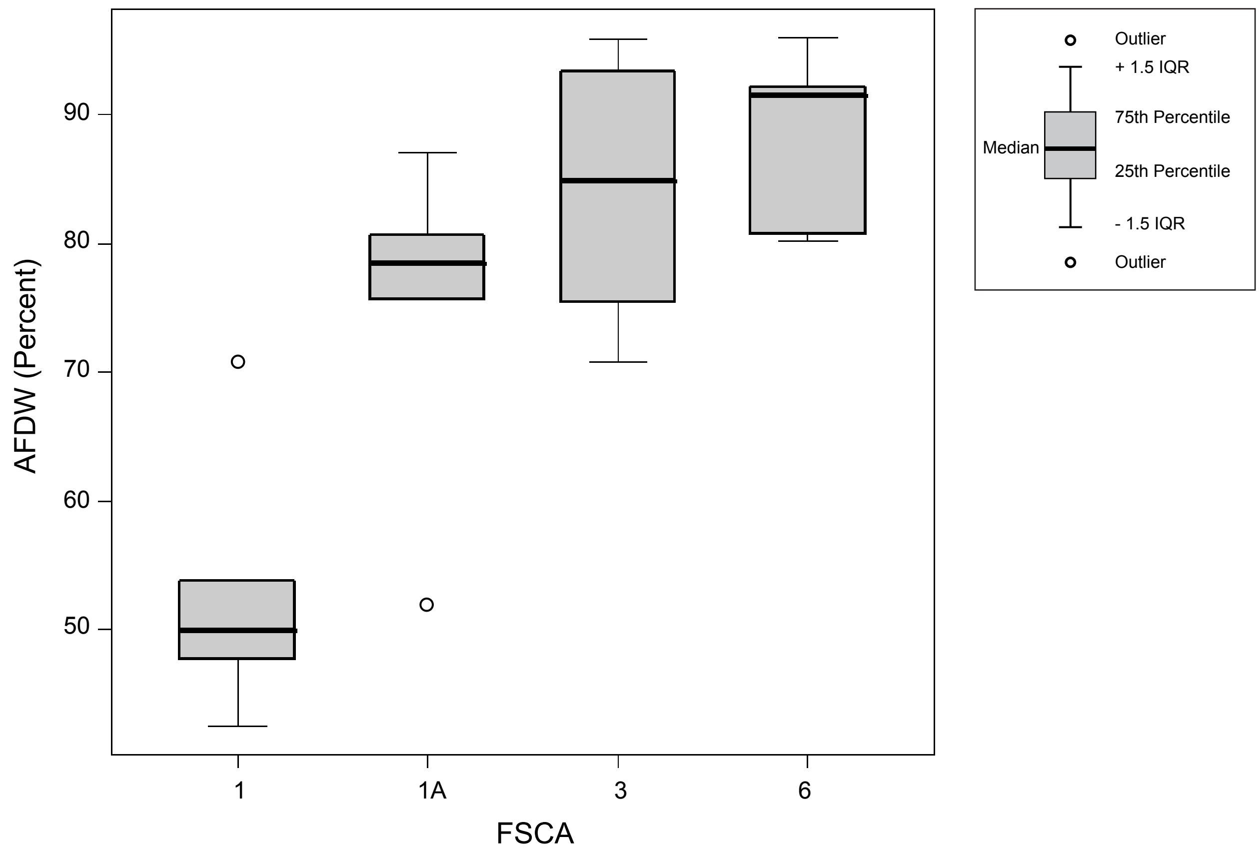


Figure 27. Ash-Free Dry Weight of Largescale Sucker Gut/Gut Contents Samples

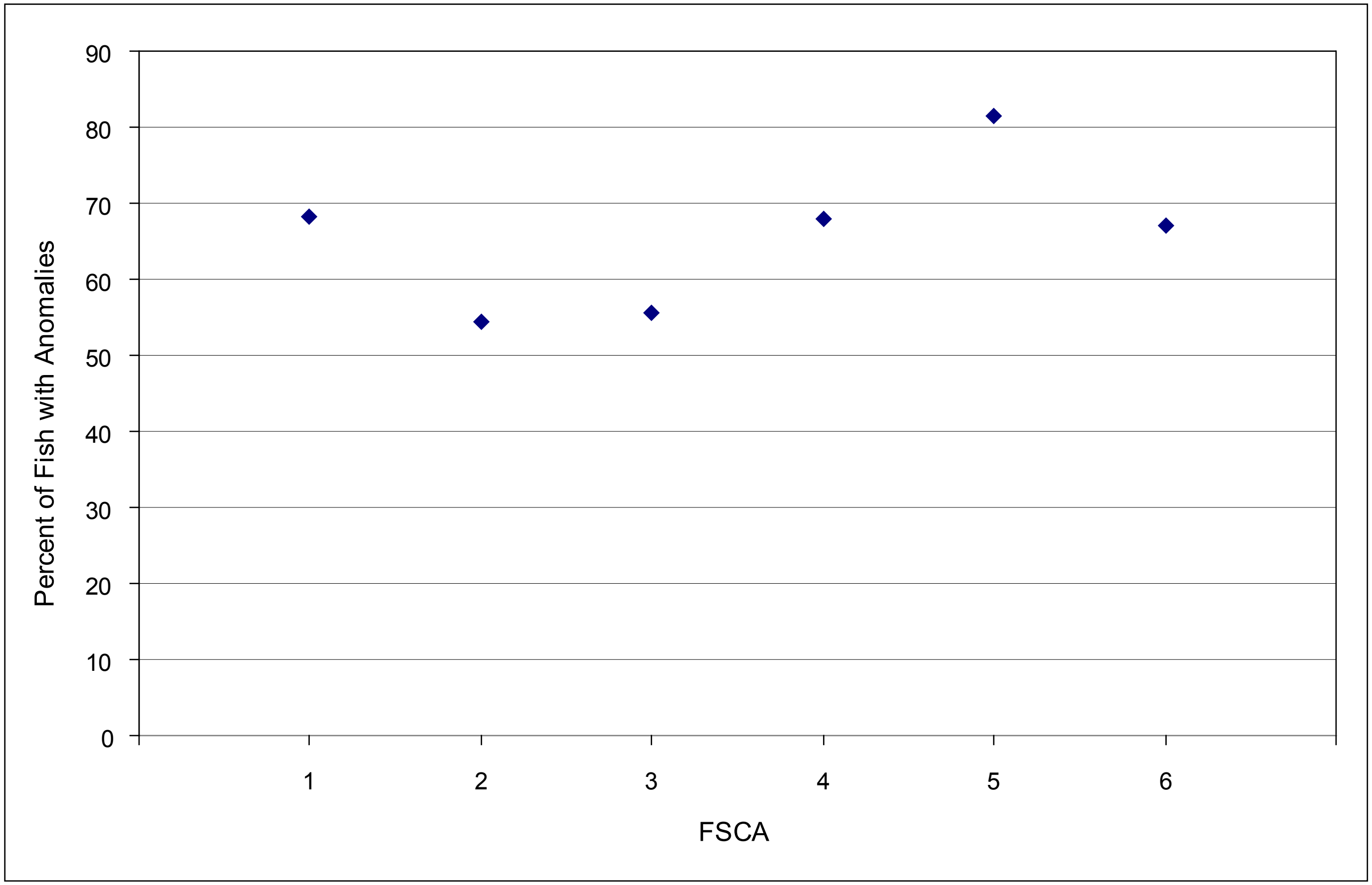


Figure 28. Percent of all Fish with External Anomalies in Each FSCA in 2005

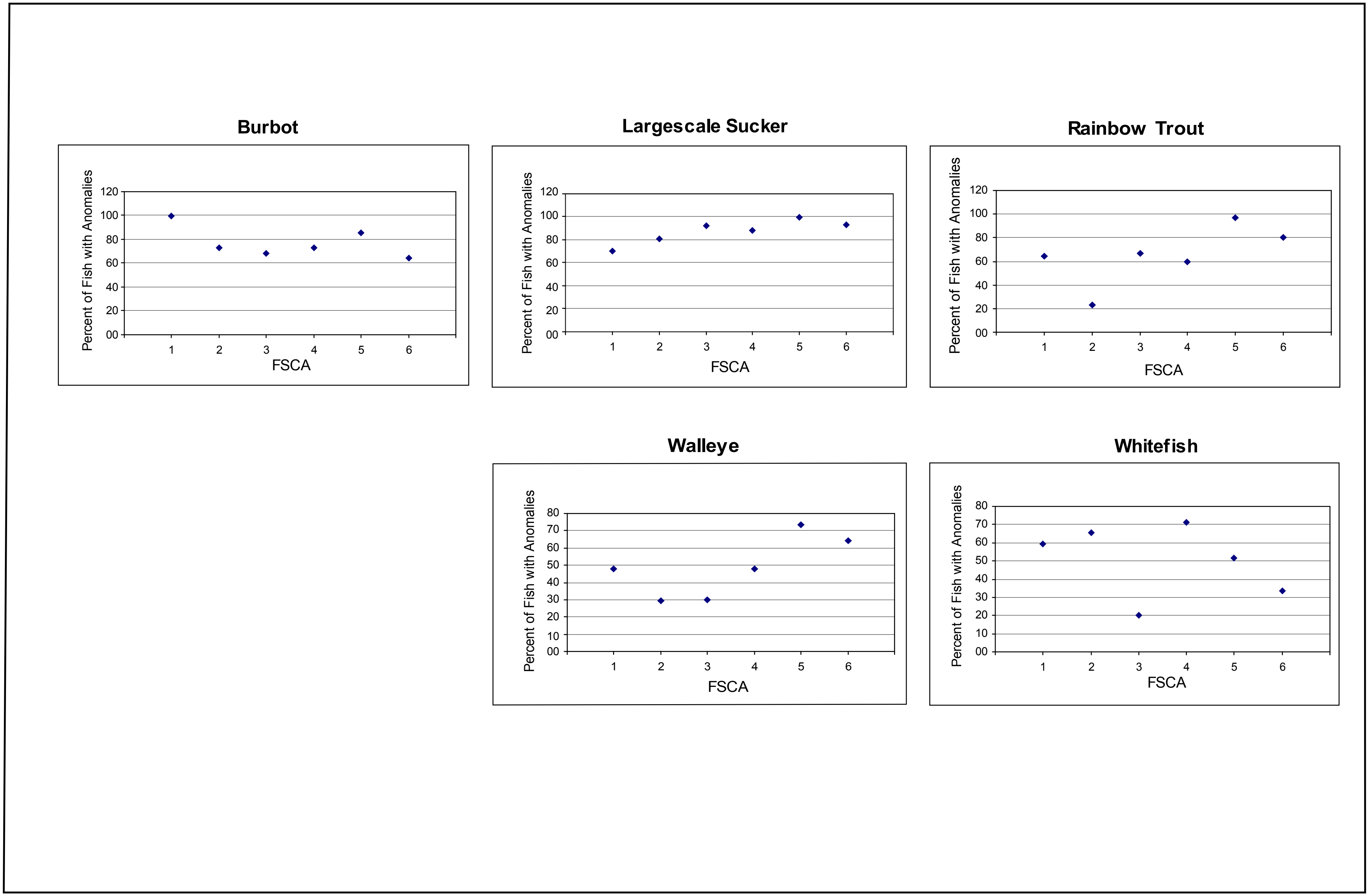


Figure 29. Percent of Fish by Species with External Anomalies in 2005
Note: Only Mountain Whitefish were Examined in FSCA1, and Only Lake Whitefish were Examined in All Other FSCAs.

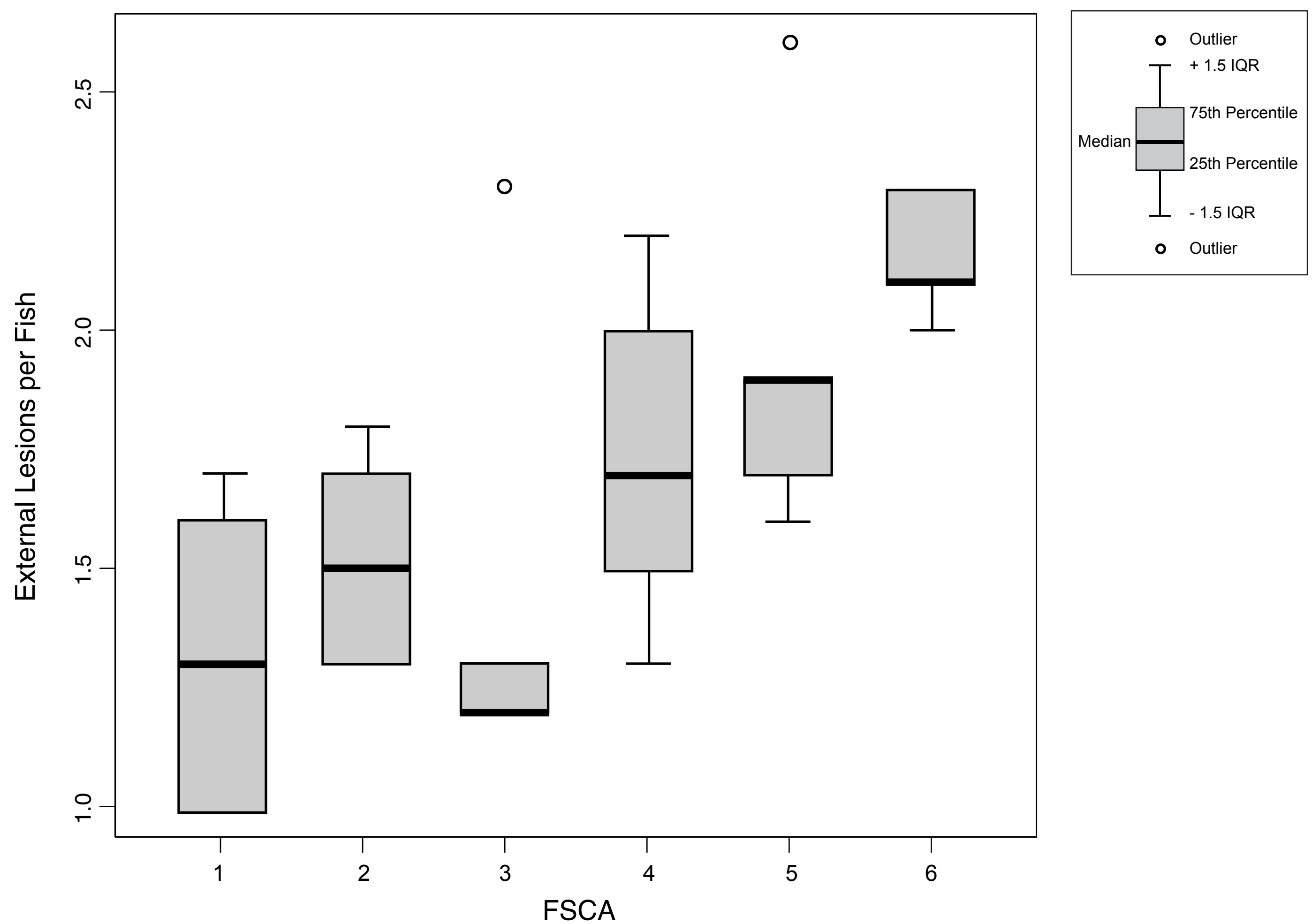


Figure 30. Number of External Anomalies per Fish
(by Species) Examined in 2005 in each FSCA

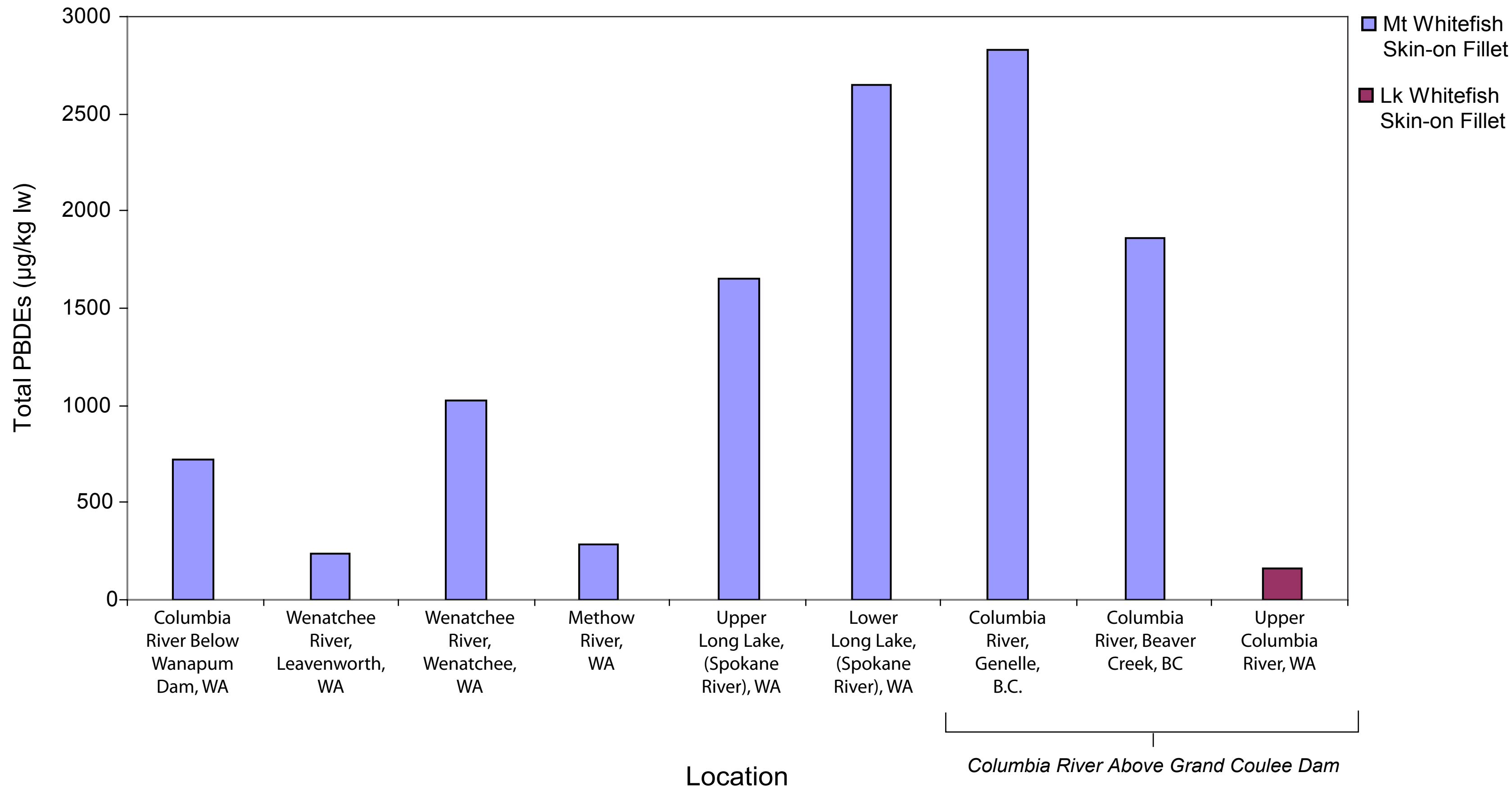
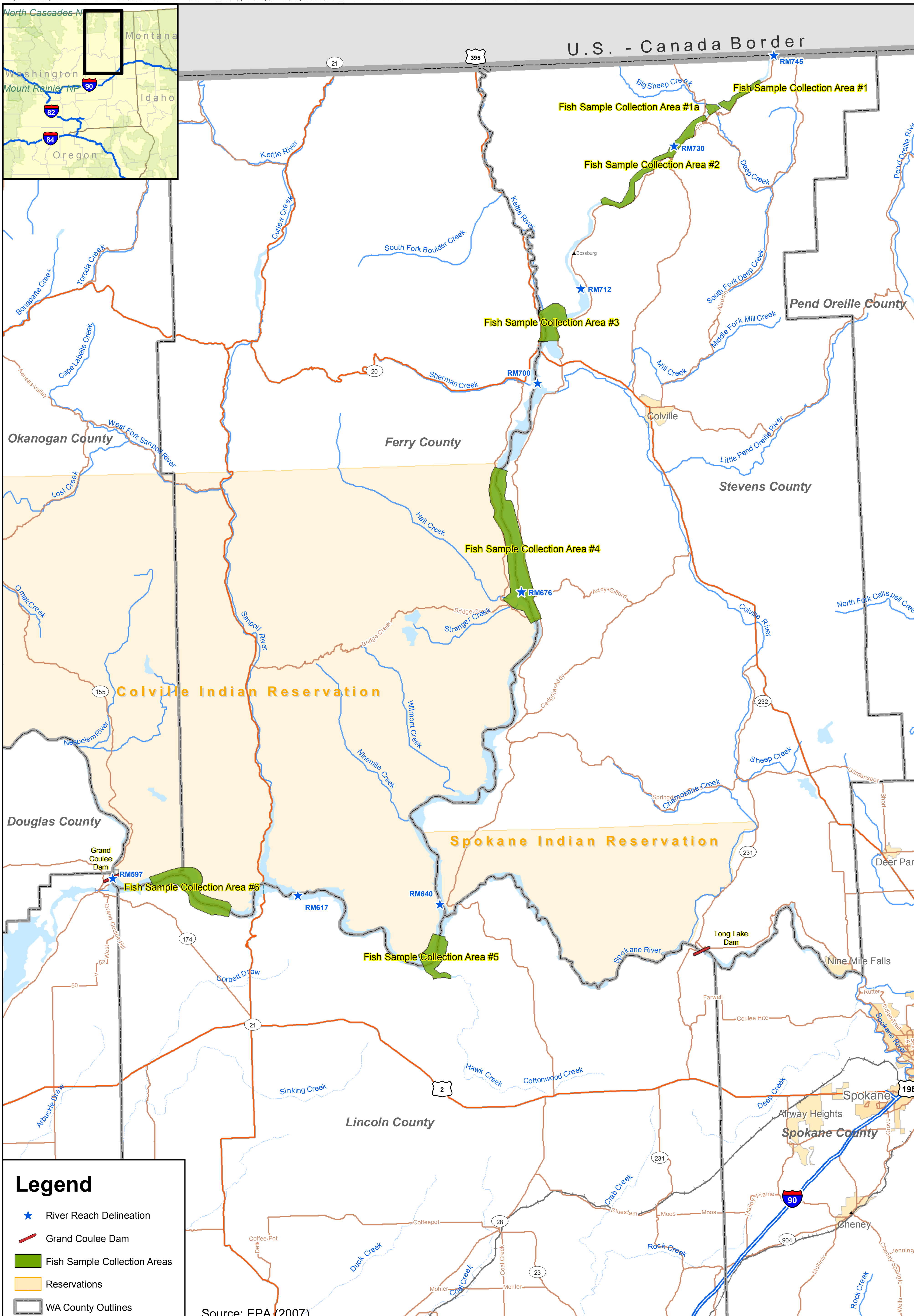


Figure 31. Lipid-Normalized PBDE Concentrations (µg/kg lw) in Lake Whitefish Fillet from the UCR and Mountain Whitefish Fillets from Other Waterbodies in Eastern Washington and British Columbia

Maps

P:\Clients\4662-Teck Cominco\598-4662-002 (UCR RI_FS)\gis\support\mapdocs\UCR_FishTissueSampleLocations.mxd Date: 13 March 2008



Exponent Parametrix

Map 1. **Fish Sample Collection Areas**

Upper Columbia River, WA

TABLES

Table 1. Summary of Fish Tissue Residue Studies Conducted in the UCR

					Chemical Analyses			
Collection Dates	Organization/Reference	UCR Collection Areas (River Mile)	Species	Sample Types	Metals (including Hg)	Pesticides	Dioxins/ Furans	PCBs
1969–1986	USGS (2006)	Grand Coulee	largescale sucker, bridgelip sucker, carp, channel catfish, black crappie, longnose sucker, chiselmouth, largemouth bass, smallmouth bass, mountain whitefish, peamouth, northern pikeminnow, walleye, white crappie, yellow perch	whole body composites (5 per composite)	X	X		X
September 5, 1984	Ecology (Hopkins et al. 1985)	Northport	bridgelip sucker	fillet composites (number per composite unspecified)	X	X		X
September 23–26,1986	Ecology (Johnson et al. 1988)	Northport (732) Gifford (680) Seven Bays (635)	largescale sucker	whole body individuals	X			
			walleye, lake whitefish, rainbow trout, yellow perch, white sturgeon	muscle tissue from individuals				
May 27–July 18, 1989	Ecology (Johnson et al. 1989)	Marcus Island Colville River	white sturgeon, walleye	muscle tissue (individuals)	X (Hg only)		X	
June 26–28, 1990	Ecology (Johnson et al. 1991a)	Northport (733) China Bend (722) Marcus Island (709) French Pt. Rocks (697) Hunters (661) Grand Coulee (600)	largescale sucker	whole body composites (5 per composite)		X	X	X
May–October 1990	Ecology (Johnson et al. 1991b)	Northport to Kettle Falls (700–735) Seven Bays to Spring Canyon (600–673)	walleye, rainbow trout, white sturgeon, lake whitefish, kokanee, burbot	muscle tissue composites (4–5 per composite) liver and egg samples (individuals)			X	
October 6, 1993	Ecology (Serdar et al. 1994)	Kettle Falls	lake whitefish	muscle tissue composites (4–5 per composite) egg samples (individuals)	X		X	
		Kettle Falls Northport	largescale suckers	whole body (individuals)				
May–June 1994	USGS (Munn et al. 1995)	Northport to Kettle Falls Spokane River to Grand Coulee	walleye, rainbow trout, smallmouth bass	fillet (individuals) fillet composites (2–8 per composite)	X			

Table 1. Summary of Fish Tissue Residue Studies Conducted in the UCR

Collection Dates	Organization/Reference	UCR Collection Areas (River Mile)	Species	Sample Types	Chemical Analyses: Metals (including Hg)	Chemical Analyses: Pesticides	Chemical Analyses: Dioxins/ Furans	Chemical Analyses: PCBs
July 11–August 7, 1994	EVS (1998)	Northport Kettle Falls Seven Bays Spring Canyon	kokanee, lake whitefish, rainbow trout, smallmouth bass, walleye, white sturgeon	fillet with skin fillet without skin dorsal muscle without skin scaled with skin composites (4–8 per composite) and individuals			X	X
November 1997	USGS (Hinck et al. 2004)	Northport Grand Coulee	largescale sucker, walleye, rainbow trout	whole body composites (2–10 per composite)	X	X		X[a]
Summer and Fall 1998	USGS (Munn 2000)	Northport to Kettle Falls Spokane River to Grand Coulee	walleye, rainbow trout, mountain whitefish	fillet (individuals)	X (Hg only)		X	X[a]
September–October 2005	USEPA (2005a, 2006, 2007)	Above Northport (735–741) Below Northport (720–734) Above Kettle Falls (702–707) Inchelium (673–689) Seven Bays (633–637) Above Spring Canyon (601–610)	burbot, largescale sucker, lake whitefish, mountain whitefish, walleye, rainbow trout	whole body composites (3–5 per composite) fillet and offal composites (3–5 per composite) whole body composites without GI tract (3–5 per composite) GI tract composites (3–5 per composite)	X		X	X[a]

Source: USEPA (2008)

Notes:
Hg = mercury
PCB = polychlorinated biphenyl
[a] Includes PCB Congeners.

Table 2. Summary of Concentrations of Metals and Organic Compounds in UCR Fish Tissues Reported by Historical Studies

Species	Sample Type [a]	Reference	Collection Year(s)	Inorganics (mg/kg-ww)							Dioxins/Furans (ng/kg-ww)		PCB Aroclors (µg/kg-ww)	
				Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc	2,3,7,8-TCDD	2,3,7,8-TCDF	Aroclor 1254	Aroclor 1260
Black Crappie	WB-C	USGS (2006)	1969-1986	6 (<0.05-0.5) [b]	6 (<0.01-0.14)	3 (0.27-0.54)	7 (0.05-0.27)	6 (<0.01-0.19)	3 (0.4-0.56)	3 (26.9-33.0)	—	—	7 (<50-900)	4 (<50-100)
Bridgelip Sucker	WB-C	USGS (2006)	1969-1986	3 (0.18-0.27)	3 (0.07-0.28)	—	5 (0.02-0.12)	3 (0.53-1.0)	3 (0.2-0.26)	—	—	—	7 (<100-700)	4 (<100-4800)
	F-C	Hopkins et al. (1985)	1984	2 (<0.03)	2 (0.1-0.71)	2 (1.8-2.1)	2 (0.05-0.07)	2 (4.3-8.1)	—	2 (29.0-30.5)	—	—	—	2 (90-97)
Burbot	M-C	Johnson et al. (1991b)	1990	—	—	—	—	—	—	—	2 (<0.1-<0.1)	2 (2.7-2.9)	—	—
Carp	WB-C	USGS (2006)	1969-1986	17 (<0.05 -0.35)	17 (<0.05-1.8)	4 (1.11-1.42)	20 (<0.01-0.24)	17 (<0.1-0.4)	9 (0.22-0.99)	4 (75.4-112.4)	—	—	24 (<100-1900)	13 (<100-300)
Channel Catfish	WB-C	USGS (2006)	1969-1986	5 (<0.05-0.61)	5 (<0.05-0.13)	—	7 (0.08-0.9)	5 (<0.1-0.21)	2 (0.07-0.18)	—	—	—	8 (<100-1400)	3 (<100-500)
Chiselmouth	WB-C	USGS (2006)	1969-1986	2 (0.11 - 0.14)	2 (0.04-0.11)	2 (1.17-1.33)	2 (0.02-0.03)	2 (0.15-0.19)	2 (0.37-0.51)	2 (33.5-35.1)	—	—	2 (100-200)	2 (<100-200)
Kokanee	M-C	Johnson et al. (1991b)	1990	—	—	—	—	—	—	—	2 (0.7-0.9)	2 (42.1-63.3)	—	—
	F-I	EVS (1998)	1994	—	—	—	—	—	—	—	8 (<0.08-<0.16)	8 (1.78-6.74)	8 (26.6-85.4)	8 (9.9-19.3)
	F-C	EVS (1998)	1994	—	—	—	—	—	—	—	4 (<0.1-<0.13)	4 (2.76-3.13)	4 (27.8-37.7)	4 (9.7-13.9)
Lake Whitefish	M-I	Johnson et al. (1988)	1986	3 (<0.02-0.28)	3 (<0.01-0.01)	3 (0.44-0.6)	3 (0.07-0.12)	3 (0.03-0.04)	—	3 (3.4-4.5)	—	—	—	—
	M-C	Johnson et al. (1991b)	1990	—	—	—	—	—	—	—	12 (0.5-2.7)	12 (41.6-205)	—	—
	M-C	Serdar et al. (1994)	1990-1993	—	—	—	—	—	—	—	18 (0.18-2.3)	18 (2.6-157)	—	—
	F-C	EVS (1998)	1994	—	—	—	—	—	—	—	3 (<0.06-<0.14)	3 (3.78-15.6)	3 (35.2-50.6)	3 (16.1-40)
	F-I	EVS (1998)	1994	—	—	—	—	—	—	—	8 (<0.07-<1.41)	8 (1.6-125.9)	8 (13-156)	8 (5.3-38.8)
	M-I	EVS (1998)	1994	—	—	—	—	—	—	—	5 (<0.13-<1.37)	5 (3.25-6.77)	—	—
	M-C	EVS (1998)	1994	—	—	—	—	—	—	—	5 (<0.12-0.67)	5 (0.3-64)	5 (18.8-81.8)	5 (6.5-28.3)
Largemouth Bass	WB-C	USGS (2006)	1969-1986	1 (<0.05)	1 (<0.05)	—	1 (0.18)	1 (<0.1)	1 (0.1)	—	—	—	1 (<100)	1 (<100)
Largescale Sucker	WB-C	USGS (2006)	1969-1986	45 (<0.05-0.61)	45 (<0.003-0.6)	23 (<0.43-3.57)	49 (<0.01-0.3)	45 (0.3-2.57)	33 (0.06-0.55)	23 (14.1-60.1)	—	—	55 (<50-3000)	38 (<50-300)
	WB-I	Johnson et al. (1988)	1986	12 (<0.02-0.3)	12 (0.22-0.43)	12 (0.62-6.4)	12 (0.08-0.25)	12 (0.24-7.34)	—	12 (20.9-86.7)	—	—	—	—
	WB-C	Johnson et al. (1991a)	1990	—	—	—	—	—	—	—	6 (0.92-2.6)	6 (16.8-48.1)	—	—
	WB-I	Serdar et al. (1994)	1993	—	30 (0.23-1.0)	30 (0.74-20.1)	30 (0.07-0.35)	30 (1.7-23.3)	—	30 (15.5-136)	—	—	—	—
	WB-C	Hinck et al. (2004)	1997	4 (<0.21-0.52)	4 (0.31-0.46)	4 (1.24-3.46)	4 (0.08-0.15)	4 (0.68-9.29)	4 (<0.26-0.31)	4 (34.8-50.9)	—	—	—	—
Longnose Sucker	WB-C	USGS (2006)	1969-1986	2 (0.07-0.09)	2 (0.05-0.06)	2 (1.1-2.2)	2 (0.03-0.04)	2 (0.14-0.24)	2 (0.22-0.25)	2 (17.5-19.5)	—	—	2 (<50)	2 (<50)
Mountain Whitefish	WB-C	USGS (2006)	1969-1986	1 (0.12)	1 (0.07)	1 (0.59)	2 (0.06-0.19)	1 (0.1)	1 (0.47)	1 (18.8)	—	—	2 (100-800)	1 (100)
	F-I	Munn (2000)	1998	—	—	—	—	—	—	—	5 (0.04-0.12)	5 (0.87-6.26)	—	—
Northern Pikeminnow	WB-C	USGS (2006)	1969-1986	14 (<0.05-0.31)	14 (0.01-1.7)	2 (0.6)	16 (<0.01-1.2)	14 (<0.1-0.3)	11 (0.11-0.4)	2 (24-30)	—	—	19 (<100-4600)	8 (<100-1200)
Peamouth	WB-C	USGS (2006)	1969-1986	2 (0.07-0.08)	2 (0.03)	2 (0.75-1.08)	2 (0.02-0.03)	2 (0.05-0.09)	2 (0.45-0.47)	2 (19.7-24.6)	—	—	2 (100)	2 (<100-100)
Rainbow Trout (wild)	M-I	Johnson et al. (1988)	1986	2 (<0.02-0.12)	2 (0.01-0.04)	2 (0.4-0.44)	2 (0.04)	2 (0.05-0.07)	—	2 (4.6-5.5)	—	—	—	—
	M-C	Johnson et al. (1991b)	1990	—	—	—	—	—	—	—	12 (<0.1-1.6)	12 (3.7-53.2)	—	—
	F-C	Munn et al. (1995)	1994	6 (<0.1)	6 (<0.03)	6 (0.28-0.68)	6 (0.16-0.24)	6 (<0.05-0.1)	6 (<0.2-0.37)	6 (4.1-15.8)	—	—	—	—
	F-C	EVS (1998)	1994	—	—	—	—	—	—	—	7 (<0.04-<0.23)	7 (0.09-1.89)	7 (15.2-49.1)	7 (6.3-71.8)
	F-I	EVS (1998)	1994	—	—	—	—	—	—	—	24 (<0.07-<0.24)	24 (0.22-7.1)	16 (9.2-68.7)	16 (4.7-164)
	WB-C	Hinck et al. (2004)	1997	2 (<0.31)	2 (<0.06)	2 (1.1-1.11)	2 (<0.06)	2 (0.22-0.29)	2 (0.42-0.43)	2 (19.5-22.9)	—	—	—	—
	F-I	Munn (2000)	1998	—	—	—	—	—	—	—	16 (<0.01-0.1)	16 (0.2-2.03)	16 (8.8-49)	16 (2.4-39)
Smallmouth Bass	WB-C	USGS (2006)	1969-1986	—	—	—	2 (0.14-0.27)	—	—	—	—	—	3 (<100-600)	1 (200)
	F-C	Munn et al. (1995)	1994	5 (0.14)	5 (<0.03)	5 (0.36-0.41)	5 (0.17-0.62)	5 (<0.05-0.06)	5 (0.25-0.31)	5 (5.3-6.1)	—	—	—	—
	F-C	EVS (1998)	1994	—	—	—	—	—	—	—	9 (<0.09-<0.17)	9 (<0.15-4.1)	9 (4.7-7.9)	9 (2.6-7.2)
Walleye	WB-C	USGS (2006)	1969-1986	9 (<0.03-0.22)	9 (0.03-0.16)	3 (0.3-0.37)	11 (0.08-0.15)	9 (0.03-0.22)	7 (0.21-0.34)	3 (12.7-13.4)	—	—	13 (<100-3600)	7 (<100-400)
	M-I	Johnson et al. (1988)	1986	11 (<0.02-0.16)	11 (<0.01-0.02)	11 (0.08-0.48)	11 (0.07-0.36)	11 (0.01-0.11)	—	11 (3.5-4.5)	—	—	—	—
	M-I	Johnson and Yake (1989)	1989	—	—	—	24 (0.05-0.24)	—	—	—	—	—	—	—
	M-I	Johnson and Yake (1990)	1989	—	—	—	—	—	—	—	2 (0.21-4.0)	2 (8.9-326)	—	—
	M-C	Johnson et al. (1991b)	1990	—	—	—	—	—	—	—	12 (<0.1-0.32)	12 (0.9-6.0)	—	—
	F-C	Munn et al. (1995)	1994	3 (<0.1-0.12)	3 (<0.03)	3 (0.27-0.38)	34 (0.11-0.44)	3 (<0.05-0.07)	3 (0.23-0.39)	3 (4.6-5.2)	—	—	—	—
	F-C	EVS (1998)	1994	—	—	—	—	—	—	—	11 (<0.08-0.55)	11 (0.08-1.57)	11 (3.3-88.8)	11 (3.8-31.5)
	F-I	EVS (1998)	1994	—	—	—	—	—	—	—	8 (<0.05-<0.11)	8 (0.08-0.61)	8 (7.4-29.4)	8 (3.8-27.3)
	WB-C	Hinck et al. (2004)	1997	1 (<0.25)	1 (<0.05)	1 (0.53)	1 (0.15)	1 (<0.1)	1 (0.32)	1 (14.3)	—	—	—	—
	F-I	Munn (2000)	1998	—	—	—	16 (0.1-0.22)	—	—	—	—	—	—	—

Table 2. Summary of Concentrations of Metals and Organic Compounds in UCR Fish Tissues Reported by Historical Studies

Species	Sample Type [a]	Reference	Collection Year(s)	Inorganics (mg/kg-ww)							Dioxins/Furans (ng/kg-ww)		PCB Aroclors (µg/kg-ww)	
				Arsenic	Cadmium	Copper	Mercury	Lead	Selenium	Zinc	2,3,7,8-TCDD	2,3,7,8-TCDF	Aroclor 1254	Aroclor 1260
White Crappie	WB-C	USGS (2006)	1969-1986	2 (0.12-0.22)	2 (0.01)	2 (0.52-0.57)	2 (0.06-0.07)	2 (0.04-1.37)	2 (0.22-0.73)	2 (15.6-28.8)	—	—	3 (<100-4600)	1 (2900)
White Sturgeon	M-I	Johnson et al. (1988)	1986	1 (0.24)	1 (0.01)	—	1 (0.12)	1 (0.04)	—	1 (3.4)	—	—	—	—
	M-I	Johnson and Yake (1989)	1989	—	—	—	10 (0.02-0.1)	—	—	—	—	—	—	—
	M-I	Johnson and Yake (1990)	1989	—	—	—	—	—	—	—	2 (<0.1-2.2)	2 (3.9-221)	—	—
	M-C	Johnson et al. (1991b)	1990	—	—	—	—	—	—	—	4 (0.8-4.4)	4 (72.5-222)	—	—
	F-C	EVS (1998)	1994	—	—	—	—	—	—	—	2 (<0.15-<0.18)	2 (16.1-24.5)	2 (15-77)	2 (12.6-103)
Yellow Perch	WB-C	USGS (2006)	1969-1986	7 (<0.03-0.25)	7 (0.01-0.07)	6 (0.34-0.56)	7 (0.03-0.05)	7 (0.02-0.16)	6 (0.34-1.16)	6 (19.1-28.5)	—	—	7 (<100-300)	7 (<50-200)
	M-I	Johnson et al. (1988)	1986	1 (<0.02)	1 (0.01)	1 (1.32)	1 (0.4)	1 (0.11)	—	1 (9.4)	—	—	—	—

Source: USEPA (2008)

Notes:
— = No data available.
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*- dioxin
2,3,7,8-TCDF = 2,3,7,8-tetrachlorodibenzofuran

[a] Sample Type coding:
F-I = Fillet tissue of individual fish
F-C = Fillet tissue of multiple fish (composite)
M-I = Muscle tissue of individual fish
M-C = Muscle tissue of multiple fish (composite)
WB-I = Whole body of individual fish
WB-C = Whole body of multiple fish (composite)
[b] Data are reported as the sample size (minimum - maximum measured concentration)

Table 3. Summary of 2005 Fish Tissue Samples Collected by EPA from the UCR

FSCA	Walleye	Wild Rainbow Trout	Hatchery Rainbow Trout	Lake Whitefish	Mountain Whitefish	Largescale Sucker	Largescale Sucker Gut	Burbot
1	5F/5O	5F/5O	0	0	5WB	3WB	10G	0
2	5WB	5WB	0	5WB	0	4WB	0	3WB
3	5F/5O	2F/2O	3F/3O	5WB	0	4WB	5G	5WB
4	5WB	0	5WB	5WB	0	5WB	0	4WB
5	3WB	1WB	5WB	5WB	0	5WB	0	5WB
6	5F/5O+2WB	1F/1O	4F/4O	5WB	0	4WB	5G	5WB

Source: USEPA (2007)

Notes:
F = fillet
FSCA = fish sample collection area
G = gut/gut contents
O = offal
WB = whole body

Table 4. Probabilities (*p*-values) for Spatial Comparisons of Each Metal among Sampling Areas for Burbot, Walleye, and Largescale Sucker in the UCR in 2005

	Burbot	Walleye			Largescale Sucker			
Metal	Whole Body	Whole Body	Fillet	Offal	Whole Body	Gut	Gutless	Reconstructed Whole Body
Arsenic	0.033	<0.001	0.024	0.009[a]	<0.001	0.007	--	--
Cadmium	--	--[a]	--[a]	--	--	0.002	0.002	<0.001
Chromium	--	--	--	--	0.007	0.014	0.015	0.027
Copper	--	0.002	--	--	<0.001	0.023	0.004	0.001
Mercury	--	0.001	0.013	0.002	0.011	--	--	--
Nickel	--	--	--	--	--	0.017	--	0.002
Lead	--	0.01[a]	--[a]	0.019	0.001	0.001	<0.001	<0.001
Selenium	0.005	0.001	--	--	0.004	0.037	--	--
Uranium	--	0.036[a]	NA	--	--	0.001	--	0.005
Zinc	--	0.015	0.003	--	0.005	0.001	<0.001	0.002

Note: Only significant values ($p \leq 0.05$) are shown
[a] Non-detects are present in the data set
-- = $p > 0.05$

Table 5. Correlations between Concentrations of Metals in Paired Whole Body and Fillet Samples of Rainbow Trout

Metal	Spearman's ρ	*p* value	Significance of linear test (*p* value)	Form of the Relationship
Aluminum	-0.40	0.138		n/r
Antimony	0.85	**0.000**	0.02	Non-Linear
Arsenic	0.76	**0.001**	0.09	Linear
Barium	0.25	0.361		n/r
Beryllium	0.76	**0.001**	0.45	Linear
Cadmium	-0.43	0.113		n/r
Calcium	-0.10	0.721		n/r
Chromium	0.76	**0.001**	0.05	Linear
Cobalt	0.43	0.113		n/r
Copper	0.62	0.014	0.49	Linear
Iron	0.34	0.213		n/r
Lead	0.52	0.045	0.59	Linear
Magnesium	0.15	0.597		n/r
Manganese	0.36	0.193		n/r
Mercury	0.89	**0.000**	0.17	Linear
Nickel	0.22	0.425		n/r
Potassium	-0.44	0.101		n/r
Selenium	0.93	**0.000**	0.29	Linear
Silver	0.81	**0.000**	0.39	Linear
Uranium	0.39	0.146		n/r
Vanadium	0.10	0.733		n/r
Zinc	0.26	0.348		n/r

Notes:
Bold = experiment-wise $p < 0.05$
n/r = no relationship

Table 6. Correlations between Concentrations of Metals in Paired Whole Body and Fillet Samples of Walleye

Metal	Spearmans ρ	*p* value	Significance of linear test (*p* value)	Form of the Relationship
Aluminum	0.58	0.023	0.52	n/r
Antimony	0.65	0.009	0.24	n/r
Arsenic	0.76	**0.001**	0.44	Linear
Barium	-0.13	0.640	0.92	n/r
Beryllium	0.78	**0.001**	0.04	Non-Linear
Cadmium	0.33	0.228	0.54	n/r
Calcium	0.31	0.253	0.72	n/r
Chromium	0.25	0.373	0.43	n/r
Cobalt	-0.14	0.629	0.01	n/r
Copper	0.24	0.390	0.22	n/r
Iron	0.03	0.909	0.21	n/r
Lead	-0.19	0.495	0.91	n/r
Magnesium	-0.03	0.918	0.64	n/r
Manganese	-0.22	0.423	0.58	n/r
Mercury	0.96	**0.000**	0.33	Linear
Nickel	0.31	0.255	0.20	n/r
Potassium	0.23	0.400	0.34	n/r
Selenium	0.63	0.012	0.05	n/r
Silver	0.67	0.006	1.00	n/r
Uranium	-0.12	0.657	0.82	n/r
Vanadium	0.65	0.009	0.24	n/r
Zinc	0.68	0.005	0.82	n/r

Notes:
Bold = experiment-wise $p < 0.05$
n/r = no relationship

Table 7. Relationships between Metals Concentrations in Paired Samples of Gutless Whole Body and Gut/Gut Contents of Largescale Sucker

Analyte	Correlation P Value	Spearman's ρ	Significance of Linear Test	Nature of Correlation
Aluminum	**< 0.001**	0.72	0.406	Linear
Antimony	0.268	0.26		n/r
Arsenic	0.513	0.16		n/r
Barium	0.521	0.15		n/r
Beryllium	0.299	0.24		n/r
Cadmium	**< 0.001**	0.80	0.621	Linear
Calcium	0.334	-0.23	0.829	n/r
Chromium	0.467	0.17	0.438	n/r
Cobalt	**0.044**	0.46	0.294	Linear
Copper	**0.001**	0.67	**< 0.001**	Non-linear
Iron	**< 0.001**	0.84	**< 0.001**	Non-linear
Lead	**< 0.001**	0.89	**< 0.001**	Non-linear
Magnesium	0.944	0.02		n/r
Manganese	**< 0.001**	0.76	**< 0.001**	Non-linear
Nickel	0.132	0.35		n/r
Potassium	0.037	0.47		n/r
Selenium	0.329	0.23		n/r
Silver	0.182	0.31		n/r
Zinc	**< 0.001**	0.85	**< 0.001**	Non-linear

Notes:
Bold = experiment-wise $p < 0.05$
n/r = no relationship

Table 8. Mean Metal Concentrations in All Sediment Collected from within Each FSCA (mg/kg dw)

FSCA	Aluminum	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Uranium	Vanadium	Zinc
1	10000	16	780	1.6	59	26	920	89000	200	1600	0.18	12	6.9	27	32	6600
2	11000	16	730	2.0	54	24	880	82000	330	1600	0.18	13	5.0	40	29	7000
3	12000	10	340	1.5	34	12	280	51000	210	960	0.14	19	6.1	29	36	3600
4	12000	6.7	190	2.5	29	9.8	60	22000	130	440	0.60	23	5.7	30	35	330
5	13000	7.8	130	2.2	22	9.4	29	23000	68	510	0.29	19	4.0	32	29	270
6	13000	6.8	130	2.3	18	8.4	29	21000	68	590	0.34	15	3.9	36	28	280

Table 9. Mean Metal Concentrations in Sediment (without Deep Channel Sediment Data) Collected from within Each FSCA (mg/kg dw)

FSCA	Aluminum	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Nickel	Selenium	Uranium	Vanadium	Zinc
1	10000	16	780	1.6	59	26	920	89000	200	1600	0.18	12	6.9	27	32	6600
2	7700	13	400	2.2	31	13	390	45000	300	800	0.21	13	4.1	27	25	4000
3	11000	7.0	210	1.5	30	9.6	49	23000	72	400	0.18	23	5.2	24	36	350
4	10000	5.7	130	1.5	24	8.6	34	19000	69	400	0.39	21	4.7	25	31	190
5	11000	7.7	120	2.2	20	8.5	24	21000	63	450	0.27	17	3.6	30	26	250
6	12000	6.5	110	1.6	16	7.5	23	20000	51	500	0.27	13	3.8	32	25	220

Notes:
Tabulated concentrations are arithmetic means
FSCA = Fish Sample Collection Area

Table 10. Correlations (Spearman's ρ) between the Mean Concentration of Metals in All Sediment Samples Collected from within an FSCA and the Individual Whole Fish Concentrations

	Burbot		Largescale Sucker		Lake Whitefish		Hatchery Rainbow Trout		Wild Rainbow Trout		All Rainbow Trout		Walleye	
COPC	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value
Aluminum	0.61	**0.003**	-0.23	0.065	--	--	-0.32	0.214	0.36	0.202	0.256	0.164	0.23	0.218
Arsenic	-0.20	0.364	-0.10	0.418	-0.19	0.396	0.22	0.395	-0.05	0.869	0.241	0.192	-0.60	**<0.001**
Barium	-0.58	**0.005**	0.04	0.765	-0.23	0.293	0.22	0.401	0.40	0.158	0.501	0.004	-0.17	0.383
Cadmium	0.39	0.073	0.06	0.622	0.41	0.057	-0.17	0.515	0.24	0.418	0.106	0.572	0.26	0.166
Chromium	0.17	0.440	-0.08	0.523	-0.61	**0.003**	0.60	0.011	0.69	**0.006**	0.813	**<0.001**	-0.24	0.206
Cobalt	-0.04	0.849	0.20	0.103	-0.36	0.105	0.01	0.963	0.40	0.157	-0.036	0.849	-0.27	0.147
Copper	0.28	0.210	0.53	**<0.001**	0.05	0.819	0.57	0.018	0.41	0.147	0.750	**<0.001**	-0.45	0.012
Iron	-0.32	0.142	0.30	0.015	-0.32	0.144	0.57	0.017	0.38	0.179	0.571	0.001	-0.17	0.359
Lead	-0.22	0.322	0.47	**<0.001**	0.54	0.010	0.52	0.033	0.13	0.650	0.749	**<0.001**	0.15	0.424
Manganese	-0.41	0.058	0.39	**0.001**	-0.82	**<0.001**	0.50	0.040	0.15	0.611	0.242	0.189	-0.66	**<0.001**
Mercury	0.39	0.077	0.19	0.352	0.48	0.023	0.49	0.047	-0.17	0.554	0.447	0.012	0.61	**<0.001**
Nickel	-0.13	0.555	-0.22	0.296	0.27	0.225	-0.19	0.476	-0.27	0.346	-0.273	0.138	-0.10	0.600
Selenium	0.80	**<0.001**	0.30	0.151	0.43	0.046	0.81	**<0.001**	0.87	**<0.001**	0.748	**<0.001**	-0.24	0.201
Uranium	-0.04	0.866	-0.48	0.016	0.05	0.812	-0.44	0.074	-0.10	0.739	-0.261	0.156	-0.22	0.239
Vanadium	0.16	0.478	0.29	0.152	--	--	--	--	--	--	--	--	--	--
Zinc	-0.21	0.347	0.73	**<0.001**	-0.13	0.568	-0.47	0.059	-0.297	0.303	-0.253	0.170	0.08	0.685

Table 11. Correlations (Spearman's ρ) between the Mean Concentration of Metals in Sediment (without Deep Channel Sediment Data) Collected from within an FSCA and Individual Whole Fish Concentrations

	Burbot		Largescale Sucker		Lake Whitefish		Hatchery Rainbow Trout		Wild Rainbow Trout		All Rainbow Trout		Walleye	
COPC	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value
Aluminum	0.61	**0.003**	-0.29	0.017	0.00	0.989	-0.32	0.214	0.22	0.441	0.147	0.430	0.00	0.994
Arsenic	0.08	0.725	-0.05	0.680	0.00	0.987	0.37	0.148	0.20	0.489	0.353	0.052	-0.68	**<0.001**
Barium	-0.58	**0.005**	0.04	0.765	-0.23	0.293	0.22	0.401	0.40	0.158	0.501	0.004	-0.17	0.383
Cadmium	-0.14	0.523	0.36	**0.004**	-0.58	**0.005**	-0.46	0.066	-0.08	0.778	-0.445	0.012	-0.32	0.081
Chromium	0.17	0.440	-0.08	0.523	-0.61	**0.003**	0.60	0.011	0.69	**0.006**	0.813	**<0.001**	-0.24	0.206
Cobalt	-0.04	0.849	0.20	0.103	-0.36	0.105	0.01	0.963	0.40	0.157	-0.036	0.849	-0.27	0.147
Copper	0.21	0.344	0.51	**<0.001**	0.13	0.552	0.87	**<0.001**	0.41	0.142	0.835	**<0.001**	-0.44	0.015
Iron	-0.18	0.410	0.23	0.069	-0.39	0.075	0.56	0.020	0.38	0.179	0.577	**0.001**	-0.29	0.126
Lead	-0.20	0.362	0.84	**<0.001**	0.49	0.020	0.28	0.268	0.48	0.080	0.708	**<0.001**	0.22	0.247
Manganese	0.11	0.639	0.47	**<0.001**	-0.20	0.371	-0.10	0.692	0.08	0.788	0.071	0.703	-0.21	0.276
Mercury	0.36	0.104	0.20	0.342	0.42	0.053	0.38	0.129	-0.17	0.570	0.416	0.020	0.65	**<0.001**
Nickel	-0.14	0.538	-0.31	0.127	0.27	0.230	0.19	0.463	-0.27	0.346	-0.108	0.565	-0.20	0.295
Selenium	0.70	**<0.001**	0.42	0.038	0.34	0.123	0.54	0.024	0.86	**<0.001**	0.693	**<0.001**	-0.31	0.096
Uranium	0.18	0.425	-0.25	0.232	-0.05	0.824	-0.44	0.074	-0.13	0.646	-0.354	0.050	-0.11	0.576
Vanadium	0.13	0.559	0.30	0.146	--	--	--	--	--	--	--	--	--	--
Zinc	-0.02	0.939	0.49	0.013	0.19	0.388	-0.07	0.799	0.43	0.127	-0.002	0.993	-0.22	0.247

Notes:
COPC - chemical of potential concern
-- = Non detects in fish tissue exceeded 50 percent
Bold = experiment-wise $p < 0.05$

Table 12. Correlations (Spearman's ρ) between the Mean Concentration of Metals in All Sediment Samples Collected from within an FSCA and the Individual Fillet Concentrations

	Hatchery Rainbow Trout		Wild Rainbow Trout		All Rainbow Trout		Walleye	
COPC	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value
Aluminum	--	--	--	--	--	--	--	--
Arsenic	--	--	0.18	0.670	0.506	0.054	-0.52	0.046
Barium	--	--	--	--	--	--	--	--
Cadmium	--	--	--	--	--	--	--	--
Chromium	-0.294	0.522	0.78	0.021	0.692	**0.004**	0.05	0.867
Cobalt	--	--	0.10	0.821	-0.511	0.051	0.28	0.321
Copper	0.882	**0.009**	0.49	0.221	0.763	**0.001**	0.21	0.449
Iron	0.073	0.877	0.40	0.331	0.493	0.062	0.45	0.096
Lead	--	--	--	--	--	--	--	--
Manganese	0.000	1	-0.39	0.337	-0.267	0.335	0.60	0.017
Mercury	0.874	0.010	0.63	0.095	0.759	**0.001**	0.50	0.056
Nickel	--	--	--	--	--	--	-0.36	0.187
Selenium	0.874	0.010	0.77	0.024	0.881	**<0.001**	-0.13	0.636
Uranium	-0.091	0.846	-0.87	**0.005**	-0.781	**0.001**	-0.03	0.904
Vanadium	--	--	--	--	--	--	--	--
Zinc	0.364	0.422	0.85	**0.007**	0.711	**0.003**	0.62	0.014

Table 13. Correlations (Spearman's ρ) between the Mean Concentration of Metals in Sediment (without Deep Water Sediment Data) within an FSCA and Individual Fillet Concentrations

	Hatchery Rainbow Trout		Wild Rainbow Trout		All Rainbow Trout		Walleye	
COPC	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value	Spearman's ρ	P-Value
Aluminum	--	--	--	--	--	--	--	--
Arsenic	--	--	0.180	0.670	0.506	0.054	-0.521	0.046
Barium	--	--	--	--	--	--	--	--
Cadmium	--	--	--	--	--	--	--	--
Chromium	-0.294	0.522	0.784	0.021	0.692	**0.004**	0.047	0.867
Cobalt	--	--	0.096	0.821	-0.511	0.051	0.275	0.321
Copper	0.882	**0.009**	0.487	0.221	0.763	**0.001**	0.211	0.449
Iron	0.073	0.877	0.397	0.331	0.493	0.062	0.446	0.096
Lead	--	--	--	--	--	--	--	--
Manganese	0.000	1	-0.168	0.691	-0.134	0.635	0.430	0.109
Mercury	0.874	0.010	0.629	0.095	0.759	**0.001**	0.504	0.056
Nickel	--	--	--	--	--	--	-0.360	0.187
Selenium	0.874	0.010	0.774	0.024	0.881	**<0.001**	-0.133	0.636
Uranium	-0.091	0.846	0.097	0.820	-0.116	0.681	0	1
Vanadium	--	--	--	--	--	--	--	--
Zinc	0.364	0.422	0.850	**0.007**	0.711	**0.003**	0.618	0.014

Notes:
COPC - chemical of potential concern
-- = Non detects in fish tissue exceeded 50 percent
Bold = experimentwise $p < 0.05$

Table 14. Types of Anomalies Recorded by the Smith et al. (2002) External Examination Protocol

Head	Gill and Opercula	Body	Eye	Fin	Barbels
Normal head	Normal	Normal	Normal	Normal	Normal
Deformed head	Slight shortening	Raised growth(s)	Exophthalmic	Mild erosion	Missing
Upper lip growth	Severe shortening	Reddened lesion(s)	Opaque	Severe erosion	Stubbed
Lower lip growth	Frayed	Spinal deformities	Missing	Frayed	Deformed
Swollen nare	Marginate	Hemorrhagic body	Hemorrhagic	Hemorrhagic	
	Pale	Focal discoloration	Emboli	Emboli	
		Body fungus			
		White spot(s)			
		Leech(es)			
		Black spot(s)			
		Anchor worm(s)			

Table 15. Incidence of Anomalies[a] Observed in External Examinations of Fish Collected by EPA in 2005 (USEPA 2007)

Species	FSCA	Number of Fish Examined	Number of Fish with Anomalies	Percent of Fish with Anomalies	Average Anomalies/Fish	Average Anomalies/ Affected Fish
Largescale Sucker	1	27	19	70	1.1	1.6
	2	21	17	81	1.4	1.8
	3	27	25	93	2.1	2.3
	4	25	22	88	1.9	2.2
	5	18	18	100	2.6	2.6
	6	30	28	93	2.1	2.3
Burbot	1	1	1	100	1.0	1.0
	2	11	8	73	0.9	1.3
	3	25	17	68	0.8	1.2
	4	22	16	73	1.5	2.0
	5	27	23	85	1.4	1.7
	6	25	16	64	1.5	2.3
Walleye	1	25	12	48	0.5	1.0
	2	44	13	30	0.5	1.7
	3	30	9	30	0.4	1.3
	4	25	12	48	0.8	1.7
	5	15	11	73	1.4	1.9
	6	45	29	64	1.3	2.1
Rainbow Trout	1	25	16	64	0.80	1.3
	1	26	6	23	0.35	1.5
	2	27	18	67	0.81	1.2
	4	30	18	60	0.77	1.3
	5	32	31	97	1.81	1.9
	6	25	20	80	1.64	2.1
Mountain Whitefish	1	32	19	59	1.00	1.7
Lake Whitefish	2	32	21	66	0.84	1.3
	3	30	6	20	0.23	1.2
	4	35	25	71	1.09	1.5
	5	27	14	52	0.85	1.6
	6	6	2	33	0.67	2.0

Notes:
a Counts of anomalies reported in this table do not include anomalies that were recorded in the "notes" sections of the field forms.
FSCA - fish sample collection area

Table 16. List of Water Bodies, Species, and Analytes in the Fish Tissue Reference Area Database

Water Body	Species	Chemical Analytes
Bonaparte Lake	Black Crappie	Arsenic
Banks Lake	Bridgelip Sucker	Cadmium
Bead Lake	Burbot	Cobalt
Buffalo Lake	Channel Catfish	Copper
Columbia River, downstream of Grand Coulee Dam	Common Carp	Lead
Curlew Lake	Lake Whitefish	Mercury
Deer Lake	Largemouth Bass	Selenium
Entiat River	Largescale Sucker	Zinc
Frenchman Hills Lake	Mountain Whitefish	Total PCBs
Lake Chelan	Northern Pikeminnow	Dioxins
Lake Wallula	Peamouth	Furans
Liberty Lake	Rainbow Trout	PBDEs
Long Lake	Smallmouth Bass	*alpha* -Chlordane
Loon Lake	Walleye	*gamma* -Chlordane
Methow River	Yellow Perch	Dachtal
Newman Lake		DDD
Okanogan River		DDE
Palmer Lake		DDT
Palouse River		Dieldrin
Patterson Lake		Endrin
Pend Oreille River		Heptachlor epoxide
Potholes Reservoir		Hexachlorobenzene
Rock Lake		*gamma* -Lindane
Roses Lake		*alpha* -Lindane
Scootney Reservoir		*cis* -Nonachlor
Snake River		*trans* -Nonchlor
Sprague Lake		Toxaphene
Stan Coffin Lake		
Walla Walla River		
Wenatchee River		

Table 17. Summary Statistics for Chemical Concentrations in Fish from Reference Areas and the UCR

Walleye		Reference Areas				UCR			
		Fillet				Fillet			
Chemical	Units	N	Min	Max	Mean	N	Min	Max	Mean
Mercury	µg/kg ww	6	51	640	210	15	180	420	270
Total PCBs	µg/kg ww	5	2.2a	46	12b	15			36

Largescale Sucker		Reference Areas				UCR			
		Whole body				Whole body			
Chemical	Units	N	Min	Max	Mean	N	Min	Max	Mean
Mercury	µg/kg ww	6	46.8	295	184	29	77	300	190

Rainbow Trout		Reference Areas				UCR				UCR			
		Fillet				Fillet				Hatchery Trout Fillet			
Chemical	Units	N	Min	Max	Mean	N	Min	Max	Mean	N	Min	Max	Mean
Mercury	µg/kg ww	5	5.8	295	102	9	65	120	88	8	63	122	86
Total PCBs	µg/kg ww	4	2.4a	8.7	5.2b	9			63	8			44

Notes:
ww = wet weight
a Minimum was non-detect = 1/2 detection limit
b Calculated using non-detects = 1/2 detection limit

Table 18. Concentrations (µg/kg ww) of Total PBDEs[a] in Fillets of Fish in the UCR Region

Species		Year	N	Mean	Min	Max
UCR						
Largescale Sucker	UCR	2005	1	9.8	--	--
Rainbow Trout	UCR	2005	1	0.92	--	--
Walleye	UCR	2005	1	1.5	--	--
Lake Whitefish	UCR	2005	1	18	--	--
Reference Areas in Washington						
Common Carp	Reference Areas	2005	2	16	2.8	30
Common Carp	Reference Areas	2006	1	0.09	--	--
Lake Whitefish	Reference Areas	2005	1	1.9	--	--
Largemouth Bass	Reference Areas	2004	1	0.47	--	--
Largemouth Bass	Reference Areas	2005	3	2.8	0.58	6.2
Largemouth Bass	Reference Areas	2006	3	0.37	0.29	0.46
Largescale Sucker	Reference Areas	2005	4	8.7	0.48	29
Mountain Whitefish	Reference Areas	2004	3	32	7.2	50
Mountain Whitefish	Reference Areas	2005	1	11.0	--	--
Northern Pikeminnow	Reference Areas	2004	1	11	--	--
Northern Pikeminnow	Reference Areas	2005	5	14	4.1	42
Peamouth	Reference Areas	2004	1	2.1	--	--
Peamouth	Reference Areas	2005	3	4.9	0.29	12
Rainbow Trout	Reference Areas	2004	1	0.99	--	--
Smallmouth Bass	Reference Areas	2005	4	4.1	0.62	8.6
Walleye	Reference Areas	2005	3	0.72	0.3	1.4
Yellow Perch	Reference Areas	2004	1	6.2	--	--
Yellow Perch	Reference Areas	2005	2	0.52	0.44	0.6
Yellow Perch	Reference Areas	2006	2	1	0.28	1.8
Spokane River						
Rainbow Trout	Plante Ferry	2005	3	90	65	107
Rainbow Trout	Misson Park	2005	3	30	27	32
Mountain Whitefish	Misson Park	2005	3	368	355	391
Rainbow Trout	Ninemile	2005	3	418	292	564
Mountain Whitefish	Ninemile	2005	3	1059	905	1222
Mountain Whitefish	Upper Long Lake	2005	3	175	161	198
Brown Trout	Upper Long Lake	2005	1	159	--	--
Smallmouth Bass	Upper Long Lake	2005	1	42	--	--
Mountain Whitefish	Lower Long Lake	2005	6	122	56	228
Smallmouth Bass	Lower Long Lake	2005	3	57	34	92
Upper Columbia River in British Columbia						
Mountain Whitefish	Genelle	1992	2	6.1	4.6	--
Mountain Whitefish	Genelle	1995	5	19.1	5.3	--
Mountain Whitefish	Genelle	2000	12	71.8	19.0	--
Mountain Whitefish	Genelle	2002	5	107	69.5	142.0
Mountain Whitefish	Genelle	2004	12	130	60.1	279.0
Rainbow Trout	Genelle	2003	10	18.4	10.5	33.9
Mountain Whitefish	Beaver Creek	1992	4	4.5	1.8	--
Mountain Whitefish	Beaver Creek	2000	9	29.2	15.4	--
Mountain Whitefish	Beaver Creek	2002	5	90.8	67.9	117
Mountain Whitefish	Beaver Creek	2004	12	85.5	15.9	351

Table 18. Concentrations (µg/kg ww) of Total PBDEs[a] in Fillets of Fish in the UCR Region

Species		Year	N	Mean	Min	Max
Upper Columbia River in British Columbia (cont'd)						
Rainbow Trout	Beaver Creek	2003	10	17.3	14.4	22.6
Mountain Whitefish	Kootenay Lake	1998	5	14.3	10.4	--
Mountain Whitefish	Slocan Lake	1996	3	0.9	0.2	--
Largescale Sucker	Kootenay River	2000	6	5.0	1.9	--

Source: Rayne et al. (2003); Johnson et al. (2006); Hatfield Consultants (2008)

Notes:

PBDE - polybrominated diphenyl ether

a Total PBDE concentration calculated as the sum of detected congeners