Data Report for the Scoping Study on Metal Contaminant Levels in Sediment and Concurrent Aquatic Habitat Evaluation for the Palmerton Zinc Natural Resource Damage Assessment, Palmerton, Pennsylvania

Prepared by

The Palmerton Natural Resource Trustee Council

Commonwealth of Pennsylvania
Department of Environmental Protection
Department of Conservation and Natural Resources
Fish and Boat Commission
Game Commission

U.S. Department of Commerce
National Oceanic and Atmospheric Administration

U.S. Department of the Interior
National Park Service
Fish and Wildlife Service

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Introduction

Metals released from the Palmerton Zinc Pile Superfund Site (the Site) have been transported aerially and hydrologically throughout the area's environment, exposing natural resources to these contaminants. Concentrations of metals (e.g., zinc and cadmium) in sediment have the potential to cause injury to biota in aquatic ecosystems such as Aquashicola Creek and the Lehigh River. For example, an independent scientific investigation by Carline and Jobsis (1989) and a Site-related risk assessment conducted by the U. S. Environmental Protection Agency (2001) showed that sediment metal concentrations in the vicinity of the Site were elevated above concentrations typically encountered in Pennsylvania. In 1998, the U. S. Army Corps of Engineers dredged approximately 0.8 miles of lower Aquashicola Creek in Palmerton Borough for flood control. This action disturbed and removed substrate, and the impact on sediment quality had not been reassessed. Evidence of metals concentrations of concern and data gaps near the Site (e.g., limited metals data exist for the Lehigh River) prompted the Palmerton Trustee Council and Blasland, Bouck & Lee, Inc. (BB&L) acting for Viacom, Inc. (now CBS), to jointly execute the Sediment Sampling and Analysis Plan (Palmerton Trustee Council 2004) on October 25, 26 and 27, 2004. This broad scale sediment characterization was designed to determine sediment metals concentrations upstream, adjacent to, within, and downstream of the Site. Post-dredging sediments in lower Aquashicola Creek following 1998 removal were also reevaluated through Plan execution. The Sediment Sampling and Analysis Plan (Palmerton Trustee Council 2004) described the locations and methodology that were used to obtain and analyze sediments in this study.

Objectives

Objectives of this sediment scoping study are the same objectives found in the Sampling and Analysis Plan (Palmerton Trustee Council 2004) that was completed to guide the sediment characterization effort. Sampling scope was expanded beyond the U. S. EPA (2001) draft Ecological Risk Assessment to systematically examine the variability of metals concentrations over a relatively broad geographic area. Objectives from the Sampling and Analysis Plan are paraphrased below:

- Characterize sediment metals concentrations in depositional areas in the vicinity of the Site that may affect Trustee resources occurring in the Lehigh River and tributaries in the vicinity of Palmerton, Pennsylvania. A geographic scope expanded beyond the U. S. Environmental Protection Agency (2001) study provided information on background concentrations and addressed some data gaps.
- Analyze sediment on a total dry weight basis for arsenic, cadmium, copper, lead and zinc, which are contaminants associated with the Site. Also analyze for total chromium, iron and aluminum, possible indicators of mining and metal-plating and pigment industry influences that could affect sediment in waters near the Site. The site-related contaminants of concern as well as metals associated with other activities were therefore identified and sampled.
- Measure total organic carbon, grain size, and percent moisture. Correlations between metals concentrations, total organic carbon and grain size may be determined if desired.
- Sample upstream and downstream of significant tributaries and potential sources of contaminant inputs. Sample both sides of the stream as well as the center of the stream when flows may cause different depositional patterns. Standard sampling techniques bracketed potential sources of contamination and showed the distribution of contaminants across the stream width.
- Concurrently characterize aquatic habitat quality in the immediate vicinity of the sediment sampling site. This exercise provided a measure of habitat quality and is

especially important if biological community data is to be correlated with sediment metal results.
- Determine latitude and longitude of sampling locations, which allows a georeferenced dataset to be developed.

Methods

Sediment sampling methods

Sediment samples were located upstream, adjacent to, within and downstream of the Palmerton Site in order to ascertain the concentrations of eight metals in stream sediments. Sample location latitude and longitudes were determined using hand-held GPS units and coordinates, and were incorporated into site-related GIS maps.

Two teams composed of a combination of Trustee and BB&L representatives performed sampling activities on October 25 – 27, 2004. Sediment sampling depths and standard operating procedures were followed as detailed in the Palmerton Trustee Council (2004) Plan. Samples were taken from the vicinity of Jim Thorpe on the Lehigh River, south to Coplay, which is downstream of the Northampton Dam. Sampling teams worked eastward from the mouth of Aquashicola Creek upstream to Buckwha Creek and points upstream of Little Gap. Figure 1 shows sediment sample and habitat assessment locations and the geographic scope of the sampling effort. Table 1 provides GPS coordinates and sample location descriptions.

Two or three inch Lexan® tubes driven to the bottom of fine deposits were used to obtain all samples. Sample cores were segregated into approximate one-foot increments. Multiple depth-specific sample cores were composited in polyethylene bags to obtain sufficient sample quantity and then placed in appropriate glass sample jars. Jars were placed in coolers, iced and shipped to EnChem, Inc. Laboratory in Kimberly, Wisconsin for analysis. Chain-of-custody documentation was performed. Sediments were sampled at locations detailed in Table 1 and Figure 1 and were analyzed for total aluminum, arsenic, cadmium, chromium, copper, iron, lead and zinc. Split samples were taken to represent 10% of the total number of samples, resulting in five samples being sent to Lancaster Laboratories, located in Lancaster, Pennsylvania, for comparative analysis. Four duplicate samples of origin unknown to the laboratory were collected and included in the samples submitted to EnChem.

Sediment sample analyses

Upon receipt of sediment samples, Enchem and Lancaster Laboratories used preparation method SW-846 3051 for metals. The analytical method for sediment metals was SW-846 6020, also known as Inductively Coupled Plasma – Mass Spectrometry. Lancaster Laboratories used method SW-846 6010B, an Inductively Coupled Plasma technique for aluminum, iron and zinc. Percent moisture was determined using method SM-2540G M by EnChem and using EPA 160.3 modified methodology by Lancaster. Total Organic Carbon was ascertained by EnChem with method SW-846 9060 (combustion, infared spectrometry) and by Lancaster Laboratory with method SM18 5310B (high temperature combustion), modified.

Habitat Characterization methods

Habitat characterization was performed by the two sampling teams using U. S. EPA Rapid Bioassessment Protocols and forms (Barbour et. al 1999). Sampling teams completed the first assessment jointly to standardize methods, and then worked independently to complete habitat characterization tasks coincident with sediment sampling.

Results

Rapid Bioassessment Protocol habitat evaluation

Habitat scores are summarized in Table 2 and Figure 2 for the Lehigh River and Table 3 and Figure 3 for Aquashicola Creek, Mill Creek and Buckwha Creek. Habitat scores in the Lehigh River reaches ranged from suboptimal to low optimal (Figure 2), which indicates good habitat. Scores in the Bowmanstown to Palmerton area were slightly lower than up- or downstream, but differences were minimal. Scores in Aquashicola Creek and tributaries were primarily in the suboptimal range (Figure 3), which indicates good habitat. Notable exceptions occurred where marginal scores showed poorer habitat in a disrupted area at AC-185/186 between the Site Cinder Bank and Stoney Ridge Materials Aggregate Sales and BC-194 on Buckwha Creek at a disturbed area downstream of the new bridge at Kunkletown.

Particle sizes were visually evaluated as part of the habitat assessment. Particle size distribution in Figures 4 and 5 showed that a combination of gravel and cobble were predominant throughout the stream reaches assessed. Depositional areas dominated by sand, silt and clay fines were relatively uncommon, even though these areas were actively sought as sediment sample locations.

Two authors (Sopper 1989 and Oyler 1988) estimated that 12 to 24 inches of contaminated soil have been eroded from Blue Mountain in recent decades. Stony Ridge has also suffered from severe erosion (PA DCNR, et al. 2003). Given the amount of material that has washed off Blue Mountain and Stony Ridge in the vicinity of the Palmerton Zinc Pile Superfund Site, the relatively high and consistent habitat scores, and the relatively large particle sizes (Figures 4 and 5); a strong case can be made that the Lehigh River, Aquashicola Creek and its tributaries are very effective sediment moving systems. This suggests that sampling may be necessary a significant distance downstream to fully characterize impacts from transported sediments.

Sediment analysis

Results

A total of 57 sediment samples, plus 4 duplicates and 5 split samples were analyzed. Complete results of sediment analyses for total aluminum, arsenic, cadmium, chromium, copper, iron, lead and zinc, as well as percent moisture, total organic carbon and grain size performed by EnChem, Inc. are shown in Table 4.

Sediment quality guidelines and predicted toxicity

The Trustee Council has agreed that presentation of results could be enhanced by providing an indication of relative predicted toxicity of sediments using peer-reviewed literature. One widely used tool provided by MacDonald et al. (2000) was selected for use in this report by the Trustees. MacDonald et al. (2000) used seventeen high quality data sets and previously established sediment quality guidelines (SQGs) to develop two related SQGs described as the Threshold Effects Concentration (TEC) and Probable Effects Concentration (PEC). The TEC is the concentrations below which toxic effects would not be expected and can be used to predict the absence of sediment toxicity. The PEC is the concentration above which toxic effects would be expected and can be used to predict the presence of sediment toxicity. MacDonald et al. (2000) indicated that SQGs function as a tool that could be used to identify contaminant "hotspots", that the magnitude by which results exceed SQGs can assist reviewers' evaluation of potential dataset toxicity, and that the predictive ability of the SQGs should increase when multiple contaminants of concern are evaluated together in sediment results analysis. The Palmerton Trustee Council (2004) recognized in their Palmerton Zinc Pile Superfund Site Natural Resource Damage Assessment Plan that biotic community and sediment exposure and effects studies may be conducted to verify toxicity that may be predictively indicated by use of

SQGs. The SQGs of MacDonald et al. (2000) were used to provide ranges used to consider Palmerton sediment data. The TEC and PEC values for contaminants of concern expressed as dry weight are shown below.

Metal	TEC	PEC
Arsenic	9.79 mg/kg	33.0 mg/kg
Cadmium	0.99 mg/kg	4.98 mg/kg
Chromium	43.4 mg/kg	111 mg/kg
Copper	31.6 mg/kg	149 mg/kg
Lead	35.8 mg/kg	128 mg/kg
Zinc	121 mg/kg	459 mg/kg

SQGs for aluminum and iron were not developed by MacDonald et al. (2000). The following concentration ranges, expressed as mg/kg dry weight, were developed using Trustee judgement to break the data into reasonably descriptive categories that subdivided the range of observed data.

	Low	Medium	Elevated	High
Aluminum	< 5,000	5,001-10,000	10,001-20,000	not applicable
Iron	<10,000	10,001-20,000	20,001-40,000	>40,000

Table 5 translates concentrations to relative toxicity using the predictive toxicity of MacDonald et. al (2000) as its basis. For the purposes of this report, concentrations less than the TEC were indicated in terms of relative toxicity as “none”, TEC to PEC relative toxicity was “low”, and PEC to 2 times PEC was termed “moderate” relative toxicity. Higher results, from 2 to 10 times the PEC, were differentiated as “high” relative toxicity and results more than 10 times the PEC were predicted to be “very high” relative toxicity.

Organic carbon
Sediment metals results were not normalized based on organic carbon content. The U.S. EPA (2001) Site-related sediment samples showed poor correlation between organic content and metals concentrations.   MacDonald, et al. (2000) did not use organic carbon-normalized data in development of their SQGs because empirical evidence showed the predictive value of SQGs was at least as good for non-normalized data.

Results summary
Some metals results were highly variable; others were not. Zinc exhibited the largest variation with results showing differences of three orders of magnitude (25 mg/kg to 23,000 mg/kg). Zinc also had the highest portion of samples (67%) in the moderate to very high relative toxicity range (exceeding the PEC). Percentages of samples in the moderate to very high predicted sediment toxicity range in declining order were cadmium (53%), lead (30%), copper (21%), arsenic (14%), and chromium (2%). Incidence of sediment samples falling within the defined SQG ranges are found in Table 6 for each metal and in Table 7 for each geographic area.

The Trustees have summarized predicted sediment toxicity levels. Table 6 shows the overall incidence of arsenic, cadmium, chromium, copper lead and zinc among three ranges of SQGs throughout the assessment area. Moderate, high and very high toxicity categories from Table 5 were consolidated for this summary since all three categories represent concentrations that exceed the PEC and sediment toxicity would be predicted.

- Incidence of samples with predicted toxicity was notably higher for zinc (67%) and cadmium (53%).
- Other metals in decreasing incidence of toxicity were lead (30%), copper (21%), arsenic (14%) and chromium (2%).

The same three ranges of predicted toxicity were used to individually examine the four streams that were sampled. Table 7 combined all metals within the Lehigh River, Aquashicola Creek and two tributaries, Mill Creek and Buckwha Creek, and summarizes the number of samples in the same three predicted toxicity categories used in Table 6.

- Aquashicola Creek and Mill Creek, had the highest incidence of samples with predicted toxicity at 48% and 50%, respectively.
- Buckwha Creek, upstream from the Palmerton Zinc Pile Site, produced sediment samples with the lowest predicted toxicity. No toxicity was predicted in 61% of samples.
- Lehigh River results showed 18% of metals samples with moderate or higher predicted toxicity. Most of these samples were located downstream of the defunct West Smelting Plant at Palmerton (Tables 1 and 4).

Predicted toxicity and geographic distribution

Maps showing sediment sample locations and relative toxicity are informative in showing where higher probability of toxicity exists. Figures 6 through 13 are GIS maps that illustrate zinc, cadmium, copper, lead, arsenic, chromium, iron, and aluminum results respectively using the predictive toxicity ranges established in Table 5. Collective results from the mapping exercise indicate the following key points:

- One locale stood out as the focal area of elevated Site-related metals concentrations in stream sediments. High to very high relative sediment toxicity, particularly with zinc (Figure 6) and cadmium (Figure 7), were shown by study samples (samples AC-185 &186 and AC-171 through AC-179) in Aquashicola Creek <u>from the upstream end of the Cinder Bank to the creek mouth</u>.
- Moderate to high predicted zinc and cadmium toxicity (Figures 6 and 7 respectively) were found downstream of the focal area delineated above. The area of moderate to high relative zinc and cadmium toxicity extended upstream in Aquashicola Creek to Little Gap near the confluence of Buckwha and Aquashicola Creeks and downstream in the Lehigh River from the West Plant (at the SW edge of Palmerton) downstream to Coplay where sampling was terminated.
- Zinc and cadmium results (Table 4 and Figures 6 and 7) were higher along the east bank of the Lehigh River adjacent to Palmerton (locations LR-208 and LR-209) than a corresponding location on the opposite bank (LR-210).
- Notable occurrences of zinc samples of moderate toxicity were found upstream of Palmerton at LR-197 near Jim Thorpe and LR-200 below the mouth of Pohopoco Creek.
- Iron and aluminum displayed concentrations termed “medium” through the preponderance of the geographic area covered by this report. Elevated to high concentrations, however, were common in lower Aquashicola Creek, Mill Creek and the Lehigh River in the vicinity of Palmerton and location in Buckwha Creek nearest to the mouth. The focal area identified under the first bullet item for Site-related metals showed a high degree of overlap with higher iron and aluminum concentrations.

The U. S. EPA (2001) sediment results from 1997 for similar locations on Aquashicola Creek were comparable to results of this study. The same focal area of greatly elevated metals was delineated from the upstream limit of the Cinder Bank downstream to the mouth. The Corps of Engineers 1998 Aquashicola Creek dredging project, which occurred between the two sampling efforts, did not appear to reduce later sediment metals concentrations. Limited Lehigh River sediment sample results from 1997 (U. S. EPA 2001) mirrored 2004 sample results. Zinc and cadmium in particular were elevated at and downstream of the West Smelter location. It is notable that at sample locations near Cementon, 1997 zinc (1,500 mg/kg) and cadmium (11 mg/kg) results (U. S. EPA 2001) were nearly identical to 2004 zinc (1,500 mg/kg at LR-215) and cadmium results (9 mg/kg at LR-215) shown in Table 4. A change in metal concentrations over time was not noted between 1997 (U. S. EPA 2001) and 2004 sample sets.

Box and whisker plots of results
Box-and-whisker plots for 2004 results showing the 10th to 90th percentile range of data and the 25th, median, and 75th percentile values are found in Figure 14 for zinc, cadmium and copper and in Figure 15 for lead, arsenic and chromium. Geographic areas were partitioned to better evaluate metals concentrations in relation to the Palmerton Zinc Pile Site. The primary benefit of box-and-whisker plots is the ability to compare like statistics for the range of data in different geographic areas.

- The Lehigh River was divided using the West Plant as a breakpoint into an upper section (sample LR-205 and lower numbered samples) and a lower section (sample LR-207 and higher numbered samples). LR206 was the location of the recently removed low head dam at Palmerton. No sediment was sampled here, so LR-206 was not part of the analysis.
- The upstream limit of the Cinder Bank was used as a breakpoint for Aquashicola Creek. Upper Aquashicola Creek included AC-189 and higher numbered samples, including Buckwha Creek. Lower Aquashicola Creek included AC-188 and lower numbered samples, including Mill Creek.
- No overlap of second and third quartiles (25th to 75th percentile data values) occurred for zinc and cadmium in the Upper and Lower Lehigh River. This separation highlights the large difference in zinc and cadmium concentrations upstream and downstream of Palmerton for the middle 50% of data. Other Lehigh River metals, with the exception of chromium, lacked separation in results.
- The magnitude of differences in data ranges for metals in Upper and Lower Aquashicola Creek was very pronounced for zinc, cadmium, copper, lead and arsenic. The 90th percentile concentration values for zinc, cadmium, lead and arsenic in upper Aquashicola Creek were less than the 25th percentile values for the same metals in lower Aquashicola Creek. For copper, the 90th percentile concentration value for upper Aquashicola samples was less than the median (50th percentile) for lower Aquashicola.
- Aluminum and iron concentrations (Table 4 and Figures 12 and 13) were somewhat elevated throughout the study area, but higher concentrations were found in the same Aquashicola Creek focal area as indicated above, as well as in the Lehigh River adjacent to and immediately downstream of Palmerton. Similar results were noted by the U.S. EPA (2001) in 1997 samples.

Quality assurance/quality control
Results of sediment duplicate and split samples are shown in Table 8. EnChem Laboratory metals results for four duplicate samples had a mean variation of 8.9% from the original result. Only 4 of 32 metals duplicate sample results exceeded a value 15% from the original sample result. Sediment metals results of original samples and split samples analyzed by Lancaster Laboratories had a mean variation of 18.1% from the original EnChem result. A total of 18 of 40 Lancaster Laboratory results for metals varied 10% or less from EnChem results. Nearly half the sample results, 17 of 40 varied more than 15% between the two results. No trend was exhibited with regard to split samples results being lower or higher than the original sample results. Total organic carbon (TOC) analysis showed the highest variability. This should not be a critical issue since results were not normalized to TOC content in this report.

Use of sediment scoping results
Discussion of these results, particularly with regard to predicted and actual toxicity, is expected to occur as additional studies associated with the *Palmerton Zinc Pile Superfund Site Natural Resource Damage Assessment Plan* (Palmerton Trustee Council 2004) are developed.

Tables and Figures

Table 1. Sediment sample locations in the vicinity of the Palmerton Zinc Pile Superfund Site, October 25-27, 2004

	Sample ID	Depth ID	Latitude	Longitude	Sample Area Description	Sample Point Description
Lehigh River	LR-197	0-1	40° 51' 51.4"	75° 43' 13.7"	W band between Jim Thorpe and Packerton	fringe deposit inside of bend
	LR-198	0-1	40° 49' 29.0"	75° 41' 38.5"	W bank just downstr Lehighton STP & mouth Mahoning Ck	downstr end of point bar between backwater & main channel
	LR-199	0-1	40° 49' 28.1"	75° 41' 31.6"	E bank just dwnstr LR198. Just downstr park/ballfield	fringe deposit along water's edge
	LR-200	0-1	40° 48' 55.0"	75° 40' 19.0"	E bank 50m dwnstr Pohopoco Ck	fine sand/silt deposit
	LR-201	0-1	40° 48' 41.9"	75° 40' 12.4"	E bank 450m downstr Pohopoco Ck	fringe deposit at water's edge
	LR-202	0-1	40° 48' 00.5"	75° 40' 13.9"	W bank 200m upstr Rt 895 bridge at Bowmanstown	fringe deposit at bank indentation
	LR-203	0-1	40° 47' 49.8"	75° 39' 57.8"	E bank at Bowmanstown downstr of Fireline Creek	collected from large depositional area at water's edge
	LR-203	1-2	40° 47' 49.8"	75° 39' 57.8"	E bank at Bowmanstown downstr of Fireline Creek	collected from large depositional area at water's edge
	LR-204	0-1	40° 47' 38.1"	75° 39' 30.9"	E side of river channel	end of point bar at dwnstr end of island
	LR-204	1-2	40° 47' 38.1"	75° 39' 30.9"	E side of river channel	end of point bar at dwnstr end of island
	LR-205	0-1	40° 47' 21.8"	75° 39' 01.6"	E bank at dwnstr end of cobbly floodplain	bar at bank indentation on inside river bend
	LR-205	1-2	40° 47' 21.8"	75° 39' 01.6"	E bank at dwnstr end of cobbly floodplain	bar at bank indentation on inside river bend
	LR-207	0-1	40° 47' 35.4"	75° 37' 54.2"	E bank dwnstr Palmerton low head dam	small deposit at water's edge behind trees along bank
	LR-208	0-1	40° 47' 37.6"	75° 37' 46.4"	E bank 200m dwnstr LR207	small deposit at water's edge behind trees along bank
	LR-209	0-1	40° 47' 36.0"	75° 37' 44.8"	W bank	minimal fringe deposit at water's edge behind log
	LR-210	0-1	40° 47' 45.2"	75° 37' 07.8"	E bank at Rt. 248 Palmerton exit	shallow water area in backwater created by highway cutoff
	AC-170	0-1	40° 47' 32.7"	75° 36' 46.1"	N shoreline near mouth of Aquashicola Creek	below timber reinforcement to left of "boat launch" area
	AC-170B	0-1	40° 47' 31.4"	75° 36' 44.3"	S shoreline at mouth of Aquashicola Creek	Sandy deposit off rip rap bank
	LR-211	0-1	40° 46' 38.7"	75° 36' 22.9"	Edge of island nearest to W bank	large deposit on side of island at water's edge
	LR-211B	0-1	40° 46' 39.2"	75° 36' 15.2"	W bank	Large sediment point bar dwnstr of breached dam
	LR-211B	1-2	40° 46' 39.2"	75° 36' 15.2"	W bank	Large sediment point bar dwnstr of breached dam
	LR-212	0-1	40° 44' 02.3"	75° 35' 15.5"	E bank downstr Walnutport adj. to municipal canal portion	Fringe sediment deposit at water's edge
	LR-213	0-1	40° 43' 34.1"	75° 32' 38.6"	W shore	120m upstr breached Treichlers Dam in shallow water
	LR-213B	0-1	40° 43' 31.7"	75° 32' 36.6"	E bank upstr Treichlers Dam	25m upstr of rock crib where landowner has cleared veg.
	LR-214	0-1	40° 43' 16.0"	75° 31' 34.4"	W bank	upstr Old Laury Dam and 100 m upstr. trib.
	LR-214	1-2	40° 43' 16.0"	75° 31' 34.4"	W bank	upstr Old Laury Dam and 100 m upstr. trib.
	LR-215	0-1	40° 41' 22.0"	75° 30' 13.0"	W shore upstr Northampton Dam at Cementon	25m upstr poured cement bldg. along W shore
	LR-216	0-1	40° 40' 36.6"	75° 29' 30.7"	W bank at Coplay	on old timber crib structure 10' from bank in 1.5' water

Table 1. continued.

	Sample ID	Depth ID	Latitude	Longitude	Sample Area Description	Sample Point Description
Aquashicola Creek	AC-171	0-1	40° 47' 37.8"	75° 36' 44.4"	S bank near mouth	deposit at edge of creek
	AC-171	1-2	40° 47' 37.8"	75° 36' 44.4"	S bank near mouth	deposit at edge of creek
	AC-172	0-1	40° 47' 39.6"	75° 36' 43.5"	S bank	deposit at edge of creek
	AC-173	0-1	40° 47' 40.7"	75° 36' 44.0"	N bank	sample taken in water 3' from bank
	AC-174	0-1	40° 48' 04.3"	75° 36' 17.6"	S bank	sample taken on bank w/in 6" of creek edge
	AC-175	0-1	40° 48' 04.7"	75° 36' 16.2"	N bank	taken at water's edge
	AC-178	0-1	40° 48' 21.7"	75° 35' 52.1"	S bank at upstr end of Corps of Engineers dredging area	dry deposit at water's edge near willow tree
	AC-179	0-1	40° 48' 20.8"	75° 35' 53.9"	N bank at upstr end of Corps of Engineers dredging area	wet deposit in 2" water at water's edge
	AC-176	0-1	40° 48' 23.3"	75° 35' 49.3"	S side @stormwater swale mouth just upstr Corps dredged area	Depositional area at mouth of stormwater swale
	AC-176	1-2	40° 48' 23.3"	75° 35' 49.3"	S side @stormwater swale mouth just upstr Corps dredged area	Depositional area at mouth of stormwater swale
	AC-176	2-3	40° 48' 23.3"	75° 35' 49.3"	S side @stormwater swale mouth just upstr Corps dredged area	Depositional area at mouth of stormwater swale
	AC-177	0-1	40° 48' 25.1"	75° 35' 48.8"	N bank just upstr Corps of Engineers dredging area	taken on dry sediment bar
	AC-185	0-1	40° 48' 40.9"	75° 34' 28.9"	S bank opposite Aggregate Sales adjacent to waste pile	narrow grass covered deposit flanking water's edge
	AC-186	0-1	40° 48' 41.3"	75° 34' 32.4"	N bank at Aggregate Sales just dwnstr from Jersey barriers	Flanking grass covered deposit taken at water's edge
	AC-183	0-1	40° 48' 59.1"	75° 33' 26.3"	N bank just upstr Cinder Bank	at water's edge just dwnstr of power line and upstr trib.
	AC-184	0-1	40° 48' 58.2"	75° 33' 25.6"	S bank just upstr Cinder Bank	at water's edge just dwnstr of power line and adj. to shrub
	AC-187	0-1	40° 48' 42.7"	75° 34' 09.5"	N band at upstr end bank indentation	just upstr Waste Pile
	AC-188	0-1	40° 48' 42.1"	75° 34' 09.1"	S bank opposite and just dwnstr AC-187	just upstr Waste Pile
	AC-189	0-1	40° 49' 00.4"	75° 32' 08.4"	Pool below Harris Lane Bridge	Nearest N shore at submerged sediment/gravel deposit
	AC-189	1-2	40° 49' 00.4"	75° 32' 08.4"	Pool below Harris Lane Bridge	Nearest N shore at submerged sediment/gravel deposit
	AC-191	0-1	40° 49' 30.1"	75° 30' 36.3"	Upstr mouth of Buckwha Ck at EPA location 8	nearest S shore approx. 75 m upstr I beams from old bridge
	AC-191	1-2	40° 49' 30.1"	75° 30' 36.3"	Upstr mouth of Buckwha Ck at EPA location 8	nearest S shore approx. 75 m upstr I beams from old bridge
	AC-221	0-1	40° 50' 48.8"	75° 22' 52.9"	Dwnstr Chicola Lake	along S shore just upstr. George Shook, Jr. residence
	AC-221	1-2	40° 50' 48.8"	75° 22' 52.9"	Dwnstr Chicola Lake	along S shore just upstr. George Shook, Jr. residence
Mill	MC-180	0-1	40° 48' 43.9"	75° 35' 33.4"	Mill Ck as it reaches valley floor	along E shore adj. to concrete wall below business bldg.
	MC-181	0-1	40° 48' 53.1"	75° 35' 41.4"	Mill Ck on flank of Stony Ridge	dwnstr Ridge Rd bridge, E bank. Raw sewage enters upstr.
Buckwha	BC-193	0-1	40° 49' 53.9"	75° 31' 18.1"	Buckwha Ck @ Little Gap approx 100 m upstr covered bridge	along S bank opposite tributary mouth
	BC-196	0-1	40° 50' 13.6"	75° 30' 30.7"	Buckwha Ck downstr Borger Ck	along S bank, fringe deposit at edge of water
	BC-194	0-1	40° 50' 50.1"	75° 26' 56.1"	Buckwha Ck just dwnstr new bridge at Kunkletown	Submerged deposit near S bank

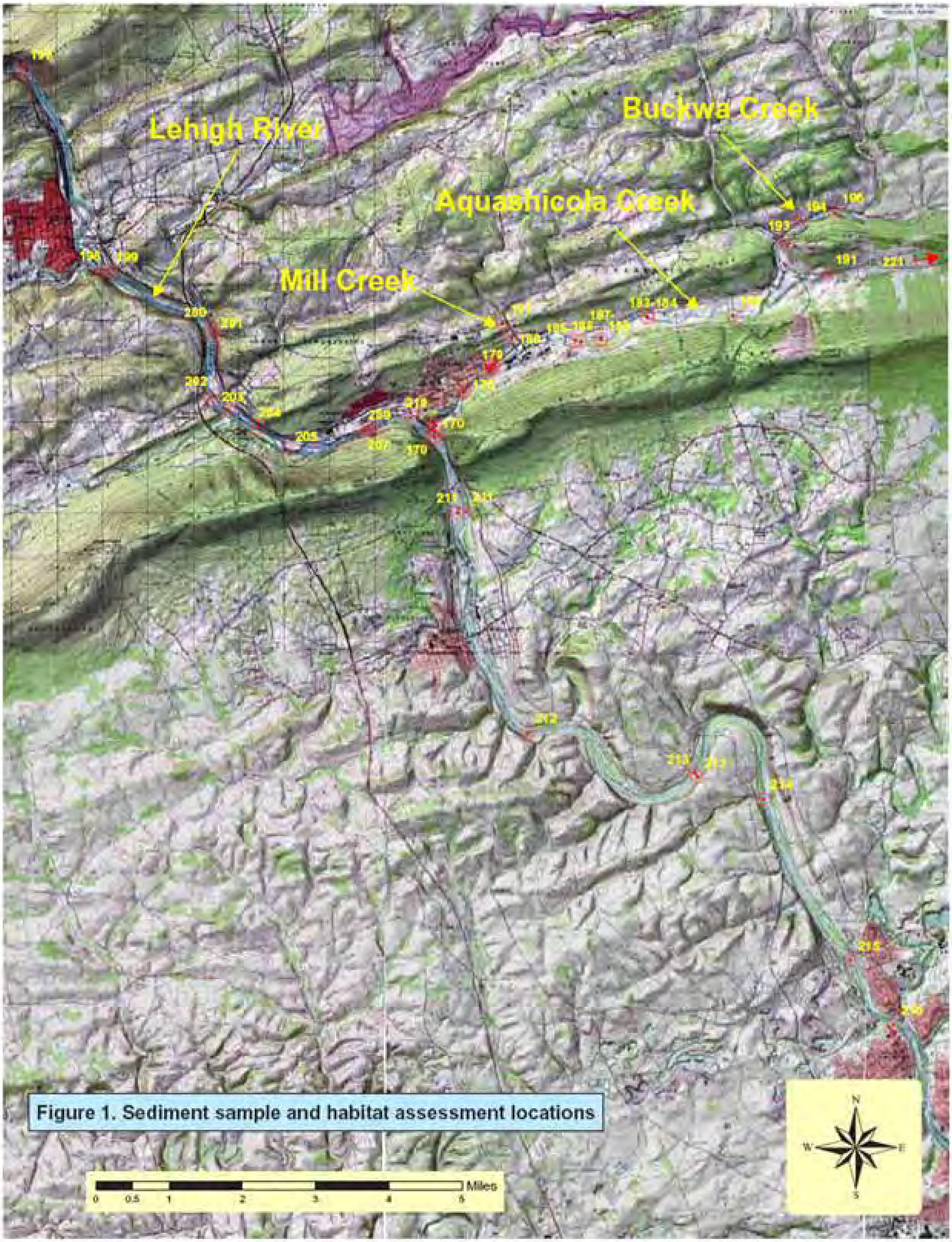

Figure 1. Sediment sample and habitat assessment locations

Table 2. Lehigh River Rapid Bioassessment Protocol Habitat Scores, October 2004.

		Location														
		LR-197	LR-198/199	LR-200/201	LR-202	LR-203	LR-204	LR-205	LR-207/208/209	LR-210	LR-211/211B	LR-212	LR-213/213B	LR-214	LR-215	LR-216
	Gradient	H	H	H	H	H	H	H	H	H	H	H	L	H	L	H
	Habitat Parameter															
1	Epifaunal Substrate/Available Cover	16	19	18	16	17	14	17	19	11	18	16	11	5	14	16
2	Embeddedness	16	18	18	15	17	11	15	18	8	15	13	18	5	18	16
3	Velocity/Depth Regime	15	14	18	18	18	17	16	14	17	20	11	16	16	14	14
4	Sediment Deposition	18	17	18	15	17	10	14	18	8	16	15	14	5	18	16
5	Channel Flow Status	20	20	19	20	16	19	18	13	20	15	20	20	20	18	20
6	Channel Alteration	13	18	19	17	19	10	13	20	9	14	19	13	13	14	14
7	Frequency of Riffles (or bends)	19	17	16	19	15	18	16	12	18	18	12	14	18	13	15
8	Bank Stability left bank	10	9	9	6	8	9	5	6	8	8	7	7	8	8	9
	right bank	8	9	8	7	7	9	9	6	9	8	10	9	7	6	9
9	Vegetative Protection left bank	1	6	8	6	7	7	8	6	3	7	6	5	9	4	8
	right bank	9	10	8	7	8	9	5	6	9	7	8	9	8	7	8
10	Riparian Veg. Zone Width left bank	9	8	7	5	7	3	6	6	1	7	8	7	8	5	5
	right bank	8	9	10	5	8	7	7	4	3	6	10	9	8	9	6
		162	174	176	156	164	143	149	148	124	159	155	152	130	148	156

Table 3. Aquashicola Creek and tributaries Rapid Bioassessment Protocol Habitat Scores, October 2004.

		Location															
		Aquashicola Creek											Mill Ck		Buckwha Ck		
		AC-170/170B	AC-171/172/173	AC-174/175	AC-178/179	AC176/177	AC-185/186	AC-183/184	AC-187/188	AC-189	AC-191	AC-221	MC-180	MC-181	BC-193	BC-196	BC-194
	Gradient	H	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H
	Habitat Parameter																
1	Epifaunal Substrate/Available Cover	13	8	11	15	15	8	17	9	17	18	14	17	16	16	18	11
2	Embeddedness	15	11	13	15	15	6	17	8	16	19	11	17	15	15	17	12
3	Velocity/Depth Regime	13	17	17	16	16	15	17	13	20	14	12	13	18	17	18	5
4	Sediment Deposition	11	7	13	13	15	12	15	13	14	15	10	16	16	18	15	17
5	Channel Flow Status	20	18	20	20	20	20	17	20	17	20	19	20	20	17	20	17
6	Channel Alteration	13	15	11	8	11	6	14	20	14	20	18	20	15	17	19	15
7	Frequency of Riffles (or bends)	18	17	9	15	17	15	11	8	11	19	12	18	18	17	20	5
8	Bank Stability left bank	9	6	7	7	9	8	7	7	8	9	5	7	9	9	9	5
	right bank	9	7	6	8	8	4	7	7	8	9	8	7	9	8	5	5
9	Vegetative Protection left bank	4	9	9	7	7	6	7	8	8	9	4	7	8	7	9	5
	right bank	4	9	4	8	5	4	9	8	8	9	10	6	8	7	7	4
10	Riparian Veg. Zone Width left bank	4	9	8	6	6	1	8	7	7	10	6	4	5	9	10	4
	right bank	4	7	3	3	3	1	5	7	5	9	9	5	5	5	5	2
		137	140	131	141	147	106	151	135	153	180	138	157	162	162	172	107

Figure 2. Lehigh River Rapid Bioassessment Protocol Habitat Scores, October 2004.

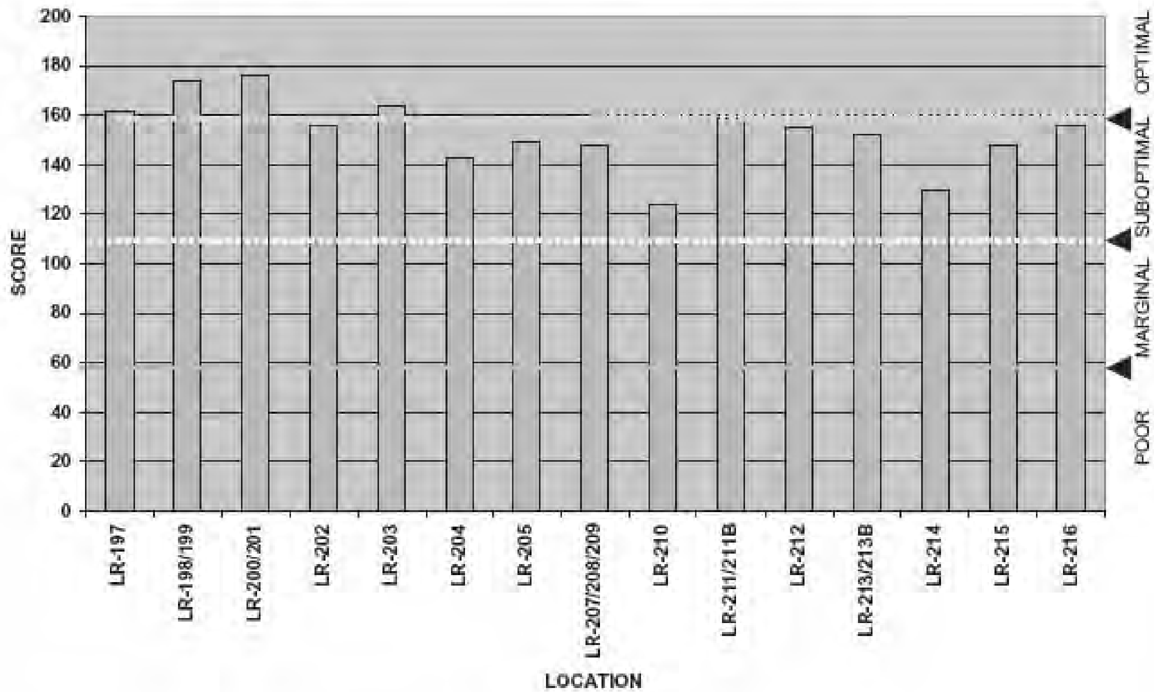

Figure 3. Aquashicola Creek and tributaries RBP habitat scores, October 2004.

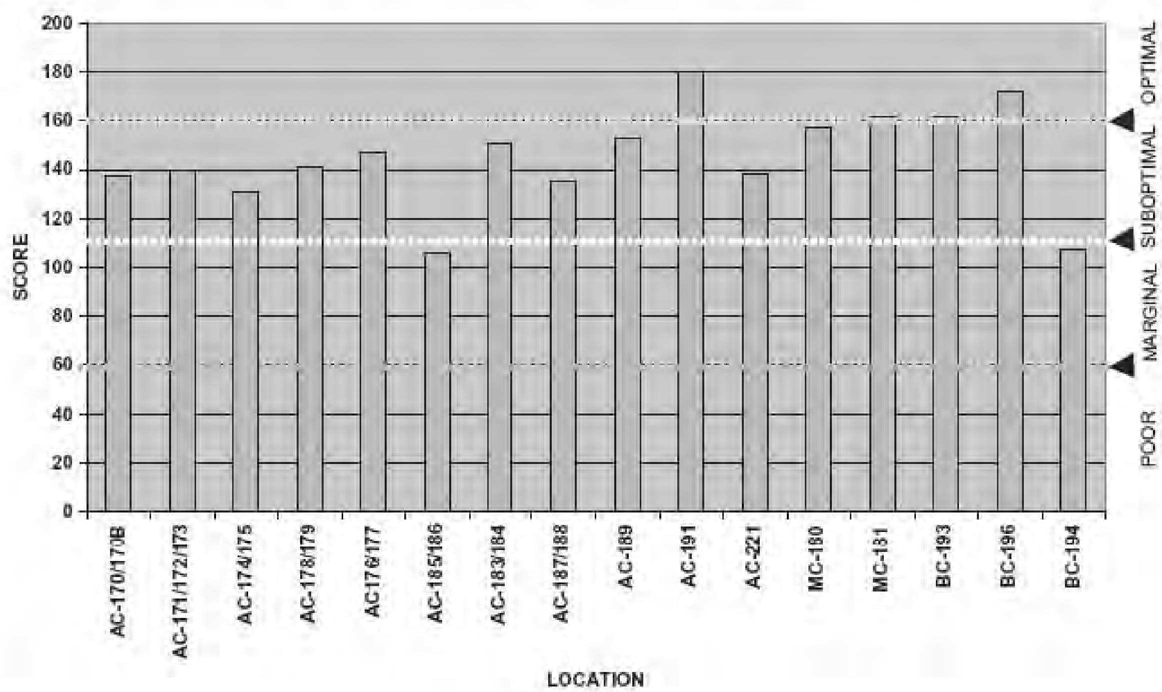

Figure 4. Lehigh River RBP Substrate Composition, October 2004.

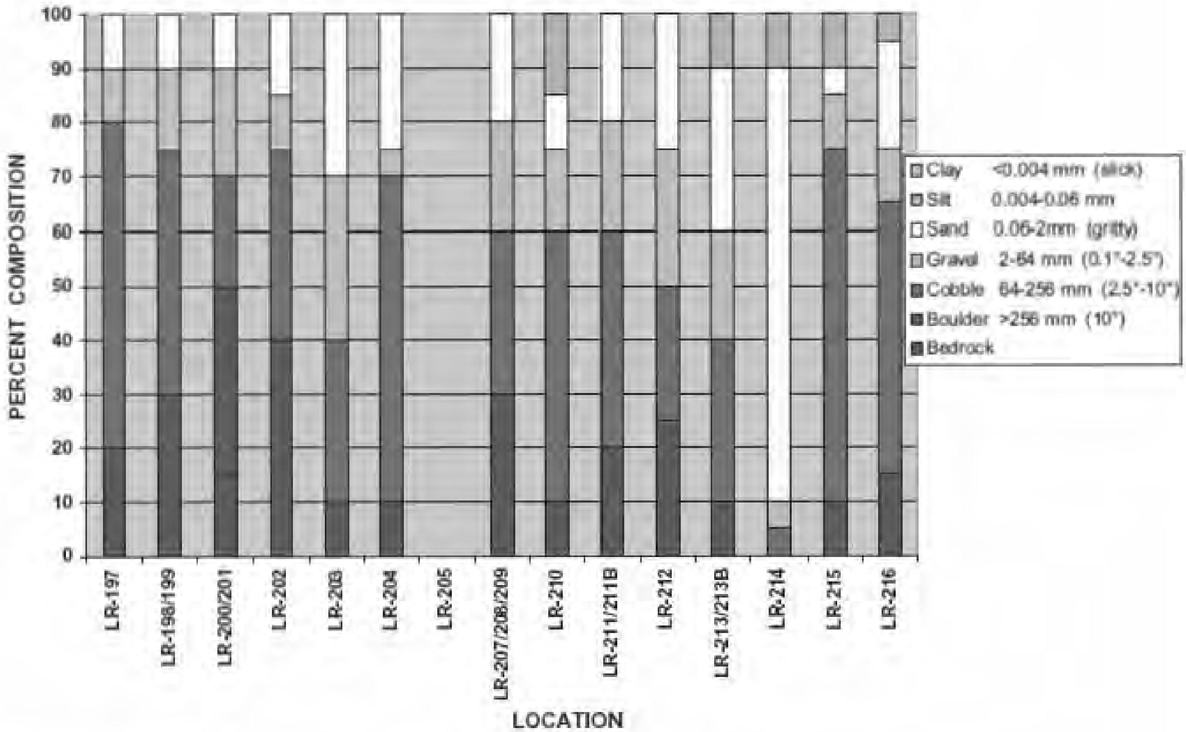

Figure 5. Aquashicola Creek and Tributaries RBP Substrate Composition, October 2004.

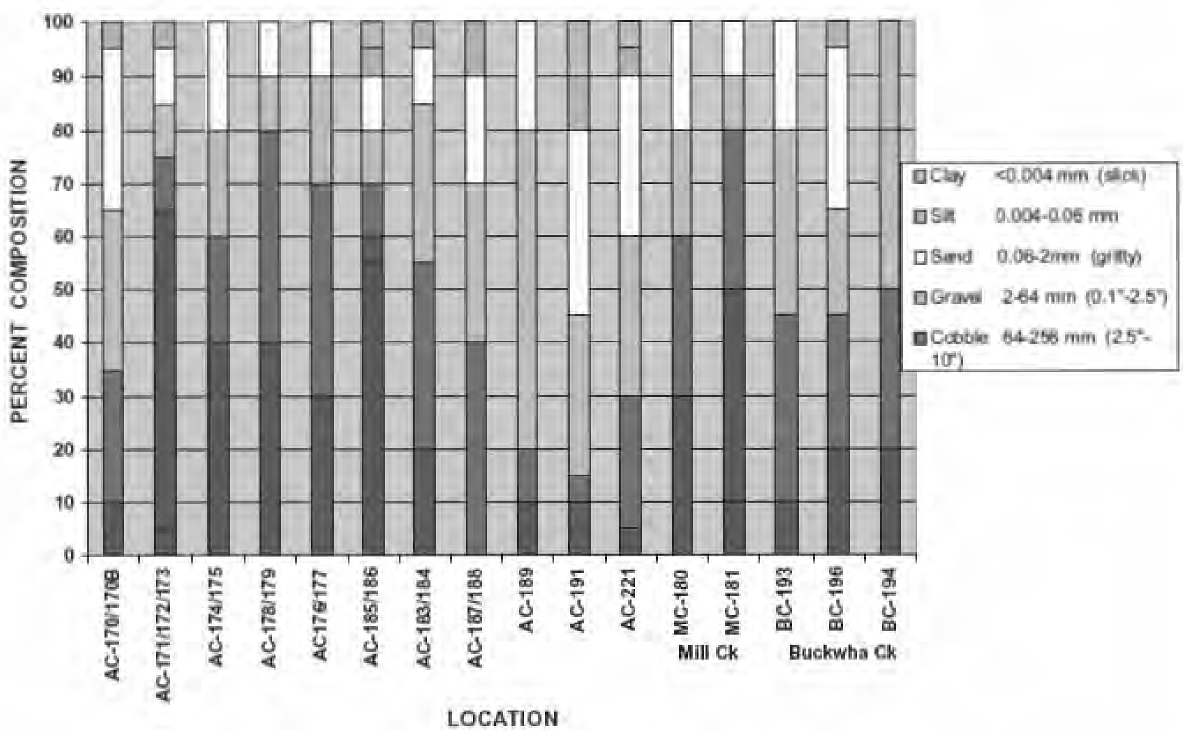

Table 4. Sediment sample results from the Lehigh River, Aquashicola Creek and selected tributaries, October 2004.

	Sample ID	Depth ID	Aluminum (mg/kg)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Iron (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Percent Solids (%)	TOC (mg/kg)
Lehigh River	LR-197	0-1	4,800	9.7	0.3	6.6	60	12,000	92	510	63.5	130,000
	LR-198	0-1	5,100	4.8	1.1	11	24	15,000	37	190	52.0	180,000
	LR-199	0-1	6,300	7.4	1.1	9.5	57	10,000	71	250	54.6	200,000
	LR-200	0-1	9,100	7.6	4.7	18	48	15,000	120	740	42.8	63,000
	LR-201	0-1	5,900	7.8	1.6	11	58	11,000	66	260	36.3	310,000
	LR-202	0-1	7,000	9.4	0.55	13	40	17,000	52	250	59.0	140,000
	LR-203	0-1	5,500	6.5	0.96	8.6	52	12,000	64	270	54.4	130,000
	LR-203	1-2	5,300	7.9	1.0	8.5	59	12,000	88	260	59.8	110,000
	LR-204	0-1	4,800	5.1	0.92	7.4	29	8,200	43	260	52.4	270,000
	LR-204	1-2	5,200	7.6	1.1	9.9	54	13,000	60	320	46.1	250,000
	LR-205	0-1	6,300	5.7	1.3	8.2	34	11,000	39	270	37.4	230,000
	LR-205	1-2	5,600	8.1	0.7	9.1	39	13,000	200	280	66.0	140,000
	LR-207	0-1	11,000	11	9.4	15	74	19,000	95	1,200	34.6	110,000
	LR-208	0-1	9,800	8.8	5.5	18	57	17,000	72	840	39.8	150,000
	LR-209	0-1	15,000	8.7	2.2	18	59	19,000	98	630	39.9	87,000
	LR-210	0-1	12,000	15	20	18	140	17,000	150	3,700	46.4	190,000
	AC-170*	0-1	7,900	69	28	18	120	26,000	190	6,100	71.0	40,000 B
	AC-170B*	0-1	7,900	31	13	14	65	24,000	72	2,900	75.6	14,000
	LR-211	0-1	5,300	6.7	1.4	55	30	13,000	43	330	67.9	120,000
	LR-211B	0-1	5,000	5.8	5.2	7.2	37	13,000	49	910	68.8	150,000
	LR-211B	1-2	7,100	10	11	14	56	16,000	84	1,600	51.5	120,000
	LR-212	0-1	6,000	8.8	3.3	15	44	20,000	42	1,300	69.0	150,000
	LR-213	0-1	14,000	3.8	0.49	15	24	18,000	15	140	53.1	88,000
	LR-213B	0-1	14,000	12	20	33	140	20,000	120	1,900	43.7	150,000
	LR-214	0-1	6,400	6	5.3	13	39	11,000	55	740	62.2	110,000
	LR-214	1-2	11,000	3.3	0.48	13	11	13,000	13	100	53.7	35,000
	LR-215	0-1	9,200	7.6	9	16	56	15,000	64	1,500	27.2	180,000
	LR-216	0-1	9,800	7.5	15	18	51	16,000	66	1,500	47.1	130,000

Notes:
Samples AC-170 and AC-170B taken at the mouth of Aquashicola Creek are reported with Lehigh River samples due to riverine depositional influence.
Samples were collected October 25-27, 2004 and sent to EnChem Inc. (Green Bay, WI) for analysis.
Duplicate samples analyzed by EnChem and split samples analyzed by Lancaster Laboratories (Lancaster, PA) are reported in a separate table.
B = Reported result is an estimated concentration that is less than the PQL, but greater than or equal to the MDL.

Table 4. continued

	Sample ID	Depth ID	Aluminum (mg/kg)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Iron (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Percent Solids (%)	TOC (mg/kg)
Aquashicola Creek	AC-171	0-1	9,000	23	15	15	58	19,000	140	5,200	61.8	54,000
	AC-171	1-2	4,700	2.9	0.12 B	8.3	6.6	11,000	8	700	74.9	12,000
	AC-172	0-1	8,500	23	28	42	120	26,000	190	6,800	58.4	65,000
	AC-173	0-1	6,300	8.4	52	11	31	11,000	160	7,300	69.1	43,000
	AC-174	0-1	14,000	15	61	37	170	27,000	190	7,900	43.9	67,000
	AC-175	0-1	7,700	21	14	23	74	33,000	96	2,900	68.3	4,500
	AC-178	0-1	8,800	36	34	23	210	38,000	240	5,300	67.6	16,000
	AC-179	0-1	11,000	37	55	37	320	30,000	390	10,000	55.3	64,000
	AC-176	0-1	9,400	21	69	55	400	25,000	590	12,000	41.0	110,000
	AC-176	1-2	11,000	32	130	61	590	32,000	1,600	22,000	37.2	67,000
	AC-176	2-3	10,000	40	140	59	710	31,000	1,700	23,000	29.5	150,000
	AC-177	0-1	9,800	43	110	25	210	25,000	680	22,000	57.6	95,000
	AC-185	0-1	14,000	90	23	26	390	36,000	410	7,200	37.3	84,000
	AC-186	0-1	8,900	63	27	290	1100	100,000	270	8,100	71.3	38,000
	AC-183	0-1	7,900	3.6	11	12	22	10,000	52	620	51.2	39,000
	AC-184	0-1	9,900	4.6	18	16	34	14,000	91	780	32.3	42,000
	AC-187	0-1	4,200	10	22	9.4	80	15,000	89	3,200	31.3	300,000
	AC-188	0-1	13,000	60	76	22	570	33,000	570	9,300	32.1	52,000
	AC-189	0-1	4,800	9.3	1.1	27	290	34,000	95	750	91.2	4,100
	AC-189	1-2	6,600	11	2.9	12	28	19,000	23	990	70.2	37,000
	AC-191	0-1	8,900	3.3	3.7	12	16	9,500	28	390	39.4	37,000
	AC-191	1-2	3,800	0.97	0.10 B	4.6	4.6	2,800	4	25	61.7	58,000
	AC-221	0-1	6,700	2.9	2.2	10	23	9,400	28	280	32.6	47,000
	AC-221	1-2	5,100	1.3	0.096 B	7	5.2	4,300	5	29	59.4	28,000
Mill	MC-180	0-1	9,900	14	11	66	84	31,000	160	1,800	56.2	50,000
	MC-181	0-1	11,000	21	6.1	52	240	59,000	70	2,000	65.7	200,000
Buckwha	BC-193	0-1	8,400	12	4	16	45	21,000	53	580	40.4	82,000
	BC-196	0-1	11,000	5.6	0.23	20	9.3	19,000	11	79	75.4	15,000
	BC-194	0-1	6,800	5.1	1.2	12	11	14,000	23	180	59.4	27,000

Notes:
Samples were collected October 25-27, 2004 and sent to EnChem Inc. (Green Bay, WI) for analysis.
Duplicate samples analyzed by EnChem and split samples analyzed by Lancaster Laboratories (Lancaster, PA) are reported in a separate table.
B = Reported result is an estimated concentration that is less than the PQL, but greater than or equal to the MDL.

Table 5. Predicted relative aquatic toxicity and associated sediment contaminant levels.

Relative Aquatic Toxicity	Sediment Quality Guideline*	Contaminant and Concentration Range in mg/kg					
		As	Cd	Cr	Cu	Pb	Zn
None	<TEC	<10	<1	<43	<32	<36	<121
Low	TEC to PEC	10-32	1-4	43-110	32-148	36-127	121-458
Moderate	PEC to 2X PEC	33-65	5-9	111-221	149-297	128-255	459-917
High	2XPEC to 10X PEC	66-649	10-89	222-2219	298-2979	256-2559	918-4589
Very High	≥ 10X PEC	≥650	≥90	≥2220	≥2980	≥2559	≥4590

*adapted from MacDonald et. al (2000)

TEC-threshold effects concentration; PEC - probable effects concentration; 2X - two times; 10X - ten times
Colors used to identify relative aquatic toxicity categories correspond to like categories in Figures 6 through 13.

Table 6. Number of samples falling within specified sediment quality guideline (SQG) ranges (percentage in parentheses).

Metal **SQG*** **Predicted toxicity**	**# of Samples** **<TEC** **none**	**# of Samples** **TEC-PEC** **low**	**# of Samples** **>PEC** **moderate**	**Totals**
Arsenic	33 (58%)	16 (28%)	8 (14%)	**57**
Cadmium	11 (19%)	16 (28%)	30 (53%)	**57**
Chromium	50 (88%)	6 (11%)	1 (2%)	**57**
Copper	15 (26%)	30 (53%)	12 (21%)	**57**
Lead	10 (18%)	30 (53%)	17 (30%)	**57**
Zinc	4 (7%)	15 (26%)	38 (67%)	**57**

Table 7. Number of samples falling within specified sediment quality guideline (SQG) ranges by sample location (percentage within each stream in parentheses).

Sample location **SQG*** *Predicted toxicity*	**# of Samples** **<TEC** *none*	**# of Samples** **TEC-PEC** *low*	**# of Samples** **>PEC** *? moderate*	**Totals**
Lehigh River	1 (4%)	11 (39%)	16 (57%)	**28**
Aquashicola Creek	2 (8%)	2 (8%)	20 (83%)	**24**
Mill Creek	0 (0%)	0 (0%)	2 (100%)	**2**
Buckwha Creek	1 (33%)	1 (33%)	1 (33%)	**3**
Totals	**4 (7%)**	**14 (25%)**	**39 (68%)**	**57**

TEC = Threshold Effects Concentration below which toxic effects would not be expected
PEC = Probable Effects Concentration above which toxic effects would be expected
*Sediment Quality Guidelines taken from MacDonald et al. (2000)
Predicted toxicity taken from Table 5

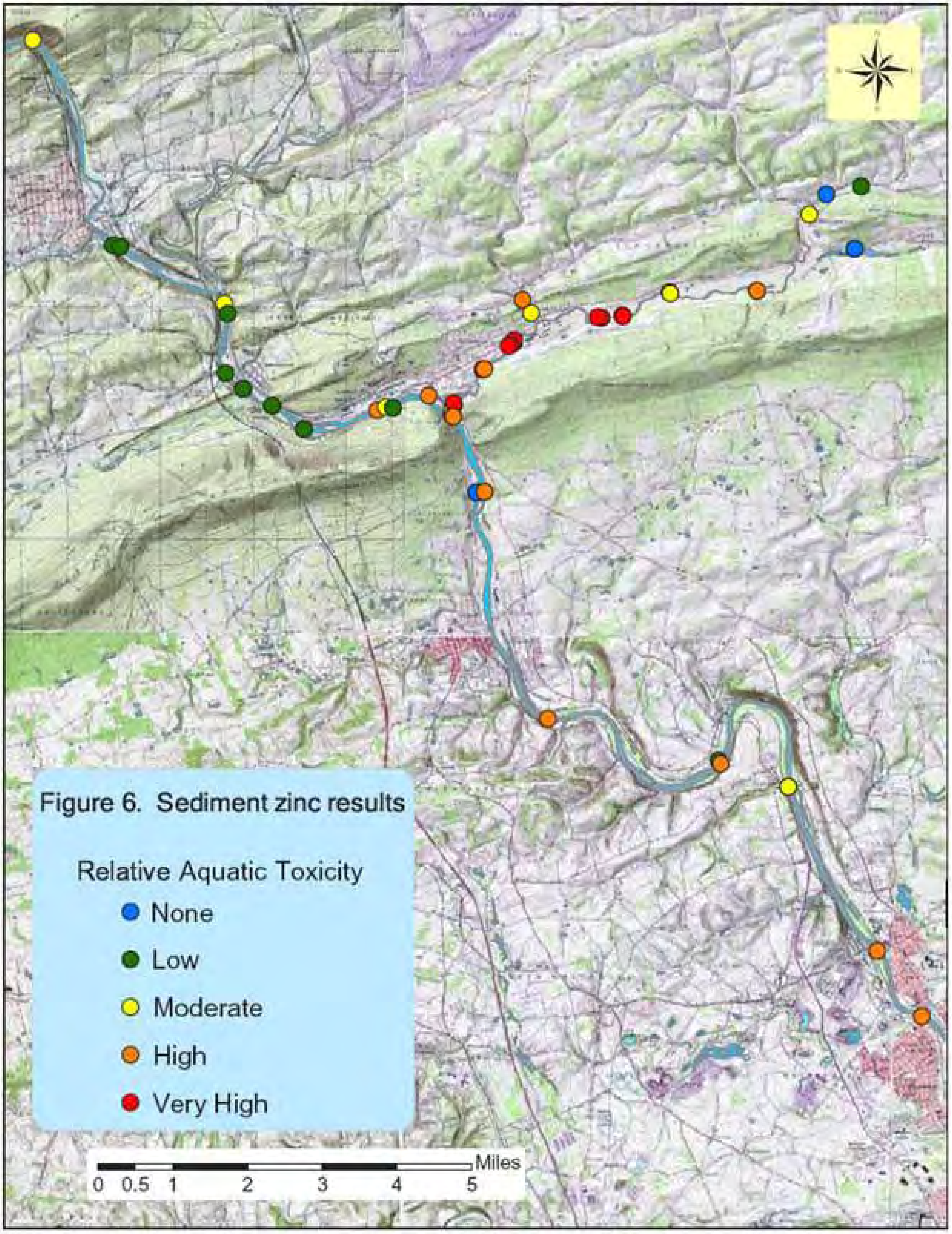
Figure 6. Sediment zinc results
Relative Aquatic Toxicity
None
Low
Moderate
High
Very High
Miles
0 0.5 1 2 3 4 5

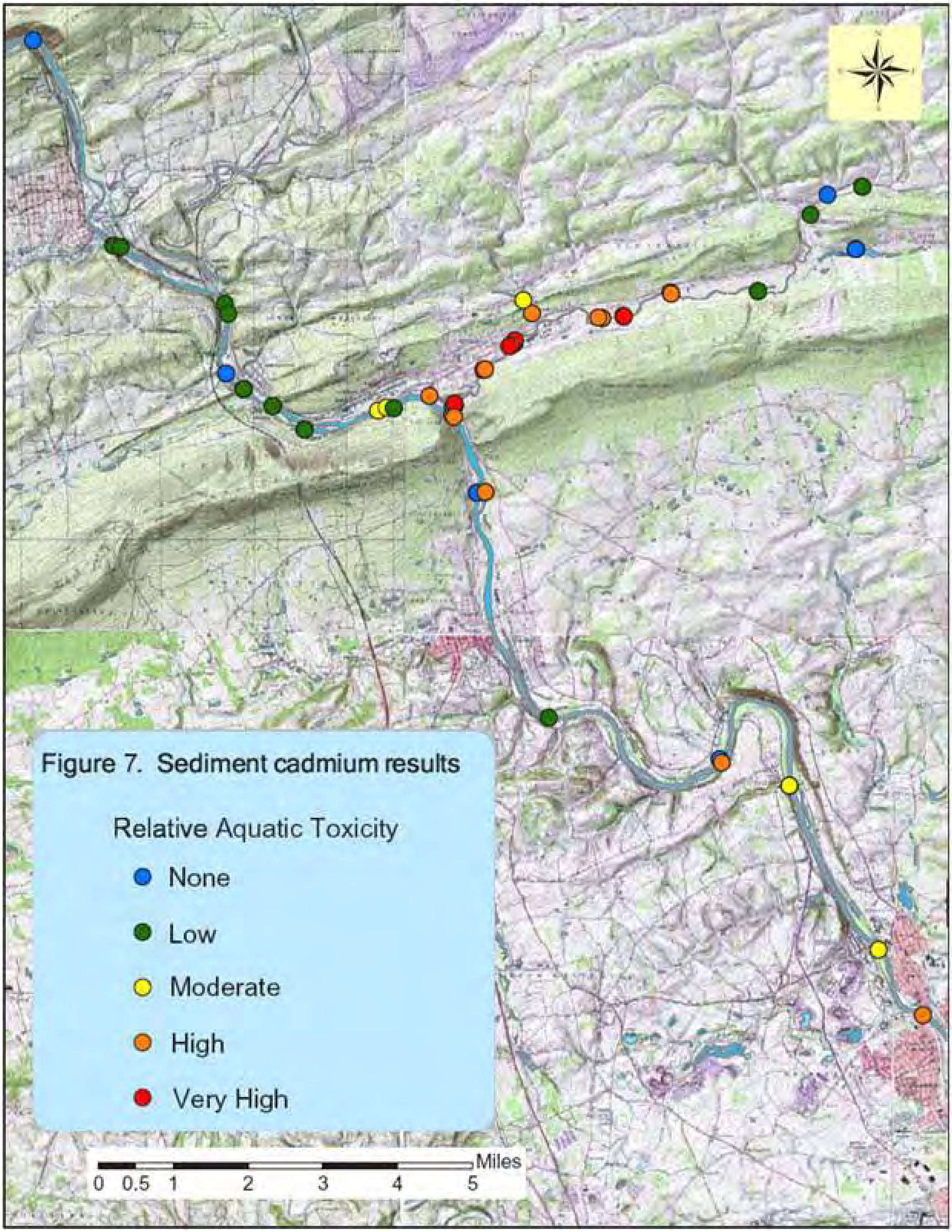

Figure 7. Sediment cadmium results

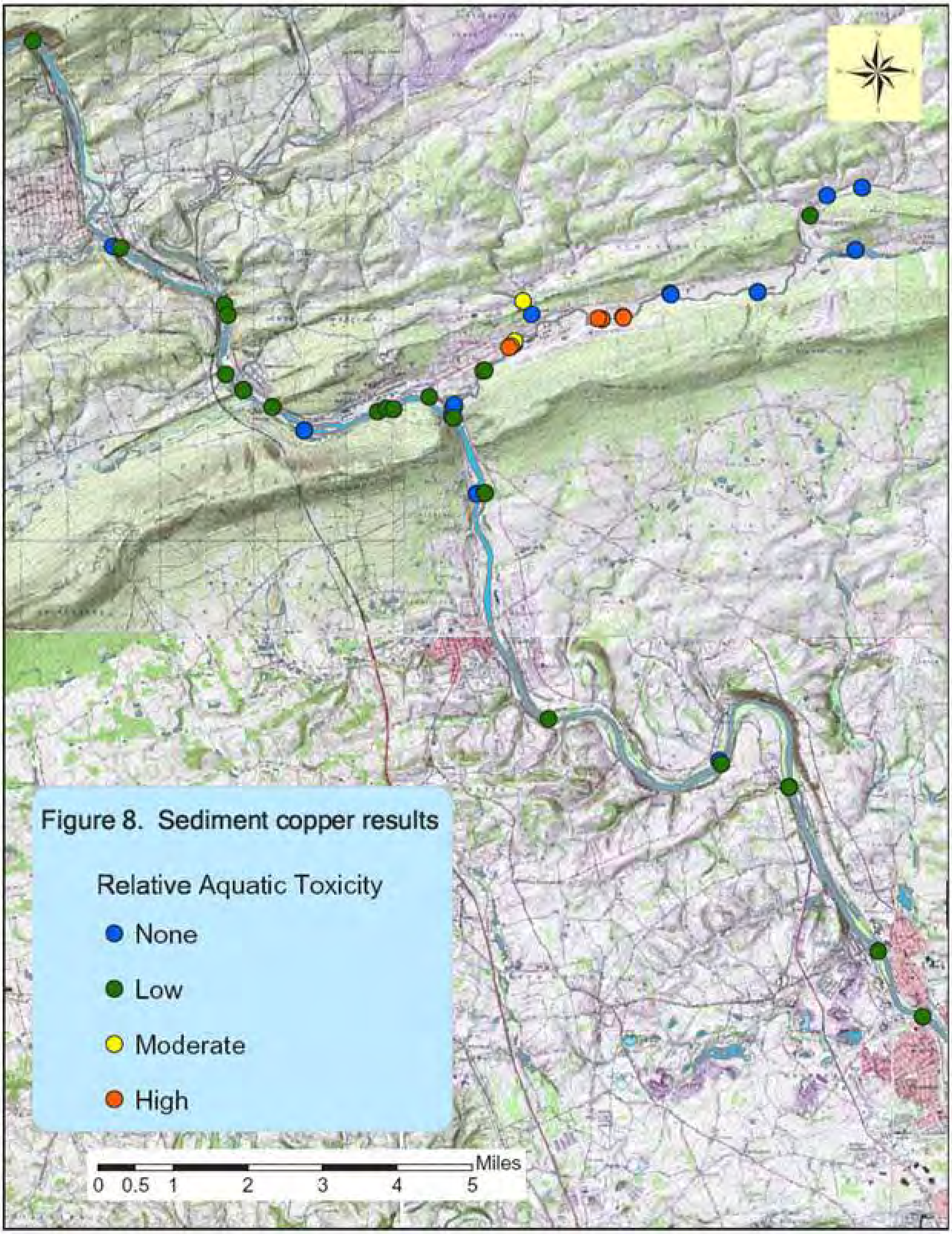
Figure 8. Sediment copper results
Relative Aquatic Toxicity
None
Low
Moderate
High
0 0.5 1 2 3 4 5
Miles

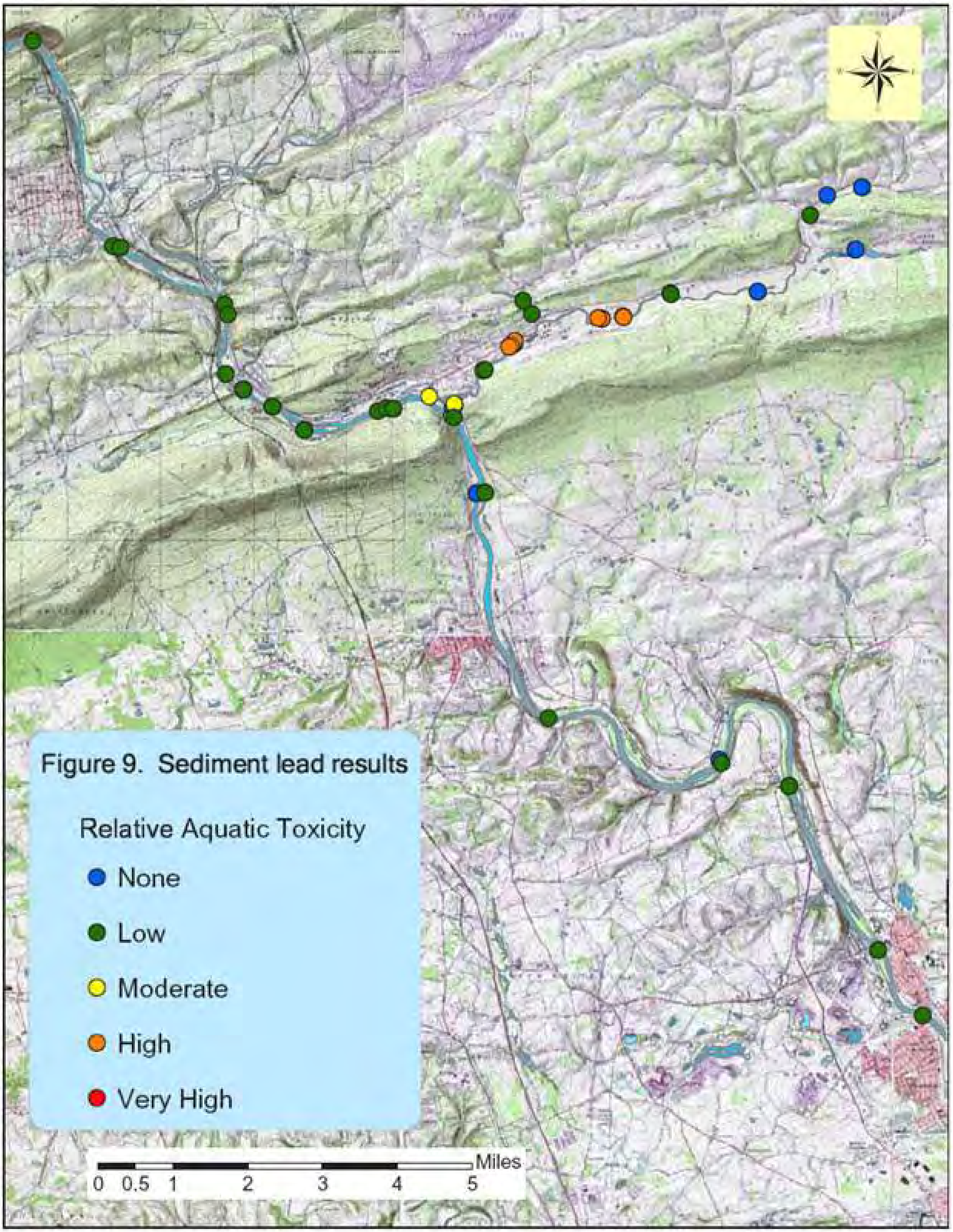

Figure 9. Sediment lead results

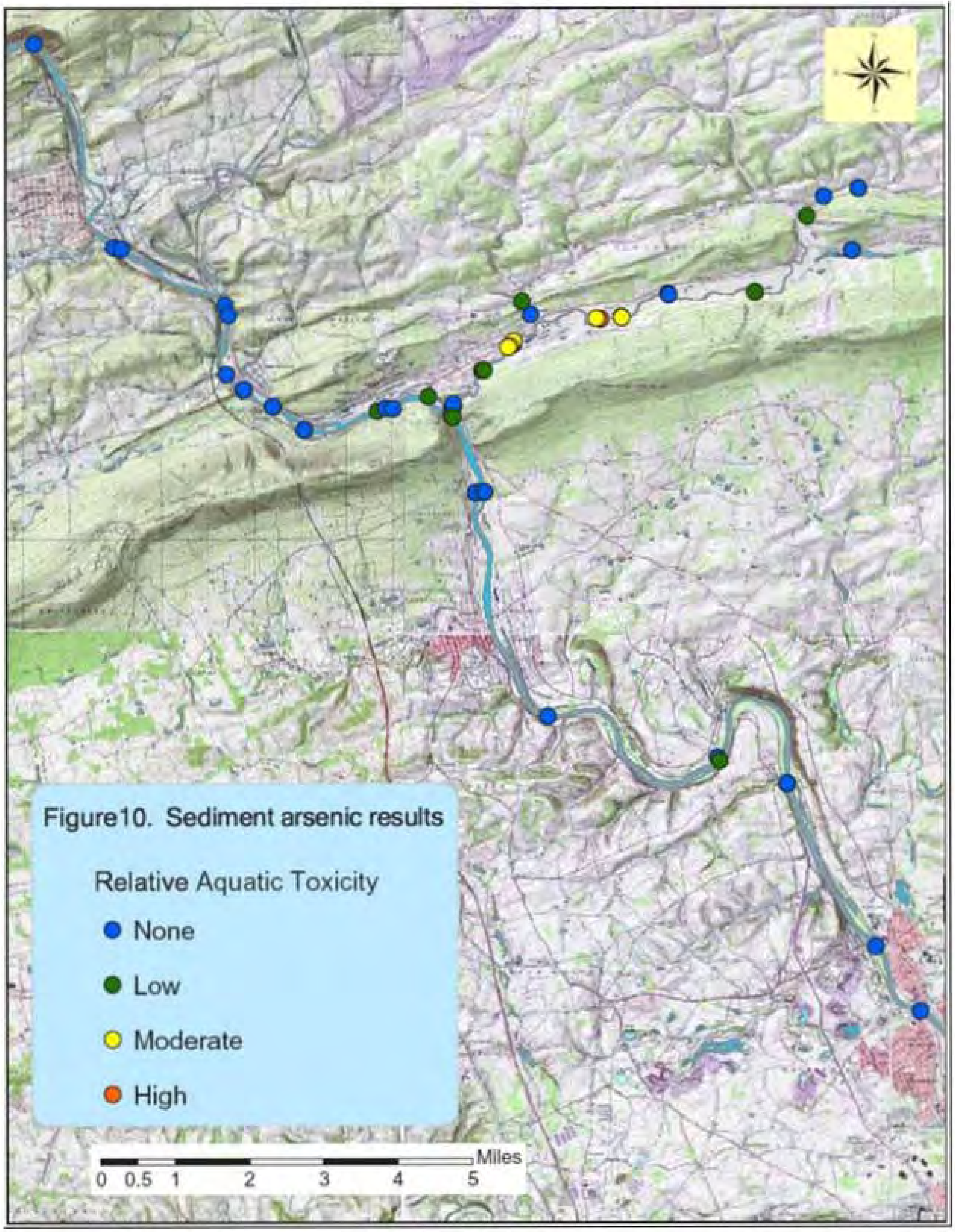
Figure10. Sediment arsenic results
Relative Aquatic Toxicity
None
Low
Moderate
High
Miles
0 0.5 1 2 3 4 5

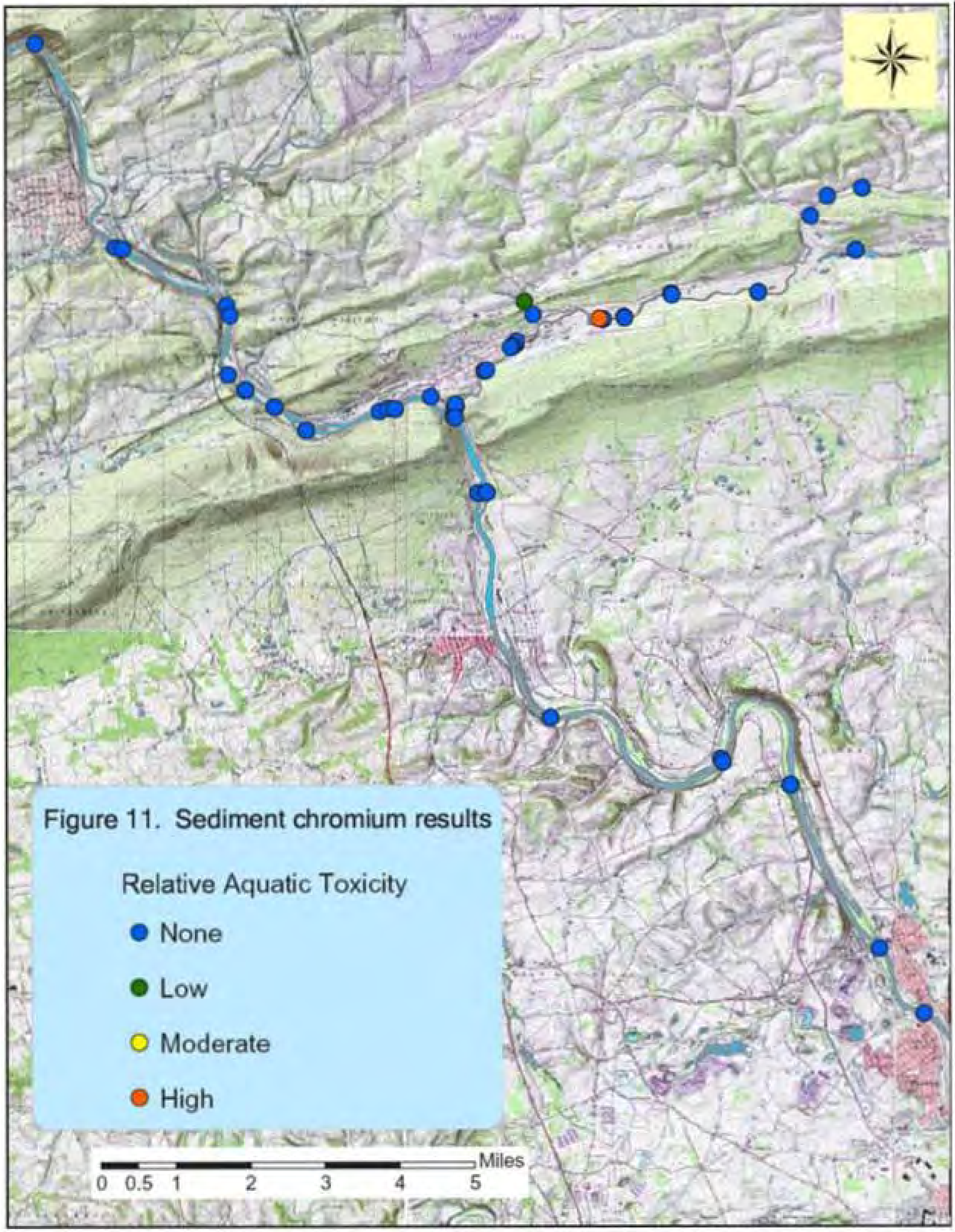
Figure 11. Sediment chromium results
Relative Aquatic Toxicity
None
Low
Moderate
High
Miles
0 0.5 1 2 3 4 5

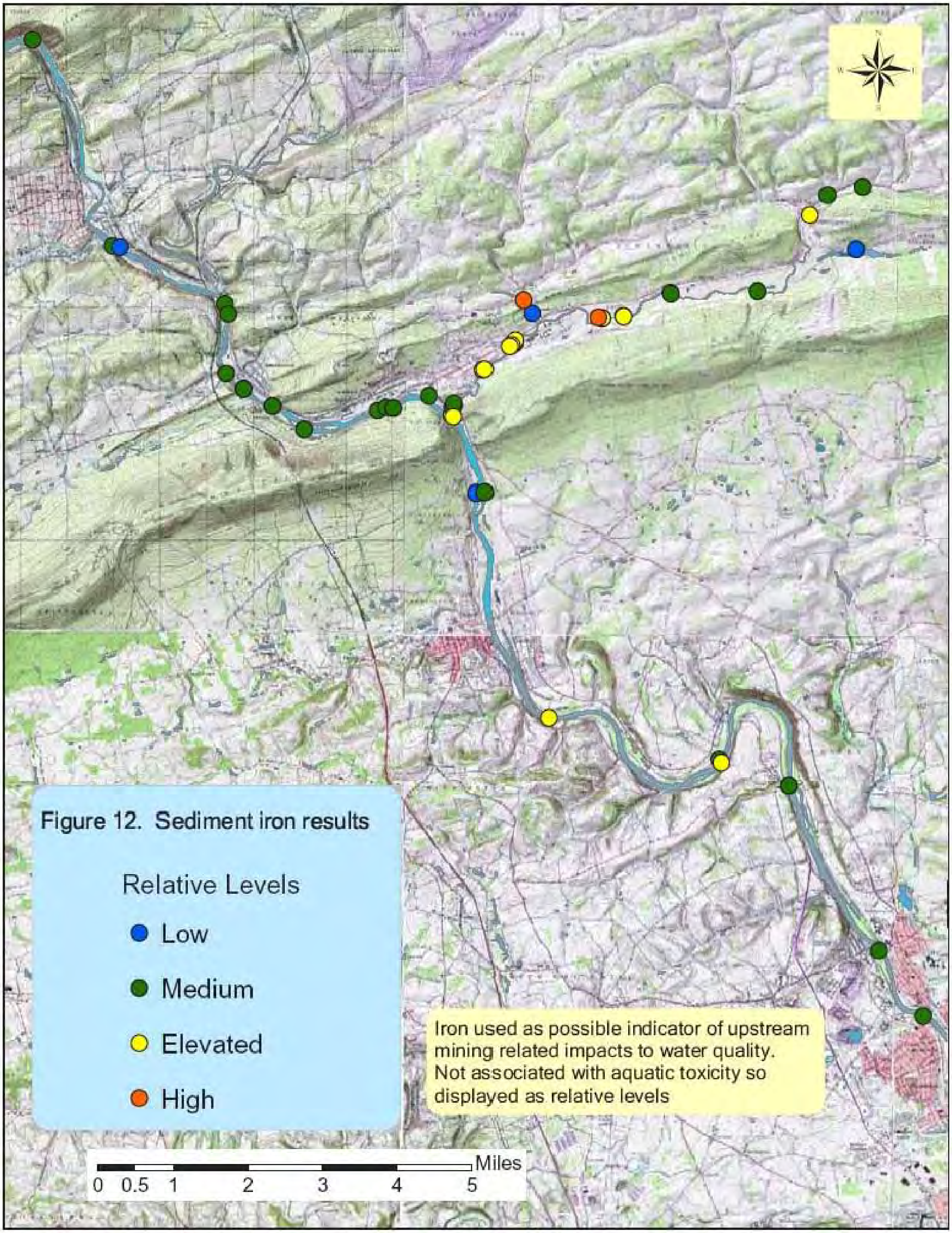

Figure 12. Sediment iron results

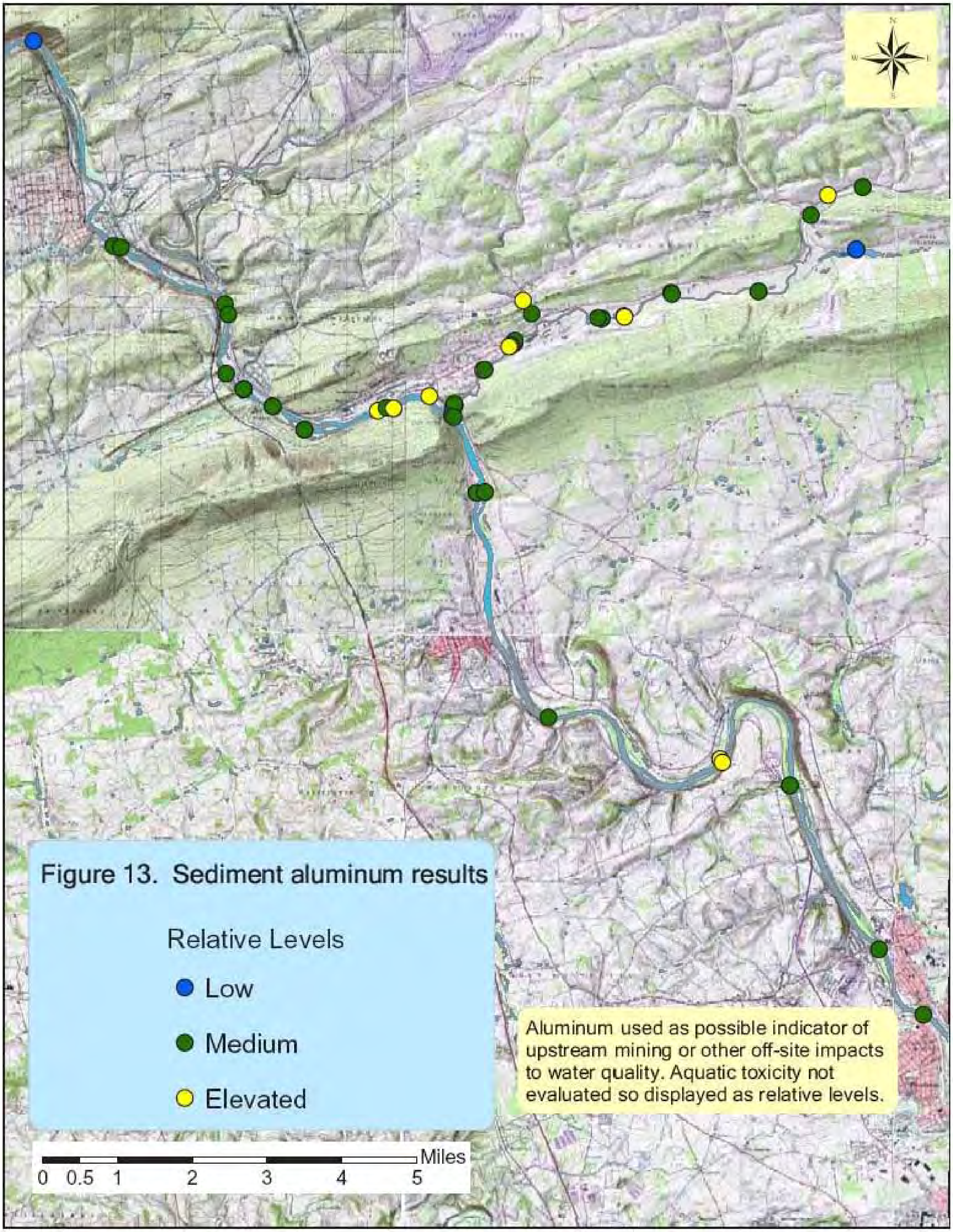

Figure 13. Sediment aluminum results

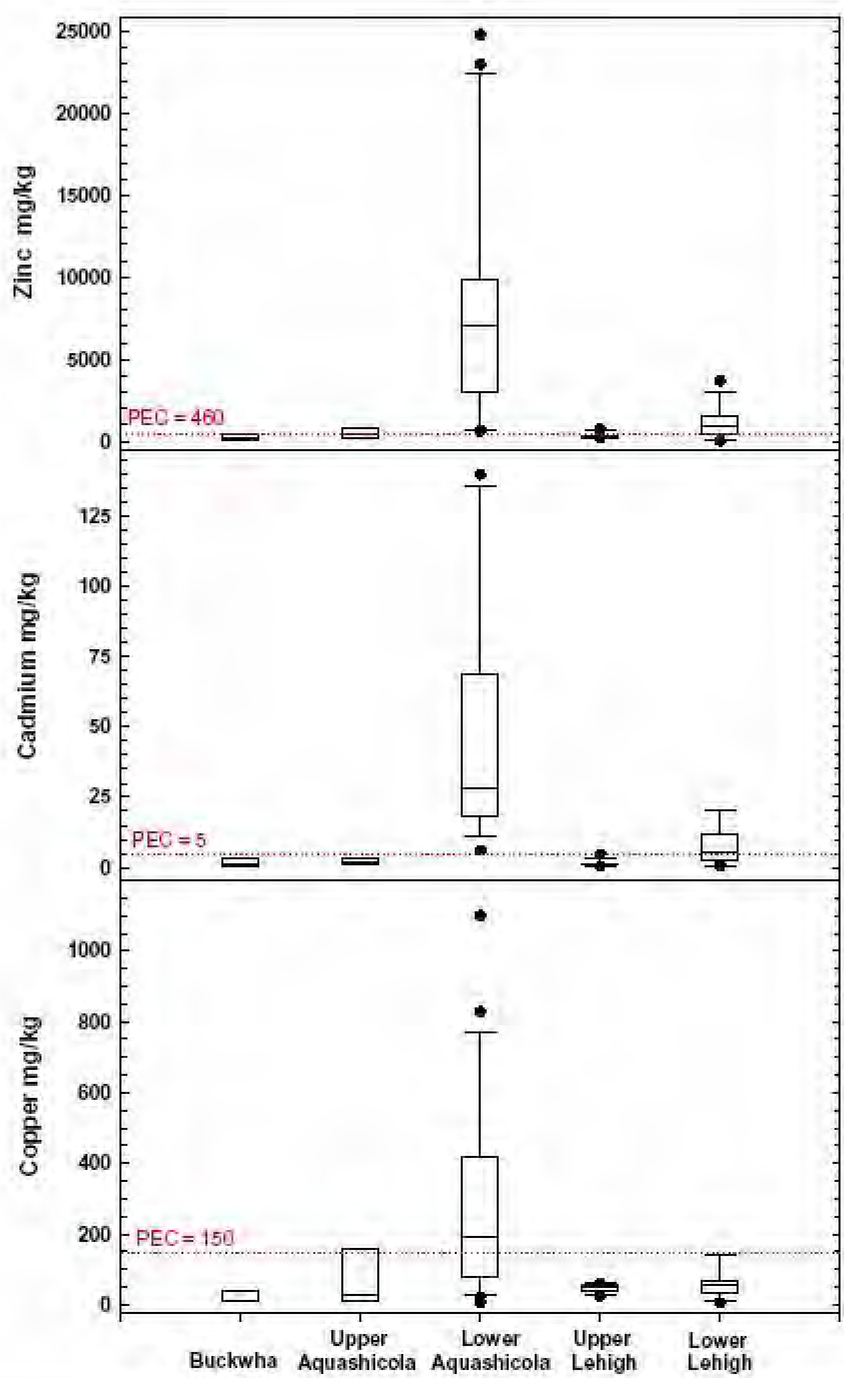

Figure 14. Zinc, cadmium and copper box and whisker plots showing the median, 2nd and 3rd quartile values, as well as a range encompassing the 10th to 90th percentiles and outliers (●) for data location subsets. PEC = probable effects concentration above which toxic effects would be expected.

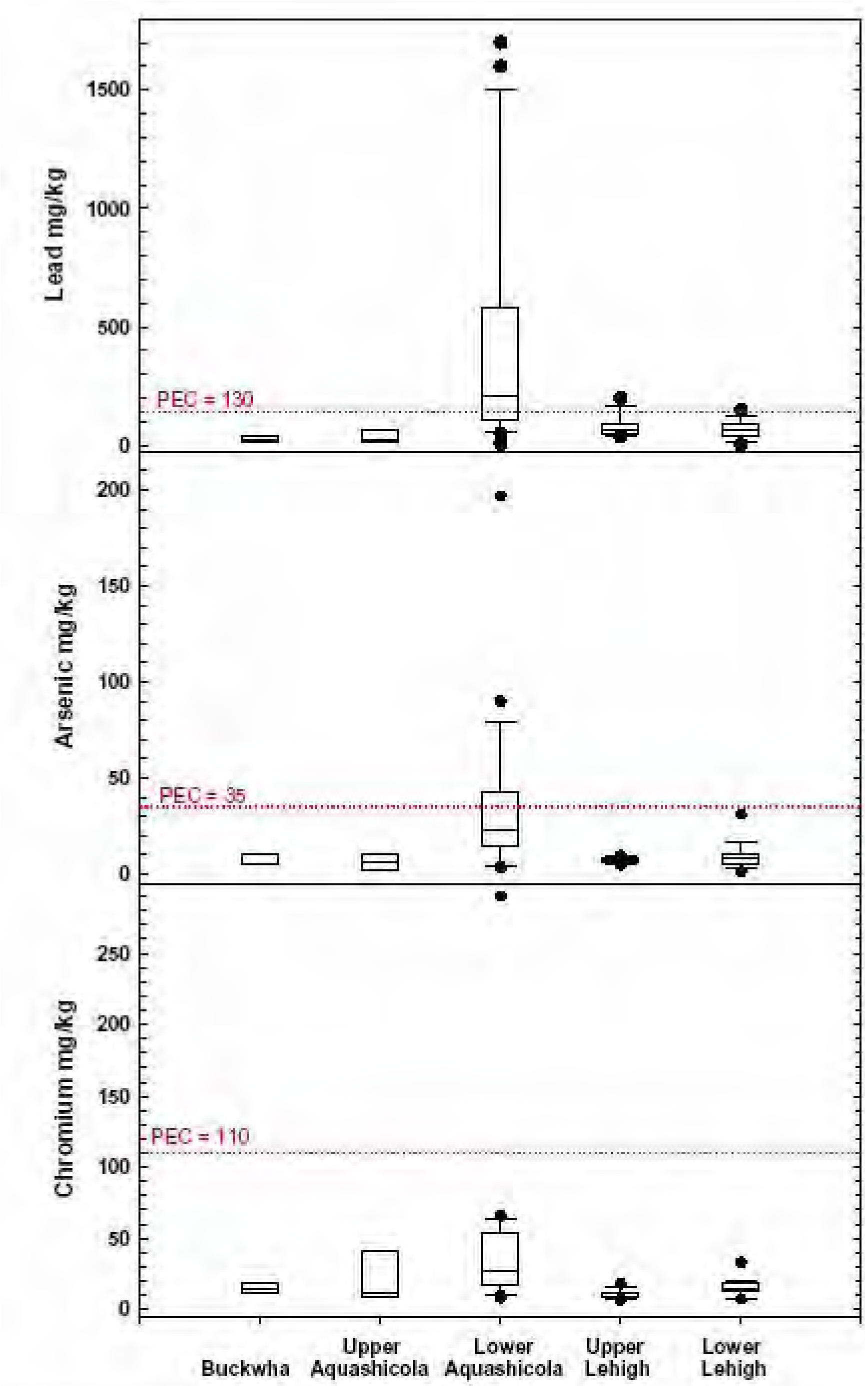

Figure 15. Lead, arsenic and chromium box and whisker plots showing the median, 2nd and 3rd quartile values, as well as a range encompassing the 10th to 90th percentiles and outliers (●) for data location subsets. PEC = probable effects concentration above which toxic effects would be expected.

Table 8. Sediment results from duplicate and split samples taken from the Lehigh River and Aquashicola Creek, Oct. 2004.

Sample Number	Aluminum (mg/kg)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Iron (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	% Solids	TOC (mg/kg)
Duplicate samples										
LR-200	9,100	7.6	4.7	18	48	15,000	120	740	42.8	63,000
LR-DUP2 = LR200	8,400	7.6	4.2	16	45	15,000	100	640	43.5	93,000
Difference from original	*7.7%*	*0.0%*	*10.6%*	*11.1%*	*6.3%*	*0.0%*	*16.7%*	*13.5%*	*-1.6%*	*-47.6%*
LR-210	12,000	15	20	18	140	17,000	150	3,700	46.4	190,000
LR-DUP1 = LR-210	11,000	13	20	16	140	14,000	140	3,500	52.1	120,000
Difference from original	*8.3%*	*13.3%*	*0.0%*	*11.1%*	*0.0%*	*17.6%*	*6.7%*	*5.4%*	*-12.3%*	*36.8%*
AC-176-1-2	11,000	32	130	61	590	32,000	1,600	22,000	37.2	67,000
AC-DUP2 = AC-176-1-2	13,000	28	120	69	650	29,000	1,500	21,000	38.7	150,000
Difference from original	*-18.2%*	*12.5%*	*7.7%*	*-13.1%*	*-10.2%*	*9.4%*	*6.3%*	*4.5%*	*-4.0%*	*-123.9%*
AC-179	11,000	37	55	37	320	30,000	390	10,000	55.3	64,000
AC-DUP1 = AC-179	11,000	32	63	36	270	31,000	440	8,700	62.8	51,000
Difference from original	*0.0%*	*13.5%*	*-14.5%*	*2.7%*	*15.6%*	*-3.3%*	*-12.8%*	*13.0%*	*-13.6%*	*20.3%*
Split samples										
LR-209	15,000	8.7	2.2	18	59	19,000	98	630	39.9	87,000
LR-209 Split	11,200	9.54	2.72	19	65.5	16,100	101	433	NA	98,900
Difference from original	*25.3%*	*-9.7%*	*-23.6%*	*-5.6%*	*-11.0%*	*15.3%*	*-3.1%*	*31.3%*		*-13.7%*
LR-214 (0-1')	6,400	6	5.3	13	39	11,000	55	740	62.2	110,000
LR-214 (0-1') Split	7,450	5.87	5.57	11.7	43.5	12,900	62	680	NA	110,000
Difference from original	*-16.4%*	*2.2%*	*-5.1%*	*10.0%*	*-11.5%*	*-17.3%*	*-12.7%*	*8.1%*		*0.0%*
AC-174	14,000	15	61	37	170	27,000	190	7,900	43.9	67,000
AC-174 Split	18,100	14.9	67.1	35	177	32,700	223	7,550	NA	85,900
Difference from original	*-29.3%*	*0.7%*	*-10.0%*	*5.4%*	*-4.1%*	*-21.1%*	*-17.4%*	*4.4%*		*-28.2%*
AC-176-2-3	10,000	40	140	59	710	31,000	1,700	23,000	29.5	150,000
AC-176-2-3 Split	15,600	37.2	140	57.9	828	40,700	1,410	24,800	NA	106,000
Difference from original	*-56.0%*	*7.0%*	*0.0%*	*1.9%*	*-16.6%*	*-31.3%*	*17.1%*	*-7.8%*		*29.3%*
AC-185	14,000	90	23	26	390	36,000	410	7,200	37.3	84,000
AC-185 Split	9,500	197	26.2	28.9	428	35,500	688	5,110	NA	48,800
Difference from original	*32.1%*	*-118.9%*	*-13.9%*	*-11.2%*	*-9.7%*	*1.4%*	*-67.8%*	*29.0%*		*41.9%*

Notes:

1. Samples were collected in October 2004 and sent to EnChem Inc. (Green Bay, WI) for analysis.
2. Split samples were taken from a subset of samples, and sent to Lancaster Laboratories (Lancaster, PA) for analysis.

B = Reported result is an estimated concentration that is less than the PQL, but greater than or equal to the MDL.

NA = Not analyzed

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