MARCELLUS SEDIMENT & WATER STUDY – SUMMER 2011

WATER QUALITY STANDARDS
BUREAU OF POINT & NON-POINT SOURCE MANAGEMENT
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INTRODUCTION

Streambed sediment is a potentially vital location of contamination detection in streams. Contaminates in discharged effluents can accumulate in streambed sediment and be detected in a sample in a location where a water grab sample could miss any detection of the proposed contaminate. Additionally, contaminates that drop out of the water column into the sediment could potentially be re-suspended during storm events. The study aim is twofold: To determine natural background concentrations of radionuclides and metals in sediment and waters, and determine if oil and gas treatment facilities elevate these levels over the expected natural background. The study examined sediment and water samples from background sites and locations that discharge oil and gas treated wastewater.

SITES AND SAMPLING METHODS

Reference Sites. Reference (background) locations were selected by looking at a variety of parameters (Figure 6, Table 2). Attempts were made to locate streams underlain by the Marcellus Shale formation and with similar bedrock types as streams containing oil and gas discharges. Exceptional value (EV) and/or high quality (HQ) streams were also prioritized. Streams with any upstream oil or gas wells were excluded. Where possible, locations were sampled that had continuous water data sondes installed. Because many streams with oil and gas discharges have large drainage areas, two streams were sampled based on having larger drainage areas and no oil and gas influences (Shermans Creek and Swatara Creek). A couple locations are outside the Marcellus region and were chosen to compare Marcellus and non-Marcellus underlain streams. All of the final streams sampled had either HQ or EV designated or existing uses, except for Shermans Creek and Swatara Creek, which are designated warm water fishes (WWF). Therefore, special attention was paid to these two streams during data analysis. These were excluded from water chemistry general statistics because much of their parameters were higher than the other reference sites (described below).

Field chemistries were taken at each location. Sediment samples were collected according to developed protocols (draft) and tested for radionuclides, metals, chloride, and bromide. Duplicate sediment samples were taken at most sites to quantify intra-site diversity. Water samples were collected according to standard protocols and tested for radionuclides, metals, and general chemistry. Samples were preserved and analyzed at the Department of Environmental Protection's Bureau of Laboratories (DEP BOL). Water samples were analyzed for radionuclides again at Pace Analytical in Greensburg, PA (details below). See Appendix A for raw reference site results.

Impacted Sites. Nine sites impacted by a variety of issues were also sampled (Figure 6, Table 1). The first impacted site sampled for radiation and metals in sediment was the location of a Marcellus Shale

spill, on an unnamed tributary to Towanda Creek in Bradford County. The rest of the sampling locations were chosen based on a variety of factors. On the maps in Figures 7 to 14, stream flow is indicated with a red arrow. Two water quality network (WQN) stations were sampled where routine water sampling for gross alpha and gross beta has been occurring. The rest of the sampling locations were based on Departmental recommendations, feasibility of sampling sediment (the largest drainage area rivers were excluded from this first season of sampling), proposed or average oil and gas wastewater flow, and type of wastewater accepted. Sample sites included existing publicly owned treatment works (POTWs) receiving indirect discharge from an existing centralized waste treatment facility (CWT), a CWT accepting only coal bed methane, and CWTs accepting a variety of oil and gas wastes. A site with suspected seepage from a coal bed/oil and gas pond was also sampled.

Field chemistries were taken at most locations. Sediment samples were collected according to developed protocol (draft) and tested for radionuclides, and, at most locations, also tested for metals, chloride, and bromide. Water samples were collected according to standard protocol and tested for radionuclides, metals, and general chemistry. Samples were taken upstream of a discharge, downstream of a discharge, and, at three locations, at the end-of-pipe discharge. Duplicate samples were taken at most upstream sites to quantify intra-site diversity. Samples were preserved and analyzed at DEP BOL. Water samples were analyzed for radionuclides again at Pace Analytical in Greensburg, PA (details below). See Appendix B for raw impacted site results.

Sediment at an unnamed tributary to Towanda Creek was also sampled for volatile and semi-volatile organic compounds. Results were non-detect for all target compounds. Some other compounds were detected, but cannot be attributed to the spill.

ANALYTICAL METHODS AND PARAMETERS TESTED

Sediment. Sediment samples were ingrown for 21 days and tested for a suite of gamma isotopes (Table 4) with DEP BOL suites RAD95S and RAD35S. Total uranium by ICP-MS was subsequently analyzed in place of Uranium-235 and Uranium 238 gamma isotopes due to the lower limits of detection (LLDs) and counting errors (CE) being very high for the uranium isotopes via the gamma method.

Sediment samples were also tested for a variety of metals (Table 4) with DEP BOL standard analysis code (SAC) 960 (with extra parameters added). Some locations at the beginning of sampling were tested for silver, arsenic, lead, mercury, chromium, cadmium, and copper, but these analytes were subsequently removed from analysis due to cost and lack of necessity.

Water. Water samples were ingrown for 21 days and tested for a suite of gamma isotopes. Upon obtaining the results, however, it became clear that the lower limits of detection (LLDs) were not low enough for the purposes of this study, and samples were re-tested for radium-226 via de-emanation, radium-228, and total uranium by an accredited laboratory, Pace Analytical, in Greensburg, PA (Table 3).

Water samples were also tested for a variety of general chemistry and metals with DEP BOL SAC 046 (Table 3).

Notes. At two of the three discharge locations that were sampled at end-of-pipe, all sediment and water parameters were tested at end-of-pipe. At the third location at end-of-pipe, all sediment parameters were tested and only radioisotopes were tested in the water (described in detail below).

BACKGROUND

Water. Pennsylvania water quality criteria can be viewed under Pennsylvania Code, Title 25, Chapter 93 (2011) at Chapter 93 - Water Quality Standards. Although Pennsylvania has no aquatic life usage water radionuclide standards, national drinking water criteria exist:

Parameter	Criteria (MCL)
Combined Radium-226 & Radium-228	5 pCi/L
Uranium	30 ug/L
Gross Alpha Emitters	15 pCi/L
Beta Particle & Photon Radioactivity	4 mrem/yr

Adapted from US EPA 2012a – "Basic Information About the Radionuclides Rule" (Basic Information)

Radium levels in surface waters can vary depending on geology. However, they are generally between 0.01 to 1 pCi/L; groundwater concentrations can be considerably higher, generally between 0.5 to 25 pCi/L (US EPA 2011). Uranium in groundwater can also vary – in southeast Pennsylvania, for example, levels ranging from <0.01 to 97 ug/L have been found (USGS 2000). In that same study, radium-226 levels of <0.02 to 98 pCi/L and radium-228 levels of <0.4 to 160 pCi/L were seen. Other chemical parameters may be related to radium levels. For example, dissolved radium activity appears to be inversely related to pH and directly related to concentrations of total dissolved solids, dissolved organic carbon, barium, and sulfate (Senior & Vogel 2003).

Sediment – Radionuclides. Pennsylvania has no sediment quality criteria. However, background soil and sediment values are generally known for a number of parameters. These can vary widely depending on the geology of an area. A study conducted on surface soils across the United States (356 locations in 33 states) determined average radium-226 levels to be 1.1 pCi/g (range = 0.23 to 4.2 pCi/g) and average uranium-238 levels to be 1.0 pCi/g (range = 0.12 to 3.8 pCi/g) (Myrick et al. 1983). The same study indicated Pennsylvania's levels (33 locations) to be: radium-226 range = 0.46 to 2.4 pCi/g and uranium-238 range = 0.41 to 1.9 pCi/g. A New York study concluded that background levels of total radium (radium-226 + radium-228) are at an average of around 5 pCi/g (NY DEC 1999a). Studies have also been conducted throughout the world documenting radionuclide sediment and soil levels. A study in Nigeria recorded naturally occurring radium-226 in sediment of <1 pCi/g; they stated a world average of 1.35 pCi/g (Jibiri & Okeyode 2011). Although Pennsylvania does not have sediment radiation criteria, the National Code of Federal Regulations (CFR) in document 40 CFR 192.12 states that:

"Remedial actions shall be conducted so as to provide reasonable assurance that, *as a result of residual radioactive materials from any designated processing site:*

(a) The concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than—

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and

(2) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface."

Sediment – Metals. These can also vary widely depending on geology in an area. Additionally, other contaminants, such as abandoned mine drainage, could drastically increase metals values in both water and sediment.

Ohio EPA has the following background values listed for selected metals:

Parameter	Reference Range (mg/kg)
Aluminum	28,000 – 53,000
Arsenic	11 - 25
Barium	170 - 360
Cadmium	0.3 - 0.96
Calcium	21,000 - 120,000
Chromium	29 - 53
Copper	25 - 42
Iron	31,000 - 51,000
Lead	47
Magnesium	7,100 - 35,000
Manganese	780 - 3,000
Mercury	0.12
Nickel	33 - 61
Potassium	5,900 - 14,000
Silver	0.43
Strontium	62 - 390
Zinc	100 – 190

Adapted from Ohio EPA (2008).

Sediment benchmarks have also been developed and implemented at many organizations and agencies. Some examples are shown below:

Parameter	Freshwater Screening Benchmark (mg/kg)*	Lowest Effect Level (ug/g)**	Severe Effect Level (ug/g)**	Lowest Effect Level (ug/g)#	Severe Effect Level (ug/g)#	Threshold Effect Concentration (mg/kg) +	Midpoint Effect Concentration (mg/kg) +	Probable Effect Concentration (mg/kg) +	Lowest Effect Level (mg/kg) @	Severe Effect Level (mg/kg) @
Arsenic	9.8	6	33	6	33	9.8	21.4	33	9.979	33
Cadmium	0.99	0.6	9	0.6	10	0.99	3	5	0.6 / 0.990	10
Chromium	43.4	26	110	26	110	43	76.5	110	26 / 43.4	110
Copper	31.6	16	110	16	110	32	91	150	16 / 31.6	110
Iron	20,000					20,000	30,000	40,000		
Lead	35.8	31	110	31	250	36	83	130	31 / 35.8	250
Manganese	460	460	1,100	460	1,100	460	780	1,100	630	1,100
Mercury	0.18	0.15	1.3	0.2	2	0.18	0.64	1.1	0.2 / 0.174	2
Nickel	22.7	16	50	16	75	23	36	49	16 / 22.7	75
Silver	1	1	2.2			1.6	1.9	2.2		
Zinc	121	120	270	120	820	120	290	460	120 / 121	820

** Adapted from US EPA 2012c*

*** Adapted from NY DEC 1999b - from Persuad et al. (1992) and Long & Morgan (1990); ug/g = mg/kg*

 # Adapted from Persuad et al. 1992 - from Long & Morgan (1990); ug/g = mg/kg

+ Adapted from Wisconsin Department of Natural Resources 2003

@ Adapted from NJ DEP 1998

RESULTS

Reference Sites - Statistical Analyses. Number of observations, minimum, maximum, range, mean, median, and standard deviation of each parameter analyzed at reference sites are shown in tables 5 to 7. Several water general chemistry parameters varied noticeably between sites, but not unexpectedly. Alkalinity fluctuated from 2.6 mg/L to 100.6 mg/L, with an average of 27.33 mg/L. Calcium also fluctuated, with a range between 1.96 mg/L to 42.3 mg/L and an average of 11.04 mg/L. Because Swatara Creek and Shermans Creek were "WWF reference" sites and had considerably different water chemistries than the other reference sites, which were all HQ or EV, statistics were then calculated for all reference sites *without* Swatara Creek and Shermans Creek results (Table 7). Sediment parameters appeared to vary greatly between sites, and Swatara Creek and Shermans Creek values often appeared in the middle rather than the highest; therefore, statistics were not recalculated for sediment excluding these sites.

Radium-226 levels in all reference water samples were < 1 pCi/L, which are background levels.

Radionuclides in sediment were also at background levels at all reference sites. Beryllium-7 ranged from 0 pCi/kg to 306 pCi/kg, with a mean of 141.47 pCi/kg. Beryllium-7 is a cosmic radionuclide often found in surficial sediment deposition whose presence can indicate the sample came from surface deposits rather than deeper deposits (personal communication, David Allard, PA DEP). Cesium-137 ranged from 0 pCi/kg to 73 pCi/kg with a mean of 29.76 pCi/kg. Cesium-137 is an isotope that can occur in the environment due to nuclear weapons testing in the 1950s and 1960s (US EPA 2012b).

There is a number of naturally occurring radiological materials (NORMs) that are present in the earth's crust. Isotopes from the uranium and thorium decay series were found at reference sites. The uranium decay series contains, among many other isotopes, uranium-238, radium-226, and lead-214. Uranium-238 levels ranged from 0 pCi/kg to 1,310 pCi/kg (mean = 504.06 pCi/kg), radium-226 ranged from 0 pCi/kg to 2,080 pCi/kg (mean = 1,068.88 pCi/kg), and lead-214 ranged from 0 pCi/kg to 906 pCi/kg (mean = 478.65 pCi/kg). However, counting errors and lower limits of detection for uranium-238 were quite high, rendering these results not as useful. For this reason, total uranium was also analyzed in sediment. Results were background. In the thorium series, radium-228 and lead-212 were detected. Radium-228 levels ranged from 0 pCi/kg to 962 pCi/kg (mean = 529.88 pCi/kg) and lead-212 ranged from 0 pCi/kg to 1,030 pCi/kg (mean = 573.71 pCi/kg).

A number of metals at reference sediment sites varied quite a bit, which is not surprising. Metals that varied the most were aluminum (range = 2,427 – 29,127 mg/kg; mean = 9,858.8 mg/kg), barium (range = 21 – 2,790 mg/kg; mean = 202.55 mg/kg), calcium (range = 101 – 16,854 mg/kg; mean = 1,392.95 mg/kg), iron (range = 3,470 – 75,934 mg/kg; mean = 20,248.45 mg/kg), magnesium (range = 154 – 9,963 mg/kg; mean = 1,885.45 mg/kg), manganese (range = 180 – 2,020 mg/kg; mean = 686.9 mg/kg), and strontium (range = 2.26 – 249 mg/kg; mean = 20.63 mg/kg).

Each site was visited one time; the only duplicates were the replicates taken on the same day. Replicate sediment samples were collected to show variation at the sample site. There is little data on sediment levels in Pennsylvania of the parameters studied, so little is known about variation at a site. Because

there are at least two related observations per sediment metals and radionuclides per site, the data was tested to determine if paired t-tests or Wilcoxon signed rank tests (the non-parametric equivalent to the paired t-test) were appropriate analyses. Normality tests were conducted on the paired differences between reference sediment samples and their replicates for each parameter examined. Results indicated that none of the data is very normally distributed. Wilcoxon signed rank tests were performed on all combinations mentioned above, and resulted in no statistically significant differences between replicates (Table 8).

Additionally, graphs were done to visually see the concentrations of selected sediment parameters and water parameters (Figures 1-5).

Impacted Sites - Statistical Analyses. Krustal Wallis tests (or one-way ANOVAs, if data would have been normally distributed) were considered to compare upstream versus discharge versus downstream samples, but could not be utilized due to the small number of discharge sites sampled (three). In order to be effective, the number of observations should be at least five (McDonald 2009).

Although all sites contained samples collected upstream and downstream of the discharges, these data cannot be statistically compared (such as with a t-test, Wilcoxon signed-rank test, etc.) due to inconsistency between distances sampled downstream. While some sites were sampled downstream close to the discharges, some were sampled further downstream (i.e. 20 meters versus ½ mile). Therefore, upstream versus downstream samples cannot be compared between sites, only within sites. Due to variability of many factors between sites, between-site comparisons may not be appropriate in general.

Because there are at least two related observations per upstream sediment metals and radionuclides per site, the data was tested to determine if paired t-tests or Wilcoxon signed rank tests (the non-parametric equivalent to the paired t-test) were appropriate analyses. Normality tests were conducted on the paired differences between impacted upstream sediment samples and their replicates, for each parameter examined. Results indicated that none of the data is very normally distributed. The natural log of strontium in sediment appeared normally distributed, so t-tests were performed on that; the t-test indicated statistically significant differences between the upstream replicates for strontium ($p = 0.006$). Wilcoxon signed rank tests were performed on all combinations mentioned above, and resulted in no statistically significant differences between upstream replicates (Table 9).

Impacted Sites – Individual Reports.

Blacklick Creek (PA Brine Treatment @ Josephine) – Figure 12.
Water Samples. General chemistry water samples were collected upstream of the discharge (1BC), of the effluent (DISBC), and downstream of the discharge (approximately 20 meters downstream (2BC) and downstream at the T660 (Old Indiana Road) bridge (3BC)) (Appendix B). The reach is aquatic life impaired for abandoned mine drainage (metals) and the designated use is trout stock fishes (TSF). Several parameters were elevated at DISBC and 2BC for which there are no aquatic life criteria: bromide, chloride, sodium, specific conductance, strontium, sulfate, and total dissolved solids. At DISBC, chloride (60,220 mg/L), TDS (130,822 mg/L), bromide (498,014 ug/L), and strontium (999,000 ug/L) were

especially elevated. pH in the effluent (9.6) was higher than the permit limit (≤ 9.5), as was total suspended solids (218 mg/L with a permit limit of 60 mg/L maximum). Osmotic pressure was higher than criteria (50 mosm) at both DISBC (2,590 mosm) and 2BC (273 mosm). The Department's Chapter 93 – Water Quality Standards (§93.7) states that osmotic pressure should not exceed 50 mosm instream to protect the aquatic life use TSF. While the permit limit states the osmotic pressure needs to be only monitored at the discharge, the instream value was exceeding. However, the value lowered to 28 mosm at site 3BC. Additionally, there is a fish and aquatic life criteria continuous concentration for selenium of 4.6 ug/L; the total selenium concentration at 3BC was 12.67 ug/L. Radium-226 levels at DISBC (9 pCi/L) appear slightly above background; however, the counting error on the sample is 8.07 pCi/L and the lower limit of detection is only 4.88 pCi/L. Twenty meters downstream of the discharge, at 2BC, the radium-226 level was 1.9 pCi/L, which is close to background. Radium-228 exhibits a similar pattern in the water samples. Total uranium levels came back low.

Sediment Samples. Sediment was collected at 1BC, DISBC, and 2BC, with a replicate taken at 1BC (Appendix B). Radium-226, radium-228, and their decay products were elevated above background levels at DISBC and 2BC. Radium-226 in the sediment at DISBC was 211,000 pCi/kg (+/- 950) and radium-228 was 73,000 pCi/kg (+/- 198). Beryllium-7 was present at 1BC, but not at DISBC or 2BC, indicating the sediment collected was probably not influenced by atmospheric deposition, but that it could have come out of the discharge. Interestingly, though, cesium-137 was present at 1BC, DISBC, and 2BC, indicating recent atmospheric deposition. Some metals and general chemistry parameters were elevated at DISBC and 2BC. At DISBC, barium was 6,056 mg/kg; calcium was 76,173 mg/kg; magnesium was 7,279 mg/kg; sodium was 11,334 mg/kg; and strontium was 29,383 mg/kg. All of these parameters remained at least slightly elevated at 2BC.

Conemaugh River (WQN810 & Tunnelton Liquids) – Figure 13.

Water Samples. A sample was collected downstream of the discharge at 1CR (Appendix B). In this reach, the aquatic life use is impaired for abandoned mine drainage (metals), upstream impoundments (water/flow variability), and flow regulation/modification (flow alterations). The reach is attaining potable water usage and fish consumption. It is designated warm water fishes (WWF). A few general chemistry water parameters were slightly elevated above background, but nothing very high. Bromide, chloride, and sulfate were slightly elevated. Sulfate was 320 mg/L. The Department's Chapter 93 – Water Quality Standards (§93.7) states that sulfate cannot exceed a maximum of 250 mg/L for potable water source use. Radionuclides were background.

Sediment Samples. Radionuclides were at background levels in both replicate samples collected at 1CR (Appendix B). Some sediment metals and general chemistries were elevated above effect concentrations from various agencies (as seen in the table on page 5): arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. Only iron was highly elevated above background (98,006 mg/kg and 100,425 mg/kg). Uranium was slightly above background; however, this can vary widely per site and it could just be a reflection of the underlying bedrock.

Jacobs Creek (Belden and Blake) – Figure 14.

Water Samples. Samples were collected upstream of the discharge (2JC), at the discharge (DISJC), and downstream of the discharge (3JC). The reach is aquatic life attaining and has a designated use of WWF. General water chemistry samples had a few elevated parameters, mainly at 2JC and 3JC, rather than at DISJC (Appendix B). The Department's Chapter 93 – Water Quality Standards (§93.8) states that total aluminum cannot exceed 750 ug/L for fish and aquatic life; both 2JC and 3JC exceed this. Iron was also elevated at 2JC and 3JC. At DISJC, ammonia (0.72 mg/L), bromide (13,660 ug/L), osmotic pressure (127 mosm), sodium (1,760 mg/L), specific conductance (7,170 umhos/cm), and total dissolved solids (4,074 mg/L) were elevated; however, they were low again immediately downstream. Radium-226 and radium-228 were very slightly above background levels directly at DISJC (radium-226 at 2JC = 0.182 pCi/L +/- 0.396; radium-226 at DISJC = 3.34 pCi/L +/- 1.16; radium-226 at 3JC = -0.065 +/- 0.34). Total uranium levels were background.

Sediment Samples. Samples were collected upstream (1JC), at the discharge (DISJC), and downstream of the discharge (3JC). Radionuclides were mainly background (Appendix B). Radium-226 appeared very slightly above background at DISJC (2,470 pCi/kg +/- 192), but is still very low, and was back down immediately downstream (1,410 pCi/kg +/- 152). Metals and general chemistry parameters were generally slightly elevated at 1JC and 3JC, and slightly at DISJC. At DISJC, chloride, aluminum, barium, calcium, iron, magnesium, nickel, potassium, sodium, strontium, and zinc were slightly elevated but all were reduced again downstream, except for aluminum and iron, which actually increased downstream.

Mahoning River (New Castle City/Advanced Waste Services) – Figure 8.

Water Samples. Samples were collected upstream (1MR) and downstream (2MR). The reach is impaired for fish consumption (source unknown – PCBs) and aquatic life (source/cause unknown). The designated use is WWF. General water chemistry parameters were generally the same at 1MR and 2MR (Appendix B). Chloride was elevated at both 1MR (78.3 mg/L) and 2MR (67.4 mg/L). Radionuclides were at background levels.

Sediment Samples. Radionuclides were at background levels at 1MR and 2MR; however, radium-226 and radium-228 and their decay products were slightly higher at 2MR than at 1MR (Appendix B). The 2 pCi/kg of barium-140 at 2MR was *not* actually a detection; the counting error was 3 pCi/kg. Some other sediment parameters were slightly elevated downstream of the discharge at 2MR compared with upstream of the discharge at 1MR: chloride, aluminum, barium, calcium, magnesium, strontium, and zinc. Iron was high at both 1MR (122,769 mg/kg) and 2MR (118,974 mg/kg), and along with manganese, nickel, and zinc, would have exceeded at least a few of various agencies' benchmarks (see table on page 5).

McKee Run (Hart Resources @ Creekside) – Figure 11.

Water Samples. Water samples were collected at the discharge (DISMKR-radionuclides only), approximately 2.25 miles upstream of the discharge (1MKR), and approximately 0.2 miles downstream of the discharge (3MKR). The reach is aquatic life impaired for AMD (metals, pH) and the designated use is cold water fishes (CWF). Several parameters were elevated at 3MKR (Appendix B). Metals such as aluminum (14,000 ug/L), manganese (2,389 ug/L), and iron (30,900 ug/L) were highly elevated at 3MKR;

however, the reach *is* impaired for abandoned mine drainage. Also elevated at 3MKR were: bromide (7,750 ug/L), chloride (931 mg/L), osmotic pressure (51 mosm), selenium (25.15 ug/L), specific conductance (3,680 umhos/cm), strontium (10,100 ug/L), total dissolved solids (2,498 mg/L), and zinc (254 ug/L). Of the above list, Pennsylvania has aquatic life criteria for osmotic pressure of 50 mosm; the downstream sample (3MKR) is slightly above this. There is also a fish and aquatic life criteria continuous concentration for dissolved selenium of 4.6 ug/L; the total selenium at 3MKR was 25.15 ug/L. Radium-226 and radium-228 at DISMKR appear slightly elevated above background (Ra-226 = 7.41 pCi/L; Ra-228 = 26.2 pCi/L), but have large counting errors (Ra-226 +/- 7.39 pCi/L; Ra-228 +/- 15.5 pCi/L) and lower limits of detection (Ra-226 = 5.02 pCi/L; Ra-228 = 27.3 pCi/L). Downstream levels at 3MKR were background. Total uranium levels were background at all sites.

Sediment Samples. Sediment samples were collected upstream of the discharge (2MKR), at the discharge (DISMKR), and downstream of the discharge (3MKR). Replicate samples were collected at 2MKR. Radium-226, radium-228, and their decay products were all slightly elevated in the sediment at DISMKR (Appendix B). Radium-226 was the highest at 15,100 pCi/kg (+/- 324 pCi/kg). Total uranium was background. Some metals were also elevated at DISMKR. Bromide was slightly above background (11.1 mg/L). Others were quite a bit higher: chloride (1,350 mg/L), barium (2,676 mg/kg), calcium (43,557 mg/kg), sodium (20,930 mg/kg), and strontium (1,466 mg/kg).

Smith Creek – Figure 9.

Water Samples. Water samples were collected upstream of a drainage seep (1SC – SAC46 only; 2SC – radionuclides only), downstream of the seepage at the mouth of an unnamed tributary (UNT) at 1USC (SAC46 only), and downstream of the UNT (3SC – SAC46 replicated, radionuclides) (Appendix B). The entire watershed is designated WWF. In the upstream portion, at stations 1SC and 2SC, the reach is attaining aquatic life usage. The main stem of the stream is already impaired for AMD (metals, oil and grease), land disposal (metals, oil and grease), and subsurface mining (metals). The UNT is also impaired for osmotic pressure and subsurface mining (oil and grease). Since this is not at a licensed facility, there are no permit limits. Water parameters were low or background at 1SC. Several parameters were elevated at 1USC and 3SC. Immediately downstream of the discharge at 1USC, elevated parameters included alkalinity (577 mg/L), arsenic (6.2 ug/L), boron (470 ug/L), bromide (4,146 ug/L), chloride (601 mg/L), manganese (229 mg/L), osmotic pressure (79 mosm), selenium (20 ug/L), sodium (1,110 mg/L), specific conductance (4,770 umhos/cm), strontium (1,838 ug/L), sulfate (1,168 mg/L), and total dissolved solids (3,286 mg/L). All of these diminished at least somewhat in samples collected at 3SC. Radionuclides appeared to be background.

Sediment Samples. Samples tested for radionuclides were collected upstream of the UNT (2SC) and downstream of the UNT (3SC) (Appendix B). Radionuclides were background. One interesting result is that beryllium-7 was detected upstream of the UNT and was not detected downstream of it, indicating lack of surface deposition; however, cesium-137 was detected at both sites. Several other non-radionuclide parameters were detected in sediment downstream of the UNT at 3SC, but were not largely elevated (these other analytes were not tested for at 2SC). Noted elevated parameters at 3SC included chloride (2.44 mg/L), iron (62,471 mg/kg), and strontium (92.5 mg/kg).

South Fork Tenmile Creek (Franklin Township Sewer Authority/Tri-County Wastes and WQN 713) – Figures 9 & 10.

Water Samples. Water was collected for general chemistry (SAC46) analyses on South Fork Tenmile Creek upstream of both Franklin Township Sewer Authority and the confluence of Smith Creek at 1SFT (Appendix B). The entire reach is designated WWF. The stream is attaining aquatic life use at 1SFT and impaired with source/cause unknown at 2SFT and 3SFT. Downstream further, at 4SFT (WQN713), the stream is attaining aquatic life usage again. A few parameters at 1SFT were slightly elevated, including aluminum (2,775 ug/L) and iron (4,971 ug/L). Water samples tested for radionuclides were collected upstream of Franklin Township Sewer Authority but downstream of WQN 713 (2SFT), downstream of Franklin Township Sewer Authority (3SFT), and at WQN 713, which is also downstream of Franklin Township Sewer Authority (4SFT). Radionuclide results were background.

Sediment Samples. Samples were collected for radionuclide analysis upstream of Franklin Township Sewer Authority but downstream of WQN 713 (2SFT), downstream of Franklin Township Sewer Authority (3SFT), and at WQN 713 (4SFT) (Appendix B). All radionuclides were at background levels. Other analyses were not conducted in the sediment on South Fork Tenmile Creek.

Towanda Creek (spill location) – Figure 7.

Sediment Samples. This site was the first impacted site collected in the study. Water samples were not collected. Sediment samples, tested for radionuclides, metals, and volatile and semi-volatile organic compounds, were collected downstream of the spill on the UNT (1UTC), upstream on the main stem of Towanda Creek (1TC), and downstream on the main stem of Towanda Creek (2TC) (Appendix B). Replicate sediment samples were collected at 1TC. The unnamed tributary is designated CWF and attaining both fish consumption and aquatic life usage. The main stem of Towanda Creek in the sample area is designated TSF and attaining both fish consumption and aquatic life usage. Again, there are no discharge permit limits in this area because this was a spill location. Volatile and semi-volatile organic compounds are described on page 2 of this report, above. Beryllium-7 and cesium-137 were detected at 1TC and 2TC, but not at 1UTC. Additionally, elevated levels of radium-226 (10,810 pCi/kg +/- 170 pCi/kg), radium-228 (1,010 pCi/kg +/- 37 pCi/kg), and other products in their decay series were found immediately below the spill at 1UTC. These all point to the spill as the cause of the elevated values. Perhaps one of the most interesting points is that the samples were collected a few weeks after the spill originally occurred, with some rain events happening in the interim, and elevated radionuclide levels were still seen in the sediment. Sediment metals were slightly elevated at 1UTC compared with 1TC and 2TC, most notably barium (154 mg/kg), iron (32,035 mg/kg), magnesium (3,983 mg/kg), manganese (740 mg/kg), and strontium (11.9 mg/kg).

Overall Observations.

Because many oil and gas treatment facilities discharge into streams already heavily impacted by other pollutants, such as abandoned mine drainage (AMD), it can be difficult to compare impacted sites with reference, non-discharge impacted sites. However, some conclusions can be reached regarding impacted versus non-impacted sites (Table 10).

In sediment at the discharges, a few metals were, on average, higher than the reference sites, including barium, calcium, iron, magnesium, sodium, and strontium (Table 10). Chloride and bromide were also higher. Sediment radioisotopes in the uranium and thorium decay series were also elevated. Many water parameters were elevated at discharge sites compared to reference sites, including but not limited to chloride, sodium, total dissolved solids (TDS), osmotic pressure, pH, arsenic, barium, boron, bromide, selenium, and strontium.

Downstream of discharge sites, some sediment parameters improve immensely, while others are actually elevated higher than the discharge sediment, and therefore even higher than reference/background levels. This is most likely due to the fact that most of the discharges are located streams already impacted by other problems (i.e. AMD); therefore, some parameters, such as aluminum, iron, and manganese, are elevated both downstream and upstream of the discharges. The discharge may actually serve to mediate the other impairments briefly. However, some parameters, such as barium, calcium, magnesium, sodium, strontium, bromide, chloride, and the isotopes of the uranium and thorium decay series are elevated at the discharges, either less or not at all downstream, and not upstream. Water quality was, for the most part, greatly improved upstream of the discharges versus at the discharges – parameters such as calcium, chloride, sodium, sulfate, TDS, osmotic pressure, barium, bromide, and strontium were much lower upstream of discharges. Other parameters, such as iron, manganese, and zinc, were elevated outside the discharges.

CONCLUSIONS

In general, suspected oil and gas waste parameters, such as radionuclides and certain metals (barium, strontium) were highly elevated in either sediment and/or water where discharges were sampled. These normally decreased markedly not very far downstream. Since discharges are normally into waters already impaired for various parameters, it can be difficult to determine exactly what was contributed by the discharge and what may have already been input upstream.

Reference sites showed a wide range of values for some sediment parameters – which may be due to other influences in the watersheds. Overall, however, this study shows a good general background of sediment parameters in the state. It also supports previous research that indicates background sediment radium-226 to be around 1 pCi/g.

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Table 1 – Impacted site locations

Region	Facility Name	Permit Number	Receiving Stream	County	Latitude	Longitude	Drainage Area (sq mi)
NCRO	Towanda Creek UNT spill	N/A	**Towanda Creek**	Bradford	41.669444	-76.713472	0.289
NWRO	New Castle City / Advanced Waste Services	PA0027511	**Mahoning River**	Lawrence	40.9667	-80.3895	1113.196
SWRO	N/A	N/A	**Smith Creek**	Greene	39.88933	-80.18513	10.704
SWRO	WQN 713	N/A	**South Fork Tenmile Creek @ WQN713**	Greene	39.923055	-80.072777	180.523
SWRO	Franklin Township Sewer Authority/ Tri-County Wastes (CWT)	PA0046426	**South Fork Tenmile Creek**	Greene	39.9025	-80.1503	139.163
SWRO	Hart Resource (Creekside)	PA0095443	**McKee Run**	Indiana	40.675	-79.1875	14.073
SWRO	PA Brine Josephine	PA0095273	**Blacklick Creek**	Indiana	40.4797	-79.1703	191.258
SWRO	Tunnelton Liquids	PA0091472	**Conemaugh River @ WQN810**	Indiana	40.4539	-79.3767	1360.664
SWRO	Belden and Blake (Scottdale)	PA0218073	**Jacobs Creek**	Westmoreland	40.106	-79.567	51.2

Table 2 – Reference site locations

Region	Receiving Stream	County	Latitude	Longitude	Drainage Area (sq mi)	Designated Use	Existing Use	Assessments
NCRO	**Wallis Run**	Lycoming	41.38149486	-76.92656444	32.2	HQ-CWF	EV	Aquatic Life - Supporting
NCRO	**Baldwin Branch**	Clinton/Potter/Lycoming	41.468854	-77.621203	30.2	EV		Aquatic Life - Supporting Fish Consumption - Supporting
NERO	**E. Br. Hemlock Creek (trib to Starrucca Creek)**	Susquehanna	41.962139	-75.490861	67.3	CWF	EV	Aquatic Life - Supporting
NERO	**Bowman Creek**	Wyoming	41.414639	-76.090694	55.4	HQ-CWF		Aquatic Life - Supporting Fish Consumption - Supporting Potable Water Supply - Supporting Recreational Use - Supporting
NERO	**Factory Creek (trib to Equinuck Creek)**	Wayne	41.854	-75.231778	57.4	HQ-CWF		Aquatic Life - Supporting
SCRO	**Shermans Creek**	Perry	40.32332515	-77.16772136	206.9	WWF		Aquatic Life - Supporting Potable Water Supply - Supporting Recreational Use - Supporting
SCRO	**Swatara Creek**	Dauphin	40.28879335	-76.6756009	484.8	WWF		Aquatic Life - Supporting Fish Consumption - Supporting Potable Water Supply - Supporting
SCRO	**Carbaugh Run**	Adams	39.898943	-77.451864	5.99	EV		Aquatic Life - Supporting
SWRO	**Clearshade Creek**	Somerset	40.169254	-78.748288	17.1	EV		Aquatic Life - Supporting Potable Water Supply - Supporting
SWRO	**Isers Run**	Somerset	39.859972	-79.198111	9.9	EV		Aquatic Life - Supporting

Table 3 – Sediment study water parameters

Parameter	Analytical Method Reference	Sample Preservation	Holding Time
Inorganic Tests (Field)			
pH	SM (Potentiometric)	None	Analyze in field
DO	SM 421	None	Analyze in field
Temperature	SM 212	None	Analyze in field
Inorganic Tests (Lab)			
Analyzed at Pace Analytical Laboratories (Greensburg, PA)			
Radium-226	EPA 903.1	N/A in field	6 months
Radium-228	EPA 904.0	N/A in field	6 months
Total Uranium	ASTM D5174.97	Fix with HNO_3 to pH<2, Hold @ $\leq 6^oC$	6 months
SAC046 (Analyzed at DEP BOL)			
pH	SM 4500H-B	Hold @ $\leq 6^oC$	none
Specific Conductance	SM 2510B	Hold @ $\leq 6^oC$	28 days
TDS @ 180 C	USGS-I-1750	Hold @ $\leq 6^oC$	7 Days
Total Suspended Solids	USGS-I-3765	Hold @ $\leq 6^oC$	7 Days
Alkalinity as $CaCO_3$	SM 2320B	Hold @ $\leq 6^oC$	14 days
Hardness as $CaCO_3$	Calculated (SM 2340B)	Hold @ $\leq 6^oC$	N/A
NH_3-N, Total	EPA 350.1	Fix with H_2SO_4 to pH<2, Hold @ $\leq 6^oC$	28 days
NO_3 & NO_2-N, Total	EPA 353.2	Fix with H_2SO_4 to pH<2, Hold @ $\leq 6^oC$	48 hours
P, Total	EPA 365.1	Fix with H_2SO_4 to pH<2, Hold @ $\leq 6^oC$	28 days
Metals (total): Ca, Mg, Na, Fe, Mn, Ba, Bo, Sr, Al, Zn	EPA 200.7 rev 4.4	Fix with HNO_3 to pH<2, Hold @ $\leq 6^oC$	1 to 6 months
Se, As	EPA 200.8 rev 5.4	Fix with HNO_3 to pH<2, Hold @ $\leq 6^oC$	1 to 6 months
Chloride	EPA 300.0	Hold @ $\leq 6^oC$	28 days
Sulfate	EPA 300.0	Hold @ $\leq 6^oC$	28 days
Osmotic Pressure	DEP BOL	Hold @ $\leq 6^oC$	48 hours
Bromide	EPA 300.1B	Hold @ $\leq 6^oC$	28 days
5-day BOD	SM 5210B	Hold @ $\leq 6^oC$	48 hours

Table 4 – Sediment study sediment parameters

Parameter	Analytical Method Reference	Sample Preservation	Holding Time
Inorganic Tests (Lab)			
Gamma-Emitting Isotopes: RAD95S + RAD35S + Ir-192 (Analyzed at DEP BOL)			
Ra-226	DOE 4.5.2.3	N/A in the field	6 months
Ra-228	DOE 4.5.2.3	N/A in the field	6 months
Mn-54	DOE 4.5.2.3	N/A in the field	6 months
Nb-95	DOE 4.5.2.3	N/A in the field	6 months
Ru-103	DOE 4.5.2.3	N/A in the field	6 months
Ru-106	DOE 4.5.2.3	N/A in the field	6 months
Zn-65	DOE 4.5.2.3	N/A in the field	6 months
Pb-212	DOE 4.5.2.3	N/A in the field	6 months
Pb-214	DOE 4.5.2.3	N/A in the field	6 months
Zr-95	DOE 4.5.2.3	N/A in the field	6 months
U-238	DOE 4.5.2.3	N/A in the field	6 months
U-235	DOE 4.5.2.3	N/A in the field	6 months
Am-241	DOE 4.5.2.3	N/A in the field	6 months
Ba-140	DOE 4.5.2.3	N/A in the field	6 months
Be-7	DOE 4.5.2.3	N/A in the field	6 months
Co-58	DOE 4.5.2.3	N/A in the field	6 months
Co-60	DOE 4.5.2.3	N/A in the field	6 months
Cs-134	DOE 4.5.2.3	N/A in the field	6 months
Cs-137	DOE 4.5.2.3	N/A in the field	6 months
Fe-59	DOE 4.5.2.3	N/A in the field	6 months
I-131	DOE 4.5.2.3	N/A in the field	6 months
La-140	DOE 4.5.2.3	N/A in the field	6 months
Ir-192	DOE 4.5.2.3	N/A in the field	6 months
SAC960 + Extras (Analyzed at DEP BOL)			
Sr, Total	EPA 200.8	Hold @ $\leq 6^{o}C$	6 months
U, Total	EPA 6020	Hold @ $\leq 6^{o}C$	6 months
Chloride	EPA 300.0	Hold @ $\leq 6^{o}C$	6 months
Bromide	EPA 300.0	Hold @ $\leq 6^{o}C$	6 months
Barium	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Aluminum	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Magnesium	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Arsenic	EPA 6020	Hold @ $\leq 6^{o}C$	6 months
Cadmium	EPA 6020	Hold @ $\leq 6^{o}C$	6 months
Calcium	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Chromium	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Copper	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Iron	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Lead	EPA 6020	Hold @ $\leq 6^{o}C$	6 months

Parameter	Analytical Method Reference	Sample Preservation	Holding Time
Manganese	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Mercury	EPA 245.1	Hold @ $\leq 6^{o}C$	6 months
Nickel	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Potassium	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Silver	EPA 6020	Hold @ $\leq 6^{o}C$	6 months
Zinc	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months
Sodium	EPA 6010C	Hold @ $\leq 6^{o}C$	6 months

Table 5 – Reference sites: Water (general chemistry) statistics (including Shermans Creek and Swatara Creek)

Test	Units	Number Of Observations	Minimum	Maximum	Range	Mean	Median	Standard Deviation
Alkalinity, Total as CaCO3	MG/L	11	2.6	100.6	98	27.33	16	34.29
Aluminum, Total	UG/L	11	200	200	0	200	200	0
Ammonia, Total as Nitrogen	MG/L	11	0.02	0.05	0.03	0.03	0.02	0.01
Arsenic, Total	UG/L	11	3	3	0	3	3	0
Barium, Total	UG/L	11	10	49	39	30.27	27	13.72
Biochemical Oxygen Demand, Inhibited 5-day	MG/L	11	0.2	0.8	0.6	0.45	0.5	0.20
Boron, Total	UG/L	11	200	200	0	200	200	0
Bromide by Ion Chromatograph	UG/L	11	50	50	0	50	50	0
Calcium, Total	MG/L	11	1.96	42.3	40.34	11.04	6.66	13.55
Chloride (ASTM-A)	MG/L	1	0.5	0.5	0	0.5	0.5	
Chloride by Ion Chromatograph	MG/L	11	0.5	25.15	24.65	4.35	2.12	7.17
Hardness (calculated)	MG/L	11	8	150	142	37.18	21	46.80
Iron, Total	UG/L	11	20	352	332	142.18	103	121.12
Magnesium, Total	MG/L	11	0.554	10.7	10.15	2.32	1.11	3.17
Manganese, Total	UG/L	11	10	59	49	22.82	11	16.95
Nitrate & Nitrite, Total as Nitrogen	MG/L	11	0.05	4.35	4.3	0.67	0.24	1.28
Osmotic Pressure	MOSM	11	1	38	37	4.73	1	11.07
Phosphorus, Total	MG/L	11	0.01	0.036	0.026	0.01	0.01	0.01
Selenium, Total	UG/L	11	7	7	0	7	7	0
Sodium, Total	MG/L	11	0.509	14.5	13.99	2.91	1.99	3.96
Specific Conductance	umhos/cm	11	21.7	375	353.3	95.11	59.3	109.84
Strontium, Total	UG/L	11	10	635	625	88.55	23	185.04
Sulfate by Ion Chromatograph	MG/L	11	2.74	31.15	28.41	8.64	6.68	7.93
Total Dissolved Solids @ 180C	MG/L	11	24	244	220	72.73	54	65.48
Total Suspended Solids	MG/L	11	5	8	3	5.64	5	1.21
Zinc, Total	UG/L	11	10	10	0	10	10	0
pH (lab)	pH units	11	6.6	8.2	1.6	7.22	7.1	0.52

Table 6 – Reference Sites: Sediment statistics (including Shermans Creek & Swatara Creek)

Test	Units	Number Of Observations	Minimum	Maximum	Range	Mean	Median	Standard Deviation
Americium 241	PCI/KG	17	0	0	0	0	0	0
Barium 140	PCI/KG	17	0	0	0	0	0	0
Beryllium 7	PCI/KG	17	0	306	306	141.47	134	111.57
Cesium 134	PCI/KG	17	0	0	0	0	0	0
Cesium 137	PCI/KG	17	0	73	73	29.76	28	17.61
Cobalt 58	PCI/KG	17	0	0	0	0	0	0
Cobalt 60	PCI/KG	17	0	0	0	0	0	0
Iodine 131	PCI/KG	17	0	0	0	0	0	0
Iridium 192	PCI/KG	17	0	0	0	0	0	0
Iron 59	PCI/KG	17	0	0	0	0	0	0
Lanthanum 140	PCI/KG	17	0	0	0	0	0	0
Lead 212	PCI/KG	17	0	1,030	1,030	573.71	597	250.95
Lead 214	PCI/KG	17	0	906	906	478.65	522	205.53
Manganese 54	PCI/KG	17	0	0	0	0	0	0
Niobium 95	PCI/KG	17	0	0	0	0	0	0
Radium 226	PCI/KG	17	0	2,080	2,080	1,068.88	1,030	485.57
Radium 228	PCI/KG	17	0	962	962	529.88	530	234.50
Ruthenium 103	PCI/KG	17	0	0	0	0	0	0
Ruthenium 106	PCI/KG	17	0	0	0	0	0	0
Uranium 235	PCI/KG	17	0	0	0	0	0	0
Uranium 238	PCI/KG	17	0	1,310	1,310	504.06	433	358.19
Zinc 65	PCI/KG	17	0	0	0	0	0	0
Zirconium 95	PCI/KG	17	0	0	0	0	0	0
Bromide	MG/L	20	0.2	0.2	0	0.2	0.2	0
Chloride	MG/L	20	0.5	1.46	0.96	0.591	0.5	0.28
Aluminum	MG/KG	20	2,427	29,127	26,700	9,858.8	6,139.5	7,502.81
Arsenic	MG/KG	8	1.81	5.85	4.04	3.79	3.88	1.22
Barium	MG/KG	20	21	2,790	2,769	202.55	62.2	610.02
Cadmium	MG/KG	8	0.452	0.706	0.254	0.60	0.632	0.10
Calcium	MG/KG	20	101	16,854	16,753	1,392.95	453	3,657.94
Chromium	MG/KG	8	2.31	14.6	12.29	7.79	8.575	4.02
Copper	MG/KG	8	1.81	16.9	15.09	8.04	7.795	5.05
Iron	MG/KG	20	3,470	75,934	72,464	20,248.45	18,299	14,534.10
Lead	MG/KG	8	7.19	11	3.81	8.80	8.235	1.46
Magnesium	MG/KG	20	154	9,963	9,809	1,885.45	1,430	2,220.37
Manganese	MG/KG	20	180	2,020	1,840	686.9	516	484.89
Mercury	MG/KG	8	0.09	0.141	0.051	0.12	0.126	0.02
Nickel	MG/KG	20	2.78	64.9	62.12	16.33	12.7	13.26
Potassium	MG/KG	20	261	5,820	5,559	1,828.8	950	1,722.50
Silver	MG/KG	8	0.452	0.706	0.254	0.60	0.632	0.10
Sodium	MG/KG	20	45.2	2,041	1,995.8	191.14	70.5	438.59
Strontium	MG/KG	20	2.26	249	246.74	20.63	8.54	54.02
Uranium, Total	MG/KG	20	4.52	7.33	2.81	6.07	6.225	0.79
Zinc	MG/KG	20	28.6	214	185.4	66.96	55.25	39.50

Table 7 – Reference sites: Water (general chemistry) statistics

(*NOT* including Shermans Creek and Swatara Creek)

Test	Units	Number Of Observations	Minimum	Maximum	Range	Mean	Median	Standard Deviation
Alkalinity, Total as CaCO3	MG/L	9	2.6	23	20.4	12.24	10.8	7.39
Aluminum, Total	UG/L	9	200	200	0	200	200	0
Ammonia, Total as Nitrogen	MG/L	9	0.02	0.05	0.03	0.02	0.02	0.01
Arsenic, Total	UG/L	9	3	3	0	3	3	0
Barium, Total	UG/L	9	10	44	34	26.22	26	11.56
Biochemical Oxygen Demand, Inhibited 5-day	MG/L	9	0.2	0.6	0.4	0.42	0.5	0.18
Boron, Total	UG/L	9	200	200	0	200	200	0
Bromide by Ion Chromatograph	UG/L	9	50	50	0	50	50	0
Calcium, Total	MG/L	9	1.96	8.51	6.55	5.10	4.45	2.53
Chloride (ASTM-A)	MG/L	1	0.5	0.5	0	0.5	0.5	
Chloride by Ion Chromatograph	MG/L	9	0.5	4.87	4.37	1.78	1.68	1.44
Hardness (calculated)	MG/L	9	8	27	19	16.78	15	7.21
Iron, Total	UG/L	9	20	352	332	112.22	64	110.04
Magnesium, Total	MG/L	9	0.55	1.38	0.82	0.98	1.018	0.25
Manganese, Total	UG/L	9	10	59	49	20.11	10	17.26
Nitrate & Nitrite, Total as Nitrogen	MG/L	9	0.05	0.33	0.28	0.17	0.14	0.10
Osmotic Pressure	MOSM	9	1	38	37	5.11	1	12.33
Phosphorus, Total	MG/L	9	0.01	0.01	0.004	0.01	0.01	0.002
Selenium, Total	UG/L	9	7	7	0	7	7	0
Sodium, Total	MG/L	9	0.51	2.78	2.27	1.59	1.49	0.91
Specific Conductance	umhos/cm	9	21.7	75.6	53.9	48.36	48.5	18.66
Strontium, Total	UG/L	9	10	40	30	21.89	22	10.81
Sulfate by Ion Chromatograph	MG/L	9	2.74	7.61	4.87	5.66	6.26	1.74
Total Dissolved Solids @ 180C	MG/L	9	24	64	40	45.56	52	13.85
Total Suspended Solids	MG/L	9	5	8	3	5.33	5	1
Zinc, Total	UG/L	9	10	10	0	10	10	0
pH (lab)	pH units	9	6.6	7.5	0.9	7.02	7	0.30

Table 8 – Reference Sites: Wilcoxon Signed-Rank Tests on Replicate Sediment Samples

Test	Variable	Statistic	P-Value
Barium	Difference between replicates	17.5	0.084
Potassium	Difference between replicates	17.5	0.084
Aluminum	Difference between replicates	16.5	0.105
Strontium	Difference between replicates	16.5	0.105
Lead	Difference between replicates	-5	0.125
Calcium	Difference between replicates	15	0.139
Lead 212	Difference between replicates	9	0.156
Radium 228	Difference between replicates	9	0.156
Sodium	Difference between replicates	14.5	0.160
Lead 214	Difference between replicates	8	0.219
Nickel	Difference between replicates	11	0.287
Beryllium 7	Difference between replicates	7	0.297
Iron	Difference between replicates	10.5	0.322
Radium 226	Difference between replicates	6	0.375
Manganese	Difference between replicates	8.5	0.432
Zinc	Difference between replicates	6	0.574
Cadmium	Difference between replicates	2	0.625
Silver	Difference between replicates	2	0.625
Cesium 137	Difference between replicates	-3	0.688
Mercury	Difference between replicates	1	0.750
Magnesium	Difference between replicates	3.5	0.770
Uranium 238	Difference between replicates	1.5	0.844
Arsenic	Difference between replicates	-1	0.875
Chromium	Difference between replicates	-1	0.875
Copper	Difference between replicates	1	0.875
Uranium, Total	Difference between replicates	1.5	0.922
Chloride	Difference between replicates	0.5	1.000

Table 9 – Impacted Sites: Wilcoxon Signed-Rank Tests on Replicate Upstream Sediment Samples

Test	Variable	Statistic	P-Value
Calcium	Difference between replicates	5	0.125
Sodium	Difference between replicates	5	0.125
Strontium	Difference between replicates	5	0.125
Nickel	Difference between replicates	3	0.250
Uranium, Total	Difference between replicates	-3	0.250
Magnesium	Difference between replicates	3	0.375
Manganese	Difference between replicates	3	0.375
Radium 226	Difference between replicates	-3.5	0.375
Uranium 238	Difference between replicates	-3	0.375
Cadmium	Difference between replicates	-1.5	0.500
Chromium	Difference between replicates	1.5	0.500
Lead	Difference between replicates	1.5	0.500
Mercury	Difference between replicates	-1.5	0.500
Silver	Difference between replicates	-1.5	0.500
Zinc	Difference between replicates	-2	0.500
Lead 212	Difference between replicates	-2	0.625
Lead 214	Difference between replicates	-2	0.625
Radium 228	Difference between replicates	-2	0.625
Aluminum	Difference between replicates	-1	0.750
Chloride	Difference between replicates	-1	0.750
Barium	Difference between replicates	1	0.875
Beryllium 7	Difference between replicates	1	0.875
Arsenic	Difference between replicates	0.5	1.000
Bromide	Difference between replicates	-0.5	1.000
Cesium 137	Difference between replicates	0	1.000
Copper	Difference between replicates	-0.5	1.000
Iron	Difference between replicates	0	1.000
Potassium	Difference between replicates	0	1.000

Table 10 – Impacted versus Reference Sites – All

Type	Medium	Test	Units	Impacted Sites - Minimum	Impacted Sites - Maximum	Impacted Sites - Mean	Reference Sites - Mean	Reference Sites - Median
Discharge	Sediment	Aluminum	MG/KG	874	8,080	4,927.67	9,858.80	6,139.50
Downstream Discharge	Sediment	Aluminum	MG/KG	5,142	28,795	14,170	9,858.8	6,139.5
Upstream Discharge	Sediment	Aluminum	MG/KG	3,544	13,546	8,372	9,858.8	6,139.5
Discharge	Sediment	Arsenic	MG/KG	9.87	9.87	9.87	3.79	3.88
Downstream Discharge	Sediment	Arsenic	MG/KG	17.2	19.2	18.13	3.79	3.88
Upstream Discharge	Sediment	Arsenic	MG/KG	14.2	39.3	26.75	3.79	3.88
Discharge	Sediment	Barium	MG/KG	154	6,056	2,296.50	202.55	62.2
Downstream Discharge	Sediment	Barium	MG/KG	80.4	3,307	547.01	202.55	62.2
Upstream Discharge	Sediment	Barium	MG/KG	50.8	115	76.85	202.55	62.2
Discharge	Sediment	Cadmium	MG/KG	0.43	0.43	0.43	0.60	0.63
Downstream Discharge	Sediment	Cadmium	MG/KG	0.419	1.75	1.16	0.60	0.63
Upstream Discharge	Sediment	Cadmium	MG/KG	0.46	0.52	0.49	0.60	0.63
Discharge	Sediment	Calcium	MG/KG	1,521	76,173	30,811.75	1,392.95	453
Downstream Discharge	Sediment	Calcium	MG/KG	613	11,032	3,761.75	1,392.95	453
Upstream Discharge	Sediment	Calcium	MG/KG	343	6,882	1,541.5	1,392.95	453
Discharge	Sediment	Chromium	MG/KG	11.2	11.2	11.2	7.79	8.58
Downstream Discharge	Sediment	Chromium	MG/KG	22.8	45.1	34.87	7.79	8.58
Upstream Discharge	Sediment	Chromium	MG/KG	13.7	25.7	19.7	7.79	8.58
Discharge	Sediment	Copper	MG/KG	13.5	13.5	13.5	8.04	7.80
Downstream Discharge	Sediment	Copper	MG/KG	24.2	70.3	51.73	8.04	7.80
Upstream Discharge	Sediment	Copper	MG/KG	20.6	23.8	22.2	8.04	7.80
Discharge	Sediment	Iron	MG/KG	5,991	32,035	21,448.75	20,248.45	18,299
Downstream Discharge	Sediment	Iron	MG/KG	22,010	142,554	78,618.63	20,248.45	18,299
Upstream Discharge	Sediment	Iron	MG/KG	17,098	158,532	66,990.88	20,248.45	18,299
Discharge	Sediment	Lead	MG/KG	10.3	10.3	10.3	8.80	8.24
Downstream Discharge	Sediment	Lead	MG/KG	17.2	62.5	44.47	8.80	8.24
Upstream Discharge	Sediment	Lead	MG/KG	13.1	15.5	14.3	8.80	8.24

Discharge	Sediment	Magnesium	MG/KG	1,291	7,279	4,071.50	1,885.45	1,430
Downstream Discharge	Sediment	Magnesium	MG/KG	834	2,937	1,844.38	1,885.45	1,430
Upstream Discharge	Sediment	Magnesium	MG/KG	504	2,746	1,352	1,885.45	1,430
Discharge	Sediment	Manganese	MG/KG	275	740	489.5	686.9	516
Downstream Discharge	Sediment	Manganese	MG/KG	215	1,968	963	686.9	516
Upstream Discharge	Sediment	Manganese	MG/KG	226	1,309	624.25	686.9	516
Discharge	Sediment	Mercury	MG/KG	0.09	0.09	0.09	0.12	0.13
Downstream Discharge	Sediment	Mercury	MG/KG	0.09	0.35	0.23	0.12	0.13
Upstream Discharge	Sediment	Mercury	MG/KG	0.09	0.10	0.10	0.12	0.13
Discharge	Sediment	Nickel	MG/KG	4.87	28.4	14.82	16.33	12.7
Downstream Discharge	Sediment	Nickel	MG/KG	22.2	102	52.6	16.33	12.7
Upstream Discharge	Sediment	Nickel	MG/KG	13.7	41.6	28.52	16.33	12.7
Discharge	Sediment	Potassium	MG/KG	714	1,475	962.75	1,828.8	950
Downstream Discharge	Sediment	Potassium	MG/KG	443	2,126	1,402.75	1,828.8	950
Upstream Discharge	Sediment	Potassium	MG/KG	315	1,397	989.38	1,828.8	950
Discharge	Sediment	Silver	MG/KG	0.43	0.43	0.43	0.60	0.63
Downstream Discharge	Sediment	Silver	MG/KG	0.419	1.75	1.16	0.60	0.63
Upstream Discharge	Sediment	Silver	MG/KG	0.46	0.52	0.49	0.60	0.63
Discharge	Sediment	Sodium	MG/KG	65.9	20,930	8,490.48	191.14	70.5
Downstream Discharge	Sediment	Sodium	MG/KG	66.9	1,726	482.46	191.14	70.5
Upstream Discharge	Sediment	Sodium	MG/KG	64.5	162	102.19	191.14	70.5
Discharge	Sediment	Strontium	MG/KG	11.9	29,383	7,744.98	20.63	8.54
Downstream Discharge	Sediment	Strontium	MG/KG	9.16	1,401	216.82	20.63	8.54
Upstream Discharge	Sediment	Strontium	MG/KG	7.355	28.1	15.76	20.63	8.54
Discharge	Sediment	Uranium	MG/KG	4.31	7.46	5.90	6.07	6.23
Downstream Discharge	Sediment	Uranium	MG/KG	4.19	17.5	7.53	6.07	6.23
Upstream Discharge	Sediment	Uranium	MG/KG	4.56	7.56	6.06	6.07	6.23
Discharge	Sediment	Zinc	MG/KG	13.7	132	62.4	66.96	55.25

Downstream Discharge	Sediment	Zinc	MG/KG	87.7	363	234.62	66.96	55.25
Upstream Discharge	Sediment	Zinc	MG/KG	45.1	235	122.47	66.96	55.25
Discharge	Sediment	Bromide	MG/L	0.2	11.1	3.9	0.2	0.2
Downstream Discharge	Sediment	Bromide	MG/L	0.2	0.2	0.2	0.2	0.2
Upstream Discharge	Sediment	Bromide	MG/L	0.2	5.5	1.08	0.2	0.2
Discharge	Sediment	Chloride	MG/L	0.5	1,350	354.02	0.59	0.5
Downstream Discharge	Sediment	Chloride	MG/L	0.5	30.88	8.93	0.59	0.5
Upstream Discharge	Sediment	Chloride	MG/L	0.5	493	62.13	0.59	0.5
Discharge	Sediment	Americium 241	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Americium 241	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Americium 241	PCI/KG	0	0	0	0	0
Discharge	Sediment	Barium 140	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Barium 140	PCI/KG	0	2	0.18	0	0
Upstream Discharge	Sediment	Barium 140	PCI/KG	0	0	0	0	0
Discharge	Sediment	Beryllium 7	PCI/KG	0	539	134.75	141.47	134
Downstream Discharge	Sediment	Beryllium 7	PCI/KG	0	382	118.64	141.47	134
Upstream Discharge	Sediment	Beryllium 7	PCI/KG	0	329	156.22	141.47	134
Discharge	Sediment	Cesium 134	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Cesium 134	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Cesium 134	PCI/KG	0	0	0	0	0
Discharge	Sediment	Cesium 137	PCI/KG	0	49	22	29.76	28
Downstream Discharge	Sediment	Cesium 137	PCI/KG	0	170	32.82	29.76	28
Upstream Discharge	Sediment	Cesium 137	PCI/KG	0	34	14.89	29.76	28
Discharge	Sediment	Cobalt 58	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Cobalt 58	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Cobalt 58	PCI/KG	0	0	0	0	0
Discharge	Sediment	Cobalt 60	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Cobalt 60	PCI/KG	0	0	0	0	0

Upstream Discharge	Sediment	Cobalt 60	PCI/KG	0	0	0	0	0
Discharge	Sediment	Iodine 131	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Iodine 131	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Iodine 131	PCI/KG	0	0	0	0	0
Discharge	Sediment	Iridium 192	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Iridium 192	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Iridium 192	PCI/KG	0	0	0	0	0
Discharge	Sediment	Iron 59	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Iron 59	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Iron 59	PCI/KG	0	0	0	0	0
Discharge	Sediment	Lanthanum 140	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Lanthanum 140	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Lanthanum 140	PCI/KG	0	0	0	0	0
Discharge	Sediment	Lead 212	PCI/KG	1,060	81,900	21,807.5	573.71	597
Downstream Discharge	Sediment	Lead 212	PCI/KG	337	2,870	927.36	573.71	597
Upstream Discharge	Sediment	Lead 212	PCI/KG	281	869	677.89	573.71	597
Discharge	Sediment	Lead 214	PCI/KG	666	231,000	61,421.5	478.65	522
Downstream Discharge	Sediment	Lead 214	PCI/KG	430	7,660	1,295.18	478.65	522
Upstream Discharge	Sediment	Lead 214	PCI/KG	275	745	593	478.65	522
Discharge	Sediment	Manganese 54	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Manganese 54	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Manganese 54	PCI/KG	0	0	0	0	0
Discharge	Sediment	Niobium 95	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Niobium 95	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Niobium 95	PCI/KG	0	0	0	0	0
Discharge	Sediment	Radium 226	PCI/KG	2,470	211,000	59,845	1,068.88	1,030
Downstream Discharge	Sediment	Radium 226	PCI/KG	849	8,280	2,123.55	1,068.88	1,030
Upstream Discharge	Sediment	Radium 226	PCI/KG	734	1,770	1,389.33	1,068.88	1,030

Discharge	Sediment	Radium 228	PCI/KG	991	73,000	19,490.25	529.88	530
Downstream Discharge	Sediment	Radium 228	PCI/KG	314	2,660	888.45	529.88	530
Upstream Discharge	Sediment	Radium 228	PCI/KG	261	800	630.89	529.88	530
Discharge	Sediment	Ruthenium 103	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Ruthenium 103	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Ruthenium 103	PCI/KG	0	0	0	0	0
Discharge	Sediment	Ruthenium 106	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Ruthenium 106	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Ruthenium 106	PCI/KG	0	0	0	0	0
Discharge	Sediment	Uranium 235	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Uranium 235	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Uranium 235	PCI/KG	0	0	0	0	0
Discharge	Sediment	Uranium 238	PCI/KG	0	1,320	702.5	504.06	433
Downstream Discharge	Sediment	Uranium 238	PCI/KG	0	1,820	745.09	504.06	433
Upstream Discharge	Sediment	Uranium 238	PCI/KG	0	1,330	674.78	504.06	433
Discharge	Sediment	Zinc 65	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Zinc 65	PCI/KG	0	0	0.00	0	0
Upstream Discharge	Sediment	Zinc 65	PCI/KG	0	0	0	0	0
Discharge	Sediment	Zirconium 95	PCI/KG	0	0	0	0	0
Downstream Discharge	Sediment	Zirconium 95	PCI/KG	0	0	0	0	0
Upstream Discharge	Sediment	Zirconium 95	PCI/KG	0	0	0	0	0
Discharge	Surface Water	Alkalinity, Total	MG/L	242.4	577	463.2	27.33	16
Downstream Discharge	Surface Water	Alkalinity, Total	MG/L	0	291.6	101.45	27.33	16
Upstream Discharge	Surface Water	Alkalinity, Total	MG/L	9.8	195	92.47	27.33	16
Discharge	Surface Water	Ammonia, Total as N	MG/L	0.3	59.29	20.10	0.03	0.02
Downstream Discharge	Surface Water	Ammonia, Total as N	MG/L	0.04	4.88	0.98	0.03	0.02
Upstream Discharge	Surface Water	Ammonia, Total as N	MG/L	0.02	0.61	0.16	0.03	0.02
Discharge	Surface Water	Biochemical Oxygen Demand	MG/L	1.3	42.6	15.97	0.45	0.5

Downstream Discharge	Surface Water	Biochemical Oxygen Demand	MG/L	0.6	9.5	3.28	0.45	0.5
Upstream Discharge	Surface Water	Biochemical Oxygen Demand	MG/L	0.4	2.6	0.97	0.45	0.5
Discharge	Surface Water	Calcium, Total	MG/L	14.5	10,300	3,458.3	11.04	6.66
Downstream Discharge	Surface Water	Calcium, Total	MG/L	47.7	891	198.01	11.04	6.66
Upstream Discharge	Surface Water	Calcium, Total	MG/L	34	71.3	50.12	11.04	6.66
Discharge	Surface Water	Chloride (Ion Chromatography)	MG/L	0.5	60,220	20,273.83	4.35	2.12
Downstream Discharge	Surface Water	Chloride (Ion Chromatography)	MG/L	45.4	5802	965.29	4.35	2.12
Upstream Discharge	Surface Water	Chloride (Ion Chromatography)	MG/L	10.98	78.3	34.17	4.35	2.12
Discharge	Surface Water	Hardness Total (Calculated)	MG/L	129	27,526	9,299.33	37.18	21
Downstream Discharge	Surface Water	Hardness Total (Calculated)	MG/L	167	2,431	591.75	37.18	21
Upstream Discharge	Surface Water	Hardness Total (Calculated)	MG/L	124	252	173.17	37.18	21
Discharge	Surface Water	Magnesium, Total	MG/L	22.3	431	158.6	2.32	1.11
Downstream Discharge	Surface Water	Magnesium, Total	MG/L	11.6	49.4	23.46	2.32	1.11
Upstream Discharge	Surface Water	Magnesium, Total	MG/L	6.332	18	11.68	2.32	1.105
Discharge	Surface Water	Nitrate & Nitrite, Total as N	MG/L	0.05	0.2	0.12	0.67	0.24
Downstream Discharge	Surface Water	Nitrate & Nitrite, Total as N	MG/L	0.05	2.49	0.71	0.67	0.24
Upstream Discharge	Surface Water	Nitrate & Nitrite, Total as N	MG/L	0.08	2.37	0.75	0.67	0.24
Discharge	Surface Water	Phosphorus, Total	MG/L	0.02	0.41	0.18	0.01	0.01
Downstream Discharge	Surface Water	Phosphorus, Total	MG/L	0.01	0.12	0.04	0.01	0.01
Upstream Discharge	Surface Water	Phosphorus, Total	MG/L	0.01	0.16	0.07	0.01	0.01
Discharge	Surface Water	Sodium, Total	MG/L	1,110	26,600	9,823.33	2.91	1.99
Downstream Discharge	Surface Water	Sodium, Total	MG/L	26.5	2,010	431.5	2.91	1.99
Upstream Discharge	Surface Water	Sodium, Total	MG/L	12.8	53	33.05	2.91	1.99
Discharge	Surface Water	Sulfate (Ion Chromatography)	MG/L	1	1,330	833	8.64	6.68
Downstream Discharge	Surface Water	Sulfate (Ion Chromatography)	MG/L	5.83	407	247.96	8.64	6.68
Upstream Discharge	Surface Water	Sulfate (Ion Chromatography)	MG/L	30.02	322	99.87	8.64	6.68
Discharge	Surface Water	Total Dissolved Solids (@ 180^{o}C)	MG/L	3,286	130,822	46,060.67	72.73	54
Downstream Discharge	Surface Water	Total Dissolved Solids (@ 180^{o}C)	MG/L	364	12,196	2,484.25	72.73	54

Upstream Discharge	Surface Water	Total Dissolved Solids (@ 180^{o}C)	MG/L	196	502	344.33	72.73	54
Discharge	Surface Water	Total Suspended Solids	MG/L	6	218	78.67	5.64	5
Downstream Discharge	Surface Water	Total Suspended Solids	MG/L	5	48	16.25	5.64	5
Upstream Discharge	Surface Water	Total Suspended Solids	MG/L	5	208	46.67	5.64	5
Discharge	Surface Water	Osmotic Pressure	MOSM	79	2,590	932	4.73	1
Downstream Discharge	Surface Water	Osmotic Pressure	MOSM	4	273	52.88	4.73	1
Upstream Discharge	Surface Water	Osmotic Pressure	MOSM	3	11	6.33	4.73	1
Discharge	Surface Water	pH (Lab)	pH units	8.5	9.6	8.97	7.22	7.1
Downstream Discharge	Surface Water	pH (Lab)	pH units	4.6	9	7.45	7.22	7.1
Upstream Discharge	Surface Water	pH (Lab)	pH units	6.9	8.3	7.7	7.22	7.1
Discharge	Surface Water	Aluminum, Total	UG/L	200	200	200	200	200
Downstream Discharge	Surface Water	Aluminum, Total	UG/L	200	14,000	2,039.88	200	200
Upstream Discharge	Surface Water	Aluminum, Total	UG/L	200	2,775	778.17	200	200
Discharge	Surface Water	Arsenic, Total	UG/L	3	1,500	503.07	3	3
Downstream Discharge	Surface Water	Arsenic, Total	UG/L	3	150	22.10	3	3
Upstream Discharge	Surface Water	Arsenic, Total	UG/L	3	3	3	3	3
Discharge	Surface Water	Barium, Total	UG/L	14	9,680	3,608.33	30.27	27
Downstream Discharge	Surface Water	Barium, Total	UG/L	41	1,108	216.88	30.27	27
Upstream Discharge	Surface Water	Barium, Total	UG/L	40	98	62.83	30.27	27
Discharge	Surface Water	Boron, Total	UG/L	370	3,000	1,280	200	200
Downstream Discharge	Surface Water	Boron, Total	UG/L	200	330	222.5	200	200
Upstream Discharge	Surface Water	Boron, Total	UG/L	200	200	200	200	200
Discharge	Surface Water	Bromide (Ion Chromatography)	UG/L	4,146	498,014	171,940	50	50
Downstream Discharge	Surface Water	Bromide (Ion Chromatography)	UG/L	50	42,876	7,116.40	50	50
Upstream Discharge	Surface Water	Bromide (Ion Chromatography)	UG/L	50	282.24	98.40	50	50
Discharge	Surface Water	Iron, Total	UG/L	263	700	470	142.18	103
Downstream Discharge	Surface Water	Iron, Total	UG/L	144	30,900	4,476.88	142.18	103
Upstream Discharge	Surface Water	Iron, Total	UG/L	90	4,971	1,455.50	142.18	103

Downstream Discharge	Surface Water	Lithium, Total	UG/L	25	25	25		
Upstream Discharge	Surface Water	Lithium, Total	UG/L	25	25	25		
Discharge	Surface Water	Manganese, Total	UG/L	11	460	233.33	22.82	11
Downstream Discharge	Surface Water	Manganese, Total	UG/L	46	2,389	536	22.82	11
Upstream Discharge	Surface Water	Manganese, Total	UG/L	50	488	226.33	22.82	11
Discharge	Surface Water	Selenium, Total	UG/L	7	3,500	1,175.67	7	7
Downstream Discharge	Surface Water	Selenium, Total	UG/L	7	350	52.85	7	7
Upstream Discharge	Surface Water	Selenium, Total	UG/L	7	7	7	7	7
Discharge	Surface Water	Strontium, Total	UG/L	1,838	999,000	334,239.67	88.55	23
Downstream Discharge	Surface Water	Strontium, Total	UG/L	243	73,800	12,523.75	88.55	23
Upstream Discharge	Surface Water	Strontium, Total	UG/L	147	387	281.17	88.55	23
Discharge	Surface Water	Zinc, Total	UG/L	10	10	10	10	10
Downstream Discharge	Surface Water	Zinc, Total	UG/L	10	254	43.5	10	10
Upstream Discharge	Surface Water	Zinc, Total	UG/L	10	26	14.33	10	10
Discharge	Surface Water	Specific Conductance (@ 25.0^{o}C)	umhos/cm	4,770	106,200	39,380	95.11	59.3
Downstream Discharge	Surface Water	Specific Conductance (@ 25.0^{o}C)	umhos/cm	494	11,220	2,778.75	95.11	59.3
Upstream Discharge	Surface Water	Specific Conductance (@ 25.0^{o}C)	umhos/cm	287	709	493.17	95.11	59.3

Figure 1 – Reference Sites: Sediment Metals
(aluminum, barium, calcium, iron, magnesium, and potassium)

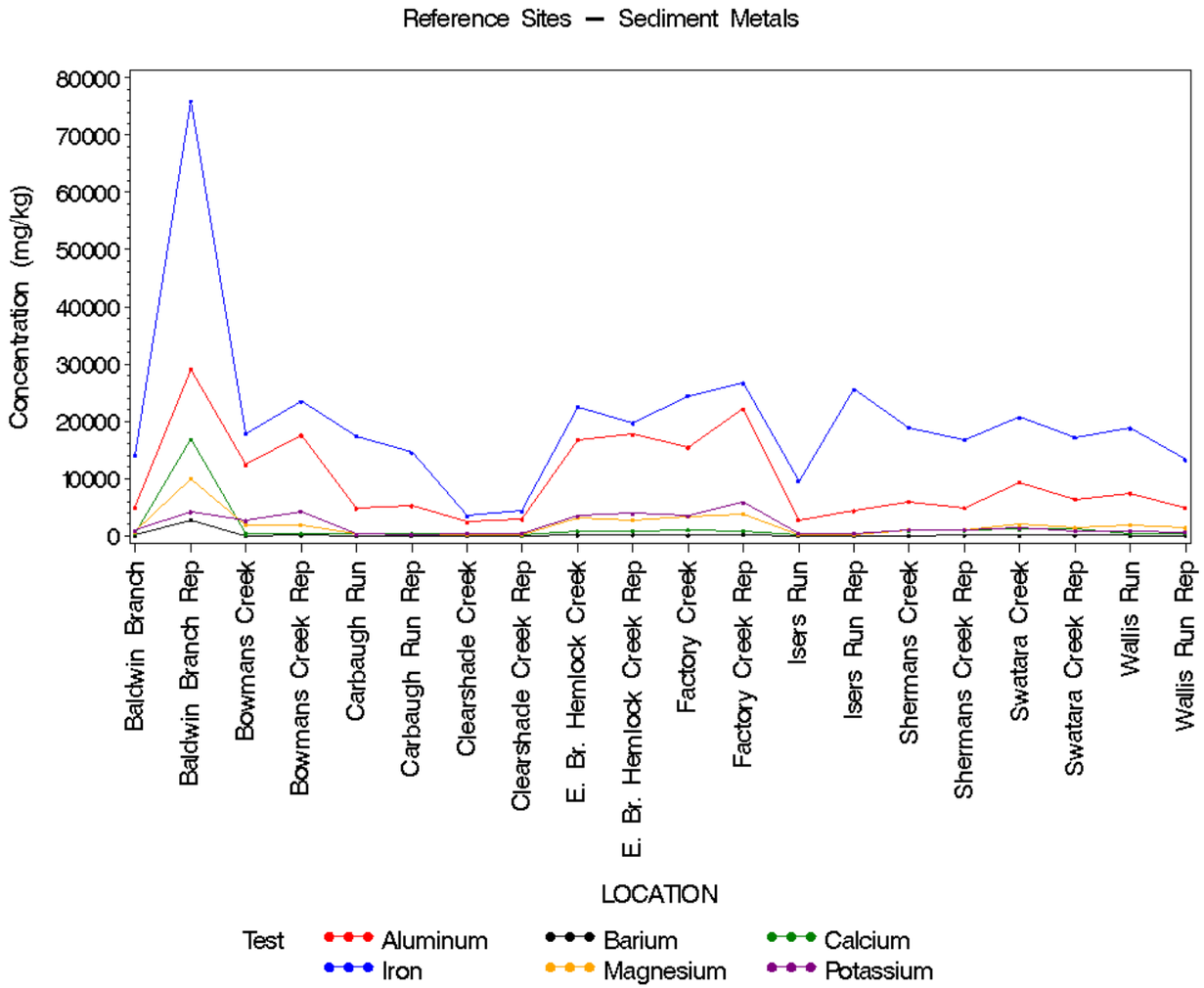


Figure 2 – Reference Sites: Sediment Metals
(manganese, nickel, sodium, strontium, zinc)

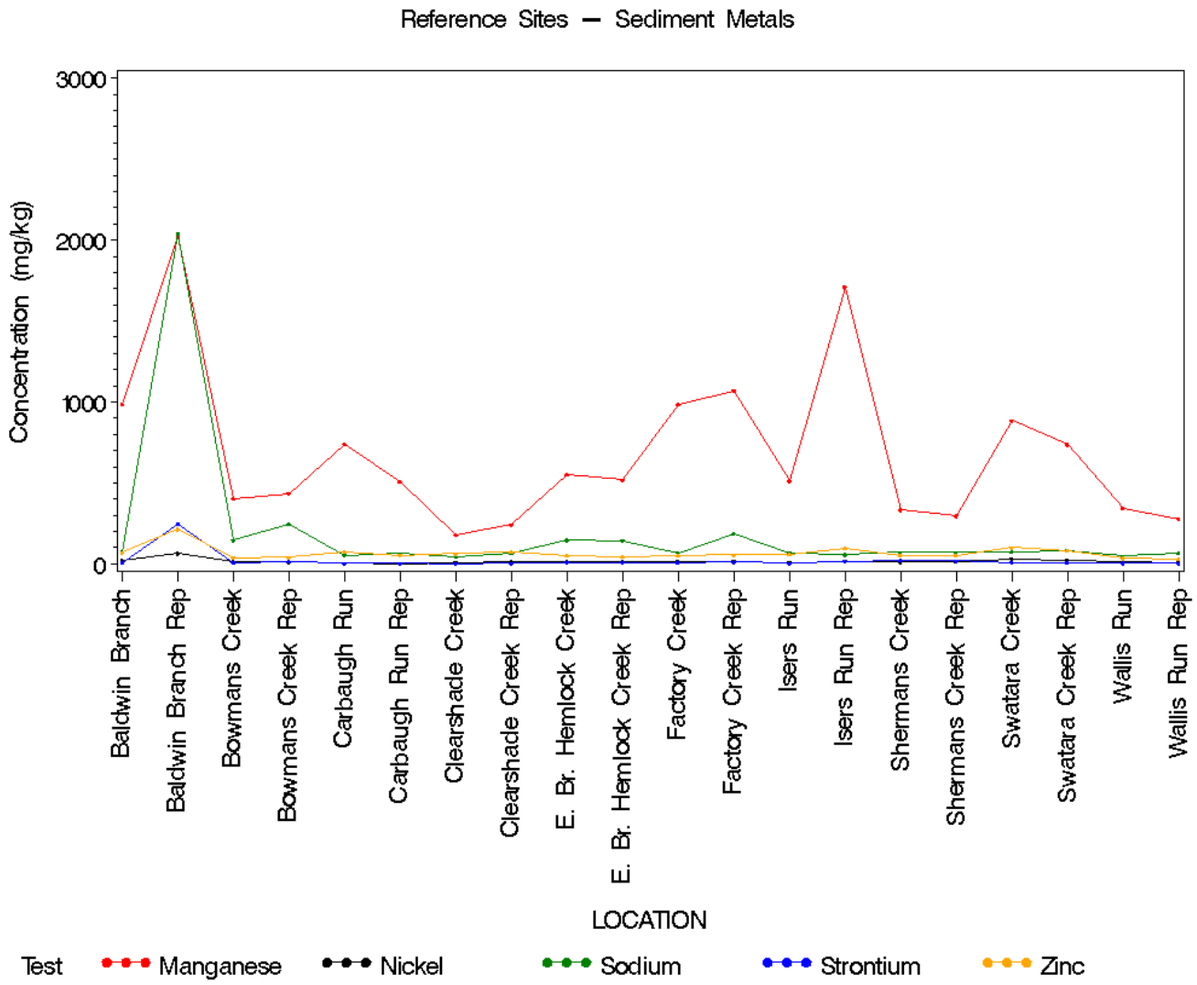


Figure 3 – Reference Sites: Sediment Metals
(arsenic, lead, cadmium, mercury, chromium, silver, copper, and uranium)

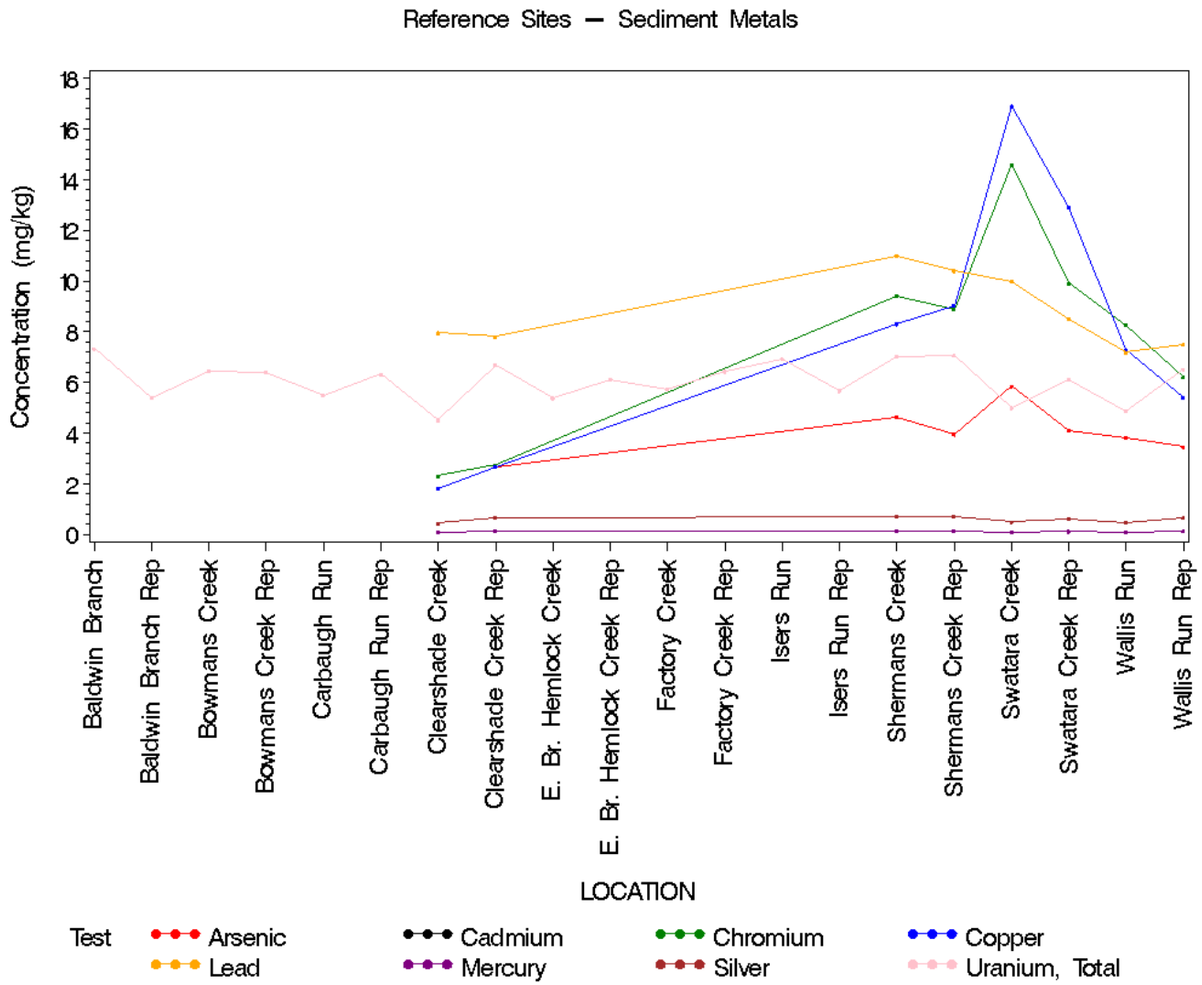


Figure 4 – Reference Sites: Sediment Radionuclides
(beryllium-7, cesium-137, lead-212, lead-214, radium-226, radium-228, and uranium-238)

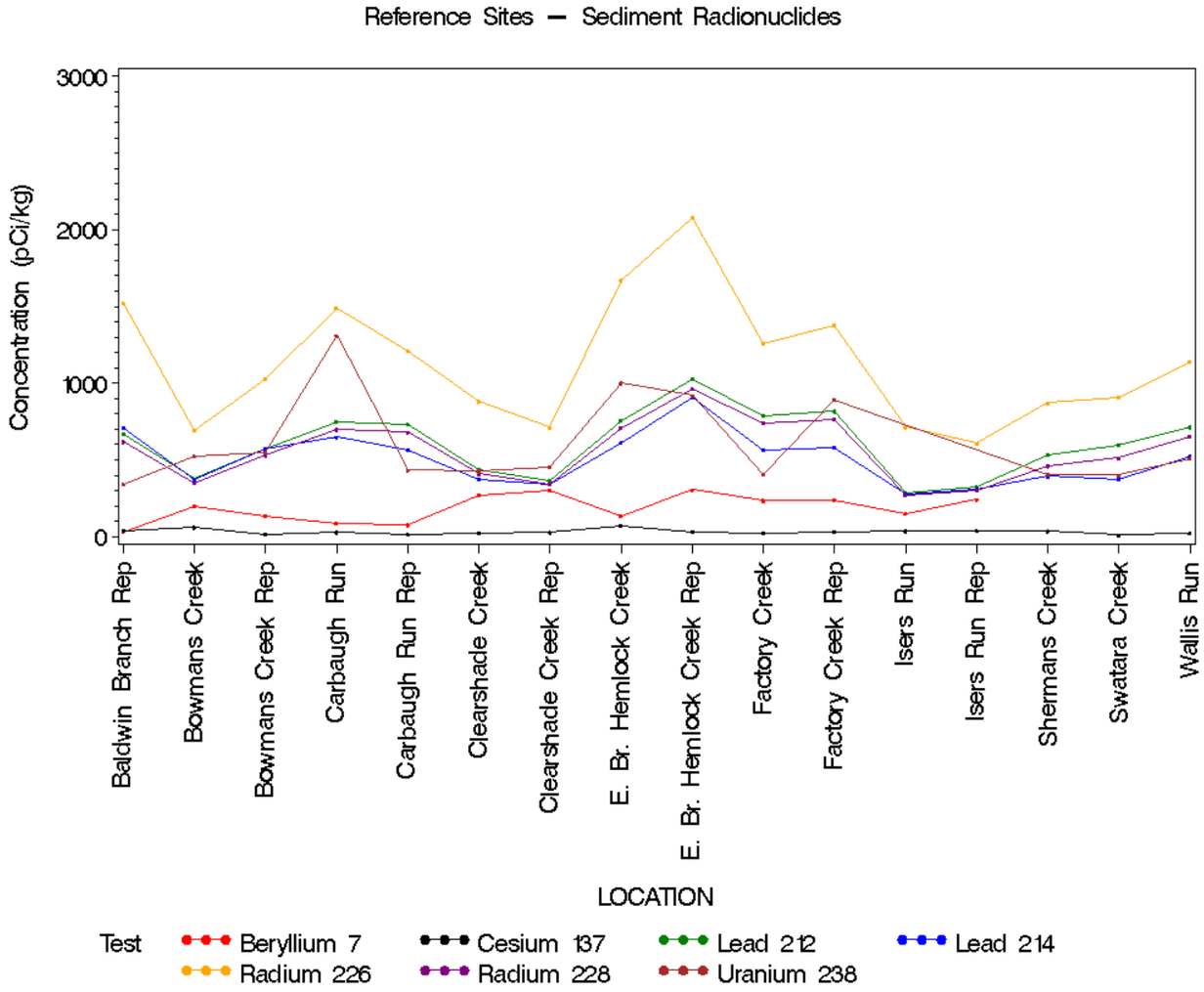

Reference Sites — Sediment Radionuclides
Concentration (pCi/kg)
3000
2000
1000
0
Baldwin Branch Rep
Bowmans Creek
Bowmans Creek Rep
Carbaugh Run
Carbaugh Run Rep
Clearshade Creek
Clearshade Creek Rep
E. Br. Hemlock Creek
E. Br. Hemlock Creek Rep
Factory Creek
Factory Creek Rep
Isers Run
Isers Run Rep
Shermans Creek
Swatara Creek
Wallis Run
LOCATION
Test
Beryllium 7
Cesium 137
Lead 212
Lead 214
Radium 226
Radium 228
Uranium 238

Figure 5 – Reference Sites: Water Radionuclides
(Radium-226, Radium-228, and Total Uranium)

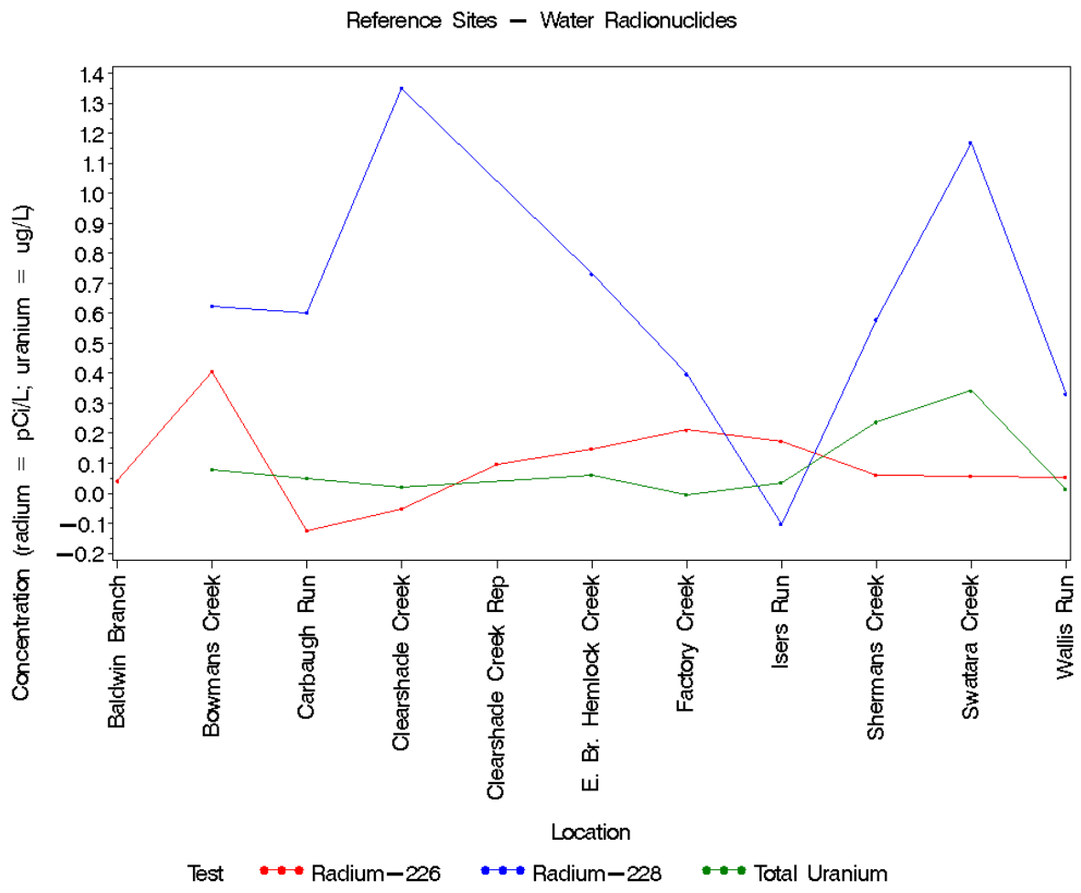


Figure 6 – Locations sampled during the summer 2011 Marcellus sediment and water study

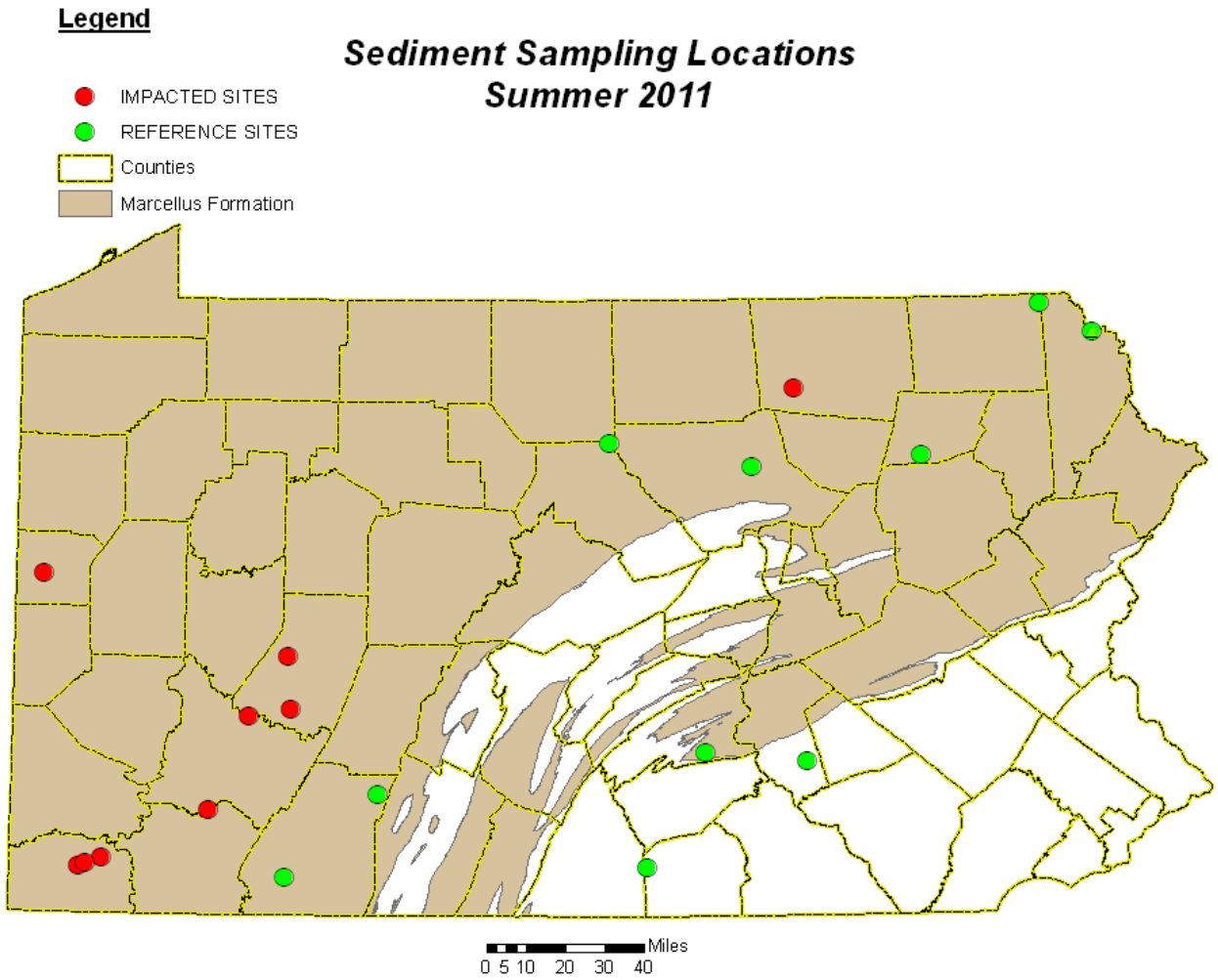


Figure 7 – Towanda Creek spill sampling locations

Figure 8 – Mahoning River (at New Castle City) sampling locations

Figure 9 – Smith Creek and South Fork Tenmile Creek (at Franklin) sampling locations

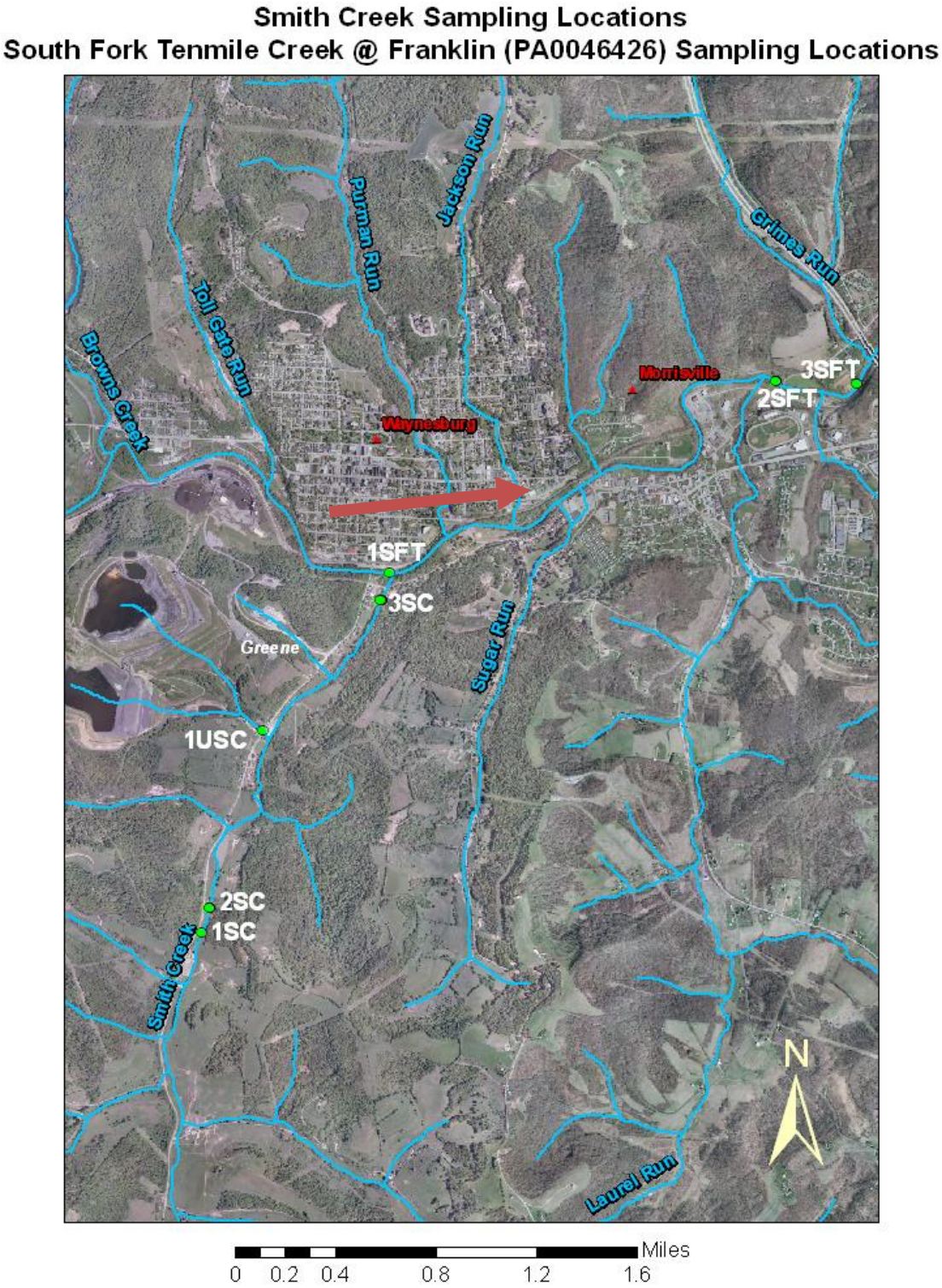


Figure 10 –South Fork Tenmile Creek (at WQN 713) sampling location

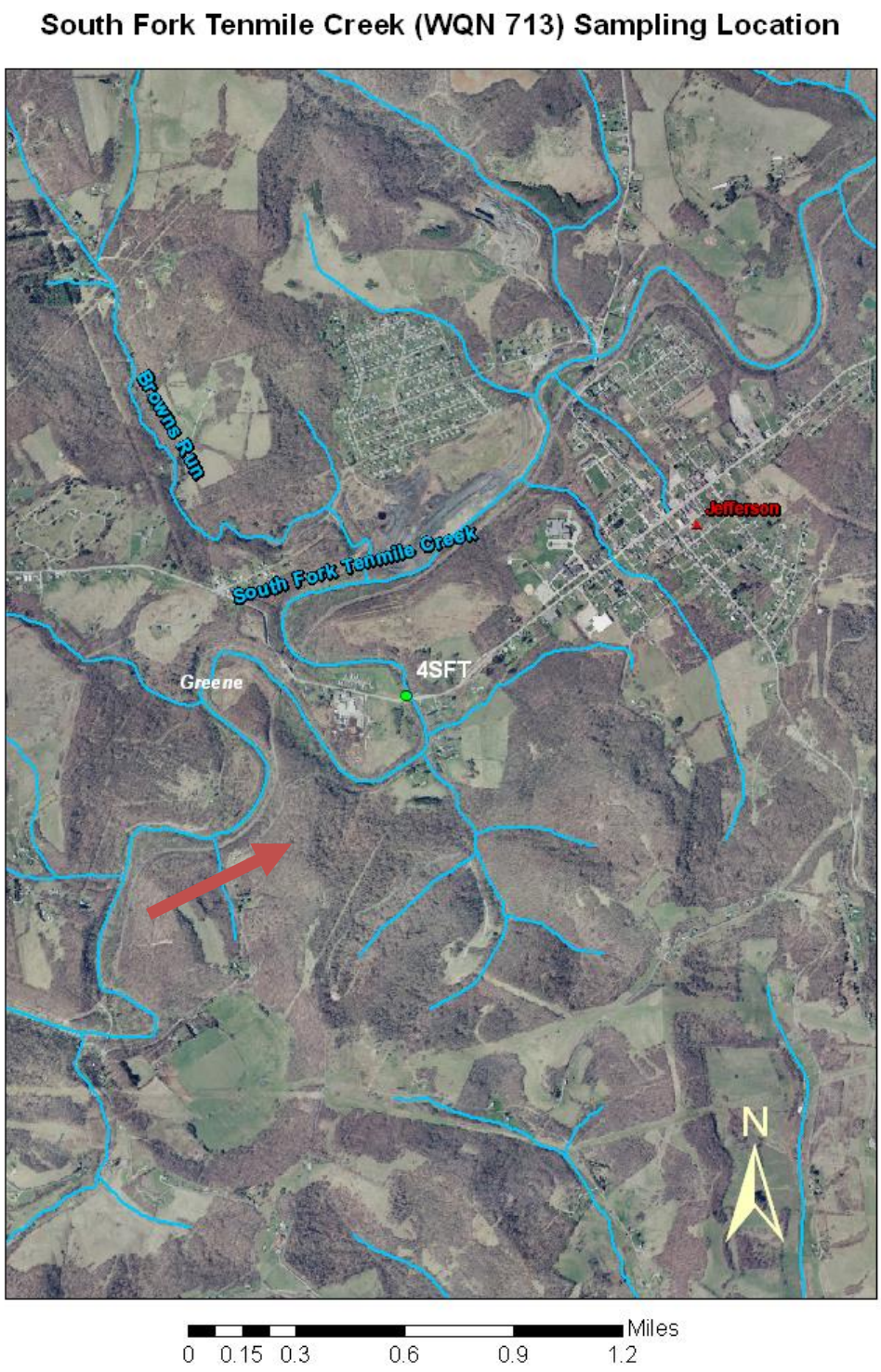


Figure 11 – McKee Run (at Creekside) sampling locations

Figure 12 – Blacklick Creek (at Josephine) sampling locations

Figure 13 – Conemaugh River (at Tunnelton) sampling location

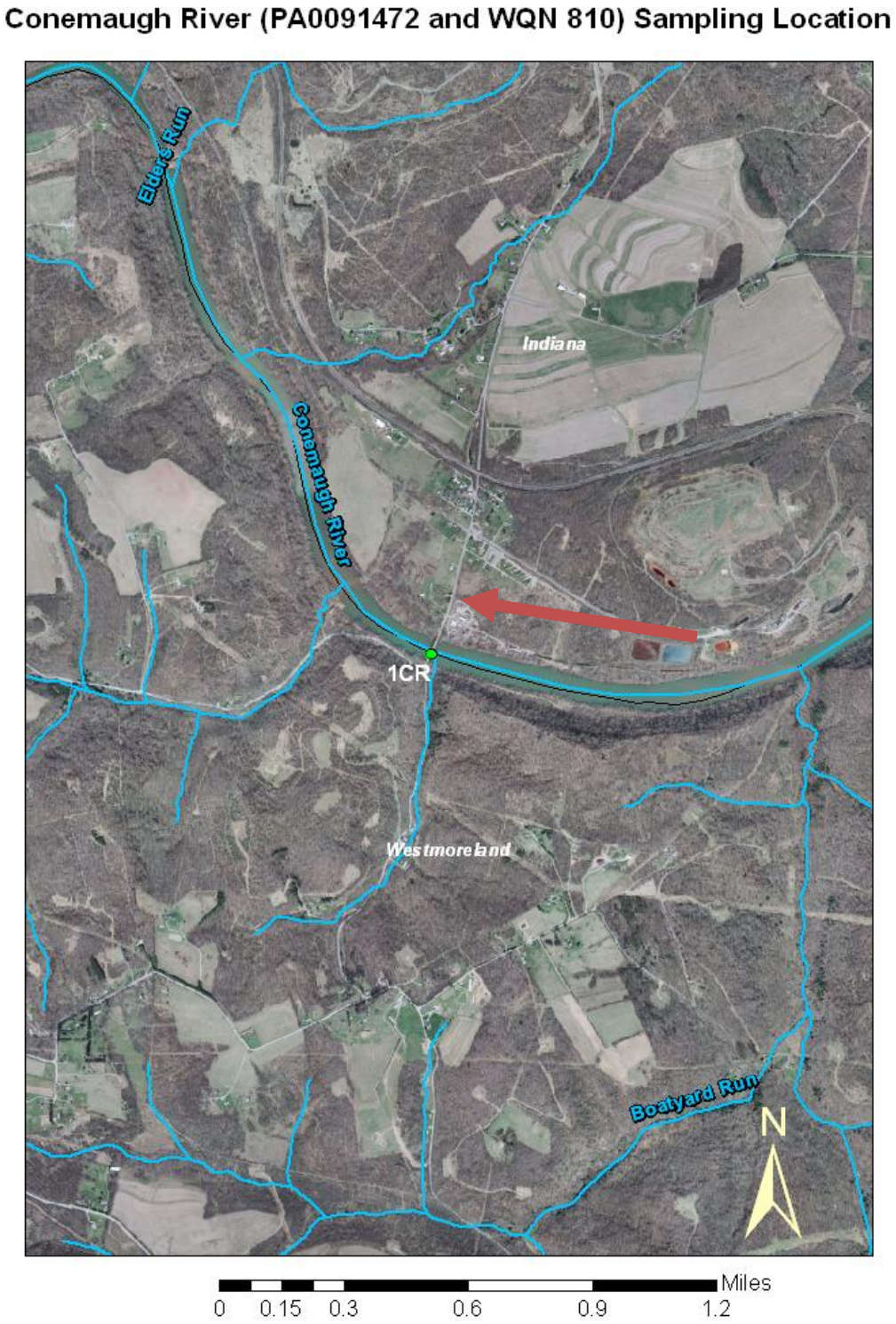
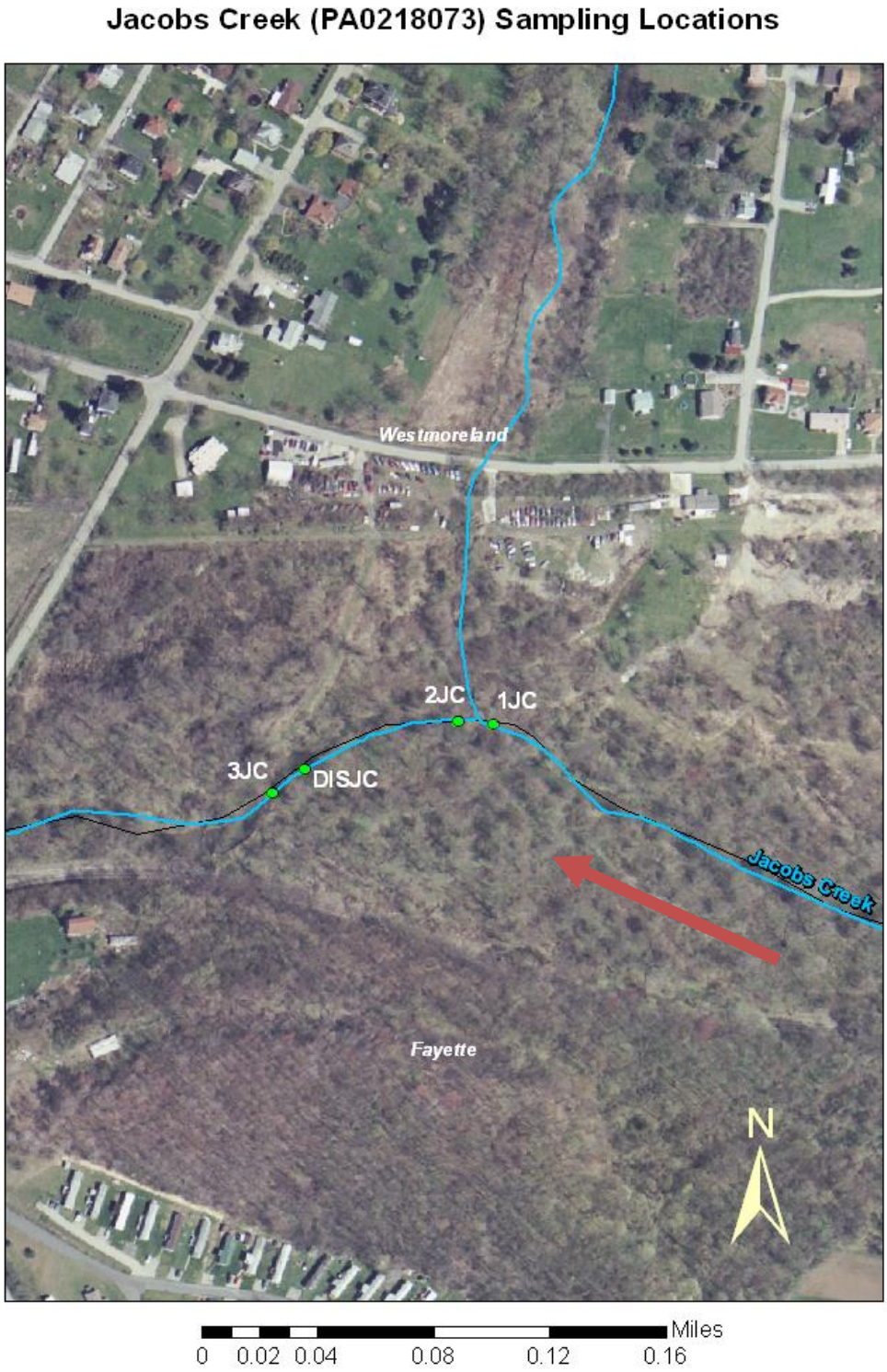


Figure 14 – Jacobs Creek (at Scottdale) sampling locations



Appendix A – Reference Sites: Raw Data

Reference Sites - Water Results

Test	Units	Baldwin Branch	Bowmans Creek	Carbaugh Run	Clearshade Creek	E. Br. Hemlock Creek	Factory Creek	Isers Run
Alkalinity, Total	MG/L	8.2	2.6	8.4	16	23	10.8	3.4
Aluminum, Total	UG/L	<200	<200	<200	<200	<200	<200	<200
Ammonia, Total as Nitrogen	MG/L	<0.02	<0.02	<0.02	0.05	<0.02	<0.02	<0.02
Arsenic, Total	UG/L	<3	<3	<3	<3	<3	<3	<3
Barium, Total	UG/L	27	14	10	36	25	16	26
Biochemical Oxygen Demand (Inhibited 5-Day)	MG/L	0.6	0.5	<0.2	0.6	0.6	<0.2	<0.2
Boron, Total	UG/L	<200	<200	<200	<200	<200	<200	<200
Bromide (Ion Chromatography)	UG/L	<50	<50	<50	<50	<50	<50	<50
Calcium, Total	MG/L	3.937	2.144	1.958	7.293	7.923	4.452	3.066
Chloride (Ion Chromatography)	MG/L	2.29	0.62	1.68	4.87	<0.5	<0.5	0.75
Chloride (ASTM-A Leach)	MG/L							
Hardness, Total (Calculated)	MG/L	15	8	8	22	25	14	11
Iron, Total	UG/L	<20	59	103	352	212	64	146
Magnesium, Total	MG/L	1.15	0.554	0.775	1.018	1.17	0.778	0.877
Manganese, Total	UG/L	<10	10	10	36	25	<10	59
Nitrate & Nitrogen, Total as Nitrogen	MG/L	0.24	<0.05	0.09	0.24	0.06	0.33	0.14
Osmotic Pressure	MOSM	<1	<1	<1	<1	<1	<1	<1
pH	pH units	7.1	6.7	6.8	7.3	7.5	7.3	6.6
Phosphorus, Total	MG/L	<0.01	<0.01	<0.01	0.013	<0.01	<0.01	<0.01
Selenium, Total	UG/L	<7	<7	<7	<7	<7	<7	<7
Sodium, Total	MG/L	1.485	0.553	2.779	2.65	1.068	0.767	0.509
Specific Conductance (@ 25.0^{o}C)	umhos/cm	48.5	21.7	32.9	68.3	59.3	39.6	29.3
Strontium, Total	UG/L	31	12	10	22	23	14	12
Sulfate (Ion Chromatography)	MG/L	6.68	4.91	2.74	7.46	4.68	3.67	6.26
Total Dissolved Solids (@ 180^{o}C)	MG/L	40	24	56	56	64	32	32
Total Suspended Solids	MG/L	<5	<5	<5	<5	<5	<5	8
Zinc, Total	UG/L	<10	<10	<10	<10	<10	<10	<10

Test	Units	Shermans Creek	Swatara Creek	Wallis Run	Wallis Run (2nd Sample)
Alkalinity, Total	MG/L	89.8	100.6	16.2	21.6
Aluminum, Total	UG/L	<200	<200	<200	<200
Ammonia, Total as Nitrogen	MG/L	0.04	0.03	0.02	0.03
Arsenic, Total	UG/L	<3	<3	<3	<3
Barium, Total	UG/L	48	49	38	44
Biochemical Oxygen Demand (Inhibited 5-Day)	MG/L	0.8	0.4	0.4	0.5
Boron, Total	UG/L	<200	<200	<200	<200
Bromide (Ion Chromatography)	UG/L	<50	<50	<50	<50
Calcium, Total	MG/L	33.2	42.3	6.662	8.506
Chloride (Ion Chromatography)	MG/L	6.67	25.15	2.12	2.72
Chloride (ASTM-A Leach)	MG/L			<0.5	
Hardness, Total (Calculated)	MG/L	108	150	21	27
Iron, Total	UG/L	225	329	26	28
Magnesium, Total	MG/L	6.025	10.7	1.105	1.379
Manganese, Total	UG/L	27	43	<10	11
Nitrate & Nitrogen, Total as Nitrogen	MG/L	1.47	4.35	0.12	0.26
Osmotic Pressure	MOSM	2	4	<1	38
pH	pH units	8.2	8	6.9	7
Phosphorus, Total	MG/L	0.028	0.036	<0.01	0.014
Selenium, Total	UG/L	<7	<7	<7	<7
Sodium, Total	MG/L	3.232	14.5	1.993	2.47
Specific Conductance (@ 25.0^{o}C)	umhos/cm	236	375	60	75.6
Strontium, Total	UG/L	635	142	33	40
Sulfate (Ion Chromatography)	MG/L	12.92	31.15	6.97	7.61
Total Dissolved Solids (@ 180^{o}C)	MG/L	146	244	52	54
Total Suspended Solids	MG/L	8	6	<5	<5
Zinc, Total	UG/L	<10	<10	<10	<10

Reference Sites - Water Radiation Results (Analyzed at Pace Analytical Laboratories, Greensburg, PA)

Parameter	Units	Baldwin Branch**	Bowmans Creek	Carbaugh Run	Clearshade Creek	Clearshade Creek (replicate)**	E. Br. Hemlock Creek	Factory Creek	Isers Run	Shermans Creek	Swatara Creek	Wallis Run
Ra-226	pCi/L	0.041	0.406	-0.125	-0.052	0.0965	0.149	0.211	0.174	0.0609	0.0574	0.0534
Ra-226 CE*	pCi/L	0.0324011	0.324	0.302	0.228	0.04504871	0.22	0.256	0.342	0.267	0.338	0.234
Ra-226 LLD#	pCi/L	0.04855425	0.374	0.753	0.559	0.0639	0.366	0.388	0.623	0.566	0.689	0.496
Ra-228	pCi/L		0.623	0.602	1.35		0.731	0.397	-0.102	0.579	1.17	0.331
Ra-228 CE	pCi/L		0.468	0.458	0.576		0.524	0.426	0.456	0.449	0.538	0.401
Ra-228 LLD	pCi/L		0.907	0.896	0.911		0.998	0.883	0.959	0.882	0.892	0.848
Total Uranium	ug/L		0.078	0.05	0.021		0.06	-0.004	0.036	0.237	0.342	0.014
Total Uranium CE	ug/L		0.003	0.002	0.001		0.002	0.001	0.001	0.006	0.009	0.001
Total Uranium LLD	ug/L		0.21	0.21	0.21		0.197	0.197	0.197	0.21	0.21	0.21

*CE = Counting Error

#LLD = Lower Limit of Detection

**Analyzed at DEP BOL

Reference Sites - Sediment Results
(Rep = Replicate)

Test	Units	Baldwin Branch	Baldwin Branch Rep	Bowmans Creek	Bowmans Creek Rep	Carbaugh Run	Carbaugh Run Rep	Clearshade Creek	Clearshade Creek Rep	E. Br. Hemlock Creek	E. Br. Hemlock Creek Rep
Americium 241	PCI/KG	0	0	0	0	0	0	0	0	0	0
Barium 140	PCI/KG	0	0	0	0	0	0	0	0	0	0
Beryllium 7	PCI/KG	0	34 +/- 54	200 +/- 71	134 +/- 50	88 +/- 67	76 +/- 62	268 +/- 45	302 +/- 70	134 +/- 55	306 +/- 99
Cesium 134	PCI/KG	0	0	0	0	0	0	0	0	0	0
Cesium 137	PCI/KG	0	40	60 +/- 6	13 +/- 4	28 +/- 6	13 +/- 7	23 +/- 4	28 +/- 5	73 +/- 6	31 +/- 8
Cobalt 58	PCI/KG	0	0	0	0	0	0	0	0	0	0
Cobalt 60	PCI/KG	0	0	0	0	0	0	0	0	0	0
Iodine 131	PCI/KG	0	0	0	0	0	0	0	0	0	0
Iridium 192	PCI/KG	0	0	0	0	0	0	0	0	0	0
Iron 59	PCI/KG	0	0	0	0	0	0	0	0	0	0
Lanthanum 140	PCI/KG	0	0	0	0	0	0	0	0	0	0
Lead 212	PCI/KG	0	670 +/- 28	378 +/- 24	570 +/- 26	749 +/- 37	731 +/- 40	439 +/- 25	366 +/- 25	756 +/- 38	1,030 +/- 47
Lead 214	PCI/KG	0	711 +/- 56	370 +/- 49	574 +/- 52	649 +/- 77	567 +/- 88	373 +/- 50	343 +/- 50	611 +/- 70	906 +/- 79
Manganese 54	PCI/KG	0	0	0	0	0	0	0	0	0	0
Niobium 95	PCI/KG	0	0	0	0	0	0	0	0	0	0
Radium 226	PCI/KG	0	1,520 +/- 142	694 +/- 92	1,030 +/- 115	1,490 +/- 149	1,210 +/- 134	881 +/- 104	712 +/- 109	1,670 +/- 140	2,080 +/- 211
Radium 228	PCI/KG	0	618 +/- 26	352 +/- 23	530 +/- 24	698 +/- 34	681 +/- 38	410 +/- 23	342 +/- 24	709 +/- 35	962 +/- 77
Ruthenium 103	PCI/KG	0	0	0	0	0	0	0	0	0	0
Ruthenium 106	PCI/KG	0	0	0	0	0	0	0	0	0	0
Uranium 235	PCI/KG	0	0	0	0	0	0	0	0	0	0
Uranium 238	PCI/KG	0	340 +/- 264	523 +/- 233	549 +/- 222	1,310 +/- 361	433 +/- 305	427 +/- 258	455 +/- 258	1,000 +/- 366	919 +/- 469
Zinc 65	PCI/KG	0	0	0	0	0	0	0	0	0	0
Zirconium 95	PCI/KG	0	0	0	0	0	0	0	0	0	0
Aluminum	MG/KG	4,988	29,127	12,400	17,542	4,786	5,208	2,427	2,881	16,768	17,728
Arsenic	MG/KG							<1.81	<2.67		
Barium	MG/KG	78.2	2,790	59.4	90.6	28.5	24.9	23.2	21	119	123
Bromide	MG/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cadmium	MG/KG							<0.452	<0.668		
Calcium	MG/KG	463	16,854	326	360	311	321	135	101	821	859
Chloride	MG/L	<0.5	<0.5	<0.5	<0.5	1.36	1.46	<0.5	<0.5	<0.5	<0.5
Chromium	MG/KG							2.31	2.74		
Copper	MG/KG							1.81	<2.67		
Iron	MG/KG	14,037	75,934	17,797	23,443	17,346	14,527	3,470	4,315	22,506	19,665
Lead	MG/KG							7.96	7.81		
Magnesium	MG/KG	727	9,963	1,866	1,921	297	268	175	174	3,163	2,696
Manganese	MG/KG	984	2,020	403	436	740	506	180	242	551	519
Mercury	MG/KG							<0.09	<0.134		
Nickel	MG/KG	20.2	64.9	12.1	11	3.63	2.78	9.59	12	15.3	13.3
Potassium	MG/KG	914	4,141	2,652	4,261	293	261	425	467	3,488	3,921
Silver	MG/KG							<0.452	<0.668		
Sodium	MG/KG	<73.3	2,041	145	246	<55	<63.3	<45.2	<66.8	147	144
Strontium	MG/KG	5.71	249	8.7	13.3	2.93	<3.16	<2.26	<3.34	8.83	10.1
Uranium	MG/KG	<7.33	<5.4	<6.45	<6.41	<5.5	<6.33	<4.52	<6.68	<5.38	<6.11
Zinc	MG/KG	71.1	214	40	41.1	74.9	54.9	63.3	73.3	50.1	44

Test	Units	Factory Creek	Factory Creek Rep	Isers Run	Isers Run Rep	Shermans Creek	Shermans Creek Rep	Swatara Creek	Swatara Creek Rep	Wallis Run	Wallis Run Rep
Americium 241	PCI/KG	0	0	0	0	0		0		0	
Barium 140	PCI/KG	0	0	0	0	0		0		0	
Beryllium 7	PCI/KG	235 +/- 67	237 +/- 60	149 +/- 59	242 +/- 45	0		0		0	
Cesium 134	PCI/KG	0	0	0	0	0		0		0	
Cesium 137	PCI/KG	26 +/- 6	30 +/- 5	36 +/- 6	37 +/- 4	36 +/- 3		11 +/- 3		21 +/- 5	
Cobalt 58	PCI/KG	0	0	0	0	0		0		0	
Cobalt 60	PCI/KG	0	0	0	0	0		0		0	
Iodine 131	PCI/KG	0	0	0	0	0		0		0	
Iridium 192	PCI/KG	0	0	0	0	0		0		0	
Iron 59	PCI/KG	0	0	0	0	0		0		0	
Lanthanum 140	PCI/KG	0	0	0	0	0		0		0	
Lead 212	PCI/KG	791 +/- 34	817 +/- 33	288 +/- 27	323 +/- 19	534 +/- 188		597 +/- 25		714 +/- 27	
Lead 214	PCI/KG	568 +/- 65	582 +/- 60	281 +/- 42	313 +/- 36	393 +/- 34		374 +/- 37		522 +/- 56	
Manganese 54	PCI/KG	0	0	0	0	0		0		0	
Niobium 95	PCI/KG	0	0	0	0	0		0		0	
Radium 226	PCI/KG	1,260 +/- 139	1,380 +/- 131	714 +/- 123	608 +/- 92	872 +/- 73		910 +/- 75		1,140 +/- 135	
Radium 228	PCI/KG	741 +/- 32	766 +/- 31	270 +/- 25	303 +/- 17	459 +/- 16		513 +/- 21		654 +/- 25	
Ruthenium 103	PCI/KG	0	0	0	0	0		0		0	
Ruthenium 106	PCI/KG	0	0	0	0	0		0		0	
Uranium 235	PCI/KG	0	0	0	0	0		0		0	
Uranium 238	PCI/KG	407 +/- 241	892 +/- 287	0	0	405 +/- 98		402 +/- 130		507 +/- 311	
Zinc 65	PCI/KG	0	0	0	0	0		0		0	
Zirconium 95	PCI/KG	0	0	0	0	0		0		0	
Aluminum	MG/KG	15,415	22,172	2,722	4,351	5,895	4,818	9,314	6,384	7,349	4,901
Arsenic	MG/KG					4.64	3.95	5.85	4.1	3.81	3.46
Barium	MG/KG	102	132	21.2	43.9	55.2	72.6	92.7	65	57.6	50.9
Bromide	MG/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cadmium	MG/KG					<0.704	<0.706	<0.5	<0.612	<0.489	<0.652
Calcium	MG/KG	1,005	845	142	196	918	944	1166	1,302	443	347
Chloride	MG/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium	MG/KG					9.43	8.89	14.6	9.92	8.26	6.2
Copper	MG/KG					8.3	9.03	16.9	12.9	7.29	5.41
Iron	MG/KG	24,458	26,667	9,540	25,577	18,877	16,846	20,712	17,186	18,801	13,265
Lead	MG/KG					11	10.4	9.99	8.51	7.19	7.5
Magnesium	MG/KG	3,398	3,827	154	178	1,087	1,016	1,985	1,474	1,954	1,386
Manganese	MG/KG	986	1,071	513	1712	333	296	885	737	345	279
Mercury	MG/KG					<0.141	<0.141	<0.1	<0.122	<0.098	<0.13
Nickel	MG/KG	15.7	16.8	10.2	16.9	11.2	14.6	32.6	24.8	11	8.02
Potassium	MG/KG	3,494	5,820	378	406	986	995	1,344	856	842	632
Silver	MG/KG					<0.704	<0.706	<0.5	<0.612	<0.489	<0.652
Sodium	MG/KG	69	187	<69.2	<56.7	<70.4	<70.6	74.4	84.8	<48.9	<65.2
Strontium	MG/KG	8.294	11.6	<3.46	16.3	20.8	18.3	10	8.38	4.5	3.59
Uranium	MG/KG	<5.72	<6.43	<6.92	<5.67	<7.04	<7.06	<5	<6.12	<4.89	<6.52
Zinc	MG/KG	52.2	55.6	57.6	96.2	53.8	52.2	101	80.5	34.7	28.6

Appendix B - Impacted Sites: Raw Data

Impacted Sites - Water Results

Test	Units	1BC	DISBC	2BC	3BC	1CR	2JC	DISJC	3JC	1MR	2MR	1MKR	3MKR	1SC	1USC	3SC	3SC (replicate)	1SFTC
Alkalinity, Total	MG/L	9.8	242.4	34	6.4	27.6	64.2	570.2	63.6	102	99.6	83.2	0	195	577	291.6	288.8	100.6
Aluminum, Total	UG/L	<200	200	<200	<200	<200	1,090	<200	1,119	204	200	<200	14,000	<200	<200	<200	<200	2,775
Ammonia, Total as Nitrogen	MG/L	<0.02	59.29	4.88	0.57	0.09	0.16	0.72	0.18	0.61	0.04	0.04	1.89	0.07	0.3	0.09	0.09	0.07
Arsenic, Total	UG/L	<3	<1,500	<150	3.63	<3	<3	<3	<3	<3	<3	<3	8.2	<3	6.2	<3	<3	<3
Barium, Total	UG/L	40	9,680	1,108	182	68	52	1,131	56	60	41	50	159	77	14	60	61	98
Biochemical Oxygen Demand (Inhibited 5-Day)	MG/L	0.8	42.6	9	2.9	0.9	2.6	4	1.8	0.6	0.8	0.7	9.5	0.4	1.3	0.7	0.6	0.7
Boron, Total	UG/L	<200	3,000	250	<200	330	<200	370	<200	<200	<200	<200	<200	<200	470	<200	200	<200
Bromide (Ion Chromatography)	UG/L	67.08	498,014	42,876	3,465	396.14	<50	13,660	<50	282.24	210.05	91.05	7,750	<50	4,146	1,057	1,127	<50
Calcium, Total	MG/L	71.3	10,300	891	157	82.8	47.7	14.5	50.7	49	47.7	34	238	58	60.4	58	58.9	40.7
Chloride (Ion Chromatography)	MG/L	16.99	60,220	5,802	489	50.5	41.08	<0.5	45.4	78.3	67.4	46.4	931	10.98	601	169	168	11.25
Hardness, Total (Calculated)	MG/L	252	27,526	2,431	484	319	170	129	183	169	167	124	733	196	243	207	210	128
Iron, Total	UG/L	90	700	553	144	580	2352	263	2,484	808	748	161	30,900	351	447	205	201	4,971
Lithium, Total	UG/L									<25	<25							
Magnesium, Total	MG/L	18	431	49.4	22.1	27.2	12.4	22.5	13.6	11.4	11.6	9.52	33.6	12.4	22.3	15	15.2	6.332
Manganese, Total	UG/L	488	460	409	517	333	437	11	455	101	92	50	2,389	66	229	46	47	216
Nitrate & Nitrogen, Total as Nitrogen	MG/L	0.47	0.11	0.46	0.33	0.83	1.17	<0.05	1.13	2.37	2.49	0.18	0.05	0.2	0.2	0.21	0.21	0.08
Osmotic Pressure	MOSM	11	2,590	273	28	7	4	127	4	7	5	3	51	9	79	28	27	4
pH	pH units	6.9	9.6	9	6.8	7.1	7.4	8.8	7.4	7.9	7.9	7.6	4.6	8.3	8.5	8.4	8.4	8.1
Phosphorus, Total	MG/L	<0.01	0.406	0.036	<0.01	0.012	0.087	0.108	0.09	0.118	0.122	0.014	0.013	0.025	0.015	0.02	0.019	0.16
Selenium, Total	UG/L	<7	<3,500	<350	12.67	<7	<7	<7	<7	<7	<7	<7	25.15	<7	20	<7	<7	<7
Sodium, Total	MG/L	49	26,600	2,010	252	42.2	23.6	1,760	26.5	53	48.3	22.9	461	37	1,110	299	313	12.8
Specific Conductance (@ 25.0°C)	umhos/cm	709	106,200	11,220	2,060	848	453	7,170	494	602	559	386	3,680	522	4,770	1,687	1,682	287
Strontium, Total	UG/L	387	999,000	73,800	13,600	689	223	1,881	243	375	261	191	10,100	364	1,838	744	753	147
Sulfate (Ion Chromatography)	MG/L	322	1,330	407	391	320	93.94	<1	97.8	57.52	57.08	30.02	5.83	65.53	1,168	353	352	30.2
Total Dissolved Solids (@ 180°C)	MG/L	502	130,822	12,196	1,510	648	382	4,074	404	396	364	236	2,498	354	3,286	1,120	1,134	196
Total Suspended Solids	MG/L	<5	218	24	6	<5	40	12	48	6	12	<5	24	16	6	<5	6	208
Zinc, Total	UG/L	<10	10	<10	20	<10	26	<10	22	13	12	<10	254	<10	<10	<10	<10	17

Impacted Sites - Water Radiation Results
(Analyzed at Pace Analytical Laboratories, Greensburg, PA)

Parameter	Units	1BC	1BC (replicate)	DISBC	2BC	1CR	2JC	DISJC	3JC	1MR	2MR	2MKR	DISMKR	3MKR	2SFT	3SFT	4SFT	2SC	3SC
Ra-226	pCi/L	0	0.146	9	1.9	0.149	0.182	3.34	-0.065	0.0609	0.254	0.103	7.41	0.526	0.342	0.0563	0.0555	0.109	0.203
Ra-226 CE*	pCi/L	0.19	0.167	8.07	0.727	0.219	0.396	1.16	0.34	0.358	0.396	0.203	7.39	0.424	0.407	0.292	0.243	0.263	0.317
Ra-226 LLD#	pCi/L	0.449	0.132	4.88	0.465	0.365	0.73	0.787	0.786	0.732	0.683	0.38	5.02	0.566	0.636	0.606	0.515	0.507	0.546
Ra-228	pCi/L	0.463	1.14	13.4	1.2	0.168	1.56	2.47	-0.171	0.409	0.28	0.966	26.2	0.332	1.35	0.582	0.621	0.294	0.531
Ra-228 CE	pCi/L	0.442	0.566	10.9	0.54	0.396	0.619	0.83	0.636	0.441	0.434	0.522	15.5	0.4	0.567	0.476	0.44	0.406	0.445
Ra-228 LLD	pCi/L	0.904	0.961	20.1	0.885	0.879	0.953	1.13	1.3	0.901	0.938	0.92	27.3	0.842	0.894	0.941	0.854	0.87	0.891
Total Uranium	ug/L	0.071	0.033	0.057	0.085	0.05	0.183	0.059	0.213	0.37	0.417	0.498	0.089	0.495	0.401	0.395	0.467	0.736	0.754
Total Uranium CE	ug/L	0.003	0.002	0.003	0.005	0.002	0.005	0.002	0.007	0.008	0.009	0.014	0.004	0.014	0.01	0.008	0.008	0.013	0.014
Total Uranium LLD	ug/L	0.21	0.21	1.05	1.05	0.21	0.21	0.21	0.21	0.21	0.21	0.21	1.05	0.21	0.21	0.21	0.21	0.21	0.21

*CE = Counting Error

#LLD = Lower Limit of Detection

Towanda Creek - Sediment Organics Results

Test	Units	1TC	1TC (replicate)	1UTC	2TC
(1,1-Dimethylethyl)benezene	UG/KG	80.8	90.8	52.1	96.4
(1-Methylethyl)benzene	UG/KG	80.8	90.8	52.1	96.4
(1-Methylpropyl)Benzene	UG/KG	80.8	90.8	52.1	96.4
1,1,1,2-Tetrachloroethanet	UG/KG	80.8	90.8	52.1	96.4
1,1,1-Trichloroethane	UG/KG	80.8	90.8	52.1	96.4
1,1,2,2-Tetrachloroethane	UG/KG	80.8	90.8	52.1	96.4
1,1,2-Trichloroethane	UG/KG	80.8	90.8	52.1	96.4
1,1-Dichloroethane	UG/KG	80.8	90.8	52.1	96.4
1,1-Dichloroethene	UG/KG	80.8	90.8	52.1	96.4
1,1-Dichloropropene	UG/KG	80.8	90.8	52.1	96.4
1,2,3-Trichlorobenzene	UG/KG	80.8	90.8	52.1	96.4
1,2,3-Trichloropropane	UG/KG	80.8	90.8	52.1	96.4
1,2,4,5-Tetrachlorobenzene	MG/KG	2.03	1.95	1.27	1.81
1,2,4-Trichlorobenzene	MG/KG	2.03	1.95	1.27	1.81
1,2,4-Trichlorobenzene	UG/KG	80.8	90.8	52.1	96.4
1,2,4-Trimethylbenzene	UG/KG	80.8	90.8	52.1	96.4
1,2-Dibromo-3-Chloropropa	UG/KG	80.8	90.8	52.1	96.4
1,2-Dibromoethane	UG/KG	80.8	90.8	52.1	96.4
1,2-Dichlorobenzene	MG/KG	2.03	1.95	1.27	1.81
1,2-Dichlorobenzene	UG/KG	80.8	90.8	52.1	96.4
1,2-Dichloroethane	UG/KG	80.8	90.8	52.1	96.4
1,2-Dichloropropane	UG/KG	80.8	90.8	52.1	96.4
1,3,5-Trimethylbenzene	UG/KG	80.8	90.8	52.1	96.4
1,3-Dichlorobenzene	MG/KG	2.03	1.95	1.27	1.81
1,3-Dichlorobenzene	UG/KG	80.8	90.8	52.1	96.4
1,3-Dichlororpropane	UG/KG	80.8	90.8	52.1	96.4
1,3-Dinitrobenzene	MG/KG	2.03	1.95	1.27	1.81
1,4-Dichlorobenzene	MG/KG	2.03	1.95	1.27	1.81
1,4-Dichlorobenzene	UG/KG	80.8	90.8	52.1	96.4
1,4-Naphthoquinone	MG/KG	2.03	1.95	1.27	1.81
1-Chloro-4-(trifluoromethyl)benzene	UG/KG	80.8	90.8	52.1	96.4
2,2-Dichloropropane	UG/KG	80.8	90.8	52.1	96.4
2,3,4,6-Tetrachlorophenol	MG/KG	4.06	3.9	2.54	3.63
2,4,5-Trichlorophenol	MG/KG	4.06	3.9	2.54	3.63
2,4,6-Trichlorophenol	MG/KG	4.06	3.9	2.54	3.63
2,4-Dichlorophenol	MG/KG	4.06	3.9	2.54	3.63
2,4-Dimethylphenol	MG/KG	4.06	3.9	2.54	3.63
2,4-Dinitrophenol	MG/KG	4.06	3.9	2.54	3.63
2,4-Dinitrotoluene	MG/KG	2.03	1.95	1.27	1.81
2,6-Dichlorophenol	MG/KG	4.06	3.9	2.54	3.63
2,6-Dinitrotoluene	MG/KG	2.03	1.95	1.27	1.81
2-Acetylaminofluorene	MG/KG	2.03	1.95	1.27	1.81
2-Butanone (MEK)	UG/KG	404	454	260	482
2-Chloronaphthalene	MG/KG	2.03	1.95	1.27	1.81
2-Chlorophenol	MG/KG	4.06	3.9	2.54	3.63
2-Hexanone	UG/KG	404	454	260	482
2-Methoxy-2-methyl propane (MTBE)	UG/KG	80.8	90.8	52.1	96.4
2-Methylnaphthalene	MG/KG	1.01	0.976	0.636	0.907
2-Methylphenol	MG/KG	4.06	3.9	2.54	3.63
2-Nitroaniline	MG/KG	2.03	1.95	1.27	1.81
2-NItrophenol	MG/KG	4.06	3.9	2.54	3.63
2-Picoline (2-Methylpyridine)	MG/KG	2.03	1.95	1.27	1.81
3&4-Methylphenol	MG/KG	8.11	7.81	5.09	7.26
3,3'-Dichlorobenzidine	MG/KG	2.03	1.95	1.27	1.81
3-Methylcholanthrene	MG/KG	1.01	0.976	0.636	0.907
3-Nitroaniline	MG/KG	2.03	1.95	1.27	1.81
4,6-DINITRO-2-methylphenol	MG/KG	4.06	3.9	2.54	3.63
4-Aminobiphenyl	MG/KG	2.03	1.95	1.27	1.81
4-Bromophenyl-phenyl ether	MG/KG	2.03	1.95	1.27	1.81
4-Chloro-3-methylphenol	MG/KG	4.06	3.9	2.54	3.63
4-Chloroaniline	MG/KG	2.03	1.95	1.27	1.81
4-Chlorophenyl-phenyl ether	MG/KG	2.03	1.95	1.27	1.81
4-Isopropyltoluene	UG/KG	80.8	90.8	52.1	96.4
4-Methyl-2-pentanone (MIBK)	UG/KG	404	454	260	482
4-Nitroaniline	MG/KG	2.03	1.95	1.27	1.81
4-Nitrophenol	MG/KG	4.06	3.9	2.54	3.63
5-Nitro-o-toluidine	MG/KG	2.03	1.95	1.27	1.81
7,12-Dimethylbenz(a)-anthracene	MG/KG	1.01	0.976	0.636	0.907
Acenaphthene	MG/KG	1.01	0.976	0.636	0.907
Acenaphthylene	MG/KG	1.01	0.976	0.636	0.907
Acetone	UG/KG	404	454	260	482
Acetophenone	MG/KG	2.03	1.95	1.27	1.81
Aniline	MG/KG	2.03	1.95	1.27	1.81
Anthracene	MG/KG	1.01	0.976	0.636	0.907
Aramite	MG/KG	2.03	1.95	1.27	1.81
Benz(a)anthracene	MG/KG	1.01	0.976	0.636	0.907
Benzene	UG/KG	80.8	90.8	52.1	96.4
Benzo(a)pyrene	MG/KG	1.01	0.976	0.636	0.907
Test	**Units**	**1TC**	**1TC (replicate)**	**1UTC**	**2TC**

Benzo(b)fluoranthene	MG/KG	1.01	0.976	0.636	0.907
Benzo(g,h,i)perylene	MG/KG	1.01	0.976	0.636	0.907
Benzo(k)fluoranthene	MG/KG	1.01	0.976	0.636	0.907
Benzyl alcohol	MG/KG	2.03	1.95	1.27	1.81
bis(2-Chloroethoxy)methane	MG/KG	2.03	1.95	1.27	1.81
bis(2-Chloroethyl)ether	MG/KG	2.03	1.95	1.27	1.81
bis(2-Chloroisopropyl)ether	MG/KG	2.03	1.95	1.27	1.81
bis(2-Ethylhexyl)phthalate	MG/KG	2.03	1.95	1.27	1.81
Bromobenzene	UG/KG	80.8	90.8	52.1	96.4
Bromodichloromethane	UG/KG	80.8	90.8	52.1	96.4
Bromoform	UG/KG	80.8	90.8	52.1	96.4
Bromomethane	UG/KG	80.8	90.8	52.1	96.4
Butylbenzylphthalate	MG/KG	2.03	1.95	1.27	1.81
Carbon disulfide	UG/KG	80.8	90.8	52.1	96.4
Carbon tetrachloride	UG/KG	80.8	90.8	52.1	96.4
Chlorobenzene	UG/KG	80.8	90.8	52.1	96.4
Chlorobenzilate	MG/KG	2.03	1.95	1.27	1.81
Chloroethane	UG/KG	80.8	90.8	52.1	96.4
Chloroform	UG/KG	80.8	90.8	52.1	96.4
Chloromethane	UG/KG	80.8	90.8	52.1	96.4
Chrysene	MG/KG	1.01	0.976	0.636	0.907
cis-1,2-Dichloroethene	UG/KG	80.8	90.8	52.1	96.4
cis-1,3-Dichloropropene	UG/KG	80.8	90.8	52.1	96.4
Diallate (Cis or Trans)	MG/KG	2.03	1.95	1.27	1.81
Dibenzo(a,h)anthracene	MG/KG	1.01	0.976	0.636	0.907
Dibenzofurans	MG/KG	2.03	1.95	1.27	1.81
Dibromochloromethane	UG/KG	80.8	90.8	52.1	96.4
Dibromomethane	UG/KG	80.8	90.8	52.1	96.4
Dichlorodifluoromethane	UG/KG	80.8	90.8	52.1	96.4
Dichloromethane	UG/KG	80.8	90.8	52.1	96.4
Diethylphthalate	MG/KG	2.03	1.95	1.27	1.81
Dimethoate	MG/KG	2.03	1.95	1.27	1.81
Dimethylaminoazobenzene	MG/KG	2.03	1.95	1.27	1.81
Dimethylphthalate	MG/KG	2.03	1.95	1.27	1.81
Di-n-butylphthalate	MG/KG	2.03	1.95	1.27	1.81
Di-n-octylphthalate	MG/KG	2.03	1.95	1.27	1.81
Dinoseb	MG/KG	4.06	3.9	2.54	3.63
Diphenylamine	MG/KG	4.06	3.9	2.54	3.63
Disulfoton	MG/KG	2.03	1.95	1.27	1.81
Ethyl methanesulfonate	MG/KG	2.03	1.95	1.27	1.81
Ethyl parathion	MG/KG	2.03	1.95	1.27	1.81
Ethylbenzene	UG/KG	80.8	90.8	52.1	96.4
Fluoranthene	MG/KG	1.01	0.976	0.636	0.907
Fluorene	MG/KG	1.01	0.976	0.636	0.907
Hexachlorobenzene	MG/KG	2.03	1.95	1.27	1.81
Hexachlorobutadiene	MG/KG	2.03	1.95	1.27	1.81
Hexachlorobutadiene	UG/KG	80.8	90.8	52.1	96.4
Hexachlorocyclopentadiene	MG/KG	2.03	1.95	1.27	1.81
Hexachloroethane	MG/KG	2.03	1.95	1.27	1.81
Hexachloropropene	MG/KG	2.03	1.95	1.27	1.81
Indeno[1,2,3-cd]pyrene	MG/KG	1.01	0.976	0.636	0.907
Isodrin	MG/KG	2.03	1.95	1.27	1.81
Isophorone	MG/KG	2.03	1.95	1.27	1.81
Isosafrole	MG/KG	2.03	1.95	1.27	1.81
m/p-Xylene	UG/KG	162	182	104	193
Methyl Methanesulfonate	MG/KG	2.03	1.95	1.27	1.81
Naphthalene	MG/KG	1.01	0.976	0.636	0.907
Naphthalene	UG/KG	80.8	90.8	52.1	96.4
N-Butylbenzene	UG/KG	80.8	90.8	52.1	96.4
Nitrobenzene	MG/KG	2.03	1.95	1.27	1.81
N-Nitrosodibutlyamine	MG/KG	2.03	1.95	1.27	1.81
N-Nitrosodiethylamine	MG/KG	2.03	1.95	1.27	1.81
N-Nitrosodimethylamine	MG/KG	2.03	1.95	1.27	1.81
N-Nitrosodipropylamine	MG/KG	2.03	1.95	1.27	1.81
N-Nitrosomethylethylamine	MG/KG	2.03	1.95	1.27	1.81
N-Nitrosomorpholine	MG/KG	2.03	1.95	1.27	1.81
N-Nitrosopiperidine	MG/KG	2.03	1.95	1.27	1.81
N-Nitrosopyrrolidine	MG/KG	2.03	1.95	1.27	1.81
n-Propylbenzene	UG/KG	80.8	90.8	52.1	96.4
O,O,O-Triethyl Phosphorothioat	MG/KG	2.03	1.95	1.27	1.81
O-Chlorotoluene	UG/KG	80.8	90.8	52.1	96.4
O-Toluidine	MG/KG	2.03	1.95	1.27	1.81
O-Xylenes	UG/KG	80.8	90.8	52.1	96.4
P-Chlorotolulene	UG/KG	80.8	90.8	52.1	96.4
Pentachlorobenzene	MG/KG	2.03	1.95	1.27	1.81
Pentachloroethane	MG/KG	2.03	1.95	1.27	1.81
Pentachloronitrobenzene	MG/KG	2.03	1.95	1.27	1.81

Test	Units	1TC	1TC (replicate)	1UTC	2TC
Pentachlorophenol	MG/KG	4.06	3.9	2.54	3.63
Phenanthrene	MG/KG	1.01	0.976	0.636	0.907
Phenol	MG/KG	4.06	3.9	2.54	3.63
Phorate	MG/KG	2.03	1.95	1.27	1.81
Pronamide	MG/KG	2.03	1.95	1.27	1.81
Pyrene	MG/KG	1.01	0.976	0.636	0.907
Pyridine	MG/KG	2.03	1.95	1.27	1.81
Safrole	MG/KG	2.03	1.95	1.27	1.81
Styrene	UG/KG	80.8	90.8	52.1	96.4
t-Butyl Alcohol	UG/KG	808	908	521	964
tert-Butyl Acetate	UG/KG	404	454	260	482
TETRACHLOROETHYLENE	UG/KG	80.8	90.8	52.1	96.4
Tetraethyl Dithiopyrophosphate	MG/KG	2.03	1.95	1.27	1.81
Tetrahydrofuran	UG/KG	162	182	104	193
Thionazine	MG/KG	2.03	1.95	1.27	1.81
Toluene	UG/KG	80.8	90.8	52.1	96.4
Trans-1,2-Dichloroethene	UG/KG	80.8	90.8	52.1	96.4
Trans-1,3-Dichloropropene	UG/KG	80.8	90.8	52.1	96.4
Trichloroethylene	UG/KG	80.8	90.8	52.1	96.4
Trichlorofluoromethane	UG/KG	80.8	90.8	52.1	96.4
Vinyl acetate	UG/KG	80.8	90.8	52.1	96.4
Vinyl chloride	UG/KG	80.8	90.8	52.1	96.4

Impacted Sites – Sediment Results

Test	Units	1BC	1BC (replicate)	DISBC	2BC	1JC	DISJC	3JC
Americium 241	PCI/KG	0	0	0	0	0	0	0
Barium 140	PCI/KG	0	0	0	0	0	0	0
Beryllium 7	PCI/KG	329 +/- 75	287 +/- 80	0	0	265 +/- 57	539 +/- 104	129 +/- 61
Cesium 134	PCI/KG	0	0	0	0	0	0	0
Cesium 137	PCI/KG	34 +/- 6	22 +/- 5	49 +/- 22	23 +/- 8	10 +/- 5	39 +/- 8	12 +/- 8
Cobalt 58	PCI/KG	0	0	0	0	0	0	0
Cobalt 60	PCI/KG	0	0	0	0	0	0	0
Iodine 131	PCI/KG	0	0	0	0	0	0	0
Iridium 192	PCI/KG	0	0	0	0	0	0	0
Iron 59	PCI/KG	0	0	0	0	0	0	0
Lanthanum 140	PCI/KG	0	0	0	0	0	0	0
Lead 212	PCI/KG	741 +/- 39	728 +/- 34	81,900 +/- 222	2,870 +/- 75	617 +/- 34	1,060 +/- 42	852 +/- 41
Lead 214	PCI/KG	662 +/-73	745 +/- 59	231,000 +/- 477	7,660 +/- 161	644 +/- 58	1,120 +/- 75	735 +/- 70
Manganese 54	PCI/KG	0	0	0	0	0	0	0
Niobium 95	PCI/KG	0	0	0	0	0	0	0
Radium 226	PCI/KG	1,590 +/-154	1,740 +/- 136	211,000 +/- 950	8,280 +/- 327	1,240 +/- 132	2,470 +/- 192	1,410 +/- 152
Radium 228	PCI/KG	685 +/- 36	673 +/- 31	73,000 +/- 198	2,660 +/- 69	579 +/- 32	991 +/- 39	799 +/- 38
Ruthenium 103	PCI/KG	0	0	0	0	0	0	0
Ruthenium 106	PCI/KG	0	0	0	0	0	0	0
Uranium 235	PCI/KG	0	0	0	0	0	0	0
Uranium 238	PCI/KG	801 +/- 306	1,330 +/- 306	0	0	763 +/- 287	1,320 +/- 548	759 +/- 352
Zinc 65	PCI/KG	0	0	0	0	0	0	0
Zirconium 95	PCI/KG	0	0	0	0	0	0	0
Bromide	MG/L	0.2	5.5	0.2	0.2	0.2	0.4	0.2
Chloride	MG/L	0.5	493	3.96	9.53	0.5	61.6	0.83
Aluminum	MG/KG	8,911	11,821	874	8,542	4,445	8,080	8,657
Arsenic	MG/KG							
Barium	MG/KG	81.7	115	6,056	3,307	50.8	300	80.8
Cadmium	MG/KG							
Calcium	MG/KG	837	806	76,173	4,884	686	1,996	1,127
Chromium	MG/KG							
Copper	MG/KG							
Iron	MG/KG	96,222	158,532	5,991	142,554	18,321	24,560	33,040
Lead	MG/KG							
Magnesium	MG/KG	684	677	7,279	909	504	1,291	834
Manganese	MG/KG	897	1,065	536	628	253	407	398
Mercury	MG/KG							
Nickel	MG/KG	39.5	37.9	4.87	46.2	18.7	28.4	22.2
Potassium	MG/KG	1,036	1,311	847	1,036	446	815	793
Silver	MG/KG							
Sodium	MG/KG	162	108	11,334	1,726	75.6	1,632	91.8
Strontium	MG/KG	28.1	19.5	29,383	1,401	8.99	119	22.1
Uranium, Total	MG/KG	5.93	6.86	5.94	8.22	7.56	7.46	6.2
Zinc	MG/KG	132	187	13.7	269	75.1	132	105

Test	Units	1MR	2MR	2MKR	2MKR (replicate)	DISMKR	3MKR
Americium 241	PCI/KG	0	0	0	0	0	0
Barium 140	PCI/KG	0	2 +/- 3	0	0	0	0
Beryllium 7	PCI/KG	235 +/- 37	141 +/- 30	65 +/- 39	0	0	111 +/- 32
Cesium 134	PCI/KG	0	0	0	0	0	0
Cesium 137	PCI/KG	6 +/- 2	0	6 +/- 3	0	0	12 +/- 3
Cobalt 58	PCI/KG	0	0	0	0	0	0
Cobalt 60	PCI/KG	0	0	0	0	0	0
Iodine 131	PCI/KG	0	0	0	0	0	0
Iridium 192	PCI/KG	0	0	0	0	0	0
Iron 59	PCI/KG	0	0	0	0	0	0
Lanthanum 140	PCI/KG	0	0	0	0	0	0
Lead 212	PCI/KG	281 +/- 14	337 +/- 14	717 +/- 22	628 +/- 20	3,200 +/- 66	565 +/- 19
Lead 214	PCI/KG	275 +/- 26	553 +/- 31	660 +/- 39	584 +/- 43	12,900 +/- 163	508 +/- 39
Manganese 54	PCI/KG	0	0	0	0	0	0
Niobium 95	PCI/KG	0	0	0	0	0	0
Radium 226	PCI/KG	734 +/- 77	849 +/- 69	1,390 +/- 97	1,240 +/- 122	15,100 +/- 324	1,100 +/- 82
Radium 228	PCI/KG	261 +/- 13	314 +/- 13	662 +/- 20	580 +/- 18	2,960 +/- 61	822 +/- 18
Ruthenium 103	PCI/KG	0	0	0	0	0	0
Ruthenium 106	PCI/KG	0	0	0	0	0	0
Uranium 235	PCI/KG	0	0	0	0	0	0
Uranium 238	PCI/KG	0	216 +/- 92	716 +/- 147	582 +/- 276	440 +/- 325	425 +/- 98
Zinc 65	PCI/KG	0	0	0	0	0	0
Zirconium 95	PCI/KG	0	0	0	0	0	0
Bromide	MG/L	0.2	0.2	0.2	0.2	11.1	0.2
Chloride	MG/L	0.66	3.53	0.66	0.72	1,350	30.88
Aluminum	MG/KG	3,544	5,142	13,546	7,965	5,829	15,361
Arsenic	MG/KG			39.3	14.2	9.87	19.2
Barium	MG/KG	58.7	184	102	56	2,676	80.4
Cadmium	MG/KG			0.456	0.519	0.431	0.419
Calcium	MG/KG	6,882	11,032	544	343	43,557	613
Chromium	MG/KG			25.7	13.7	11.2	22.8
Copper	MG/KG			23.8	20.6	13.5	24.2
Iron	MG/KG	122,769	118,974	62,603	38,916	23,209	51,469
Lead	MG/KG			15.5	13.1	10.3	17.2
Magnesium	MG/KG	1,654	2,249	1,381	1,027	3,733	1,575
Manganese	MG/KG	1,309	1,196	249	226	275	215
Mercury	MG/KG			0.091	0.104	0.086	0.093
Nickel	MG/KG	41.6	45.4	19.7	13.7	11.2	24.8
Potassium	MG/KG	315	443	1,363	846	714	1,847
Silver	MG/KG			0.456	0.519	0.431	0.419
Sodium	MG/KG	103	167	135	101	20,930	427
Strontium	MG/KG	24.3	72.6	17.9	10.1	1,466	45.2
Uranium, Total	MG/KG	6.27	5.24	4.56	5.19	4.31	4.19
Zinc	MG/KG	235	265	60.6	45.1	41.5	87.7

Test	Units	2SC	3SC	2SFT	3SFT	4SFT
Americium 241	PCI/KG	0	0	0	0	0
Barium 140	PCI/KG	0	0	0	0	0
Beryllium 7	PCI/KG	107 +/- 67	0	70 +/- 90	0	130 +/- 49
Cesium 134	PCI/KG	0	0	0	0	0
Cesium 137	PCI/KG	24 +/- 5	30 +/- 5	18 +/- 5	11 +/- 6	0
Cobalt 58	PCI/KG	0	0	0	0	0
Cobalt 60	PCI/KG	0	0	0	0	0
Iodine 131	PCI/KG	0	0	0	0	0
Iridium 192	PCI/KG	0	0	0	0	0
Iron 59	PCI/KG	0	0	0	0	0
Lanthanum 140	PCI/KG	0	0	0	0	0
Lead 212	PCI/KG	869 +/- 33	1020 +/- 29	714 +/- 31	601 +/- 39	562 +/- 23
Lead 214	PCI/KG	714 +/- 54	840 +/- 48	551 +/- 60	588 +/- 77	430 +/- 37
Manganese 54	PCI/KG	0	0	0	0	0
Niobium 95	PCI/KG	0	0	0	0	0
Radium 226	PCI/KG	1,770 +/- 156	1,830 +/- 116	1,370 +/- 151	1,330 +/- 166	1,040 +/- 84
Radium 228	PCI/KG	800 +/- 31	943 +/- 27	650 +/- 28	553 +/- 36	518 +/- 21
Ruthenium 103	PCI/KG	0	0	0	0	0
Ruthenium 106	PCI/KG	0	0	0	0	0
Uranium 235	PCI/KG	0	0	0	0	0
Uranium 238	PCI/KG	736 +/- 362	987 +/- 208	725 +/- 331	873 +/- 293	407 +/- 120
Zinc 65	PCI/KG	0	0	0	0	0
Zirconium 95	PCI/KG	0	0	0	0	0
Bromide	MG/L					
Chloride	MG/L		2.44			
Aluminum	MG/KG					
Arsenic	MG/KG					
Barium	MG/KG		229			
Cadmium	MG/KG					
Calcium	MG/KG		6,848			
Chromium	MG/KG					
Copper	MG/KG					
Iron	MG/KG		62,471			
Lead	MG/KG					
Magnesium	MG/KG		2,822			
Manganese	MG/KG		1,634			
Mercury	MG/KG					
Nickel	MG/KG					
Potassium	MG/KG		2,048			
Silver	MG/KG					
Sodium	MG/KG		547			
Strontium	MG/KG		92.5			
Uranium, Total	MG/KG		6.85	4.75	4.48	4.9
Zinc	MG/KG					

Test	Units	1CR	1CR (replicate)	1TC	1TC (replicate)	1UTC	2TC
Americium 241	PCI/KG	0	0	0	0	0	0
Barium 140	PCI/KG	0	0	0	0	0	0
Beryllium 7	PCI/KG	288 +/- 92	382 +/- 107	68 +/- 23	50 +/- 40	0	54 +/- 17

Cesium 134	PCI/KG	0	0	0	0	0	0
Cesium 137	PCI/KG	70 +/- 9	170 +/- 10	14 +/- 3	18 +/- 7	0	15 +/- 4
Cobalt 58	PCI/KG	0	0	0	0	0	0
Cobalt 60	PCI/KG	0	0	0	0	0	0
Iodine 131	PCI/KG	0	0	0	0	0	0
Iridium 192	PCI/KG	0	0	0	0	0	0
Iron 59	PCI/KG	0	0	0	0	0	0
Lanthanum 140	PCI/KG	0	0	0	0	0	0
Lead 212	PCI/KG	827 +/- 48	943 +/- 55	712 +/- 19	808 +/- 32	1,070 +/- 39	910 +/- 27
Lead 214	PCI/KG	891 +/- 93	883 +/- 92	473 +/- 34	580 +/- 58	666 +/- 65	608 +/- 43
Manganese 54	PCI/KG	0	0	0	0	0	0
Niobium 95	PCI/KG	0	0	0	0	0	0
Radium 226	PCI/KG	2,120 +/- 184	2,490 +/- 221	1,220 +/- 86	1,580 +/- 162	10,810 +/- 170	1,540 +/- 119
Radium 228	PCI/KG	772 +/- 45	881 +/- 51	674 +/- 18	764 +/- 31	1,010 +/- 37	861 +/- 26
Ruthenium 103	PCI/KG	0	0	0	0	0	0
Ruthenium 106	PCI/KG	0	0	0	0	0	0
Uranium 235	PCI/KG	0	0	0	0	0	0
Uranium 238	PCI/KG	1,330 +/- 475	1,820 +/- 504	537 +/- 89	608 +/- 291	1,050 +/- 395	654 +/- 345
Zinc 65	PCI/KG	0	0	0	0	0	0
Zirconium 95	PCI/KG	0	0	0	0	0	0
Bromide	MG/L	0.2	0.2				
Chloride	MG/L	20.68	3.02	0.5	0.5	0.5	0.5
Aluminum	MG/KG	18,523	28,795				
Arsenic	MG/KG	17.2	18				
Barium	MG/KG	197	201	91.5	59.1	154	96.9
Cadmium	MG/KG	1.3	1.75				
Calcium	MG/KG	2,700	1,398	1,366	868	1,521	1,492
Chromium	MG/KG	45.1	36.7				
Copper	MG/KG	60.7	70.3				
Iron	MG/KG	98,006	100,425	21,466	17,098	32,035	22,010
Lead	MG/KG	62.5	53.7				
Magnesium	MG/KG	1,637	1,792	2,746	2,143	3,983	2,937
Manganese	MG/KG	1,968	998	610	385	740	667
Mercury	MG/KG	0.26	0.35				
Nickel	MG/KG	102	75				
Potassium	MG/KG	1,648	2,126	1,397	1201	1,475	1,281
Silver	MG/KG	1.3	1.75				
Sodium	MG/KG	520	314	68.4	64.5	65.9	66.9
Strontium	MG/KG	56	36	9.844	7.355	11.9	9.16
Uranium, Total	MG/KG	13	17.5				
Zinc	MG/KG	318	363				