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SEDIMENT QUALITY ASSESSMENT OF ST. MARY'S LAKE, ST. MARY'S COUNTY, MARYLAND

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Abbreviation	***Description***
Act Labs	Activation Laboratories, Inc.
Al, Ca, Fe, K, Na and Mg	major rock forming elements aluminum, calcium, iron, potassium, sodium and magnesium
As, Cd, Cr, Cu, Mn, Ni, Pb and Zn	trace elements arsenic, cadmium, chromium, copper, manganese, nickel, lead and zinc.
°C	Degrees Celsius
C, N, S and P	carbon, nitrogen, sulfur and phosphorus
CNS	carbon, nitrogen, and sulfur (gas chromatograph analysis)
cm	Centimeters
CRC	Canadian Research Council
DNR	Maryland Department of Natural Resources
EF	Enrichment Factor
EPA	Environmental Protection Agency
GIS	Geographical Information System
INAA	Instrumental Neutron Activation Analysis
HCl	Hydrochloric Acid
LEL	Lowest Effect Level
MGS	Maryland Geological Survey
mg/kg	Milligrams per kilogram (part per million)
ml	Milliliter
mmol/kg	Milli-mole per kilogram
NAD83	North America [Horizontal] Datum of 1983
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
ppm	part per million
RAS	Resource Assessment Service (DNR)
RTK GPS	Real-Time Kinematic Global Positioning System
SAV	Submerged Aquatic Vegetation
SEL	Severe Effect Level
SRM	Standard Reference Material
TD-ICP	“near total” Digestion Inductively Coupled Plasma Spectrophotometer
TEA	Tidewater Ecosystem Assessment (DNR)
ug/g	Microgram per gram (parts per million)
US SCS	U.S. Soil Conservation Service (in 1994, name changed to NRCS)
UTM	Universal Transverse Mercator (coordinate system)

Executive Summary

Maryland Geological Survey, in conjunction with other Maryland Department of Natural Resources programs, including Tidewater Ecosystem Assessment (TEA) and Fishing and Boating Services, was asked to perform sediment quality assessments of state-owned lakes in Maryland. The goal is to provide surficial sediment data for each lake to determine general sediment physical and chemical characteristics as a pre-assessment for potential future lake sediment dredging. Physical and chemical analysis of the sediments from each lake will pose as a baseline for the lake's sediment data. The sediment data will be incorporated into other study aspects, including fish populations, water quality, and submerged aquatic vegetation (SAV) abundance and distribution in order to generate an overall lake health and status.

This report focuses on St. Mary's Lake in St. Mary's County, Maryland. The lake is 250 acres and is located within St. Mary's River State Park. In September 2019, 35 surficial sediment samples were collected throughout the lake, and coordinates were stored using Real-Time Kinematic Global Positioning System (RTK GPS). Sediment at each site was described and sampled for analysis. The analysis includes physical properties, including bulk density and grain size, and elemental analysis.

Total carbon (C) content measured in St. Mary's Lake sediments had an average of 2.5% by dry weight. Total nitrogen (N) averaged, 0.15%, total phosphorus (P) averaged 0.016% and total sulfur (S) averaged 0.07%. Concentrations of C, N, P and S were similar to that found in other reservoirs within the state. Concentrations of N and P were the lowest of any of the freshwater lakes and reservoirs studied by MGS. C, N and S concentrations were well inter-correlated at St. Mary's Lake, which is suspected to be due to the high amount of fresh organic material in the sediments.

The elemental concentrations of 35 surficial sediments followed similar spatial patterns to each other when plotted by station, and correlated well with clay content. This was true for major rock-forming elements aluminum (Al), calcium (Ca), iron (Fe), potassium (K), sodium (Na) and magnesium (Mg). Most trace elements had quite similar profiles to each other, and they also are well correlated with clay content. These include arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn), whereas manganese (Mn) concentrations were only partially paired with clay content. When compared relative to two eco-toxicological screening levels for freshwater sediments, only a few of the metals of concern (As, Cr, Fe and Ni) are above the more conservative lowest effect level (LEL) in some or most sediments, while no concentrations of these metals are higher than the severe effect level (SEL) value. Since these concentrations represent more than that which is environmentally available, no eco-toxicological harm is anticipated. When compared to relative crustal abundance via the use of Fe-normalized enrichment factors, the elements. As, Cs, Eu, Pb, Hf, Sb, Th, U and Y were elevated. However, these elements are often encountered in high concentrations in clay-rich sediments, clay-rich sedimentary rocks and sandstones, as well as in minerals where they may substitute for K.

No abnormalities were found in regard to the physical or chemical properties of the bottom sediments of St. Mary's Lake.

Introduction

Study Area

St. Mary’s Lake is a man-made lake at the headwaters of the St. Mary’s River in St. Mary’s County, Maryland. The lake is 250 acres and is located in the St. Mary’s River State Park and is owned by the State of Maryland.

The St. Mary’s Lake watershed is located within the Coastal Plain Physiographic Province of Maryland. The Coastal Plain is a wedge of unconsolidated sediments including gravel, sand, silt and clay. Deep drilling has revealed that bedrock similar to rocks of the Piedmont Physiographic Province (i.e. metamorphic and igneous rock) underlie the sedimentary rocks of the Coastal Plain at greater depth, estimated at 2,500 feet below grade in the vicinity of St. Mary’s Lake. Almost all of St. Mary’s Lake is located within the Paleogene (Tertiary) aged St. Marys Formation, which is comprised of greenish-blue to yellowish-gray sandy clay and argillaceous, fine-grained sand. A small amount of the lake and all of its surrounding upland is located within Quaternary aged upland deposits, which are comprised of: sand and gravel which is commonly orange-brown and locally limonite-cemented; minor silt and red, white or gray clay (Cleaves *et al*, 1968).

Study Objectives

The objectives of this study are to:

1. Document sediment through the collection of grab samples from St. Mary’s Lake.
2. Analyze the samples for physical properties, including bulk density and grain size.
3. Process each sample for carbon, nitrogen and sulfur (CNS) and elemental analysis.

Methods

Field Methods

On September 27, 2019, MGS staff collected 35 sediment grab samples in St. Mary’s Lake (Figure 1). A 16-foot aluminum jon boat with an electric motor was used to collect the samples within the lake. Prior to sampling, using ESRI ArcMap 10.3, 35 proposed sample locations were placed throughout the lake to ensure full lake coverage. During sample collection, a TopCon Real-Time Kinematic Global Positioning System (RTK GPS) antenna and Carlson SurvPC software were used to locate each of the proposed locations and record the actual grab sample coordinates for each sample. Location coordinates were documented in UTM NAD83 Zone 18 State Plane, meters (Appendix A). Pictures were captured for each sample, displaying sediment properties and any present submerged aquatic vegetation (SAV). Pictures can also be found in Appendix A.

Sediment samples were collected with a hand-operated LaMotte stainless-steel dredge that sampled a bottom surface area of 19 centimeters (cm) x 14 cm and a mean sediment depth of 10 cm. Upon collection, samples were photographed, described, placed in Whirl-Pak^{TM} bags and kept cool until delivery to the MGS laboratory. Samples were refrigerated at 4° Celsius (C) until analysis. Descriptions of each sample along with sample coordinates can be found in Appendix A.

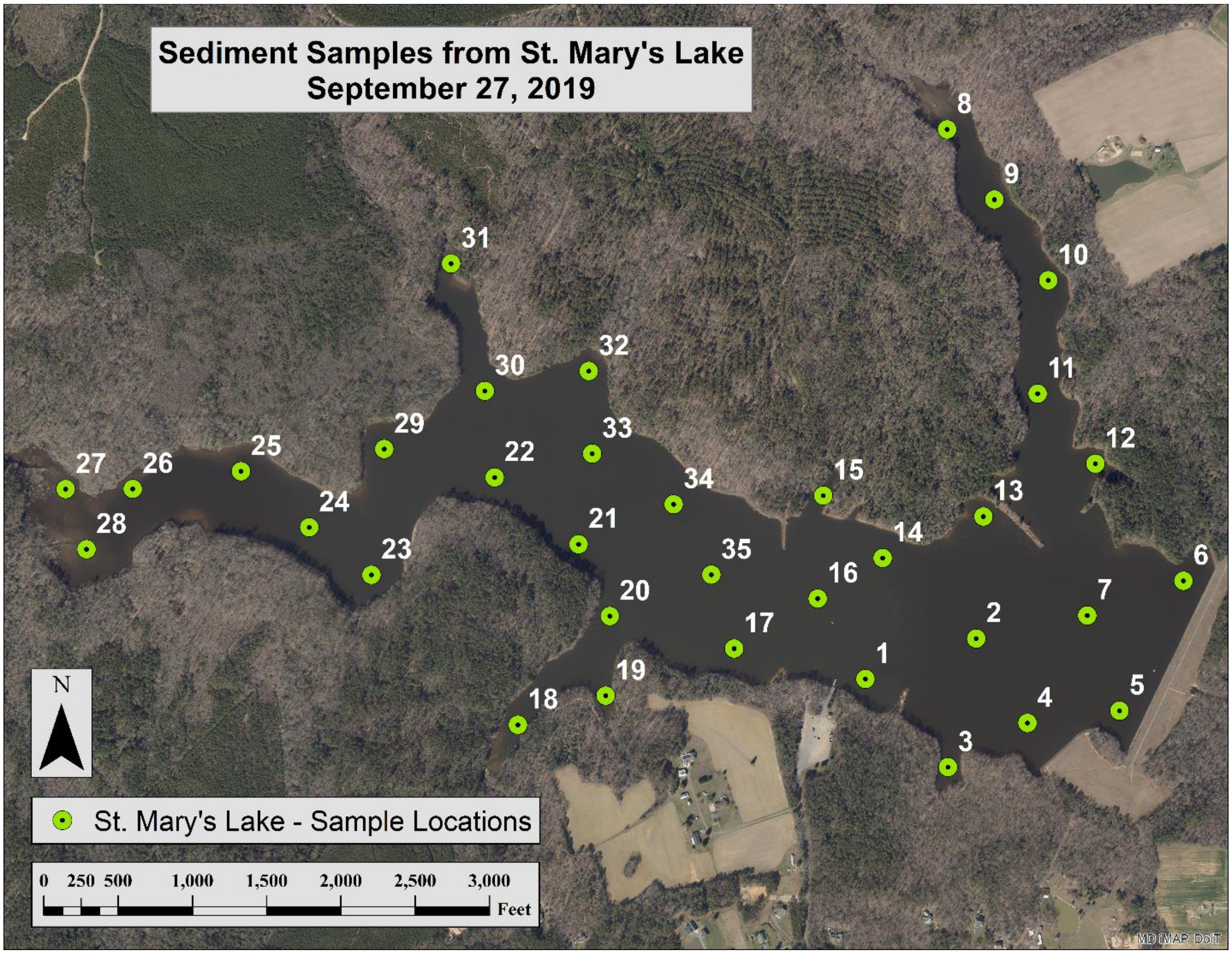

Figure 1. Map of grab sample locations.

Laboratory Methods

Grain Size

Sediment grab samples were analyzed for water content, bulk density and grain size (sand, silt and clay contents, as well as gravel, when present). Two homogeneous splits of each sample were processed, one for bulk property analysis and the other for grain size characterization. Analyses were performed within one week of sample collection and all samples were stored at 4° C prior to analysis.

Water content was determined by weighing 20-30 grams (g) of sediment. The sediment was then dried at 65° C and then re-weighed. Water content was calculated as the percentage of water weight to the weight of the wet sediment using Equation 1.

$$\%Water = \frac{W_w}{W_t} * 100 \qquad \textbf{Equation 1}$$

where: W_w is the weight of water; and
W_t is the weight of wet sediment.

Wet Bulk Density (ρ_B) is calculated from water content utilizing Equation 2 by assuming an average grain density (ρ_s) of 2.72 g/cm^3 and saturation of voids with water of density ρ_w = 1.0 g/cm^3. This method was adopted from the work of Bennett and Lambert (1971):

$$\rho_B = \frac{W_t}{W_d \ / \ 2.72 + W_w}$$ **Equation 2**

where: $\boldsymbol{W_d}$ is the weight of dry sediment.

Gravel, sand, silt and clay contents were determined using the textural analysis detailed in Kerhin and others (1988). Grain size, in this report (Table 1), is given in phi units, a scale devised by Krumbein (1936) where phi is defined as the negative log (to the base 2) of the particle diameter (millimeters (mm)). For example, 4 phi corresponds to a particle with a diameter of $1/2^4$ mm (=1/16 mm, or 0.0625 mm or 62.5 microns).

Grain size analysis consisted of cleaning the sediment samples in solutions of 10 percent hydrochloric acid (HCl) and 6 or 15 percent hydrogen peroxide (determined by water content) with subsequent rinsing with deionized water. This process removed soluble salts, carbonates and organic matter that could interfere with the dis-aggregation of the individual grains. The samples were then treated with a 0.26 percent solution of the dispersant sodium hexametaphosphate [$(NaPO_3)$] to ensure that individual grains did not re-aggregate (flocculate) during pipette analysis.

The separation of sand and silt-clay (mud) portions of the sample was accomplished by wet-sieving through a 4-phi mesh sieve (0.0625 mm, U.S. Standard Sieve #230). The gravel-sand fraction (*i.e*. that portion of the sample not passing through the sieve) was dried and weighed, and saved for further analysis. The finer silt and clay-sized particles (*i.e.*, passing through the sieve) were suspended in a 1000 milliliter (ml) cylinder in a solution of 0.26 percent sodium hexametaphosphate. The suspension was agitated and, at specified times thereafter; 20 ml pipette withdrawals were made (Carver, 1971; Folk, 1974). The rationale behind this process is that larger particles settle faster than smaller ones (Stoke's law). By calculating the settling velocities for different sized particles, times for withdrawal can be determined at which all particles of a specified size will have settled past the point of withdrawal. Sampling times were calculated to permit the determination of the amount of particles corresponding to 4 phi (silt class) and 8 phi (clay class) particles in the suspension. Withdrawn samples were dried at 65°C and weighed. From these data, the percentages by dry weight of sand, silt and clay were calculated for each sample and classified according to Shepard (1954) and Pejrup (1988) nomenclatures (Figures 2 and 3). Sample weight loss due to cleaning was determined; the weight loss approximates the amount of non-clastic components in the sediment.

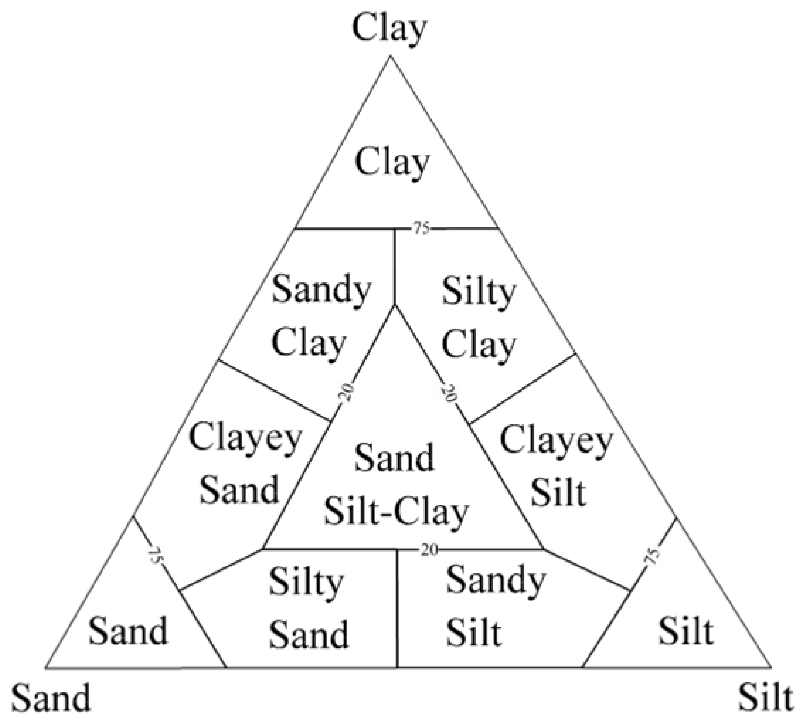

Figure 2. Shepard (1954) classification of sediment types. Sediment type classification is based on relative percentages of each size component (sand, silt, and clay).

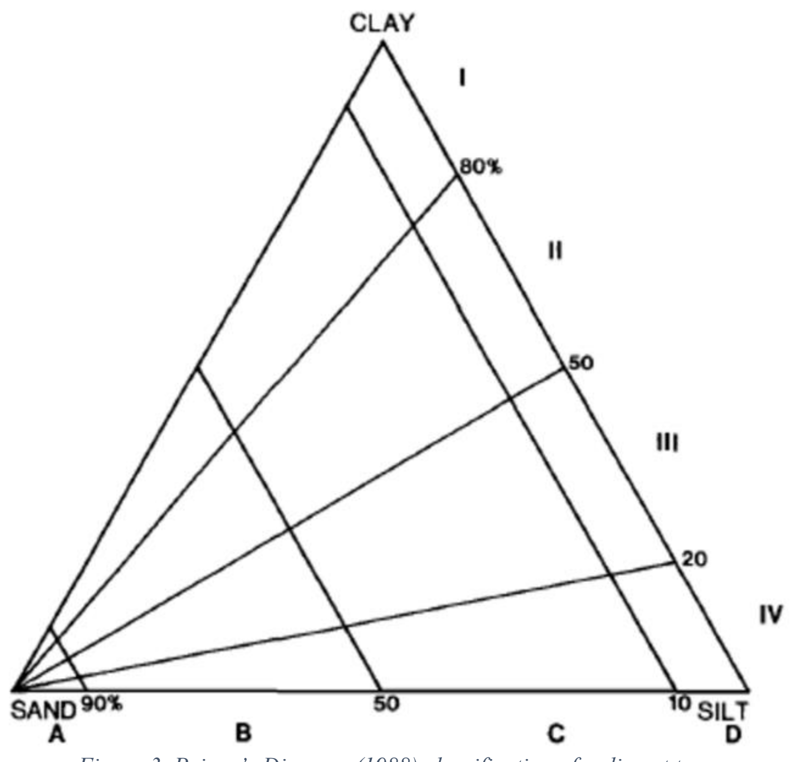

Figure 3. Pejrup's Diagram (1988) classification of sediment type.

Table 1. Sediment grain size definitions used in this study are based on the Wentworth (1922) scale. The term Mud is used to describe all particles smaller than sand (less than 0.0625 millimeters). The term Gravel is used to

describe all rock fragment particles that are 2 millimeters or larger.

Descriptor	Grain Size (millimeters)	Class Sizes (phi)
Mud	< 0.0625	> 4
Clay	< 0.004	> 8
Silt	0.004 to 0.0625	> 4 to 8
Sand	0.0625 to 2	4 to -1
Very Fine Sand	0.0625 to 0.125	4 to 3
Fine Sand	0.125 to 0.25	3 to 2
Medium Sand	0.25 to 0.5	2 to 1
Coarse Sand	0.5 to 1	1 to 0
Very Coarse Sand	1 to 2	0 to -1
Gravel	2 to 4,096	-1 to -12
Granule	2 to 4	-1 to -2
Pebble	4 to 64	-1 to -6
Cobble	64 to 256	-6 to -8
Boulder	256 to 4,096	-8 to -12

Elemental Analysis

Samples were ground in-house to the point until 95 percent of the sample could pass through a 200-mesh sieve (0.074 mm screen opening). Each sample was divided, with a three to five gram portion of the sample submitted to Activation Laboratories Inc. (Act Labs), while the remainder of the sample was retained for in-house analysis of total carbon, nitrogen and sulfur (CNS).

The quality assurance and quality control of Act Labs has proved to meet MGS standards and requirements. Fifty elements (Ag, Al, As, Au, Ba, Be, Bi, Br, Ca, Cd, Ce, Co, Cr, Cs, Cu, Eu, Fe, Hf, Hg, Ir, K, La, Li, Lu, Mg, Mn, Mo, Na, Nd, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Th, Ti, U, V, W, Y, Yb and Zn; refer to Appendix C for symbol key) were analyzed. Samples were prepared and ground in-house and sent to Act Labs for analyses using both Instrumental Neutron Activation Analysis (INAA) and a four acid "near total" digestion technique followed by analysis on a "near total" Digestion Inductively Coupled Plasma Spectrophotometer (TD-ICP). In addition to the standards and blanks used by Act Labs, National Institute for Standards and Technology (NIST) Standard Reference Materials (SRMs) were inserted every eighth sample to run as blind, known sample analyses. Replicates of the St. Mary's samples were also placed throughout the batch and were blindly run every eighth sample.

Carbon, Nitrogen and Sulfur Analysis

Sediments were analyzed by MGS for total carbon, nitrogen and sulfur (CNS) contents using a Carlo Erba NA1500 analyzer. This analyzer uses complete combustion of the sample followed by separation and analysis of the resulting gases by gas chromatographic techniques employing a thermal conductivity detector. The NA1500 Analyzer was configured for CNS analysis using the manufacturer's recommended settings. As a primary standard, sulfanilamide was used and was run after every eight unknown sediment samples. As a secondary standard, one of several NIST SRMs was run after every eight sediment samples. Blanks (tin capsules containing only vanadium pentoxide) were run at the beginning and end of the analyses each day. Replicates of every eighth sample were also run.

Results and Discussion

Physical Analysis

Based on the textural analyses of the 35 surficial sediment samples (representing the top 10 cm of the sediment column), the majority of the samples collected are fine-grained sediments, with an average textural content of 25% sand, 51% silt and 23% clay. The most common grain-size class was “clayey-silt” with 17 samples included, followed by “sand-silt-clay”, “sandy-silt” and “silty-sand” (Table 2). Silt represents the major component of the collected samples, common on the coastal plain, which is comprised of unconsolidated sediments including sand, silt, clay and gravel. There are 13 sites that contained gravel in the sample; while site #17 contained 7% gravel, the other 12 sites contained less than 4% gravel. Complete sample field descriptions, including coordinates and pictures for each sample can be found in Appendix A.

The physical and chemical behavior of sediment is influenced by its texture. Particle diameter reflects the energy environment in which the sediment was deposited. Generally, coarse grained sediments (i.e., sand and gravel) are found in higher energy environments, such as areas subjected to wave activity or high water currents, which tend to winnow out any fine grained sediment. Fine-grained sediments, which are transported further from the source and take a long time to settle, are usually found in areas that are not subjected to high waves or winds, or below the depth of wave motion, such as deeper areas in the central area of the lake, or coves that are sheltered from high waves and winds. In St. Mary’s Lake, the sediment distribution follows this pattern (Figure 4). The finest-grained sediments (i.e., sediment with highest clay content) are in the deepest part of the lake (sites 4, 5, 14, 16 and 34), whereas sandier sediments are found in shallower depths and in the up-stream areas (sites 26 and 31). However, the two coarsest samples, 17 and 21, are located within the main pool of the Lake close to the southern shore. Neither of them, sample 17 nor 21, are in particularly shallow or deep areas of the Lake, 12 feet and 8 feet, respectively. Textural QA/QC analyses can be found in Appendix B.

Size also reflects the mineral composition of the sediments, which, in turn, is a product of the parent rock. St. Mary’s Lake is found within the St. Marys Formation in the Coastal Plain Physiographic Province in Maryland. The area in southern Maryland where St. Mary’s Lake watershed lies, is comprised of unconsolidated sedimentary formations consisting of gravel, sand, silt and clay. Sand and mud (silt plus clay) are abundant in the lake since unconsolidated sedimentary formations are extensive throughout the Coastal Plain. Further weathering of the sand and silt particles leads to the accumulation of clay particles. Clay particles are small, plate-like particles, with a diameter of less than two microns and have a relatively large surface area. Depending on the crystalline lattice, clays have an enormous capacity to incorporate both organic and metal cations onto the lattice surface, and water and organic compounds within lattice layers. These bound substances, in turn, contribute to the cohesiveness of the clays. Organic rich clays, in turn, support active benthic bacteria and plankton communities.

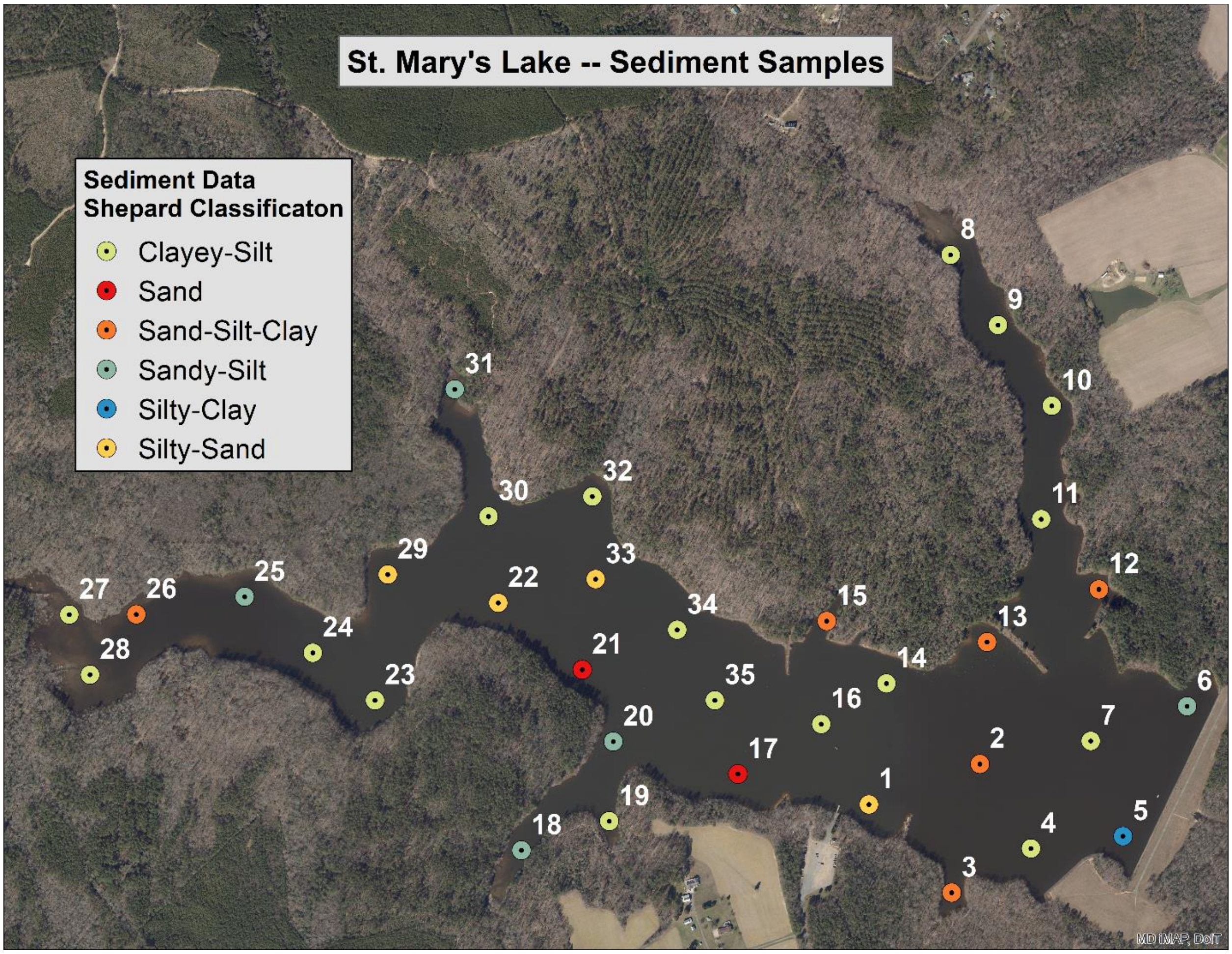

Figure 4. Distribution of sediment types based on Shepard (1954) classification. Deepest samples are #4, 5, 14, 16 and 34 which were collected at a depth of about 15 to 16 feet (approximate depths were measured with rope while sample was retrieved).

Table 2. Summary table of physical properties results for St. Mary's Lake.
[1]Approximate depths were measured with rope while the sample was retrieved.

Sample ID	% H2O	Bulk Density	% Gravel	% Sand	% Silt	% Clay	Shepard Class	Pejrup Class	Clay:Mud	Approx. Depth[1] (feet)
1	35.38	1.69	0.00	56.41	27.60	15.98	Silty-Sand	B,III	0.37	Not recorded
2	36.03	1.68	0.00	36.01	41.38	22.62	Sand-Silt-Clay	C,III	0.35	Not recorded
3	35.67	1.69	0.00	40.08	39.64	20.28	Sand-Silt-Clay	C,III	0.34	6
4	45.71	1.52	0.00	5.39	53.67	40.94	Clayey-Silt	D,III	0.43	15
5	53.67	1.41	0.00	8.82	44.58	46.60	Silty-Clay	D,II	0.51	15
6	41.68	1.58	0.00	36.36	45.68	17.97	Sandy-Silt	C,III	0.28	6
7	31.44	1.77	0.00	19.40	52.08	28.51	Clayey-Silt	C,III	0.35	12
8	66.11	1.27	0.00	14.50	65.25	20.25	Clayey-Silt	C,III	0.24	3
9	48.65	1.48	0.00	7.01	61.83	31.17	Clayey-Silt	D,III	0.34	5
10	40.39	1.61	0.00	9.22	65.05	25.73	Clayey-Silt	D,III	0.28	7
11	50.45	1.46	0.00	16.34	54.37	29.29	Clayey-Silt	C,III	0.35	10
12	50.31	1.46	0.00	24.39	50.30	25.30	Sand-Silt-Clay	C,III	0.33	7
13	23.81	1.93	0.83	33.63	42.17	23.37	Sand-Silt-Clay	C,III	0.36	5
14	50.78	1.45	0.00	6.69	56.06	37.25	Clayey-Silt	D,III	0.40	15-16
15	49.17	1.47	0.00	26.92	52.57	20.52	Sand-Silt-Clay	C,III	0.28	6
16	35.49	1.69	0.76	11.91	64.65	22.68	Clayey-Silt	C,III	0.26	15
17	34.04	1.72	7.26	74.93	13.31	4.50	Sand	B,III	0.25	12
18	39.03	1.63	0.13	38.60	50.24	11.03	Sandy-Silt	C,IV	0.18	4
19	40.65	1.60	0.46	12.97	68.77	17.79	Clayey-Silt	C,III	0.21	4
20	37.39	1.66	0.27	27.19	55.30	17.25	Sandy-Silt	C,III	0.24	10-12
21	25.55	1.89	2.28	85.93	8.02	3.78	Sand	B,III	0.32	8
22	35.83	1.68	1.94	42.10	40.00	15.95	Silty-Sand	C,III	0.29	8
23	56.68	1.38	0.00	1.31	60.91	37.79	Clayey-Silt	D,III	0.38	8
24	43.89	1.55	0.00	11.26	61.23	27.51	Clayey-Silt	C,III	0.31	7
25	43.99	1.55	3.64	30.03	48.37	17.97	Sandy-Silt	C,III	0.27	4
26	57.53	1.37	1.07	28.05	48.16	22.72	Sand-Silt-Clay	C,III	0.32	2
27	58.90	1.35	0.00	10.50	66.23	23.27	Clayey-Silt	C,III	0.26	2
28	61.86	1.32	0.00	2.53	74.12	23.36	Clayey-Silt	D,III	0.24	1.5
29	33.41	1.73	0.00	45.61	38.11	16.27	Silty-Sand	C,III	0.30	5-6
30	44.27	1.54	0.00	14.16	61.70	24.14	Clayey-Silt	C,III	0.28	10-11
31	52.63	1.43	0.00	28.12	52.01	19.87	Sandy-Silt	C,III	0.28	1.5
32	51.47	1.44	0.56	12.66	59.74	27.03	Clayey-Silt	C,III	0.31	6-7
33	32.99	1.74	2.52	40.16	38.10	19.22	Silty-Sand	C,III	0.34	12
34	39.93	1.61	0.00	13.70	60.59	25.71	Clayey-Silt	C,III	0.30	16
35	30.25	1.79	1.76	17.17	60.81	20.26	Clayey-Silt	C,III	0.25	12

Carbon, Nitrogen, Sulfur and Phosphorus Analysis

Results of nitrogen (N), carbon (C), phosphorus (P) and sulfur (S) of each sample are shown in Table 3.

Table 3. Nitrogen, Carbon, Phosphorus and Sulfur results for St. Mary's Lake.

Sample ID	% Nitrogen	% Carbon	% Phosphorus	% Sulfur
1	0.088	1.362	0.008	0.038
2	0.097	1.615	0.011	0.064
3	0.104	1.984	0.015	0.038
4	0.161	2.681	0.027	0.083
5	0.192	2.357	0.048	0.113
6	0.104	1.461	0.015	0.039
7	0.069	1.086	0.019	0.044
8	0.247	4.553	0.023	0.098
9	0.212	2.861	0.028	0.072
10	0.143	2.359	0.018	0.055
11	0.221	4.886	0.035	0.156
12	0.187	2.592	0.02	0.082
13	0.040	0.718	0.008	0.020
14	0.177	3.367	0.024	0.094
15	0.222	3.880	0.016	0.084
16	0.095	1.826	0.012	0.040
17	0.084	2.273	0.002	0.088
18	0.103	1.986	0.007	0.044
19	0.134	1.877	0.01	0.047
20	0.111	1.984	0.011	0.043
21	0.038	0.620	0.001	0.028
22	0.096	1.857	0.011	0.043
23	0.323	5.128	0.031	0.157
24	0.182	2.618	0.016	0.082
25	0.158	3.788	0.014	0.063
26	0.225	2.895	0.014	0.093
27	0.260	4.584	0.012	0.097
28	0.279	3.941	0.014	0.104
29	0.094	1.361	0.011	0.043
30	0.160	2.914	0.02	0.071
31	0.212	3.160	0.01	0.071
32	0.230	3.447	0.016	0.085
33	0.097	1.695	0.011	0.028
34	0.107	1.957	0.016	0.055
35	0.079	1.487	0.009	0.029

Total C contents measured in St. Mary's Lake sediments range from 0.6% to 5.1% (dry weight), with an average of 2.5%. These values are similar to that of the average C reported for Rocky Gorge Reservoir (Table 4).

Total C in the sediments is the sum of organic and inorganic carbon. Organic carbon is present in SAV, algal, bacterial, and detrital terrigenous plant biomass, whereas inorganic carbon is present in detrital limestone. As carbon is deposited with the sediments, most of it is remineralized to carbon dioxide by decomposing bacteria. These bacteria utilize a sequence of electron acceptors to decompose organic matter, starting with dissolved oxygen, followed by dissolved nitrate, amorphous Fe and Mn oxyhydroxides, and dissolved sulfate. Pore-water dissolved oxygen is often consumed within the top 2 cm of the interface in clayey sediments, although plant roots can release oxygen deeper into micro-environments in the sediments, often observed as precipitation of iron solids along a root fiber (Appendix A).

Table 4. Comparison of total N, C, P and S in surficial sediment in Maryland freshwater reservoirs/lakes. Values given are percent dry sediment weight.

Reservoir/Lake	Physiographic Province	% N		% C		% P		%S	
		Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Loch Raven (Ortt et al, 1999)	Piedmont	0.32	0.24-0.40	3.17	2.53-3.94	0.16	0.12-0.19	0.057	0.0-0.15
Triadelphia Reservoir (Wells et al, 2007)	Piedmont	0.26	0.11-0.48	2.77	1.48-4.12	0.10	0.04-0.17	0.074	0.027-0.28
Rocky Gorge Reservoir (Wells et al, 2007)	Piedmont	0.22	0.05-0.41	2.67	0.83-4.17	0.09	0.03-0.16	0.08	0.02-0.17
New Germany Lake (Ortt and Wells, 2009)	Appalachian Plateau	0.51	0.09-0.81	6.20	2.02-7.54	0.06	0.01-0.10	0.08	0.01-0.21
Deep Creek Lake (Wells and Ortt, 2011)	Appalachian Plateau	0.33	0.12-0.62	4.11	1.55-9.60	0.06	0.01-0.13	0.26	0- 0.98
Little Seneca Lake (Ortt et al., 2011)	Piedmont	0.29	0.18-0.34	3.25	2.07-5.06	0.08	0.06-0.14	0.11	0.04-0.15
Blairs Valley Lake	Ridge and Valley	0.27	0.19-0.40	3.06	2.06-6.20	0.05	0.04-0.08	0.08	0.05-0.11
Herrington Lake	Appalachian Plateau	0.38	0.12-0.56	5.12	1.33-6.61	0.07	0.05-0.11	0.10	0.03-0.15
St. Mary's Lake (this study)	**Coastal Plain**	**0.15**	**0.04-0.32**	**2.55**	**0.62-5.13**	**0.02**	**0.00-0.05**	**0.07**	**0.02-0.16**

Total N measured in St. Mary's Lake sediments average 0.15%, with values ranging from 0.04% to 0.32% (Table 4). These values are most similar to the N values measured at Rocky Gorge Reservoir. The Rocky Gorge Reservoir is located within the Piedmont Physiographic Province, just west of the contact with the Coastal Plain Physiographic Province, where St. Mary's Lake can be found. St. Mary's Lake is the only freshwater lake or reservoir with data from within the Coastal Plain province. The concentrations of sedimentary N measured in the St. Mary's Lake were the lowest of this set of freshwater lakes and reservoirs studies conducted by MGS.

Sources of N to the lake include atmospheric input, septic flow and fertilizers. Nitrogen is buried as organic nitrogen in biomass and as inorganic nitrate in pore-water. It is then utilized by decomposers and may be reduced to N_2 gas which will diffuse upwards and out of a sedimentary system or to dissolved ammonium (NH_4^+). As organic matter is "cycled through the natural system", relative proportions of P and, to a lesser degree, N increase as C decreases. Table 5 lists the Redfield ratios (Redfield *et al.*, 1963) for N, C and P for different sources and in sediment from several Maryland fresh and marine environments. The ratios of C to N, C to P, and N to P in St. Mary's Lake sediments are calculated using total C. Redfield ratios are the stoichiometric proportions of C, N and P in organic matter; they were first recognized in seawater receiving only plankton biomass, but have since been expanded to describe biomass produced in terrestrial, riverine, lacustrine or estuarine sources. The ratios of C to N, C to P, and N to P in the St. Mary's

Lake sediments are calculated using total C.

Table 5. Comparison of mass ratios of C, N and P observed in different sample sources.

	C:N	C:P	N:P
Global forest litter (McGroddy *et al.*, 2004)	57.3	1166.1	20.4
Global forest foliage (McGroddy *et al.*, 2004)	37.1	470.0	12.7
Dried marsh plant (Wells *et al.*, 2002)	32.3	711.2	21.7
Marsh sediments (Wells *et al.*, 2002)	18.1	243.6	13
St. Mary's Lake (this study)	**16.7**	**158.4**	**9.5**
Herrington Lake (Sylvia *et al.*, 2020)	13.7	68.9	5.0
New Germany (Ortt *et al.*, 2009)	13.5	109.2	8.1
Dried algae (Wetzel, 1983)	13.3	40.0	3.0
Deep Creek Lake sediments (Wells and Ortt, 2011)	12.9	87.5	6.5
Rocky Gorge Reservoir (Wells *et al.*, 2007)	12.5	31.2	2.5
Blairs Valley Lake (Sylvia *et al.*, 2020)	11.1	66.2	5.8
Triadelphia Reservoir (Wells *et al.*, 2007)	11.1	29.2	2.6
Loch Raven (Ortt *et al.*, 1999)	10.1	19.9	2.0
Coastal Bays bottom sediments (Wells *et al.*, 1994)	7.0	65.1	9.3
Plankton (Redfield *et al.*, 1963)	5.7	41	7.2

Total P measured in the sediments average 0.016%, with values ranging from 0.001% to 0.048% (Table 4). The concentrations of sedimentary P measured in the St Mary's Lake were also the lowest of this set of the freshwater lakes and reservoirs studies conducted by MGS. Total P is often associated with the sediment clay content, as it was at St. Mary's Lake (Table 6). P also shows a good correlation with Fe, due to binding to ferric oxyhydroxides, as well as correlation to Al, Mg and Ni. When comparing the relative amounts of C, N and P in the St. Mary's Lake sediments to those of dried algae, P appears to be the limiting nutrient; thus, mean C:P and N:P ratios are greater than those of dried algae.

Regarding P, although total P does not directly undergo reduction-oxidation processes in sediments, its cycling within the lake is controlled, in part, by the redox state of certain metals, particularly S and Fe, and by the concentration of organic material (C). Sources of P include weathering of natural soils and rocks, runoff from agricultural land and seepage from septic systems. Phosphate (PO_4^{-3}) from fertilizers binds to soils, which erode during storm events adding suspended phosphate to streams that drain into the lake. Septic seepage may contribute phosphate in the form of orthophosphate and organic phosphorus. Unlike N and C, P has no gaseous form. Therefore, P does not cycle out of the system like N by way of denitrification or C by respiration. Thus, P tends to accumulate in the sediments. Once in the sediments, P is slowly released into the interstitial water as organic material is oxidized. Free phosphate is rapidly bound to ferric oxyhydroxides and oxidized manganese which are found in the upper, oxidized layer of the sediments (i.e., oxidized flocculant layer on sediment surface). Deeper in the sediment column where anoxic conditions prevail and metals oxides have been reduced, P is released into the interstitial water and, if sulfide is low or absent, reacts with reduced forms of metals, particularly Fe, forming hydrous phosphates. However, if present, free sulfide will bind more readily to the reduced Fe and the phosphate remains free to diffuse upward to the oxidized layer where it is "captured" by excess ferric oxyhydroxides (FeOOH) and manganese oxides found in the upper sediment layer. If the overlying water column becomes anoxic, the “captured” P may be released in the overlying water column where it can contribute to increased algae/plankton production. The portion of total P active in this cycle includes the loosely sorbed phosphate, fresh, leachable, organic P and iron-bound phosphate. These available forms of P make up 40% to 50% of the total P in the upper one centimeter of sediments and are largely depleted below three centimeters in the sediment column (Jorgensen, 1996). Any P below this depth usually consists of the more stable forms, bound to clay minerals, or associated with apatite or calcium carbonate minerals, and become permanently buried in the sediments.

Trace amounts of S were measured in the sediments, averaging 0.07% with values ranging from 0.02% to 0.16% (Table 4).

Reduced S and dissolved sulfate (SO_4^{-2}) concentration is an important variable controlling P release from sediments (Caraco *et al.* 1989; Wetzel, 1983). The increased P release from sediments at higher sulfate concentrations may help explain why primary production in freshwater systems (with relatively low S concentrations) tends to be P limited, whereas in many saline systems (with high sulfate concentrations) production is often P sufficient. Sulfur also plays an important role in arsenic cycling (Fisher *et al.*, 2008). At St. Mary’s Lake, S was found to be strongly associated with carbon and nitrogen at statistical significance, suggesting fresh sediments. Interestingly, S was not found to be well correlated with Fe, suggesting that the S present in the sediments was more likely to be present in fresh organic material and not yet in biogenic sulfide (pyrite) minerals present in mature sediments.

Quality assurance and quality control (QA/QC) of C, N, S and P analysis can be found in Appendix B.

Table 6. Correlation matrix for textural, nutrient and target metal data based on all of the sediment samples collected at St. Mary’s Lake. The correlations were determined using a Pearson product-moment technique (Johnson and Wichern, 1982). Values listed in the table are Pearson correlation coefficients (r). Shaded values are statistically significant at the 95% confidence level (p < 0.05). Bolded values are correlation coefficients above 0.9.

	% H2O	% GRAVEL	% SAND	% SILT	% CLAY	%N	%C	%S	%P	As	Cr	Cu	Mn	Ni	Pb	Zn	%Al	%Ca	%Fe	%K	%Mg	%Na
%H2O		-0.34	-0.60	0.56	0.46	**0.94**	0.86	0.79	0.55	0.31	0.45	0.52	0.25	0.58	0.54	0.67	0.45	0.67	0.27	0.49	0.48	0.50
%GRAVEL	-0.34		0.58	-0.56	-0.52	-0.33	-0.16	-0.14	-0.43	-0.57	-0.60	-0.67	-0.39	-0.58	-0.57	-0.53	-0.64	-0.45	-0.56	-0.62	-0.59	-0.55
%SAND	-0.60	0.58		-0.93	-0.79	-0.63	-0.54	-0.47	-0.64	-0.47	-0.75	-0.69	-0.17	-0.68	-0.80	-0.66	-0.86	-0.73	-0.58	-0.91	-0.76	-0.85
%SILT	0.56	-0.56	-0.93		0.50	0.58	0.51	0.32	0.37	0.23	0.55	0.52	0.13	0.44	0.62	0.45	0.63	0.71	0.34	0.76	0.51	0.80
%CLAY	0.46	-0.52	-0.79	0.50		0.50	0.38	0.54	0.87	0.75	0.85	0.78	0.23	0.89	0.83	0.80	**0.96**	0.52	0.81	0.87	**0.93**	0.66
%N	**0.94**	-0.33	-0.63	0.58	0.50		**0.92**	0.85	0.55	0.29	0.43	0.52	0.23	0.58	0.55	0.64	0.47	0.60	0.22	0.51	0.45	0.51
%C	0.86	-0.16	-0.54	0.51	0.38	**0.92**		0.86	0.49	0.14	0.32	0.40	0.16	0.43	0.50	0.54	0.34	0.64	0.05	0.41	0.32	0.46
%S	0.79	-0.14	-0.47	0.32	0.54	0.85	0.86		0.67	0.31	0.38	0.44	0.11	0.59	0.49	0.61	0.45	0.48	0.24	0.43	0.48	0.37
%P	0.55	-0.43	-0.64	0.37	0.87	0.55	0.49	0.67		0.76	0.79	0.80	0.30	**0.91**	0.76	0.87	0.84	0.51	0.81	0.76	0.89	0.55
As	0.31	-0.57	-0.47	0.23	0.75	0.29	0.14	0.31	0.76		0.73	0.73	0.32	0.77	0.66	0.67	0.77	0.31	0.85	0.64	0.82	0.48
Cr	0.45	-0.60	-0.75	0.55	0.85	0.43	0.32	0.38	0.79	0.73		0.80	0.25	0.84	0.72	0.80	**0.91**	0.59	0.82	0.86	**0.91**	0.72
Cu	0.52	-0.67	-0.69	0.52	0.78	0.52	0.40	0.44	0.80	0.73	0.80		0.35	0.85	0.80	0.81	0.83	0.51	0.76	0.78	0.84	0.62
Mn	0.25	-0.39	-0.17	0.13	0.23	0.23	0.16	0.11	0.30	0.32	0.25	0.35		0.41	0.36	0.53	0.27	0.33	0.27	0.25	0.27	0.26
Ni	0.58	-0.58	-0.68	0.44	0.89	0.58	0.43	0.59	**0.91**	0.77	0.84	0.85	0.41		0.78	**0.94**	0.89	0.56	0.83	0.82	**0.94**	0.61
Pb	0.54	-0.57	-0.80	0.62	0.83	0.55	0.50	0.49	0.76	0.66	0.72	0.80	0.36	0.78		0.77	0.85	0.64	0.67	0.88	0.83	0.76
Zn	0.67	-0.53	-0.66	0.45	0.80	0.64	0.54	0.61	0.87	0.67	0.80	0.81	0.53	**0.94**	0.77		0.81	0.70	0.70	0.78	0.86	0.66
%Al	0.45	-0.64	-0.86	0.63	**0.96**	0.47	0.34	0.45	0.84	0.77	**0.91**	0.83	0.27	0.89	0.85	0.81		0.61	0.85	**0.94**	**0.96**	0.76
%Ca	0.67	-0.45	-0.73	0.71	0.52	0.60	0.64	0.48	0.51	0.31	0.59	0.51	0.33	0.56	0.64	0.70	0.61		0.29	0.74	0.59	0.79
%Fe	0.27	-0.56	-0.58	0.34	0.81	0.22	0.05	0.24	0.81	0.85	0.82	0.76	0.27	0.83	0.67	0.70	0.85	0.29		0.71	0.90	0.46
%K	0.49	-0.62	-0.91	0.76	0.87	0.51	0.41	0.43	0.76	0.64	0.86	0.78	0.25	0.82	0.88	0.78	**0.94**	0.74	0.71		**0.91**	0.89
%Mg	0.48	-0.59	-0.76	0.51	**0.93**	0.45	0.32	0.48	0.89	0.82	**0.91**	0.84	0.27	**0.94**	0.83	0.86	**0.96**	0.59	0.90	**0.91**		0.69
%Na	0.50	-0.55	-0.85	0.80	0.66	0.51	0.46	0.37	0.55	0.48	0.72	0.62	0.26	0.61	0.76	0.66	0.76	0.79	0.46	0.89	0.69	

Elemental Analysis

Laboratory results are located in Appendix C.

Table 7 lists summary statistics for those metals having reported threshold limits listed in National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (SQuiRTs) (Buchman, 2008). Most elements listed in Table 7 are above background levels for freshwater sediments. Because the St. Mary’s Lake samples were analyzed using a vigorous near total decomposition method (four-acid digestion), some caution is warranted when comparing the resulting concentration values of some metals to screening limits given in the NOAA tables. The values listed in the NOAA tables are based on Environmental Protection Agency (EPA) sample digestion methods which direct partial decomposition of sediment samples and thus reflect that portion of any element that may become biologically available/mobile under environmental conditions. For example, the NOAA tables list background levels in soil/sediments for Al as 0.26% which reflects the average Al which is biologically available. However, Act Labs’ results for Al range from 1.06% to 7.33%, reflecting the total recovery of the element by the stronger digestion method used. Al is a major component of most minerals found in native rock and soils. Likewise, average concentrations of Fe and Mn exceed the NOAA background levels for the same reasons given for Al.

Table 7. Summary statistics of select metal concentration measured in St. Mary’s Lake sediments. All values are ppm unless otherwise indicated. For comparison, benchmark levels for freshwater sediments are included along with the number of lake samples exceeding the respective limit values. These benchmarks for freshwater sediments are based upon chronic, long-term impacts of contamination to benthic organisms (Buchman, 2008). The Lowest Effect Level (LEL) is a level of sediment contamination that can be tolerated by the majority of benthic organisms. The Severe Effect Level (SEL) is that at which pronounced disturbance of the sediment-dwelling community can be expected. This is the concentration that would be detrimental to the majority of the benthic community.

	As	Cd	Cr	Cu	Fe (%)	Mn	Ni	Pb	Zn
Average	4.7	< 0.3	46	9	1.65	178	14	21	50
Std. Dev.	2.1	0.0	16	3	0.59	45	5	5	16
min	< 0.5	< 0.3	12	2	0.32	68	3	7	13
max	11.0	< 0.3	82	16	3.87	315	31	30	92
Background[1]	1.1	0.3	13	25	1.8	400	9.9	17	35
LEL	6	0.6	26	16	2	460	16	31	120
SEL	33	10	110	110	4	1100	75	250	820
#>Background	33	0	34	0	11	0	31	29	29
#>LEL	8	0	33	0	8	0	7	0	0
#>SEL	0	0	0	0	0	0	0	0	0
[1] Background as provided in NOAA SQuiRTs for freshwater sediments (Buchman, 2008).									

The two screening levels considered here were the freshwater lowest effect level (LEL) and severe effect level (SEL). The freshwater LEL is a level of sediment concentration that can be tolerated by the majority of benthic organisms. The SEL is the concentration that would be detrimental to the majority of the benthic community. Derivations of these screening limits are explained in the reference, but briefly: a survey of at least 20 aquatic species presence is performed, and the LEL corresponds to 5th percentile concentrations and the SEL corresponds to the 95% percentile of concentrations where the benthic community is observed to exist.

Only a few of the metals of concern (As, Cr, Fe and Ni) are above more conservative LEL in some or most sediments (Table 7), while no concentrations of these metals are higher than the SEL value. Concentrations of As, Fe and Ni were above LEL in sediments collected from 7-8 stations each, mainly located in the eastern portion of the lake (As, Fe and/or Ni above LEL in the sediments collected from stations #1, 4, 5, 7, 9, 10, 11, 12, 14 and 23). Concentrations of Cr were more uniformly above LEL at 33 of the 35 stations. The average Cr content of the St Mary's Lake sediments was 46 parts per million (ppm), where the LEL is 26 ppm. However, as stated above, these elemental concentrations were generated with a more vigorous total digestion than were the screening concentrations in the SQuiRTs tables, and represent a concentration greater than that which would be environmentally available through mineral decomposition in natural settings. Therefore, no ecotoxicological harm is anticipated.

As was shown in Table 6, many of the metals show significant correlations with clay, amongst themselves and with certain "major" ions found in greater abundance in rock forming minerals and the sediments derived from them. For instance, Fe is significantly correlated with clay at the 95% confidence interval, with nutrient P, with trace metals (As, Cr and Ni) as well as with major rock formers (Al and Mg), all with correlation coefficients above 0.8. To examine some of the associations more closely, plots of the elemental concentrations by station number can be found in Figures 5 and 6. Concentrations are shown in milli-moles per kilogram (mmol/kg, where a milli-mole is Avogadro's number divided by 1000). On these plots, the profiles of major rock forming elements Al and Fe are shown in the upper panel, and major rock forming elements Ca, K, Mg and Na are shown in the lower panel, along with clay content. Al was the most abundant major rock-forming element, followed in descending order by Fe, K, Na, Mg and Ca. These six elements follow a very similar profile to each other; with local low concentrations located at stations 13, 17 and 21 and local high concentrations located at stations 5, 14 and 23. The similarity in profile implies either common source (clay minerals) or common process which redistributes and deposits these elements together. The clay content is shown as a dashed line in the lower plot of Figure 5, and because the major rock-forming elements show good similarity with clay, we infer that they are largely present in clay minerals. Shown next is the same plot by-station number for several trace metals (Cr, Cu, Ni, Pb and Zn). These five trace metals are found at lower absolute abundance than the major rock forming elements, but the by-station number profile for these elements is quite similar to that of the major rock-forming elements. The most abundant trace metal was Mn, followed in descending order by Cr, Zn, Ni, Cu, Pb and As. Local low concentrations of trace metals were again located at stations 13, 17 and 21 and local high concentrations were located at stations 5, 14 and 23. The trace metals again show good similarity with clay content. An exception was Mn, which sometimes paired well with the clay profile (for example, at stations 16, 17, 18 and 19) and sometimes appeared unpaired to clay content (for example, at stations 4 and 29).

From these observations, some preliminary interpretations are offered. It is hypothesized that the major rock forming elements (here Al, Ca, Fe, K, Mg and Na) share a common source, and that source is likely to be clays and silts encountered in the local unconsolidated Coastal Plain deposits. The St Marys Formation is comprised of sandy clay and argillaceous fine-grained sand, yellowish-gray in color where subaerial and weathered, and greenish-blue in color where unweathered. It is interpreted to have been deposited in a continuously regressive marine sequence ranging from marine shelf at depth upward to nearshore and marginal marine facies in the upper portion of the St. Marys Formation (Glazer, 1994). Several of the trace metals (here As, Cr, Cu, Ni, Pb and Zn) also followed a similar pattern to major rock-forming elements and to clay content. The mineralogy of the local unconsolidated St Marys Formation includes glauconite, lignite and quartz sands (Groot *et al.*, 1990). The mineralogy of the local upland deposits (located at greater elevation than the Lake but forming its watershed) includes unspecified red, white or gray clays (Cleaves *et al.*, 1968). It is reasonable to presume that these clays include chlorite, kaolinite, illite and smectite. Glauconite, technically a closely related mica mineral, is a characteristic mineral of nearshore, organic-rich and reducing depositional environments; its presence defines greensands deposits of the Coastal Plain and it is often found to be associated with high concentrations of trace metals like As and Cr. Lignite is soft, organic rich coal-like rock. The mineralogical composition of glauconite is $(K,Ca,Na)_{1.2}(Fe^{3+},Al,Mg,Fe^{2+})_4[Si_{7.8}Al_1O_{20}]_4(nH_2O)$. The mineralogical composition of kaolinite is $Al_2Si_2O_5$, illite is $(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$, chlorite is $(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2$ and smectite is variable in composition, but montmorillonite is provided as example smectite: $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2(nH_2O)$.

These clay and mica minerals would therefore be reasonably inferred sources of Ca, Al, Fe, K, Mg and Na. The trace metals As, Cr, Cu, Pb and Zn may be adsorbed to the surfaces of these clay and mica minerals, and Ni may be either adsorbed or incorporated into chlorite. The trace metals Cu, Ni, Pb and Zn, when dissolved, are likely to exist as positively charged ions at circum-neutral pH and transitional redox (declining dissolved oxygen) environment, and to adhere to negatively charged clay particle surfaces. Trace metal Mn, when dissolved, is also likely to exist as a positively charged ion (Mn^{2+}) in circum-neutral pH and transitional redox and be attracted to clay surfaces. However as discussed above, sedimentary Mn paired well with the clay profile at some locations and was unpaired at others, suggesting additional processes influencing the distribution of solid-phase Mn in the sediments. In circum-neutral and transitional to reducing sedimentary environments, dissolved As^{3+} may exist as an oxyanion with negative charge ($H_2AsO_3^-$) or as an uncharged species. These forms of As would be less affected by sorption since they would be less attracted to a negatively charged clay surface than would be a positively charged ion. However, in this case, sedimentary As was found to be well paired to the clay profile. While the exact mechanism is not known for this lake, it is known that As has a high affinity for absorption onto and incorporation into glauconite and greensands.

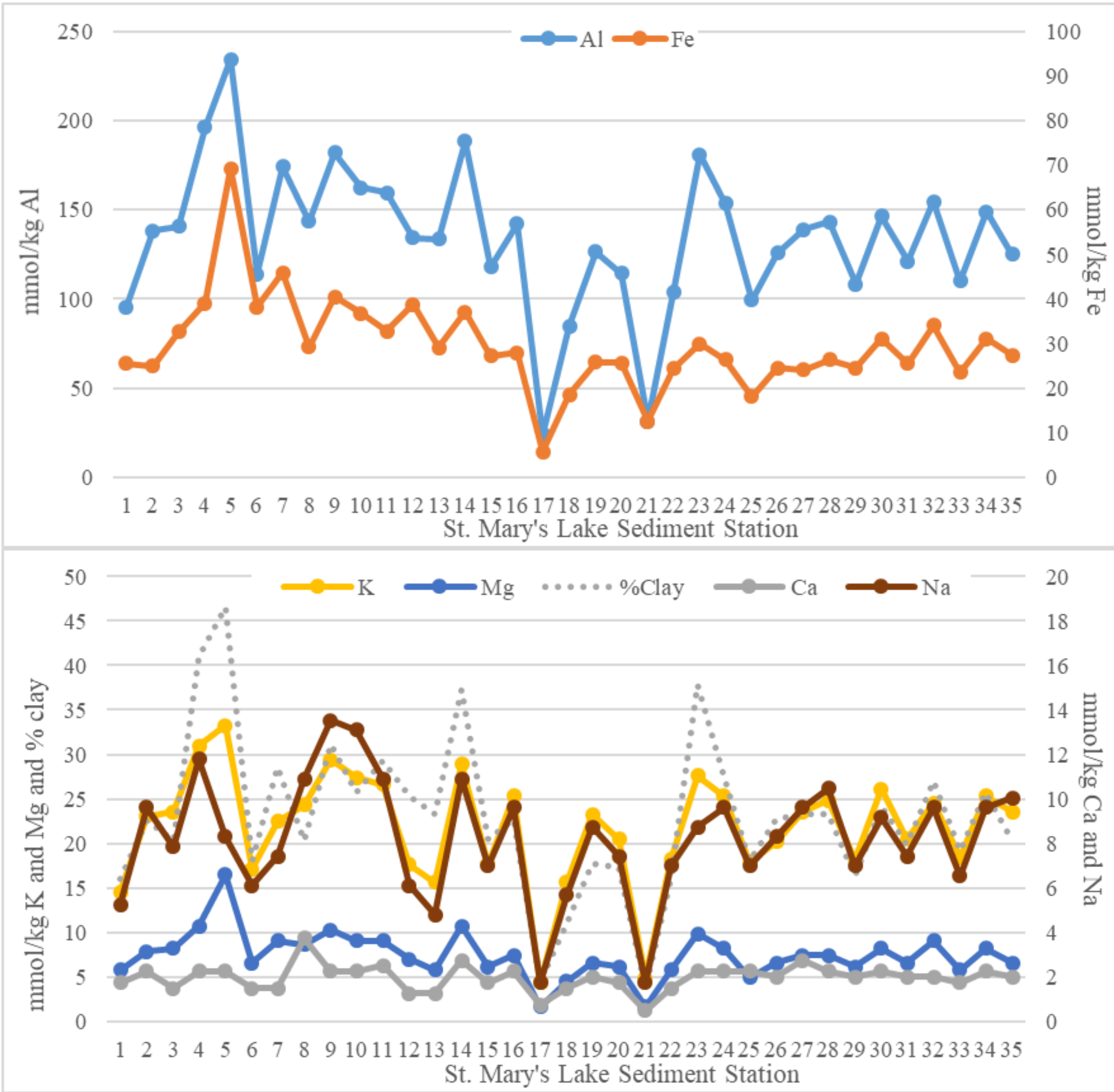
Al
Fe
mmol/kg Al
mmol/kg Fe
St. Mary's Lake Sediment Station
K
Mg
%Clay
Ca
Na
mmol/kg K and Mg and % clay
mmol/kg Ca and Na
St. Mary's Lake Sediment Station

Figure 5. Concentration profile plots of major elements by St. Mary's station number, shown with clay content. Concentrations are in percent for clay, and in milli-moles per kilogram for the elements shown.

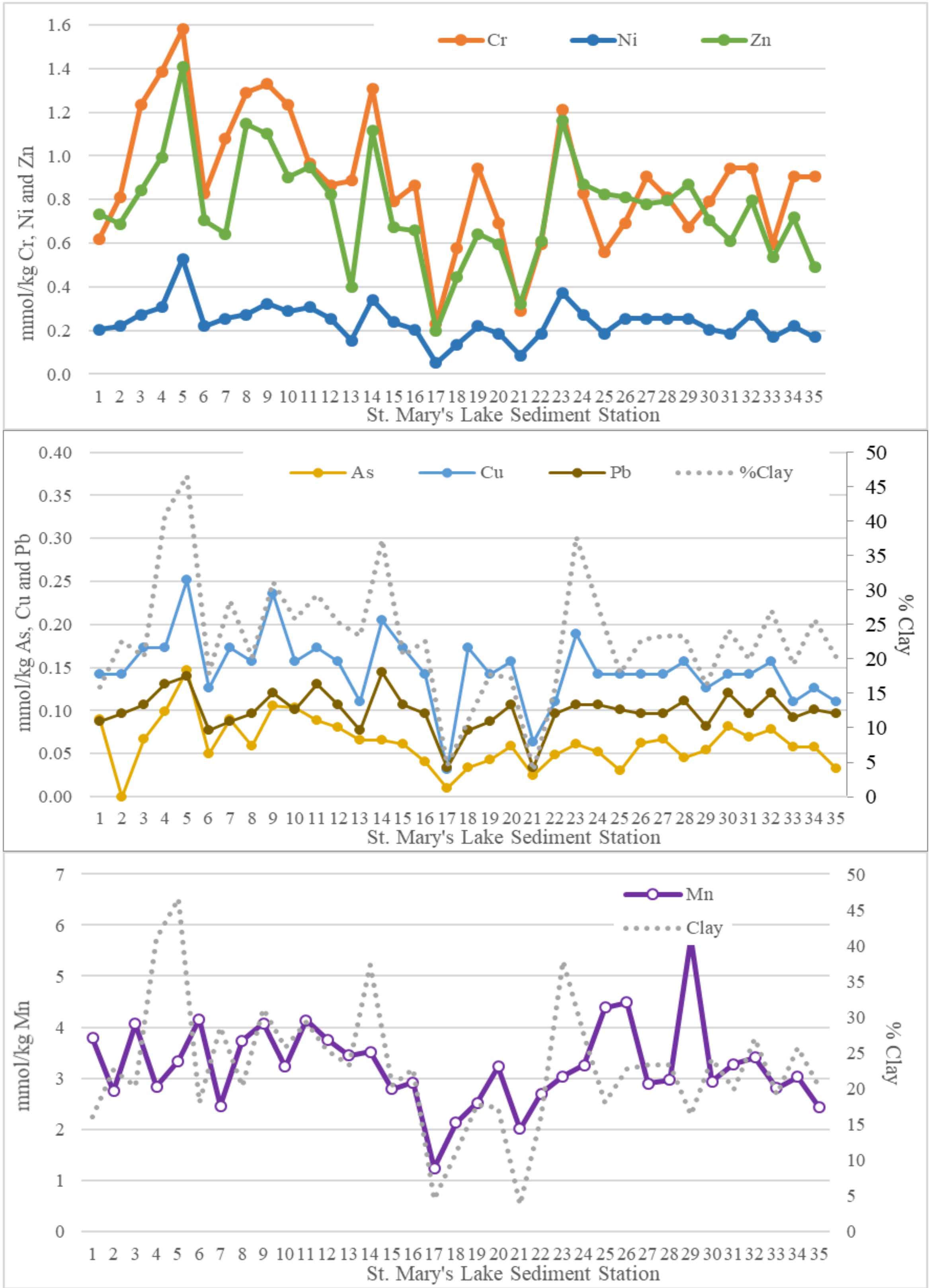

Figure 6. Concentration profile plots of trace elements by St. Mary's station number, shown with clay content. Concentrations are in percent for clay, and in milli-moles per kilogram for the elements shown.

Enrichment Factors

Because of the wide range of sediment types analyzed, comparisons of absolute metal concentrations between the surficial sediments are difficult. Therefore, metal concentrations are discussed in terms of enrichment factors (EF). The enrichment factor approach normalizes a concentration of an element, or a ratio of concentrations of elements in the sediment, to those found in a standardized material like average crustal rock. The use of enrichment factors also allows for comparisons of sediments from different environments and the comparisons of sediments whose trace metal contents were obtained by different analytical techniques (Cantillo, 1982; Hill *et al*., 1990; Sinex and Helz, 1981). However, the use of enrichment factors to assess metal data does not entirely eliminate the influence of textural variation.

Enrichment factor is defined as:

Equation 3

$$EF_{(x)} = X/Fe_{(sample)} \,/\, X/Fe_{(reference)}$$

where: $EF_{(x)}$ is the enrichment factor for the metal X;
$X/Fe_{(reference)}$ is the ratio of the concentrations of metal X to Fe in a reference material, such as an average continental crust rock.

Fe is chosen as the element for normalizing because anthropogenic sources for Fe are small compared to natural sources (Helz, 1976). Taylor's (1964) average continental crust is used as the reference material. Average crustal abundance data may not be representative of St. Mary’s Lake sediments because there is a higher proportion of clay and silt in the sediments compared to the average crustal rock. However, abundance data is useful as a relative indicator when comparing the data with other studies.

The average EF values for most metals are within the range of values obtained for other freshwater lakes and reservoirs in Maryland (Table 8). The sediments in St. Mary’s Lake are significantly enriched (*i.e*., average EF>3) in As, Cs, Eu, Hf, Pb, Sb, Th, U and Y with respect to average continental crust rock. St. Mary’s Lake is located within the Coastal Plain Physiographic Region of Maryland, and regional formations consist of unconsolidated sedimentary deposits. These have been identified as the St. Marys Formation, comprised of sandy clay and argillaceous fine-grained sand and the local upland deposits, comprised of gravel, sand, minor silt and clay.

St. Mary’s Lake is the only lake or reservoir studied in the Coastal Plain among these MGS studies, and as such, the EFs observed at St. Mary’s Lake may not be directly analogous to the EFs observed at the other lakes in Maryland, although many are generally similar. Triadelphia and Rocky Gorge are the nearest geographically, both located in the Piedmont Physiographic Province. Rocky Gorge is located just upgradient of the Coastal Plain contact. Some of the EFs for metals in sediment at St. Mary’s Lake are most similar to those at Rocky Gorge (Eu and Y), but many other metals are most similar to any of the other lakes or reservoirs, without general trend by physiographic province.

As stated above, the sediments in St. Mary’s Lake are significantly enriched on average (*i.e*., average EF>3) in As, Cs, Eu, Hf, Pb, Sb, Th, U and Y with respect to average continental crust rock. Most of the other lake sediments studied were similarly enriched in four of these nine; these were As, Cs, Pb and Sb. The EFs for the remaining five of nine (Eu, Hf, Th, U and Y) more commonly had an EF above 3 in the sediments from St. Mary’s Lake than they were in the other lakes.

There were four elements present in St Mary's Lake sediments which were similarly enriched as the other lakes studied (As, Cs, Pb and Sb). As is present at concentrations greater than crustal abundance in clay rich sediments, where it is often found, assuming the sediment has little free oxygen, in the uncharged or 3+ valence, and in anionic forms (e.g. $HAsO_4^{2-}$). As is most commonly associated with clay minerals, hydroxides and organic matter. Cs is present at concentrations greater than crustal abundance in clay rich sediments and also felsic igneous rocks, where it behaves similarly to K. Radio-Cs was also introduced atmospherically by nuclear weapons testing. Pb has been introduced to soils and sediments by combustion of leaded fuel and atmospheric deposition. Pb is present at concentrations greater than crustal abundance in soils and clay rich sediments, where it is often found in the 2+ valence, most commonly associated with clay minerals, hydroxides and organic matter, and occasionally associated with phosphates and carbonates. Once in sediments, Pb is less mobile. Sb is present at concentrations greater than crustal abundance in clay rich sediments and generally behaves similarly to As. Sb has also been introduced to soils and sediments atmospherically by metals refining smelting activities.

There were five elements present in St Mary's Lake sediments which were slightly different in enrichment compared to the other lakes studied (Eu, Hf, Th, U and Y). Eu is a light rare earth element and a lanthanide which is present at concentrations similar to crustal abundance in clay rich sediments, but at greater abundance when complexed by peaty organic matter. It is often found associated with organic matter and hydroxides. Hf is a transition metal which is present in St Mary's Lake sediments at concentrations above both crustal abundance and also averages for clay rich sediments. Hf substitutes for zirconium in the mineral zircon, and is often found enriched in sandstones. U and Th are heavy rare earth elements and actinides which are present at greater concentrations that crustal abundance in clay rich sediments and in felsic igneous rocks, where they may substitute for K. U and Th are often found associated with clays, organic matter, and also inorganic species such as carbonate and phosphate ions. Y is a transition metal often closely associated with rare earth elements and alkali earth metals. It can be incorporated into oxides, carbonates, silicates and phosphates. Y appears to be less associated with organic matter.

These elements are enriched when normalized to to crustal abundance, but when compared relative to the ranges for argillaceous (clay-rich) sedimentary rocks (Kabata-Pendias 2011), the average concentrations of As, Cs, Eu, Hf, Pb, Sb, Th, U and Y were all within range. Several of these elements are normally found associated with clay-rich sediments, oxyhydroxides and organic matter, all of which would be expected in sediments. The elements Cs, Eu, Th, U and Y are also present in clay minerals where they may substitute for K. The element Hf is found in sands and sandstones.

In summary, the sediments at St. Mary's Lake contained concentrations of As, Cs, Eu, Hf, Pb, Sb, Th, U and Y with enrichment values above 3, when compared to normalized crustal abundance. However, the un-normalized concentrations were typical of the ranges encountered in argillaceous sediments and rocks.

Table 8. Comparisons of average enrichment factors in several Maryland freshwater reservoirs/lakes. Enrichment factors are relative to the average earth's crust (Taylor, 1964.)

Element	Loch Raven (Ortt *et al.*, 1999)	Triadelphia Reservoir (Wells *et al.* 2007)	Rocky Gorge Reservoir (Wells *et al.*, 2007)	New Germany Lake (Ortt *et al.*, 2009)	Deep Creek Lake (Wells *et al.*, 2011)	Blairs Valley Lake (Sylvia, *et al.*, 2020)	Herrington Lake (Sylvia, *et al.*, 2020)	St. Mary's Lake (this study)
Cd	0.28	4.93	1.89	0.9	8.90	2.47	11.81	
Cr	1.62		0.93	1.05	1.19	0.96	0.99	1.61
Cu	0.85	0.83	0.95	0.52	0.62	0.93	0.47	0.61
Mn	1.25	1.09	1.45	0.50	0.94	0.72	0.89	0.70
Ni	0.86	0.80	0.77	0.69	0.91	0.80	0.83	0.65
Pb	4.35	4.26	3.83	3.46	5.24	4.00	3.49	5.94
Zn	2.87	1.98	1.92	2.62	4.09	2.49	4.49	2.51
Al		0.78	1.27	1.24	0.94	1.07	1.02	1.52
As			3.61	9.13	15.61	10.20	8.79	8.98
Ce			2.41	1.88	2.21	2.19	1.77	0.00
Co		1.74	1.17	0.87	2.13	1.44	1.88	1.31
Cs			1.87	2.99	3.54	3.14	2.44	3.96
Eu			2.56	1.83	2.16	1.62	1.21	3.23
Hf			3.79	6.77	7.48	4.26	3.65	22.8
Sb			3.19	10.64	24.41	5.65	5.26	11.27
Th		0.08	1.64	1.91	1.78	1.68	1.37	3.22
Ti			1.21	0.94	1.05	0.69	0.81	1.44
U			1.64	3.10	2.32	2.46	1.76	4.01
V		1.09	1.00	0.78	0.85	0.71	0.71	0.67
Y		2.25	2.29	1.48	1.39	1.42	1.14	3.36

Summary and Conclusions

In September 2019, 35 surficial sediment samples were collected from St. Mary's Lake, and based on the textural analyses of the samples, the majority of the samples collected are fine-grained sediments, with an average textural content of 1% gravel, 25% sand, 51% silt and 23% clay. This area in southern Maryland, where the St. Mary's Lake watershed lies, is comprised of unconsolidated sediments, including gravel, sand, silt and clay particles.

Total C contents measured in St. Mary's Lake sediments ranged from 0.6% to 5.1% (dry weight), with a mean of 2.5%. Total N measured in the lake's sediment averaged 0.15%, with values ranging from 0.04% to 0.32%. Total P measured in the sediments average 0.016%, with values ranging from 0.001% to 0.048%. Total S in the lake ranged from 0.02% to 0.16% with an average of 0.07%. Concentrations of C, N, P and S were similar to that found in other reservoirs within the state. Concentrations of N and P were the lowest of any of the freshwater lakes and reservoirs studied by MGS. C, N and S concentrations were well inter-correlated at St. Mary's Lake, which is hypothesized to be due to the fresh organic material in the sediments.

The elemental concentrations of 35 surficial sediments followed similar spatial patterns when plotted by station, and correlated well with clay content. This was true for major rock forming elements aluminum (Al), calcium (Ca), iron (Fe), potassium (K), sodium (Na) and magnesium (Mg). Most trace elements had quite similar profiles, also well correlated with clay content. These include arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn), whereas manganese (Mn) concentrations were only partially paired with clay content. When compared relative to two eco-toxicological screening levels for freshwater sediments, only a few of the metals of concern (As, Cr, Fe and Ni) are above more conservative lowest effect level (LEL) in some or most sediments, while no concentrations of these metals are higher than the severe effect level (SEL) value. The data from St. Mary's lake sediments were made with a more vigorous digestion technique than was used to prepare the screening levels, and so direct comparisons to the screening levels are not advised. Since these concentrations represent more than that which is environmentally available, no eco-toxicological harm is anticipated. When compared to relative crustal abundance via the use of Fe-normalized enrichment factors, the elements. As, Cs, Eu, Pb, Hf, Sb, Th, U and Y were elevated. However, these elements are often encountered in high concentrations in clay-rich sediments, clay-rich sedimentary rocks and sandstones, as well in minerals where they may substitute for K.

No abnormalities were found in regard to physical or chemical properties of the bottom sediments of St. Mary's Lake.

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Appendix A

Field Descriptions, Sample Coordinates and Pictures

Table A-1. Sample descriptions and coordinates, with approximate water depth. *Approx. depths were collected as a reference and were not recorded at all stations due to collection limitations.				
Sample Number	**Approx. Water Depth (ft.)***	**Northing (NAD83 State Plane, meters)**	**Easting (NAD83 State Plane, meters)**	**Description**
1	Not recorded	440197	65134	5Y 4/1 top 2 cm soft silty mud over firmer very fine silty sand, some organic material, no SAV, roots
2	Not recorded	440424	65217	5Y 4/1 gritty silty mud soft soupy slightly firmer with depth, small gravel at depth, piece of woody debris, no roots, no SAV
3	6	440366	64953	Top 2 cm soft slightly gritty slightly soupy watery mud over firmer gritty silty mud with pebbles entrained, woody debris over sandy sticky mud, very sandy
4	15	440529	65043	5Y 4/1 to N5, top 2 cm soft soupy watery mud over firmer lumpy gassy very smooth silty mud, not watery. Some organic material detritus, no roots
5	15	440718	65069	5Y 4/1 soft soupy watery slightly gritty, 2nd layer firmer smooth silty mud with lumps of really firm slightly clay with sand, couple of small gravel
6	6	440850	65335	Upper 1 cm slightly gritty soupy water mud grades to sandy mud firmer, silty. Nodules of sand/silt, pea gravels, no roots, no SAV, little organics
7	12	440652	65264	5Y 4/1 top 1 cm soft smooth, slightly firm mud over firmer with depth slightly lumpy very smooth mud, woody debris, no roots
8	3	440364	66262	5Y 4/1, SAV visually similar to Rosemary, top few inches very gassy lots of SAV, soft watery very slightly gritty mud over thick detritus (1 cm) layer over silty sand, very sandy, high SAV
9	5	440461	66118	5Y 4/1 top 0.5 cm slightly gritty soupy mud woody debris at surface, roots, no SAV. Firmer with depth over very smooth silty and clayey sticky mud
10	7	440572	65952	5Y 4/1 firm lumpy detritus, roots, no SAV, smooth silty sticky, high clay content, mud. Clay (reduced) is N6 /light gray, lumps mostly feel dry / consolidated – not wet
11	10	440550	65719	5Y 4/1 top 1.5 cm soft slightly gritty watery mud with organic detritus material over (grading to) firmer lumpy organic material (roots) feels dry sticky high clay content, mud smooth, clayey
12	7	440669	65575	(Similar to #11) 5Y 4/1 top 1 cm slightly gritty watery mud smooth grades to lumpy dry clayey sticky mud organic material firm roots, no SAV
13	5	440439	65467	SAV, no other organics, top 2 cm floc 5Y 4/1 slightly gritty soupy watery mud over firm lumpy gritty clayey sticky fine gravel mud. Slightly mottled 5Y 5/6 oxidation, 5Y 7/2 (yellowish gray) – main color
14	15+	440232	65382	5Y 4/1 top 1 cm soft watery smooth mud slightly firm over firmer with depth slightly lumpy very smooth silty mud with some roots and organic material, no SAV

Table A-1 con't. Sample descriptions and coordinates, with approximate water depth. *Approx. depths were collected as a reference and were not recorded at all stations due to collection limitations.				
Sample	**Approx.**	**Northing**	**Easting**	**Description**

Number	Water Depth (ft.)*	(NAD83 State Plane, meters)	(NAD83 State Plane, meters)	
15	6	440110	65510	5Y 4/1 veneer of slightly gritty soupy watery mud loose over firmer lumpy drier detritus, roots, no SAV, slightly gritty silty mud
16	15	440099	65299	5Y 4/1 top 0.5 cm soupy silty watery mud over N5 firm sticky lumpy clayey mud few organic material, no SAV, some small roots
17	12	439927	65196	Top 1 cm soft slightly gritty watery mud 5Y 4/1 over woody debris firmer sandy (gritty) silty, pea gravels mud 5Y 2/1 mottled with N5 which is sandier, some roots, no SAV
18	4	439483	65040	Top 0.5 cm slightly gritty silty watery mud over lumpy clayey firm slightly gritty mud with many roots, SAV present
19	4	439664	65099	5Y 4/1 top 1 cm slightly gritty soupy watery mud over firmer slightly lumpy smooth not gritty silty mud with roots, no SAV
20	10-12	439672	65263	Similar to #19. 5Y 4/1 top 1 cm smooth not gritty soupy watery silty mud over lumpy, lots of organic material, slightly gritty silty firmer-than-above mud
21	8	439608	65410	5Y 4/1 top 0.5 cm slightly fine mud over sand, sticky pea gravels, little organic matter, no SAV, no roots
22	8	439436	65548	5Y 4/1 top 1 cm slightly firm, slightly gritty not watery mud over sandy slightly clayey lumpy mud with roots and pea gravels, gritty, no SAV
23	8	439183	65347	5Y 4/1 top 0.5 cm smooth silty watery mud over lumpy very dry very silty firm smooth mud with roots and SAV / organics, stringy
24	7	439055	65445	Veneer of slightly gritty watery mud over firm lumpy smooth very silty mud, no grit, SAV with roots
25	4	438915	65560	Top 1 cm slightly gritty watery mud over firmer lumpy, lots of roots, few fine gravels, not gritty smooth mud
26	2	438693	65524	Top 2-3 cm soft soupy watery mud slightly gritty over N5 (gray) grades from top 5Y 4/1 lumpy smooth dry silty mud with some thin zones of grittiness, SAV, few fine roots
27	2	438555	65523	Thick SAV, water lilies, top 1-2 cm slightly gritty soupy water mud firmer with depth over smooth slightly gritty organic material, few roots near surface mud 5Y 4/1
28	15	438598	65400	Thick SAV, water lilies, top 2 cm slightly gritty soupy watery mud 5Y 4/1 firmer with depth to a slightly lumpy silty mud with abundant roots (fine) organic material/detritus 5Y 4/1
29	5-6	439209	65606	Top 1 cm slightly firm slightly gritty watery mud over firmer very lumpy gritty dry silty mud with sand roots 5Y 4/1

Table A-1 con't. Sample descriptions and coordinates, with approximate water depth.
*Approx. depths were collected as a reference and were not recorded at all stations due to collection limitations.

Sample Number	Approx. Water Depth (ft.)*	Northing (NAD83 State Plane,	Easting (NAD83 State Plane,	Description

		meters)	meters)	
30	10-11	439416	65725	Top 2 cm smooth slightly firm silty watery mud over slightly silty lumpy mud with lots of organic (leaves) and detritus, few roots, no SAV 5Y 4/1
31	1.5	439346	65986	Thick SAV, top 3 cm slightly gritty soupy watery mud lots of SAV over slightly firmer lumpy smooth not gritty silty mud 5Y 4/1, roots, detritus
32	6-7	439629	65766	Thin veneer slightly gritty watery mud over firmer not gritty smooth silty dry very silty lumpy mud with lots of roots, detritus, plant material, no SAV, 5Y 4/1
33	12	439636	65596	Top 4-5 cm slightly gritty watery mud over lumpy firmer slightly gritty silty mud, some organic material, few roots, no SAV 5Y 4/1
34	16	439803	65492	Top 5 cm very slightly gritty smooth mud watery slightly firm organic material over very firm smooth very silty slightly gassy 5Y 4/1 clayey silt
35	12	439880	65348	Top 3 cm slightly gritty slightly firm watery mud 5Y 4/1 organic material over lumpy smooth but gritty in areas, most is smooth very firm clayey silty mud N6 some roots, no SAV

Sample 1

Sample 2

Sample 3

Sample 4

Sample 5

Sample 6

Sample 7

Sample 8

Sample 9

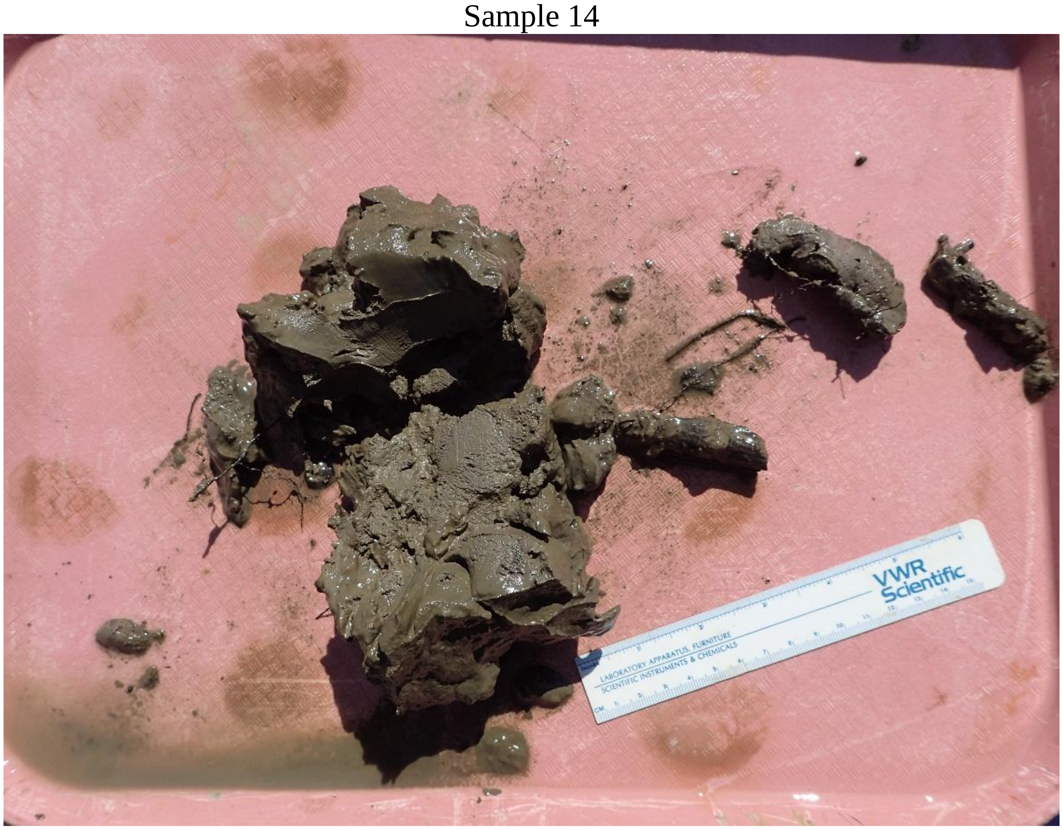
Sample 10

Sample 11

Sample 12

Sample 13

Sample 14



Sample 15

Sample 16

Sample 17

Sample 18

Sample 19

Sample 20

Sample 21

Sample 22

Sample 23

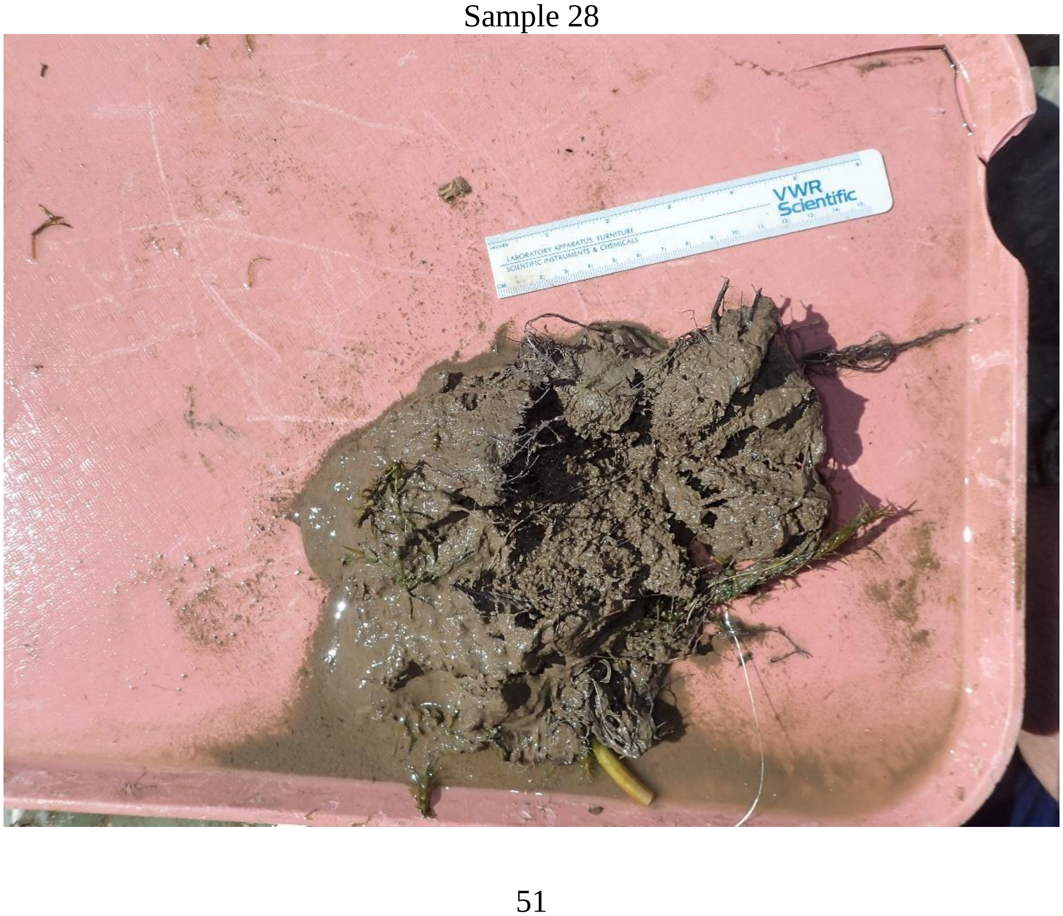
Sample 24

Sample 25

Sample 26

Sample 27

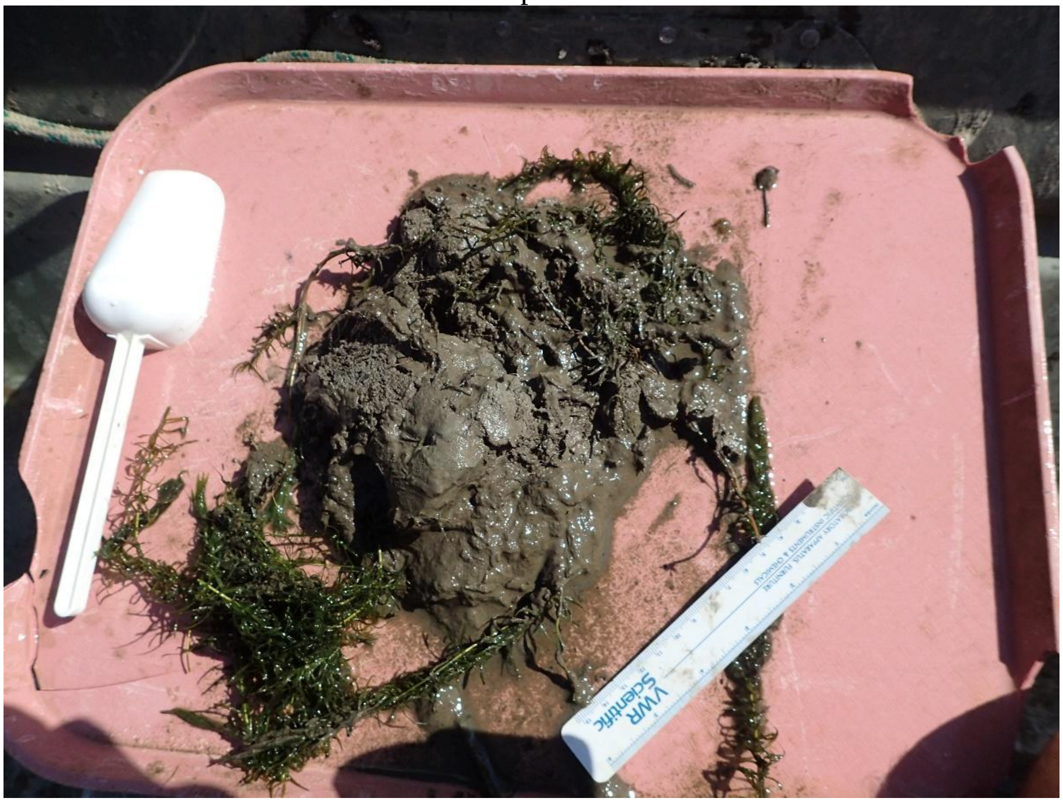
Sample 28



Sample 29

Sample 30

Sample 31



Sample 32

Sample 33

Sample 34

Sample 35


VWR
Scientific
LABORATORY APPARATUS, FURNITURE
SCIENTIFIC INSTRUMENTS & CHEMICALS

Appendix B

QA/QC

Textural Analyses

Although the techniques used to determine grain size are based on traditional analytical methods developed for the sedimentology laboratory, some analytical error is inherent to the techniques. For example, results can be affected by level of technician skill and/or changes in laboratory conditions (such as sudden temperature changes). Furthermore, there is no standard reference material available that includes the broad range of particle sizes and shapes contained in natural sediment. To maximize consistency of textural analysis, several "checks" are used to monitor results. The calculated sand, silt, clay and gravel (when present) percentages are checked against 1) sample field descriptions; 2) calculated water contents; and 3) calculated weight loss of sample during processing. These comparisons are made to determine if the size components match the visual description of the sample and/or fall within an expected classification with respect to water content and weight loss. Any discrepancy is "flagged" and the results are reviewed further to determine if re-analysis is warranted.

Carbon, Nitrogen and Sulfur Analyses

Table B-1. Results of nitrogen, carbon and sulfur analyses of the standard reference materials (SRMs) compared to the certified or known values. MGS values were obtained by averaging the results of all SRM analyses run during this study.

Element	NIST SRM 8704 Buffalo River Sediment			NIST SRM 1646a Estuarine Sediment			NIST SRM 2702 Inorganics in Marine Sediment			Canadian SRM MESS 4 Marine Sediment		
	NIST Values [1]	MGS Results	% Recovery	NIST Values [2]	MGS Results	% Recovery	NIST Values [3]	MGS Results	% Recovery	NIST Values [4]	MGS Results	% Recovery
Total Nitrogen (% dry weight)	0.188	0.179 +/-0.006	95.3	0.058	0.056 +/-0.004	96.4	0.25	0.253 +/-0.007	101.1	0.142	0.138+/-0.010	96.8
Carbon (% dry weight)	3.351 +/-0.017	3.235 +/-0.054	96.6	0.583	0.563 +/-0.017	95.9	3.36	3.167 +/-0.091	94.2	1.79	1.780+/-0.103	99.5
Sulfur (% dry weight)	0.261	0.206 +/-0.060	78.91	0.352 +/- 0.004	0.347 +/-0.017	98.6	1.5	1.577 +/-0.069	105.12	0.158 +/-0.020	0.169+/-0.019	106.2

[1] For NIST 8704, the value for carbon is certified by NIST. The value of nitrogen and sulfur was obtained from repeated analyses in-house and by other laboratories (Haake Buchler Labs and U.S. Dept. of Agriculture).

[2] For NIST SRMs 1646a, the value for sulfur are certified values reported by NIST; nitrogen and carbon values were obtained from repeated analyses in-house and by Act Labs.

[3] For NIST SRM 2702, the value for sulfur are information values reported by NIST; nitrogen and carbon values were obtained from repeated analyses in-house and by Act Labs.

[4] For Canadian SRM, the value for sulfur is certified from the National Research Council Canada (NRCC). The value for carbon is an information value reported by the NRCC. The value for nitrogen was obtained from repeated analyses in-house.

Appendix C

Elemental Analysis Results and QA/QC

Table C-1. Elements (analytes) reported in this study include 50 elements analyzed by Act Labs. Methods abbreviations: High Temp. Combustion-GC: High Temperature combustion, following by Gas Chromatography; TD-ICP: Total Digestion followed by Inductively Coupled Plasma Spectrometry; INAA: Instrumental Neutron Activation Analysis.

Element	Symbol	Reporting Unit	Detection Limit	Analysis Method	Element	Symbol	Reporting Unit	Detection Limit	Analysis Method
Aluminum	Al	%	0.01	TD-ICP	Mercury	Hg	ppm	1	INAA
Antimony	Sb	ppm	0.1	INAA	Molybdenum	Mo	ppm	1	TD-ICP
Arsenic	As	ppm	0.5	INAA	Neodymium	Nd	ppm	5	INAA
Barium	Ba	ppm	50	INAA	Nickel	Ni	ppm	1	INAA / TD-ICP
Beryllium	Be	ppm	1	TD-ICP	Phosphorus	P	%	0.001	TD-ICP
Bismuth	Bi	ppm	2	TD-ICP	Potassium	K	%	0.01	TD-ICP
Bromine	Br	ppm	0.5	INAA	Rubidium	Rb	ppm	15	INAA
Cadmium	Cd	ppm	0.3	TD-ICP	Samarium	Sm	ppm	0.1	INAA
Calcium	Ca	%	0.01	TD-ICP	Scandium	Sc	ppm	0.1	INAA
Cerium	Ce	ppm	3	INAA	Selenium	Se	ppm	3	INAA
Cesium	Cs	ppm	1	INAA	Silver	Ag	ppm	0.3	INAA / TD-ICP
Chromium	Cr	ppm	2	INAA	Sodium	Na	%	0.01	INAA
Cobalt	Co	ppm	1	INAA	Strontium	Sr	ppm	1	TD-ICP
Copper	Cu	ppm	1	TD-ICP	Sulfur	S	%	0.01	TD-ICP
Europium	Eu	ppm	0.2	INAA	Tantalum	Ta	ppm	0.5	INAA
Gold	Au	ppb	2	INAA	Terbium	Tb	ppm	0.5	INAA
Hafnium	Hf	ppm	1	INAA	Thorium	Th	ppm	0.2	INAA
Iridium	Ir	ppb	5	INAA	Tin	Sn	%	0.01	INAA
Iron	Fe	%	0.01	INAA	Titanium	Ti	%	0.01	TD-ICP
Lanthanum	La	ppm	0.5	INAA	Tungsten	W	ppm	1	INAA
Lead	Pb	ppm	3	TD-ICP	Uranium	U	ppm	0.5	INAA
Lithium	Li	ppm	1	TD-ICP	Vanadium	V	ppm	2	TD-ICP
Lutetium	Lu	ppm	0.05	INAA	Ytterbium	Yb	ppm	0.2	INAA
Magnesium	Mg	%	0.01	TD-ICP	Yttrium	Y	ppm	1	TD-ICP
Manganese	Mn	ppm	1	TD-ICP	Zinc	Zn	ppm	1	INAA / TD-ICP

Table C-2. St. Mary's Lake sediment elemental data. All values are ppm (mg/kg) unless indicated otherwise.

Station	Ag	%Al	As	Au	Ba	Be	Bi	Br	%Ca	Cd	Ce	Co
1	< 0.3	2.57	6.7	< 2	< 50	1	< 2	5.2	0.07	< 0.3	45	9
2	< 0.3	3.72	< 0.5	< 2	240	1	< 2	3.6	0.09	< 0.3	52	8
3	< 0.3	3.79	5	< 2	290	5	< 2	1.7	0.06	< 0.3	77	6
4	< 0.3	5.28	7.4	< 2	420	2	< 2	6.2	0.09	< 0.3	82	9
5	0.4	6.31	11	< 2	250	2	< 2	11.2	0.09	< 0.3	86	11
6	0.4	3.07	3.7	2	110	1	< 2	5.8	0.06	< 0.3	53	4
7	< 0.3	4.69	6.7	< 2	< 50	1	< 2	< 0.5	0.06	< 0.3	66	6
8	0.4	3.86	4.4	< 2	310	2	< 2	10.6	0.15	< 0.3	77	10
9	< 0.3	4.9	7.9	< 2	360	2	< 2	8.5	0.09	< 0.3	80	9
10	< 0.3	4.37	7.7	< 2	400	2	< 2	7.9	0.09	< 0.3	72	9
11	0.4	4.3	6.6	< 2	390	2	< 2	8.9	0.1	< 0.3	70	19
12	0.3	3.61	6	< 2	170	1	< 2	11.4	0.05	< 0.3	62	16
13	< 0.3	3.6	4.9	< 2	130	< 1	< 2	1.2	0.05	< 0.3	48	6
14	< 0.3	5.07	4.9	< 2	440	2	< 2	11.9	0.11	< 0.3	79	14
15	< 0.3	3.17	4.6	< 2	290	1	< 2	8.9	0.07	< 0.3	61	11
16	< 0.3	3.83	3	< 2	300	1	< 2	< 0.5	0.09	< 0.3	59	11
17	0.6	0.64	0.7	< 2	50	< 1	< 2	3.9	0.03	< 0.3	19	4
18	< 0.3	2.28	2.5	< 2	110	< 1	< 2	3	0.06	< 0.3	49	6
19	< 0.3	3.4	3.2	< 2	300	1	< 2	2.5	0.08	< 0.3	62	8
20	< 0.3	3.08	4.4	< 2	290	1	< 2	3.7	0.07	< 0.3	61	8
21	< 0.3	0.84	1.8	< 2	50	< 1	< 2	2.7	0.02	< 0.3	21	5
22	< 0.3	2.79	3.6	4	290	1	< 2	1.8	0.06	< 0.3	54	6
23	< 0.3	4.87	4.6	< 2	500	2	< 2	15.6	0.09	< 0.3	86	16
24	< 0.3	4.13	3.9	6	350	2	< 2	8.1	0.09	< 0.3	72	12
25	< 0.3	2.67	2.3	< 2	170	1	< 2	5.9	0.09	< 0.3	56	10
26	< 0.3	3.38	4.7	< 2	260	1	< 2	12.5	0.08	< 0.3	62	10
27	< 0.3	3.74	5	< 2	140	1	< 2	13.1	0.11	< 0.3	66	7
28	< 0.3	3.85	3.4	< 2	250	2	< 2	11.5	0.09	< 0.3	74	8
29	< 0.3	2.91	4.1	< 2	270	1	< 2	1.9	0.08	< 0.3	70	10
30	< 0.3	3.94	6.1	< 2	200	1	< 2	7.1	0.09	< 0.3	71	6
31	< 0.3	3.26	5.2	< 2	290	1	< 2	10.7	0.08	< 0.3	61	6
32	< 0.3	4.16	5.9	< 2	310	2	< 2	10.6	0.08	< 0.3	74	9
33	< 0.3	2.96	4.3	< 2	230	< 1	< 2	1.8	0.07	< 0.3	53	7
34	< 0.3	4.01	4.3	< 2	390	1	< 2	2.7	0.09	< 0.3	63	6
35	< 0.3	3.37	2.4	< 2	150	< 1	< 2	< 0.5	0.08	< 0.3	67	7

Table C-2 con't. St. Mary's Lake sediment elemental data. All values are ppm (ug/g) unless indicated otherwise.												
Station	**Cr**	**Cs**	**Cu**	**Eu**	**%Fe**	**Hf**	**Hg**	**Ir**	**%K**	**La**	**Li**	**Lu**
1	32	< 1	9	0.5	1.42	17	< 1	< 5	0.57	31	22	0.17
2	42	3	9	0.7	1.39	15	< 1	< 5	0.9	21.2	31	0.41
3	64	3	11	1.5	1.82	17	< 1	< 5	0.92	30.6	34	0.46
4	72	7	11	1.1	2.18	14	< 1	< 5	1.21	38.6	39	0.48
5	82	7	16	1.1	3.87	12	< 1	< 5	1.3	39.9	42	0.44
6	43	3	8	0.9	2.13	21	< 1	< 5	0.67	23.7	25	0.42
7	56	4	11	0.9	2.56	19	< 1	< 5	0.88	29	33	0.5
8	67	2	10	1.1	1.63	19	< 1	< 5	0.95	31.6	31	0.45
9	69	5	15	1.3	2.26	17	< 1	< 5	1.15	35.8	36	0.55
10	64	3	10	0.9	2.05	17	< 1	< 5	1.07	32.1	32	0.47
11	50	5	11	1.1	1.83	16	< 1	< 5	1.04	33.9	31	0.33
12	45	4	10	1.1	2.16	19	< 1	< 5	0.69	28.1	28	0.32
13	46	4	7	0.8	1.62	15	< 1	< 5	0.61	24.1	27	0.27
14	68	5	13	1.4	2.07	16	< 1	< 5	1.13	38.1	37	0.41
15	41	3	11	1.2	1.52	21	< 1	< 5	0.69	27.6	27	0.36
16	45	4	9	0.9	1.56	16	< 1	< 5	0.99	20.1	30	0.37
17	12	< 1	2	< 0.2	0.32	17	< 1	< 5	0.17	8.3	9	0.12
18	30	1	11	1	1.03	18	< 1	< 5	0.61	25.3	21	0.47
19	49	4	9	1.2	1.44	17	< 1	< 5	0.91	33	25	0.52
20	36	2	10	1.1	1.43	18	< 1	< 5	0.8	32.5	25	0.58
21	15	< 1	4	0.5	0.7	14	< 1	< 5	0.19	11.4	12	0.22
22	31	2	7	0.8	1.36	16	< 1	< 5	0.71	27.7	25	0.42
23	63	4	12	1.7	1.67	11	< 1	< 5	1.08	44	35	0.62
24	43	4	9	1.2	1.47	15	< 1	< 5	0.99	37.7	31	0.57
25	29	3	9	1	1.01	18	< 1	< 5	0.7	28.9	23	0.47
26	36	3	9	0.8	1.37	17	< 1	< 5	0.79	27.6	28	0.5
27	47	3	9	1.5	1.34	18	< 1	< 5	0.92	29.7	29	0.59
28	42	3	10	1.4	1.47	18	< 1	< 5	0.97	30.6	28	0.68
29	35	2	8	1.6	1.37	18	< 1	< 5	0.71	26.1	25	0.53
30	41	5	9	1.4	1.73	17	< 1	< 5	1.02	29.9	35	0.58
31	49	3	9	1.1	1.42	19	< 1	< 5	0.8	25.8	27	0.57
32	49	5	10	1.5	1.9	19	< 1	< 5	0.96	30.9	32	0.64
33	31	3	7	0.9	1.31	16	< 1	< 5	0.72	22.6	25	0.48
34	47	5	8	1	1.73	16	< 1	< 5	0.99	28.3	31	0.55
35	47	2	7	1	1.53	17	< 1	< 5	0.92	28.8	26	0.6

Table C-2 con't. St. Mary's Lake sediment elemental data. All values are ppm (ug/g) unless indicated otherwise.

Station	%Mg	Mn	Mo	%Na	Nd	Ni	%P	Pb	Rb	%S	Sb	Sc
1	0.14	208	< 1	0.12	25	12	0.008	18	< 15	0.02	0.4	5.1
2	0.19	151	< 1	0.22	18	13	0.011	20	43	0.06	0.7	5.5
3	0.2	223	< 1	0.18	30	16	0.015	22	101	0.03	0.6	7.5
4	0.26	156	< 1	0.27	43	18	0.027	27	94	0.08	0.9	10
5	0.4	183	< 1	0.19	30	31	0.048	29	144	0.1	0.8	12.8
6	0.16	228	< 1	0.14	31	13	0.015	16	17	0.03	0.6	6.4
7	0.22	135	< 1	0.17	26	15	0.019	18	68	0.04	0.9	8.8
8	0.21	205	< 1	0.25	31	16	0.023	20	53	0.09	0.9	7.7
9	0.25	224	< 1	0.31	27	19	0.028	25	36	0.06	0.6	9.4
10	0.22	177	< 1	0.3	31	17	0.018	21	99	0.04	1.2	8.3
11	0.22	227	< 1	0.25	27	18	0.035	27	78	0.15	0.5	8.1
12	0.17	206	< 1	0.14	30	15	0.02	22	46	0.05	0.8	7.3
13	0.14	189	< 1	0.11	20	9	0.008	16	26	0.01	0.6	6.8
14	0.26	193	< 1	0.25	35	20	0.024	30	106	0.08	0.8	9.8
15	0.15	153	< 1	0.16	33	14	0.016	22	51	0.08	0.6	6.7
16	0.18	160	< 1	0.22	24	12	0.012	20	< 15	0.03	0.6	6.7
17	0.04	68	< 1	0.04	< 5	3	0.002	7	< 15	0.09	0.3	1.6
18	0.11	117	< 1	0.13	25	8	0.007	16	59	0.03	0.5	4.5
19	0.16	138	< 1	0.2	34	13	0.01	18	25	0.03	0.8	6.3
20	0.15	177	< 1	0.17	37	11	0.011	22	73	0.03	0.6	5.9
21	0.04	110	< 1	0.04	14	5	0.001	7	< 15	0.02	0.1	1.9
22	0.14	148	< 1	0.16	22	11	0.011	20	18	0.03	0.4	4.9
23	0.24	167	< 1	0.2	41	22	0.031	22	72	0.14	0.5	9
24	0.2	179	< 1	0.22	35	16	0.016	22	51	0.06	0.6	7.2
25	0.12	241	< 1	0.16	32	11	0.014	21	35	0.05	0.5	5.1
26	0.16	246	< 1	0.19	39	15	0.014	20	22	0.08	0.7	6.4
27	0.18	159	< 1	0.22	38	15	0.012	20	66	0.09	0.6	6.9
28	0.18	163	< 1	0.24	40	15	0.014	23	35	0.09	0.6	7.5
29	0.15	315	< 1	0.16	35	15	0.011	17	32	0.03	0.5	5.4
30	0.2	161	< 1	0.21	35	12	0.02	25	57	0.05	0.6	7.4
31	0.16	180	< 1	0.17	26	11	0.01	20	70	0.05	0.7	6.4
32	0.22	187	< 1	0.22	39	16	0.016	25	65	0.07	0.6	8.3
33	0.14	154	< 1	0.15	31	10	0.011	19	55	0.02	0.6	5.5
34	0.2	166	< 1	0.22	36	13	0.016	21	69	0.04	0.5	7.3
35	0.16	134	< 1	0.23	24	10	0.009	20	78	0.02	0.6	6.9

Table C-2 con't. St. Mary's Lake sediment elemental data. All values are ppm (ug/g) unless indicated otherwise.

Station	Se	Sm	%Sn	Sr	Ta	Tb	Th	%Ti	U	V	W	Y	Yb	Zn
1	< 3	3.9	< 0.02	30	< 0.5	< 0.5	4.9	0.09	2	11	< 1	29	2.3	48
2	3	3.3	< 0.02	50	< 0.5	0.8	6.1	0.1	3	22	< 1	28	2.3	45
3	< 3	5.7	< 0.02	44	< 0.5	0.8	9.8	0.18	4	24	< 1	30	3.4	55
4	< 3	6.3	< 0.02	61	< 0.5	0.7	11.6	0.12	4.5	30	< 1	27	3.9	65
5	< 3	6.7	< 0.02	57	< 0.5	< 0.5	11.8	0.4	4.3	73	< 1	25	3.6	92
6	< 3	4.2	< 0.02	35	0.9	< 0.5	7.7	0.13	3.3	16	< 1	24	3.2	46
7	< 3	5	< 0.02	46	< 0.5	1.1	10.2	0.1	4	25	< 1	21	3.6	42
8	< 3	5.4	< 0.02	51	< 0.5	1.1	9.4	0.28	4.5	32	< 1	31	3.4	75
9	< 3	6	< 0.02	56	< 0.5	0.6	11.2	0.31	4.9	44	< 1	28	4	72
10	< 3	5.5	< 0.02	55	< 0.5	< 0.5	11	0.21	3.6	31	< 1	28	3.4	59
11	< 3	5.3	< 0.02	55	< 0.5	1	9.8	0.29	4.3	23	< 1	28	3.5	62
12	< 3	4.8	< 0.02	39	< 0.5	0.9	8.1	0.14	2.7	25	< 1	29	3.4	54
13	< 3	3.6	< 0.02	36	< 0.5	< 0.5	8.3	0.1	2.4	14	< 1	20	2.8	26
14	< 3	6.2	< 0.02	61	< 0.5	1.2	10.1	0.25	4.3	40	< 1	29	4.1	73
15	< 3	4.9	< 0.02	40	< 0.5	0.5	7.9	0.21	2.8	26	< 1	29	3.2	44
16	< 3	4.6	< 0.02	54	< 0.5	< 0.5	9.1	0.14	2.7	20	< 1	26	3.5	43
17	< 3	1.4	< 0.02	13	< 0.5	< 0.5	2.4	0.26	0.6	14	< 1	23	1.2	13
18	< 3	3.7	< 0.02	33	< 0.5	< 0.5	7	0.1	2.1	9	< 1	27	2.8	29
19	< 3	4.8	< 0.02	47	< 0.5	< 0.5	8.3	0.12	3.2	15	< 1	32	3.4	42
20	< 3	4.9	0.04	44	< 0.5	0.5	8.7	0.11	2.8	15	< 1	30	3.2	39
21	< 3	1.7	< 0.02	13	< 0.5	< 0.5	3.2	0.24	1.3	14	< 1	20	1.2	21
22	< 3	4.1	< 0.02	38	< 0.5	0.6	6.4	0.37	1.7	30	< 1	26	2.2	40
23	< 3	6.5	< 0.02	56	< 0.5	0.6	10.3	0.47	2.8	55	< 1	31	3.6	76
24	< 3	5.5	< 0.02	53	1.3	< 0.5	9.2	0.42	2.3	41	< 1	31	3.4	57
25	< 3	4.4	< 0.02	41	< 0.5	< 0.5	8.2	0.33	2.7	27	< 1	26	2.8	54
26	< 3	5.1	< 0.02	43	< 0.5	< 0.5	8.1	0.16	1.7	22	< 1	33	3.2	53
27	< 3	5.2	< 0.02	52	< 0.5	1	8.7	0.12	3.9	20	< 1	33	4	51
28	< 3	5.5	< 0.02	53	0.8	< 0.5	10.2	0.21	2.9	24	< 1	37	3.9	52
29	< 3	5.5	< 0.02	39	< 0.5	< 0.5	8.2	0.17	3.2	16	< 1	34	2.9	57
30	< 3	5.2	< 0.02	54	< 0.5	1.2	9.5	0.14	5.1	24	< 1	29	3.8	46
31	< 3	4.6	0.05	43	< 0.5	< 0.5	8.5	0.23	1.9	24	< 1	32	3.3	40
32	< 3	5.8	< 0.02	49	< 0.5	1.1	10.3	0.13	2.7	28	< 1	28	4	52
33	< 3	4.1	< 0.02	39	< 0.5	< 0.5	8.6	0.11	2.1	13	< 1	25	2.6	35
34	< 3	4.9	< 0.02	52	0.7	1	9	0.1	3.8	21	< 1	24	3.3	47
35	< 3	4.8	< 0.02	51	< 0.5	< 0.5	10.4	0.1	4.3	12	< 1	26	3.8	32

Table C-3. Results of analyses of Standard Reference Material (NIST SRM #8704 - Buffalo River Sediment) submitted as blind unknowns with the St. Mary's Lake surficial samples. Also given are the method detection limits for each element reported by Act Labs, Inc. Shaded values, if any, differ from

the certified or known value by >25%.								
Analyte	**Symbol**	**Unit**	**Detection Limit**	**Certified value**	**Std dev**	**Act Labs Results**		
						Average	**Std dev**	**% recovery**
Silver	Ag	ppm	0.3			0.5	0.1	
Gold	Au	ppb	2			6	6	
Aluminum	Al	%	0.01	6.1	0.18	5.68	0.07	93.1
Arsenic	As	ppm	0.5	17		19.9	1.8	117.3
Barium	Ba	ppm	50	413	13	577	93	139.6
Beryllium	Be	ppm	1			2	0	
Bismuth	Bi	ppm	2			< 2		
Bromide	Br	ppm	0.5			8.8	0.9	
Calcium	Ca	%	0.01	2.641	0.083	2.71	0.01	102.7
Cadmium	Cd	ppm	0.3	2.94	0.29	3.1	0.0	105.4
Cerium	Ce	ppm	3	66.5	2	64	8	96.2
Cobalt	Co	ppm	1	13.57	0.43	14	3	103.2
Chromium	Cr	ppm	2	121.9	3.8	128	13	104.7
Cesium	Cs	ppm	1	5.83	0.12	8	1	131.5
Copper	Cu	ppm	1			91	2	
Europium	Eu	ppm	0.2	1.31	0.038	1.2	0.1	89.1
Iron	Fe	%	0.01	3.97	0.1	4.28	0.15	107.8
Hafnium	Hf	ppm	1	8.4	1.5	8	1	99.2
Mercury	Hg	ppm	1			1	1	
Iridium	Ir	ppb	5			< 5		
Potassium	K	%	0.01	2.001	0.041	1.92	0.04	96.1
Lanthanum	La	ppm	0.5			30.6	2.6	
Lithium	Li	ppm	1			47	0	
Lutetium	Lu	ppm	0.05			0.42	0.05	
Magnesium	Mg	%	0.01	1.2	0.018	1.15	0.01	95.6
Manganese	Mn	ppm	1	544	21	554	11	101.8
Molybdenum	Mo	ppm	1			2	1	
Sodium	Na	%	0.01	0.553	0.015	0.66	0.06	118.7
Neodymium	Nd	ppm	5			26	8	
Nickel	Ni	ppm	1	42.9	3.7	44	1	103.3
Phosphorus	P	%	0.001			0.081	0.005	
Lead	Pb	ppm	3	150	17	155	5	103.1
Rubidium	Rb	ppm	15			117	36	
Sulfur	S	%	0.01			0.35	0.01	
Antimony	Sb	ppm	0.1	3.07	0.32	2.9	0.2	94.5
Scandium	Sc	ppm	0.1	11.26	0.19	11.7	0.4	104.2
Selenium	Se	ppm	0.1			< 3		
Samarium	Sm	ppm	0.1			6.1	0.3	
Tin	Sn	%	0.01			0.02	0.03	
Strontium	Sr	ppm	1			132	1	

Table C-3 con't. Results of analyses of Standard Reference Material (NIST SRM #8704 - Buffalo River Sediment) submitted as blind unknowns with the St. Mary's Lake surficial samples. Also given are the method detection limits for each element reported by Act Labs, Inc. Shaded values, if any, differ from the certified or known value by >25%.

Analyte	**Symbol**	**Unit**	**Detection**	**Certified**	**Std dev**	**Act Labs Results**

			Limit	value		Average	Std dev	% recovery
Tantatum	Ta	ppm	0.5			< 0.5		
Terbium	Tb	ppm	0.5			< 0.5		
Thorium	Th	ppm	0.2	9.07	0.16	9.7	0.6	106.6
Titanium	Ti	%	0.01	0.457	0.02	0.40	0.01	88.3
Uranium	U	ppm	0.5	3.09	0.13	3.2	0.2	104.6
Vanadium	V	ppm	2	94.6	4	83	4	88.1
Tungsten	W	ppm	1			< 1		
Yttrium	Y	ppm	1			23	1	
Ytterbium	Yb	ppm	0.2			3.1	0.2	
Zinc	Zn	ppm	1	408	15	403	13	98.8

Table C-4. Results of analyses of Standard Reference Material (NIST SRM #1646a- Estuarine Sediment) submitted as blind unknowns with the St. Mary's Lake surficial samples. Also given are the method detection limits for each element reported by Act Labs, Inc. Shaded values, if any, differ from the certified or known value by >25%.

Analyte	Symbol	Unit	Detection Limit	Certified value	Std dev	Act Labs Results		
						Average	Std dev	% recovery
Silver	Ag	ppm	0.3			0.2	0.2	
Gold	Au	ppb	2			4	4	
Aluminum	Al	%	0.01	2.297	0.018	2.22	0.03	96.8
Arsenic	As	ppm	0.5	6.23	0.21	10.0	2.5	160.0
Barium	Ba	ppm	50			223	188	
Beryllium	Be	ppm	1			< 1		
Bismuth	Bi	ppm	2			< 2		
Bromide	Br	ppm	0.5			58.9	1.8	
Calcium	Ca	%	0.01	0.519	0.02	0.59	0.01	114.3
Cadmium	Cd	ppm	0.3	0.148	0.007	< 0.3		
Cerium	Ce	ppm	3			36	2	
Cobalt	Co	ppm	1			7	1	
Chromium	Cr	ppm	2	40.9	1.9	42	6	101.9
Cesium	Cs	ppm	1			< 1		
Copper	Cu	ppm	1	10.01	0.34	10	0	99.9
Europium	Eu	ppm	0.2			0.6	0.2	
Iron	Fe	%	0.01	2.008	0.039	2.21	0.08	109.9
Hafnium	Hf	ppm	1			12	1	
Mercury	Hg	ppm	1			< 1		
Iridium	Ir	ppb	5			< 5		
Potassium	K	%	0.01	0.864	0.016	0.87	0.01	100.7
Lanthanum	La	ppm	0.5			19.7	4.5	
Lithium	Li	ppm	1			19	1	
Lutetium	Lu	ppm	0.05			0.17	0.06	
Magnesium	Mg	%	0.01	0.388	0.009	0.39	0.01	101.4
Manganese	Mn	ppm	1	234.5	2.8	237	6	101.2
Molybdenum	Mo	ppm	1			< 1		
Sodium	Na	%	0.01	0.741	0.017	0.78	0.06	105.3
Neodymium	Nd	ppm	5			15	8	
Nickel	Ni	ppm	1			25	1	
Phosphorus	P	%	0.001	0.027	0.001	0.027	0.000	100.0
Lead	Pb	ppm	3	11.7	1.2	10	1	88.3
Rubidium	Rb	ppm	15			8	14	
Sulfur	S	%	0.01	0.352	0.004	0.35	0.01	99.4
Antimony	Sb	ppm	0.1			0.2	0.1	
Scandium	Sc	ppm	0.1			4.9	0.1	
Selenium	Se	ppm	0.1	0.193	0.028	< 3		
Samarium	Sm	ppm	0.1			3.3	0.1	
Tin	Sn	%	0.01			< 2		
Strontium	Sr	ppm	1			73	1	

Table C-4 con't. Results of analyses of Standard Reference Material (NIST SRM #1646a- Estuarine Sediment) submitted as blind unknowns with the St. Mary's Lake surficial samples. Also given are the method detection limits for each element reported by Act Labs, Inc. Shaded values, if any, differ from the certified or known value by >25%.								
Analyte	**Symbol**	**Unit**	**Detection Limit**	**Certified value**	**Std dev**	**Act Labs Results**		
						Average	**Std dev**	**% recovery**
Tantatum	Ta	ppm	0.5			< 0.5		
Terbium	Tb	ppm	0.5			< 0.5		
Thorium	Th	ppm	0.2			5.5	0.3	
Titanium	Ti	%	0.01	0.456	0.021	0.43	0.06	95.0
Uranium	U	ppm	0.5			2.1	0.7	
Vanadium	V	ppm	2	44.84	0.76	34	14	76.6
Tungsten	W	ppm	1			< 1		
Yttrium	Y	ppm	1			10	0	
Ytterbium	Yb	ppm	0.2			1.4	0.2	
Zinc	Zn	ppm	1	48.9	1.6	50	1	101.6

Table C-5. Results of analyses of Standard Reference Material (NIST SRM #2702- Inorganics in marine sediment) submitted as blind unknowns with the St. Mary's Lake surficial samples. Also given are the method detection limits for each element reported by Act Labs, Inc.

Analyte	Symbol	Unit	Detection Limit	Certified value	Std dev	Act Labs Results		
						Average	Std dev	% recovery
Silver	Ag	ppm	0.3	0.622	0.078	1.2	0.1	192.9
Gold	Au	ppb	2			17	20	
Aluminum	Al	%	0.01	8.41	0.22	7.63	0.26	90.7
Arsenic	As	ppm	0.5	45.3	1.8	49.8	2.6	110.0
Barium	Ba	ppm	50	397.4	3.2	170	151	42.8
Beryllium	Be	ppm	1			3	0	
Bismuth	Bi	ppm	2			6	2	
Bromide	Br	ppm	0.5			65.8	3.4	
Calcium	Ca	%	0.01	0.343	0.024	0.35	0.01	103.0
Cadmium	Cd	ppm	0.3	0.817	0.011	0.9	0.1	106.1
Cerium	Ce	ppm	3	123.4	5.8	117	8	94.8
Cobalt	Co	ppm	1	27.76	0.58	30	6	109.3
Chromium	Cr	ppm	2			324	28	
Cesium	Cs	ppm	1			6	2	
Copper	Cu	ppm	1	117.7	5.6	115	5	97.4
Europium	Eu	ppm	0.2			2.0	0.3	
Iron	Fe	%	0.01			7.78	0.24	
Hafnium	Hf	ppm	1			10	2	
Mercury	Hg	ppm	1	0.4474	0.0069	< 1		
Iridium	Ir	ppb	5			< 5		
Potassium	K	%	0.01	2.054	0.072	1.91	0.15	93.2
Lanthanum	La	ppm	0.5	73.5	4.2	64.5	5.4	87.8
Lithium	Li	ppm	1			77	2	
Lutetium	Lu	ppm	0.05			0.55	0.15	
Magnesium	Mg	%	0.01	0.990	0.074	0.92	0.02	93.3
Manganese	Mn	ppm	1	1757	58	1653	35	94.1
Molybdenum	Mo	ppm	1	10.8	1.6	9	1	83.3
Sodium	Na	%	0.01	0.681	0.020	0.75	0.05	109.6
Neodymium	Nd	ppm	5			63	14	
Nickel	Ni	ppm	1	75.4	1.5	77	2	102.1
Phosphorus	P	%	0.001	0.1552	0.0066	0.133	0.012	85.9
Lead	Pb	ppm	3	132.8	1.1	126	4	94.6
Rubidium	Rb	ppm	15	127.7	8.8	89	78	69.4
Sulfur	S	%	0.01			1.50	0.09	
Antimony	Sb	ppm	0.1	5.6	0.24	4.9	0.7	86.9
Scandium	Sc	ppm	0.1	25.9	1.1	24.1	1.1	93.2
Selenium	Se	ppm	0.1	4.95	0.46	< 3		
Samarium	Sm	ppm	0.1			10.6	0.7	
Tin	Sn	%	0.01	31.6	2.4	< 0.02		
Strontium	Sr	ppm	1	119.7	3.0	118	4	98.9
Tantatum	Ta	ppm	0.5			3.4	3.4	

Table C-5 con't. Results of analyses of Standard Reference Material (NIST SRM #2702- Inorganics in marine sediment) submitted as blind unknowns with the St. Mary's Lake surficial samples. Also given are the method detection limits for each element reported by Act Labs, Inc.

Analyte	Symbol	Unit	Detection Limit	Certified value	Std dev	Act Labs Results		
						Average	Std dev	% recovery
Terbium	Tb	ppm	0.5			< 0.5		
Thorium	Th	ppm	0.2	20.51	0.96	19.5	0.1	95.1
Titanium	Ti	%	0.01	0.884	0.082	0.81	0.05	91.3
Uranium	U	ppm	0.5			9.0	1.4	
Vanadium	V	ppm	2	357.6	9.2	327	12	91.5
Tungsten	W	ppm	1			1	2	
Yttrium	Y	ppm	1			34	1	
Ytterbium	Yb	ppm	0.2			3.9	0.3	
Zinc	Zn	ppm	1	485.3	4.2	473	10	97.4

Table C-6. Results of Act Labs analyses of Reference material for the TD-ICP method. Act Labs' measure values compared to the certified values. Reference materials include USGS geochemical exploration references.

Analyte Symbol	Unit Symbol	Detection Limit	USGS DNC-1a Dolerite		USGS DNC-1a Dolerite		USGS SBC-1 Shale		Method Blank
			Measured value	Certified value	Measured value	Certified value	Measured value	Certified value	
Ag	ppm	0.3							< 0.3
Cu	ppm	1	97	100	97	100	32	31	< 1
Cd	ppm	0.3					0.4	0.4	< 0.3
Mo	ppm	1					< 1	2	< 1
Pb	ppm	3	< 3	6.3	< 3	6.3	30	35	< 3
Ni	ppm	1	248	247	248	247	87	83	< 1
Zn	ppm	1	59	70	60	70	187	186	< 1
S	%	0.01							< 0.01
Al	%	0.01							< 0.01
Be	ppm	1					3	3.2	< 1
Bi	ppm	2					< 2	0.7	< 2
Ca	%	0.01	7.63	8.21	7.76	8.21			< 0.01
K	%	0.01							< 0.01
Li	ppm	1	5	5.2	6	5.2	181	163	< 1
Mg	%	0.01							< 0.01
Mn	ppm	1							2
P	%	0.001							< 0.001
Sr	ppm	1	136	144	138	144	185	178	< 1
Ti	%	0.01	0.27	0.29	0.28	0.29	0.5	0.51	< 0.01
V	ppm	2	133	148	135	148	207	220	< 2
Y	ppm	1	16	18	16	18	34	36.5	< 1