SPECIAL PROJECT REPORT **FY10-MEFO-3-EC**

Maine Field Office – Ecological Services **August 2011**

Mercury Assessment of Brandy Pond
T39 MD, Maine

Fish and Wildlife Service

U.S. Department of the Interior

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Suggested citation: Mierzykowski S.E. 2011. Mercury assessment of Brandy Pond, T39 MD, Maine. USFWS. Spec. Proj. Rep. FY10-MEFO-3-EC. Maine Field Office. Orono, ME. 29 pp.

U.S. Fish and Wildlife Service
Maine Field Office
Special Project Report FY10-MEFO-3-EC

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Region 5 ID: 53411-1130-5F47
DEQ ID: 200950004.1
(filename: 5F47BrandyPondReport.pdf)

by

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August 2011

Congressional District #2

EXECUTIVE SUMMARY

Brandy Pond is a remote, shallow, pond in east-central Maine. A bald eagle (*Haliaeetus leucocephalus*) nest territory has existed on the pond since the mid 1960s. Since the establishment of the nest, the bald eagle territory at Brandy Pond has had extremely poor productivity. Researchers have collected ten non-viable eagle eggs at the pond over the past five decades and mercury levels in eggs have chronically been well above suggested reproductive effect thresholds.

The source of mercury contamination in the Brandy Pond watershed is not known. A tannery, the Thirty-Nine Tannery, once existed approximately one mile northwest of Brandy Pond and was active throughout the mid to late 1800s and early 20th century before burning around 1906. Buffalo Stream runs past the former tannery site and connects to the western shore of Brandy Pond by an intermittent stream. The Thirty-Nine Tannery processed animal hides for sole leather. The tannery process in Maine in the 1800s was primarily an organic- or vegetable-process using tannic acids from hemlock bark. It is not known if the Thirty-Nine Tannery switched to a chemical tanning process at the beginning of the 1900s. Mercury was once a common element used in the leather tanning process. It has long been locally debated whether mercury contamination in fish and wildlife from Brandy Pond is from the former tannery or from other sources. Mercury in the pond may be more likely associated with watershed and chemistry characteristics that influence the bioavailability of atmospherically-deposited mercury.

To resolve the issue, sediments and fish were collected from Brandy Pond and from Eagle Lake, a nearby reference lake, and analyzed for mercury. Sediments were also collected from Buffalo Stream, above and below the location of the former tannery.

• There were no significant differences in mercury concentration or size in chain pickerel collected from Brandy Pond and Eagle Lake, the reference area. Chain pickerel are upper trophic level piscivorous fish. Since mercury biomagnifies in food chains, upper trophic level species typically contain elevated mercury burdens. Mercury levels in chain pickerel from Brandy Pond (0.54 ppm, wet weight) and Eagle Lake (0.43 ppm) exceed guidelines for consumption by humans (0.20 ppm) and for protection of ecological receptors (0.20 ppm). Forage fish species in both water bodies contained substantially lower mercury concentrations (0.10 ppm) than pickerel.

• Mercury was below analytical detection limits in sediments from the Brandy Pond and Eagle Lake (i.e., < 0.100 ppm, dry weight). In Buffalo Stream, mercury was below detection limits in sediments collected above the former tannery site and at the detection limit (0.10 ppm) below the former tannery site. These sediment mercury concentrations would be below sediment

quality guidelines for harmful effects. Sediments collected in the lower, deadwater reach of Buffalo Stream, however, were extremely peaty and moisture content in the samples influenced data quality.

Based on the results of sediment and fish sampling, and a review of historical literature related to the tanning process in Maine in the 1800s, Brandy Pond does not appear to have a mercury point-source in the watershed. Elevated mercury concentrations in bald eagle eggs at Brandy Pond appear to be the product of adult birds foraging on a fish species (i.e., chain pickerel) with a propensity for mercury accumulation in a water body with characteristics suitable for methylation of atmospherically-deposited mercury.

Keywords: mercury, bald eagle, Buffalo Stream, Brandy Pond, Eagle Lake, Maine

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Abbreviations and Acronyms

APHA	American Public Health Association
DEQ	Division of Environmental Quality (USFWS)
DO	dissolved oxygen
dw	dry weight
g	grams
Hg	mercury
LC_{50}	lethal concentration that kills 50% of a sample population
LOM	Lakes of Maine
MEDEP	Maine Department of Environmental Protection
MEFO	Maine Field Office - USFWS
MIDAS	Maine Information Display and Analysis System
mg/L	milligrams per liter
MVLMP	Maine Volunteer Lake Monitoring Program
µg/g	micrograms per gram (parts-per-million)
µS/cm	micro-siemens per centimeter
mm	millimeters
PCU	Platinum-Cobalt Units
PEC	Probable Effect Concentration
ppm	parts-per-million (µg/g)
QA/QC	quality assurance/quality control
SS	stainless steel
TEC	Threshold Effect Concentration
USFWS	U.S. Fish and Wildlife Service
ww	wet weight

PREFACE

This report summarizes mercury concentrations in sediments from Buffalo Stream, Brandy Pond, and Eagle Lake, and in fish from Brandy Pond and Eagle Lake. Analytical work for this project was completed under U.S. Fish and Wildlife Service Analytical Control Facility Catalog Numbers 5100038 (Purchase Order 94420-09-Y051) and 5100043 (Purchase Order 94420-A-Y091).

Questions, comments, and suggestions related to this report are encouraged. Written inquiries should refer to Report Number FY10-MEFO-3-EC and be directed to:

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ACKNOWLEDGEMENTS

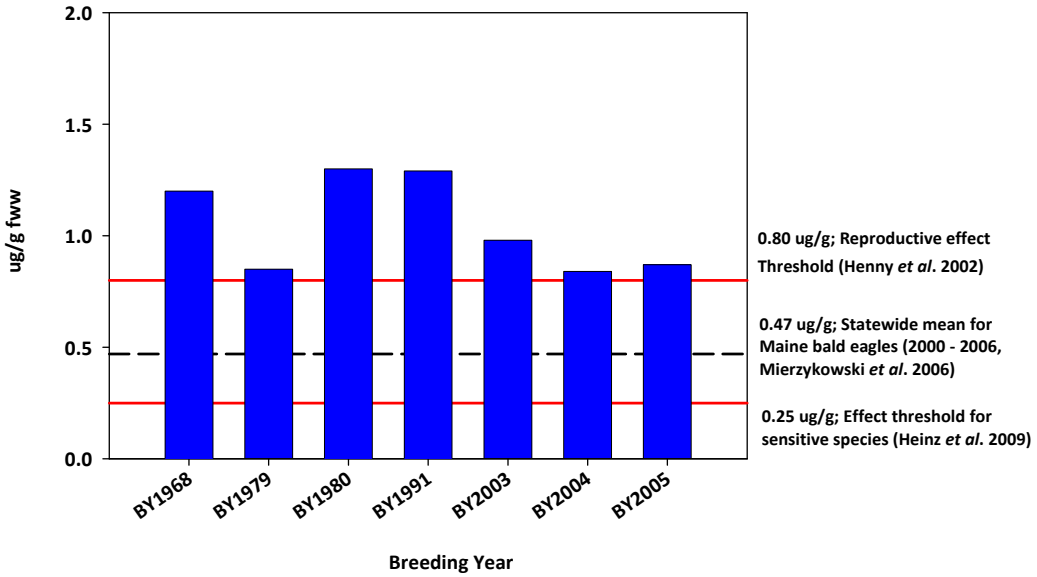
Funding for this project was provided by the U.S. Fish and Wildlife Service's Division of Environmental Quality in Washington, DC, and by Timothy Fannin, Ph.D., USFWS Region 5 Chief of Habitat Conservation, Hadley, MA. Wesley Hatch, Forest Ranger for the Maine Forest Service, provided assistance during field reconnaissance of Buffalo Stream. Ron Joseph, retired wildlife biologist from the U.S. Fish and Wildlife Service, provided assistance with fish collections. Fred Seavey, USFWS, provided assistance with interpreting whole-body to fillet regression equations. Peer review of the draft report was provided by Barry F. Mower, Ph.D, Maine Department of Environmental Protection. Final editorial review was provided by F. Timothy Prior, USFWS retired.

1. Introduction

Brandy Pond is a remote, shallow, pond in east-central Maine with a fish population dominated by warmwater species. Brandy Pond has several camps along its shores and is popular with anglers during the summer and winter months.

A bald eagle (*Haliaeetus leucocephalus*) nest territory has existed on the pond since the mid 1960s. Since the establishment of the nest, the bald eagle territory at Brandy Pond has had extremely poor productivity. In the time period of 1995 through 2005, the mean productivity rate of the Brandy Pond eagle nest territory was 0.56 eaglets fledged/nesting pair – well below the target for sustaining populations (i.e., 1.0 eaglets fledged/nesting pair) and well below the statewide annual mean for the same time period (0.87 eaglets fledged/nesting pair; Todd 2006). Researchers have collected ten non-viable eggs at the Brandy Pond bald eagle nest territory over the past five decades and mercury levels in eggs have chronically been well above the suggested reproductive effect threshold (Figure 1; Krantz *et al*. 1970, Wiemeyer *et al*. 1984, Wiemeyer *et al*. 1993, Welch 1994, Mierzykowski *et al*. 2006).

Figure 1. Mercury in eggs from bald eagle nest territory #075 (Brandy Pond)



(Values in 1979, 1991, and 2003 represent mean of two eggs)

Mercury levels in recently collected bald eagle eggs (2003 – 2005, n = 4) from Brandy Pond have been nearly twice the statewide mean mercury concentration (0.47 µg/g, Mierzykowski *et al*.

2006) and are consistently above suggested avian reproductive effect thresholds for Hg (Heinz 1979, Henny *et al*. 2002, Heinz *et al*. 2009).

The source of Hg contamination in the Brandy Pond watershed is not known. In the 1800s, a tannery existed approximately one mile northwest of Brandy Pond (Stiles 1998) and remnants are still visible (D. Stiles, Nova Scotia Agricultural College. 2008. Personal communication). The Thirty-Nine Tannery was active throughout the 1800s and lost in a fire in the early 1900s (Baker and Baker 1972). Buffalo Stream runs past the former tannery site and connects to the western shore of Brandy Pond by an intermittent stream and Brandy Stream. The Thirty-Nine Tannery processed animal hides for sole leather (BILS 1897). In the 1800s, the tannery process in Maine was primarily an organic- or vegetable-process using tannic acids from hemlock bark. It has been speculated by local residents and others that the Thirty-Nine Tannery could be a potential Hg source in the watershed. Mercury was once a common element used in the leather tanning process (EPA 2001).

As noted earlier, it was not known if Hg contamination in Brandy Pond is from the former tannery or from non-point sources. Elevated Hg in Brandy Pond may be associated with watershed and chemistry characteristics that influence the bioavailability of atmospherically-deposited mercury (e.g., dissolved organic carbon levels, Driscoll *et al*. 1995). This study was undertaken to characterize Hg contamination in the watershed and to evaluate a potential point source – the Thirty-Nine Tannery.

2. Study Objective

Determine if Hg contamination in Brandy Pond bald eagle eggs is related to a former tannery in the watershed.

3. Study Area

The study design included three areas. Buffalo Stream is a watercourse beside the former tannery and Brandy Pond is the focus water body in the study; both are in the Union River watershed. Eagle Lake was the reference water body for the study and it is located in the Narraguagus River watershed approximately four miles southeast of Brandy Pond (Figure 2).

3.1 Buffalo Stream. Buffalo Stream is a second order stream originating in Grand Falls Township, Penobscot County, that receives drainage from the southern side of Passadumkeag Mountain and west side of Lord Mountain. Buffalo Stream drains south along the west side of Brandy Pond.

A small tributary brook from Buffalo Stream forms a connection with Brandy Pond. An old road to the tannery existed along the east side of Baker Hill and crossed this tributary brook. The road was upgraded for logging operations in the late 1980s and again in 2008. A bridge over Buffalo Stream was also removed during the 2008 road upgrade (W. Hatch, Maine Forest Service. 2011. Personal communication). During high runoff events, backflow from Buffalo Stream may also enter Brandy Pond via Brandy Stream.

The mainstem of Buffalo Stream connects below Brandy Pond with Brandy Pond Stream, and flows into Main Stream which flows into Great Pond. Buffalo Stream supports brook trout (*Salvelinus fontinalis*) and fallfish (*Semotilis corporalis*) (R. Dill, Maine Department of Marine Resources. 2011. Personal communication)

3.2 Brandy Pond. Brandy Pond is a remote 733-acre pond located in east-central Maine in T39 MD, Hancock County. The Maine Information Display and Analysis System (MIDAS) code number for Brandy Pond is 9561. The pond is relatively shallow with a mean depth of 10 feet and a maximum of 24 feet (LOM 2011). The pond receives the drainage of Runt Brook, Guagus Stream, Indian Brook, and Buffalo Stream. Outflow is to Brandy Stream which drains into Main Stream. Fish species in the pond include chain pickerel (*Esox niger*), yellow perch (*Perca flavescens*), pumpkinseed (*Lepomis gibbosus*), brown bullhead (*Ameiurus nebulosus*), and white sucker (*Catostomus commersoni*) (KnowledgeBase 2011). In the past, the Maine Department of Inland Fisheries and Wildlife has stocked the pond with brown trout (*Salmo trutta*).

3.3 Eagle Lake. Eagle Lake is also a remote, shallow pond with an area of approximately 239-acres, a mean depth of 10 feet, and a maximum depth of 24 feet (LOM 2011). The MIDAS code number for Eagle Lake is 4514. The pond receives drainage from Eagle Brook and Partridge Brook. Outflow is to the Narraguagus River. The fish species composition in the lake is similar to Brandy Pond comprised of chain pickerel, yellow perch, white sucker, but with a diadromous species component consisting of American eel (*Anguilla rostrata*) and sea-run alewife (*Alosa pseudoharengus*) (KnowledgeBase 2011).

4. Methods

4.1 Sediment. Twenty four surficial (i.e., top 2 inches) sediment samples were collected from Buffalo Stream, Brandy Pond, and Eagle Lake with an Ekman dredge or stainless steel spoon (Table 1). All collection equipment was decontaminated prior to sampling with a wash of tap water and biodegradable detergent followed by a rinse with de-ionized water. Nine sediment samples were collected from Buffalo Stream. Five samples were collected upstream from the former tannery and four samples were collected below the former tannery. In Brandy Pond, ten sediment samples were collected - five along the west shore and five along the east shore. In Eagle Lake, five sediment samples were collected from the western half of the lake.

4.2 Fish. Twenty chain pickerel were collected by angling – 10 from Brandy Pond and 10 from Eagle Lake (Table 3). Forage fish were collected by angling, trap nets, and minnow traps in the pond and lake. Twelve forage fish samples were collected at Brandy Pond and ten were collected at Eagle Lake (Table 4). Total length in millimeters and total weight in grams were determined for fish submitted as individual, whole-body samples. Smaller forage fish collected from Brandy Pond were formed into eight composite samples of ten, whole-body fish of similar size. The average length and total sample weight were determined in composite samples. All forage fish samples collected from Eagle Lake were processed as individual, whole-body fish. Fish samples were wrapped in plastic wrap, placed in labeled zip-loc plastic bags and frozen.

4.3 Laboratory Analyses. All samples were analyzed for Hg by Laboratory and Environmental Testing, Inc. in Columbia, Missouri, a contract laboratory of the U.S. Fish and Wildlife Service's Analytical Control Facility. Mercury concentrations in sediment and fish tissue were determined by cold vapor atomic absorption. Sediment particle size analyses were determined by the hydrometer method. Total organic carbon in sediment was estimated by the loss-on-ignition method.

Analytical work was completed under U.S. Fish and Wildlife Service Analytical Control Facility Catalog Numbers 5100038 (Purchase Order 94420-09-Y051) and 5100043 (Purchase Order 94420-A-Y091).

4.4 Quality Assurance/Quality Control (QA/QC). Quality assurance and quality control procedures at the analytical laboratory included procedural blanks, duplicates, spike recoveries, and certified reference material. The USFWS Analytical Control Facility reviewed QA/QC results and accepted both mercury analytical data packages.

4.5 Data Presentations and Statistical Analyses. Analytical results are presented in Table 2 (sediments), Table 3 (chain pickerel), and Table 4 (forage fish). Mercury concentrations are presented in µg/g (parts-per-million) dry weight for sediments and in µg/g wet weight for fish. Mercury was measured in whole-body fish. For chain pickerel, Hg concentrations in fillets were estimated based on a regression equation in Peterson *et al*. (2007) formed for Microsoft Excel 2007:

Fillet Hg Concentration = 10^ (0.2545 + (1.0623*LOG10 (Whole-body Hg Concentration)))

Statistical comparisons between locations were performed using Systat®12.0 (Systat Software, Inc. 2007). Datasets were tested for normality using the Kolmogorov-Smirnov test. Differences in datasets between locations were tested using the student t-test with a significance level of 0.05.

5. Results

5.1 Sediments.

5.1.1 Buffalo Stream – Sediments were collected from five locations above and four locations below the former tannery (Figure 3). Sediments ranged from coarse sand and gravel in the upper reaches of Buffalo Stream to organic, dense, peaty mud in the lower reaches (Table 1). The deadwater reach of Buffalo Stream had a very soft bottom, making sediment sampling difficult. Multiple attempts were made in the field to collect true sediment in the deadwater. The presence of peat in five sediment samples, however, greatly increased moisture content and negatively affected data quality (Table 2). One sediment sample from the lower reach had an approximated result of 0.100 µg/g dry weight of Hg. Three acceptable sediment samples from the upper reach were below Hg detection limits (< 0.100 µg/g dry weight) (Table 2).

5.1.2 Brandy Pond and Eagle Lake – Sediments were collected along the east and west shore of Brandy Pond (Figure 4) and the west side of Eagle Lake (Figure 5). Mercury was below detection limits (< 0.100 µg/g dry weight) in all sediment samples from Brandy Pond and Eagle Lake (Table 2). Sediments in both water bodies were comprised of sand with ten percent or less of silt (Table 2).

5.2 Fish.

5.2.1 Chain Pickerel - Mean length of chain pickerel was 416.1 ± 50.5 mm in Brandy Pond and 434.3 ± 61.6 mm in Eagle Lake with no significant difference ($p = 0.480$) between water bodies (Table 3). Chain pickerel weights were also not significantly different ($p = 0.391$) between Brandy Pond (408.7 ± 141.6 grams) and Eagle Lake (472.7 ± 181.2 grams). Mercury content was not significantly different ($p = 0.086$) in chain pickerel from Brandy Pond (0.536 ± 0.160 µg/g wet weight) and Eagle Lake (0.428 ± 0.093 µg/g wet weight) (Table 3).

5.2.2 Forage Fish – A mix of forage fish species were collected at Brandy Pond. Yellow perch were collected from Eagle Lake. Due to the different species compositions in the two waters, statistical comparisons of weights and lengths between water bodies were not attempted. Mean Hg content in forage fish samples was 0.092 µg/g wet weight from Brandy Pond (range: 0.060 – 0.280 µg/g) and 0.096 µg/g wet weight in Eagle Lake (range: 0.060 – 0.190 µg/g) (Table 4).

6. Discussion

6.1 Sediments. Surficial sediment Hg concentrations in the three collection areas were compared to Threshold Effect Concentrations (TEC) and Probable Effect Concentrations (PEC) suggested by MacDonald *et al*. (2000). Threshold Effect Concentrations are concentrations below which harmful effects are unlikely to be observed, while Probable Effect Concentrations are concentrations above which harmful effects are likely to be observed. MacDonald *et al*. (2000) suggested a Hg consensus-based TEC of 0.18 µg/g and a PEC of 1.06 µg/g, dry weight.

The sediment samples from Buffalo Stream with acceptable data quality were either below the TEC or at the detection limit. Buffalo Stream sediment analytical results suggest that Hg was not used in the tanning process in the Thirty-Nine tannery and that the tannery was not a point-source for mercury in Brandy Pond. Issues associated with sediment data quality in this investigation (i.e., three of four Buffalo Stream sediment samples below the former tannery site contained too much moisture) leave the possibility that deeper sediment in Buffalo Stream may contain historically-deposited Hg covered by decades of deposition. Bottom sediments were quite soft in the reach below the former tannery, and it is likely the sediments collected many decades of deposition.

Surficial sediments in Brandy Pond and Eagle Lake were below the Hg detection limit (< 0.100 µg/g) which was lower than the TEC. Sediment data quality objectives were met in Brandy Pond and Hg was not detected in any surficial samples. Average sedimentation rates in Maine lakes and ponds average 1.5 mm per year, so a surficial sediment sample (i.e., 0 – 6 inch depth) likely represents an integration of up to 100 years of deposition (B. Mower, MEDEP. 2008. Personal communication).

6.2 Fish. Elevated Hg levels were found in chain pickerel from Brandy Pond and Eagle Lake. Concentrations of Hg in pickerel samples from both areas would exceed thresholds for fish, birds, and humans.

6.2.1 Comparative Data – Regionally and in Maine, high Hg concentrations are often found in upper trophic level fish species (Kamman *et al*. 2005, Stafford and Haines 1997).

In a review of fish tissue monitoring databases from northeastern North America, chain pickerel had a mean fillet Hg concentration of 0.553 µg/g (n = 238, mean length 410 mm) and a whole-body concentration of 0.362 µg/g (n = 22, mean length 202 mm) (Kamman *et al*. 2005). Stafford and Haines (1997) examined Hg content in fillets of nine species of Maine sportfish. Among the species, they found the highest mean Hg concentrations in chain pickerel (n = 8, mean length 436 mm, mean 0.88 µg Hg/g wet weight, range: 0.58 – 1.22 µg/g).

Chain pickerel from Brandy Pond and Eagle Lake were of similar size, but had mean whole-body (Brandy 0.536 µg/g, Eagle 0.428 µg/g, Table 3) and estimated fillet (Brandy 0.929 µg/g, Eagle 0.730 µg/g, Table 3) Hg concentrations higher than the two references cited above.

6.2.2 Endpoints for Fish - Beckvar *et al*. (2005) suggested a whole-body tissue threshold-effect level (t-TEL) of 0.20 µg Hg/g wet weight to be protective of juvenile and adult fish. Whole-body Hg concentrations of 0.3 – 0.7 µg/g and fillet concentrations of 0.5 – 1.2 µg/g may affect biochemical processes, damage cells and tissues, and reduce reproduction in fish (Sandheinrich and Wiener 2011). Chain pickerel from Brandy Pond and Eagle Lake fall within or exceed these suggested effect thresholds.

6.2.3 Endpoints for Birds - A generally accepted reproductive effect endpoint for Hg in bird eggs has not been established. Some researchers have suggested 0.80 µg/g as an endpoint (Heinz 1979, Henny *et al*. 2002), while other investigators and ecological risk assessors use 0.50 µg/g or 1.00 µg/g as ecological effect threshold or screening benchmark values (Scheuhammer *et al*. 2007, RAIS 2009). A dosing study of several avian species by Heinz *et al*. (2009), however, categorized two raptor species (American kestrel *Falco sparverius* and osprey *Pandion haliaetus*) as highly sensitive to methylmercury[a] with LC_{50}s less than 0.25 µg/g. The sensitivity of bald eagles to Hg has not been established, but the Hg content in Brandy Pond eagle eggs was higher than the LC_{50} for sensitive raptors.

Bald eagles using nest territory #075 at Brandy Pond are likely affected by Hg. Chronically elevated Hg concentrations in non-viable eggs and the presence of quantities of pickerel bones in the nest bowl and below the nest indicate that Hg is likely a contributing factor to poor reproductive success at the Brandy Pond territory.

6.2.4 Endpoints for Humans - The FDA action level for methylmercury[b] in fish is 1.00 µg/g (FDA 2000). The EPA has a monthly consumption limit for fish with methylmercury concentrations greater than 0.47 µg/g to 0.94 µg/g (EPA 2000). The action level for Hg in fish fillets in Maine is 0.20 µg/g wet weight (Maine DHHS 2009).

A conversion of mean Hg in chain pickerel fillets from whole-body data (Peterson *et al*. 2007) for Brandy Pond (estimated fillet conc. 0.93 µg/g, Table 3) and Eagle Lake (estimated fillet conc. 0.73 µg/g, Table 3) would allow these fish to be consumed with unrestricted limits under the FDA guidelines. Under the EPA consumption limits, only one meal/month would be allowed with the pickerel from Brandy Pond and Eagle Lake. Under the Maine advisory recommendation, one meal per week of pickerel from either lake would exceed the Hg

[a] Methylmercury may account for nearly all of the total Hg in bird eggs (Schwarzbach *et al*. 2006).

[b] Most of the Hg in fish tissue is comprised of methylmercury (Grieb *et al*. 1990).

threshold. Consumption of forage fish from either area would not exceed FDA and Maine action levels. Under the EPA limits, consumption of forage fish from Brandy Pond and Eagle Lake would be restricted to 8 fish meals/month.

6.3 Water Quality in Brandy Pond. Limited water quality information is available for Brandy Pond and Eagle Lake. Maine DEP has collected water temperature, DO, conductivity, pH, and secchi disk readings in 2003 and 2004 (Knowledgebase 2011). Additional measurements were taken for this investigation using a field-deployed, daily-calibrated, multi-parameter water quality probe. Apparent color was determined in the field by visual comparison with a color wheel scaled in APHA Platinum-Cobalt Units (PCU).

Brandy Pond has tea-colored water with an apparent color value of 35 PCU. Eagle Lake is less colored with an apparent color value of 25 PCU. Among the lakes monitored by the Maine Volunteer Lake Monitoring Program (MVLMP 2011), the mean color was 28 Standard Platinum Units. Conductivity in Brandy Pond and Eagle Lake is low (~ 24 µS/cm). Low conductivity is common in many Maine lakes. The mean specific conductance of 988 Maine lakes was 47 µS/cm (MVLMP 2011). Summer measurements of mean secchi depth in Brandy Pond and Eagle Lake were 2.5 and 3.5 meters, respectively (MVLMP 2011). Mean transparency in 1354 Maine lakes was 4.84 meters (MVLMP 2011). August readings of DO were 7.9 mg/L for Brandy Pond and 7.8 mg/L for Eagle Lake (MVLMP 2011).

6.4 Thirty-Nine Tannery. A review of historical literature indicates that vegetable process tanning rather than chemical (i.e., chromium) tanning was the method used during the operational period of the Thirty-Nine Tannery on Buffalo Stream (BILS 1897, Riley 1935).

Vegetable process tanning using hemlock bark was the widely-used tanning method in Maine during the 1800s. In this process, dry hides were soaked for three to five days in water vats, hung in sweat vaults for another four to eight days, milled to remove hair, grained with a beam knife to remove scurf and any remaining hair, exposed to an acid process or sour liquor for thirty-six hours or more to open pores in the hide, placed in handling vats to remove the acid, and then moved into vats with varying strengths of bark liquor. Tannin is infused into the hide over six to eight months to as much as a year to preserve and firm the skin, and to provide it with weight. Hides were then removed, scrubbed, drained for twenty-four hours, and oiled with cod oil. After three to six days, the oil is absorbed by the skin. The leather is hung to dry for four days to two weeks. The leather is then rolled and thoroughly dried (BILS 1897). No mention of mercury was found in descriptions of the bark tanning process.

It was only after the 1880s that the employment of chromium compounds was instituted in the tanning process, which was a cheaper and quicker method of tanning (Riley 1935). In the early 1900s, leather production moved from northern New England to the northeastern portion of

Massachusetts into communities such as Peabody, Danvers, and Woburn where the chromium tanning process was employed (Riley 1935, Tarr 1987).

Maine tanneries closed in the late 1800s and early 1900s as the hemlock forest and its bark in the surrounding areas was consumed (Riley 1935). The Thirty-Nine Tannery burned and was abandoned in 1906 (Baker and Baker 1972). Based on the historical information, it appears unlikely the Thirty-Nine Tannery was a Hg source for Brandy Pond.

7. Summary and Management Recommendation

To determine if Hg contamination in Brandy Pond bald eagle eggs is related to a former tannery in the watershed, sediments were collected from Buffalo Stream, above and below the location of the former Thirty-Nine Tannery. Fish and sediment were also collected from Brandy Pond and from Eagle Lake, a nearby reference lake. All sediment and fish samples were analyzed for Hg.

There were no significant differences in Hg concentration ($p = 0.086$) or size (length $p = 0.480$, weight ($p = 0.391$) in chain pickerel collected from Brandy Pond and Eagle Lake. Mercury levels in whole-body chain pickerel from Brandy Pond (mean 0.54 µg/g, wet weight) and Eagle Lake (mean 0.43 µg/g) exceed thresholds or guidelines for consumption by humans or the protection of ecological receptors. Forage fish species in both water bodies contained substantially lower Hg concentrations (0.09 µg/g) than pickerel.

Mercury was below analytical detection limits in sediments from the Brandy Pond and Eagle Lake (i.e., < 0.100 µg/g, dry weight). In Buffalo Stream, Hg was below detection limits in sediments collected above the former tannery site and at the detection limit (0.10 µg/g) below the former tannery site. These sediment Hg concentrations would be below sediment quality guidelines for harmful effects. Sediments collected in the lower, deadwater reach of Buffalo Stream, however, were extremely peaty, unconsolidated, and contained high moisture content that negatively influenced data quality.

Based on the results of sediment and fish sampling, and a review of historical literature related to the tanning process in Maine in the 1800s, Brandy Pond does not appear to have a Hg point-source in the watershed. Elevated Hg concentrations in bald eagle eggs at Brandy Pond appear to be the result of adult birds foraging on an upper trophic level fish species (i.e., chain pickerel) with propensity for Hg accumulation in a water body with characteristics suitable for methylation of atmospherically-deposited Hg.

No immediate management recommendation is offered. Maine has an aggressive program to reduce Hg deposition from local sources. Additional efforts may be required, however, at the

national and international level to further reduce atmospheric deposition of Hg into New England from sources outside the region.

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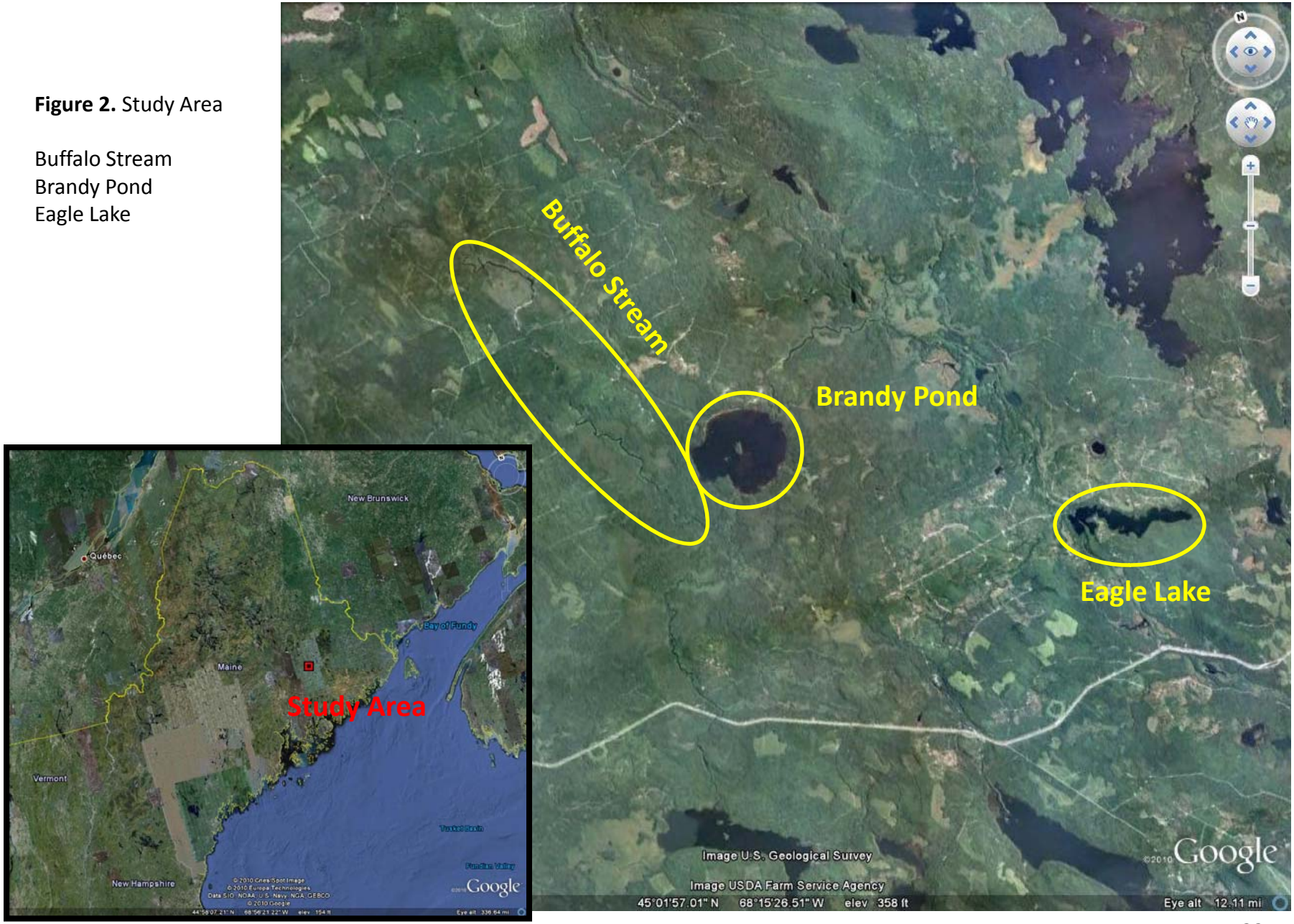
Figure 2. Study Area

Buffalo Stream
Brandy Pond
Eagle Lake



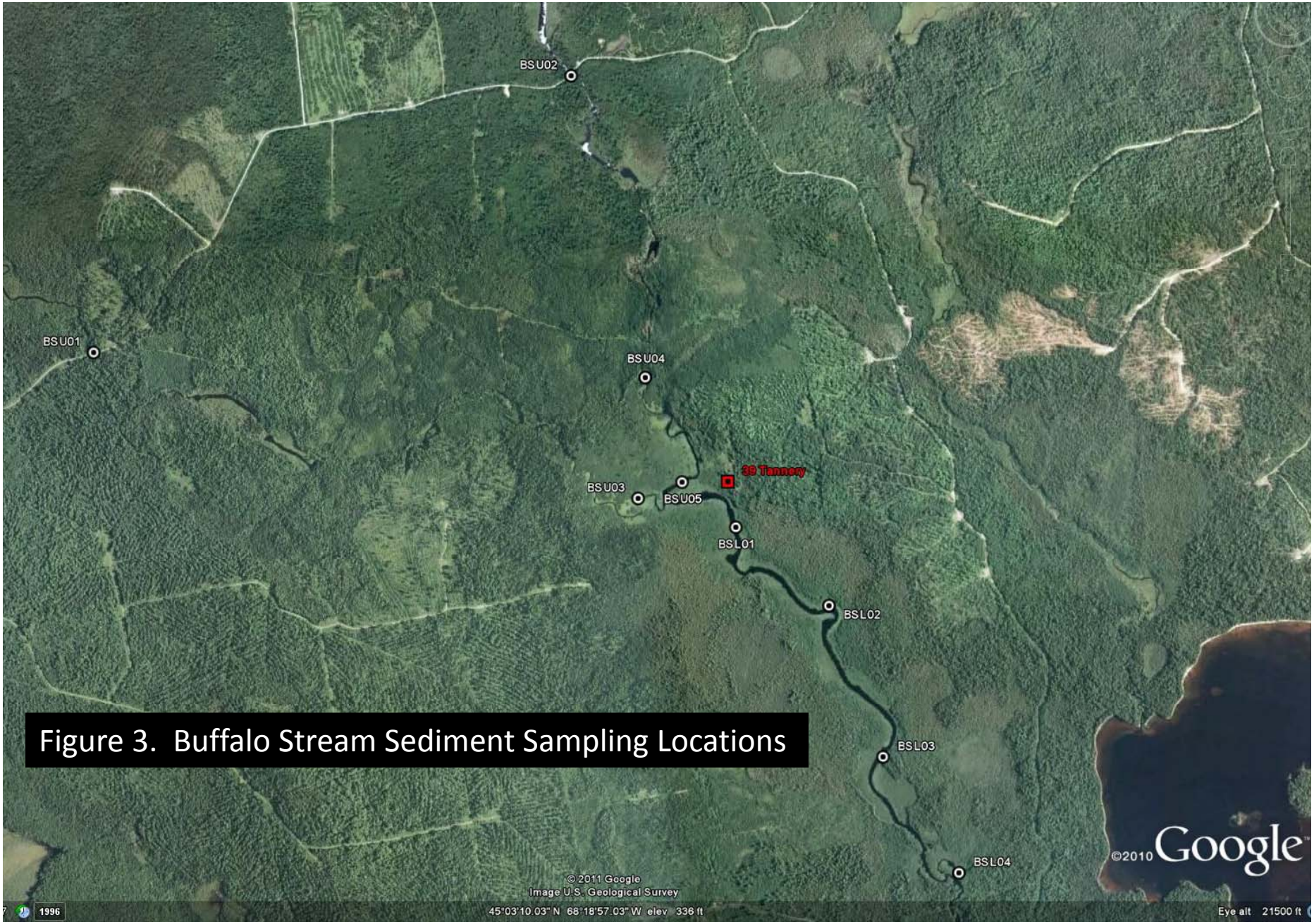


Figure 3. Buffalo Stream Sediment Sampling Locations

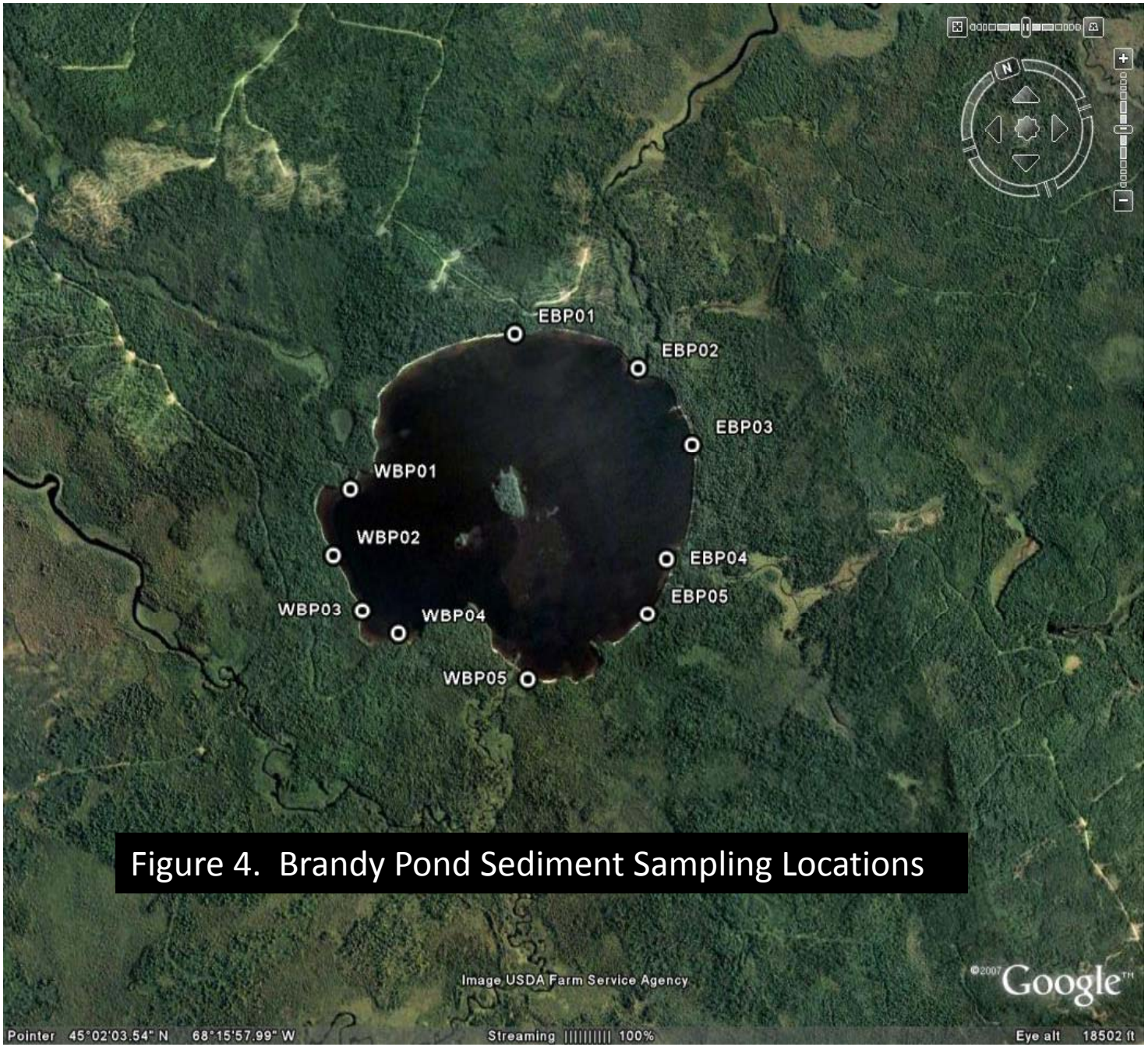


Figure 4. Brandy Pond Sediment Sampling Locations

Figure 5. Eagle Lake Sediment Sampling Locations

Table 1. Sediment sampling locations at Buffalo Stream, Brandy Pond, and Eagle Lake

Sample Number	Location	Collection Date	Sample Weight g	Coordinates Latitude	Coordinates Longitude	Sampling Tool	Sample Description & Comments
BSU01	Buffalo Stream - upper, above tannery	9/5/2009	172	45° 03' 25.8"	068° 20' 57.2"	SS Spoon	Little Buffalo Stream above logging road. Hard bottom. Coarse gravel and sand.
BSU02	Buffalo Stream - upper, above tannery	9/5/2009	188	45° 04' 12.0"	068° 19' 04.6"	SS Spoon	Buffalo Stream above logging road. Hard bottom. Coarse gravel and sand.
BSU03	Buffalo Stream - upper, above tannery	9/5/2009	115	45° 03' 01.5"	068° 18' 48.8"	Ekman	Outlet of Little Buffalo Stream into Buffalo Stream deadwater. Organic, dense peaty mud.
BSU04	Buffalo Stream - upper, above tannery	9/5/2009	156	45° 03' 21.7"	068° 18' 47.1"	Ekman	Outlet of Buffalo Stream into deadwater. Gravel bottom. Coarse sediments.
BSU05	Buffalo Stream - upper, above tannery	9/5/2009	113	45° 03' 04.2"	068° 18' 38.4"	Ekman	Buffalo Stream deadwater. Adjacent to one reported location of tannery. Soft organic peaty mud.
BSL01	Buffalo Stream - lower, below tannery	9/5/2009	106	45° 02' 56.7"	068° 18' 25.7"	Ekman	Buffalo Stream deadwater. 1st sediment sample below reported tannery locations. Soft organic peaty mud.
BSL02	Buffalo Stream - lower, below tannery	9/5/2009	107	45° 02' 43.5"	068° 18' 03.7"	Ekman	Buffalo Stream deadwater. Soft organic peaty mud.
BSL03	Buffalo Stream - lower, below tannery	9/5/2009	112	45° 02' 18.2"	068° 17' 50.9"	Ekman	Buffalo Stream deadwater. Soft organic peaty mud.
BSL04	Buffalo Stream - lower, below tannery	9/5/2009	111	45° 01' 58.9"	068° 17' 33.0"	Ekman	Buffalo Stream deadwater outlet to Brandy Pond. Soft organic peaty mud.
WBP01	Brandy Pond - west shore	8/17/2009	162	45° 02' 23.0"	068° 16' 50.0"	Ekman	Runt Brook inlet. Soft organic sediments.
WBP02	Brandy Pond - west shore	8/17/2009	201	45° 02' 13.1"	068° 16' 59.6"	SS Spoon	Pond shore. Hard bottom. Coarse, cobbly sediments.
WBP03	Brandy Pond - west shore	8/17/2009	209	45° 02' 02.1"	068° 16' 57.0"	SS Spoon	Buffalo Stream connection. Hard bottom. Coarse, cobbly sediments.
WBP04	Brandy Pond - west shore	8/17/2009	195	45° 01' 56.1"	068° 16' 50.0"	SS Spoon	Pond shore. Hard bottom. Coarse, cobbly sediments.
WBP05	Brandy Pond - west shore	8/17/2009	217	45° 01' 40.6"	068° 16' 21.9"	SS Spoon	Outlet to Brandy Stream. Sandy bottom with small cobble.
EBP01	Brandy Pond - east shore	8/17/2009	219	45° 02' 39.0"	068° 15' 56.7"	SS Spoon	Sandy, coarse sediment with mussel shells.
EBP02	Brandy Pond - east shore	8/17/2009	212	45° 02' 25.8"	068° 15' 29.1"	SS Spoon	Guagus Stream inlet. Coarse with small stones and sand.
EBP03	Brandy Pond - east shore	8/17/2009	209	45° 02' 09.8"	068° 15' 22.1"	SS Spoon	Hard bottom. Small gravel with sand.
EBP04	Brandy Pond - east shore	8/17/2009	211	45° 01' 52.3"	068° 15' 37.8"	SS Spoon	Outlet to Indian Brook. Sandy, coarse sediments with vegetation.
EBP05	Brandy Pond - east shore	8/17/2009	231	45° 01' 44.3"	068° 15' 47.0"	SS Spoon	Sandy bottom with small cobble and mussel shells.
EAL01	Eagle Lake	9/18/2009	178	45° 00' 21.3"	068° 11' 10.2"	SS Spoon	Near boat launch. Dug below top vegetation/organic layer. Grey coarse sediment.
EAL02	Eagle Lake	9/18/2009	194	45° 00' 06.2"	068° 10' 59.6"	SS Spoon	Near outlet to Eagle Brook. Coarse gravelly sediment with lots of elliptio present.
EAL03	Eagle Lake	9/18/2009	202	45° 00' 21.9"	068° 10' 54.3"	SS Spoon	Inlet of intermittent stream. Sandy, coarse sediment with mussel shells.
EAL04	Eagle Lake	9/18/2009	204	45° 00' 08.8"	068° 10' 45.7"	SS Spoon	Hard bottom. Coarse, sandy, gravelly sediment.
EAL05	Eagle Lake	9/18/2009	179	45° 00' 16.1"	068° 10' 27.5"	SS Spoon	Dug below soft vegetation/organic layer. Coarse gravelly sediment.

Table 2. Percent moisture, percent solids, grain size, total organic carbon, mercury content, and data quality in sediment samples

Location and Sample Number	Moisture %	Solids %	Grain Size-Clay %	Grain Size-Sand %	Grain Size-Silt %	Total Organic Carbon %	Hg Content µg/g dry weight	Data Quality
Buffalo Stream - Upper Reach (above former tannery site)								
BSU01	33.0	67.0	6	73	21	5.00	< 0.100	A
BSU02	20.4	79.6	0	95	5	0.80	< 0.100	A
BSU03	84.0	16.0	19	16	65	20.40	< 0.100	R
BSU04	37.4	62.6	7	76	17	9.00	< 0.100	A
BSU05	85.1	14.9	17	41	42	24.60	< 0.100	R
Buffalo Stream - Lower Reach (below former tannery site)								
BSL01	90.1	9.9	23	31	46	32.10	0.200	R
BSL02	90.5	9.5	29	30	41	36.90	0.100	R
BSL03	84.4	15.6	19	36	45	26.50	0.100	J
BSL04	76.5	23.5	10	78	12	14.70	< 0.100	R
Brandy Pond - West Shore								
WBP01	39.4	60.6	0	95	5	1.90	< 0.100	A
WBP02	23.2	76.8	0	95	5	0.40	< 0.100	A
WBP03	18.4	81.6	0	97	3	0.30	< 0.100	A
WBP04	21.8	78.2	0	93	7	0.50	< 0.100	A
WBP05	18.5	81.5	0	97	3	0.20	< 0.100	A
Brandy Pond - East Shore								
EBP01	21.1	78.9	0	92	8	0.40	< 0.100	A
EBP02	25.5	74.5	0	96	4	2.30	< 0.100	A
EBP03	13.9	86.1	0	100	0	0.10	< 0.100	A
EBP04	18.5	81.5	0	100	0	0.20	< 0.100	A
EBP05	15.4	84.6	0	100	0	0.20	< 0.100	A
Eagle Lake (reference lake)								
EAL01	15.9	84.1	0	90	10	0.60	< 0.100	A
EAL02	22.6	77.4	0	96	4	1.60	< 0.100	A
EAL03	23.5	76.5	0	95	5	0.60	< 0.100	A
EAL04	20.9	79.1	2	94	4	0.80	< 0.100	A
EAL05	18.6	81.4	0	96	4	0.70	< 0.100	A

µg/g = parts-per-million
Hg concentrations in red and preceded by < symbol indicate non-detects and detection limit

Data Quality: **A** = Accepted (% solids > 30%)
J = Approximated (positive results approximated when % solids ≥ 10% or ≤ 30%)
R = Rejected (non-detects rejected when % solids ≥ 10% or ≤ 30% and positive results rejected when % solids < 10%)

Table 3. Sample metrics and mercury content - chain pickerel

Species	Sample No.	Date of Collection	Length (mm)	Weight (g)	Whole-body Hg Content µg/g wet weight	Estimated Fillet Hg Content µg/g wet weight
Brandy Pond						
Chain Pickerel	BPCP01	8/11/2009	445	560	0.530	0.915
Chain Pickerel	BPCP02	8/11/2009	407	418	0.420	0.715
Chain Pickerel	BPCP03	8/11/2009	402	315	0.640	1.118
Chain Pickerel	BPCP04	8/11/2009	392	351	0.310	0.518
Chain Pickerel	BPCP05	8/11/2009	320	161	0.320	0.536
Chain Pickerel	BPCP06	8/11/2009	361	245	0.490	0.842
Chain Pickerel	BPCP08	8/11/2009	476	571	0.820	1.455
Chain Pickerel	BPCP09	8/11/2009	482	571	0.530	0.915
Chain Pickerel	BPCP10	8/11/2009	446	476	0.670	1.174
Chain Pickerel	BPCP11	8/11/2009	430	419	0.630	1.100
Mean			416.1	408.7	0.536	0.929
StdDev			50.5	141.6	0.160	0.294
Eagle Lake						
Chain Pickerel	EACP01	8/13/2009	489	702	0.500	0.860
Chain Pickerel	EACP02	8/13/2009	454	529	0.420	0.715
Chain Pickerel	EACP03	8/13/2009	511	661	0.530	0.915
Chain Pickerel	EACP04	8/13/2009	450	538	0.430	0.733
Chain Pickerel	EACP05	8/13/2009	496	661	0.570	0.989
Chain Pickerel	EACP06	8/13/2009	461	522	0.430	0.733
Chain Pickerel	EACP07	8/13/2009	411	354	0.420	0.715
Chain Pickerel	EACP08	8/13/2009	387	302	0.280	0.465
Chain Pickerel	EACP09	8/13/2009	329	223	0.410	0.697
Chain Pickerel	EACP10	8/13/2009	355	235	0.290	0.482
Mean			434.3	472.7	0.428	0.730
StdDev			61.6	181.2	0.093	0.167

µg/g = parts-per-million
StdDev = standard deviation
Estimated Hg fillet content derived from regression formula in Peterson *et al* . 2007

Table 4. Sample metrics and mercury content - forage fish

Species	Sample No.	Date of Collection	Length (mm)	Total Sample Weight (g)	Hg Content µg/g wet weight
Brandy Pond					
Yellow Perch	BPYW01	8/11/2009	277	256	0.280
Yellow Perch	BPYW02-C	8/27/2010	4.5 Ave.	13.5	0.070
Yellow Perch	BPYW03-C	8/27/2010	4.5 Ave.	12.6	0.063
Yellow Perch	BPYW04-C	8/27/2010	4.5 Ave.	12.3	0.078
Yellow Perch	BPYW05-C	8/27/2010	4.5 Ave.	11.7	0.068
Yellow Perch	BPYW06-C	8/27/2010	4.5 Ave.	11.3	0.060
Yellow Perch	BPYW07-C	8/27/2010	4.5 Ave.	12.7	0.064
Yellow Perch	BPYW08-C	8/27/2010	4.5 Ave.	10.8	0.071
Pumpkinseed	BPPU1	8/26/2009	146	64	0.070
Pumpkinseed	BPPU2	8/26/2009	152	70	0.080
Redbreast Sunfish	BPBG1	8/26/2009	137	56	0.099
Redbreast Sunfish	BPBG2	8/26/2009	114	31	0.100
Mean					0.092
Eagle Lake					
Yellow Perch	EAYW01	10/2/2009	210	109	0.190
Yellow Perch	EAYW02	10/2/2009	196	77	0.140
Yellow Perch	EAYW03	10/2/2009	151	38	0.091
Yellow Perch	EAYW04	10/2/2009	157	37	0.100
Yellow Perch	EAYW05	10/2/2009	150	36	0.074
Yellow Perch	EAYW06	10/2/2009	144	31	0.089
Yellow Perch	EAYW07	10/2/2009	139	30	0.060
Yellow Perch	EAYW08	10/2/2009	132	27	0.062
Yellow Perch	EAYW09	10/2/2009	138	29	0.098
Yellow Perch	EAYW10	10/2/2009	139	31	0.060
Mean			155.6	44.5	0.096
StdDev			26	26.9	0.041

µg/g = parts-per-million
Sample numbers ending in C indicate composites of 10 fish. All other samples are individual fish.
StdDev = standard deviation