U.S. Fish and Wildlife Service
Maine Field Office
Special Project Report: FY04-MEFO-2-EC

Contaminant Survey of
Sunkhaze Stream and Baker Brook

Sunkhaze Meadows National Wildlife Refuge
Milford, Maine

April 2004

Mission Statement
U.S. Fish and Wildlife Service

"Our mission is working with others to conserve, protect, and enhance the nation's fish and wildlife and their habitats for the continuing benefit of the American people."

Suggested citation: Mierzykowski S.E. and K.C. Carr. 2004. Contaminant Survey of Sunkhaze Stream and Baker Brook - Sunkhaze Meadows National Wildlife Refuge. USFWS. Maine Field Office. Spec. Proj. Rep. FY04-MEFO-2-EC. Old Town, ME.

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Sunkhaze Meadows National Wildlife Refuge Milford, Maine

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April 2004

ABSTRACT

In 1993 a screening-level contaminant survey of the Sunkhaze Meadows National Wildlife Refuge was conducted by the Maine Field Office of the U.S. Fish and Wildlife Service. Elevated levels of polychlorinated biphenyls (PCBs) were found in a Baker Brook sediment sample (0.78 parts per million, ppm) and high chromium levels were found in chain pickerel (10.59 ppm) and yellow perch (13.20 ppm) samples from Sunkhaze Stream. In 2001, a follow-up contaminant survey was conducted using additional locations along these watercourses to validate the earlier results and to determine the extent of contamination in fish and sediments.

Between August and September 2001, eighteen wholebody composite fish samples and five sediment samples were collected from Sunkhaze Meadows National Wildlife Refuge. Four composite samples and one individual sample of wholebody chain pickerel (*Esox niger*), and five composite samples of wholebody yellow perch (*Perca flavescens*) were collected from five stations on Sunkhaze Stream. In Baker Brook, sediments samples were collected from five locations. Eight composite samples of wholebody brown bullhead (*Ameriurus nebulosus*) were also collected from four Baker Brook sites co-located with sediment collection locations. Bullheads were not available at the fifth sediment collection site.

Fish and sediment samples were analyzed for Total PCB, 21 organochlorine compounds, chromium, and 20 other inorganic elements. The contaminants of concern in the 1993 collections (i.e., PCBs in sediment and chromium in fish tissue), were not found at elevated levels in the 2001 collections. In 2001, fish tissue samples in Sunkhaze Stream and Baker Brook did not contain detectable levels of Total PCB or chromium. No other organochlorine compound or inorganic elements were found at elevated concentrations in fish tissue during the follow-up study. In 2001 collections in Baker Brook, Total PCB was not detected in the five sediment samples. Chromium was detected in Baker Brook sediments at low levels, but the element was not detected in any fish samples from the brook.

An examination of sediment data suggests that the former Milford Municipal Landfill, closed since 1995, may be influencing Baker Brook. Of the 21 inorganic elements in the analytical scan, ten elements exhibited their highest concentrations in the Baker Brook sediment collection site approximately one-half mile downstream of the former landfill - Baker 4. Of the ten elements, however, only cadmium (1.18 ppm) occurred at an elevated concentration, and at a level only slightly above the threshold effect concentration (TEC; cadmium TEC is 0.99 ppm). The only other element to occur above the respective sediment TEC was arsenic (TEC 9.79 ppm), which was found at 10.2 ppm at location Baker 5 at the confluence of Baker Brook and Sunkhaze Stream.

PREFACE

This report summarizes analytical results of fish and sediment samples collected on two watercourses within the Sunkhaze Meadows National Wildlife Refuge in Milford, Maine. Analytical work for this survey was completed under Patuxent Analytical Control Facility Catalog Number 510002 - Purchase Orders No. 94420-02-Y067 (Organochlorines) and 94420-02-Y068 (Inorganics).

Questions, comments, and suggestions related to this report are encouraged. Written inquiries should refer to Report Number FY04-MEFO-2-EC and be directed to:

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ACKNOWLEDGEMENTS

Sunkhaze Meadows National Wildlife Refuge personnel that provided assistance during fish collections at Sunkhaze Stream Station 5, the Thibodeau Cabin, are Jason Lyle and Heath Martin (summer interns) and John Meister and Wesley Hatch (forestry technicians). Their assistance is greatly appreciated.

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1. INTRODUCTION

Sunkhaze Meadows National Wildlife Refuge (NWR) is located in the Town of Milford, Penobscot County, Maine. The Refuge is bisected by Sunkhaze Stream and includes extensive tracts of regionally unique peat bogs. The area surrounding the Refuge is largely undeveloped timberland except for two old landfills that border the federal parcel. The former Town of Milford Municipal Landfill along the Refuge's southern boundary and adjacent to Baker Brook, was closed and capped in 1995. The Fort James Corporation landfill, located along the northern edge of the Refuge and north of Sunkhaze Stream, was used to dispose of paper mill sludge. The Fort James Landfill was closed and capped in 1996.

In 1993, a limited screening-level contaminant survey was conducted on Sunkhaze Meadows NWR (Mierzykowski *et al.* 2000). Three pairs of surface water - sediment samples were collected from each of the three major watercourses within the Refuge. Fish samples were collected from three reaches on Sunkhaze Stream. All sediment samples were analyzed for inorganic elements, organophosphate compounds and organochlorine compounds. Fish were analyzed for the same contaminant suites except organophosphates, which do not persist in fish tissue. Results from the screening-level survey suggested elevated levels of total PCBs in sediments in Baker Brook and elevated concentrations of chromium in fish tissue from Sunkhaze Stream.

2. STUDY PURPOSES

The purposes of this follow-up study were to:

Validate fish and sediment contaminant results from the 1993 study and,

Determine the extent of PCB and chromium contamination in 2001.

3. STUDY AREAS

3.1 Sunkhaze Meadows NWR - The 3,778-ha (9,337 ac) Milford Unit of the Sunkhaze Meadows NWR encompasses nearly 8 km (~5 mi) of Sunkhaze Stream and another 19 km (~12 mi) of tributary streams including Buzzy Brook, Little Buzzy Brook, Johnson Brook, Birch Stream, Little Birch Stream, and Baker Brook. The streams of the Refuge that pass through the open expanses of Sunkhaze Meadows and Spencer Meadows support fish species such as smallmouth bass (*Micropterus dolomieu*) and chain pickerel (*Esox niger*), while the smaller tributaries passing through forested or shrubby areas provide habitat for coldwater fish species like brook trout (*Salvelinus fontinalis*) and cusk (*Lota lota*; Rupp 1955, Smithwood and McKeon 1999).

Sunkhaze Meadows NWR is within the USGS Lower Penobscot hydrologic unit #01020005. The waters of the Refuge tend to be soft (specific conductance 28-43 µS/cm; USFWS, unpublished data) and highly-colored (82-260 Platinum-Cobalt Units; UMaine-Water Research Institute, unpublished data). Although a bog habitat, the waters of the Refuge do not appear to be highly acidic. In August 1997, pH values ranged from 6.05 to 7.0 (Smithwood and McKeon

1999). In May 1999, pH values in 5 Refuge streams ranged from 6.73 to 7.67 (UMaine-Water Research Institute, unpublished data).

The Refuge follow-up contaminant survey was conducted on two waterways - Baker Brook and Sunkhaze Stream. Baker Brook was selected because of potentially elevated levels of PCBs in sediment and surface water found during the 1993 survey. Sunkhaze Stream was included in the 2001 survey because the previous collection (1993) indicated elevated chromium levels in yellow perch and chain pickerel.

3.2 Sunkhaze Stream - Sunkhaze Stream is approximately 22-km (~13 mi) in length. It begins in Township 32 MD and flows southerly then westerly through Sunkhaze Meadows NWR before draining into the Penobscot River. The Sunkhaze Stream reach on refuge land is approximately 13-km (~8 mi). Indian Brook, Wiley Brook, and Halfway Brook contribute flow to Sunkhaze Stream before the stream enters the Refuge. Above the Stud Mill Road Bridge, Sunkhaze Stream is typical of many Maine streams; narrow (3 m or ~10 ft), braided, and densely bordered by alder (*Alnus* sp.). On the Refuge, the riparian characteristics of Sunkhaze Stream are considerably different from its headwaters. The stream widens considerably (average width 30-m (~100 ft)) as it flows through the 0.25 to 0.50-km wide sedge-dominated expanses of Sunkhaze Meadows and Spencer Meadows.

3.3 Baker Brook - Baker Brook is a meandering 10-km (~6 mi) stream that originates in the Town of Bradley near Maine Public Reserve Land (Number 26 Swamp). Baker Brook flows from south to north for 4-km (~2.5 mi) within Refuge boundaries, to its confluence with Sunkhaze Stream. At the County Road bridge, the brook is bordered by scrub-shrub vegetation dominated by speckled alder (*Alnus rugosa*). Within the Refuge, the brook courses through sedge tussocks and small, narrow stands of red maple (*Acer rubrum*). A vegetation transect established west of Baker Brook in 1996 (Famous and Famous 1997) includes the following species: spatterdock (*Nuphar variegatum*), pickerel weed (*Pontederia cordata*), uptight sedge (*Carex stricta*), sweet gale (*Myrica gale*), large cranberry (*Vaccinium macrocarpon*), sphagnum (*Sphagnum* spp.), sheep laurel (*Kalmia angustifolia*), leatherleaf (*Chamaedaphne calyculata*), and black spruce (*Picea mariana*). Baker Brook supports several beaver (*Castor canadensis*) colonies, and over twenty of their dams may exist on the watercourse in some years.

Figure 1.

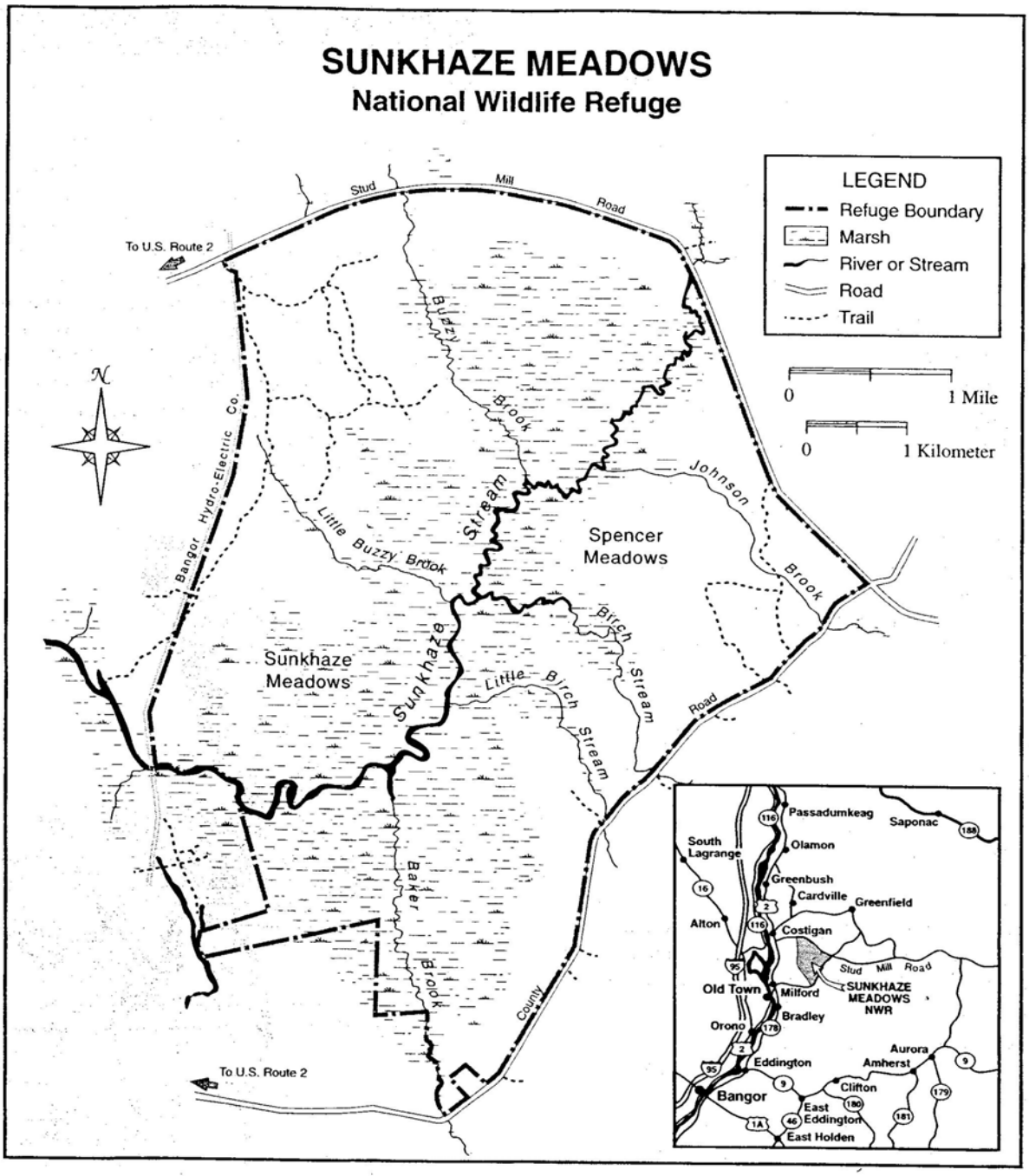
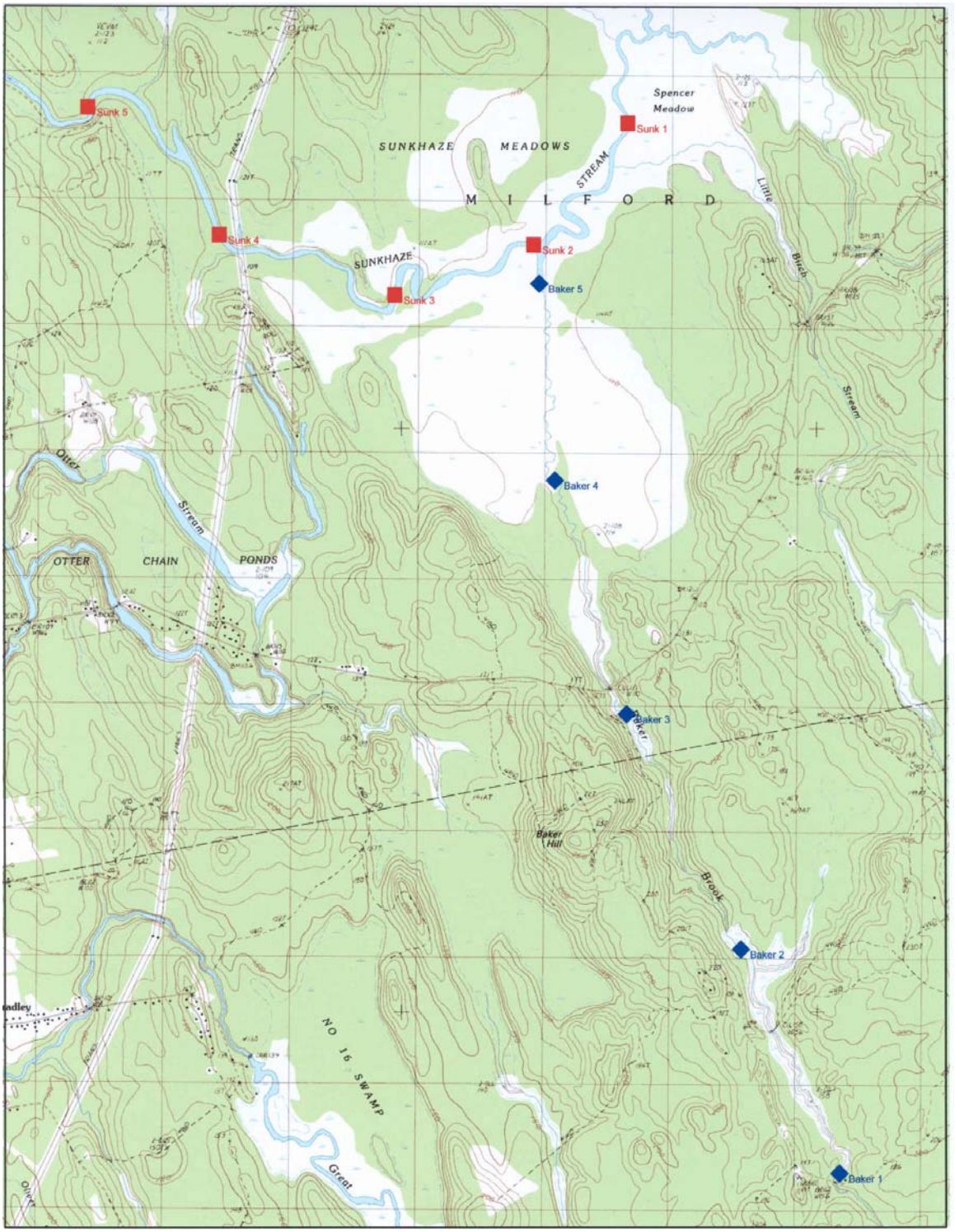

SUNKHAZE MEADOWS
National Wildlife Refuge
LEGEND
Refuge Boundary
Marsh
River or Stream
Road
Trail
0 1 Mile
0 1 Kilometer
N
To U.S. Route 2
Stud Mill Road
Buzzy Brook
Bangor Hydro-Electric Co.
Little Buzzy Brook
Stream
Johnson Brook
Spencer Meadows
Sunkhaze Meadows
Sunkhaze
Little Birch Stream
Birch Stream
Road
Baker Brook
County
To U.S. Route 2
Passadumkeag
Saponac
South Lagrange
Olamon
Greenbush
Cardville
Greenfield
Alton
Costigan
Stud Mill Road
Old Town
Milford
SUNKHAZE MEADOWS NWR
Bradley
Orono
Aurora
Amherst
Eddington
Clifton
Bangor
East Eddington
East Holden

Figure 2. Collection sites at Sunkhaze Meadows NWR



4. METHODS

4.1 Fish and Sediment Collections - Fish and sediment collections for the study occurred in August and September 2001. Fish were collected by angling, with modified minnow traps, or with experimental gill nets (1-hour sets) under a Scientific Collectors Permit issued by the Maine Department of Inland Fisheries and Wildlife. Each collected fish was measured (centimeters) and weighed (grams). Individual, wholebody fish were wrapped in aluminum foil (dull side towards sample), labeled, placed in plastic zip-loc bags, and frozen. Sediments were collected with a pole-mounted Ekman dredge. Contents of the dredge were placed in a stainless steel bucket. A stainless steel scoop was used to collect the top 2-cm of sediments from the grab. Sediments were placed in contaminant-free glass jars with teflon lids. Prior to sampling or processing, sediment sampling gear and fish measuring tools were washed with Alconox®, rinsed with tap water, and rinsed with deionized water.

For Sunkhaze Stream fish, five collection reaches (100 to 200 meters in length) separated at 2-km intervals were established on the stream. One reach was established 2-km above the confluence with Baker Brook as a background location (Sunkhaze 1). One reach was located at the confluence with the Baker Brook (Sunkhaze 2), and the others at 2-km intervals downstream. The last reach, Sunkhaze 5, was located adjacent to the Thibodeau cabin. At each Sunkhaze Stream location, yellow perch (*Perca flavescens*) and chain pickerel (*Esox niger*) were collected. Most fish were caught by angling; two pickerel and one perch were captured in gill nets. Sunkhaze Stream fish samples were combined to form composites of two or three individuals of the same species and of similar size (Table 2).

Similarly, for fish and sediment collection on Baker Brook, five locations were established at 2-km intervals along the brook. The first collection point was established at the Baker Brook and Sunkhaze Stream confluence (Baker 5), and the others at 2-km intervals on the brook upstream from the confluence. Baker 4 was located downstream of the former Town of Milford landfill and Baker 3, 2 and 1 were situated above the landfill. Baker 2 and 1 were background locations. Two 500-ml jars of sediment were collected at each Baker Brook location. Baker Brook fish were collected in modified minnow traps baited with canned tuna. Brown bullhead (*Ameiurus nebulosus*) were collected at all locations except Baker 1, where no fish were found. Three or two similar-sized individuals from each Baker Brook location were used to make two composite bullhead samples (Table 3).

4.2 Laboratory Analytical Methods - Fish and sediment samples were analyzed for organochlorine pesticides, polychlorinated biphenyls (Total PCB), and inorganic elements. Moisture content and percent lipids were measured in fish samples. Sediments were measured for percent solids, grain size, and total organic content.

4.2.1 Organochlorines - The organochlorine scan performed by the Mississippi State Chemical Laboratory (MSCL) included the following 22 compounds: HCB (hexachlorobenzene), Total PCB, *alpha* BHC (hexachlorocyclohexane), *beta* BHC, *delta* BHC, *gamma* BHC (lindane), *alpha* chlordane, *gamma* chlordane, oxychlordane, *cis*-nonachlor, *trans*-nonachlor, dieldrin, endrin, heptachlor epoxide, mirex, *o,p'*-DDD, *o,p'*-DDE, *o,p'*-DDT, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, and toxaphene. The analytical methods used by MSCL are listed on

pages 23 through 27 of Appendix A.

4.2.2 Inorganic elements - The inorganics scan performed by the Trace Element Laboratory (TERL) at Texas A&M University included the following 24 elements: aluminum, arsenic, boron, barium, beryllium, cadmium, cobalt, chromium, copper, iron, mercury, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, sulphur, selenium, strontium, titanium, vanadium, and zinc. The analytical methods used by TERL are listed on pages 29 through 41 of Appendix B.

Table 1. Coordinates of collection locations

Location - Types of Samples	**Latitude**	**Longitude**
Baker 1 - Sediment	N44^{o} 54' 17"	W068^{o} 32' 22"
Baker 2 - Sediment and Fish (brown bullhead)	N44^{o} 55' 15"	W068^{o} 32' 56"
Baker 3 - Sediment and Fish (brown bullhead)	N44^{o} 56' 15"	W068^{o} 33' 38"
Baker 4 - Sediment and Fish (brown bullhead)	N44^{o} 57' 16"	W068^{o} 34' 04"
Baker 5 - Sediment and Fish (brown bullhead)	N44^{o} 58' 16"	W068^{o} 34'10"
Sunkhaze 1 - Fish (chain pickerel, yellow perch)	N44^{o} 58' 48"	W068^{o} 33' 37"
Sunkhaze 2 - Fish (chain pickerel, yellow perch)	N44^{o} 58' 17"	W068^{o} 34' 11"
Sunkhaze 3 - Fish (chain pickerel, yellow perch)	N44^{o} 58' 04"	W068^{o} 35' 02"
Sunkhaze 4 - Fish (chain pickerel, yellow perch)	N44^{o} 58' 19"	W068^{o} 36' 05"
Sunkhaze 5 - Fish (chain pickerel, yellow perch)	N44^{o} 58' 52"	W068^{o} 36' 52"

Table 2. Sunkhaze Stream - Fish Metrics by Composite

Species	Length (cm)	Weight (g)	Collection Date	Composite Sample No.
Sunkhaze 1 (2 km Upstream of Baker Brook Confluence)				
Yellow Perch	22.0	142	8/3/2001	Sunk1-YwP
Yellow Perch	26.9	250	8/3/2001	
Yellow Perch	23.7	186	8/6/2001	
		578		
Chain Pickerel	54.6	965	8/3/2001	Sunk1-CP
Chain Pickerel	53.9	1080	8/3/2001	
Chain Pickerel	56.7	958	8/6/2001	
		3003		
Sunkhaze 2 (Baker Brook/Sunkhaze Stream Confluence)				
Yellow Perch	27.4	239	7/30/2001	Sunk2-YwP
Yellow Perch	25.1	189	8/1/2001	
Yellow Perch	26.3	223	8/1/2001	
		651		
Chain Pickerel	54.4	636	7/30/2001	Sunk2-CP
Chain Pickerel	48.5	531	7/30/2001	
Chain Pickerel	47.0	699	8/1/2001	
		1866		
Sunkhaze 3 (Beaver Dam)				
Yellow Perch	18.9	78	8/6/2001	Sunk3-YwP
Yellow Perch	19.6	85	8/6/2001	
Yellow Perch	16.8	56	8/6/2001	
		219		
Chain Pickerel	28.3	131	8/6/2001	Sunk3-CP
Chain Pickerel	39.2	347	8/8/2001	
Chain Pickerel	36.9	272	8/8/2001	
		750		
Sunkhaze 4 (Powerline)				
Yellow Perch	23.9	158	8/9/2001	Sunk4-YwP
Yellow Perch	23.9	162	8/9/2001	
Yellow Perch	23.5	170	8/9/2001	
		490		
Chain Pickerel	41.6	447	8/2/2001	Sunk4-CP
Chain Pickerel	50.3	727	8/9/2001	
Chain Pickerel	36.7	256	8/9/2001	
		1430		

Table 2. Sunkhaze Stream - Fish Metrics by Composite (continued)

Species	Length (cm)	Weight (g)	Collection Date	Composite Sample No.
Sunkhaze 5 (Thibodeau Cabin)				
Yellow Perch	21.6	121	8/2/2001	Sunk5-YwP
Yellow Perch	21.0	114	8/9/2001	
Yellow Perch	23.1	166	8/9/2001	
		401		
Chain Pickerel	27.1	117	8/9/2001	Sunk5-CP
Chain Pickerel	31.1	192	7/12/2002	
		309		

Table 3. Baker Brook - Fish Metrics by Composite

Species	Length (cm)	Weight (g)	Collection Date	Composite Sample No.
Baker 5 (Confluence of brook and Sunkhaze Stream)				
Brown Bullhead	16.6	54	9/19/2001	Bk5-BH-1
Brown Bullhead	17.0	57	9/19/2001	
Brown Bullhead	16.9	55	9/19/2001	
		166		
Brown Bullhead	17.6	58	9/19/2001	Bk5-BH-2
Brown Bullhead	17.1	58	9/19/2001	
Brown Bullhead	16.7	57	9/19/2001	
		173		
Baker 4 (Downstream of Former Milford Municipal Landfill)				
Brown Bullhead	16.6	56	10/11/2001	Bk4-BH-1
Brown Bullhead	15.7	48	10/11/2001	
		104		
Brown Bullhead	18.0	71	10/11/2001	Bk4-BH-2
Brown Bullhead	17.7	66	10/11/2001	
Brown Bullhead	17.8	73	10/11/2001	
		210		
Baker 3 (Immediately Upstream of County Road Bridge)				
Brown Bullhead	17.5	75	10/3/2001	Bk3-BH-1
Brown Bullhead	17.9	70	10/4/2001	
Brown Bullhead	17.5	67	10/4/2001	
		212		
Brown Bullhead	16.3	55	10/3/2001	Bk3-BH-2
Brown Bullhead	16.2	55	10/3/2001	
Brown Bullhead	16.2	53	10/4/2001	
		163		
Baker 2 (2 km Downstream from Snowmobile/ATV Bridge)				
Brown Bullhead	16.0	50	9/24/2001	Bk2-BH-1
Brown Bullhead	16.5	53	9/24/2001	
Brown Bullhead	16.2	49	9/24/2001	
		152		
Brown Bullhead	18.0	74	9/24/2001	Bk2-BH-2
Brown Bullhead	19.6	87	9/24/2001	
		161		

5. ANALYTICAL RESULTS

Analytical results are summarized below. Laboratory results are reported in the appendices in micrograms per gram dry weight and wet weight. To facilitate comparisons with other studies and datasets, fish analytical results in the text and tables of this report are presented in micrograms per gram (µg/g = parts-per-million) on a **wet weight basis**. For the same reasons, sediment results are presented in this report in milligrams per kilogram (mg/kg = parts-per-million) on a **dry weight basis**.

5.1 Organochlorine compounds

5.1.1 Sunkhaze Stream - None of the 22 organochlorine compounds included in the 2001 analytical scan were found above detection limits in Sunkhaze Stream chain pickerel or yellow perch composite tissue samples.

5.1.2 Baker Brook - Except for one bullhead composite sample from Baker Brook Station 2 that had a detection of 0.015 µg/g, wet weight, of p,p'-DDE, none of the organochlorine compounds in the analytical scan were found above detection limits in Baker Brook fish samples. None of the 22 organochlorine compounds included the analytical scan were detected in Baker Brook sediments.

5.2 Inorganic Elements. Sixteen inorganic elements were detected in all fish tissue samples, while eight elements (As, B, Be, Co, Cr, Mo, Ni, V) were not detected in any tissue samples (Tables 4, 5, and 6). Twenty-one inorganic elements were detected in Baker Brook sediment samples (Table 7).

5.2.1 Sunkhaze Stream and Baker Brook Fish - All concentrations in fish tissue are reported in µg/g (parts-per-million) on a wet-weight basis.

Aluminum (Al) - Mean Al concentrations were similar between chain pickerel (14.3 µg/g) and brown bullhead (13.0 µg/g) with greater variation among samples appearing in chain pickerel. With the exception of one sample, yellow perch composites had a narrow range of Al levels between 12.4 µg/g and 13.2 µg/g.

Barium (Ba) - Barium concentrations were similar among the three species sampled: chain pickerel mean 0.45 µg/g, yellow perch mean 0.45 µg/g, and brown bullhead mean 0.49 µg/g.

Cadmium (Cd) - Among all fish composite samples, Cd ranged from 0.01 µg/g to 0.04 µg/g.

Copper (Cu) - Mean Cu concentrations were highest in brown bullhead (0.67 µg/g) and lowest in yellow perch (0.39 µg/g). The mean Cu level in chain pickerel was 0.47 µg/g.

Iron (Fe) - Iron levels were substantially higher in brown bullhead composites (mean 38.3 µg/g) than yellow perch (mean 16.1 µg/g) or chain pickerel (mean 12.2 µg/g) composites.

Mercury (Hg) - Chain pickerel samples had a mean Hg level of 0.53 µg/g (range: 0.30 - 0.94

µg/g). Average Hg concentrations in yellow perch and brown bullhead composite samples were 0.22 µg/g and 0.20 µg/g, respectively.

Manganese (Mn) - The mean Mn concentration in chain pickerel samples was 6.93 µg/g. In yellow perch, the average was 10.8 µg Mn/g. Bullhead composites exhibited the lowest mean 5.89 µg/g and, among the three species, and the widest range of Mn concentrations (2.83 µg/g - 9.91 µg/g).

Sodium (Na) - Mean Na levels in the three study species were 957 µg/g in brown bullhead, 994 µg/g in yellow perch, and 1198 µg/g in chain pickerel. This element was not included in the 1993 catalog.

Phosphorus (P) - Phosphorus was highest in brown bullhead (mean 8800 µg/g) with decreasing concentrations in chain pickerel (mean 7341 µg/g) and brown bullhead (mean 5339 µg/g). This element was not included in the 1993 catalog.

Lead (Pb) - Mean Pb levels in brown bullhead and yellow perch samples were identical (0.10 µg/g) with similar standard deviations. Lead levels in chain pickerel samples (mean 0.04 µg/g) were half the concentrations found in bullhead and perch.

Sulphur (S) - The lowest S concentration was detected in a brown bullhead composite sample (1477 µg/g) and the highest (2357 µg/g) occurred in a yellow perch sample. Mean S levels among the three species were 1543 µg/g for brown bullhead, 1986 µg/g for chain pickerel, and 2248 µg/g for yellow perch. This element was not included in the 1993 catalog.

Selenium (Se) - Mean Se levels in chain pickerel (0.17 µg/g) and brown bullhead (0.16 µg/g) were similar. Higher Se concentrations were found in yellow perch composite samples, range: 0.21 µg/g - 0.27 µg/g.

Strontium (Sr) - Yellow perch and brown bullhead composite samples had the same mean Sr level of 18 µg/g. In chain pickerel samples, the mean was 14.8 µg Sr/g.

Titanium (Ti) - Among the three species examined, yellow perch exhibited the highest Ti level (0.31 µg/g) followed by chain pickerel (0.24 µg/g) and brown bullhead (0.18 µg/g). This element was not included in the 1993 catalog.

Zinc (Zn) - Zinc was substantially higher in chain pickerel (mean 57.9 µg/g) samples than yellow perch (15.6 µg/g) or brown bullhead (mean 14.6 µg/g) composite samples.

5.2.2 Baker Brook Sediments - All inorganic element concentrations in sediments are reported in mg/kg (parts-per-million) on a dry-weight basis.

Aluminum (Al) - The mean Al concentration in sediments among the five locations was 9168 mg/kg with the highest level occurring in the collection location downstream of the landfill, Baker 4 (12200 mg/kg), and the lowest level in one of the off-refuge upstream locations, Baker 2 (5280 mg/kg).

Arsenic (As) - The highest As concentration was found in sediments at the confluence of Baker Brook and Sunkhaze Stream (Baker 5, 10.2 mg/kg). Arsenic was detected below 5 mg/kg in the other four locations (range: 2.12 mg/kg - 4.76 mg/kg).

Boron (B) - Boron was detected at only one sediment location, Baker 5 (3.26 mg/kg) - the confluence of the two study watercourses.

Barium (Ba) - Barium was found at the highest concentration below the former Milford Landfill (Baker 4 at 57.9 mg/kg). Barium levels tended to be lower in sediments from the upper reaches of Baker Brook than the lower reaches. The mean for all locations was 41.9 mg Ba/kg.

Beryllium (Be) - Beryllium concentrations at the most upstream sediment location (Baker 1) and below the landfill site (Baker 4) were identical (0.34 mg/kg). The highest Be level occurred at Baker 5 (0.43 mg/kg).

Cadmium (Cd) - The highest Cd sediment level was detected downstream of the landfill (Baker 4 at 1.18 mg/kg). The mean concentration of the five locations was 0.54 mg Cd/kg.

Cobalt (Co) - Similar to cadmium, Co was also highest at sediment location Baker 4. The Co range among the five Baker Brook sites was 1.92 mg/kg to 7.66 mg/kg (mean 4.48 mg/kg).

Chromium (Cr) - The mean Cr level in sediment was 14.5 mg/kg and the range was 11.6 mg/kg (Baker 2) to 18.3 mg/kg (Baker 4).

Copper (Cu) - Copper sediment concentrations at the confluence of Baker Brook and Sunkhaze Stream (14.7 mg/kg at Baker 5) were more than double the mean (6.3 mg/kg) and nearly twice as high as next highest location (Baker 4, 7.4 mg/kg). Copper concentrations in upstream sediment locations Baker 1, 2, and 3, were one-half to four times less than the levels found downstream.

Iron (Fe) - Iron exhibited no discernable pattern among the five sediment locations on Baker Brook. The mean Fe concentration in sediment samples was 6774 mg/g (range: 4770 - 8760 mg/kg).

Mercury (Hg) - The mean Hg concentration (0.16 mg/kg) north of the County Road (i.e., Baker 4 and 5) was twice as high as the sediment sites in the upper reaches of the brook (Baker 1, 2 and 3; mean 0.05 mg/kg, range: 0.03 - 0.08 mg/kg).

Magnesium (Mg) - Magnesium concentrations followed a bell curve along the collection reach. The highest concentration was found at the middle location (Baker 3, 2870 mg/kg) and lowest at the collection sites forming the ends of the sampling reach (1310 mg/kg @ Baker 1 and 1650 mg/kg @ Baker 5).

Manganese (Mn) - The lowest Mn level was found in the upgradient sediment sampling location, Baker 1 (62 mg/kg). The highest concentration was detected at Baker 3 (334 mg/kg), upstream from the County Road.

Molybdenum (Mo) - Molybdenum was detected at only one sediment location, Baker 5 the confluence of Baker Brook and Sunkhaze Stream (1.02 mg/kg).

Nickel (Ni) - The mean Ni sediment concentration was 12.1 mg/kg with a relatively narrow range of 7.0 mg/kg (Baker 1) to 13.5 mg/kg (Baker 4).

Lead (Pb) - Lead at Baker 3 (27.5 mg/kg) was twice as high as the mean (12.9 mg/kg). The five collection locations did not reveal any pattern of Pb contamination along the reach.

Selenium (Se) - Selenium was lowest in the sediment location above the County Road (Baker 3, 0.14 mg/kg), slightly higher in the upstream locations (0.20 mg/kg @ Baker 1, 0.24 mg/kg @ Baker 2) and highest in the lower parts of the reach (0.67 mg/kg @ Baker 4, 0.90 mg/kg @

Strontium (Sr) - Strontium in sediments was highest at the end of the reach (Baker 5, 91.8 mg/kg) and lowest at the beginning of the reach (Baker 1, 11.4 mg/kg). The mean Sr concentration was 38.4 mg/kg.

Titanium (Ti) - As with iron and magnesium, Ti was highest at location Baker 3 (143.0 mg/kg), the sediment location above the County Road bridge. Baker 2 had a Ti level identical to the mean of the five locations (101 mg/kg). The other three locations had Ti concentrations less than the mean.

Vanadium (V) - Vanadium was highest in sediments below the former landfill site (16.2 mg/kg @ Baker 4). The other four locations had V sediment levels ranging between 9.7 mg/kg (Baker 1) and 11.8 mg/kg (Baker 3).

Zinc (Zn) - Baker 4, below the former landfill, exhibited the highest Zn level (68.8 mg/kg). The mean and lowest Zn concentration of the five sediment locations was 36.3 mg/kg and 9.7 mg/kg, respectively.

Table 4. Inorganic elements in chain pickerel wholebody composite samples from Sunkhaze Stream, ug/g WW.

Element	Location and Sample Number					Mean	St Dev
	Sunkhaze 1 Sunk1CP	Sunkhaze 2 Sunk2CP	Sunkhaze 3 Sunk3CP	Sunkhaze 4 Sunk4CP	Sunkhaze 5 Sunk5CP		
Al	5.31	11.20	5.46	25.40	24.00	14.27	9.822
Ba	0.60	0.51	0.36	0.53	0.24	0.45	0.143
Cd	0.02	0.02	0.02	0.02	0.03	0.02	0.002
Cu	0.55	0.49	0.39	0.55	0.40	0.47	0.076
Fe	13.10	11.20	9.51	16.20	11.10	12.22	2.562
Hg	0.94	0.76	0.35	0.33	0.30	0.53	0.294
Mg	437	449	387	485	373	426	46.0
Mn	6.62	7.18	6.49	8.59	5.76	6.93	1.058
Na	1499	1255	946	1252	1037	1198	215.7
P	8299	8352	5954	8814	5288	7341	1600.6
Pb	0.04	0.05	0.05	0.05	0.04	0.04	0.006
S	1880	1740	2024	1981	2305	1986	209.2
Se	0.15	0.18	0.18	0.17	0.17	0.17	0.012
Sr	18.1	17.7	10.7	18.4	9.0	14.8	4.55
Ti	0.26	0.22	0.15	0.32	0.24	0.24	0.064
Zn	53.6	60.2	54.1	65.8	56.0	57.9	5.105

ug/g = parts per million; WW = wet weight
Elements not detected in all samples are not shown (As, B, Be, Co, Cr, Mo, Ni, V).

Table 5. Inorganic elements in yellow perch wholebody composite samples from Sunkhaze Stream, ug/g WW.

Element	Sample Number					Mean	St Dev
	Sunkhaze 1 Sunk1YwP	Sunkhaze 2 Sunk2YwP	Sunkhaze 3 Sunk3YwP	Sunkhaze 4 Sunk4YwP	Sunkhaze 5 Sunk5YwP		
Al	13.2	3.71	12.4	12.5	12.5	10.86	4.011
Ba	0.26	0.48	0.51	0.56	0.44	0.45	0.113
Cd	0.04	0.04	0.03	0.03	0.04	0.03	0.006
Cu	0.37	0.38	0.29	0.57	0.34	0.39	0.105
Fe	17.9	12.5	12.9	18.5	18.9	16.1	3.16
Hg	0.20	0.31	0.12	0.25	0.24	0.22	0.073
Mg	355	533	487	454	474	461	65.8
Mn	7.2	11.6	16.3	8.9	10.1	10.8	3.47
Na	846	1095	956	1088	984	994	103.1
P	6096	10142	9792	8701	9270	8800	1606.8
Pb	0.10	0.17	0.06	0.07	0.11	0.10	0.043
S	2357	2255	2094	2302	2232	2248	98.5
Se	0.27	0.26	0.25	0.23	0.21	0.24	0.023
Sr	10.1	20.6	17.2	20.4	22.0	18.1	4.78
Ti	0.27	0.26	0.29	0.40	0.32	0.31	0.057
Zn	14.7	16.6	15.0	15.2	16.3	15.6	0.84

ug/g = parts per million; WW = wet weight
Elements not detected in all samples are not shown (As, B, Be, Co, Cr, Mo, Ni, V).

Table 6. Inorganic elements in brown bullhead wholebody composite samples from Baker Brook, ug/g WW.

Element	Location and Composite Sample Number								Mean	St Dev
	Baker 2		Baker 3		Baker 4		Baker 5			
	Bk2-BH-1	Bk2-BH-2	Bk3-BH-1	Bk3-BH-2	Bk4-BH-1	Bk4-BH-2	Bk5-BH-1	Bk5-BH-2		
Al	17.3	11.8	21.2	16.2	7.3	11.7	8.5	10.0	13.0	4.78
Ba	0.55	0.80	0.47	0.41	0.48	0.49	0.36	0.39	0.49	0.139
Cd	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.004
Cu	0.63	0.62	0.71	0.76	0.73	0.75	0.62	0.51	0.67	0.087
Fe	40.4	34.3	46.0	40.1	38.5	39.6	34.9	32.8	38.3	4.25
Hg	0.28	0.39	0.17	0.17	0.15	0.15	0.12	0.15	0.20	0.091
Mg	338	370	338	316	399	346	310	334	344	28.827
Mn	3.98	4.28	8.02	9.91	9.59	5.44	3.08	2.83	5.89	2.881
Na	908	966	980	928	988	972	889	1025	957	45.176
P	5026	5977	5436	4995	6723	5253	4446	4856	5339	715.8
Pb	0.09	0.11	0.14	0.13	0.17	0.04	0.04	0.09	0.10	0.047
S	1588	1505	1566	1524	1487	1477	1537	1656	1543	59.3
Se	0.16	0.14	0.17	0.16	0.15	0.14	0.19	0.18	0.16	0.018
Sr	17.0	21.9	19.0	16.0	22.6	19.3	14.4	15.3	18.2	3.02
Ti	0.12	0.15	0.30	0.22	0.20	0.16	0.13	0.13	0.18	0.061
Zn	13.7	15.0	15.8	15.0	17.4	13.2	13.3	13.7	14.6	1.46

ug/g = parts per million; WW = wet weight

Two composites per location. No fish collected at Baker 1.

Elements not detected in all samples are not shown (As, B, Be, Co, Cr, Mo, Ni, V).

Table 7. Inorganic elements in sediments from Baker Brook, mg/kg dry weight

Element	Locations						SQG[1]	
	Baker 1	Baker 2	Baker 3	Baker 4	Baker 5	Mean	TEC	PEC
Al	10300	5280	9330	12200	8730	9168		
As	4.03	2.12	3.14	4.76	**10.2**	4.85	9.79	33
B	nd	nd	nd	nd	3.26	nc		
Ba	34.2	28.5	40.0	57.9	48.7	41.9		
Be	0.34	0.14	0.18	0.34	0.43	0.28		
Cd	0.09	0.37	0.18	**1.18**	0.88	0.54	0.99	4.98
Co	1.92	3.13	5.13	7.66	4.55	4.48		
Cr	14.0	11.6	15.9	18.3	12.7	14.5	43.4	111
Cu	3.7	3.6	2.3	7.4	14.7	6.3	31.6	149
Fe	4770	6130	8760	7740	6470	6774		
Hg	0.05	0.08	0.03	0.16	0.17	0.10	0.18	1.06
Mg	1310	2280	2870	2200	1650	2062		
Mn	62	174	108	334	207	177		
Mo	nd	nd	nd	nd	1.02	nc		
Ni	7.0	10.2	11.6	13.5	12.1	10.9	22.7	48.6
Pb	7.2	13.4	5.1	27.5	11.3	12.9	35.8	128
Se	0.20	0.24	0.14	0.67	0.90	0.43		
Sr	11.4	31.4	17.4	39.9	91.8	38.4		
Ti	76.4	101.0	143.0	87.7	97.7	101.2		
V	9.7	10.7	11.8	16.2	11.3	11.9		
Zn	9.7	30.6	24.5	68.8	47.5	36.2	121	459

mg/kg = parts-per-million

nd = non-detect, nc = not calculated

[1] Freshwater Sediment Quality Guidelines (MacDonald *et al.* 2000)

TEC = Threshold Effect Concentration below which harmful effects are unlikely to be observed

PEC = Probable Effect Concentration above which harmful effects are likely to be observed

Bold/colored numbers exceed TEC

5.3 Other Analyses

5.3.1 Lipids - Percent lipid was measured in each fish sample. The highest lipid content was found in yellow perch composites, followed by chain pickerel and brown bullhead (Table 8).

Table 8. Percent lipid in fish composite samples.

Species	Lipid Content %	
	Mean and Standard Deviation	Range
Chain Pickerel	1.79 ± 0.690	0.67 - 2.45
Yellow Perch	5.53 ± 1.382	4.15 - 7.06
Brown Bullhead	1.33 ± 0.422	0.81 - 1.93

5.3.2 Particle size, moisture content, and Total Organic Carbon (TOC) - Particle size analyses were conducted to measure the percentage of sand, silt, and clay in sediment samples. Sediment types were subsequently determined using the basic soil texture triangle and classification criteria. The five sediment samples from Baker Brook were overwhelmingly sandy (> 95% sand separates; Table 9). Two samples from the upper portion of the brook (Baker Brook 5 and 4) contained small percentages of silt and clay. Baker Brook 5 sediment had sufficient amounts of silt (2.7%) and clay (7.5%) to be classified as a loamy sand.

Moisture content in Baker Brook sediment samples ranged from 34.1% (Baker 3) to 90.1% (Baker 5). Baker Brook meanders through a peat bog downstream of the County Road bridge. Relatively high moisture content found in sediment samples Baker 4 and Baker 5 is not surprising.

Total Organic Carbon (TOC) content in Baker Brook sediment samples exhibited a similar pattern as moisture content. In samples above the County Road bridge, TOC was substantially lower than samples collected in the peat bog downstream of the bridge.

Table 9. Characteristics of Baker Brook sediment samples.

	Percent Clay	Percent Sand	Percent Silt	Percent Moisture	TOC
Baker 1	0.90	98.50	0.70	42.0	4.08
Baker 2	0.50	99.20	0.30	63.6	9.92
Baker 3	0.50	98.40	1.10	34.1	2.00
Baker 4	4.10	90.70	5.20	79.1	18.50
Baker 5	7.50	89.80	2.70	90.1	36.50
Mean	2.70	95.32	2.00	61.8	14.20
Std Dev	3.079	4.649	2.007	23.784	14.012

5.4 Quality Assurance/Quality Control (QA/QC) - The Service's Patuxent Analytical Control Facility reviewed the data packages provided by the contract laboratories. QA/QC procedures were approved by the Patuxent Analytical Control Facility with minor comments. See pages 21 and 22 in Appendix A for organochlorines QA/QC comments, and page 28 in Appendix B for trace elements. As noted above, only one organochlorine compound was detected in one sample in the study. At the request of the investigators, a subset of fish and sediments samples were re-analyzed at the PACF to confirm organochlorine results. The results were the same, and no

detection anomalies were found in the second organochlorine analyses of the samples.

6. DISCUSSION

6.1 Fish Tissue. Fish tissue data (µg/g, wet weight) from Sunkhaze Meadows NWR are compared with values reported from regional and national studies reported in the scientific literature. The two studies used for comparison were the northeastern results of the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) and the U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program (NCBP). EMAP whole fish inorganic element results for 167 lakes in the northeastern portion of the United States (New England states, New York, New Jersey) were reported by Yeardley *et al.* (1998). In the northeastern EMAP, between 1992 and 1994, six species of warm-water fish (e.g., largemouth bass, yellow perch) and 5 species of cold-water fish (e.g., brook trout, brown trout) were collected throughout the region and analyzed for 11 trace elements. The NCBP (Schmitt and Brumbaugh 1990, Schmitt *et al.* 1990) tracked temporal and geographic trends in contaminant concentrations in composite samples of several species of whole fish collected from 112 riverine stations throughout the United States. As with any regional or nationwide programs that cover different species, habitats, and levels of contamination, there are limitations associated with the EMAP and NCBP data sets. The datasets are useful, however, for general comparisons and in placing contaminant concentrations in site-specific studies in a broader context.

6.1.1 Sunkhaze Stream Fish - As in the 1993 screening-level survey of the refuge, two species were examined in Sunkhaze Stream in 2001 - chain pickerel and yellow perch. Chain pickerel are upper trophic level fish predators that are common in the waters of Sunkhaze Stream, particularly in the stream reach that traverses the open, expanse formed by Sunkhaze and Spencer Meadows. Yellow perch are also common in Sunkhaze Stream. Immature insects, larger invertebrates, and fish are the preferred food items of yellow perch (Scott and Crossman 1973).

Sixteen inorganic elements were detected in chain pickerel samples. Three elements (Al, Hg, and Zn) in pickerel tissue from Sunkhaze Stream were higher than regional and national mean levels (Table 10). In yellow perch, 16 inorganic elements were also detected, but only Al and Zn were found in potentially elevated concentrations. Zinc levels in yellow perch were less than the EMAP or NCPB geometric means.

Aluminum (Al) - The mean Al level reported in the northeast EMAP program was 8.3 µg/g and the maximum was 114.5 µg/g (Yeardley *et al.* 1998). Aluminum concentrations in chain pickerel (mean 14.3 µg/g), and yellow perch (10.9 µg/g) collected in the refuge follow-up study exceeded the EMAP mean, but did not approach the maximum. In Sunkhaze Stream chain pickerel, Al varied widely with two composites containing 5 µg/g, one with 11 µg/g and two at 24 µg/g. There was less Al variability in yellow perch composite samples. One perch composite had 4 µg Al/g, while the other four were in the vicinity of 12.5 µg/g. Aluminum levels in yellow perch from Sunkhaze Stream were lower than the concentrations found in 1993.

Under acidic conditions, dissolved Al in water adversely affects fish physiology and behavior (MaGee et al. 2001). However, it is not known if there are adverse biological effects in fish with

elevated Al body burdens (Sparling and Lowe 1996, RAIS 2004). Piscivorous wildlife may be at risk if their prey contains greater than 1,000 µg/g of Al (Sparling and Lowe 1996). Fish tissue residue Al levels in Sunkhaze Stream appear to be slightly above regional background concentrations and well below dietary limits for the protection of piscivorous wildlife.

Mercury (Hg) - The NCBP (Schmitt and Brumbaugh 1990) geometric mean Hg concentration was 0.10 µg/g and the 85th percentile was 0.37 µg/g. The EMAP (Yeardley *et al.* 1998) mean Hg (reported as MeHg, methylmercury) concentration for fish in 167 northeastern U.S. lakes was 0.18 µg/g (range: 0.01 - 2.93 µg/g). In a study of 120 randomly selected Maine lakes, the mean Hg level in chain pickerel was 0.88 µg/g (range: 0.58 - 1.22 µg/g), while in yellow perch the mean was 0.28 µg/g (range: 0.18 - 0.81 µg/g; Stafford and Haines 1997). In 2001, mean Hg levels in Sunkhaze Stream chain pickerel and yellow perch were 0.53 µg/g and 0.22 µg/g, respectively. These levels, although higher than the NCBP and EMAP means, are lower than the species-specific, state-wide means reported by Stafford and Haines (1997).

Mercury is a mutagen, teratogen, and carcinogen which bioconcentrates in organisms and biomagnifies through food chains (Eisler 1987). Upper trophic level, long-lived, piscivorous fish species, such as bass and pickerel (Stafford and Haines 1997) or species at the top of extended food chains (Cabana *et al.* 1994), typically have higher Hg concentrations than lower trophic species (Akielaszek and Haines 1981). Methylmercury, an organic form of mercury, is a potent neurotoxin that accounts for over 95% of the total Hg in adult fish tissue (Grieb *et al.* 1990). Mercury accumulates in the axial muscle tissue (i.e., fillet) of fish (Schmitt and Finger 1987). Wholebody concentrations of 1-5 µg Hg/g may have chronic effects in trout, while concentrations of 10-20 µg/g could be lethal (Niimi and Kissoon 1994). Piscivorous birds and mammals are also at risk from Hg in fish tissue. Barr (1986) reported that loons (*Gavia immer*) feeding on fish with Hg concentrations of 0.30 to 0.40 µg/g appeared to have impaired reproduction. Mercury can be lethal to mink (*Mustela vison*) at dietary concentrations of 1.1 µg/g (Kucera 1983) and to river otter (*Lutra canadensis*) at dietary concentrations above 2 µg/g (O'Connor and Nielsen 1980).

Mercury levels in chain pickerel and yellow perch from Sunkhaze Stream are elevated and should not be considered safe for consumption by humans or wildlife. Eisler (1987) recommended a fish Hg concentration of 0.10 µg/g for the protection of sensitive piscivorous birds and mammals. An Hg piscivorous Wildlife Criterion Value based on the common loon recently has been proposed by Evers *et al.* (2003). In calculating the WCV, a prey effect level was determined based on fish size. Adverse effects would be likely if Hg in loon prey exceeded 0.14 µg/g in fish between 10 - 15 cm, 0.27 µg/g in fish between 15 - 20 cm, and 0.45 µg/g in fish between 20 - 25 cm. Based on size and mercury content, Sunkhaze Stream chain pickerel and yellow perch would exceed the proposed WCV suggesting piscivorous wildlife may be at risk (Evers D. 2004. Personal communication).

The potential risk to humans consuming Sunkhaze Stream fish may also be elevated. The U.S. Food and Drug Administration action level for Hg in the edible portion of fish is 1.0 µg/g (FDA 1992). Several states, including Maine, have adopted lower Hg action levels for the protection of human health. Maine currently has a fish tissue action level of 0.20 µg Hg/g (Maine Bureau of Health 2001). Wholebody Sunkhaze Stream chain pickerel and yellow perch have Hg levels in

excess of the state consumption advisory. However, Hg concentrations in the edible portion of Sunkhaze Stream fish are unknown. More restrictive fish consumption advisories exist for vulnerable receptor groups. In March 2004, FDA and EPA issued updated fish consumption recommendations for women who might become pregnant, women who are pregnant, nursing mothers, and young children (EPA 2004).

Zinc (Zn) - The mean Zn level in chain pickerel from Sunkhaze Stream was 57.9 µg/g. The mean Zn levels reported in the EMAP and NCBP were 21.1 µg/g and 21.7 µg/g, respectively (Table 10; Yeardley *et al.* 1998, Schmitt and Brumbaugh 1990), so Zn in Sunkhaze Stream pickerel is considerably higher than regional or national averages. In contrast, Sunkhaze Stream yellow perch (mean 15.6 µg/g) and Baker Brook brown bullhead (mean 14.6 µg/g) were below the regional and national means for Zn in fish tissue.

Zinc is an essential element for vertebrates. Generally, Zn is efficiently regulated by wildlife and tissue concentrations are not reliable indicators of exposure (Beyer and Storm 1995). Spry *et al.* (1988) found no toxic effects in rainbow trout from exposure to high dietary and waterborn concentrations of Zn as measured by growth, mortality, major plasma ions, hematocrit, and plasma protein. However, Eisler (1993) reported that elevated concentrations of waterborne Zn have adverse effects on growth, behavior, and reproduction of sensitive fish, with early life stages being the most sensitive.

Although the Zn levels in Sunkhaze Stream chain pickerel exceed the EMAP and NCBP means, elevated levels are not highly unusual in undisturbed systems. Citing several sources, Murphy *et al.* (1978) reported average whole fish Zn concentrations from uncontaminated areas ranging from 12 µg/g to 43 µg/g. Maximum Zn levels reported in the NCBP (118.4 µg/g) and EMAP (63.7 µg/g) programs were higher than the concentrations found in Sunkhaze Stream chain pickerel (mean 57.9 µg/g; range: 53.6 - 65.8 µg/g). The State of Maine fish tissue action level for Zn is 648 µg/g (Maine BOH 2001). The Zn levels in Sunkhaze Stream pickerel and perch are well below the state action level.

6.1.2 Baker Brook Fish - Fish were not collected from Baker Brook during the 1993 screening-level contaminant survey. Fish were collected in 2001 because they are useful bioindicators of contamination. If PCBs occurred at elevated levels in sediment during the 1993 survey then uptake is expected to also occur in fish tissue. In preliminary sampling, the most common fish species encountered in the four Baker Brook collection locations was the brown bullhead. Bullheads are bottom-feeders that regularly come in contact with sediment. The species is omnivorous and feeds on offal, mollusks, immature insects, leeches, crayfish, algae, plant material, fish, and fish eggs (Scott and Crossman 1973). The bullhead was selected as an indicator species for Baker Brook.

Sixteen inorganic elements were detected in eight brown bullhead composite samples. Three elements (Al, Fe, and Hg) in bullhead tissue from Baker Brook were higher than regional and national mean levels (Table 10).

Aluminum (Al) - Aluminum concentrations in Baker Brook brown bullhead (13.0 µg/g) exceeded the EMAP mean (8.3 µg/g), but did not approach the maximum (114.5 µg/g). In

locations Baker 4 and Baker 5, Al varied between same-location composites. One bullhead composite from the location would be below the EMAP mean, while the other sample would exceed the mean. Of the eight composite samples, the highest Al concentrations occurred in samples from the upper reaches of the brook. As noted above in the Sunkhaze Stream discussion, it is not known if these elevated Al body burdens will cause adverse biological effects in fish (Sparling and Lowe 1996, RAIS 2004). The mean bullhead Al concentration in Baker Brook is well below the suggested piscivorous wildlife risk level (1,000 µg/g; Sparling and Lowe 1966), so the potential hazard to predators of these fish should be minimal.

Iron (Fe) - The EMAP mean for Fe was 34.8 µg/g and the maximum was 1,446.5 µg/g (Yeardley et al. 1998). Iron concentrations in brown bullhead composite samples were similar among the Baker Brook collection locations (mean 38.3 µg/g, standard deviation 4.25), and only slightly higher than the EMAP mean. Iron is an essential element and it is unlikely that the slightly elevated levels in Baker Brook bullhead composite samples pose a potential risk to the fish or their predators.

Mercury (Hg) - Three of the four Baker Brook locations exhibited similar Hg concentrations in composite samples (range: 0.12 - 0.17 µg/g in Baker 3, 4, and 5). Bullheads from Baker 2, the most upstream location, had Hg levels of 0.28 µg/g and 0.39 µg/g in two composites samples. Based on size and mercury content (Evers *et al.* 2003), bullhead may not pose a significant risk to piscivorous predators foraging in the lower reaches of the brook. In the upper reach of Baker Brook, however, Hg levels in bullhead may be high enough to pose a risk to piscivorous wildlife.

Table 10. Mean concentrations of inorganic elements in Sunkhaze Meadows NWR fish compared to regional and national levels, ug/g wet weight

Element	Sunkhaze Stream		Baker Brook	EMAP[1]	NCBP[2]
	Chain Pickerel	Yellow Perch	Brown Bullhead	Many Species	
Al	**14.3**	**10.9**	**13.0**	8.3	
Ba	0.45	0.45	0.49		
Cd	0.02	0.03	0.02	0.02	0.03
Cu	0.47	0.39	0.67	0.89	0.65
Fe	12.2	16.1	**38.3**	34.8	
Hg	**0.53**	**0.22**	**0.20**	0.18	0.10
Mg	426	461	344		
Mn	6.93	10.81	5.89		
Na	1198	994	957		
P	7341	8800	5339		
Pb	0.04	0.10	0.10	0.09	0.11
S	1986	2248	1543		
Se	0.17	0.24	0.16	0.37	0.42
Sr	14.8	18.1	18.2		
Ti	0.24	0.31	0.18		
Zn	**57.9**	15.6	14.6	21.1	21.7

[1] Yeardley et al. 1998 - northeastern USA means

[2] Schmitt and Brumbaugh 1990 - nationwide USA means

Bold/colored numbers exceed EMAP and/or NCBP means

Figure 3. Mercury concentrations in chain pickerel and yellow perch composites from Sunkhaze Stream, ug/g wet weight.

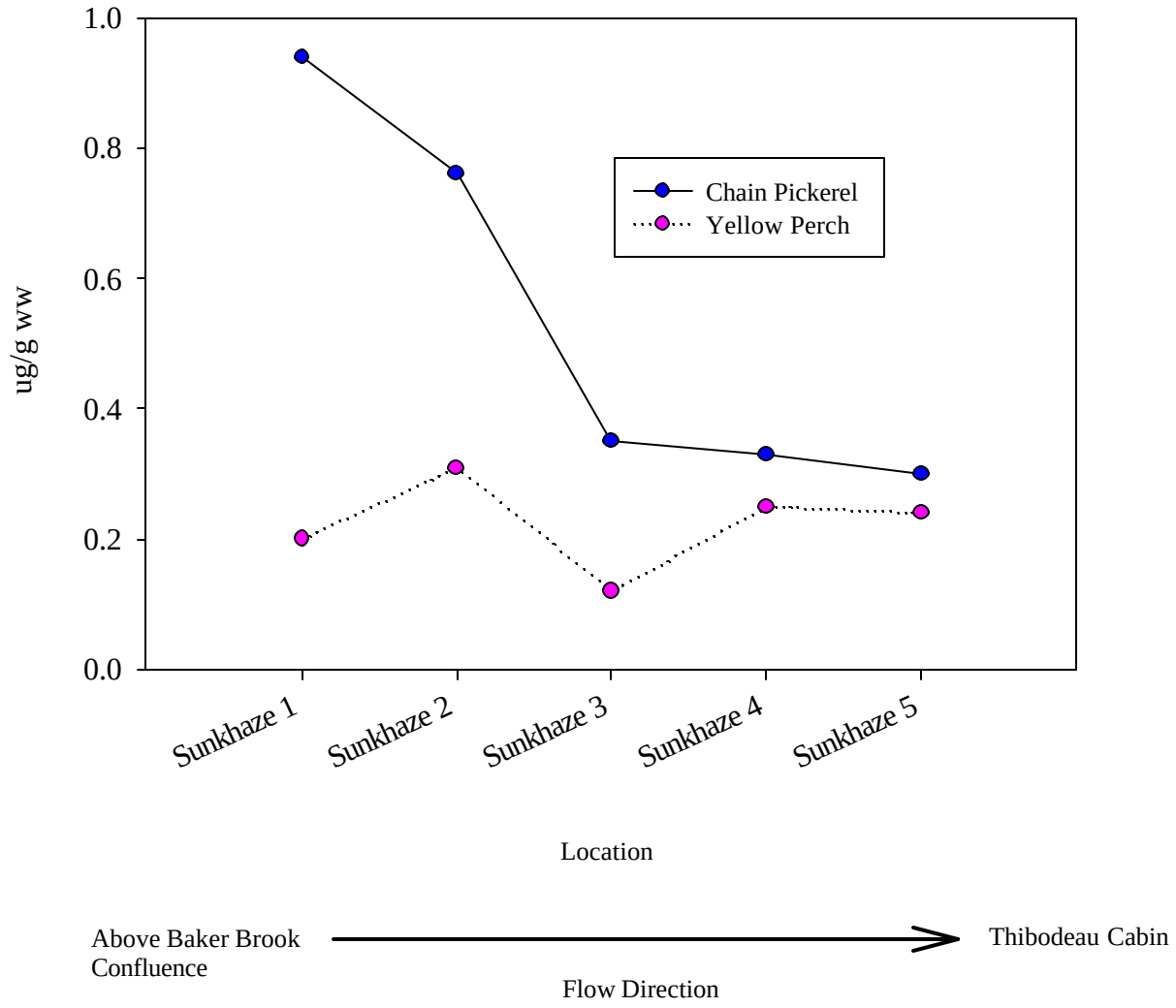
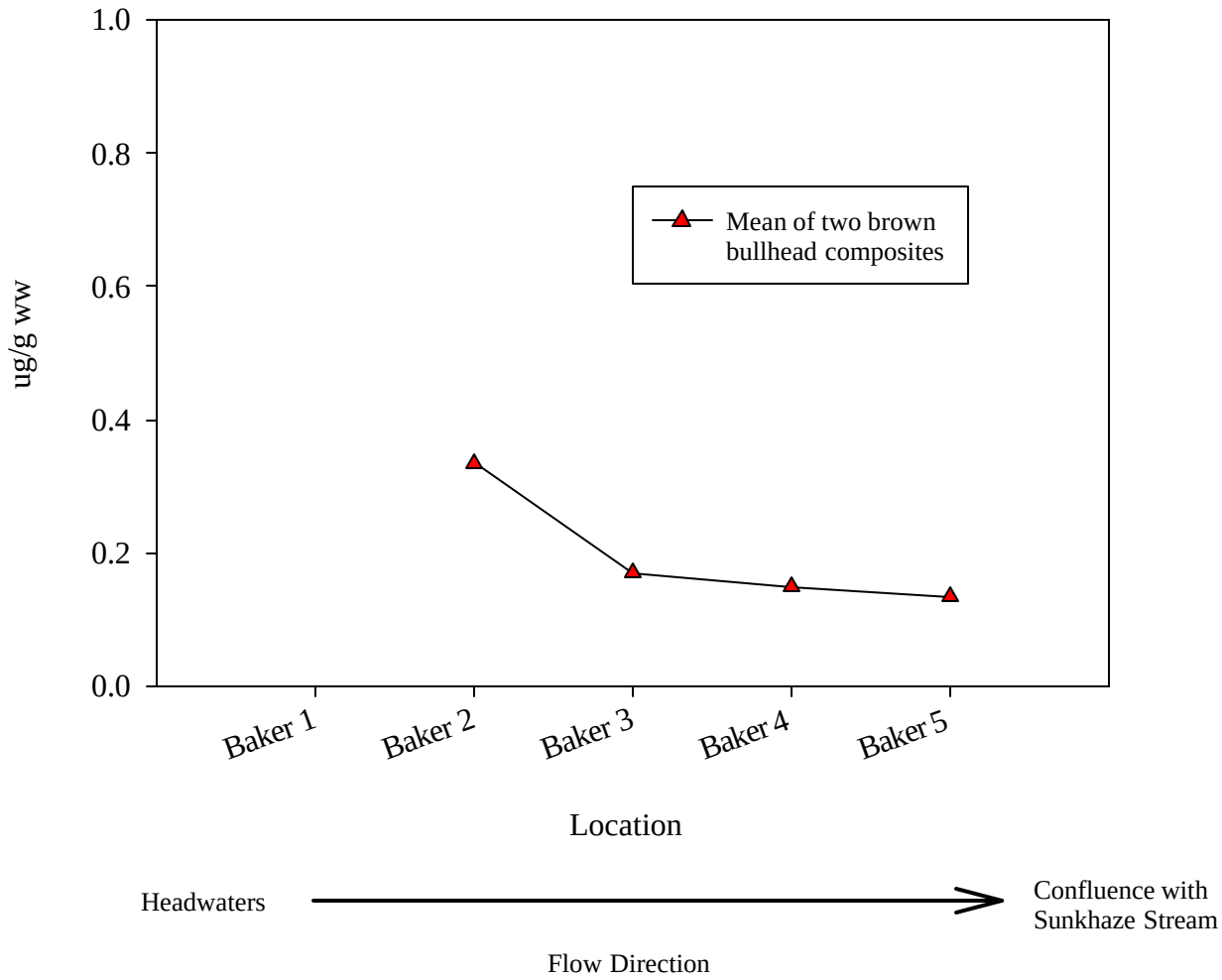


Figure 4. Mean mercury concentration in bullhead composites from Baker Brook, ug/g wet weight.



6.2 Sediment. There are no nationally-accepted sediment effects criteria in the United States. Sediment sampling results from Baker Brook are compared to guidelines with two tiers of biological effect concentrations (MacDonald *et al.* 2000). Basically, these effect concentrations summarize the results of numerous toxicity tests with sediment-dwelling organisms from several regions of the continent. Guidelines or effect concentrations are not available for all sediment contaminants. However, most of the ecologically-harmful contaminants have a proposed guideline. In MacDonald *et al*. (2000), two effect concentrations were proposed: the Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC). The TEC is the concentration below which harmful effects are unlikely to be observed, while the PEC is the concentration above which harmful effects are likely to be observed. In the broadest sense, sediments with concentrations below the TEC are probably not affecting biota, while sediments with levels between the TEC and PEC may be affecting biota, and sediments with values above the PEC are probably having some biological impact. Different organisms have different sensitivities to contaminants under different environmental conditions, so it is quite difficult to derive "standard" levels of contamination. Subsequently, suggested biological effect concentrations must be viewed with caution.

6.2.1 Baker Brook Sediments - The analytical results of Baker Brook sediment sampling are presented in Table 7 (page 24). TEC and PEC values for contaminants with sediment quality guidelines were included in the table. None of the contaminants with sediment quality guidelines had concentrations that approached the Probable Effect Concentration (PEC). In general, contaminant concentrations in Baker Brook sediment were low. Among the five sediment collection locations in Baker Brook, however, the Baker 4 location, approximately 800 meters (0.5 miles) downstream of the former landfill, had the highest levels of aluminum, barium, cadmium, cobalt, chromium, manganese, nickel, lead, vanadium, and zinc. Of the ten elements, only cadmium (1.18 mg/kg) occurred at an elevated level - a level only slightly above the threshold effect concentration (As TEC 0.99 mg/kg; MacDonald *et al.* 2000). The only other element to occur above the TEC (9.79 mg/kg) was arsenic, which was found at 10.2 mg/kg at Baker 5, the confluence of Baker Brook and Sunkhaze Stream.

6.3 Comparison of 1993 and 2001 data. One of the purposes of the follow-up survey was to validate contaminant levels of the 1993 collections. To the extent possible, the 2001 fish and sediment samples were taken in the vicinity of the collection areas used in 1993.

6.3.1 Sunkhaze Stream fish - Neither Total PCBs, nor any other of the 22 organochlorine compound in the analytical scan, were found above the detection limit in any of the 2001 Sunkhaze Stream chain pickerel or yellow perch composite samples. In 1993, Total PCB, dieldrin, and p,p'-DDE were found at low levels in three of four fish composite samples (Total PCB max. 0.008 µg/g based on congener-specific analyses).

Chain pickerel in Sunkhaze Stream, with the exception of cadmium and lead, had lower inorganic element levels in 2001 than in 1993 (Table 11). Cadmium and lead were not detected in 1993, but the elements were detected at low levels in 2001. Yellow perch samples also had lower inorganic element concentrations in the second round of sampling. The only elements exhibiting increased levels were cadmium, lead, and strontium (Table 12).

6.3.2 Baker Brook sediments - Of the 5 Baker Brook collection sites in 2001, two were located in the vicinity of 1993 collection locations - Baker 3 and Baker 4. Baker 3 (2001) and BB 1 (the 1993 location) were taken immediately above the County Road bridge. Baker 4 (2001) and BB 2 (the 1993 location) were taken downstream of the former Milford Municipal Landfill.

None of the 22 organochlorine compounds in the 2001 analytical scan were detected in Baker Brook sediments. In 1993, 15 of 23 organochlorine compounds were detected in Baker Brook sediment samples. However, except for Total PCB, the other organochlorine compounds were only detected at, or slightly above, sample detection limits. PACF contract detection limits between years did not differ, and sample detection limits between catalogs also appear similar.

The 1993 and 2001 sediment samples collected from the County Road collection location had similar Total Organic Carbon levels (i.e., 1.75 - 2.00 %), but inorganic element levels varied between years (Table 13). In 2001 at the Baker 3/BB 1 location, nine elements were found in higher concentrations and eight elements were found in lower concentrations than in 1993. None of the ecologically-relevant elements at the location had concentrations that approached the Threshold Effect Concentration suggested by MacDonald *et al.* (2000).

The Total Organic Carbon levels at Baker 4/BB 2, downstream of the former landfill, were substantially different between the two sampling years (3.47 vs. 18.50 %, Table 13) suggesting that the 2001 location may have been a beaver dam or too distant from the 1993 location. In 2001 at Baker 4/BB 2, 11 inorganic elements were found at higher concentrations and six at lower concentrations than in 1993 (Table 13). The 2001 inorganic element levels downstream of the former landfill, although elevated compared to 1993, were not at concentrations approaching the Threshold Effect Concentration (MacDonald *et al.* 2000).

Table 11. Inorganic elements in chain pickerel wholebody composite samples from Sunkhaze Stream, 1993 and 2001 means, ug/g WW.

Element	1993 2 Samples	2001 5 Samples	Change from 1993
Al	17.70	14.27	**-3.42**
Ba	0.58	0.45	**-0.13**
Cd	nd	0.02	**0.02**
Cr	3.56	nd	**-3.56**
Cu	1.98	0.47	**-1.51**
Fe	30.46	12.22	**-18.23**
Hg	0.74	0.53	**-0.21**
Mg	924.35	426.20	**-498.15**
Mn	9.62	6.93	**-2.69**
Pb	nd	0.04	**0.04**
Se	0.19	0.17	**-0.02**
Sr	15.61	14.78	**-0.83**
Zn	64.68	57.94	**-6.74**

ug/g = parts per million; WW = wet weight
nd = nondetect

Elements not included in 1993 scan and elements not detected in both years are not listed.

Table 12. Inorganic elements in yellow perch wholebody composite samples from Sunkhaze Stream, 1993 and 2001 means, ug/g WW.

Element	1993 2 Samples	2001 5 Samples	Change from 1993
Al	37.30	10.86	**-26.44**
Ba	0.60	0.45	**-0.15**
Cd	nd	0.03	**0.03**
Cr	11.90	nd	**-11.90**
Cu	1.78	0.39	**-1.39**
Fe	91.38	16.14	**-75.24**
Hg	0.27	0.22	**-0.04**
Mg	1001.50	460.60	**-540.90**
Mn	18.13	10.81	**-7.32**
Pb	nd	0.10	**0.10**
Se	0.34	0.24	**-0.10**
Sr	16.96	18.06	**1.11**
Zn	24.93	15.56	**-9.37**

ug/g = parts per million; WW = wet weight
nd = nondetect

Elements not included in 1993 scan and elements not detected in both years are not listed.

Table 13. Inorganic elements in sediments from two similar Baker Brook locations, 1993 and 2001, mg/kg DW

Element	Above County Road Bridge			Below Milford Landfill		
	1993 BB1	2001 Baker 3	Change from 1993	1993 BB2	2001 Baker 4	Change from 1993
Al	5088	9330	**4242**	8167	12200	**4033**
As	nd	3.14	**3.14**	1.24	4.76	**3.52**
Ba	27.0	40.0	**13.0**	30.5	57.9	**27.4**
Be	0.50	0.18	**-0.32**	0.37	0.34	**-0.03**
Cd	0.77	0.18	**-0.59**	nd	1.18	**1.18**
Cr	30.2	15.9	**-14.3**	34.4	18.3	**-16.1**
Cu	nd	2.30	**2.30**	17.5	7.4	**-10.1**
Fe	5950	8760	**2810**	12750	7740	**-5010**
Hg	nd	0.03	**0.03**	nd	0.16	**0.16**
Mg	1679	2870	**1191**	2966	2200	**-766**
Mn	150	108	**-42**	291	334	**43.4**
Ni	11.8	11.6	**-0.2**	16.6	13.5	**-3.09**
Pb	13.6	5.1	**-8.5**	13.6	27.5	**13.9**
Se	0.50	0.14	**-0.36**	nd	0.67	**0.67**
Sr	16.2	17.4	**1.2**	13.8	39.9	**26.1**
V	9.4	11.8	**2.4**	13.2	16.2	**3.1**
Zn	29.0	24.5	**-4.5**	48.3	68.8	**20.5**
TOC %	1.75	2.00	**0.25**	3.47	18.50	**15.03**

mg/kg = parts-per-million, DW = dry weight
nd = non-detect

7. SUMMARY AND CONCLUSIONS

Elevated levels of chromium and Total PCBs that were detected in the 1993 screening-level contaminant survey were not found in the 2001 follow-up study. Chain pickerel and yellow perch from Sunkhaze Stream did not contain detectable levels of chromium in 2001. Similarly, sediment samples from Baker Brook in 2001 did not contain detectable levels of Total PCBs.

As with most waters of Maine and the Northeast, mercury in fish tissue at Sunkhaze Meadows NWR continues to be a potential hazard to piscivorous wildlife and anglers. Refuge anglers should adhere to the Maine Bureau of Health recommended consumption guidelines for mercury that are published in the state fishing regulation book.

A potential landfill effect appears to exist in sediments below the former Milford landfill. Concentrations of several inorganic elements in sediment samples below the landfill in Baker Brook are higher than four other brook locations. Baker Brook sediments do not contain highly elevated levels for inorganic elements. Except for single elevated hits of cadmium and arsenic, the sediment threshold effect concentrations (TEC) for several elements were not exceeded. The TEC is the level below which harmful effects are unlikely to be observed. The detections of cadmium and arsenic, although above the TEC, are well below their respective probable effect concentration (PEC). The PEC is the level above which harmful effects are likely to be observed.

In general, there is an apparent decrease in contaminant levels in sediment and fish tissue samples between the 1993 and 2001 Refuge collections.

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APPENDIX A

ORGANOCHLORINES

Analytical Laboratory
Mississippi State Chemical Laboratory (MSCL)
Mississippi State, MS

An electronic version of this appendix is available from the Maine Field Office of the U.S. Fish and Wildlife Service upon request.

APPENDIX B

TRACE ELEMENTS

Analytical Laboratory
Trace Element Research Laboratory, TERL
College Station, TX

An electronic version of this appendix is available from the Maine Field Office of the U.S. Fish and Wildlife Service upon request.