<u>South Middleton Dam, Ipswich River</u>
<u>Partial Feasibility Study</u>
<u>Phase I Technical Memorandum</u>

1. Introduction

Inter-Fluve was contracted by the Ipswich River Watershed Association (IRWA) to conduct a partial feasibility study for the removal of the South Middleton Dam on the Ipswich River in Middleton, MA. This dam is a complete fish passage barrier and is the most downstream obstruction on the Ipswich River that does not provide opportunities for fish to move up and downstream. One of the primary objectives for removing the dam is to restore the natural riparian habitat and upstream fish passage. Dam removal will improve conditions for blueback herring, alewife, sea lamprey, American eel, American shad, eastern brook trout, white sucker, fallfish, creek chubsucker and the common shiner. Dam removal will also eliminate maintenance costs and safety and liability concerns for the dam owner, Bostik, Inc.

South Middleton Dam is located about 500 ft west of the Boston Street bridge over the Ipswich River in South Middleton (Figure 1). The watershed upstream of the dam is approximately 44 mi^2, 32% of which is forested land. South Middleton Dam is approximately 110 ft long with a spillway length of about 45 ft; the structural height is 9 ft and the hydraulic height is 7.5 ft (GEI Consultants, Inc., 2006). The impoundment is approximately 0.5 miles long with a maximum pool storage of about 75 acre-ft (GEI Consultants, Inc., 2006). The dam was built in 1900, modified in 1953 and is currently in fair condition (GEI Consultants, Inc., 2006).

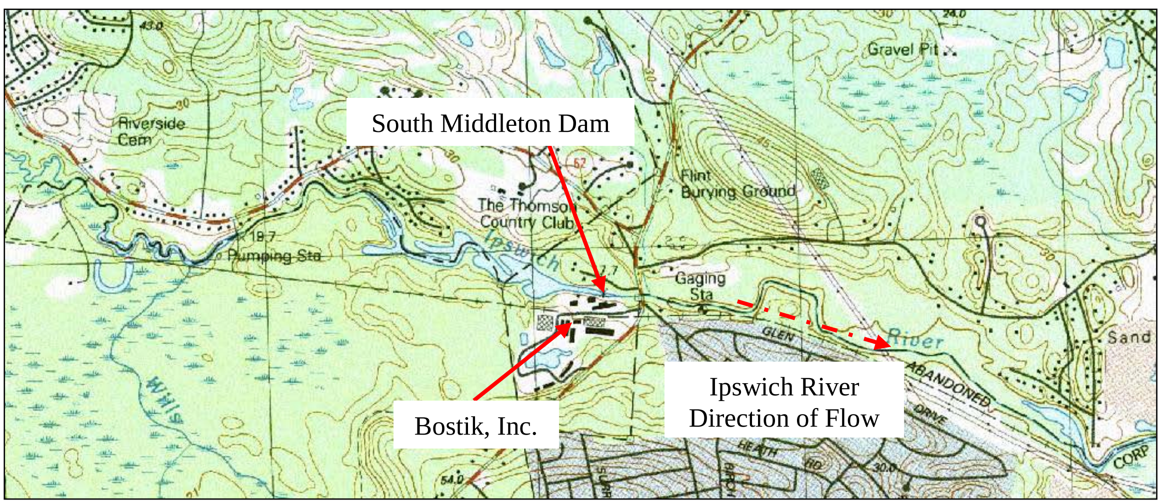

Figure 1: Ipswich River in South Middleton, MA showing the location of the South Middelton Dam and the dam owner, Bostik, Inc.

There are two primary concerns regarding the removal of South Middleton Dam. Since its construction, the dam has been trapping sediments moving downstream. In addition, the water stored in the impoundment has served many uses since the construction of the dam, but it currently functions as the primary water supply for the fire suppression system of Bostik. The goals of this study are to identify the options and costs for managing the impounded sediment and identifying alternative water supply sources for the fire suppression system of Bostik, Inc.

2. Review of Existing Materials

The Ipswich River is a well-studied river and information ranging from GIS data to macroinvertebrate studies is available. In this section, we will summarize the information gathered.

2.1. Bostik, Inc.

Bostik maintains the detailed reports from site assessments, dam inspections, human health assessments, and other studies undertaken since the late 1980s. We reviewed the site, environmental, and human health assessments for information regarding possible contamination in the Ipswich River sediments. This review is summarized in the due diligence section below. We reviewed dam inspection reports for information regarding the construction of South Middleton Dam and this information is summarized in the introduction above. The documents reviewed include:

- Phase II Comprehensive Site Assessment (Vol. 1-3), 12/11/1989
- Phase II Comprehensive Site Assessment (Resubmit, Vol. 1-3), 3/23/1990
- Phase II Comprehensive Site Assessment Addendum Report, (Vol. 1-3), 6/1995
- Human Health Risk Assessment for the Bostik Property, 5/26/1995 (submitted as Appendix to Phase II Comprehensive Addendum Report)
- Phase III Remedial Action Plan, Bostik Inc, DEP RTN 3-1494, 1/4/2001
- Method 3 Stage I Environmental Screening, 3/6/1997 (Ecological Risk Assessment)
- Loss Prevention Survey, 12/11/2008 (contains fire suppression system information
- Ipswich River Dam Phase I Inspection/Evaluation Report, 10/24/2006

2.2. GIS and Mapping Information

GIS data was compiled from a number of different sources and a base map was created (Appendix A). The following GIS information was gathered from the US Geological Survey (USGS), MA GIS clearinghouse, Plum Island Ecosystems Long Term Ecological Research (PIE LTER), University of New Hampshire (UNH), and Clark University:

- Current air photos
- Topographic maps
- Watershed boundaries
- Digital elevation model
- Land use maps from 1971, 1985, 1991, and 1999
- Wetlands maps
- Rivers and ponds
- Major transmission lines
- Parcel boundaries in Middleton, North Reading, Lynnfield, and Peabody
- Roads
- Impervious surfaces

2.3. Hydrology

The USGS gage #01101500 (Ipswich River at South Middleton, MA) is located on the Ipswich River about 1200 ft downstream from South Middleton Dam and there is only a small stream contributing additional flows between the dam and the gage. Mean daily discharge and instantaneous annual peak discharge has been measured at this site since 1938 (Figure 2). Although there does not appear to be substantial changes in the mean daily flows over time, there does appear to be a higher frequency of large floods in the last few decades.

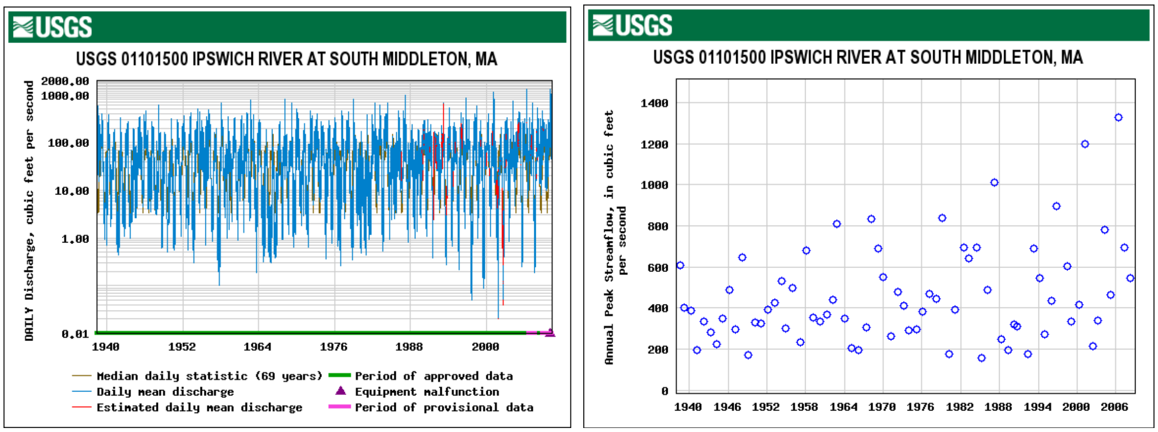

Figure 2: Hydrographs of the Ipswich River just downstream of South Middleton Dam showing mean daily discharge (left) and annual peak discharge (right) since 1938.

Because of the location of South Middleton Dam and the impoundment, two FEMA flood insurance rate maps (FIRM) cover the study area (Figure 3). These maps indicate that an area slightly larger than the impoundment and river boundaries are within the 100-yr flood zone.

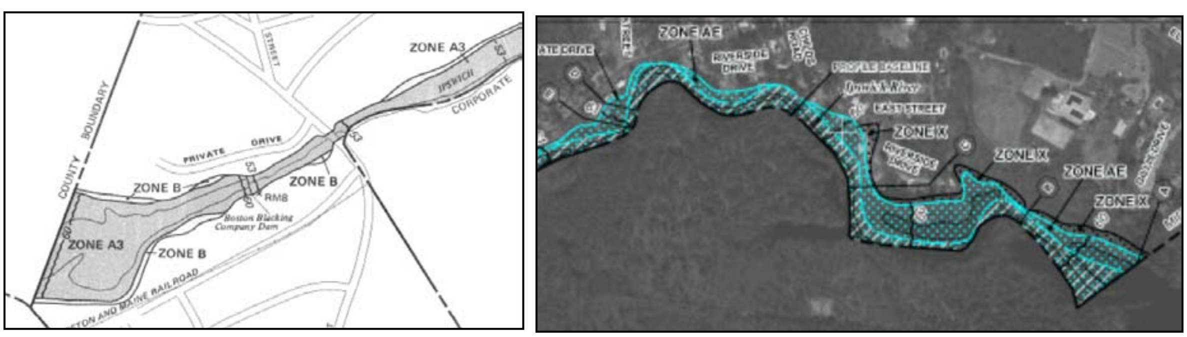

Figure 3: FEMA flood insurance rate maps for the Ipswich River impoundment and downstream (left) and for the impoundment and upstream (right).

The USGS Stream Stats program was used to obtain basin characteristics upstream of the South Middleton Dam. The watershed area was calculated as 43.8 mi^2, average area slope is 1.17%, total stream length is 73.6 miles (Ipswich River and tributaries), area of forest land is 31.8%, and the area of sand and gravel deposits is 52.6%. Stream Stats was also used to estimate flow duration and flood frequency statistics based on the downstream gage and on regional regression equations (Appendix B). Estimated flood flows range from a 2-year flood of 351 ft^3/s to a 100-yr flood of 1160 ft^3/s. Based on these estimates, the March 16, 2010 flood of 1320 ft^3/s exceeded the 200-yr flood (1270 ft^3/s).

2.4. Water Quality

The Ipswich River has been on the MA Department of Environmental Protection (MA DEP) Section 303(d) list of impaired waterways since 1998 for failing to meet low water flow and dissolved oxygen (DO) water quality standards (IRWA, 2000). The Total Maximum Daily Load (TMDL) thresholds for pathogen indicators was also exceeded. These indicators, such as fecal coliform, *E. coli,* and enterococcus bacteria may be coming from failing septic systems, sanitary sewer overflows, and combined sewer and storm water pipes. At Boston Street, near South Middleton Dam, fecal coliform sampling resulted in 5 colonies/100 mL for the spring and 50 colonies/100 mL for the fall of 1999 (IRWA, 2000). Low baseflows due to groundwater withdrawals in multiple towns in the watershed resulted in portions of the river drying up in 1995, 1997, 1999, and 2002 (MA DEP, 2004).

The IRWA RiverWatch program has been collecting water quality data for the Ipswich River watershed since 1997 (IRWA 2007, 2010). They have collected data on water temperature, DO, and water flow. In the 10 years of sampling, only four samples throughout the watershed exceeded the Class B temperature threshold for a warm water fishery (maximum temperature of 28.3° Celsius, or 83° F). However, 21% of all samples fell below the DO concentration standard (5.0 mg/L) and 38% fell below the DO percent concentration standard (60%). One of the RiverWatch sampling locations is between South Middleton Dam and the USGS gage downstream of Boston Street. Although this location is in the upper half of the watershed, where many of the sampling locations did not meet the DO standards, the DO concentration and % saturation were one of the highest in the watershed. This is likely due to the aeration from water spilling over South Middleton Dam and flowing over the long riffle downstream.

2.5. Fish

The Ipswich River is classified as a warm water fishery, as indicated in the water quality reports summarized above. Two separate studies in 1998 (MA DEP, 2004) and from 1998 to 1999 (Ipswich Fisheries Restoration Task Group, 2002) found that the dominant fish species in the Ipswich River were macrohabitat generalists. These include redfin pickerel (36%), American eel (21%), and pumpkinseed (12%). All fluvial specialists and fluvial dependent species were below 5% (Ipswich Fisheries Restoration Task Group, 2002). Just downstream of South Middleton Dam, the results were similar: redfin pickerel (53 individuals), pumpkinseed (111), American eel (78), yellow perch (20), and bluegill (28) (MA DEP, 2000). Small numbers of other species included white sucker (13), creek chubsucker (6), and sea lamprey (3).

3. Impounded Sediment

The removal of South Middleton Dam will involve the removal of accumulated sediment, either through active or passive means. Understanding the quality of the impounded sediment that will need to be removed - grain size and type and degree of contamination - is essential for designing the dam removal and estimating associated costs. We are considering two primary methods of sediment removal and these are dependent on contamination levels:

1. No contamination of sediment: sediment would be released downstream during a staged draw-down of the impoundment and removal of the dam. Additional sediment excavated during channel construction could also be released downstream or reused on site.
2. Contaminated sediment: the impoundment water level would be lowered without releasing sediments downstream. The sediments excavated during the construction of the new channel would be reused on site and capped so as to prevent flow of contaminants to the channel.

In addition to the industrial history of towns within the watershed upstream, there has been a long history of industrial use at the site currently owned by Bostik (D. Welch, pers. comm.):

- 1674: John Phelps opened a sawmill
- 1685: John McCarty and John Buxton started a "fulling mill" for cleaning and finishing wool cloth
- 1709: Ezekial Upton bought the property and opened a grist mill
- 1832: Colonel Francis Peabody bought the property, built a paper mill and added a building to produce linseed oil
- 1843: Zenas and Luther Crane bought the property and began manufacturing fine quality paper
- 1885: Edward Hickey opened a wallpaper business
- 1908-1920: the property was used as a leather finishing factory
- 1920s: the property became a dyeing establishment
- Since 1928, the property has produced shoe blacking and adhesives under various ownerships from Boston Blacking Co, The B B Chemical Co., and Bostik, Inc.

With such a long history of industrial use, determining what contaminants, and in what quantities, are located in the impounded sediment is necessary before plans for removing South Middleton Dam can progress.

3.1. Due diligence summary

In order to determine the appropriate sediment quality testing regime, a due diligence review of potential contaminant sources was completed. This review utilized the archives of state and federal agencies as well as documents provided by Bostik to examine watershed landuses and potential point sources of contaminants such as large chemical users, historic spills, underground utilities and storage tanks. The watershed upstream of South Middleton Dam is approximately 43 mi^2 (GEI Consultants, Inc., 2006) and has a long history of industrial use. The towns within this watershed include Middleton, Andover, North Andover, Burlington, Danvers, Lynnfield, Peabody, Reading, North Reading and Wilmington. Because of proximity and long-time use of oils and chemicals on site, particular attention was focused on the Bostik facilities.

3.1.1. Entire Watershed Upstream of South Middleton Dam

Multiple state and federal agency sources were searched for information relating to contaminants in the watershed. The following is a summary of the information gathered:

- No MEPA listings for solid and hazardous waste, wastewater or water thresholds
- No superfund sites on National Priorities List
- 4 sites in Middleton and Peabody were listed on the superfund short-term removal list - clean up was completed for all of these by 1999
- 7 CERCLIS/NFRAP sites in North Andover, North Reading, Reading and Wilmington
- 74 small quantity waste generators and 23 large quantity waste generators listed under the Resource Conservation and Recovery Act (RCRA) in Middleton, North Andover, North Reading, Reading and Wilmington; 1 current violation in North Andover; Bostik listed as corrective action site
- Over 1500 waste sites reported releases and 86 sites have activity and use limitations listed with MA DEP; these sites are in Middleton, Andover, Burlington, Danvers, Lynnfield, North Andover, North Reading, Peabody, Reading and Wilmington
- 188 of 399 underground storage tanks are in use and contain unleaded and diesel gas, fuel oil, waste oil, kerosene, hazardous waste, ethyl acetate, vinyl, aroma 100, castor oil, naphthalene, toluene, xylene, cellosolv, dioctyl phthalate, and isobutyl acetate

3.1.2. Bostik, Inc. Property

A *Phase II Comprehensive Site Assessment* of the Bostik property was completed in 1995. The property was divided into 12 areas to be studied; Area 4 focused on the surface water and sediments of water bodies on the property as well as in the Ipswich River. A total of 20 on-site and 28 off-site sediment samples were analyzed for PCBs and VOCs and a subset of these samples were also analyzed for SVOCs and TPH fingerprinting (Figure 4). The water bodies on the property include Upper Pond, Lower Pond and a small stream draining these ponds into the 'Cove' of the Ipswich River. The Ipswich River was sampled in the 'Cove' and the main channel upstream and downstream of the dam. Sediment was sampled and analyzed downstream of the dam to determine the type and amount of contaminants that passed over the dam. Samples collected upstream of the 'Cove' were used as background samples and were indicators of contaminants originating from upstream sources (GEI Consultants, Inc., 1995).

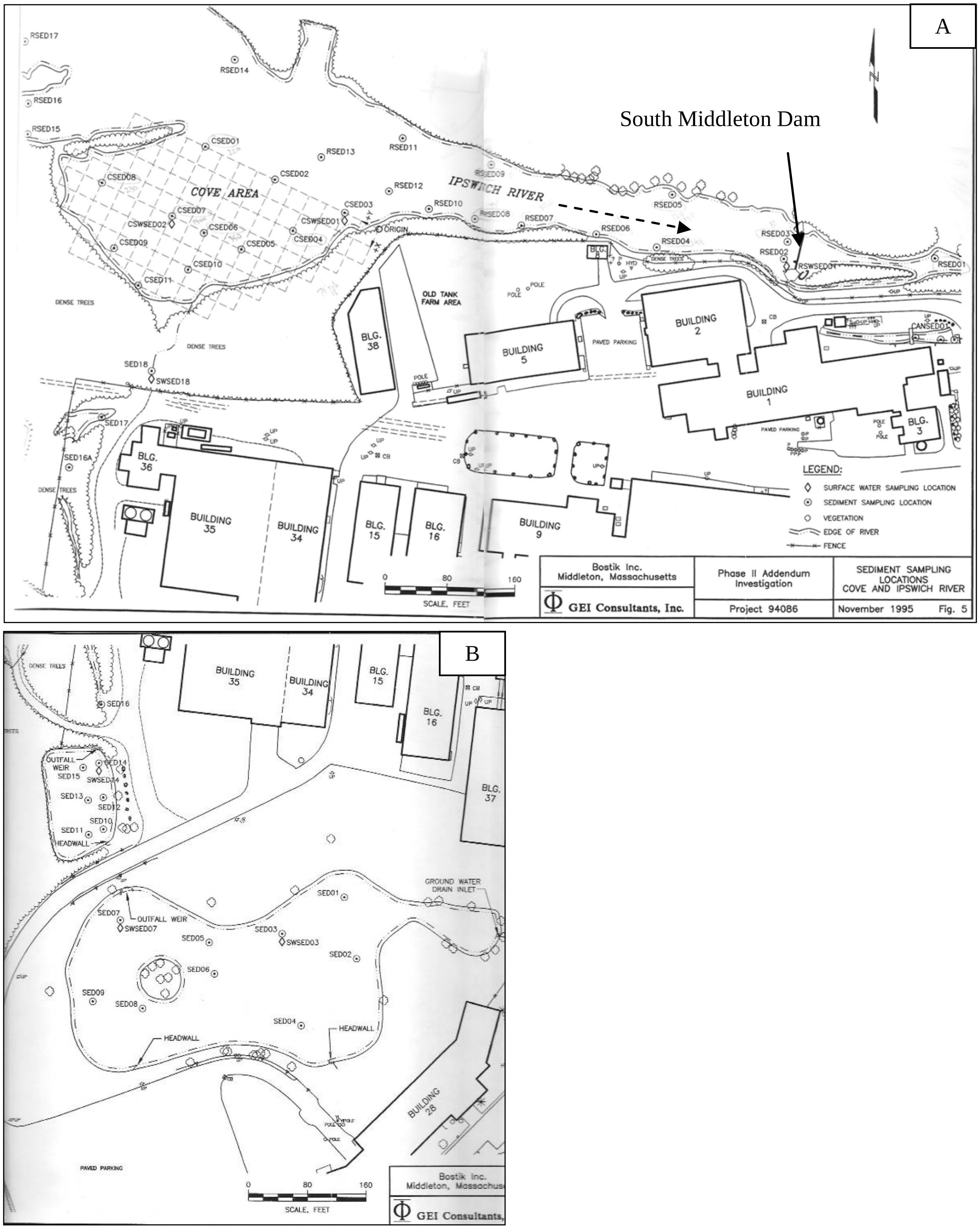

Figure 4: Sediment samples collected and analyzed for contaminants in the (A) Ipswich River and (B) on-site water bodies (modified from Figures 5 and 6 of GEI Consultants, Inc., 2006). Direction of flow is indicated by the dashed arrow.

PCBs and low concentrations of VOCs were found in the areas of potential excavation in the Cove and Ipswich River. PCBs were detected in 18 of 84 sediment samples in the Cove and Ipswich River, but the concentrations of all but one were below the MCP S-2 threshold of 3000 ppb (Table 1). The soil category of S-2 is appropriate for comparison in the study area because once the dam is removed and the sediments become soil, the soil will be accessible, but the frequency and intensity of use by children and adults is low and will be limited by an Activity and Use Limitation (AUL). Bostik, Inc. owns the land on both sides of the impoundment area, and there is evidence of only occasional use of the surface water for boating. Only one sample contained PCB concentrations greater than the MCP S-2 threshold and this sample (RSED07) was located in the Ipswich River adjacent to the Old Tank Farm (between the Cove and the dam) and had a concentration of 5100 ppb. PCB concentrations below the dam and upstream of the site were low or not detected (GEI Consultants, Inc., 1995).

Table 1: PCB contamination of soils sampled in the Cove and Ipswich River (concentration values from GEI Consultants, Inc., 1995). See map above for exact location of samples. ND = not detected.

Sample #	Location	Concentration (ppb)	S-1 Standard (ppb)	S-2 Standard (ppb)
CSED-01	Cove	ND	2000	3000
CSED-02	Cove	ND	2000	3000
CSED-03	Cove	ND	2000	3000
CSED-04	Cove	71	2000	3000
CSED-05	Cove	ND	2000	3000
CSED-06	Cove	350	2000	3000
CSED-07	Cove	1500	2000	3000
CSED-08	Cove	230	2000	3000
CSED-10	Cove	ND	2000	3000
CSED-11	Cove	220	2000	3000
RSED-01	Ipswich River downstream from dam	57	2000	3000
RSED-02	Ipswich River between dam and Cove	ND	2000	3000
RSED-03	Ipswich River between dam and Cove	32	2000	3000
RSED-04	Ipswich River between dam and Cove	44	2000	3000
RSED-05	Ipswich River between dam and Cove	340	2000	3000
RSED-06	Ipswich River between dam and Cove	140	2000	3000
RSED-07	Ipswich River between dam and Cove	5100	2000	3000
RSED-08	Ipswich River between dam and Cove	750	2000	3000
RSED-09	Ipswich River between dam and Cove	54	2000	3000
RSED-10	Ipswich River between dam and Cove	ND	2000	3000
RSED-11	Ipswich River adjacent to Cove	ND	2000	3000
RSED-12	Ipswich River adjacent to Cove	ND	2000	3000
RSED-13	Ipswich River adjacent to Cove	ND	2000	3000
RSED-14	Ipswich River upstream from Cove	ND	2000	3000
RSED-15	Ipswich River upstream from Cove	ND	2000	3000
RSED-16	Ipswich River upstream from Cove	ND	2000	3000
RSED-17	Ipswich River upstream from Cove	ND	2000	3000

Total VOC contamination levels were less than 6 ppm in most of the sediment samples throughout the portions of Area 4 with potential sediment excavation. In the Ipswich River adjacent to the Old Tank Farm (between the Cove and the dam), total VOC concentrations were 23 and 94 ppm in samples RSED08 and RSED10. In the main channel adjacent to and upstream of the Cove, concentrations reached 24 and 21 ppm in samples RSED14 and RSED15. The concentrations in the upstream samples increased with depth, suggesting a historic upstream source of contamination (GEI Consultants, Inc., 1995).

No samples contained detectable levels of SVOCs and only low concentrations of TPH fingerprinting (14-77 ppm as compared to the MCP S-2 Standard of 3000 ppm) were found in a few samples. No contamination of surface water was detected (GEI Consultants, Inc., 1995).The results from the 1995 study described above indicate that contamination levels of PCBs, total VOCs, SVOCs and TPH in sediments that would potentially be excavated during dam removal are very low. All but one sediment sample in the Cove and Ipswich River contained concentrations of contaminants that were less than the MCP S-2 standards. The one exception was a sample in the Ipswich River between the Cove and dam that contained higher levels of PCBs.

Human Health Risk Assessment *The* generally low levels of contamination suggests that currently (with the dam in place) the risk to human health is minimal. Following the chemical analysis of the soils, a Human Health Risk Assessment was completed for Bostik (GEI Consultants, Inc., 1995b). This Assessment concluded that there were no human health risks (non-cancer or cancer risks) associated with the Cove or Ipswich River. In addition, studies of chemicals found in fish in the Ipswich River found contamination levels that were not deemed to be a health risk according to comparisons with standards from the US FDA. The low human health risk of the sediments that may be excavated during dam removal suggests that sediment could be released downstream in a staged draw-down of the impoundment or reused on site.

RCRA As noted above, Bostik was listed as one of the (RCRA) corrective action sites. According to RCRA files, the facility generates organic solvent wastes and stores them in drums or tanks. A Tier 1 permit was issued to clean up this area and Bostik complied by implementing numerous remedial actions. Chemicals potentially present in levels above published risk levels in the ground water include C5-C8 aliphatics; those found in the surface and subsurface soils include C11-C22 aromatics, PCBs, extractable petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAHs). It was noted that no contaminants have been found in the surface water since the groundwater extraction system was shut down in 2002.

Underground Storage Tanks The MA Department of Environmental Protection (MA DEP) listed 13 incidents of underground storage tank releases or potential for releases on the Bostik property since 1995. Substances cited included oil and hazardous materials, primarily methyl ethyl ketone. These incidents were addressed within a few months of notification and no further action was necessary.

The due diligence results, particularly the history of industrial use in the watershed, indicates a probability of contamination from aromatic hydrocarbons, volatile organic compounds, PCBs and possibly heavy metals. The sampling and analyses described below reflects the presence of these chemical groups.

3.1.3. Bostik, Inc. Property - Current Conditions

Remedial actions have been ongoing on the Bostik property since the 1990s to address the issues discussed above (D. Welch, pers. comm.). Bostik will soon be submitting a Response Action Outcome report that will describe these actions and their results. These remedial actions may be a contributing factor to the decreased concentrations of contaminants found in the Ipswich River in this feasibility study as discussed below.

3.2. 2010 Sediment Sampling and Analysis

For this partial feasibility study, Inter-Fluve Inc. collected ten sediment samples around the South Middleton Dam in the spring of 2010. Five samples came from within the impoundment, and these five include two floodplain samples, two samples from the channel, and two samples from the Cove (Appendix C). Two samples are from downstream of the dam, and we did collect a third sample that could be analyzed if necessary. One sample from upstream of the impoundment is included in the analysis. Each sample that has been analyzed is a composite of two or three cores from an area with a similar sediment composition. These individual cores are preserved and can be analyzed to refine the level of contamination at sites deemed necessary. Based on information gathered during our due diligence analysis, we tested the soil samples for metals, SVOCs (PAHs), VOCs, EPH, PCBs, and physical characteristics. We then compared the results to the MCP S-1 and S-2 standards (310 CMR 40.0975(6)(a)) as well as the PEC (probable effects concentration). The S-2 thresholds were used because the land around the impoundment is owned by Bostik, Inc., which is considering limiting use on the property through an Activity and Use Limitation (AUL).

No samples exceeded the S-2 thresholds in any contaminant tested (Table 2). Only the two cove samples and one of the downstream samples had levels of any of the tested contaminants that exceeded either the MCP S-1 or PEC standards. Chromium (42 mg/kg) and Nickel (21.8 mg/kg) in the Cove 1 sample exceeded the MCP S-1 thresholds (30 mg/kg and 20 mg/kg respectively) but not the PEC thresholds (111 mg/kg and 48.6 mg/kg). This sample also had levels of lead (201 mg/kg) and zinc (608 mg/kg) that exceeded the PEC threshold (128 mg/kg and 459 mg/kg) but not the MCP S-1 thresholds (300 mg/kg and 2500 mg/kg). The lead concentration in the Cove 1 sample also exceeded the TCLP threshold (100 mg/kg). Downstream of the dam, the DS3 sample had levels of chromium (38 mg/kg) that exceeded the MCP S-1 standards. This sample also had elevated levels of the SVOC Benzo[a]anthracene (1040 ug/kg) that exceeded the MCP S-1 standard (700 ug/kg).

Overall, contaminant levels in the impoundment sediments are similar to those of the Ipswich River downstream of the dam and upstream of the impoundment. Contaminant levels in sediments downstream of the dam decreased with downstream distance. The sediment analysis results suggest that downstream release of sediments may be possible for most or all of the impounded sediments. Although the level of contamination for a few metals are slightly higher in the Cove 1 sample than the downstream samples, many other parameters have equal or lower levels of contamination. Contamination levels in the main channel upstream from the dam indicate that downstream release is feasible. The sediments in the Cove may also be released downstream, or they could be re-used as floodplain material. All of this is dependent on review by MA DEP.

Table 2: Contaminant results for sediment samples in the impoundment and in Ipswich River. Contaminants where no concentrations were detectable in any samples are not included in this table, but can be provided. FPLT=floodplain left; FPRT=floodplain right.

Parameter	**Screening Benchmarks**			**Dam Impoundment Samples**									**Downstream Samples**			**Upstream Samples**	
(Units listed by category below)	**MCP S1 / GW1**	**MCP S2 / GW1**	**PEC**														
	Human Health			CH1	CH1A	CH2	CH3	FPLT	FPRT	COVE1	COVE2	COVE2A	DS1	DS3	DS3B	US1	US1A
Metals [mg/kg]																	
Arsenic	20.0	20	33.0	16		7.3	9.52	7.76	6.42	6.36	5.35		6.44	4.58		5.41	
Cadmium	2.0	30	5.0	0.227		0.124	0.127	0.171	0.085	1.72	0.494		0.402	1.19		0.177	
Chromium (TOTAL)	30.0	200	111.0	19.2		21	14.1	16.3	19.2	42	25		21.9	38		14	
Chromium (III)	1,000.0	3000															
Chromium (VI)	30.0	200															
Copper	NC		149.0	23.8		15.8	10.2	12.1	12.7	75.8	29.2		22.7	51.1		12.2	
Lead	300.0	300	128.0	20.4		13.3	8.13	11.6	10.3	201	37		36.8	98.5		12.5	
Mercury	20.0	30	1.1	0.02		0.017	0.025	ND	0.047	0.054	ND		0.044	0.038		ND	
Nickel	20.0	700	48.6	10.1		14.2	9.33	11	13.4	21.8	17.6		15.5	15.8		9.37	
Zinc	2,500.0	3000	459.0	49.7		52.8	37.6	58.6	39.3	608	210		148	422		52.5	
SVOCs (**PAHs**)[ug/kg]																	
Acenaphthene	4,000.0	4000		ND		ND	ND	ND	29.1	ND	ND		ND	62.8		ND	
Acenaphthylene	1,000.0	1000		14.4		ND	ND	ND	27.6	ND	ND		ND	120		ND	
Anthracene	1,000,000.0	3000000	845.0	14.6		ND	ND	ND	56.3	ND	17.4		ND	163		ND	
Benz[a]anthracene	700.0	40000	1,050.0	83		25.8	ND	78.1	330	132	144		30.5	1040		26.8	
Benzo[a]pyrene	2,000.0	4000	1,450.0	61.7		20.1	ND	58.2	264	86.2	90.4		20.9	840		17.6	
Benzo[b]fluoranthene	7,000.0	40000	13,400.0	102		37.9	ND	101	310	152	141		43.8	1070		36.3	
Benzo[g,h,i]perylene	1,000,000.0	3000000		56.3		21.4	ND	62.8	194	81.8	82.2		25.1	603		19.1	
Benzo[k]fluoranthene	70,000.0	400000		43.2		17.9	ND	61.1	174	90.7	92.2		23.5	581		13.9	
Chrysene	70,000.0	400000	1,290.0	68.9		25.6	ND	72.5	284	128	137		32.3	847		26.1	
Dibenz[a,h]anthracene	700.0	4000	260.0	16.7		ND	ND	17.4	60.8	24.2	25.5		ND	199		ND	
Fluoranthene	1,000,000.0	3000000	2,230.0	171		54.9	ND	157	495	292	245		69	1870		49	
Fluorene	1,000,000.0	3000000	536.0	ND		ND	ND	ND	27.8	29.9	16.7		ND	76.3		ND	
Indeno[1,2,3-cd]pyrene	7,000.0	40000		50.3		17.8	ND	55.6	163	69.9	69.2		21.9	553		16.1	
Phenanthrene	10,000.0	10000	1,170.0	89		15.7	ND	51.1	322	169	123		24.6	850		17.9	
Pyrene	1,000,000.0	3000000	1,520.0	152		52.6	ND	144	524	242	227		59.2	1500		48.6	
Naphthalene	4,000.0	4000	561.0	ND		ND	ND	ND	ND	ND	35.6		ND	29.6		ND	
Total PAHs			22,800.0	923.1		289.7	0	858.8	3261.6	1497.7	1446.2						
PCBs (ug/kg)																	
Cl3-BZ318				ND		ND	ND	ND	6.34	ND	3.71		ND	ND		ND	
Cl3-BZ3#28				ND		1.79	ND	3.73	16.4	5.54	12.3		ND	1.99		ND	
Cl4-BZ#52				ND		1.95	ND	3.61	32.3	3	26.1		ND	8.85		ND	

CI4-BZ#49				ND		ND	ND	ND	16	ND	7.61		ND	3.71		ND	
CI4-BZ#44				ND		2.06	ND	2.36	26.6	2.95	18.3		ND	5.62		ND	
CI4-BZ#66				ND		1.23	ND	1.61	9.02	ND	11.6		ND	3.38		ND	
CI5-BZ#101				ND		1.5	ND	1.85	13.3	ND	10.2		ND	6.83		ND	
CI5-BZ#87				ND		ND	ND	ND	4.39	ND	4.07		ND	2.26		ND	
CI5-BZ#118				ND		ND	ND	1.52	10.6	ND	8.62		ND	4.41		ND	
CI6-BZ#153				ND		ND	ND	ND	1.81	ND	3.55		ND	2.09		ND	
CI5-BZ#105				ND		ND	ND	ND	4.7	ND	8.04		ND	2.79		ND	
CI6-BZ#138				ND		ND	ND	ND	3.81	ND	4.29		ND	2.94		ND	
CI6-BZ#128				ND		ND	ND	ND	1.29	ND	ND		ND	ND		ND	
CI7-BZ#180				ND		ND	ND	ND	ND	ND	3.34		ND	1.41		ND	
Total PCBs	2,000.0	3000	676.0	0		8.53	0	14.68	146.56	11.49	121.73		0	46.28		0	
VOCs (ug/kg)																	
Acetone	6,000.0	6000	NC		57							424			167		149
2-Butanone	NC		NC		12.5							103			75.9		34.8
Chlorobenzene	1,000.0	1000			ND							12.3			ND		ND
EPH (mg/kg)																	
C19-C36 Aliphatics	3,000.0	5000	NC	ND		15.4	ND	34.8	14	28.7	78		ND	22.8		ND	
C11-C22 Aromatics	1,000.0	1000	NC	12.5		ND	ND	18.1	15.3	ND	53		ND	27.6		ND	
Unadjusted C11-C22 Aromatics	NC		NC	12.5		ND	ND	18.1	15.3	ND	53		ND	32.4		ND	
Physical Characterisitcs																	
Total Organic Carbon (%) Rep1				1.06		0.93	0.186	2.73	1.38	6.47	4.48		1.07	4.31		1.43	
Total Organic Carbon (%) Rep2				1.26		1.1	0.13	2.12	1.53	5.19	4.52		1.36	4.17		1.25	
Solids (%)					64.8	61.9	75.9	50	61.8	31.6	51.2	21.2	55.4	64.7	38.9	61.8	44.2
Percent Moisture (%)				35.2		38.1	24.1	50	38.2	68.4	48.8		44.6	35.3		38.2	
Grain Size Distribution (%)																	
Sieve No. 4				95.9		99.7	99.8	95.1	90.8	99.9	99.9		99.7	97.6		98.8	
Sieve No. 10				89.2		99.3	99.6	91.2	85.1	94	98.2		98.8	92.9		97.4	
Sieve No. 40				69.2		76.7	70.7	63.7	67.2	69.8	81.7		70.1	41.9		84.3	
Sieve No. 60				49.6		48.4	13	46.6	46.1	62.1	63.2		41.3	22.5		40.6	
Sieve No. 200				8.5		6.4	0.4	12.1	8.7	34	21.8		5.7	3.1		4.9	

4. Fire Suppression Alternatives

The City of Peabody Main Service water system serves the majority of the City of Peabody and is also the primary water supply for the Bostik facility. Peabody's 12-inch cement lined water main in Russell Street ends at Boston Street, and was installed in 1959 according to their records. A ten inch main extends to the Bostik facility to meet domestic and fire protection demands. The typical hydraulic grade line of this system is about 275 feet, which can deliver normal domestic demands at a pressure of about 90 psi to Bostik under normal conditions. We reviewed past flow tests and utilized the City of Peabody water system hydraulic model to approximate the maximum flow that could be available to the Bostik facility for fire suppression from the Peabody Main Service. Under normal conditions, a flow of up to 2,000 gpm at 20 psi could be available at the facility, a pressure lower than the required minimum of 80 psi. A pump is used to increase pressure in this system for fire suppression, but the system is unable to sustain this pressure for long periods of time and it quickly switches to a fire pump in the Ipswich River.

The South Middleton Dam impoundment on the Ipswich River is used to supplement the Peabody water system described above for fire suppression needs at Bostik. A vertical turbine pump set over a 14-foot deep wetwell is reported to have capacity to pump 2,000 gallons per minute (gpm) at 80 psi into the fire protection piping network. The network includes fire sprinkler systems within various buildings and fire hydrants on site. With the removal of the dam, the current source of water for fire protection will no longer be available. This will require developing an alternate source of water and replacing the pumped system with a new system that will deliver the required flow and pressure.

For the purpose of this report, we have assumed that the flow requirement for the fire protection system will be 2,000 gpm in the future. According to Mr. Phil Crain, CFPS, of XL Capital Group, fire protection consultant for Bostik, this volume is needed over a duration of three hours, resulting in a total volume requirement of 360,000 gallons. The delivery pressure design point will be 100 psi, which is an increase from the current 80 psi. For the purpose of this evaluation, pressures are assumed to be measured from ground level at the lower buildings nearest the river (assumed at 60 feet ground elevation). A pressure of 100 psi at ground elevation of 60 feet is equal to a hydraulic grade line of 290 feet. This pressure should be verified with Bostik's fire protection consultant prior to any facility design or improvement.

Several alternatives and combinations of alternatives were considered for replacing the existing fire protection supply, as follows:

- Connect to the City of Peabody High Service water system.
- Build new on site ground level fire storage capacity.
- Reinstate the existing steel elevated water storage facility.
- Build a new steel elevated water storage facility.
- Utilize on-site ponds.

Peabody High Service water system. This water system serves the areas of West Peabody at higher elevation. Peabody's 8-inch cement lined water main in Catherine Drive ends at Boston Street and was installed in 1959 according to their records. The typical hydraulic grade line of this system is about 310 feet, which can deliver normal domestic demands at a pressure of over 100 psi to Bostik under normal conditions. We utilized the City of Peabody water system hydraulic model to approximate the flow that could be available to the Bostik facility from the Peabody High Service. Under normal conditions, a flow of up to 1,500 gpm at 20 psi could be available if approximately 1,500 feet of 8-inch pipeline is extended from the Catherine Street to the vicinity of the existing water storage tank.

On Site Ground Level Fire Storage Tank. A new tank would be sized to provide water storage for fire protection supply, with or without augmenting supply from the City of Peabody. Full supply would require a large volume for all sprinklers and hydrant hose streams. Typical flow duration for public fire suppression would be three hours for a flow of 2,000 gpm, for a total volume of 360,000 gallons. For the purpose of estimation of a tank volume we have assumed this flow and duration, with an allowance for pump suction volume, for a total of 400,000 gallons capacity. This flow and duration should be verified, as confirmation of that flow and duration is beyond the scope of this evaluation.

An alternative to the 400,000 gallon ground storage tank would be a smaller tank that would utilize water supply from either or both of the Peabody Systems for refilling the tank during a fire event. The hydraulic model indicates that at least 2,000 gallons could be available from Peabody under normal conditions. To avoid low pressures and disruption in the Peabody Systems during all conditions, we estimate that no more than 800 to 1,000 gpm should be taken from the Main Service and no more than 500 to 700 gpm from the High Service. Supplementing flow from the Peabody Main Service would result in a fire storage tank volume of 250,000 gallons. Additional supplementing with flow from the Peabody High Service would result in a fire storage tank volume 150,000 gallons. 1,000 feet of dedicated 10-inch water main from the water tank to the City water supply at Boston Street would be necessary to allow the supplemental flows to refill the tank during its use.

Since the water in the tank is stored until needed, it must be kept from freezing during the winter. For this reason, the tank should be insulated and the water circulated and heated as necessary. When needed, the water would be pumped to meet the fire demand. Most often, the pumping station would include one engine driven pump and a fire department backup connection. Controls would be automatic. A duplex pumping arrangement with electric pump motors would provide redundancy should the single pump fail, but is not often used. If desired and not already available, a generator can be provided for power to the electric motors if electric power is lost. The tank and pump station should be located near the existing fire protection piping network, and away from existing buildings, possibly in the vicinity of the existing pump.

Reinstate Elevated Water Storage Tank. The existing steel elevated water storage tank was reported to have been built around 1950, is about 140 feet tall, has a capacity of 150,000 gallons and is currently out of service. Several years ago, due to structural issues it was determined to be no longer useful for its intended purpose. For this reason, it was determined that it is not an option for future consideration.

Build new Elevated Water Storage Tank. A new steel elevated water storage tank would have to be about 180 to 200 feet tall, with a capacity of at least 100,000 gallons. A tank of this height and capacity would cost far in excess of the cost of a ground storage tank with pumps. For this reason, it was determined that it is not an option for future consideration.

Utilize On-site Ponds. There are several ponds on site. They are generally shallow and are not easily usable in winter when they are frozen. In addition, fire departments only like to use them as a source of last resort. For these reasons, it was determined that ponds are not an option for future consideration.

Suggested Alternative. Although a significant fire flow volume is available directly from the City of Peabody water system, 2,000 gpm is not available at the 100 psi pressure desired. For this reason, the flow must be pumped to meet the pressure requirement. To accomplish this, a pumping system with a fire storage tank is needed. Supplementing the volume stored in the tank from at least one of the City of Peabody water distribution systems is also suggested to decrease the size of the storage tank and increase reliability. For the purpose of estimating the probable cost of improvements, we have assumed the following. It should be noted that these are conservative estimates and that final costs may be lower.

- 250,000 gallon insulated fire storage tank with recirculation system. Estimated cost $375,000.
- 2,000 gpm at 100 psi engine driven single pumping system. Estimated cost $225,000.
- 1,000 feet of 10-inch water main connection from the storage tank to the 10-inch water main in Boston Road. Estimated cost $75,000.

The total estimated cost of the replacement fire protection system is approximately $675,000.

Alternatives include the following:

- Increase the size of the insulated fire storage tank with recirculation system to 400,000 gallon. Estimated **additional** cost $100,000.
- Decrease the size of the insulated fire storage tank with recirculation system to 150,000 gallon. Estimated **reduction** in cost $100,000.
- Install a duplex electric motor driven pump system with backup generator in lieu of single pump system with direct drive diesel engine. Estimated **additional** cost $120,000.
- Install 1,500 feet of 8-inch water main to the Peabody high service system for a second water connection. Estimated **additional** cost $110,000.

The final tank size and location pump size and number, pump power source, as well as the lengths of water mains should be confirmed prior to finalizing a proposed plan.

5. Next Phase of Work for Dam Removal

In addition to understanding the sediment quantity and quality within the impoundment and identifying alternative water supply sources for Bostik, the removal of South Middleton Dam is dependent on the costs of future phases of work including an advanced feasibility study, design and permitting, construction, and construction oversight. Below we present a draft scope of work and cost estimate for the advanced feasibility study. Cost estimates for additional phases of work will be better estimated following this advanced feasibility study.

5.1. Advanced Feasibility Study - Cost Estimate: $42,000

The advanced feasibility phase includes a topographic survey, a base map, hydrology and hydraulic analysis, meetings with MA DEP and a sediment management plan, and concept renderings. At the completion of this phase, the project partners will have all of the data necessary to move directly into the design phase.

Task 1 Project Management

1.1. *Project management* –Timely deliverables and completion of all tasks.

1.2. *Conference calls* –Participation in up to 8 hours of conference calls.

Task 2 Surveying

2.1. *Topographic survey* –Complete topographic survey to create a working basemap. The survey will include cross-sections and profile data sufficient to create a continuous project HEC-RAS model for assessment of flood management, fish passage feasibility, sediment management and restoration design. Cross section spacing will reflect local hydraulic conditions and will be sufficient for modeling purposes.

2.1.1. Approximately 55-65 cross-sections will be surveyed at varying widths. This will include dense coverage near the dams, infrastructure and low chords of bridges, and cross-sections upstream and downstream of bridges. For steep valley walls, we will survey to the 100 year flood elevation, and for wide floodplain areas we will incorporate the terrace edges to the 100-year elevation.

2.2. *Bathymetric survey* – A depth of refusal survey has already been completed. The topographic survey will tie into this depth of refusal survey so above ground and bathymetry data are in one dataset.

Task 3 Mapping

3.1. *Base map* –a base map will include:

- 1-ft. contours in the area of potential construction near the dam site sufficient to provide cut and fill volume estimation.
- Cross-sections and profile sufficient to create a project HEC-RAS model for assessment of flood management, fish passage feasibility, sediment management and restoration design.
- Any relevant aesthetic, historic, or recreational resources as well as relevant aspects of, the city's riverfront revitalization plans
- Sediment depth and volume information
- Utilities, FEMA flood boundaries and property boundaries if available in GIS format

Task 4 Hydrologic and Hydraulic (H&H) Analysis

4.1. Existing and proposed topographic data will be integrated with a hydraulic model to develop a plan view of proposed changes under baseflow, 2, 5, 10 and 100 year flood occurrences, and present the HEC-RAS profiles for the 2, 10, 25 and 100 year floods.

4.2. Incipient motion analysis –channel and bank stability requirements will be reviewed and refined, sizing and other requirements for stabilization measures such as riprap, bank toe or riffle material will be developed.

4.3. Bridge scour analysis will be conducted at the Boston Street bridge.

Task 5 Sediment Management Plan

5.1. *Regulatory Meeting #1* - Meet with MA DEP to discuss the results of the sediment sampling and contaminant analysis undertaken in the Partial Feasibility Study. Discuss potential management alternatives and request recommendations regarding the analysis of additional samples. As the extent of this additional sampling is unknown, it is not included in the budget estimate. Typically, the lab fees for a full suite of contaminants is about $1000/sample.

5.2. *Draft Sediment Management Plan Technical Memorandum* –The sediment management plan will summarize the contaminant data gathered in the Partial Feasibility Study and in Task 5.1 aboveand will also include the following:

- Summary of proposed sediment management alternatives.
- Sediment disposal plan –summary of proposed removal, disposal and/or stabilization of any sediment that is required to be removed and re-used.
- Regulatory meeting #2 - meet with MA DEP to discuss sediment management alternatives and get feedback. DEP may require additional tests of frozen cores.

5.3. *Final Sediment Management Plan Technical Memorandum* – Based on comments received from project partners and MA DEP, finalize the Sediment Management Plan Tech Memo including the chosen sediment management alternative. The final plan will be sufficient to begin final design and the permitting process.

Task 6 Concept Rendering

6.1. Concept renderings are not detailed designs, but they provide the project partners with a visual understanding of what the restored system will look like following dam removal. With the topographic survey data available, this could be a relatively detailed concept rendering with contour information for existing and proposed conditions. These renderings could also include features such as access locations, utility information, location of structures, natural resource boundaries, and the area of potential effect. The renderings could easily be used to move into the more detailed design phase.

Task 7 Final Report

7.1. This final report will include a summary of all data collected to date, description of the preferred sediment management option, discussion of hydraulics results including figures cross sections and stream profiles, base map showing detailed topographic information and other details described in Task 3, and discussion of the concept designs.

Table 3: Typical permits necessary for dam removal in MA.

Permit	*Regulating Agency*	*Details*	*Review period*
Wetlands Protection Act (Order of Conditions)	Local Conservation Commission	Submission to both Mass DEP and Cons. Comm. of a Notice of Intent with the Conservation Commission, followed by a hearing(s) and public comment. When approved, the project will be issued an Order of Conditions. Mass DEP will review and determine whether or not a 401 Certification is required. Need to show notification of abutters and coordinate public hearing.	Minimum of 5-6 weeks – The Con Com needs 14 days to advertise in the paper. Con Com has 21 days after close of public hearing.
Clean Water Act: Section 404	US Army Corps of Engineers and Mass Historic Commission	Section 404 of the Clean Water Act established a program to regulate the discharge of dredged or fill material into navigable waters of the United States. The program is jointly administered by the U.S. Army Corps of Engineers and the Environmental Protection Agency. The fundamental rationale of the program is that no discharge of dredged or fill material should be permitted if there is a practicable alternative that would be less damaging to our aquatic resources or if significant degradation would occur to the nation's waters. Need to show Area of Project Extent in separate filing to Mass DEP.	60 days – mainly due to Mass Historic review
Mass Environmental Protection Act (MEPA)	MEPA - EOEA	Technically not a permitting process, MEPA review is a check on permitting activities by state employees, to minimize damage to the environment, defined as "Any destruction or impairment (not including insignificant damage or impairment), actual or probable, to any of the natural resources of the Commonwealth including, but not limited to, … impairment and eutrophication of rivers, streams, flood plains, lakes, ponds or other surface or subsurface water resources, destruction of seashores, dunes, marine resources, underwater archaeological resources, wetlands, open spaces, natural areas, parks, or historic districts or sites."	Environmental Notification Form (ENF), Draft Environmental Impact Report (EIR), and EIR each have a 37 day review period – so minimum of 74 days if Draft EIR is combined to the final EIR
Mass General Law: Chapter 91	Mass DEP	Chapter 91 affects structures in waterways and the ability of the public to fish or fowl in navigable waters of the state. Prior to filing an application for a Chapter 91 license for a nonwater-dependent use project, the proponent must file an Environmental Notification Form (ENF) with the Massachusetts Environmental Policy Act (MEPA) Unit. If the project exceeds the MEPA thresholds set forth in 301 CMR 11, a copy of the ENF Certificate must be included with the Chapter 91 application.	Application review time and a 30 day public comment period
Dam Safety	Mass Department of Conservation and Recreation	In accordance with MGL Chapter 253 and 302 CMR 10.09 and 10.10: Any person(s), who proposes to construct, repair, materially alter, breach or remove a dam, must file with the Commissioner a notice for jurisdictional determination and/or file for a permit (if applicable). Further, any maintenance work or water level change(s) that affect safety conditions must file for a determination. No work is to commence before a determination is made by the Commissioner. All permit applications must comply with design and construction criteria as specified in 302 CMR 10.00: Dam Safety Rules and Regulations effective November 4, 2005.	Variable
Federal Water Pollution Control Act: Section 401 Water Quality Certification	Mass DEP	Section 401 Certification governs dredging and/or fill projects in waters and wetlands subject to federal permitting requirements. Generally, any project resulting in the dredging of more than 100 cubic yards of material is subject to federal regulation. The Coles Brook project would be considered a Minor Project (under 5,000 CY)	30 day Army Corps review and 90 day technical review = 120 days
Building Permit	Local government		

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GEI Consultants, Inc., 1995. Phase II Comprehensive Site Assessment Addendum Report for Bostik, Inc.: Volume I - Text, Tables and Figures. Middleton, MA.

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IRWA, 2007. RiverWatch Water Quality Volunteer Monitoring Program, 10-Year Summary Report, 1997-2006. Ipswich River Watershed Association, Ipswich, MA. 55pp.

IRWA, 2010. RiverWatch Water Quality Volunteer Monitoring Program, 2008 Results Report. Ipswich River Watershed Association, Ipswich, MA. 22pp.

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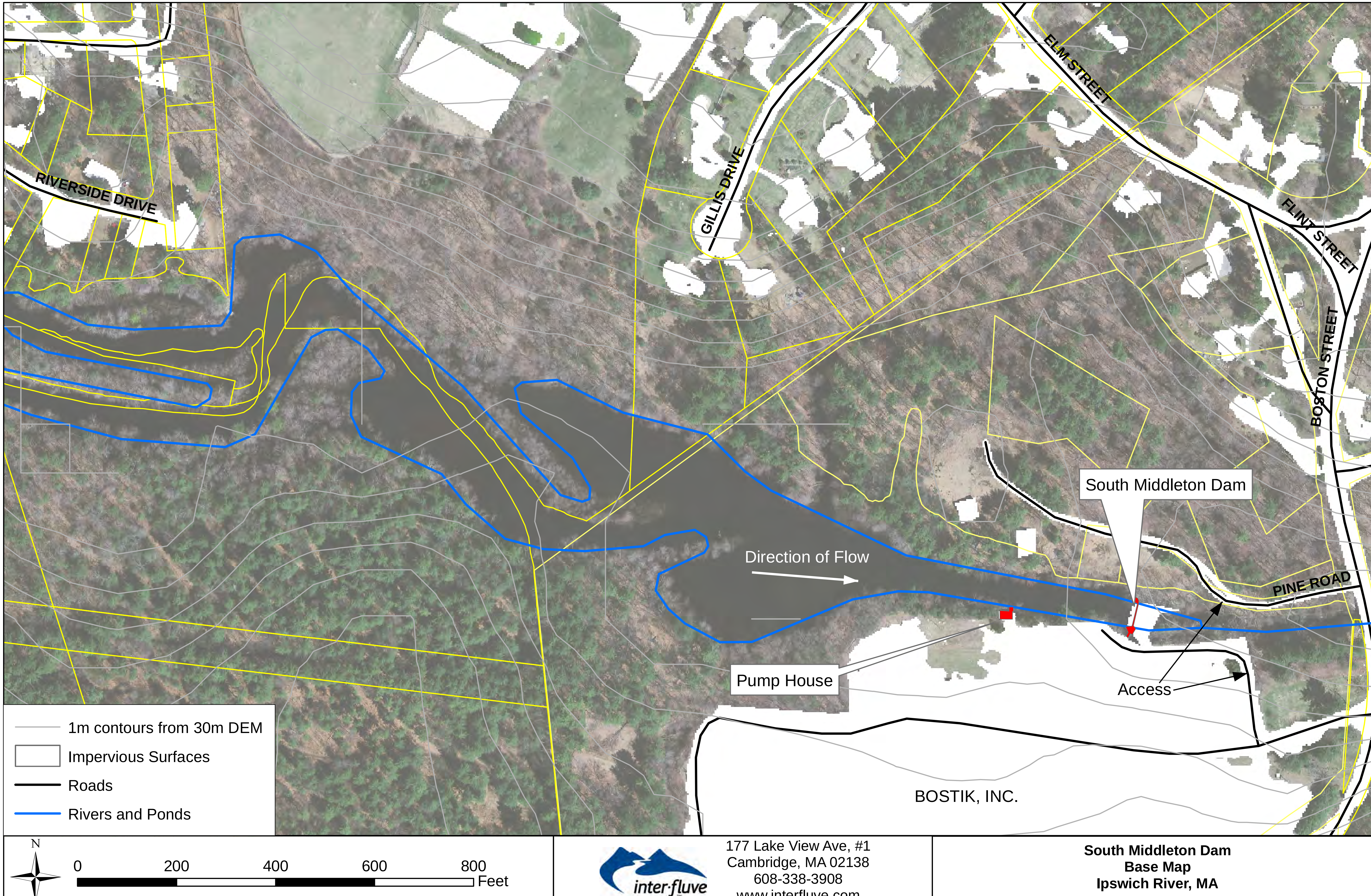
MA DEP, USEPA, ENSR International, 2005. Draft Pathogen TMDL for the Ipswich River Watershed. MA DEP, DWM, Worcester, MA. 59pp.

APPENDIX A

BASE MAP



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South Middleton Dam
Base Map
Ipswich River, MA

APPENDIX B

STREAM STATS HYDROLOGY

USGS Massachusetts StreamStats

Flow Estimates Based on Flows at Nearby Streamgaging Stations

Date: Sat Jun 12 2010 11:07:05 Mountain Daylight Time
NAD27 Latitude: 42.5698 (42 34 11)
NAD27 Longitude: -71.0315 (-71 01 54)
NAD83 Latitude: 42.5699 (42 34 12)
NAD83 Longitude: -71.0310 (-71 01 52)
ReachCode: 01090001000057
Measure: 4.25
User-Selected Site Watershed Area, in square miles: 43.8
Use Regulated Station: Yes

Upstream Gage(s)

STATID	NAME	AREA (mi^2)	RATIO	ISREGULATED
01101300	MAPLE MEADOW BROOK AT WILMINGTON, MA	4.04	0.0922	No

Downstream Gage(s)

STATID	NAME	AREA (mi^2)	RATIO	ISREGULATED
01101500	IPSWICH RIVER AT SOUTH MIDDLETON, MA	44.5	1.0160	Yes

The following flows were estimated based on the closest downstream streamgage for the selected ungaged site.

Downstream drainage-area ratio estimates based on station 01101500

Peak-Flow Statistics

Flow types	Flow description	Flow factor	Streamgage flows	Streamgage years of record	Estimated ungaged flows
PK2	2_Year_Peak_Flood	0.9843	357.000		351
PKMEAN	Mean_Annual_Flood	0.9843	378		372
PK5	5_Year_Peak_Flood	0.9843	511.000		503
PK100	100_Year_Peak_Flood	0.9843	1180		1160
PK200	200_Year_Peak_Flood	0.9843	1290.00		1270
PK500	500_Year_Peak_Flood	0.9843	1580		1560

Flood-Volume Statistics

Flow types	Flow description	Flow factor	Streamgage flows	Streamgage years of record	Estimated ungaged flows
V7D2Y	7_Day_2_Year_Maximum	0.9843	282.000		278
V7D10Y	7_Day_10_Year_Maximum	0.9843	468.000		461
V7D50Y	7_Day_50_Year_Maximum	0.9843	646.000		636

Low-Flow Statistics

Flow types	Flow description	Flow factor	Streamgage flows	Streamgage years of record	Estimated ungaged flows
M7D10Y	7_Day_10_Year_Low_Flow	0.9843	0.41		0.4
M7D2Y	7_Day_2_Year_Low_Flow	0.9843	1.4		1.38

Flow-Duration Statistics

Flow types	Flow description	Flow factor	Streamgage flows	Streamgage years of record	Estimated ungaged flows
D99	99_Percent_Duration	0.9843	0.32	66	0.31
D95	95_Percent_Duration	0.9843	0.99	66	0.97
D90	90_Percent_Duration	0.9843	2.2	66	2.17
D80	80_Percent_Duration	0.9843	6.1	66	6
D75	75_Percent_Duration	0.9843	8.7	66	8.56
D70	70_Percent_Duration	0.9843	12	66	11.8
D60	60_Percent_Duration	0.9843	23	66	22.6
D50	50_Percent_Duration	0.9843	38	66	37.4
D40	40_Percent_Duration	0.9843	56	66	55.1
D30	30_Percent_Duration	0.9843	78	66	76.8
D25	25_Percent_Duration	0.9843	91	66	89.6
D20	20_Percent_Duration	0.9843	106	66	104

D10	10_Percent_Duration	0.9843	155	66	153
D5	5_Percent_Duration	0.9843	218	66	215
D1	1_Percent_Duration	0.9843	370	66	364
General Flow Statistics					
Flow types	**Flow description**	**Flow factor**	**Streamgage flows**	**Streamgage years of record**	**Estimated ungaged flows**
MINDV	Minimum_daily_flow	0.9843	0.02	66	0.0197
AVE_DV	Average_daily_streamflow	0.9843	64.164	66	63.2
SDQD	Std_Dev_of_daily_flows	0.9843	80.67	66	79.4
MAXDV	Maximum_daily_flow	0.9843	1160	66	1140

Estimated flows for the user-selected site determined by weighting of regression equation-based estimates and nearby streamgaging station estimates.

Weighted flows based on regression and gage station estimates					
Low-Flow Statistics					
Flow types	**Flow description**	**Regression estimates**	**Drainage-area ratio estimates**	**Weighted estimates**	**Weighted equivalent years of record**
M7D10Y	7_Day_10_Year_Low_Flow	2.51999998	0.4	0.47	
M7D2Y	7_Day_2_Year_Low_Flow	6.01000022	1.38	1.52	
Flow-Duration Statistics					
Flow types	**Flow description**	**Regression estimates**	**Drainage-area ratio estimates**	**Weighted estimates**	**Weighted equivalent years of record**
D99	99_Percent_Duration	2.75999999	0.31	0.39	
D95	95_Percent_Duration	5.1999998	0.97	1.11	
D90	90_Percent_Duration	8.61999988	2.17	2.37	
D80	80_Percent_Duration	15.5	6	6.3	
D75	75_Percent_Duration	20.5	8.56	8.94	
D70	70_Percent_Duration	25.20000076	11.8	12.2	
D60	60_Percent_Duration	36.20000076	22.6	23.1	
D50	50_Percent_Duration	45.09999847	37.4	37.6	

APPENDIX C

SEDIMENT SAMPLING LOCATIONS

N

0 750 1,500 2,250 3,000 Feet

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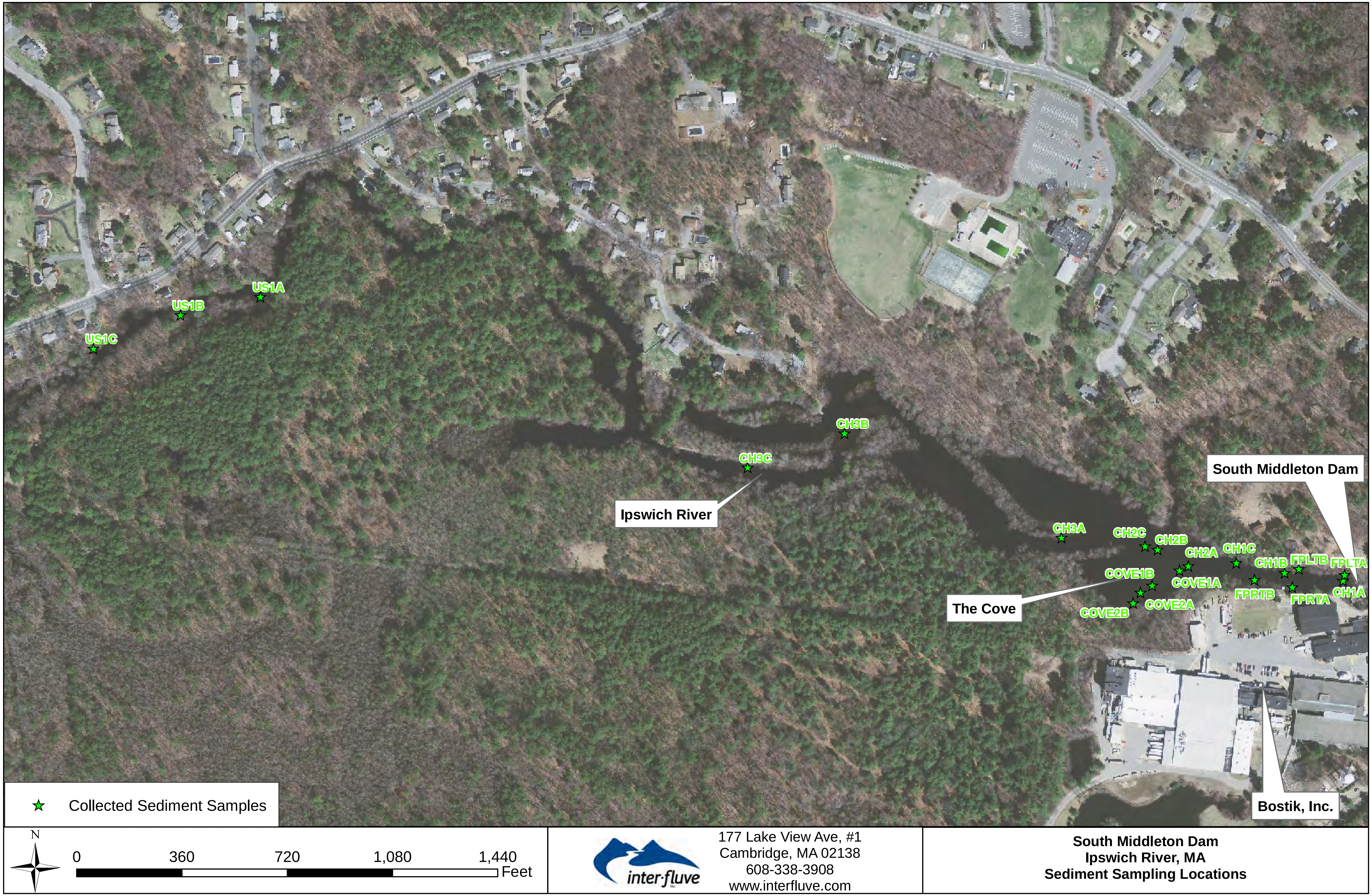
South Middleton Dam
Ipswich River, MA
Sediment Sampling Locations



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