

MASSACHUSETTS DIVISION OF MARINE FISHERIES
SPORTFISHERIES TECHNICAL ASSISTANCE PROGRAM

MASSACHUSETTS BAY SMELT SPAWNING HABITAT MONITORING PROGRAM

Final Report on the Forest River, Salem: 1989-1990

prepared by

Bradford C. Chase and Allison Roderick

October 1994

Massachusetts Division of Marine Fisheries
Cat Cove Marine Laboratory
92 Fort Avenue
Salem, Massachusetts 01970

ABSTRACT

Following extensive monitoring during the smelt sampling seasons of 1989 and 1990, it was determined that the Forest River does not support a run of anadromous rainbow smelt. Approximately 75 m² of potential spawning substrate above the fresh and saltwater interface was monitored for smelt egg deposition. This habitat was found to be ill-suited for smelt spawning due to the following conditions: low freshwater volume and velocity, siltation of substrate, and encroachment of the common reed (Phragmites australis). The flow and siltation problems could be a function of the reeds expanding into the stream channel. Subsequent visits to the sample location in 1994 found a large increase in the density of reeds and area occupied since 1990. At present, it appears that passage from the brackish marsh region up to the freshwater zone would not be possible for adult smelt. Due to this overall lack of potential of smelt spawning habitat, no recommendations are offered for introducing/restoring smelt to the Forest River.

ACKNOWLEDGEMENTS

The Massachusetts Bay Smelt Spawning Habitat Monitoring Program is supported by the Federal Aid in Sportfish Restoration Act, and conducted under authority of the Massachusetts Division of Marine Fisheries, Department of Fisheries, Wildlife and Environmental Law Enforcement. We are grateful for the assistance provided by Division of Marine Fisheries staff. Thanks are also due to the many local sportfishermen and neighborhood naturalists who offered their experience and knowledge along the way.

TABLE OF CONTENTS

	<u>page</u>
INTRODUCTION.....	1
STUDY AREA.....	2
METHODS.....	6
RESULTS.....	7
DISCUSSION.....	8
LITERATURE CITED.....	12
APPENDIX.....	14-19

LIST OF FIGURES AND TABLES

	<u>page</u>
FIGURE 1. Massachusetts Bay Area.....	3
FIGURE 2. Forest River.....	4
FIGURE 3. Sample Location FR-3.....	5
TABLE 1. Ichthyoplankton Summary.....	9
TABLE 2. Ichthyoplankton samples.....	10
TABLE 3. Water Chemistry summary.....	11
TABLE 4. Water Chemistry, FR-3, 1989.....	14
TABLE 5. Water Chemistry, FR-3, 1990.....	15
TABLE 6. Water Chemistry, FR-2, 1989.....	16
TABLE 7. Water Chemistry, FR-1, 1989.....	17
TABLE 8. Water Chemistry, FR-1, 1990.....	18
TABLE 9. Weather Index.....	19

INTRODUCTION

The Forest River (Salem, Mass.) was monitored in 1989 and 1990 to determine if a rainbow smelt, Osmerus mordax, spawning run was present. Prior to this study, it was not known if smelt spawned in the Forest River. The Forest River was included in the Massachusetts Bay Smelt Spawning Habitat Monitoring Program because an earlier survey found substrate in the freshwater zone with potential to provide spawning habitat. The primary objective of the program is to document temporal, spatial and biological characteristics of smelt spawning in Massachusetts Bay river systems. The resulting baseline data can be applied to resource management goals of protecting valuable estuarine and river habitats and sustaining the Commonwealth's smelt fisheries.

A valuable fall and winter fishery for smelt exists in many communities along the coast of Massachusetts. Smelt migrate from coastal waters into estuaries in the fall and are fished by hook and line until the fishery is closed from March 15th to June 15th to protect spawning fish. Massachusetts Bay smelt populations are suspected to be well below historical levels of abundance. Consequently, sportfishing catch and effort has sharply declined in the past decade. Smelt are anadromous, maturing in coastal waters and the lower reaches of estuaries, then ascend into the freshwater zone to spawn in the increased flow of shallow riffles during springtime spawning runs. Eggs adhere to the substrate and aquatic vegetation. Observations of deposited eggs form the basis for delineating smelt spawning habitat.

New England smelt populations exhibit much variability between river systems in the timing of spawning and selection of spawning habitat, using a range of water temperature, salinity and substrate type (Kendall 1927; Bigelow and Schroeder 1953; Rupp 1959). Past investigations of Massachusetts smelt runs found that spawning typically initiates in early to mid-March when water temperatures reach 4-6 C°, and concludes in May (Crestin 1973; Lawton et al. 1990). Spawning smelt concentrate at suitable habitat beyond the interface of fresh and brackish water at night during flood tides (Clayton 1976; Murawski et al. 1980). After spawning, smelt usually leave the spawning habitat to inhabit deeper downstream areas during daylight. Spatial and seasonal variability in spawning, nocturnal spawning, and a closed season for fishing all contribute to a lack of familiarity and documentation of smelt spawning habitat in many coastal river systems.

Secondary objectives of the program include the characterization of river systems through the collection of baseline water chemistry data, the collection of ichthyoplankton data, and the documentation of the occurrence of other anadromous species. This report documents sampling in the Forest River system, which is one of approximately thirty Massachusetts Bay river systems chosen for study since the program was initiated in 1988.

STUDY AREA

The Forest River is located in the North Coastal Basin of Massachusetts (Halliwell et al. 1982), between Boston Harbor and Cape Ann (Figure 1). Freshwater flow in the Forest River originates from Thompsons Meadows and other wetlands in western Salem. The Forest River flows into Salem Harbor at the boundary between Salem and Marblehead (Figure 2). Tidal influence occurs for approximately 1.5 km upstream of the Salem Harbor mouth. For about 0.5 km above tidal influence, and before Thompson Meadows, the river takes the appearance of a small, woodland creek.

Very few studies of any kind have been conducted in the Forest River, and the hydrology has not been described. The total freshwater flow has not been documented, but it is apparent that freshwater is a small portion of the total water volume found in the estuary relative to the tidal exchange during most weather conditions and tide stages. The mouth of Forest River is known locally as the "Lead Mills". A lead mill operated there for approximately 100 years, beginning in 1826 (Essex Institute 1971). A study conducted by DMF on heavy metal concentrations in soft-shell clams (*Mya arenaria*) found average lead concentrations in Forest River samples to be 10 times greater than the average concentrations from other Salem Harbor locations and samples collected from Boston Harbor (Schwartz et al. 1993). Moore and Delpapa (1992) presented dissolved oxygen sampling and discussed the potential ecological impacts of the Forest River tide gates located near the river mouth. These tide gates are required to operate from June 1st until the first Monday in September for the purpose of retaining water in an upstream wading pond (MGL, Chapter 593) and have been in operation for over 60 years.

The Forest River was selected for monitoring after a 1988 survey by this program found a small stretch of potential spawning habitat upstream of the tidal marsh. No previous studies have documented smelt spawning in the Forest River. Adult smelt were caught in the Forest River in the early 1970s by DMF biologist using hoop nets upstream of Route 1A, but no evidence of smelt spawning has been reported (C.O. Anderson, pers. comm.)¹.

Three sites were selected for sampling during the 1989 and 1990 smelt spawning seasons. The abandoned railroad trestle at the mouth of Forest River on Salem Harbor (FR-1) was selected for water chemistry and ichthyoplankton sampling. This site is immediately downstream of the Route 114 tide gates. A second water chemistry site was selected at the Route 1A intersection with the river (FR-2). A third site was selected for water chemistry and spawning habitat sampling above the fresh and saltwater interface (FR-3). This site was 130 m upstream of the wood walk bridge in the marsh near the Salem State South Campus property (Figure 3).

¹ C.O. Anderson, Senior Marine Fisheries Biologist, DMF, Salem.

MASSACHUSETTS BAY SMELT SPAWNING HABITAT MONITORING PROGRAM

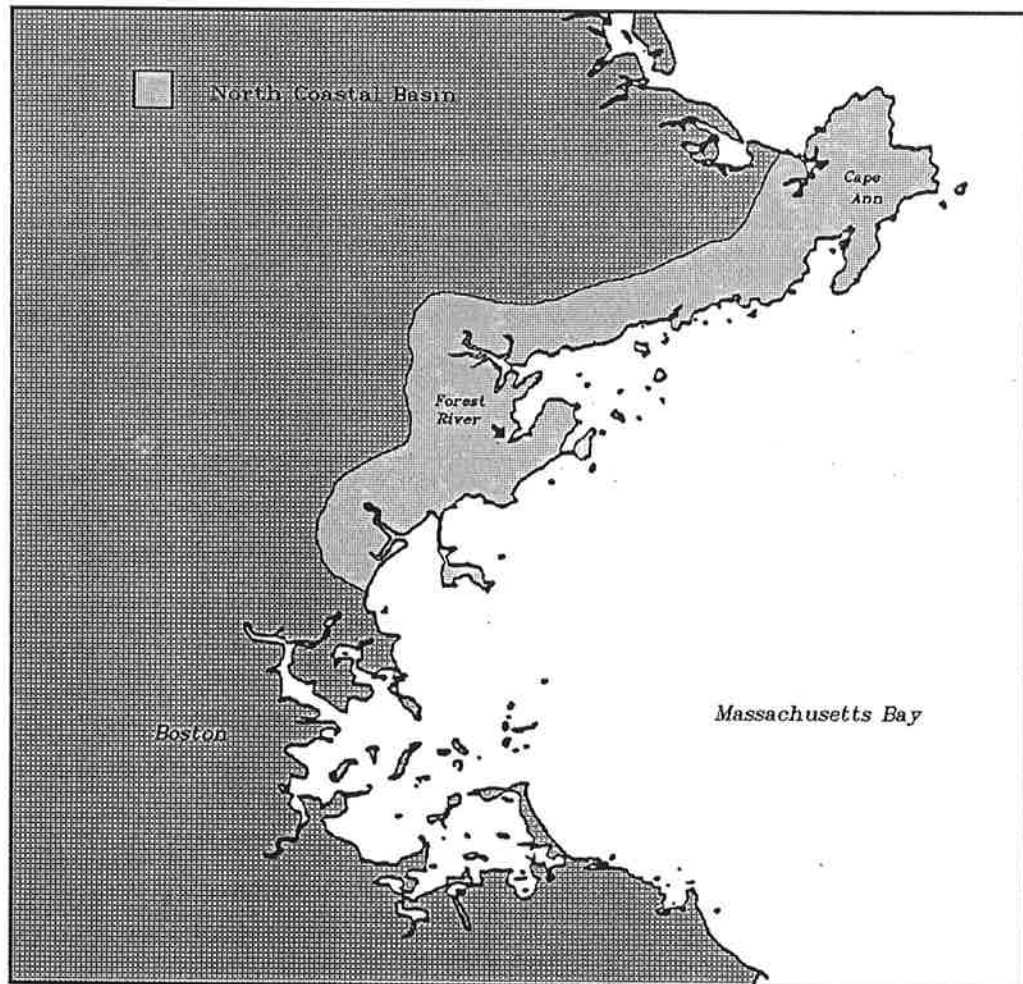
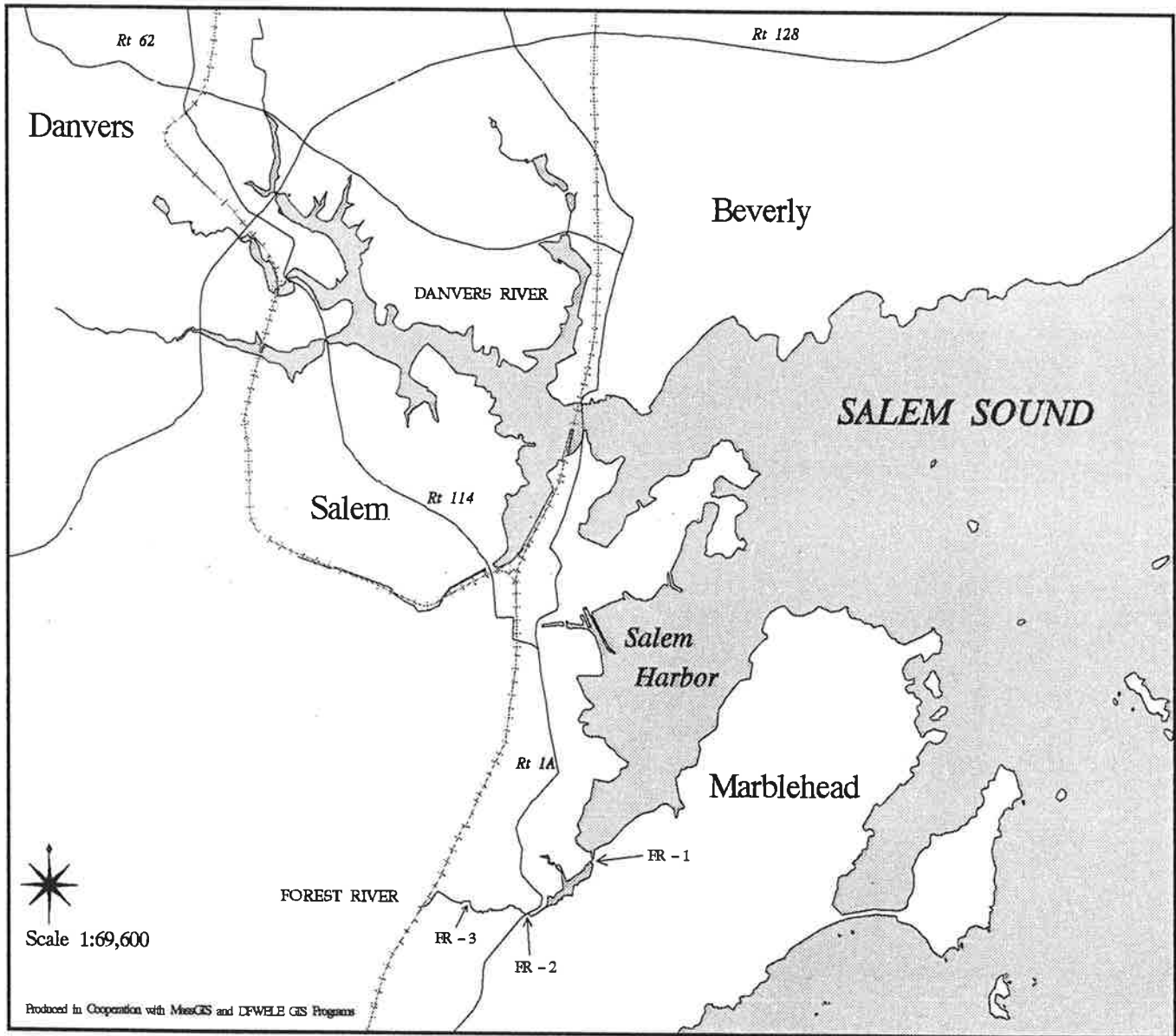


Figure 1. North Coastal Basin

MASSACHUSETTS DIVISION OF MARINE FISHERIES

Massachusetts Bay Smelt Spawning Habitat Monitoring Program

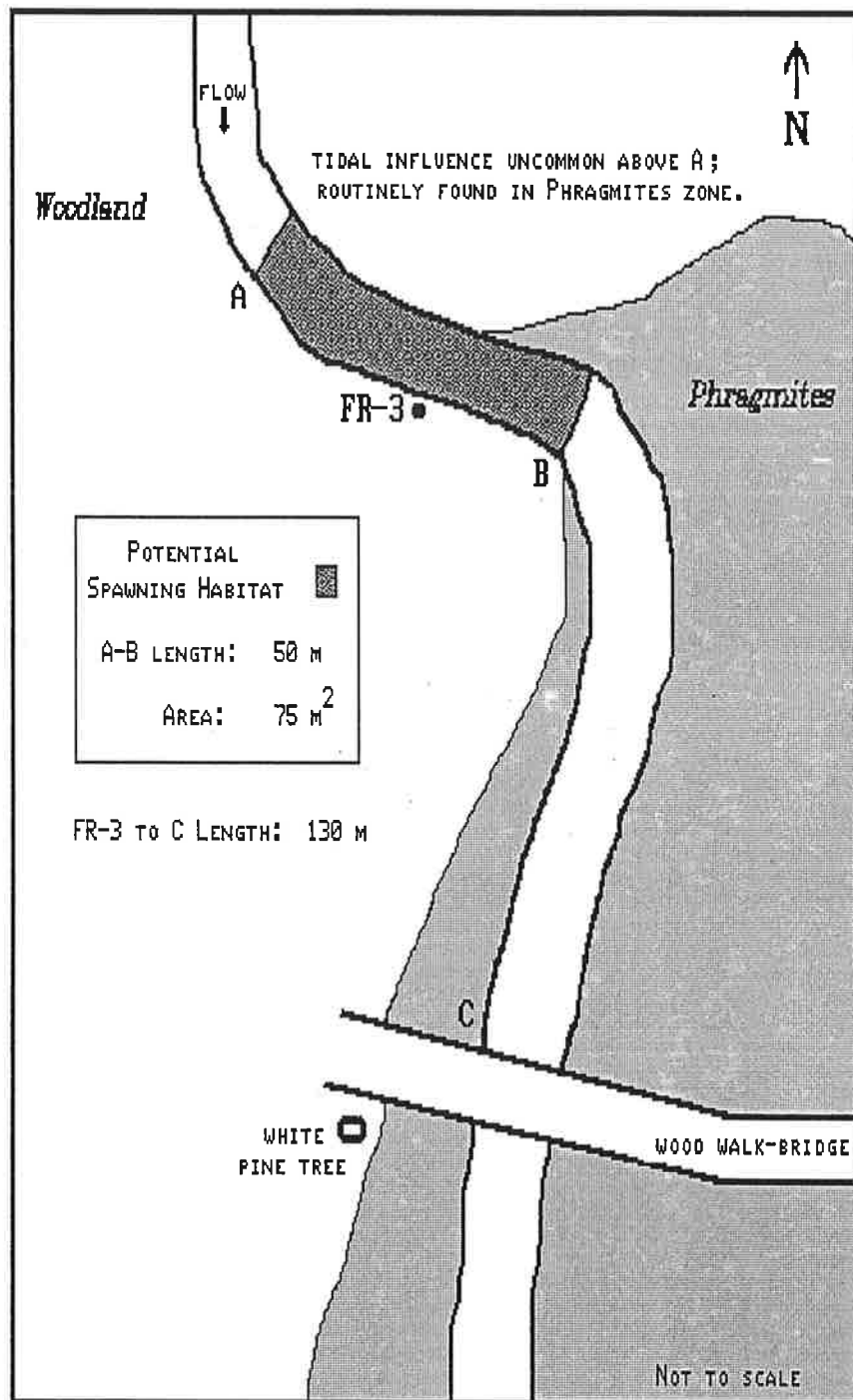
Figure 2. Forest River



Sample Locations:

FR - 1	Forest River, railroad bridge
FR - 2	Forest River, Rt. 1A
FR - 3	Forest River, freshwater interface

Figure 3. FOREST RIVER: LOCATION FR-3



METHODS

Spawning sites were surveyed twice each week during March, April, and May. During each visit, the substrate was inspected for smelt eggs and water chemistry was sampled. Eggs were identified on the basis of size, oil globule, and seasonal comparison with other species (Elliot and Jimenez 1981). Site visits were not fixed to a targeted time of day or tide stage, but cannot be described as random due to travel logistics and constraints within the sampling schedule.

Water chemistry, weather and tidal influence data were recorded at all sample sites. Air and water temperature measurements were taken with stem thermometers ($\pm 0.5^{\circ}\text{C}$). Salinity was measured using a Reichart temperature compensated salinity refractometer (± 1.0 ppt). Water pH was measured with an Orion SA 250 pH meter (± 0.1 pH). Dissolved oxygen was measured with a YSI model 51B meter (± 0.2 mg/l). Weather conditions were noted using a descriptive index (Appendix). Tidal conditions for Boston Harbor (White 1989 and 1990) were used along with local observations to determine tidal influence and tide stage (± 0.5 hour).

Prior to sampling, and at three hour intervals, the pH meter was calibrated using standard pH buffers, and the D.O. meter was calibrated to the ambient oxygen level. The salinity refractometer was zeroed each week with distilled water. Stem thermometers were calibrated with a certified thermometer before each season (acceptable range of $\pm 0.5^{\circ}\text{C}$). Bottom water samples were collected with a Van-Dorn style horizontal water sampler.

Ichthyoplankton were collected from location FR-1 for the purpose of confirming smelt larvae presence and characterizing the spring ichthyoplankton community in the Forest River. A 0.14 m^2 rectangular plankton net with 0.505 mm mesh, was used to sample the ebb flow of surface water, within 2 hours of high tide. A 2030-R General Dynamics flowmeter attached to the net frame was used to measure stream flow rates (m/sec) and water volume sampled (m^3). Samples were preserved in 5% phosphate buffered formalin and returned to the laboratory for sorting and microscopic analysis. All finfish eggs and larvae were measured to the nearest 0.1 mm and identified with the aid of manuals by Colton and Marak (1969), Scotton et al. (1973), Lippson and Moran (1974), and Elliot and Jimenez (1981).

After the completion of two sampling seasons, stream measurements were made of potential smelt spawning habitat. The area of stream bed where smelt could potentially spawn was determined by wetted perimeter measurements with a tape measure ($\pm 0.5\text{ m}$). Measurements were made in locations where suitable substrate and water flow conditions existed for attracting spawning smelt.

RESULTS

No conclusive evidence of smelt spawning in the Forest River was found during 1989 and 1990 sampling visits. Two demersal eggs were found on April 4, 1989, adhered to a rock near location FR-3. The eggs were approximately 1 mm in diameter, and had the general appearance of smelt eggs. The eggs were not brought back to the laboratory for identification because it was assumed many more would be collected in subsequent visits. The two eggs were gone a few days later and no other eggs were found throughout extensive sampling efforts for the remainder of the 1989 season and in 1990. Nine ichthyoplankton samples taken at location FR-1 produced eight species of fish, but no smelt larvae (Tables 1 and 2). Sand lance (Ammodytes americanus) were the most common fish larvae caught for the March-May sampling period, in terms of frequency of occurrence and frequency by number. No observations of adult smelt were made in the Forest River estuary during the two seasons.

Upstream conditions were found to have very limited potential for smelt spawning habitat: freshwater flow was minimal to attract adult smelt, much of the substrate was covered with fine sediments, and the common reed (Phragmites australis) had encroached the stream channel becoming an impediment to fish passage. Above the wood walk-bridge, reeds had begun to colonize the stream channel with roots that trap detritus and slow down water velocity. This location was revisited in September 1994 and the reeds were found to have expanded greatly since 1990. Full size reed stalks presently are found in thick patches in the stream channel above the walk-bridge. Under these conditions, the stream channel is now poorly defined and smelt passage is probably not possible.

Surface water chemistry measurements of temperature, salinity, pH, and dissolved oxygen did not produce unusual results during the study period (Table 3). Spring-time dissolved oxygen levels were at or near saturation for all measurements. Measurements of pH at the upstream sample site (FR-3) did not reflect acidic conditions as seen in other Massachusetts Bay drainages studied in this program. The pH at FR-3 averaged 7.6 in 1989 and 7.5 in 1990. Tidal influence was observed occasionally at FR-3, yet salinity was not detected during routine sampling visits. During a recent visit coinciding with a very high tide (Sept. 8, 1994, 11.6 ft., high +0.5 hrs.) a strong presence of the salt wedge was observed at FR-3. With freshwater flow seasonally depressed, the salt wedge raised the stream depth at FR-3 to approximately 0.75 m with 6 ppt salinity on the surface and 20 ppt on the bottom. Tidal influence extended up over 50 m above FR-3. Surface salinity at FR-1 averaged 24.8 ppt in 1989 and 23.2 ppt in 1990. Eight bottom water measurements were made at FR-1 during the two seasons and averaged 29.4 ppt (high tide $\pm$ 2 hours). The water chemistry, particularly pH and salinity, at the mid-estuary location FR-2 varied widely, depending on the tide stage.

Measurements were made of the stream bed near FR-3 with limited potential for smelt spawning. The stream length of 50 m matched with a width of 1.5 m to produce a maximum area of 75 m².

DISCUSSION

It is reasonable to conclude that a smelt run was not present in the Forest River during the 1989 and 1990 seasons. The two eggs observed but not identified in April of 1989 could have been the following: smelt eggs from a stray of a near-by run (Saugas River or Danvers River), smelt eggs from a remnant of a dwindling Forest River population, or eggs from another species. No other eggs were found during extensive searches over the small amount of potential habitat (75 m²). It is possible that the Forest River once supported a smelt population, but historical documentation is lacking. The present encroachment of reeds in the stream channel and related reduction of freshwater flow velocity offers little attraction for spawning smelt and may prevent upstream passage. Given these conditions, and superior alternative locations in Massachusetts Bay, it is recommended that the Forest River is not considered for smelt restoration projects.

It is possible that the operation of the tide gates has contributed to the encroachment of Phragmites and resulted in degraded substrate conditions at the saltwater/freshwater interface. Moore and DelPapa (1990) hypothesized that increased tide gate operations have denied the upland border of the marsh periodic saltwater flushing and this has resulted in the Phragmites invasion. They further note that changes in marsh vegetation have been noticed over the last 25 years and changes have been especially pronounced in the five years prior to their study. This conclusion is consistent with the sharp increases in Phragmites densities 50 m above and below the wood walk bridge observed between 1990 and recent visits in 1994. It is recommended that studies be conducted to quantify potential impacts of tide gate operations on marsh vegetation and river substrate conditions. A time series of aerial photographs from the past few decades may allow for estimates of vegetation changes. It is also recommended that local authorities evaluate tide gate operation alternatives that will allow natural conditions of tidal flooding to return.

In addition to fish species collected during ichthyoplankton sampling, other species were observed during site visits. American eels (Anguilla rostrata) were observed on several occasions in the Forest River, usually of the size class of first year glass eels. Sand shrimp (Crangon septemspinosa) were observed on 9-8-94 during a very high tide that brought the salt wedge well above FR-3. The shrimp were moving upstream with the flooding salt wedge, staying below the fresher surface water (6 ppt salinity). Mummichogs (Fundulus sp.) and freshwater yellow perch (Perca flavescens) were observed below the shrimp, mingling in the 20 ppt salinity bottom water. These salinity conditions were not observed during the spring sampling at FR-3 when freshwater flow was much higher.

Table 1. Summary of Forest River Ichthyoplankton Samples: 1989-1990

Pooled Samples

Sample number:	9		
Sampling period:	March 17th - May 24th	Ave. density:	9.6 larvae/ 100 m ³
Ave. tide stage:	high + 1.0 hrs.	Density range:	0.0 - 100 larvae/ 100 m ³
Average velocity:	0.526 m/sec.		
Velocity range:	0.315 - 1.067 m/sec.		

SPECIES LIST

<u>Larvae</u>		<u>Total Number</u>	<u>Percent of Total</u>	<u>Frequency of Occurrence</u>	
sand lance	<i>Ammodytes americanus</i>	86	85.1	44.4 %	(4/9)
grubby	<i>Myoxocephalus aeneus</i>	7	6.9	33.1 %	(3/9)
radiated shanny	<i>Ulvaria subbifurcata</i>	3	3.0	11.1 %	(1/9)
three-spined stickleback	<i>Gasterosteus aculeatus</i>	1	1.0	11.1 %	(1/9)
Atlantic silverside	<i>Menidia menidia</i>	1	1.0	11.1 %	(1/9)
yellowtail flounder	<i>Limanda ferruginea</i>	1	1.0	11.1 %	(1/9)
seasnail	<i>Liparis sp.</i>	2	2.0	11.1 %	(1/9)
		102	100 %		
<u>Eggs</u>					
Paralichthyes-Scophthalmus group		53	100 %	11.1 %	(1/9)

Notes: Samples were collected from the railroad trestle at the mouth of Forest River (FR-1), using a 0.14 m² 0.505 mm mesh plankton net on the surface during the outgoing tide.

Paralichthyes-Scophthalmus group eggs are most likely windowpane flounder, *Scophthalmus aquosus*

Table 2.

Forest River Ichthyoplankton Samples: 1989-1990

Date	Velocity (m/sec.)	Sample Volume (m ³)	Species	Type	Number	Average Size (mm)	Number (/100m ³)
3-17-89	0.455	76.4	sand lance grubby	larvae	10	8.7	13.1
				larvae	5	4.4	6.5
4-18-89	0.354	77.3	Liparis sp. sand lance	larvae	2	4.3	2.6
				larvae	9	11.6	11.7
5-02-89	0.391	75.56	none	none			
5-16-89	0.315	52.99	3-spined stickleback P-S group	juvenile	1	41.0	1.9
				egg	53	1.0	100.0
3-15-90	0.627	105.41	sand lance grubby	larvae	63	9.2	59.8
				larvae	1	5.4	1.0
3-21-90	0.537	58.60	none	none			
4-20-90	0.550	92.36	sand lance grubby yellowtail flounder Unidentified fish	larvae	4	6.4	4.3
				larvae	1	4.7	1.1
				larvae	1	5.0	1.1
				egg	1		1.1
5-10-90	0.443	74.39	none				
5-24-90	1.067	161.40	radiated shanny Atl. silverside Unidentified fish	larvae	3	8.0	1.9
				larvae	1	5.1	0.6
				egg	1		0.6

notes: Samples taken from abandon railroad trestle downstream of Route 114.
Ave. size: total length for larvae, diameter for eggs
P-S group eggs: Paralichthyes-Scophthalmus group

Table 3. Forest River Water Chemistry Summary

Forest River Spawning Location (FR-3)

Year	Site Visits	SURFACE WATER CHEMISTRY							
		Air Temp. (Ave. C)	NOAA Air Temp. (Ave. C)	Temp. (Ave. C)	Salinity (Ave. ppt)	pH (Ave.)	(S.D.)	D.O. (Ave. mg/l)	(S.D.)
1989	21	8.0	8.3	10.2	0.0	7.6	0.26	11.5	1.61
1990	23	9.2	8.2	10.8	0.0	7.5	0.16	11.6	1.71

Forest River Railroad Trestle (FR-1)

Year	Site Visits	SURFACE WATER CHEMISTRY							
		Air Temp. (Ave. C)	NOAA Air Temp. (Ave. C)	Temp. (Ave. C)	Salinity (Ave. ppt)	pH (Ave.)	(S.D.)	D.O. (Ave. mg/l)	(S.D.)
1989	19	7.7	8.3	9.5	24.8	8.0	0.22	9.7	1.26
1990	17	9.2	8.2	10.6	23.2	7.9	0.19	10.8	1.41

Notes:

NOAA Air temperature data are from Peabody, Ma., station (NOAA 1989-1990).

Date are averages of individual samples taken in March, April and May (reported in Appendix).

LITERATURE CITED

- Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish and Wild. Serv., Fish. Bull. No. 74, Vol. 53. 577 pp.
- Clayton, G.R. 1976. Reproduction, first year growth, and distribution of anadromous rainbow smelt, Osmerus mordax, in the Parker River and Plum Island Sound estuary, Massachusetts. M.S. Thesis, Univ. of Mass., Amherst, Mass. 105 pp.
- Colton, J.B., and R.L. Marak. 1969. Guide for identifying the common planktonic fish eggs and larvae of continental shelf water, Cape Sable to Block Island. U.S. Bur. Comm. Fish. Biol. Lab., Woods Hole, Mass. Ref. 69-6. 72 pp.
- Crestin, D.S. 1973. Some aspects of the biology of adult and early life stages of the rainbow smelt, Osmerus mordax (Mitchill), from the Weweantic River estuary, Wareham-Marion, Mass., 1968. M.S. Thesis, Univ. of Mass., Amherst, Mass. 108 pp.
- Elliot, E.M., and D. Jimenez. 1981. Laboratory manual for the identification of ichthyoplankton from the Beverly-Salem harbor area. Comm. of Mass., Div. of Mar. Fish. Dec. 1981, Salem, MA. 230 pp.
- Essex Institute, 1971. 1868, Essex Institute Historical Collections, second series; Vol. 1, part 2, 65 pp. Essex Institute Press, Salem, MA., reprinted 1971.
- Halliwel, D.B., W.A. Kimball, and A.J. Screpetis. 1982. Massachusetts Stream Classification Program Part I: Inventory of rivers and streams. Comm. of Mass., Dept. of Fish. Wildl. and Rec. Veh., and Dept. of Environ. Qual. Eng., Westborough, Mass., 126 pp.
- Kendall, W.C. 1927. The smelts. Bull. U.S. Bur. Fish. No. 42: 217-375.
- Lawton, R.P., P. Brady, C. Sheehan, S. Correia, and M. Borgatti. 1990. Final report on spawning sea-run rainbow smelt Osmerus mordax, in the Jones River and impact assessment of Pilgrim Station on the population, 1979-1981. Pilgrim Nuclear Power Station Mar. Environ. Monit. Pro. Rep. Ser. No. 4, Mass. Div. Mar. Fish., Sandwich, MA. 72 pp.
- Lippson, A.J., and R.L. Moran. 1974. Manual for the identification of early development stages of fishes of the Potomac River estuary. Environ. Tech. Center, Martin Marietta Corp., Baltimore, MD. Dec. 1974. 282 pp.

- Moore, J.K., and C. DelPapa. 1992. A report to the Salem Conservation Commission on the results of preliminary sampling of dissolved oxygen levels in the Forest River Estuary over the summer of 1991. April, 1992, 13 pp.
- Murawski, S.A., G.R. Clayton, R.J. Reed, and C.F. Cole. 1980. Movements of spawning rainbow smelt, Osmerus mordax, in a Massachusetts estuary. *Estuaries*, Vol. 3, 4: 308-314.
- NOAA. 1989. Climatological Data Annual Summary: New England 1989. National Oceanic and Atmospheric Admn., National Climatic Data Center, Asheville, NC., Vol. 101, No. 13.
- NOAA. 1990. Climatological Data Annual Summary: New England 1990. National Oceanic and Atmospheric Adm., National Climatic Data Center, Asheville, NC., Vol. 102, No. 13.
- Rupp, R.S. 1959. Variation in the life history of the American smelt in inland waters of Maine. *Trans. Amer. Fish. Soc.* 88(4): 241-252.
- Scotton, L.N., R.E. Smith, N.S. Smith, K.S. Price, and D.P. DeSylva. 1973. Pictorial guide to fish larvae of the Delaware Bay, with information and bibliographies useful for the study of fish larvae. Univ. Del., Del. Bay Report, Ser. 7. 206 pp.
- Schwartz, J.P., N.M. Duston, and C.A. Batdorf. 1993. Metal concentrations in winter flounder, American lobster, and bivalve molluscs, from Boston Harbor, Salem Harbor and coast Massachusetts. A summary of data on tissues collected from 1986-1991. Mass. Div. of Mar. Fish., Aug. 1993, 65 pp.
- White, R.E. 1989. Eldridge tide and pilot book. Published by R.E. White, Boston, MA., 272 pp.
- White, R.E. 1990. Eldridge tide and pilot book. Published by R.E. White, Boston, MA., 272 pp.

APPENDIX

Table 4. Water Chemistry

Sample Site:

Forest River, Spawning Location (FR-3)

Year:

1989

DATE	TIME OF DAY	TIDE STAGE	TIDAL INFLUENCE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)	SALINITY (ppt)	pH	D.O. (ppm)
3-03-89	1503	low +0.5 hrs	No	9.4	4	1.0	4.0	0.0	7.7	12.5
3-07-89	1312	high +1.5	Yes	11.5	3	-6.5	1.0	0.0	7.7	14.2
3-10-89	1615	high +2.0	Y	11.2	1	-1.0	3.5	0.0	7.6	13.2
3-14-89	1522	low +4.0	N	8.6	1	7.0	5.5	0.0	7.7	12.6
3-17-89	1016	high +2.0	N	9.3	2	10.0	5.5	0.0	7.7	13.6
3-21-89	1405	high +2.5	N	9.8	4	6.0	5.5	0.0	6.9	13.0
3-24-89	1638	high +3.0	N	9.5	5	3.0	7.0	0.0	7.7	12.4
3-28-89	1545	low +5.5	Y	8.3	2	21.0	13.5	0.0	7.5	13.3
4-04-89	1230	high +1.0	Y	10.9	5	6.5	8.0	0.0	7.2	11.9
4-07-89	1610	high +2.5	N	11.2	1	8.5	12.5	0.0	7.4	10.4
4-11-89	1530	low +4.5	N	9.1	2	7.5	10.0	0.0	7.6	11.6
4-14-89	1615	low +3.0	N	9.2	1	10.0	11.0	0.0	7.8	10.7
4-18-89	1045	low +5.5	N	9.3	4	12.0	11.0	0.0	7.8	11.5
4-22-89	1410	high tide	N	9.2	2	3.0	11.5	0.0	7.8	11.3
4-25-89	1255	low +3.0	N	8.7	1	12.0	12.5	0.0	7.9	11.0
4-28-89	1425	low +2.0	N	8.6	1	7.5	14.5	0.0	7.9	10.1
5-02-89	1135	high +1.5	N	10.3	6	9.0	11.0	0.0	7.4	11.7
5-05-89	1558	high +3.0	N	10.7	3	13.0	17.0	0.0	7.9	9.6
5-12-89	1751	low +5.0	N	8.7	3	13.0	16.5	0.0	7.4	9.5
5-16-89	1310	high +3.0	N	8.8	4	12.5	15.5	0.0	7.3	9.1
6-07-89	1325	low +4.0	N	9.4	5	13.5	17.5	0.0	7.7	8.2
Season Average						8.0	10.2	0.0	7.6	11.5

Tidal delay: 1 hour from Boston

APPENDIX

Table 5. Water Chemistry

Sample Site: Forest River, Spawning Location (FR-3)

Year: 1990

DATE	TIME OF DAY	TIDE STAGE	TIDAL INFLUENCE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)	SALINITY (ppt)	pH	D.O. (ppm)
3-02-90	1248	low +3.0 hrs	No	9.8	1	3.5	4.0	0.0	7.3	14.1
3-05-90	1220	low tide	N	10.1	1	-3.0	4.0	0.0	7.5	14.2
3-09-90	1150	high +1.0	N	10.2	1	1.0	4.0	0.0	7.4	14.8
3-15-90	1445	high tide	N	9.2	2	13.0	10.0	0.0	7.5	12.2
3-21-90	0808	high +1.0	N	8.9	5	3.0	6.0	0.0	7.5	12.0
3-22-90	1650	low +3.0	N	9.2	2	10.0	9.0	0.0		12.0
3-26-90	1249	high +1.5	N	10.9	2	9.5	8.5	0.0	7.8	12.8
3-30-90	0815	low tide	N	10.3	3	2.5	5.5	0.0	7.5	12.9
4-02-90	1125	high +5.5	N	10.4	4	4.5	6.0	0.0	7.7	12.6
4-06-90	1805	low +1.5	N	9.7	4	4.5	8.5	0.0	7.5	12.0
4-12-90	1915	high +4.5	N	9.3	3	2.0	9.5	0.0	7.5	11.6
4-16-90	1055	low tide	N	9.4	1	12.0	10.0	0.0	7.5	12.8
4-20-90	1045	high +2.0	N	9.3	4	9.0	10.0	0.0	7.5	13.0
4-23-90	1555	high +4.5	N	10.4	2	12.5	17.0	0.0	7.5	10.2
4-27-90	1030	low +2.0	N	10.5	2	25.0	15.0	0.0	7.4	11.5
4-30-90	1030	high +5.5	N	11.0	6	7.5	11.0	0.0	7.3	9.9
5-08-90	1037	low +4.5	N	9.2	4	9.5	12.5	0.0	7.7	11.0
5-10-90	1500	high +1.5	N	9.1	4	20.5	19.0	0.0	7.6	9.2
5-15-90	1042	low tide	N	8.5	2	20.5	17.5	0.0	7.7	10.4
5-17-90	1445	low +2.5	N	9.4	4	9.5	14.0	0.0	7.3	9.0
5-21-90	1605	low tide	N	9.8	4	6.0	11.0	0.0	7.2	10.0
5-24-90	1440	high +2.0	N	10.4	2	10.0	15.0	0.0	7.7	10.6
5-28-90	1526	low +5.5	Y	9.9	1	19.0	22.0	0.0	7.7	8.4
Season Average						9.2	10.8	0.0	7.5	11.6

Tidal Delay: 1 hour from Boston

APPENDIX

Table 6. Water Chemistry

Sample Site:

Forest River, Route 1A, (FR-2)

Year:

1989

DATE	TIME OF DAY	TIDE STAGE	TIDAL INFLUENCE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
							Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-07-89	1322	high +2.0	Yes	11.5	3	-6.0	-1.0	0.0	23.0	23.0	7.8	7.8	11.6	11.6
3-10-89	1554	high +2.0	Y	11.2	1	0.0	3.0		25.0		7.7		11.4	
3-14-89	1512	low +4.0	Y	8.6	1	7.0	9.0		1.0		7.7		14.5	
3-17-89	1045	high +2.5	Y	9.3	3	9.0	6.0		9.0		7.5		12.3	
3-21-89	1418	high +3.0	Y	9.8	4	5.0	5.5		0.0		7.0		13.1	
3-24-89	1626	high +3.0	Y	9.5	5	5.0	7.5		1.0		7.9		13.4	
3-28-89	1538	high tide	Y	8.3	2	21.0	14.5		3.0		7.8		11.0	
4-04-89	1220	high +1.5	Y	10.9	4	6.0	7.0	7.0	24.0	24.0	7.7		9.5	
4-07-89	1558	high +2.5	Y	11.2	1	9.0	13.0		5.0		7.6		11.2	
4-14-89	1558	low +3.0	No	9.2	1	8.0	12.0		0.0		7.9		11.2	
4-18-89	1118	high tide	Y	9.3	4	11.5	11.0	10.0	3.0	27.0	7.8	8.3	10.5	9.0
4-22-89	1500	high +1.0	Y	9.2	2	3.0	12.0		7.0		7.8		10.5	
4-25-89	1320	low +3.5	Y	8.7	1	12.0	14.5		2.0		7.9		10.7	
4-28-89	1605	low +4.0	Y	8.6	1	10.0	18.5		0.0		8.1		10.8	
5-02-89	1151	high +2.0	Y	10.3	6	9.0	10.0		2.0		7.6		11.2	
5-05-89	1551	high +3.5	Y	10.7	3	12.5	17.0		2.0		7.9		10.0	
5-16-89	1255	high +3.0	Y	8.8	4	11.0	15.5		0.0		7.5		9.0	
Season Average						7.8	10.3		6.3		7.7		11.3	

Tidal delay: 45 minutes from Boston.

APPENDIX

Table 7. Water Chemistry

Sample Site:

Forest River, railroad trestle (FR-1)

Year:

1989

DATE	TIME OF DAY	TIDE STAGE	TIDE AMP. (ft.)	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-03-89	1527	low +1.5 hrs	9.4	4	1.5	6.5		7.0		7.6		12.6	
3-07-89	1245	high +1.5	11.5	3	-3.0	1.0		32.0		7.9		9.9	
3-10-89	1636	high +3.0	11.2	1	-0.5	3.0		27.0		7.9		10.8	
3-14-89	1542	low +4.5	8.6	1	5.5	7.5		31.0		8.0		10.4	
3-17-89	0908	high +1.0	9.3	3	7.0	6.0	6.5	31.0	31.0	8.0		10.8	10.7
3-21-89	1430	high +3.5	9.8	4	5.0	6.0		25.0		7.9		10.0	
3-24-89	1655	high +4.0	9.5	5	3.5	6.0		18.0		7.9		10.5	
3-28-89	1613	high +0.5	8.3	2	22.0	11.5	11.5	31.0	31.0	8.1		10.9	10.9
4-04-89	1315	high +2.5	10.9	4	6.0	6.5		27.0		7.8		9.5	
4-07-89	1643	high +3.5	11.2	1	9.0	11.0		26.0		8.0		9.6	
4-14-89	1640	low +4.0	9.2	1	9.0	12.0		27.0		8.2		9.9	
4-18-89	1133	high +0.5	9.3	4	10.0	10.5	10.0	21.0	29.0	8.3	8.3	9.3	9.4
4-22-89	1516	high +1.5	9.2	2	3.0	9.0		29.0		8.2		9.5	
4-25-89	1238	low +3.0	8.7	1	9.5	12.0		30.0		8.2		8.7	
5-02-89	1044	high +1.5	10.3	5	9.0	11.5	11.5	28.0	28.0	7.9		8.6	
5-05-89	1638	high +4.5	10.7	3	11.0	12.0		22.0		8.3		9.5	
5-12-89	1815	high tide	9.5	3	13.0	19.5		12.0		7.8		7.8	
5-16-89	0957	high +0.5	8.8	4	11.0	13.0	15.0	18.0	28.0	7.7	7.9	7.4	6.8
6-07-89	1325	low +4.5	9.4	5	14.0	16.5		30.0		7.5		7.8	
Season Average					7.7	9.5		24.8		8.0		9.7	

Tidal delay: 30 minutes from Boston

APPENDIX

Table 8. Water Chemistry

Sample Site:

Forest River, railroad trestle (FR-1)

Year:

1990

DATE	TIME OF DAY	TIDE STAGE	TIDE AMP.	WEATHER INDEX	AIR TEMP. (C)	WATER TEMP. (C)		SALINITY (ppt)		WATER pH		D.O. (mg/l)	
						Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
3-02-90	1225	low +3.0 hrs.	9.8	1	4.0	4.5		32.0		8.0		11.5	
3-05-90	1236	high +5.0	10.1	1	-4.0	6.0		5.0		7.5		14.2	
3-09-90	1210	high +2.0	10.2	1	3.0	4.0		31.0		8.1		12.3	
3-15-90	1518	high +1.0	9.2	2	9.0	9.0	9.0	33.0	33.0	8.2	8.2	11.7	11.6
3-21-90	0836	high +2.0	8.9	6	3.0	6.0		27.0		7.9		10.1	
3-26-90	1237	high +1.5	10.9	2	9.0	7.0		30.0		8.1		10.8	
4-02-90	1110	high +5.5	10.4	4	5.0	6.5		14.0		7.7		11.6	
4-06-90	1839	low +2.5	9.7	4	4.0	8.0		26.0		8.0		10.1	
4-12-90	1941	high +5.5	9.3	3	1.0	8.0		6.0		7.7		11.1	
4-20-90	1000	high +2.0	9.3	3	8.0	8.0	8.0	27.0	27.0	8.0	8.0	11.6	11.6
4-27-90	1058	low +3.0	10.5	2	23.0	13.5		30.0		7.8		10.5	
5-03-90	1439	low +1.0	9.5	2	9.5	19.5		6.0		8.0		11.1	
5-08-90	1025	low +5.0	9.2	4	19.0	17.0		31.0		7.9		9.0	
5-10-90	1422	high +1.0	9.1	4	17.0	15.0		30.0		7.9		8.4	
5-15-90	1027	low tide	8.5	2	15.5	17.0		7.0		8.2		11.5	
5-24-90	1359	high +2.0	10.4	2	12.0	14.0	14.0	28.0	28.0	7.8		9.2	
5-28-90	1554	high tide	9.9	2	19.0	17.0		31.0		8.0		9.4	
Season Average					9.2	10.6		23.2		7.9		10.8	

Tidal Delay: 30 minutes from Boston

APPENDIX

Table 9. Weather Index

- | | | |
|----|---------------|-----------------------|
| 1. | clear sky | (< 5% clouds) |
| 2. | partly cloudy | (5 to < 25% clouds) |
| 3. | mostly cloudy | (25 to < 75% clouds) |
| 4. | cloud cover | (> 75% clouds) |
| 5. | light rain | |
| 6. | medium rain | |
| 7. | heavy rain | |
| 8. | snow | |
| 9. | other | (ex. hail, fog) |

