

CONTENTS

Abstract	1
Introduction	2
Purpose and Scope	3
Description of Study Area	3
Previous Studies	5
Acknowledgments	5
Relations Among Streamflow, Aquatic Habitat, and Fish Communities.....	6
Historical and Recent Low Flows in the Ipswich River	8
Historical Low-Flow Conditions	8
Recent Low-Flow Conditions.....	8
Historical Fish Communities in the Ipswich River	14
Methods.....	14
Habitat Assessment	15
Macrohabitat Delineation.....	15
Habitat Quality	15
Physical Habitat Survey	16
Fish-Community Assessment.....	16
Fish-Community Sampling	16
Index of Biotic Integrity	19
Development of a Target Fish Community	20
Streamflow Requirements for Habitat Protection	21
Tennant Method.....	21
New England Aquatic-Base-Flow Method.....	22
Wetted-Perimeter Method	22
R2Cross Method.....	23
Range of Variability Approach	24
Flow Statistics	25
Habitat Assessment	25
Habitat Types in the Ipswich River	30
Glide-and-Pool Habitats with Open Canopy.....	30
Glide-and-Pool Habitats with Partially Open Canopy	31
Glide-and-Pool Habitats with Partially Closed and Closed Canopy.....	32
Riffle-and-Run Habitats	33
Ponded Habitats.....	34
Habitat Scoring by the Rapid Bioassessment Protocol	35
Fish-Community Assessment.....	38
1998–99 Fish Sampling.....	38
Index of Biotic Integrity	40
Fish-Community Description	41
Streamflow Requirements for Habitat Protection	44
Critical Riffle Sites	45
Mill Street, North Reading/Reading.....	45
Log Bridge Road, Middleton/Danvers	45
Route 1, Topsfield.....	49
Mill Road, Ipswich/Hamilton.....	49
Tennant Method.....	49
New England Aquatic-Base-Flow Method.....	50
Wetted-Perimeter Method	50

Mill Street, North Reading/Reading.....	51
Log Bridge Road, Middleton/Danvers	52
Route 1, Topsfield.....	52
Mill Road, Ipswich/Hamilton.....	52
R2Cross Method.....	52
Range of Variability Approach	53
Flow Statistics	59
Comparison of Streamflow Requirements and Methods.....	61
Needs for Further Study	65
Summary	65
References Cited	68
Appendix A: Photographs of Selected Study Sites, Ipswich River Basin, Massachusetts, 1998–99.....	CD-ROM
Appendix B: Physical Habitat Data Collected at Habitat Transects, Ipswich River Basin, Massachusetts, 1998–99.....	CD-ROM
Appendix C: Length-Frequency Distributions by Species, Ipswich River Basin, Massachusetts, 1998–99	CD-ROM
Appendix D: Length-Frequency Distributions by Site, Ipswich River Basin, Massachusetts, 1998–99	CD-ROM

FIGURES

(Photographs are shown in color on CD-ROM)

1. Map showing location of towns, drainage network, impoundments, gaging stations, and fish and habitat assessment sites, Ipswich River Basin, Massachusetts.....	4
2. Box plots showing distribution of monthly mean flow for August for 30 gaging stations in southern New England.....	9
3. Photographs showing (A) fish kills and (B) mussel die-offs in the Ipswich River, 1995 and 1999.....	10
4. Hydrograph showing daily mean discharge and median of daily mean discharge for period of record for (A) South Middleton and (B) Ipswich gaging stations, water years 1998–99	11
5, 6. Photographs showing:	
5. Stream habitats on the mainstem Ipswich River, during low-flow conditions, 1999. (A) Dry streambed downstream of I-93, North Reading/Reading, downstream view; (B) Dry streambed, North Reading/Reading, upstream view; (C) Isolated pool downstream of I-93 North Reading/Reading, view of left bank; (D) Isolated pool upstream of Mill Street, North Reading/Reading, upstream view.....	13
6. Massachusetts Division of Fisheries and Wildlife personnel backpack electrofishing on the Ipswich River	18
7,8. Schematic diagrams showing:	
7. (A) Hypothetical stream-channel cross section and (B) Graph of relation between wetted perimeter and discharge.....	23
8. Habitat types of the Ipswich River mainstem.....	28
9–16. Photographs showing:	
9. Common habitat features along the Ipswich River: (A) woody debris, downstream view; (B) undercut banks and exposed roots, view of right bank ; (C) overhanging shrubs, downstream view, and (D) submerged, emergent, and floating aquatic vegetation, upstream view.....	29
10. Glide-and-pool habitats with an open canopy, Audubon Wildlife Sanctuary, Ipswich River, downstream view	30
11. Glide-and-pool habitats with a partially open canopy, upstream of Route 114, Middleton/Danvers, Ipswich River, downstream view.....	31
12. Glide-and-pool habitats with a partially closed or closed canopy, Massachusetts Audubon Society, Ipswich River Wildlife Sanctuary, Ipswich River, Topsfield, upstream view	32
13. Riffle-and-run habitat: (A) Naturally occurring riffle downstream of Route 1, Topsfield, downstream view; and (B) Altered riffle, Washington Street, North Reading, upstream view, Ipswich River	34
14. Poned habitat, Salem–Beverly water supply canal, Topsfield, Ipswich River, southeast view	35
15. (A) South Middleton Dam, Middleton, view of right bank; (B) Willowdale Dam, Ipswich/Hamilton, upstream view; and (C) Sylvania Dam with fish ladder, view of right bank Ipswich River	36

16–19.	Pie charts showing:	
16.	Fish-species habitat classifications on the (A) Mainstem in 1998, and (B) Tributaries in 1999, Ipswich River.....	42
17.	Fish-species habitat classifications for tributaries to the Ipswich River: (A) Howlett Brook, (B) Martins Brook, young-of-year removed, (C) Fish Brook, young-of-year removed.....	43
18.	Fish-species habitat classifications for two New England streams: (A) Quinebaug River, Massachusetts, and (B) Lamprey River, New Hampshire.....	44
19.	Target fish community, Quinebaug River.....	44
20.	Photographs showing stream channels at six critical riffle sites under flowing and dry (or nearly dry) conditions, Ipswich River: (A) Downstream of Mill Street, North Reading/Reading, upstream view; (B) Upstream of Russell Street and Middleton gage (01101500), Middleton, downstream view; (C) Log Bridge Road, Middleton/Danvers, upstream view; (D) Downstream of Route 1, Topsfield, upstream view; (E) Downstream of Ipswich gage (01102000), Ipswich/Hamilton, upstream view; Ipswich/Hamilton (F) Downstream of Mill Road, Ipswich/Hamilton, upstream view.....	46
21–25.	Graphs showing:	
21.	Mean annual flow (Q_{MA}) and streamflow requirements determined by the Tennant method for (A) Mill Street, North Reading/Reading, (B) Ipswich River at South Middleton (01101500), (C) Log Bridge Road, Middleton/Danvers, (D) Route 1, Topsfield, (E) Ipswich River near Ipswich (01102000), and (F) Mill Road, Ipswich/Hamilton.....	50
22.	Streamflow requirements determined by the New England Aquatic-Base-Flow summer-default flow and the median of monthly mean flows for August at (A) Mill Street, North Reading/Reading, (B) Ipswich River at South Middleton (01101500), (C) Log Bridge Road, Middleton/Danvers, (D) Route 1, Topsfield, (E) Ipswich River near Ipswich (01102000), and (F) Mill Road, Ipswich/Hamilton.....	51
23.	Streamflow requirements determined by the wetted-perimeter method at four riffle sites: (A) Mill Street, North Reading/Reading, (B) Log Bridge Road, Middleton/Danvers, (C) Route 1, Topsfield, and (D) Mill Road, Ipswich/Hamilton.....	51
24.	Streamflow requirements determined by the R2Cross method at four riffle sites: (A) Mill Street, North Reading/Reading, (B) Log Bridge Road, Middleton/Danvers, (C) Route 1, Topsfield, and (D) Mill Road, Ipswich/Hamilton.....	53
25.	Flow-duration curves for six sites on the Ipswich River.....	60

TABLES

1.	One-day and 7-day annual low flows at the Ipswich River at South Middleton (01101500) gaging station, Middleton/Peabody, Massachusetts.....	12
2.	Criteria for measurement of physical habitat features.....	17
3.	Index of Biotic Integrity Metrics.....	20
4.	Relations between aquatic habitat condition and mean annual flow described by the Tennant method for small streams.....	22
5.	Seasonal New England Aquatic-Base-Flow default streamflow requirements.....	22
6.	R2Cross criteria for hydraulic parameters for protection of aquatic habitat.....	24
7.	Range of variability approach: flow statistics for characterization of intra-annual hydrologic variation.....	24
8.	Site name, site identifier, date sampled, and location of sample sites, Ipswich River Basin.....	26
9.	Location and length of riffle reaches on the mainstem Ipswich River.....	33
10.	U.S. Environmental Protection Agency Rapid Bioassessment Protocol habitat scores for Ipswich River study reaches, 1998–99.....	37
11.	Fish sampling date, electroshocking effort, reach length, on the mainstem in 1998 and tributaries in 1999, Ipswich River.....	39
12.	Mean length, number, and percent of total fish by species collected in the mainstem in 1998 and tributaries in 1999, Ipswich River.....	40
13.	Habitat-use classifications of fish in the Ipswich River Basin.....	41
14.	The mean annual flow statistic used by the Tennant method and the streamflows representing summer habitat conditions determined by the 10- and 30-percent values of the mean annual flow, normalized for drainage area at six sites in the Ipswich River Basin.....	49

15. Median, upper, and lower quartiles of monthly mean flow, simulated for four sites for the 1961 to 1995 period with the Ipswich River Basin model for no withdrawals and 1991 land-use conditions.....	54
16. Hydrologic data simulated for the 1961 to 1995 period for the South Middleton gage (01101500) with the Ipswich River Basin model for no withdrawals and 1991 land-use conditions	55
17. Hydrologic data simulated for the 1961 to 1995 period for the Ipswich gage (01102000) with the Ipswich River Basin model for no withdrawals and 1991 land-use conditions.....	57
18. Average streamflow requirements for six sites on the Ipswich River	61
19. Streamflow requirements computed by Tennant, Aquatic-Base-Flow (median of monthly mean flow for August), Wetted-Perimeter, and R2Cross methods for four riffle study sites, Ipswich River.....	62

CONVERSION FACTORS, AND VERTICAL DATUM

CONVERSION FACTORS

	Multiply	By	To obtain
cubic foot per second (ft ³ /s)		0.02832	cubic meter per second
cubic foot per second per square mile [(ft ³ /s)/mi ²]		0.01093	cubic meter per second per square kilometer
foot (ft)		0.3048	meter
foot per mile (ft/mi)		0.1894	meter per kilometer
foot per second (ft/s)		0.3048	meter per second
gallon (gal)		3.785	liter
inch (in.)		2.54	centimeter
inch (in.)		25.4	millimeter
mile (mi)		1.609	kilometer
million gallons per day		0.04381	cubic meter per second
square mile (mi ²)	259.00		hectare
square mile (mi ²)	2.590		square kilometer
Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F = 1.8°C+32			
Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C=(°F-32)/1.8			

VERTICAL DATUM

Sea Level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.