BACTERIA TOTAL MAXIMUM DAILY LOAD FOR FROST FISH CREEK CHATHAM, MASSACHUSETTS

Report Number: MA96-49-2004-01
Control Number: CN207.0

MARCH 2005

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
ELLEN ROY HERTZFELDER, SECRETARY
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
ROBERT GOLLEDGE, COMMISSIONER
BUREAU OF RESOURCE PROTECTION
GLENN HAAS, ACTING ASSISTANT COMMISSIONER
DIVISION OF WATERSHED MANAGEMENT
GLENN HAAS, DIRECTOR

THIS INFORMATION IS AVAILABLE IN ALTERNATE FORMAT BY CALLING OUR ADA COORDINATOR AT (617) 574-6872.
http://www.mass.gov/dep • Phone (508)792-7650 • Fax (508)792-7621 • TDD # (508)767-2788

NOTICE OF AVAILABILITY

Limited copies of this report are available at no cost by written request to:

Massachusetts Department of Environmental Protection
Division of Watershed Management
627 Main Street
Worcester, MA 01608

This report is also available from MassDEP's home page on the World Wide Web at:

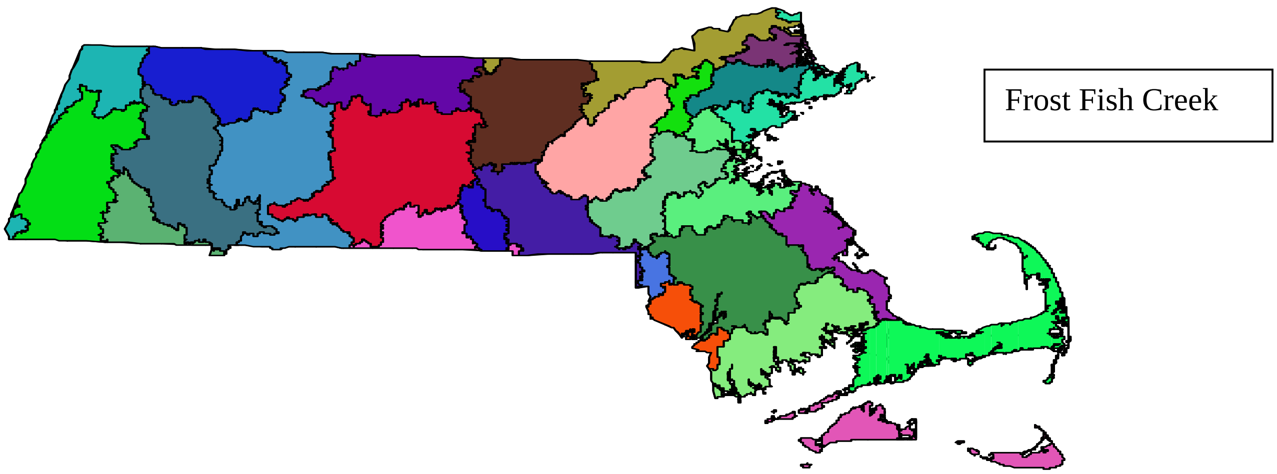
http://www.mass.gov/dep/water/resources/tmdls.htm

This report was a collaboration between the School for Marine Science and Technology (SMAST) and the Massachusetts Department of Environmental Protection (MassDEP) prepared by Howes, B.L., R.I. Samimy , D.S. White and A.M. Rojko.

DISCLAIMER

References to trade names, commercial products, manufacturers, or distributors in this report do not constitute endorsement or recommendation by the Division of Watershed Management for any purpose.

BACTERIA TMDL FOR FROST FISH CREEK (Cape Cod Watershed)
Chatham, Massachusetts
Report MA96-49-2004-01
2005



Key Feature:	Fecal Coliform Bacteria TMDL for Frost Fish Creek
Location:	EPA Region 1
Land Type:	New England Coastal
303d Listing:	Pathogens (MA 96-49 Outlet from cranberry bog northwest of Stony Hill Road to confluence with Ryder Cove, Chatham)
Data Sources:	University of Massachusetts – Dartmouth/School for Marine Science and Technology; Massachusetts Division of Marine Fisheries; Chatham High School; Massachusetts Department of Revenue; GIS
Data Mechanism:	Massachusetts Surface Water Quality Standards for Fecal Coliform, Ambient Data, and Best Professional Judgment
Monitoring Plan:	Chatham High School Monitoring
Control Measures:	Storm Water Management and Investigation for Source Identification

Table of Contents

List of Figures

List of Tables

Acknowledgements

The Massachusetts Estuaries Project staff would like to express their gratitude to the Massachusetts Division of Marine Fisheries (DMF) for providing valuable bacterial data and shellfish growing area maps. Additionally, the DMF has been very generous with its staff time for interviews, queries and general discussions regarding the interpretation of its historical bacterial data records. The Division of Marine Fisheries exemplifies the spirit of collaboration in environmental science, which is needed for the restoration and management of the coastal environment.

A special thank you is extended to The Town of Chatham High School Senior Honors II Chemistry Class for their bacterial data collection efforts undertaken over the past 7 years under the guidance of Ms. Jean Avery, filling the role of Program Manager for the bacterial sampling program as described in the US EPA approved Quality Assurance Project Plan (QAPP). The bacterial data collected by the Honors Chemistry class over the past handful of years was essential to the analysis provided herein and the efforts by all the students were by no means an academic exercise. Rather, their data collection served as a fundamental element in the development of this Bacterial TMDL that is the road map towards managing bacterial contamination in the Frost Fish Creek System

The Massachusetts Estuaries Project would also like to thank the Town of Chatham Water Quality Laboratory for its sustained water quality monitoring efforts for all of the Town's embayments. The additional periodic collection of bacteria data was critical, providing comparative data to the other studies and increasing the available data during the critical summer interval.

Executive Summary

The Massachusetts Department of Environmental Protection (MassDEP) is responsible for monitoring the waters of the Commonwealth, identifying those waters that are impaired, and developing a plan to bring them into compliance with the Massachusetts Water Quality Standards (314 CMR 4.0). The list of impaired waters, formerly known as the “303d list” and now as “Category 5 of the Integrated List”, identifies river, lake, and coastal waters not meeting standards and the reasons for impairment.

Once a water body is identified as impaired, MassDEP is required by the Federal Clean Water Act to develop essentially a “pollution budget” designed to restore the health of the impaired body of water. The process of developing this budget, generally referred to as a Total Maximum Daily Load (TMDL), includes identifying the source(s) of the pollutant from direct discharges (point sources) and indirect discharges (non-point sources), determining the maximum amount of the pollutant, including a margin of safety, that can be discharged to a specific water body while maintaining water quality standards for designated uses, and outlining a plan to meet that goal.

This report represents the development of a TMDL relating to bacteria contamination within the Frost Fish Creek System. Frost Fish Creek extends from the outlet of the cranberry bog northwest of Stony Hill Road to the confluence with Ryder Cove in Chatham. It is divided into an upper and lower basin by the dike/weir and Route 28 culverts. Frost Fish Creek has been classified by the Massachusetts Surface Water Quality Standards as a Class SA water.

Frost Fish Creek has been placed on the Massachusetts Year 2002 Integrated List of Waters (Category 5) as impaired for Pathogens since historical samplings and analyses indicate it does not meet the Massachusetts Surface Water Quality Standards for fecal coliform bacteria. In addition, since 1980 the Frost Fish Creek area has been classified as “prohibited” for shell fishing by the Division of Marine Fisheries (DMF) due to high bacterial concentrations.

A review of both historical and current data indicates significant bacterial contamination during both the summer and winter seasons in upper Frost Fish Creek. A comparison of the wet and dry weather data indicates higher fecal coliform counts during wet weather. It is likely that the primary sources of bacterial contamination to upper Frost Fish Creek are the adjacent wetlands (which could be “natural” resulting from wildlife) and runoff from Route 28. Upper Frost Fish Creek is a contributing source of bacteria to lower Frost Fish Creek (between Route 28 and Ryder Cove).

The goal for Frost Fish Creek is to achieve state water quality standards for Class SA waters. In order to meet this goal, effective implementation of this TMDL will require reducing bacteria sources by 78 to 98% for Frost Fish Creek. It is recommended that actions focus on the upper basin of Frost Fish Creek, in particular, the adjacent wetlands and the area around the Route 28 bridge. Further focused sampling in these areas will help to better define the nature and magnitude of the sources. In order to determine the impact from wildlife, bacterial testing to differentiate between anthropogenic and non-anthropogenic sources should be considered. The information provided from this type of sampling will be useful in identifying what measures, if any, would be appropriate to remediate the bacterial contamination. Additionally an investigation should be undertaken to determine if septic systems are a problem in residential areas and if there are any contributing bacteria sources around the Chatham Middle and High Schools.

Authority to regulate sources of bacterial contamination and thus the successful implementation of a bacterial TMDL for Frost Fish Creek generally rests with local government. Cooperation from local volunteers, watershed associations, municipal government, and other entities could greatly facilitate source identification and remediation efforts. Financial support for remedial activities may be available from both federal and state agencies through existing, competitive grant and loan programs.

.

I. Introduction

The State of Massachusetts is responsible under section 303 (d) of the federal and state adopted Clean Waters Act to evaluate the quality of waters in the state, identify those that exhibit water quality problems and to develop a plan to return the waters to compliance with acceptable standards.

This report on the bacterial water quality in Frost Fish Creek, Chatham, MA is part of the ongoing Massachusetts Estuaries Project (MEP). Although the Estuaries Project focuses primarily on estuarine health as related to nutrient inputs, it was deemed cost effective to simultaneously evaluate those estuaries in the Project study area that are listed on the state's 2002 Integrated List of Waters for bacterial contamination. Frost Fish Creek is included on this list as impaired for pathogens since historical samplings and analyses indicate it does not meet the Massachusetts Surface Water Quality Standards for fecal coliform bacteria.

This report describes and presents existing and new bacteriological water quality data and recommends, based on a comprehensive water quality data/land use evaluation, sections of Frost Fish Creek that exhibit poor water quality and warrant a more detailed undertaking such as a sanitary survey in order to identify specific sources of bacterial contamination. Fecal coliform contamination is indicative of human waste and sewage and the wastes of other warm blooded animals and can cause significant risk to human health and limits resource utilization by restricting shellfish harvest and at higher levels, primary and secondary contact recreation.

Though ambient water quality data are available for comparison to state bacterial standards, limited data have been collected that allow for the identification of specific sources of contamination. As such, the goal is to point to likely geographic sections of the Frost Fish Creek system that are the most likely sites of bacterial entry, and therefore should receive additional targeted source identification efforts. This focusing of potential additional effort is primarily based upon spatial and temporal analysis of bacterial levels within Frost Fish Creek waters and how they respond to rainfall.

A TMDL is a pollution budget or pollution allocation that accounts for the multitude of variables that influence water quality and that establishes the acceptable limits of pollution based on the combined influence of these variables and the sensitivity and use of the water body. A TMDL also includes a plan or program for repairing the water quality problem over a designated time period. This recommended restoration plan is developed with the communities associated with the specific water resource and involves public input.

II. Frost Fish Creek

Frost Fish Creek is located in the Town of Chatham, Massachusetts on the southeastern-most side of Cape Cod. (See Figure II-1). The Creek is approximately ¾ of a mile long, is tidally influenced in its lower reaches but restricted by culverts. Both the culverts at Route 28 and a dike and weir system immediately up gradient serve to maintain approximately three feet of water at low tide within the main basin, while the limited tide range supports fringing saltwater wetland. The ponding of estuarine waters within Frost Fish Creek contrasts with the adjacent tidal basin (outer Frost Fish Creek), in the reach between the Rt. 28 culverts and Ryder Cove. This outer basin is nearly completely drained at ebb slack tide and as a result supports extensive tidal flats. The separation of Frost Fish Creek and outer Frost Fish Creek are a man-made construct from the placement of water control structures and also the construction of Route 28 and its culverts.

Upper Frost Fish Creek has a significant amount of groundwater entry from its watershed. Tidal waters from Pleasant Bay enter through Bassing Harbor, Ryder Cove and finally outer Frost Fish Creek before entering through the Route 28 culverts. This whole portion of the Chatham coastline is separated from the Atlantic Ocean by Nauset Beach, a barrier beach spit truncated to the north at Nauset Harbor and to the south at Chatham Harbor.

II.1 Land Use Analysis

The three sub-watersheds portrayed in Figure II-2 contribute ground and surface water to Frost Fish Creek. These sub-watersheds were delineated by the United States Geological Survey for the Massachusetts Estuaries Project and utilize the most current physical information and modeling based upon MODFLOW/MODPATH. The sub-watersheds to Frost Fish Creek range in size from approximately 30 – 110 acres and have similar and consistent patterns and distribution of land use. The total watershed area to upper Frost Fish Creek (basin inland and south of Rt. 28) is approximately 210 acres.

The land use data for upper Frost Fish Creek was derived from Town of Chatham assessors' maps (2002 update) with land-use codes consistent with the MA Department of Revenue classification scheme. Tables II-1 and II-2 present the land use categories with acres of coverage and % coverage. The land use was derived from a parcel by parcel analysis, with uses apportioned into several general categories that were further subdivided to refine land use descriptions. For example, the residential land use grouping includes single family, two, three and multiple family dwellings, apartments, and boarding houses to name a few. In this report the primary groupings will be employed. Below is the general description for land uses in the three watersheds:

Land Use	Sub-Watershed ID		
	50	51	52
	% Total Watershed Area		
Residential:	21.7	1.3	8.4
Business/storage	0.0	0.0	1.7
Public Service	18.3	3.4	16.8
Cemetery	0.0	0.0	3.6
Park/school	4.7	7.5	0.0
Roads	3.0	2.8	3.1
Water	3.7	0.0	0.0

The predominant land use type is residential, primarily single-family dwellings on individual on-site septic systems and "public service" which are parcels that are non-taxable (exempt property) owned by government, charitable organizations, churches, etc. In the Frost Fish Creek sub-watersheds (#50, 51, 52 in Figure II-2) the Public Service lands are almost completely partitioned between the Chatham High School parcel (41% or 33 acres) and open space owned by the Chatham Conservation Foundation (53% or 43 acres). Important for assessing bacterial contamination, the conservation parcel includes much of the shoreline of Frost Fish Creek (including the wetlands) and does not appear to contain any anthropogenic sources related to bacterial contamination. When considered cumulatively as one watershed the land use types occupy the following percent of the watershed:

- Residential: 31.4%
- Business/storage: 1.7%
- Public Service: 38.5%
- Cemetery: 3.6%
- Park/school: 12.2%
- Roads: 8.9%
- Water: 3.7%

Common sources of fecal coliform bacteria to coastal water bodies, in general, include "failing" septic systems, stormwater runoff from impermeable surfaces, combined sewer overflows, congregation of waterfowl and wildlife associated with wetlands and other shoreline resources. The majority of the watershed to upper Frost Fish Creek is unsewered thus combined sewer overflows (CSOs) are not an issue.

Figure II-1. Location of Frost Fish Creek, Cape Cod, Town of Chatham, Massachusetts. Frost Fish Creek is part of the Bassing Harbor Estuarine System a tributary to Pleasant Bay. Frost Fish Creek exchanges tidal water with Ryder Cove within the Bassing Harbor System through culverts under Rt. 28.

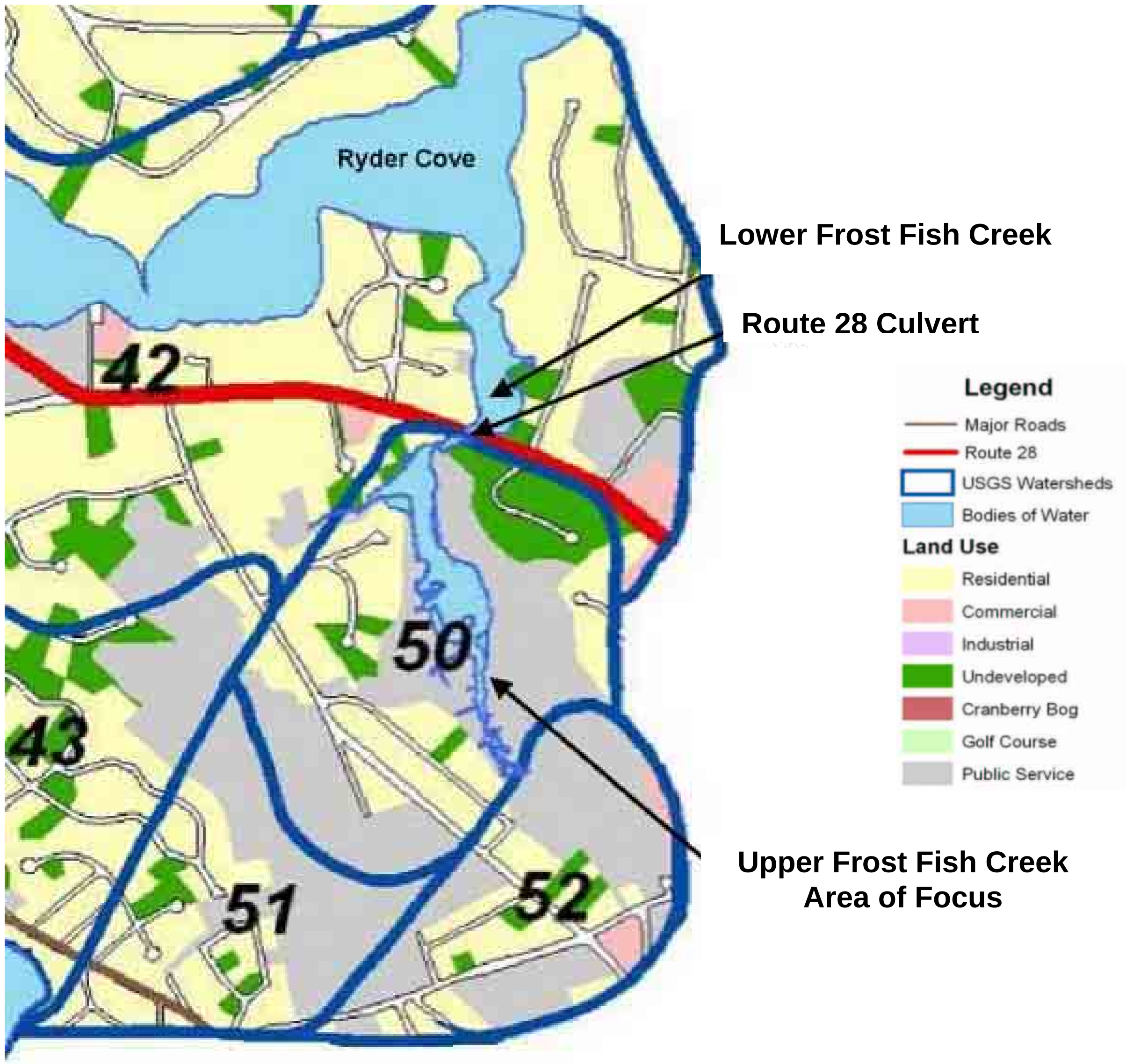


Figure II-2. Land-use by parcel for the Frost Fish Creek system (50, 51, and 52). Frost Fish Creek and its watershed falls entirely within the confines of the Town of Chatham, MA.

Frost Fish Creek Sub-watersheds	Land Use Category and Acres of Coverage								
	Multiple Use (acres) Code 0*	**Residential (acres) Code 1***	**Comm/ Business (acres) Code 3***	**Forest Property (acres) Code 6***	**Public Service (acres) Code 9***	**Cemetary (acres)**	**Park / School (acres)**	**Rights of way ROW (acres)**	**Water/ Ponds H2O (acres)**
Frost Fish Creek (sub-watershed 50)	0.00	45.67	0.00	0.00	38.54	0.00	9.85	6.32	7.86
Frost Fish Creek 10 (sub-watershed 51)	0.00	2.72	0.00	0.00	7.24	0.00	15.89	5.91	0.00
Upper Frost Fish Creek (sub-watershed 52)	0.00	17.67	3.54	0.00	35.38	7.67	0.00	6.44	0.02
TOTAL	**0.00**	**66.06**	**3.54**	**0.00**	**81.16**	**7.67**	**25.74**	**18.67**	**7.88**

* Massachusetts Department of Revenue Property Type Classification Codes Revised November 2002

Table II-1 Land Use distribution for the Upper Frost Fish Creek Watershed. Sub-watershed I.D.'s refer to the numbers in Figure II-2.

Frost Fish Creek Sub-watersheds	Land Use Category and % of Coverage								
	Multiple Use Code 0*	Resident Code 1*	Comm/ Business Code 3*	Forest Property Code 6*	Public Service Code 9*	Cemetary	Park / School	Rights of way ROW	Water/ Ponds H2O
Frost Fish Creek (sub-watershed 50)	0.0%	21.7%	0.0%	0.0%	18.3%	0.0%	4.7%	3.0%	3.7%
Frost Fish Creek 10 (sub-watershed 51)	0.0%	1.3%	0.0%	0.0%	3.4%	0.0%	7.5%	2.8%	0.0%
Upper Frost Fish Creek (sub-watershed 52)	0.0%	8.4%	1.7%	0.0%	16.8%	3.6%	0.0%	3.1%	0.0%
TOTAL	**0.0%**	**31.3%**	**1.7%**	**0.0%**	**38.5%**	**3.6%**	**12.2%**	**8.9%**	**3.7%**

* Massachusetts Department of Revenue Property Type Classification Codes Revised November 2002

Table II-2 Landuse distribution as percentage of the upper Frost Fish Creek Watershed

III. Problem Assessment

A significant amount of bacteria related water quality information has been gathered for upper Frost Fish Creek and to a lesser extent its adjacent basin (outer Frost Fish Creek). While both Frost Fish basins are under shellfish closure by DMF, the data review indicates that the major source to the outer basin is most likely outflow from the highly contaminated upper basin.

Frost Fish Creek (particularly the upper basin inland and south of Rt. 28) was one of seven coastal systems selected to undergo further bacterial evaluation from the original list of 20 estuaries initially prioritized under the Massachusetts Estuaries Project. It was selected because segments of the waters exceeded the state's Water Quality Standards for bacteria in historical samplings and analyses. The area was also an active shellfish resource area prior to closure around 1980 by the Division of Marine Fisheries (DMF), due to bacterial concentrations exceeding Water Quality Standards for shell fishing areas. All of Frost Fish Creek has been classified by DMF as Prohibited for shellfishing since at least 1980.

Bacterial data available for Frost Fish Creek TMDL analysis consists of:

1. DMF fecal coliform survey data (6 sites) -1985 to 1996,
2. Chatham High School survey data[1](4 sites) - 1996 to 2002,
3. SMAST time series data (1 site) – 2002-03

[1]The High School information has been obtained and processed under an EPA approved QAPP at a sampling rate of 14 events per year.

The State of Massachusetts utilizes a fecal coliform standard of 14 CFU /100 mL for maintaining open and fishable shellfish resource areas. This standard has been exceeded frequently at multiple sampling stations in each sampling year. These observations support the contention that the system has a chronic contamination issue. In addition, the whole of the data suggests bacterial inputs in both the spring and winter. The most likely sources of fecal coliform bacteria are waterfowl and other wildlife throughout the upper basin and stormwater runoff from roads and paved surfaces near the tidal inlet at Rt. 28. The hydraulics of the Frost Fish system has been altered by the use of culverts associated with roadways and a separate dike and weir just up gradient from the roadway. These restrictions maintain a water depth of approximately three feet in the Creek's upper reaches. Creating standing water and decreasing flushing typically results in a concentration of contaminant inputs, but also supports a greater period for bacterial "die-off" before export downgradient.

IV. Water Quality Standards

Frost Fish Creek (Segment ID MA96-49_2002), considered a tributary to Ryder Cove, is in the coastal and marine Class and has been classified by the Massachusetts State Water Quality Standard as a Class SA water. From the Massachusetts Year 2002 Integrated List of Waters (Massachusetts Category 5 Waters), Frost Fish Creek is considered those waters from the outlet of a cranberry bog northwest of Stony Hill Road to the confluence with Ryder Cove, Chatham. The basin is ecologically and functionally divided into an upper and lower basin by the dike/weir and Rt. 28 culverts. Frost Fish Creek is classified by the Massachusetts Division of Marine Fisheries (DMF) as shellfish growing area SC:57.0 that encompasses Lower Frost Fish Creek starting at the confluence with Ryder Cove to the headwaters of Upper Frost Fish Creek.

At a regulatory level, two bacterial contamination standards must be met in order to safe guard the quality and value of the water resource and public health. The first regulatory standard, Massachusetts Surface Water Quality Standards 314 CMR 4.05(4)(a)(4), is intended to protect the water resource and its shellfish habitat using fecal coliform as the indicator organism. The second is a minimum standard for bathing beaches, 105 CMR 445.000, and is commonly regarded as a swimming standard aimed at protecting public health using Enterococci as the indicator organism in marine waters or E.coli in fresh water.

Based on the Surface Water Quality Standard (SWQS), fecal coliform criteria for coastal and marine Class SA waters specify that: a) waters approved for open shellfishing shall not exceed a geometric mean MPN of 14 organisms per 100 mL, nor shall more than 10 percent of the samples exceed a MPN of 43 per 100 mL and, b) waters not designated for shellfishing shall not exceed a geometric mean of 200 organisms in any representative set of samples, nor shall more than 10 percent of the samples exceed 400 organisms per 100 ml. With regard to safe guarding public health relative to primary and secondary contact recreation, as specified for marine waters in 105 CMR 445.031(A)(1), the indicator organism shall be Enterococci and no single Enterococci sample shall exceed 104 colonies per 100 mL and the geometric mean of the most recent five (5) Enterococci levels within the same bathing season shall not exceed 35 colonies per 100 mL.

At this time for protection of shellfish resources, fecal coliform bacteria is the pathogenic indicator utilized by the State of Massachusetts as the measure for whether a coastal marine water body is in compliance with bacteria based Water Quality Standards. Fecal coliform will remain the standard for shellfish waters. However, for bathing waters the State of Massachusetts anticipates replacing the bacterial indicator fecal coliform with enterococci in marine waters as recommended by EPA. The goal of the TMDL for Frost Fish Creek, which will evolve from this technical report, will be to decrease or eliminate fecal coliform bacterial contamination or determine that it is not wastewater derived (i.e. not linked to pathogens). The goal is to protect human health and return these waters to their most beneficial use as a shellfish resource.

V. Fecal Contamination of the Frost Fish Creek System

V.1 Levels of Bacterial Indicators within the Estuary

The history of bacterial contamination in Frost Fish Creek is briefly reviewed in, The Massachusetts Estuary Project Embayment Water Quality Assessment Interim Report: Priority Embayments 1-20 (2002). All of Frost Fish Creek has been classified as Prohibited for shellfish harvest, since at least 1980. The Massachusetts Division of Marine Fisheries (DMF) collected samples for Fecal Coliform bacteria at its designated stations 1, 2, 3, 4 and 5 (Figure V-1) up to 1986. From 1987 to present, DMF only sampled Frost Fish on one occasion, in 1996.

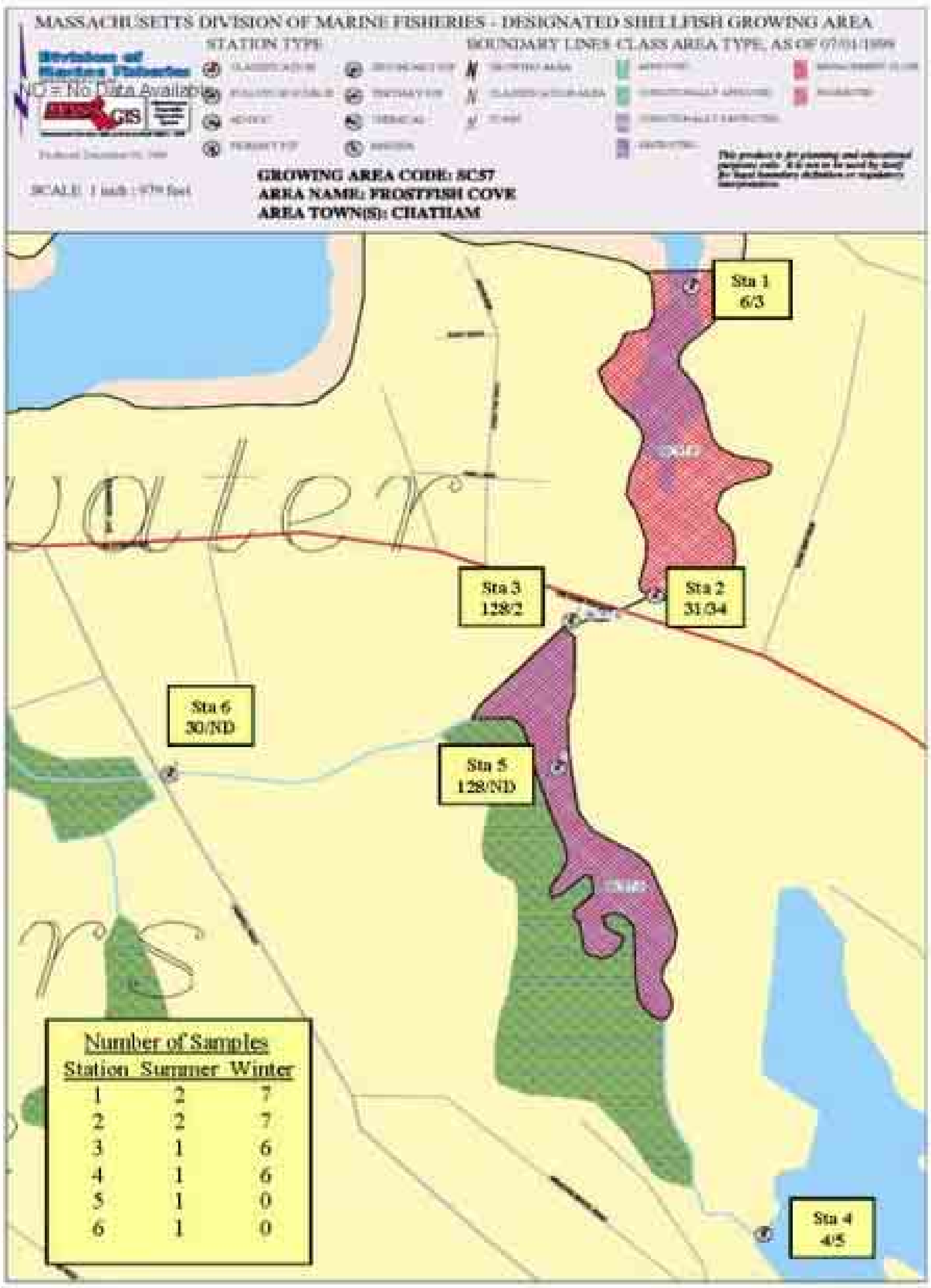
In 1996 the Honors II Chemistry class at Chatham High School (CHS) began a sampling program for the fall and spring months at 4 stations, some of which are in close proximity to the DMF stations (Figure V-2). In 2002, the Coastal Systems Program at the School for Marine Science and Technology, UMass.D. (SMAST) began a weekly sampling program just up-gradient of the mouth of Frost Fish Creek near DMF Station 3. Both CHS and SMAST collected samples for Fecal Coliforms and E. coli bacteria. Fecal coliform is a general classification of bacteria that are typically associated with warm blooded animal (birds, mammals) and human waste. E. coli is a subset of fecal coliform bacteria and is typically found in the intestines of animals and humans. In addition, SMAST sampled for Enterococcus, a bacterium thought to be a better indicator of human health risk from pathogens than fecal coliforms. Table V-1A provides a summary of the sampling stations and locations which are depicted in Figure V1-A.

Station	Location	Data Source
1	Mouth of Frost Fish Creek at Ryder Cove	DMF
2	North of Route 28 Culvert (Outer Frost Fish Creek)	DMF
3	South of Route 28 Culvert (Upper Frost Fish Creek)	DMF
4	Head of Frost Fish Creek (Upper Frost Fish Creek)	DMF
5	Adjacent to Wetland Area on East Side of Upper Frost Fish Creek	DMF
6	Adjacent to Western Tributary Wetland Area	DMF
HS1	Adjacent to Wetland Area in southern portion of Upper Frost Fish Creek	Chatham High School
HS2	Adjacent to Wetland Area in southern portion of Upper Frost Fish Creek	Chatham High School
HS3	South of Route 28 Culvert (Upper Frost Fish Creek)	Chatham High School
HS4	North of Route 28 Culvert (Outer Frost Fish Creek)	Chatham High School
SM	South of Route 28 Culvert (Upper Frost Fish Creek)	SMAST

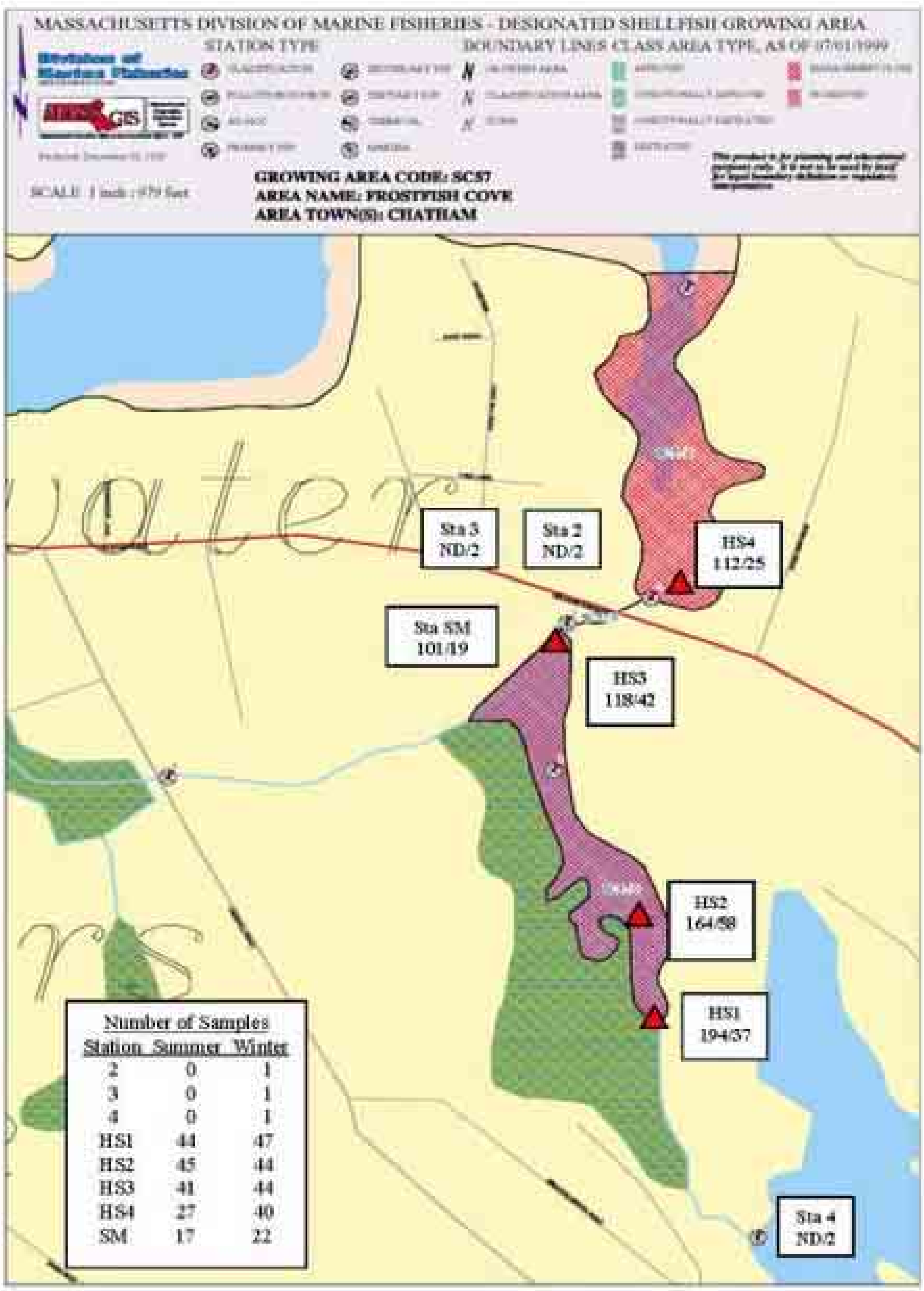
Table V-1A. Frost Fish Creek Sampling Station Locations

Data from all 3 sources have been compiled and analyzed for the TMDL. Data was grouped by year (1985-1995 and 1996-2003), by season (November through April for winter and May through October for summer) and by wet

Figure V-1A. Frost Fish Creek Sampling Station Locations



Figgure V-1 Summer and winter fecal coliform bacteria counts (CFU/100 mls), 1985-1995. Numbers indicate geometric means for summer/winter from samplings by Massachusetts Division of Marine Fisheries.



ND = No Data Available

Figure V-2 Summer and winter fecal coliform bacteria counts (CFU/100 mls), 1996-2003
Numbers indicate geometric means for summer/winter samplings by Massachusetts Division of Marine Fisheries, Chatham High School (HS) and SMAST (SM).

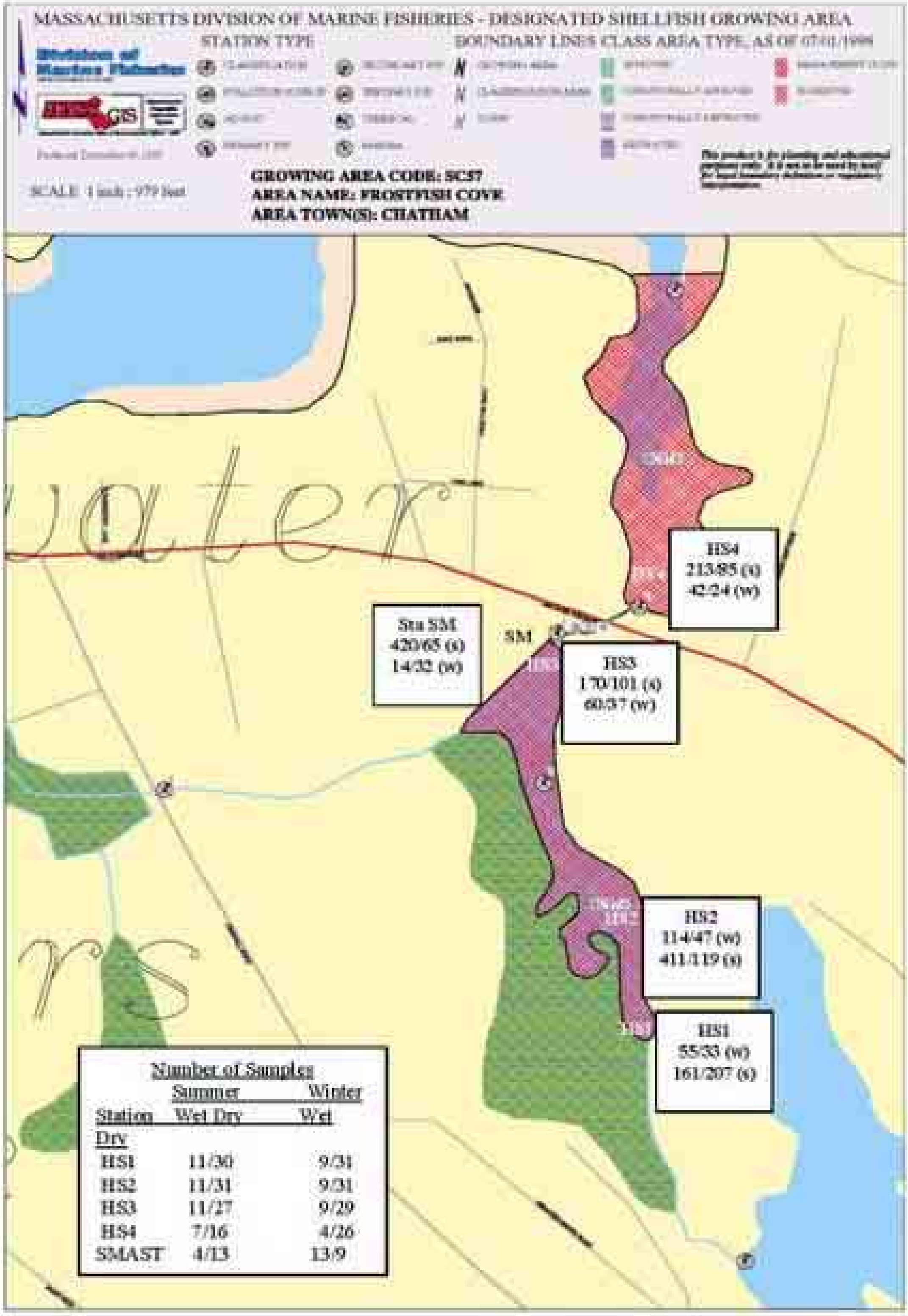


Figure V-3 Wet and Dry fecal coliform bacteria counts (CFU/100 mls), 1996-2003. Numbers indicate geometric means of wet/dry data for summer (s) and winter (w) samplings by Chatham High School (HS) and SMAST (SM).

weather or dry weather status. However, wet and dry weather comparisons could only be made for the 1996-2003 data, where rainfall amounts were available. Wet/Dry samplings were based on the total rainfall amount at the site over the three days prior to sampling (less than 0.25 inches was considered to be a dry weather event and greater than 0.25 inches was designated as wet weather sampling).

For each sampling station, the geometric mean, standard deviation (SD) and number of samples taken (N) were computed for winter and summer for each time interval (1985-1995 and 1996-2003) (Tables V-1 and V-2). Geometric means that exceeded the water quality standard for Class SA Waters of 14 CFU/100 mls for Fecal Coliforms and E. coli, and 35 CFU/100 mL for Enterococcus are highlighted (CFU= colony forming units, theoretically a count of individual viable bacteria). In addition, sampling stations were highlighted where more than 10% of the samples exceeded the water quality standard of 43 CFU/100 mL for Fecal coliforms and E. coli, or where any sample exceeded the water quality standard of 104 colonies/100 mL for Enterococcus. The ratio of the summer to winter geometric means was also determined for each sampling station as indicators of the degree of summer versus winter contamination levels.

Wet and Dry data were compiled in the same manner for each station. Geometric means and standard deviations were calculated seasonally for wet and dry data from each station during the years 1996-2003. Means that exceeded the water quality standards were highlighted. Data were highlighted when more than 10% of the samples exceeded the water quality standard of 43 CFU/100 mL for Fecal coliforms and E. coli or where any sample exceeded the water quality standard of 104 colonies/100 mL for Enterococcus.

Summer Sampling Results – 1985-1995

From 1985-1995, there were a total of 8 summer sampling events. Summer values of fecal coliform counts ranged from 4 CFU/100 mls at Station 4 (single sample) at the head of Frost Fish Creek to 128 CFU/100 mL at Stations 3 and 5 (single samples) (Figures V-1, V-4a, and Table V-1a). Station 3 is located south of the Route 28 culvert and Station 5 is proximate to a wetland area (Figure V-1). Both values exceeded the water quality standard of 14 CFU/100 mls. Station 2 located north of the Route 28 culvert had a summer geometric mean of 31 (2 samples), also exceeding the standard, and 50% of the samples exceeded 43 CFU/100 mls (Figures V-1, V-4a, and Table V-1a). At Station 6, also adjacent to a wetland area (Figure V-4a), the summer geometric mean was 30 (single sample). Station 1 at Ryder Cove had a mean of 6 CFU/100 mL (2 samples) with none of the counts exceeding 43 CFU/100 mls.

Winter Sampling Results – 1985-1995

During the winter months, 1985-1995, there were 26 sampling events (Figure V-1). Winter geometric means for fecal coliform bacteria were lower than summer means at all stations except Station 2, north of the Route 28 culvert (34 CFU/100 a

Fecal Coliforms Year	Station	Summer Geomean	S.D.	N	% Samples >14	% Samples >43	Winter Geomean	S.D.	N	% Samples >14	% Samples >43	Geomean Ratio: Summer/Winter
1985-1995	1	6	2	2	0%	0%	3	4	7	14%	0%	2.0
1985-1995	2	31	8	2	50%	50%	34	4	7	57%	43%	0.9
1985-1995	3	128	0	1	100%	100%	20	5	6	67%	17%	6.3
1985-1995	4	4	0	1	0%	0%	5	9	6	17%	17%	0.8
1985-1995	5	128	0	1	100%	100%	ND	ND	ND	ND	ND	ND
1985-1995	6	30	0	1	100%	0%	ND	ND	ND	ND	ND	ND
1996-2003	2	ND	ND	ND	ND	ND	2	0	1	0%	0%	ND
1996-2003	3	ND	ND	ND	ND	ND	2	0	1	0%	0%	ND
1996-2003	4	ND	ND	ND	ND	ND	2	0	1	0%	0%	ND
1996-2003	HS1	194	7	41	95%	83%	37	5	40	73%	43%	5.2
1996-2003	HS2	164	6	42	95%	76%	58	6	40	78%	55%	2.9
1996-2003	HS3	118	5	38	95%	74%	42	5	38	76%	55%	2.8
1996-2003	HS4	112	6	23	87%	70%	25	5	30	67%	43%	4.4
2002-2003	SM	101	6	17	82%	71%	19	5	22	45%	27%	5.2

b

E. coli Year	Station	Summer Geomean	S.D.	N	% Samples >14	% Samples >43	Winter Geomean	S.D.	N	% Samples >14	% Samples >43	Geomean Ratio: Summer/Winter
1996-2003	HS1	188	7	40	95%	83%	44	4	43	77%	49%	4.3
1996-2003	HS2	155	6	41	95%	76%	64	6	41	78%	59%	2.4
1996-2003	HS3	113	5	37	92%	70%	52	5	41	83%	59%	2.2
1996-2003	HS4	110	6	24	88%	67%	25	6	38	71%	42%	4.3
2002-2003	SM	52	7	17	76%	59%	11	4	22	36%	14%	4.6

c

Enterococcus Year	Station	Summer Geomean	S.D.	N	% Samples >104	Winter Geomean	S.D.	N	% Samples >104	Geomean Ratio: Summer/Winter
2002-2003	SM	69	4	17	35%	12	5	22	9%	5.8

ND = No Data Available

Table V-1 Comparison of geometric means (CFU/100 mls) of summer and winter samplings for (a) Fecal Coliforms, (b) E. coli and (c) Enterococcus bacteria (colonies/100 mL) by Massachusetts Division of Marine Fisheries, Chatham High School and SMAST during the years 1985-1995 and 1996-2003.

a

Fecal Summer Year	Coliform Station	Wet Geomean	S.D.	N	% Samples >14	% Samples >43	Dry Geomean	S.D.	N	% Samples >14	% Samples >43	Geomean Ratio: Wet/Dry
1996-2003	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996-2003	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996-2003	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996-2003	HS1	161	7	12	83%	75%	207	7	32	91%	78%	0.8
1996-2003	HS2	411	4	12	92%	83%	119	6	33	88%	67%	3.5
1996-2003	HS3	170	4	12	92%	67%	101	5	29	86%	69%	1.7
1996-2003	HS4	213	5	9	78%	56%	85	7	18	72%	61%	2.5
2002-2003	SM	420	5	4	100%	100%	65	5	13	77%	62%	6.5
Fecal Winter Year	**Coliform Station**	**Wet Geomean**	**S.D.**	**N**	**% Samples >14**	**% Samples >43**	**Dry Geomean**	**S.D.**	**N**	**% Samples >14**	**% Samples >43**	**Geomean Ratio: Wet/Dry**
1996-2003	2	2	0	1	0%	0%	ND	ND	ND	ND	ND	ND
1996-2003	3	2	0	1	0%	0%	ND	ND	ND	ND	ND	ND
1996-2003	4	2	0	1	0%	0%	ND	ND	ND	ND	ND	ND
1996-2003	HS1	55	5	11	73%	45%	33	4	36	58%	36%	1.7
1996-2003	HS2	114	10	10	70%	60%	47	5	34	71%	47%	2.4
1996-2003	HS3	60	8	11	64%	64%	37	4	33	67%	42%	1.6
1996-2003	HS4	42	6	8	38%	38%	24	5	32	53%	31%	1.8
2002-2003	SM	14	3	13	38%	31%	32	7	9	56%	22%	0.4

b

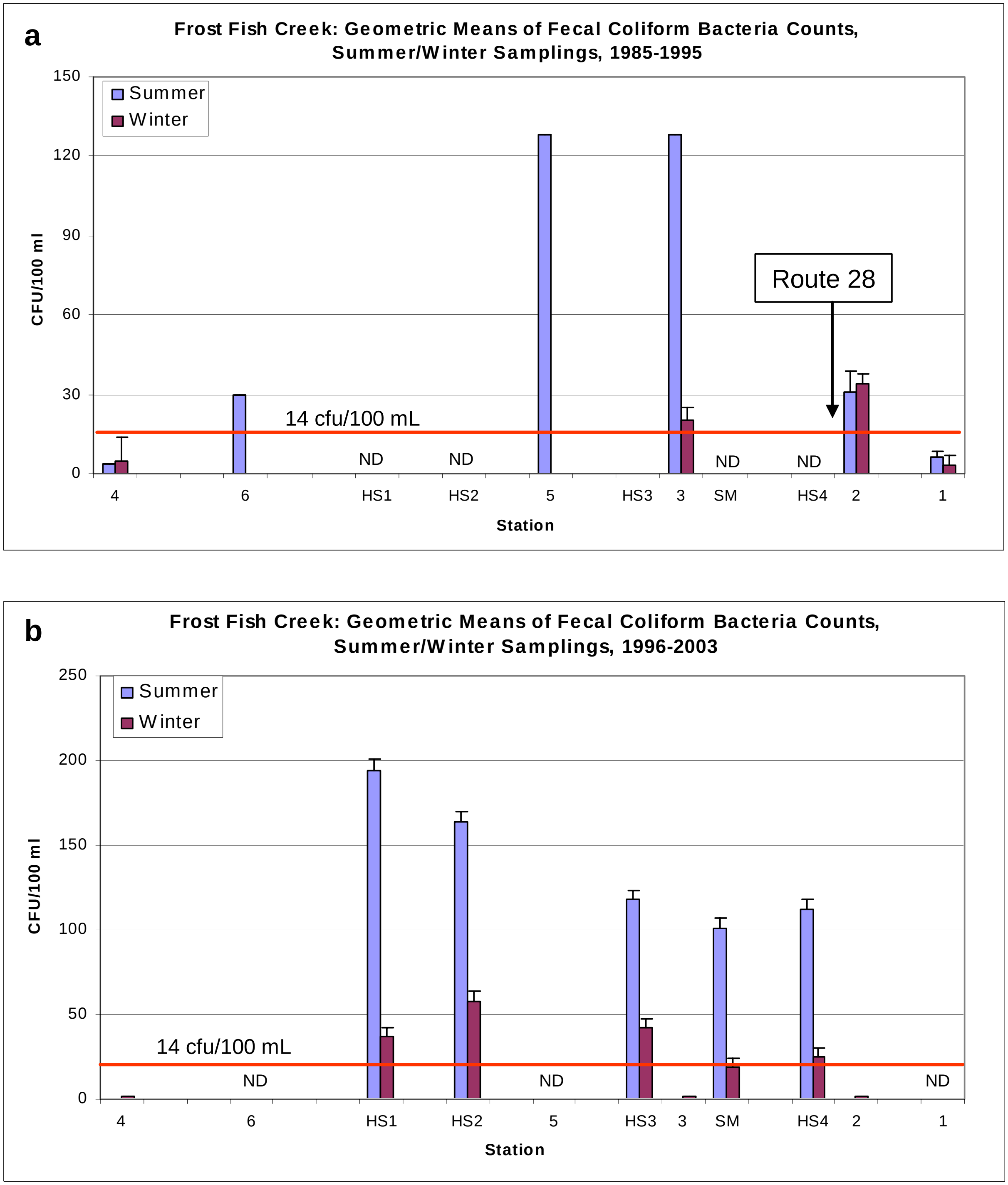
E. coli Summer Year	Station	Wet Geomean	S.D.	N	% Samples >14	% Samples >43	Dry Geomean	S.D.	N	% Samples >14	% Samples >43	Geomean Ratio: Wet/Dry
1996-2003	HS1	167	7	12	75%	75%	195	7	32	91%	75%	0.9
1996-2003	HS2	337	4	12	83%	75%	120	6	33	88%	67%	2.8
1996-2003	HS3	167	5	12	83%	58%	98	5	29	83%	66%	1.7
1996-2003	HS4	167	5	9	89%	56%	89	6	18	72%	61%	1.9
2002-2003	SM	153	5	4	100%	75%	37	7	13	69%	54%	4.1
E. coli Winter Year	**Station**	**Wet Geomean**	**S.D.**	**N**	**% Samples >14**	**% Samples >43**	**Dry Geomean**	**S.D.**	**N**	**% Samples >14**	**% Samples >43**	**Geomean Ratio: Wet/Dry**
1996-2003	HS1	97	3	11	82%	64%	36	4	36	69%	42%	2.7
1996-2003	HS2	286	6	10	70%	70%	45	5	34	74%	50%	6.4
1996-2003	HS3	118	6	11	73%	64%	42	4	33	79%	52%	2.8
1996-2003	HS4	73	5	8	75%	63%	20	5	32	66%	34%	3.6
2002-2003	SM	8	3	13	31%	8%	19	6	9	44%	22%	0.4

c

Enterococcus Summer Year	Station	Wet Geomean	S.D.	N	% Samples >104	Dry Geomean	S.D.	N	% Samples >104	Geomean Ratio: Wet/Dry
2002-2003	SM	208	2	4	75%	49	4	13	23%	4.2
Enterococcus Winter Year	**Station**	**Wet Geomean**	**S.D.**	**N**	**% Samples >104**	**Dry Geomean**	**S.D.**	**N**	**% Samples >104**	**Geomean Ratio: Wet/Dry**
2002-2003	SM	10	5	13	8%	15	5	9	11%	0.7

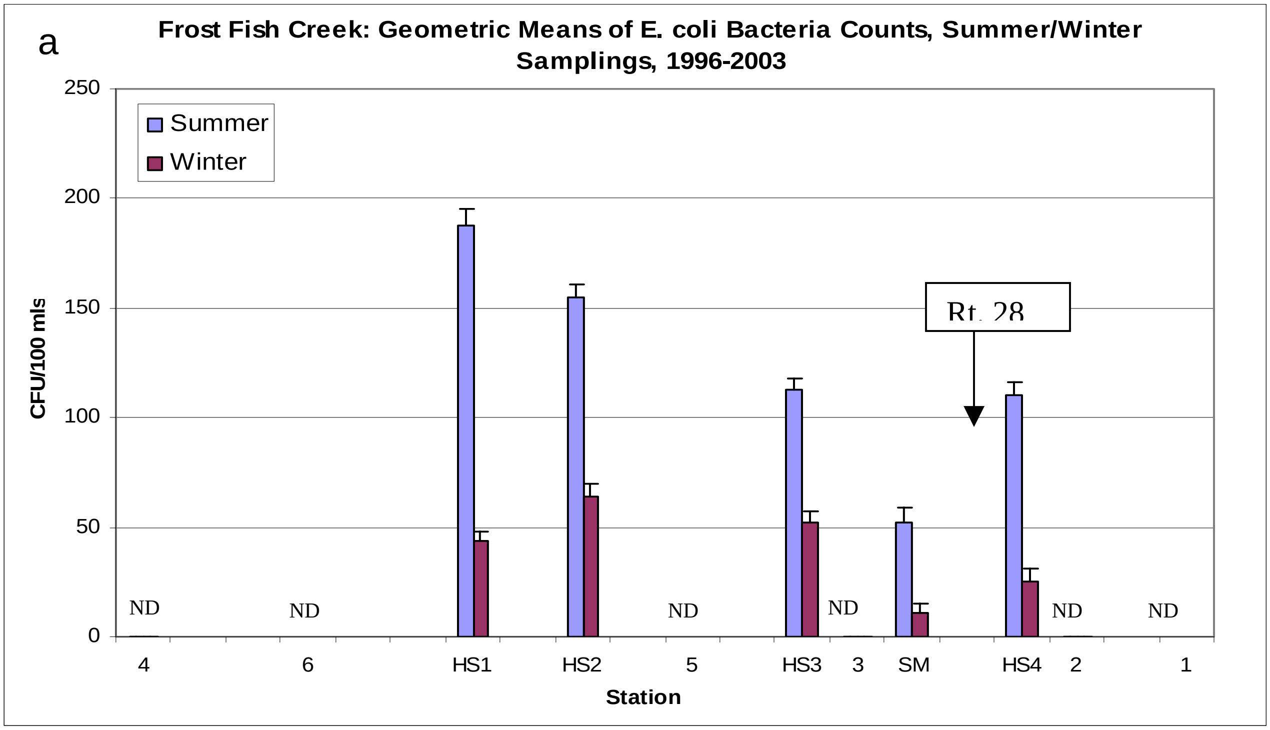
ND = No Data Available

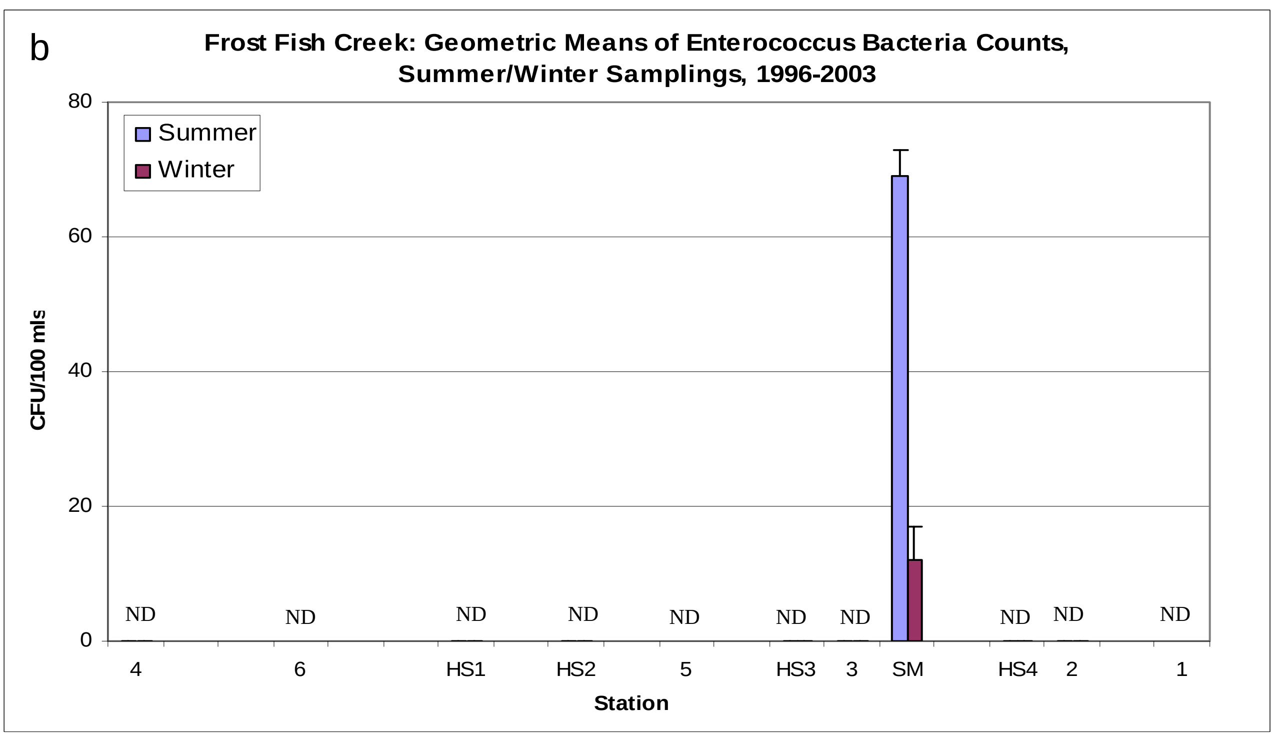
Table V-2 Comparison of geometric means (CFU/100 mls) from both summer and winter wet and dry samplings for (a) Fecal Coliforms, (b) E. coli and (c) Enterococcus bacteria (colonies/100 mL) by DMF, Chatham High School and SMAST 1996-2003.



ND = No Data Available

Figure V-4 Summer and winter Fecal Coliform bacteria counts (CFU/100 mls) during the years (a) 1985-1995 and (b) 1996-2003. Numbers indicate geometric means for summer/winter samplings by Massachusetts Division of Marine Fisheries, Chatham High School (HS) and SMAST (SM).





ND = No Data Available

Figure V-5 Summer and winter E. coli (a) and Enterococcus (b) bacteria counts (CFU/100 mls) during the years 1996-2003. Numbers indicate geometric means for summer/winter samplings by, Chatham High School (HS) and SMAST (SM).

mL and 43% of the counts exceeded 43 CFU/100 mL (Figures V-1, V-4a, Table V-1a). Means at Stations 1 and 4 were below 14 CFU/100 mL, although 17% of the samples at Station 4 were above 43 CFU/100 mls. Station 3 south of the culvert had a geometric mean of 20 CFU/100 mL and 17% of the samples were greater than 43 CFU/100 mls. There were no winter data for Stations 5 and 6.

Summer/Winter Ratios – 1985-1995

The ratio of the summer geometric mean to the winter mean ranged from 0.8 CFU/100 mL at Station 4 to 2.0 at Station 1 at the mouth of Frost Fish Creek to 6.3 CFU-100 mL at Station 3 at the tidal outlet to Ryder Cove (at the Route 28 culvert). Values within the outer Frost Fish basin (Stations 1 and 2) were similar in summer and winter. However, values at station 2 tended to be lower than within upper Frost Fish Creek due to dilution of out flowing waters with “clean” Ryder Cove waters. The overall summer to winter ratios indicate both higher levels of contamination in summer versus winter and that the contamination is highest within the upper basin (Table V-1a).

Summer Sampling Results – 1996-2003

From 1996-2003 there were a combined total of 174 summer fecal coliform samples taken by Chatham High School students (CHS) and SMAST. No DMF samples were taken in the summer during this period. Summer geometric means among all 5 stations ranged from 194 CFU/100 mL at CHS Station HS1 to 101 CFU/100 mL at SMAST Station SM (Figures V-3, V-4b, and Table V-1a). All summer means exceeded the water quality standard of 14 CFU/100 mL. At all stations, more than 10% of the samples were greater than 43 CFU/100 mL. Stations HS1 and HS2 are adjacent to wetland areas and Stations HS3, HS4 and SM are located near the Route 28 culvert close to DMF Stations 2 and 3 (Figure V-3). Summer geometric means for E. coli and Enterococcus (Station SM only) were also above the water quality standards. A total of 159 summer E. coli samples and 17 summer Enterococcus samples (SMAST only) were taken (Table V-1b, V-1c). Geometric means for E. coli samples ranged from 52 CFU/100 mL at Station SM to 188 CFU/100mL at HS1 (Figure 5a, b, Table V-1b, V-1c). More than 10% of all the samples at all stations exceeded the water quality standard of 43 CFU/100 mL (Table V-1b). The geometric mean for Enterococus at SM was 69 colonies/100 mL with 35% of the samples higher than 104 colonies/100 mL (Table V-1c). A clear pattern of bacterial contamination was seen in this composite dataset, where higher bacterial levels were seen in stations HS1 and HS2 versus stations HS3, HS4 and SM. While the absolute levels were higher in summer than winter, the gradient in bacterial levels was similar. The pattern is consistent with a major source in the upper region with dilution towards the tidal inlet. However, it should be emphasized that the bacterial levels were high at all stations.

Winter Sampling Results – 1996-2003

A total of 173 fecal coliform samples were taken at all stations during the winter 1996-2003. Geometric means were higher than the water quality standard of 14

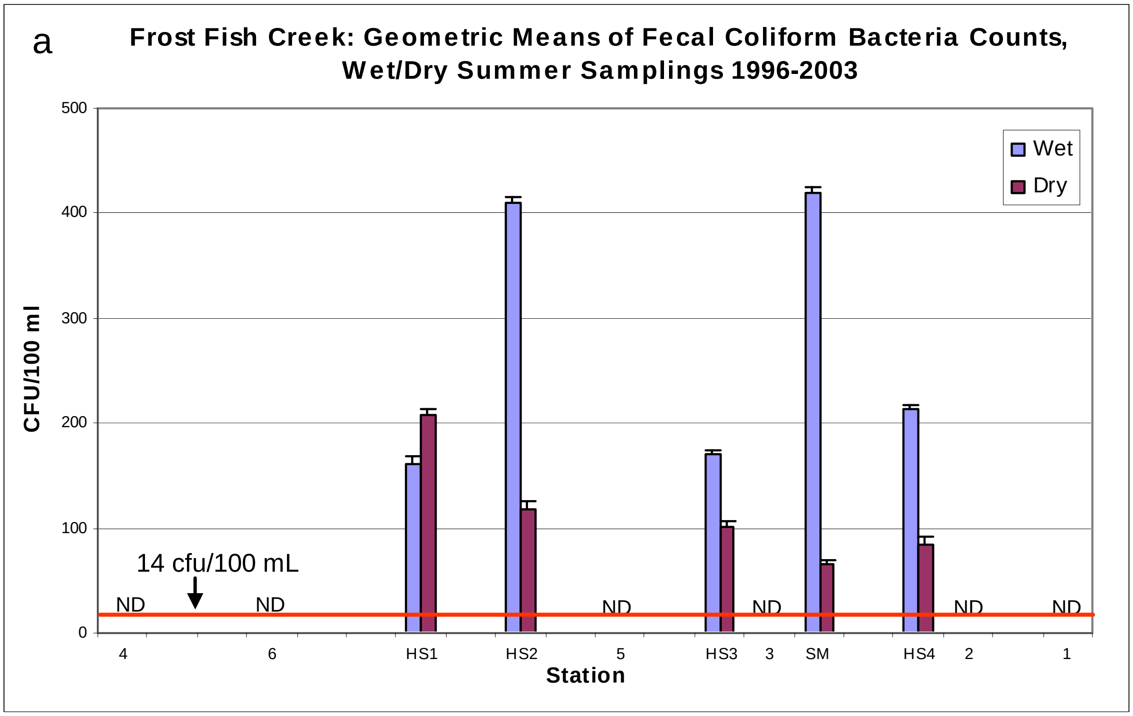
CFU/100 mL but were significantly lower than summer means (no summer data for DMF stations), ranging from 2 CFU/100 mL at DMF Stations 2, 3, and 4 (single samples) to 58 CFU/100 mL at Station HS2 (Figures V-2, V-4b, Table V-1a). More than 10% of the samples were greater than the water quality standard of 43 CFU/100 mL at all stations except 2, 3, and 4 (single samples). There were 185 E. coli samples taken at the Chatham High School and SMAST stations and 22 Enterococcus samples taken at the SMAST station (SM) (Table V-1b, V-1c). All geometric means for E. coli exceeded 14 CFU/100 mL, except for Station SM, ranging from 11 CFU/100 mL at SM to 64 CFU/100 mL at HS2. More than 10% of the samples exceeded 43 CFU/100 mL at all stations (Figure V-5a, Table V-1b). The geometric mean for Enterococcus at the SMAST station was 12 colonies/100 mL and 9% of the samples were greater than 104 colonies/100 mL. The ratio of the summer to winter geometric mean for Fecal coliforms ranged from 2.8 at Station HS3 to 5.2 at Stations HS1 and SM (Table V-1a). Ratios for E. coli ranged from 2.2 at Station HS3 to 4.6 at SM (Table V-1b). The summer to winter ration for Enterococcus at Station SM was 5.8 (Table V-1c).

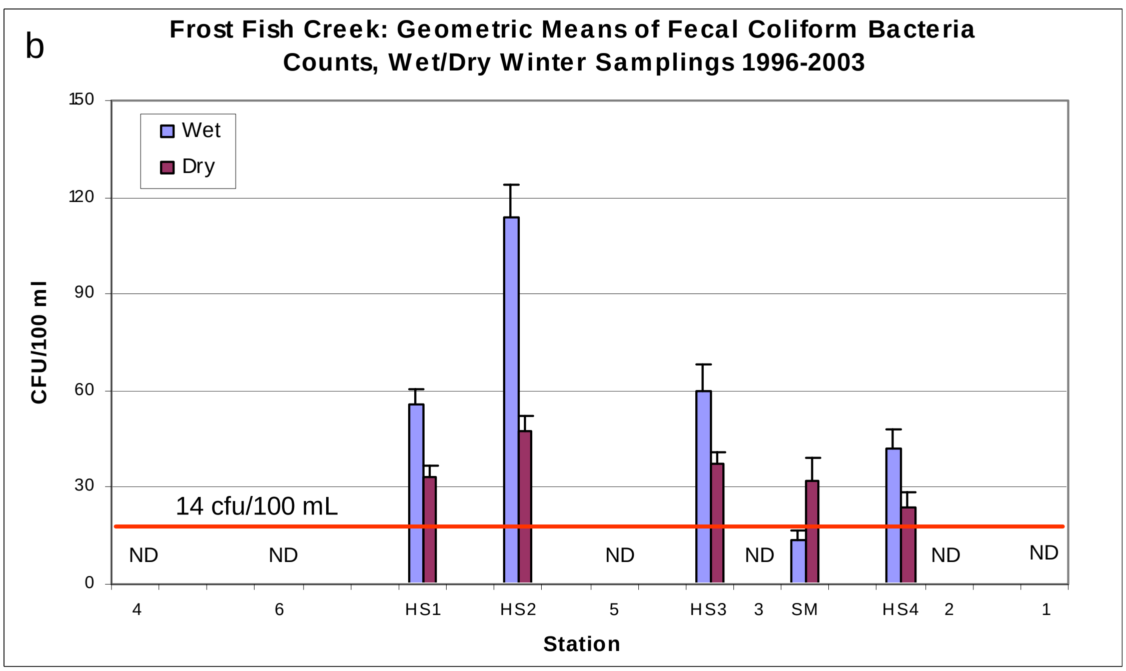
Summer Wet and Dry Weather Sampling

During the years 1996-2003, samplings were separated into wet and dry events based on the total rainfall for the 3 days prior to sampling. A total of 49 wet samples and 125 dry samples were taken during the summer for fecal coliforms. For the summer, wet geometric means ranged from161 CFU/100 mL at Station HS1 to 420 CFU/100 mL at Station SM. Dry means ranged from 65 CFU/100 mL at SM to 207 CFU/100 mL at HS1 (Figure V-3, V-6a, Table 2a). Both wet and dry geometric means at all stations exceeded 14 CFU/100 mL. Exceedences of 43 CFU/100 mL occurred in 56%-100% of the wet samples and in 61%-78% of the dry samples (Table V-2a). The ratio of wet to dry geometric means ranged from 0.8 CFU/100 mL at HS1 to 6.5 CFU/100 mL at SM. At all but one station (HS1), wet bacterial inputs were approximately 2-7 times dry inputs in the summer and summer levels of contamination were generally 3-5 times winter levels. Clearly, runoff apparently from wetland areas is implicated in the bacterial contamination of the upper basin.

Winter Wet & Dry Weather Sampling Results – 1996-2003

A total of 56 wet and 144 dry samples were taken during the winter (Figure V-3, V-6, Table V-2a). For winter samplings, wet geometric means ranged from 14 CFU/100 mL at SM to 114 CFU/100 mL at HS2. Wet geometric means exceeded 14 CFU/100 mL at all of the Chatham High School stations, located at the Route 28 culvert (HS3 and HS4) and adjacent to wetland areas (HS1 and HS2) (Figure V-3, V-6a, Table V-2a). Sample exceedences of 43 CFU/100 mL ranged from 31% at Station SM to 64% at Station HS3 (Table V-2). Dry geometric means ranged from 24 CFU/100 mL at HS4 to 47 CFU/100 mL at HS2 (Figure V-3, V-6a, Table V-2a). All values exceeded 14CFU/100 mL. Sample exceedences of 43 CFU/100 mL ranged from 22% at Station SM to 47% at Station HS2. Ratios of wet to dry means ranged from 0.4 CFU/100 mL at SM to 2.4 CFU/100 mL at HS2, indicating that except for Station SM, wet winter





ND = No Data Available

Figure V-6 Wet and Dry fecal coliform bacteria counts (CFU/100 mls) during 1996-2003. Numbers indicate geometric means of wet/dry data for a) summer and b) winter samplings by Chatham High School (HS) and SMAST (SM).

bacterial inputs to Frost Fish Creek were approximately 2 times dry inputs (Figure V-6, Table V-2a).

E. Coli Summer Wet & Dry Sampling Results – 1996-2003

For E. coli, there were 49 wet and 125 dry samples in the summer (Table V-2b). Summer wet geometric means ranged from 153 CFU/100 mL at Station SM to 337 CFU/100 mL at HS2 (Table V-2b). All geometric means exceeded 14 CFU/100 mL. Sample exceedences of 43 CFU/100 mL ranged from 56% at Station HS4 to 75% at Stations HS1, HS2 and SM (Table V-2b). Dry geometric means ranged from 37 CFU/100 mL at SM to 195 CFU/100 mL at HS1. All means exceeded 14 CFU/100 mL and sample exceedences of 43 CFU/100 mL ranged from 54% at Station SM to 75% at Station HS1 (Table V-2b). Wet mean to dry mean ratios ranged from 0.9 CFU/100 mL at HS1 to 4.1 CFU/100 mL at SM indicating that wet summer inputs were approximately 1-4 times dry inputs fro E. coli (Table V-2b). The highest ratios were at Stations SM and HS2 at the culvert.

E. Coli Winter Wet & Dry Sampling Results – 1996-2003

In the winter there were 53 wet and 144 dry samples collected for E. coli (Table V-2b). Winter wet means for E. coli ranged from 8 CFU/100 mL at SM to 286 CFU/100 mL at HS2. All means exceeded 14 CFU/100 mL except at Station SM and sample exceedences of 43 CFU/100 mL ranged from 8% at Station SM to 70% at Station HS2. Only Station SM was below the 10% criterion. Dry means ranged from 19 CFU/100 mL at SM to 45 CFU/100 mL at HS2. All means exceeded 14 CFU/100mL and sample exceedences of 43 ranged from 22% at Station SM to 52% at Station HS3 (Table V-2b). Wet mean to dry mean ratios ranged from 0.4 CFU/100 mL at SM to 6.4 CFU/100 mL at HS2 (Table V-2b). Except for Station SM wet inputs were approximately 3-6 times dry inputs during the winter.

Enterococcus Sampling Results – 1996-2003

For Enterococcus, there were 4 wet and 13 dry samples in the summer and 13 wet and 9 dry samples in the winter at Station SM (Table V-2c). The summer wet mean was 208 colonies/100 mL and the dry mean was 49 colonies/100 mL for a wet mean to dry mean ratio of 4.2. Both means exceeded 35 colonies/100 mL and sample exceedences of 104 colonies/100 mL were 75% for wet samples and 23% for dry samples (Table V-2c). Wet summer inputs of Enterococcus were approximately 4 times dry inputs. The winter wet mean was 10 colonies/100 mL and the dry mean was 15 colonies/100 mL for a wet mean to dry mean ratio of 0.7 (Table V-2c). Neither mean exceeded 35 colonies/100 mL and sample exceedences of 104 colonies/100 mL were 8% for wet samples and 11% for dry samples (Table V-2c). Wet winter inputs were approximately the same as dry inputs.

Data Summary

Taken as a whole, the data show a gradient in bacterial contamination from the upper to outer basin, likely resulting from bacterial inputs to the upper basin and with dilution with clean inflowing water as one moves toward Ryder Cove. There is a clear and large (several fold) pattern of higher levels of all indicator bacteria in summer versus winter. There is also a clear and large affect of rainfall, with several fold higher levels of each indicator in wet versus dry weather. This likely relates to rainfall and can be seen at most stations in both summer and winter.

V.2 Bacterial Contamination Relative to Watershed Land-use

As previously discussed in Section II.1, a large portion (38.5%) of the Frost Fish Creek watershed land use is classified as public service (municipalities, districts, charitable organizations, churches). In the Frost Fish Creek watershed, the public service designated land use immediately adjacent to the shoreline is predominantly associated with the Town of Chatham High School (41%) or owned by the Chatham Conservation Foundation (53%). The land owned by the Chatham Conservation Foundation is maintained as open, undeveloped space suitable for avian or wildlife populations. The next largest land use category in the Frost Fish Creek watershed is residential (31.3%). Figures V-7 (1985 – 1995 data set) and Figure V-8 (1996 – 2003 data set) depict the watershed land use categories relative to bacteria sampling stations and the level of bacterial contamination under summer/winter conditions.

There are three stormwater Phase II discharges to the upper portion of Frost Fish Creek located in the western portion of the watershed. They are the following:

> CHA-25 Crowell Road. There are eleven catch basins along Crowell Road which discharge via two 18" pipes into the west fork of Frost Fish Creek. There is a third pipe coming under the road that drains the abandoned cranberry bogs and wetlands to the west.
>
> CHA-26 Crowell Road. There are eight catch basins along Crowell Road which discharge via an 18" pipe into a fringing wetland of Frost Fish Creek.
>
> CHA-31 Stony Hill Road. There are nine catch basins along Crowell Road, Stony Hill Road and Lake Street which discharge via a pipe into the abandoned cranberry bog at the head of Frost Fish Creek.

Based on the 1985 – 1995 DMF bacterial data as depicted in Figure V-7, bacterial contamination appears most prevalent at stations 2, 3, 5, and 6 under summer conditions. Stations 2 and 3 are both in the immediate vicinity of the Route 28 culvert and maybe most influenced by stormwater runoff from the road surface. Station 5 is located up gradient in the upper portion of Frost Fish Creek (see Figure II-3) and receives groundwater flows from areas of the watershed that are categorized as both public service (Chatham Conservation Foundation open space) or less immediately, residential area. Exceedances at station 5 appear to be most prevalent under summer conditions and may be most likely related to waterfowl or wildlife attracted by the area during summer months. Due to the proximity of residential area to this station, it may be possible that some of the bacterial contamination may be coming from failing individual on-site septic systems. Station 6 located at the headwaters of a small tributary stream also shows bacterial exceedances in summer months though the level of contamination is moderate in comparison to station 5 under summer conditions. The moderate level of bacterial contamination observed at station 6 may be related to failing onsite septic systems in the vicinity of the tributary stream as the area proximal to station 6 is categorized as primarily residential. The storm drain from Crowell Road may also contribute to the bacterial contamination.

A more current examination of the bacterial contamination in Frost Fish Creek is depicted in Figure V-8 and is based primarily on bacterial data generated by the Town of Chatham High School Honors II Chemistry Class and SMAST. Bacterial contamination is represented by station relative to land use type under both summer and winter conditions. Levels of contamination are highest at stations HS3 and HS4 (high school) and SM (SMAST). These 3 stations are clustered up gradient and down gradient of the Route 28 culvert. Stations SM and HS3 are located up gradient of the culvert on the ebbing tide and station HS4 is down gradient of the culvert on the ebbing tide. It is possible that these stations

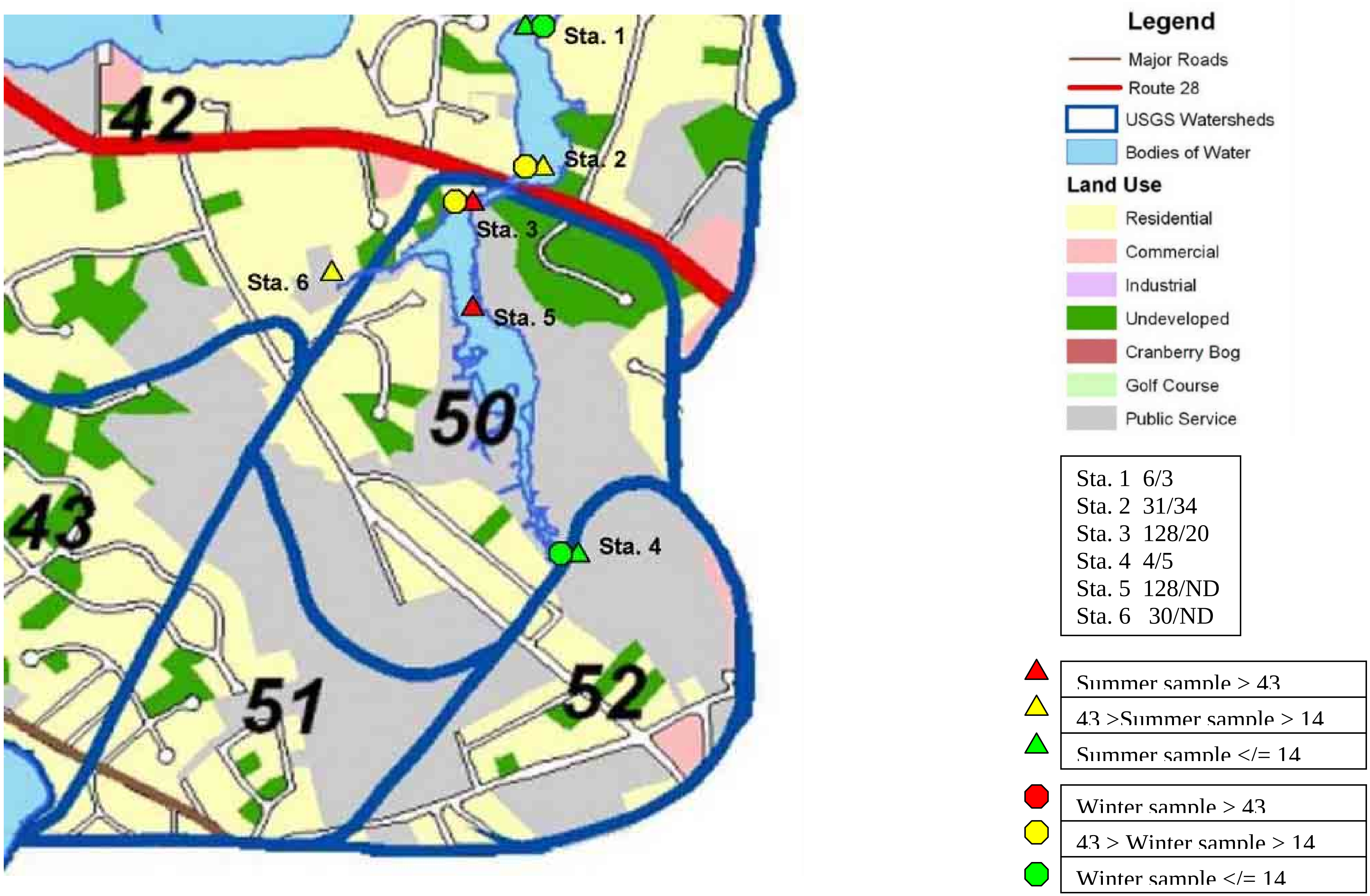


Figure V-7. Land-use by parcel for the Frost Fish Creek system relative to DMF sampling station locations. Numbers indicate geometric means for summer/winter fecal coliform samplings (CFU/100mL) by Massachusetts Division of Marine Fisheries during the period 1985 – 1995

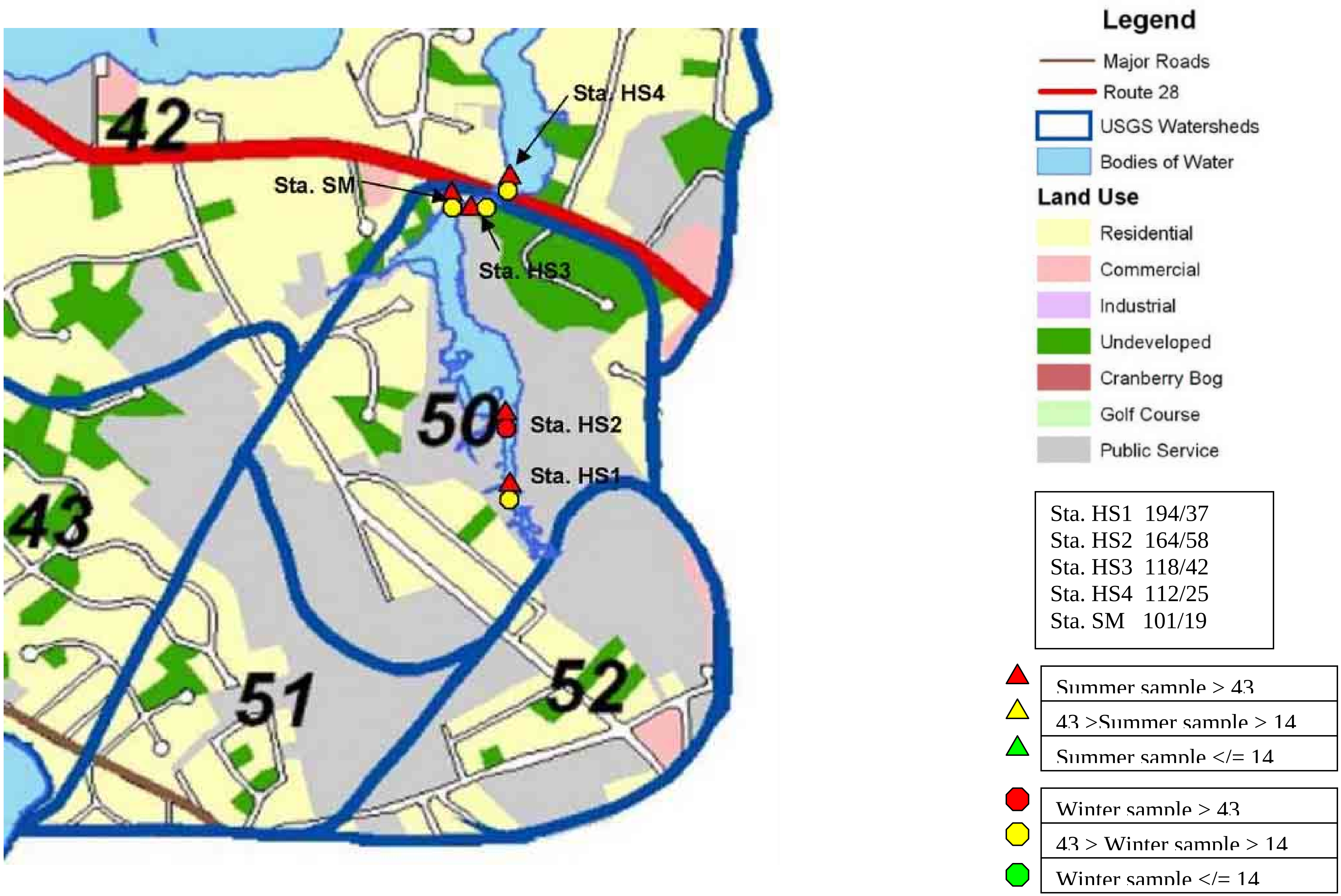


Figure V-8. Land-use by parcel for the Frost Fish Creek system relative to CHS and SMAST sampling station locations. Numbers indicate geometric means for summer/winter fecal coliform samplings (CFU/100mL) by Town of Chatham High School Honors II Chemistry Class, and SMAST during the period 1996 – 2003 receive contamination associated with road runoff from Route 28 during summer weather conditions. It is important to consider that tidal influence on these stations is significant and bacterial contamination may be transported to these stations on the ebb or flood tide. However, it is certain that there is bacterial contamination carried down from the upper portion of the inner basin of upper Frost Fish Creek on the ebbing tide. This latter contamination is likely closely related to the land use of that portion of Frost Fish Creek (predominantly open space supportive of waterfowl and wildlife). This possibility is emphasized by the fact that bacterial exceedances under summer conditions are also high at stations HS1 and HS2, up gradient of the stations proximal to Route 28. Both stations HS1 and HS2 are located on a section of Frost Fish Creek with a public service land use designation. It has been confirmed that the land use is open space as maintained by the Chatham Conservation Foundation and as such, is likely habitat for avian populations or wildlife during summer months. Under winter conditions, bacterial exceedances are moderate in comparison to summer conditions (stations HS3 and HS4 and SM), however, at stations HS1 and HS2, bacterial contamination is still apparent albeit lower than in the summer. It should be noted that the Town of Chatham Middle and High School is located in the vicinity of both HS1 and HS2 and this area may warrant investigation as to whether or not there may be a source for bacterial contaminants as it operates during the winter and into the early summer weather season.

It is important to note that the level of bacterial contamination may be increasing in this system. The level and pattern of contamination observed by DMF in the 1985-1995 period was lower and was highest adjacent Rt. 28. In contrast, the 1996-2003 data suggests important upper basin sources and higher levels of contamination. While some of the differences may be ascribed to different assay methods, these do not address the different spatial patterns observed.

Based on the 1996 – 2003 data set, Figures V-9 and V-10 depict wet/dry bacterial contamination during both summer and winter months respectively. The most extensive bacterial contamination occurs under both wet and dry conditions during the summer. All stations (HS1, HS2, HS3, HS4, and SM) show exceedances greater than the 43 CFU/100 ml criteria established in the Massachusetts SWQS. It is unclear as to the connection between bacterial contamination and land use categories under these conditions, however it is apparent that bacteria are clearly a problem during summer months. During winter conditions, wet/dry bacterial levels do appear lower than during the summer, however, all stations still exceed the 14 CFU/100 ml criteria established in the SWQS. Under winter conditions, bacterial contamination still appears consistently at stations HS1 and HS2. Whether that contamination is related to the open space surrounding that portion of Frost Fish Creek or some other point source would require more in depth investigation similar to a sanitary survey of the area.

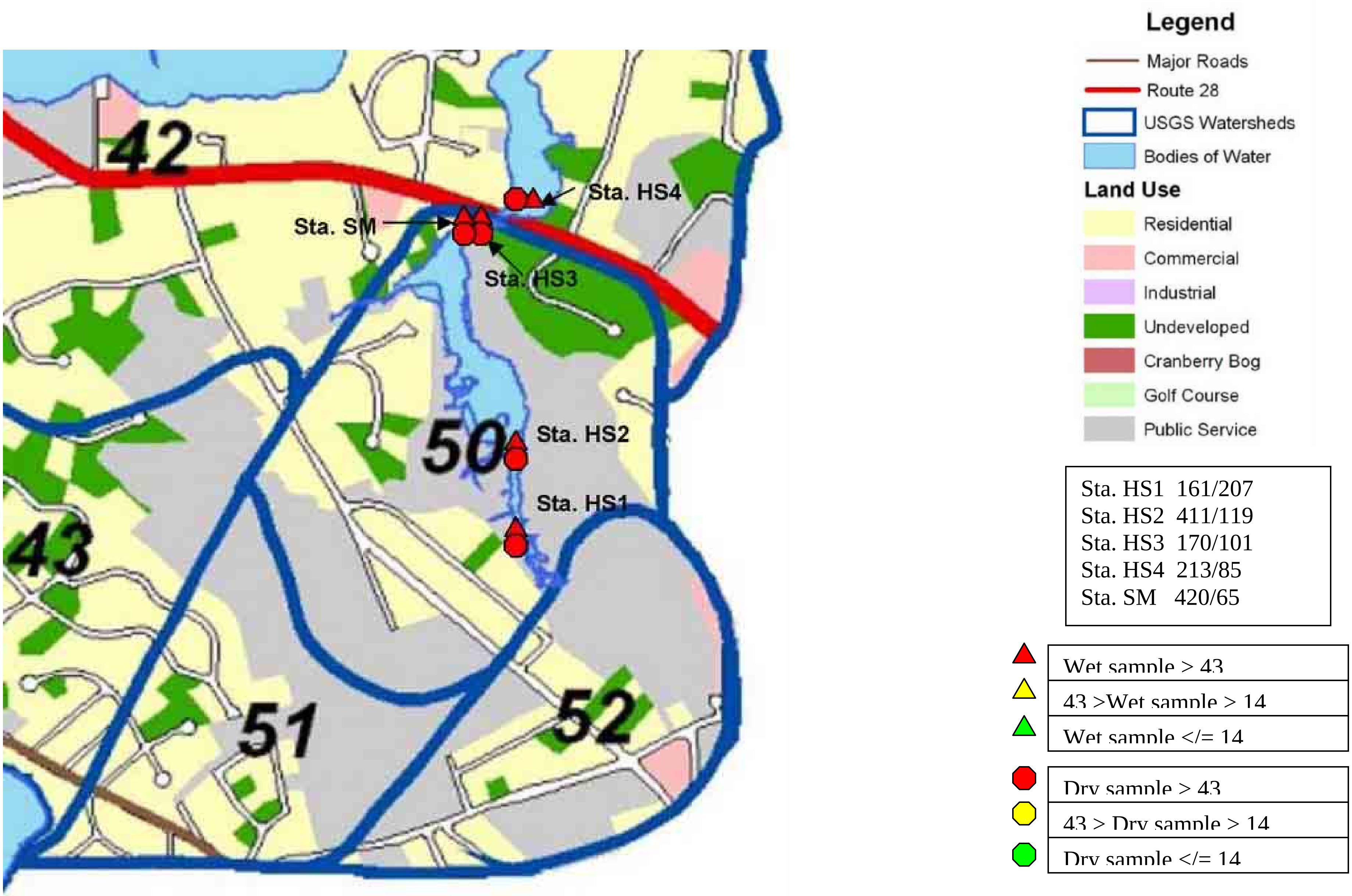


Figure V-9. Land-use by parcel for the Frost Fish Creek system relative to CHS and SMAST sampling station locations. Numbers indicate geometric means for wet/dry summer fecal coliform samplings (CFU/100mL) by Town of Chatham High School Honors II Chemistry Class, and SMAST during the period 1996 – 2003

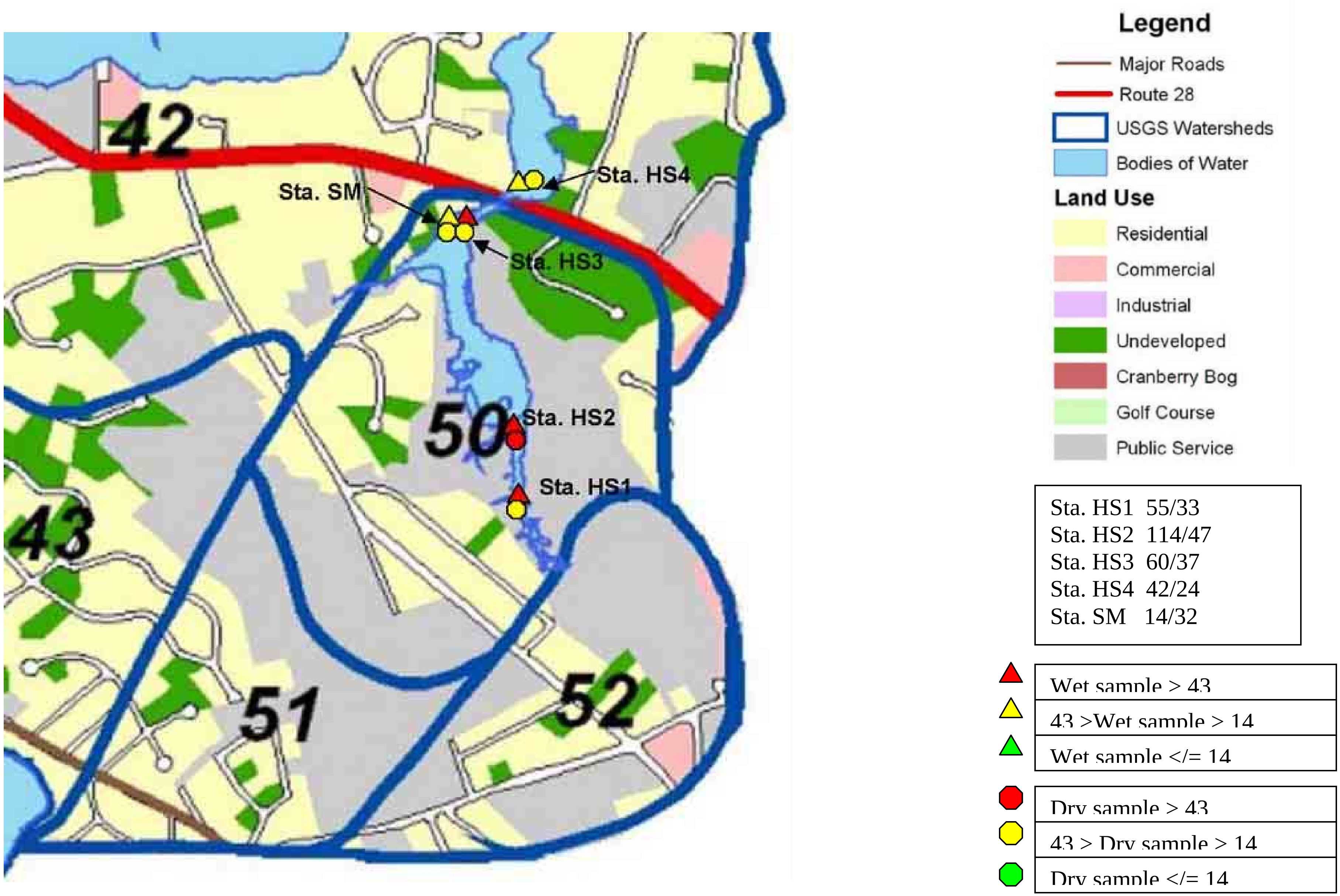


Figure V-10. Land-use by parcel for the Frost Fish Creek system relative to CHS and SMAST sampling station locations. Numbers indicate geometric means for wet/dry winter fecal coliform samplings (CFU/100mL) by Town of Chatham High School Honors II Chemistry Class, and SMAST during the period 1996 – 2003

VI. Evaluation of Freshwater Flow and Nitrogen Attenuation

Hydrodynamic and water quality modeling was completed for Frost Fish Creek as part of a comprehensive nutrient analysis and threshold development effort undertaken by the Massachusetts Estuaries Project (MEP) for all of the Town of Chatham embayment systems. In addition, given its role in the attenuation of watershed derived nutrients prior to discharge to Ryder Cove/Bassing Harbor, detailed hydrodynamic and nutrient exchange studies were conducted at the Frost Fish Creek tidal inlet. Though the nitrogen dynamics (MEP Nutrient Thresholds Report) are not directly related to the development of a bacterial TMDL for Frost Fish Creek, future nutrient management alternatives could potentially affect water circulation and flushing in Frost Fish Creek. These alternatives need to be considered relative to both the management of bacterial contamination and the potential for impacts on the systems ability to attenuate nutrients. Also warranting consideration are the shellfish resources of the downgradient system, Ryder Cove/Bassing Harbor should flushing rates be increased thus allowing greater export of bacteria from Frost Fish Creek. As such, discussions regarding the effects of changing water circulation patterns in the Frost Fish Creek system on nutrient attenuation and migration of bacterial contamination are included herein.

Frost Fish Creek (above the Rt. 28 culverts) is a tidal basin with fringing salt marsh. Given that it is a tidal basin, continuous stream gauging could not be conducted in the Frost Fish Creek discharge to the Bassing Harbor system. Instead, intensive discrete tidal flux analyses were conducted for the Massachusetts Estuaries Project (MEP) on four separate occasions (Summer 2002) in order to quantify freshwater inflow to Frost Fish Creek and nitrogen attenuation by this tributary system to Bassing Harbor.

Freshwater and tidal flows were measured over 4 complete tidal cycles in July, August, and September of 2002 during dry weather periods. Direct flow measurements were made at the weir near the mouth of Frost Fish Creek combined with high frequency (hourly during ebb and flood, every half hour around the turn of each tide) water quality sampling for nutrients. The combination of both records allowed for the calculation of nitrogen load into and out of the embayment over complete tidal cycles. Comparison of measured nitrogen loads resulting from the freshwater fraction of the Frost Fish Creek flow enabled the calculation of a nitrogen attenuation term applicable to the calculated watershed based nitrogen loads for the Frost Fish Creek sub-watershed.

A net nitrogen outflow from Frost Fish Creek to lower Ryder Cove was observed in each sampling event. In fact, Frost Fish Creek was a net exporter of each of the major nitrogen related water quality constituents assayed.

In summary, the mass of nitrogen entering lower Ryder Cove from Frost Fish Creek is approximately 19 percent lower than the nitrogen load calculated from the sub-watershed land use analysis (which has been adjusted accordingly for development of management alternatives).

It was found that tidal inlet (culverts/weir) significantly restrict the tidal exchange in this system and hold water in the basin during low tide. However, increasing the tidal exchange, hence decreasing the residence time of water in Frost Fish Creek, would almost certainly have the double effect of transferring bacterial contamination more readily to receiving waters such as Ryder Cove, as well as reducing the Frost Fish Creek systems ability to reduce the current nitrogen load during its transport to the Harbor. This is further supported by the existence of active shellfishing areas downgradient. Therefore, it seems most effective to manage bacterial contamination by reducing the inputs to Frost Fish Creek (to the extent that they are anthropogenic) rather than increasing the outputs through tidal exchange. Further, in the long term, increasing tidal exchange to the extent that it increases nitrogen transport to the shellfish beds could gradually degrade the ecological health of the shellfish beds thus impacting the shellfish resource beyond the potential benefits of bacterial management within the Frost Fish Creek system.

VII. Total Maximum Daily Load Development

Section 303 (d) of the Federal Clean Water Act (CWA) requires states to place water bodies that do not meet the water quality standards on a list of impaired waterbodies. The CWA requires each state to establish Total Maximum Daily Loads (TMDLs) for listed waters and the pollutant contributing to the impairment(s). TMDLs determine the amount of a pollutant that a waterbody can safely assimilate without violating the water quality standards. Both point and nonpoint pollution sources are accounted for in a TMDL analysis. Point sources of pollution (those discharges from discrete pipes or conveyances) receive a wasteload allocation (WLA) specifying the amount of pollutant each point source can release to the waterbody. Nonpoint sources of pollution (all sources of pollution other than point) receive a load allocation (LA) specifying the amount of a pollutant that can be released to the waterbody by this source. In accordance with the CWA, a TMDL must account for seasonal variations and a margin of safety, which accounts for any lack of knowledge concerning the relationship between effluent limitations and water quality. Thus:

TMDL = WLAs + LAs + Margin of Safety

Where

WLA = Waste Load Allocation which is the portion of the receiving water's loading capacity that is allocated to each existing and future point source of pollution.
LA = Load Allocation which is the portion of the receiving water's loading capacity that is allocated to each existing and future nonpoint source of pollution.

Loading Capacity
The pollutant loading that a waterbody can safely assimilate is expressed as either mass-per-time, toxicity or some other appropriate measure (40 C.F.R. § 130.2(i)). Typically, TMDLs are expressed as total maximum daily loads. However, MassDEP believes it is appropriate to express bacteria TMDLs in terms of concentration because the fecal coliform standard is also expressed in terms of the concentration of organisms per 100 ml. Since source concentrations may not be directly added, the previous equation does not apply. To ensure attainment with Massachusetts' water quality standards for bacteria, the goal of this TMDL is to have all sources (at their point of discharge to the receiving water) equal to or less than the standard. Expressing the TMDL in terms of daily loads is difficult to interpret given the very high numbers of bacteria and the variation in flow conditions. Therefore, the magnitude of the bacteria load that is allowable within water quality standards will vary as flow rates change. For example, a very high number of bacteria may be allowable if the volume of water that transports the bacteria is high too provided water quality standards are still met. Conversely, a relatively low number of bacteria may exceed the water quality standard if flow

rates are low. For all the above reasons the TMDL is simply set equal to the standard and may be expressed as follows:

$$\textbf{TMDL = Fecal Coliform Standard} = WLA_{(p1)} = LA_{(n1)} = WLA_{(p2)} = \textbf{etc.}$$

Where:
$WLA_{(p1)}$ = allowable concentration for point source category (1)
$LA_{(n1)}$ = allowable concentration for nonpoint source category (1)
$WLA_{(p2)}$ = allowable concentration for point source category (2) etc.

For Class SA surface waters the fecal coliform TMDL is set to protect the shellfish use goal and includes two components: (1) the geometric mean of a representative set of fecal coliform samples shall not exceed 14 organisms per 100 ml; and (2) no more than 10% of the samples shall exceed 43 organisms per 100 ml.

The goal to attain water quality standards at the point of discharge is environmentally protective, and offers a practical means to identify and evaluate the effectiveness of control measures. In addition, this approach establishes clear objectives that can be easily understood of the public and individuals responsible for monitoring activities. Also, the goal of attaining standards at the point of discharge minimizes human health risks associated with exposure to pathogens because it does not consider losses due to die-off and settling that are known to occur.

Wasteload Allocations (WLAs) and Load Allocations (LAs)
Although there are no permitted discharges of fecal coliform to Frost Fish Creek, direct stormwater discharges from storm drainage systems occur. Discharges from stormwater conveyances (including pipes, channels, roads with drainage systems and municipal streets) are by definite, point sources and are subject to the requirements of NPDES Phase II stormwater permits. Therefore, a WLA set equal to the fecal coliform standard will be assigned to the portion of the stormwater that discharges to surface waters via stormwater conveyances.

WLAs and LAs to Frost Fish Creek have been identified for all suspected source categories including both dry and wet weather sources. Establishing WLAs and LAs that only address dry weather bacteria sources would not ensure attainment of standards because there is a noteworthy contribution of wet weather bacteria sources to fecal coliform criteria exceedences. The most likely sources of fecal coliform bacteria are waterfowl and other wildlife throughout the upper basin, stormwater runoff from roads and paved surfaces near the tidal inlet at Route 28 and potentially failing individual on-site septic systems.

Table VII-1 presents the fecal coliform bacteria WLAs and LAs for the various potential source categories. Source categories representing discharges of stormwater from distinct point sources (stormwater conveyances) are set equal to the fecal coliform standard for SA waters in order to ensure that standards for shellfish harvesting can be met in the creek.

Surface Water Classification	Bacteria Source Category	WLA (Organisms per 100 mL)	LA (Organisms per 100 mL)
SA	Failing Septic Systems	N/A	0
SA	Stormwater Runoff	GM $\leq$ 14 10% $\leq$ 43	GM $\leq$ 14 10% $\leq$ 43
SA	Wildlife*	N/A	N/A

Table VII.1 Fecal Coliform Wasteload Allocations (WLAs) and Load Allociations (LAs) for Frost Fish Creek

*Given that sources of fecal coliform from wildlife is naturally occurring no allocation has been assigned.

The TMDL should provide a discussion of the magnitude of the pollutant reductions needed to attain the goals of the TMDL. Since accurate estimates of existing sources are generally unavailable, it is difficult to estimate the pollutant reductions for specific sources. For illicit sources such as failing septic systems, the goal is complete elimination (100% reduction). Source categories representing discharges of stormwater from distinct point sources are set equal to the fecal coliform standard for SA waters in order to ensure that standards for shellfish harvesting can be met in the creek.

Overall reductions needed to attain water quality standards are estimated using the ambient fecal coliform data that is available. Using ambient data is beneficial because it provides a realistic estimate of existing conditions and the magnitude of cumulative loading to the surface waters. Reductions are calculated using data that was collected in the summer and winter during both wet and dry weather conditions. Percent reductions to attain the water quality standard of 14 organisms per 100 mL are presented in Table VII.2. The summer data is representative of the worst-case scenario which would be the time period where the greatest reduction in bacterial concentration is needed. As indicated in Table VII.2, bacteria reductions of 91.3 to 96.7% are needed during summer wet weather conditions and from 78.5 to 93.2% during summer dry weather conditions. Table VII.3 lists the 90% observation and percent reductions necessary to attain the water quality standard which states that no more than 10% of the samples exceed 43 organisms per 100 mL. The 90% observation indicates that 90% of the samples collected at that station fall below the value that is listed. For example, at Station HS1 90% of the samples collected fall below the value of 2400 organisms per 100 mL. Again the summer data represents the worst-case scenario with reductions between 95.5 and 98.2% necessary to meet water quality standards.

	SUMMER			WINTER		
Station #	Overall Geomean (% Reduction)	Wet Geomean (% Reduction)	Dry Geomean (% Reduction)	Overall Geomean (% Reduction)	Wet Geomean (% Reduction)	Dry Geomean (% Reduction)
1	6* (0%)	ND	ND	3 (0%)	ND	ND
2	31* (54.8%)	ND	ND	34 (58.8%)	ND	ND
3	128** (89.1%)	ND	ND	20 (30%)	ND	ND
4	4** (0%)	ND	ND	5 (0%)	2* (0%)	ND
5	128** (89.1%)	ND	ND	ND	ND	ND
6	30** (53.3%)	ND	ND	ND	ND	ND
HS1	194 (92.8%)	161 (91.3%)	207 (93.2%)	37 (62.2%)	55 (74.5%)	33 (57.6%)
HS2	164 (91.5%)	411 (96.6%)	119 (88.2%)	58 (75.9%)	114 (87.7%)	47 (70.2%)
HS3	118 (88.1%)	170 (91.8%)	101 (86.1%)	42 (66.7%)	60 (76.6%)	37 (62.2%)
HS4	112 (87.5%)	213 (93.4%)	85 (83.5%)	25 (44%)	42 (66.6%)	24 (41.6%)
SM	101 (86.1%)	420* (96.7%)	65 (78.5%)	19 (26.3%)	14 (0%)	32 (56.3%)

Table VII.2 Estimates of fecal coliform loading reductions to Frost Fish Creek necessary to meet the 14 organisms per 100 mL Water Quality Standard.

* Too few data for accurate geometric mean (less than five samples collected)
** Value represented is one data point
ND=No Data

Station#	**Summer** 90% Observation (% Reduction)	**Winter** 90% Observation (% Reduction)
1	ND	6.8 (0%)
2	ND	128 (66.4%)
3	ND	33 (0%)
4	ND	11 (0%)
HS1	2400 (98.2%)	200 (78.5%)
HS2	1800 (97.6%)	620 (93.1%)
HS3	945 (95.5%)	200 (78.5%)
HS4	1220 (96.5%)	150 (71.3%)
SM	1400 (96.9%)	<100 (57%)

Table VII.3 90% observation and estimates of fecal coliform loading reductions to Frost Fish Creek necessary to meet the 43 organisms per 100 mL Water Quality Standard.

ND= No Data

Margin of Safety
For this analysis, margin of safety is implied. First, the TMDL does not account for mixing in the receiving waters and assumes that zero dilution is available. Realistically, influent water will mix with the receiving water and become diluted provided that the influent water concentration does not exceed the TMDL concentration. Second, the goal of attaining standards at the point of discharge does not account for losses due to die-off and settling that are known to occur with bacteria.

Seasonal Variability
This TMDL recognizes that the concentration of bacteria, the pollutant of concern, is greater during the summer season, however, the WLAs and LAs for all known and suspected source categories are set equal to the fecal coliform criteria independent of seasonal conditions. This will ensure the attainment of water quality standards regardless of seasonal and climatic conditions. Any controls that are necessary will be in place throughout the year, and, therefore, will be protective of water quality year round.

Monitoring Plan
Monitoring is important to assess the effectiveness of efforts to reduce bacteria and determine if water quality standards are being attained. In-stream monitoring at established ambient sampling stations will be used to assess water quality standards attainment. Efforts by groups to monitor on a frequent basis as was

demonstrated by the Chatham High School in 1996 to 2003 should continue. MassDEP will work with any and all such groups to ensure all data are compatible and comparable. Data will be used to evaluate progress and will serve as a baseline to evaluate future controls resulting from implementation activities.

TMDL Implementation

The objective of this TMDL is to specify reductions in bacterial pollutant loads so that water quality standards for aquatic life and shellfish harvesting can be met. The following presents a summary of the specific measures that should be taken:

> Further investigation and water quality sampling is needed to gauge the bacterial inputs from the wetland region near sampling station HS2 and in the region of Route 28. The Chatham High School should continue with its sampling program and focus its efforts in these areas. Bacterial testing relative to targeting waterfowl as a potential source of contamination should consider analytical testing to differentiate anthropogenic versus non-anthropogenic sources of bacterial contamination for definite proof that waterfowl are the source. The information provided from this type of sampling will be useful in identifying what measures, if any, would be appropriate to remediate the bacterial contamination.
>
> The 1985-1995 DMF data show bacterial exceedences at DMF sampling stations 5 and 6. The land use data indicates that these stations are in close proximity to residential areas. These areas should be investigated by the Board of Health to determine if there are any failing on-site septic systems. Station 6 may also be affected by the storm drain system on Crowell Road which should be evaluated. Additionally the impacts from pet waste and the need for a public awareness program should be evaluated.
>
> Since it is located near HS1 and HS2, the area around the Chatham Middle and High School should be investigated to determine if there is a source of bacteria. A survey by the Board of Health is recommended in this area.
>
> The Massachusetts Highway Department should determine the Route 28 roadway drainage area discharging to Frost Fish Creek and install best management structures and/or operational practices to the maximum extent practicable and at a minimum, must be designed to meet the water quality standard for bacteria in SA waters. Given this is a waterway with an approved TMDL, the MHD must meet the requirements of EPA's NPDES General Permit for Stormwater Discharges from Small MS4s (Phase II), Part I D(1-4), as it pertains to approved TMDLs

Reasonable Assurances
Reasonable assurances that the TMDL will be implemented include availability of financial incentives; programs for pollution control at the local, state and federal level; and compliance with current regulations. Financial incentives include federal monies available under the 319 NPS program and the 604 and 104b programs, which are provided as part of the Performance Partnership Agreement between MassDEP and the USEPA. MassDEP will work with the Town to assist in the development of projects under these grant programs. MassDEP is particularly interested in developing protocols/guidelines to conduct waterfowl/wildlife habitat assessments that will account for the bacteria load from these sources. This will provide for a better understanding of bacteria sources and in turn a better assessment of water quality management alternatives.

Additional financial incentives include state income tax credits for Title 5 upgrades and low interest loans for Title 5 septic system upgrades through municipalities participating in this portion of the state revolving fund program.

Stormwater NPDES permit coverage will address discharges from municipal owned stormwater drainage systems. Existing regulations that will be effective in controlling nonpoint discharges include the state's Wetlands Protection Act and Rivers Protection Act, Title 5 regulations for septic systems and various local regulations including zoning regulations.

Public Participation
A public meeting was held on November 29, 2004 at the Chatham Town Offices to present the findings and receive comments on the draft bacteria TMDL for Frost Fish Creek (along with the bacteria TMDL for Muddy Creek). A summary of the meeting, the questions asked, and the responses of the comments raised is presented in Appendix B. A notice of the meeting was sent through mailings to town officials in Chatham. It also was distributed electronically to interested agencies and parties and appeared in the Massachusetts Environmental Monitor and on MassDEP's web site.

VIII. Conclusions and Recommendations

The data during the period from 1985-1995 indicate high summer coliform geometric means in exceedences of the water quality standard of 14 CFU/100 mls. These exceedences were found adjacent to wetland areas within the inner basin of (upper) Frost Fish Creek (no winter samplings were conducted) at Stations 5 and 6. High summer and winter means were found adjacent to the Route 28 culvert at Stations 2 and 3. Summer to winter ratios of the geometric means vary with no consistent trend, with 2 slightly below 1 and 2 others significantly above 1.

The larger data set from the years 1996-2003 further substantiates the earlier data. However, the levels of contamination appear to be higher and there is a clear pattern of high levels in the upper portion of the upper basin (not seen in the earlier data) indicating a source and another high point in the region of Rt. 28. Summer means for fecal coliforms and for E. coli and Enterococcus at all stations are significantly higher than the water quality standards and higher than winter geometric means. Winter geometric means were also above the water quality standards at all 5 of the stations. These data indicate significant contamination during both the summer and winter in upper Frost Fish Creek. The ratios of summer to winter geometric means at all stations are significantly above 1, showing that summer bacterial inputs are approximately 2-6 times winter inputs.

In addition, wet/dry data show that wet samplings result generally in higher bacteria counts for fecal coliforms, E. coli and Enterococcus than dry samplings by a factor of approximately 2-7.

From the available data (1) it is appears that bacterial contamination within the adjacent basin of outer Frost Fish Creek (between Rt. 28 and Ryder Cove) results primarily from contaminated outflows through the Rt. 28 culverts from upper Frost Fish Creek and (2) it is likely that sources of bacterial contamination to Frost Fish Creek include adjacent wetlands and runoff from the Route 28 culvert. Wildlife could make a substantial contribution to the contamination. Most of the land surrounding the inner basin of upper Frost Fish Creek is conservation or public land and wetlands. It is unlikely that contaminant levels in the inner basin result from anthropogenic activities. In addition bacteria levels remain high (although lower than summer levels) during the winter suggesting that wildlife are using the basin year round. Bacterial testing relative to targeting waterfowl as a potential source of contamination should consider analytical test to differentiate anthropogenic versus non-anthropogenic sources of bacterial contamination for definitive proof that waterfowl are the source. The information provided from this type of sampling will be useful in identifying appropriate measures to remediate the bacterial contamination.

In order to reduce bacterial pollutant loads so that water quality standards are met, it is recommended that the focus be on the inner basin of upper Frost Fish Creek and include an investigation to gauge the inputs from the wetland region (near HS2) and for a source in the region of Rt. 28 that is influenced by rainfall (including runoff from Route 28). Further focused sampling in this portion of the Frost Fish system will help to better define the nature and magnitude of the sources which will, in turn, lead to effective management actions to reduce or eliminate the sources. Additionally an investigation should be undertaken to determine if septic systems are a problem in residential areas and if there are any contributing sources around the Chatham Middle and High Schools.

References

Code of Massachusetts Regulations, 105 CMR 445.031(A)(1), Minimum Standards for Bathing Beaches, State Sanitary Code, Chapter VII

Code of Massachusetts Regulations, Massachusetts Surface Water Quality Standards 314 CMR 4.05(4)(a)4

Massachusetts Department of Environmental Protection, 2003. Final Massachusetts Year 2002 Integrated List of Waters. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA. Document CN 125, Final September 2003.

Massachusetts Division of Marine Fisheries (DMF), 2004. Fecal Coliform Data for Shellfish Growing Area SC57. DMF Data Base. Annisquam River Marine Fisheries Station. Gloucester, MA

Massachusetts Estuaries Project (MEP) 2003. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor, and Muddy Creek, Chatham Massachusetts.

Massachusetts Estuaries Project (MEP), 2002. The Massachusetts Estuaries Project Embayment Water Quality Assessment Interim Report: Priority Embayments 1 – 20.

Millham, N.P. and B.L. Howes, (1994). Freshwater flow into a coastal embayment: groundwater and surface water inputs. Limnology and Oceanography 39: 1928-1944.

Smith, K. 1999. Salt Marsh Uptake of Watershed Nitrate. Boston University Masters Thesis, Department of Earth Sciences.

Appendix A - Frost Fish Creek Bacteria Data

Frost Fish Creek Bacteria Data					
Date	Station	Collected By	Fecal Coliform	E. Coli	Enterococcus
			CFU/100mL	CFU/100mL	CFU/100mL
8/5/1985	1	DMF	9.1		
8/5/1985	2	DMF	7.3		
11/20/1985	1	DMF	23		
11/20/1985	2	DMF	11		
12/16/1985	1	DMF	4		
12/16/1985	2	DMF	240		
12/16/1985	3	DMF	240		
12/16/1985	4	DMF	240		
1/21/1986	1	DMF	6.8		
1/21/1986	2	DMF	13		
1/21/1986	3	DMF	33		
1/21/1986	4	DMF	11		
2/12/1986	1	DMF	3.6		
2/12/1986	2	DMF	11		
2/12/1986	3	DMF	3.6		
2/12/1986	4	DMF	0.85		
3/31/1986	1	DMF	0.85		
3/31/1986	2	DMF	18		
3/31/1986	3	DMF	30		
3/31/1986	4	DMF	0.85		
4/16/1986	1	DMF	0.85		
4/16/1986	2	DMF	128		
4/16/1986	3	DMF	3.6		
4/16/1986	4	DMF	5.8		
4/17/1986	1	DMF	0.85		
4/17/1986	2	DMF	64		
4/17/1986	3	DMF	23		
4/17/1986	4	DMF	1.7		
5/13/1986	1	DMF	3.6		
5/13/1986	2	DMF	128		
5/13/1986	3	DMF	128		
5/13/1986	4	DMF	3.6		
5/13/1986	5	DMF	128		
5/13/1986	6	DMF	30		
1/30/96	2	DMF	1.9		
1/30/96	3	DMF	1.9		
1/30/96	4	DMF	2		
1/15/2002	SM	SMAST	<10	<4	<2
11/7/2002	SM	SMAST	310	184	18
11/13/2002	SM	SMAST	>2000	>800	>400
11/20/2002	SM	SMAST	<100	<10	<10
12/5/2002	SM	SMAST	80	48	26
12/10/2002	SM	SMAST	30	16	38
12/17/2002	SM	SMAST	10	24	132
12/23/2002	SM	SMAST	50	24	76
1/6/2003	SM	SMAST	20	16	52
1/23/2003	SM	SMAST	10	<4	2
1/29/2003	SM	SMAST	40	12	12

2/6/2003	SM	SMAST	50	8	4
2/10/2003	SM	SMAST	10	4	2
2/25/2003	SM	SMAST	<10	<4	24
3/6/2003	SM	SMAST	<10	16	66
3/10/2003	SM	SMAST	<10	4	4
3/20/2003	SM	SMAST	<10	12	6
3/24/2003	SM	SMAST	<10	4	4
4/3/2003	SM	SMAST	10	12	10
4/7/2003	SM	SMAST	20	8	6
4/17/2003	SM	SMAST	<10	8	2
4/23/2003	SM	SMAST	10	4	12
5/1/2003	SM	SMAST	40	24	36
5/5/2003	SM	SMAST	10	<4	2
5/19/2003	SM	SMAST	<10	<4	36
5/29/2003	SM	SMAST	70	44	26
6/2/2003	SM	SMAST	1830	>800	382
6/12/2003	SM	SMAST	230	328	60
6/16/2003	SM	SMAST	60	20	130
6/26/2003	SM	SMAST	200	76	94
6/30/2003	SM	SMAST	660	468	274
7/10/2003	SM	SMAST	1400	>800	>400
7/14/2003	SM	SMAST	90	104	80
7/21/2003	SM	SMAST	95	48	18
7/28/2003	SM	SMAST	10	8	86
8/6/2003	SM	SMAST	70	8	20
8/12/2003	SM	SMAST	1420	448	>400
8/20/2003	SM	SMAST	100	36	56
8/26/2003	SM	SMAST	20	48	150
10/3/1996	HS-1	HS FFC Project	74	71	
10/10/1996	HS-1	HS FFC Project	740	740	
10/17/1996	HS-1	HS FFC Project	73	73	
10/24/1996	HS-1	HS FFC Project	655	655	
10/31/1996	HS-1	HS FFC Project	32	nd	
10/3/1996	HS-2	HS FFC Project	35	35	
10/10/1996	HS-2	HS FFC Project	1800	1800	
10/17/1996	HS-2	HS FFC Project	40	40	
10/24/1996	HS-2	HS FFC Project	625	625	
10/31/1996	HS-2	HS FFC Project	147	nd	
10/3/1996	HS-3	HS FFC Project	94	94	
10/10/1996	HS-3	HS FFC Project	2100	2100	
10/17/1996	HS-3	HS FFC Project	33	33	
10/24/1996	HS-3	HS FFC Project	775	775	
10/31/1996	HS-3	HS FFC Project	30	nd	
10/3/1996	HS-4	HS FFC Project	77	77	
10/10/1996	HS-4	HS FFC Project	3000	3000	
10/17/1996	HS-4	HS FFC Project	28	28	
10/24/1996	HS-4	HS FFC Project	505	505	
10/31/1996	HS-4	HS FFC Project	22	nd	
5/5/1997	HS-1	HS FFC Project	5	5	
5/12/1997	HS-1	HS FFC Project	4	4	
5/20/1997	HS-1	HS FFC Project	48	46	
6/2/1997	HS-1	HS FFC Project	490	nd	
6/9/1997	HS-1	HS FFC Project	37	37	

9/23/1997	HS-1	Duncanson	285	285	
10/6/1997	HS-1	HS FFC Project	214	214	
10/14/1997	HS-1	HS FFC Project	210	210	
10/20/1997	HS-1	HS FFC Project	26250	26250	
10/27/1997	HS-1	HS FFC Project	7100	7100	
5/5/1997	HS-2	HS FFC Project	17	17	
5/12/1997	HS-2	HS FFC Project	4	4	
5/20/1997	HS-2	HS FFC Project	330	300	
6/2/1997	HS-2	HS FFC Project	1800	nd	
6/9/1997	HS-2	HS FFC Project	20	20	
9/23/1997	HS-2	Duncanson	110	110	
10/6/1997	HS-2	HS FFC Project	12	12	
10/14/1997	HS-2	HS FFC Project	45	45	
10/20/1997	HS-2	HS FFC Project	430	415	
10/27/1997	HS-2	HS FFC Project	960	960	
5/5/1997	HS-3	HS FFC Project	22	22	
5/12/1997	HS-3	HS FFC Project	9	9	
5/20/1997	HS-3	HS FFC Project	230	225	
6/2/1997	HS-3	HS FFC Project	170	nd	
6/9/1997	HS-3	HS FFC Project	45	45	
9/23/1997	HS-3	Duncanson	46	46	
10/6/1997	HS-3	HS FFC Project	140	140	
10/14/1997	HS-3	HS FFC Project	295	295	
10/20/1997	HS-3	HS FFC Project	53	47	
10/27/1997	HS-3	HS FFC Project	345	345	
5/18/1998	HS-1	HS FFC Project	22	22	
5/18/1998	HS-1	HS FFC Project	28	28	
5/26/1998	HS-1	HS FFC Project	285	285	
5/26/1998	HS-1	HS FFC Project	67	67	
6/1/1998	HS-1	HS FFC Project	3100	3100	
6/1/1998	HS-1	HS FFC Project	2200	2200	
6/8/1998	HS-1	HS FFC Project	250	250	
6/8/1998	HS-1	HS FFC Project	220	220	
10/6/1998	HS-1	HS FFC Project	98	95	
10/13/1998	HS-1	HS FFC Project	85	85	
10/19/1998	HS-1	HS FFC Project	60	nd	
10/26/1998	HS-1	HS FFC Project	56	nd	
5/18/1998	HS-2	HS FFC Project	48	48	
5/18/1998	HS-2	HS FFC Project	60	60	
5/26/1998	HS-2	HS FFC Project	67	67	
5/26/1998	HS-2	HS FFC Project	85	85	
6/1/1998	HS-2	HS FFC Project	208	208	
6/1/1998	HS-2	HS FFC Project	1100	1100	
6/8/1998	HS-2	HS FFC Project	490	490	
6/8/1998	HS-2	HS FFC Project	730	730	
10/6/1998	HS-2	HS FFC Project	230	230	
10/13/1998	HS-2	HS FFC Project	700	700	
10/19/1998	HS-2	HS FFC Project	110	nd	
10/26/1998	HS-2	HS FFC Project	18	nd	
5/18/1998	HS-3	HS FFC Project	3	3	
5/26/1998	HS-3	HS FFC Project	945	945	
6/1/1998	HS-3	HS FFC Project	23	23	
6/8/1998	HS-3	HS FFC Project	220	220	

10/6/1998	HS-3	HS FFC Project	160	160	
10/13/1998	HS-3	HS FFC Project	60	60	
10/19/1998	HS-3	HS FFC Project	66	nd	
10/26/1998	HS-3	HS FFC Project	18	nd	
10/6/1998	HS-4	HS FFC Project	120	120	
10/13/1998	HS-4	HS FFC Project	140	140	
10/19/1998	HS-4	HS FFC Project	58	nd	
10/26/1998	HS-4	HS FFC Project	16	nd	
6/1/1999	HS-1	HS FFC Project	47	47	
6/7/1999	HS-1	HS FFC Project	450	150	
6/14/1999	HS-1	HS FFC Project	2400	2400	
6/21/1999	HS-1	HS FFC Project	330	330	
10/5/1999	HS-1	HS FFC Project	1530	1530	
10/12/1999	HS-1	HS FFC Project	110	110	
10/18/1999	HS-1	HS FFC Project	9170	9170	
10/25/1999	HS-1	HS FFC Project	190	190	
6/1/1999	HS-2	HS FFC Project	68	68	
6/7/1999	HS-2	HS FFC Project	45	45	
6/14/1999	HS-2	HS FFC Project	350	340	
6/21/1999	HS-2	HS FFC Project	30	30	
10/5/1999	HS-2	HS FFC Project	6100	6100	
10/12/1999	HS-2	HS FFC Project	100	100	
10/18/1999	HS-2	HS FFC Project	12300	12300	
10/25/1999	HS-2	HS FFC Project	400	380	
6/1/1999	HS-3	HS FFC Project	85	85	
6/7/1999	HS-3	HS FFC Project	35	35	
6/14/1999	HS-3	HS FFC Project	195	195	
6/21/1999	HS-3	HS FFC Project	65	65	
10/5/1999	HS-3	HS FFC Project	1030	1010	
10/12/1999	HS-3	HS FFC Project	40	40	
10/18/1999	HS-3	HS FFC Project	1130	1130	
10/25/1999	HS-3	HS FFC Project	170	170	
6/1/1999	HS-4	HS FFC Project	152	152	
6/7/1999	HS-4	HS FFC Project	8	8	
6/14/1999	HS-4	HS FFC Project	430	430	
6/21/1999	HS-4	HS FFC Project	13	13	
10/5/1999	HS-4	HS FFC Project	1420	1420	
10/12/1999	HS-4	HS FFC Project	40	40	
10/18/1999	HS-4	HS FFC Project	680	680	
10/25/1999	HS-4	HS FFC Project	180	180	
10/30/2000	HS-1	HS FFC Project	83	83	
10/30/2000	HS-2	HS FFC Project	1255	1250	
10/30/2000	HS-3	HS FFC Project	585	520	
10/30/2000	HS-4	HS FFC Project	590	540	
10/1/2001	HS-1	HS FFC Project	200	200	
10/10/2001	HS-1	HS FFC Project	95	90	
10/15/2001	HS-1	HS FFC Project	530	530	
10/29/2001	HS-1	HS FFC Project	32	30	
10/1/2001	HS-2	HS FFC Project	2000	1900	
10/10/2001	HS-2	HS FFC Project	130	130	
10/10/2001	HS-2	HS FFC Project	60	60	
10/15/2001	HS-2	HS FFC Project	370	370	
10/29/2001	HS-2	HS FFC Project	30	30	

10/1/2001	HS-3	HS FFC Project	445	445	
10/10/2001	HS-3	HS FFC Project	130	130	
10/15/2001	HS-3	HS FFC Project	2250	2200	
10/29/2001	HS-3	HS FFC Project	200	200	
10/29/2001	HS-3	HS FFC Project	170	170	
10/1/2001	HS-4	HS FFC Project	530	520	
10/10/2001	HS-4	HS FFC Project	70	70	
10/15/2001	HS-4	HS FFC Project	1220	1200	
10/29/2001	HS-4	HS FFC Project	52	52	
10/7/2002	HS-1	HS FFC Project	102	98	
10/15/2002	HS-1	HS FFC Project		60	
10/21/2002	HS-1	HS FFC Project		38	
10/28/2002	HS-1	HS FFC Project		142	
10/7/2002	HS-2	HS FFC Project	33	33	
10/15/2002	HS-2	HS FFC Project		88	
10/21/2002	HS-2	HS FFC Project		38	
10/28/2002	HS-2	HS FFC Project		102	
10/7/2002	HS-3	HS FFC Project	23	23	
10/15/2002	HS-3	HS FFC Project		40	
10/21/2002	HS-3	HS FFC Project		13	
10/28/2002	HS-3	HS FFC Project		28	
10/7/2002	HS-4	HS FFC Project	2	2	
10/15/2002	HS-4	HS FFC Project		23	
10/21/2002	HS-4	HS FFC Project		93	
10/28/2002	HS-4	HS FFC Project		23	
10/28/2002	HS-4b	HS FFC Project		32	
11/7/1996	HS-1	HS FFC Project	10	10	
11/21/1996	HS-1	HS FFC Project	9	9	
12/19/1996	HS-1	HS FFC Project	200	195	
11/7/1996	HS-2	HS FFC Project	12	12	
11/21/1996	HS-2	HS FFC Project	20	20	
12/19/1996	HS-2	HS FFC Project	<10	<10	
11/7/1996	HS-3	HS FFC Project	40	40	
11/21/1996	HS-3	HS FFC Project	36	36	
12/19/1996	HS-3	HS FFC Project	<5	<5	
11/7/1996	HS-4	HS FFC Project	35	35	
11/21/1996	HS-4	HS FFC Project	40	40	
12/19/1996	HS-4	HS FFC Project	<5	<5	
4/16/1997	HS-1	Duncanson	3	nd	
4/28/1997	HS-1	HS FFC Project	200	200	
11/3/1997	HS-1	HS FFC Project	45	45	
11/10/1997	HS-1	HS FFC Project	860	860	
11/17/1997	HS-1	HS FFC Project	23	23	
11/24/1997	HS-1	HS FFC Project	21	21	
12/1/1997	HS-1	HS FFC Project	1049	1049	
12/22/1997	HS-1	HS FFC Project	2	2	
12/22/1997	HS-1	HS FFC Project	8	7	
4/16/1997	HS-2	Duncanson	2	nd	
4/28/1997	HS-2	HS FFC Project	83	83	
11/3/1997	HS-2	HS FFC Project	255	255	
11/10/1997	HS-2	HS FFC Project	1200	1200	
11/17/1997	HS-2	HS FFC Project	180	180	
11/24/1997	HS-2	HS FFC Project	180	180	

12/1/1997	HS-2	HS FFC Project	640	640	
12/22/1997	HS-2	HS FFC Project	5	5	
4/16/1997	HS-3	Duncanson	1	nd	
4/28/1997	HS-3	HS FFC Project	83	83	
11/3/1997	HS-3	HS FFC Project	370	370	
11/10/1997	HS-3	HS FFC Project	100	100	
11/17/1997	HS-3	HS FFC Project	335	325	
11/24/1997	HS-3	HS FFC Project	86	82	
12/1/1997	HS-3	HS FFC Project	55	55	
1/5/1998	HS-1	HS FFC Project	10	10	
1/5/1998	HS-1	HS FFC Project	7	7	
11/2/1998	HS-1	HS FFC Project	44	44	
11/9/1998	HS-1	HS FFC Project	33	33	
11/16/1998	HS-1	HS FFC Project	18	18	
11/23/1998	HS-1	HS FFC Project	25	nd	
12/14/1998	HS-1	HS FFC Project	23	23	
12/22/1998	HS-1	HS FFC Project	17	nd	
1/5/1998	HS-2	HS FFC Project	5	5	
11/2/1998	HS-2	HS FFC Project	600	600	
11/9/1998	HS-2	HS FFC Project	23	23	
11/16/1998	HS-2	HS FFC Project	16	16	
11/23/1998	HS-2	HS FFC Project	38	nd	
12/14/1998	HS-2	HS FFC Project	15	15	
12/22/1998	HS-2	HS FFC Project	9	nd	
1/5/1998	HS-3	HS FFC Project	1	1	
11/2/1998	HS-3	HS FFC Project	130	130	
11/9/1998	HS-3	HS FFC Project	66	66	
11/16/1998	HS-3	HS FFC Project	129	129	
11/23/1998	HS-3	HS FFC Project	74	nd	
12/14/1998	HS-3	HS FFC Project	8	8	
12/22/1998	HS-3	HS FFC Project	10	nd	
11/2/1998	HS-4	HS FFC Project	100	100	
11/9/1998	HS-4	HS FFC Project	25	25	
11/16/1998	HS-4	HS FFC Project	71	71	
11/23/1998	HS-4	HS FFC Project	58	nd	
12/14/1998	HS-4	HS FFC Project	8	8	
12/22/1998	HS-4	HS FFC Project	8	nd	
1/4/1999	HS-1	HS FFC Project	158	158	
11/1/1999	HS-1	HS FFC Project	150	150	
11/8/1999	HS-1	HS FFC Project	130	130	
11/15/1999	HS-1	HS FFC Project	260	250	
11/22/1999	HS-1	HS FFC Project	110	110	
12/20/1999	HS-1	HS FFC Project	35	35	
1/4/1999	HS-2	HS FFC Project	395	395	
11/1/1999	HS-2	HS FFC Project	100	100	
11/1/1999	HS-2	HS FFC Project	50	50	
11/8/1999	HS-2	HS FFC Project	210	210	
11/15/1999	HS-2	HS FFC Project	1650	1650	
11/22/1999	HS-2	HS FFC Project	20	20	
12/20/1999	HS-2	HS FFC Project	83	83	
1/4/1999	HS-3	HS FFC Project	1430	1430	
11/1/1999	HS-3	HS FFC Project	20	20	
11/8/1999	HS-3	HS FFC Project	170	170	

11/15/1999	HS-3	HS FFC Project	200	190	
11/22/1999	HS-3	HS FFC Project	30	30	
12/20/1999	HS-3	HS FFC Project	7	7	
1/4/1999	HS-4	HS FFC Project	710	710	
11/1/1999	HS-4	HS FFC Project	15	15	
11/8/1999	HS-4	HS FFC Project	90	90	
11/15/1999	HS-4	HS FFC Project	120	120	
11/22/1999	HS-4	HS FFC Project	<3	<3	
12/20/1999	HS-4	HS FFC Project	1	1	
1/3/2000	HS-1	HS FFC Project	25	25	
1/10/2000	HS-1	HS FFC Project	19	19	
11/6/2000	HS-1	HS FFC Project	162	162	
11/13/2000	HS-1	HS FFC Project	68	68	
11/20/2000	HS-1	HS FFC Project	27	27	
12/12/2000	HS-1	HS FFC Project	5	5	
12/18/2000	HS-1	HS FFC Project	63	63	
1/3/2000	HS-2	HS FFC Project	8	8	
1/10/2000	HS-2	HS FFC Project	15	15	
11/6/2000	HS-2	HS FFC Project	1150	1117	
11/13/2000	HS-2	HS FFC Project	520	490	
11/20/2000	HS-2	HS FFC Project	6	6	
12/12/2000	HS-2	HS FFC Project	45	45	
12/18/2000	HS-2	HS FFC Project	90	88	
1/3/2000	HS-3	HS FFC Project	5	5	
1/10/2000	HS-3	HS FFC Project	32	32	
11/6/2000	HS-3	HS FFC Project	97	83	
11/13/2000	HS-3	HS FFC Project	210	200	
11/20/2000	HS-3	HS FFC Project	5	5	
12/12/2000	HS-3	HS FFC Project	88	87	
12/18/2000	HS-3	HS FFC Project	135	135	
1/3/2000	HS-4	HS FFC Project	3	3	
1/10/2000	HS-4	HS FFC Project	25	25	
11/6/2000	HS-4	HS FFC Project	170	132	
11/13/2000	HS-4	HS FFC Project	150	145	
11/20/2000	HS-4	HS FFC Project	<2	<2	
12/12/2000	HS-4	HS FFC Project	83	83	
12/18/2000	HS-4	HS FFC Project	100	100	
1/2/2001	HS-1	HS FFC Project	5	5	
11/5/2001	HS-1	HS FFC Project	TNTC	TNTC	
11/13/2001	HS-1	HS FFC Project	33	33	
11/19/2001	HS-1	HS FFC Project	10	10	
11/19/2001	HS-1	HS FFC Project	10	10	
11/26/2001	HS-1	HS FFC Project	415	410	
12/17/2001	HS-1	HS FFC Project	50	50	
1/2/2001	HS-2	HS FFC Project	60	60	
11/5/2001	HS-2	HS FFC Project	620	620	
11/13/2001	HS-2	HS FFC Project	17	17	
11/19/2001	HS-2	HS FFC Project	5	5	
11/26/2001	HS-2	HS FFC Project	350	350	
12/17/2001	HS-2	HS FFC Project	50	50	
12/17/2001	HS-2	HS FFC Project	<50	<50	
1/2/2001	HS-3	HS FFC Project	12	12	
11/5/2001	HS-3	HS FFC Project	20	20	

11/13/2001	HS-3	HS FFC Project	17	17	
11/19/2001	HS-3	HS FFC Project	28	28	
11/26/2001	HS-3	HS FFC Project	85	85	
12/17/2001	HS-3	HS FFC Project	100	100	
1/2/2001	HS-4	HS FFC Project	7	7	
11/5/2001	HS-4	HS FFC Project	50	50	
11/13/2001	HS-4	HS FFC Project	8	8	
11/13/2001	HS-4	HS FFC Project	15	15	
11/19/2001	HS-4	HS FFC Project	38	25	
11/26/2001	HS-4	HS FFC Project	5	5	
12/17/2001	HS-4	HS FFC Project	100	100	
1/7/2002	HS-1	HS FFC Project	200	195	
11/4/2002	HS-1	HS FFC Project		23	
11/12/2002	HS-1	HS FFC Project		225	
11/18/2002	HS-1	HS FFC Project		233	
12/2/2002	HS-1	HS FFC Project		127	
12/9/2002	HS-1	HS FFC Project		52	
1/7/2002	HS-2	HS FFC Project	280	280	
11/4/2002	HS-2	HS FFC Project		5	
11/18/2002	HS-2	HS FFC Project		1125	
12/2/2002	HS-2	HS FFC Project		77	
1/7/2002	HS-3	HS FFC Project	70	70	
1/7/2002	HS-3	HS FFC Project	90	90	
11/4/2002	HS-3	HS FFC Project		218	
11/12/2002	HS-3	HS FFC Project		73	
11/18/2002	HS-3	HS FFC Project		1395	
12/2/2002	HS-3	HS FFC Project		60	
12/9/2002	HS-3	HS FFC Project		28	
1/7/2002	HS-4	HS FFC Project	180	180	
11/4/2002	HS-4	HS FFC Project		<2	
11/12/2002	HS-4	HS FFC Project		17	
11/18/2002	HS-4	HS FFC Project		148	
12/9/2002	HS-4	HS FFC Project		53	
11/12/2002	HS-4c	HS FFC Project		52	
11/18/2002	HS-4c	HS FFC Project		680	
12/2/2002	HS-4c	HS FFC Project		3	
12/9/2002	HS-4c	HS FFC Project		38	
1/6/2003	HS-1	HS FFC Project		18	
1/6/2003	HS-2	HS FFC Project		8	
1/6/2003	HS-3	HS FFC Project		23	
1/6/2003	HS-4	HS FFC Project		22	
1/6/2003	HS-4c	HS FFC Project		15	

DMF – Division of Marine Fisheries
SMAST – School for Marine Science and Technology
HS FFC Project – (Chatham) High School Frost Fish Creek Project

Appendix B - Public Participation

MEETING SUMMARY AND RESPONSE TO COMMENTS
FOR BACTERIA TOTAL MAXIMUM DAILY LOAD (TMDL)
FOR FROST FISH CREEK AND MUDDY CREEK

A public meeting was held at the Chatham Town Offices on November 29, 2004 to present the findings and receive comments on the draft Bacteria TMDLs for Frost Fish and Muddy Creeks. Approximately 23 people were in attendance, including representatives from USEPA, MassDEP-SERO and the Town of Chatham. A copy of the attendance list for the meeting is attached. Additionally, the meeting was telecast on the local public access television cable channel for Chatham.

The following is a summary of the meeting, the questions asked, and responses to the comments raised.

Presentations:
Bob Duncanson, Town of Chatham Health & Environment, began the meeting by introducing the presenters and describing the purpose of the public meeting.
Steve Halterman, MassDEP, presented a brief overview of the project.
Russell Isaac, MassDEP, presented an overview of the TMDL process and background information on bacteria.
Alice Rojko, MassDEP, presented the results of the Frost Fish Creek TMDL report including a summary and analysis of the data with recommendations for future action.
Andrea Langhauser, MassDEP, presented the results of the Muddy Creek TMDL report that also included a summary and analysis of the data with recommendations for future action. Information on grants and technical assistance available at the state level to assist with implementation efforts was also presented.

Handouts provided at the meeting:
Printout of power point presentation for Frost Fish and Muddy Creeks
Report - Draft Bacteria Total Maximum Daily Load for Frost Fish Creek Chatham, Massachusetts
Report - Draft Bacteria TMDL for Muddy Creek
Information Sheet – TMDLs Another Step to Cleaner Waters; 604(b) grant announcement

Questions and Responses:
The questions that arose during the public meeting are subsumed in the following responses .

Question – Since there are high bacteria counts in areas near wildlife and there are also storm drains in those areas, how can we differentiate the impact of waterfowl, from other sources, on bacteria counts?

Response – In order to determine the impact of these different sources, there needs to be a way to differentiate the sources of bacteria. One technique that can be used as a screening tool is analyzing for Fluorescent Whitening Agents/Optical Brighteners. This testing is a way of determining whether or not laundry detergents (which potentially indicate the presence of other human wastes e.g. fecal bacteria) are entering a waterbody either through a direct discharge or after traveling through the ground via a septic system. Ciba-Geigy Specialty Chemicals Corp., the principal chemical manufacturer of these substances, named its products as FWA-1, FWA-2, FWA-4, OB-1, and OB-2. All are fluorescent and are added to laundry detergents and papers to make these materials look whiter and brighter. In areas of elevated bacterial counts, the presence of optical brighteners/fluorescent whitening agents helps establish the link to humans rather than to domestic or wildlife animals. The chemical analysis of water samples for FWAs/OBs by high-performance liquid chromatography with a fluorescent detector definitively establishes the presence of these individual compounds and thus the likely presence of human wastewater. However, simple measurement of gross fluorescence alone may produce false positive for human wastewater since there are naturally occurring substances in watersheds not related to human wastewater that fluoresce (e.g., certain aquatic organisms). The best approach would be to first screen samples in the field for gross fluorescence, and if detected, then collect samples for laboratory HPLC-FL analysis to confirm the presence of individual FWAs/OBs.

Other methods under development to differentiate the sources of bacteria are genetic fingerprinting including DNA sequencing and ribotyping. However, these microbial source tracking (MST) methods are not as definitive as had been anticipated and their accuracy in field-study situations has been questioned because of various problems associated with the target organisms, level of complexity and stability of markers used. Recent research has demonstrated that fecal source library-dependent whole genome DNA fingerprinting methods for E. coli (e.g., ribotyping, rep-PCR, etc.) are unable to accurately determine the animal source of fecal waste. On the other hand, there is growing evidence that library-independent methods relying on the detection of individual source-specific genetic markers in fecal bacteria can accurately determine the source of fecal waste. The Wall Experiment Station is currently validating two human-marker polymerase-chain-reaction (PCR) assays for the detection of fecal bacteria from human sources using human and non-human fecal samples from Massachusetts sources. One of the PCR assays is a library-independent method involving the detection of human-specific rDNA markers in fecal Bacteroidetes. Fecal Bacteroidetes is a group of anaerobic bacteria present in high concentrations in human and other animal feces that has shown promise as a source-tracking indicator of human fecal contamination. The other PCR assay, also a library-independent method, involves the detection of a human-specific genetic marker (i.e., genes encoding for the enterococcal surface protein, esp, a putative virulence factor) in Enterococcus faecium, a current fecal contamination indicator. Once validated with Massachusetts fecal samples, these two human-marker PCR assays will allow us to identify the presence of human fecal pollution and associated risks from human enteric pathogens in Massachusetts watersheds.

A joint government-academic researcher meeting sponsored by USEPA and USGS was organized to validate the use of current microbial source tracking (MST) methods. As a result the U.S. EPA National Exposure Research Laboratory in Cincinnati is actively working on a comprehensive microbial source tracking (MST) guidance document that addresses the strengths and weaknesses of all MST methods currently in use. The best analytical approach for microbial source tracking will likely involve several validated testing methods combined to demonstrate the presence or absence of human wastewater (e.g., detection of human-specific genetic markers in fecal bacteria as well as detection of FWAs/OBs, caffeine, and/or pharmaceutical substances used exclusively in human medicine). Until the science is further developed and guidance is provided, caution should be exercised in the use of these methods.

Question - The data that were collected on Muddy Creek indicate that there is a spike in the level of bacteria at Route 28 which may be caused by runoff. Is it possible to measure this?

Response – The level of fecal coliform triples after a rain event at Route 28 and this has not been observed at the other stations on Muddy Creek. The next steps are to define the contributing area of the storm drain and collect additional stormwater samples with the ultimate goal of identifying and eliminating potential bacterial sources that may be contributing to the problem.

Question – The Division of Marine Fisheries (DMF) uses Most Probable Number (MPN) while other samplers have used Membrane Filtration (MF). Can the results of these different techniques be compared?

Response – Shellfish closures are based on MPN, however, the shellfish program does accept data based on the MF technique. In the SMAST Technical Reports, the data from the two methods were kept separate in the statistical analysis. The synthesis bar graphs contain separately identified values so it is possible to easily identify the source of the data. These synthesis graphs illustrate the spatial trends and wet/dry weather effects on fecal coliform levels. This is important, since the difference in methods should not change the general bacterial distribution and trends, but rather can result in different absolute numbers. In addition, the individual data sets are also discussed in the report as to what they alone show and how they fit into the overall pattern.

Question – What happens if it is determined that wildlife is the cause of the bacteria problem?

Response –Since the presence of wildlife is naturally occurring in Frost Fish and Muddy Creeks, the TMDL reports are not recommending any implementation measures be taken to reduce the elevated bacteria levels from wildlife. Shellfishing areas would have to remain closed, however, until the bacteria levels meet water quality standards for harvesting shellfish.

Question – Will this type of TMDL process be applied to other waterbodies that may have bacteria problems? In particular, are there any plans for Cockle Cove Creek?

Response – Currently, MassDEP is focusing on waterbodies that are on the Integrated List of Impaired Waters. Cockle Cove Creek is not on the Integrated List at this time but this does not preclude the town from taking action to locate and correct sources of bacteria that may be present.

Questions presented to MassDEP in letter dated October 15, 2004 from Robert Duncanson, Director of Health and Environment, Town of Chatham

Question – It is unclear what the expectation is in doing testing (i.e. Bacterial Source Tracking) to differentiate anthropogenic (human induced) versus non-anthropogenic sources (naturally occurring, i.e. waterfowl/wildlife). The current standards, for both shellfish harvesting and swimming, do not make any distinction from a regulatory perspective. This has been a source of debate for a number of years, i.e. is the risk any different based on the source of the fecal coliform and can it be quantified? While this type of testing can help target remediation efforts, if the source is "natural" and cannot be remediated the water quality goal may never be achievable.

Response – From a practical standpoint differentiating human from natural sources will not in and of itself change any decision on whether or not the shellfish beds can be opened. The information provided from this type of bacterial source tracking will, however, be useful in identifying what measures, if any, would be appropriate to remediate the bacterial contamination, particularly those that are human induced. Although there is no regulatory significance as it may relate to shellfishing there is some regulatory difference under the state Water Quality Standards and TMDL programs. The state Water Quality Standards set goals for the uses of the waters of the Commonwealth and are intended to protect those uses from degradation caused by point and non-point anthropogenic sources. The Standards however at 314 CMR 4.03 (5) state “Excursions from criteria due to solely natural conditions shall not be interpreted as violations of standards and shall not affect the water use classifications adopted by the Department”. In addition, a TMDL must be developed for impaired waters where those impairments are caused by anthropogenic sources but not if the sole source is a natural condition. The point of the above is to illustrate that there is some regulatory significance to demonstrating if the sources are of anthropogenic origin or not. It is possible that if the anthropogenic sources are eliminated the water in question may meet some or all of their designated uses.

Question – It is unclear why the swimming standard is being applied to either Frost Fish Creek or Muddy Creek. Neither presently have any swimming beaches nor are they used for swimming purposes due to lack of access, fringing marsh, etc. Neither area would seem to meet the definition of “Bathing Water” in 310 CMR 445.010.

Response – Although there is no swimming actually taking place under current conditions, the MA Water Quality Standards define both Creeks as Class SA waters and have designated the water quality goals as excellent habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. Given this they must be protected for those uses. Data on *Enterococci* was collected by SMAST because it is thought to be a better indicator of human health risk from pathogens than fecal coliform bacteria. Currently there is no standard for *Enterococci* for shellfishing areas thus the DPH swimming standard of 104 *Enterococci*/100 mL was utilized in analyzing the data. In order to safe guard the quality and value of a water resource and protect public health, it is imperative that the water resource meet surface water quality standards. At the very minimum, Frost Fish Creek and Muddy Creek should be meeting the swimming standard even though there are no swimming beaches. The ultimate goal is to protect human health and return these waters to their most beneficial use as a shellfish resource.

Question – Discuss the rationale for using 0.25 inches as the cutoff between wet and dry weather.

Response – This is a commonly used standard since it has been determined that the potential for runoff is generally relatively low for anything less than 0.25 inches.

Question – The use of geometric means for single samples is inappropriate. It may also be useful to provide the range of the data.

Response – It has been noted in the tables where the value represented is only one data point and where too few data were available to calculate an accurate geometric mean. Data tables are included in appendices to the final reports.

Question - The role of tide and its affect on bacterial levels at the various stations is not adequately addressed.

Response –The affects of changing water circulation patterns in the Frost Fish Creek and Muddy Creek systems on nutrient attenuation and migration of bacterial contamination are briefly summarized in the bacteria TMDL reports under the Evaluation of Freshwater Flow and Nitrogen Attenuation section. It was found that the tidal inlets (culverts/weir) significantly restrict the tidal exchange in these systems and hold water in the basin during low tide. Increasing the tidal exchange would have the affect of transferring bacterial contamination more readily to receiving waters such as Ryder Cove. The most effective way to manage bacterial contamination is by reducing the inputs to Frost Fish Creek and Muddy Creek rather than by increasing the outputs through tidal exchange. Hydrodynamic and water quality modeling was completed for Frost Fish and Muddy Creek as part of a comprehensive nutrient analysis and threshold development effort undertaken by the Massachusetts Estuaries Project (MEP) and detailed information on this issue is presented in the MEP Chatham Nutrient TMDL Technical Report.

Transmitted Via E-mail from Michael Hill – EPA New England, Office of Ecosystem Protection

Question – MassDEP should consider adding the water quality standard for swimming to these TMDLs and making recommendations in the TMDL Implementation section regarding swimming and recreational activities.

Response – The reports include the water quality standard for swimming in the Water Quality Standards Section. Neither Frost Fish Creek nor Muddy Creek have swimming beaches and are not used for swimming purposes because there is relatively little access due to fringing marsh, etc. Both creeks are navigable, so it is reasonable to assume there could be direct human contact with the water. As pointed out in the response above, at the very minimum, Frost Fish Creek and Muddy Creek should be meeting the swimming standard in order to protect human health.

Question - EPA agrees with MassDEP that the role of wildlife needs to be further investigated. However, are there other actions related to controlling wildlife that can be recommended right now? For example, is there anyway to discourage the birds from congregating on the power lines -- such as installing fishing line above the lines to prevent roosting?

Response – The technical reports for Frost Fish and Muddy Creeks did not present detailed information on the species of wildlife that were present. In order to account for the bacteria load from these sources an evaluation of the wildlife present in the area must be made. This will provide for a better understanding of bacteria sources and in turn a better assessment of water quality management alternatives. Once this has been accomplished, the Department of Fish and Game should be consulted for control methods.

Cormorants and other seabirds have been observed on the transmission lines crossing Muddy Creek by the water quality monitors and authors of the technical and TMDL reports. The 2001 Shellfish Survey by MA Division of Marine Fisheries noted large flocks of sea ducks (200+) offshore during the winter months but concluded that water sampling did not indicate any adverse impact on water quality from the presence of these animals during the open harvest season.

Transmitted electronically from Henry Barbaro - MassHighway on December 15, 2004

Question Both reports have comments that pertain to MassHighway operations. Unfortunately, MassHighway has not been provided the opportunity to coordinate with MassDEP in developing these TMDL requirements. As sister State agencies, coordination is absolutely necessary in order to develop requirements that MassHighway can comply with. For example, requiring stand-alone drainage upgrades to roadways that are not programmed for improvements simply is not practicable considering MassHighway's construction schedule and budget.

Response –Meetings have been held between MassHighway and MassDEP over the last several years for the purpose of coordinating the objectives of both agencies. The purpose of the draft TMDL reports is to elicit comments and it also presents an excellent opportunity for coordination.

Question – Muddy Creek TMDL Implementation Plan (p.51) – "The Massachusetts Highway Department should determine the Route 28 roadway drainage area discharging to Muddy Creek and install appropriate best management structures or operational practices" should read:
"As part of the next Route 28 reconstruction project, the Massachusetts Highway Department should determine the Route 28 roadway drainage area discharging to Muddy Creek and install practicable best management structures, or operational practices, as warranted by the magnitude of contaminant loading to Muddy Creek."

Response – **Response** – Wording has been changed in the Muddy Creek report in the following manner: "The Massachusetts Highway Department should determine the Route 28 roadway drainage area discharging to Muddy Creek and install best management structures and/or operational practices to the maximum extent practicable with a goal of meeting the water quality standard for bacteria in SA waters. Given this is a waterway with an approved TMDL, the MHD must meet the requirements of EPA's NPDES General Permit for Stormwater Discharges from Small MS4s (Phase II), Part I D(1-4), as it pertains to approved TMDLs." MassDEP has not deferred to the Route 28 reconstruction project since we do not have any information about the extent or the time schedule for it. MassDEP also suggests that the Massachusetts Highway Department work with the town of Chatham to work out a reasonable schedule for these activities.

Question – Frost Fish Creek TMDL Implementation (p.49) – "The Massachusetts Highway Department should work with the Town to mitigate the Route 28 roadway drainage in the immediate area by determining any sources and identifying appropriate Best Management structures and operational practices that should be implemented." should read:
"As part of the next Route 28 reconstruction project, the Massachusetts Highway Department should work with the Town to mitigate the Route 28 roadway drainage in the immediate area by installing practicable best management structures, or operational practices, as warranted by the magnitude of contaminant loading to Frost Fish Creek."

Response – Wording has been changed in the Frost Fish Creek report in the following manner: "The Massachusetts Highway Department should determine the Route 28 roadway drainage area discharging to Frost Fish Creek and install best management structures and/or operational practices to the maximum extent practicable with a goal of meeting the water quality standard for bacteria in SA waters. Given this is a waterway with an approved TMDL, the MHD must meet the requirements of EPA's NPDES General Permit for Stormwater Discharges from Small MS4s (Phase II), Part I D(1-4), as it pertains to approved TMDLs." MassDEP has not deferred to the Route 28 reconstruction project since we do not have any information about the extent or the time schedule for it. MassDEP also suggests that the Massachusetts Highway Department work with the town of Chatham to work out a reasonable schedule for these activities.

Participants at the Frost Fish Creek and Muddy Creek TMDL meeting at the Chatham Town Offices.

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Protection
Division of Watershed Management, 627 Main Street, Worcester, MA 01608

MEETING ATTENDANCE

Meeting: Bacteria TMDL - Muddy & Frost Fish Creeks

Presenters: A Rojko A Langhauser

Date: 11/29/04 Location: Chatham Town Offices

Name	Affiliation/Address	Phone/Email
Terry Campbell	Stearns & Wheeler, LLC	tlcampbell@stearnswheeler.com
Ron Broman	44 Parliament	bevc6443 @ hotmail.c
Fred Jensen	Wastewater CAC	fredjensen@comcast.net
Lynne Pleffner	Planning Board - Chatham	lpleffner@comcast.net
[illegible]	Cape Cod [illegible]	[illegible]
Robert Duncanson	Town of Chatham	508-945-5165
Brian Howes	SMAST	508-999-6316
Brian Dudley	DEP - SERO	508-946-2753
Russ Isaac	DEP - DWM	508-767-2876
Steve Halterman	DEP - DWM	508-849-4012
Andrea Langhauser	DEP - DWM	617-348-4084
Alice Rojko	DEP - DWM	508-849-4001

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Protection
Division of Watershed Management, 627 Main Street, Worcester, MA 01608

MEETING ATTENDANCE

Meeting: Nov 29th 2004 Bacteria TMDL Muddy + Frost Fish

Presenters: A. Rojko, A. Langhauser

Date: 11-29-04 Location: Chatham Town Hall

Name	Affiliation/Address	Phone/Email
William G. Redfield	Town of Chatham Water & Sewer	308-945-5150
Marianne Farnsworth	Stearns and Wheler	508-790-1707
Frank Simpson	Harwich, WQTF	508 430 1915
Paul R. Kallen	Chair BOH	508-945-5575
Marylou Gray	BOH	508-945-2011
Mike Hill	USEPA	617-918-1398
Martha Stone	Friends of Chatham Waterways	508-945-2716
Chuck Pollard	CAC	508 945-4665
Bob Deneen	CAC	508 945-7746
John Payson	CAC	508-945-7475
Walter Butler	FCW, Chatham	508-945-0936