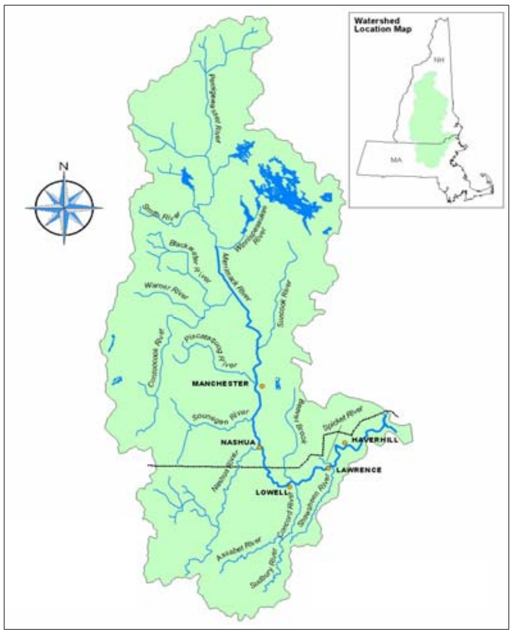


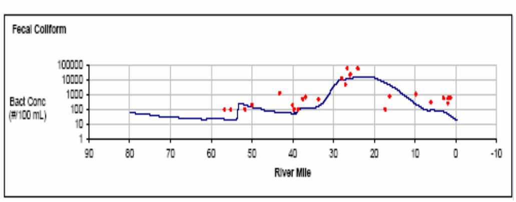
Merrimack River Watershed Assessment Study

Final Phase I Report

Prepared for:

New England District
U.S. Army Corps of Engineers

Sponsor Communities:
Manchester, NH
Nashua, NH
Lowell, MA
Greater Lawrence Sanitary District, MA
Haverhill, MA



September 2006

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Executive Summary

This report summarizes Phase I of the Merrimack River Watershed Assessment Study, whose overall purpose is to develop a comprehensive Watershed Management Plan for the Merrimack River watershed. The plan will be used to guide investments in local environmental resources and infrastructure, with the goal of achieving water quality and flow conditions to support uses such as drinking water supply, recreation, fisheries, and aquatic life support.

Work conducted during Phase I quantitatively compared alternative management strategies for the watershed designed to reduce the impact of pollutants such as bacteria and nutrients. Further, opportunities are evaluated for ecological improvements in the watershed.

Phase I of the Merrimack River Watershed Assessment Study was a jointly-funded effort between the Federal government, through the United States Army Corps of Engineers (USACE) New England District, and the five local-community sponsors of Manchester and Nashua, New Hampshire; Lowell and Haverhill, Massachusetts; and the Greater Lawrence Sanitary District (GLSD), Massachusetts. Collectively, these communities formed the Merrimack River Basin Community Coalition (MRBC). The Merrimack watershed and the sponsor communities are shown in Figure ES–1.

The study was divided into numerous tasks that were structured around the six-step USACE planning process, as outlined in Table ES–1. While many of the tasks were aggregated into larger task orders, the reference numbers below represent the original task designations in the Project Study Plan (PSP).

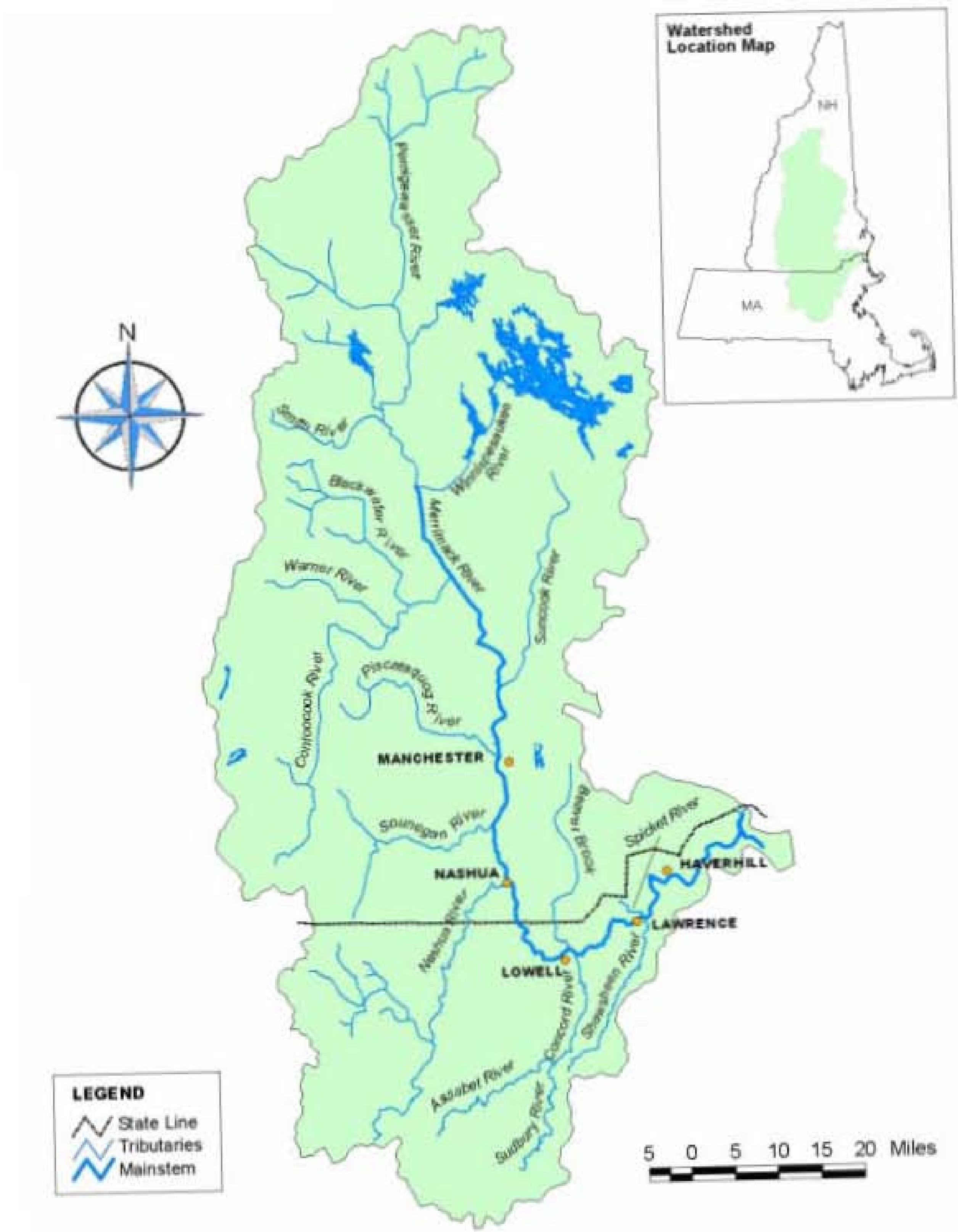


Figure ES–1: Merrimack River Watershed

Table ES-1: Implementing the Study with the Corps Six-Step Planning Process

Corps Planning Step	Task ID # per PSP	Task Description	Deliverables*	Utility of Study Output
Step 1: Problem Identification and Opportunities	1	Summarize Existing Conditions (hydrology, climate, water quality, land uses, regulations)	*Summary of Existing Conditions (CDM, 2003)*	Identified baseline causes and impacts of pollution throughout watershed
	2	Summarize Current Water Uses	Included in Existing Conditions Report	
	3	Summarize Pollution Sources (point and nonpoint) throughout the watershed	*Summary of Pollution Sources Report (CDM, 2003)*	
Step 2a: Inventory	7	Hydrology and Hydraulics Survey of the Mainstem Merrimack River	*Hydrology and Hydraulics Report (CDM, 2003)*	Established a high-quality and targeted database of water quality and flow information throughout the watershed
	8	Develop Water Quality Sampling Program – Bacteria, Nutrients, and Nutrient Impacts	Approved *Field Sampling Plan (CDM, 2003)*	
	9	Develop Quality Assurance Project Plan (QAPP)	Approved *Quality Assurance Project Plan* (CDM, 2003)	
	10	Water Quality Sampling and Flow Monitoring – 6 surveys of the river and its key tributaries during dry and wet weather	*Field Monitoring Report (CDM, 2006)* *Electronic Database of Field Data*	
Step 2b: Forecast	6	Screening Level Model – Low resolution screening tool to estimate relative annual pollutant loads	*Screening Model Report (CDM, 2003)*	Provided predictive tools for identifying key pollution sources and evaluating alternatives for abatement quantitatively
	4	Develop a detailed modeling plan	*Modeling Methodology Report (CDM, 2003)*	
	11	Develop dynamic simulation models: Hydrology, watershed loads, hydraulic routing, and instream water quality	*Simulation Model Development Report (CDM, 2005)*	
Step 3: Formulation	13	Plan Formulation: Develop a comprehensive list of planned abatement projects, including future alternatives.	Memorandum dated June 28, 2005	Identify planned improvements and develop metrics for river improvements
	Integrated	Stakeholder Workshop to identify planning objectives and key performance measures	Summary memorandum dated June 17, 2004	
Step 4: Evaluation	12	River Analysis with Simulation Models: Simulate incremental pollutant reductions for point sources and nonpoint sources and planned abatement projects.	Results included in Phase I Report (this report)	Associate pollution abatement plans with quantitative improvements in the river.
Step 5: Comparison	14	Alternatives Analysis: Associate costs with abatement plans and their simulated river improvements.	Results included in Phase I Report (this report)	Understand the value of dollars spent on pollution abatement in terms of quantitative river improvements.
Step 6: Select Recommended Plan	19	A recommended plan for the Merrimack River Watershed is the responsibility of local, state, and federal agencies responsible for the uses and regulation of the Merrimack River and its tributaries. A recommended plan is not included in this report.		

In Step 1, the *Summary of Existing Conditions* reviews and discusses existing documentation on the Merrimack River watershed, including water quality, water quantity, dams and impoundments, sediment quality, biological resources and habitat, designated water uses and attainment, and limited discussion of pollution sources within the watershed. The report includes no new findings, but summarizes other documents issued primarily within the past ten years.

Several conclusions emerged from this review: Previous studies indicated that the four largest causes of non-support of designated uses in the basin are pollution from (1) urban runoff, (2) natural sources, (3) municipal point sources, and (4) combined sewer overflow (CSO) discharges.

This study also identified elevated bacteria levels as the primary cause of non-supporting use in the basin, followed by low dissolved oxygen concentrations and high nutrient levels. Other issues of concern include low-flow conditions, water supply, flooding, contamination of shellfishing beds, and fish and wildlife habitat and contamination issues.

The *Summary of Pollutant Sources* identified many of the current and potential pollutant sources in the watershed. This interim report did not attempt to quantify or rank their impact, but to summarize existing data, and to identify data needs. Much of the data collected in this task was collected via literature review, contact with communities, or from state and national sources (e.g. NPDES database, US Census). Other information was collected via field work; e.g. river bank erosion and storm drain locations. This interim report described the following pollutant sources:

- Combined Sewer Overflows (CSOs) in the five sponsor communities of Manchester and Nashua, New Hampshire; Lowell and Haverhill, Massachusetts; and the Greater Lawrence Sanitary District (GLSD), Massachusetts

- Stormdrain outfalls in 22 communities along the mainstem Merrimack River downstream of Hooksett, New Hampshire

- Quantity and quality of discharges from municipal and privately-owned treatment plants and industrial point sources along the Merrimack River

- Other sources of pollutants, including sediments, air deposition, groundwater plumes from landfills, erosion along streambanks, areas with failing septic systems, pump station overflows, and illicit wastewater discharges to stormdrains

- Tributary sources, including storm drains, point sources, septic systems etc.

Work under Step 2a, Inventory, began the collection of watershed data that was used for analysis and decision-making, including an extensive water quality sampling/monitoring program.

Water quality and streamflow data collected under this task were instrumental in the calibration and validation of water quality and hydrologic/hydraulic models. The field data also helped to determine whether segments of the mainstem Merrimack River are likely meeting state water quality standards.

The monitoring area encompassed the mainstem of the Merrimack River from Concord, New Hampshire to its estuary in Newburyport, Massachusetts, and also included the mouths of eleven major tributaries adjoining the mainstem. Forty-two sampling locations were strategically located in-stream to measure streamflow and concentration of pollutants such as bacteria and nutrients. Additionally, numerous stormdrain outfalls and combined sewer overflow (CSO) outfalls were sampled during wet-weather events to monitor contributing pollutant loads from urbanized areas.

From 2003–2005, three dry-weather surveys and four wet-weather surveys were conducted. Additionally, a continuous survey of dissolved oxygen and temperature was conducted at two locations for a one-month period during low-flow conditions in August and September 2003.

The monitoring work was conducted in accordance with a Q*uality Assurance Project Plan* (QAPP) developed in conjunction with Massachusetts DEP and New Hampshire DES, and approved by the USACE and USEPA.

The following conclusions were drawn from the water-quality surveys:

- The mainstem of the river from Manchester to the Atlantic Ocean is impaired with respect to bacteria standards, although many reaches exhibit satisfactory bacteria levels during dry weather.

- Many of the tributaries are impaired with respect to bacteria standards, as measured upstream of combined sewer outfalls.

- The mainstem of the river from Manchester to the Atlantic Ocean is not impaired with respect to dissolved oxygen standards. Measured and simulated concentrations of dissolved oxygen were always well above the regulatory threshold of 5 mg/l.

- While currently there are no regulatory requirements for nutrient levels in riverine waters, levels of nutrients (phosphorus and nitrogen) in rivers can be indicative of the likelihood of excessive in-stream organic production, which can deplete oxygen levels in the water and degrade aquatic habitat quality. Mainstem concentrations of nitrogen and phosphorus exhibited a wide range that is generally thought to be acceptable.

- Levels of chlorophyll-a, another indicator of organic productivity in the water, were generally not excessive in the New Hampshire reaches of the river. Levels in the mainstem downstream of Lowell ranged as high as 42 µg/L under 7Q10 conditions. Despite these high levels of Chlorophyll-a, no impairment of dissolved oxygen were found, indicating that the river can support high levels of algae growth.

Modeling

In Step 2b, Plan Formulation, a suite of hydrologic, hydraulic, and water quality models were developed as tools to assist in evaluating and comparing watershed management strategies and in prioritizing potential improvements in the watershed. The goals of the modeling effort were to:

- Simulate the generation of pollutant loads (primarily bacteria and nutrients) throughout the watershed, both from point sources and nonpoint sources.
- Simulate the water quality and flow regimes in the mainstem Merrimack River under dry weather and wet weather conditions.
- Simulate the dynamic nature of storm events as well as seasonal patterns and their effect on water quality and hydraulic conditions in the mainstem Merrimack River.
- Calibrate the models to observed measurements from the comprehensive field monitoring program executed under Task 4 of this Watershed Assessment Study, and to USGS flow records. Figure ES-2 illustrates examples of model calibration graphs. Full sets of calibration results are included in the Interim Report for Task 6: *Simulation Model Development.*

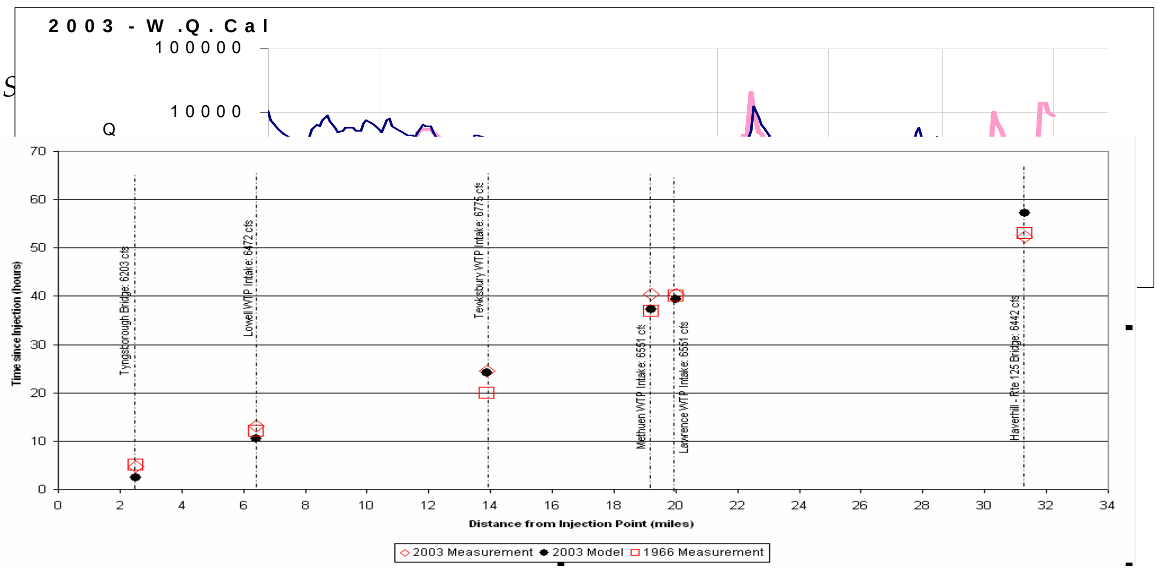
These goals were achieved by combining the strengths of several different public domain models. Existing models of combined sewer systems developed in USEPA Storm-Water Management Model (SWMM) and MOUSE for each of the five major CSO communities in the basin were incorporated.

The Hydrologic Simulation Program – Fortran (HSPF) was used to model the remainder of the watershed hydrology, including all major tributaries, as well as non-point source loads for the basin. The CSO and HSPF flow inputs were entered into the EXTRAN block of the SWMM model, which simulated the hydraulic routing and dynamics of the mainstem Merrimack River.

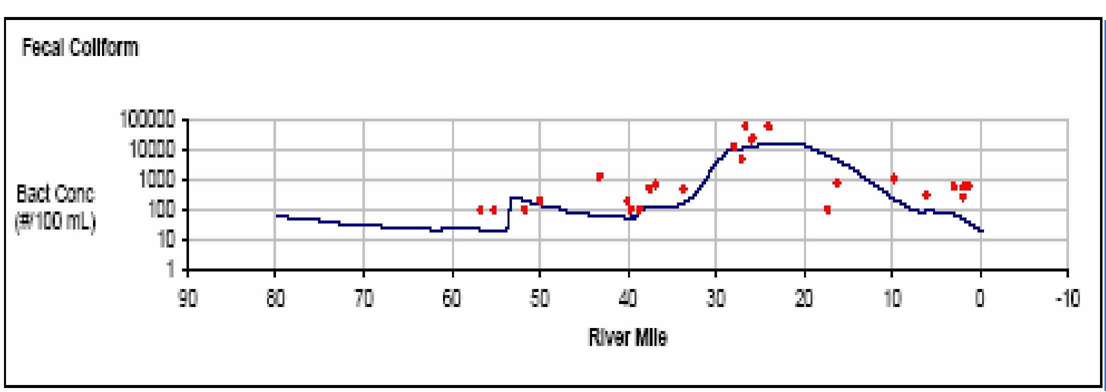
The Water Quality Simulation Program (WASP) was used to simulate dynamic concentrations of bacteria, nutrients, dissolved oxygen, chlorophyll-a, and BOD in the river.

Prior to being used in a predictive mode, the models were compared to measured data to first calibrate and then verify that they were accurately simulating real conditions in the river. Hydrologic flow from the HSPF model was calibrated to USGS flow records throughout the basin. Watershed loads, predominantly evidenced as mass loading into the mainstem via the tributaries, were calibrated to observed tributary loads from the dry and wet weather monitoring conducted under Task 4 of this watershed assessment study.

Hydraulic routing characteristics in the mainstem were compared to travel time measurements obtained under Task 3 of this watershed assessment study, and to additional measurements conducted by the USGS in Massachusetts and New Hampshire, and federal measurements of travel times in the river from earlier studies. Finally, instream water quality responses were calibrated to observed concentrations of pollutants obtained from the dry and wet weather monitoring conducted under Task 4 of this watershed assessment study.



Sample verification plot of travel times in the mainstem Merrimack River (See Section 4.0)



Sample calibration plot of bacteria concentrations in the Merrimack River

Figure ES–2: Sample Watershed Simulation Model Calibration Plots

In Step 4, a series of abatement strategies in Step 3, were evaluated in terms of their ability to bring about improvements to the river. Potential projects were identified in consultation with stakeholders in Step 3. The stakeholders included representatives from the following agencies:

- United States Army Corps of Engineers, New England District
- Sponsor Communities
- United States Environmental Protection Agency
- Massachusetts Department of Environmental Protection
- New Hampshire Department of Environmental Services
- United States Geological Survey
- Merrimack Valley Planning Commission
- Merrimack River Watershed Council

Furthermore, metrics by which "river improvements" are to be judged were determined with stakeholder input in Step 3.

The four key metrics of potential river improvements were: (1) River segments & duration below state thresholds or EPA guidance limits for bacterial indicators in the context of recreational uses of the river; (2) River segments/duration above state thresholds for dissolved oxygen in the context of aquatic habitat as a beneficial use; (3) Flux of bacteria into the estuary; and (4) Flux of nitrogen into the estuary.

Table ES–2 lists the alternatives selected for modeling and evaluation, briefly discusses the reason that each alternative was included in this study, and why certain alternatives were combined:

Table ES–2: Scenarios simulated with the Merrimack watershed model

Scenario Code	Scenario Description	Details	Reason for Selection
6A	Phase I CSO Control Plan: **Manchester**	• WWTP upgraded to 70 mgd • Elimination of CSOs discharging to Piscataquog • Elimination of CSOs at Victoria St, Crescent Rd, Poor St, and Schiller Rd.	Ongoing programs in accordance with EPA consent agreements – selected in order to understand quantitative benefits to be expected. These alternatives are combined into #6F because all communities are expected to complete Phase I programs.
6B	Phase I CSO Control Plan: **Nashua**	• WWTP upgraded to 110 mgd • Upgraded and/or separated CSOs 001, 002, 003, 004, 005	
6C	Phase I CSO Control Plan: **Lowell**	• WWTP upgraded to 110 mgd • Improved grit and diversion facilities • Partial sewer separation: Sixth/ Emory Ave, Gorham St, Warren St.	
6D	Phase I CSO Control Plan: **GLSD**	• Improved grit removal and screening • Increased secondary treatment capacity • Secondary bypass/disinfection facilities • 10-acre disconnecton at Honeywell site • Separation along Broadway	
6E	Phase I CSO Control Plan: **Haverhill**	• Improved primary treatment • Improved grit removal • WWTP upgraded to 60 mgd • Numerous overflow weirs raised • Essex and Lafayette CSOs closed • Siphon gates remain open during storms	
6F	All Phase I CSO Control Plans	All 5 communities simulated with Phase I CSO improvements listed in 6A – 6E	
7A1	Long-Term CSO Control Alternatives: **Manchester**	• Screening/Disinfection of remaining CSOs to 4 OF/year level (Pennacook, Cemetery, Stark, Granite Street, Tannery Brook & East Bridge.) • Use 3-month design storms for sizing	Alternatives for Manchester subsequent to Phase I CSO Control
7A2		• Full separation of remaining CSOs	
7A3		• Storage to 3-month level at Pennacook, Cemetery, Stark, Granite Street, Tannery Brook & East Bridge. • Use design storms for sizing	
7A4		• Storage to 6-month level at Pennacook, Cemetery, Stark, Granite Street, Tannery Brook & East Bridge. • Use design storms for sizing	
7B1	Long-Term CSO Control Alternatives: **Nashua**	• Full Separation	Alternatives for Nashua subsequent to Phase I CSO Control
7B2		• Screening/Disinfection at E. Hollis/Burke St (49.4 MGD peak capacity) • 40,000 Gallon storage at Farmington Road CSO • 10,000 Gallon storage at Burke Street CSO	
7C1	Long-Term CSO Control Alternatives: **Lowell**	• Separation of Warren Street (Area A, ~757 ac) • WWTP upgrade (to 150 MGD) • Beaver Brook – Pipeline storage • Tilden Street – $6 million partial storage • Merrimack – Separate 110 acres	Alternatives for Lowell subsequent to Phase I CSO Control
7C2		• Storage of remaining Warren St area (Area B- ~727 ac and Area C- ~542 ac) • WWTP upgrade (to 150 MGD)	

Scenario Code	Scenario Description	Details	Reason for Selection
		• Beaver Brook – Pipeline storage • Tilden Street – $6 million partial storage • Merrimack – Separate 110 acres	
7D1	Long-Term CSO Control Alternatives: **GLSD**	• Do Nothing	Alternatives for GLSD subsequent to Phase I CSO Control
7D2		• Expand WWTP to 165 MGD	
7D3		• Partial separation to 3-month level of control	
7D4		• Satellite storage facilities, 0.245 mg at CSO 002 and 3.39 mg at CSO 004 (Table 7-10, LTCP)	
7E1	Long-Term CSO Control Alternatives: **Haverhill**	• Do Nothing	Alternatives for Haverhill subsequent to Phase I CSO Control
7E2		• 7.8 MGD (0.2 acre) Treatment facility at Bradford Ave (3 Month Control Level) • 9.1 MGD (0.45 acre) treatment facility at Little River (3 Month Control Level)	
7F	All Communities: Representative Long-Term CSO Alternatives	Combination of Scenarios 7A3, 7B2, 7C2, 7D2, 7E2, implemented together	Combination of most likely long-term control plans
8	Full CSO Separation	All combined sewer systems simulated as fully separated	Basis of comparison to specific options
9A	NPS Reduction Only	Bacteria concentrations in stormwater throughout watershed reduced by approximately 20%. Also, background concentrations of fecal coliform in extremely polluted tributaries (Salmon Brook, Spickett River, Shawsheen River) reduced to 5,000 counts per 100 ml.	Understand the quantitative impacts of nonpoint source pollution abatement by itself and in conjunction with CSO abatement to see if a balanced approach is warranted

The following conclusions were drawn from the analysis of alternative scenarios:

- Phase I and Long-Term CSO improvements, including partial separation, storage, increased treatment capacity, etc. will reduce the frequency, magnitude, and duration of overflows, but will not significantly improve compliance with bacterial water quality standards. This is because overflow events taken as a whole occur for a very small percentage of the time in any given year. The remainder of the time, the river system is dominated by stormwater and background concentrations that often exceed bacteria standards. The river would still be significantly impaired after all the Long-Term CSO plans are implemented.

- Full Separation of combined sewers would offer very little improvement in river water quality for the same reasons as stated above.

- Reasonable levels of nonpoint source control, as defined by approximately 20% reduction in all runoff concentrations and reduction of background concentrations in highly polluted tributaries to 5,000 org/100ml (still well above standard), will offer significant improvements in compliance with bacteria standards.

- Nonpoint Source (NPS) controls coupled with Phase I CSO controls may be sufficient to achieve compliance. In fact, the implementation of the nonpoint source reductions described above would actually increase the effectiveness of Phase I CSO controls by bringing the river closer to compliance and closing the gap that CSO abatement would need to bridge. Model results suggest that under normal hydrologic conditions, the river would be fully compliant with bacteria standards with the suggested nonpoint source reductions and Phase I CSO abatement. During abnormally dry and wet years, there may still be small isolated reaches that do not fully comply.

- Long-Term CSO abatement offers very little additional improvement in compliance when compared to either Phase I abatement alone or to Phase I abatement AND nonpoint source reductions. There are very few appreciable instream benefits of Long-Term CSO control plans beyond the Phase I programs already in progress, whether or not such plans are coupled with nonpoint source abatement. However, the long-term alternatives will reduce the occurrence of very high bacteria levels in the river, though these occur during a total of just a few days during each year.

- By far, the greatest value in abatement dollars can be realized with nonpoint source abatement and Phase I CSO controls. Phase II CSO offers much lower value. In this case, value is measured in terms of river miles or days of compliance that can be achieved for every million dollars spent. Results suggest that a balanced watershed management plan that includes modest CSO abatement coupled with reasonable levels of nonpoint source reduction should form the basis of watershed management decisions in the Merrimack Basin. A balanced approach includes:

    - Phase I CSO plans,

    - 20% reduction in bacteria concentrations in runoff, and

    - Reducing background levels of bacteria in highly polluted tributaries to 5,000 org/100ml

  Using the metric of miles of river brought into compliance per million dollars spent, this approach is approximately 4 times more cost-effective than Long-Term CSO control plans. Results also suggest that such a balanced strategy would be 8 times more cost-effective than full CSO separation using this same metric. In addition to being more cost-effective, the balanced approach would offer significantly more benefits than CSO abatement alone, and would result in a river that would likely comply with water quality standards under most conditions.

Ecological Opportunities

Ecological restoration opportunities have been organized into six categories. These are: fisheries/aquatic species, water quality, soils/erosion control, terrestrial rare species and wetlands, marine/estuarine, and riparian resources. A survey of published plans and local contacts revealed many projects in each of the categories. Section 5 lists many specific examples, a summary of which is included below.

- Fisheries/aquatic species—Opportunities exist to enhance the health of fish and other aquatic species by improving their habitat. This include activities such as streambed enhancement or naturalization, riparian habitat improvement, upstream and downstream fish passage improvement, provision of adequate stream flow, and mitigation of temperature changes.

- Water quality—Nonpoint source water quality problems exist throughout the watershed and contribute to degraded water quality on the mainstem of the Merrimack and the major tributaries. These watershed-wide water-quality issues are primarily the result of a combination of increased development and agricultural practices.

  Implementation of best management practices (BMPs) for the control of nonpoint source pollution throughout the watershed (both urban and agricultural) as well as maintenance of existing BMPs is critical to the ultimate success of nonpoint source control. Development using low impact development (LID) techniques also has the potential to minimize development impacts on water quality.

  In addition, wetlands are important buffers against upland non-point pollutant sources by filtering and cleansing runoff before it reaches a surface water body. Wetland protection, creation or restoration can also improve water quality in the river.

- Soils/erosion control— Erosion in the Merrimack watershed can be split into two general categories: (1) Loss of topsoil in the watershed due to disturbances such as site development and transportation projects; and (2) river shoreline or bank erosion. Both types of erosion can significantly alter the water quality and ecology of receiving waters by adding nutrients, covering critical aquatic habitat, filling wetlands and impounded areas and reducing water clarity.

  The restoration of riverbanks to reduce the contribution of sediment and their associated nutrients to the Merrimack River could be accomplished using a phased approach. Section 5.The first phase, identification of eroding banks, has been partly completed and is summarized in

  The second phase would be to prioritize the riverbanks based on the risk posed to important infrastructure (bridges, roads, houses and utilities) and aquatic/riparian habitat. In the third phase the sites identified as being high priority would be surveyed in more detail so that conceptual restoration designs could be prepared. The advantages of bioengineering techniques are discussed, and should be given consideration during conceptual design.

- Terrestrial rare species and wetlands—Protection/enhancement of rare or declining non-game species and communities can best be achieved through enhancement, restoration and protection of targeted habitats. These include habitat for the New England cottontail rabbit (*Sylvilagus transitionalis*), brook floater mussel (*Alasmidonta varicosa*), eastern hognose snake (*Heterodon platyrhinos*), and Blanding's turtle (*Emydoidea blandingii*), as well as pine barrens and forested floodplain communities.

- Marine/estuarine—The estuary may be among the most vulnerable resources in the Merrimack; its downstream location means it receives the cumulative impact of all activities in the watershed. Impacts to the estuary result from nutrient and bacteria loading, sedimentation, shoreline erosion. These effects have resulted in changes in populations of anadromous and catadromous fish species. Marine and estuarine opportunities include restoration of critical habitats such as eelgrass and salt marsh, as well as restoration of soft-shell clam harvesting areas.

- Riparian resources—The riparian zone provides habitat for a number of plant and animal species, and provides a critical buffer which can minimize the impact of activities on the land. Development near the river is often desirable; the challenge is to do it in a manner that showcases the river while preserving natural functions of the riparian zone and supporting the species that depend upon it. Potential projects include converting old rail lines to greenway trails, reducing paved area in the riparian zone, and providing buffer zones and conservation easements.

Section 1
Study Authority

1.1 Background

The cities of Manchester and Nashua, New Hampshire, the Cities of Lowell and Haverhill, Massachusetts, and the Greater Lawrence Sanitary District (GLSD), Massachusetts, are currently working separately to develop and implement long-term Combined Sewer Overflow (CSO) control plans in compliance with the Federal Clean Water Act. The collective cost of these potential CSO improvements may exceed 500 million dollars over the next 20 years. Given this sizable investment, the communities are concerned that decisions regarding the potential mitigation measures are being made without adequate understanding of the existing conditions in the Merrimack River, the pollution sources to the River, and the potential benefits of the proposed CSO improvements.

1.2 Study Authority

The Federal government, through the United States Army Corps of Engineers (USACE), is providing 50 percent of the cost share for the Merrimack River Watershed Assessment Study (hereafter referred to as the "Study"), as well as technical assistance. Involvement of the USACE is authorized under Section 729 of the Water Resources Development Act (WRDA) of 1986 entitled "Study of Water Resources Needs of River Basins and Regions" as amended by Section 202 of WRDA 2000. This report was prepared in response to specific language contained in Section 437 of WRDA 2000 that directed the USACE to conduct a comprehensive study of the water resource needs of the Merrimack River basin in Massachusetts (MA) and New Hampshire (NH).

Directed funds for this effort were provided to the USACE by Congress in the fiscal year 2001 and 2002 Energy and Water Development Appropriation. The City of Lowell, Massachusetts, serving as the local sponsor of this project, entered into a Memorandum of Understanding with the four other communities in the watershed (Haverhill and GLSD, Massachusetts; Manchester and Nashua, New Hampshire) to provide the remaining financial support for the Study.

1.3 Consultant Project Team

The primary consultant for this study was CDM. Numerous subconsultants and firms assisted during the course of the study:

- Normandeau Associates, Incorporated: Conducted hydraulic surveys of the river, conducted an erosions survey of the river, helped orchestrate and conduct the water quality surveys of the river, and conducted an assessment of ecological restoration opportunities in the watershed.

Section 2
Study Purpose and Scope

2.1 Background

The Merrimack River Watershed encompasses approximately 14,000 square kilometers (approximately 5,000 square miles), originating in Northern New Hampshire and discharging into the Atlantic Ocean in Newburyport, Massachusetts. The river and its associated canals and tributaries helped fuel the industrial revolution in the 1800s, and today the river system supports a variety of designated uses, including water supply, recreation, aquatic habitat, and hydropower. Although the watershed is heavily forested (approximately 75% of the land area is covered with forest), its southern region is characterized by five major urban/industrial cities along the river: Manchester NH, Nashua NH, Lowell MA, Lawrence MA (Greater Lawrence Sanitary District, GLSD), and Haverhill MA.

Many reaches of the river are listed on NH and MA 303(d) lists for violations of bacterial water quality standards. The five communities, each of which are serviced by aging combined sewer systems, have signed individual consent agreements with the United States Environmental Protection Agency and their respective states to commit large sums of money to the abatement of combined sewer overflows (CSOs), in accordance with the federal Clean Water Act. In accordance with the consent agreements, each community is in various stages of development and implementation of CSO Long-Term Control Plans (LTCPs). Since enforcement protocols are specific to individual communities, these plans are being developed in isolation from the rest of the watershed, and from the other CSO communities along the mainstem. Collectively, these communities may need to spend up to $500 million on CSO control alone to comply with EPA mandates, and there is insufficient information regarding the benefits to be achieved.

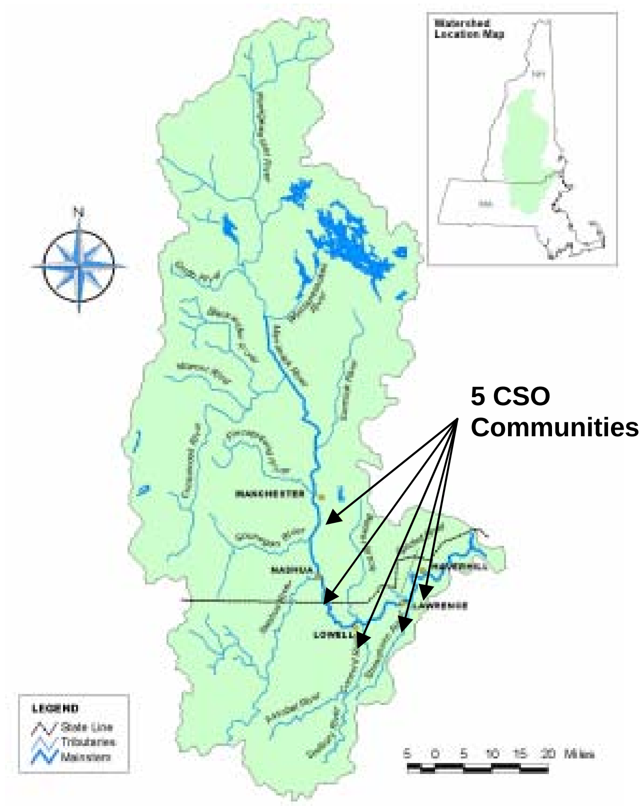


Figure 2-1: Merrimack Watershed

This study was initiated in order to add clarity to the expected benefits that could be achieved from various watershed management strategies (including CSO abatement plans, nonpoint source abatement plans, and blended plans), as measured by improvements in river conditions. The underlying principle is that such information is necessary in order to evaluate and compare the value of dollars spent on both point source and nonpoint source abatement.

2.2 Purpose

The overall purpose of the Merrimack River Watershed Assessment Study is to develop a comprehensive Watershed Management Plan. The Plan will be used to guide investments in the environmental resources and infrastructure of the basin and will be aimed at achieving water quality and flow conditions that support beneficial uses, including water supply, recreation, hydropower, fisheries, and other ecological habitat. The Plan will encompass the diverse interests and goals of the various partners and stakeholders throughout the Merrimack River watershed, including state, local, and Federal governments, industry, and environmental groups.

2.3 Watershed Overview

The Merrimack River is formed by the confluence of the Pemigewasset and Winnipesaukee Rivers in Franklin, New Hampshire. The River flows southward for approximately 78 miles in New Hampshire; it turns abruptly across the New Hampshire - Massachusetts border and flows in a northeasterly direction for approximately another 50 miles before discharging to the Atlantic Ocean at Newburyport, Massachusetts. The final 22 miles of the River, downstream of Haverhill, Massachusetts, are tidally influenced.

The Merrimack River watershed covers an area of approximately 5,000 square miles in New Hampshire (76-percent of the drainage area) and the northeastern portion of Massachusetts (24-percent of the drainage area), making it the fourth largest watershed in New England. It encompasses a variety of terrain and climate conditions, from the mountainous White Mountain region in northern New Hampshire to the estuarine coastal basin of northeastern Massachusetts. Precipitation in the watershed is fairly evenly distributed throughout the year. There are, however, large inter-basin variations in the amount and type of precipitation (*i.e.* rain versus snow) primarily as a result of the effects of terrain, elevation, latitude, and proximity to the ocean (Flanagan *et al.* 1999). Temperatures in the basin generally vary widely on an annual basis. Based on a review of climate data, July is typically found to be the warmest month and January is generally the coldest.

A mix of deciduous and evergreen forest, covering approximately 77 percent of the watershed area, dominates the land use in the basin. Urban areas, including residential, industrial, commercial and commercial land uses, make up the second