Merrimack River Watershed Assessment Study

Screening Level Model

Prepared for:

New England District
U.S. Army Corps of Engineers

Sponsor Communities:
Manchester, NH
Nashua, NH
Lowell, MA
GLSD, MA
Haverhill, MA

March 2004

Executive Summary

The purpose of this interim report is to present the results of the screening level analysis performed under Task Order 3 of the Merrimack River Watershed Assessment Study. The screening level analysis was performed using the Watershed Management Model (WMM). This report provides a brief summary of the model structure and data requirements, as well as an assessment of the relative contribution of pollutant sources from geographic and physical source areas throughout the watershed. More detailed analysis of these sources and their impact on water quality will be performed in subsequent tasks using detailed, dynamic water quality and hydrologic/hydraulic models developed for the basin.

Screening Level Model Objectives

The primary objectives of the screening level analysis are as follows:

- Assess the relative contribution of pollutants from various sources, including stormwater runoff from land use based pollutant loadings, Combined Sewer Overflows (CSOs), industrial point sources, and wastewater treatment plants (WWTPs)

- Assess the relative contribution of pollutants from geographic source areas, such as the major tributaries, mainstem segments, and five sponsor communities

- Identify key pollutants and geographic focus areas for future water quality and hydrology/hydraulic modeling efforts

- Evaluate the sensitivity of model results to various WMM assumptions, including pollutant loading rates, percentage of failing septic systems, and pollutant attenuation factors

The model objectives provided above were used as a guide for the development of the WMM model, as well as for the selection of model scenarios. The WMM model was not used to evaluate pollutant abatement scenarios; this work will be performed during subsequent modeling efforts.

Overview of the Watershed Management Model

The Watershed Management Model (WMM) was developed as a database model to estimate relative changes in annual or seasonal pollutant loads from various sources within a watershed as a result of changes in land use or implementation of stormwater Best Management Practices (BMPs). The model may also be used to compare the relative non-point and point source loads by source or geographic area. The non-point source loads in WMM are calculated as a combination of pollutant loads resulting from stormwater runoff (all constituents) and from "failing" septic systems (total phosphorus and nitrogen only). WMM uses land use categories and associated pollutant loading rates, or Event Mean Concentrations (EMCs), to simulate pollutant loads carried in stormwater runoff. The model may also be used to estimate loads from other sources, including WWTPs, industrial point sources, CSOs, and failing septic systems. WMM is a public-domain model that was originally developed by CDM for the Florida Department of Environmental Protection and enhanced as part of the Rouge River National Wet Weather Demonstration Project.

WMM is only appropriate for the prediction of pollutant loads at the annual or seasonal level. The model should only be applied to the appropriate spatial (watershed-wide) and temporal (annual or seasonal) scales.

Existing Watershed Characteristics

For the purposes of the screening level analysis, the Merrimack River watershed was divided into 28 sub-catchments in accordance with the following boundaries:

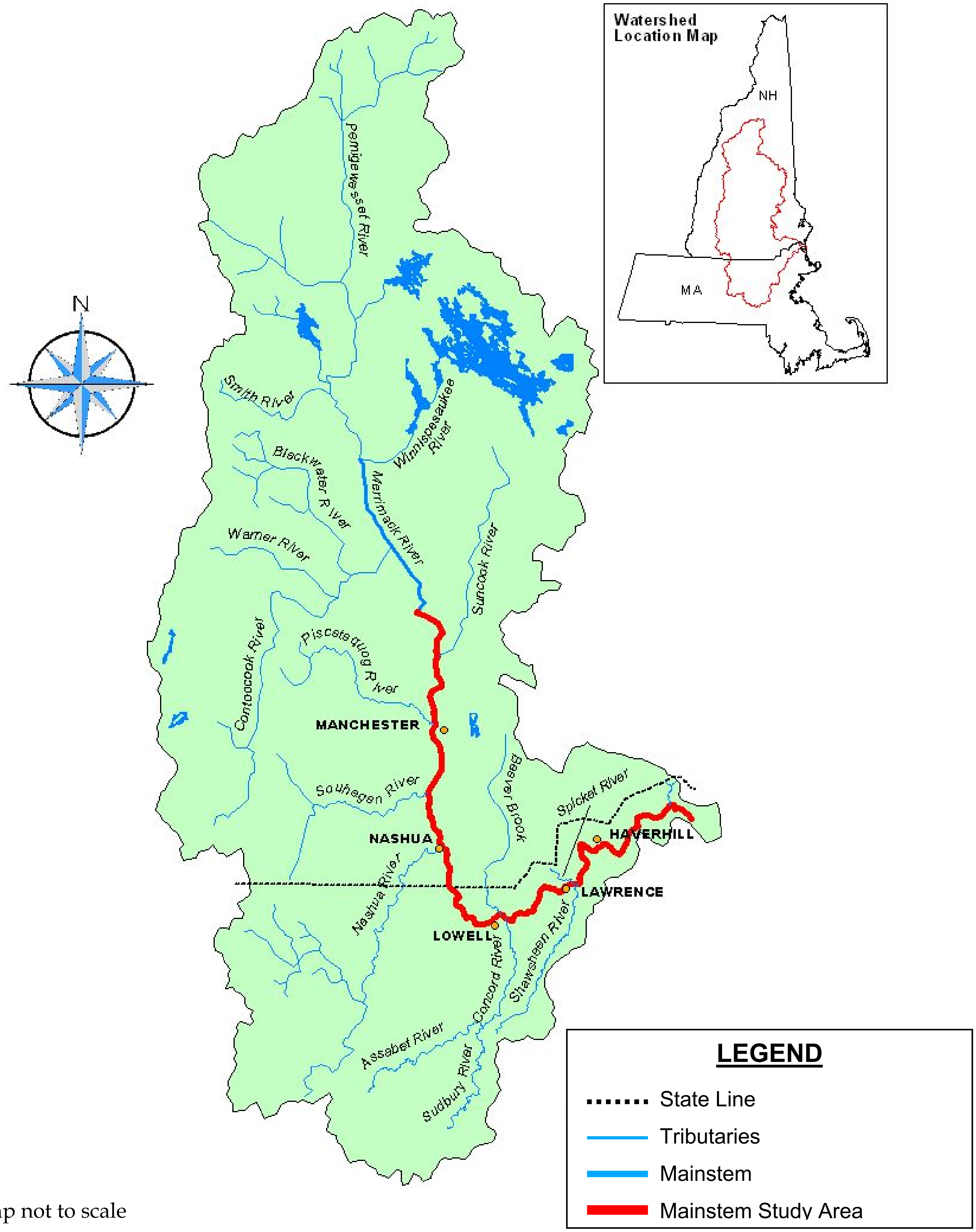
- Watershed delineations for the Pemigewasset and Winnipesaukee Rivers, which join to form the Merrimack River in Franklin, New Hampshire
- The contributing drainage area to the mainstem Merrimack River from its start in Franklin, New Hampshire to north of Hooksett, New Hampshire (including major tributaries)
- The contributing drainage area of 11 major tributaries that join the Merrimack River downstream of Hooksett, New Hampshire
- Separate delineations for each of the five sponsor communities or Manchester and Nashua, New Hampshire and Lowell, Lawrence, and Haverhill, Massachusetts
- Six "corridors" delineating the drainage area (outside of the major tributaries and sponsor communities) contributing directly to the mainstem Merrimack River south of Hooksett, New Hampshire (all located in the immediate vicinity of the mainstem)

A map of the overall watershed is provided in Figure ES-1.

The land use composition of each sub-watershed was determined using a Geographic Information System (GIS). The following eight land use categories were used:

- Forest/ Rural Open
- Urban Open
- Agricultural/ Pasture
- Medium Density Residential
- Commercial
- Industrial
- Highway
- Water/ Wetlands

Figure ES-1: Merrimack River Watershed



Note: Map not to scale

Pollutant loading rates in the form of event mean concentrations (EMCs) were associated with each of the land use values to simulate pollutant loads carried in the stormwater runoff. The EMC values were developed from a variety of sources including (1) default values available in WMM, (2) regional values averaged from studies in the New England area, and (3) national values averaged throughout the United States. In general, the EMCs were fairly consistent across all the sources. As a result, CDM recommended the use of the regional data, where available (*i.e.* for commercial, industrial, and medium density residential land use), and the use of the default WMM values for all other land uses.

Information on existing point source discharges, including CSOs and municipal and industrial dischargers, was also input into WMM. CSO concentrations and annual discharge volumes were based on information contained in the Long-Term Control Plans for the five sponsor communities. Information on the point source discharge concentrations and volumes was based on data obtained from the USEPA. Data for each source was summarized in the "*Summary of Information on Pollutant Sources*" Report prepared under Task 2C of this Study.

WMM was used to estimate the annual pollutant loads from failing septic systems in the watershed. Since the model does not account for the portion of the loading that may be attributed to *operational* septic systems, this value was estimated outside of WMM using a method accepted by the Massachusetts Department of Environmental Protection.

For the purposes of WMM, the following three hydrologic conditions were evaluated: drought, normal, and wet conditions corresponding to the 5th, 50th, and 95th percentiles of annual precipitation data, based on statistical analysis of precipitation records at nine COOP stations throughout the watershed. An average of the precipitation totals corresponding to the drought, normal, and wet conditions at the nine stations was used in the WMM analysis, as noted below:

- **Drought:** 33.68 inches
- **Normal:** 43.84 inches
- **Wet:** 55.68 inches

WMM Scenarios

A total of six scenarios were evaluated in WMM; a matrix of these scenarios is presented in Figure ES-1. Each of the six scenarios was run under drought, normal, and wet hydrologic conditions.

Figure ES-1: Matrix of WMM Scenarios

MODEL FEATURE	SCENARIO					
	1	2	3	4	5	6
Land Use	GIS Data	GIS Data	GIS Data	GIS Data	GIS Data	GIS Data
Annual Hydrology	Calibrated	Calibrated	Calibrated	Calibrated	Calibrated	Calibrated
Point Source Load	Monitoring Reports	Monitoring Reports	Monitoring Reports	Monitoring Reports	Monitoring Reports	Monitoring Reports
CSO Load	LTCP Data	LTCP Data	LTCP Data	LTCP Data	LTCP Data	LTCP Data
NPS EMCs	WMM Defaults	Regional Averages	Regional Averages	Regional Averages	Regional Averages	Regional Averages
Septic Load	Average	Average	Worst case failure & load rates	Best case failure & load rates	Average	Average
Pollutant Delivery Ratio	Average	Average	Average	Average	Worst case: 100% Delivery	Best case: Least estimated delivery

LTCP= Long-Term Control Plan

The following items are evaluated in the six scenarios, as shown above:

- Scenario 1 and 2 evaluate the impact of EMC values on model results
- Scenario 3 and 4 evaluate the impact of septic tank failure rates on model results
- Scenario 5 and 6 evaluate the effect of pollutant delivery ratios on model results; these ratios govern the amount of pollutant from a given watershed that make it to the outlet of a river

Model Findings

As previously discussed, the goal of this modeling task was to evaluate the relative contribution of pollutants from the major geographic source areas, such as the sponsor communities and major tributaries, as well as from the primary physical sources, such as non-point sources. Key model findings are provided below in bullet form, as well as a brief comparison of the model results from the six scenarios discussed in the previous section.

- The WMM results suggest that non-point sources from the major tributaries dominate the annual pollutant loads for eight of the 10 parameters evaluated in this study, with the exceptions being the two nutrient parameters, total nitrogen and total phosphorus. These results were consistent across the six scenarios and three hydrologic conditions evaluated as part of this study.

- The total phosphorus results suggest that annual loads are dominated by point sources in the sponsor communities (primarily the WWTPs). For total nitrogen, the results suggest that the annual loads are fairly evenly split between point source discharges in the communities and non-point source discharges in the tributaries. It is important to note, however, that no monitoring data was available for total phosphorus or total nitrogen effluent concentrations at the WWTPs.

- In general, the WMM results were fairly insensitive to charges in the model assumptions, regarding EMC values, failing septic systems, and pollutant delivery ratios.

- Minor changes were seen in the resulting annual loads in response to changes between the pairs of scenarios (i.e. Scenario 1 and 2, 3 and 4, and 5 and 6). These variations typically did not result in changes to the overall relative contribution of pollutant loads from the geographic and physical sources.

- The model performed as expected in response to variations in the hydrologic regime between dry, normal, and wet conditions. The annual loads for each constituent increased proportionally in response to increases in the annual precipitation and changes in the pervious runoff coefficients.

Pie chart comparisons of the physical sources are provided in Figure ES-2 for the Scenario 6 results under "average" hydrologic conditions. This scenario was assumed to be the most "realistic" due to the variable pollutant delivery ratios and the average septic failure rate used.

Although the WMM results are only rough approximations of the annual loads, they do at least initially support the Merrimack River Basin Community Coalition's hypothesis that other sources beyond CSOs may play important roles in pollutant loadings to the Merrimack River. The WMM results suggest that CSOs had little impact on the annual loads for most parameters. They were most significant in the fecal coliform and E. coli results, contributing approximately 19 and eight-percent of the annual loads, respectively.

Limitation of WMM Results

The WMM results represent pollutant loads at the annual scale. Therefore, these results are not necessarily indicative of water quality conditions and primary sources at the time-scale at which water quality exceedances occur. These results should not be used to infer information about the relative contribution of pollutants at the daily or weekly scale. For example, the WMM results suggest that non-point source pollution from the tributaries is the primary source of annual bacteria loads in the River. Although these sources may be significant at the annual level, it is possible that other factors, such as CSO discharges, could play a more important role in water quality exceedances at the daily scale, due to the distribution of loads throughout the year.

The detailed water quality and hydrologic/hydraulic models to be developed during subsequent phases of this project will be used to further refine this evaluation. These models will be able to assess water quality conditions at time steps on the order of hours and even minutes, as necessary, to identify dynamic response patterns and dominant loads over a range of events.

Figure ES-2: Annual Loads for Representative WMM Scenarios

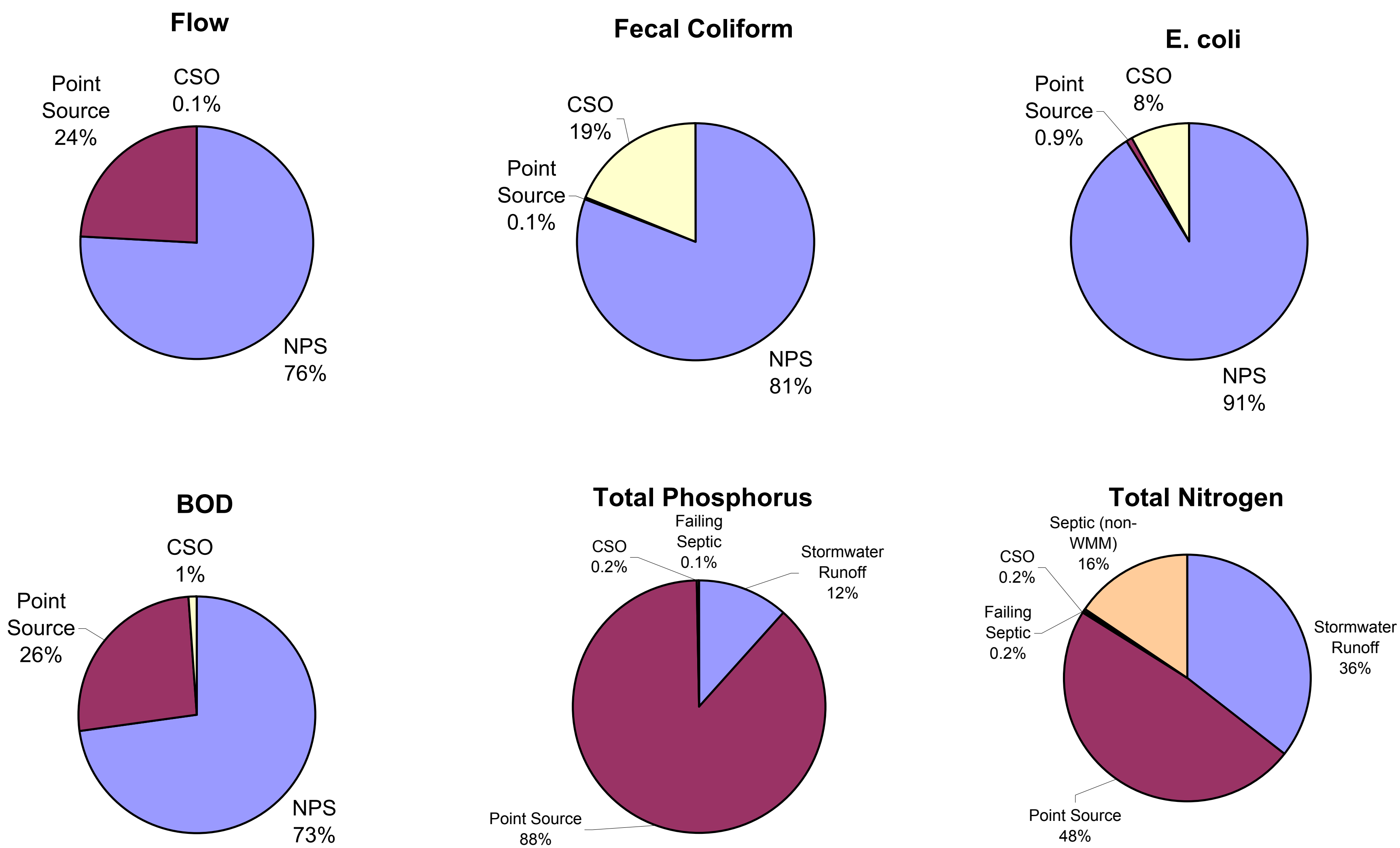
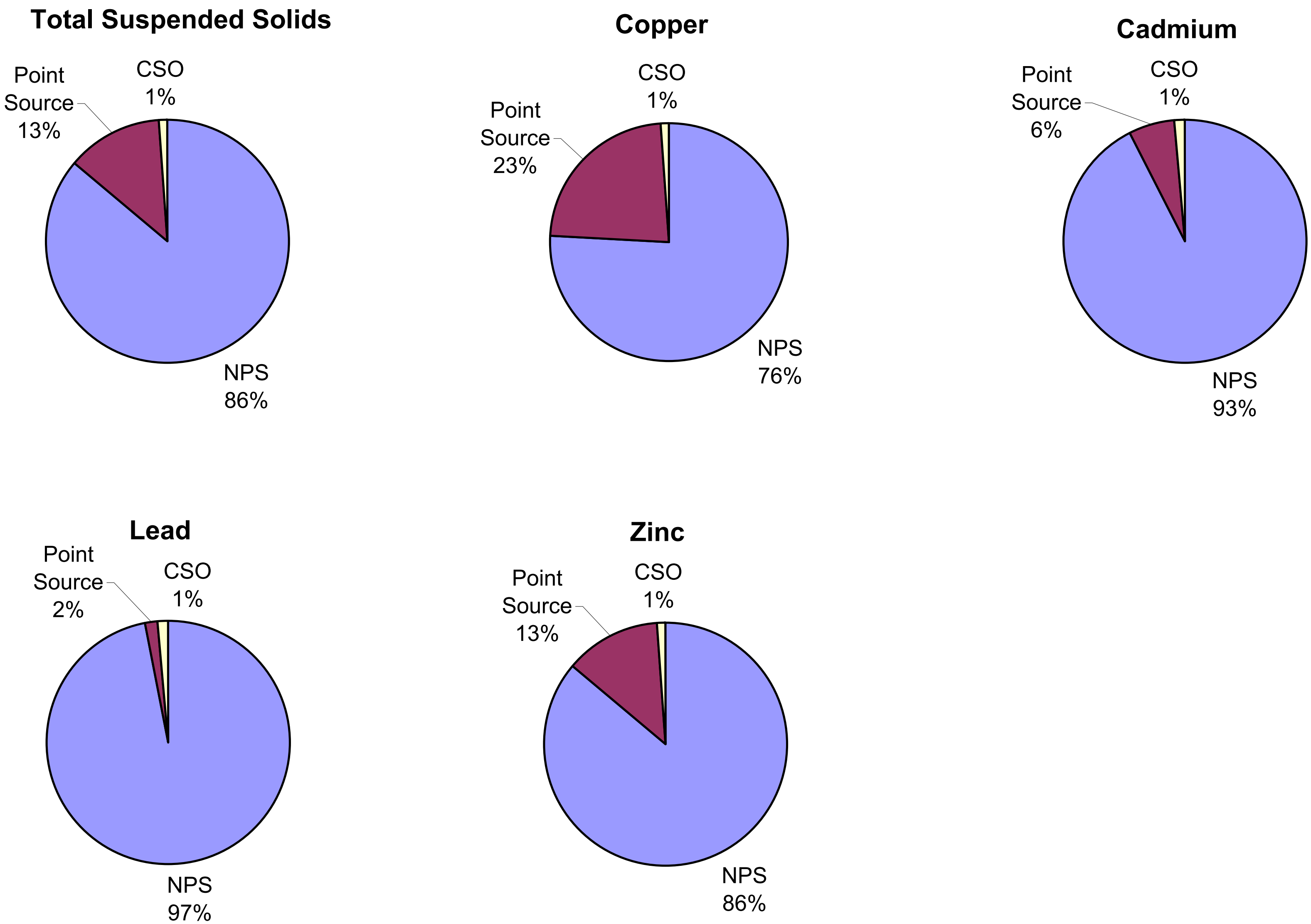


Figure ES-2 (cont'd)



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Section 1 Background

1.1 Interim Report Scope

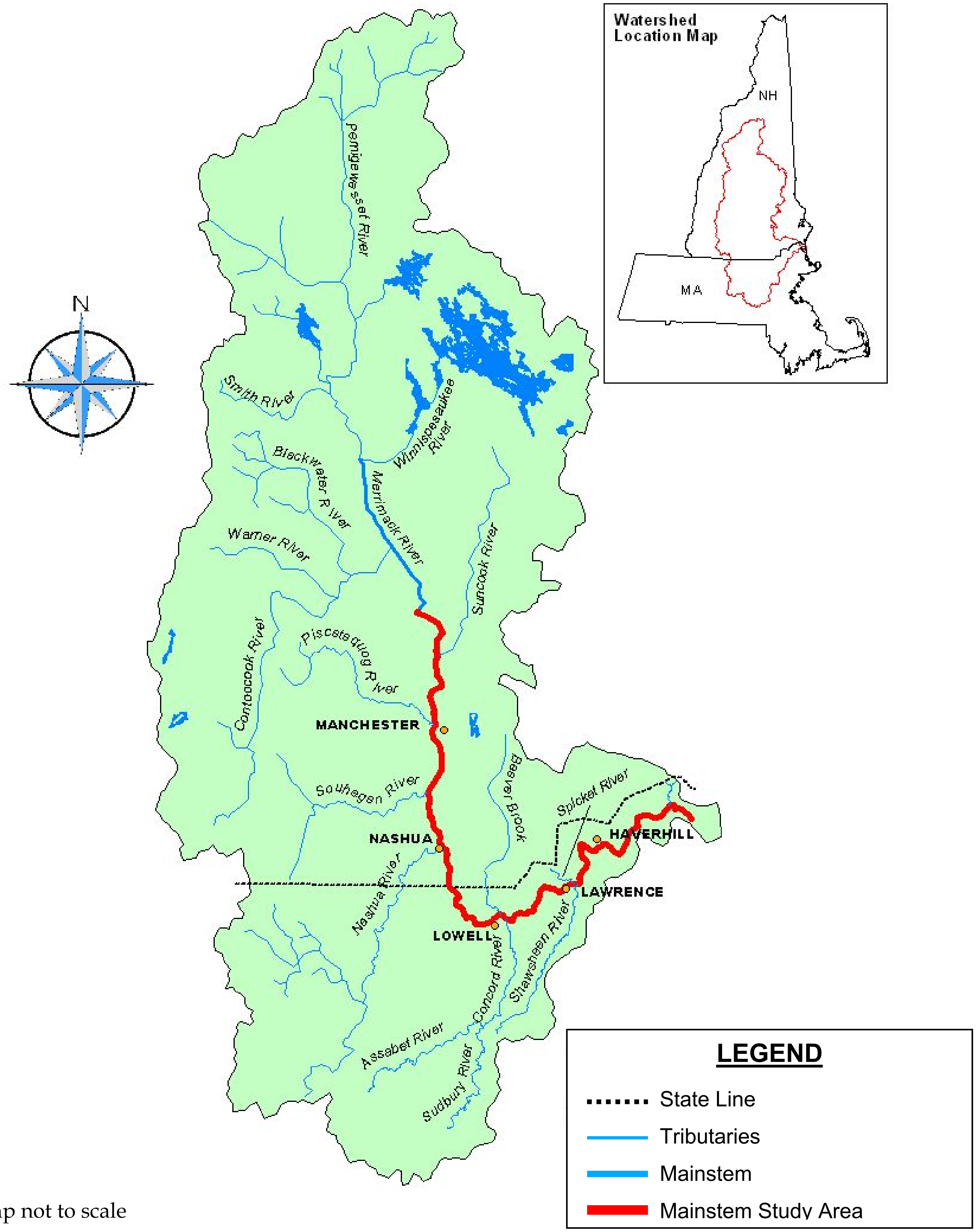
The purpose of this Interim Report is to present the results of the screening level analysis performed under Task Order 3 of the Merrimack River Watershed Assessment Study. This report describes the scope and objectives of the screening level analysis, provides a brief summary of the structure, required input data, and data sources for the Watershed Management Model (WMM) employed in this study, outlines the existing watershed characteristics central to the screening level analysis, and provides an assessment of the relative contribution of pollutant sources from throughout the watershed on an annualized level. More detailed water quality and hydrologic/hydraulic models developed in subsequent tasks of this Study will further define these pollutant sources and their relative impacts at time scales on the order of days and hours.

1.2 Study Area

For the purposes of the screening level model, the entire Merrimack River watershed, including its tributaries, was included in the model to evaluate the relative impacts of all tributaries and mainstem segments. This Study Area includes the five sponsor communities of Manchester and Nashua, New Hampshire, Lowell and Haverhill, Massachusetts, and the Greater Lawrence Sanitary District (GLSD), Massachusetts. Additional information on the watershed characteristics and drainage area delineations within the Study Area is provided in Section 4.1.

For the purposes of the water quality monitoring program and future modeling efforts, the project Study Area has been defined as the portion of the Merrimack River mainstem located south of the Hooksett Falls Dam in Hooksett, New Hampshire to the mouth of the River at the Atlantic Ocean near Salisbury and Newburyport, Massachusetts. A map of the overall watershed is provided in Figure 1-1; the mainstem Study Area for the monitoring and future modeling efforts is highlighted in red.

Figure 1-1: Merrimack River Watershed



Note: Map not to scale

Section 2 Objectives

This section discusses the overall study objectives, as well as the specific objectives for the screening level model analysis.

2.1 Study Objectives

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 concerned citizen groups.

The assessment will include a water resources and ecosystem restoration investigation of the Merrimack River and will be used to answer the following questions:

1. What are the impacts of pollutants on the Merrimack River mainstem with respect to state water quality standards and hence, the designated uses of water supply, recreation, and aquatic habitat?

2. What is the relative contribution of pollutants from various sources?

3. What are the existing and potential future beneficial uses of the Merrimack River?

4. What projects or "investments" will provide the most significant return on investment?

5. Which projects should have the highest priority?

The assessment study is divided into two phases, only the first of which is currently funded. The model development and analysis tasks are included in Phase I. The general purpose of each phase is discussed below:

Phase I (Funded): The primary purpose of Phase I is to identify the relative causes and impacts of pollution problems in the Merrimack River basin as they pertain to designated uses. This will be accomplished through characterization, field monitoring, simulation modeling, and planning-level review of alternative pollution abatement and management strategies. Ultimately, the output from Phase I should help decision-makers to understand the relative contributions of pollutants from various sources and the basin-wide impacts of these pollutants. The sensitivity of the mainstem water quality to incremental reductions in pollutant loads from specific sources will also be evaluated. Scenarios providing the most significant return on investments will be identified. This information may be used to guide decisions about how best to direct funding to yield the greatest overall benefits with respect to the designated uses of the River.

Phase II (Not Yet Funded): Phase II will build on the results from Phase I, and may potentially include additional field monitoring to investigate specific areas of interest or concern identified during Phase I. Additionally, it is excepted that a detailed cost-benefit analysis will be conducted during Phase II to evaluate a wide array of possible abatement, control, and restoration initiatives, building upon those scenarios identified during Phase I. The simulation modeling and planning-level alternatives analysis performed during Phase I will serve as the basis for the development of optimization models during this second phase of the project. The optimization models may help to identify potential alternatives that are both economically and environmentally successful. Ultimately, the output from Phase II will be a prioritized list of recommended investments throughout the Merrimack River watershed aimed at improving beneficial uses and restoring ecosystems.

2.2 Screening Level Model Objectives

The primary objectives of the screening level model are as follows:

- Assess the relative annual mass contribution of pollutant from various sources, including stormwater runoff from land use based pollutant loadings, Combined Sewer Overflows (CSOs), industrial point sources, and wastewater treatment plants (WWTPs)
- Assess the relative contribution of pollutant from geographic source areas, such as the major tributary basins, mainstem segments, and five sponsor communities
- Identify key pollutants and geographic focus areas for future water quality and hydrology/hydraulic modeling efforts
- Evaluate the sensitivity of model results to various WMM assumption, including event mean concentrations (EMCs), percentage of failing septic tanks, and pollutant attenuation factors

The model objectives discussed above will be used as a guide for the development of the WMM model and the choice of model scenarios. The WMM model will not be used to evaluate pollutant abatement scenarios; this work will be performed during subsequent, more detailed modeling efforts. A description of WMM is provided in Section 3.0, including a general model overview, a discussion of data requirements, and model limitations.

Section 3
Overview of the Watershed Management Model (WMM)

The following section provides an overview of the Watershed Management Model (WMM), including the model structure, the required input data, methods for estimating annual runoff and non-point source pollutant loadings, and the model limitations.

3.1 Model Overview

The Watershed Management Model (WMM) was developed as a database model to estimate relative changes in the annual or seasonal pollutant loads from various sources within a watershed as a result of changes in land use or due to the implementation of stormwater Best Management Practices (BMPs). The model was developed specifically as a planning-level tool to address the watershed management needs of non-point source pollution and to compare the relative contribution of loads by source or geographic area. WMM uses land use categories and associated event mean concentrations (EMCs), depending on the constituent of concern, to simulate pollutant loads carried in stormwater runoff. The model may also be used to estimate loads from other pollution sources, including wastewater treatment plants (WWTPs), industrial point sources, Combined Sewer Overflows (CSOs), and failing septic systems. Within a given watershed, multiple subbasins may be evaluated using WMM. Subbasins may be delineated based on hydrologic divides or jurisdictional boundaries, such as town lines. WMM is a public domain model originally developed by CDM for the Florida Department of Environmental Protection and enhanced for the USEPA as part of the Rouge River National Wet-Weather Demonstration Project.

Some key features of WMM include:

- Estimates average annual runoff pollutant loads and concentrations for nutrients, oxygen demand, and sediment based upon EMCs, land use, imperviousness, annual precipitation, and annual baseflow

- Estimates annual pollutant loads from stream baseflow

- Estimates annual pollutant loads from CSOs

- Estimates point source loads for comparison with relative magnitude of other watershed pollutant loads

- Estimates pollutant loads from failing septic systems

- Applies a delivery ratio to account for reduction in runoff pollutant load due to uptake or removal in stream courses

WMM may also be used to evaluate the effectiveness of various pollutant abatement strategies. For example, WMM may be used to evaluate alternative non-point source pollution management strategies, such as combinations of source and treatment control options, as well as various CSO controls. Both structural and non-structural controls may be evaluated. The use of this tool in the context of the Merrimack River Watershed Assessment Study will be evaluated following the development of more detailed simulation models and the identification of alternatives.

As noted above, WMM may be used to evaluate pollutant loads from baseflow components. However, it was decided that this feature would not be used in the model of the Merrimack River watershed due to concern over the potential for double counting of pollutant loads from point sources and septic systems in the baseflow. In WMM, the baseflow loads are calculated from observed dry-weather water quality data and user-defined estimates of the annual baseflow volume. Although dry-weather water quality data was available in the Merrimack River, these values do not purely represent the "baseflow" water quality, as discharges from septic systems and point source discharges are included in these values. Since there was no way to easily disaggregate the pollutant contributions in the dry-weather monitoring data from these sources, the decision was made to only use the WMM capabilities for evaluating non-point sources, point sources, and CSO discharges.

3.1.1 Water Quality Constituents

WMM estimates loads from pollutants that are most frequently associated with non-point pollution sources. Table 3-1 provides a summary of the default constituents included in the model.

Table 3-1: WMM Default Water Quality Parameters

Pollutant Category	Constituent
Oxygen Demand	Biochemcial Oxygen Demand (BOD) Carbonaceous Oxygen Demand (COD)[1]
Sediment	Total Suspended Solids (TSS) Total Dissolved Solids (TDS)[1]
Nutrients	Total Phosphorus Dissolved Phosphorus[1] Total Kjeldahl Nitrogen Nitrate + Nitrite
Metals	Lead Copper Zinc Cadmium
Bacteria	Fecal Coliform

[1]Parameter not evaluated as part of the Watershed Management Model prepared for the Merrimack River watershed

For the Merrimack River Watershed Assessment Study, *E. coli* bacteria will also be evaluated as part of the screening level model. It is assumed that the dynamics of the *E. coli* bacteria perform similar to the fecal coliform bacteria, which is a default parameter in WMM.

COD, dissolved phosphorus, and total dissolved solids were not considered to be of interest in the Merrimack River watershed, and as such, were not included in the model developed for this study.

3.2 Data Requirements

The WMM interface consists of several data input modules, which require the user to enter information on the existing watershed characteristics and the existing pollutant sources. A summary of the data required to run WMM is provided in Table 3-2. Additional information on the data used in the model for the Merrimack River watershed is provided in Section 4.0 of this report.

Table 3-2: WMM Data Requirements

Data Type	Data
Watershed Characteristics	Watershed or sub-watershed area (in acres)
	Existing land use coverage for each watershed or sub-catchment (values calculated as percent of total drainage area)
	Percentage of impervious cover by land use category
Hydrologic Data	Long-term average annual precipitation
	Average annual baseflow
Water Quality Data	Event Mean Concentrations (EMCs) by land use for each water quality parameter
	Inventory of point source discharges, include estimate of average annual discharge volume and pollutant concentrations
Combined Sewer Overflows	Estimate of CSO average annual discharge volume and pollutant concentrations
On-site Wastewater Disposal Systems	Estimate of septic system service area
	Estimate of septic tank failure rate

3.3 Annual Runoff Calculations

WMM calculates the annual runoff from pervious and impervious areas in each land use category by multiplying the average annual rainfall volume by a runoff coefficient. A runoff coefficient of between 0.85 and 1.0 is typically used for impervious areas (i.e. 85-percent to 100-percent of the rainfall is assumed to be converted to runoff from the impervious fraction of each land use). A pervious area runoff coefficient of between 0.05 and 0.30 is typically used.

The total average annual surface runoff from land use "L" is calculated by weighting the impervious and pervious area runoff factors for each land use category as follows:

$$R_L = \left\lfloor C_p(1 - IMP_L) + C_I(IMP_L) \right\rfloor \times I \qquad (3\text{-}1)$$

where:

R_L= Total average annual surface runoff from land use L (inches/year)

IMP_L= Fractional imperviousness of land use L

I= Long-term average annual precipitation (inches/year)

C_P= Pervious area runoff coefficient

C_I= Impervious area runoff coefficient

(Source: Rouge River National Wet Weather Demonstration Project 1998)

Total runoff in a watershed is the area-weighted sum of R_L for all land uses. Information on the percent of imperviousness for each watershed in the Merrimack River model is provided in Section 4.2.

3.4 Non-Point Source Pollutant Loading Factors

The model estimates non-point pollutant loadings based on loading factors that vary by land use and the associated percent imperviousness. The pollutant loading factor M_L is computed for each land use "L" by the following equation:

$$M_L = EMC_L \times R_L \times K \qquad (3\text{-}2)$$

Where:

M_L= Loading factor for land use L (lbs/acre/year)

EMC_L= Event Mean Concentration (EMC) of runoff from land use L (EMC varies by land use and pollutant)

R_L= Total average annual surface runoff from land use L computed by Equation 3-1 (inches/year)

K= 0.2266, a unit conversion constant

(Source: Rouge River National Wet Weather Demonstration Project 1998)

The total annual pollutant load from a sub-basin may be calculated by multiplying the pollutant loading factor by the acreage in each land use and summing for all land uses. For fecal coliform, a conversion multiplier allows an annual load with units of counts per year to be calculated.

3.5 Uncertainty Analysis

Since the non-point pollutant loading factors used in WMM are typically derived from literature values, the model includes the capability to perform an uncertainty analysis with a range of literature values for each land use category. The EMC generally used in the model are assumed to be representative of a "medium" or "most probable" estimate of non-point pollutant loading for each respective land use. Thus, the purpose of the uncertainty analysis is to develop estimates of the extremes, i.e. high and low pollutant loading values, and to assess whether these estimates would result in significantly different outcomes. For the purposes of the Merrimack model, EMCs were based on regional values wherever appropriate.

The statistical approach used in WMM is to estimate the "high" and "low" loading factors for each pollutant. Based on a review of the available EMC data, a Coefficient of Variation (CV) is applied to value for each land use and pollutant. An EMC in the 90th percentile will be exceeded during only 10-percent of the storm events, whereas an EMC in the 10th percentile will be exceeded during 90-percent of the events.

The "high" and "low" EMCs are then computed from the mean EMC and the CV, according to the following relationship:

$$EMC_{(High,Low)} = e^{(U+Z+W)} \tag{3-3}$$

Where:

EMC= "High" or "low" EMC

U= log mean = LN(M/SQRT(1+CV^2))

Z= Standard normal deviate

Z= 1.645 for 95th percentile

Z= 1.282 for 90th percentile

Z= -1.645 for 5th percentile

Z= -1.282 for 10th percentile

W= log standard deviation= SQRT(LN(1+CV^2))

(Source: Rouge River National Wet Weather Demonstration Project 1998)

By varying the standard normal deviate (Z), any pair of percentiles can be used to generate the "high" and "low" EMC values. The modeler may select a single EMC estimate (i.e. low, medium, or high) or all three to evaluate the sensitivity of the model to the EMC values.

3.6 Model Limitations

The Watershed Management Model predicts average annual or seasonal pollutant loadings discharged from the watershed. As previously discussed, the model may also be used to predict the cumulative effects of alternative watershed management decisions (i.e. CSO controls). The model should only be applied to the appropriate spatial (watershed-wide) and temporal (annual or seasonal) scale.

Section 4
Existing Watershed Characteristics

The following section provides a summary of the existing watershed characteristics that were used to develop the Watershed Management Model (WMM) for the Merrimack River watershed. This includes information on the existing land uses, hydrologic characteristics, baseflow concentrations, on-site wastewater disposal systems, and existing point source discharges.

4.1 Watershed Physical Features

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, before it turns abruptly across the New Hampshire-Massachusetts border and flows in a northeasterly direction for approximately another 50 miles in Massachusetts before discharging to the Atlantic Ocean at Newburyport. The mainstem Merrimack River flows past the five major urban centers of Manchester and Nashua, New Hampshire and Lowell, Lawrence, and Haverhill, Massachusetts. The final 22 miles of the River are tidally influenced below Haverhill, Massachusetts.

The Merrimack River watershed covers an area of approximately 5,010 square miles in the south-central portions of New Hampshire (76-percent of the drainage area) and the northeastern portions of Massachusetts (24-percent of the drainage area) (see Figure 1-1), making it the fourth largest watershed in New England. Geographically, the basin encompasses a variety of terrain, from the relatively steep conditions of the White Mountain region in northern New Hampshire to the estuarine coastal basin of northeastern Massachusetts.

4.1.1 Drainage Area Delineation

For the purposes of the screening level analysis, the Merrimack River watershed was divided into 28 sub-catchments, in accordance with the following boundaries:

- Watershed delineations for the Pemigewasset and Winnipesaukee Rivers, which join to form the Merrimack River in Franklin, New Hampshire

- The contributing drainage area to the mainstem Merrimack River from its start in Franklin, New Hampshire to north of Hooksett, New Hampshire (including major tributaries, such as the Contoocook, Soucook, and Suncook Rivers which join the Merrimack River in this region)

- The contributing drainage area to 11 major tributaries (see Table 1-1) that join the Merrimack River downstream of Hooksett, New Hampshire

- Separate delineations for each of the five sponsor communities of Manchester and Nashua, New Hampshire and Lowell, Lawrence, and Haverhill, Massachusetts in order to determine the relative contribution of pollutants from each community

- Six “corridors” delineating the drainage area (outside of the major tributaries) contributing directly to the mainstem Merrimack River south of Hooksett, New Hampshire

The delineations were made in Geographic Information System (GIS) format, based on available coverages from MassGIS and New Hampshire’s Geographically Referenced Analysis and Information Transfer System (GRANIT) and available topographic information from United States Geological Survey (USGS) quad sheets. The watershed delineations are provided in Figure 4-1.

Table 4-1 provides a summary of the 28 sub-basins and the associated drainage area. This information was used as the basis for the development of the Watershed Management Model.

Table 4-1: Merrimack River Sub-watersheds

Category	**Sub-watershed Name**	**Drainage Area (mi^2)**
Sponsor Communities	Manchester, New Hampshire	34.9
	Nashua, New Hampshire	31.7
	Lowell, Massachusetts	14.5
	Lawrence, Massachusetts	7.4
	Haverhill, Massachusetts	35.6
Mainstem Merrimack River	Upper Merrimack (Franklin to Hooksett, NH including major tributaries)	1291
	Merrimack Corridor 1 (Hooksett to Manchester, NH)	51.2
	Merrimack Corridor 2 (Manchester to Nashua, NH)	87.8
	Merrimack Corridor 3 (Nashua, NH to Lowell, MA)	44.4
	Merrimack Corridor 4 (Lowell to Lawrence, MA)	48.6
	Merrimack Corridor 5 (Lawrence to Haverhill, MA)	39.5
	Merrimack Corridor 6 (Haverhill, MA to Atlantic Ocean)	61.1
Major Tributaries	Assabet River	188
	Beaver Brook	114
	Cohas Brook	57.2
	Concord River	81.8
	Upper Nashua River	181
	Lower Nashua River	221

Category	Sub-watershed Name	Drainage Area (mi^2)
Major Tributaries (cont'd)	Pemigewasset River	1017
	Piscataquog River	215
	Powwow River	55.4
	Salmon Brook	22.9
	Shawsheen River	74.9
	Souhegan River	219
	Spickett River	74.9
	Stony Brook	45.6
	Sudbury River	162
	Winnipesaukee River	482

This drainage area delineation allows for the calculation and comparison of pollutant loads from each of the major tributary areas, the sponsor communities, and the portion of the watershed discharging directly to the mainstem Merrimack River between each community. Only the major tributaries discharging downstream of Hooksett, New Hampshire will be evaluated separately, as this is the upper boundary of the Study Area for the monitoring and future modeling efforts, as discussed in Section 1.1. All tributaries discharging between Franklin and Hooksett, New Hampshire have been consolidated into one drainage area, the "Upper Merrimack" watershed.

Figure 4-1
Merrimack River Watershed
Merrimack River Tributary and
Sponsor Community Delineations

CDM

4.2 Land Use Summary

The quality and quantity of stormwater runoff in WMM is directly related to the land use and its associated imperviousness. Table 4-2 provides a summary of the 10 default land use categories specified in the model; users may add additional land use categories to the model, as necessary.

Also included in the table is a summary of the default percent imperviousness assigned to each land used category in WMM, as well as the range of percent directly connected impervious area (DCIA) used in the development of the Watershed Management Model prepared for the Rouge River. The percent DCIA is defined as the portion of the total impervious area which discharges directly to the hydraulic system. Using a single-family home as an example, precipitation falls on the impervious rooftops, sidewalks, and driveways. The sum of these impervious surfaces may represent 30-percent or more of the total lot. However, much of the rain that falls on the roof may drain to the grass, where it can infiltrate. Therefore, not all of the 30-percent impervious area actually contributes runoff to the stormdrain system. According to the WMM User's Manual (1998), the DCIA percentage is typically on the order of one-half of the total impervious area percentage. For the purposes of the Rouge model, the percent DCIAs listed in Table 4-2 were used to calculate the WMM runoff volumes. These percentages were calculated for the Rouge sub-watersheds based on field evaluations in sample areas. As can be seen in Table 4-2, the default percent impervious values provided in WMM fall within the range of percent DCIA calculated for the Rouge River watershed, indicating that these values have been corrected to account for the estimated percent of impervious area directly connected to the hydraulic system.

Table 4-2: Default WMM Land Use, Percent Imperviousness, and Range of Percent DCIA used in the Rouge Watershed Management Model

Land Use Category	WMM Default Percent Imperviousness	Range of % DCIA for the Rouge River watershed
Forest/Rural Open	0.5%	0%- 15.1%
Urban Open	0.5%	0%- 15.4%
Agricultural/Pasture	0.5%	0%- 4.6%
Low Density Residential[1]	3.0%	0%- 11.8%
Medium Density Residential	16.6%	5.0%- 26.5%
High Density Residential[1]	19.6%	0%- 54.8%
Commercial	37.1%	11.3%- 58.9%
Industrial	67.7%	2.2%- 90.3%
Highway	5.0%	0%- 60.9%
Water/Wetlands	56.7%	28.0%- 100%

[1]Land use not used in the WMM for the Merrimack River watershed

The default percentages listed in Table 4-2 were used in the development of the Watershed Management Model for the Merrimack River, since existing information on the impervious cover was not available basin-wide for the Merrimack River watershed. However, the estimated percentage of impervious area was verified during the hydrologic calibration, discussed further in Section 4.4.

It should be noted that the estimated percent imperviousness used in WMM for the highway land use category falls on the low end of the range of typically expected percent DCIA. A sensitivity analysis was performed using the calibrated WMM for the Merrimack River watershed to assess the impact of this estimated percentage on the overall model results. A discussion of this analysis is provided in Section 5.3.

4.2.1 Existing Land Use in the Merrimack River Watershed

Land use information was available for the Merrimack River watershed in GIS format from MassGIS and New Hampshire GRANIT. In cases where these land use categories did not map directly to the ten default categories available in WMM (Table 4-2), categories were combined as appropriate. Information was not available on the density of the residential land use in the Merrimack River watershed. As such, all residential land use was assumed to be “medium” density. Table 4-3 provides a summary of the land use breakdowns for each of the 28 sub-watersheds listed in Table 4-1. The land use composition of the watershed is also shown graphically in Figure 4-1.

The majority of the Merrimack River watershed is comprised of the Forest/Rural Open land use (78.8-percent). In total, urban areas, including medium density residential, commercial, industrial, and urban open land use categories, combine for a distant second at approximately 10.3-percent of the total watershed area. However, the major urban centers, such as the five sponsor communities, are more closely centered around the Merrimack River mainstem, which increases the potential pollutant impacts from these urbanized areas.

4.2.2 Comparison to the Rouge River Watershed

The following section provides a brief description of the Rouge River watershed, and compares the general watershed characteristics to that of the Merrimack River watershed.

The Rouge River watershed, located in southeast Michigan, runs through the most densely populated and urbanized land area in the state. The watershed is approximately 466 square miles in size and includes all or part of 48 municipalities in three counties, with a population of over 1.5 million. The Rouge River empties into the Detroit River, which is the connecting channel between Lakes St. Clair and Erie.

The topography varies throughout the watershed as a result of glacial activity from the prehistoric period. The headwaters of the Rouge, primarily in the north and west areas of the watershed are hilly, while the southeast is relatively flat. The watershed contains a range of land uses, from rural, undeveloped areas in the west and north, to urban, highly developed areas in the east and south. Nearly 67-percent of the Rouge River watershed is comprised of urban land uses. The majority of the urban development (47-percent) consists of single and multi-family residential developments. Approximately 20-percent of the watershed is in the commercial, industrial, and transportation land use category. Approximately 24-percent of the Rouge River watershed is open/undeveloped, and another ten-percent is agricultural.

Eleven of the 48 communities in the Rouge River watershed are entirely or partially served by combined sewer systems. The combined sewer service area of these communities is approximately 58,000 acres (nearly 90 square miles), which is close to 20-percent of the total drainage area. There are approximately 115 CSO outfalls in the Rouge River watershed.

By comparison, the Merrimack River watershed as a whole has a significantly lower percentage of urbanized area. However, the land use composition of the five sponsor communities is fairly similar to that of the Rouge River watershed.

Table 4-3: Merrimack River Watershed Land Use Summary

CATEGORY	SUBBASIN	TOTAL AREA (mi^2)	LAND USE CATEGORY															
			Forest/Rural Open		**Urban Open**		**Agriculture/Pasture**		**Medium Density Residential**		**Commercial**		**Industrial**		**Highway**		**Water/Wetland**	
			%	*Area*	*%*	*Area*	*%*	*Area*	*%*	*Area*	*%*	*Area*	*%*	*Area*	*%*	*Area*	*%*	*Area*
Sponsor Communities	Manchester, NH	34.9	38.68%	13.51	5.09%	1.78	1.24%	0.43	31.67%	11.07	9.23%	3.22	3.44%	1.20	3.79%	1.32	6.87%	2.40
	Nashua, NH	31.7	43.48%	13.79	4.92%	1.56	3.89%	1.23	27.59%	8.75	8.52%	2.70	3.39%	1.08	3.50%	1.11	4.71%	1.49
	Lowell, MA	14.5	16.50%	2.40	7.50%	1.09	0.00%	0.00	52.49%	7.63	14.09%	2.05	2.94%	0.43	0.88%	0.13	5.60%	0.81
	Lawrence, MA	7.4	5.53%	0.41	5.66%	0.42	0.00%	0.00	54.09%	4.01	13.54%	1.00	12.89%	0.96	3.01%	0.22	5.29%	0.39
	Haverhill, MA	35.6	45.65%	16.27	4.50%	1.60	12.63%	4.50	20.53%	7.32	4.83%	1.72	0.71%	0.25	2.41%	0.86	8.75%	3.12
Mainstem Merrimack River	Upper Merrimack	1290.6	86.91%	1121.69	0.34%	4.39	5.17%	66.73	2.65%	34.20	0.36%	4.65	0.07%	0.90	0.69%	8.91	3.80%	49.04
	Merrimack Corridor 1	51.2	86.67%	44.33	0.17%	0.09	4.93%	2.52	3.47%	1.78	0.19%	0.10	0.14%	0.07	1.58%	0.81	2.85%	1.46
	Merrimack Corridor 2	87.8	74.86%	65.69	1.10%	0.96	9.13%	8.01	7.79%	6.83	2.06%	1.80	0.45%	0.40	1.27%	1.12	3.35%	2.94
	Merrimack Corridor 3	44.4	66.19%	29.37	2.74%	1.22	9.74%	4.32	11.95%	5.30	2.15%	0.95	0.21%	0.09	0.88%	0.39	6.13%	2.72
	Merrimack Corridor 4	48.6	64.99%	31.62	2.24%	1.09	7.94%	3.86	16.12%	7.84	1.57%	0.77	0.00%	0.00	3.22%	1.57	3.90%	1.90
	Merrimack Corridor 5	39.5	51.40%	20.31	2.29%	0.91	11.62%	4.59	16.73%	6.61	3.18%	1.25	0.56%	0.22	2.79%	1.10	11.44%	4.52
	Merrimack Corridor 6	61.1	52.98%	32.38	1.71%	1.05	13.41%	8.19	15.24%	9.31	3.34%	2.04	0.19%	0.12	0.84%	0.52	12.29%	7.51
Major Tributaries	Assabet River	187.9	72.46%	136.19	1.24%	2.33	7.93%	14.90	13.00%	24.43	2.14%	4.02	0.05%	0.09	1.15%	2.17	2.23%	4.19
	Beaver Brook	113.6	66.56%	75.58	1.15%	1.31	7.28%	8.27	19.17%	21.77	1.76%	2.00	0.07%	0.08	1.30%	1.47	2.29%	2.60
	Cohas Brook	57.2	86.62%	49.55	0.39%	0.22	1.25%	0.72	3.90%	2.23	0.53%	0.30	0.00%	0.00	0.20%	0.11	7.12%	4.07
	Concord River	81.8	67.79%	55.48	0.55%	0.45	5.77%	4.72	19.20%	15.71	2.63%	2.15	0.10%	0.08	2.96%	2.42	0.99%	0.81
	Upper Nashua River	181.1	81.87%	148.30	0.32%	0.58	10.07%	18.24	4.18%	7.57	0.62%	1.12	0.14%	0.26	0.14%	0.26	2.67%	4.83
	Lower Nashua River	221.3	68.57%	151.78	2.26%	5.00	9.64%	21.34	10.29%	22.78	3.65%	8.08	0.84%	1.85	0.80%	1.78	3.94%	8.73
	Pemigawasset River	1016.5	92.31%	938.33	0.43%	4.37	2.59%	26.33	1.43%	14.54	0.15%	1.52	0.03%	0.30	0.55%	5.59	2.49%	25.31
	Piscataquog River	214.9	90.16%	193.80	0.35%	0.75	5.37%	11.53	1.62%	3.49	0.25%	0.55	0.03%	0.06	0.00%	0.00	2.21%	4.75
	Powwow River	55.4	68.46%	37.89	0.92%	0.51	11.37%	6.29	9.19%	5.09	1.31%	0.72	0.06%	0.03	0.13%	0.07	8.56%	4.74
	Salmon Brook	22.9	77.74%	17.78	0.63%	0.14	12.88%	2.94	2.02%	0.46	0.29%	0.07	0.00%	0.00	0.00%	0.00	6.44%	1.47
	Shawsheen River	74.9	45.04%	33.74	3.16%	2.37	2.66%	2.00	35.36%	26.49	10.81%	8.10	0.57%	0.43	1.87%	1.40	0.54%	0.40
	Souhegan River	218.8	84.63%	185.20	0.73%	1.59	7.76%	16.98	4.26%	9.31	0.75%	1.64	0.09%	0.21	0.21%	0.45	1.58%	3.45
	Spickett River	74.9	62.61%	46.89	1.42%	1.07	8.86%	6.64	14.15%	10.60	4.09%	3.06	0.10%	0.08	1.43%	1.07	7.33%	5.49
	Stony Brook	45.6	70.67%	32.25	0.39%	0.18	8.56%	3.90	13.99%	6.38	1.79%	0.82	0.04%	0.02	1.75%	0.80	2.82%	1.29
	Sudbury River	161.6	54.51%	88.09	2.41%	3.89	8.06%	13.02	22.90%	37.00	5.36%	8.66	0.49%	0.78	1.30%	2.09	4.98%	8.05
	Winnipesauke River	481.9	66.90%	322.36	0.88%	4.24	4.14%	19.95	6.55%	31.56	0.87%	4.19	0.04%	0.19	0.34%	1.64	20.29%	97.77

Source: MassGIS and New Hampshire GRANIT GIS coverages

4.3 Event Mean Concentrations

Non-point source loads calculated by WMM are a combination of pollutant loads resulting from stormwater runoff and from "failing" septic systems (total phosphorus and nitrogen). WMM uses land use categories and associated event mean concentrations (EMCs), depending on the constituent of concern, to simulate pollutant loads carried in stormwater runoff. Thus, EMCs are a key component of the non-point source pollution estimates in WMM. The following section provides a summary of the regional EMCs developed for the Merrimack River watershed, as well as the default WMM EMC values.

4.3.1 EMCs in the Merrimack River Watershed

Pollutant EMCs are widely available in published literature at both the national and regional scale for most of the primary pollutants of concern. EMCs are flow-weighted average concentrations calculated for a given storm event. They are defined as the sum of individual measurements of stormwater pollutant loads divided by the total storm runoff volume.

On May 15, 2003, CDM issued a memorandum summarizing the available EMC values both nationally and regionally from the following sources:

- *Default EMC values available in the Watershed Management Model (WMM).* These values were based on data from the USEPA's National Urban Runoff Program (NURP) (1983), the Northern Virginia Planning District Commission (1979, 1983), and the Federal Highway Administration (1990)

- *Regional values averaged from New England studies.* Mean regional EMCs were computed from available data collected in the Boston area during the USEPA's NURP and stormwater sampling data from other sampling programs in Boston, Massachusetts (1999-2000), Worcester, Massachusetts (2002-2003), Manchester, New Hampshire (1992), and Lowell, Massachusetts (1992)

- *National values averaged throughout the United States.* Mean national EMCs were computed from several sources, including USEPA's NURP, the Rouge River National Wet Weather Demonstration Project, USGS, USEPA's National Pollutant Discharge Elimination System (NPDES) database, and monitoring data from Maryland, Michigan, and Virginia

A copy of this memorandum is included in Appendix A. Following the release of this memo, the regional values were updated based on EMC values provided in additional studies received from the USEPA that were conducted in urbanized New England areas.

A review of the available data revealed that the relative magnitude of the reported EMCs was fairly consistent among the data sources. As a result, CDM recommended the use of the New England regional EMC values for the land use categories and pollutant constituents for which this data was available (*i.e.* commercial, industrial, and medium density residential), and the use of default values in the WMM model for all others. A sensitivity analysis was performed during the model runs to evaluate the sensitivity of the WMM results to changes in the EMCs between the default WMM values and the regional values (where available). Additional information on the model scenarios is provided in Section 5.

A summary of the regional and default WMM EMC values for the pollutants of concern are provided in Table 4-4 for the eight land use categories listed in Table 4-3. The coefficient of variation (CV) for each EMC is also provided, defined as the standard deviation of the available EMC values divided by their mean for each pollutant and respective land use category. The coefficient of variation is a relative measure of the variability in a data set; the higher the value, the larger the variability. In WMM, it is used to assess the uncertainty of the pollutant loading factors, as discussed in Section 3.5 of this report. Figure 4-2 provides a graphical comparison of the default WMM and regional EMCs for the commercial, industrial, and medium density residential land uses.

E. coli values were only available for the regional medium density residential land use category. Therefore, a standard conversion factor of 125 E. coli= 200 Fecal coliform bacteria was used to convert the available Fecal coliform data into E. coli values for all other land uses. Is important to note, however, that this ratio did not hold true for the medium density residential land uses, where regional data was available. In contrast, the regional data points to higher E. coli values as compared to the fecal coliform concentrations.

Table 4-4: Summary of WMM Default and Regional Event Mean Concentrations by Land Use Category

Parameter	Units	EMCs BY LAND USE CATEGORY																					
		Agriculture/ Pasture		Commercial				Forest/Rural Open		Highway		Industrial				Medium Density Residential				Urban Open		Water/ Wetlands	
		WMM Default		WMM Default		Regional EMC		WMM Default		WMM Default		WMM Default		Regional EMC		WMM Default		Regional EMC		WMM Default		WMM Default	
		EMC	*CV*	*EMC*	*CV*	*EMC*	*CV*	*EMC*	*CV*	*EMC*	*CV*	*EMC*	*CV*	*EMC*	*CV*	*EMC*	*CV*	*EMC*	*CV*	*EMC*	*CV*	*EMC*	*CV*
BOD	mg/L	3.0	0.5	21	0.3	10	0.15	3.0	0.5	24	0.3	24	0.3	12	0	38	0.4	23	1.13	3.0	0.5	4.0	0.3
Total Suspended Solids	mg/L	145	0.5	77	0.9	44	0.16	51	0.5	141	0.9	149	0.9	42	0.19	70	1	49	0.94	51	0.5	6.0	0.9
Total Phosphorus	mg/L	0.37	0.7	0.33	0.7	0.15	0.31	0.11	0.7	0.43	0.7	0.32	0.7	0.11	0.03	0.52	0.7	0.41	0.5	0.11	0.7	0.08	0.7
TKN	mg/L	1.92	0.5	1.74	0.4	1.25	0.4	0.94	0.5	1.82	0.4	2.08	0.4	2.9	0	3.32	0.7	2.38	0.45	0.94	0.5	0.79	0.4
Nitrate/Nitrite	mg/L	4.06	0.5	1.23	0.5	0.6	0.47	0.8	0.5	0.83	0.5	1.89	0.5	1.11	0.38	1.83	0.8	1.12	0.65	0.8	0.5	0.59	0.5
Lead	mg/L	0	0	0.049	0.7	0.101	0.54	0	0	0.049	0.7	0.072	0.7	0.063	0	0.057	0.8	0.057	1.42	0.014	0	0.011	0.7
Copper	mg/L	0	0	0.037	0.8	0.084	0.46	0	0	0.037	0.8	0.058	0.8	0.113	0	0.026	1	0.033	0.84	0	0	0.007	0.8
Zinc	mg/L	0	0	0.156	1.1	0.151	0.24	0	0	0.156	1.1	0.671	1.1	0.164	0	0.161	0.8	0.134	0.45	0.04	0	0.03	1.1
Cadmium	mg/L	0	0	0.003	1.1	0.002	1.08	0	0	0.003	1.1	0.005	1.1	0.005[1]	1.1	0.004	0.8	0.004[1]	0.8	0.001	0	0.001	1.1
Fecal Coliform	#/100mL	5,000	1	2,600	1	9,306	1	300	1	600	1	600	1	1,467	1	25,001	1	12,360	1	5,000	1	300	1
E. coli[2]	#/100mL	3,125	1	N/A	N/A	5,816	1	188	1	375	1	N/A	N/A	917	1	N/A	N/A	26,982	2	3,125	1	188	1

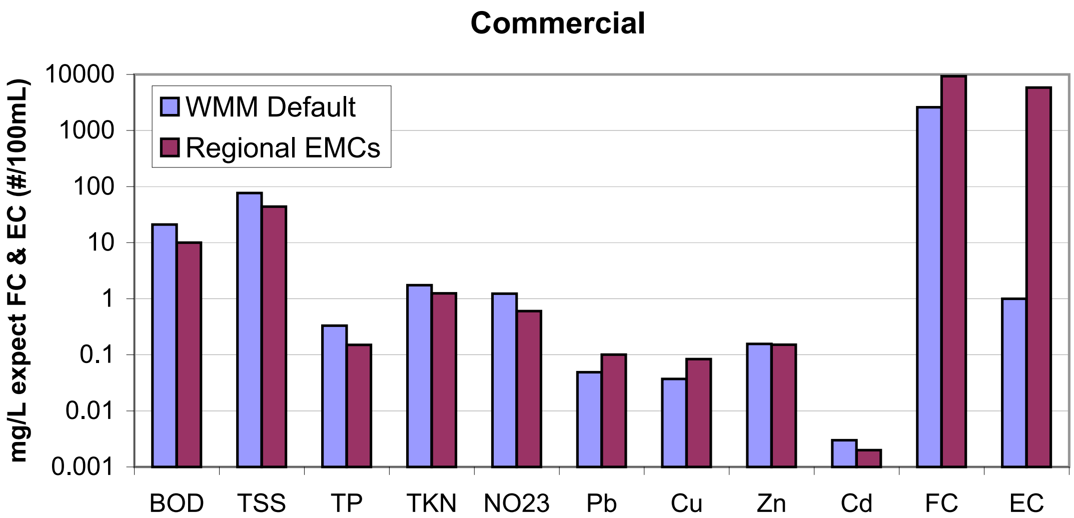
<u>Note</u>: Regional EMCs were not available for the following land use categories: agricultural/pasture, forest/rural open, highway, urban open, and water/wetlands

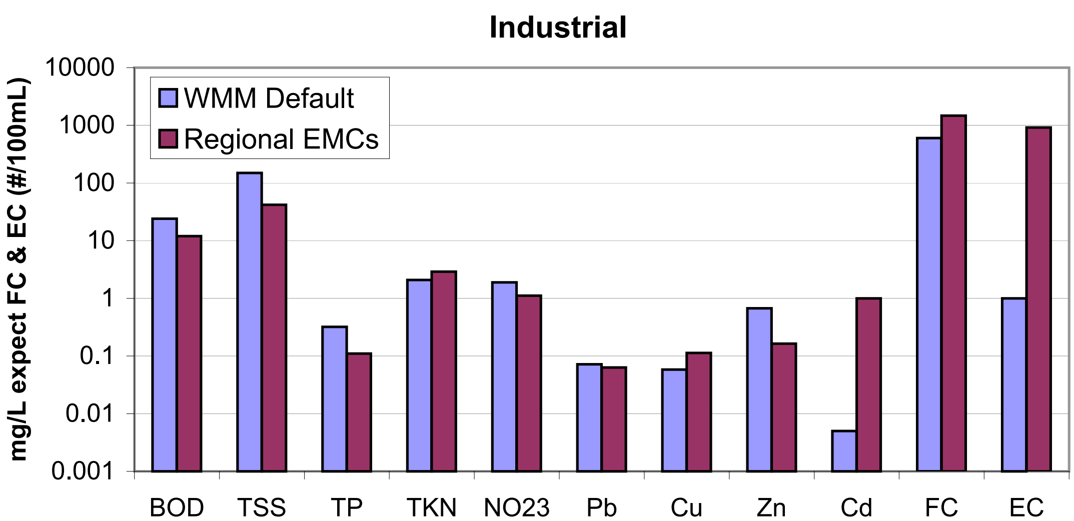
[1]Indicates default WMM EMC and CV was used in place of regional value

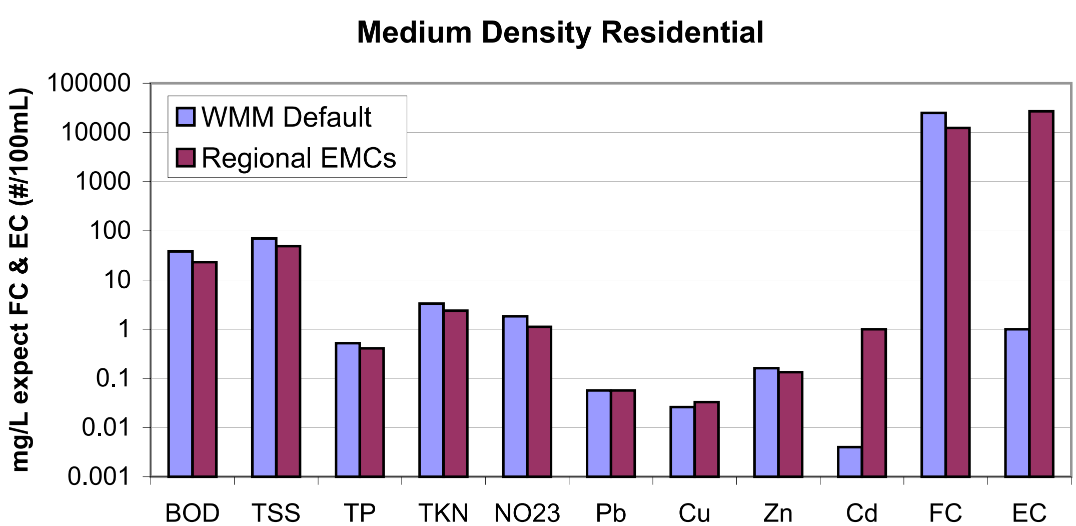
[2]All E. coli values except for the medium density residential (where regional data was used), are based on a conversion factor of 125 E. coli= 200 Fecal coliform

CV= Coefficient of Variation

Figure 4-2: Comparison of WMM Default and Regional EMC values







Note: All plots are in log scale

4.4 Hydrologic Characteristics

The following section provides a summary of the existing hydrologic characteristics of the Merrimack River watershed, including annual precipitation, annual baseflow volume and water quality, and pervious and impervious runoff coefficients.

4.4.1 Annual Precipitation

Precipitation in the Merrimack River watershed is fairly evenly distributed throughout the year. There are, however, large spatial variations in the amount and type of precipitation (*e.g.* rain versus snow), primarily as a result of the effects of terrain, elevation, latitude, and proximity to the ocean (Flanagan *et al.* 1999).

There are currently several climate stations in the basin that operate under the National Weather Service's Cooperative Station Network (COOP). Meteorological data collected at the COOP stations is generally limited to daily measurements of maximum and minimum temperatures, precipitation, snowfall and depth of snow on the ground. One observation is typically made at the same time each day; however, several stations in the Merrimack River watershed also record hourly precipitation. The National Weather Service also runs one "first-order" station in the watershed at the municipal airport in Concord, New Hampshire. This station records a variety of climatic parameters, including precipitation, every hour throughout the day. Additional information on these monitoring stations and precipitation characteristics in the basin is provided in Section 3.0 of "Hydraulics and Hydrology Assessment " Report prepared under Task 3B of this Study.

For the purposes of the Watershed Management Model, the following three precipitation scenarios were analyzed (1) drought conditions, (2) normal or average conditions, and (3) wet conditions. A statistical analysis of precipitation records was performed at nine COOP stations in the watershed with long-term rainfall records (defined as 30 years or more of data). At each station the precipitation amount corresponding to the 5^{th}, 50^{th}, and 95^{th} percentiles was identified. The precipitation values from the nine stations were averaged to come up with a single value that represented the drought, normal, and wet year precipitation amounts. Table 4-5 provides a summary of the climate stations used in this analysis, the station period of record, and the corresponding rainfall amount for each condition.

Table 4-5: Summary of Drought, Normal, and Wet Year Precipitation Characteristics

State	Climate Station	COOP ID	Period of Record	Precipitation (inches)		
				Drought	*Normal*	*Wet*
NH	Concord Municipal Airport	271683	1921-2001	27.85	36.45	47.99
	MacDowell Dam, Peterborough	275013	1951-1991	36.92	48.47	56.31
	Nashua	275712	1949-1996	33.98	43.28	52.12
	Plymouth	276945	1952-2001	33.04	42.45	55.07
MA	Ashburnham	190190	1949-2001	36.02	48.17	58.66
	Bedford	190535	1958-2001	36.04	45.83	58.12
	Haverhill	193505	1950-2001	32.51	44.22	59.63
	Lawrence	194105	1926-2001	32.54	42.06	53.32
	Newburyport	195285	1949-2001	34.23	43.62	59.90
AVERAGE=				**33.68**	**43.84**	**55.68**

Note:

Drought= 5th percentile

Normal= 50th percentile

Wet= 95th percentile

4.4.2 Annual Baseflow Characteristics

The Merrimack River and its major tributaries evaluated in this study exhibit dry-weather flow due to baseflow, permitted industrial and municipal discharges, and illegal discharges. As discussed in Section 3.1, the baseflow pollutant load capabilities in WMM were not used for the model of the Merrimack River watershed due to concerns over the potential for double counting pollutant loads from point sources and septic systems. However, the hydrologic component of the baseflow was used to help calibrate the model.

Annual Baseflow Volume

The baseflow volume contribution was estimated from daily streamflow records recorded at the USGS gaging station in the Merrimack River below the confluence of the Concord River in Lowell, Massachusetts (01100000) using a streamflow partitioning method developed by the USGS (Rutledge 1993). The USGS developed a series of FORTRAN computer programs, know as "PART", that estimate the recession of groundwater discharge and estimate the mean groundwater recharge and discharge. The USGS analysis is based on the following two assumptions:

- All groundwater discharges to the stream (except losses due to riparian evapotranspiration)

- Regulation and diversion of flow is negligible

These assumptions are generally valid for the Merrimack River. However, it is important to note that there are numerous lakes and aquifers in the watershed that may intercept and store groundwater throughout the watershed; most notably is Lake Winnipesaukee, which covers an area of approximately 72 square miles. However, as discussed in the "Hydrology and Hydraulics Assessment" report prepared under Task 3B of this Study, the impoundments along the mainstem Merrimack River are typically operated under "run-of-the-river" conditions, which validates the second assumption on the mainstem.

PART estimates that baseflow is equal to streamflow on days that fit required antecedent recession conditions. The program linearly interpolates the baseflow on other days (Rutledge 1993). Daily baseflow volumes are summed for a particular year or period of record in order to obtain an average annual or period of record baseflow (Harold 1994).

Separate baseflow estimates were developed for daily streamflow data in recorded in the mainstem Merrimack River at a USGS gage in Lowell, Massachusetts (01100000) using PART for the "drought", "normal", and "wet" year precipitation conditions discussed in Section 4.4.1. The years for the baseflow analysis were selected based on precipitation records at the NWS station in Lawrence, Massachusetts, which is the closest COOP station to the USGS gaging station in Lowell, Massachusetts. Using the drought, normal, and wet year precipitation statistics provided in Table 4-5, data from the Lawrence station was evaluated to identify the years that most closely approximated the three statistical values. The streamflow data from those years was then used to estimate the baseflow volume.

Table 4-6 provides a summary of the baseflow volume for each condition, as well as the period of streamflow record on which this value was based.

Table 4-6: Summary of Mean Discharge and Baseflow Volumes at Merrimack River in Lowell, Massachusetts

Hydrologic Condition	Year	Mean Discharge		Mean Baseflow		Baseflow Index[2]
		cfs	*in/yr*	*cfs*	*in/yr*	
Drought	1980	5445	16.72	3763	11.55	69.1%
Normal	1960	9010	27.22	6260	19.22	69.5%
Wet	1954	10,706	32.87	7400	22.72	69.1%

[1]Baseflow analysis performed on data collected at the USGS gaging station in the Merrimack River downstream of the confluence with the Concord River in Lowell, Massachusetts (01100000; drainage area= 4425mi^2). Values are based on the calendar year, not water year
[2]Defined as mean baseflow/ mean discharge

It is important to note these baseflow volumes do not reflect a purely groundwater component. They also include discharges from WWTP and industrial dischargers (see Section 4.6) and any water released from storage in upstream lakes and ponds. In other words, all flows not directly attributable to storm runoff are termed "baseflow".

4.4.3 Pervious and Impervious Runoff Coefficients

As part of the hydrologic parameters in WMM, the user is asked to specify pervious and impervious runoff coefficients. These parameters may be used to calibrate the model to the average annual or seasonal runoff during the calibration period. These coefficients may be used to account for surface runoff, initial abstraction, and evapotranspiration (Rouge River National Wet Weather Demonstration Project 1998). Typical ranges of the runoff coefficients are as follows:

- *Pervious:* 0.05 to 0.30 (FDOT 1987)

- *Impervious:* 0.85 to 1.0 (Linsley and Franziani 1979)

A different set of calibration values was developed for the each of the three hydrologic conditions evaluated in this study (i.e. drought, normal, and wet year precipitation), since soil moisture content can either increase or decrease runoff potential during different climatic conditions. The model was calibrated to the average annual streamflow at the following two USGS gaging stations:

- Merrimack River near Goffs Falls, below Manchester, New Hampshire (01092000)

- Concord River below R. Meadow Brook at Lowell, Massachusetts (01099500)

Total flow estimated in WMM for the appropriate contributing sub-areas was summed to provide an estimate of the streamflow at each these stations. The model was then validated based on the average annual flows at the USGS gaging station on the Merrimack River below Concord River at Lowell, Massachusetts (01100000).

Table 4-7 provides summary of the calibrated runoff coefficients and the model calibration/validation results as compared to the actual streamflow values for each of the three hydrologic scenarios. The calibrated/validated values were generally well within five to 10-percent of the measured average annual discharge, indicating good agreement between the model results and the average annual hydrologic conditions.

Due to the dominance of the forested/open space land use category in the Merrimack River watershed, the predicted annual streamflow values are more sensitive to variations in the pervious runoff coefficient, as opposed to the impervious value. The calibrated pervious coefficients are low during the drought conditions, and increase during the normal and wet years, indicating that, as one would expect, a higher percentage of the annual precipitation is infiltrated during the drier conditions. A constant value of 0.9 was used for the impervious coefficient, indicating very little variation in this parameter in response to the governing climatic conditions.

Table 4-7: Summary of WMM Hydrology Calibration/ Validation

Hydrologic Condition/USGS Gaging Station[1,2]	Calibration/ Validation Year	Actual Average Annual Q (cfs)	WMM Calibrated/ Validated Average Annual Q (cfs)	Percent Difference	Calibrated Runoff Coefficients	
					Pervious	*Impervious*
Drought Conditions:						
Merrimack River near Goffs Falls	1980	3,330	3,781	11.9%		
Concord River at Lowell, MA		479	490	2.2%	0.05	0.9
Merrimack River at Lowell, MA		5,445	5,466	0.4%		
Normal Conditions:						
Merrimack River near Goffs Falls	1960	6,484	5,963	-8.7%		
Concord River at Lowell, MA		678	787	13.9%	0.077	0.9
Merrimack River at Lowell, MA		9,010	8,671	-3.9%		
Wet Conditions:						
Merrimack River near Goffs Falls	1954	7,352	7,280	-1.0%		
Concord River at Lowell, MA		933	995	6.2%	0.1	0.9
Merrimack River at Lowell, MA		10,710	10,614	-0.9%		

[1]Tributary sub-watersheds in WMM:

Merrimack River near Goffs Falls: Pemigewasset River, Winnipesaukee River, Upper Merrimack, Piscataquog River, Merrimack Corridor 1, and Manchester, New Hampshire

Concord River at Lowell, MA: Assabet River, Sudbury River, and Concord River

Merrimack River at Lowell, MA: Pemigewasset River; Winnipesaukee River; Upper Merrimack; Piscataquog River; Merrimack Corridor 1, 2, & 3; Manchester & Nashua, New Hampshire; Lowell, Massachusetts; Cohas Brook; Souhegan River; Upper and Lower Nashua River; Salmon Brook; Stony Brook; and Beaver Brook

[2]Runoff coefficients were calibrated to the annual average flows at Goffs Falls and on the Concord River; the model hydrology was validated on the annual flows at Lowell, MA

4.5 Existing Combined Sewer Overflows

Combined sewer overflows (CSOs) currently exist in the following five sponsor communities of the Merrimack River Watershed Assessment Study: Manchester and Nashua, New Hampshire and Lowell, Greater Lawrence Sanitary District (GLSD), and Haverhill, Massachusetts. These CSOs discharge combined sanitary and stormwater flows of varying quantity and quality to the Merrimack River and several of its major tributaries. Table 4-8 presents a summary of the maximum number of discharge events and the total annual discharge volumes for each community.

Table 4-8: Summary of Average Annual CSO Discharges

Community	Maximum Number of Discharge Events per Year	Average Annual Discharge Volume (MG)
Manchester, New Hampshire	49	220
Nashua, New Hampshire	25	26
Lowell, Massachusetts	37	352
GLSD, Massachusetts	14	112
Haverhill, Massachusetts	41	71
TOTAL/MAXIMUM=	**49**	**781**

MG= million gallons

Source: CDM 1995, 1997, 2001, 2002a, and 2002b; Personal communication with Metcalf & Eddy (5/23/03)

Additional information on the CSO systems in each of the five communities is provided in Section 2.0 of the "Summary of Information on Pollutant Sources" Report developed under Task 2C of this study.

Table 4-9 provides a summary of the CSO water quality concentrations for the constituents of concern, as well as the CSO flow (in million gallon per day) for each of the five communities. These values are based on the representative CSO concentrations selected for each community and identified in each community's respective Long-Term Control Plans (LTCPs). In situations where water quality data for a particular parameter was not available for a community, the average of the available data from the other communities was used in place of the missing data. It should be noted that the E. coli data for the Manchester CSOs appears low in comparison to that for the two other communities where monitoring data was available. CSO sampling performed as part of the Merrimack River Watershed Assessment Study will provide a more accurate estimate of existing concentrations. This data will be used during the subsequent, more detailed modeling work.

Monitoring data for nitrate/nitrite and cadmium was not available for any of the five communities. In both cases, the recommended CSO concentrations from WMM were used for these parameters. These recommended values were derived from CSO data collected as part of the Rouge River National Wet Weather Demonstration Project.

Table 4-9: Summary of CSO Water Quality Concentrations

Parameter	Unit	Manchester, NH	Nashua, NH	Lowell, MA	GLSD, MA	Haverhill, MA
BOD[1]	mg/L	53	18	60	41	43
Total Suspended Solids	mg/L	211	45	107	120	53
Total Phosphorus	mg/L	0.5	0.693	1.1	0.7	0.84
TKN[2]	mg/L	7.6	1.51	3.78	2.24	3.78
Nitrate/Nitrite[3]	mg/L	0.33	0.33	0.33	0.33	0.33
Lead	mg/L	0.053	0.025	0.06	0.073	0.032
Copper	mg/L	0.052	0.029	0.044	0.041	0.057
Zinc	mg/L	0.211	0.084	0.129	0.157	0.15
Cadmium[3]	mg/L	0.004	0.004	0.004	0.004	0.004
Fecal Coliform[4]	cfu/100mL	172,750	172,750	172,750	165,000	180,500
E. coli[5]	cfu/100mL	40,000[6]	215,000	126,500	126,500	124,500

[1]BOD value for Haverhill, MA is average of four other communities

[2]TKN value for Lowell and Haverhill, MA is average of three other communities

[3]Nitrate/Nitrite and Cadmium values based on recommended concentrations in WMM. Values were derived from the Rouge River CSO data.

[4]Fecal Coliform value for Manchester, NH, Nashua, NH, and Lowell, MA is an average of two other communities

[5]E. coli value for Lowell, MA and GLSD is an average of three other communities

[6]E. Coli value for Manchester CSOs appears low in comparison to other communities. Wet-weather sampling conducted as part of the Merrimack River Watershed Assessment Study will provide a better estimate.

4.6 Existing Point Source Discharges

Information on the existing municipal and industrial points source discharges to the Merrimack River watershed were collected under Task 2C of the Merrimack River Watershed Assessment Study, and summarized in the DRAFT "Summary of Information on Pollutant Sources" Report, dated September 2003. This information was compiled from a database of results from monthly monitoring reports submitted to USEPA by each of the respective dischargers in accordance with their NPDES permits. The USEPA supplied CDM with data from this database on March 21, 2003 for monthly reports submitted between 1997 and 2002; however, in some cases, only information from a limited number of years was available.

A total of 46 municipal and privately-owned wastewater treatment plants are permitted to discharge to the mainstem Merrimack River and its tributaries throughout the watershed. Of these, 32 are classified as "major" dischargers by the U.S. Environmental Protection Agency (USEPA); the remaining 14 are classified as "minor" dischargers. The USEPA defines major dischargers as those facilities with design flows greater than one million gallons per day.

Additionally, according to information received from USEPA on March 21, 2003, there are a total of 48 industrial facilities that currently discharge in the Merrimack River watershed. Of these, 11 are classified as "major" dischargers by USEPA; the remaining 37 are classified as "minor" dischargers.

Table 4-10 provides a summary of the total volume of WWTP and industrial dischargers in the Merrimack River watershed, organized by sub-watershed categories as provided in Table 4-1.

Table 4-10: Summary of Total WWTP and Industrial Discharges in the Merrimack River Watershed

Drainage Area Category	Total WWTP Flow (MGD)	Total Industrial Flow (MGD)
Sponsor Communities	108	6.19
Mainstem Merrimack River	23.3	243[1]
Major Tributaries	44.7	4.10
TOTAL=	**176**	**253**

[1]Note: 238 MGD of flow is from a hydropower cooling water discharge from PSNH
MGD= Million gallons per day

Table 4-11 provides a summary of the flow-weighted concentrations used in the Watershed Management Model; these values include both industrial and WWTP discharges. Point source information was only entered into the model for the dischargers along the mainstem. It was assumed that the point sources on the tributaries would have limited impact due to (1) the attenuation of pollutants before they entered the mainstem Merrimack River, and (2) the relatively small portion of the total flow that may be attributed to the point source discharges.

Monitoring data was not available for total phosphorus, nitrate/nitrite, or TKN at any of the municipal dischargers in the watershed. As a result, the following concentrations were used based on literature values:

- Total Phosphorus: 3.0mg/L
- Nitrate/Nitrite: 3.0mg/L
- TKN: 15mg/L

These concentrations were applied to all WWTP discharges and were used to develop flow-weighted concentrations for the sub-watersheds. A value of zero was assigned to all other parameters where no data was available.

Similarly, E. coli monitoring data was only available for the WWTPs in Manchester and Nashua, New Hampshire. As a result, this information was used to develop a typical WWTP E. coli discharge concentration, which was then applied to each of the other WWTPs in the Merrimack River watershed. It is important to note that both WWTPs reported only the maximum E. coli discharge concentration, so an average of these concentrations was used.

Table 4-12 provides a summary of the WWTP and industrial dischargers in each sub-watershed, as well as the average discharge in million gallons per day. All average flow values are based on monthly monitoring report data collected from the USEPA and summarized under Task 2C.

Table 4-11: Summary of Point Source Water Quality

Watershed	Total Flow (MGD)	Flow-Weighted Concentration (mg/L), except as noted[1]										
		BOD	*TSS*	*TP*	*TKN*	*NO_2/NO_3*	*Lead*	*Copper*	*Zinc*	*Cadmium*	*Fecal Coliform*[2]	*E. coli*[2]
Manchester, NH	23.25	22.9	16.4	2.91	14.6	2.91	0.0013	0.0056	0.067	0.0005	14.6	176
Nashua, NH	13.83	34.6	14.6	42.9	14.7	2.93	0.0055	0.037	0.077	0.0005	14.7	226
Lowell, MA	34.00	15.2	14.4	2.81	14.0	2.81	0	0	0	0	11.5	255
Lawrence, MA	31.18	14.5	8.87	2.91	14.6	2.91	0	0	0	0	14.1	265
Haverhill, MA	11.76	11.3	9.01	2.44	12.2	2.44	0	0	0	0	4.24	222
Upper Merrimack	249	0.96	5.02	0.13	0.67	0.13	0.0001	0.006	0.0016	0.00004	0.67	30
Merrimack Corridor 1	0.63	16.5	19.9	3	15	3	0	0.008	0.055	0.0005	15	79
Merrimack Corridor 2	5.33	14.0	15.6	3	15	3	0.0031	0.012	0.148	0.0018	15	129
Merrimack Corridor 3	3.39	0	18.0	0	0	0	0	0	0	0	0	0
Merrimack Corridor 4	0.58	0	6.43	0	0	0	0	0	0	0	0	0
Merrimack Corridor 5	0.014	0	0	0	0	0	0	0.050	0	0	0	0
Merrimack Corridor 6	6.04	20.9	16.8	2.95	14.76	2.95	0	0.022	0.00006	0	80	268

[1]Values based on information received from USEPA on March 21, 2003 and presented in the "Summary of Information on Pollutant Sources" Report

[2]Units in cfu/100mL

Table 4-12: Summary of WWTP and Industrial Discharges

Sub-watershed[1]	Discharger Name	Average Flow (MGD)
Manchester, NH	Manchester WWTF	22.56
	Osram Sylvania, Inc.	0.03
	Nylon Corp of America	0.66
Nashua, NH	Nashua WWTF	13.58
	Hampshire Chemical Corp	0.25
Lowell, MA	Lowell Regional W&WW Utility	31.83
	Majilite Manufacturing, Inc.	0.005
	Boott Hydropower- E.L. Field	0.23
	Lowell National Historic Park	1.00
	Boott Hydropower- Hamilton	0.002
	Boott Hydropower- John St. Station	0.01
	Lowell Regional WTF	0.93
Lawrence, MA	Greater Lawrence Sanitary District	30.29
	Newark Atlantic Paperboard	0.16
	Lawrence Hydroelectric Assoc.	0.73
Haverhill, MA	Haverhill WPAF	9.58
	Haverhill Paperboard Corp	2.19
Upper Merrimack	Concord-Penacook WWTP	0.54
	Concord-Hall Street WWTF	4.39
	Suncook WWTF	0.66
	Merrimack Co. Nursing Home	0.04
	Winnipesaukee River Basin WWTP	5.50
	P.S. of NH- Merrimack Station	238
Merrimack Corridor 1	Hooksett WWTF	0.63
Merrimack Corridor 2	Derry WWTP	1.80
	Merrimack WWTF	3.53
Merrimack Corridor 3	Fletcher Granite Co.	1.09
	Stickney & Poor Spice	0.004
	East Chelmsford WTP	0.30
	Browning-Ferris	2.01
Merrimack Corridor 4	Andover WTP	0.58
Merrimack Corridor 5	Lucent	0.008
	Sweetheart Cup	0.006
Merrimack Corridor 6	Newburyport WPCF	3.19
	Amesbury WWTP	1.82
	Salisbury WWTF	0.55
	Merrimac WWTP	0.38
	Ferraz Shawmut	0.007
	Newburyport WTP	0.06
	Merrimac WTP	0.028

[1]Point source discharges on the tributaries were not included in the model

4.7 On-site Wastewater Disposal Systems

Septic systems are used for the subsurface disposal of wastewater, particularly in residential developments. These systems typically have a useful life expectancy and failures are known to occur, causing localized water quality problems. However, even properly operating septic systems may cause adverse impacts on water quality. Conventional septic systems are designed primarily for the removal of pathogens; thus even well-maintained systems provide minimal treatment of other constituents, such as nutrients, which may contribute to non-point source pollution.

The following section provides a summary of the percentage of the medium density residential land use category in the Merrimack River sub-basins serviced by septic systems, as well as the pollutant loading from these systems for the constituents of concern.

4.7.1 Summary of Watershed Area Serviced by Septic Systems

Information on the number of septic systems in the Merrimack River watershed was collected under Task 2C of the Merrimack River Watershed Assessment Study and presented in the DRAFT "Summary of Information on Pollutant Sources" Report, dated September 2003. This information was obtained from the 1990 U.S. Census, which provided information on number of housing units serviced by septic systems on a town or county-wide basis.

To evaluate the impact of failing septic systems on non-point source pollution, the Watershed Management Model requires an estimate of the total land area in the low, medium, and high residential land use categories that are serviced by septic systems. For the purposes of the Merrimack model, data was not available basin-wide on the total residential land use category with septic systems. Thus, a one-to-one ratio was assumed between the percentage of housing units with septic systems (collected under Task 2C) and the percentage of residential land use with septic systems. As previously mentioned, all residential land use in the Merrimack watershed was assumed to be "medium" density.

Table 4-13 provides a summary of the input to WMM on percentage of residential land area serviced by septic systems for each sub-watershed. For the five sponsor communities, information was collected directly for each of the respective cities from the U.S. Census data. For the other sub-watersheds, an area-weighted average was developed based on the estimated number of septic system in each county (from the U.S. Census) and the percentage of the sub-basin area intersecting each county.

Table 4-13: Summary of Population, Housing, and Septic System Statistics

Category	Sub-Watershed	Population	Housing Units	People per Household	Medium Density Land Use (mi²)	Percentage of area serviced by septic systems
Sponsor Communities	Manchester, NH	99,567	44,361	2.2	11.1	5.4%
	Nashua, NH	79,662	33,383	2.4	8.75	5.5%
	Lowell, MA	103,439	40,302	2.6	7.63	1.2%
	Lawrence, MA	70,207	26,915	2.6	4.01	1.0%
	Haverhill, MA	51,418	21,321	2.4	7.32	11.2%
Mainstem Merrimack	Merrimack Corridor 1	7,967	3,332	2.4	1.78	47.4%
	Merrimack Corridor 2	45,986	18,862	2.4	6.83	38.0%
	Merrimack Corridor 3	93,921	37,611	2.5	5.30	24.8%
	Merrimack Corridor 4	146,121	58,373	2.5	7.84	19.4%
	Merrimack Corridor 5	181,831	72,868	2.5	6.61	19.2%
	Merrimack Corridor 6	52,098	21,212	2.5	9.31	33.3%
Major Tributaries	Upper Merrimack	221,140	94,687	2.3	34.2	47.4%
	Assabet River	202,682	78,975	2.6	24.4	24.3%
	Beaver Brook	46,434	18,699	2.5	21.8	46.6%
	Cohas Brook	22,704	9,366	2.4	2.23	53.1%
	Concord River	99,026	38,507	2.6	15.7	19.0%
	Upper Nashua River	199,598	78,122	2.6	7.57	25.3%
	Lower Nashua River	130,229	51,074	2.5	22.8	30.2%
	Pemigewasset River	55,810	30,916	1.8	14.5	54.9%
	Piscataquog River	76,869	31,071	2.5	3.49	33.6%
	Powwow River	30,982	12,708	2.4	5.09	50.5%
	Salmon Brook	40,769	15,901	2.6	0.46	22.6%
	Shawsheen River	120,778	47,427	2.5	26.5	18.7%
	Souhegan River	87,334	35,142	2.5	9.31	31.8%
	Spickett River	37,297	15,314	2.4	10.6	51.5%
	Stony Brook	71,368	27,758	2.6	6.38	19.9%
	Sudbury River	235,393	91,592	2.6	37.0	21.1%
	Winnipesaukee River	43,088	26,538	1.6	31.6	63.8%

4.7.2 Failing Septic Systems

As previously discussed, non-point sources in WMM are calculated as a combination of pollutant loads resulting from stormwater runoff (all constituents) and from "failing" septic systems (total phosphorus and nitrogen only). Therefore, the septic system impacts evaluated in WMM are limited only to those resulting from "failing" septic systems. Previous work done as part of the Rouge River National Wet Weather Demonstration Project in Detroit, Michigan indicated that during an average year, five to 15-percent of the septic systems in the Rouge watershed were assumed to be failing. This information was found to be consistent with other studies conducted in Jacksonville, Florida.

In WMM, pollutant loading rates for failing septic systems were developed from a review of septic tank leachate monitoring studies. The following concentrations for total phosphorus and total nitrogen were developed for WMM from literature values for the "low", "medium", and "high" concentrations evaluated as part of the sensitivity analyses discussed in Section 3.5:

Table 4-14: Summary of Septic Loading Rates

Concentration Level	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
Low	1.0	7.5
Medium	2.0	15.0
High	4.0	30.0

Annual "per acre" loading rates for septic tank failures are estimated in WMM by assuming a daily per capita wastewater flow of 50 gallons. The loading rates are applied to the percentage of all non-sewered residential land uses with failing septic systems. In WMM, the septic tank loading factors are included in the runoff pollution loading factors.

Table 4-15 provides a summary of the concentration multipliers used in the uncertainty analysis. These multipliers are used to increase the stormwater pollutant load in areas affected by failing septic system impacts. It is important to note that only the concentration values for total phosphorus, TKN, and nitrate/nitrite are varied in this analysis.

Table 4-15: Septic Tank Uncertainty Analysis for Medium Density Residential

Parameter	Multiplier by Concentration Level		
	Low	*Medium*	*High*
BOD	1	1	1
COD	1	1	1
Total Suspended Solids	1	1	1
Total Dissolved Solids	1	1	1
Total Phosphorus	1.6	2.1	3.3
Dissolved Phosphorus	1.6	2.1	3.3
TKN	1.5	2.0	3.0
Nitrate/Nitrite	1.5	2.0	3.0
Lead	1	1	1
Copper	1	1	1
Zinc	1	1	1
Cadmium	1	1	1
Fecal Coliform	1	1	1
E. coli	1	1	1

4.7.3 Septic Calculations Outside of WMM

As discussed above, the septic system pollutant loads generated in WMM are primarily linked to the rate of failing septic systems. The model does not, however, account for the portion of loading that may be attributed to operational septic systems. Conventional septic systems are primarily designed for the removal of pathogens; therefore, even properly maintained systems provide limited treatment of other constituents, such as nutrients.

To account for the potential nutrient loads, specifically the total nitrogen load, in the Merrimack River watershed, calculations outside of WMM were performed based on accepted methods developed by the Massachusetts Department of Environmental Protection. This method is based on the following:

- Total annual nitrogen load of 5.9 lbs of nitrogen per year per person

- Residential occupation of three persons per household

Thus, using this information and the number of housing units in each sub-watershed and the percent of homes served by septic systems, as listed in Table 4-14, the total annual pollutant load from each subwatershed can be determined. Based on literature values and previous research in the New England area, forty-five percent of this load was then estimated to be lost to nutrient uptake before it reached the receiving waterbody. Thus the total nutrient load was equal to 55-percent of the original calculated value. Back-up calculations are provided in Appendix B.

Section 5
Model Results

The following section provides a summary of the scenarios evaluated using the Watershed Management Model developed for the Merrimack River watershed, as well as a summary of the model results.

5.1 WMM Scenarios

A total of six scenarios were evaluated using the Watershed Management Model developed for the Merrimack River watershed. These scenarios were designed to evaluate the impact of the following three key assumptions on the model results:

- Non-point source event mean concentrations (EMCs)
- Septic tank failure rates
- Pollutant delivery ratios from tributaries to mainstem

All other information used in the development of the model was based on data collected for the Merrimack River watershed or from literature values, as presented in Section 4 of this report. A matrix of the six scenarios is provided in Figure 5-1. Each scenario was evaluated under the dry, normal, and wet conditions discussed in Section 4.

Figure 5-1: Matrix of WMM Scenarios

MODEL FEATURE	SCENARIO					
	1	2	3	4	5	6
Land Use	GIS Data	GIS Data	GIS Data	GIS Data	GIS Data	GIS Data
Annual Hydrology	Calibrated	Calibrated	Calibrated	Calibrated	Calibrated	Calibrated
Point Source Load	Monitoring Reports	Monitoring Reports	Monitoring Reports	Monitoring Reports	Monitoring Reports	Monitoring Reports
CSO Load	LTCP Data	LTCP Data	LTCP Data	LTCP Data	LTCP Data	LTCP Data
NPS EMCs	WMM Defaults	Regional Averages	Regional Averages	Regional Averages	Regional Averages	Regional Averages
Septic Load	Average	Average	Worst case failure & load rates	Best case failure & load rates	Average	Average
Pollutant Delivery Ratio	Average	Average	Average	Average	Worst case: 100% Delivery	Best case: Least estimated delivery

5.1.1 Scenario 1 & 2- Event Mean Concentrations

The WMM default and regional average EMC values used in Scenarios 1 and 2, respectively, are presented in Table 4-4. As noted in Section 4.3, regional values were not available for the following land use types: agriculture/pasture, forest/rural open, highway, urban open, and water/wetlands. In these cases, the WMM default values were used in both Scenario 1 and 2. Therefore, only the EMC values for commercial, industrial, and medium density residential land uses differed between the two scenarios.

In both scenarios, an average septic failure rate of seven-percent and an average pollutant delivery ratio of 50-percent were used.

5.1.2 Scenario 3 & 4- Septic Impact

A summary of information on septic system failure rates was presented in the DRAFT "Summary of Information on Pollutant Sources" Report, dated September 2003. As summarized in this report, a review of the available literature did not reveal any information regarding septic system failure rates for communities in the Merrimack River watershed. However, previous work done as part of the Rouge River National Wet Weather Demonstration Project in Detroit, Michigan indicated that during an average year, five to 15-percent of the septic systems in the Rouge watershed were assumed to be failing. Thus, for the Merrimack study, a three-percent failure rate was assumed for the "best case" scenario (Scenario 4) and a 15-percent failure rate was assumed for the "worst case" scenario (Scenario 3).

In both Scenario 3 and 4, the regional EMC values were used and an average pollutant delivery ratio of 50-percent was assumed.

5.1.3 Scenario 5 & 6- Pollutant Delivery Ratio

In WMM, a pollutant delivery ratio is applied to each sub-watershed to account for the reduction in runoff pollutant load due to uptake or removal in stream courses. Under the "worst-case" conditions (Scenario 5), a pollutant delivery ratio of 100% was assumed, meaning that 100-percent of the pollutant load running off the land entered the river channel and made it to the downstream most point in the channel.

Under the "best-case" scenario (Scenario 6), a varied pollutant delivery ratio was estimated based on the size of the watershed, according to the criteria provided in Table 5-1. It was assumed that larger watersheds would have smaller delivery ratios, since it would take a proportionally longer period of time for the pollutant to reach the river channel and the downstream most point in the watershed.

Table 5-1: Pollutant Delivery Ratio Criteria

Watershed Size	Watershed Area Range (mi^2)	Pollutant Delivery Ratio
Small	0-100	75%
Medium	100-200	50%
Large	200-1300	25%

Regional EMCs were used in both Scenario 5 and 6. An average septic failure rate of seven-percent was also used.

5.2 Summary of Results

The goal of this modeling task was to evaluate the relative contribution of pollutants from the major geographic source areas, such as the sponsor communities and major tributaries, and from the primary physical sources, such as non-point sources at the annual scale. As such, the model results presented in this section will be interpreted in terms of relative magnitudes from the various geographic and physical sources, as opposed to absolute pollutant loading values.

A summary of the model output is provided in Appendix C in the form of raw data and bar charts. The bar charts are organized on the x-axis by the following geographic sources discussed in Section 4.1.1:

- Sponsor communities
- Merrimack River corridors
- Major tributaries (including the Upper Merrimack River and its tributaries between Franklin and Hooksett, NH)

Separate results are provided for the average, drought, and wet year conditions. The stacks on the charts represent the relative magnitude of the various physical sources, including non-point sources, CSOs, and point sources. The values presented in these plots represent the "medium" loading factor type under the uncertainty analysis for the event mean concentrations.

The following sections provide a comparison of the modeling results from the six scenarios for each of the 11 parameters evaluated in WMM. Each section also provides a summary of the pollutant contributions organized by geographic and physical source areas under average, drought, and wet hydrologic conditions. Section 6.0 provides a summary of the overall WMM findings, including the identification of overriding trends throughout the suite of parameters evaluated. Pie charts summarizing the results from the Scenario 6 model runs under average conditions are also provided.

5.2.1 Flow

The WMM results suggest that of the three major physical sources evaluated in this study, non-point sources are the largest contributor to total annual flow in the Merrimack River watershed under each of the three hydrologic conditions evaluated. However, it is important to note that this study did not evaluate baseflow contributions, which would most likely be the dominant source of streamflow in the Merrimack River. Point sources contribute the next largest percentage of annual flow, while CSO discharges are a fairly insignificant source. From a geographic perspective, the tributaries provide the vast majority of the streamflow (over 80-percent), with sponsor communities and Merrimack River corridors splitting the remaining approximately 20-percent.

Table 5-2 provides a summary of the total annual flow contributions from the various physical and geographic sources under the three hydrologic conditions evaluated in this study: drought, average, and wet years.

Table 5-2: Summary of total annual flow contributions under drought, average, and wet hydrologic conditions (values are percent of total)

Hydrologic Condition	**Geographic Sources**			**Physical Sources**		
	Communities	*MR Corridors*	*Tribs*	*NPS*[1]	*Point Source*	*CSOs*
Average	7%	7%	86%	76%	24%	0.1%
Drought	11%	7%	83%	65%	35%	0.2%
Wet	5%	7%	88%	83%	17%	0.1%

[1]Includes stormwater runoff and septic system impacts
[2]Values have been rounded to the nearest whole number

Bar charts of the WMM flow results organized by geographic source areas are provided in Appendix C (pages C.1, C. 7, C.13, C.19, C.25, and C.31).

5.2.2 Fecal Coliform

In general, non-point sources in the major tributaries dominated the annual fecal coliform loads in the Merrimack River watershed in each of the six scenarios evaluated as part of this study. This theme was common among the three hydrologic conditions evaluated with WMM.

In the sponsor communities, the highest fecal coliform loads consistently resulted from the CSOs, with point sources as the next largest source. It is important to note here that WMM assumes that 100-percent of a watershed with combined sewers is converted to CSO discharge; as such, there is no non-point source load from the five sponsor communities. This is only a rough approximation in the Merrimack River watershed, as each of the communities has some (small) portion of their runoff discharging to separated stormdrains.

In the Merrimack River corridors and the major tributaries, non-point sources were the primary source of fecal coliform, with point sources providing the second largest discharge. Table 5-3 provides a summary of the percentage contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the total annual fecal coliform load. Only values for the "average" hydrologic conditions are presented.

Table 5-3: Summary of fecal coliform contributions under average hydrologic conditions (values are percent of total load)

Scenario	**Geographic Sources**			**Physical Sources**		
	Communities	*MR Corridors*	*Tribs*	*NPS*[1]	*Point Source*	*CSOs*
1	13%	10%	77%	87%	0.1%	13%
2	18%	9%	72%	82%	0.1%	18%
3	18%	9%	72%	82%	0.1%	18%
4	18%	9%	72%	82%	0.1%	18%
5	12%	10%	78%	88%	0.1%	12%
6	19%	13%	68%	81%	0.1%	19%

[1]Includes stormwater runoff and failing septic system impacts
[2]Values have been rounded to the nearest whole number

It is important to recognize that these values represent pollutant loads on the annual scale. Therefore, although the non-point sources may represent a larger portion of the total annual fecal coliform load, other sources, such as CSOs, may still be the prevailing cause of water quality exceedances in the lower reaches of the basin at the daily-scale. Detailed dynamic simulation models will be developed to address this issue.

Scenario Comparison

The non-point source loads from Scenario 1 were higher than those from Scenario 2 (though still within the same order of magnitude), indicating that the default EMCs provide a slightly more conservative estimate of the annual fecal coliform load in stormwater runoff. As noted previously, regional EMCs were only available for commercial, industrial, and medium density land uses.

No difference was observed in the fecal coliform loads between Scenarios 3 and 4, indicating that the septic system failure rates do not play a role in these loads, at least at the annual level.

As expected, the fecal coliform loads from Scenario 5, where the pollutant delivery ratio was set at 100-percent, were higher than those in Scenario 6, where the delivery ratios varied based on watershed size. The conditions evaluated in Scenario 6 are most likely more representative of the actual conditions in the watershed. It is highly unlikely that 100-percent of the pollutant load from the larger watersheds reaches the downstream point of the respective waterbody due to travel times, pollutant die-off, and natural filtration.

Bar charts of the WMM fecal coliform results are provided in Appendix C (on pages C.1, C.7, C.13, C.19, C.25, and C.31).

5.2.3 E. coli

The WMM results suggest that non-point source pollution from the major tributaries dominate the E. coli loads in the Merrimack River watershed at the annual scale. This was true in each of the six scenarios and the three hydrologic regimes evaluated in this study. CSOs and point sources consistently contributed the second and third largest percentage, respectively, of the total annual load. From a geographic perspective, the loads were fairly evenly divided between the sponsor communities and the Merrimack River corridors.

From a geographic/pollutant source standpoint, the total E. coli load in the communities were dominated by discharges from the CSOs, with point source discharges contributing the second largest portion of the annual load. Non-point sources dominated the total annual load in both the Merrimack River corridors and the major tributaries.

Table 5-4 provides a summary of the percentage contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the total annual E. coli load. Only values for the "average" hydrologic conditions are presented.

Table 5-4: Summary of E. coli contributions under average hydrologic conditions (values are percent of total load)

Scenario	Geographic Sources			Physical Sources		
	Communities	*MR Corridors*	*Tribs*	*NPS*[1]	*Point Source*	*CSOs*
1	14%	10%	76%	86%	2%	13%
2	9%	11%	80%	91%	1%	8%
3	9%	11%	80%	91%	1%	8%
4	9%	11%	80%	91%	1%	8%
5	5%	11%	83%	95%	1%	5%
6	9%	15%	76%	91%	1%	8%

[1]Includes stormwater runoff and failing septic system impacts
[2]Values have been rounded to the nearest whole number

As with the fecal coliform results, it is important to note that these values represent pollutant loads on the annual scale. Therefore, although the non-point sources may represent a larger portion of the annual E. coli load, other sources, such as CSOs, may actually be the prevailing cause of water quality exceedances at the daily-scale in the lower reaches of the basin.

Scenario Comparison

As expected, the non-point source loads increased between Scenario 1 and 2 in response to increased EMCs between the default WMM values and the regional values. No changes in the relative contribution of geographic and physical sources was seen between Scenario 3 and 4 in response to variations in the rate of septic system failures. Finally, a drop in non-point source pollution was seen between Scenario 5 and 6 in response to a decrease in the pollutant delivery ratio.

Bar charts of the WMM E. coli results are provided in Appendix C (pages C.2, C.8, C.14, C.20, C.26, and C.32).

5.2.4 Biochemical Oxygen Demand (BOD)

In general, the largest percentage of the annual BOD load may be attributed to non-point source pollution from the tributaries. Point sources from the five sponsor communities were shown to be the second largest contributor to the annual load. Within each community, the wastewater treatment plants (WWTPs) contributed the most significant portion of the BOD discharges. Alternately, CSO discharges represented only a small portion of the total annual BOD load within the communities and within the larger watershed area.

Table 5-5 provides a summary of the percent contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the total annual BOD load. Only values for the "average" hydrologic conditions are presented in the table.

Table 5-5: Summary of BOD contributions under average hydrologic conditions (values are percent of total load)

Scenario	Geographic Sources			Physical Sources		
	Communities	*MR Corridors*	*Tribs*	*NPS*[1]	*Point Source*	*CSOs*
1	18%	10%	72%	79%	21%	1%
2	23%	9%	68%	73%	26%	1%
3	23%	9%	68%	73%	26%	1%
4	23%	9%	68%	73%	26%	1%
5	23%	9%	68%	73%	26%	1%
6	23%	9%	68%	73%	26%	1%

[1]Includes stormwater runoff and failing septic system impacts

[2]Values have been rounded to the nearest whole number

Scenario Comparison

As shown in Table 5-5, the non-point source load in Scenario 1 was higher than that in Scenario 2, indicating the that WMM default EMCs (Scenario 1) provide a slightly more conservative estimate of the BOD loads. In general, the relative BOD loads were not impacted by changes to the failing septic system rates (Scenarios 3 and 4) or changes to the delivery ratios (Scenario 5 and 6).

Bar charts of the WMM BOD results are provided in Appendix C (pages C.2, C.8, C.14, C.20, C.26, and C.32).

5.2.5 Total Phosphorus

The WMM results suggest that the annual phosphorus loads in the Merrimack River watershed are dominated by point source discharges from the sponsor communities. Although WWTPs are the largest dischargers in each of the communities, it is important to note that no total phosphorus monitoring data was available for the treatment plants. As discussed in Section 4.6, an average discharge concentration of 3mg/L was assumed for each WWTP and then a flow-weighted average was calculated for the sub-watershed. Future modeling studies will be better able to define the total phosphorus contributions from the WWTPs. Additionally, effluent samples collected from the sponsor community's WWTPs during the three dry-weather sampling events were analyzed for total phosphorus.

In each of the six scenarios, stormwater runoff contributed the second largest percentage of the total annual phosphorus load. The majority of the phosphorus load in stormwater runoff may be attributed to the tributaries sources. The tributary loads were dominated by non-point source pollution, with point sources contributing only a small portion of the total load. In contrast, the point sources were a larger contributor than the point sources in the Merrimack River corridors. The annual septic system and CSO loads are inconsequential in comparison to the other loads.

Table 5-6 provides a summary of the percent contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the annual total phosphorus load. Only values for the "average" hydrologic conditions are presented in the table.

Table 5-6: Summary of Total Phosphorus contributions under average hydrologic conditions (values are percent of total load)

Scenario	Geographic Sources			Physical Sources			
	Communities	*MR Corridors*	*Tribs*	*Stormwater Runoff*	*Point Source*	*CSOs*	*Failing Septic*
1	80%	5%	16%	14%	86%	0.2%	0.1%
2	81%	4%	14%	12%	87%	0.2%	0.1%
3	81%	5%	15%	12%	87%	0.2%	0.2%
4	81%	4%	14%	12%	87%	0.2%	0.1%
5	78%	5%	17%	16%	84%	0.2%	0.1%
6	82%	5%	13%	12%	88%	0.2%	0.1%

[1]Values have been rounded to the nearest whole number

Scenario Comparison

As shown in Table 5-6, the total phosphorus loads calculated using the default WMM EMCs (Scenario 1) were higher than those calculated using the regional values (Scenario 2). In Scenarios 3 and 4, varying the rate of failing septic systems had minimal impact on the relative total phosphorus loads. Slightly higher septic loads were found at failure rates of 15-percent (Scenario 3). However, as noted previously, these loads were minor in comparison to those from other sources. As is expected, the stormwater loads decreased between Scenario 5 and 6, in response to changes in the pollutant delivery ratio.

Bar charts of the WMM total phosphorus results are provided in Appendix C (pages C.3, C.9, C.15, C.21, C.27, and C.33).

5.2.6 Total Nitrogen (Nitrate/ Nitrite + TKN)

The results from WMM and manual calculations (see Section 4.7.3) suggest that annual total nitrogen loads are fairly evenly divided between point sources discharges from the communities and non-point sources from the tributaries. In general, failing septic systems and CSO discharges have very little impact on the overall pollutant load, together contributing less than one-percent of the total annual load. Non-failing septic contribute approximately 15-percent of the total annual load.

From a geographic perspective, the total nitrogen loads in tributaries are generally dominated by non-point source pollution, followed by septic discharges. In general, the largest septic load of the three geographic source areas comes from the tributary watersheds, which typically have a larger number of number of homes with private septic systems. Annual loads in the Merrimack River corridors are fairly equally divided between non-point sources, point sources, and operational septic systems. The total nitrogen load in the sponsor communities is dominated by point source discharges, the primary source of which is WWTPs. As with the total phosphorus data, it is important to note that no nitrogen monitoring data was available for the WWTPs. An average concentration of 3mg/L was assumed for the nitrate/nitrite component and 15mg/L was assumed for the TKN component (Note: the total nitrogen load was calculated as the sum of the NO_2/NO_3 and TKN results). These values were based on accepted literature values and those used for similar point sources in the Rouge River National Wet Weather Demonstration Project. Flow-weight averages were developed for each sub-watershed using these values.

Table 5-7 provides a summary of the percent contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the annual total nitrogen load. Only values for the "average" hydrologic conditions are presented in the table for those parameters calculated in WMM.

Table 5-7: Summary of Total Nitrogen contributions under average hydrologic conditions (values are percent of total load)

Scenario	Geographic Sources			Physical Sources				
	Communities	*MR Corridors*	*Tribs*	*Stormwater Runoff*	*Point Source*	*CSO*	*Failing Septic*	*Septic (non WMM)*
1	38%	10%	52%	40%	45%	0.2%	0.1%	15%
2	40%	10%	50%	37%	47%	0.2%	0.3%	15%
3	40%	10%	50%	37%	47%	0.2%	0.5%	15%
4	40%	10%	50%	37%	47%	0.2%	0.02%	15%
5	36%	10%	55%	44%	42%	0.2%	0.4%	14%
6	41%	11%	48%	35%	49%	0.2%	0.2%	16%

Scenario Comparison

The stormwater runoff total nitrogen load was slightly higher in Scenario 1 using the default WMM EMC values, as compared to Scenario 2, where the regional EMC values were used. Little variation was seen in the results between Scenarios 3 and 4 in response to changes in the septic tank failure rates. Finally, as expected, the stormwater loads decreased between Scenario 5 and 6, in response to changes in the pollutant delivery ratio.

Bar charts of the WMM total nitrogen results are provided in Appendix C (pages C.3, C.9, C.15, C.21, C.27, and C.33).

5.2.7 Total Suspended Solids (TSS)

In each of the six scenarios evaluated in WMM, non-point sources from the tributaries dominated the annual TSS load in the Merrimack River watershed. Point sources were the second largest physical source, with CSOs contributing only a small portion of the total annual load.

From a geographic standpoint, point source discharges dominated the pollutant loads from the five sponsor communities, while non-point sources were the predominate contributors to the annual TSS load in the tributaries and the Merrimack River corridors.

Table 5-8 provides a summary of the percent contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the annual TSS load. Only values for the "average" hydrologic conditions are presented in the table.

Table 5-8: Summary of TSS contributions under average hydrologic conditions (values are percent of total load)

Scenario	**Geographic Sources**			**Physical Sources**		
	Communities	*MR Corridors*	*Tribs*	*NPS*[1]	*Point Source*	*CSOs*
1	5%	8%	86%	90%	9%	1%
2	6%	8%	86%	89%	10%	1%
3	6%	8%	86%	89%	10%	1%
4	6%	8%	86%	89%	10%	1%
5	3%	8%	89%	94%	5%	0.5%
6	8%	15%	78%	86%	13%	1%

[1]Includes stormwater runoff and failing septic system impacts

[2]Values have been rounded to the nearest whole number

Scenario Comparison

A minimal impact was seen between Scenarios 1 and 2 in the relative contribution of loads from the geographic and physical sources, indicating that there was little difference between the regional and default WMM values. No impact was seen in Scenarios 3 and 4 by varying the percentage of failing septic systems. As expected, the percent contribution from non-point sources dropped between Scenarios 5 and 6 as a result of changes to the pollutant delivery ratio. The percent contribution from the tributaries decreased in response to these changes.

Bar charts of the WMM total suspended solids results are provided in Appendix C (pages C.4, C.10, C.16, C.22, C.28, and C.34).

5.2.8 Copper

The WMM results suggest that, in general, the annual copper load to the Merrimack River watershed is dominated by non-point sources in the major tributaries. Point sources in the tributaries make up the second largest sources of annual load, with CSO discharges contributing approximately one-percent of the annual copper contribution.

From a geographic source perspective, copper loads in the five sponsor communities are dominated by point source discharges. CSOs contribute only a small portion to the communities' annual load. Non-point pollution is the dominant source in the tributaries and the Merrimack River corridors.

Table 5-9 provides a summary of the percent contributions from each physical and geographic source the six scenarios; values are calculated as percent of the annual copper load. Only values for the "average" hydrologic conditions are presented in the table.

Table 5-9: Summary of copper contributions under average hydrologic conditions (values are percent of total load)

Scenario	Geographic Sources			Physical Sources		
	Communities	*MR Corridors*	*Tribs*	*NPS*[1]	*Point Source*	*CSOs*
1	10%	11%	80%	69%	30%	1%
2	7%	11%	82%	77%	22%	1%
3	7%	11%	82%	77%	22%	1%
4	7%	11%	82%	77%	22%	1%
5	5%	11%	90%	83%	16%	1%
6	8%	14%	79%	76%	23%	1%

[1]Includes stormwater runoff and failing septic system impacts
[2]Values have been rounded to the nearest whole number

Scenario Comparison

As expected, the stormwater runoff load was slightly higher in Scenario 2 using the regional EMC values, as opposed to Scenario 1, where the lower WMM default EMCs were used. In Scenarios 3 and 4, variations in the percentage of failing septic systems had no impact on the WMM results. Finally, as expected, the stormwater loads decreased between Scenario 5 and 6, in response to changes in the pollutant delivery ratio.

Bar charts of the WMM copper results are provided in Appendix C (pages C.4, C.10, C.16, C.22, C.28, and C.34).

5.2.9 Cadmium

The WMM results suggest that in each of the six scenarios, the annual cadmium loads are dominated by non-point source discharges in the tributaries. Point source loads are a distant second, with CSOs contributing only a small portion of the total annual load (i.e. less than 1.5-percent). Geographically, the Merrimack River Corridors and the sponsor communities contribute the second and third largest pollutant loads, respectively, of the three sources evaluated.

Table 5-10 provides a summary of the percent contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the annual cadmium load. Only values for the "average" hydrologic conditions are presented in the table.

Table 5-10: Summary of cadmium contributions under average hydrologic conditions (values are percent of total load)

Scenario	Geographic Sources			Physical Sources		
	Communities	*MR Corridors*	*Tribs*	*NPS*[1]	*Point Source*	*CSOs*
1	4%	12%	84%	93%	6%	1%
2	4%	12%	84%	93%	6%	1%
3	4%	12%	84%	93%	6%	1%
4	4%	12%	84%	93%	6%	1%
5	3%	12%	86%	96%	4%	1%
6	4%	17%	79%	92%	6%	1%

[1]Includes stormwater runoff and failing septic system impacts
[2]Values have been rounded to the nearest whole number

Scenario Comparison

Slight differences were noted in the geographic and pollutant source contributions between Scenarios 1 and 2 and Scenarios 5 and 6 in response to changes in the EMC values and pollutant delivery ratios, respectively. However, these differences were typically minor and did not change the overall ranking of pollutant source contributions. No impact was seen in the model results from changes to the septic system failure rates (Scenarios 3 and 4).

Bar charts of the WMM cadmium results are provided in Appendix C (pages C.5, C.11, C.17, C.23, C.29, and C.35).

5.2.10 Lead

In each of the six scenarios evaluated with WMM, the total annual lead load in the Merrimack River watershed was dominated by non-point source pollution from the tributaries. Point sources and CSO discharge each contribute less than two-percent of the total annual load.

From a geographic perspective, the annual lead loads in the sponsor communities are split fairly evenly between CSO and point source contributions. Non-point sources are the dominant contributors in the both the tributaries and the Merrimack River corridors.

Table 5-11 provides a summary of the percent contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the annual lead load. Only values for the "average" hydrologic conditions are presented in the table.

Table 5-11: Summary of lead contributions under average hydrologic conditions (values are percent of total load)

Scenario	Geographic Sources			Physical Sources		
	Communities	*MR Corridors*	*Tribs*	*NPS*[1]	*Point Source*	*CSOs*
1	3%	11%	86%	97%	2%	2%
2	2%	11 %	86%	97%	2%	1%
3	2%	11%	86%	97%	2%	1%
4	2%	11%	86%	97%	2%	1%
5	1%	11%	87%	98%	1%	1%
6	3%	17%	80%	97%	2%	1%

[1]Includes stormwater runoff and failing septic system impacts

[2]Values have been rounded to the nearest whole number

Scenario Comparison

Unlike the other constituents, the non-point source load in Scenario 1 was lower than that in Scenario 2 where the regional EMC values were used. This is to be expected, as higher regional EMCs were used in the model for commercial land uses. In Scenarios 3 and 4, variations in the rate of failing septic systems had no impact on the relative geographic or physical source contributions. Only minor variations in the relative contribution of annual pollutant lead loads were observed between Scenario 5 and 6. As expected, a slight drop in the non-point source load was seen between Scenario 5 and 6.

Bar charts of the WMM lead results are provided in Appendix C (pages C.5, C.11, C.17, C.23, C.29, and C.35).

5.2.11 Zinc

In general, the WMM results suggest that the annual zinc load is dominated by non-point source pollution from the tributaries. These results hold through each of the six scenarios and three hydrologic conditions evaluated in this study. Point sources are a distant second in terms of contributions to the total annual pollutant load, with CSOs contributing only a small portion of the zinc load. The Merrimack River corridors provide slightly more of the pollutant load than do the five sponsor communities. Non-point sources are the predominate source of zinc pollution in the corridors, while point sources are the largest source in the communities.

Table 5-12 provides a summary of the percent contributions from each physical and geographic source in the six scenarios; values are calculated as percent of the annual zinc load. Only values for the "average" hydrologic conditions are presented in the table.

Table 5-12: Summary of zinc contributions under average hydrologic conditions (values are percent of total load)

Scenario	Geographic Sources			Physical Sources		
	Communities	*MR Corridors*	*Tribs*	*NPS[1]*	*Point Source*	*CSOs*
1	8%	13%	79%	89%	10%	1%
2	9 %	13%	78%	87%	12%	1%
3	9%	13%	78%	87%	12%	1%
4	9%	13%	78%	87%	12%	1%
5	7%	12%	81%	90%	9%	1%
6	10%	15%	75%	86%	13%	1%

[1]Includes stormwater runoff and failing septic system impacts
[2]Values have been rounded to the nearest whole number

Scenario Comparison

Non-point source loads drop slightly between the Scenario 1 and 2, indicating that there is little impact on the overall model results from differences between the regional versus WMM default EMC values. No changes were observed in the model results between Scenario 3 and 4 in response to variations in the septic system failure rates. Additionally, changes to the pollutant delivery ratio in Scenarios 5 and 6 had limited impact on the model results.

Bar charts of the WMM zinc results are provided in Appendix C (pages C.6, C.12, C.18, C.24, C.30, and C.36).

5.3 Sensitivity Analysis to Percent Imperviousness

As discussed in Section 4.2, a sensitivity analysis was performed to evaluate the impact of the estimated percent imperviousness for the highway land use category on the overall model results. This land use category makes up less than one-percent of the total area of the Merrimack River watershed.

As part of this analysis, the calibrated model was re-run for Scenario 1 and 5 under average conditions using a revised percent imperviousness of 55-percent, rather than the default value of five-percent. As expected, the annual pollutant loads increased in response to the higher percent imperviousness. In general, an increase of between 0 and 15-percent was observed, depending on the constituent. This increase does not substantially impact the overall study conclusions with respect to the relative contribution of pollutant loads from geographic and physical source areas in the basin. Therefore, it may be concluded that the Watershed Management Model developed for the Merrimack River watershed is fairly insensitive to an increase in the percent imperviousness for the highway land use category.

Furthermore, as discussed in Section 4.2, the percent DCIA is expected to be much lower than the 55-percent imperviousness used as the upper bound in this sensitivity analysis. In general, for most highway systems, very few stormdrains are connected to highway pavement. Most major interstates convey stormwater runoff via overland flow to an undeveloped drain system, such as a roadside vegetated swale, and have only a limited number of catchbasins collecting runoff at bridges and in urban areas. This results in a much lower percentage of impervious area that is directly connected to the hydraulic system; this value is reflected in the default WMM percent impervious values.

Section 6
Summary of Findings

The Watershed Management Model (WMM) was used to evaluate the relative contribution of pollutant sources from various geographic and physical sources in the watershed. A total of six scenarios were evaluated for 11 parameters of concern (including flow). The scenarios were designed to evaluate the sensitivity of the WMM results to key assumptions, including EMC values, septic tank failure rates, and pollutant delivery ratios. The following section provides a summary of the significant model findings.

It is important to recognize that the WMM results represent pollutant loads at the annual scale. Therefore, these results are not necessarily indicative of water quality conditions at the scale on which water quality exceedances are measured.

6.1 Relative Contribution of Physical and Geographic Sources

The WMM results suggest that, at the annual scale, non-point sources from the major tributaries typically dominate the pollutant loads for the eight of the 10 constituents evaluated in this study; the exceptions were the annual nutrient loads for nitrogen and phosphorus. These results were consistent across the six scenarios and three hydrologic regimes evaluated as part of this study. This finding is not surprising, as both the tributaries and the non-point sources are the largest contributors to total flow in the Merrimack River, as analyzed the respective geographic and physical sources.

The WMM results suggest that the annual total phosphorus loads were dominated by point sources in the communities (primarily WWTPs). The results suggest that for total nitrogen, the annual loads were fairly evenly split between point source discharges in the communities and non-point sources in the tributaries. It is important to note, however, that no monitoring data was available for total phosphorus or total nitrogen effluent concentrations at the WWTPs. Therefore, an assumed total phosphorus discharge concentration of 3.0 mg/L was used for all WWTPs. Similarly for the total nitrogen analysis, an average effluent concentration of 3.0 mg/L was assumed for the nitrate/nitrite component and 15 mg/L was assumed for the TKN component (Note: the total nitrogen load was calculated as the sum of the NO_2/NO_3 and TKN results). As previously discussed these concentrations were based on literature values. However, WWTP effluent samples from the five sponsor communities were analyzed for total phosphorus, TKN, and nitrate/nitrite during the three dry-weather sampling event conducted during the summer and early fall of 2003. These monitoring data will be used in lieu of literature values during the development of the more detailed models in subsequent tasks.

It is interesting to note that, according to the WMM results, the CSO discharges generally play a very small role in the annual pollutant loadings to the Merrimack River mainstem for the 10 constituents evaluated in this study. They were most significant in the fecal coliform and E. coli results, contributing approximately 19 and eight-percent of the annual loads, respectively, under Scenario 6. CSO contributions were generally below 1.5-percent of the total annual loads for the other constituents of concern.

Table 6-1 provides a summary of the dominant geographic and physical sources in the watershed for each water quality parameter of concern. This table presents results for the "average" hydrologic conditions; however, similar results were typically found in the three hydrologic regimes evaluated under this study.

Table 6-1: Summary of dominant physical and geographic sources under "average" hydrologic conditions

WQ Parameter	**Dominant Source**			
	Geographic	*Scenario*	*Physical*	*Scenario*
Fecal Coliform	Tributaries	1 to 6	Non-point source	1 to 6
E. Coli	Tributaries	1 to 6	Non-point source	1 to 6
BOD	Tributaries	1 to 6	Non-point source	1 to 6
Total Phosphorus	Communities	1 to 6	Point Sources	1 to 6
Total Nitrogen	Tributaries	1 to 6	Septic (non-WMM)	1 to 6
TSS	Tributaries	1 to 6	Non-point source	1 to 6
Copper	Tributaries	1 to 6	Non-point source	1 to 6
Cadmium	Tributaries	1 to 6	Non-point source	1 to 6
Lead	Tributaries	1 to 6	Non-point source	1 to 6
Zinc	Tributaries	1 to 6	Non-point source	1 to 6

Pie chart comparisons of the physical sources are provided in Figure 6-1 for each of the constituents. This figure presents the WMM results for Scenario 6 under "average" hydrologic conditions, which is assumed to be most "realistic" due to the variable pollutant delivery ratio and septic system failure rate provided as input to the model. The regional EMC values were used in this scenario where available (i.e. for commercial, industrial, and medium density residential land use types); default WMM EMCs were used in all other cases.

Despite the fact that the WMM results present only rough approximations of conditions in the watershed, they at least initially support the Merrimack River Basin Community Coalition's hypothesis that other sources beyond the CSOs may play an important role in the pollutant loadings to the Merrimack River.

6.2 Scenario Comparison

In general, the WMM results were fairly insensitive to changes in the model assumptions regarding EMC values, failing septic systems, and pollutant delivery ratios. As expected, minor changes were seen in the non-point source loads between Scenario 1 and 2 in response to increases or decreases in the EMC values between the default WMM values and the regional values. These variations typically did not result in changes to the overall relative contribution of pollutant loads from the geographic and physical sources. Similar results were seen between Scenario 5 and 6 in response to variations in the pollutant delivery ration. For all parameters except for total phosphorus and total nitrogen, no change was observed in the WMM results between Scenario 3 and 4. Only slight changes (i.e. less than 0.5-percent) were observed for these nutrients between the two scenarios.

Additionally, the model performed as expected in response to variations in the hydrologic regime between dry, normal, and wet conditions. Throughout each scenario and water quality constituent, the annual loads increased proportionally in response to increases in the annual precipitation and changes in the pervious runoff coefficients, as discussed in Section 4.4.

6.3 Model Limitations

It is important to note that the WMM results are applicable only to the assessment of pollutant loads at the annual scale. The results presented in Table 6-1 and Figure 6-1 should not be used to infer information on the relative contribution of pollutants at the weekly or daily-scale. For example, the WMM results for both fecal coliform and E. coli suggest that non-point source pollution from the tributaries is the major source of annual bacteria loads in the Merrimack River watershed. Although these non-point sources may represent a larger portion of the total annual load, other sources such as CSOs may still actually be the primary contributor to water quality exceedances in the lower reaches of the basin at the daily-scale.

The detailed water quality and hydrologic/hydraulic models to be developed during subsequent phases of this project will be used to further refine this evaluation. These models will be capable of assessing water quality conditions and impacts at time steps on the order of hours and even minutes, as necessary.

Figure 6-1: Scenario 6 Pie Chart Comparison- Average Hydrologic Conditions

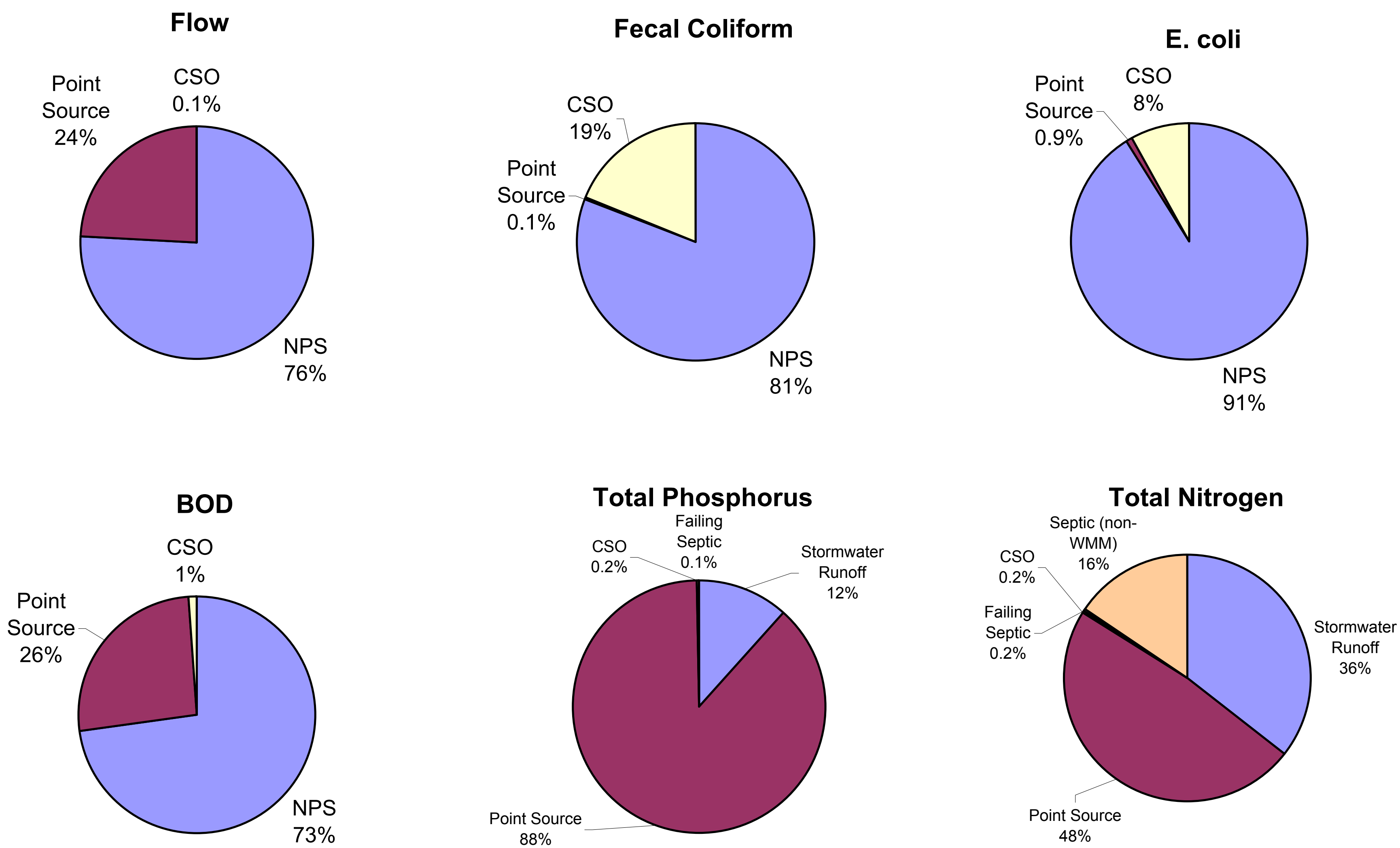
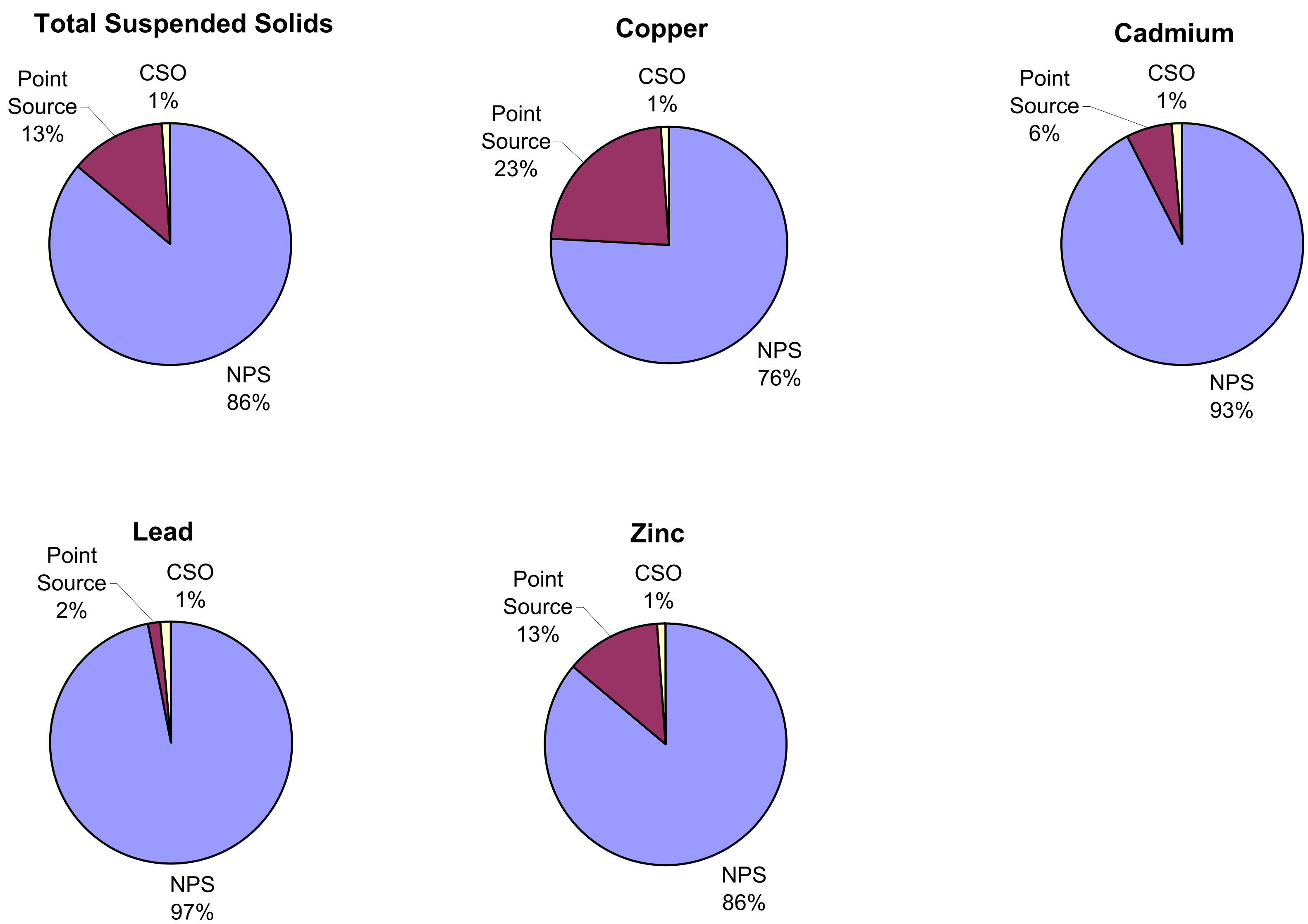


Figure 6-1 (cont'd)



Section 7
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Appendix A: EMC Memorandum

CDM

May 15, 2003

Ms. Barbara Blumeris, Study Manager
United States Army Corps of Engineers
New England District
696 Virginia Road
Concord, Massachusetts 01742-2751

Subject: Comparison of Stormwater Event Mean Concentration (EMC) values for use in CDM's Screening Level Model for Merrimack River Watershed Pollutant Loads

Dear Ms. Blumeris:

In accordance with Task Order 3C of the Merrimack River Watershed Assessment Study, CDM is developing a screening level model to estimate pollutant loads in the watershed. The primary purpose of the model is to identify relative contributions of pollutants from different sources and sub-basins within the larger Merrimack River Watershed.

CDM will use the Watershed Management Model (WMM), originally developed by CDM for the Rouge River study in Michigan, for the screening level analysis. The model will simulate annual levels of point source pollution from wastewater treatment plants, annual CSO loads, and annual non-point source pollutant loads associated with stormwater runoff. The non-point source loads will be estimated using normal hydrologic patterns and Event Mean Concentration (EMC) values associated with various land use categories within the watershed. Ultimately, the model should provide initial indications of what sources of pollution, and what specific pollutant types, are likely to dominate the aggregate loading into the Merrimack River.

Pollutant EMC values for stormwater runoff are widely available in published literature. The intent of this letter is to condense and summarize alternative sources of these values, and to promote consensus among project participants with respect to the values that will be used in the screening model.

The following three sets of values are offered for consideration by project participants; each is described in more detail below:

- Default values in the WMM database
- Regional values averaged from numerous studies in New England
- National values averaged from multiple studies throughout the United States

Default EMC Values in the WMM Model:

Default EMC values in the WMM model are based on data from three sources:

a. Pooled USEPA Nationwide Urban Runoff Program (NURP) median national statistics (1983)
b. Northern Virginia Planning District Commission (1979, 1983)
c. Federal Highway Administration (1990)

Regional Values Averaged from New England Studies:

Mean regional EMC values were computed from the following studies or data sets for New England communities:

a. USEPA NURP data obtained from Boston Area locations (per Rouge River National Wet Weather Project, Technical Memorandum, Appendix A, 1998).
b. Sampling results from 1999 – 2000 in Boston, MA: Vanasse Hangen Brustlin, Inc. (VHB) report for the Boston Water and Sewer Commission: *Commercial Area Stormwater Monitoring Program,* September, 2000.
c. Sampling results from 2002-2003 in Worcester, MA: CDM report, 2003. Values from multiple sampling sites and times are reported here as single average values.
d. Sampling results from Manchester, NH and Lowell, MA, collected by CDM in 1992 and 1999, respectively. Values from multiple sampling sites are reported here as single average values.

National Values Averaged from Throughout the United States

Mean national EMC values were computed from the following sources:

a. Values compiled from NURP, Rouge River, and local measurements for Phase I NPDES permit for the Greater Lawrence Sanitary District (MA) – CDM Report on Baseline Conditions, 2000.
b. NURP mean values, from Rouge River Technical Memorandum (1998) and *Updating the U.S. Nationwide Urban Runoff Quality Database*, Smullen, J.T. *et al*, 1999.
c. Pooled national mean values from NURP, USGS, and EPA NPDES database, per *Updating the U.S. Nationwide Urban Runoff Quality Database*, Smullen, J.T. *et al*, 1999.
d. USEPA national values, reported in a Local Government Workshop publication, "*Tools for Watershed Protection,*" by Horsley and Witten, Inc.
e. Values from Maryland, Michigan, and Virginia – used in CDM's 1999 *Wachusett Watershed Stormwater Management Study.*

Average EMC values for each of the above three categories are tabulated and graphed on the following pages (note that the graphs are plotted on logarithmic scales to illustrate relative magnitudes of all values – actual variability between specific values can best be understood by reviewing the numeric tables). The data indicate that the relative magnitudes of reported EMCs are fairly consistent among the data sources. As a result, CDM recommends that the regional (New England) values be used for the land use categories and pollutant constituents for which regional data is available, and that the default values in the WMM model be used where regional values are not available.

We would appreciate your feedback on these proposed values. Please feel free to contact Mr. Kirk Westphal at westphalks@cdm.com or 617-452-6440, or Ms. Beth Rudolph at rudolphbe@cdm.com or 617-452-6356. Please let us know if you are comfortable with the proposed values, or if you prefer to suggest alternative values for consideration by the project team. In order to expedite the modeling effort, we ask that you respond by May 30, 2003.

Sincerely,

Kirk S. Westphal
Water Resources Engineer
CDM

Cc:

Mr. Arthur Screpetis
MADEP
Mr. Paul Currier
NHDES
Mr. David Gray, P.E.
USEPA
Mr. Harold Costa, P.E.
City of Lowell, MA
Mr. Thomas Siegle, P.E.
City of Manchester, NH
Mr. George Crombie, P.E.
City of Nashua, NH
Mr. Richard Hogan, P.E.
Greater Lawrence Sanitary District
Mr. William Pauk, P.E.
City of Haverhill, MA

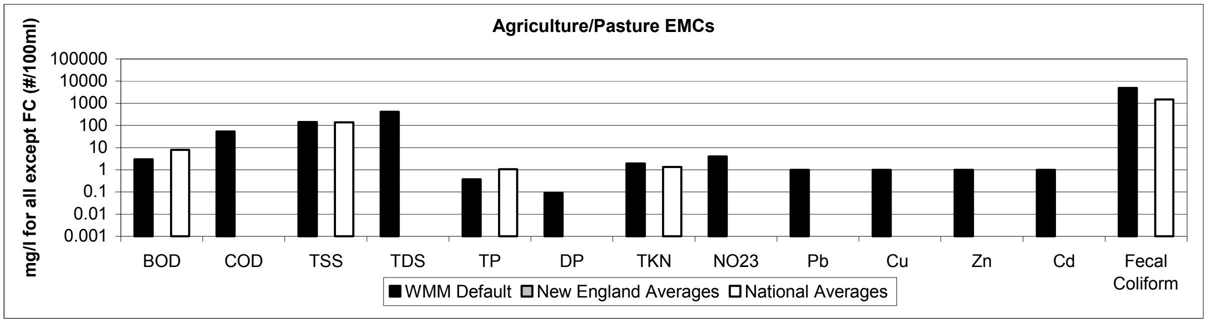
Comparative EMC Values for Merrimack Watershed Screening Model

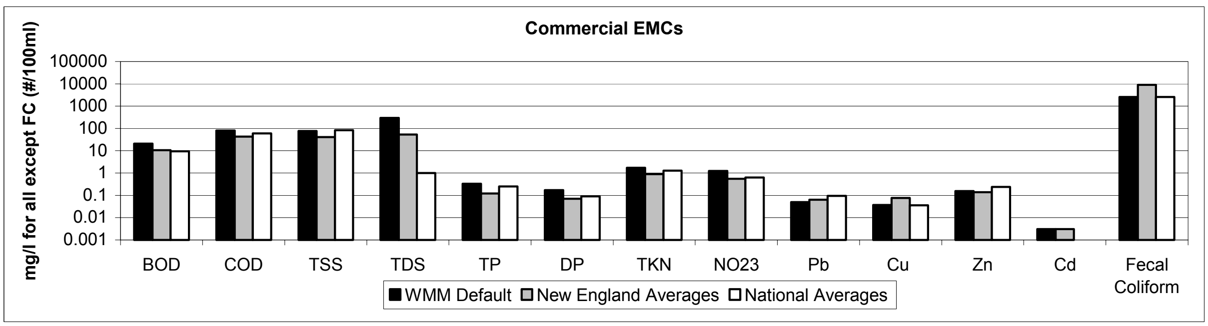
Default EMC Values for the Watershed Management Model (WMM)								
	Ag. & Pasture	Comm.	Forest/ Rural Open	Highway	Industrial	Medium Density Res.	Urban Open	Water/ Wetland
BOD (mg/l)	3	21	3	24	24	38	3	4
COD (mg/l)	53	80	27	103	85	124	27	6
TSS (mg/l)	145	77	51	141	149	70	51	6
TDS (mg/l)	415	294	415	294	202	144	415	12
TP (mg/l)	0.37	0.33	0.11	0.43	0.32	0.52	0.11	0.08
DP (mg/l)	0.09	0.17	0.03	0.22	0.11	0.27	0.03	0.04
TKN (mg/l)	1.92	1.74	0.94	1.82	2.08	3.32	0.94	0.79
NO23 (mg/l)	4.06	1.23	0.80	0.83	1.89	1.83	0.80	0.59
Pb (mg/l)	0.000	0.049	0.000	0.049	0.072	0.057	0.014	0.011
Cu (mg/l)	0.000	0.037	0.000	0.037	0.058	0.026	0.000	0.007
Zn (mg/l)	0.000	0.156	0.000	0.156	0.671	0.161	0.040	0.030
Cd (mg/l)	0.000	0.003	0.000	0.003	0.005	0.004	0.001	0.001
Fecal Coliform (#/100ml)	5000	2600	300	600	600	25001	5000	300
E-coli (#/100ml)								

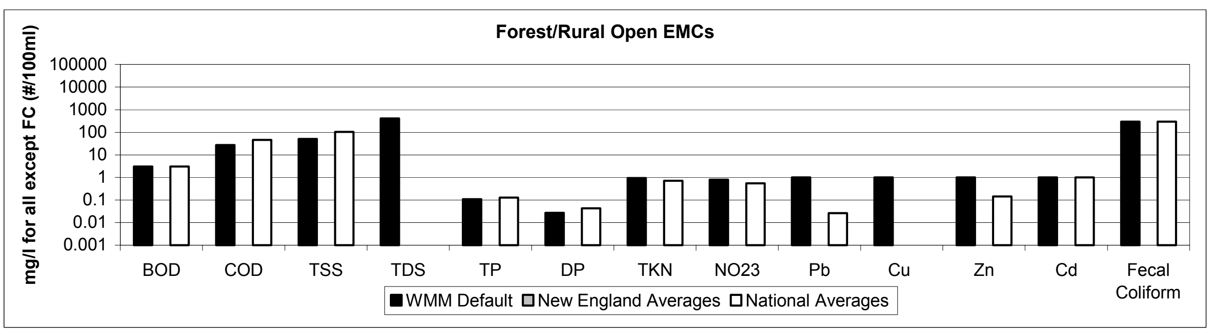
Regional Average EMC Values (New England)								
	Ag. & Pasture	Comm.	Forest/ Rural Open	Highway	Industrial	Medium Density Res.	Urban Open	Water/ Wetland
BOD (mg/l)		11			12	32		
COD (mg/l)		43				92		
TSS (mg/l)		41			42	58		
TDS (mg/l)		54						
TP (mg/l)		0.12			0.11	0.37		
DP (mg/l)		0.07			0.75	0.18		
TKN (mg/l)		0.90			2.90	2.06		
NO23 (mg/l)		0.55			1.11	1.20		
Pb (mg/l)		0.063			0.063	0.068		
Cu (mg/l)		0.077			0.113	0.037		
Zn (mg/l)		0.137			0.164	0.154		
Cd (mg/l)		0.003						
Fecal Coliform (#/100ml)		9008			1467	7861		
E-coli (#/100ml)						38607		

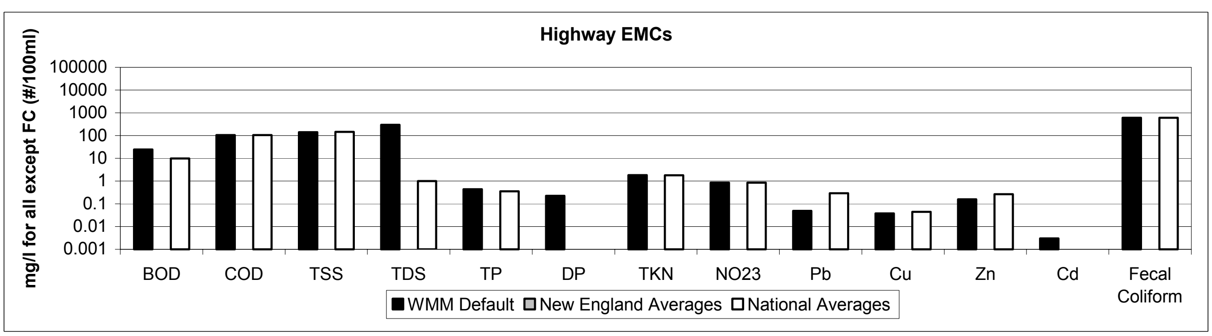
National Average EMC Values								
	Ag. & Pasture	Comm.	Forest/ Rural Open	Highway	Industrial	Medium Density Res.	Urban Open	Water/ Wetland
BOD (mg/l)	8	10	3	10	10	11	11	3
COD (mg/l)		59	46	103		78	59	17
TSS (mg/l)	140	84	104	142	140	127	114	17
TDS (mg/l)		0		0				
TP (mg/l)	1.04	0.25	0.13	0.35	0.29	0.40	0.30	0.03
DP (mg/l)		0.09	0.04			0.15	0.11	0.01
TKN (mg/l)	1.36	1.28	0.71	1.78	1.28	2.35	1.56	0.60
NO23 (mg/l)		0.64	0.54	0.83		0.78	0.75	0.60
Pb (mg/l)		0.094	0.027	0.290	0.072	0.127	0.086	0.006
Cu (mg/l)		0.035		0.044	0.058	0.036	0.027	0.004
Zn (mg/l)		0.237	0.142	0.263	0.671	0.159	0.126	0.070
Cd (mg/l)			0.000					
Fecal Coliform (#/100ml)	1500	2600	300	600	1000	3000	1500	300
E-coli (#/100ml)								

Note: Graphs are plotted on a logarithmic scale for comparison of relative magnitude. Actual values are listed in the preceding tables.

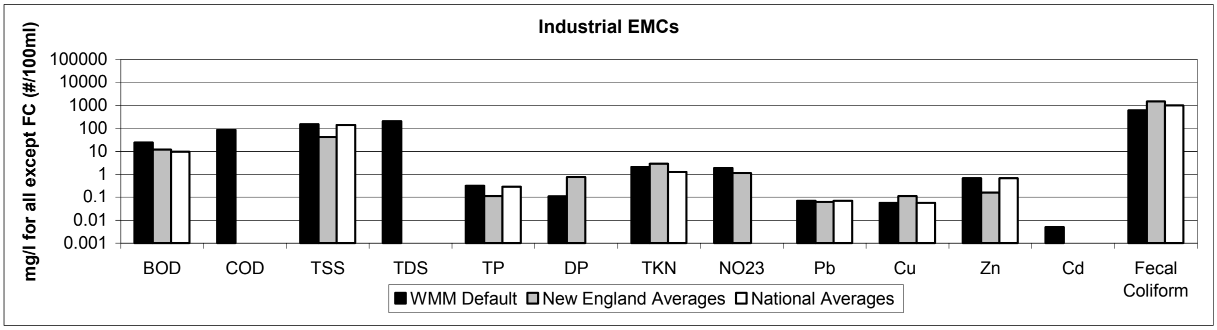


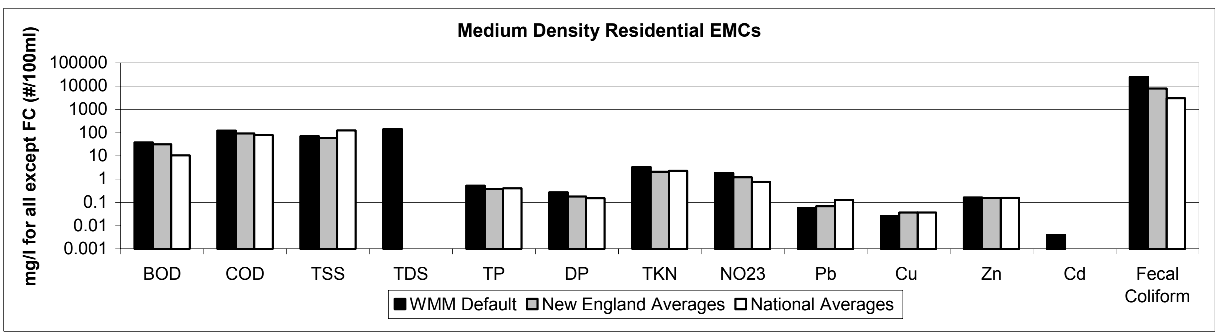


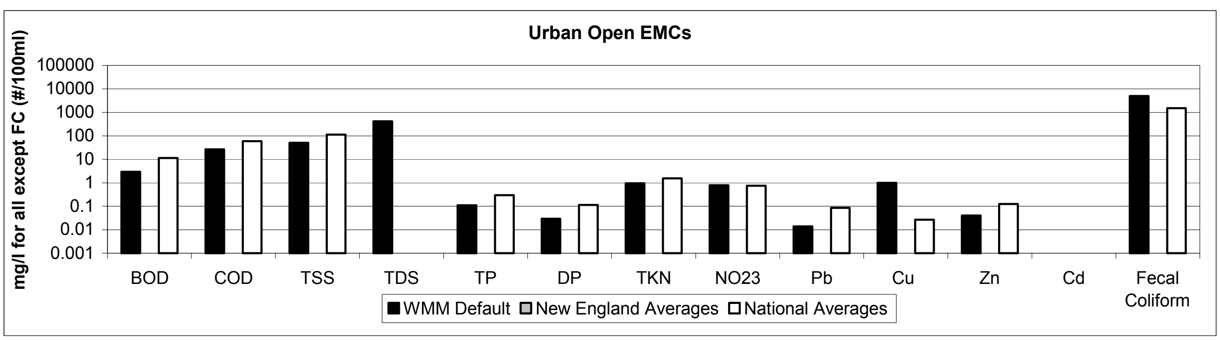


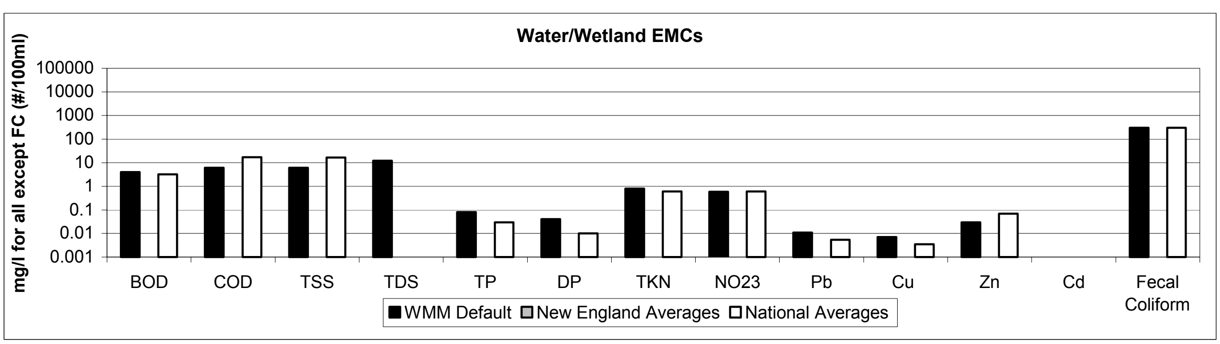


Note: Graphs are plotted on a logarithmic scale for comparison of relative magnitude. Actual values are listed in the preceding tables.









Appendix B: Manual Septic Calculations

Total Nitrogen Septic Load Calculations

Persons per house= 2.5
Total N load= 5.9lbs/person/year

Watershed	# Housing Unit	% Septic	Housing Units with Septic	Total Population on Septic	Total Nitrogen Load (lbs/yr)	Total w/ 45% Reduction for uptake	Total
Assabet	78,975	24.26%	19,158	47,895	282,583	155,420	
Beaver	18,699	46.53%	8,701	21,752	128,335	70,584	
Cohas	9,366	53.13%	4,976	12,440	73,396	40,368	
Concord	38,507	19.00%	7,316	18,291	107,916	59,354	
Lower Nashua	51,074	30.19%	15,417	38,543	227,403	125,072	
Pemigewasset	30,916	54.93%	16,981	42,452	250,466	137,756	
Piscataquog	31,071	33.59%	10,437	26,092	153,942	84,668	
Powwow	12,708	50.46%	6,413	16,031	94,586	52,022	
Salmon	15,901	22.61%	3,595	8,987	53,022	29,162	
Shawsheen	47,427	18.73%	8,883	22,208	131,025	72,064	
Souhegan	35,142	31.79%	11,172	27,929	164,781	90,630	
Spickett	15,314	51.53%	7,891	19,728	116,394	64,017	
Stony	27,758	19.87%	5,514	13,786	81,336	44,735	
Sudbury	91,592	21.08%	19,311	48,278	284,840	156,662	
Upper Merrimack	94,687	47.72%	45,181	112,952	666,415	366,529	
Upper Nashua	78,122	25.26%	19,737	49,341	291,114	160,113	
Winnipesaukee	26,538	63.78%	16,927	42,317	249,673	137,320	1,846,475
Manchester	44,361	5.40%	2,395	5,989	35,334	19,433	
Nashua	33,383	5.50%	1,836	4,590	27,082	14,895	
Lowell	40,302	1.20%	484	1,209	7,133	3,923	
Lawrence	26,915	1.00%	269	673	3,970	2,183	
Haverhill	21,321	11.20%	2,388	5,970	35,222	19,372	59,808
Merrimack Corridor 1	3,332	47.43%	1,580	3,951	23,310	12,821	
Merrimack Corridor 2	18,862	38.03%	7,174	17,934	105,813	58,197	
Merrimack Corridor 3	37,611	24.78%	9,321	23,303	137,489	75,619	
Merrimack Corridor 4	58,373	19.42%	11,335	28,337	167,190	91,954	
Merrimack Corridor 5	72,868	19.18%	13,974	34,934	206,110	113,360	
Merrimack Corridor 6	21,212	33.31%	7,065	17,662	104,207	57,314	409,265

Appendix C: WMM Results

SCENARIO 1

Parameter	Unit	Pollutant Source	Average			Drought			Wet		
			Communities	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*
Fecal Coliform	counts/yr	NPS	0.00E+00	4.04E+15	3.05E+16	0.00E+00	2.71E+15	2.04E+16	0.00E+00	5.66E+15	4.29E+16
		Point Source	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12
		CSO	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00
		TOTAL	5.07E+15	4.05E+15	3.05E+16	5.07E+15	2.72E+15	2.04E+16	5.07E+15	5.67E+15	4.29E+16
E. coli	counts/yr	NPS	0.00E+00	2.51E+15	1.88E+16	0.00E+00	1.70E+15	1.28E+16	0.00E+00	3.53E+15	2.68E+16
		Point Source	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12
		CSO	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00
		TOTAL	3.43E+15	2.54E+15	1.88E+16	3.43E+15	1.73E+15	1.28E+16	3.43E+15	3.56E+15	2.68E+16
BOD	lbs/yr	NPS	0	3,170,000	26,999,802	0	2,140,000	17,820,715	0	4,480,000	38,370,000
		Point Source	6,510,000	641,694	730,000	6,510,000	641,694	730,000	6,510,000	641,694	730,000
		CSO	344,726	0	0	344,726	0	0	344,726	0	0
		TOTAL	6,854,726	3,811,694	27,729,802	6,854,726	2,781,694	18,550,715	6,854,726	5,121,694	39,100,000
Total P	lbs/yr	NPS	0	44,916	426,544	0	28,779	262,723	0	65,110	633,589
		Point Source	2,667,436	108,732	98,596	2,667,436	108,732	98,596	2,667,436	108,732	98,596
		CSO	5,443	0	0	5,443	0	0	5,443	0	0
		Septic	0	462	4,341	0	319	2,982	0	642	5,025
		TOTAL	2,672,879	154,110	529,481	2,672,879	137,830	364,301	2,672,879	174,484	737,210
Total N	lbs/yr	NPS	0	575,576	5,806,671	0	359,250	3,498,509	0	843,568	8,792,905
		Point Source	5,947,436	647,528	608,596	5,947,436	647,528	608,596	5,947,436	647,528	608,596
		CSO	31,827	0	0	31,827	0	0	31,827	0	0
		Failing Septic (WMM)	0	4,416	17,148	0	3,035	20,345	0	3,868	64,467
		Septic (non-WMM)	59,808	409,265	1,846,475	59,808	409,265	1,846,475	59,808	409,265	1,846,475
		TOTAL	6,039,071	1,636,785	8,278,890	6,039,071	1,419,078	5,973,925	6,039,071	1,904,229	11,312,443
Copper	lbs/yr	NPS	0	1,873	14,212	0	1,325	10,106	0	2,539	19,195
		Point Source	1,958	623	4,399	1,958	623	4,399	1,958	623	4,399
		CSO	302	0	0	302	0	0	302	0	0
		TOTAL	2,260	2,496	18,611	2,260	1,948	14,505	2,260	3,162	23,594
Cadmium	lbs/yr	NPS	0	223	1,734	0	158	1,228	0	306	2,349
		Point Source	55	31	30	55	31	30	55	31	30
		CSO	26	0	0	26	0	0	26	0	0
		TOTAL	81	254	1,764	81	189	1,258	81	337	2,379
Lead	lbs/yr	NPS	0	2,747	21,043	0	1,928	14,862	0	3,747	28,561
		Point Source	322	51	91	322	51	91	322	51	91
		CSO	365	0	0	365	0	0	365	0	0
		TOTAL	687	2,798	21,134	687	1,979	14,953	687	3,798	28,652
TSS	lbs/yr	NPS	0	7,430,000	81,250,000	0	4,400,000	45,630,000	0	11,300,000	125,320,000
		Point Source	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000
		CSO	850,971	0	0	850,971	0	0	850,971	0	0
		TOTAL	5,330,971	8,229,567	85,050,000	5,330,971	5,199,567	49,430,000	5,330,971	12,099,567	129,120,000
Zinc	lbs/yr	NPS	0	12,337	90,365	0	8,719	64,046	0	16,735	122,348
		Point Source	7,992	2,511	1,206	7,992	2,511	1,206	7,992	2,511	1,206
		CSO	1,019	0	0	1,019	0	0	1,019	0	0
		TOTAL	9,011	14,848	91,571	9,011	11,230	65,252	9,011	19,246	123,554
Flow	ac-ft/yr	NPS	0	103,969	1,229,257	0	64,857	739,471	0	153,197	1,859,548
		Point Source	127,727	17,905	280,000	127,727	17,905	280,000	127,727	17,905	280,000
		CSO	2,392	0	0	2,392	0	0	2,392	0	0
		TOTAL	130,119	121,874	1,509,257	130,119	82,762	1,019,471	130,119	171,102	2,139,548

SCENARIO 2

Parameter	Unit	Pollutant Source	Average			Drought			Wet		
			Communities	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*
Fecal Coliform	counts/yr	NPS	0.00E+00	2.57E+15	2.00E+16	0.00E+00	1.72E+15	1.33E+16	0.00E+00	1.72E+15	1.33E+16
		Point Source	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12
		CSO	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00
		Total	5.07E+15	2.58E+15	2.00E+16	5.07E+15	1.73E+15	1.33E+16	5.07E+15	1.73E+15	1.33E+16
E. coli	counts/yr	NPS	0.00E+00	4.33E+15	3.18E+16	0.00E+00	2.93E+15	2.19E+16	0.00E+00	5.93E+15	4.45E+16
		Point Source	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12
		CSO	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00
		Total	3.43E+15	4.36E+15	3.18E+16	3.43E+15	2.96E+15	2.19E+16	3.43E+15	5.96E+15	4.45E+16
BOD	lbs/yr	NPS	0	2,170,000	19,738,657	0	1,440,000	12,812,973	0	3,080,000	28,580,000
		Point Source	6,510,000	641,694	730,000	6,510,000	641,694	730,000	6,510,000	641,694	730,000
		CSO	344,726	0	0	344,726	0	0	344,726	0	0
		Total	6,854,726	2,811,694	20,468,657	6,854,726	2,081,694	13,542,973	6,854,726	3,721,694	29,310,000
Total P	lbs/yr	NPS	0	37,383	372,125	0	23,447	224,218	0	54,903	558,408
		Point Source	2,667,436	108,732	98,596	2,667,436	108,732	98,596	2,667,436	108,732	98,596
		CSO	5,443	0	0	5,443	0	0	5,443	0	0
		Septic	0	365	3,420	0	251	2,351	0	507	3,960
		Total	2,672,879	146,480	474,141	2,672,879	132,430	325,165	2,672,879	164,142	660,964
Total N	lbs/yr	NPS	0	490,235	5,170,196	0	299,919	3,058,587	0	729,087	7,906,077
		Point Source	5,947,436	647,528	608,596	5,947,436	647,528	608,596	5,947,436	647,528	608,596
		CSO	31,827	0	0	31,827	0	0	31,827	0	0
		Failing Septic (WMM)	0	3,020	45,303	0	2,076	18,724	0	3,446	23,493
		Septic (non-WMM)	59,808	409,265	1,846,475	59,808	409,265	1,846,475	59,808	409,265	1,846,475
		Total	6,039,071	1,550,048	7,670,570	6,039,071	1,358,788	5,532,382	6,039,071	1,789,326	10,384,641
Copper	lbs/yr	NPS	0	2,816	21,002	0	2,008	15,023	0	3,793	28,231
		Point Source	1,958	623	4,399	1,958	623	4,399	1,958	623	4,399
		CSO	302	0	0	302	0	0	302	0	0
		Total	2,260	3,439	25,401	2,260	2,631	19,422	2,260	4,416	32,630
Cadmium	lbs/yr	NPS	0	213	1,652	0	150	1,168	0	291	2,246
		Point Source	55	31	30	55	31	30	55	31	30
		CSO	26	0	0	26	0	0	26	0	0
		Total	81	244	1,682	81	181	1,198	81	322	2,276
Lead	lbs/yr	NPS	0	3,211	24,527	0	2,267	17,420	0	4,356	33,158
		Point Source	322	51	91	322	51	91	322	51	91
		CSO	365	0	0	365	0	0	365	0	0
		Total	687	3,262	24,618	687	2,318	17,511	687	4,407	33,249
TSS	lbs/yr	NPS	0	6,400,000	74,380,000	0	3,680,000	41,120,000	0	9,800,000	115,310,000
		Point Source	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000
		CSO	850,971	0	0	850,971	0	0	850,971	0	0
		Total	5,330,971	7,199,567	78,180,000	5,330,971	4,479,567	44,920,000	5,330,971	10,599,567	119,110,000
Zinc	lbs/yr	NPS	0	9,695	73,060	0	6,797	51,511	0	6,797	51,511
		Point Source	7,992	2,511	1,206	7,992	2,511	1,206	7,992	2,511	1,206
		CSO	1,019	0	0	1,019	0	0	1,019	0	0
		Total	9,011	12,206	74,266	9,011	9,308	52,717	9,011	9,308	52,717
Flow	ac-ft/yr	NPS	0	103,969	1,229,257	0	64,857	739,471	0	64,857	739,471
		Point Source	127,727	17,905	280,000	127,727	17,905	280,000	127,727	17,905	280,000
		CSO	2,392	0	0	2,392	0	0	2,392	0	0
		Total	130,119	121,874	1,509,257	130,119	82,762	1,019,471	130,119	82,762	1,019,471

SCENARIO 3

Parameter	Unit	Pollutant Source	Average			Drought			Wet		
			Communities	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*
Fecal Coliform	count/yr	NPS	0.00E+00	2.57E+15	2.00E+16	0.00E+00	1.72E+15	1.33E+16	0.00E+00	3.63E+15	2.81E+16
		Point Source	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12
		CSO	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00
		Total	5.07E+15	2.58E+15	2.00E+16	5.07E+15	1.73E+15	1.33E+16	5.07E+15	3.64E+15	2.81E+16
E. coli	count/yr	NPS	0.00E+00	4.33E+15	3.18E+16	0.00E+00	2.93E+15	2.19E+16	0.00E+00	5.93E+15	4.45E+16
		Point Source	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12
		CSO	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00
		Total	3.43E+15	4.36E+15	3.18E+16	3.43E+15	2.96E+15	2.19E+16	3.43E+15	5.96E+15	4.45E+16
BOD	lbs/yr	NPS	0	2,170,000	19,738,657	0	1,440,000	12,812,973	0	3,080,000	28,580,000
		Point Source	6,510,000	641,694	730,000	6,510,000	641,694	730,000	6,510,000	641,694	730,000
		CSO	344,726	0	0	344,726	0	0	344,726	0	0
		Total	6,854,726	2,811,694	20,468,657	6,854,726	2,081,694	13,542,973	6,854,726	3,721,694	29,310,000
Total P	lbs/yr	NPS	0	37,383	372,125	0	23,447	224,218	0	54,903	558,408
		Point Source	2,667,436	108,732	98,596	2,667,436	108,732	98,596	2,667,436	108,732	98,596
		CSO	5,443	0	0	5,443	0	0	5,443	0	0
		Septic	0	782	7,331	0	537	5,038	0	1,083	8,484
		Total	2,672,879	146,897	478,052	2,672,879	132,716	327,852	2,672,879	164,718	665,488
Total N	lbs/yr	NPS	0	490,235	5,170,196	0	299,919	3,058,587	0	729,087	7,906,077
		Point Source	5,947,436	647,528	608,596	5,947,436	647,528	608,596	5,947,436	647,528	608,596
		CSO	31,827	0	0	31,827	0	0	31,827	0	0
		Failing Septic (WMM)	0	6,469	71,357	0	4,446	38,098	0	7,383	47,485
		Septic (non-WMM)	59,808	409,265	1,846,475	59,808	409,265	1,846,475	59,808	409,265	1,846,475
		Total	6,039,071	1,553,497	7,696,624	6,039,071	1,361,158	5,551,756	6,039,071	1,793,263	10,408,633
Copper	lbs/yr	NPS	0	2,816	21,002	0	2,008	15,023	0	3,793	28,231
		Point Source	1,958	623	4,399	1,958	623	4,399	1,958	623	4,399
		CSO	302	0	0	302	0	0	302	0	0
		Total	2,260	3,439	25,401	2,260	2,631	19,422	2,260	4,416	32,630
Cadmium	lbs/yr	NPS	0	213	1,652	0	150	1,168	0	291	2,246
		Point Source	55	31	30	55	31	30	55	31	30
		CSO	26	0	0	26	0	0	26	0	0
		Total	81	244	1,682	81	181	1,198	81	322	2,276
Lead	lbs/yr	NPS	0	3,211	24,527	0	2,267	17,420	0	4,356	33,158
		Point Source	322	51	91	322	51	91	322	51	91
		CSO	365	0	0	365	0	0	365	0	0
		Total	687	3,262	24,618	687	2,318	17,511	687	4,407	33,249
TSS	lbs/yr	NPS	0	6,400,000	74,380,000	0	3,680,000	41,120,000	0	9,800,000	115,310,000
		Point Source	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000
		CSO	850,971	0	0	850,971	0	0	850,971	0	0
		Total	5,330,971	7,199,567	78,180,000	5,330,971	4,479,567	44,920,000	5,330,971	10,599,567	119,110,000
Zinc	lbs/yr	NPS	0	9,695	73,060	0	6,797	51,511	0	13,228	99,294
		Point Source	7,992	2,511	1,206	7,992	2,511	1,206	7,992	2,511	1,206
		CSO	1,019	0	0	1,019	0	0	1,019	0	0
		Total	9,011	12,206	74,266	9,011	9,308	52,717	9,011	15,739	100,500
Flow	ac-ft/yr	NPS	0	103,969	1,229,257	0	64,857	739,471	0	153,197	1,859,548
		Point Source	127,727	17,905	280,000	127,727	17,905	280,000	127,727	17,905	280,000
		CSO	2,392	0	0	2,392	0	0	2,392	0	0
		Total	130,119	121,874	1,509,257	130,119	82,762	1,019,471	130,119	171,102	2,139,548

SCENARIO 4

Parameter	Unit	Pollutant Source	Average			Drought			Wet		
			Communities	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*
Fecal Coliform	counts/yr	NPS	0.00E+00	2.57E+15	2.00E+16	0.00E+00	1.72E+15	1.33E+16	0.00E+00	3.63E+15	2.81E+16
		Point Source	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12
		CSO	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00
		Total	5.07E+15	2.58E+15	2.00E+16	5.07E+15	1.73E+15	1.33E+16	5.07E+15	3.64E+15	2.81E+16
E. coli	counts/yr	NPS	0.00E+00	4.33E+15	3.18E+16	0.00E+00	2.93E+15	2.19E+16	0.00E+00	5.93E+15	4.45E+16
		Point Source	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12
		CSO	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00
		Total	3.43E+15	4.36E+15	3.18E+16	3.43E+15	2.96E+15	2.19E+16	3.43E+15	5.96E+15	4.45E+16
BOD	lbs/yr	NPS	0	2,170,000	19,738,657	0	1,440,000	12,812,973	0	3,080,000	28,580,000
		Point Source	6,510,000	641,694	730,000	6,510,000	641,694	730,000	6,510,000	641,694	730,000
		CSO	344,726	0	0	344,726	0	0	344,726	0	0
		Total	6,854,726	2,811,694	20,468,657	6,854,726	2,081,694	13,542,973	6,854,726	3,721,694	29,310,000
Total P	lbs/yr	NPS	0	37,383	372,125	0	23,447	224,218	0	54,903	558,408
		Point Source	2,667,436	108,732	98,596	2,667,436	108,732	98,596	2,667,436	108,732	98,596
		CSO	5,443	0	0	5,443	0	0	5,443	0	0
		Septic	0	156	1,465	0	108	1,008	0	216	1,697
		Total	2,672,879	146,271	472,186	2,672,879	132,287	323,822	2,672,879	163,851	658,701
Total N	lbs/yr	NPS	0	490,235	5,170,196	0	299,919	3,058,587	0	729,087	7,906,077
		Point Source	5,947,436	647,528	608,596	7,627,436	647,528	608,596	7,627,436	647,528	608,596
		CSO	31,827	0	0	35,123	0	0	35,123	0	0
		Failing Septic (WMM)	0	1,294	2,272	0	889	13,737	0	1,477	11,497
		Septic (non-WMM)	59,808	409,265	1,846,475	59,808	409,265	1,846,475	59,808	409,265	1,846,475
		Total	6,039,071	1,548,322	7,627,539	7,722,367	1,357,601	5,527,395	7,722,367	1,787,357	10,372,645
Copper	lbs/yr	NPS	0	2,816	21,002	0	2,008	15,023	0	3,793	28,231
		Point Source	1,958	623	4,399	1,958	623	4,399	1,958	623	4,399
		CSO	302	0	0	302	0	0	302	0	0
		Total	2,260	3,439	25,401	2,260	2,631	19,422	2,260	4,416	32,630
Cadmium	lbs/yr	NPS	0	213	1,652	0	150	1,168	0	291	2,246
		Point Source	55	31	30	55	31	30	55	31	30
		CSO	26	0	0	26	0	0	26	0	0
		Total	81	244	1,682	81	181	1,198	81	322	2,276
Lead	lbs/yr	NPS	0	3,211	24,527	0	2,267	17,420	0	4,356	33,158
		Point Source	322	51	91	322	51	91	322	51	91
		CSO	365	0	0	365	0	0	365	0	0
		Total	687	3,262	24,618	687	2,318	17,511	687	4,407	33,249
TSS	lbs/yr	NPS	0	6,400,000	74,380,000	0	3,680,000	41,120,000	0	9,800,000	115,310,000
		Point Source	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000
		CSO	850,971	0	0	850,971	0	0	850,971	0	0
		Total	5,330,971	7,199,567	78,180,000	5,330,971	4,479,567	44,920,000	5,330,971	10,599,567	119,110,000
Zinc	lbs/yr	NPS	0	9,695	73,060	0	6,797	51,511	0	13,228	99,294
		Point Source	7,992	2,511	1,206	7,992	2,511	1,206	7,992	2,511	1,206
		CSO	1,019	0	0	1,019	0	0	1,019	0	0
		Total	9,011	12,206	74,266	9,011	9,308	52,717	9,011	15,739	100,500
Flow	ac-ft/yr	NPS	0	103,969	1,229,257	0	64,857	739,471	0	153,197	1,859,548
		Point Source	127,727	17,905	280,000	127,727	17,905	280,000	127,727	17,905	280,000
		CSO	2,392	0	0	2,392	0	0	2,392	0	0
		Total	130,119	121,874	1,509,257	130,119	82,762	1,019,471	130,119	171,102	2,139,548

SCENARIO 5

Parameter	Unit	Pollutant Source	Average			Drought			Wet		
			Communities	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*
Fecal Coliform	counts/yr	NPS	0.00E+00	4.31E+15	3.30E+16	0.00E+00	2.90E+15	2.22E+16	0.00E+00	5.96E+15	4.69E+16
		Point Source	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12
		CSO	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00
		Total	5.07E+15	4.32E+15	3.30E+16	5.07E+15	2.91E+15	2.22E+16	5.07E+15	5.97E+15	4.69E+16
E. coli	counts/yr	NPS	0.00E+00	7.15E+15	5.33E+16	0.00E+00	4.86E+15	3.60E+16	0.00E+00	9.99E+15	7.43E+16
		Point Source	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12
		CSO	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00
		Total	3.43E+15	7.18E+15	5.33E+16	3.43E+15	4.89E+15	3.60E+16	3.43E+15	1.00E+16	7.43E+16
BOD	lbs/yr	NPS	0	2,170,000	19,738,657	0	1,440,000	12,812,973	0	3,080,000	28,580,000
		Point Source	6,510,000	641,694	730,000	6,510,000	641,694	730,000	6,510,000	641,694	730,000
		CSO	344,726	0	0	344,726	0	0	344,726	0	0
		Total	6,854,726	2,811,694	20,468,657	6,854,726	2,081,694	13,542,973	6,854,726	3,721,694	29,310,000
Total P	lbs/yr	NPS	0	50,451	496,482	0	31,741	304,083	0	73,962	754,436
		Point Source	2,667,436	108,732	98,596	2,667,436	108,732	98,596	2,667,436	108,732	98,596
		CSO	5,443	0	0	5,443	0	0	5,443	0	0
		Septic	0	457	3,576	0	315	2,938	0	633	4,477
		Total	2,672,879	159,640	598,654	2,672,879	140,788	405,617	2,672,879	183,327	857,509
Total N	lbs/yr	NPS	0	638,444	6,773,460	0	394,258	4,058,977	0	944,727	10,316,547
		Point Source	5,947,436	647,528	608,596	5,947,436	647,528	608,596	5,947,436	647,528	608,596
		CSO	31,827	0	0	31,827	0	0	31,827	0	0
		Failing Septic (WMM)	0	3,545	66,123	0	2,436	28,943	0	2,736	63,605
		Septic (non-WMM)	59,808	409,265	1,846,475	59,808	409,265	1,846,475	59,808	409,265	1,846,475
		Total	6,039,071	1,698,782	9,294,654	6,039,071	1,453,487	6,542,991	6,039,071	2,004,256	12,835,223
Copper	lbs/yr	NPS	0	4,167	31,569	0	2,978	22,641	0	5,608	42,359
		Point Source	1,958	623	4,399	1,958	623	4,399	1,958	623	4,399
		CSO	302	0	0	302	0	0	302	0	0
		Total	2,260	4,790	35,968	2,260	3,601	27,040	2,260	6,231	46,758
Cadmium	lbs/yr	NPS	0	343	2,714	0	242	1,927	0	467	3,670
		Point Source	55	31	30	55	31	30	55	31	30
		CSO	26	0	0	26	0	0	26	0	0
		Total	81	374	2,744	81	273	1,957	81	498	3,700
Lead	lbs/yr	NPS	0	5,877	45,181	0	4,162	32,160	0	7,962	60,981
		Point Source	322	51	91	322	51	91	322	51	91
		CSO	365	0	0	365	0	0	365	0	0
		Total	687	5,928	45,272	687	4,213	32,251	687	8,013	61,072
TSS	lbs/yr	NPS	0	12,800,000	146,860,000	0	7,250,000	81,300,000	0	19,800,000	230,600,000
		Point Source	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000
		CSO	850,971	0	0	850,971	0	0	850,971	0	0
		Total	5,330,971	13,599,567	150,660,000	5,330,971	8,049,567	85,100,000	5,330,971	20,599,567	234,400,000
Zinc	lbs/yr	NPS	0	12,908	99,977	0	9,096	70,935	0	17,548	135,253
		Point Source	7,992	2,511	1,206	7,992	2,511	1,206	7,992	2,511	1,206
		CSO	1,019	0	0	1,019	0	0	1,019	0	0
		Total	9,011	15,419	101,183	9,011	11,607	72,141	9,011	20,059	136,459
Flow	ac-ft/yr	NPS	0	103,969	1,229,257	0	64,857	739,471	0	153,197	1,859,548
		Point Source	127,727	17,905	280,000	127,727	17,905	280,000	127,727	17,905	280,000
		CSO	2,392	0	0	2,392	0	0	2,392	0	0
		Total	130,119	121,874	1,509,257	130,119	82,762	1,019,471	130,119	171,102	2,139,548

SCENARIO 6

Parameter	Unit	Pollutant Source	Average			Drought			Wet		
			Communities	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*	*Communities*	*MR Corridors*	*Tributaries*
Fecal Coliform	counts/yr	NPS	0.00E+00	3.43E+15	1.81E+16	0.00E+00	2.30E+15	1.22E+16	0.00E+00	4.82E+15	2.54E+16
		Point Source	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12	1.97E+13	7.93E+12	2.30E+12
		CSO	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00	5.05E+15	0.00E+00	0.00E+00
		Total	5.07E+15	3.44E+15	1.81E+16	5.07E+15	2.31E+15	1.22E+16	5.07E+15	4.83E+15	2.54E+16
E. coli	counts/yr	NPS	0.00E+00	5.68E+15	2.95E+16	0.00E+00	3.91E+15	2.02E+16	0.00E+00	7.99E+15	4.14E+16
		Point Source	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12	3.26E+14	3.22E+13	2.30E+12
		CSO	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00	3.10E+15	0.00E+00	0.00E+00
		Total	3.43E+15	5.71E+15	2.95E+16	3.43E+15	3.94E+15	2.02E+16	3.43E+15	8.02E+15	4.14E+16
BOD	lbs/yr	NPS	0	2,170,000	19,738,657	0	1,440,000	12,812,973	0	3,080,000	28,580,000
		Point Source	6,510,000	641,694	730,000	6,510,000	641,694	730,000	6,510,000	641,694	730,000
		CSO	344,726	0	0	344,726	0	0	344,726	0	0
		Total	6,854,726	2,811,694	20,468,657	6,854,726	2,081,694	13,542,973	6,854,726	3,721,694	29,310,000
Total P	lbs/yr	NPS	0	43,918	336,597	0	27,596	202,575	0	64,433	507,613
		Point Source	2,667,436	108,732	98,596	2,667,436	108,732	98,596	2,667,436	108,732	98,596
		CSO	5,443	0	0	5,443	0	0	5,443	0	0
		Septic	0	410	3,261	0	280	2,242	0	568	3,836
		Total	2,672,879	153,060	438,454	2,672,879	136,608	303,413	2,672,879	173,733	610,045
Total N	lbs/yr	NPS	0	564,340	4,681,819	0	347,090	2,734,538	0	840,641	7,149,912
		Point Source	5,947,436	647,528	608,596	5,947,436	647,528	608,596	5,947,436	647,528	608,596
		CSO	31,827	0	0	31,827	0	0	31,827	0	0
		Failing Septic (WMM)	0	3,283	26,109	0	2,254	18,907	0	2,848	13,915
		Septic (non-WMM)	59,808	409,265	1,846,475	59,808	409,265	1,846,475	59,808	409,265	1,846,475
		Total	6,039,071	1,624,416	7,162,999	6,039,071	1,406,137	5,208,516	6,039,071	1,900,282	9,618,898
Copper	lbs/yr	NPS	0	3,492	19,225	0	2,494	13,719	0	4,701	25,892
		Point Source	1,958	623	4,399	1,958	623	4,399	1,958	623	4,399
		CSO	302	0	0	302	0	0	302	0	0
		Total	2,260	4,115	23,624	2,260	3,117	18,118	2,260	5,324	30,291
Cadmium	lbs/yr	Stormwater	0	281	1,438	0	196	1,012	0	379	1,962
		Point Source	55	31	30	55	31	30	55	31	30
		CSO	26	0	0	26	0	0	26	0	0
		Total	81	312	1,468	81	227	1,042	81	410	1,992
Lead	lbs/yr	Stormwater	0	4,544	21,487	0	3,215	15,209	0	6,159	29,124
		Point Source	322	51	91	322	51	91	322	51	91
		CSO	365	0	0	365	0	0	365	0	0
		Total	687	4,595	21,578	687	3,266	15,300	687	6,210	29,215
TSS	lbs/yr	Stormwater	0	9,600,000	51,370,000	0	5,500,000	28,780,000	0	14,700,000	80,510,000
		Point Source	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000	4,480,000	799,567	3,800,000
		CSO	850,971	0	0	850,971	0	0	850,971	0	0
		Total	5,330,971	10,399,567	55,170,000	5,330,971	6,299,567	32,580,000	5,330,971	15,499,567	84,310,000
Zinc	lbs/yr	Stormwater	0	11,301	67,211	0	7,947	47,193	0	15,389	91,616
		Point Source	7,992	2,511	1,206	7,992	2,511	1,206	7,992	2,511	1,206
		CSO	1,019	0	0	1,019	0	0	1,019	0	0
		Total	9,011	13,812	68,417	9,011	10,458	48,399	9,011	17,900	92,822
Flow	ac-ft/yr	Stormwater	0	103,969	1,229,257	0	64,857	739,471	0	153,197	1,859,548
		Point Source	127,727	17,905	280,000	127,727	17,905	280,000	127,727	17,905	280,000
		CSO	2,392	0	0	2,392	0	0	2,392	0	0
		Total	130,119	121,874	1,509,257	130,119	82,762	1,019,471	130,119	171,102	2,139,548