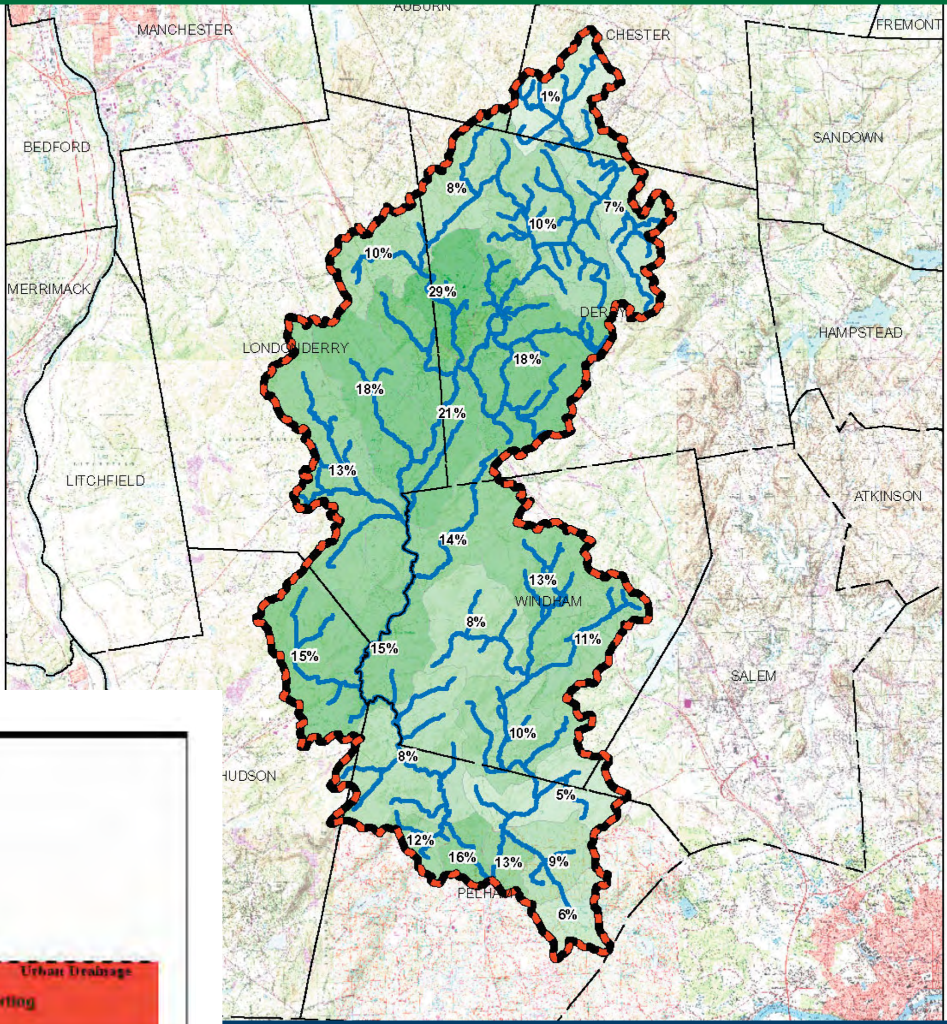
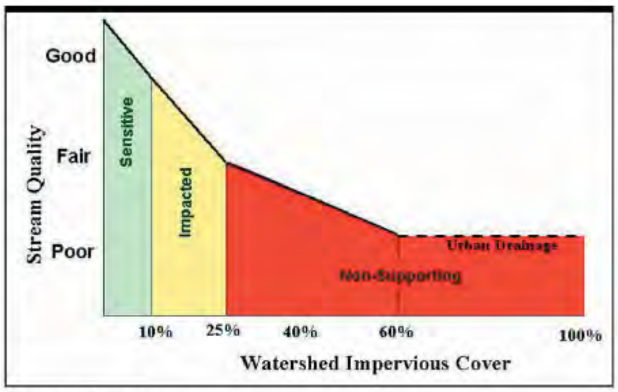
Submitted to:

United States Environmental
Protection Agency
Region I





(Source: Schueler, 2003)

Pilot TMDL Applications using the Impervious Cover Method

Submitted by:

2 Technology Park Drive
Westford, MA 01886

ENSR Corporation

October 2005

Project No.: 10598-001-002

CV05083

CONTENTS

CONTENTS (Cont'd)

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

This report provides a description of the Impervious Cover (IC) method and tests its feasibility as a TMDL development tool using watersheds nominated by five New England States. In the report, we describe the IC method and apply it to complete a set of seven total maximum daily load (TMDL) allocations for impaired watersheds throughout New England. EPA Region I has identified the IC method as a potentially useful, innovative TMDL approach for water bodies impaired by stormwater. This work has been conducted by EPA Region I as part of an initiative to select and apply scientifically appropriate and resource efficient methods to complete TMDL allocation projects.

The IC method uses percent impervious cover in a watershed as a surrogate TMDL target. The IC method may be applicable for completing TMDLs in smaller stormwater-impaired streams with biological impairments (e.g., aquatic life, macroinvertebrate, or habitat impairments). The IC method appears to be well-suited to support phased implementation of TMDLs using adaptive management techniques to achieve environmental improvements. The IC Method TMDL applications described herein are pilot projects designed to test the feasibility of using the IC Method within the TMDL framework.

The IC metric in the TMDL analysis (EPA generally recommends 9%, unless a state has more site-specific information that indicates a different target is appropriate) is a target to guide implementation of best management practices (BMPs). Based on extensive data and the best information available, it appears that if the IC target is met (by reducing actual IC, reducing directly connected IC, or other measures – see Chapter 5) stormwater-impaired waters will be brought back into compliance with water quality standards (WQS). The IC target, however, is not intended to assess ultimate compliance with State WQSs. Compliance will be determined by monitoring of appropriate state-specific parameters in the affected water body and comparison to water quality criteria. The IC Method is most applicable to smaller watersheds or sub-watersheds with greater than 9% IC, where the IC model indicates a strong correlation between %IC and aquatic life standards attainment.

EPA notes that all sources contributing to an impairment need to be acknowledged in a TMDL analysis. If stormwater runoff volume represented by the surrogate impervious cover is not the only likely contributor, other causes will have to be identified, assessed, and possibly provided TMDL targets.

EPA Region 1 and representatives of the New England states reviewed and evaluated numerous candidate TMDL methods for feasibility in completing TMDLs in New England. The Impervious Cover Method was selected primarily because it provides a strong and straightforward link between water quality impairments and causal factors. The IC Method is based on the scientific relationship between the portion of impervious cover in a watershed and its stream quality. Stream quality is defined in this context to include a broad set of parameters characterizing hydrologic, physical, water quality, and biological conditions. The method is largely based on the work of The Center for Watershed Protections which has compiled and evaluated extensive data relating watershed impervious cover to hydrologic, physical, water quality, and biological conditions (Schueler, 2003).

Application of the Impervious Cover Method requires use of watershed land use information to estimate watershed impervious cover. Watershed impervious cover is then correlated to extensive datasets to support prediction of stream quality. Through this method, stream quality may be predicted in each watershed (and sub-basin) based on percent impervious cover. Where impairment is predicted (i.e., where stream quality is unacceptable), the IC method may be applied to specify modifications (e.g., BMPs) designed to remove impairments. The process of applying the IC method to complete TMDL allocations is described herein and applied to complete seven pilot TMDL allocations.

The IC Method is very useful for developing TMDLs for aquatic life impairments caused by stormwater runoff. It is particularly helpful for developing stormwater TMDLs where no specific pollutant can be identified as the cause of the impairment. If a water body is 303(d)-listed for both an aquatic life impairment caused by stormwater and specific pollutants, the IC Method may be used to address the aquatic life impairment. Specific TMDL targets for the listed pollutants should also be developed. Where any specific 303(d)-listed pollutants are primarily related to stormwater runoff, the techniques outlined in this report may be appropriate. If the specific listed pollutants causing the impairment are related to sources other than stormwater volume, then other more appropriate techniques should be used to develop these TMDL targets.

This report contains the following components:

- Section 2 – an overview of the impervious cover method;
- Section 3 - a description of how the IC method is applied to complete the TMDL development;
- Section 4 – a description of the application of the IC method to complete TMDL development for seven watersheds throughout New England; and
- Section 5 – a brief description of the TMDL implementation process.

The watersheds assessed in Chapter 4 do not all match our selection criteria for using the IC method, nor do they all have impervious cover greater than 9%, which is generally our suggested initial TMDL target (unless a state has more site-specific information that indicates a different target is appropriate). For each example watershed, we note what worked and what didn't work in the analysis, and discuss whether the watershed is an appropriate selection for this approach. The ICM was identified as an appropriate method for TMDL development for four of the seven pilot TMDL applications. For the remaining three pilot watershed TMDL applications, the ICM method was deemed inappropriate based on the presence of additional known and specific impairments and/or %IC below the TMDL metric in the subject watershed. The seven pilot applications successfully tested the feasibility of using the ICM for TMDL development by identifying both appropriate and inappropriate TMDL application scenarios.

2.0 IMPERVIOUS COVER METHOD

This section provides a description of the impervious cover method and a description of how the IC method has been applied to evaluate stream conditions. A step-by-step description of how the IC method was applied to complete the seven pilot TMDL allocations is also provided.

2.1 Overview of the Impervious Cover Model

The impervious cover model (ICM) relates an aquatic system's health (i.e., state of impairment) to the percentage of impervious cover in its contributing watershed. This method is largely based on the work of the Center for Watershed Protection, which has compiled and evaluated extensive data relating watershed impervious cover to the hydrologic, physical, water quality, and biological conditions of aquatic systems (Schueler, 2003).

The relative portion of a watershed's impervious cover can be used as an effective means of determining aquatic system health. Urbanization, primarily through the construction of impervious cover, causes progressive hydrologic, physical, water quality and biological impacts to aquatic health. Agricultural and other land-modifying activities can also contribute significantly to aquatic health degradation.

Figure 2-1 provides a schematic representation of modification to the water budget that can accompany increased IC in a watershed. Increasing impervious cover reduces the amount of infiltration/recharge and increases the amount of runoff. As a result, the stream experiences lower low flows, due to reduced baseflow, and higher high flows, due to large stormwater runoff volumes.

Table 2-1 provides a tabulation of specific stream impacts associated with increasing impervious cover. Hydrologic impacts are illustrated in Figure 1. Physical impacts are directly related to modification in stream hydrology. For example, flooding causes channel enlargement and incision, while low flows can result in warmer in-stream temperatures. Water quality impacts are due primarily to direct conveyance of additional materials into the steam with stormwater runoff. Lastly, biological impacts are the result of degradation of hydrology, physical, and water quality conditions in the stream ecosystem. Impervious cover serves as an excellent surrogate for many types of stormwater-related impairments because it relates primary causal factors to specific impairments.

Figure 2-2 provides a representation of the relationship between stream quality and watershed impervious cover, based on the ICM. This research indicates that a decline in stream quality occurs when impervious cover (IC) for a watershed exceeds 10% and that severe impairment can be expected when the IC exceeds 25%. For the New England pilot TMDLs using the ICM, a target of 9% IC was selected as a surrogate for a whole suite of stressors related to stormwater. The 9% IC metric is a target to attain water quality standards (WQSs) through implementation of BMPs. Based on extensive data and the best information available, it appears that if the IC target is met, stormwater-impaired waters will be brought back into compliance with WQSs. The IC target, however, is not intended to assess ultimate compliance with State WQSs. Compliance will be determined by monitoring of appropriate state-specific parameters in the affected water body and comparison to water quality criteria. Depending on specific state water quality classifications and site-specific assessment data, targets lower or higher than 9% may be appropriate. For instance, a water body classified as class C might not need an IC target as low as 9%, as would a water body which needed to attain class B. Similarly, a water body impaired by stormwater runoff may already have an IC rating of 9% and require a lower target and TMDL targets to address other stressors in addition to stormwater runoff volume.

The IC Method provides direct guidance toward removing impairments and evaluating management scenarios because this surrogate relates the cause of an impairment directly to the impairment. The IC Method is also relatively efficient to apply. Thus, it is suitable for evaluating the sub-watersheds of large watersheds and is capable of rapidly identifying problem areas (i.e., hot spots).

Table 2-1 Hydrologic, Physical, Water Quality, and Biological Impacts Associated with IC

Hydrologic Impacts
- Increased runoff volume
- Increased peak flow rates
- Increased bankfull flow
- Decreased baseflow

Biological Impacts
- Reduced aquatic insect diversity
- Reduced fish diversity
- Reduced amphibian diversity
- Reduced wetland plant diversity

Physical Impacts
- Modified sediment transport
- Channel enlargement
- Channel incision
- Stream embeddedness
- Loss of large woodsy debris
- Changes in pool/riffle structure
- Loss of riparian cover
- Reduced channel sinuosity
- Warmer in-stream temperatures

Water Quality Impacts
- Increased sediment concentrations
- Increased nutrient concentrations
- Increased trace metal concentrations
- Increased hydrocarbon conc.
- Increased bacteria and pathogens
- Increased organic carbon conc.
- Increased MTBE concentrations
- Increased pesticide concentrations
- Increased deicer concentrations

Figure 2-1 Schematic Water Balance: Natural Conditions vs. Developed Conditions

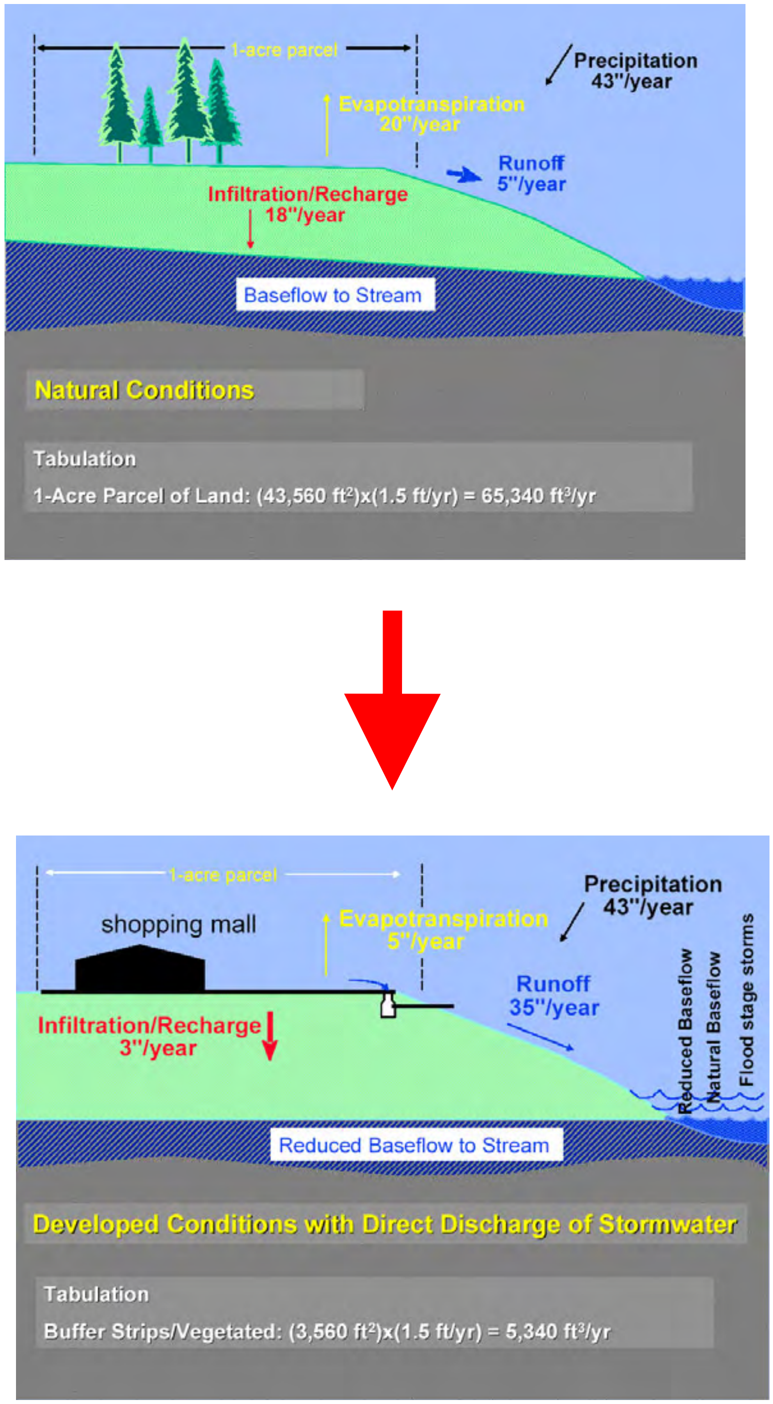
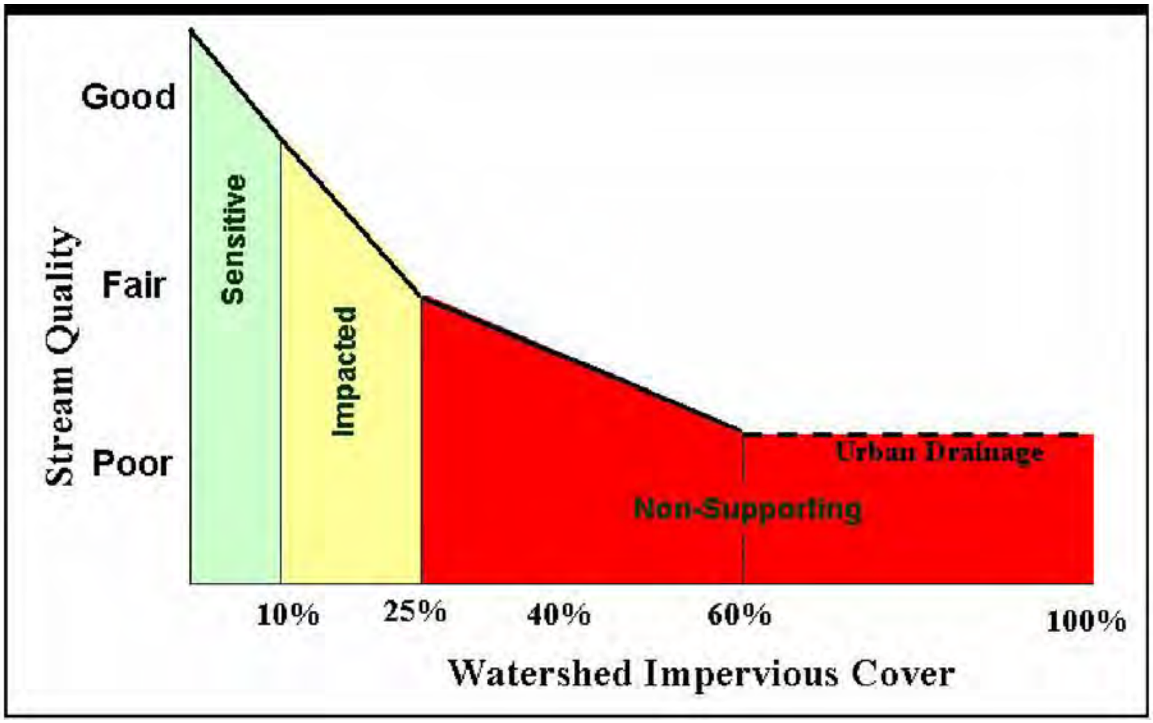


Figure 2-2 Stream Quality vs. Watershed Impervious Cover



(Source: Schueler, 2003)

2.2 IC Method Application Process

The IC Method may be described in several steps as outlined below.

1. Watershed Delineation including delineation of each sub-watershed in an area of interest and development of a GIS data-layer.

2. Impervious Cover Mapping including development of watershed coverages for land cover and impervious cover within a GIS data-layer.

3. Impervious Cover Determination for overall watershed and sub-watershed impervious cover magnitude and percentage of watershed area

4. Estimation of Annual Runoff Volume – Expanded Application of the Basic, Recommended Procedure This parameter may be calculated and is strongly correlated with stormwater impairments in streams.

5. Pollutant Selection and Estimation of Pollutant Loads – Expanded Application of the Basic, Recommended Procedure This step uses precipitation, event mean pollutant concentration, and other data to estimate average annual pollutant loads.

Each of these steps is described below.

2.2.1 Watershed Delineation

This step requires development or acquisition of a GIS datalayer of the watershed for the subject water body or water bodies. Topographic data sources for watershed delineation, such as USGS quad maps (preferably scanned images), serve as the default data sources for these analyses, but more detailed information are used, if available. Digital elevation models may be employed to automate delineation of watersheds using GIS. Storm sewer network maps can also be useful for delineating watersheds in urbanized areas.

For a TMDL analysis, the watershed should be divided into sub-watersheds or by other features (such as tributaries) for separate IC calculation, unless it is very small or homogenous. Sub-watersheds should then be evaluated individually to support identification of problem areas (with high IC values) where investigators should focus water quality remediation efforts. This will prevent localized problem areas from getting overshadowed by areas with low IC values. Investigators may concentrate water quality protection efforts in areas with low %IC. Generally, the analysis should begin at the bottom of the impaired water body segment, and work upstream delineating sub-basins and/or sub-watersheds.

2.2.2 Impervious Cover Mapping

Land cover and impervious cover GIS data are required to support determination of watershed impervious cover. If general land cover and land use datalayer information is used, then imperviousness may be determined based on a typical percentage of each land use. Impervious cover also may be determined using computer image analysis of multi-spectral orthophotographs.

In some cases, the best-available land cover datalayer may require additional editing for use with the impervious cover method. For example, some datalayers use lumped or broad land use categories that include a wide range of land cover types or intensity of development, such as commercial/industrial/residential. If available, orthophotos may be used to assist with manual splitting and attributing of the ambiguous data, but this approach is more labor intensive.

2.2.3 Determination of Watershed Impervious Cover

Watershed impervious cover is determined by digitally intersecting watershed, land cover, and impervious cover GIS data layers and then calculating an area-weighed average impervious cover percentage for each sub-watershed and for the overall watershed. This information may be presented in both tabular and graphical formats.

2.2.4 Annual Runoff Volume Estimate – Expanded Application

The IC method is particularly useful for aquatic life criteria violations where specific pollutants are not known. However, we include discussion of runoff volume estimation for illustrative purposes as these expanded applications may become more feasible as the IC method is refined over time.

Annual runoff volume is the total volume of stormwater that runs off watershed land and into the stream each year. Runoff increases in areas with increasing % IC because water cannot infiltrate IC and more water runs over land and into the receiving water body, as described in Section 2.1. The ICM can estimate annual stormwater runoff volume using two empirically derived equations presented in Steps 1 and 2 of Figure 2-1 below. In Step 1, a runoff volume coefficient is calculated that increases directly with % IC (expressed as "Ia" in the Step 1 equation).

In Step 2, total annual runoff volume is calculated as a component of total annual precipitation. Total runoff volume is directly proportional to the runoff volume coefficient calculated in Step 1. As a result, total annual runoff volume (R) increases with increasing % IC. The equation in Step 2 also accounts for the portion of precipitation events that do not produce runoff. Lastly, annual runoff as a component of total precipitation is multiplied by watershed area (acres) to obtain total annual runoff volume in acre*ft.

Stormwater runoff volume is calculated and provided as an optional TMDL target parameter because it has been strongly correlated with stormwater impairments in streams. Existing and target stormwater runoff volumes may be calculated using the IC method in impaired streams. These values may then be compared and used to support development of TMDL targets and specification of TMDL implementation BMPs.

2.2.5 Pollutant Selection and Estimation of Pollutant Loads – Expanded Application

The IC method is particularly useful for aquatic life criteria violations where specific pollutants aren't known. However, we include discussion of pollutant load estimation for illustrative purposes as these expanded applications may become more feasible as the IC method is refined over time.

The IC Method may be applied to estimate loads for various pollutants. The method may be applied to estimate existing loads contributing to watershed impairments. It may also be applied to estimate target loads required to remove impairments (based on the target watershed impervious cover values). Pollutant selection and estimation of pollutant loads are described below.

<u>Pollutant Selection Process</u>

For stormwater-impaired streams, EPA Region 1 is considering the feasibility of using %IC as a surrogate for both the pollutant and non-pollutant stressors involved. Stormwater volume, which is proportional to %IC, is being investigated as a surrogate of pollutant, as well. Using the ICM, target loads for specific pollutants may also be calculated and may serve as *surrogates* for the suite of pollutants in stormwater runoff. Pollutants of choice could potentially be those listed in the 303(d) list or related to impairments in the 303(d) listings. These calculated pollutant loadings are also proportional to %IC and stormwater volume.

<u>Estimation of Pollutant Loads</u>

Figure 2-3, Step 3, provides the calculations required to apply the IC method to estimate pollutant loads. The IC Method uses Event Mean Concentrations (EMCs) to predict storm water pollutant loads for urban watersheds, using IC as the key predictive variable. EMCs represent the average concentration of the pollutant during an entire stormwater runoff event. EMCs are empirically derived from large stormwater data sets compiled by the Nationwide Urban Runoff Program, the US. Geological Survey, and the EPA' NDPES Phase I stormwater program (Schueler, 2003). EMC estimates were selected because they are based on field data collected from thousands of storm events. These estimates are based on nationwide data, however, so they do not account for regional variation in soil types, climate, and other factors. Thus, EMCs applied to support the New England pilot TMDLs should be considered to be screening-level estimates.

This method accounts for pollutant loadings generated by storm events and could be used for estimating loadings of sediment, nutrient and metals. While estimates can be made for other constituents, such as bacteria, hydrocarbons, and pesticides, these constituents are not as dependent on stormwater and the resulting correlations are less robust. Thus, use of other parameters in ICM applications is not recommended. EMC values are provided in the Impacts of Impervious Cover document (Schueler, 2003) for a variety of constituents including:

- TSS
- Total P
- Soluble P
- Total N
- KN
- Chromium
- Nitrite & Nitrate
- Copper
- Lead
- Zinc
- Cadmium

The EMC variable may then be used, along with the annual rainfall and impervious area, to estimate an annual pollutant loading rate for the watershed. If available, watershed or region-specific EMC data are preferred to published values, such as those contained in the impervious cover document. Regional rainfall records also will be required to identify average annual rainfall depth for the determination of annual runoff volumes.

Using EMC data will provide reasonable accuracy over long time periods (i.e., annual loads), but since concentrations vary significantly from storm to storm, this method should not be used for calculating loads for individual storm events.

Figure 2-3 IC Method for Calculating Runoff Volume and Constituent Loads

Step 1 – Calculate Runoff Volume Coefficient

Rv = Runoff Volume Coefficient = 0.05 + 0.9Ia, where
Ia = Impervious Fraction (from GIS analysis)

Step 2 – Calculate Annual Runoff Volume

R = Annual runoff (acre*ft) =P * Pj * Rv*A, where
P = Annual rainfall (ft)
Pj = Fraction of rainfall events producing runoff = 0.9
A = Watershed area (acres)

Step 3 – Calculate Annual Pollutant Load

L = Annual pollutant load (lbs) = R * C * U, where
C = Pollutant concentration in stormwater, EMC (mg/l) from literature
U = Unit conversion factor = 0.226

2.3 Modifications to the Basic IC Method

The impervious cover method may be applied in various levels of detail and sophistication depending on several factors, including the specific watershed and available data. The most efficient and cost-effective studies rely on maximizing the use of existing data. The pilot TMDL applications described herein were conducted efficiently using available data. Available land cover data and event mean concentration estimates were obtained and applied to estimate impervious cover and associated pollutant loads. This approach is generally suitable for conducting initial or screening level evaluations. In cases where more precise predictions are required, the following modifications to the IC method are recommended. These modifications serve to increase the resolution of the impervious cover method:

- Project-specific impervious cover datalayer,
- Project-specific estimates of directly-connected impervious cover,
- Incorporation of storm sewer networks to refine watershed delineation and directly connected impervious cover, and
- Accounting for existing BMPs in IC and load determinations.

These modifications to the IC method were not applied to the pilot TMDL project applications in Chapter 4, but some may be required to support identification and implementation of management plans.

2.4 Assumptions and Limitations of the IC Method

The impervious cover method can be employed to efficiently characterize watershed impairments and establish pollutant reduction goals for watersheds impaired by stormwater. However, this method is not intended for detailed analysis of instream water quality and includes the following limitations and limiting assumptions:

- This method does not account for wastewater pollutant loadings, but wastewater point source loading may be added to the TMDL allocation process in a straightforward manner.
- This method does not account for in-stream water quality processes.
- The impervious cover model applies to 1^{st} through 3^{rd} order streams.
- Additional site specific information is required for identification and specification of BMPs to achieve TMDL goals.

The ICM can provide an evaluation of stream condition throughout the watershed. Detailed and on-the-ground evaluation will be required to support identification and implementation of management actions (e.g., installation of BMPs).

3.0 APPLICATION OF THE IC METHOD FOR TMDL DEVELOPMENT

This section provides a step-by-step description of how the IC Method may be applied to meet the requirements of the TMDL development process. A compilation of required TMDL components is provided below, including allocation of loading capacity, margin of safety, and seasonal variability. TMDL implementation is introduced below and described in Section 5.

A TMDL calculation is an analysis that establishes the maximum pollutant loadings that a water body may receive and maintain its water quality standards and support designated uses, including compliance with numeric and narrative standards and consideration of antidegradation policies. The TMDL requires specification of existing conditions, specification of reductions required to remove impairments, and a margin of safety. The TMDL development process may be described in the four steps described below. The approach for applying the IC method to meet each TMDL requirement is described in italics and described in detail in subsequent sections.

1. Establish Impaired Status. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses, and if impaired, for what designated use. *Impaired status for each of the IC Method applications was established as part of the 303(d) listing process*.

2. Evaluate Impairments. This step requires assessment of present water quality conditions in the water body, including estimation of present loadings of constituents of concerns from both point and non-point sources. *The IC method provides estimation of present stormwater loading of constituents through empirical correlation between percent IC to stream quality parameters. Loadings from wastewater sources are not included in the pilot applications because the cause of impairment is believed to be primarily stormwater. Wastewater source loadings could be readily added, however, to the overall loading budget for each application. Section 3.1 provides a description of the impairment evaluation process.*

3. Specifying TMDL Targets. This step requires determination of the water body's loading capacity and specification of load allocations for non-point sources (NPS) and point sources (PS), that will ensure that the water body will not violate water quality standards (i.e., will remove impairments). Loading capacity is defined as the greatest amount of loading that a water body may receive without violating water quality standards (WQS). If the water body is not presently meeting its WQS, then the loading capacity will represent a reduction relative to present loadings. *Evaluation of extensive watershed data has led to the finding that stream impairment is generally present in watersheds with 10% or greater impervious cover. A TMDL target of 9% IC has been selected for the pilot TMDL applications. Point source loadings other than stormwater (industrial and municipal waste water discharges) were not*

included in the TMDL pilot projects because the watersheds were believed to be impaired by NPS. TMDL targets are described in Section 3.2.

4. Allocating Loading Capacity. This step requires allocating the TMDL or loading capacity among:

   - Waste load allocations for point source discharge and regulated stormwater,
   - Load allocations for nonpoint sources, background, and non-regulated stormwater,
   - Margin of safety to compensate for uncertainty, and
   - Consideration of seasonal variation.

   Section 3.3 provides a description of allocating loading capacity.

5. TMDL Management and Implementation. This task is conducted after the TMDL development process is complete. This task requires generating a plan to (a) implement load allocations and wasteload allocations developed based on the water body loading capacity determination, and (b) monitor the water body to ensure compliance with water quality standards. Although not a part of the TMDL required for EPA review and approval, management planning and TMDL implementation are the most critical steps towards achieving and verifying improvements in water quality. *The impervious cover approach includes evaluation of the relative effectiveness of various best management practices (BMPs) in reducing the impact of impervious cover. Section 5 provides an overview and a general description of BMPs designed to reduce the impact of impervious cover on aquatic systems.*

The following sections describe how each of the TMDL development components may be developed using the impervious cover method.

3.1 Evaluation of Impairments

The first step in the TMDL process is to evaluate watershed impairments. The impervious cover method, coupled with geographic information system (GIS) analysis, is well suited for rapidly assessing the impairment of watersheds and identifying the relative contribution of sub-watersheds to the impairments. Implementation of the impervious cover method to quantify impairments involves the following:

- Develop watershed boundary GIS datalayer based on best available topographic data. Subdivide watershed into sub-watersheds based on tributary drainage areas and other major outfalls.

- Acquire and analyze land cover and impervious cover GIS datalayers for the watershed.
- Develop a table correlating land cover to impervious cover based either on published values (e.g., TR-55) or based on watershed-specific data.
- Calculate overall watershed and sub-watershed impervious cover percentages. Rank sub-watersheds by impervious cover percentage. Sub-watershed assessment is important to identify problem areas and support specification of BMPs during TMDL implementation.
- Assess watershed impairments. Watersheds with greater than 10 percent overall impervious cover are likely to be impaired. Watersheds with greater than 25 percent impervious cover likely to be significantly impaired.

3.2 Specifying TMDL Targets

A TMDL target is the water body's loading capacity or the sum of the WLA, LAs, and MOS that will result in removal of impairments. Using the impervious cover method, the target TMDL should aim to achieve a total watershed impervious cover of 9 percent or less, consistent with meeting applicable water quality standards. This may be achieved by either removing impervious cover, which may not be practicable, or by implementing management practices designed to mitigate the effects of impervious cover, as well as with stream restoration measures that address aquatic habitat, riparian, and floodplain recovery (see Section 5).

A TMDL target of 9% IC has been selected and applied for the pilot TMDL projects presented in Section 4.

3.3 Allocating Loading Capacity

Loading capacity is the amount of a pollutant that has been identified through the TMDL process as the maximum that a water body can receive and maintain its water quality standards and designated uses. Allocating loading capacity is the process of assigning those reduced pollutant loads to a set of sources (PS and NPS) in the watershed. The three key components of the allocation process are allocations, margin of safety, and seasonal variation. Each component is described below.

3.3.1 Allocations

Targets for % IC can serve as surrogates for establishing loading capacity and for determining the necessary pollutant load reductions or allocations. Whether the allocations are characterized as

WLAs or LAs depends on whether the stormwater runoff is from regulated or unregulated areas under the NPDES stormwater regulations. Whereas traditional point source TMDLs must present discharge-specific WLAs, regulated stormwater (technically point sources in NPDES) can receive an allocation expressed as a *gross allotment*, as do LAs from nonpoint sources. Therefore, if the stormwater runoff is from regulated urbanized areas (MS4 communities under Phase I and II of the stormwater regulations), then the gross allotment should be expressed as WLAs. If the stormwater runoff is unregulated, along with other NPS and background sources, then the gross allotment can be expressed as LA. If there is a complex mix of regulated and unregulated stormwater (which cannot be subdivided into regulated (MS4) and non-regulated components), a simple solution for the TMDL is to assign the same allocation to both the WLA and LA (i.e., WLA = LA = 9% IC).

3.3.2 Margin of Safety (MOS)

The ICM-based TMDLs in this report include an implicit margin of safety through the relatively conservative selection of the numeric water quality target of 9% IC, which is less than the lowest end of the range of % IC cover for the range of “impacted stream quality” from 10 – 25% (Figure 2-2; less than 10% is “sensitive”.) This range is based on data from the Center for Watershed Protection. It may be necessary, in some cases, to set an even lower IC target to maintain a margin of safety if, for example, an impaired water body already has a IC rating close to 9%. These assumptions provide a margin of safety to account for any uncertainty in determining the water body’s loading capacity.

3.3.3 Seasonal Variation

Critical conditions can occur for aquatic life and habitat in stormwater-impaired streams at both low and high flows. High flows can cause channel alterations, increased pollutant loads from scouring and bank erosion, wash-out of biota, and high volume pollutant loading. Increased % IC, and the resulting increase in surface runoff, reduces the amount of infiltrating rainfall that recharges groundwater. The resulting diminished base flow can further stress aquatic life and cause or contribute to aquatic life impairments through loss of aquatic habitat and increased susceptibility of pollutants at low flow.

Specific BMPs implemented will be designed to address loadings during all seasons.

Section 4 below presents pilot TMDL applications developed using the ICM throughout New England and Section 5 describes the TMDL implementation process using the ICM.

4.0 TMDL APPLICATIONS

The feasibility of using the IC Method for TMDL development was tested by applying it to complete TMDL applications for the following seven impaired watersheds nominated by five of the New England states.

- Beaver Brook, New Hampshire
- Goodwives River, Connecticut
- Peters River, Massachusetts
- Three Ponds Brook, Rhode Island
- Cohas Brook, New Hampshire
- Artic Brook, Maine
- Tributary to Bond Brook, Maine

The watersheds assessed in Chapter 4 do not all match our selection criteria for using the IC method, nor do they all have impervious cover greater than 9%, which is generally our suggested initial TMDL target and screen for applying this method (unless a state has more site-specific information that indicates a different target is appropriate). For each example watershed, we note what worked and what didn't work in the analysis, and discuss whether the watershed is an appropriate selection for this approach.

The IC Method is very useful for developing TMDLs for aquatic life impairments caused by stormwater runoff. It is particularly helpful for developing stormwater TMDLs where no specific pollutant can be identified as the cause of the impairment. If a water body is 303(d)-listed for both an aquatic life impairment caused by stormwater and specific pollutants, the IC Method may be used to address the aquatic life impairment. Specific TMDL targets for the listed pollutants should also be developed. Where any specific 303(d)-listed pollutants are primarily related to stormwater runoff, the techniques outlined in this report may be appropriate. If the specific listed pollutants causing the impairment are related to sources other than stormwater volume, then other more appropriate techniques should be used to develop these TMDL targets. In the seven pilot TMDL applications which follow, we present calculations of stormwater runoff volume and individual pollutant loads for illustrative purposes only, using expanded applications of the basic, recommended IC method procedure.

Use of the IC method to complete TMDLs for each of these watersheds is described below. Key elements to screen a watershed for IC applicability (listed impairment(s), size of watershed and

%IC, along with a discussion of the ease of application and applicability of the IC method to the example) are provided in a summary after each example.

4.1 Beaver Brook

An IC method analysis for New Hampshire's Beaver Brook watershed was performed to complete a TMDL allocation. The IC method was applied to estimate existing and target % IC in the overall watershed and in each sub-watershed.

4.1.1 Watershed Description

The watershed for the Beaver Brook is located within Pelham, Salem, Hudson, Londonderry, Auburn, Derry, and Chester town boundaries and is shown on Figure 4-1. The watershed is characterized by forest, cleared land, roads, and residential development, as tabulated in Table 4-1. The drainage area is 46,735 acres (73.02 sq. miles). Beaver Brook has a hydrologic unit code is 01070002-240 (NHDES, 2004) and is a part of the Merrimack River Basin. Beaver Brook begins at the juncture of Golden Brook in Pelham, NH and drains into the Merrimack River in Lowell, MA. The Merrimack River Basin covers 5,010 square miles in south-central New Hampshire, extending into Massachusetts.

Beaver Brook has been placed on the Clean Water Act 303(d) list for several parameters including pH, benthic-marcoinvertebrates, mercury, and *Escherichia coli* (State of New Hampshire 305(b) and 303(d), 2004). Under the 2004 New Hampshire Consolidated Assessment and Listing Methodology, impairment is listed for pH by having a pH less than 6.5 or greater than 8.0. Benthic-Macroinvertebrate Bioassessments protocol lists impaired due to a benthic index of biologic integrity score less than 45. Mercury is listed based on results falling between 0.77ug/L to 1.40ug/L (based on dissolved metal results). According to the State of New Hampshire Section 305(b) and 303(d), Beaver Brook does not support aquatic life, fish consumption and primary contact recreation (NHDES, 2004).

Table 4-1 Beaver Brook: Major Landuse Distribution

Landuse	Percentage of Watershed
Mixed forest	23%
Cleared/other open Tundra	18%
Beech/oak	13%
Transportation Active agricultural land	10%
Other hardwoods	8%
White/red pine	7%
Hay/rotation/permanent pasture	4%
Open water Wetlands	4%
Other	12%

4.1.2 Available Data

The New Hampshire Department of Environmental Services (NHDES), provided GIS coverage data for the Beaver Brook's watershed. The other GIS coverages required for the analysis, including Landcover, were acquired from the NH GRANIT website. The 2001 New Hampshire Land Cover Assessment categorizes land cover and land use into 23 classes.

Figure 4-2 provides a landuse map for the Beaver Brook watershed. The coverage was created for to provide a multi-purpose data set to support regional analysis, with as much detail as possible in the forested and agricultural classes. The landcover dataset was based on LandSat TM Satellite Imagery.

The New Hampshire landcover dataset was problematic for the IC Method and required significant additional analysis to yield useful coverage information. Specifically, The NH landcover categories were focused on forest and agricultural classes and lumped all non-transportation development categories together (i.e., commercial, industrial, high density residential, medium density residential, and low density residential were considered the same category). This is problematic because the different development-related landuses have significantly different impervious cover characteristics. To refine the dataset to be more useful for impervious cover determination, we manually split the development class into five sub classes; commercial, industrial, high density residential, medium density residential, and low density residential. This was accomplished by comparing the development class to the Digital Ortho Quarter Quadrangles, and modifying it to one of the sub classes. The Beaver Brook watershed was fairly large for this approach. Thus, the watershed layer was also split into twenty-four sub-basins.

4.1.3 Impervious Cover and Pollutant Load Calculation

To calculate watershed impervious cover, the Beaver Brook's sub-basins were digitally intersected with the revised NH landcover assessment, and the area of each landuse category in each sub-basin calculated. Sub-basin impervious percentages were then calculated based on the assumed impervious percentages for each landuse as shown in Table 4-2. The assumed percentage of impervious cover for each landuse was derived using recommended percentages in TR-55, Urban Hydrology for Small watersheds (USDA, 1986). The results of this analysis indicate the Beaver Brook watershed is 12 percent impervious, with one sub-basin with 29 percent impervious cover.

Figure 4-3 shows the impervious cover estimate for each Beaver Brook sub-basin. Table 4-3 provides the percent impervious cover for each sub-basin in a tabular form. The Impervious Cover Model predicts impacted stream quality for greater than 10 percent impervious cover and severe degradation of stream quality for greater than 25 percent impervious cover. Thus, the impervious cover model predicts that the Beaver Brook watershed has impacted water quality with severe water quality degradation in some sub-basins within the watershed.

Table 4-2 Beaver Brook: Estimated Percent Impervious Cover by Landcover

Landuse	Estimated Percent Impervious Cover
Commercial	85%
High Density Residential (smaller than 1/4 acre lots)	65%
Industrial	72%
Low Density Residential (greater than 1/2 acre lots)	16%
Medium Density Residential (1/4 to 1/2 acre lots)	31%
Transportation Active agricultural land	100%
Other	0%

Table 4-4 provides estimated existing % IC and target % IC values for the Beaver Brook watershed. For illustrative purposes, estimated annual stormwater runoff volume and estimated annual pollutant loads for selected parameters are also provided, using annual rainfall and estimated event mean concentration of pollutants from (Schueler, 2003). For this watershed, an annual rainfall of 36.4 inches (Concord, NOAA.com) and a fraction of annual rainfall events that produced runoff of 0.9 (Schueler, 2003) were used.

Table 4-3 Beaver Brook: Sub-basin Estimated Impervious Cover

Sub-basin	Estimated Percent Impervious Cover
1	12.0%
2	16.5%
3	7.6%
4	14.8%
5	15.1%
6	12.9%
7	14.4%
8	18.3%
9	20.6%
10	28.7%
11	10.0%
12	8.1%
13	18.1%
14	1.1%
15	10.2%
16	6.9%
17	6.1%
18	12.5%
19	8.8%
20	5.2%
21	11.3%
22	10.0%
23	7.6%
24	12.6%

Table 4-4 Beaver Brook: Estimated Existing and Target TMDL Values for Key Parameters

Parameter	Estimated Conditions	
	Existing	TMDL Target
Impervious Cover	12%	9%
Optional:		
Annual Runoff Volume	20,700. acre-ft	16,700 acre-ft
Total Suspended Solids	4,400,000 lbs	3,600,000 lbs
Total P	18,000 lbs	14,000 lbs
Soluable P	7,300 lbs	5,900 lbs
Total N	130,000 lbs	110,000 lbs
TKN	97,000 lbs	78,000 lbs
Nitrate & Nitrite	37,000 lbs	30,000 lbs
Copper	750 lbs	610 lbs
Lead	3,800 lbs	3,100 lbs
Zinc	9,100 lbs	7,300 lbs

4.1.4 Summary and Conclusions

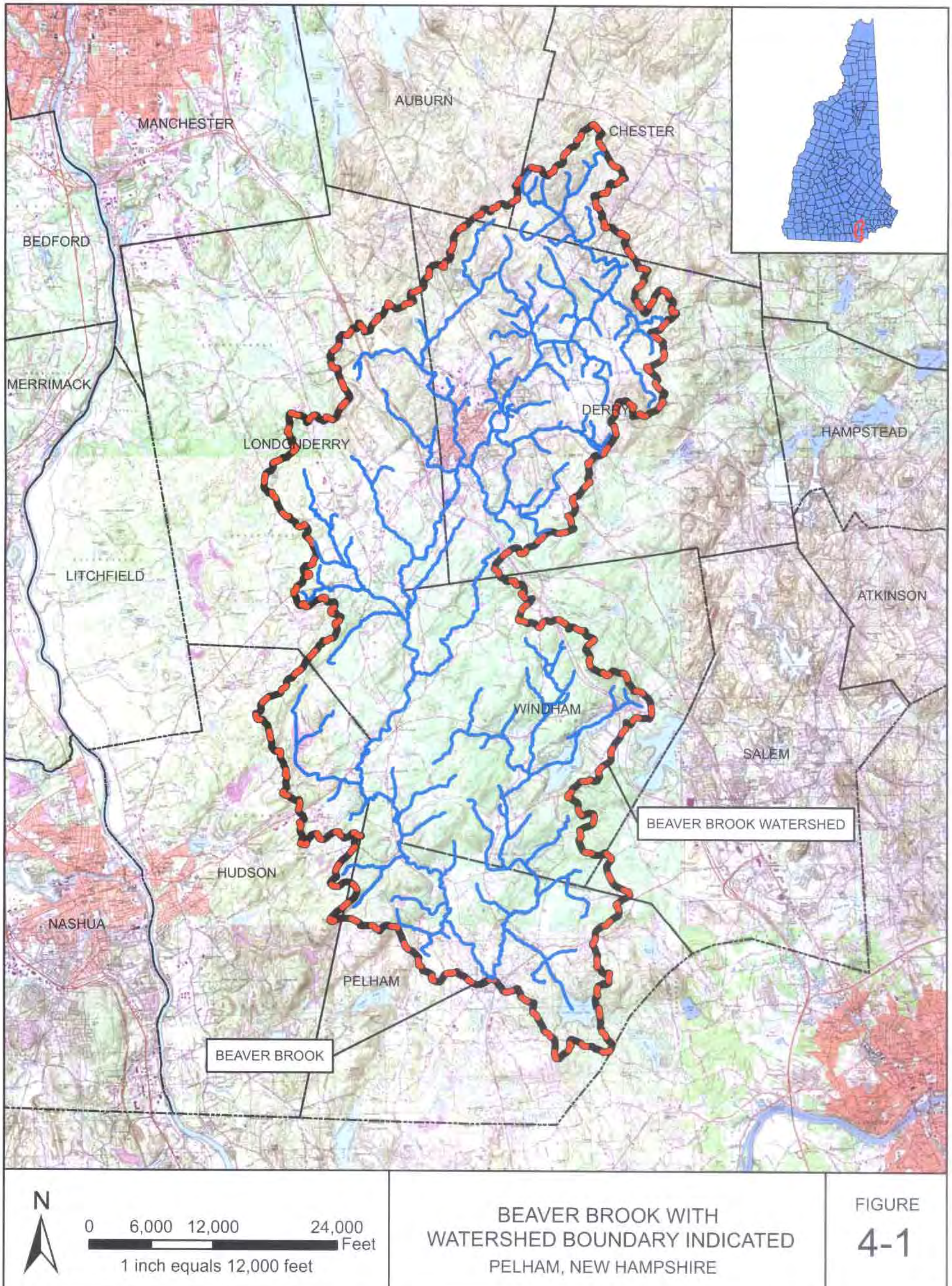
Beaver Brook, New Hampshire

Section 303(d) listed impairments:	Aquatic life support
	Fish consumption (mercury)
	Primary contact recreation (e-coli bacteria)
Size of watershed:	73 square miles
Percent of IC in watershed:	12% (sub-basin range = 1 – 29%)

<u>Applicability of IC method to this watershed</u>

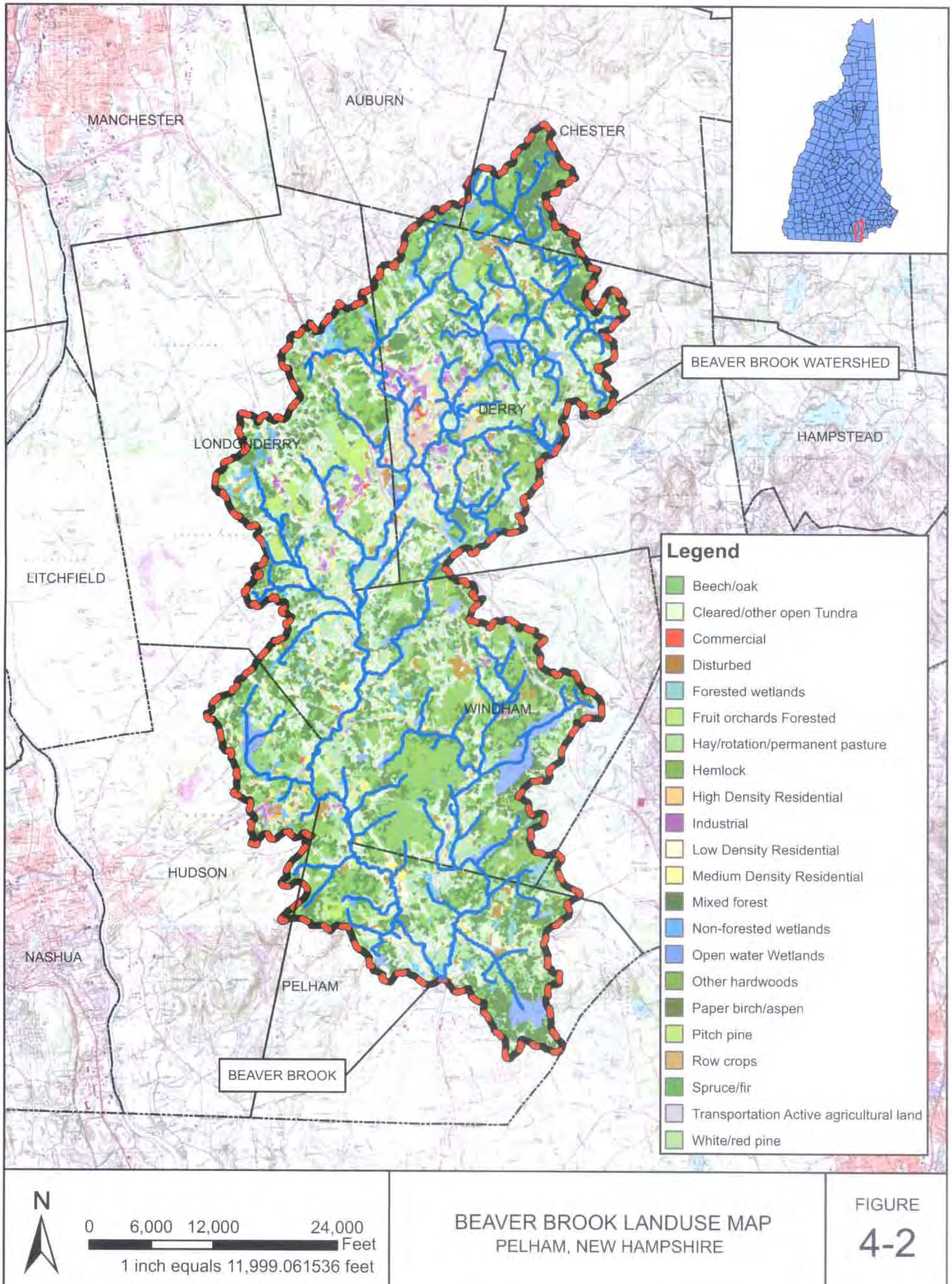
As noted in the case study, the NH dataset proved problematic for the analysis, and required a lot of manipulation to generate the land use detail needed. Also, the watershed was large and required breaking into 24 sub-basins, which were then analyzed for their percent IC. The resulting analysis showed that a number of sub-basins had IC levels substantially higher than the target. This finding allows resource professionals to target TMDL development and implementation efforts at those sub-basins which have the worst conditions, thereby addressing the worst problems and perhaps more quickly reaching restored conditions for the watershed as a whole.

Consequently, the IC method appears to be a good approach for the aquatic life support impairment in this watershed, although EPA would expect additional specific TMDLs to be developed for the other 303(d)-listed impairments.



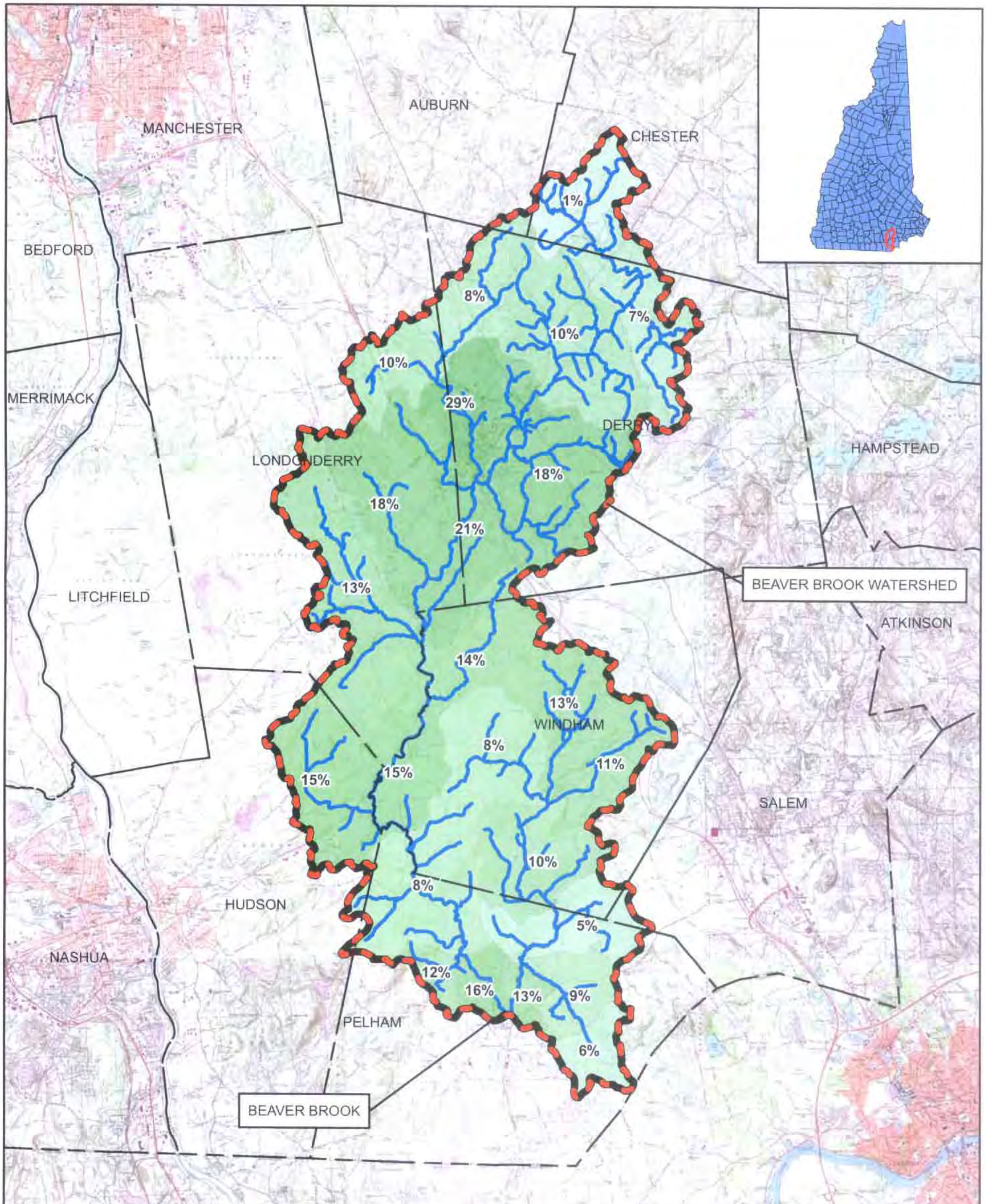
BEAVER BROOK WITH
WATERSHED BOUNDARY INDICATED
PELHAM, NEW HAMPSHIRE

FIGURE
4-1



BEAVER BROOK LANDUSE MAP
PELHAM, NEW HAMPSHIRE

FIGURE
4-2



N

0 6,000 12,000 24,000 Feet

1 inch equals 12,002.394323 feet

BEAVER BROOK SUB WATERSHED
IMPERVIOUS COVER MAP
PELHAM, NEW HAMPSHIRE

FIGURE
4-3

4.2 Goodwives River

An IC method analysis for Connecticut's Goodwives River watershed was performed to complete a TMDL allocation. The IC method was applied to estimate existing and target % IC in the overall watershed and in each sub-watershed.

4.2.1 Watershed Description

The watershed for the Goodwives River is located within Darien and New Canaan town boundaries and is shown on Figure 4-4. The watershed is characterized by residential development, commercial, industrial, and forest as provided in Table 4-5. The drainage area is 1,223 acres (1.9 sq. miles).

Goodwives River is a part of the Goodwives River Drainage Basin. The Goodwives River Drainage Basin is 7.4 square miles. The Goodwives River is located on the Southern Coast of Connecticut and drains into Long Island Sound. According to the Goodwives River Management Plan, the mouth of Goodwives River is classified as SB/SA. The current designated uses of the Goodwives River Drainage Basin include marine fishing, shellfish and wildlife habitat, recreation, industrial and other uses including navigation, and shellfish harvesting for direct human consumption (Fuss & O'Neil, 2004).

Under the State of Connecticut Water Quality Standards, Goodwives River is listed on the Clean Water Act 303(d) for pathogens located at the mouth of the Goodwives River (CTDEP, 2004). According to Connecticut Consolidated Assessment and Listing Methodology for 305(b) and 303(d), the criteria for fecal coliforms in the use of salt water shell fishing fecal coliforms (pathogens) should have a geometric mean less than 14 colonies per 100ml and 90% of samples less than 43 colonies per 100ml (CTDEP, 2004). According to the State of Connecticut Water Quality Standards, Goodwives River is assessed as not supporting shellfishing designated use (CTDEP, 2004).

Table 4-5 Goodwives River: Major Landuse Distribution

Landuse	Percentage of Watershed
Low Intensity Residential	47%
Urban/Recreational Grasses	16%
Mixed Forest	11%
Commercial/Industrial/Transportation	8%
Deciduous Forest	8%
Woody Wetlands	5%
Evergreen Forest	3%
High Intensity Residential	2%
Other	1%

4.2.2 Available Data

The State of Connecticut provided a PDF of a report titled "Goodwives River Watershed Management Plan", dated February 2004. This report included a figure showing the watershed boundary. Figure 4-5 provides a landuse map for the Goodwives River watershed. The watershed boundary GIS layer and landcover was obtained from the University of Connecticut Map and Geographic Information Center (MAGIC). The Connecticut Landcover Data Set was compiled from the USGS national Multi Resolution Landcover Characterization (MRLC) landcover. The MRLC landcover datasets were based on circa 1992 LandSat TM Satellite Imagery.

4.2.3 Impervious Cover and Pollutant Load Calculation

To calculate watershed impervious cover, the Goodwives River watershed was digitally intersected with the Connecticut landcover dataset, and the area of each landuse category calculated. Watershed impervious percentage was then calculated based on the assumed impervious percentages for each landuse as shown in Table 4-6. The assumed percentage of impervious cover for each landuse was derived using recommended percentages in TR-55, Urban Hydrology for Small watersheds (USDA, 1986). The results of this analysis indicate the Goodwives River watershed is 19 percent impervious. The Impervious Cover Model predicts impacted stream quality for greater than 10 percent impervious cover. Thus, the impervious cover model predicts impacted water quality in the Goodwives River.

Table 4-6 Goodwives River: Estimated Percent Impervious Cover by Landcover

Landuse	Estimated Percent Impervious Cover
Commercial/Industrial/Transportation	78.5%
High Intensity Residential	65%
Low Intensity Residential	25%
Other	0%

4.2.4 Summary and Conclusions

Goodwives River, Connecticut

Section 303(d) listed impairments:	Shellfishing (pathogens)
Size of watershed:	1.9 square miles
Percent of IC in watershed:	19%

Applicability of IC method to this watershed

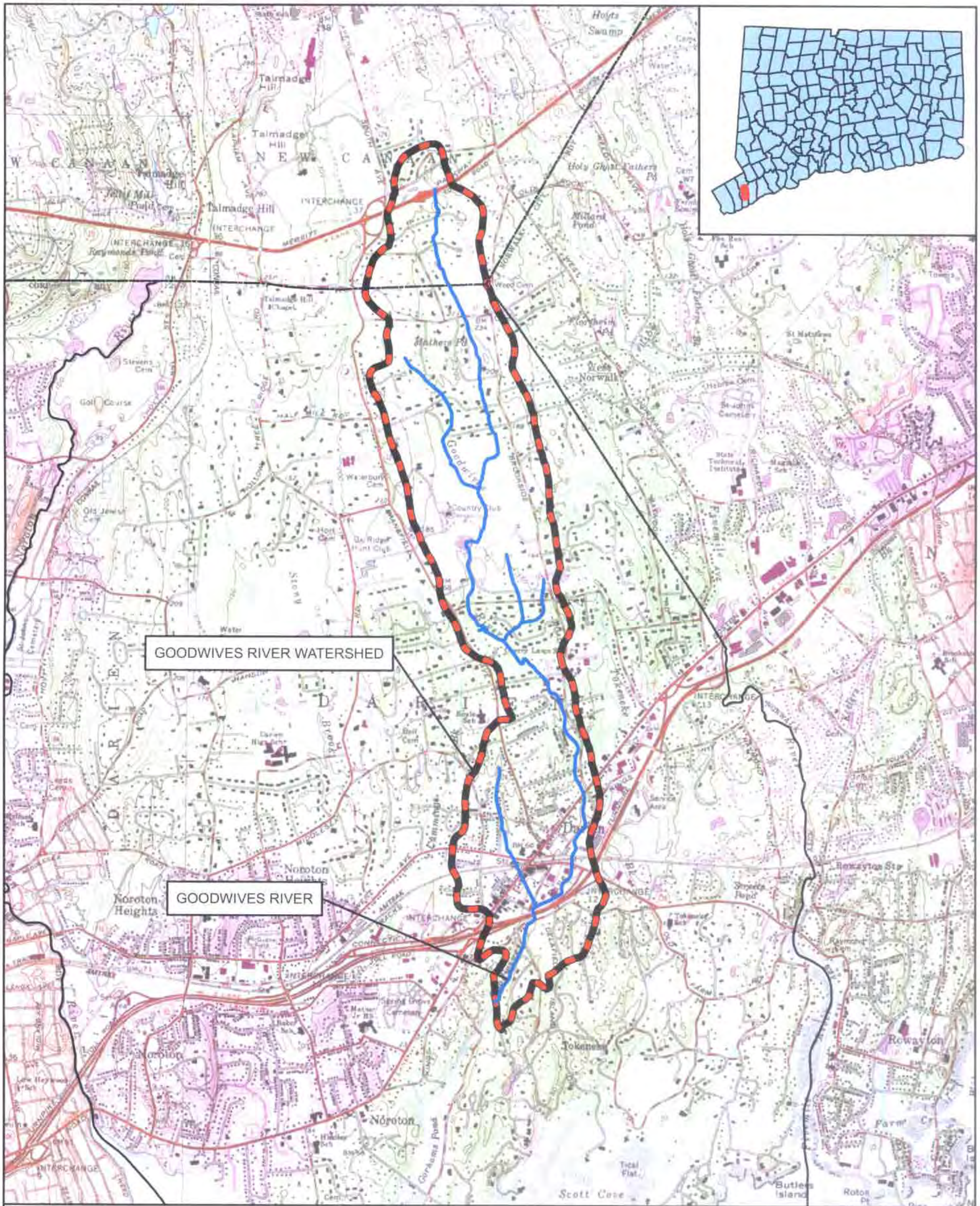
There were no problems using available data to calculate the percent IC for this watershed. It is a small watershed and the land cover map provides adequate detail on the types of development and their concentrations in the watershed.

If aquatic life impairment had been documented, the IC method could have been used to address this impairment. However, the cause of the impairment appears to be specific and known and consequently, EPA would expect a specific TMDL to be developed for pathogens (fecal coliforms). Consequently, the IC method is not the appropriate method for TMDL development in this watershed.

Table 4-7 provides estimated existing % IC and target % IC values for the Goodwives River watershed. For illustrative purposes, estimated annual stormwater runoff volume and estimated annual pollutant loads for selected parameters are also provided, using annual rainfall and estimated event mean concentration of pollutants from (Schueler, 2003). For this watershed, an annual rainfall of 44.14 inches (Hartford, NOAA.com) and a fraction of annual rainfall events that produced runoff of 0.9 (Center for Watershed Protection, 2003) were used.

Table 4-7 Goodwives River: Estimated Existing and Target TMDL Values for Key Parameters

Parameter	Estimated Conditions: Existing	Estimated Conditions: TMDL Target
Impervious Cover	19%	9%
Optional:		
Annual Runoff Volume	900 acre-ft	530 acre-ft
Total Suspended Solids	190,000 lbs	110,000 lbs
Total P	780 lbs	460 lbs
Soluable P	320 lbs	190 lbs
Total N	5,800 lbs	3,400 lbs
TKN	4,200 lbs	2,500 lbs
Nitrate & Nitrite	1,600 lbs	950 lbs



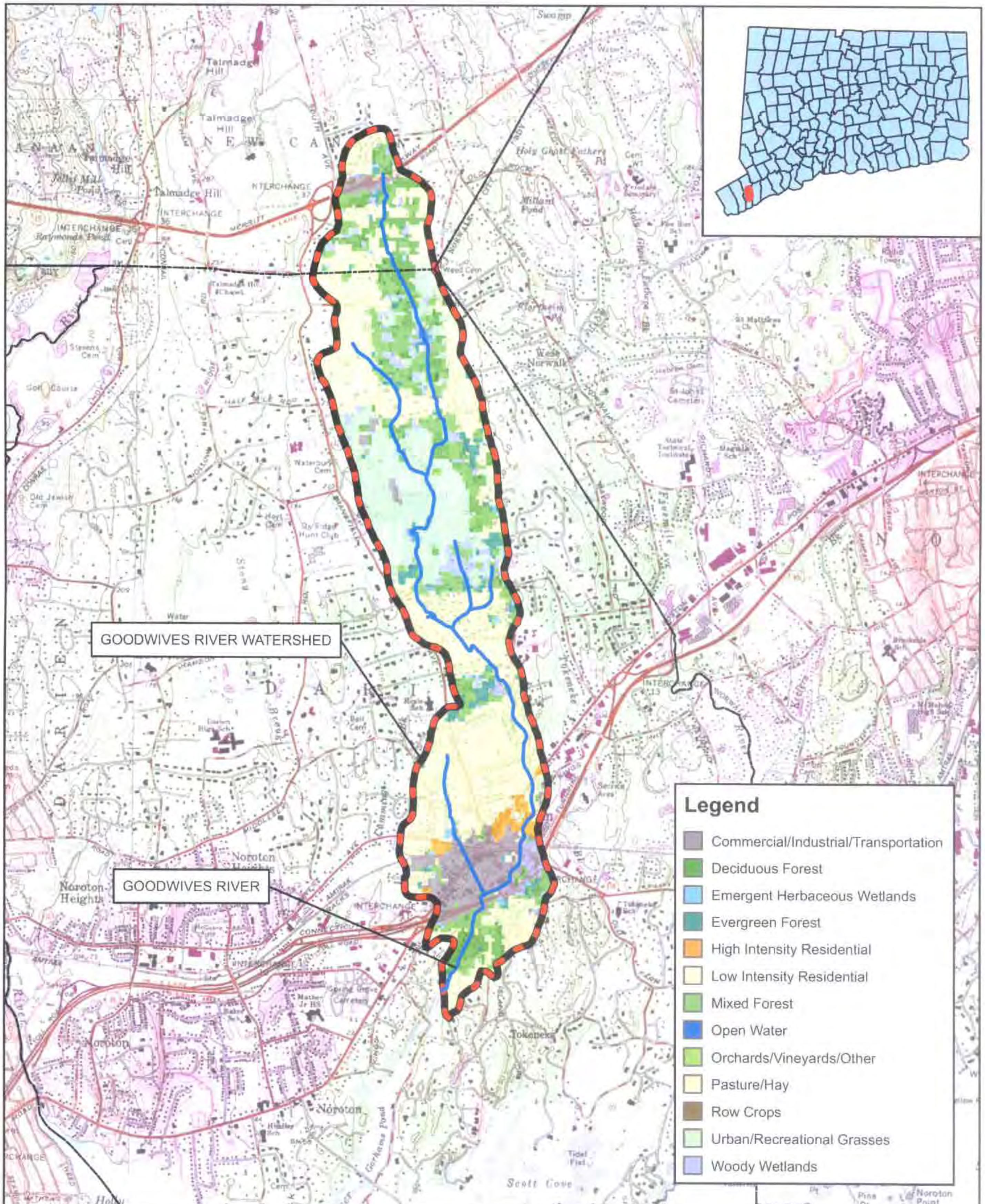
0 1,550 3,100 6,200 Feet

1 inch equals 3,001.295510 feet

GOODWIVES RIVER WITH WATERSHED BOUNDARY INDICATED

DARIEN, CONNECTICUT

FIGURE 4-4



N

0 1,500 3,000 6,000 Feet

1 inch equals 3,001.295510 feet

GOODWIVES RIVER LANDUSE MAP
DARIEN, CONNECTICUT

FIGURE
4-5

4.3 Peters River

An IC method analysis for Massachusetts' Peters River watershed was performed to complete a TMDL allocation. The IC method was applied to estimate existing and target % IC in the overall watershed and in each sub-watershed.

4.3.1 Watershed Description

The watershed for the Peters River is located within Bellingham, Franklin, and Wrentham town boundaries and is shown on Figure 4-6. The watershed is characterized by forest, residential development, and agriculture, as tabulated in Table 4-8. The drainage area is 5,039 acres (7.9 sq. miles).

The Peters River is situated in South Central Massachusetts and is a major tributary within the Blackstone River Basin. The Peters River, at 7.1 miles, begins at the Outlet Curtis Pond in Bellingham, Ma. The River joins the Mill River and drains into the Blackstone River in Rhode Island. The drainage area of the Blackstone River Basin is 540 square miles of which approximately 335 square miles lie in Massachusetts including portions of Bristol, Middlesex, Norfolk, and Worcester counties (MADEP, 2001).

The Peters River is designated as a Class B river. The Massachusetts Blackstone River Basin 1998 Water Quality Assessment Report states that: "These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated, they shall be suitable as a source of water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value" (MADEP, 2001).

Present uses of Peters River have not been assessed. The Peters River has been placed on the Clean Water Act 303(d) list for metals and fecal coliform bacteria. Under the Massachusetts Water Quality Standards 314 CMR 4.00, fecal coliform bacteria shall not exceed a geometric mean of 200 organisms per 100 ml in any representative set of samples nor shall more than 10% of the samples exceed 400 organisms per 100 ml (MADEP, 2002).

Table 4-8 Peters River: Major Landuse Distribution

Landuse	Percentage of Watershed
Forest	56%
Residential: Larger than 1/2 acre lots	14%
Residential: 1/4 - 1/2 acre lots	11%
Cropland	4%
Abandoned agriculture; power lines;	4%
Pasture	3%
Other	9%

4.3.2 Available Data

The State of Massachusetts provided a GIS shapefile containing sampling locations within the watershed. The watershed boundary GIS layer and landcover was obtained from MassGIS. Figure 4-7 provides a landuse map for the Peters River watershed. The MassGIS Landuse datalayer has 37 land use classifications interpreted from 1999 aerial photography.

4.3.3 Impervious Cover and Pollutant Load Calculation

To calculate watershed impervious cover, the Peters River watershed was digitally intersected with the MassGIS landuse datalayer, and the area of each landuse category calculated. Watershed impervious percentage was then calculated based on the assumed impervious percentages for each landuse as shown in Table 4-9. The assumed percentage of impervious cover for each landuse was derived using recommended percentages in TR-55, Urban Hydrology for Small watersheds (USDA, 1986). The results of this analysis indicate the Peters River watershed is 7 percent impervious. The Impervious Cover Model predicts sensitive stream quality for less than 10 percent impervious cover. Thus, the impervious cover model predicts sensitive water quality in the Peters River.

Table 4-9 Peters River: Estimated Percent Impervious Cover by Landcover

Landuse	Estimated Percent Impervious Cover
Transportation	90%
Commercial	85%
Industrial	72%
Residential: Multi-family	65%
Residential: Smaller than 1/4 acre lots	52%
Residential: 1/4 - 1/2 acre lots	31%
Residential: Larger than 1/2 acre lots	16%
Other	0%

Table 4-10 provides estimated existing % IC and target % IC values for the Peters River watershed. For illustrative purposes, estimated annual stormwater runoff volume and estimated annual pollutant loads for selected parameters are also provided, using annual rainfall and estimated event mean concentration of pollutants from (Schueler, 2003). For this watershed, an annual rainfall of 41.51 inches (Boston, NOAA.com) and a fraction of annual rainfall events that produced runoff of 0.9 (Center for Watershed Protection, 2003) were used.

Table 4-10 Peters River: Estimated Existing and Target TMDL Values for Key Parameters

Parameter	Estimated Conditions	
	Existing	TMDL Target
Impervious Cover	7%	9%
Optional:		
Annual Runoff Volume	1,813 acre-ft	2,055 acre-ft
Total Suspended Solids	390,000 lbs	440,000 lbs
Total P	1,600 lbs	1,800 lbs
Soluable P	640 lbs	720 lbs
Total N	12,000 lbs	13,000 lbs
TKN	8,500 lbs	9,600 lbs
Nitrate & Nitrite	3,200 lbs	3,700 lbs
Copper	66 lbs	75 lbs
Lead	330 lbs	380 lbs
Zinc	800 lbs	900 lbs

4.3.4 Summary and Conclusions

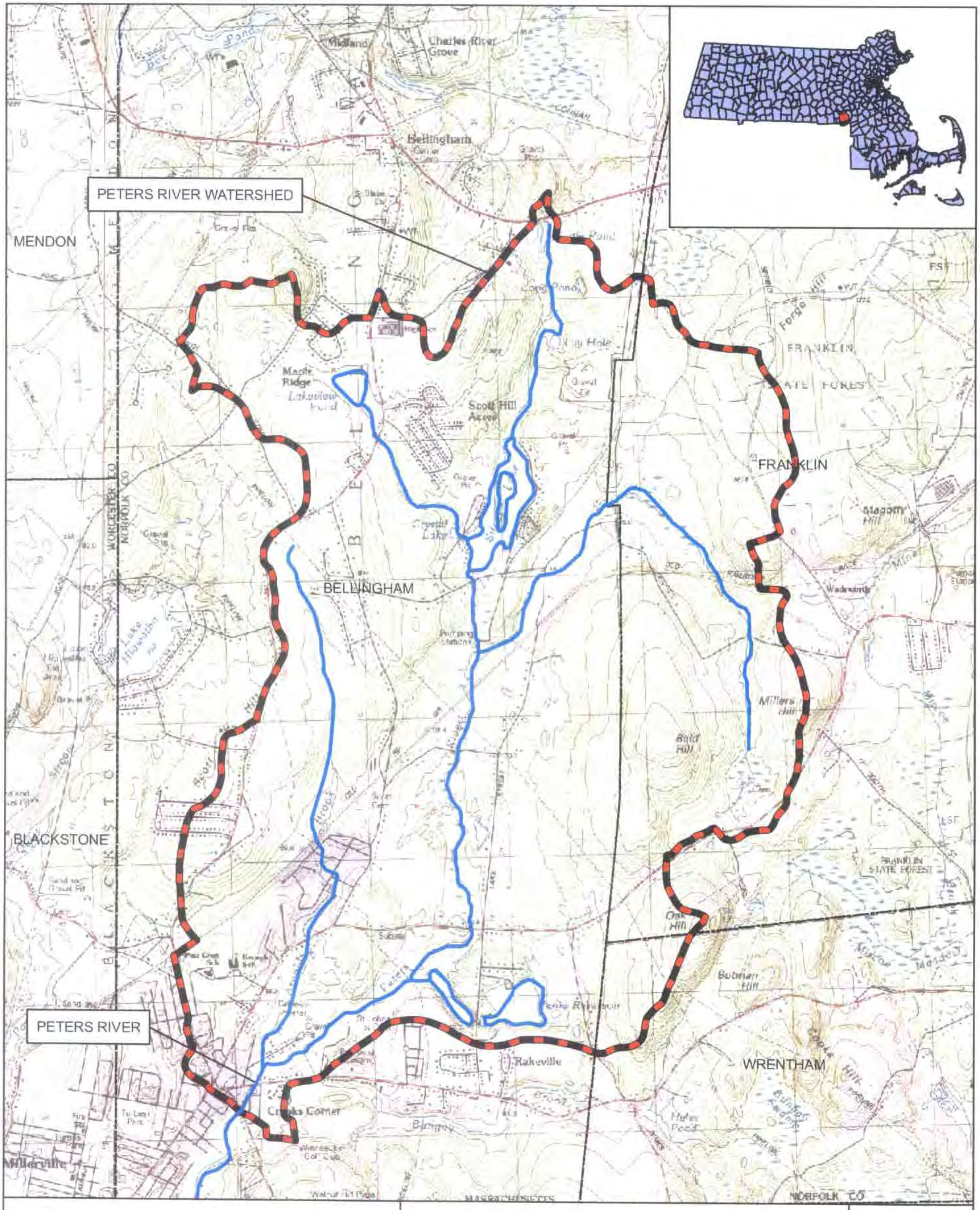
Peters River, Massachusetts

Section 303(d) listed impairments:	Metals
	Fecal coliform bacteria
Size of watershed:	7.9 square miles
Percent of IC in watershed:	7%

Applicability of IC method to this watershed

There were no problems using available data to calculate the percent IC for this watershed. It is a relatively small watershed and the land cover map provides adequate detail on the types of development and their concentrations in the watershed, although it might have been productive to separate the watershed into sub-basins based on the river branches shown on the map.

However, the cause of the impairment appears to be specific and known, and consequently, EPA would expect a specific TMDL to be developed for fecal coliform bacteria and metals. The fact that the existing %IC is lower than the TMDL target %IC indicates that stormwater runoff volume may not be the cause, and additional stressor identification is necessary. For these reasons, the IC method is not the appropriate method for TMDL development in this watershed.



N

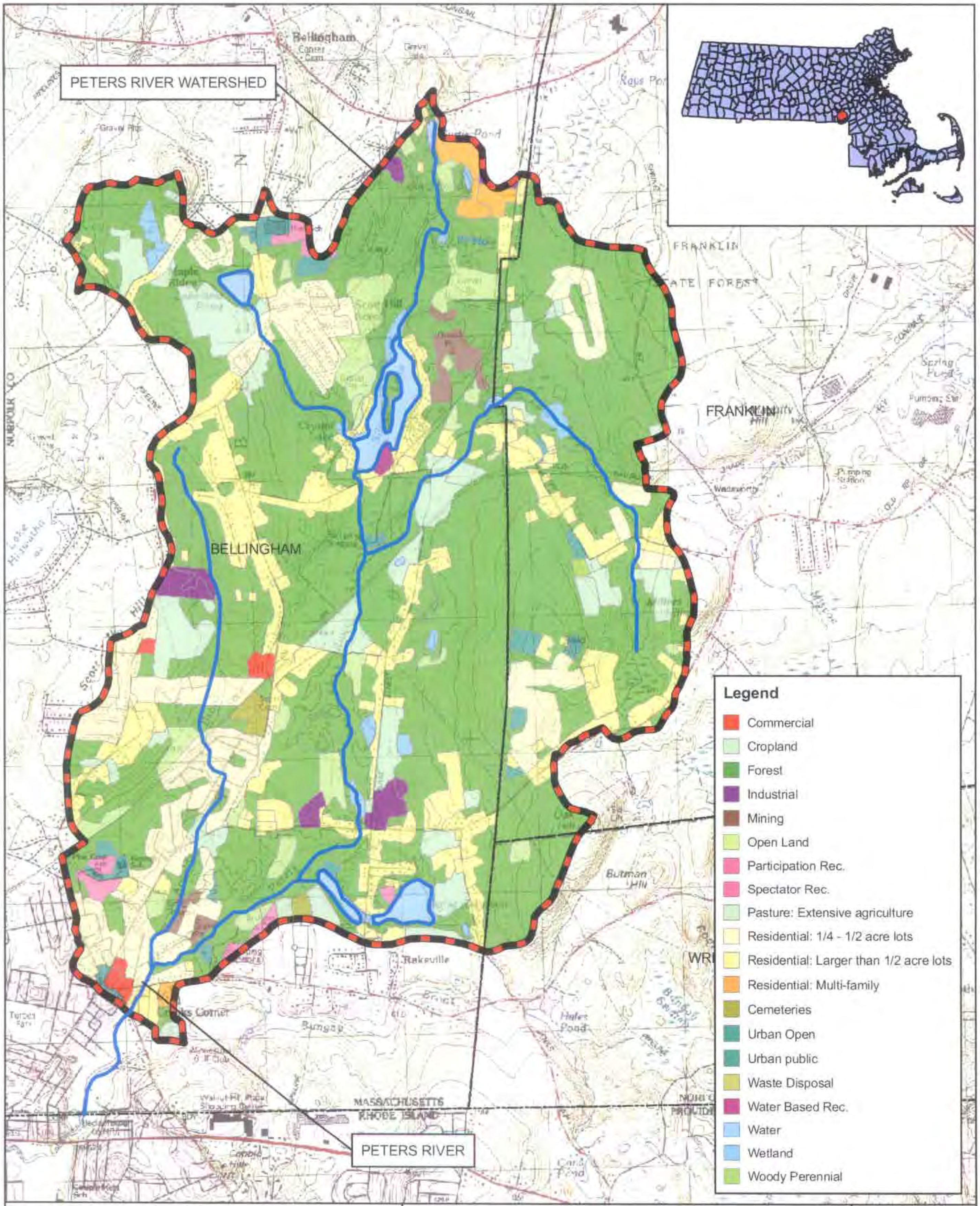
0 1,500 3,000 6,000 Feet

1 inch equals 3,000 feet

PETERS RIVER WITH
WATERSHED BOUNDARY INDICATED
BELLINGHAM, MASSACHUSETTS

NOTE:
PETERS RIVER WATERSHED DOES NOT INCLUDE BANGAY BROOK.

FIGURE
4-6



PETERS RIVER LANDUSE MAP

BELLINGHAM, MASSACHUSETTS

NOTE:
PETERS RIVER WATERSHED DOES NOT INCLUDE BANGAY BROOK

FIGURE 4-7

4.4 Three Ponds Brook

An IC method analysis for Rhode Island's Three Ponds Brook watershed was performed to complete a TMDL allocation. The IC method was applied to estimate existing and target % IC in the overall watershed and in each sub-watershed.

4.4.1 Watershed Description

The watershed for the Three Ponds Brook is located within Warwick and Cranston town boundaries and is shown on Figure 4-8. The watershed is characterized by wetland, commercial, residential development, and roadways (Table 4-11). The drainage area is 1,075 acres (1.7 sq. miles).

Three Ponds Brook is part of the Pawtuxet River Basin located between Warwick and Cranston Rhode Island. Three Ponds Brook joins the Pawtuxet River, which drains into Providence River. The Providence River is a part of the Narragansett Bay Watershed.

Three Ponds Brook is a Class B stream. Under the Rhode Island Water Quality Classification Descriptions, waters listed as Class B are designated for fish and wildlife habitat and primary and secondary contact recreational activities. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value (RIDEP, 1997).

Under the Rhode Island Final 2002 List of Impaired Waters List, Three Ponds Brook has been placed on the Clean Water Act 303(d) for the following: Copper, Lead, Dissolved Oxygen / Nutrients (RIDEM, 2003). According to Federal Regulations 40 CFR 131.36 (USEPA, 2000), the criteria for Copper is 17ug/L and 11ug/L for maximum and continuous concentrations, respectively. The criteria for Lead is 65ug/L and 2.5ug/L for maximum and continuous concentrations, respectively. Under the State Water Quality Regulations (RIDEM, 1997), the criteria for nutrients is that the average Total Phosphorus shall not exceed 0.025 mg/l in any lake, pond, kettlehole or reservoir ,and the average Total Phosphorus in tributarie shall not cause exceedances of this criteria in downstream water bodies. The criteria for dissolved oxygen (cold water fish habitat) is the DO (dissolved oxygen) content of not less than 75% saturation, based on daily average, and an instantaneous minimum DO of at least 5 mg/l.

According to the State of Rhode Island Section 305(b), Three Ponds Brook is assessed as not supporting aquatic life use. Also, Three Pond Brook is unassessed for swimming use to to lack of bacteria data (RIDEM, 2002).

Table 4-11 Three Ponds Brook: Major Landuse Distribution

Landuse	Percentage of Watershed
Wetland	27%
Commercial/Industrial Mixed	24%
Developed Recreation	8%
Transitional Areas (urban open)	8%
Medium High Density Residential (1/4 to 1/8 acre lots)	7%
Roads (divided highways >200 ft plus related facilities)	6%
Mines, Quarries and Gravel Pits	6%
Vacant Land	4%
Water	3%
Other	7%

4.4.2 Available Data

The State of Rhode Island provided a PDF with an aerial view map with Three Ponds Brook highlighted. Figure 4-9 provides a landuse map for the Three Ponds Brook watershed. The watershed boundary was delineated by hand from the USGS Quadrangles and landcover was obtained from Rhode Island Geographic Information System (RIGIS). The RIGIS Landuse datalayer has 16 landuse classifications interpreted from 1985 aerial photography.

4.4.3 Impervious Cover and Pollutant Load Calculation

To calculate watershed impervious cover, the Three Ponds Brook watershed was digitally intersected with the RIGIS landuse datalayer, and the area of each landuse category calculated. Watershed impervious percentage was then calculated based on the assumed impervious percentages for each landuse as shown in Table 4-12. The assumed percentage of impervious cover for each landuse was derived using recommended percentages in TR-55, Urban Hydrology for Small watersheds (USDA, 1986). The results of this analysis indicate the Three Ponds Brook watershed is 47 percent impervious. The Impervious Cover Model predicts severe degradation of stream quality for greater than 25 percent impervious cover. Thus, the impervious cover model predicts severe water quality degradation in the Three Ponds Brook.

Table 4-12 Three Ponds Brook: Estimated Percent Impervious Cover by Landcover

Landuse	**Estimated Percent Impervious Cover**
Commercial (sale of products and services)	85%
Commercial/Industrial Mixed	79%
High Density Residential (<1/8 acre lots)	65%
Industrial (manufacturing, design, assembly, etc.)	72%
Institutional (schools, hospitals, churches, etc.)	85%
Medium High Density Residential (1/4 to 1/8 acre lots)	38%
Other Transportation (terminals, docks, etc.)	90%
Other	0%

Table 4-13 provides estimated existing % IC and target % IC values for the Three Ponds River watershed. For illustrative purposes, estimated annual stormwater runoff volume and estimated annual pollutant loads for selected parameters are also provided, using annual rainfall and estimated event mean concentration of pollutants from (Schueler, 2003). For this watershed, an annual rainfall of 45.53 inches (Providence, NOAA.com) and a fraction of annual rainfall events that produced runoff of 0.9 (Center for Watershed Protection, 2003) were used.

Table 4-13 Three Ponds Brook: Estimated Existing and Target TMDL Values for Key Parameters

Parameter	Estimated Conditions	
	Existing	TMDL Target
Impervious Cover	47%	9%
Optional:		
Annual Runoff Volume	1,751 acre-ft	481 acre-ft
Total Suspended Solids	370,000 lbs	100,000 lbs
Total P	1,500 lbs	420 lbs
Soluable P	610 lbs	170 lbs
Total N	11,000 lbs	3,100 lbs
TKN	8,100 lbs	2,300 lbs
Nitrate & Nitrite	3,100 lbs	860 lbs
Copper	63 lbs	17 lbs
Lead	320 lbs	88 lbs
Zinc	760 lbs	210 lbs

4.4.4 Summary and Conclusions

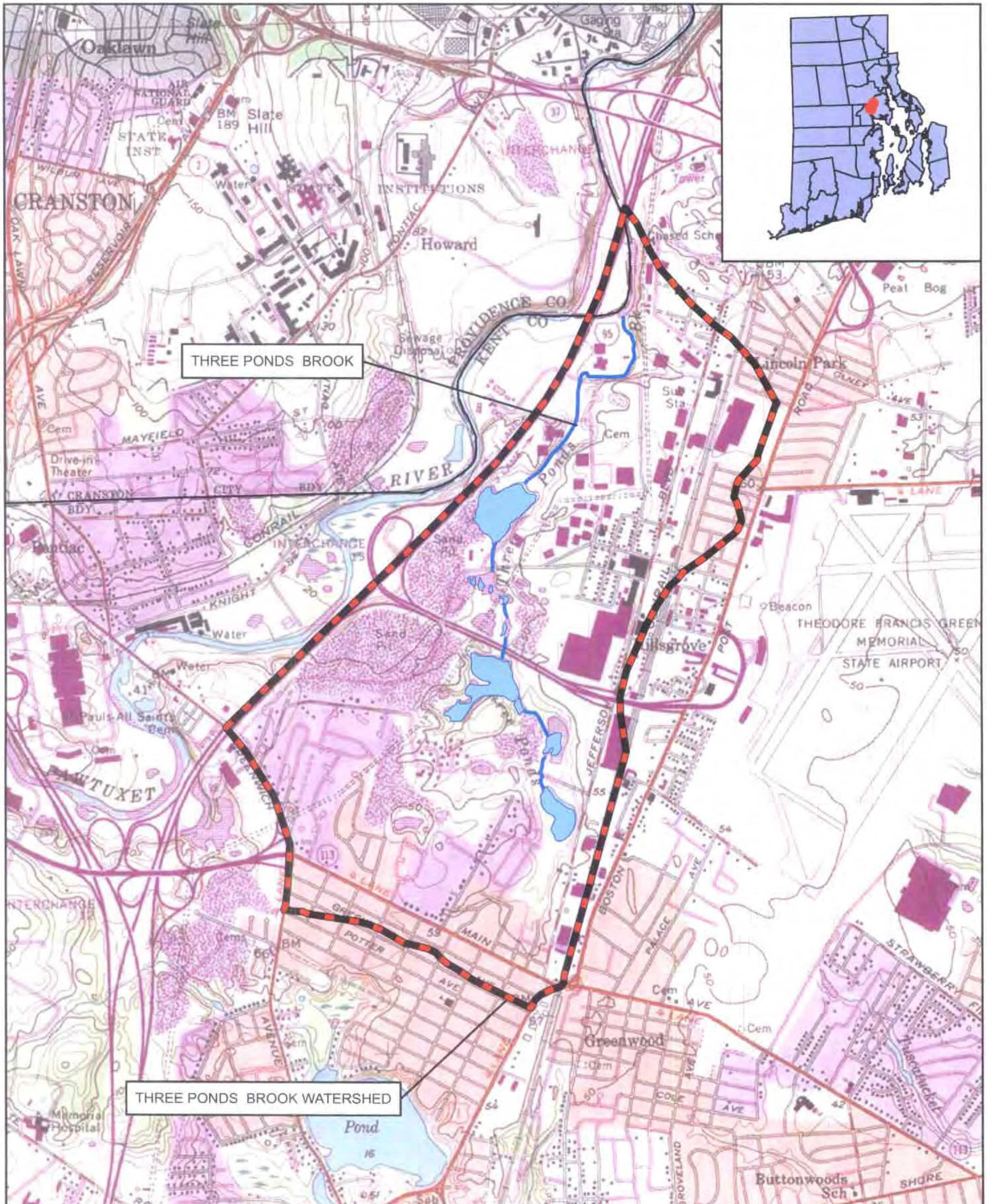
Three Ponds Brook, Rhode Island

Section 303(d) listed impairments:	Copper
	Lead
	Dissolved oxygen
	Nutrients (phosphorus)
Size of watershed:	1.7 square miles
Percent of IC in watershed:	47%

Applicability of IC method to this watershed

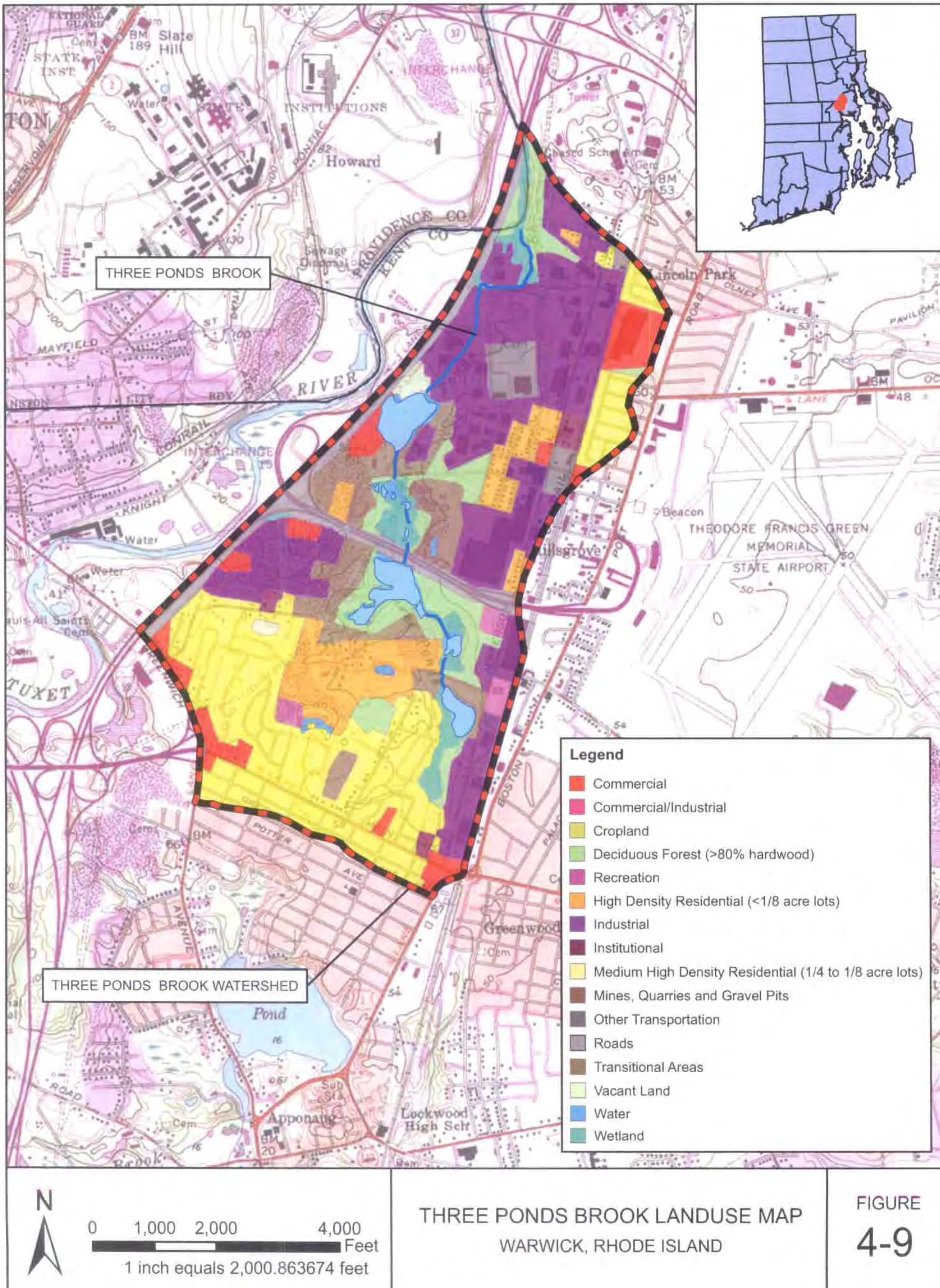
There were no problems using available data to calculate the percent IC for this watershed. It is a small watershed and the land cover map provides adequate detail on the types of development and their concentrations in the watershed.

However, the cause of the impairment is specific and known and consequently, EPA would expect specific TMDLs to be developed for copper, lead, dissolved oxygen, and nutrients. Consequently, the IC method is not the appropriate method for TMDL development in this watershed.



THREE PONDS BROOK WITH WATERSHED BOUNDARY INDICATED
WARWICK, RHODE ISLAND

FIGURE 4-8



THREE PONDS BROOK LANDUSE MAP

WARWICK, RHODE ISLAND

FIGURE 4-9

4.5 Cohas Brook

An IC method analysis for New Hampshire's Cohas Brook watershed was performed to complete a TMDL allocation. The IC method was applied to estimate existing and target % IC in the overall watershed and in each sub-watershed.

4.5.1 Watershed Description

The watershed for the Cohas Brook is located within the Manchester, Londonderry, Auburn, Derry, and Chester town boundaries and is shown on Figure 4-10. The watershed is characterized by forest, cleared land, roads (Table 4-14). The drainage area is 9,568 acres (14.95 sq. miles).

Cohas Brook is a part of the Merrimack River Basin, located in Southeastern New Hampshire. The Cohas Brook hydrologic unit code is 01070002-130 (NHDES, 2004). Cohas Brook begins at the outlet of Massabesic Lake in Manchester, NH and drains into Pine Island Pond which leads to the Merrimack River. The Merrimack River Basin covers 5,010 square miles in south-central New Hampshire, extending into Massachusetts.

Cohas Brook has been placed on the Clean Water Act 303(d) for the following: pH, habitat assessment, benthic-marcoinvertebrate bioassessment, mercury, and *Escherichia coli* (NHDES, 2004). Under the 2004 New Hampshire Consolidated Assessment and Listing Methodology, impairment is listed for pH by having a pH less than 6.5 or greater than 8.0. Benthic-Macroinvertebrate Bioassessments were impaired due to a benthic index of biologic integrity score less than 45. The habitat assessment was listed due to a score less than or equal to ten, where for more than one parameter and biological assessment supports the designation. Mercury was listed based on results falling between 0.77ug/L to 1.40ug/L (based on dissolved metal results). According to the State of New Hampshire Section 305(b) and 303(d), Cohas Brook does not support aquatic life, fish consumption and primary contact recreation (NHDES, 2004).

Table 4-14 Cohas Brook: Major Landuse Distribution

Landuse	Percentage of Watershed
Mixed forest	34%
Cleared/other open Tundra	14%
Beech/oak	13%
Other hardwoods	10%
White/red pine	9%
Transportation Active agricultural land	6%
Open water Wetlands	4%
Disturbed	4%
Other	7%

4.5.2 Available Data

The New Hampshire Department of Environmental Services (NHDES), provided GIS coverage data for the Cohas Brook watershed. The other GIS coverages required for the analysis, including Landcover, were acquired from the NH GRANIT website. The 2001 New Hampshire Land Cover Assessment categorizes land cover and land use into 23 classes.

Figure 4-11 provides a landuse map for the Cohas Brook watershed. The coverage was created for to provide a multi-purpose data set to support regional analysis, with as much detail as possible in the forested and agricultural classes. The landcover dataset was based on LandSat TM Satellite Imagery.

The New Hampshire landcover dataset was problematic for the IC Method and required significant additional analysis to yield useful coverage information. Specifically, The NH landcover categories were focused on forest and agricultural classes and lumped all non-transportation development categories together (i.e., commercial, industrial, high density residential, medium density residential, and low density residential were considered the same category). This is problematic because the different development-related landuses have significantly different impervious cover characteristics. To refine the dataset to be more useful for impervious cover determination, we manually split the development class into five sub classes; commercial, industrial, high density residential, medium density residential, and low density residential. This was accomplished by comparing the development class to the Digital Ortho Quarter Quadrangles, and modifying it to one of the sub classes. The Cohas Brook watershed was split into five sub-basins.

4.5.3 Impervious Cover and Pollutant Load Calculation

To calculate watershed impervious cover, the Cohas Brook's sub-basins were digitally intersected with the revised NH landcover assessment, and the area of each landuse category in each sub-basin calculated. Sub-basin impervious percentages were then calculated based on the assumed impervious percentages for each landuse as shown in Table 4-15 The Impervious Cover Model predicts sensitive stream quality for less than 10 percent impervious cover and impacted stream quality for greater than 10 percent impervious cover. Thus, the impervious cover model predicts sensitive water quality in the Cohas Brook.

The assumed percentage of impervious cover for each landuse was derived using recommended percentages in TR-55, Urban Hydrology for Small watersheds (USDA, 1986). The results of this analysis indicate the Cohas Brook watershed is 7 percent impervious, with a sub-basin as high as 12 percent impervious.

Figure 4-12 shows impervious cover estimates for each Cohas Brook sub-basin. Table 4-16 provides percent impervious cover for each sub-basin in a tabular format. The Impervious Cover Model predicts sensitive stream quality for less than 10 percent impervious cover and impacted stream quality for greater than 10 percent impervious cover. Thus, the impervious cover model predicts sensitive water quality in the Cohas Brook.

Table 4-15 Cohas Brook: Estimated Percent Impervious Cover by Landcover

Landuse	Estimated Percent Impervious Cover
Commercial	85%
High Density Residential (smaller than 1/4 acre lots)	65%
Industrial	72%
Low Density Residential (greater than 1/2 acre lots)	16%
Medium Density Residential (1/4 to 1/2 acre lots)	31%
Transportation Active agricultural land	100%
Other	0%

Table 4-16 Cohas Brook: Sub-basin Estimated Impervious Cover

Sub-basin	Estimated Percent Impervious Cover
1	9.2%
2	11.6%
3	6.6%
4	3.7%
5	4.4%

Table 4-17 provides estimated existing % IC and target % IC values for the Cohas Brook watershed. For illustrative purposes, estimated annual stormwater runoff volume and estimated annual pollutant loads for selected parameters are also provided, using annual rainfall and estimated event mean concentration of pollutants from (Schueler, 2003). For this watershed, an annual rainfall of 36.4 inches (Concord, NOAA.com) and a fraction of annual rainfall events that produced runoff of 0.9 (Schueler, 2003) were used.

Table 4-17 Cohas Brook: Estimated Existing and Target TMDL Values for Key Parameters

Parameter	Estimated Conditions	
	Existing	TMDL Target
Impervious Cover	7%	9%
Optional:		
Annual Runoff Volume	2,860 acre-ft	3,420 acre-ft
Total Suspended Solids	630,000 lbs	730,000 lbs
Total P	2,600 lbs	3,000 lbs
Soluable P	1,000 lbs	1,200 lbs
Total N	19,000 lbs	22,000 lbs
TKN	14,000 lbs	16,000 lbs
Nitrate & Nitrite	5,300 lbs	6,100 lbs
Copper	110 lbs	120 lbs
Lead	540 lbs	630 lbs
Zinc	1,300 lbs	1,500 lbs

4.5.4 Summary and Conclusions

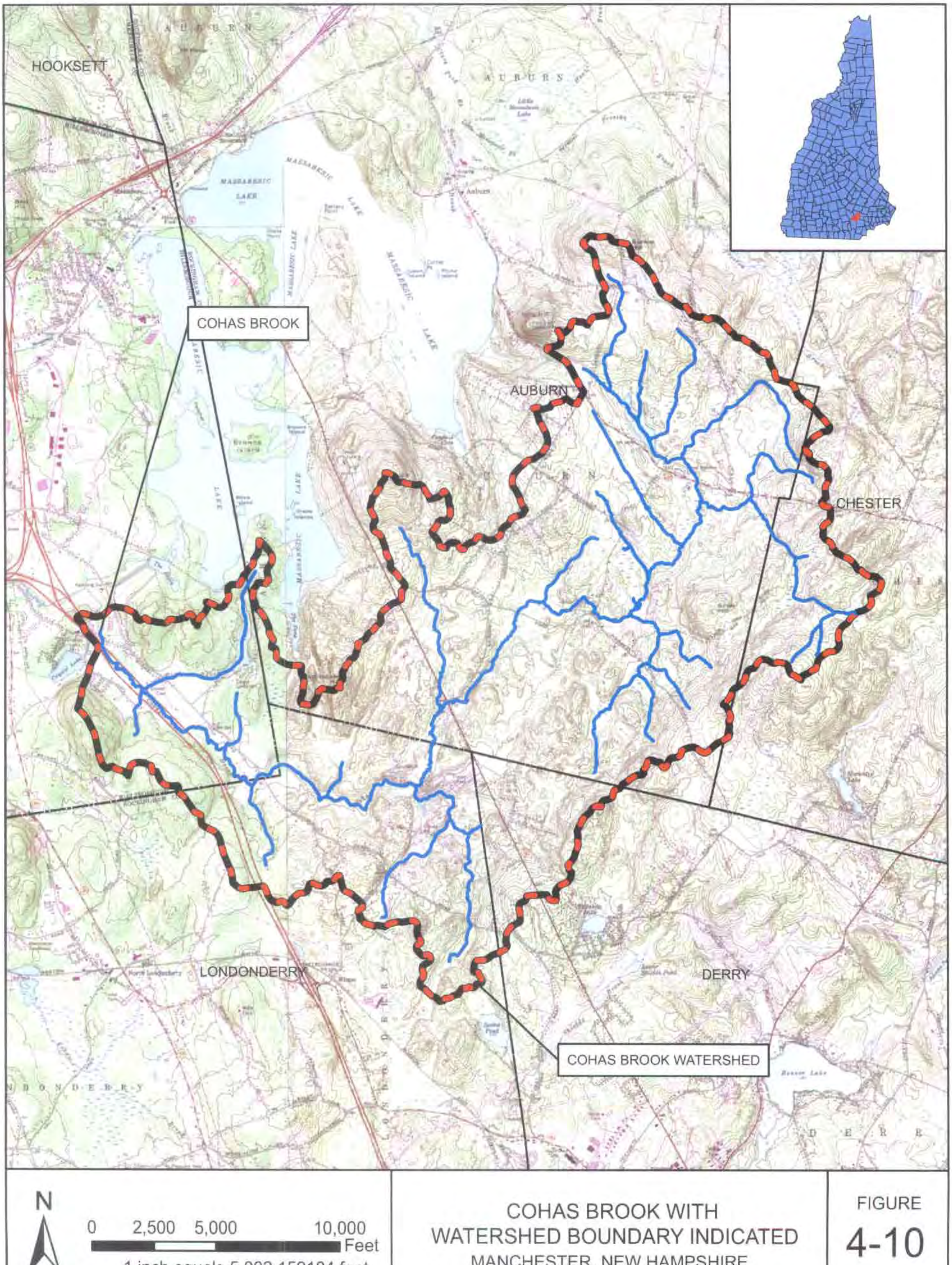
Cohas Brook, New Hampshire

Section 303(d) listed impairments:	Aquatic life support
	Fish consumption (mercury)
	Primary contact recreation (e-coli bacteria)
Size of watershed:	15 square miles
Percent of IC in watershed:	7% (sub-basin range = 4-12%)

Applicability of IC method to this watershed

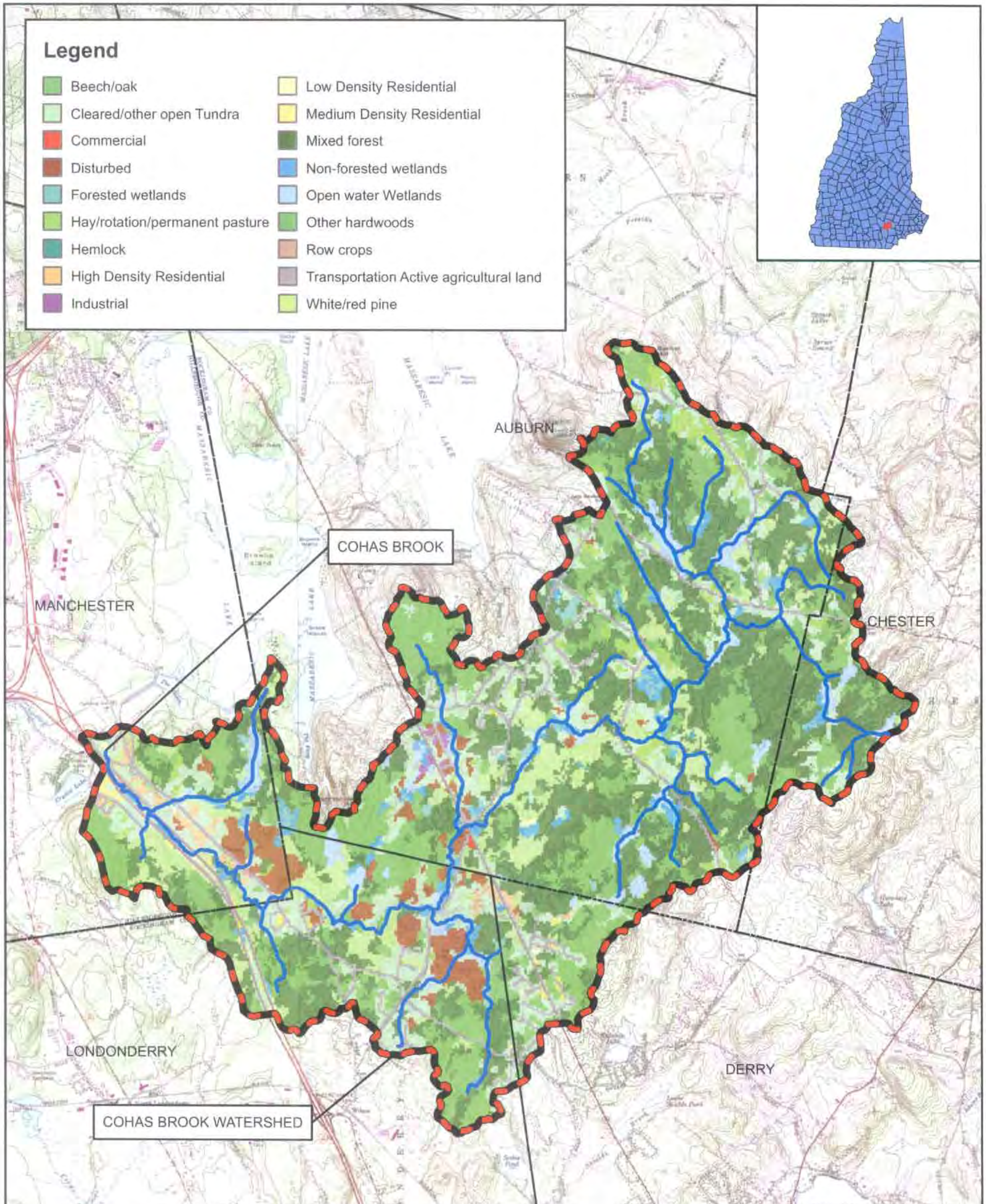
As noted in the case study, the NH dataset proved problematic for the analysis, and required a lot of manipulation to generate the land use detail needed. Also, the watershed was medium sized and required breaking into 5 sub-basins, which were then analyzed for their percent IC. The resulting analysis showed that one sub-basin has an IC level higher than the target, one is at the target level, and another tributary whose IC level was not assessed has a substantial amount of development and might have an IC level higher than the target. This was helpful for identifying sub-watersheds in need of attention.

After careful analysis of the data available, it may be reasonable to apply the IC method to deal with aquatic life impairments in the areas of the watershed exceeding the IC target. Other causes for the types of impairment observed should also be carefully considered and additional TMDL targets developed as deemed necessary. EPA would expect additional specific TMDLs to be developed for the other 303(d)-listed impairments.



COHAS BROOK WITH WATERSHED BOUNDARY INDICATED
MANCHESTER, NEW HAMPSHIRE

FIGURE 4-10



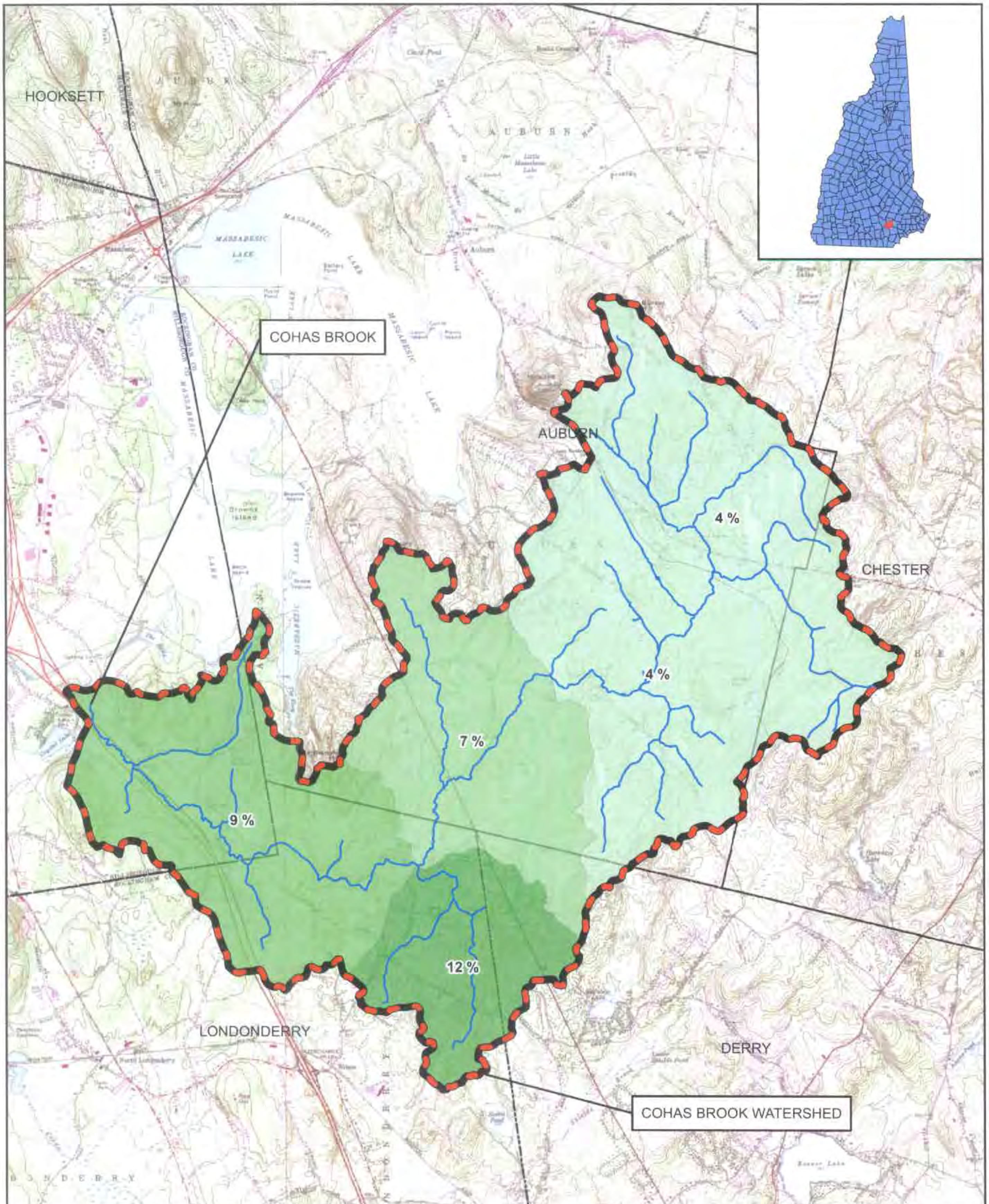
N

0 2,500 5,000 10,000 Feet

1 inch equals 5,002.159184 feet

COHAS BROOK LANDUSE MAP
MANCHESTER, NEW HAMPSHIRE

FIGURE
4-11



COHAS BROOK SUB WATERSHED
IMPERVIOUS COVER MAP
MANCHESTER, NEW HAMPSHIRE

FIGURE
4-12

4.6 Artic Brook (aka, Stream on Valley Ave)

An IC method analysis for Maine's Artic Brook watershed was performed to complete a TMDL allocation. The IC method was applied to estimate existing and target % IC in the overall watershed and in each sub-watershed.

4.6.1 Watershed Description

The watershed for the Artic Brook is located within the city of Bangor, ME and is shown on Figure 4-13. The watershed is characterized by forest, commercial, industrial, and residential development (Table 4-18). The drainage area is 621 acres (0.97 sq. miles).

Artic Brook (HUC: ME0102000510) is located in Bangor, Maine and is part of the Kenduskeag Drainage Basin. Artic Brook drains into the Kenduskeag Stream, which leads into the Penobscot River. Artic Brook is a Class B river at 0.5 miles in length. According to the Maine Integrated Water Quality Report, Class B waters are defined as general-purpose water and are managed to attain good quality water. Well-treated discharges with ample dilution are allowed (MEDEP, 2004).

Under the 2004 Maine Integrated Water Quality Report, Artic Brook is listed for aquatic life. According to the Water Quality Report the impairment listing criteria for aquatic life is the following: discharges shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes to the resident biological community (MEDEP, 2004).

Table 4-18 Artic Brook: Major Landuse Distribution

Landuse	Percentage of Watershed
Commercial-Industrial-Transportation	24%
Low Intensity Residential	19%
Grasslands	12%
High Intensity Residential	11%
Dense Residential Developed	10%
Coniferous/Deciduous Forest	9%
Crops/Ground	3%
Other	11%

4.6.2 Available Data

The State of Maine Department of Environmental Protection (MEDEP) provided a CD containing the state's best available GIS coverages for the Artic Brook watershed. This data included landuse for the State of Maine, a shapefile of the Artic Brook watershed, and an orthophoto of the watershed area.

Figure 4-14 provides a landuse map for the Artic Brook watershed. The landuse coverage is a combination of Maine Gap Analysis (GAP) landcover and USGS Multi Resolution Landcover Characterization (MRLC) landcover and was created by MEDEP. This coverage includes those classes from the GAP and MRLC layers that were best suited to calculating impermeability of watersheds. Both GAP and MRLC landcover datasets were based on 1992 LandSat TM Satellite Imagery, so the combined coverage also would be dated 1992.

4.6.3 Impervious Cover and Pollutant Load Calculation

To calculate watershed impervious cover, the Artic Brook's watershed was digitally intersected with the Maine combined landcover layer, and the area of each landuse category calculated. Watershed impervious percentage was then calculated based on the assumed impervious percentages for each landuse as shown in Table 4-19 assumed percentage of impervious cover for each landuse was derived using recommended percentages in TR-55, Urban Hydrology for Small watersheds (USDA, 1986). The results of this analysis indicate the Artic Brook watershed is 38 percent impervious. The Impervious Cover Model predicts severe degradation of stream quality for greater than 25 percent impervious cover. Thus, the impervious cover model predicts severe water quality degradation in the Artic Brook.

Table 4-19 Artic Brook: Estimated Percent Impervious Cover by Landcover

Landuse	Estimated Percent Impervious Cover
Commercial-Industrial-Transportation	79%
Dense Residential Developed	65%
High Intensity Residential	65%
Highways/Runways	75%
Low Intensity Residential	25%
Sparse Residential Developed	20%
Urban/Industrial	72%
Other	0%

Table 4-20 provides estimated existing % IC and target % IC values for the Artic Brook watershed. For illustrative purposes, estimated annual stormwater runoff volume and estimated annual pollutant loads for selected parameters are also provided, using annual rainfall and estimated event mean concentration of pollutants from (Schueler, 2003). For this watershed, an annual rainfall of 41.4 inches (Augusta Airport, WorldClimate.com) and a fraction of annual rainfall events that produced runoff of 0.9 (Schueler, 2003) were used.

Table 4-20 Artic Brook: Estimated Existing and Target TMDL Values for Key Parameters

	Estimated Conditions	
Parameter	Existing	TMDL Target
Impervious Cover	38%	9%
Optional:		
Annual Runoff Volume	780 acre-ft	260 acre-ft
Total Suspended Solids	160,000 lbs	55,000 lbs
Total P	670 lbs	220 lbs
Soluable P	270 lbs	91 lbs
Total N	5,000 lbs	1,700 lbs
TKN	3,600 lbs	1,200 lbs
Nitrate & Nitrite	1,400 lbs	460 lbs
Copper	28 lbs	9 lbs
Lead	140 lbs	47 lbs
Zinc	340 lbs	110 lbs

4.6.4 Summary and Conclusions

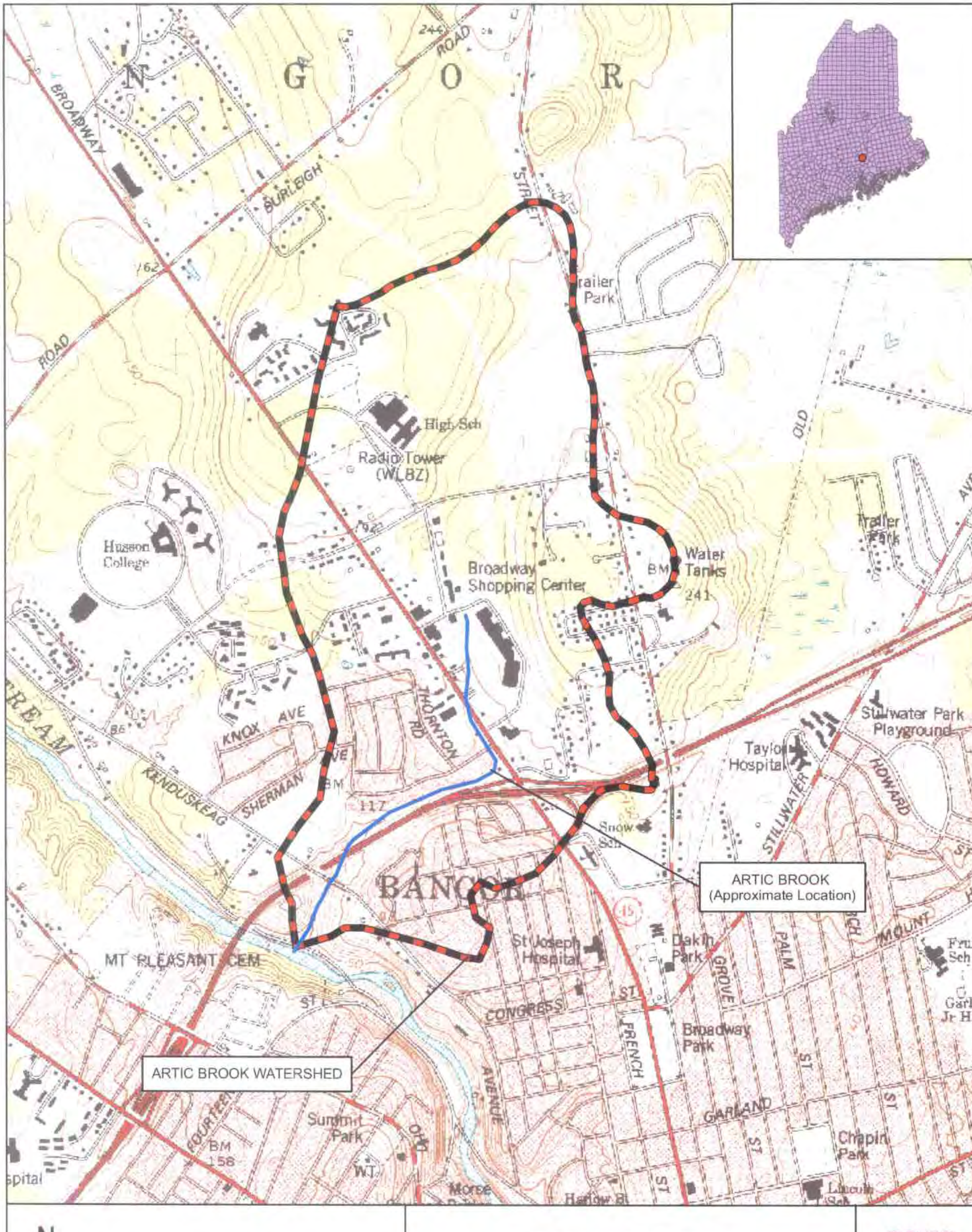
Artic Brook, Maine

Section 303(d) listed impairments:	Aquatic life support
Size of watershed:	1 square mile
Percent of IC in watershed:	38%

Applicability of IC method to this watershed

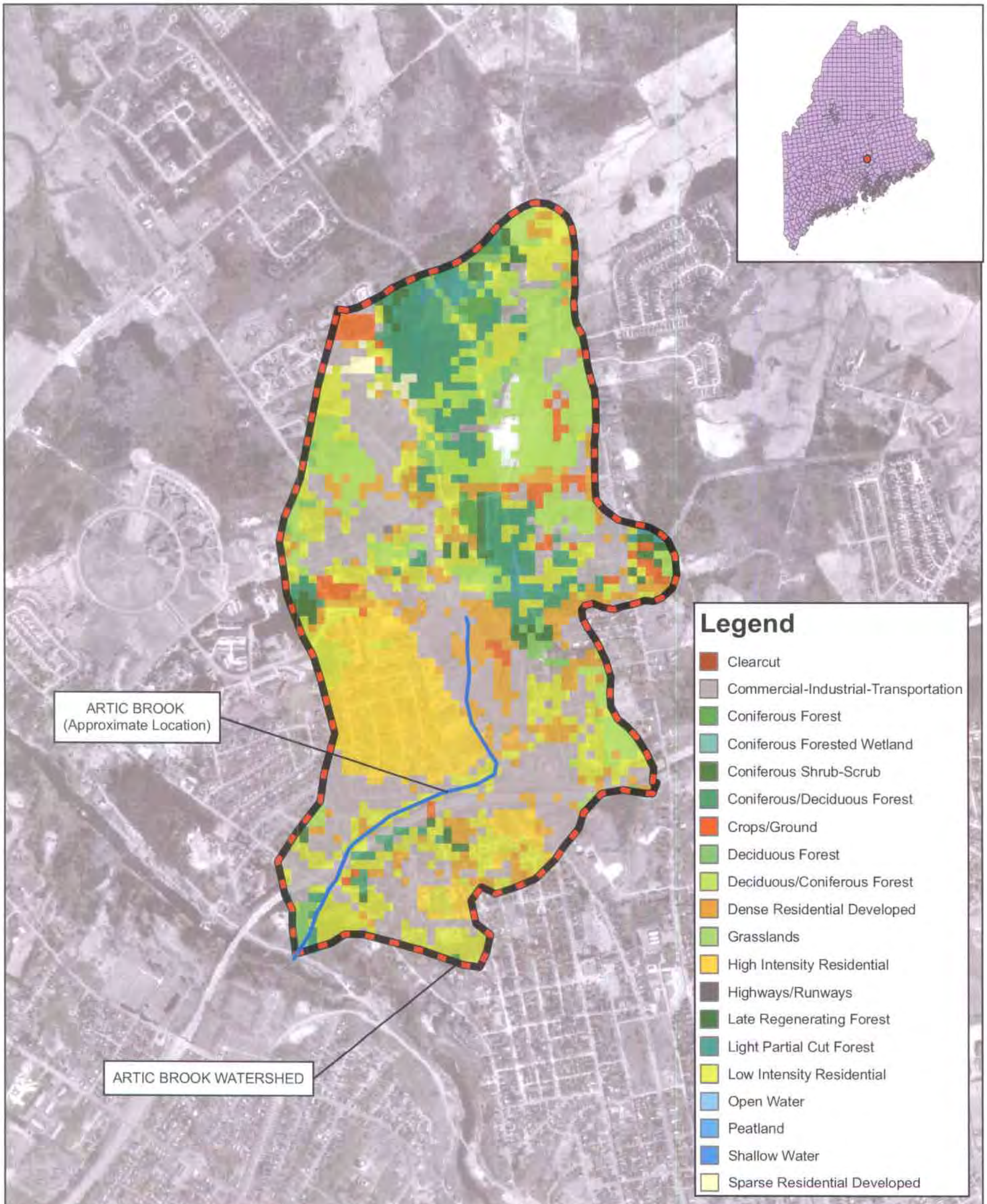
There were no problems using available data to calculate the percent IC for this watershed. It is a small watershed and the land cover map provides adequate detail on the types of development and their concentrations in the watershed.

The analysis shows a large difference between the existing and target (9%) IC levels. Consequently, the IC method appears to be a good approach for the aquatic life support impairment in this watershed.



ARTIC BROOK WITH
WATERSHED BOUNDARY INDICATED
BANGOR, ME

FIGURE
4-13



N

0 750 1,500 3,000 Feet

1 inch equals 1,500 feet

ARTIC BROOK LANDUSE MAP

BANGOR, ME

FIGURE

4-14

4.7 Tributary to Bond Brook, Maine

An IC method analysis for Maine's Tributary to Bond Brook watershed was performed to complete a TMDL allocation. The IC method was applied to estimate existing and target % IC in the overall watershed and in each sub-watershed.

4.7.1 Watershed Description

The watershed for the unnamed Tributary to Bond Brook is located within the city of Augusta, ME and is shown on Figure 4-15. The watershed is characterized by commercial, industrial, forest, and residential development, as provided in Table 4-21. The drainage area is 1,114 acres (1.74 sq. miles).

The unnamed Tributary to Bond Brook (HUC: ME0103000312) is part of the Lower Kennebec River Watershed. The Tributary begins near Augusta, Maine and joins Bond Brook. Bond Brook drains into the Kennebec River, which flows into the Gulf of Maine. The Tributary to Bond Brook is a Class B river at 2.0 miles in length. According to the Maine Integrated Water Quality Report, Class B waters are defined as general-purpose waters and are managed to attain good quality water. Well-treated discharges with ample dilution are allowed (MEDEP, 2004).

Under the 2004 Maine Integrated Water Quality Report, Tributary to Bond Brook is listed for Aquatic Life impairment. According to the Water Quality Report, the impairment listing criteria for aquatic life is as follows; "discharges shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes to the resident biological community" (MEDEP, 2004).

Table 4-21 Tributary to Bond Brook: Major Landuse Distribution

Landuse	Percentage of Watershed
Commercial-Industrial-Transportation	25%
Deciduous Forest	19%
Low Intensity Residential	11%
Grasslands	10%
Deciduous/Coniferous Forest	9%
Dense Residential Developed	6%
Coniferous/Deciduous Forest	5%
Crops/Ground	4%
Coniferous Forest	4%
Sparse Residential Developed	4%
Other	4%

4.7.2 Available Data

The State of Maine Department of Environmental Protection (MEDEP) provided a CD containing the state's best available GIS coverages for the Tributary to Bond Brook watershed. This data included landuse for the State of Maine, a shapefile of the Tributary of Bond Brook watershed, and an orthophoto of the watershed area.

Figure 4-16 provides a landuse map for the Tributary to Bond Brook watershed. The landuse coverage is a combination of Maine Gap Analysis (GAP) landcover and USGS Multi Resolution Landcover Characterization (MRLC) landcover and was created by MEDEP. This coverage includes those classes from the GAP and MRLC layers that were best suited to calculating impermeability of watersheds. Both GAP and MRLC landcover datasets were based on 1992 LandSat TM Satellite Imagery, so the combined coverage also would be dated 1992.

4.7.3 Impervious Cover and Pollutant Load Calculation

To calculate watershed impervious cover, the Tributary to Bond Brook's watershed was digitally intersected with the Maine combined landcover layer and the area of each landuse category calculated. Watershed impervious percentage was then calculated based on the assumed impervious percentages for each landuse as shown in Table 4-22. The assumed percentage of impervious cover for each landuse was derived using recommended percentages in TR-55, Urban Hydrology for Small watersheds (USDA, 1986). The results of this analysis indicate the Tributary to Bond Brook is 27 percent impervious. The Impervious Cover Model predicts severe degradation of stream quality for greater than 25 percent impervious cover. Thus, the impervious cover model predicts severe water quality degradation in the Tributary to Bond Brook.

Table 4-22 Tributary to Bond Brook: Estimated Percent Impervious Cover by Landcover

Landuse	Estimated Percent Impervious Cover
Commercial-Industrial-Transportation	79%
Dense Residential Developed	65%
High Intensity Residential	65%
Highways/Runways	75%
Low Intensity Residential	25%
Sparse Residential Developed	20%
Urban/Industrial	72%
Other	0%

Table 4-23 provides estimated existing % IC and target % IC values for the tributary to Bond Brook watershed. For illustrative purposes, estimated annual stormwater runoff volume and estimated annual pollutant loads for selected parameters are also provided, using annual rainfall and estimated event mean concentration of pollutants from (Schueler, 2003). For this watershed, an annual rainfall of 41.4 inches (Augusta Airport, WorldClimate.com) and a fraction of annual rainfall events that produced runoff of 0.9 (Schueler, 2003) were used.

Table 4-23 Tributary to Bond Brook: Estimated Existing and Target TMDL Values for Key Parameters

Parameter	Estimated Conditions	
	Existing	TMDL Target
Impervious Cover	27%	9%
Optional:		
Annual Runoff Volume	1,040 acre-ft	480 acre-ft
Total Suspended Solids	220,000 lbs	96,000 lbs
Total P	900 lbs	390 lbs
Soluable P	370 lbs	160 lbs
Total N	6,700 lbs	2,900 lbs
TKN	4,900 lbs	2,100 lbs
Nitrate & Nitrite	1,900 lbs	810 lbs
Copper	40 lbs	20 lbs
Lead	200 lbs	80 lbs
Zinc	500 lbs	200 lbs

4.7.4 Summary and Conclusions

Tributary to Bond Brook, Maine

Section 303(d) listed impairments:	Aquatic life support
Size of watershed:	1.7 square miles
Percent of IC in watershed:	27%

Applicability of IC method to this watershed

There were no problems using available data to calculate the percent IC for this watershed. It is a small watershed and the land cover map provides adequate detail on the types of development and their concentrations in the watershed.

The analysis shows a large difference between the existing and target IC levels. Consequently, the IC method appears to be a good approach for the aquatic life support impairment in this watershed.

N

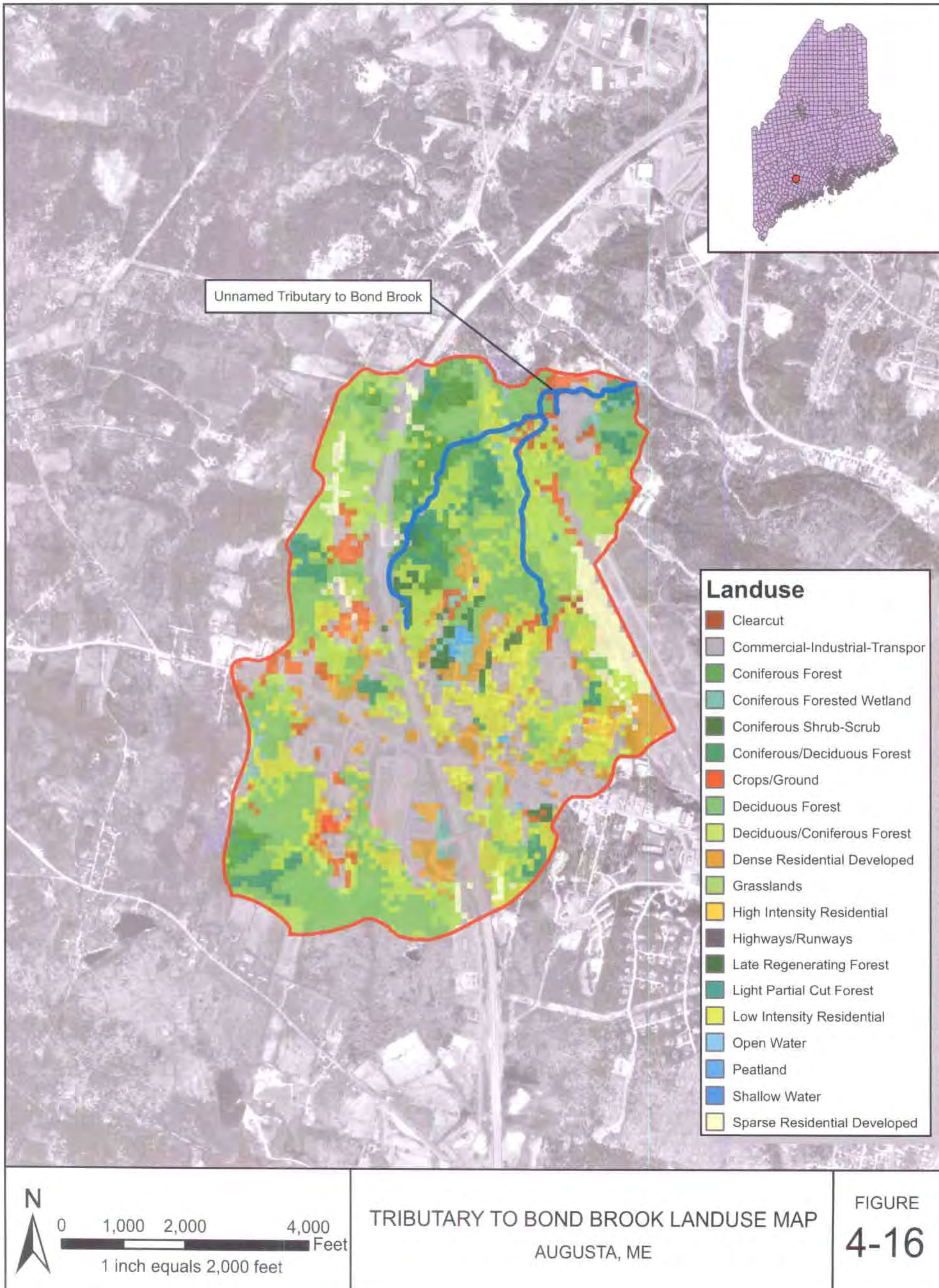
0 1,000 2,000 4,000 Feet

1 inch equals 2,000 feet

TRIBUTARY TO BOND BROOK WITH WATERSHED BOUNDARY INDICATED

AUGUSTA, ME

FIGURE 4-15



TRIBUTARY TO BOND BROOK LANDUSE MAP

AUGUSTA, ME

FIGURE 4-16

4.8 Summary

The Impervious Cover Method was applied as a tool to support TMDL development. Specifically, the IC method was applied to support specification of existing conditions, TMDL target conditions, allocation, and MOS. The pilot TMDL applications were completed to support evaluation of the ICM as a TMDL development tool.

Each pilot watershed was evaluated by obtaining and analyzing watershed landuse data provided by the states. Land use coverage data was evaluated to obtain impervious cover maps for each sub-basin within each watershed. A TMDL target of 9% impervious cover was established for each watershed and existing %IC were estimated and compared to the 9% target. In expanded applications of the basic, recommended IC method, stormwater runoff volume and selected pollutant loads were also identified and evaluated for illustrative purposes.

Table 4-24 provides a summary of the size and estimated percent IC for each pilot TMDL watershed. The IC Method analysis predicted that five of the seven watersheds were impacted (IC > 10%) and that three of those (Tributary to Bond Brook, Three Ponds Brook, and Artic Brook) experienced severe degradation (IC > 25%). Two watersheds, Peters River and Cohas Brook were not predicted to be impacted overall from stormwater volume, so additional stressor and source identification appears warranted. The Cohas Brook watershed is relatively large, however, and two of its five sub-basins had percent IC of 11.6% and 9.2%. Thus, the Cohas Brook TMDL evaluation served to identify sub-basins within the watershed where stream quality impacts may originate.

The seven pilot TMDL applications completed using the IC method are under evaluation for feasibility for use in large TMDL applications. These pilot TMDL applications will be evaluated based on several criteria including scientific appropriateness, and defensibility and compliance with TMDL process protocols (e.g., targets, allocations, and MOS). The ICM may also be applied to support TMDL implementation including planning, BMP specification, and monitoring activities. TMDL implementation is described in Section 5 below.

Table 4-24 Pilot TMDL Watersheds with Area and Estimated Percent IC

Watershed	Area (Sq. Mi.)	Estimated Percent Impervious Cover
Tributary to Bond Brook, Maine	1.7	27%
Beaver Brook, New Hampshire	73.0	12%
Goodwives River, Connecticut	1.9	19%
Peters River, Massachusetts	7.9	7%
Three Ponds Brook, Rhode Island	1.7	47%
Cohas Brook, New Hampshire	15.0	7%
Artic Brook, Maine	1.0	38%

5.0 TMDL IMPLEMENTATION

Once the TMDL development process is complete, an implementation plan is developed to ensure that appropriate management actions are taken to remove impairments. Management actions typically include identifying specific control measures (e.g., installing BMPs) that will be taken to reduce pollutant loadings and monitoring to assess water quality improvements. Sources of stormwater impairments are typically many and diffuse. As a result, phased TMDL implementation using adaptive management techniques will likely be required to remove impairments from streams.

A description of the phased TMDL implementation approach is provided below, followed by an introduction to management actions designed to reduce stormwater impacts to streams. A detailed Stormwater TMDL Implementation Support Manual for Stakeholders is presently under development and will soon be available to support TMDL implementation actions.

5.1 TMDL Implementation Approach

The TMDL implementation strategy should be part of a comprehensive watershed-specific management program. Recommended steps for developing and applying phased TMDL implementation for each watershed are as follows:

1. Review available watershed data and reports, including TMDLs and watershed assessment documents;
2. Conduct a detailed source identification and characterization program:
   - Use local knowledge (e.g., from local Department of Public Works, Boards of Health, and watershed groups) and draw on other ongoing programs (e.g., NPDES Phase 2 Municipal Separate Storm Sewer System (MS4) stormwater discharge inventories and illicit discharge inspection programs)
   - Conduct on-the-ground reconnaissance to identify potential sources;
   - Review infrastructure maps (e.g., storm sewer, sanitary sewer, and CSO maps) to identify potential sources; and
   - Review other available information to identify potential sources.
3. Prioritize sources for mitigation. High priority should be assigned to the sources that can be addressed most cost effectively;

4. Identify specific management techniques to mitigate or remove each source or type of source;
5. Develop detailed site-specific designs and programs for each local management practice;
6. Obtain funding to remediate highest priority sources;
7. Implement management practices to mitigate sources;
8. Monitor changes in receiving waters as management practices are implemented (including pre-implementation monitoring) and re-evaluate sources; and
9. Revisit and/or repeat Steps 3 through 8, as needed until TMDLs are attained.

In most watersheds, sources of stormwater impairments are many and diffuse. As a result, appropriate management practices must be selected, designed, and implemented at numerous locations in each watershed to mitigate adverse impacts and control impairments. The most appropriate suite of management practices vary depending on land use and impairment cause. The implementation strategy is an iterative process where data are gathered on an ongoing basis, sources are identified and eliminated if possible, and control measures including Best Management Practices (BMPs) are implemented, assessed, and modified as needed.

5.2 Evaluation of Alternative Management Actions

This section provides an introduction to stormwater management actions. A detail stormwater TMDL implementation support manual for stakeholders is presently under development. The management practices outlined below are designed to address a wide range of impacts associated with different types of land use. When these practices are implemented, major improvements in watershed health, well beyond reductions in loadings, will be realized, including improvements in stream physical, hydrologic, water quality, and biologic characteristics. Thus, development and application of the TMDL implementation plan will have far reaching benefits to the watershed.

Table 5-1 provides a matrix of management practices vs. mitigation provided and land use applicability. This matrix is intended to assist resource managers in evaluating the suitability of each management practice at specific locations. Various stormwater BMP options are identified and their ability to mitigate hydrologic, sediment, and pollutant impacts are rated. Also, the applicability of each BMP to various land use conditions is rated. The ratings for applicability and mitigation are color coded in the table and are subjective.

Stormwater BMPs to mitigate impacts in urban and suburban areas, defined as residential, commercial, and industrial areas are emphasized in Table 5-1. Agricultural land uses and other land-modifying uses can also contribute significantly to stormwater impairments. Stormwater

BMPs to mitigate impacts in these areas are also important and are described in a companion stormwater TMDL implementation support manual (under development).

Practices which mitigate for multiple impervious cover impacts are preferred over those which mitigate for a single impact. For example, stormwater retention/recharge practices are preferable to stormwater detention practices. Retention/recharge practices mitigate peak rates of discharge, volume of discharge, and reduced baseflow, whereas detention only mitigates peak rates of discharge.

Priority should be given to management practices based on their ability to treat the causal factors of the impairment as opposed to the symptoms. Therefore, the following hierarchy of impacts should be used for evaluation of management scenarios, in descending order of priority:

- Hydrologic impacts
- Physical impacts
- Water quality and biological impacts

Since mitigating measures should be evaluated based on their ability to mitigate for all of the impacts of impervious cover (hydrologic, physical, biological, and water quality), the most effective best management practices (BMPs) have the following characteristics

- Designed for very small events and large events (traditional BMPs were only designed for large events),
- Provide for significant recharge of runoff, and
- Provide enhanced pollutant removal using biofiltration

Sub-watersheds with BMPS that meet the above criteria could be considered effectively pervious for evaluation of existing and future conditions. BMPs that do not meet the critera for full treatment will still provide some pollutant reduction, but may not mitigate as well for hydrologic and physical impacts. Since many of these BMPs do not reduce runoff volumes, pollutant loads will still be elevated compared with more pervious conditions. According to the Impacts of Impervious Cover document, approximately 140 monitoring studies were evaluated by R. Winer as part of the *National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition* in 2000. This study summarized the effectiveness of stormwater treatment practices in removing pollutants. Removal rates, such as those developed in the Winer study, can be used in developing pollutant loading rates from sites with BMPs that do not render their watersheds as effectively pervious.

One important BMP concept for consideration with the IC model is disconnection of impervious areas. One of the most effective low-impact development strategies (LIDS) for retrofits is to "disconnect" impervious areas. Impervious areas that drain directly to closed drainage systems produce runoff in all but the smallest of rain events. If runoff from paved surfaces is allowed to flow over pervious/vegetated surfaces before entering a drainage collection system, some or all of the runoff from small storm events will be intercepted and percolated into the ground. Disconnecting impervious areas from storm sewer systems can have significant benefits for small storm events, which make up the majority of all storm events. Methods of disconnecting impervious areas include:

- Removing curbs on roads and parking lots;
- Locating catch basins in pervious areas adjacent to (rather than in) parking lots; and
- Adding gravel or vegetated strips adjacent to roof areas.

LIDS can be an effective component of a comprehensive stormwater TMDL implementation plan.

5.3 Summary

Stormwater TMDL implementation plans and actions will likely be costly and time-consuming to complete. It is critically important to move forward with a phased implementation approach to removing stormwater impairments. A detailed stormwater TMDL support manual will soon be available to support stakeholders in mitigating stormwater impacts to New England's streams.

Table 5-1. Management Practices, Mitigation Provided, and Land Use Applicability Matrix

Management Practice	Mitigation Provided: Runoff Volume (↑)	Peak Flow Rates (↑)	Baseflow (↓)	Sediment concentration (↑)	Pollutant concentration[1] (↑)	Applicability: New Development	Retrofit	Urban	Sub-Urban	Agricultural	Residential Sub-Division	Commercial	Industrial
Stormwater Infiltration/Retention													
Infiltration Basin	Good Mitigation	Good Mitigation	Good Mitigation	Good Mitigation	Good Mitigation	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Infiltration Trench	Good Mitigation	Good Mitigation	Good Mitigation	Good Mitigation	Good Mitigation	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Infiltration/Biofilter Swale	Good Mitigation	Good Mitigation	Good Mitigation	Good Mitigation	Good Mitigation	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Vegetated Filter Strip	Good Mitigation	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Stormwater Detention													
Created Wetland	Moderate Mitigation	Good Mitigation	Minimal Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Extended Detention Ponds	Minimal Mitigation	Good Mitigation	Minimal Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Vegetated Riparian Buffer Zones	Moderate Mitigation	Moderate Mitigation	Minimal Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Swales	Moderate Mitigation	Good Mitigation	Minimal Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Other Stormwater Treatment													
Sand Filter/Filter Beds	Minimal Mitigation	Minimal Mitigation	Minimal Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Oil and Grit Chambers	Minimal Mitigation	Minimal Mitigation	Minimal Mitigation	Moderate Mitigation	Minimal Mitigation	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited
Catchbasins with Sumps & Hoods	Minimal Mitigation	Minimal Mitigation	Minimal Mitigation	Moderate Mitigation	Minimal Mitigation	Well Suited	Well Suited	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited
Combined Sewer Overflow													
Combined Sewer Separation	Minimal Mitigation	Minimal Mitigation	Minimal Mitigation	Moderate Mitigation	Good Mitigation	Not Applicable	Well Suited	Well Suited	Well Suited	Not Applicable	Not Applicable	Well Suited	Well Suited
CSO Prevention Practices	Minimal Mitigation	Minimal Mitigation	Minimal Mitigation	Moderate Mitigation	Good Mitigation	Not Applicable	Well Suited	Well Suited	Well Suited	Not Applicable	Not Applicable	Well Suited	Well Suited
Low Impact Development Practices													
Disconnecting Impervious Area	Good Mitigation	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Well Suited	Moderately Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited
Bioretention	Good Mitigation	Moderate Mitigation	Moderate Mitigation	Good Mitigation	Good Mitigation	Well Suited	Well Suited	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited
Soil Amendment	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Moderately Suited	Moderately Suited
Pervious Pavement	Good Mitigation	Good Mitigation	Good Mitigation	Good Mitigation	Good Mitigation	Well Suited	Well Suited	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited
Green Roof	Good Mitigation	Good Mitigation	Minimal Mitigation	Good Mitigation	Good Mitigation	Well Suited	Moderately Suited	Well Suited	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited
Rain Barrels/Cisterns	Good Mitigation	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Moderate Mitigation	Well Suited	Well Suited	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited
Rain Garden	Good Mitigation	Moderate Mitigation	Moderate Mitigation	Good Mitigation	Good Mitigation	Well Suited	Well Suited	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited

[1]Pollutants mitigated include nutrients, metals, and other constituents

Key
- Minimal Mitigation
- Moderate Mitigation
- Good Mitigation
- Not Applicable
- Moderately Suited
- Well Suited

6.0 REFERENCES

Augusta Airport, Kennebec County, http://www.worldclimate.com/cgi-bin/data.pl?ref=N44W069+2200+170275C.

Center for Watershed Protection, March 2003, "Impacts of Impervious Cover on Aquatic Systems."

CTDEP, 2004. Connecticut Consolidated Assessment and Listing Methodology for 305(b) and 303(d) Reporting (CT CALM). April 2004.

CTDEP, 2004. List of Connecticut Waterbodies Not Meeting Water Quality Standards, under Section 303(d) of the Federal Clean Water Act. April 28, 2004.

Fuss & O'Neill, 2004. Goodwives River Management Plan, Friends of Goodwives River Inc. Darien, CT. February 2004.

MADEP, 2001. Blackstone River Basin 1998 Water Quality Assessment Report, Division of Watershed Management. May 2001.

MADEP, 2002. 314 CMR 4.00: Massachusetts Surface Water Quality Standards, Division of Water Pollution Control. May 2002.

Maine DEP, 2004. Integrated Water Quality Monitoring and Assessment Report.

NHDES, 2004. Final 2004 Section 305(b) and 303(d) Surface Water Quality Report. March 2004.

NHDES, 2004. Final 2004 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology. March 2004.

NHDES, 2004. Watershed Management Bureau, Biomonitoring Program – Merrimack Basin.

RIDEM, 1997. State of Rhode Island and Providence Plantations Water Quality Regulations, DEM Water Resources. August 1997.

RIDEM, 1997. Water Quality Classification Descriptions Appendix A, Water Resources. August 1997.

RIDEM, 2003. State of Rhode Island 2002 303(d) List, List of Impaired Waters – Final. March 2003.

RIDEM, 2002. State of Rhode Island and Providence Plantations: 2002 Section 305(b) State of the State's Water Report Appendix. Surface Water Quality Assessment Summaries. 2002.

U.S. Department of Agriculture, Soil Conservation Service, Engineering Division, June 1986, “Urban Hydrology for Small Watersheds.”

USEPA, 2000. Code of Federal Regulations, 40 CFR 131.36. 2000.