Total Maximum Daily Load (TMDL) Report

Penjajawoc Stream & Meadow Brook
Bangor, Maine

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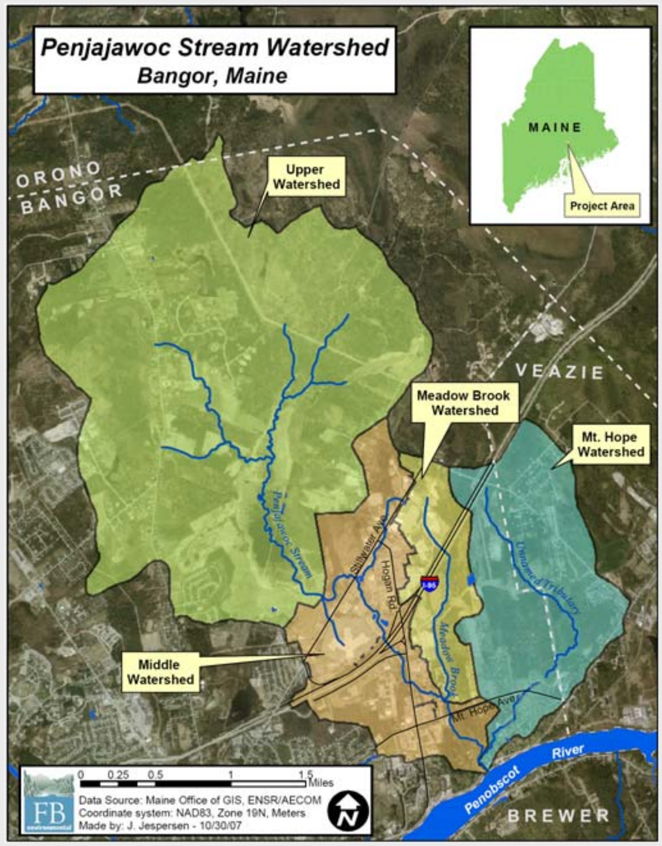
Description of the Watershed

Penjajawoc Stream, situated in Bangor, Maine, drains a watershed area of approximately 5,600 acres. For purpose of analysis, the watershed has been divided into four subwatersheds based on the ENSR SWMM Model (ENSR 2006b). These include: 1) the Upper, 2) Middle, 3) Meadow Brook, and 4) Mt. Hope Watersheds (see map at right). The Upper watershed drains a 300 acre marsh known as Penjajawoc Marsh. The most developed watershed is the middle watershed, which drains development along Stillwater Avenue, the Bangor Mall, and both sides of Hogan Road. The Meadow Brook watershed drains development on the east side of Hogan Rd. including an area of recent commercial growth north of the I-95 turnpike. Meadow Brook joins Penjajawoc Stream just above Mt. Hope Avenue. The Penjajawoc flows southeast through a wooded area that is primarily residential, where it joins with an unnamed tributary that drains the Mt. Hope Cemetery. From here, the stream flows directly to the Penobscot River.

This TMDL applies to Penjajawoc Stream and Meadow Brook on Maine's 2006 303(d) list.



Why do a 'TMDL' on Penjajawoc Stream?

Penjajawoc Stream has multiple water quality problems due in large part to a complex array of pollutants transported by nonpoint-source, urban stormwater runoff. Waters, such as Penjajawoc Stream, that do not meet Maine's water quality standards are called impaired and placed on the **303(d) list**. Penjajawoc Stream violates Maine's Class B standards for dissolved oxygen, aquatic life and habitat. The Clean Water Act requires that all 303(d) listed waters undergo a **TMDL** assessment that describes the impairments and identifies the measures needed to restore water quality. The goal is for all waterbodies to comply with each state's water quality standards.

Sampling Results & Pollutant Sources

The Penjajawoc Stream TMDL is based on sampling data collected over a three year period (2001-2003) which includes monitoring of the macroinvertebrate community, physical habitat parameters and water chemistry. Sampling results were compared to Maine's statutory Class B water quality standards and the stream was listed due to non-attainment of dissolved oxygen and aquatic life criteria which indicates the health of the aquatic insect community. According to Maine's *2006 303(d) list*, aquatic life impairment is probably due to urban nonpoint source pollution and habitat impairment. Development and impervious surfaces result in increases in stormwater volume that alter stream stability and cause in-stream habitat degradation: bank erosion, siltation, scour, over-widening of stream channel, and wash-out of biota. The impervious surface also prevents seepage of rainfall to local groundwater which in turn reduces summer base flow and habitat availability. Since the impairment cannot be attributed to a specific pollutant, and is likely due to hydraulic stress and the suite of pollutants in urban stormwater, **impervious cover (IC)** was used as a surrogate measure of the range of pollutants in stormwater. Recent studies (as summarized in CWP 2003) have shown that the percentage of impervious cover (% IC) in a watershed strongly affects the health of aquatic systems because land surfaces that block infiltration of rainwater cause increased amounts of stormwater to run off into gutters, untreated storm sewers or directly to streams. In general, stream quality declines as imperviousness exceeds 10% of watershed area, and may be severely compromised at greater than 25% (Schueler 1994, CWP 2003, Appendix 2). Therefore, IC is an appropriate surrogate measure of impacts caused by stormwater, while aquatic life assessments (biomonitoring) provide an appropriate endpoint to measure the progress of TMDL implementation.

Required TMDL Elements and Impervious Cover Results

Impervious cover in the four subwatersheds of Penjajawoc Stream was determined to be 3% in the Upper watershed, 33% in the Middle watershed, 19% in the Meadow Brook watershed, and 7% in the Mt. Hope watershed (see Section 6). Analysis of land cover data shows that the Penjajawoc Stream watershed contains dense areas of developed land, including commercial, industrial and residential land uses. Changes in land use resulting in a high percentage of impervious surface in the Penjajawoc Stream watershed has resulted in changes to the hydrologic cycle of Penjajawoc Stream and increased surface water flow during storm conditions.

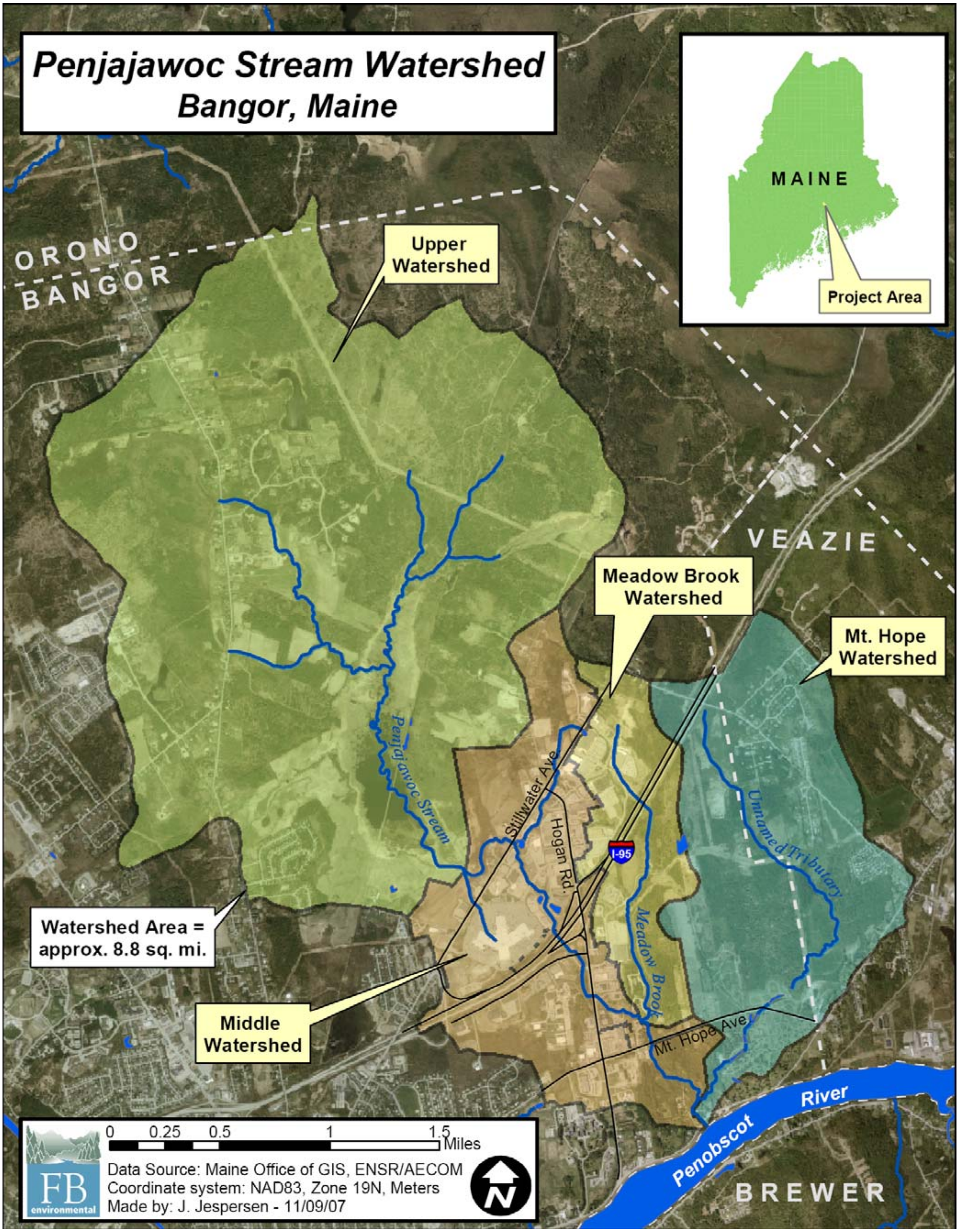
The Penjajawoc Stream and Meadow Brook TMDL report contains elements required by the Clean Water Act, which are summarized in the table below. The ultimate goal of the TMDL process is to attain water quality standards. The target goal provides technical guidance to initiate a strategy for **BMP** implementation.

TMDL Element	Clean Water Act Definitions	Penjajawoc Stream Findings & Goals
Goal (End Point)	Achieve water quality consistent with Maine's Class B standards	A biological community consistent with Maine's Class B standards
TMDL Target (Loading Capacity)	Maximum loading of pollutants that attains the goal	Analysis of Maine's biomonitoring data indicate that a watershed with characteristics of 10% IC would achieve the goal
Margin of Safety (MOS)	The MOS accounts for uncertainty in target-setting and adds a safety factor to increase the likelihood of attainment	A 1% IC reduction is reserved from the target as a MOS
Pollutant Loads	Estimate of the existing pollutant loads	As high as 33% IC in Middle watershed (conservative estimate of development impact and the associated stormwater runoff volume and pollutants (e.g., nutrients, metals))- see table next page
Load Allocation & Waste Load Allocation Targets	Pollutant loads from watershed sources that are required to achieve the water quality target and goal	9% IC, which represents as much as a 73% reduction in volume and stormwater constituents when existing pollutant loads are compared to the target
TMDL Implementation	Actions or engineered **BMP** solutions that will achieve the reductions and ultimately restore the stream	A Watershed Management Plan (WMP) is currently being developed by community stakeholders (Arter 2007) which will incorporate the recently completed BMP Retrofit Design Plan (WBRC 2007)

Definitions

- **303d List** *identifies water quality limited waters within the state, the causes and sources of nonattainment of standards, and a timetable for the development of TMDLs.*
- **TMDL** *is an acronym for* ***Total Maximum Daily Load****, representing the total amount of a pollutant that a waterbody can receive annually and still meet water quality standards.*
- **Impervious Cover** *refers to landscape surfaces (covered by pavement or buildings) that no longer absorb rain and may direct large volumes of runoff into the stream.*
- **BMPs or Best Management Practices** *are engineered solutions or techniques designed to reduce the impacts of developed impervious cover, pollutants, and the altered flow associated with stormwater runoff.*

Figure 1. Map of Penjajawoc Stream Watershed (Meadow Brook Watershed shown in yellow).



1. INTRODUCTION

Penjajawoc Stream in Bangor, Maine is an urban drainage with an impaired aquatic community and degraded habitat that violates Maine's water quality standards. Penjajawoc Stream was listed on Maine Department of Environmental Protection's (MDEP) *2006 Integrated Water Quality Monitoring and Assessment Report (2006 305(b) List)* due to exceedances of the aquatic life criteria and dissolved oxygen as defined in Maine's *Water Quality Classification Program* (38 MRSA Sections 464-470). Under section 303(d) of the Federal Clean Water Act (CWA), states are required to develop a Total Maximum Daily Load (TMDL) analysis for impaired waters to define the pollutant reductions needed to restore healthy in-stream conditions. The TMDL report describes the impairments, pollutants or pollutant surrogates, water quality targets, and the loading that a waterbody can receive without exceeding water quality criteria.

Penjajawoc Stream flows through the heavily urbanized Bangor Mall area (photo: ME Dennis)

Biological Monitoring & Impairments

MDEP has an ongoing biological monitoring program with tiered biological criteria for the different classes of rivers and streams in Maine (38 MRSA § 465). Biomonitoring assesses the health of rivers and streams by evaluating the composition of resident biological communities (mainly benthic macroinvertebrates). This approach is particularly useful for small streams, such as Penjajawoc Stream, impaired by the mix of pollutants associated with stormwater runoff and altered flow patterns. Benthic communities act as continuous monitors of environmental quality by integrating the range of environmental conditions that occur over time, beyond sampling events. Impairments to the aquatic life in Penjajawoc Stream were identified using biological criteria, land use analysis and directly measuring the chemical and physical properties of the stream.

Maine's *2006 303(d) List* of impaired waters identified stormwater runoff from urban sources (regulated and non-regulated) as the most probable cause of impairment in Penjajawoc Stream. This finding is consistent with Stressor Identification analysis conducted on other small urban streams in Maine (PETE 2005). This TMDL was developed using Impervious Cover (IC) as a surrogate parameter for the complex array of pollutants conveyed in stormwater and the impacts of altered stream hydrology.

TMDL Requirements

The TMDL prescribes a reduction in the existing IC condition of the watershed to resemble the IC conditions that are known to achieve the designated aquatic life use. In an IC TMDL analysis, the loadings are expressed as a % IC target, and these targets are derived by establishing the % IC in streams that attain aquatic life criteria (Appendix 2). TMDL analyses are required by Federal regulations to allocate a proportion of total loading to point sources through the use of Waste Load Allocations (WLAs) and to nonpoint sources and background conditions through the use of Load Allocations (LAs). TMDLs must also address the inherent ambiguities in relating water quality standards to pollutant loadings by using a Margin of Safety (MOS). Finally, TMDL analyses must also account for seasonal variations with respect to pollutant loads and the corresponding attainment of water quality standards. All of these factors have been considered in this TMDL.

States submit completed TMDLs to the US Environmental Protection Agency (US EPA) for final review and approval. Prominent features of a TMDL are establishing the scientific justification and setting goals that guide the development of TMDL implementation plans. Target % IC values are used to establish a meaningful process for selecting, designing and implementing appropriate stormwater best management practices (BMPs) that reduce IC or mitigate its effects. A TMDL implementation plan designed around attainment of water quality standards includes stakeholder involvement and a schedule for activities. This report includes a general TMDL Implementation Plan with these components along with an explanation of ongoing water quality monitoring. This preliminary plan with specific recommendations is based on an initial sub-watershed-level GIS analysis (presented in Appendix 1 of this report), and essential field reconnaissance recommended in Section 10 of this report. The Watershed Management Plan for the Penjajawoc Stream Watershed (Arter 2007) integrates the recommended components and presents specific BMPs to achieve reductions.

2. WATERBODY DESCRIPTION AND PRIORITY RANKING

Penjajawoc Stream and its impaired tributary, Meadow Brook, located in Bangor, Maine (Penobscot County, 44°48'N, 68°46'W, HUC 0102000513), are approximately 5.2 miles and 1.5 miles long, respectively. The direct watershed area for Penjajawoc Stream is 5,600 acres (8.8 sq. mi.). Meadow Brook is one of ten tributaries that flow into the Penjajawoc. The headwaters of Penjajawoc Stream drain a 300 acre marsh known as Penjajawoc Marsh. Penjajawoc Stream also drains a heavily developed area along Stillwater Avenue, including the Bangor Mall, and development on both sides of Hogan Road. The Meadow Brook watershed drains development on the east side of Hogan Rd. including an area of recent commercial growth north of the I-95 highway. Meadow Brook joins Penjajawoc Stream just above Mt. Hope Avenue. The Penjajawoc continues southeast through a wooded area that is primarily residential, where it joins with an unnamed tributary that drains the Mt. Hope Cemetery. From here, the stream flows directly to the Penobscot River.

Soils in the watershed consist of marine/lacustrine deposits and silty glacial till. Glacial till such as the Howland series is more predominant in the upper watershed, while the marine/lacustrine deposits of the Scantic series are more common in the lower reaches of the watershed closer to the Penobscot River. These fine, silty soils have very slow infiltration rates, high potential for erosion if not vegetated, and can be easily mobilized by streamflow and intensified by increased stormwater runoff (Parish 2006). The Penjajawoc Stream watershed is highly developed, with an impermeable surface area as high as 33% in the middle watershed. As such, the urban stream has been dramatically impacted by stormwater run-off, removal of

Table 1. The status of impairment for Penjajawoc Stream and Meadow Brook and the TMDL development priority as documented on the *2006 303(d) List.*[1]

ASSESSMENT UNIT ID	SEGMENT NAME	SEGMENT SIZE	SEGMENT CLASS	TMDL PRIORITY	CAUSE
ME0102000513_226R03	Penjajawoc Stream/Meadow Brook	6.76 mi	Class B	2007	Habitat Assessment
ME0102000513_226R03	Penjajawoc Stream/Meadow Brook	6.76 mi	Class B	2007	Dissolved Oxygen
ME0102000513_226R03	Penjajawoc Stream/Meadow Brook	6.76 mi	Class B	2007	Benthic-Macroinvertebrate Bioassessments

[1]*In Maine's 2006 303(d) list, Penjajawoc Stream and Meadow Brook are combined into the same ADB Assessment Unit ID (ME0102000513_226R03).*

riparian vegetation, and channel alteration among other concerns.

Classified as a Class B stream, Penjajawoc Stream (and Meadow Brook) was included in Maine's *2006 303 (d)* list (MDEP 2006) of waters that do not meet State water quality standards. The listing was based on stream assessments and sampling results from the Biological Monitoring Program of the Maine Department of Environmental Protection from 1997, 2001 and 2002 (MDEP; see next section). Additional data collected throughout the watershed in 2004-2006 indicate continuing water quality impairments in the stream. Penjajawoc Stream was assigned a TMDL completion date of 2007.

3. POLLUTANTS OF CONCERN AND POLLUTANT SOURCES

The most probable cause of aquatic life impairment in Penjajawoc Stream is a combination of unmitigated stormwater flow, and a complex array of pollutants transported by nonpoint-sources and urban stormwater run-off (both regulated and non-regulated). The stream was listed due to non-attainment of Maine's statutory Class B aquatic life criteria, based on MDEP Biomonitoring data collected on macroinvertebrate communities at multiple locations in both the upper and lower watershed in 1997, 2001 and 2002. Results of the 2006 sampling confirm the listing. Sampling protocols are outlined in Maine's *Quality Assurance Project Plan for Biological Monitoring of Maine's Rivers, Streams, and Freshwater Wetlands* (MDEP 2004). Macroinvertebrate populations reflect a combination of intricate environmental factors and impairments generally indicate stream habitat degradation due to sedimentation and physical alterations.

Since the impairment cannot be attributed to a specific pollutant, impervious cover (IC) was selected as a surrogate measure of the range of pollutants in stormwater. The Center for Watershed Protection (2003) has shown that the percentage of impervious cover (% IC) in a watershed strongly affects the health of aquatic systems. Impervious surfaces block infiltration of rainwater and alter hydrology by sending increased amounts of untreated stormwater into storm sewers or directly to streams. In general, stream quality declines as imperviousness exceeds 10% of watershed area, and may be severely compromised at greater than 25% (Schueler 1994, CWP 2003). Therefore, IC is an appropriate surrogate measure of impacts caused by stormwater, while aquatic life assessments (biomonitoring) provide an appropriate endpoint to measure the progress of TMDL implementation.

4. APPLICABLE SURFACE WATER QUALITY STANDARDS

Water quality in Penjajawoc Stream must meet Class B standards as defined under Maine's Water Classification Program, as designated by the Maine Legislature (Title 38 MRSA 464-468). Table 2

Table 2. Maine water quality criteria for classification of Class B streams (38 MRSA § 465).

Water Quality Criteria	
Habitat	Habitat for fish and other aquatic life. The habitat must be characterized as unimpaired.
Aquatic Life (Biological)	Numeric standards were adopted by Maine in 2004 (DEP Rule, Chapter 579). 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 in the resident biological community.
Statewide Water Quality Criteria (SWQC)	The chronic and maximum allowable instream values for specified toxic pollutants designated to protect uses specified in the Water Classification Program includes metals identified in NPS stormwater- Cadmium, Chromium, Copper, Lead and Zinc.

summarizes the narrative and numeric water quality standards applicable to Penjajawoc Stream.

The Maine Legislature also defined designated uses for all classified waters, which state that "Class B waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life."

MDEP uses macroinvertebrate sampling and associated community structure modeling to determine tiered aquatic life criteria and promulgated these numeric standards as a rule in 2004. The Class B results from the statistical model are used as the numeric water quality measure or TMDL end point for Penjajawoc Stream. Maine's anti-degradation policy requires that "existing in-stream water uses and the level of water quality necessary to sustain those uses, must be maintained and protected." Additionally, MDEP must consider aquatic life, wildlife, recreational use, and social significance when determining "existing uses".

5. WATER QUALITY TARGET

The TMDL for Penjajawoc Stream was developed using the percent IC as a surrogate for a complex array of pollutants transported by stormwater runoff that impacts aquatic life. The aquatic life criteria are included in Maine's water quality standards (see previous section), and assessment of attainment of aquatic life criteria is described in DEP Rule, Chapter 579.4. Required sampling methods are referenced in Chapter 579.2 and included in the document entitled, *Methods for Biological Sampling and Analysis of Maine's Rivers and Streams* (DEP LW0387-B2002). A guidance document was developed in 2005 (Appendix 2) and recommended a TMDL target range of 7-10% IC for Maine Class B streams. Assessments took into account local conditions and factors which both lessen or increase the volume of stormwater runoff. A TMDL target of 10% IC was set for Penjajawoc Stream because of the lack of riparian buffers along significant portions of the stream, and extensive areas of paved surfaces and buildings creating impermeable land cover. The 10% IC target represents the level of imperviousness (in the contributing watershed) at which the stream is capable of supporting a macroinvertebrate community that meets Class B aquatic life use goals and criteria in Maine water quality standards.

The TMDL Target is 10% Impervious Cover

A percent reduction approach was used to assign load reductions to the Waste Load Allocation (WLA) and Load Allocation (LA) and a Margin of Safety (MOS) was included to account for uncertainty in the analysis. The IC TMDL target is not intended to be used as the basis for permit limits, limits on development, or a measure of compliance with Water Quality Standards. Rather, the goal is to reduce impacts from stormwater on the aquatic life in Penjajawoc Stream. Meeting the TMDL will be assessed by measuring the aquatic life directly and not by measuring IC reduction.

The 10% IC target is based on the statistical relationship between existing watershed IC and the attainment of aquatic life criteria in Maine streams. This value is also consistent with the IC thresholds linked to stream degradation generally reported in the literature (CWP 2003). The regional documentation linking % IC and the integrity of aquatic communities is also strong. A recent study from USGS in New Hampshire confirmed that the % IC surface in a watershed can be used as an indicator of stream quality (Deacon et al. 2005). Additionally, a study of benthic monitoring sites sampled by Connecticut DEP demonstrates a threshold level of 12% IC is needed to meet Connecticut's aquatic life criteria (CT DEP 2006).

As discussed in the margin of safety (MOS) section below, a 1% IC margin of safety (MOS) was subtracted from the total TMDL target to account for uncertainty in the analysis, resulting in a combined WLA and LA target of 9%.

6. WASTELOAD ALLOCATION (WLA) AND LOAD ALLOCATION (LA)

Portions of the Penjajawoc Stream watershed are classified as a "regulated area" under the MEPDES Phase II Stormwater Program. Under this program, stormwater discharges are considered as point sources and are allocated as waste loads. In the case of Penjajawoc Stream, MDEP has determined that because stormwater discharges are highly variable in quality, frequency and duration, it is not feasible to establish specific % IC allocations for each source of stormwater. This variability also makes it impossible to determine with any precision the actual and projected loadings for individual discharges or groups of discharges. Because insufficient data are available for each parcel in the watershed, it is infeasible to draw a distinction between stormwater from regulated point sources, and stormwater from nonpoint sources and non-regulated point sources. As such, the LA target for nonpoint sources in the watershed has been set at zero. Therefore this TMDL applies the 9% IC target to all stormwater drainage areas, affecting both regulated and unregulated sources in the watershed (LA= 0, WLA= 9% IC), in order to reduce pollutant loads and restore hydrologic and biological integrity of the watershed as a whole.

This 9% IC target for WLA and LA can also be expressed as a % reduction in impervious cover compared

The WLA and LA Target is 9% Impervious Cover

to current conditions, and can provide a benchmark for implementation of best management practices (BMPs) to reduce the impacts of impervious cover on aquatic biota living in the stream. The WLA and LA % IC target, and any required percent reduction to meet the target, will be applied to both the WLA and LA because of the practical difficulty of separating stormwater loadings contributed by background, nonpoint, and point sources.

To calculate the % impervious cover reductions required to achieve the WLA and LA target:

Percent IC reduction = ((IC Current Condition – IC Target)/IC Current Condition) x 100, where IC Target = 9%

Impervious cover in the Penjajawoc Stream watershed was determined to be 3% in the Upper watershed, 33% in the Middle watershed, 19% in the Meadow Brook watershed, and 7% in the Mt. Hope watershed (Figure 2). IC in the Upper, Middle, and Meadow Brook watershed is based on the Percent Impervious Area determined by ENSR (2006b). IC in the Mt. Hope watershed is an interpolation of the ENSR Percent Impervious Area calculations, and 5 meter SPOT imagery collected in the summer of 2004 (referred to as "IMPERV" by the Maine Office of GIS). Based on the *IC Current Condition* in the watershed, the percent reduction from WLA required to meet the TMDL target is 73% for the Middle watershed and 52% for the Meadow Brook watershed. No reductions are required for the Upper or Mt. Hope watersheds (see Table 3).

Future development activities have the potential to increase effective impervious cover and resulting stormwater runoff and associated pollutants. A build out analysis was conducted for the Penjajawoc Stream

Figure 2. Map of Impervious Cover in the Penjajawoc Stream watershed.

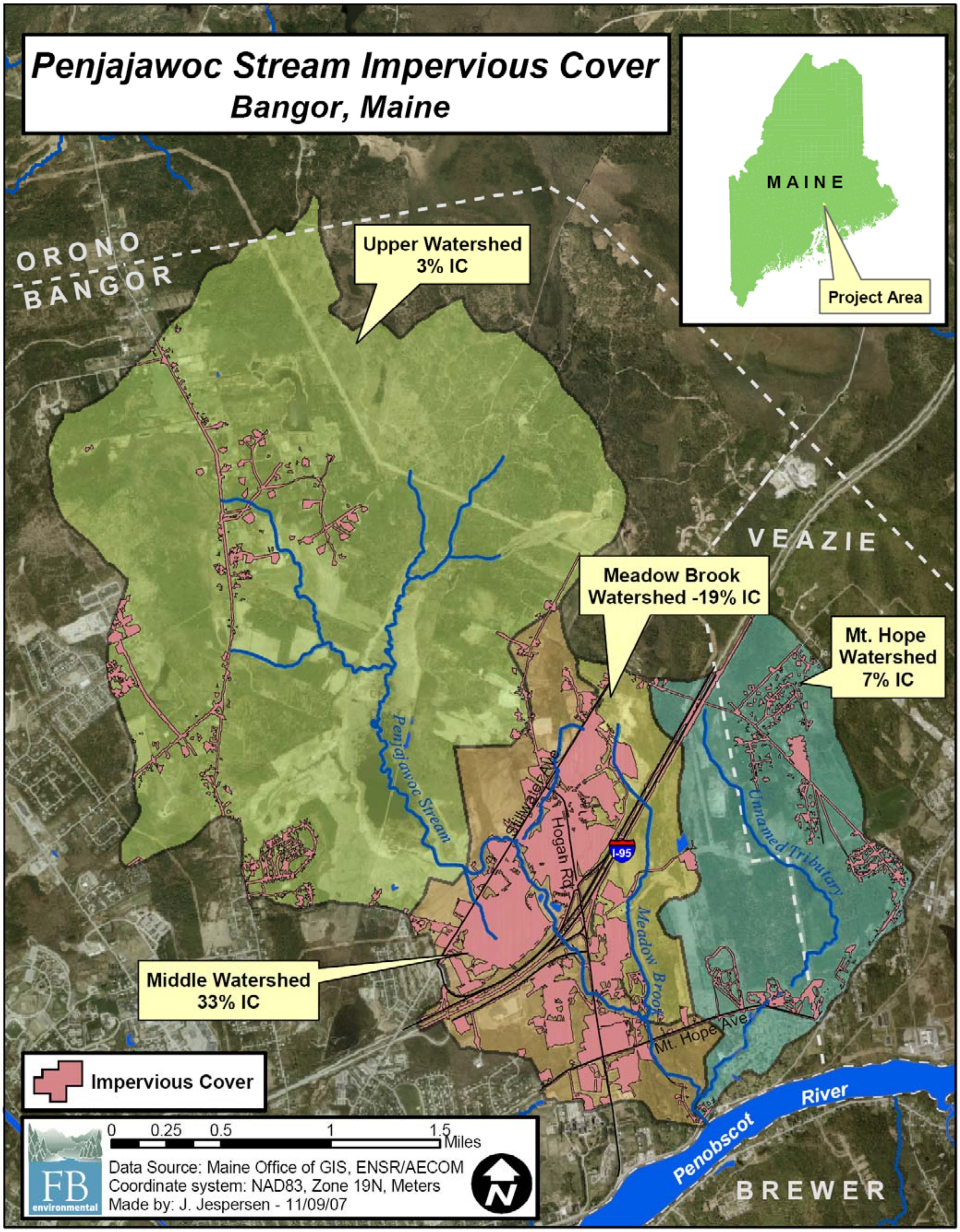


Table 3. Summary of TMDL analysis for Penjajawoc Stream (Segment ID 226R03).

Penjajawoc Stream Subwatershed	Percent Impervious Cover				TMDL Implementation Objective
	TMDL Target	WLA and LA	MOS	Current Condition	
Upper	10%	9%	1%	3%	0% Reduction in % IC
Middle	↓	↓	↓	33%	73% Reduction in % IC
Meadow Brook	↓	↓	↓	19%	52% Reduction in % IC
Mt. Hope	↓	↓	↓	7%	0% Reduction in % IC

watershed to determine what affect the current zoning in the City of Bangor would have on stream health (Dillon 2007). Results of this analysis showed that the city's current zoning would allow for the development of an additional 505 acres of land resulting an in increase in the current IC by 77%. This scenario has the potential to cause irreversible damage to the health of Penjajawoc Stream. To ensure that the TMDL target is attained, future development will need to be constructed and operated in such a way that there is no net increase in stormwater runoff. Additionally, stormwater runoff from existing IC sites will need to be reduced to achieve targets.

EPA's guidance recommends that TMDL submittals express allocations in terms of daily time increments (US EPA 2006). In this case, the TMDL's % IC targets are not explicitly expressed in terms of a daily increment. However, they are, in effect, daily targets because they will achieve reductions in stormwater runoff volume in all storm events whenever they occur (e.g., on any given day) throughout the year.

7. MARGIN OF SAFETY (MOS)

TMDL analyses are required by law to include a MOS to account for uncertainties regarding the relationship between load and wasteload allocations, and water quality. The MOS may be either explicit or implicit in the analysis. This % IC TMDL provides an explicit MOS of 1% IC in the contributing watershed, which is reserved from the total loading capacity of 10%. This MOS of 1% IC is the level specified for Class B waters in Maine's guidance for setting % IC TMDL targets and represents the difference between the TMDL IC Target and the WLA and LA IC Target. When compared to the TMDL target of 10% IC, this explicit MOS of 1% IC represents a 10% MOS. [Calculation: MOS = (1 ÷10) x 100 = 10%]

8. SEASONAL ANALYSIS

Stormwater events that occur over the entire year contribute to the aquatic life impairments documented in Penjajawoc Stream. Therefore, the percent IC targets and the expected IC reductions to satisfy the IC targets are applicable year round. Benefits realized from IC reductions will occur in all seasons. There is no need to apply different targets on a seasonal basis because the stormwater controls to be implemented to meet the IC targets will reduce adverse impacts (pollutant loading and damaging flows) for the full spectrum of storms throughout the year. Therefore, the TMDL adequately accounts for all seasons.

9. LIMITATIONS OF THE IMPERVIOUS COVER METHOD

The impervious cover (IC) method can be used to efficiently characterize water quality impairment and establish surrogate TMDL targets for % IC, or stormwater runoff volume. Four limitations that affect the use of the method in Penjajawoc Stream are as follows (ENSR 2005):

1. ***Limitation:*** The IC model applies to 1st through 3rd order streams.
   Effect: Penjajawoc Stream is a 1st to 3rd order stream, i.e., use of the model is appropriate.

2. ***Limitation:*** This method does not account for non-stormwater sources of pollutant loadings.
   Effect: Because insufficient data are available for each parcel in the watershed, it is infeasible to a draw distinction between stormwater from regulated point sources, and stormwater from nonpoint sources and non-regulated point sources.

3. ***Limitation:*** This method does not account for dynamic internal stream processes that effect water quality.
   Effect: Generally, TMDL methods do not account for in-stream physical processes that directly affect habitat and biological organisms. Internal movement and shifting of the sediment has a direct effect on habit suitability, but is not easy to quantify and is therefore not included in the TMDL analysis.

4. ***Limitation:*** Site specific information is required for identification and specification of Best Management Practices (BMPs) to achieve TMDL goals.
   Effect: Suggestions for BMPs, remedial actions, and restoration techniques aimed at removing identified stressors, or mitigating their effects have been documented by Parish (2006) and WBRC (2007), see Section 10 and Appendix 5. Implementation of these BMPs will aid substantially in reducing the % IC and/or its effects. Reduction of the IC (or its effects) by the full 73% in the Middle watershed, and 52% in the Meadow Brook watershed will require using these site specific recommendations for optimal implementation of BMPs.

10. TMDL IMPLEMENTATION PLAN

The goal of this TMDL is to have Penjajawoc Stream meet applicable water quality criteria, i.e. to have the macroinvertebrate community attain Class B standards. Statistical evidence suggests that aquatic life attainment may occur prior to the realization of full % IC reductions, since some streams that exceed 9% IC do attain Class B standards. The impairments observed in the aquatic communities in Penjajawoc Stream have been attributed to urban stormwater runoff, therefore the following recommendations are specific to Penjajawoc Stream and will be implemented under Maine's MEPDES Stormwater Program:

- Implement BMPs strategically through a phased program which focuses on getting the most reductions, for least cost, in high priority areas first;
- Follow through with the long term 'Watershed Management Plan' that identifies strategic restoration activities (Arter 2007), and consider a Compensation Fee Utilization Plan (CFUP), as defined in Maine's Stormwater Program;
- Monitor ambient water quality to assess stream improvement;
- Compare monitoring results to water quality standards (aquatic life criteria);
- Continue BMP implementation in a phased manner until water quality standards are attained.

Abatement measures include: altering the characteristics of stormwater runoff, general stream restoration techniques (including flood plain and habitat restoration), disconnection of impervious surfaces from the stream, conversion of impervious surfaces to pervious surfaces. In general, practices that achieve multiple goals are preferred over those that achieve only one goal (ENSR 2005).

Getting Started

Following is a suggested phased TMDL implementation approach adapted from the *Stormwater TMDL Implementation Support Manual* (ENSR 2006a). The TMDL implementation method is a process of identifying problem areas and taking management actions to iteratively move toward attaining target conditions in Penjajawoc Stream.

a. ***Investigate***

Investigating current conditions in the watershed is the first step in the implementation process. This initial process will help identify potential areas for mitigation in the watershed. Several recent studies have documented existing conditions both along the stream (Parish 2003, 2006), and within the watershed (ENSR 2006b, WBRC 2007). These studies provide a comprehensive sub-watershed survey of outlet structures and storm drainages to completely differentiate the amount of 'effective' IC. The current extent of impervious cover in the high priority areas of the Penjajawoc Stream watershed include the Middle watershed (33% IC), and the Meadow Brook watershed (19% IC). This TMDL sets a WLA/LA target of 9% impervious cover which can guide implementation efforts. In any watershed, the runoff from impervious cover reaches the stream through both direct and indirect conduits that represent varying levels of stormwater treatment. The IC calculations in this TMDL attempt to distinguish between directly connected and disconnected surfaces based on the ENSR (2006b) Storm Water Management Model (SWMM). The SWMM includes a routing component which incorporates runoff through a system of pipes, channels, storage/treatment devices, pumps and regulators, and can track the quantity and quality of runoff from each subcatchment including flow rate, flow depth and the quality of water in each pipe and channel.

Effective IC presents the greatest pollution risk to Penjajawoc Stream and its tributaries. Therefore, efforts to disconnect or convert impervious surfaces should be directed primarily at these areas to ensure maximum benefit. This approach of "disconnecting" directly connected IC is likely to accelerate stream recovery and reaching the ultimate goal of this TMDL (attaining aquatic life criteria instream). If all water quality criteria are attained before the target % IC is reached, the need for further reductions in impervious cover would be reduced (or possibly eliminated).

b. ***Prioritize***

After current conditions in the watershed have been inventoried, the next step is to identify and prioritize specific "hot-spot" areas, or areas of greatest stormwater impact, for stormwater mitigation actions. Subwatersheds and specific locations may be ranked and prioritized based on factors such as the extent, proximity, and connectedness of IC to Penjajawoc Stream. Areas with high IC, particularly effective IC, will have highest priority. Directly connected impervious areas contribute to stream impairment more significantly than areas that are not directly connected. Areas of high stormwater impact may include stream sections with inadequate riparian buffers or with IC connected to, or within close proximity to, the stream. The Penjajawoc Watershed BMP Retrofit Design Project identified twenty-five existing BMPs that were built prior to the update of Maine's stormwater regulations in 2005. Therefore, these BMPs do not comply with current water quality standards (WBRC 2007), and will require retrofits as part of the phased TMDL approach. The purpose of these retrofits is to treat runoff prior to discharge; to improve thermal conditions in the stream; to improve base flow; and to reduce frequency of 1 and 2 year peak flow events that cause the most damage to the stream. The WBRC report outlined three basic approaches to retrofitting existing BMPs. These include:

1) Construct new Low Impact Development infiltration swales to filer, attenuate, and cool runoff that currently discharges directly to Penjajawoc Stream;
2) Modify existing wet ponds to promote infiltration and base flow, while cooling runoff prior to discharge to the stream;
3) Intercept underdrain runoff prior to entering ponds to promote base flow to the stream.

Four sites, encompassing 172 acres and 3% of the watershed area, were chosen for BMP implementation. Collectively, these sites are owned/operated by state, city and private landowners, and therefore are represented by a diverse group of stakeholders. The four sites include:

1) K-Mart Vicinity;
2) Bangor Mall Vicinity;
3) I-95 Vicinity;
4) Eastern Maine Community College (EMCC) Campus.

Based on the MDEP BMP matrix (Appendix 3), WBRC created a matrix specific to individual subcatchments (Appendix 4). This matrix indicates which BMPs are appropriate for either retrofitting existing BMPs, or installing new ones. This matrix was designed to help incorporate Low Impact Development (LID) BMPs into the retrofit process as often as possible. A summary of recommendations for the four sites listed above are provided in Appendix 5. Additional Stormwater Mitigation Techniques are listed in Appendix 6.

c. *Mitigate*

Once highest priority areas have been identified, specific management options may be determined. Beginning with highest priority areas, develop detailed site specific mitigation plans and obtain funding to implement mitigation. Abatement measures may take one of three forms: general stream restoration techniques (including flood plain and habitat restoration), disconnection of impervious surfaces from the stream, or conversion of impervious surfaces to pervious surfaces (general BMP categories are described in Appendix 3, specific examples are described in Appendix 4). Implementation of any BMPs will require coordination among local authorities, industry and businesses, and the public. Advice on the selection, design, and implementation of any remedial measures can be obtained from the MDEP (Bureau of Land and Water Quality, Division of Watershed Management), the Penobscot County Soil and Water Conservation District, the *Stormwater TMDL Implementation Support Manual* (ENSR 2006a), or web-based resources (see Appendix 7 for suggestions).

d. *Monitor*

Monitoring should continue until impairments are removed and/or water quality standards are achieved. The water quality monitoring plan for Penjajawoc Stream is described in Section 11 of this report.

e. ***Assess and Repeat***

After monitoring, if water quality standards have not been achieved, return to the prioritized list of sites and implement the next series of corrective actions. Repeat the process until applicable water quality standards in Penjajawoc Stream are met.

In summary, implementation of remedial measures will occur under an adaptive management approach in which certain measures are implemented, their outcome evaluated, and future measures selected so as to achieve maximum benefit based on new insights gained. Appendix 3 and 4 present both general and specific lists of BMPs in a matrix format in which traditional and newly developed ("Low Impact Development") BMP types are rated according to their ability to mitigate for impacts of impervious cover and applicability to certain urban situations. The order in which measures are implemented should be determined with input from all concerned parties (e.g., city, businesses, industry, residents, regulatory agencies, watershed protection groups).

The City has already initiated this process with the development of Watershed Management Plan for the Penjajawoc Stream Watershed (Arter 2007). With the assistance of DEP, the Penjajawoc Stakeholder Working Group, and BSA Environmental Consulting, the city of Bangor is developing a Watershed Management Plan for the Penjajawoc Stream Watershed, which will be adopted in spring 2008. This plan is written in accordance with EPA guidelines for watershed management plan designed to achieve improvements in water quality. The working group is comprised of municipal, state, residential, commercial, and conservation representatives and was formed in fall 2007 to provide input, develop recommendations, and review of the plan. The plan provides specific recommendations on pollution education and prevention, riparian and channel restoration, retrofitting existing structural BMPs, installing new BMPs, and ordinance and administration review regarding development.

11. WATER QUALITY MONITORING PLAN

There are currently four water chemistry stations and five biomonitoring stations in the watershed. MDEP will evaluate the progress towards attainment of Maine's water quality standards by monitoring the macroinvertebrate community in Penjajawoc Stream under the Biomonitoring Unit's existing rotating basin sampling schedule (next due in 2010). Benthic macroinvertebrates will provide the primary metric to measure the progress of meeting aquatic life criteria in Penjajawoc Stream. At the same time, the Streams TMDL unit will collect water chemistry samples during stormflow conditions to detect in-stream sediment trends and determine whether acute criteria of the Maine Statewide Water Quality Criteria for certain toxic contaminants are exceeded. Adaptive implementation of the remedial measures listed above should be pursued until water quality standards are met. Once water quality standards have been met in at least two sampling events with normal summer conditions (as defined by MDEP Biomonitoring Protocols) within a 10-year period (i.e., by 2017), no further remedial measures are required. If water quality standards continue to be violated once BMPs and restoration techniques have been implemented, this TMDL will enter a secondary phase in which the approach proposed in this document will be reassessed.

12. REASONABLE ASSURANCE

The Maine Department of Environmental Protection will work with watershed partners, including the Penobscot County Soil and Water Conservation District, the City of Bangor, and conservation organizations to implement better stormwater management in the Penjajawoc Stream watershed. Technical assistance by the MDEP and the PC-SWCD is available to mitigate export from existing pollution sources and to prevent excess loading from future sources. A teamwork approach will result in an eventual and overall improvement in Penjajawoc Stream through BMP implementation and increased public involvement and awareness.

13. PUBLIC PARTICIPATION

Public participation in the Penjajawoc Stream TMDL development was ensured through several review avenues: reviewed by MDEP staff (D. Courtemanch, J. Dennis, M. Dennis, D. Albert, R. Mohlar, L. Tsomides, Bureau of Land and Water Quality), and was distributed to watershed stakeholder organizations including: City of Bangor, Penobscot County Soil and Water Conservation District, University of Maine, George Mitchell Center, Maine Audubon– Penobscot Valley Chapter, the Penjajawoc Stream Watershed Work Group, and Bangor Area Citizens Organized for Responsible Development (BACORD). Paper and electronic forms of the Penjajawoc Stream TMDL Draft Report were made available for public review in three ways: the report was available for viewing at the Augusta office of the MDEP; it was posted on the MDEP Internet Website; and a notice was placed in the 'legal' advertising section of local newspapers. The following ad was printed in the Bangor Daily News on the third and fourth weekends in December 2007:

***PUBLIC NOTICE FOR PENJAJAWOC STREAM AND MEADOW BROOK** -In accordance with Section 303(d) of the Clean Water Act, and implementation regulations in 40 CFR Part 130, the Maine Department of Environmental Protection has prepared Total Maximum Daily Load (TMDL) reports for Penjajawoc Stream in Bangor and Meadow Brook **(DEP-LW0867)** in Bangor, Penobscot County. These TMDL reports estimate the current extent of impervious surfaces, the reductions in impervious surfaces and the application of general stream restoration techniques required to enable each stream to meet Maine's Water Quality Criteria.*
*A Public Review draft of these reports may be viewed at the MDEP Offices in Augusta (Ray Building, Hospital St., Rt. 9) or on-line at: http://www.maine.gov/dep/blwq/comment.htm. Send all written comments by **January 15, 2007** to Melissa Evers, MDEP, State House Station #17, Augusta, ME 04333, or email: Melissa.Evers@maine.gov.*

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APPENDIX 1

Land Use Analysis for Penjajawoc Stream

Urban development primarily affects aquatic systems due to the high percentage of impervious cover (IC) present in urban areas. Effects include impairments in water quality, stream morphology, hydrology and aquatic communities (CWP 2003). As mentioned previously, in this TMDL, IC serves as a surrogate for a variety of impairments related to stormwater runoff. Stormwater runoff is water that does not soak into the ground during a rain event but flows over the surface of the ground until it reaches a nearby waterbody. Stormwater runoff often picks up pollutants such as soil, fertilizers, pesticides, animal waste, and petroleum products. These pollutants may originate from driveways, roads, golf courses, and lawns located within a watershed.

Impervious cover in the Penjajawoc Stream watershed was determined to be approximately 3% in the Upper watershed, 33% in the Middle watershed, 19% in the Meadow Brook watershed, and 7% in the Mt. Hope watershed 27% based on IC determinations from ENSR (2006). Analysis using the 2004 land cover data from MDEP (MELCD) shows that land uses in the Penjajawoc Stream watershed are dominated by forestland and agriculture which accounts for 47% and 14% of the watershed, respectively. High-medium intensity development (commercial and residential uses with impervious surfaces from 50-100%), accounts for approximately 13% of the total land area, developed open space (public parks, lawns, athletic fields, etc., with impervious surfaces <20%) accounts for 10% of the total land area, while low intensity development (low density residential development with impervious surfaces from 21-49%), accounts for approximately 3% of the total watershed area. The remaining 12% of the watershed is comprised of scrub-shrub (4%) and wetlands (8%).

Changes in land use resulting in a high percentage of impervious surface in the Penjajawoc Stream watershed has resulted in changes to the hydrologic cycle of Penjajawoc Stream and increased surface water flow during storm conditions. These problems may be exacerbated by inadequate riparian buffers along many sections of the stream. This can be attributed not only to the current land uses along the stream, but also the historical use of the land adjacent to the stream as a dairy farm. As such, areas that should contain lush native woody vegetation are covered with short-lived species such that are common to old fields and pastures (Parish 2006).

Figure A1. Land Use Classification for the Penjajawoc Stream Watershed.

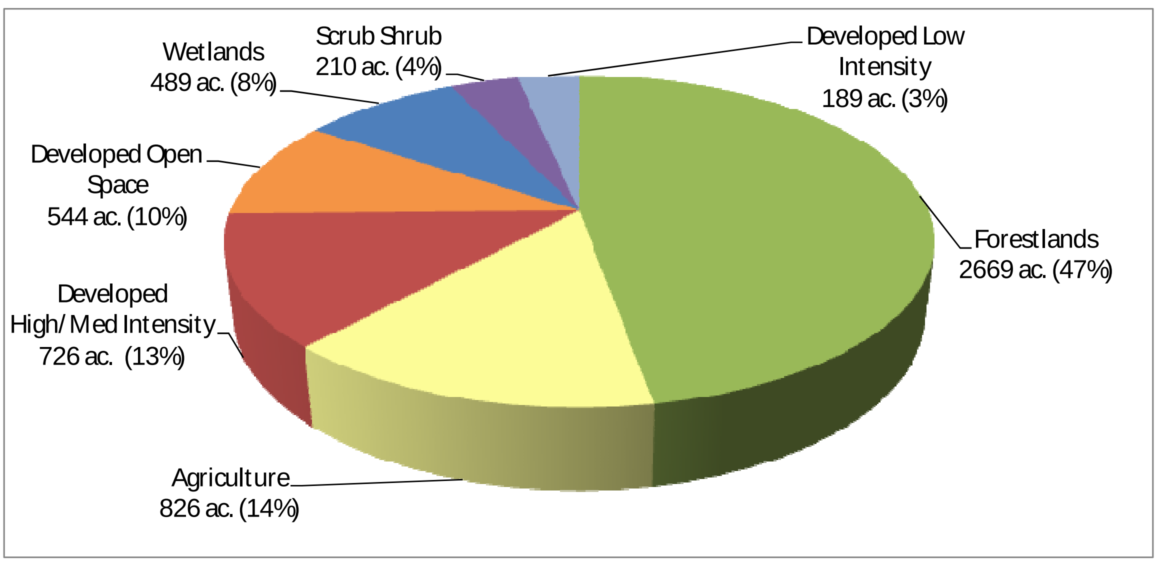
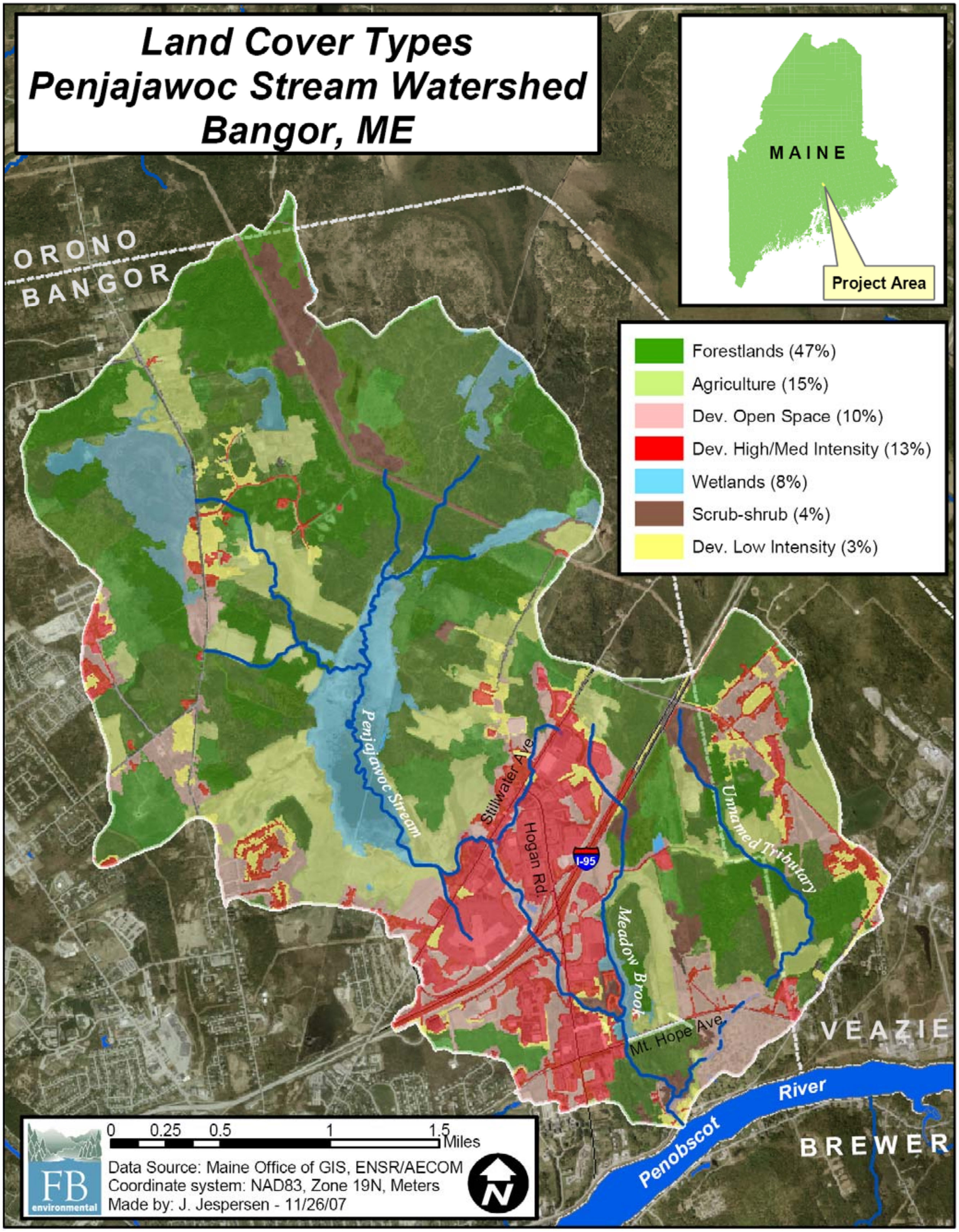


Figure A2. Map of Land Uses in the Penjajawoc Stream Watershed.



APPENDIX 2

DRAFT Maine Department of Environmental Protection
Percent Impervious Cover TMDL Guidance for Attainment of Tiered Aquatic Life Uses

This policy pertains to the innovative Impervious Cover Method (% IC) which was developed for Total Maximum Daily Load (TMDL) assessments in urban impaired rivers and streams (ENSR 2005). The guidelines in Table 1 apply biomonitoring data from the Maine Department of Environmental Protection (MDEP) to the % IC TMDL approach which links watershed impervious cover to stream quality.

Table 1. Percent Impervious Cover (IC) Policy guidelines for expected attainment of Maine's designated aquatic life uses. WLA, Waste Load Allocation; MOS, Margin of Safety

Statutory Class	**Class attainment demonstrated in MDEP data at % IC**	**TMDL Target Values for % IC (TMDL = WLA + MOS)**		
		TMDL	**WLA**	**MOS**
Class AA	~6 % [1]	<6 % [2]	<5 % [2]	1 %
Class A				
Class B	~8 %	7 - 10 % [2]	6 – 9 % [2]	1 %
Class C	~15 %	10 - 15 % [2]	8 – 13 % [2]	2 %

[1] For attainment determination, Classes AA and A are combined.
[2] Stream-specific targets will be chosen for each TMDL

The goal of the TMDL is attainment of Maine's aquatic life criteria and the % IC target provides an engineering means to achieve that end. Target values represent the level of impervious cover that generally coexists with a biological community that meets aquatic life criteria as defined by Statutory Class. Achieving the % IC target requires the long-term implementation of Best Management Practices (BMPs) to effectively reduce stormwater quantity and improve quality. The TMDL will suggest short-term implementation of stream-specific BMPs to immediately reduce % IC impacts while long-term adaptive approaches are developed. No further reductions in % IC or implementation of BMPs will be required once aquatic life criteria are met (as determined by biological monitoring).

For each TMDL, MDEP staff will employ best professional judgment to set a single % IC value based on knowledge of site-specific conditions. These conditions can be either ameliorating or exacerbating, leading to a % IC recommendation near the upper or lower end of the range shown in Table 1 (column "TMDL"), respectively. Ameliorating conditions include existence of an adequate riparian buffer, demonstrated cold water input into the stream, or a highly permeable soil group. Exacerbating conditions include absence of an adequate riparian buffer, an impermeable soil group, naturally stressful in-stream conditions (e.g., lower dissolved oxygen concentrations or elevated temperature due to an upstream wetland) or a documented pollution legacy of the watershed (e.g., from long-established industrial site). Other ameliorating or exacerbating circumstances may be considered on a case by case basis.

The % IC guidelines in Table 1 are based on analysis of MDEP Biomonitoring Program data from 43 macroinvertebrate samples collected between 1994 and 2004 from 32 watersheds of first to third order in size that were influenced by differing amounts of % IC (minimum 5 %) upstream of the sampled location (Appendix 1). Detectable changes in structural characteristics of aquatic assemblages (fish and benthic macroinvertebrates) are noted, in the scientific literature, to occur above ~10 % IC (Paul and Meyer 2001, CWP 2003). Analysis of Maine macroinvertebrate data supports this finding, with streams above 8 % IC rarely attaining Class B aquatic

APPENDIX 2. Cont.

life numeric criteria (Code of Maine Rules 06-096, Chapter 579*: "Classification Attainment Evaluation Using Biological Criteria for Rivers and Streams").* Class B criteria are designed to support the narrative standard of "no detrimental change in the resident biological community" (Title 38 MRSA §465). The Maine data also indicate that impervious cover of 15 % is adequate, in most cases, for attainment of Class C numeric aquatic life criteria supporting the narrative standard of "maintenance of structure and function of the resident biological community". Class C is the lowest condition allowed for Maine rivers and streams. The % IC guideline ranges specified in Table 1, column "TMDL", were selected to cover % IC values found adequate to support water quality Classes B and C in Maine, while also accounting for the % IC quoted in the literature (10 %, CWP 2003) as impacting aquatic systems.

Tiered designated uses in Maine's water quality standards are designed to provide four levels of protection for rivers and streams. Waterbodies are assigned to a designated use class that represents the highest attainable goal condition, taking into account current environmental conditions (e.g., attainment status for dissolved oxygen, bacteria and aquatic life standards) as well as socioeconomic factors. As shown in Table 2, most river and stream miles in the state are managed for Class AA/A or Class B conditions and thus would require application of the <6 % or 7-10 % IC guidelines, respectively.

Statutory Class	% of total miles
Class AA	6 %
Class A	45 %
Class B	47 %
Class C	2 %

If existing data or application of the Stressor Identification protocol indicate that % IC is a significant cause of non-attainment of a designated use class, two circumstances may trigger the need for reductions in % IC below the ranges shown in Table 1:

1. if % IC at the time the TMDL is written is below the relevant guideline range; or
2. if aquatic life does not attain standards once target % IC reductions have been attained.

In such circumstances it is recommended that the % IC be lowered by an amount deemed to be most appropriate for stream-specific conditions, either in the original TMDL (case 1.) or during a secondary phase of % IC reductions (case 2).

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[1]Very few Class AA/A waterbodies are currently in urban areas so that the % IC policy will be applied only rarely to such streams. MDEP's 2006 303(d) list includes no Class AA/A streams with "Urban NPS" as the potential source of aquatic life impairment.

[2]The % IC method for urban stream TMDLs is only appropriate for streams of 1st to 3rd order.

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APPENDIX 3. Best Management Practices Selection Matrix

Management Practice	Ability to Mitigate																Applicability						
	Runoff Volume (↑)	Peak Flow Rates (↑)	Bankfull Flow (↑)	Baseflow (↓)	Mod. Sed. Transport	Channel Morph. Changes[1]	In-Stream Temp. (↑)	Sediment conc. (↑)	Nutrient conc. (↑)	Metal Conc. (↑)	Hydrocarbon Conc. (↑)	Bacteria/Pathogens (↑)	Organic carbon Conc. (↑)	MTBE Conc. (↑)	Pesticide conc. (↑)	Deicer conc. (↑)	New Development	Existing Dev. (Retrofit)	Urban	Sub-Urban	Residential Sub-Division	Commercial/Industrial	Roads and Highways
Recharge / Exfiltration Practices[2]																							
Exfiltration Trench/Galley	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well	Well	Well	Well	Well	Well	Well
Exfiltration Swale	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well	Moderately	Moderately	Well	Well	Well	Well
Retention/Exfiltration Basin	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well	Moderately	Moderately	Well	Well	Well	Well
Low Impact Development Practices																							
Minimize Disturbance Area[4]	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Well	Not Applicable	Well	Well	Well	Well	Well
Minimize Site Imperviousness[5]	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Well	Not Applicable	Well	Well	Well	Well	Well
Porous Pavement	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Well	Well	Well	Well	Well	Well	Not Applicable
Green Roof	Good	Good	Good	Minimal	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Well	Moderately	Well	Well	Moderately	Well	Not Applicable
Bioretention	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well	Well	Well	Well	Well	Well	Well
Rain Garden	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well	Well	Well	Well	Well	Well	Moderately
Preserve Infiltratable Soils[4]	Good	Moderate	Moderate	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well	Not Applicable	Well	Well	Well	Well	Well
Rain Barrels/Cisterns	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well	Well	Well	Well	Well	Well	Not Applicable
Disconnecting Impervious Area	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Well	Well	Moderately	Well	Well	Well	Well
Vegetated Filter Strip	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Minimal	Minimal	Well	Well	Moderately	Well	Well	Well	Well
Flow Path Practices[3]	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well	Not Applicable	Well	Well	Well	Well	Moderately
Preserve Natural Depression Areas[4]	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well	Not Applicable	Well	Well	Well	Well	Moderately
Soil Amendment[4]	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well	Well	Moderately	Well	Well	Moderately	Moderately
Vegetation Preservation[4]	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well	Not Applicable	Well	Well	Well	Well	Well
Extended Detention Practices																							
Extended Detention Pond	Minimal	Good	Moderate	Minimal	Moderate	Moderate	Adverse	Moderate	Moderate	Moderate	Good	Moderate	Moderate	Minimal	Moderate	Minimal	Well	Moderately	Moderately	Well	Well	Well	Well
Wet Detention	Minimal	Good	Moderate	Minimal	Moderate	Moderate	Adverse	Moderate	Moderate	Moderate	Good	Adverse	Moderate	Minimal	Moderate	Minimal	Well	Moderately	Moderately	Well	Well	Well	Well
Created Wetland/Biofilter Detention	Moderate	Good	Moderate	Minimal	Moderate	Moderate	Adverse	Moderate	Moderate	Moderate	Moderate	Minimal	Moderate	Moderate	Moderate	Moderate	Well	Moderately	Moderately	Well	Well	Well	Well
Other Best Management Practices																							
Swale[7]	Moderate	Good	Moderate	Minimal	Moderate	Moderate	Minimal	Moderate	Moderate	Moderate	Good	Moderate	Moderate	Minimal	Moderate	Minimal	Well	Moderately	Moderately	Well	Well	Well	Well
Deep Sump Catch Basins[6]	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Moderate	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Well	Well	Well	Well	Well	Well	Well
Sand/Organic Filter	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Well	Well	Well	Well	Well	Well	Well
Water Quality Inlet[6,8]	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Moderate	Minimal	Minimal	Moderate	Minimal	Minimal	Minimal	Minimal	Minimal	Well	Well	Well	Well	Well	Well	Well

[1] Impacts include channel enlargement/incision/embededness, changes in pool/riffle structure, and reduced channel sinousity.

[2] Recharge and exfiltration measures require permeable soils. Pre-treatment is recommended. See specific BMP descriptions for more information.

[3] Includes increasing roughness, sheet flow, flow path length, and flattenting slopes.

[4] Use as a component of LID site design.

[5] Includes imiting use of sidewalks, and reducing road/driveway length/width.

[6] Pre-treatment prior to exfiltration BMPs

[7] Dry swale with some exfiltration.

[8] Includes proprietary hydrodynamic devices.

Key

Ability to Mitigate
- Good Mitigation
- Moderate Mitigation
- Minimal Mitigation
- Adverse Impact

Applicability
- Well Suited
- Moderately Suited
- Not Applicable

Source:
2006. Best Management Practices for Mitigating Impacts of Impervious Cover. ENSR Corporation, Westford, MA.

APPENDIX 4. BMP Retrofit Matrix for Penjajawoc Stream

TABLE 4.0 - BMP RETROFIT MATRIX

● = applicable
○ = applicable with careful design
□ = existing

BMPs		BMP #											
	Desc						BFCU	Evergreen Woods	Quirk	Small section of Hogan Road	Quirk	Quirk	Small section of Hogan Road
	WBRC WS #		10	11	100	110	200	300	310	311	320	321	322
	AREA (ACRES)		38.2	8.4	49.9	15.1	10.2	11.9	9.6	0.5	3.8	0.9	1.0
	HSG		C	C	B	C	C	C	C	C	C	C	C
HSG	A												
	B				●								
	C		●	●		●	●	●	●	●	●	●	●
	D												
	Detention Basin	3-1, 3-2	●		●	●	●	●	□		□		
	Wet Pond	4-1, 4-2	●		●	●	●	●					
Buffer	Veg. Buffer w/ Level Spreader	5-2								●	●	●	●
	Downhill Side of Road	5-3											
	Ditch Turn-Out	5-4								●	●	●	●
	Residential	5-1	●		●								
Infiltration	Drywell	6-1											
	Trench	6-2, 6-3											
	Basin	6-4			●								
Filters	Veg. Soil Filter	7-1, 7-2, 7-5		●					●				
	Bioret. Cell	7-3, 7-4								●	●	●	●
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●	●	●	●
	Level Spreader	8-3					□			●	●	●	●
Separator BMPs	WQ Inlet	9-1								●	●	●	●
	Oil/Grit, Oil/Water Sep.	9-2								●	●	●	●
	Proprietary Systems									●	●	●	●
	LID	10-1, 10-2	●	●	●	●	●	●	●	●	●	●	●
BMP Land Required	Small Area			●					●	●	●	●	●
	Large Area		●		●	●	●	●	□	●	□	●	●
Applicability	Peak Control		●	○	●	●	●	●	□	○	□	○	○
	WQ Control		●	●	●	●	●	●	●	●	●	●	●
	Pretreatment		●	●	●	●	●	●	●	●	●	●	●
	Conveyance		●	●	●	●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	□	●	●	●	●	●	●

BMPs		BMP #											
	Desc		Freeway	Bangor Ford	Bangor Dodge	Gas station	EMCC & Darling's Honda	United Technology Center	Freeway	Freeway	Wendy's and stream banks	Freeway	Hampton Inn/99
	WBRC WS #		400	410	411	412	500	520	600	800	1000	1010	1030
	AREA (ACRES)		8.7	6.5	1.7	5.5	123.1	28.5	5.8	6.5	6.1	10.2	5.2
	HSG		C	C	C	C		C	C	C	C	C	C
HSG	A												
	B												
	C		●	●	●	●		●	●	●	●	●	●
	D												
	Detention Basin	3-1, 3-2					□ ●	●				●	□
	Wet Pond	4-1, 4-2					□ ●	●				●	
Buffer	Veg. Buffer w/ Level Spreader	5-2			●								
	Downhill Side of Road	5-3											
	Ditch Turn-Out	5-4			●								
	Residential	5-1											
Infiltration	Drywell	6-1											
	Trench	6-2, 6-3											
	Basin	6-4											
Filters	Veg. Soil Filter	7-1, 7-2, 7-5	●	●		●			●	●	●		●
	Bioret. Cell	7-3, 7-4			●								
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●	●	●	●
	Level Spreader	8-3			●								
Separator BMPs	WQ Inlet	9-1			●								
	Oil/Grit, Oil/Water Sep.	9-2			●								
	Proprietary Systems				●								
	LID	10-1, 10-2	●	●	●	●	●	●	●	●	●	●	●
BMP Land Required	Small Area		●	●	●	●			●	●	●		●
	Large Area				●		●	●				●	□
Applicability	Peak Control		○	○	○	○	□	●	○	○	○	●	□
	WQ Control		●	●	●	●	□	●	●	●	●	●	●
	Pretreatment		●	●	●	●	●	●	●	●	●	●	●
	Conveyance		●	●	●	●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●	●	●	●

BMPs		BMP #										
	Desc		Toys R Us	Lamey Wellehan etc.	East side Hogan Rd	Kmart etc	Maine Square Mall etc.	Stream banks	Arby's	Best Buy	Kmart etc	Retail
	WBRC WS #		1040	1090	1091	1092	1093	1200	1210	1220	1230	1240
	AREA (ACRES)		10.1	9.2	9.9	12.2	7.1	5.2	1.3	4.6	2.9	2.2
	HSG		C	C	B	C	C	C	C	C	C	C
HSG	A											
	B				●							
	C		●	●		●	●	●	●	●	●	●
	D											
	Detention Basin	3-1, 3-2	□ ●		□	●						
	Wet Pond	4-1, 4-2	●			●						
Buffer	Veg. Buffer w/ Level Spreader	5-2		●					●	●	●	●
	Downhill Side of Road	5-3							●	●	●	●
	Ditch Turn-Out	5-4		●					●	●	●	●
	Residential	5-1										
Infiltration	Drywell	6-1										
	Trench	6-2, 6-3			●							
	Basin	6-4			●							
Filters	Veg. Soil Filter	7-1, 7-2, 7-5			●		●	●				
	Bioret. Cell	7-3, 7-4		●					●	●	●	●
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●	●	●
	Level Spreader	8-3		●					●	●	●	●
Separator BMPs	WQ Inlet	9-1		●					●	●	●	●
	Oil/Grit, Oil/Water Sep.	9-2		●					●	●	●	●
	Proprietary Systems			●					●	●	●	●
	LID	10-1, 10-2	●	●	●	●	●	●	●	●	●	●
BMP Land Required	Small Area			●			●	●	●	●	●	●
	Large Area		□	●	●	●			●	●	●	●
Applicability	Peak Control		□	○	□	●	○	○	○	○	○	○
	WQ Control		●	●	●	●	●	●	●	●	●	●
	Pretreatment		●	●	●	●	●	●	●	●	●	●
	Conveyance		●	●	●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●	●	●

<u>Source:</u>
WBRC. 2007. WBRC Architects-Engineers. Penjajawoc Watershed BMP Retrofit Design Project. A low impact development approach to mitigate flow and runoff in the Penjajawoc Stream watershed. Bangor, Maine. March 13, 2007. 125 pp.

APPENDIX 4. cont.

TABLE 4.0 - BMP RETROFIT MATRIX cont.

● = applicable; ○ = applicable with careful design; □ = existing

BMPs	Desc	BMP #	Dunkin Donuts	Retail	Roadway section	Sylvan Rd New	Crossroads south	Grassy area	Crossroads north	Inn
	WBRC WS #		1297	1298	1299	1300	1410	1410B	1412	1413
	AREA (ACRES)		1.3	1.0	0.4	1.5	3.4	5.0	4.4	5.3
	HSG		C	C	C	D	C	C	B	C
HSG	A									
	B								●	
	C		●	●	●		●	●		●
	D					●				
	Detention Basin	3-1, 3-2					□		□	
	Wet Pond	4-1, 4-2								
Buffer	Veg. Buffer w/ Level Spreader	5-2	●	●	●	○	●		●	
	Downhill Side of Road	5-3				●				
	Ditch Turn-Out	5-4	●	●	●	○	●			
	Residential	5-1				○				
Infiltration	Drywell	6-1							●	
	Trench	6-2, 6-3							●	
	Basin	6-4								
Filters	Veg. Soil Filter	7-1, 7-2, 7-5						●		●
	Bioret. Cell	7-3, 7-4	●	●	●	●	●		●	
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●
	Level Spreader	8-3	●	●	●	●	●		●	
Separator BMPs	WQ Inlet	9-1	●	●	●	●	●		●	
	Oil/Grit, Oil/Water Sep.	9-2	●	●	●	●	●		●	
	Proprietary Systems		●	●	●	●	●		●	
	LID	10-1, 10-2	●	●	●	●	●	●	●	●
BMP Land Required	Small Area		●	●	●	●	●	●		●
	Large Area		●	●	●	●	□		●	
Applicability	Peak Control		○	○	○	○	□	○	□	○
	WQ Control		●	●	●	●	●	●	●	●
	Pretreatment		●	●	●	●	●	●	●	●
	Conveyance		●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●

BMPs	Desc	BMP #	Retail	Parking lots	Substation		Rangely Hall and part of Sylvan Rd	O. Sylvania		
	WBRC WS #		1420	1500	1700	1710	1711	1712	1900	2100
	AREA (ACRES)		3.9	4.7	0.9	6.7	11.1	12.0	0.5	5.0
	HSG		C	C	C	C	C	C	C	C
HSG	A									
	B									
	C		●	●	●	●	●	●	●	●
	D									
	Detention Basin	3-1, 3-2	□				●	●		
	Wet Pond	4-1, 4-2					●	●		
Buffer	Veg. Buffer w/ Level Spreader	5-2	●	●	●				●	●
	Downhill Side of Road	5-3		●	●				●	●
	Ditch Turn-Out	5-4	●	●	●				●	●
	Residential	5-1								
Infiltration	Drywell	6-1								
	Trench	6-2, 6-3								
	Basin	6-4								
Filters	Veg. Soil Filter	7-1, 7-2, 7-5				●				
	Bioret. Cell	7-3, 7-4	●	●	●				●	●
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●
	Level Spreader	8-3	●	●	●				●	●
Separator BMPs	WQ Inlet	9-1	●	●	●				●	●
	Oil/Grit, Oil/Water Sep.	9-2	●	●	●				●	●
	Proprietary Systems		●	●	●				●	●
	LID	10-1, 10-2	●	●	●	●	●	●	●	●
BMP Land Required	Small Area		●	●	●	●			●	●
	Large Area		□	●	●		●	●	●	●
Applicability	Peak Control		□	○	○	○	●	●	○	○
	WQ Control		●	●	●	●	●	●	●	●
	Pretreatment		●	●	●	●	●	●	●	●
	Conveyance		●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●

BMPs	Desc	BMP #			Freeway	Cinema	Oriental Jade	Lawn area	Freeway	Bangor Mall
	WBRC WS #		2300	2500	2510	2511	2512	2513	2514	2550
	AREA (ACRES)		3.8	3.4	25.2	9.2	6.7	7.4	3.2	74.3
	HSG		C	C	C	C	C	C	C	C
HSG	A									
	B									
	C		●	●	●	●	●	●	●	●
	D									
	Detention Basin	3-1, 3-2			●	□				●□
	Wet Pond	4-1, 4-2			●					●□
Buffer	Veg. Buffer w/ Level Spreader	5-2	●	●					●	
	Downhill Side of Road	5-3	●						●	
	Ditch Turn-Out	5-4	●	●					●	
	Residential	5-1								
Infiltration	Drywell	6-1								□
	Trench	6-2, 6-3								
	Basin	6-4								
Filters	Veg. Soil Filter	7-1, 7-2, 7-5				●	●	●		
	Bioret. Cell	7-3, 7-4	●	●					●	
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●
	Level Spreader	8-3	●	●					●	
Separator BMPs	WQ Inlet	9-1	●	●					●	
	Oil/Grit, Oil/Water Sep.	9-2	●	●					●	
	Proprietary Systems		●	●					●	□
	LID	10-1, 10-2	●	●	●	●	●	●	●	●
BMP Land Required	Small Area		●	●		●	●	●	●	
	Large Area		●	●	●	□			●	●
Applicability	Peak Control		○	○	●	□	○	○	○	□
	WQ Control		●	●	●	●	●	●	●	□
	Pretreatment		●	●	●	●	●	●	●	□
	Conveyance		●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●

BMPs	Desc	BMP #	Goodwill store	Small section of Stillwater Ave	Happy China	Sportshoe center	Lawn area	Mall lawn	Penn Plaza	Penn Plaza east
	WBRC WS #		2700	2710	2720	2730	2740	2750	2900	2910
	AREA (ACRES)		4.1	0.3	1.7	1.1	1.6	5.9	8.0	3.5
	HSG		C	C	C	C	C	C	C	C
HSG	A									
	B									
	C		●	●	●	●	●	●	●	●
	D									
	Detention Basin	3-1, 3-2								
	Wet Pond	4-1, 4-2								
Buffer	Veg. Buffer w/ Level Spreader	5-2	●	●	●	●	●			●
	Downhill Side of Road	5-3	●				●			●
	Ditch Turn-Out	5-4	●	●			●			●
	Residential	5-1								
Infiltration	Drywell	6-1								
	Trench	6-2, 6-3								
	Basin	6-4								
Filters	Veg. Soil Filter	7-1, 7-2, 7-5						●	●	
	Bioret. Cell	7-3, 7-4	●	●	●	●	●			●
Conveyance & Distribution	Veg. Swale	8-1	●	●	●	●	●	●	●	●
	Flow Splitter	8-2	●	●	●	●	●	●	●	●
	Level Spreader	8-3	●	●	●	●	●			●
Separator BMPs	WQ Inlet	9-1	●	●	●	●	●			●
	Oil/Grit, Oil/Water Sep.	9-2	●	●	●	●	●			●
	Proprietary Systems		●	●	●	●	●			●
	LID	10-1, 10-2	●	●	●	●	●	●	●	●
BMP Land Required	Small Area		●	●	●	●	●	●	●	●
	Large Area		●	●	●	●	●			●
Applicability	Peak Control		○	○	○	○	○	○	○	○
	WQ Control		●	●	●	●	●	●	●	●
	Pretreatment		●	●	●	●	●	●	●	●
	Conveyance		●	●	●	●	●	●	●	●
	Distribution		●	●	●	●	●	●	●	●

Source:

WBRC. 2007. WBRC Architects-Engineers. Penjajawoc Watershed BMP Retrofit Design Project. A low impact development approach to mitigate flow and runoff in the Penjajawoc Stream watershed. Bangor, Maine. March 13, 2007. 125 pp.

APPENDIX 5. BMP Retrofit Recommendations for Penjajawoc Stream

As a result of hydrologic model's predictions for 1– and 2-year storm events and the observations within the SWMM and geomorphic analysis, four BMPs were identified:

1a. K-Mart #1—Install in-system storage facility to attenuate and treat surface runoff from KMART roof and parking area that currently discharges directly to the stream. (Goal– Reduce frequency of damaging 2-year peak flow event, treat runoff prior to discharge, improve base flow condition, improve thermal conditions.)

1b. K-Mart #2– Install underdrained vegetated swales along existing grassed area to treat runoff from paved areas. (Goal—Treat direct runoff, promote stream base flow conditions, improve thermal conditions).

2a. Bangor Mall #1– Modify the existing Bangor Mall detention basin outlets to attenuate a 1-year storm event, decrease the discharge during a 2-year storm event, and permit a slightly higher discharge during 10– and 25-year events for a 66-acre contributing impervious area. (Goal—Reduce frequency of damaging 2-year peak flow events.)

2b. Bangor Mall #2– Modify the inflow entering the Bangor Mall detention basins to permit bypass of low flow cool, clear underdrain discharges to enter the stream directly, instead of mixing with the warmer runoff contained in the wet pond for a 66-acre contributing impervious area. (Goal– Promote or restore stream base flow conditions, improve thermal conditions).

3. MDOT #1– Install underdrained grass swales (bioretention swales) within the invert of the existing I-95 drainage swales to reduce frequency of damaging 2-year peak flow events, filter runoff through underdrain soil media and promote stream base flow and improved thermal conditions for approximately 20 acres of contributing impervious area. (Goal-Treat direct runoff, promote or restore stream base flow conditions, improve thermal conditions).

4. EMCC #1– Modify the existing EMCC detention basin by modifying the existing outlet structure weir to detain a 1-year runoff and installing a new small diameter outlet to drain off the storage over an extended period, and cooling the discharge with an extended buried pipe run prior to discharge into the stream for a 15.5- acre contributing impervious area. (Goal– Reduce frequency of damaging 2-year peak flow events, promote or restore stream base flow conditions, improve thermal conditions).

Zoning Recommendations

Grandfathered private landowners need incentives to properly retrofit their stormwater systems. One suggestion would be to allow more development with the caveat that some funds would go toward mitigation. This tactic has been successfully implemented in many municipalities.

The concept of watershed-based zoning is one in which in order to minimize the creation of additional impervious area at the regional scale, development is concentrated in high-density clusters. Again, we recommend the creation of a watershed manager position. This would enable a "whole-watershed" approach to future development and would enable information to be compiled in a practical and accessible way.

Source:
2007. Penjajawoc Watershed Retrofit Design. WBRC Architects-Engineers Bangor, ME, and Sarasota, FL.

APPENDIX 6. Stormwater Mitigation Techniques

Following is a list of options available for BMPs aimed at stream restoration techniques, and disconnection and conversion of impervious surfaces. Because many factors must be considered when choosing specific structural BMPs (e.g., target pollutants, watershed size, soil type, cost, runoff amount, space considerations, depth of water table, traffic, patterns, etc.), the sections below only suggest categories of BMPs, not particular types for particular situations (see Appendix 5 for site specific BMP techniques).

General Stream Restoration Techniques

Following is a list of general BMPs and stream restoration techniques and how they can alleviate stressors and improve stream health.

- Maintaining the riparian buffer where it is adequate, i.e., has a width of at least 23 m (75 feet), wherever possible, and is composed of native plants, including mature trees.
- Enhancing or replanting the riparian buffer where it is inadequate. An adequate buffer will filter runoff from commercial and residential lots, improves shading (which helps to keep water temperature low), and increases large woody debris availability, and food input. It will also provide terrestrial and aquatic stages, thus enhancing recolonization potential of the macroinvertebrate community.
- Reclamation of flood plains by returning these areas to a natural state will naturally moderate floods; reduce stress on the stream channel; provide habitat for fish, wildlife, and plant resources; promote ground-water recharge; and help maintain water quality. Protection of intact flood plains should be a high priority.
- Improving channel morphology (restoring sinuosity, pool availability and diversity, and flow diversity) by installing double wing deflectors and low crib walls in the stream (see Field 2003, Fig. 9a, or PETE/MDEP 2005, Chapter 5, Fig. 23) will improve flow conditions and habitat for macroinvertebrates. Because of the complex nature of channel restoration, any improvement activity will require the extensive involvement of a trained professional.
- Reducing erosion from land use activities with mulches, grass covers, geotextiles or riprap will reduce excess sedimentation. In streambank stabilization projects, use of woody vegetation is preferred over riprap in most cases.
- Reducing the input of winter road sand and road dirt by sweeping roads, parking areas or driveways will reduce excess sedimentation.
- Reducing the incidence of spills (accidental and deliberate) for example by improving education and training will reduce toxic contaminant input.
- Minimizing waste input from pets by picking up waste will reduce bacteria and nutrient input.
- Eliminating the potential for sewer/septic system leaks by regularly inspecting and maintaining sewer/ septic systems will reduce toxic contaminant and nutrient input.
- Eliminating illicit discharges by detecting and eliminating discharges will reduce toxic contaminant and nutrient input.
- Minimizing lawn/landscaping runoff by minimizing fertilizer/pesticide use and using more efficient application methods will reduce nutrient and toxic contaminant input.
- Reducing the temperature of water discharged from a detention structure by redesigning and retrofitting existing detention with outlet structures (e.g., underdrains) that cool the discharge will reduce negative temperature effects on the stream.
- Investing in education and outreach efforts will raise public awareness for the connections between urbanization, impervious cover, stormwater runoff, and overall stream health.
- Encouraging responsible development by promoting Smart Growth or Low-Impact Development guidelines and the use of pervious pavement techniques will minimize overall effects of urbanization.
- Reducing new impervious cover by promoting shared parking areas between homes or between facilities that require parking at different times will reduce impacts related to impervious surfaces. Lowering minimum parking requirements for businesses and critically assessing the need for new impervious surfaces will have the same effect.

APPENDIX 6. Cont.

- Eliminating septic systems in the watershed by expanding the municipal sewer system will reduce toxic contaminant and nutrient input.
- Discouraging the use of pavement sealants on driveways and parking lots will reduce the input of toxic contaminants. A recent study showed that runoff from sealed parking lots could account for the majority of the PAH load in urban streams (Mahler et al. 2005). PAHs are a group of toxic contaminants with known negative effects on aquatic communities. Sealants are often applied for aesthetic reasons only, and decreasing their use represents a simple way to reduce the toxics load in runoff.

<u>Disconnection of Impervious Surfaces</u>
The purpose here is to prevent stormwater runoff from reaching the stream directly (via the storm drain system), thus reducing % IC. There are various options for achieving this goal:

- Channel runoff from large parking lots, roads or highways into detention/retention BMPs (e.g., dry/wet pond, extended detention pond, created wetland), preferably one equipped with a treatment system (e.g., underdrains); vegetative BMPs (e.g., vegetated buffers or swales); infiltration BMPs (e.g., dry wells, infiltration trenches/basins, bio-islands/cells); underdrained soil filters (e.g., bioretention cells, dry swales).
- Redesign and retrofit existing detention to provide extended detention for 6 month and 1 year storms.
- Guide runoff from paved driveways and roofs towards pervious areas (grass, driveway drainage strip, decorative planters, rain gardens).
- Remove curbs on roads or parking lots.
- Collect roof runoff in rain barrels and discharge into pervious areas.

All of these options for disconnection of impervious surfaces provide for a virtual elimination of runoff during light rains (which account for the majority of runoff events but not the majority of pollutant or stormwater input), reduction in peak discharge rate and volume during heavy rains, sedimentation or filtration of some pollutants, and improvement in groundwater recharge. Disconnection of impervious surfaces can often be achieved at reasonable cost and, unlike the removal of impervious surfaces (below), does not generally create material for disposal. These BMPs cover most sizes of impervious surfaces (private driveways and small building roofs to large parking lots and highways), and many have been widely used in cold climates. Disconnection of impervious surfaces is a particularly useful option in watersheds with relatively high imperviousness, such as the Penjajawoc Stream watershed.

<u>Conversion of Impervious Surfaces</u>
This is achieved by replacing impervious surfaces with pervious surfaces, for example by using the following BMPs:
• Replace asphalt on little-used parking lots, driveways or other areas with light vehicular traffic with porous pavement blocks or grass/gravel pave.
• Replace small areas of asphalt on large parking lots with bioretention structures (bioislands/ cells).
• Replace existing parking lot expanses with more space-efficient multistory parking garages (i.e., go vertical).
• Replace conventional roofs with green roofs.

These options for conversion of impervious surfaces also provide for a virtual elimination of runoff during light rains (which account for the majority of runoff events), reduction in peak discharge rate and volume during heavy rains, filtration of some pollutants, and improvement in groundwater recharge. However, a number of problems exist with these options (e.g., removed asphalt or roofing shingles must be landfilled or recycled), and removal of existing impervious surfaces may be operationally unfeasible. Some of these BMPs are still in the experimental stage for cold climates and may not prove suitable for widespread implementation. As far as possible, construction or building projects should, however, consider these and other possibilities for reducing new impervious cover during the planning stages.

APPENDIX 7

Web-Based Resources for Information on Stormwater Issues and Best Management Practices

Note that this list is only a starting point and does not attempt to be comprehensive.

Center for Watershed Protection. Publications and Stormwater Management.
http://www.cwp.org/pubs_download.htm
http://www.cwp.org/stormwater_mgt.htm

City of Nashua, New Hampshire. 2003. Alternative Stormwater Management Methods. Part 2 – Designs and Specifications. City of Nashua, New Hampshire
http://ceiengineers.com/publications/nashuamanualpart2.pdf

Connecticut NEMO (Non-point Education for Municipal Officials). Reducing Runoff.
http://nemo.uconn.edu/reducing_runoff/index.htm

Connecticut River Joint Commissions (CRJC). 2000. Introduction to Riparian Buffers for the Connecticut River Watershed. CRJC, Charlestown, NH. 4 pp. www.crjc.org/buffers/Introduction.pdf

Maine Department of Environmental Protection (MDEP). Stormwater Program, "think blue", Nonpoint Source Pollution education, and riparian buffer information.
http://www.maine.gov/dep/blwq/docstand/stormwater/
http://www.thinkbluemaine.org/
http://www.maine.gov/dep/blwq/doceducation/nps/background.htm
http://www.maine.gov/dep/blwq/docstream/team/riparian.htm

2003a. Maine Erosion and Sediment Control BMPs. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW 0588.
http://www.maine.gov/dep/blwq/docstand/escbmps/

2006. Maine Stormwater Best Management Practices Manual. Maine Department of Environmental Protection, BLWQ, Augusta, ME; DEPLW0738
http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterbmps/index.htm

Maine NEMO (Non-point Education for Municipal Officials). Fact sheets.
http://www.mainenemo.org/publication.htm

Maine State Planning Office (MSPO). Sprawl & Smart Growth Resources.
http://www.state.me.us/spo/landuse/resources/sprawl.php

Penobscot County Soil and Water Conservation District. Technical Assistance.
http://www.penobscotswcd.org

The Stormwater Manager's Resource Center.
http://www.stormwatercenter.net/

U.S. Department of Agriculture (USDA). USDA National Agroforestry Center, Visual Simulation for Resource Planning.
http://www.unl.edu/nac/simulation/

APPENDIX 8
Photos of Penjajawoc Stream & Meadow Brook

***December 2004:** Impervious Cover in the Bangor Mall area contributes stormwater runoff and associated pollutants to Penjajawoc Stream.*

***August 2002:** Algal growth in Penjajawoc Stream as a result of nutrient laden stormwater and other pollutants in the watershed.*

***July 2003:** Channelization and invasive weeds (Purple loosestrife shown) degrade stream habitat.*

***December 2004:** Detention ponds and other BMPs can help reduce the impacts of impervious cover.*

***August 2004:** Silt laden water at the confluence of Meadow Brook and Penjajawoc Stream.*

***July 2005:** Increased stormwater runoff causes stream bank erosion and sediment deposition resulting in poor habitat for macroinvertebrates.*

** Photos courtesy of M. Dennis, MDEP*