ARCTIC BROOK

WATERSHED-BASED MANAGEMENT PLAN

DECEMBER 2016

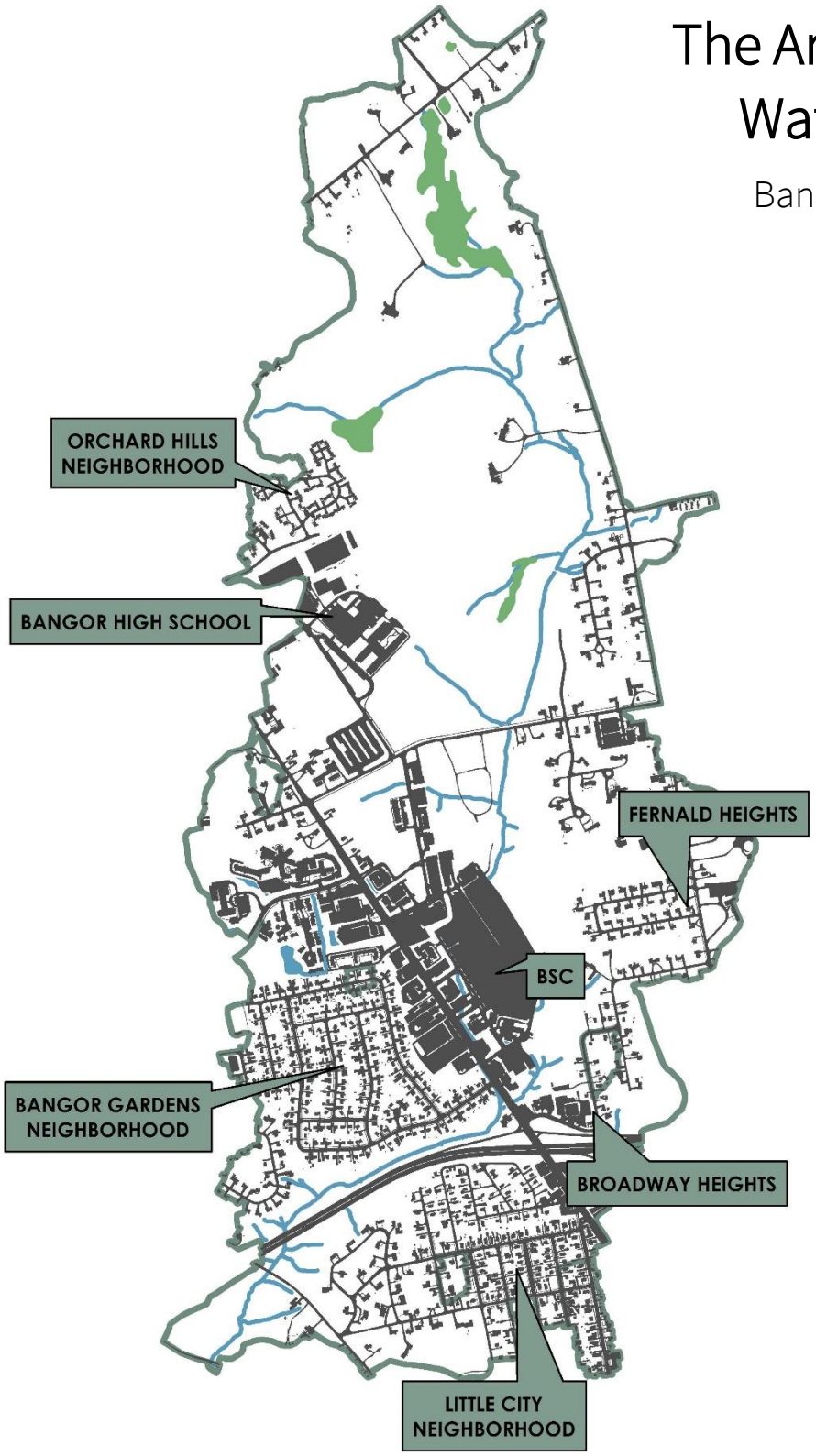
FIRST DRAFT

PREPARED FOR:
City of Bangor
73 Harlow Street
Bangor, ME 04401
www.bangormaine.gov

PREPARED BY:
FB Environmental Associates
97A Exchange Street, Suite 305
Portland, ME 04101
www.fbenvironmental.com

The Arctic Brook Watershed

Bangor, Maine



EXECUTIVE SUMMARY

PROJECT OVERVIEW

The purpose of the 2016 Arctic Brook watershed-based management planning project was to produce a detailed, user-friendly Watershed-Based Management Plan (WBMP) outlining effective actions to improve water quality and aquatic habitat conditions in Arctic Brook. The plan aims to build upon local support to address polluted runoff in the watershed, and provides the City of Bangor with a road map for restoration.

The overall goal of this plan is to provide management recommendations that will help Arctic Brook meet Class B water quality standards through improvement of aquatic habitat and water quality of the stream. This includes working towards reducing effective impervious cover in the watershed from 23% to 8% by focusing efforts in the high-density commercial development along Broadway. These goals can only be accomplished with the commitment of a coordinated group of local community leaders, conservation groups, city, state and federal partners, and citizens of the watershed working together to implement this plan and its recommendations. The Arctic Brook WBMP provides key actions needed to restore the stream, the timing of these actions, and the mechanisms by which they will be accomplished.

GOAL: to provide management recommendations that will help Arctic Brook meet Class B water quality standards through improvement of aquatic habitat and water quality of the stream.

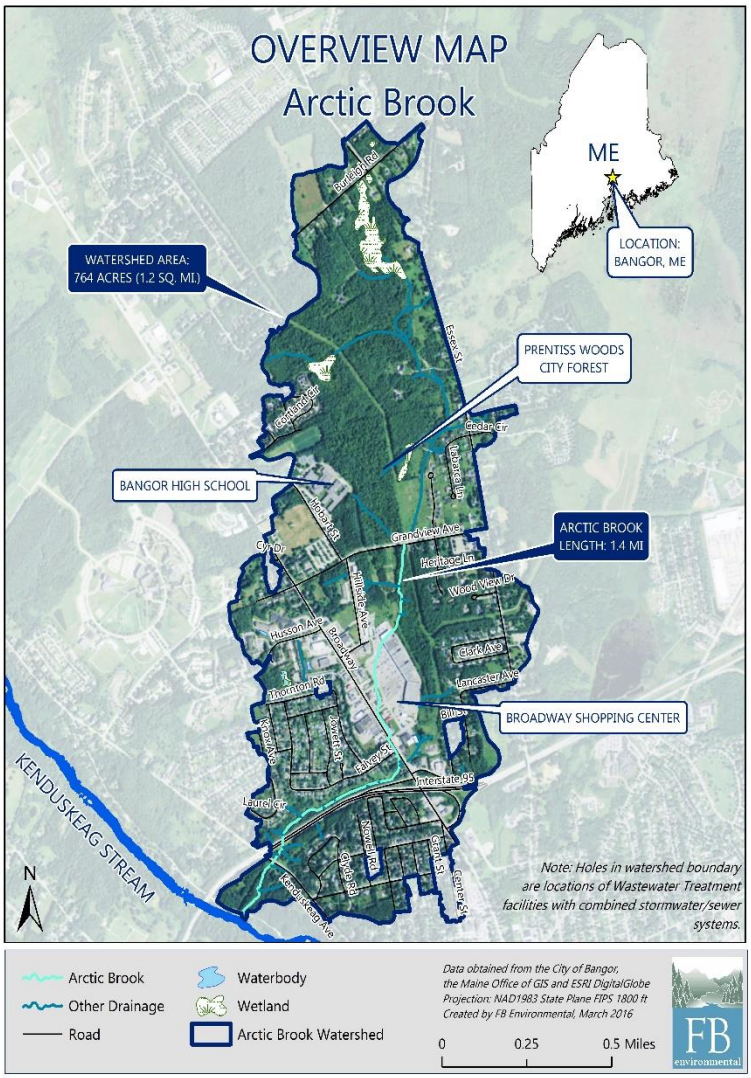
THE ARCTIC BROOK WATERSHED

Located in Central Maine, Arctic Brook flows through both high-density commercial and residential development. The 1.2 square-mile (768 acres) watershed of Arctic Brook begins as a wetland bordering the Prentiss Woods City Forest. The stream then continues across Grandview Avenue and is directed through a series of culverts underneath the Broadway Shopping Center and Broadway (Route 15). It then runs through a straightened channel parallel to the I-95 interstate before crossing underneath the interstate and opening up to a more naturalized channel before making its way into Kenduskeag Stream. The Arctic Brook watershed includes prominent features such as Bangor High School, the City Nursery, and the Broadway Shopping Center. Additionally, the I-95 corridor runs through the watershed and parallels Arctic Brook before it reaches Kenduskeag Stream. When the I-95 corridor was built in 1961, Arctic Brook was relocated around the interstate through substantial channel armoring. Significant residential development exists within the watershed, centered around five large neighborhoods (Broadway Heights, Bangor Gardens, Fernald Heights, Little City, and Orchard Hills). The watershed is entirely encompassed within the City of Bangor, Maine.

THE PROBLEM

Arctic Brook is a designated Class B freshwater stream. According to Maine's Water Classification Program under the Maine Legislature (Title 38 MRSA 464-468), "Class B waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as

prohibited under Title 12, Section 403; navigation; and as habitat for fish and other aquatic life." A summary of the narrative and numeric water quality standards for Class B freshwaters is provided in Table 3.1.



Arctic Brook was first listed by Maine DEP in the 2002 303(d) list of impaired waters (Maine DEP 2012a). In 2005, ENSR International completed a Pilot IC method TMDL for Arctic Brook (ENSR 2005) and a finalized TMDL was completed in 2012 (Maine DEP 2012b). The initial listing of Arctic Brook on the State's 303d list identified the impaired section of stream beginning at the Broadway Shopping Center, however, more recent macroinvertebrate data collected upstream indicates that the impairment may extend farther upstream to Grandview Avenue. More information is needed to understand the extent and causes of the impairment upstream of the Broadway Shopping Center.

Arctic Brook has been identified as not meeting water quality standards for aquatic life, due to impairments determined through benthic macroinvertebrate monitoring and stream habitat assessments. The 2012 IC TMDL used stormwater as a surrogate for the many pollutants in stormwater that flows off developed areas in the watershed. A high percentage of the Arctic Brook watershed (23.3%) contains impervious cover, including parking lots, roads and buildings. The 2012 IC TMDL set a goal of reducing the effects of IC by 65%- ultimately reducing the quantity, quality and rate at which stormwater reaches the stream so that it functions like a stream in a watershed with 8% IC. This plan can be considered an interim document which works towards this goal of 8% effective IC. Water quality must be monitored continuously to identify progress made towards this goal.

WHY DEVELOP A WATERSHED-BASED MANAGEMENT PLAN?

A watershed-based management plan (WBMP) helps identify problems, priorities, and actions that are needed to improve the water quality of a waterbody. Since each watershed is unique, the Arctic Brook WBMP is also unique in order to address the major issues and concerns of both the community and the stream. The Arctic Brook WBMP builds upon the goal of reducing polluted stormwater runoff from reaching the stream and describes restoration objectives to meet this challenge. An Action Plan (Section 4) was developed based on feedback from the City of Bangor, and the technical advisory committee (TAC).

Arctic Brook during high flows in 2016.
Photo Credit: *Richard May, City of Bangor.*

Successful development of this plan, including final selection of key restoration strategies, requires an integrative and adaptive approach and depends primarily on the involvement of the City, its partners, and the watershed community. These partnerships help strengthen the plan by increasing both public awareness of the problems and public commitment to the solutions. A community-based plan also provides other benefits such as attracting private, state, and federal dollars for green jobs and green infrastructure, and provides opportunities for both recreational and aesthetic improvements. This plan will help foster further thinking about long-term strategies for improving the water quality and related natural resources within the Arctic Brook watershed, and help to promote communication among citizens, municipalities, and state agencies. This plan is contingent on landowner cooperation, since the largest portion of the watershed targeted for restoration over the next 10 years is privately owned commercial property.

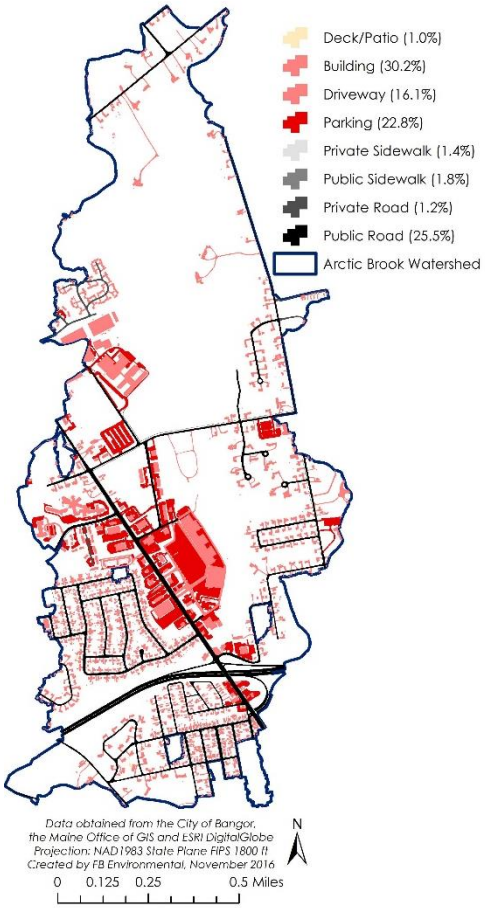
WHAT THE PLAN INCLUDES

The plan is divided into six major sections. Summaries of the key outcomes from each section are described below and in more detail throughout the full WBMP.

- Introduction & Purpose: The purpose of this WBMP is to provide a roadmap to move forward with restoration of Arctic Brook to meet Class B water quality standards by improving aquatic life. This plan identifies the goals, restoration recommendations, costs, and milestones to reach restoration.
- Watershed Characterization: The Arctic Brook watershed totals 764 acres with 23.3% impervious cover (IC). This IC is centered around Broadway (Route 15), the I-95 corridor, and high density residential development. The northern watershed is forested, including upland forest, and wetlands. Conserved land includes Prentiss Woods which has walking paths along the Arctic Brook headwaters and to the Bangor High School.
- Causes of Impairment and Assessment: Arctic Brook has been listed as impaired for not meeting Class B aquatic life use standards. This impairment is attributed to channelized flow and stormwater runoff from roads and commercial and residential development in the watershed. The most significant problems caused by stormwater runoff into Arctic Brook are elevated chloride levels from winter salting practices, and “flashy” flows (large swings between high and low flow events). Additionally, the floodplain and stream corridor have experienced significant habitat degradation due to encroaching development and alteration of the channel through armoring and culverts. Cool water temperatures

have been observed in Arctic Brook and would not need to be addressed as part of aquatic life restoration.

- Management Strategies: Through this watershed planning process, the City of Bangor with the help of consultant staff, conducted multiple reconnaissance-level assessments of the stream and watershed. This included a geomorphic assessment (physical characteristics of the stream corridor and floodplain), a stream corridor assessment to evaluate culverts and unusual conditions in the stream, and a retrofit reconnaissance assessment to identify locations for retrofit implementation in the watershed (primarily on commercial property). A drive-by "windshield" survey of the high density residential neighborhoods was conducted to note any hot spots in these areas. Overall, it was noted that stream alteration and loss of floodplain is a significant contributor to habitat degradation for aquatic life. Long culverts create obstacles for upstream fish passage and alter proper hydraulic conveyance. Eighteen high priority retrofit opportunities were identified to eliminate and/or slow stormwater runoff into the stream with an additional 19 opportunities to be considered if this WBMP does not bring the stream to its Class B standards.



- Plan Implementation: The City should implement the plan as funding is available and spending priorities allow for funds to be dedicated to Arctic Brook restoration efforts. A WBMP should be seen as a dynamic document to be revised and refreshed as new information is acquired.
- Methodologies for Measuring Success: This last Section provides benchmarks to act as interim goals for the completion of the WBMP. These benchmarks are set at 2020, 2023, and 2027 and include goals related to environmental, programmatic, and social indicators. Key examples of these benchmarks can be found below in the Executive Summary and/or in Section 6.3.

ADMINISTERING THE PLAN

The City of Bangor will administer the Arctic Brook WBMP. City representatives should convene at least annually to provide periodic updates to the plan, track and record progress made toward restoration, maintain and sustain action items, and make the plan relevant on an ongoing basis by adding new tasks as they develop. The City will track achievements, press coverage, outreach activities, number of retrofits sites repaired, number of volunteers, and amount of funding received.

The full implementation of this plan will cost approximately $524,300 - $983,150 per year over the next 10 years. Cost estimates are based on tasks identified in the action plan, which will need to be updated as the plan is implemented and as new actions are added. Implementation of this plan over the next 10 years will require the dedication and hard work of state and municipal employees, and cooperation of

residents, business owners and volunteers to ensure that the actions identified in this plan are carried out accordingly.

10-YEAR COST ESTIMATE FOR RESTORING ARCTIC BROOK (2017 – 2027)			
	Category	**Estimated Annual Costs**	**10-year Total**
STRUCTURAL BMPS			
	Stream Corridor Restoration	$376,500 – $787,500	$3,765,000 - $7,875,000
	Structural Retrofit Sites	$129,800 – 165,000	$1,298,000 - $1,650,000
	Retrofit Maintenance	$5,000 - $10,000	$50,000 - $100,000
NON-STRUCTURAL BMPS			
	Administrative & Funding	In House	In House
	Education & Outreach	$750 - $1,150	$7,500 - $11,500
	Municipal Maintenance	$250 - $500	$2,500 - $5,000
	Land Use Planning and Conservation	$2,000 - $4,000	$20,000 - $40,000
MONITORING PROGRAM			
	Monitoring	$10,000 - $15,000	$100,000 - $150,000
GRAND TOTAL (10-YR)		**$524,300 - $983,150**	**$5,243,000 - $9,831,500**

NEXT STEPS

The success of this plan can be measured in several ways, as outlined in Section 6.3, Measurable Milestones. These milestones fall under three categories: environmental, programmatic, and social indicators and are evaluated based on benchmarks in 2020, 2023, and 2027. Indicators can be used as performance measures to determine how well implementation activities are working and provides a means to track progress toward established goals and objectives. Key milestones identified in this plan are provided in the table on the following page.

Successful implementation of the Arctic Brook WBMP depends primarily on the commitment and involvement of community members. Therefore, the success of this plan will weigh heavily on the support and cooperation of the City and key stakeholders. The City will need to enthusiastically engage the community in restoration activities, work together to maintain the sustainable funding plan, and acquire additional funds to implement the suggested Phase II work. The City should officially adopt the plan, thereby raising awareness about the importance of restoration efforts and the need for immediate action.

KEY MILESTONES

ENVIRONMENTAL INDICATORS			
Indicators	**Benchmarks**		
	2020	2023	2027
Monitor chloride (or specific conductivity) to bring levels below the chronic and acute thresholds recommended by the Maine DEP. (note that groundwater toxicity could cause a delayed response to mitigation) *GOAL: Reduce chloride toxicity to the stream while maintaining safe roadways*	Below 860 µS/cm in baseflow	Below 860 µS/cm in baseflow and stormflow	Below 230 µS/cm in baseflow[1]
Replace and/or repair failing culverts to improve hydraulic conveyance *GOAL: Stabilize flow volumes*	1 culvert addressed	2 culverts addressed	3 culverts addressed
PROGRAMMATIC INDICATORS			
Number of structural BMP retrofits installed *GOAL: Reduce effective IC contributing nutrients and stormwater runoff to the stream*	5	10	18
Acres of effective IC disconnected by retrofit BMP installations *GOAL: Reduce effective IC contributing nutrients and stormwater runoff to the stream*	6.9 acres	10.3 acres	13.7 acres
Amount of funding secured for plan implementation *GOAL: Maintain a consistent funding mechanism and City support for project implementation*	$2,621,500 - $4,915,750	$3,932,250 - $7,373,625	$5,243,000 - $9,831,500
SOCIAL INDICATORS			
Number of certified contractors completing a BMP or LID training and certification program *GOAL: Raise awareness and community support*	1	3	5
Number of volunteers for stream clean-ups and plantings. Volunteer goals are cumulative. *GOAL: Raise awareness and community support*	10	20	30

[1] Given current monitoring efforts and limited available funds for additional monitoring, it is uncertain how long it will take for chloride contamination in the aquifer to be reduced to allow baseflow chloride to be below this level. Additionally, public safety is the highest priority and must be considered in attempting to meet the chloride reductions necessary to reach this goal.

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Technical Advisory Committee (TAC):
Greg Beane, Maine Department of Environmental Protection
Forrest Bell, FB Environmental
Michele Benoit, Bangor High School
Peralie Burbank, City of Bangor
Margaret Burns, FB Environmental
Pam Delfino, Representative Broadway Shopping Center
Jeff Dennis, Maine Department of Environmental Protection
Alice Dyer, Representative Bangor Shopping Center
Jennifer Jespersen, Ecological Instincts
Richard May, City of Bangor
John Theriault, City of Bangor
Thomas Palmer, City of Bangor
Rhonda Poirier, Maine Department of Transportation
Phil Ruck, Stillwater Environmental Engineering
Andy Rudzinski, City of Bangor

Technical Consultants:
Forrest Bell, FB Environmental
Margaret Burns, FB Environmental
Laura Diemer, FB Environmental
John Field, Field Geology Services
Jennifer Jespersen, Ecological Instincts
Deborah Mayo, FB Environmental
Phil Ruck, Stillwater Environmental Engineering

Members of the public that provided input on the plan:

Bonnie Heyer, Citizen of Bangor

Cover photo credit, (top) FBE, (bottom) John Field.

ACRONYMS (IN ALPHABETICAL ORDER)

BASWG	Bangor Area Stormwater Group
BSC	Broadway Shopping Center
BMPs	Best Management Practices
IC	Impervious Cover
Maine DEP	Maine Department of Environmental Protection
MS4	Municipal Separate Stormwater Sewer System
RRI	Retrofit Reconnaissance Inventory
SCS	Stream Corridor Survey
SOPs	Standard Operating Procedures
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
WBMP	Watershed-Based Management Plan

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1 INTRODUCTION

1.1 PURPOSE AND BACKGROUND

Arctic Brook is a small headwater stream that drains into Kenduskeag Stream, which flows into the Penobscot River in downtown Bangor. Small headwater streams such as Arctic Brook are vital to the success of both the aquatic and terrestrial ecosystems. Significant development has occurred within the Arctic Brook watershed, especially within the Broadway commercial corridor and along I-95, which has altered the original water chemistry, habitat, and hydrology of the stream, making it difficult for survival of aquatic life. Extensive armoring of the stream channel and manipulation of floodplains and riparian corridors has resulted in significant channel alteration.

To date, the water quality in Arctic Brook is not meeting State Class B standards, and is threatening the health of aquatic life in the stream. The 2012 Total Maximum Daily Load (TMDL) assessment, written by the Maine Department of Environmental Protection (Maine DEP) classifies 0.86 miles of Arctic Brook as impaired, from the Broadway Shopping Center (BSC) until its confluence with Kenduskeag Stream. The impaired section of Arctic Brook was listed as not meeting standards for aquatic life use. However, Arctic Brook extends further north past Grandview Avenue, and begins as a wetland and upland forest west and north of Whisper Drive and Labarca Lane.

Dense commercial development of the Arctic Brook watershed and modification of the stream channel have resulted in an increase in overland flow during storm conditions. Overland flow carries pollutants from impervious cover (IC) into Arctic Brook via catch basins, ditches and tributaries. The effects of IC are extensive, resulting in low levels of dissolved oxygen, chronic levels of conductivity (from road salting),

Arctic Brook during high flows in 2015. ***Photo Credit:*** *FBE*

excess sediment (from sanding and erosion), elevated water temperature that interrupts or prevents reproduction of native fish, elevated nutrients that provides food for algae, and a change in the hydrology of the stream that results in high flows that damage stream banks and stream habitat. Of most concern to Arctic Brook are the elevated levels of chloride (especially downstream of Broadway), extreme high and low flows (i.e. "flashiness"), and poor habitat conditions due to historic channel and floodplain alterations.

The City of Bangor has been working diligently to monitor and evaluate Arctic Brook (as well as the other five impaired streams within city limits). Since 2015, the City has established long-term continuous monitoring sites on Arctic Brook to monitor for dissolved oxygen, temperature, specific conductivity, and stage height. The purpose of these efforts is to build upon the baseline data for Arctic Brook to help focus restoration efforts in the watershed and to monitor their success.

The purpose of the 2016 watershed-based management planning project was to produce a detailed, user-friendly Watershed-Based Management Plan (WBMP) outlining effective actions to improve water quality and aquatic habitat conditions in Arctic Brook. The plan aims to build upon local support to address polluted runoff in the watershed, and provides the City with a road map for restoration.

Project tasks included:

- Building strong local support for the project by forming a technical advisory committee, hosting a public meeting, and meeting with key landowners;
- Developing a water quality database that can be used to track future water quality data;
- Conducting a comprehensive water quality analysis using all sources of available water quality data;
- Conducting a gap analysis to determine what additional data or research is needed to enhance restoration activities;
- Assessing stream and watershed conditions through detailed field assessments including a geomorphic assessment, stream corridor/culvert survey and watershed retrofit survey;
- Reviewing restoration activities that have been completed to date and determining the pollutant loading reductions that have resulted from their implementation; and
- Creating an action plan that includes recommendations from recent field assessments so that the plan is relevant for the next 10 years of implementation efforts.

The overall goal of this plan is to provide management recommendations that will help Arctic Brook meet Class B water quality standards through improvement of aquatic habitat and water quality of the stream. More goals include working towards reducing effective impervious cover in the watershed from 23% to 8% by focusing efforts in the high-density commercial development along Broadway. These goals can only be accomplished with the commitment of a coordinated group of local community leaders, conservation groups, city, state and federal partners, and citizens of the watershed working together to implement this plan and its recommendations. The Arctic Brook WBMP provides key actions needed to restore the stream, the timing of these actions, and the mechanisms by which they will be accomplished.

1.2 INCORPORATING EPA'S NINE ELEMENTS

The plan is divided into six major sections and includes the US EPA's nine key planning elements for watershed-based management plans *(referred to as elements a through i)*:

- Section 1 (Introduction) describes the purpose of the plan, provides background information about Arctic Brook, a description of the planning process, and a brief description of recent efforts in the watershed *(element a).*
- Section 2 (Watershed Characterization) describes the watershed, including local climate, demographics and growth trends in the City of Bangor, land cover, topography, land conservation, soils and geology, and stormwater/sewer infrastructure.
- Section 3 (Causes of Impairment and Assessment) describes causes of impairment and applicable water quality standards, summarizes water quality and biological assessment data collected from Arctic Brook, and summarizes the results of a Geomorphic Assessment (2015), a Stream Corridor Assessment (2016), and a Retrofit Reconnaisance Inventory (2016) *(element a).*
- Section 4 (Management Strategies) describes watershed restoration goals and objectives. Both structural and non-structural restoration opportunities and recommendations are discussed. Action strategies are presented in tables describing what needs to be done, how it will be done, who will help get it done, when it will be done, and how much it will cost. Restoration strategies are divided into several primary categories (shown above). Section 3 provides the results of a pollutant loading reduction analysis for the recommended structural management measures *(elements, b, c, e, f)*.
- Section 5 (Plan Implementation) describes plan implementation, including who is in charge of administering the plan, and summarizes actions, costs, and technical assistance needed to ensure progress *(element d).*

EPA identifies 9 important elements for a successful WBMP

a) Identification of causes of impairment and pollutant sources

b) Estimated load reductions from management efforts

c) Non-point source management efforts

d) Necessary technical and financial assistance needed

e) Information and education component

f) Project timeline

g) Measurable milestones and indicators of progress

h) Criteria to measure success

i) Water quality monitoring plan

**Elements are paraphrased from EPA for brevity*

- Section 6 (Methodologies for Measuring Success) describes specific recommendations for monitoring and evaluating the effectiveness of restoration efforts. This includes criteria for measuring progress and measurable milestones along the way *(elements g, h, i).*

1.3 DEVELOPING A COMMUNITY-BASED WATERSHED MANAGEMENT PLAN

A WBMP helps identify problems, list priorities, and outline actions that are needed to improve the water quality of a stream (EPA 2008). A good plan acts as a road map pointing out where to start, how long it will take to get there, how much it will cost, and how you know you've arrived. Since each watershed is unique, the WBMP is also unique in order to address the major issues and concerns of the watershed's community.

Successful development of this watershed restoration plan depended heavily on the commitment and involvement of community members. These partnerships helped strengthen the plan by increasing both public awareness of the problems and public commitment to the solutions. Many of the recommendations in the plan will require landowner cooperation with the City of Bangor to implement retrofits on private land. As such, it will be important to develop a strong education and outreach program that targets residents of the Arctic Brook watershed in an effective and trusting way; once landowners understand the importance of restoring Arctic Brook, they may be more likely to participate in the restoration process. The WBMP is a 'living breathing, document', meaning that it should be revisited and updated as restoration continues in the Arctic Brook watershed.

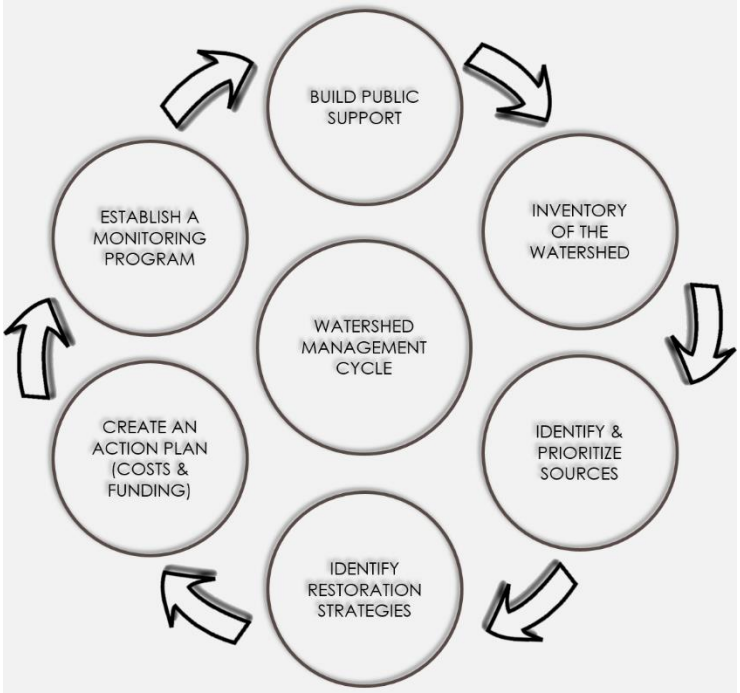


Figure 1.1. The watershed management cycle.

The following groups or individuals have been identified as potential public participants to help implement recommendations described in this plan:

- Bangor High School
- Bangor Area Stormwater Group (BASWG)
- Broadway Shopping Center
- City of Bangor
- Maine Department of Environmental Protection
- Maine Department of Transportation

Local partners have demonstrated a strong commitment to improving water quality conditions in Arctic Brook. Technical Advisory Committee (TAC) meetings held on January 21, April 25, and October 4, 2016, helped guide the watershed planning process. The TAC provided valuable insight in both preparation and synthesis of 2016 field surveys. At the final meeting, stakeholders helped prioritize best management

practice (BMPs) identified in the 2016 stormwater retrofit reconnaissance survey, as well as the action items that address identified stressors in the watershed.

To ensure that restoration goals are achieved, the community should consider this plan a "living document". In other words, the goals and objectives of the Arctic Brook WBMP should be collaboratively revisited and revised on an annual basis by the City of Bangor (Figure 1-1).

1.4 RECENT EFFORTS IN THE WATERSHED

- Arctic Brook Water Quality Monitoring - The City of Bangor began collecting water quality data in 2009 in order to document stream conditions throughout the year. Since 2012 the City has added parameters including temperature, DO, salinity, conductivity, chloride, pH, color and flow. Benthic monitoring began in 2013.
- Level 1 Stream Corridor Survey - In 2010, a Level 1 stream corridor survey (rapid habitat and geomorphic assessment) was conducted by DEP, City of Bangor and AmeriCorps staff for four Bangor streams, including Arctic Brook. Results of the survey indicate that riparian cover for several of the stream reaches have been severely impacted by development, resulting in undercut banks, severe bank erosion and degradation of streamside cover, and that shallow stream reaches in culverts are likely a barrier to fish passage. All four reaches surveyed ranked "poor", indicating that actions are needed to improve riparian conditions in the stream.

- Arctic Brook Impervious Cover TMDL (IC TMDL) - An IC TMDL and IC analysis was completed by Maine DEP in 2011-2012. The report revealed that the watershed is 23% impervious, with a target goal for the watershed of 8% effective impervious cover. This will require a 65% reduction in impervious cover or the equivalent effective impervious cover. (Maine DEP 2012b).
- City of Bangor Stormwater Utility – In 2012, the City of Bangor established a stormwater utility, which generates funds through pro-rated fees from property owners. These funds can be used on various stormwater-related projects throughout the City, including the Arctic Brook watershed.
- NPDES MS4 Stormwater Program – To meet permit regulations under the Municipal Separate Storm Sewer System (MS4) program, the City of Bangor reviews BMPs to better regulate stormwater within the City, including the Arctic Brook watershed. These ongoing efforts include revised construction ordinances, City vehicle spill kits and reporting protocols, road salt/sand storage, street sweeping, catch basin cleaning, and illicit discharge detection in stormwater.
- Bangor Area Storm Water Group – BASWG is an active group comprised of representatives from the City of Bangor, City of Brewer, Town of Hampden, Town of Milford, City of Old Town, Town of Orono, Town of Veazie, the University of Maine at Orono, University of Maine at Augusta, Eastern Maine Community College, the Dorothea Dix Psychiatric Center, and the Maine Air National Guard. The purpose of this group is help municipalities comply with the education, outreach, and public involvement requirements that are part of the six Minimum Control Measures mandated by the NPDES Stormwater Program for MS4 communities. The BASWG uses a variety of techniques to promote better

stormwater management and awareness, such as hosting public events, staff trainings, workshops, and stream clean-ups. Refer to their website for more information on current activities (www.baswg.org).

2 WATERSHED CHARACTERIZATION

2.1 LOCATION AND CLIMATE

Located in Central Maine, Arctic Brook flows through both high-density commercial and residential development. The 1.2 square-mile (768 acres) watershed of Arctic Brook begins as a wetland bordering the Prentiss Woods City Forest. The stream then continues across Grandview Avenue and is directed through a series of culverts underneath the Broadway Shopping Center and Broadway (Route 15). It then runs through a straightened channel parallel to the I-95 interstate before crossing underneath the interstate and opening up to a more naturalized channel before making its way into Kenduskeag Stream. The Arctic Brook watershed includes prominent features such as Bangor High School, the City Nursery, and the Broadway Shopping Center. Additionally, the I-95 corridor runs through the watershed and parallels Arctic Brook before it reaches Kenduskeag Stream. When the I-95 corridor was built in 1961, Arctic Brook was relocated around the interstate through substantial channel armoring. Significant residential development exists within the watershed, centered around five large neighborhoods (Broadway Heights, Bangor Gardens, Fernald Heights, Little City, and Orchard Hills). The watershed is entirely encompassed within the City of Bangor, Maine.

Over the last three decades (1981-2010), climate in the Bangor region has seen normal annual temperatures of 66.3 °F in summer, 20.8 °F in winter, and an average of 44.3 °F overall, as well as a mean annual precipitation of 41.93 inches (NOAA 2015). Mean monthly air temperature and precipitation data have remained relatively consistent from 1953-2014.

2.2 POPULATION DEMOGRAPHICS

Understanding population growth and demographics, and ultimately development patterns, provides critical insight into watershed management, particularly as it pertains to water quality in streams. According to the U.S. Census Bureau, the population of Bangor in 2010 was 33,039, representing a 16.4% increase in population since the 2000 census (US Census Bureau 2015). There is semi-limited public transportation in the area (primarily the Community Connector Bus), and most people use personal vehicles in their daily commute. Broadway, or State Route 15, is a major commuter access to the city and supports heavy thru-traffic. Residents and commercial entities are attracted to the area within the Arctic Brook watershed for its central location and access to both northern and southern Maine, easy on-off access to I-95 and nearby shopping, and local institutions including Husson College, Bangor High School, and St. Joseph's Hospital. Based on census data, experienced annual growth rates are continuing to rise but at a slower rate (Table 2.1).

Table 2.1. Decadal census population and growth rates for Bangor, Maine

Town	1960	1970	1980	1990	2000	2010	50-Yr Annual Growth Rate (1960-2010)	20-Yr Annual Growth Rate (1990-2010)	10-Yr Annual Growth Rate (2000-2010)
Bangor	714	1,178	1,979	3,124	3,678	4,280	499.4%	37.0%	16.4%

The majority of the population in Bangor falls within the 20-64 age category. Residences in Bangor are comprised almost entirely of owner occupied houses (42.7%) and rental units (49.7%). Seasonal residences are an insignificant portion of Bangor housing (0.8%) (Table 2.2). These statistics illustrate that the region

is an attractive destination for those seeking a temporary or permanent residence, and that increased development is a possibility as population increases.

Table 2.2. 2010 population demographics for Bangor, Maine

Town	Total Pop	Aged 0-19	Aged 20-64	Aged 65+	Total Houses	Total Occ Houses	Owner Occ Houses	Seasonal Houses	Renter Occ Houses
Bangor	33,039	7,409	20,876	4,754	15,674	92.4%	42.7%	0.8%	49.7%

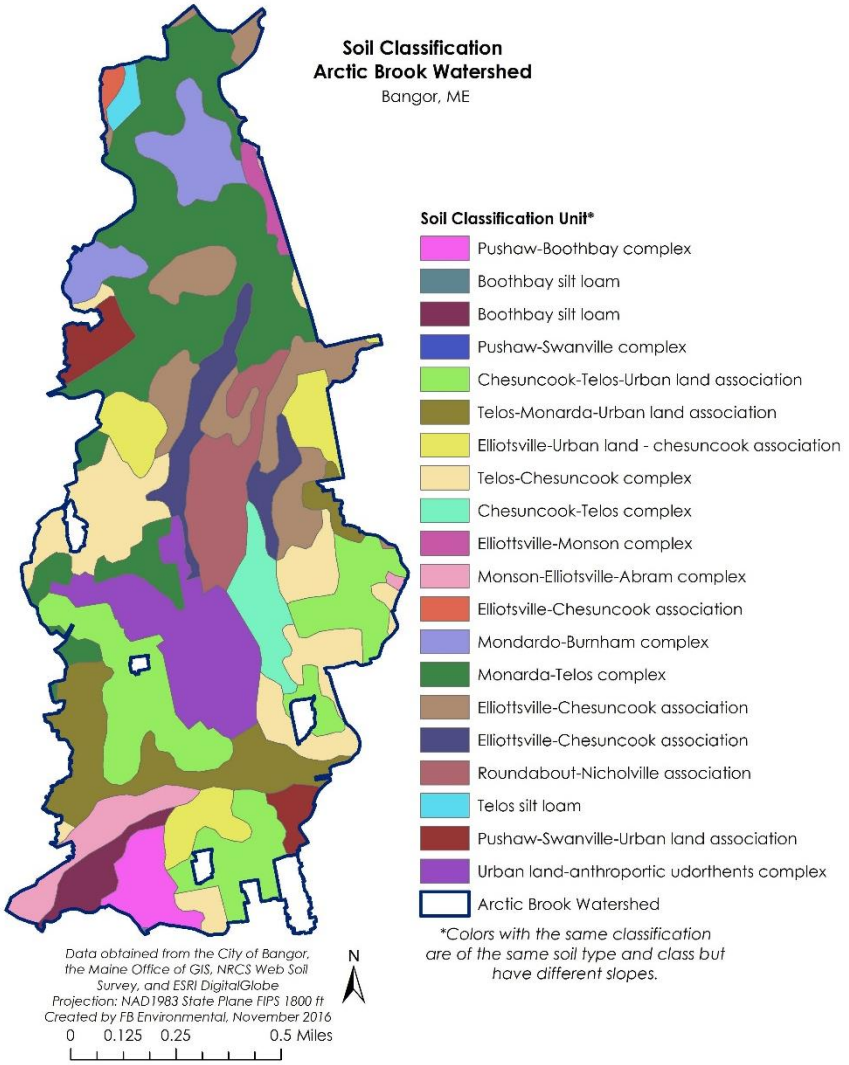
2.3 PHYSICAL FEATURES OF THE WATERSHED

2.3.1 TOPOGRAPHY

Arctic Brook is situated in the Kenduskeag Stream basin in the Maine highlands about 30 linear stream miles from Penobscot Bay and the Atlantic Ocean. The lowest point within the watershed (30 feet above sea level) is located at its convergence with the Kenduskeag Stream. The highest point (270 feet above sea level) is located in the northwest corner of the watershed. See Appendix A, Map 2.

2.3.2 SOILS AND GEOLOGY

The Arctic Brook watershed is characterized by multiple soil series and are highly variable. The most dominant soil series (Monarda-Telos complex) covers 21% of the watershed, and is located mostly in the upper watershed.[2] These soils are very stony and typical profiles include highly decomposed plant materials underlain by silt loam and gravelly loam. Soils within undeveloped sections of the stream channel (Elliottsville-Chesuncook, Telos-Chesuncook, Ellliotsville-Monson, Boothbay silt loam) are located on steeper slopes (8-25% slope) and are rocky and very rocky soils with profiles comprised primarily of silt loam. The developed areas of the watershed are dominated by urban soils including the area around the Broadway shopping center (Urban land-Anthropiortic Udorthents

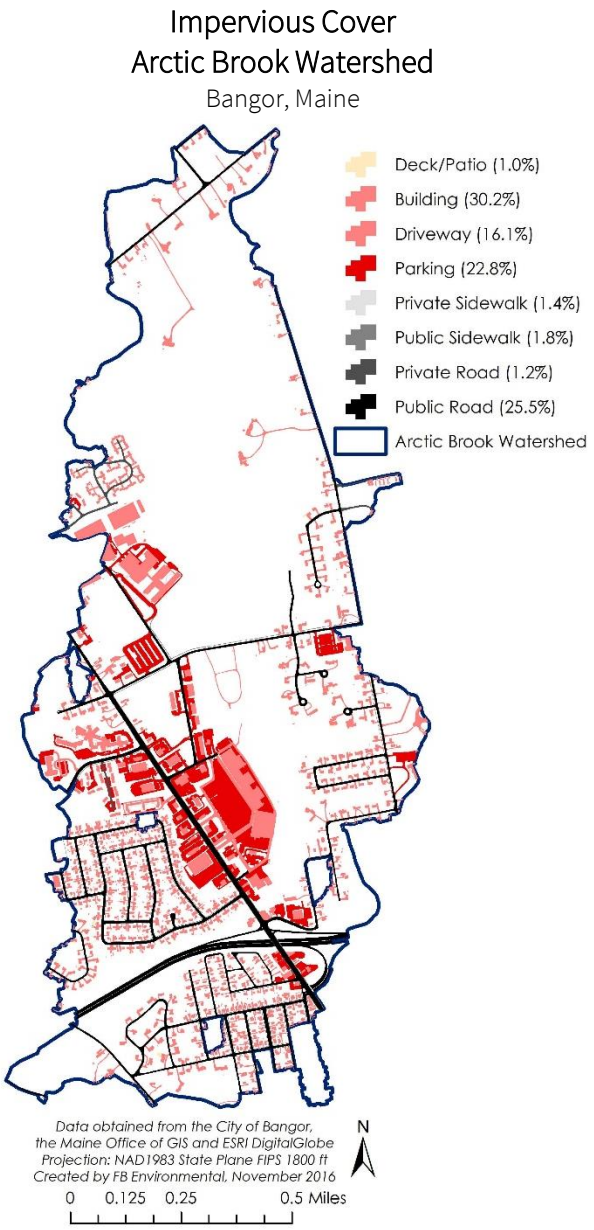


[2] http://websoilsurvey.sc.egov.usda.gov/WssProduct/40t1ui3meigm14bvh2to15bh/GN_00001/20161202_13574601830_1_Soil_Report.pdf

complex) and the high-density residential neighborhoods to the south (Chesuncook-Telos-Urban land Association) which makes up 11.4% of the watershed area. The third dominant soil type is the Elliottsville-Chesuncook Association which abuts the steam and freshwater forested wetland in the upper watershed. Soils in the urban areas have been greatly altered and compacted over the years by roads and parking lots. These soils are typically moved from elsewhere in the watershed and therefore have similar properties, in this case consisting of silt loam in the upper 15 - 30 inches and ranging from moderately well-drained to somewhat poorly-drained. (See Appendix A, Map 3).

Soil erosion potential is dependent on a combination of factors, including land contours, climate conditions, soil texture, soil composition, permeability, and soil structure (O'Geen et al. 2006). Soil erosion potential should be a primary factor in determining the rate and placement of development within a watershed. Soils with negligible soil erosion potential are primarily low-lying wetland areas near abutting streams.

Surficial geology in the Arctic Brook watershed is primarily glacial till, with fine-grained glacial marine materials below Kenduskeag Avenue. This was caused by dynamic geological processes that occurred over millions of years. Specifically, 30,000 years ago, the region was covered by a slow-moving continental glacier that scraped over mountains and valleys, whittling the landscape to the form we recognize today. As the glacier began to recede, the sea flooded coastal river basins including the Penobscot River Valley in which the Arctic Brook watershed is situated. Immense deposits of sediment (glacial till and finer glacio-marine silts and clays) washed out of the melting ice sheet. Sand and gravel accumulated in meltwater stream within the glacier and deposited as ridges, also known as eskers.



2.3.3 LAND USE

Characterizing land cover within a watershed on a spatial scale can highlight potential sources of nonpoint source (NPS) pollution that would otherwise go unnoticed in a field survey of the watershed. For instance, a watershed with large areas of developed land and minimal forestland will likely be more at risk for NPS pollution than a watershed with well-managed development and large tracts of undisturbed forest, particularly along headwater streams.

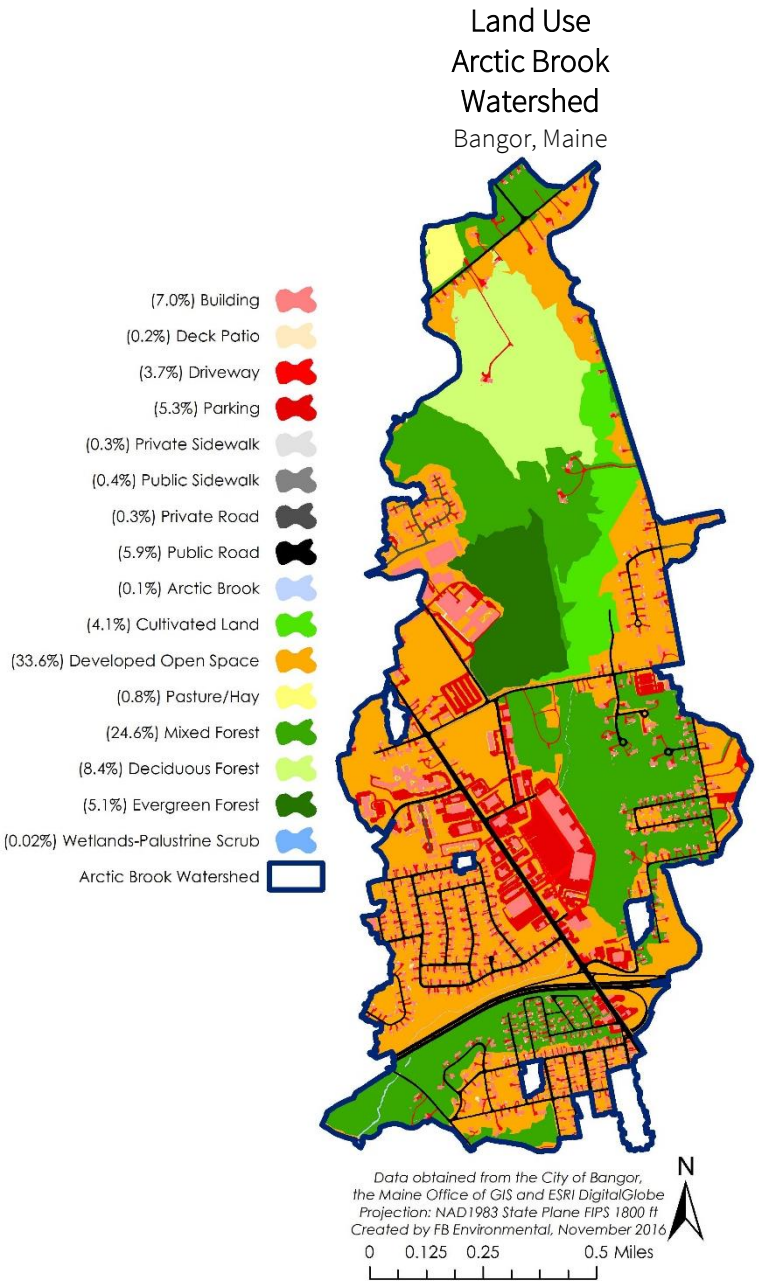
Today, impervious cover (IC) accounts for 23.3% of the watershed, with forested areas totaling 38.1% (Appendix A Maps 4 & 5).[3] Developed areas within the Arctic Brook watershed are characterized by impervious surfaces, including areas with asphalt, concrete, and rooftops that force rain and snow that would otherwise soak into the ground to runoff as stormwater. Stormwater runoff carries pollutants to waterbodies that may be harmful to aquatic life, including sediments, nutrients, pathogens, pesticides, hydrocarbons, and metals. Studies have shown a link between the amount of impervious area in a watershed and water quality conditions (CWP 2003). In one study, researchers correlated the amount of pathogens in a waterbody to the percentage of land with impervious cover in a watershed (Mallin et al. 2000). At 23.3%, IC in the watershed is significant and is concentrated along the Broadway corridor. High-density residential development, characterized as a mix of developed open space (orange on the map on the following page) and buildings/driveways (red on the map on the following page), is prominent in the southern half of the watershed.

An aerial view of the commercial development along Broadway in the Arctic Brook watershed. From Google Earth imagery. Imagery Date: May 14, 2015

[3] Land uses presented in this plan were created with a 2004 land-cover shapefile from the Maine Office of GIS, and refined by overlaying the impervious cover shapefile delineated by the City of Bangor in 2014. All land categorized as "High, Medium or Low Developed" in the 2004 shapefile that was not listed as impervious cover in the City's database, was labeled as "Developed Open Space". Additionally, waterbodies and the stream were integrated into this shapefile. This combined file was further refined using ESRI aerial imagery by visual land use interpretation. This final land-cover dataset should not be used as exact boundaries, but provides a more accurate generalization of land cover in the watershed.

2.3.4 LAND CONSERVATION

The Arctic Brook watershed is highly urbanized, leaving little opportunity for conserved land. However, there are three separate conserved land parcels within the watershed, with only one (Prentiss Woods) entirely within the watershed. Total conserved land in the watershed is approximately 29.0 acres.



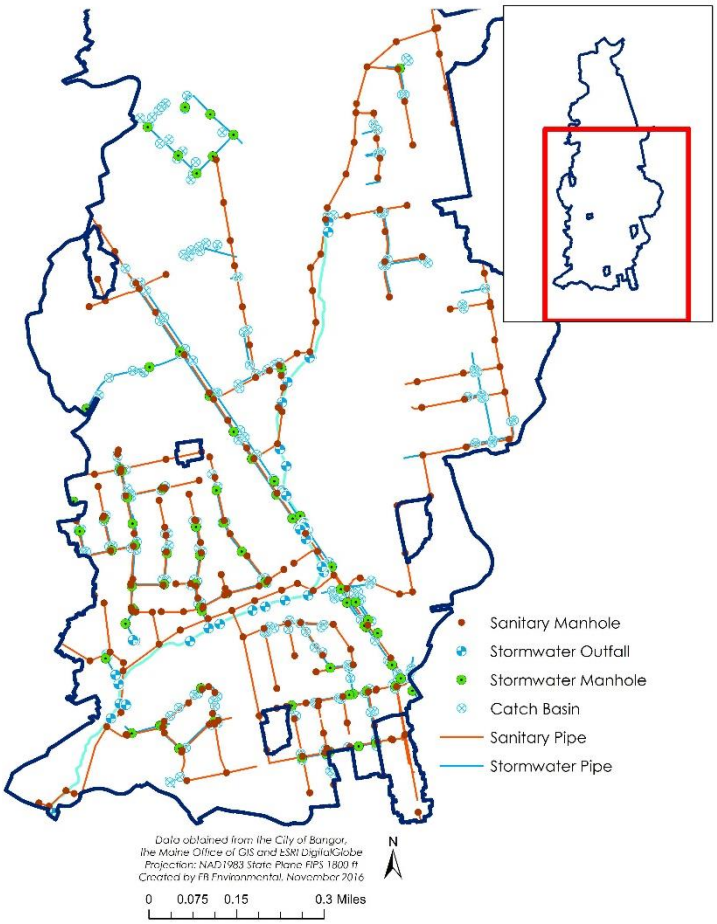
- Prentiss Woods (24.6 acres) is located north of Grandview Avenue parallel to the headwaters of Arctic Brook. It is accessible via Grandview Avenue or the Bangor High School.
- Kenduskeag Stream Park (1.2 acres) protects the shoreline of Kenduskeag Stream and provides walking path access for the community. The section within Arctic Brook is only a portion of a much larger network of conserved land along Kenduskeag Stream (12 parcels making up 57.5 acres total).
- Little City Park (0.2 acres) only barely makes it over the border into the Arctic Brook watershed. This neighborhood park is 1.9 acres total and includes a playground for children living in the Little City neighborhood.
- Whispering Meadows Open Space (3.0 acres) is located within the Whispering Meadows neighborhood and is owned by the Whispering Meadows Homeowners Association.

2.3.5 STORMWATER AND SEWER INFRASTRUCTURE

STORMWATER SYSTEM

There are a total of 6.7 miles of stormwater pipe within the watershed, connecting 221 catch basins with 37 stormwater outfalls that lead directly to the stream. Outfalls are locations were a stormwater pipe discharges directly to Arctic Brook. The significant contribution of stormwater runoff from impervious surfaces conveyed through stormwater pipes is a huge burden on a small stream, causing rapid or "flashy" response to storm events, with surges in high flows, and significant deposition of urban pollutants including road sand, salt, heavy metals, nutrients, oils & grease and trash.

Stormwater and Sewer Infrastructure
Arctic Brook
Watershed
Bangor, Maine



The stormwater system is largely concentrated within the commercial development around the Broadway commercial corridor, and was initially designed to get water off of pavement (parking lots and roads). Catch basins and stormwater pipes are located within commercial parking lots and at regular intervals along Broadway, and along I-95.

With guidance from the City, and as required for new construction under State law (Chapter 500), newer commercial businesses have installed stormwater best management practices (BMPs) to help reduce both the quantity of stormwater entering the system, as well as to remove pollutants carried in the stormwater. Examples of existing BMPs in the Arctic Brook watershed are bioretention basins, underdrain filters, and detention basins. The city has 16 known existing BMPs in the Arctic Brook watershed. While these existing stormwater treatments are important, more BMPs to treat the large amount of runoff that flows directly to the stream from buildings, parking lots and roads.

Currently, the City inspects catch basins every two years, and the sump is cleaned if it is greater than 50% filled with sediment. This applies only to city-owned roadways; private catch basins are cleaned at the discretion of the individual landowners.

SANITARY SEWER SYSTEM

The majority of the Arctic Brook watershed is serviced by City sewer as a means of human waste disposal. There are currently 227 manholes and 10.6 miles of sanitary pipes in the watershed (Appendix A, Map 6). Sanitary sewer lines and manholes parallel Arctic Brook for its entire length, making it imperative that sewer

pipes are inspected and maintained regularly to prevent leakage into the stream. Currently, the City has a robust sanitary sewer management program which includes constant assessment of all aspects of the system. The sewer collections system is large, so the City aims for an assessment of 10% of the assets each year. Defects found during these routine assessments are analyzed and are then addressed by priority.

3 CAUSES OF IMPAIRMENT AND ASSESSMENT

3.1 APPLICABLE WATER QUALITY STANDARDS AND CRITERIA

Arctic Brook is a designated Class B freshwater stream. According to Maine's Water Classification Program under the Maine Legislature (Title 38 MRSA 464-468), "Class B waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, Section 403; navigation; and as habitat for fish and other aquatic life." A summary of the narrative and numeric water quality standards for Class B freshwaters is provided in Table 3.1.

Arctic Brook was first listed by Maine DEP in the 2002 303(d) list of impaired waters (Maine DEP 2012a). In 2005, ENSR International (a private consulting firm later acquired by AECOM) completed a Pilot IC method TMDL for Arctic Brook (ENSR 2005) and a finalized TMDL was completed in 2012 (Maine DEP 2012b). The initial listing of Arctic Brook on the State's 303d list identified the impaired section of stream beginning at the Broadway Shopping Center, however, more recent macroinvertebrate data collected upstream indicates the impairment may extend farther upstream to Grandview Avenue. More information is needed to understand the extent and causes of the impairment upstream of the Broadway Shopping Center.

Arctic Brook has been identified as not meeting water quality standards for aquatic life, due to impairments determined through benthic macroinvertebrate monitoring and stream habitat assessments. The 2012 IC TMDL used stormwater as a surrogate for the many pollutants in stormwater that flows off developed areas in the watershed. A high percentage of the Arctic Brook watershed (23.3%) contains impervious cover, including parking lots, roads and buildings. The 2012 IC TMDL set a goal of reducing the effects of IC by 65%- ultimately reducing the quantity, quality and rate at which stormwater reaches the stream so that it functions like a stream in a watershed with 8% IC. This plan can be considered an interim document which works towards this goal of 8% effective IC. Water quality must be monitored continuously to identify progress made towards this goal.

Table 3.1. Maine water quality criteria for Class B waters (38 MRSA § 465) (Maine DEP 2006).

PARAMETER	CRITERIA FOR COMPLIANCE
DISSOLVED OXYGEN (YEAR-ROUND)	May not be less than 7 ppm or 75% saturation, whichever is higher.
DISSOLVED OXYGEN (OCTOBER 1ST-MAY 15TH)	To ensure spawning and egg incubation of indigenous fish species, the 7-day mean dissolved oxygen concentration may not be less than 9.5 ppm and the 1-day minimum dissolved oxygen concentration may not be less than 8 ppm in identified fish spawning areas.
AQUATIC LIFE / DISCHARGES	Must not cause adverse impact to aquatic life, and the receiving waters must be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community.
BACTERIA (*E. COLI*)	64 / 100 mL (geometric mean) 236 / 100 mL (instantaneous)
HABITAT	Unimpaired

3.2 WATER QUALITY AND BIOLOGICAL ASSESSMENTS

Water quality data has been collected at 13 stations along Arctic Brook since 1997 by the Maine Department of Environmental Protection (Maine DEP), James W. Sewall Company, City of Bangor, and FB Environmental. The vast number of unique sites at Arctic Brook is a result of a series of channelized and culverted sections of the stream. Sampling sites attempt to capture differences in water quality in these various reaches to help determine where the pollution is coming from, and what the effects of impervious cover are located within the different stream reaches. Table 3.2 provides a summary of the sample collection history by site, including years collected, who collected it, and the type of data collected.[4] A map of all sampling locations is provided on page 18 (and Appendix A, Map 7), labeled according to the aliases provided in Table 3.2.

The following section provides a description of water quality results for Arctic Brook. Analyses of these data will provide a baseline to compare to changes in the stream's water quality in the future, as the management plan is implemented over the next 10 years and beyond.

A photo during high flows on October 28, 2016 of the continuous monitoring site on Arctic Brook, below Kenduskeag Avenue. ***Photo Credit:*** *Richard May, City of Bangor.*

DEFINITIONS

Total Mean Abundance: a count of all individuals in all replicate samples from a single site divided by the number of replicates.

Generic Richness: a count of the number of different genera found in all replicates from one site.

Relative Chironomidae Abundance: a count of all individuals from the order Chironomidae in all replicate samples from a single site divided by the number of replicates, and then divided again by the total mean abundance.

EPT Generic Richness: a count of the number of different genera from the order Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) in all replicate samples.

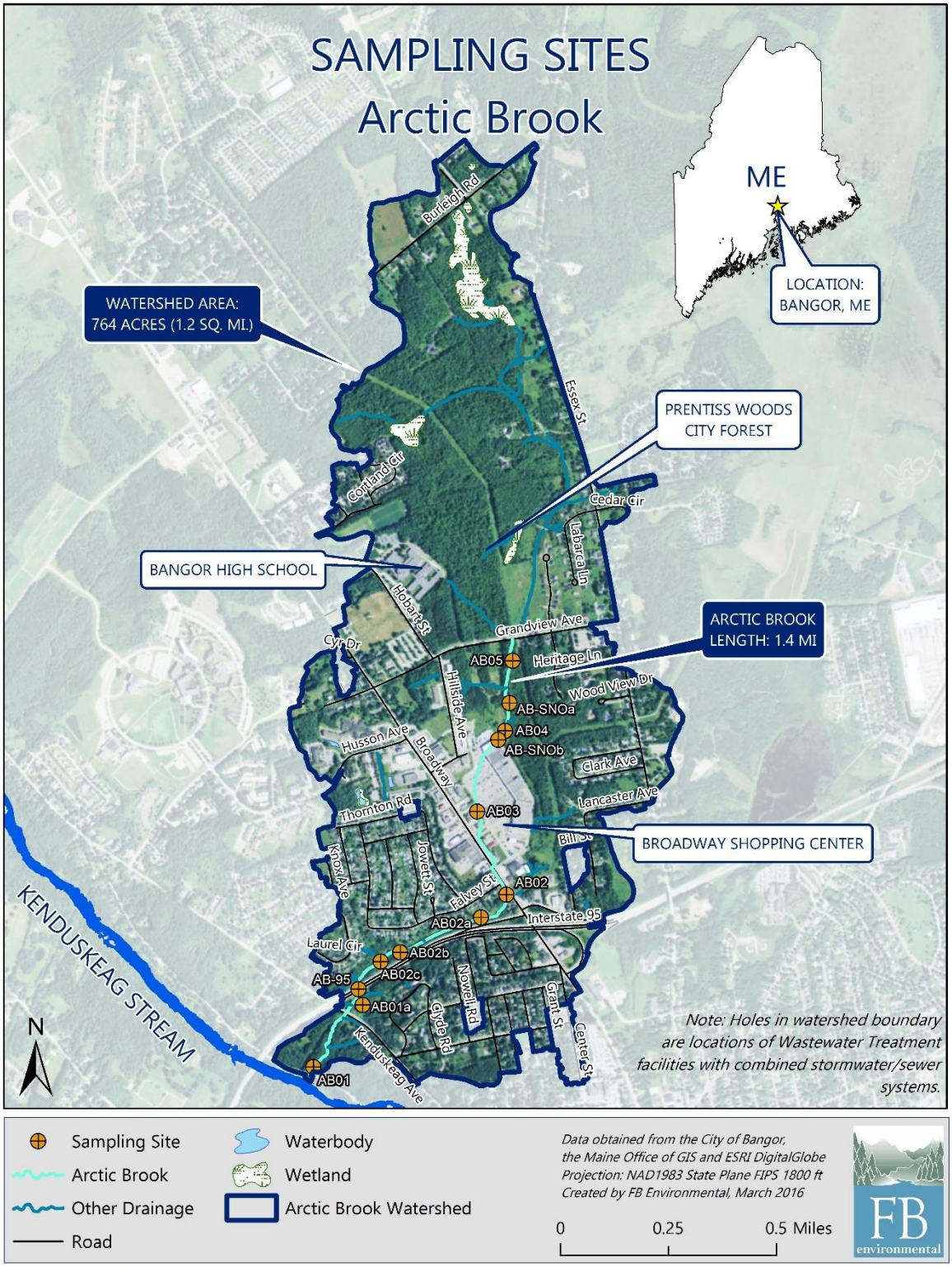
*Definitions extracted directly from **Appendix C-1**: Methods for the Calculation of Indices and Measures of Community Structure Used in the Linear Discriminant Models from *Methods for Biological Sampling and Analysis of Maine's Rivers and Brooks* (ME DEP LW0387-B2002).

[4] Due to inconsistencies in nomenclature across multiple groups collecting the data, the water quality analysis resulted in the development of 'alias' names for each site. This alias retains the structure of the City of Bangor nomenclature, starting with AB05 at Grandview Avenue, and decreasing until AB01 at Valley Avenue just above the confluence with Kenduskeag Stream.

Table 3.2. List of available water quality monitoring data for Arctic Brook by site, year collected, and organization the data was collected by. Maine DEP=Maine Department of Environmental Protection; S.E.E.D.=Students Ending Environmental Destruction; FBE=FB Environmental; Sewall= James W. Sewall Company.

ALIAS	SITE DESCRIPTION	YEARS COLLECTED	COLLECTED BY	DATA COLLECTED
AB05	Below Grandview Avenue	2009-2012	Sewall	Continuous water quality
		2013	Maine DEP	Continuous water quality
		2014	Maine DEP	Continuous water quality
		2009-2010	Sewall	Physical and chemical water quality
		2011-2014	Maine DEP	Physical and chemical water quality
		2009-2011; 2013	City of Bangor	Physical and chemical water quality
		2015	FBE	Macroinvertebrate Assessment
AB-SNOa	Above Snow Dump Upstream of Broadway Shopping Center	2011	Maine DEP	Physical and chemical water quality
AB-SNOb	Below Snow Dump Upstream of Broadway Shopping Center	2011	Maine DEP	Physical and chemical water quality
AB04	Upstream of Broadway Shopping Center	2012	Maine DEP	Physical and chemical water quality
		2014	Maine DEP	Physical and chemical water quality
		2013	City of Bangor	Physical and chemical water quality
AB-SEED	At Broadway Shopping Center – Site Discarded	2013	S.E.E.D. (w/ Maine DEP)	Physical and chemical water quality
		2013	S.E.E.D. (w/ Maine DEP)	Continuous water quality
AB03	Broadway Shopping Center	2013	City of Bangor	Physical and chemical water quality
		2012, 2014	Maine DEP	Physical and chemical water quality
AB02	Below Broadway Avenue Crossing	2013	Maine DEP	Continuous water quality
		2012	Maine DEP	Physical and chemical water quality
		2013	Maine DEP	Physical and chemical water quality
		2013	City of Bangor	Physical and chemical water quality
AB02a	Behind Falvey Avenue House #32	2015	FBE	Macroinvertebrate Assessment

ALIAS	SITE DESCRIPTION	YEARS COLLECTED	COLLECTED BY	DATA COLLECTED
AB02b	Approximately 250 yards Upstream of I-95	2012	Maine DEP	Physical and chemical water quality
AB02c	Approximately 150 yards Upstream of I-95	2012	Maine DEP	Physical and chemical water quality
AB-95	Above I-95 Crossing	2012	Maine DEP	Physical and chemical water quality
AB01a	Above Kenduskeag Avenue Crossing	2009 - 2010	Sewall	Continuous water quality
		2012	Maine DEP	Continuous water quality
		2009 - 2012	Sewall; Maine DEP	Physical and chemical water quality
		2009-2011	City of Bangor	Physical and chemical water quality
AB01	Above Valley Avenue Crossing	2011	Maine DEP	Continuous water quality
		2015	FBE	Continuous water quality
		2011, 2012, 2013	Maine DEP	Physical and chemical water quality
		2013	City of Bangor	Physical and chemical water quality
		1997, 2014	Maine DEP (1997), Maine DEP/FBE (2014)	Macroinvertebrate Assessment
		2015	FBE	Macroinvertebrate Assessment


SAMPLING SITES
Arctic Brook
ME
LOCATION: BANGOR, ME
WATERSHED AREA: 764 ACRES (1.2 SQ. MI.)
PRENTISS WOODS CITY FOREST
BANGOR HIGH SCHOOL
ARCTIC BROOK LENGTH: 1.4 MI
BROADWAY SHOPPING CENTER
KENDUSKEAG STREAM
Burleigh Rd
Essex St
Cortland Cir
Cedar Cir
Labarce Ln
Hobart St
Grandview Ave
Cyr Dr
Heritage Ln
Wood View Dr
Hillside Ave
Husson Ave
Broadway
Clark Ave
Lancaster Ave
Thornton Rd
Bill St
Knox Ave
Jowett St
Falvey St
Interstate 95
Laurel Cir
Newell Rd
Grant St
Center St
Clyde Rd
Kenduskeag Ave
AB05
AB-SNOa
AB04
AB-SNOb
AB03
AB02
AB02a
AB02b
AB02c
AB-95
AB01a
AB01
N
Note: Holes in watershed boundary are locations of Wastewater Treatment facilities with combined stormwater/sewer systems.
Sampling Site
Arctic Brook
Other Drainage
Road
Waterbody
Wetland
Arctic Brook Watershed
Data obtained from the City of Bangor, the Maine Office of GIS and ESRI DigitalGlobe
Projection: NAD1983 State Plane FIPS 1800 ft
Created by FB Environmental, March 2016
0
0.25
0.5 Miles
FB environmental

3.2.1 BIOLOGICAL ASSESSMENT

Macroinvertebrates are aquatic insects, including mayflies, dragonfly larvae, caddisfly larvae, aquatic worms, amphipods, leeches, clams, and snails, that live on stream bottom substrates, such as rocks, logs, sediment, and plants. They serve as excellent indicators of water quality, depending on the amount and type of species present and their associated pollutant tolerances. EPT is an index of three orders of aquatic insects: Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies). These taxa are generally intolerant of pollutants and are found in less impacted, oligotrophic streams. Chironomidae (midges) are more tolerant of pollutants and are found in greater abundances in eutrophic streams.

The protocol for sampling and analysis of macroinvertebrate surveys include deploying rock bags on the stream bottom for approximately four weeks, which allows macroinvertebrates to colonize the rocks (Maine DEP 2011). Bags are collected along with physical data (water velocity, dissolved oxygen, temperature, conductivity, description of substrate and site). The macroinvertebrate communities within the rock bags are identified by lowest taxonomic group (genus or species) to generates data on the abundance and generic richness of the macroinvertebrate community present within the stream.

Macroinvertebrate surveys were conducted in Arctic Brook in 1997, 2014, and 2015 at three sites (Maine DEP, 2015; Table 3.3). Site AB01 (Maine DEP Station S-313), located above Valley Avenue, was sampled in all years and resulted in "non-attainment", indicating that the site did not meet class A, B, or C aquatic life criteria. Interestingly, the 2015 results indicated higher total abundance and lower EPT generic richness and relative abundance Chironomidae. This suggests that Site AB01 has seen an increase in tolerant species and a decrease in sensitive species. Because habitat at this site is relatively stable, it is most likely that high levels of toxic pollutants are removing sensitive species from the area. Additionally, extreme high and low flows could be barriers for organisms with longer life cycles. In 2015, two additional sites were added including AB05 (Maine DEP Station S-1078) and AB02a (Maine DEP Station S-1077). Macroinvertebrate monitoring at Site AB05 were characteristic of a Class C stream, which indicates better water quality and/or habitat compared to Site AB01, but it still did not meet the statutory Class B standard. Like Site AB01, modeling results at Site AB02a indicate low total mean abundance. Non-attainment is likely due to urban pollutants, altered hydrology, and poor habitat.

Biomonitoring by the Maine DEP is generally conducted on a five-year rotation, but Arctic Brook has been sampled at a lower frequency. According to the Maine DEP Biomonitoring Protocols, macroinvertebrate communities must meet water quality standards for two consecutive sampling events within a 10-year period for the stream to be moved from a status of not attaining to attaining aquatic life criteria.

Table 3.3. Summary of biomonitoring surveys at Arctic Brook by the Maine DEP, City of Bangor, and FBE.

SITE	YEAR	STATUTORY CLASS	ATTAINED CLASS*	TOTAL ABUNDANCE	GENERIC RICHNESS	RELATIVE ABUNDANCE CHIRONOMIDAE	EPT GENERIC RICHNESS	COLLECTED BY
AB05	2015	B	C	56.67	28	0.56	4	FBE
AB02a	2015	B	NA	46.00	30	0.28	4	FBE
AB01	1997	B	NA	23.00	17	0.09	4	MEDEP
	2014	B	NA	30.67	24	0.10	4	MEDEP
	2015	B	NA	38.33	13	0.02	2	FBE

**NA= non-attaining*

3.2.2 DISSOLVED OXYGEN

Dissolved oxygen (DO) is the concentration of oxygen dissolved in the water that is available for aquatic organisms and macrophytes. It is measured in mg/L, equivalent to parts per million (ppm). DO facilitates critical chemical reactions within the channel and benthic sediments that support life processes and functions. Depletion of available oxygen (known as hypoxia or anoxia) inhibits physiological functioning of aquatic life and its persistence can reduce the diversity and abundance of biota. DO fluctuates naturally on a diurnal basis depending on a suite of interactions and resource availability (e.g. light, nutrients, organic matter, temperature, etc.). DO is often highest during the day when sunlight drives photosynthesis (produces oxygen), while DO is often lowest at night when autotrophic respiration and decomposition of organic matter dominates (consumes oxygen). The Maine DEP uses diurnal swings > 2 ppm as an indicator of nutrient enrichment. For Class B streams, the State of Maine and EPA sets a numeric criteria for DO at 7 ppm from May 15 to September 30. From October 1 to May 14, daily mean DO must be greater than 8 ppm and the 7-day mean must be at least 9.5 ppm.

Both instantaneous and continuous monitoring of DO has occurred at Arctic Brook. Continuous water quality monitoring for three sites in Arctic Brook (AB05, AB01a, and AB01) show variable patterns for DO (Figure 3.1). Strong diurnal fluctuations in DO are evident across sites. Site AB05, measured in 2014, shows persistent levels of DO below the recommended 7 ppm in August (Figure 3.1, top panel). Site AB05 experiences large swings in diurnal DO with a range of approximately 0.4 – 4.0 ppm. These large swings coincide with the late August – September fluctuations below 7 ppm, which is commonly a result of increased algal production in first order streams (however, significant algal production has not been observed in Arctic Brook at baseline sampling locations). Stream water at this site during very low baseflow conditions is stagnant with limited riffles for replenishment of DO in the water column. Continuous monitoring of Site AB01a in 2012 shows multiple periods of low DO between May and September, specifically around June 11, late July, and early September (Figure 3.1, middle panel). These low values are caused by a combination of in-stream production and precipitation events. While lower than Site AB05, Site AB01a also experiences large diurnal swings in DO ranging from approximately 0.1 – 2.4 ppm. Dissolved oxygen data at Site AB01 never dropped below 7 ppm during the monitoring period July to December 2015 (Figure 3.1, bottom panel). From July to September, DO remains relatively stable, however, late September

A photo of the continuous monitoring site on Arctic Brook, below Kenduskeag Avenue. ***Photo credit:*** *Richard May, City of Bangor.*

Arctic Brook shows notable signs of DO impairment at site AB05 below Grandview Avenue with significant periods of DO below 7 ppm in the late summer. However, DO is fairly stable at the lower study reaches, with Site AB01a (above Kenduskeag Avenue) having only minimal periods below 7 ppm and Site AB01 (above Valley Avenue) never dropping below 7 ppm from July to December 2015.

reveals a steady increase in DO, with supersaturated levels (>10.0 ppm or 100%) reaching its maximum concentration of 16.7 ppm on October 27. Diurnal swings at site AB01 were low, with swings of 0.3 – 0.9 ppm, indicating low productivity at this site.

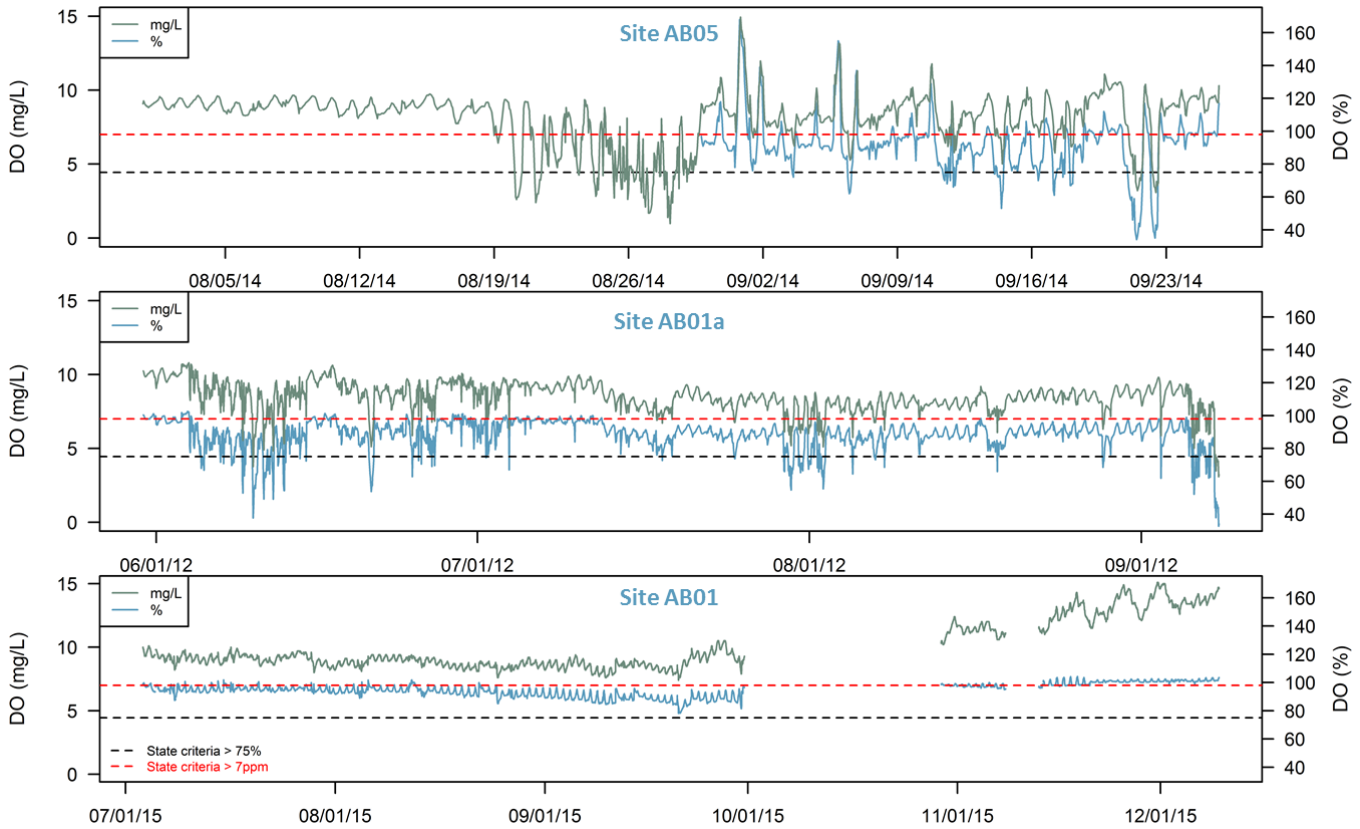


Figure 3.1. Sub-hourly dissolved oxygen (DO) concentrations for Site AB05, Site AB01a, and Site AB01. Data from Site AB05 and AB01a are from the Maine DEP and data from Site AB01 is from FB Environmental. Missing data from October and November of 2015 was due exposure of the sensor to air during low flows. The red dashed line indicates 7 ppm, the Maine Class B numeric threshold for aquatic life attainment. Note the differences in the collection period (x-axis) among the sites.

3.2.3 CHLORIDE/SPECIFIC CONDUCTIVITY

Specific conductivity is used as a surrogate measure for chloride concentrations, but it also represents other charged particles within a parcel of water, including cations (Ca^{2+}, Na^{+}, K^{+}, Mg^{2+}) and anions (Cl^{-}, NO_3^{-}, SO_4^{2}). Many of these ions are weathering products and reflect differences in parent geology. Chloride, and thus specific conductivity, is of primary interest to management because it represents a large anthropogenic source of pollutants from road salt, septic systems, wastewater treatment plants, and stormwater runoff. Because of this, the concentration of chloride is directly linked to population density and percent impervious cover and is thus linked to urban watersheds where greater runoff from developed areas impacted by road salt application leads to high inputs of chloride. Once chloride enters the groundwater system, it remains dissolved in the water and is virtually impossible to remove making prevention key.

The Maine DEP sets a standard of a mean 1-hour (acute) exposure of 860 mg/L for chloride and a mean 4-day (chronic) exposure of 230 mg/L for chloride (DEP 06-096 Chapter 584). Any chloride results greater than these standards are considered toxic to aquatic life. This standard does not directly apply to specific conductivity since it represents other elements in addition to chloride, but a relationship between the two can be established.

Continuous monitoring of specific conductivity indicates potential chloride toxicity in Arctic Brook (Figs. 3.2 & 3.3). Site AB02, below the Broadway Shopping Center has the highest observed specific conductivity reading, reaching a peak of 8,380 μS/cm on March 2, 2013 (Figure 3.2), however, spatial and temporal changes in sampling as well as differences in groundwater inputs make comparisons across space and time difficult in the Arctic Brook watershed. Upstream of the Shopping Center, Site AB05 has much lower observed specific conductivity levels between 200 and 600 μS/cm. Sites AB01a and AB01 both below the Shopping Center and the interstate, have consistently higher conductivity, with values reaching above 2,000 μS/cm at AB01 (Figure 3.2). Elevated chloride is most likely a result of salt (sodium chloride) application during the winter as a method of de-icing roadways and parking lots. However, chloride contamination is not limited to stormwater and meltwater events in the winter, but groundwater contamination causes a slow release of chloride throughout the summer baseflow months.

Chloride toxicity is an acute concern for Arctic Brook, with elevated chloride levels observed from Broadway to the Kenduskeag Stream. Chloride toxicity is not limited to winter melt events, but is contaminating the groundwater and causing chronic toxicity in the stream during summer baseflow. Once chloride has entered the groundwater, it is extremely difficult to remove from the system making it a high priority to reduce salt application in winter months.

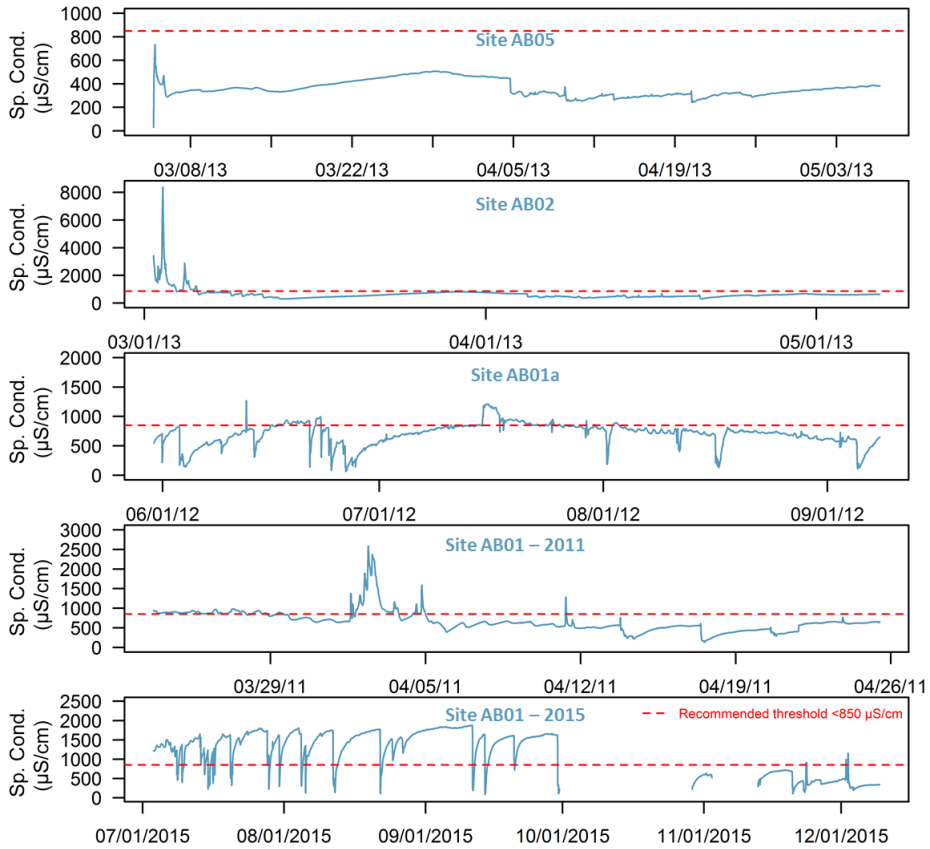


Figure 3.2. Continuous monitoring for specific conductivity at Sites AB05, AB02, AB01a, and AB01 from 2011 – 2015 (when available). Data from 2011 – 2013 was obtained from the Maine DEP and 2015 data was collected by FB Environmental. Note the differences in the collection period (x-axis) and scale (y-axis) among the sites.

Instantaneous grab samples for chloride have been collected at 11 sites along Arctic Brook with the highest median and maximum chloride at Site AB03 (within the Broadway Shopping Center), and the lowest at Site AB05 (above the major development) (Figure 3.3). High chloride concentrations at AB03 are most likely a result of winter salting in commercial parking along Broadway.

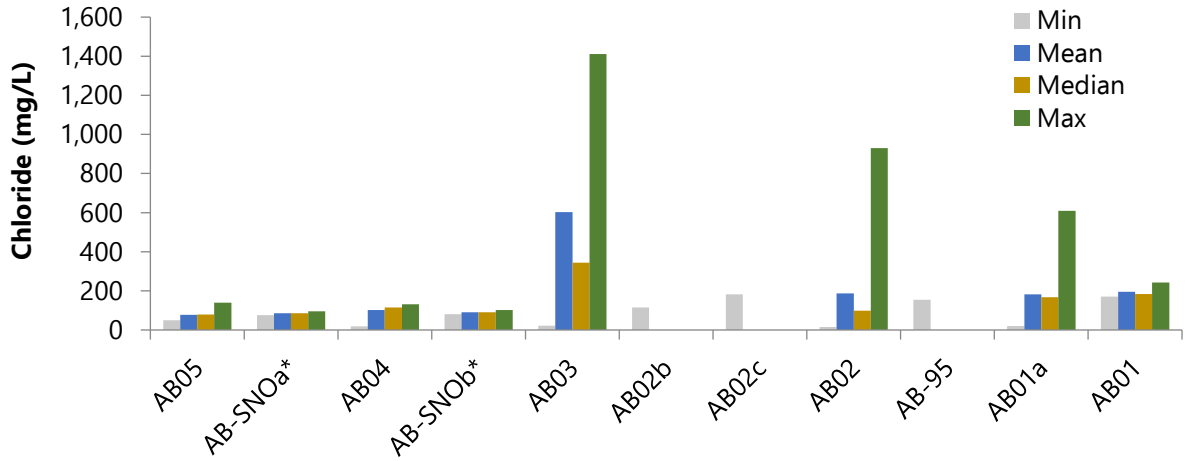


Figure 3.3. Summary figure showing the minimum, mean, median, and maximum measured chloride samples (mg/L) from Arctic Brook. Graphical display of these summary parameters highlights significant spikes at sites AB03, AB02, and AB01a.

Liability for injuries due to slip and fall accidents pressures landowners to use excessive salt (typically sodium chloride or NaCl) on their parking lots and roadways. Efforts to address excessive salt are being made nationwide and include a program pioneered by New Hampshire , the Green SnowPro Program, available here. Additionally, options such as heated sidewalks can improve traction and limit the need for NaCl application. For more information, visit them at :

http://t2.unh.edu/green-snowpro-certification.

3.2.4 WATER TEMPERATURE

Stream water temperature plays an important role in regulating chemical reactions (e.g. dissolvability of elements) within the water and can be adversely impacted by urban development. Impervious surfaces heat up quickly when exposed to direct sunlight. Stormwater runoff over these hot impervious surfaces delivers unnaturally warm water to streams, also known as thermal pollution. High volumes of warm water from overland flow or groundwater mixes with cooler stream water, leading to increases in stream water temperature (UNHSC 2011). Stream temperature is also regulated by the amount of shading by riparian vegetation along immediate stream banks. Canopies that are more open allow sunlight to reach surface waters, which can heat up quickly during the day. Many fish species thrive under optimal water temperatures, which trigger reproductive functions and regulate growth of juvenile fish. Maximum weekly and instantaneous temperature means of 19° and 24°C were found to be the limit for juvenile brook trout survival (Brungs and Jones 1977).

Instantaneous readings show the highest maximum temperatures at Sites AB04 and AB03, both with a maximum measured temperature of 22°C. Mean temperatures for instantaneous readings are highest between sites AB04 and AB02; sites located near the Broadway Shopping Center most likely receiving the highest inputs of stormwater runoff. However, sites AB02c and AB02d only have one reading, pointing out a need for more consistent readings to draw significant conclusions on temperature gradients.

All continuous data is below 24°C except for a brief period in 2015 where Site AB01 reached 24.4°C in August. Aside from this, AB05 had the warmest median temperatures of all continuous monitoring during its 2012 deployment period. Recorded temperatures for continuous monitoring at Sites AB02 and AB01 have all been below 15°C. Instantaneous grab samples have low mean and median temperatures, with the lowest value at Site AB05 of 0.70°C and the maximum tied at Sites AB03 and AB04 at 22°C.

Both instantaneous sampling and continuous monitoring for stream water temperature have consistently shown that Arctic Brook has cool waters, making it potentially viable habitat for coldwater fish species. All measured data, collected both by instantaneous measurements and by continuous monitoring, are less than 24°C for all sites.

3.2.5 pH

pH is a measure of the concentration of hydrogen ions in water on a logarithmic scale of 0 (acid) to 14 (basic). pH is determined by bedrock, acid rain deposition, wastewater discharge, and natural carbon dioxide fluctuations. pH regulates the solubility and biological availability of elements, including primary nutrients (phosphorus and nitrogen) and heavy metals. Low pH can release toxic metals and interfere with primary life functions. pH fluctuates naturally on a daily basis due to photosynthesis that consumes hydrogen ions for reaction processes. pH tends to be higher (more basic) during the day and be lower (more acidic) at night. These same daily patterns can be applied at the seasonal scale when photosynthesis becomes more prominent during the growing season. These fluctuations are typically very minor since there are buffering agents within the water (depending on contributing geology) that help protect against large swings in pH. Most aquatic organisms thrive under a pH environment of 6.5 to 8.5. Any values below or above this range can reduce the reproductive capacity of fish populations.

pH has been recorded at six sites along Arctic Brook and monitored continuously at sites AB05 and AB02. pH from grab samples ranged from 6.7 to 8.1, however, continuous monitoring by the Maine DEP revealed pH levels approaching the upper limit of the optimal range with values as high as 8.4 in early May of 2013. Therefore, while mean pH levels for grab samples were within an acceptable range (7.5 – 7.9), continuous monitoring reveals periods of elevated pH which could be causing stress for aquatic life. This elevated pH was documented at Site AB02, located below the Broadway Shopping Center. Continuous pH values during the same period at Site AB05 above the shopping center are within the optimal range.

3.2.6 STAGE HEIGHT/DISCHARGE

Stage height is a measure of the water level in the stream at a specific location. Stage height gives insight into the responsiveness of the stream to precipitation events, with highly reactive streams considered "flashy". While stage height is useful in itself, discharge is a more powerful measure of stream flow. Discharge typically measures stream flow in units of cubic feet per second (cfs), and is calculated as mean width multiplied by mean depth multiplied by mean water velocity. Calculated flow transects across the stream can be used to create a stage-discharge relationship to interpret estimated discharge from stage height. Although no numeric criterion exists for either stage height or discharge, it is an important component of stream health, and should be incorporated in any stream monitoring design. Streams in urban environments with a lot of impervious surfaces are most at risk for flashy responses to storm events. High volumes of water flow off of impervious surfaces and into receiving waters such as Arctic Brook. To accommodate these influxes of water, most streams often experience expansion of stream bank width at the high-water line, scouring of streambeds, and erosion of sediment. Eroded sediment along stream banks are deposited downstream in sand plumes where bottom substrates often become embedded with silts and sands. These large-scale disturbances can reduce habitat diversity for aquatic communities and alter habitat structure and function.

Stage height data is available from monitoring completed by the James W. Sewall Company from 2009-2010 at Sites AB05 and AB01a, the Maine DEP in 2013 at Sites AB05, AB02, and AB01a, and FB Environmental in 2015 at Site AB01. A stage-discharge relationship has not yet been created for Arctic Brook; therefore, discharge approximations are not available at this time. FB Environmental collected flow transect measurements in 2015 to establish an initial flow rating curve. However, more measurements are needed to establish a stage-discharge relationship. Overall, Arctic Brook is a flashy stream with spikes in stage height peaking during or directly after precipitation events and returning to baseflow conditions rapidly after the storm (Figure 3.4). Sites AB01a and AB01 appear to have steeper response curves, which is most likely a result of the greater impervious cover in the upslope accumulated area above these sites. In September of 2015, the City of Bangor observed no flow in the stream behind the Broadway Shopping Center, indicating that summer low flows could be an additional stressor on aquatic life (R. May, personal communication, March 8, 2016). To date, precipitation data has not been graphed with stage height, however, it is recommended that all future data be linked to local precipitation. Note that differences in the x-axis scales in Figure 3.4 cause visual distortion of the response times (ex. Site AB05 appears more responsive because the x-axis is covering a larger period of time).

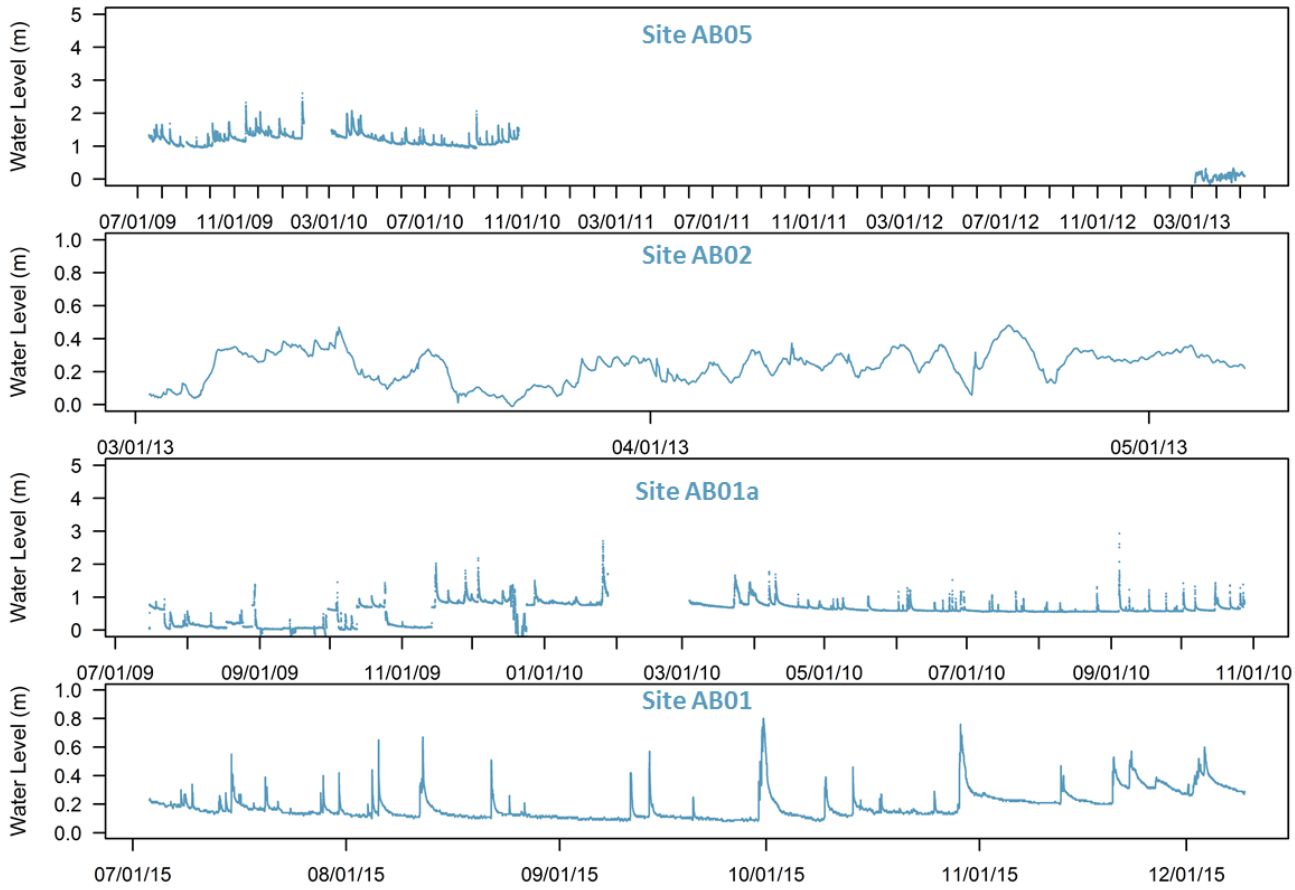


Figure 3.4. Sub-hourly stage height for Sites AB05, AB02, AB01a, and AB01. Data from 2009 – 2010 is from the James W. Sewall Company, 2013 from Maine DEP, and 2015 from FB Environmental.

3.3 GEOMORPHIC, RIPARIAN, AND IN-STREAM HABITAT ASSESSMENTS

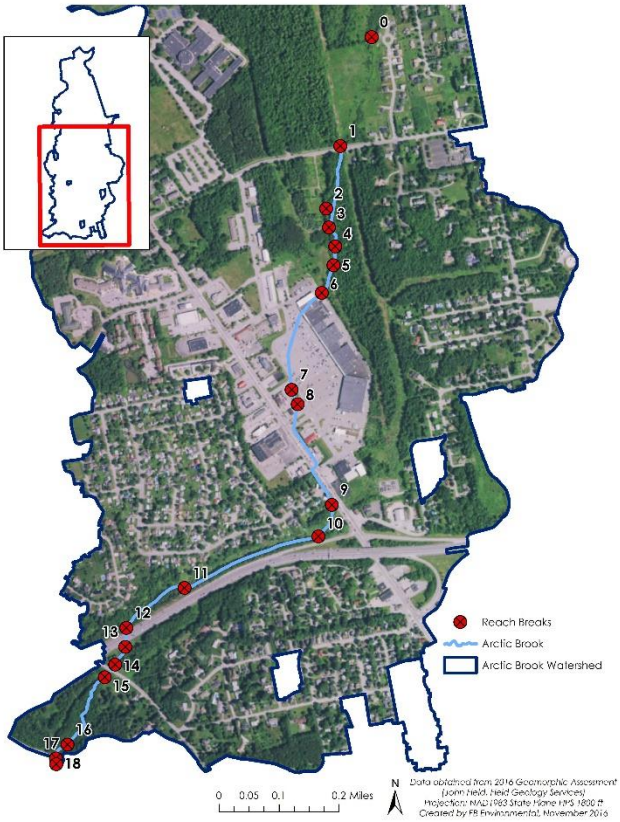
3.3.1 GEOMORPHIC ASSESSMENT

A fluvial geomorphic assessment of Arctic Brook was completed by Field Geology Services in December 2015 to determine the impact of urbanization on channel morphology and to prioritize sites for the restoration of habitat and channel stability. The major components of the assessment included: a historic assessment, reach delineation, a rapid geomorphic assessment, mapping of channel conditions, topographic surveying, and development of conceptual restoration options. Conceptual restoration options included a description of existing impacts and constraints, restoration concepts and intended results, a rough cost estimate, ease of completion (easy to very difficult) and priority (low to high) for eighteen distinct geomorphic reaches. Survey reaches were further prioritized by the Arctic Brook TAC.

Human activities in and around Arctic Brook including artificial channel straightening, armoring of the banks and sometimes bed of the channel, and fill placed on floodplains have resulted in channel instability and habitat degradation that is in part responsible for the brook failing to meet state water quality standards. Below are a few key points from the geomorphic assessment:

- Over 50% of Arctic Brook has been straightened (over 80% if culverted reaches are included), and more than 20% of the banks armored. Arctic Brook was moved for construction of interstate I-95.
- Long and undersized culverts, artificial fill placed on floodplains, bank and bed armor, and artificial channel straightening have largely prevented natural channel migration while increasing flow energy that has degraded aquatic habitat and increased channel instability downstream.
- Four of the 18 designated reaches are culverts and taken together have a total length of 2,146 ft,

Geomorphic Assessment: Reach Identification
Arctic Brook Watershed
Bangor, Maine



Arctic Brook reach delineation (adapted from: Field 2016)

A cascade at Arctic Brook. ***Photo Credit:*** *Field 2016.*

representing 26% of the channel length. This length does not include two shorter culverts at Grandview Avenue and Valley Avenue that were not designated as separate reaches. These culverts result in the absence of normal fluvial processes and morphological conditions within the culverts themselves (e.g., no floodplain, unnatural bottom and banks, no flow complexity), and disjoint the channel to a great degree such that the normal longitudinal passage of floodwaters, sediment, aquatic organisms and nutrients is greatly disrupted.

A straightened and armored reach of Arctic Brook parallel to I-95. ***Photo Credit****: Field 2016.*

Artificial step created by a chain-link fence and organic debris near I-95. ***Photo Credit:*** *Field 2016.*

- The placement of the brook in two long culverts in close proximity (one under the Broadway Shopping Center and the other under Broadway) represents a significant human alteration of the channel that could potentially be impacting channel stability and geomorphic function to this day.
- Bank erosion and bed scour immediately downstream of the Grandview Avenue culvert is evident and has created potential aquatic organism passage issues at the now perched culvert outlet.
- Depositional features are largely absent from Arctic Brook, and the hard pan bottom for long lengths of Reaches 2-6 suggests excess stream power is washing away sediment and organics. The lack of wood in these reaches reduces the channel's ability to retain channel bottom sediment and further suggests Reaches 2-6 are still adjusting to past channel straightening.
- The absence of high wood densities in Arctic Brook results in limited structure and roughness in the river channel that, in turn, reduces the amount of ecologically important sediment and organic matter in the channel (for spawning and food for macroinvertebrates, respectively).
- Restoration concepts need further development, but envision the removal of artificial constraints, day-lighting of long culverts, and the addition of wood structures to accelerate the processes of channel evolution that will lead to channel equilibrium and improved aquatic habitat.
- The use of boulder weirs in Reach 11 will provide habitat benefits and reductions in flow energy in a long section of Arctic Brook while maintaining the static channel condition and artificial constraints that must persist due to nearby infrastructure.

- Control of stormwater runoff from impervious surfaces in the watershed will be essential to ensure the long-term restoration of the watershed, but some of the in-stream restoration concepts identified will enable rapid improvements in channel stability and aquatic habitat while other more complex and costly projects in the channel and upland areas are advanced.

See Tables 3.4 on the following page for a summary and key characteristics of each evaluated reach and Table 3.5 for associated recommendations (p. 32).

Table 3.4. Summary characteristics of each reach evaluated in the 2016 geomorphic assessment. Table adapted from: Field 2016.

REACH #	LOCATION	CHANNEL TYPE	LENGTH (ft)	NOTES
1	Upstream of Grandview Avenue	Unconfined	1,063	Artificially straightened channel through former wetland
2	Downstream of Grandview Avenue	Unconfined	619	Meandering channel w/ pool-riffle sequences; best habitat on Arctic Brook
3	Downstream of Grandview Avenue	Unconfined	181	Channel has good width:depth ratio but much of the bed is hardpan
4	Downstream of Grandview Avenue	Unconfined	193	Good substrate and mostly stable despite minor incision
5	Upstream of Broadway Shopping Center	Partially confined	169	Confined by fill on one bank; some side channel formation
6	Upstream of Broadway Shopping Center	Unconfined	272	Most of reach is over steepened riffle due to deposition upstream of culvert
7	Underneath Broadway Shopping Center	Culvert	897	Long undersized culvert under Broadway Shopping Center w/ no substrate
8	Behind Governor's Restaurant	Confined	140	Armored channel taking in parking lot drainage; minimal habitat
9	Underneath Broadway	Culvert	936	Another long undersized culvert with no substrate under Broadway
10	Downstream of Broadway culvert outlet	Unconfined	328	Erosion into confining fill and creation of side channels
11	Flows along I-95 road grade	Confined	1,273	Confined by fill; armoring of bed and banks; minimal pool habitat
12	Upstream of I-95 culvert	Unconfined	663	Some space for meandering and adjustment to upstream confinement
13	Culvert underneath I-95	Culvert	168	Culvert underneath I-95 undersized at bankfull conditions but little to no substrate and uniform channel bottom creates shallow water during periods of low flow
14	In between 1-95 and Kenduskeag Avenue	Confined	182	Completely armored channel; backwatering behind wood caught on fence
15	Culvert underneath Kenduskeag Ave	Culvert	145	Steep riffle entering undersized culvert; deep pool at perched outlet
16	Downstream of Kenduskeag Avenue	Confined	726	Dynamic reach w/ coarse bed, significant erosion, bars, and flood chutes
17	Downstream of concrete weir in channel	Unconfined	167	More incised and straightened than upstream reach
18	Confluence with Kenduskeag Stream	Unconfined	51	Short aggrading reach as enters Kenduskeag Stream

Table 3.5. Restoration recommendations and associated priority and cost for all stream reaches evaluated in the 2016 geomorphic assessment. Adapted from Field 2016.

REACH #	LENGTH (ft)	EXISTING IMPACTS/CONSTRAINTS	RESTORATION CONCEPT	INTENDED RESULTS	EASE OF COMPLETION	PRIORITY	ROUGH COST ESTIMATE*
1	1,063	Straightening and armoring	Wood additions/armor removal	Recreate wetland and reform meanders	Easy	Moderate	$50,000-$100,000
2	619	Limited cover & upstream culvert	Wood additions/culvert replacement	Increase cover, trap sediment, and reduce scour at culvert	Moderate	Moderate	$25,000-$50,000 (wood additions) $125,000 (culvert replacement)
3	181	Limited cover & hardpan substrate	Wood additions	Increase cover and trap sediment	Easy	Low	$25,000-$30,000
4	193	Limited cover & hardpan substrate	Wood additions	Increase cover and trap sediment	Easy	Low	$25,000-$30,000
5	169	Limited cover and confinement by artificial fill on one bank	Wood additions and fill removal	Increase cover and floodplain access	Moderate	Low	$25,000-$30,000 (wood additions) $50,000-$100,000 (fill removal)
6	272	Limited cover & hardpan substrate	Wood additions	Increase cover and trap sediment	Easy	Low	$25,000-$30,000
7	897	Long undersized culvert	Reroute channel behind Broadway Shopping Center	Daylight culvert	Very difficult	High	$2-$5 million
8	140	Armored and confined	Reroute channel behind Broadway Shopping Center	More natural channel	Very difficult	High	Accrued benefit of Reach 7 restoration
9	936	Long undersized culvert	Reroute channel behind Broadway Shopping Center	Daylight most of culvert length	Very difficult	High	Accrued benefit of Reach 7 restoration
10	328	Armored and limited cover	Add wood and remove armor	Increase cover and promote planform changes	Easy	Low	$25,000-$30,000
11#	1,273	Armored and straightened	Construct boulder weirs and partial fill removal	Create pools and reduce downstream flow energy	Moderate	High	$150,000-$300,000 for full reach length
12	663	Limited cover and fence across channel	Wood additions and raise or remove fence	Increase cover & distribute sediment	Difficult (access)	Low	$25,000-$30,000 (wood additions)

REACH #	LENGTH (ft)	EXISTING IMPACTS/CONSTRAINTS	RESTORATION CONCEPT	INTENDED RESULTS	EASE OF COMPLETION	PRIORITY	ROUGH COST ESTIMATE*
				concentrated at fence			Unknown (fence replacement)
13	168	Limited substrate in undersized culvert	Add baffles on culvert bottom	Trap sediment to create natural substrate	Difficult	Moderate	$200,000-$300,000
14	182	Fence across channel and armor	Remove armor and raise or remove fence	Enable planform change and reduce ponding behind fence	Moderate	Moderate	$50,000-$100,000 (remove armor) Unknown (fence replacement)
15	145	Undersized culvert	Culvert replacement	Reduce scour downstream and ponding upstream	Moderate	Low	$250,000-$350,000
16	726	Limited cover	Wood additions	Increase cover	Easy	Low	$50,000-$100,000
17	167	Concrete weir in channel and armored bank	Remove weir and armor	Restore natural flow and riparian vegetation	Difficult (sewer line)	Low	$500,000-$1,000,000
18	51	Limited cover & upstream culvert	Wood additions/culvert replacement	Increase cover and reduce scour at culvert	Moderate	Low	$15,000-$20,000 (wood additions) $150,000 (culvert replacement)
							$3,765,000 - $7,875,000

** Costs assume restoration to be completed in given reach only with cost savings likely if multiple reaches restored simultaneously*

3.3.2 STREAM CORRIDOR SURVEY: CULVERT INVENTORY

A stream corridor survey (SCS) of Arctic Brook was conducted on June 30, 2016, by staff from FB Environmental, Ecological Instincts, and the City of Bangor. The survey team walked the entire length of stream from the headwaters near Labarca Lane to its terminal discharge into the Kenduskeag Stream. The team assessed all road crossings and unusual conditions in the stream channel.

At the time of the survey, there were a total of seven road crossings on Arctic Brook (Lupine Way, Grandview Avenue, Underneath Broadway Shopping Center, Broadway, I-95, Kenduskeag Avenue, and Valley Avenue). The culvert that runs under the Broadway Shopping Center accounts for approximately 13% of Arctic Brook's total stream length. (See full report on the City's webpage: Link will be added when available). The following provides key points and a brief summary of each of the seven crossings and the recommended actions to improve/maintain the crossings. Recommendations are aimed at improving flow, reducing erosion, and improving habitat connectivity.

(Above) the crossing at Labarca Lane and (Below) the Grandview Avenue culvert. ***Photo Credit:*** *FBE.*

- Lupine Way: Assessment of this culvert revealed that it was constructed properly at the stream grade, creating continuity in the stream channel. Vegetation frames the culvert, and no significant signs of erosion were present at the time of assessment.
- Grandview Avenue Crossing: The crossing at Grandview Avenue has a perched outlet with a large tailwater scour pool. High traffic volume on Grandview Avenue and a steep embankment makes this culvert at risk from erosion and road runoff. This culvert poses a significant barrier for the continuity of Arctic Brook to fish and other aquatic species from downstream to upstream. This site is an ideal candidate for a culvert replacement that has a natural stream bottom and is adequately sized for flow conditions (large tailwater scour pool indicates that it is currently undersized for flow conditions).
- Underneath Broadway Shopping Center: This culvert directs Arctic Brook underneath the BSC. A full assessment of this culvert was not performed as part of this survey because of access issues associated with the culvert length. Strictly because of its length, this culvert is a severe impediment to aquatic life passage and natural stream channel migration processes. A survey of this culvert was completed by the BSC in 2008. Recommended repairs and maintenance were completed at that time. The culvert was noted as structurally sound and in good working condition and no infiltration of groundwater was noted. Daylighting the stream could be considered one option for improving stream

conditions and habitat connectivity, yet the culvert also acts to insulate the stream and is most likely helping keep water temperatures low in the stream which benefits downstream aquatic life.

- Underneath Broadway Avenue: Arctic Brook daylights behind Governor's for approximately 200 feet before re-entering a corrugated metal culvert until it reaches a concrete structure at the corner of the main entrance of the BSC and Broadway Avenue. This culvert is of the same size and material (metal) as the culvert underneath the BSC and poses similar problems for the stream. From here, water is directed into a 72" (w) x 36" (h) box culvert which runs underneath Broadway Avenue to a structure located near Tim Hortons. From here, flow is split between two 42" diameter round concrete pipes which outlet just below Broadway Avenue by the I-95 before running parallel to the I-95. Theoretically, flow should be evenly split between the two concrete pipes, however, significant sediment buildup in the primary (or upstream right culvert) is redirecting flow to the secondary pipe. The stream has significant foam build-up and a foul odor at the outlet. Immediate attention should turn to the upstream source of this foam and foul odor. This may include water testing to determine the source of the foam. Invasive species at this site include purple loosestrife and Oriental bittersweet *(Celastrus orbiculatus).*
- I-95 Crossing: The culvert that runs underneath I-95 is a concrete box culvert with an 8.8 foot span and a 7.0 foot clearance. It is 153 feet in length and is flow-aligned with the stream channel (see Photo 12 above). Unfortunately, both the water depth and velocity do not match the stream channel, again posing a barrier for fish passage. Significant sand build-up has occurred in the culvert at the outlet and downstream of the culvert. This could be a result of either upstream stormwater runoff or most-likely, road sand runoff from the I-95 corridor. Invasive species at this site include purple loosestrife. This culvert would benefit from a natural bottom or internal structures to restore the depth and velocity of the stream.
- Kenduskeag Avenue Crossing: The crossing at Kenduskeag Avenue is through a 9 foot by 7 foot concrete box culvert. This culvert is 143 feet in length and has significant downstream armoring. This is the first site where the upstream and downstream substrate expand to include boulders as well as cobble and gravel previously seen upstream. Invasive species at this site include honeysuckle *(Lonicera sp.)* and glossy buckthorn *(Frangula alnus).* Steep embankments and retaining walls act as potential barriers for wildlife access to the stream.

Looking downstream from the Kenduskeag Avenue culvert. This is also a long-term monitoring site evidenced by the PVC stilling well in the right of the frame. ***Photo Credit:*** *Richard May, City of Bangor*

- Valley Avenue: The final road crossing occurs at Valley Avenue, slightly upstream from the discharge into the Kenduskeag Stream. This crossing has three culverts; the middle culvert is considered the primary culvert, and the two outside culverts secondary culverts. High traffic volume, fencing, and low water depth in the culvert all pose barriers to wildlife. Invasive species noted at this site include Japanese knotweed *(Fallopia japonica)*, multiflora rose, and Oriental bittersweet.

The three culvert outlets below Valley Avenue. ***Photo Credit:*** *FBE.*

3.3.3 STREAM CORRIDOR SURVEY: UNUSUAL CONDITION OBSERVATIONS

The SCS included documentation of any "unusual conditions" in the stream corridor within the channel or along the banks. Unusual conditions may include stormwater outfalls, areas of significant algae, invasive species, strange odors, or change in color of water, trash & debris, unusual wildlife observations, or other nonpoint source pollution. A GPS unit was used to document the location of these sites. Twenty-five individual sites were noted along the full 1.4 mile length of the stream and ranged from significant presence of invasive species to heavy foam, odors, and algae. Each site was scored based on Severity, Correctability, and Access (see Figure 3.5 on the following page).

Seven locations where the stream crosses the road were evaluated during the stream corridor survey. In general, culverts pose a significant threat to habitat connectivity in the stream channel. This is primarily due to both culvert length and water depth (e.g., BSC and Broadway Avenue culverts) and structural deficiencies (e.g., Grandview Avenue). Habitat connectivity is important for both larger fish species and smaller macroinvertebrate species. Many unusual conditions were documented during the survey and may serve as indicators of poor water quality. Major findings included significant algal growth, particularly between Grandview Avenue and the BSC, odors and foam below the Broadway culvert, and heavy armoring between Broadway and the I-95 corridor as well as between Kenduskeag and Valley Avenues. Unusual condition sites were distributed throughout the stream channel from the headwaters to the Kenduskeag

Stream (see Appendix A, Map 10). Unusual conditions sites were named starting with "A" upstream to "Y" downstream.

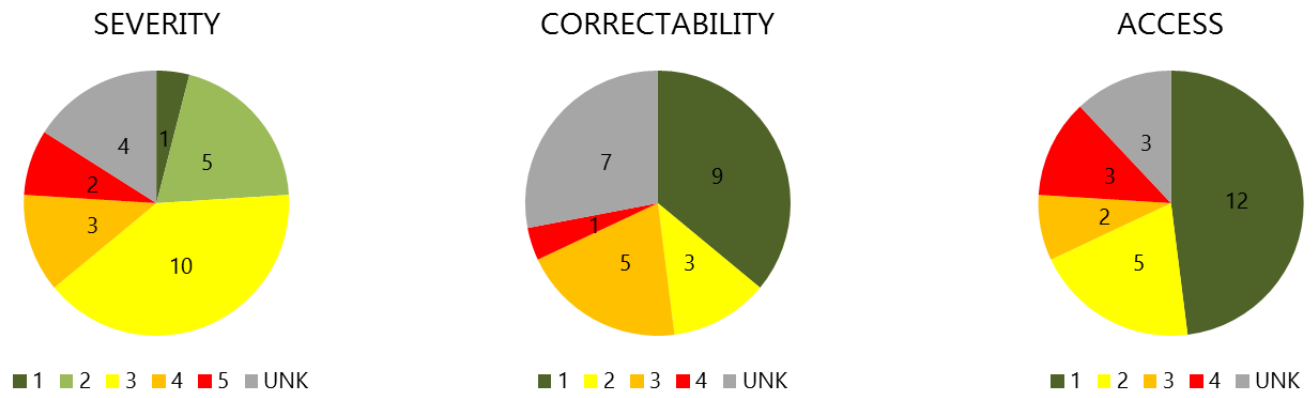


Figure 3.5. Overall scores of the 25 unusual condition sites documented as part of the stream corridor survey. Scores are as follows: Severity (1-minor; 5-severe), Correctability (1-easy; 4-difficult); and Access (1-easy; 4-difficult). UNK = Unknown.

3.4 ARCTIC BROOK STORMWATER RETROFIT SURVEY

A retrofit reconnaissance inventory (RRI) is a survey of both existing and new BMPs in the watershed that address stormwater runoff from impervious surfaces such as parking lots, buildings and driveways. BMPs are designed to address water quantity and quality, so that runoff is treated to remove pollutants or reduce flow velocity before it enters the stream.

Sixteen existing BMPs were on file at the City of Bangor. These sites were surveyed for condition, sizing, and placement in order to determine if the BMP was functioning as it was intended, or if it required maintenance or upgrading. All other parcels containing large areas of IC in the watershed were surveyed to identify sites that could support BMPs that would control stormwater and therefore, work towards improving the water quality of Arctic Brook. Currently, 16 BMPs are identified in the Arctic Brook watershed and a total of 41 sites were identified as posing an opportunity for BMP retrofits to reduce stormwater runoff.

The map on the following page (Figure 3.6) shows all sites identified in the 2016 RRI survey. This includes existing BMPs that are in good condition (green), existing BMPs that require maintenance or repair (yellow), and new opportunities for BMP implementation (red). Large areas of IC in the watershed are located around Broadway and the Broadway Shopping Center, therefore, the map provides a closer view of this area. The northern portion of Arctic Brook is primarily forested with low-density residential development. Forested areas naturally filter and slow the transport of runoff, so BMPs are not always necessary in these areas, though long-term protection of these undeveloped forested areas are important. Appropriate BMP installations minimize stormwater runoff at new development in this area.

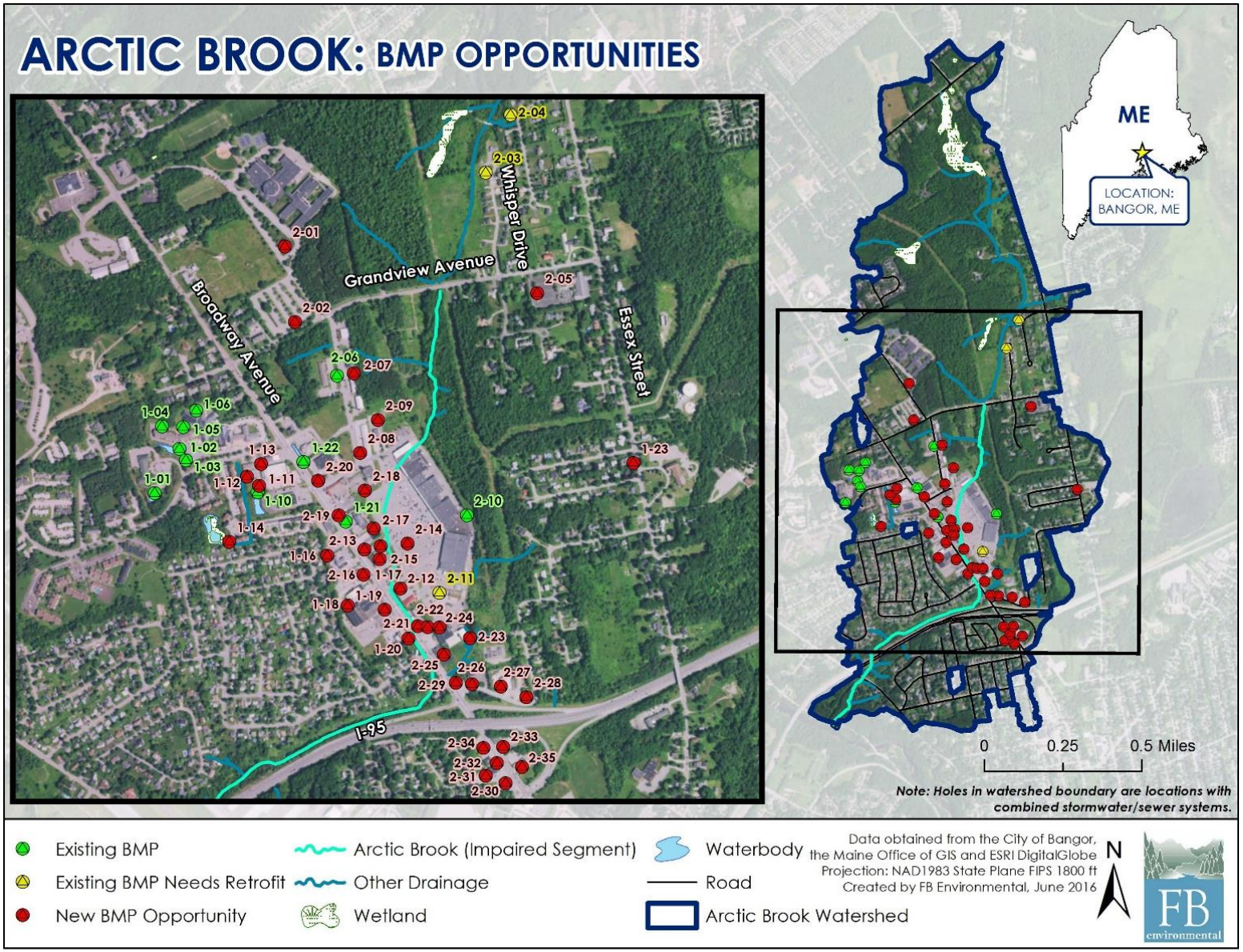


Figure 3.6. A map displaying both existing (green/yellow) and recommended (red) BMPs in the Arctic Brook watershed.

Results of the RRI survey were presented to the Arctic Brook TAC by FB Environmental (FBE). Each member was asked to rank the BMPs according to a set of criteria that were developed by FBE and refined by the TAC to reflect BMPs that were best suited to the watershed (Table 3.6). Scores were totaled and ranked from highest to lowest to determine the top twenty BMPs for implementation.

Table 3.6. Criteria used to prioritize recommended BMPs.

PRIORITIZATION CRITERIA				
INTENSITY OF USE High: 6 Medium: 4 Low: 2	**POLLUTANT REDUCTION** High: 6 Medium: 4 Low: 2 Very Low: 1	**MAINTENANCE** Low: 5 Moderate: 3 High: 1	**EASE OF IMPLEMENTATION** Easy: 3 Moderate: 2 Difficult: 1	**AWARENESS AND VISIBILITY** High: 2 Low: 1

While pollutant load reductions were calculated for all identified BMPs[5], cost estimates were only provided for the top 18 BMPs. These top 18 BMPs are recommended for implementation through the length of this plan. If the top 18 BMPs are implemented through this plan in conjunction with high priority in-stream recommendations, and non-structural measures, and Arctic Brook still is not meeting its Class B water quality designation, then it is recommended that the Steering Committee move forward with installing the additional 18 BMPs lower on the list of priorities as a starting point.

Table 3.7 lists the top 18 highest priority BMP retrofits identified during the RRI survey and the associated pollutant load reductions and cost estimates. Costs are estimated using literature figures, primarily through the UNH Stormwater Center in New Hampshire and are presented as ranges and may be subject to change over time as prices and technology change. Specific cost estimates can only be determined through a professional site evaluation.

[5] Calculated using the EPA Region 5 model.

Table 3.7. Pollutant load reductions and cost estimates for recommended BMP retrofits in the Arctic Brook watershed.

SITE INFORMATION					REGION 5: ESTIMATED LOAD REDUCTIONS (load reduction lbs/yr)			COST ESTIMATES	
PRIORITY	**SITE ID**	**LOCATION DESCRIPTION**	**LAND USE**	**RETROFIT DESCRIPTION**	**TSS**	**TN**	**P**	**Estimated IC Treated** (acres)	**COST RANGE**
1	**1-18**	Behind McDonald's (Near Dumpster)	Commercial	Underdrained Soil Filter	874	14.68	0.70	0.2	$25,000 - $30,000
2	**2-14b**	BSC Parking	Commercial	Underground Storage	5,099	52.93	4.21	7	$800,000 - $1,000,000
3	**1-19**	The Furniture Gallery Parking Area	Commercial	Pavement Reduction & Bioretention System	727	10.34	0.69	0.8	$60,000 - $70,000
4	**2-01**	Bangor High School	Commercial	Bioretention System	244	8.01	0.54	0.6	$50,000 - $60,000
5	**2-02**	Bangor High School - Lower Lot	Commercial	Series of Level Spreaders	3,413	U	3.32	3	$60,000 - $70,000
6	**2-13**	In Front of Amato's (North Entrance)	Highway	Flow through Treatment Swale	509	1.39	0.22	0.7	$20,000 - $30,000
7	**2-20**	Rite Aid Overflow Catch Basin	Commercial	Grassed Underdrained Soil Filter	190	2.71	0.18	0.2	$20,000 - $25,000
8	**1-16**	Behind Dairy Queen (Behind Building and Dumpster)	Commercial	Bioretention System	367	5.22	0.35	0.4	$15,000 - $25,000
9	**2-15**	Governor's Erosion into Stream	Commercial	Bioretention System	347	4.93	0.33	0.4	$15,000 - $25,000
10	**2-23**	Salvation Army Building	Commercial	Infiltration Basin	172	2.45	0.16	0.2	$10,000 - $20,000

SITE INFORMATION					REGION 5: ESTIMATED LOAD REDUCTIONS (load reduction lbs/yr)			COST ESTIMATES	
PRIORITY	**SITE ID**	**LOCATION DESCRIPTION**	**LAND USE**	**RETROFIT DESCRIPTION**	**TSS**	**TN**	**P**	**Estimated IC Treated** (acres)	**COST RANGE**
11	**2-18**	Grass Area at BSC behind Kelley Auto	Commercial	Increase Buffer & Raise Mow Height	na	na	na	0	na
12	**2-07**	Between Modern Screen Printing and Home Thrift Store	Commercial	Level Spreader	786	U	0.76	0.7	$3,000 - $5,000
13	**1-23**	First United Methodist Lawn/Green Space	Commercial	Bioretention System/Infiltration Basin	509	7.24	0.49	0.57	$50,000 - $60,000
14	**2-22**	Dorr Lobster Seafood Market Parking Area	Commercial	Remove Impervious Surface	UNK	UNK	UNK	0.06	$10,000 - $15,000
15	**2-33 / 2-35**	Broadway Avenue - UPS / Irving Circle K	Commercial	Vegetated Swale with Underdrain	427	1.17	0.18	0.06	$50,000 - $60,000
16	**2-08**	Family Dollar Hillside Ave	Commercial	Flow through Treatment Swale/Underground Storage	628	1.72	0.27	0.82	$15,000 - $25,000
17	**2-05**	Church of Latter Day Saints	Commercial	Aboveground or Underground Sand Filter	1,272	9.90	0.88	1.35	$90,000 - $120,000
18	**2-24**	Salvation Army Parking	Commercial	Bioretention System	145	2.07	0.14	0.2	$5,000 - $10,000
					15,707.7	**124.8**	**13.4**		**$1,298,000 - $1,650,000**

4 MANAGEMENT STRATEGIES

Watershed studies and community stakeholder involvement provide an excellent framework for identifying and understanding the sources of pollution and habitat impairment in the Arctic Brook watershed. This information has led to the development of locally-driven solutions, organized and prioritized in the action plan (Section 4.1.1 and 4.1.2). Successful restoration of the stream requires setting goals and developing objectives to help meet those goals. The following restoration plan provides key actions needed to restore the stream, the timing of these actions, and the mechanisms by which these actions will be accomplished.

4.1 GOALS AND OBJECTIVES FOR RESTORATION

The City of Bangor in coordination with the Arctic Brook TAC set the following goals for this WBMP:

- Provide sound management recommendations that will help Arctic Brook meet Class B water quality standards through improvement of aquatic habitat and water quality of the stream. Protect the stream and its tributaries from current and future impacts.
- Reduce the effects of IC in the watershed by focusing efforts on stormwater retrofits within the high-density commercial development along Broadway.
- Improve in-stream habitat through strategic restoration of impacted stream reaches including replacing high priority sites identified in the stream corridor survey and fluvial geomorphic assessment.
- Build upon existing community support to raise awareness about Arctic Brook by working with key landowners including the Broadway Shopping Center and commercial property owners in the Broadway Corridor, Bangor High School and Maine DOT.

These ambitious goals can only be achieved with the commitment of a coordinated group of local community leaders, conservation groups, state and federal partners, and citizens of the watershed working together to accomplish common goals and objectives.

4.1.1 ACTION PLAN TO PROTECT AND RESTORE WATER QUALITY AND HABITAT

Actions are needed to address the major environmental stressors in Arctic Brook (chloride, geomorphology and hydrology, nutrients, and stream habitat). Table 4.1 provides a list of these actions from high to low priority.

The two major categories for stream restoration include structural and non-structural BMPs. Structural BMPs are those that involve construction, installation, or other physical changes to the built environment or landscape. Typically, structural BMPs focus on reduction or treatment of stormwater by redirecting piped stormwater drainage to engineered soil and/or vegetative filter systems or natural vegetated areas, pervious pavement, or detention or retention ponds. Non-structural BMPs are those which involve operational changes, such as allowing natural vegetation to grow along stream banks rather than aggressively mowing, reducing fertilizer application, optimizing de-icing procedures to use the minimum amount of salt necessary, relocating snow dumps to less sensitive areas, regular street sweeping, and

maintaining existing stormwater treatment systems. A combination of structural and non-structural BMPs is usually the most effective and both will be needed to restore Arctic Brook.

Example of a functioning existing BMP; an infiltration swale located along Broadway in front of the former People's United Bank. ***Photo Credit:*** *FBE.*

4.1.2 ACTIONS TO RAISE PUBLIC AWARENESS AND COMMUNITY SUPPORT

Public awareness and support are critical to Arctic Brook's restoration and protection. Due to the presence of Bangor High School as well as many high-density residential neighborhoods in the watershed, there is ample opportunity to draw on community support.

This WBMP provides action items to use for building and maintaining this support over time. Table 4.1 on the next page lists recommendations, potential partners, timeframes, and costs for action items that raise public awareness and community support. Often, these action items are intimately linked with the success of structural BMPs (i.e. outreach to reduce chloride application) and thus, are included in the same action table.

Education & Outreach action items will promote awareness of the connection between land use, water quality, and stream health. Therefore, efforts should focus on engaging community groups, commercial businesses, city, state and private maintenance crews, residents, and school groups.

Administrative & Funding action items are a vital part of bringing both structural and non-structural BMP recommendations to fruition. Obtaining additional funding should be a high priority throughout plan implementation. The City's Stormwater Utility will help with implementing the action plan, but will not be enough to complete all of the work required. Therefore, the City and its partners should be aware of and apply for funding opportunities as they arise.

Table 4.1. Action plan for the Arctic Brook watershed. Action items include reference to implementations recommended through the Fluvial Geomorphic Assessment and the Retrofit Reconnaissance Inventory. Details of these recommendations with associated itemized costs can be found in tables 3.5 and 3.7, respectively.

ACTION	HOW	WHO	WHEN	COST
CHLORIDE **GOAL:** Reduce chloride toxicity to the stream while maintaining safe roadways				
Understand the extent of salt use in the watershed	Using either surveys or targeted landowner visits, obtain information regarding snow management on private property.	City of Bangor	2017 - 2020	In House
Promote reduced salt application in hotspots	Work with commercial landowners to identify minimally used parking areas that can be closed during winter months (January - April).	City of Bangor/Commercial Landowners	2017 - 2020	In House
	Create a list of local contractors and businesses applying salt. Initiate conversation with DOT regarding I-95 salt application.	City of Bangor/Commercial Landowners	2017	In House
	Ensure that snow storage is located/contained on impervious areas set back from water resources, to reduce infiltration into groundwater. Encourage recycling of meltwater for pre-wetting if possible.	City of Bangor/Commercial Landowners	Ongoing	In House
Encourage equipment calibration and proper application rates	Ensure that contractors and the City Public Works Department are properly calibrating their instruments and applying brining and pre-wetting techniques when needed.	City of Bangor/Public Works Department	2017 - 2020	In House
Promote use of heated sidewalks	Provide Stormwater Utility Credits and outreach for new (or existing) businesses with heated sidewalks.	City of Bangor	Incentivize by 2020/ Ongoing	In House
Encourage maintenance of stormwater system infrastructure.	Follow-up with commercial landowners on maintenance of their stormwater infrastructure to identify areas lacking structural integrity and/or groundwater - stormwater exchange. Make sure any identified problems are corrected.	City of Bangor/Commercial Landowners	Inspection/certification of BMPs every five years (per City ordinance)	Included in Current Practices

ACTION	HOW	WHO	WHEN	COST
Infiltrate roof runoff to dilute chloride in groundwater	Work with commercial landowners to infiltrate roof runoff into the groundwater to dilute the chloride contaminating groundwater.	City of Bangor/Commercial Landowners	Ongoing	TBD
GEOMORPHOLOGY & FLOW VOLUME **GOAL:** Stabilize flow volumes				
Implement priority recommendations from the 2016 Geomorphic Assessment Report	See Table 3.5 for a prioritized list of geomorphic recommendations from the 2016 assessment.	City of Bangor Engineering Department	2017 – 2020 (Prioritize recommendations addressing volume control/floodplain restoration)	$3,765,000 - $7,875,000 (see Table 3.5)
Replace and/or repair failing culverts	Prioritize the perched Grandview Avenue culvert for replacement to improve connectivity for both flow and aquatic life. See Section 3.3.2 for additional culvert improvements and prioritize these sites for improved stream habitat and flow.	City of Bangor/Maine DOT	By 2020	Cost included in Table 3.5 (see above)
	Evaluate fish passage at Kenduskeag Avenue (through both culvert replacement or modifications and downstream riprap repair).			
	Begin conversation with Maine DOT to improve I-95 culvert to reduce impact to the stream (i.e. increase depth and bottom substrate to accommodate fish passage).			
Identify sections with poor flow conditions	Using continuous monitoring and visual observation, note sections of the stream that experience extreme high and/or low flows that inhibit aquatic life survival.	City of Bangor/Consultants	Ongoing	See Monitoring
NUTRIENTS **GOAL:** Reduce effective IC contributing nutrient inputs to the stream				
Implement stormwater infiltration and treatment retrofits	See the Structural Retrofit Prioritization Table (p. 40-41) for the top 18 prioritized BMP retrofit opportunities. Create annual goals for implementation.	City of Bangor	Implement top 18 by 2027	$1,383,000 - $1,765,000 (see Table 3.7)

ACTION	HOW	WHO	WHEN	COST
	Following the completion of this WBMP and the implementation of the top 18 BMPs, re-assess water quality at Arctic Brook and consult the list of additional retrofit opportunities available, if further restoration is needed to meet attainment. See Appendix 3 for full list of identified retrofits.	City of Bangor/Consultants	2027	TBD
Reduce impervious cover	Where possible, reduce impervious cover. Encourage green infrastructure for new development with reduced impervious cover.	City of Bangor	Ongoing	In House
Create a Nutrient Management Plan	Provide recognition and/or awards and demonstration sites to promote nutrient management. Target large landowners in the watershed (i.e. schools, commercial businesses).	City of Bangor	Develop by 2018	In House
IN-STREAM HABITAT **GOAL**: Improve in-stream habitat for aquatic life				
Implement recommendations from the 2016 Geomorphic Assessment and Stream Corridor Survey	Carry out recommendations in the 2016 Geomorphic Assessment and Stream Corridor Survey to address priority channel alteration, in-stream habitat, soil erosion, buffer, yard waste, and invasive species issues in and around Arctic Brook.	City of Bangor (with help from consultants)	2017 – 2020 (Prioritize recommendations addressing volume control/floodplain restoration)	See Table 3.5
Extend shoreland zoning to protect small streams	Consider requiring shoreland zoning for first order streams in the City.	City of Bangor	2017 - 2027	In House**
Remove fish barriers	See section "Geomorphology & Flow Volume" to address barriers to fish within the stream.	City of Bangor, Consultants, Maine DIFW, Maine DOT	2017 - 2021	Costs included in Table 3-10
EDUCATION & OUTREACH **GOAL:** Raise public awareness and community support				
Educate landowners on chloride and aquatic toxicity.	Target outreach to landowners in areas with known chloride hotspots to examine salt use and BMP adjustments (i.e. seasonal valve on BMPs to limit stormwater access to infiltration BMPs).	City of Bangor/BASWG	2017 - 2020	In House**

ACTION	HOW	WHO	WHEN	COST
	Identify "reduced salt" areas and encourage proper application rates and/or "reduced salt" signage. Goal: Install five signs, one per year for first five years.	City of Bangor/BASWG	2017 - 2021	$1,250 - $2,000
	Encourage citizens and school groups to "Adopt" a segment of stream or portion of the watershed to keep clean.	City of Bangor/BASWG	2017 – 2027	In House**
Empower residents with information on residential BMPs that reduce sediment erosion and nutrient input to the stream.	Specifically, raise awareness with regard to fertilizer and pesticide application and disposal of lawn waste. Encourage residents to use stream-friendly landscaping practices. Conduct a fertilizer survey in the watershed to determine what portion of residential lawns are fertilized and by how much annually.	City of Bangor	Ongoing	$5,000 - $7,500
	Target neighborhood gatherings focusing on one residential neighborhood each year for the first five years of plan implementation.	City of Bangor/Residential Neighborhoods	2017 - 2021	$1,250 - $2,000
Educate City staff on maintenance needs.	Educate staff regarding the connection between maintenance and water quality.	City of Bangor	Annually	In House**
ADMINISTRATION & FUNDING **GOAL**: Maintain a consistent funding mechanism and City support for project implementation				
Maintain a consistent funding mechanism	Develop a city-wide funding plan for impaired streams that incorporates funding for Arctic Brook.	City of Bangor	Ongoing/Current	In House
	Apply for state and federal grants and/or seek other funding to support implementation of planning recommendations.			
Maintain a working relationship with private landowners for funding support and implementation	Coordinate with private landowners regarding BMP implementation on their property.	City of Bangor	2017- 2027	NA

ACTION	HOW	WHO	WHEN	COST
Ensure that there is sufficient support to enact the plan	Host an annual meeting to ensure support for Arctic Brook.	City of Bangor	2017/annually	In House**
	Develop an annual work plan by anniversary date of approved WBMP.			
	Implement programs, enforce ordinances, oversee construction, implement BMPs, and educational programs.			
Prioritize restoration	Prioritize stressors to surface water quality by reach to focus restoration efforts.	City of Bangor/Stakeholders	2017	In House
Ensure that there is sufficient organizational structure to enact plan	Adopt the Arctic Brook Watershed-Based Management Plan.	City of Bangor	2017	NA
Strategize plan for use of stormwater utility fee funding	Create a roadmap to identify the best ways to apply the stormwater utility fee monies and ensure public awareness of stormwater mitigation through these funds. Create annual goals and revisit/re-evaluate each year.	City of Bangor	2017 and revisit annually	In House
MAINTENANCE **GOAL:** Maintain existing and newly installed infrastructure to maintain benefit of structural implementations				
Re-evaluate the City's existing maintenance schedule	Work with Public Works to continue ongoing maintenance of catch basins, culverts, and ditches.	City of Bangor	Inspected every two years and cleaned if sump is > 50% filled with sediment	In House**
Re-assess and make improvements to City salt/sand spreading and storage	Work with Public Works to limit winter sand/salt spreading on City-maintained road surfaces.	City of Bangor	2012 - 2027	In House
	Ensure winter sand/salt is properly stored.			
Review record of annual municipal maintenance practices	Hire third party consultant to review record of annual municipal maintenance	City of Bangor (with help from consultants)	2017-2027	$2,500 - $5,000**

ACTION	HOW	WHO	WHEN	COST
	practices developed and maintained by the City.			
	Continue to review annual maintenance plans submitted under the Chapter 268 Stormwater Maintenance ordinance.	City of Bangor	Ongoing/Increased Effort	In House
Inventory and encourage increased frequency of street sweeping	Identify current street sweeping practices at commercial businesses and encourage increased sweeping if needed.	City of Bangor, Businesses, Maine DOT	2017 - 2027	In House
	Continue annual street sweeping ASAP in spring on City/DOT maintained roadways and increase in areas of high sediment accumulation. Increase frequency as needed.			
LAND USE PLANNING & CONSERVATION **GOAL:** Increase the amount of land in permanent conservation				
Increase the amount of land in permanent conservation	Work with the Bangor Land Trust to expand the amount of land currently held in conservation, when opportunities arise, specifically in the headwaters, where large tracts of forested land are still in place.	BLT (with help from City of Bangor)	2017-2027	$20,000 - $40,000
Incorporate the Arctic Brook Action Plan into the City Comprehensive Plan	Ensure that the Arctic Brook Action Plan is incorporated into the next City Comprehensive Plan (last updated in 2012).	City of Bangor	2022	In House
MONITORING **GOAL:** Monitor water quality of Arctic Brook to identify success of plan				
Continue water quality monitoring	Continue current water quality monitoring for chloride and specific conductivity to quantify the level of chloride toxicity on aquatic life in melt water, stormflow, and summer baseflow. (Cost estimate includes continuous monitoring at established site and annual grab samples).	City of Bangor (with help from consultants)	Ongoing	$5,000 - $7,500/yr.

ACTION	HOW	WHO	WHEN	COST
Continue flow monitoring efforts	Continue monitoring stage height using pressure transducers at the established site below Kenduskeag Avenue. As needed, conduct flow monitoring to improve the stage-discharge relationship for Arctic Brook. (Cost estimate for two sites.)	City of Bangor (with help from consultants)	2017 - 2027	$2,500 - $5,000/yr.
	Add an additional monitoring site below Grandview Avenue to identify any seasonally dry periods in the headwaters. (Cost estimate for one additional site).	City of Bangor (with help from consultants)	2017	$5,000 - $7,500/yr.

4.2 POLLUTANT REMOVAL AND STORMWATER FLOW REDUCTION

A pollutant loading analysis was conducted for Arctic Brook by FB Environmental to estimate the load reductions that could be achieved in the stream by installing the 37 recommended BMPs from the RRI survey. Estimated pollutant load reductions are for total suspended sediments (TSS), total phosphorus (TP), and total nitrogen (TN) (Table 4.2).[6] Retrofits to existing infrastructure (such as updating wet ponds) are not included in this analysis as further engineering design is needed to estimate pollutant load reductions. Caution should be used when interpreting the modeled pollutant loading values, as these values may change with a more thorough site-specific evaluation of runoff and soil infiltration rates by a qualified engineering firm.

Table 4.2. Estimated load reductions for existing and proposed retrofit opportunities in the Arctic Brook watershed. Retrofits include: (1) functioning existing BMPs, (2) possible load reduction with maintenance to existing BMPs, (3) the top 18 high priority proposed BMP retrofits, and (4) the additional 19 retrofit opportunities identified in the 2016 survey.

	ESTIMATED LOAD REDUCTION (lbs/yr)*		
CATEGORY	**TSS**	**TN**	**TP**
Functioning Existing BMPs**	5,224.8	57.1	4.3
Maintenance to Non-functioning Existing BMPs+	81.3	1.2	0.1
Top 18 BMPs (Implemented in this WBMP)	15,707.7	124.8	13.4
Additional 19 BMPs	1,875.3	14.2	1.5
TOTAL:	**22,889.1**	**197,3**	**19.3**

**Estimated using the EPA Region 5 Model*
***Note only existing BMPs that are functioning properly were included in this estimate.*
+ Does not include BMPs at Whisper Drive or Lupine Way because these have not been constructed.

Additionally, it is important to note that pollutant reduction does not highlight the benefit of structural BMP implementation projects that reduce the volume of stormwater. Reducing the volume of stormwater via infiltration or storage both reduces the physical pressure on the stream channel from pulse flow events as well as by providing treatment of the water by slowing the water down, allowing sediments to settle out, and possibly adsorbing pollutants to soil particles. Infiltration of water with low chloride concentration (ex. roof runoff) can help dilute the contaminated groundwater. Therefore, it is imperative that both treatment and flow reduction be a valued part of the conversation regarding BMP implementation. This was considered during the TAC prioritization of retrofits, found in Section 3.4. Table 4.3 on the following page highlights the potential effective IC that could be disconnected from the stream with the implementation of BMPs in the watershed. While this still does not directly address flow, it is a measure of progress towards reducing the amount of stormwater that can enter the stream.

[6] Each BMP was evaluated using the Region 5 model and was assigned pollutant load reduction numbers.

Table 4.3. Effective IC reductions from existing and recommended BMPs.

CATEGORY	TOTAL DISCONNECTED IC AREA (post-development) (acres)	EFFECTIVE IC REDUCTION (post development) (%)
Functioning Existing BMPs	20.5	4.9
Maintenance to Non-functioning Existing BMPs*	0.01	<1
Top 18 BMPs (implemented in this WBMP)	13.0	7.3
Additional 19 BMPs	*1.9*	*1.1*
TOTAL:**	**35.4**	**13.7**

**Does not include BMPs at Whisper Drive or Lupine Way because these have not been constructed.*
***Total represents the acres of disconnected IC and the percent IC reduction accounting for all existing BMPs (functioning and non-functioning) and all recommended BMPs.*

Open space in front of the Broadway Shopping Center as an example of space potentially available for treating parking lot runoff. ***Photo Credit:*** *FBE.*

5 PLAN IMPLEMENTATION

5.1 PLAN OVERSIGHT AND ADOPTION

It is the recommendation of this plan that a Steering Committee be formed to administer the Arctic Brook WBMP. The City of Bangor will take a lead role in convening the group and serve on the committee. Other stakeholders including elected officials, business owners, Maine DOT and other interested groups such as Bangor High School and the Bangor Land Trust will also be involved. The Committee will meet annually to provide periodic updates to the plan, track and record progress made toward restoration, maintain and sustain action items, and make the plan relevant on an ongoing basis by adding new tasks as needed. The Committee should track achievements, press coverage, outreach activities, number of retrofits sites repaired, number of volunteers, and amount of funding received.

City staff meeting with Bangor High School representatives to discuss retrofit opportunities for the parking lot. ***Photo Credit:*** *Ecological Instincts.*

The plan may take 10 years or more to implement, depending on funding sources and availability. Sustainable funding, a good administrative process, and cooperation by partners and landowners are all variables that will lead to the success of the plan. If Arctic Brook meets Class B water quality standards before implementation of recommended actions are complete, then the goal of the plan has been met.

Developing a funding plan, which garners the approval of the community, is essential to success. A community restoration effort should include the collaboration and support of the entire community, including local businesses and property owners, community groups, conservation groups, corporate sponsors, and municipalities. In some cases, it may be possible to attain additional state or federal grants to help implement the plan. Broad community support is a major strength when applying for such funding. Adoption of the WBMP by the City is highly recommended to help raise local awareness about the need for restoration efforts and to garner support needed to implement various aspects of the plan.

5.2 ESTIMATED COSTS AND TECHNICAL ASSISTANCE NEEDED

The cost of successfully implementing the Arctic Brook WBMP is estimated at approximately $5,243,000 - $9,831,500 or approximately $524,300 - $983,150 per year over the course of the next 10 years (2017 – 2027) based on the recommended actions in Section 4.1. This includes structural BMPs, non-structural BMPs (Section 4.1), and monitoring efforts (discussed further in Section 6.2). This general 'best guess' estimate is based on the following assumptions in Table 5.1.

Table 5.1. Estimated costs for implementing the 2016 Arctic Brook WBMP.

10-YEAR COST ESTIMATE FOR RESTORING ARCTIC BROOK (2017 – 2027)			
	Category	**Estimated Annual Costs**	**10-year Total**
STRUCTURAL BMPS			
	Stream Corridor Restoration	$376,500 – $787,500	$3,765,000 - $7,875,000
	Structural Retrofit Sites	$129,800 – 165,000	$1,298,000 - $1,650,000
	Retrofit Maintenance	$5,000 - $10,000	$50,000 - $100,000
NON-STRUCTURAL BMPS			
	Administrative & Funding	In House	In House
	Education & Outreach	$750 - $1,150	$7,500 - $11,500
	Municipal Maintenance	$250 - $500	$2,500 - $5,000
	Land Use Planning and Conservation	$2,000 - $4,000	$20,000 - $40,000
MONITORING PROGRAM			
	Monitoring	$10,000 - $15,000	$100,000 - $150,000
GRAND TOTAL (10-YR)		**$524,300 - $983,150**	**$5,243,000 - $9,831,500**

The City's Stormwater Utility Fund will be an excellent resource for funding a portion of the restoration activities over the next 10 years. Stormwater utility funds are designated only for stormwater related uses. Most of these funds go towards maintenance, pollution prevention and installation of BMPs. Because of the number of impaired streams in the City, it is difficult to fund projects to restore each of them simultaneously. Additional funding through grants and partnerships with landowners can help to bridge this gap, but will likely be insufficient to fund action plans in this and other WMPs. Additional funding will be needed from state and federal grants, and private investments including local businesses and property owners, community groups, conservation groups, and corporate sponsors. The City of Bangor will take the lead on seeking funding from outside sources, coordinating with landowners on cost-share opportunities, and contributing funding from the Stormwater Utility.

Education & Outreach: Education and Outreach for the current MS4 permit focuses on BMPs for lawn and garden maintenance by homeowners aged 30-55 in the MS4. Due to the elevated chloride in the Arctic Brook watershed, the City will direct education & outreach towards chloride reduction in the watershed. Additionally, the City supports any state-wide efforts to address liability concerns with reduced salt use, similar to the NH Green SnowPro program.

Stormwater Retrofits & In-Stream Restoration: State and federal agencies, such as the Maine DEP, Maine DOT, and USEPA, offer competitive grant programs to implement high-priority stormwater retrofits in the watershed and in-stream restoration efforts, as well as select education and outreach activities. See Section 6.1 "Maintaining a Funding Mechanism" for grant opportunities to implement stormwater retrofits.

Municipal Maintenance: Actions such as culvert repair, enhanced storm drain cleanout, and street sweeping programs, as well as ordinance revisions, should be supported by both municipalities. Other funding sources, such as local planning grants, may help supplement these projects.

Land Use Planning & Conservation: Conserving undeveloped land in the Arctic Brook watershed supports the goal of reducing the effects of IC in the watershed, and is of great importance for protecting habitat in the upper watershed. The City should work closely with the Bangor Land Trust to obtain additional land for conservation with a particular focus on large tracts of forest and land

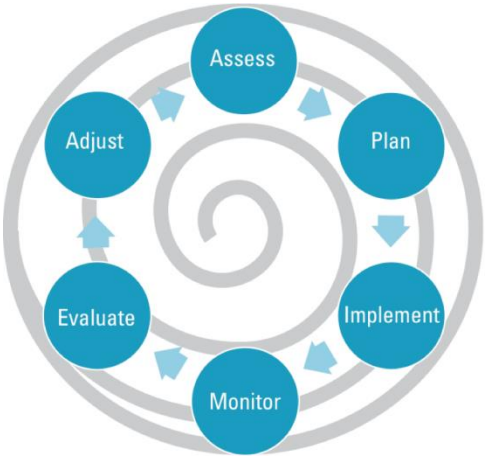
adjacent to wetlands (if available). Long-term land conservation efforts will need the support of local conservation groups, conservation enthusiasts, and individual donors to prevent poorly-planned development and on-going degradation of water quality in the watershed. Options such as obtaining easements within the riparian areas on the stream should be considered in lieu of outright purchase. Utilizing conserved lands for public trail systems and education kiosks are a good way to educate the public about watershed restoration efforts.

Monitoring and Assessment: Future monitoring and assessment efforts will require a variety of funding sources, including the City of Bangor, and private foundation grants.

6 METHODOLOGY FOR MEASURING SUCCESS

While this plan provides specific goals and key actions needed to restore Arctic Brook, it is inevitable that new information, technology, and techniques will be learned and developed in the years to come that may change the priorities of identified goals and actions. Therefore, the goals and priority of actions identified in this plan should be revisited and revised on an annual basis using an adaptive management approach.

6.1 ADAPTIVE MANAGEMENT APPROACH



An adaptive management approach is widely recommended for restoring urban watersheds. Adaptive management enables stakeholders to conduct restoration activities in an iterative manner. This provides opportunities for utilizing available resources efficiently through BMP performance testing and restoration monitoring activities. Stakeholders can evaluate the effectiveness of one set of restoration actions and either adopt or modify them before implementing effective measures in the next round of restoration activities. The adaptive management approach recognizes that the entire watershed cannot be restored with a single restoration action or within a short-time frame (e.g., 2 years). Rather, adaptive management establishes an ongoing program that provides adequate funding, stakeholder guidance, and an efficient coordination of restoration activities. Implementation of this approach will ensure that required restoration actions are implemented and that Arctic Brook is monitored to document restoration over an extended period.

The adaptive management components of the Arctic Brook WBMP will include:

- CREATING AN ORGANIZATIONAL STRUCTURE FOR IMPLEMENTATION- Since watershed restoration will require a considerable effort, key personnel and elected officials from the City of Bangor should be officially appointed and be responsible for leading the Arctic Brook Steering Committee, which will be formed to administer the Arctic Brook WBMP. Other stakeholders including business owners, residents, state and federal partners, and other interested community groups will also be involved.
- MAINTAINING A FUNDING MECHANISM- The following list summarizes six possible outside funding options available to the Arctic Brook restoration project. A combination of grant funding, private donations, and municipal funding must be used to ensure completion of the plan.

  US EPA/Maine DEP 319 Grants – This nonpoint source (NPS) grant is designed to assist municipalities with restoring waters named as NPS Priority Watersheds and are available for the implementation of watershed-based management plans.
  http://www.maine.gov/dep/water/grants/319.html

  US EPA Urban Waters Small Grants - The Urban Waters Small Grants program helps local residents and their organizations, particularly those in underserved communities, restore their urban waters in ways that also benefit community and economic revitalization. Grants are

awarded every two years, with individual award amounts of up to $60,000.
https://www.epa.gov/urbanwaters/urban-waters-small-grants

Five Star and Urban Waters Grants – Projects seek to address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from stormwater runoff, and degraded shorelines caused by development. Grants are awarded annually and range from $20,000 to $50,000 with an average size of $30,000.
http://www.nfwf.org/fivestar/Pages/home.aspx

Clean Water Bond – Maine voters approved the Clean Water Bond in November 2012. Of the $10 million bond, $5.4 million will be used to upgrade stream crossings and culverts to help reconnect habitat for fish and other wildlife.
http://www.maine.gov/dep/land/water_bond_rfp.html

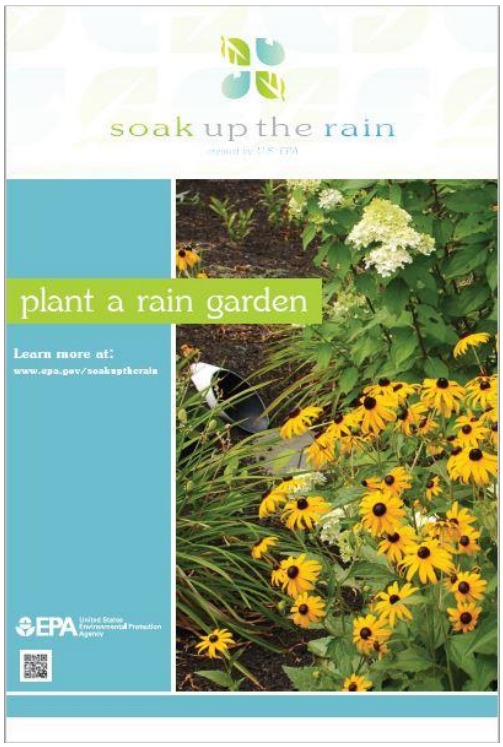
Maine Coastal Program Grants – Municipalities and regional organizations in Maine's coastal zone are eligible to apply for small grants that provide funds for projects designed to improve water quality, increase resiliency and adaptation to erosion and flooding, conserve coastal habitat, promote sustainable development, and enhance the coastal-dependent economy while preserving natural coastal resources. In Fiscal Year 2016, $250,000 was awarded to eleven projects ranging from $5,000 - $48,000.
http://www.maine.gov/dacf/municipalplanning/index.shtml

Compensation Fee Utilization Plan – The Stormwater Management Law authorizes the DEP to accept a compensation fee in lieu of meeting all or part of water quality standards, and Chapter 500, Section 6, establishes compensation fee requirements for projects located in the watersheds of urban impaired streams. Bangor has an established CFUP that should be used to mitigate stormwater runoff.

Stormwater Utility Fee - The City of Bangor has an established stormwater utility fee to generate revenue towards mitigating the effects of development on downstream water quality. The City should create a roadmap to identify the best ways to use this money and to inform the public on mitigation projects. The City should create annual goals and re-evaluate the efficacy of these goals each year.

- DETERMINING RESTORATION ACTIONS- This plan provides a unified watershed restoration strategy with prioritized recommendations for restoration using a variety of methods, including structural, non-structural, in-stream, and riparian restoration actions. The City of Bangor should use the proposed designs in this Plan as a starting point for current proposal writing and additional engineering for actual retrofit designs.
- IMPROVING THE COMMUNITY PARTICIPATION PROCESS- Implementation of this plan will require ongoing community outreach efforts to involve more stakeholders, both in the watershed and in the larger community. A sustained public awareness and outreach campaign is essential to secure the long-term community support that will be necessary to successfully implement this project. Much of the success of implementing the recommendations will be contingent on landowner cooperation. The US EPA has developed an excellent stormwater outreach program, Soak Up the Rain, which is intended to help municipalities educate the community about the effects of stormwater and ways to eliminate the

volume of water (i.e. "soak up") reaching the stream channel. Their website offers customizable tools and program material. https://www.epa.gov/soakuptherain



- DEVELOPING A FIELD MONITORING PROGRAM- A field monitoring program is necessary to track the anticipated improvements to aquatic health within the Arctic Brook watershed as restoration actions are implemented. The monitoring program will provide feedback on the effectiveness of restoration practices at the catchment and/or subwatershed level, and will support optimization of restoration actions through an adaptive management approach. See Section 6.2, below, for details of the recommended monitoring plan.
- ESTABLISHING MEASURABLE MILESTONES- A restoration schedule that includes milestones for measuring the implementation of restoration actions and monitoring activities in the Arctic Brook watershed is critically important. Once the level of funding has been established to determine the extent of recommended action strategies that can be implemented each year, a detailed schedule featuring iterative implementation and monitoring activities should be developed. Refer to Section 6.3 for more details.

6.2 MONITORING PROGRAM

An overall goal of the ambient monitoring program is to track the improvement of the watershed's overall aquatic health over time. A representative set of aquatic health indicators should be measured and interpreted on a predetermined timeframe (Maine DEP collects data every 5 years). The set of aquatic health indicators should include characteristics that have been degraded by the urbanization of the Arctic Brook watershed. Measuring these characteristics each year will support accurate assessment of the success of restoration actions. The ambient monitoring program should include the following components:

HYDROLOGY

- Continue to conduct flow measurements during both high and low flows at the established long-term stage monitoring site (Site AB01) to create a stage-discharge rating curve to calculate discharge. Link local precipitation data to stage height data for more accurate interpretation of stage height results.
- Add continuous monitoring at Site AB05 below Grandview Avenue for stage height/flow. Visual observation has indicated that this portion of the stream may experience no flow conditions during long periods without precipitation. Monitoring at Site AB05 would identify periods of no flow that could be stressors to macroinvertebrates and other aquatic life.

WATER QUALITY

- Conduct consistent annual monitoring at a few targeted sites rather than irregular measurements across multiple sites.

- Conduct ongoing continuous monitoring at Site AB01 for stage height, temperature, and dissolved oxygen.
- Add continuous monitoring at Site AB05 below Grandview Avenue for dissolved oxygen, temperature, (and stage height, mentioned above). Despite visually having good condition, this site had poor macroinvertebrate richness and diversity in 2015 and shows significant DO impairments in 2014.
- Collect field measurements for pH and turbidity at Sites AB05 and AB01 during routine maintenance checks for continuous monitoring equipment to establish a baseline understanding of pH and turbidity.

BIOLOGY

- Continue City-funded biannual macroinvertebrate monitoring. This will provide crucial information on stream health and help gauge the success of restoration efforts in the watershed. Ensure macroinvertebrate bags are deployed at sites AB01, and AB05.
- Re-assess as determined by the City of Bangor as the goals of the monitoring program become clear based on available resources and funding.

The ambient monitoring program should build on and enhance previous monitoring efforts in the watershed. After each sampling event, data should be analyzed and compared to data collected during previous years. This data collection program and data analysis and interpretation protocol will support assessment of progress in restoring Arctic Brook.

6.3 MEASURABLE MILESTONES

It is critically important that a watershed restoration project schedule be established that provides clear and measurable milestones for success. These include environmental indicators, which measure response of the stream (Table 6.1), as well as programmatic indicators, which measure actions taken (Table 6.2), and social indicators, which measure financial and community support (Table 6.3). Once funding mechanisms and oversight authority have been established for the Arctic Brook restoration effort, a more detailed list and schedule of measurable milestones may be developed. Measurable milestones are presented based on three “benchmarks” at 2020, 2023, and 2027 that represent estimated competition by the benchmark date.

- Environmental Indicators are a direct measure of environmental conditions. They are measurable quantities used to evaluate the relationship between pollutant sources and environmental conditions. They assume that BMP recommendations outlined in the Action Plan will be implemented accordingly and will indirectly result in reductions in stream TP concentrations (Table 6.1).

Table 6.1. Environmental indicators used to monitor the success of the Arctic Brook restoration project.

ENVIRONMENTAL INDICATORS			
Indicators	**Benchmarks**		
	2020	2023	2027
Improvement of stream hydrology and water quality			
Monitor chloride (or specific conductivity) to bring levels below the chronic and acute thresholds recommended by the Maine DEP. (note that groundwater toxicity could cause a delayed response to mitigation) *GOAL: Reduce chloride toxicity to the stream while maintaining safe roadways*	Below 860 µS/cm in baseflow	Below 860 µS/cm in baseflow and stormflow	Below 230 µS/cm in baseflow[7]
Replace and/or repair failing culverts to improve hydraulic conveyance *GOAL: Stabilize flow volumes*	1 culvert addressed	2 culverts addressed	3 culverts addressed
Reduce effective impervious cover to decrease flow volumes *GOAL: Disconnect 13.7 acres of effective IC through implementation of top 18 priority BMPs*	6.9 acres	10.3 acres	13.7 acres
Reduce nutrients in stream (TSS, TN, TP) *GOAL: Disconnect 13.7 acres of effective IC through implementation of top 18 priority BMPs*	6.9 acres	10.3 acres	13.7 acres
Improvement of in-stream and riparian habitat			
Implement priority recommendations from the 2016 Geomorphic Assessment and Stream Corridor Survey *GOAL: Improve in-stream habitat to meet Class B aquatic life thresholds*	1 projects	5 projects	9 projects
Prioritize culvert repair projects that improve fish passage *GOAL: Improve connectivity of stream channel to encourage fish passage*	1 culvert addressed	2 culverts addressed	3 culverts addressed

[7] given current monitoring efforts and limited available funds for additional monitoring, it is uncertain how long it will take for chloride contamination in the aquifer to be reduced to allow baseflow chloride to be below this level. Additionally, public safety is highest priority and must be considered in attempting to meet the chloride reductions necessary to reach this goal.

- **Programmatic Indicators** are indirect measures of watershed protection and restoration activities. Rather than indicating that water quality reductions are being met, these programmatic measurements list actions intended to meet the water quality goal (Table 6.2).

Table 6.2. Programmatic Indicators used to monitor the success of the Arctic Brook restoration project.

PROGRAMMATIC INDICATORS			
Indicators	**Benchmarks**		
	2020	2023	2027
Number of structural BMP retrofits installed *GOAL: Reduce effective IC contributing nutrients and stormwater runoff to the stream*	5	10	18
Acres of effective IC disconnected by retrofit BMP installations *GOAL: Reduce effective IC contributing nutrients and stormwater runoff to the stream*	6.9 acres	10.3 acres	13.7 acres
Number of residential BMP demonstration project completed *GOAL: Raise awareness and community support*	1	2	3
Number of watershed-based educational materials distributed, specifically focused on reducing chloride toxicity in Arctic Brook *GOAL: Raise awareness and community support*	250	500	1,000
Number of structural BMPs inspected and maintained *GOAL: Maintain existing and newly installed infrastructure to maintain benefit of structural implementations*	25	40	53
Amount of funding secured for plan implementation *GOAL: Maintain a consistent funding mechanism and City support for project implementation*	$2,621,500 - $4,915,750	$3,932,250 - $7,373,625	$5,243,000 - $9,831,500
Number of acres of new land in conservation *GOAL: Increase the amount of land in permanent conservation*	1	5	10

- **Social Indicators** measure changes in social or cultural practices and behavior that lead to implementation of management measures and water quality improvement (Table 6.3).

Table 6.3. Social indicators used to monitor the success of the Arctic Brook restoration project.

SOCIAL INDICATORS			
Indicators	**Benchmarks**		
	2020	2023	2027
Number of certified contractors completing a BMP or LID training and certification program *GOAL: Raise awareness and community support*	1	3	5
Number of volunteers for stream clean-ups and plantings. Volunteer goals are cumulative. *GOAL: Raise awareness and community support*	10	20	30
Number of people participating in educational events *GOAL: Raise awareness and community support*	10	50	100
Number of businesses participating in restoration activities *GOAL: Disconnect 13.7 acres of effective IC through BMP retrofit implementation*	3	5	10

**Benchmarks are cumulative from Year 1*
***Contingent on landowner cooperation*

6.4 CONCLUSION

Watershed residents, business owners, and the community at large should have a vested interest in improving the long-term water quality of Arctic Brook so that everyone can have access to clean water. The objective of the Arctic Brook WBMP is to provide a structured plan for reducing the effects of impervious cover on the stream so that it meets Class B water quality standards. Additionally, this plan is meant to be a catalyst to begin significant efforts across the City to educate business owners and residents on the non-structural (i.e. behavioral) changes needed to reduce chloride toxicity in the stream.

The full implementation of this plan will cost approximately $524,300 - $983,150 per year over the next 10 years. Cost estimates are based on tasks identified in the action plan, which will need to be updated as the plan is implemented and as new actions are added. Implementation of this plan over the next 10 years will require the dedication and hard work of state and municipal employees, and cooperation of residents, business owners and volunteers to ensure that the actions identified in this plan are carried out accordingly.

7 REFERENCES

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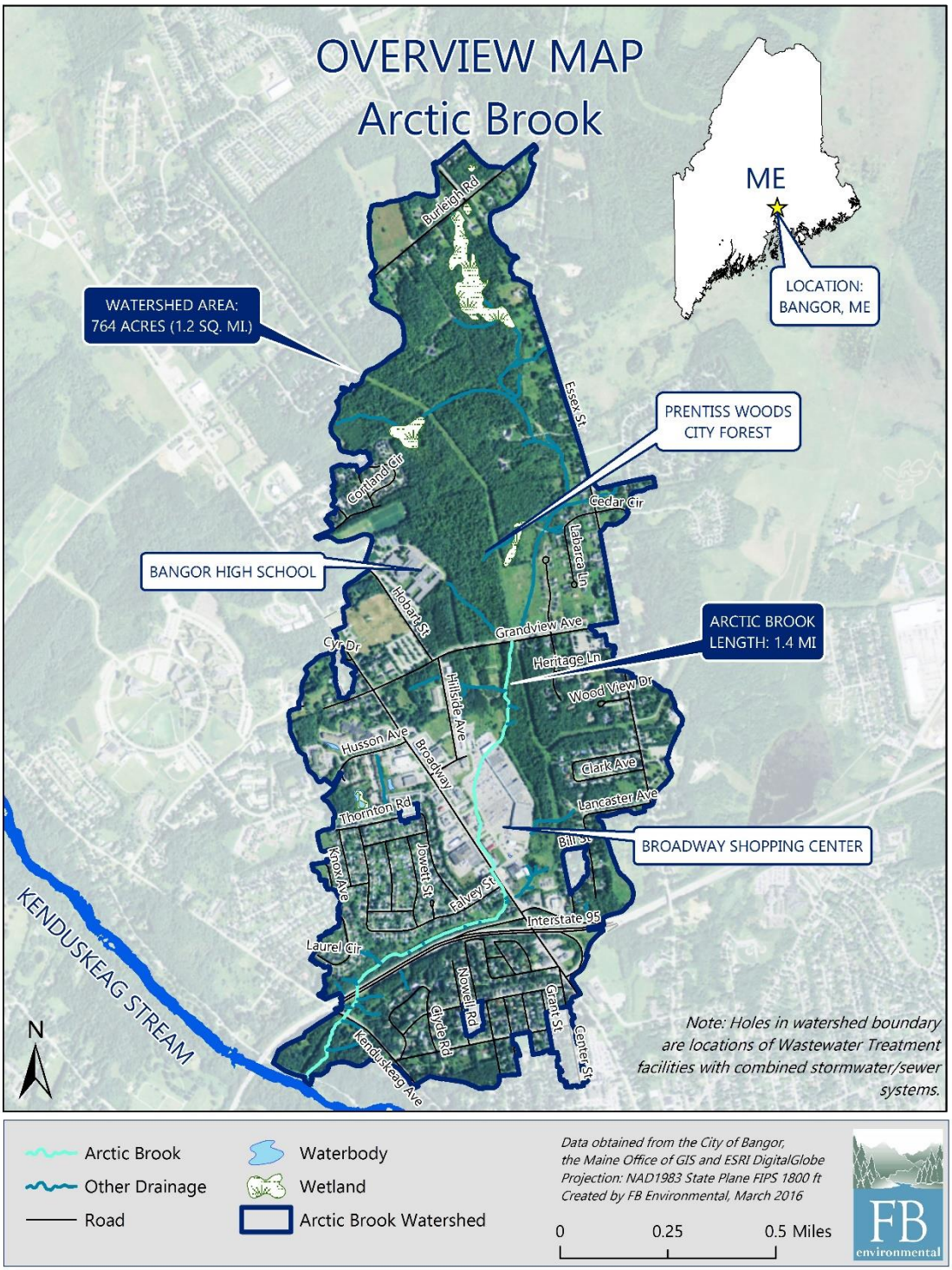
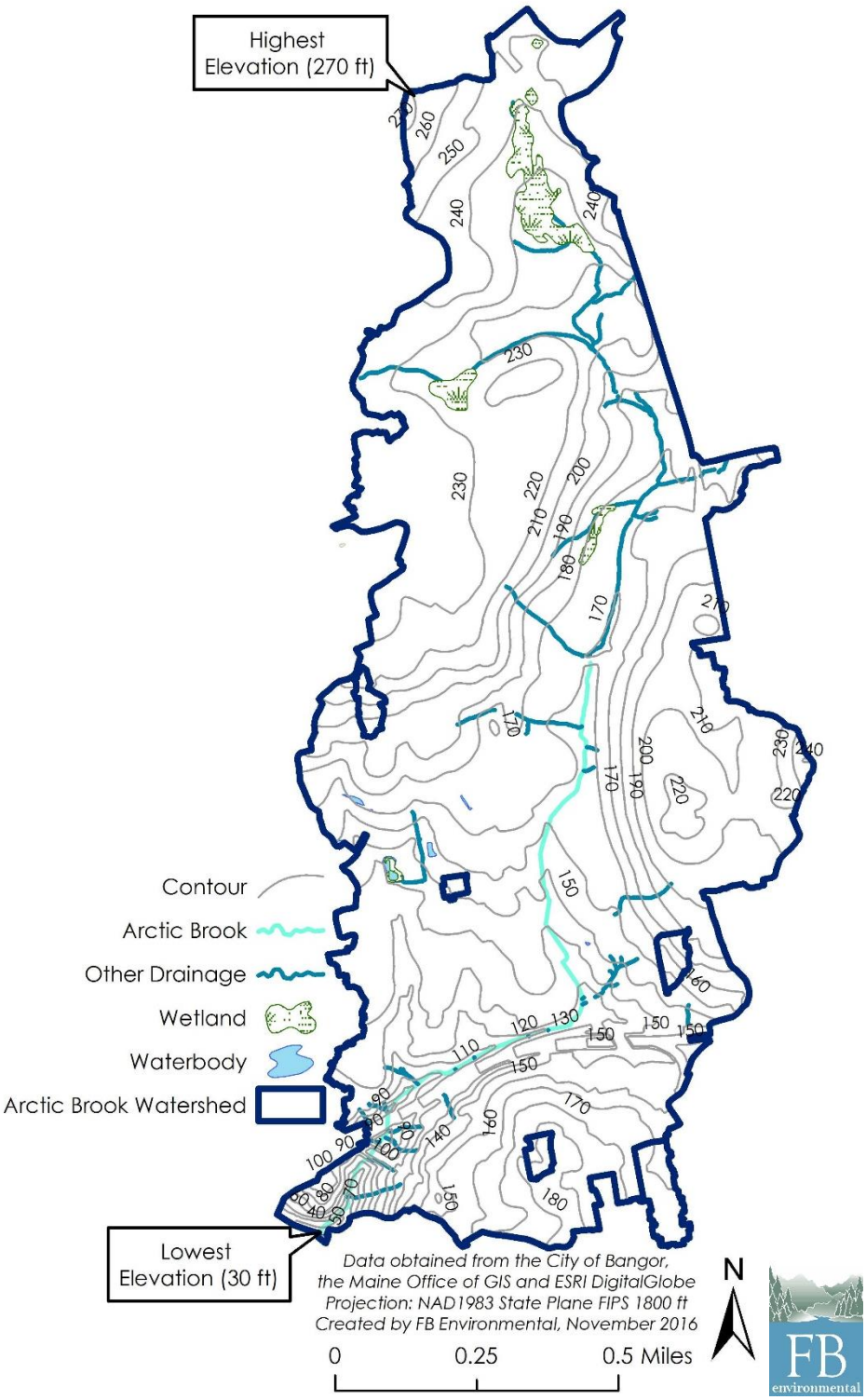
8 APPENDIX I: MAPS

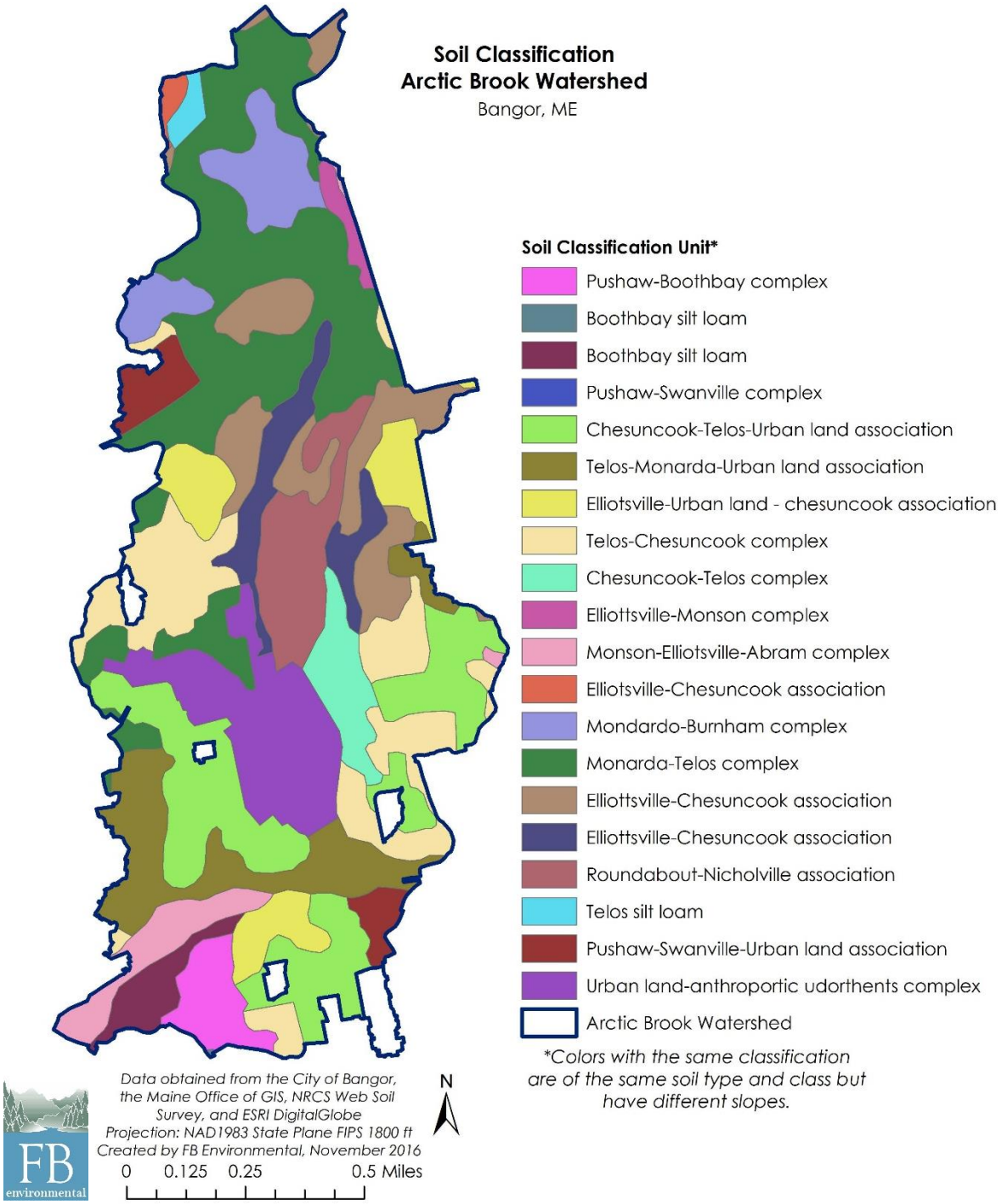
MAP 1 – OVERVIEW MAP



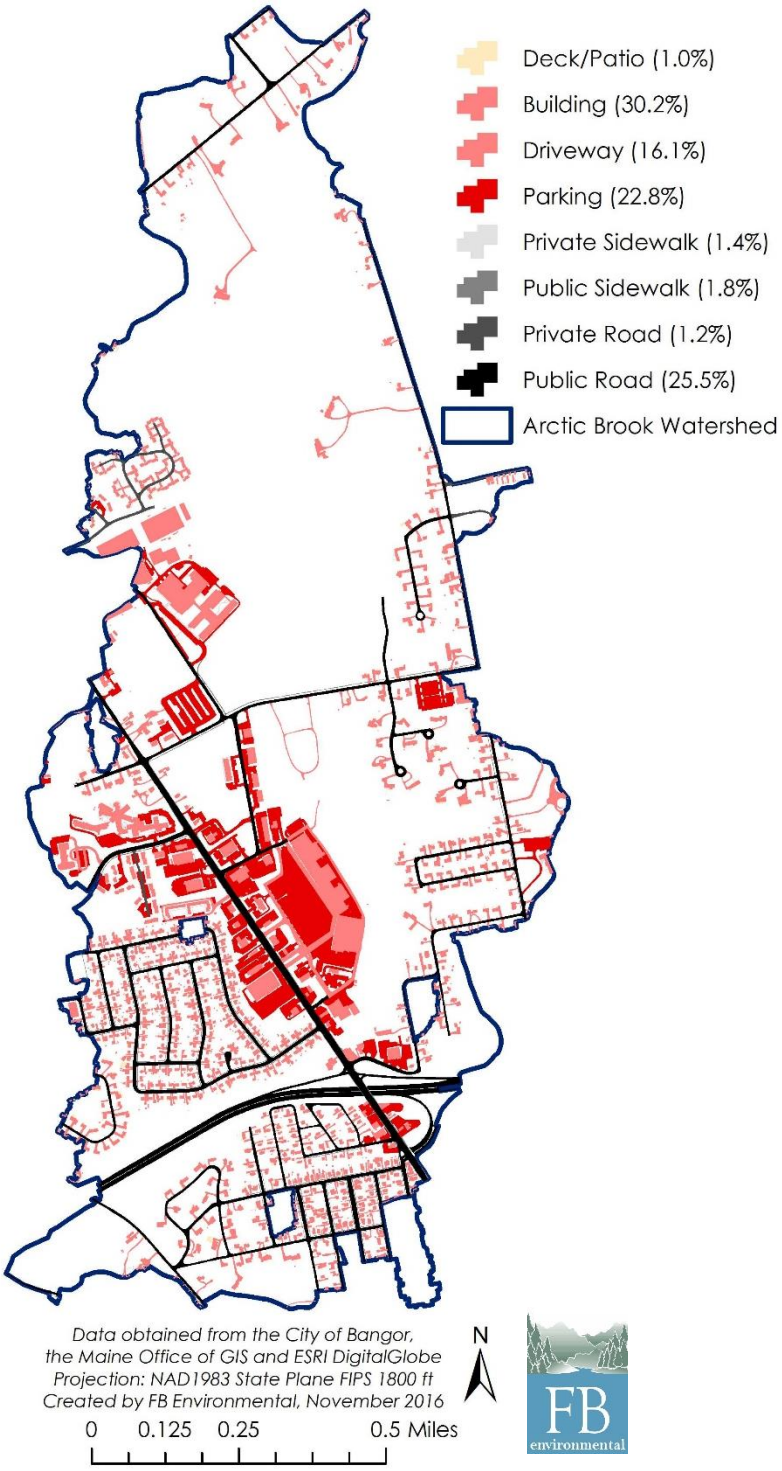
MAP 2 – TOPOGRAPHY



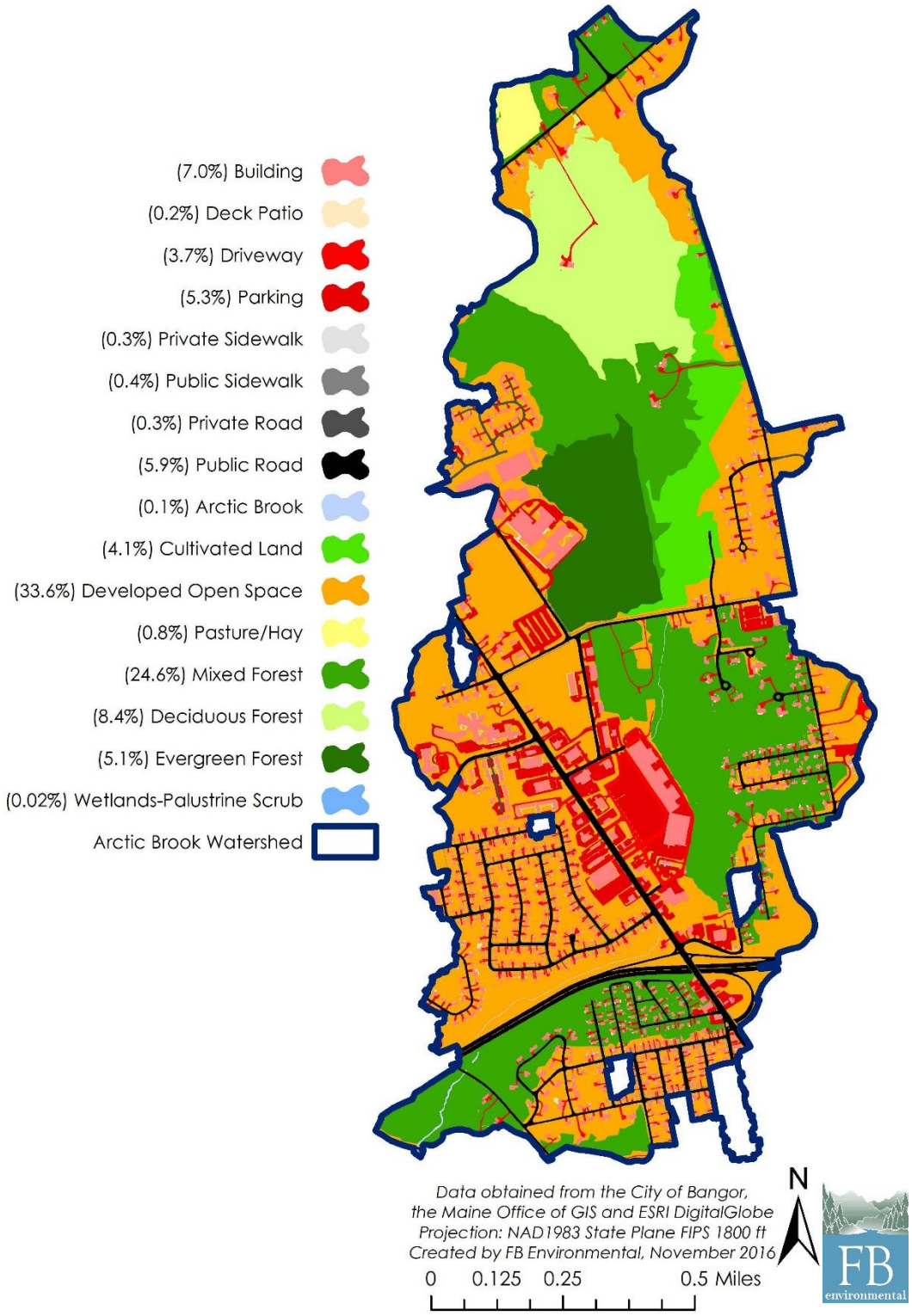
MAP 3 - SOILS


Soil Classification
Arctic Brook Watershed
Bangor, ME
Soil Classification Unit*
Pushaw-Boothbay complex
Boothbay silt loam
Boothbay silt loam
Pushaw-Swanville complex
Chesuncook-Telos-Urban land association
Telos-Monarda-Urban land association
Elliotsville-Urban land - chesuncook association
Telos-Chesuncook complex
Chesuncook-Telos complex
Elliottsville-Monson complex
Monson-Elliotsville-Abram complex
Elliotsville-Chesuncook association
Mondardo-Burnham complex
Monarda-Telos complex
Elliottsville-Chesuncook association
Elliottsville-Chesuncook association
Roundabout-Nicholville association
Telos silt loam
Pushaw-Swanville-Urban land association
Urban land-anthroportic udorthents complex
Arctic Brook Watershed
*Colors with the same classification are of the same soil type and class but have different slopes.
Data obtained from the City of Bangor, the Maine Office of GIS, NRCS Web Soil Survey, and ESRI DigitalGlobe
Projection: NAD1983 State Plane FIPS 1800 ft
Created by FB Environmental, November 2016
0 0.125 0.25 0.5 Miles
N
FB
environmental

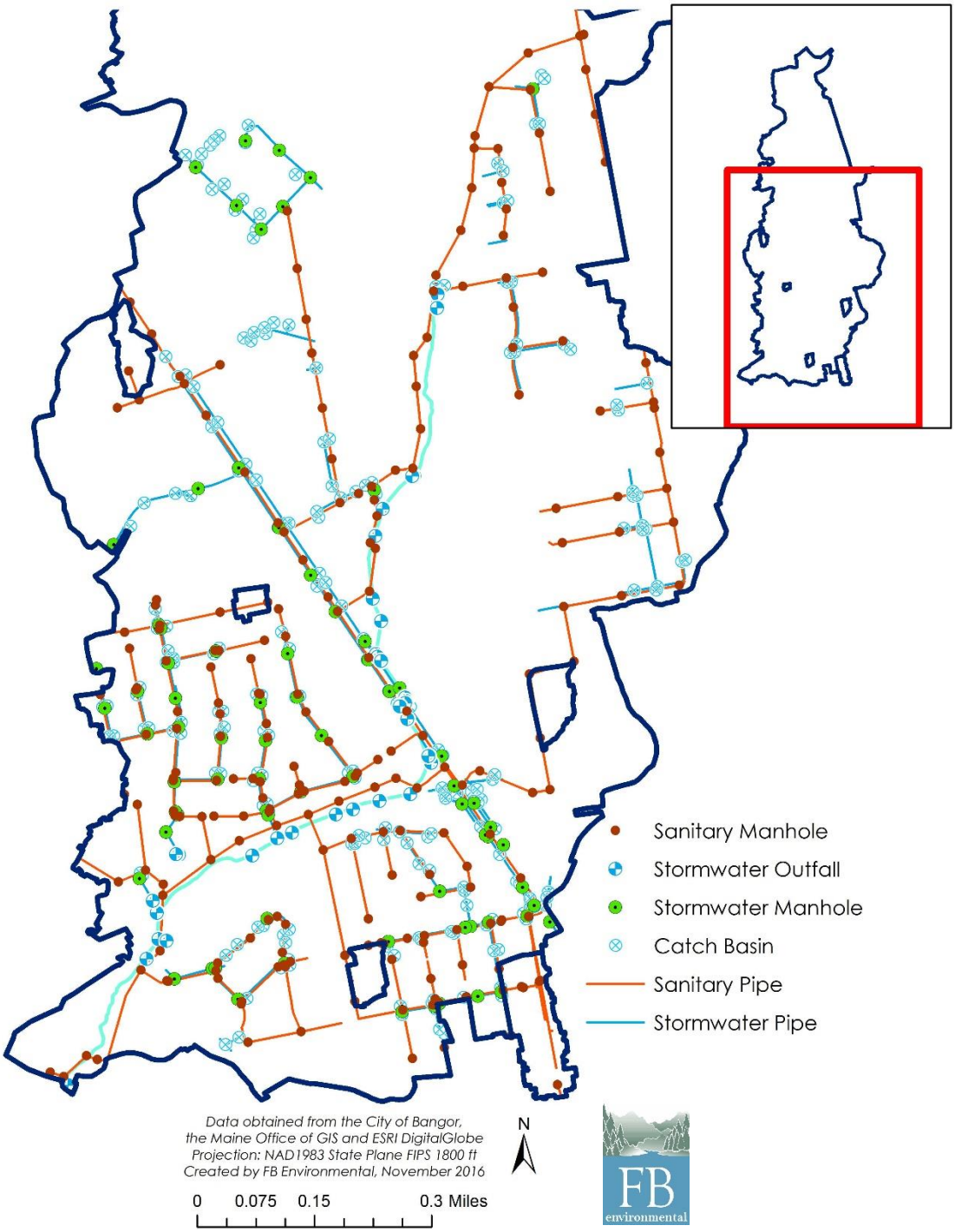
MAP 4 – IMPERVIOUS COVER



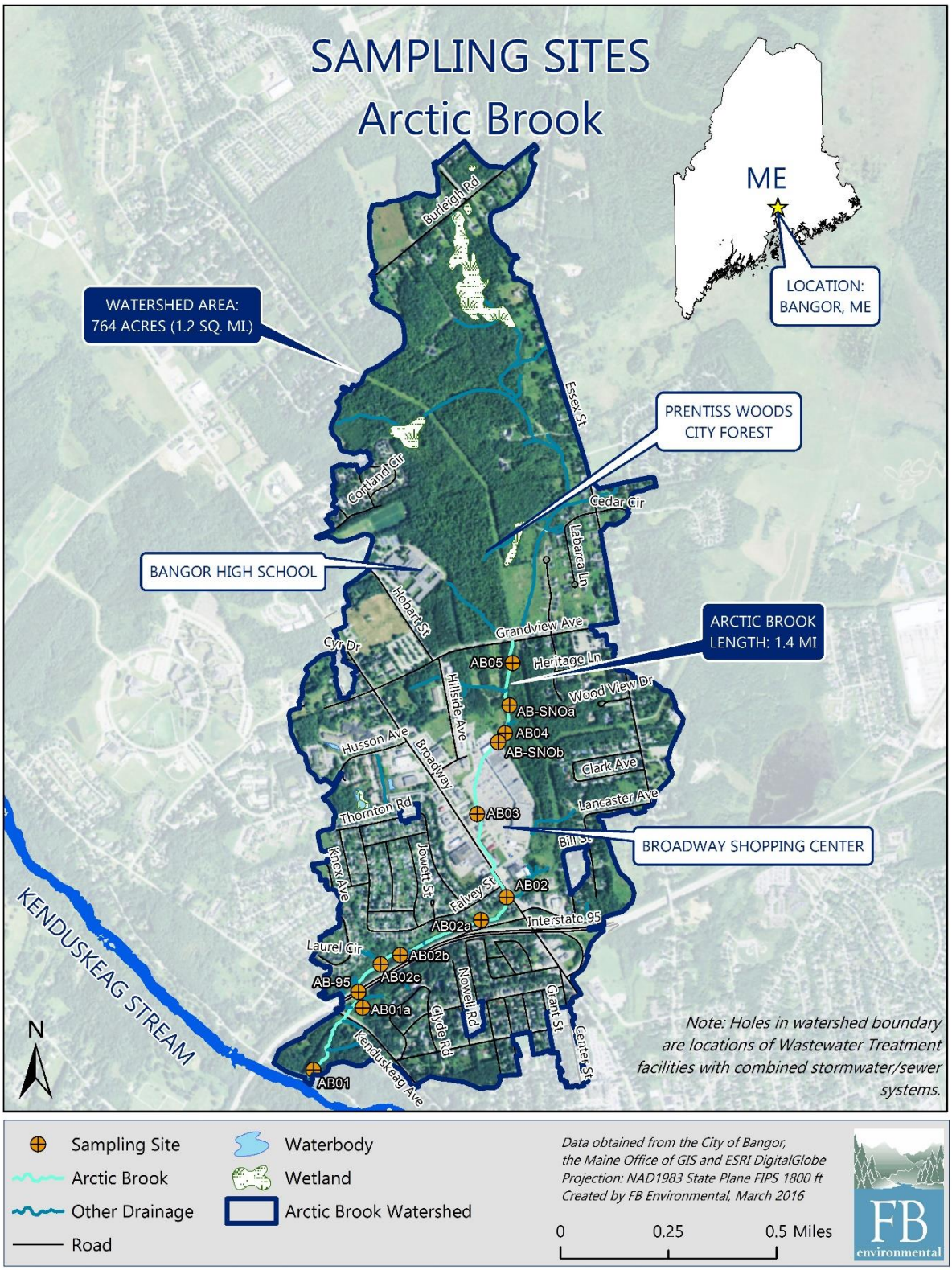
MAP 5 – LAND USE



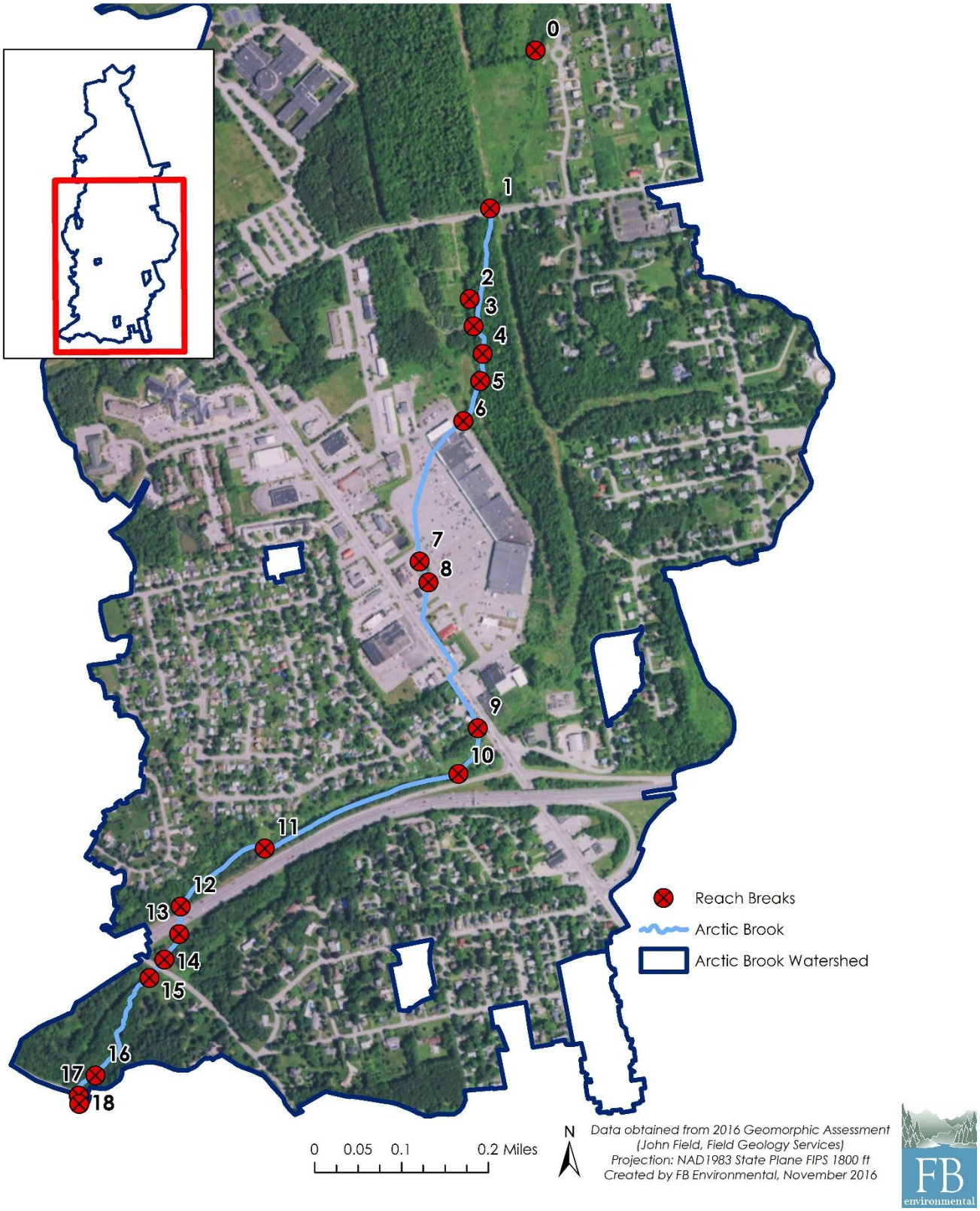
MAP 6 – STORMWATER AND SEWER



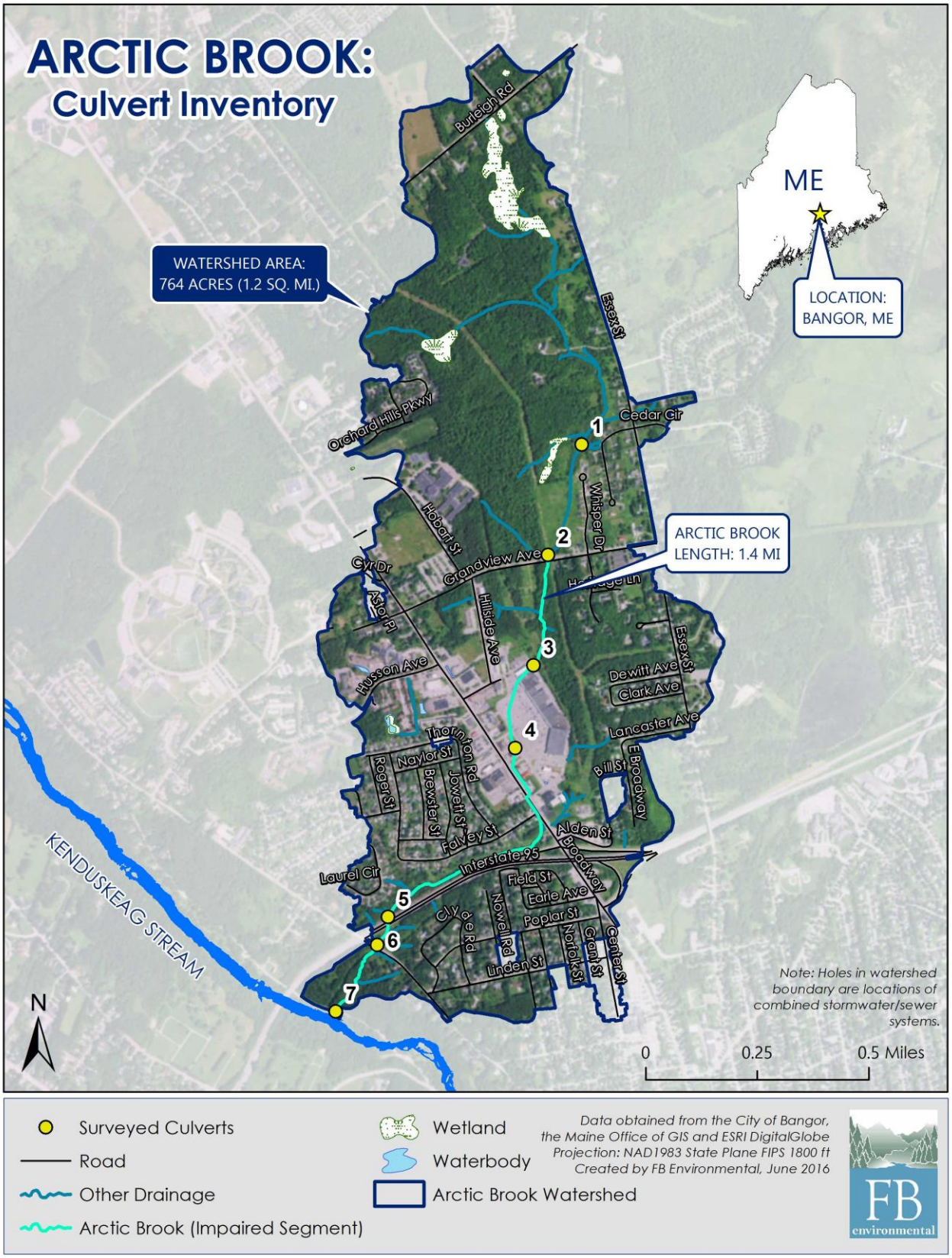
MAP 7 - SAMPLING SITE MAP



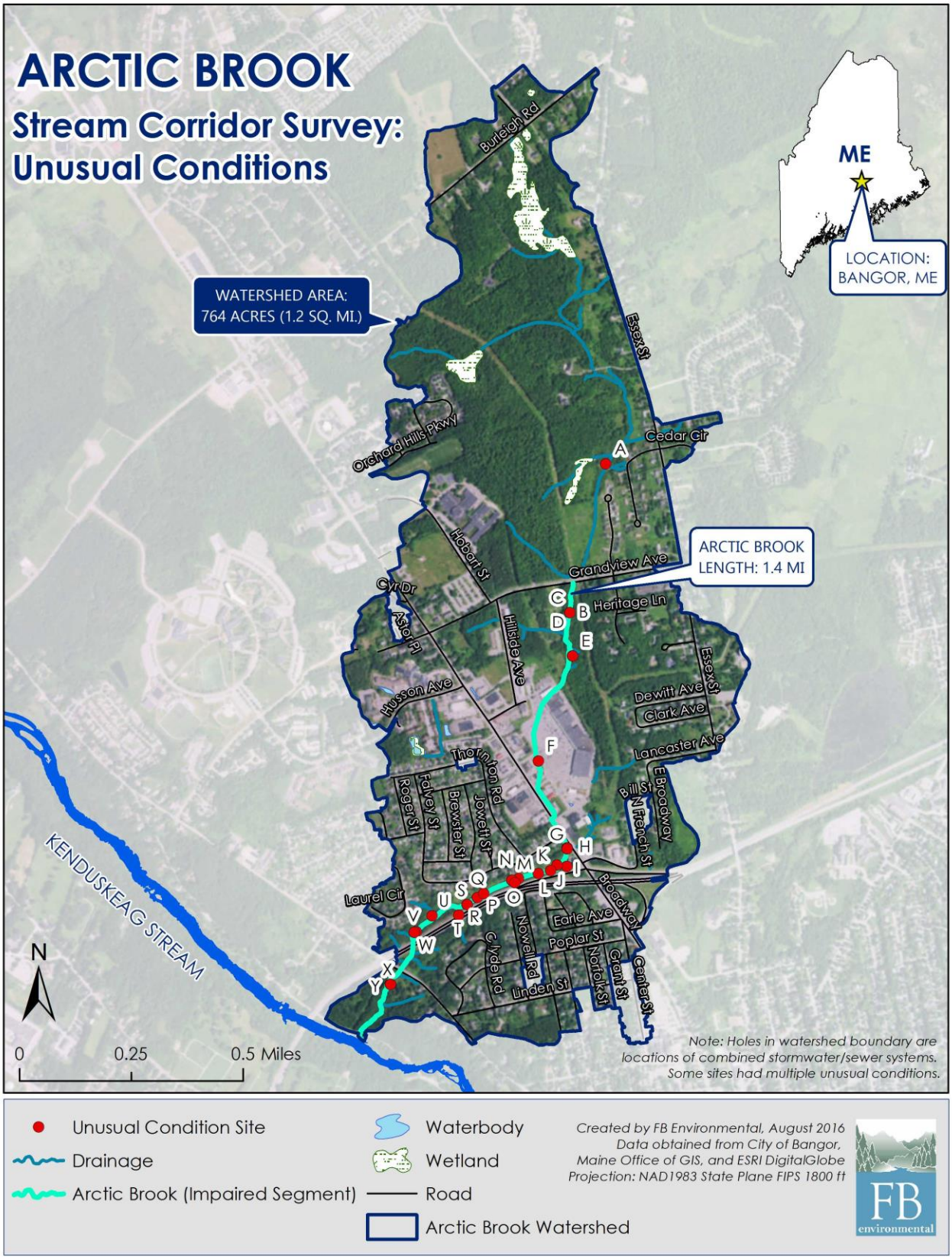
MAP 8 – RGA REACH IDENTIFICATION



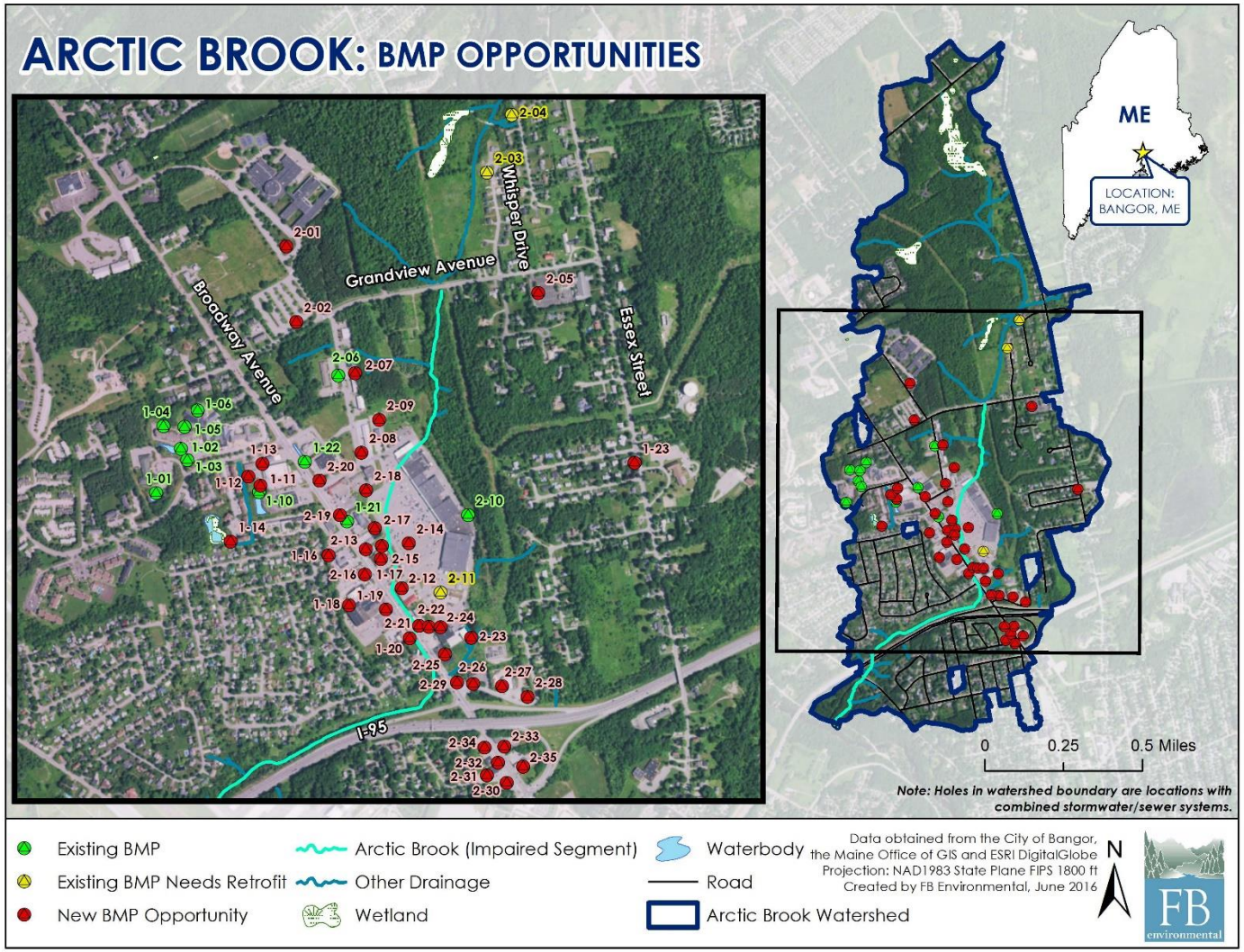
MAP 9 – SCS CULVERT INVENTORY



MAP 10 – SCS: UNUSUAL CONDITIONS



MAP 11 – BMP OPPORTUNITIES



9 APPENDIX II: REPORT LINKS

The following lists major reports completed during the planning and development of this Arctic Brook WBMP. The goal of this WBMP is to provide a summary of each of these reports. Further detail can be found at the City of Bangor website for Arctic Brook.

(http://www.bangormaine.gov/content/2037/1885/1905/default.aspx).

See City website for the following reports:

FB Environmental. 2016. Arctic Brook 2016 Field Survey Report. Prepared By: FB Environmental; Prepared For: City of Bangor.

FB Environmental. 2016. Arctic Brook Water Quality Report. Prepared By: FB Environmental; Prepared For: City of Bangor.

Field Geology Services. 2016. Fluvial Geomorphic Assessment of Arctic Brook in Bangor, Maine. Prepared By: Field Geology Services; Prepared For: City of Bangor.