



## Penjajawoc Stream & Meadow Brook

### Watershed Description

This Total Maximum Daily Load (TMDL) applies to a 5.2-mile section of Penjajawoc Stream, and a 1.5-mile section of Meadow Brook, located in the City of Bangor, Maine. The watershed is made up of four subwatersheds including the Upper Subwatershed, Middle Subwatershed, Meadow Brook Subwatershed, and Mt. Hope Subwatershed. The Upper Subwatershed drains a large 300-acre emergent freshwater marsh known as Penjajawoc Marsh. The Middle and Meadow Brook Subwatersheds drain the Bangor Mall and other intensely developed commercial areas on Stillwater Avenue and Hogan Road (Figure 1). Meadow Brook flows into Penjajawoc Stream just above Mt. Hope Avenue and then Penjajawoc Stream flows southeasterly into the Penobscot River. The Mt. Hope subwatershed drains the eastern portion of the watershed and joins Penjajawoc Stream a small distance before it flows into the Penobscot River. This subwatershed is primarily comprised of older, low-density residential development and a cemetery (Figure 2) (CH2MHILL, 2009; BSA, 2008).

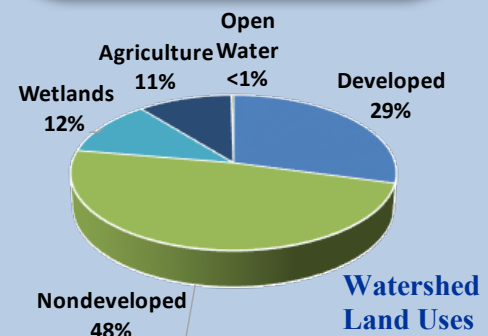
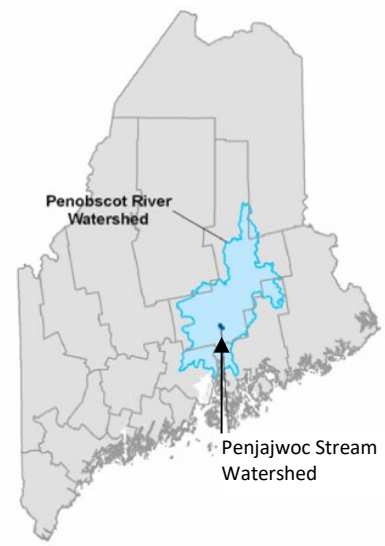
- Stormwater runoff from **impervious cover (IC)** flows quickly off impervious surfaces, carrying sediment, oils, metals, salt, and other pollutants. IC contributes to altered stream stability, in-stream habitat degradation, and impaired stream biological communities.
- The percent IC for the entire Penjajawoc watershed is 11%, but varies greatly among the four subwatersheds:
  - 3% in the Upper Subwatershed
  - 45% in the Middle Subwatershed
  - 25% in the Meadow Brook Subwatershed
  - 8% in the Mt. Hope subwatershed

### Definitions

- **TMDL** is an acronym for **Total Maximum Daily Load**, representing the total amount of a pollutant that a water body can receive and still meet water quality standards.
- **Impervious cover (IC)** refers to landscape surfaces (e.g. roads, sidewalks, driveways, parking lots, and rooftops) that no longer absorb rain and may direct large volumes of stormwater runoff into the stream.

### Waterbody Facts

- **Segment ID:** ME0102000513\_226R03
- **City:** Bangor, ME
- **County:** Penobscot
- **Impaired Segment Length:** 6.76 miles
- **Classification:** Class B
- **Direct Watershed:** 8.8 mi<sup>2</sup> (~5,600 acres)
- **Watershed Impervious Cover:** 11%
- **Major Drainage Basin:** Penobscot River



**Why is a TMDL Assessment Needed?**

Penjajawoc Stream and Meadow Brook have been assessed by DEP as not meeting water quality standards for Class B freshwater streams. Penjajawoc Stream violates water quality standards for dissolved oxygen and aquatic life use, causing it to be listed on Maine’s 303(d) list of impaired waters. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes waterbody impairments and establishes a target to guide the measures needed to restore water quality. The goal is to bring listed waterbodies back into attainment with Maine water quality standards.



*Penjajawoc Stream flows through the highly developed Bangor Mall area. (Photo: DEP)*

The IC TMDL assessment for Penjajawoc Stream and Meadow Brook addresses water quality impairments for dissolved oxygen and aquatic life use (benthic-macroinvertebrate, periphyton (algae), and stream habitat assessments). These impairments are associated with a variety of pollutants in urban stormwater as well as erosion, habitat loss, and unstable stream banks caused by excessive amounts of runoff.

**Sampling Results & Pollutant Sources**

Sampling Station	Statutory Class	Sample Result by Sample Date							
		2008	2009	2011	2012	2014	2015	2016	
314	B	C		C/C <sup>a</sup>	NA				
315	B	NA		C/C <sup>a</sup>				NA/NA <sup>a</sup>	
511	B	C	C	C/C <sup>a</sup>				NA	
513	B	C			NA			NA/C <sup>a</sup>	
918	B	C	C						
927	B	C	NA						
1045	B					C			
1079	B							NA	

**Recent DEP biomonitoring results for Penjajawoc Stream.**  
 NA = Non Attaining. Does not meet Class A, B, or C criteria.  
<sup>a</sup> = Algae assessment result. All others benthic macroinvertebrate results.

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). For benthic macroinvertebrates, DEP makes aquatic life use determinations using a statistical model that incorporates 30 variables of data collected from rivers and streams, including the richness and abundance of streambed organisms, to determine the probability of a sample meeting Class A, B, or C criteria. Biologists use the model results

and supporting information to determine if samples comply with the numeric aquatic life criteria of the class assigned to the stream or river (Davies and Tsomides, 2002). Maine DEP uses an analogous model to aid in the assessment of algal communities but makes aquatic life use determinations based on narrative standards. Both benthic macroinvertebrate and algae biomonitoring assessments were conducted at

various sampling stations since 1997, with the most recent assessments in 2016. Data indicate that Class B Penjajawoc Stream did not attain its statutory class at any of the eight sampling locations.

### Impervious Cover Analysis

There are two general ways to quantify impervious cover: total impervious cover and effective impervious cover. Total IC is all the impervious area in a watershed. Effective IC is only the impervious cover in a watershed that is directly connected to a stream via hard surfaces or stormwater conveyances, without treatment or detention. Effective IC presents the greatest pollution risks to streams, and efforts at improving water quality are generally aimed at disconnecting and preventing the addition of connected IC rather than the literal removal or prevention of impervious cover in a watershed. The % IC calculations in this TMDL are the total IC because the level of effort that would be required to determine effective IC is beyond the scope of the TMDL analysis.

To calculate the estimated Penjajawoc Stream watershed percent impervious cover (% IC), Maine DEP staff used the City of Bangor's IC layer. The City of Bangor created this detailed impervious surface GIS data layer from high resolution aerial photography (City of Bangor, 2014).<sup>1</sup> This layer was determined to be the best available IC dataset for the the portion of the watershed located within the City of Bangor, which is the majority of the watershed. The very small portion of the watershed in Orono was determined to have no IC. For the portion of the watershed in Veazie, the IC dataset created by the State of Maine and Sanborn (Sanborn and State of Maine, 2007) was used as a base product. This layer was created from 2007 data, and therefore did not contain any impervious additions between 2007 and present. Additional impervious area was added to the Veazie dataset by DEP staff, using 2021 NAIP (National Agriculture Imagery Program) imagery with 1 meter resolution.

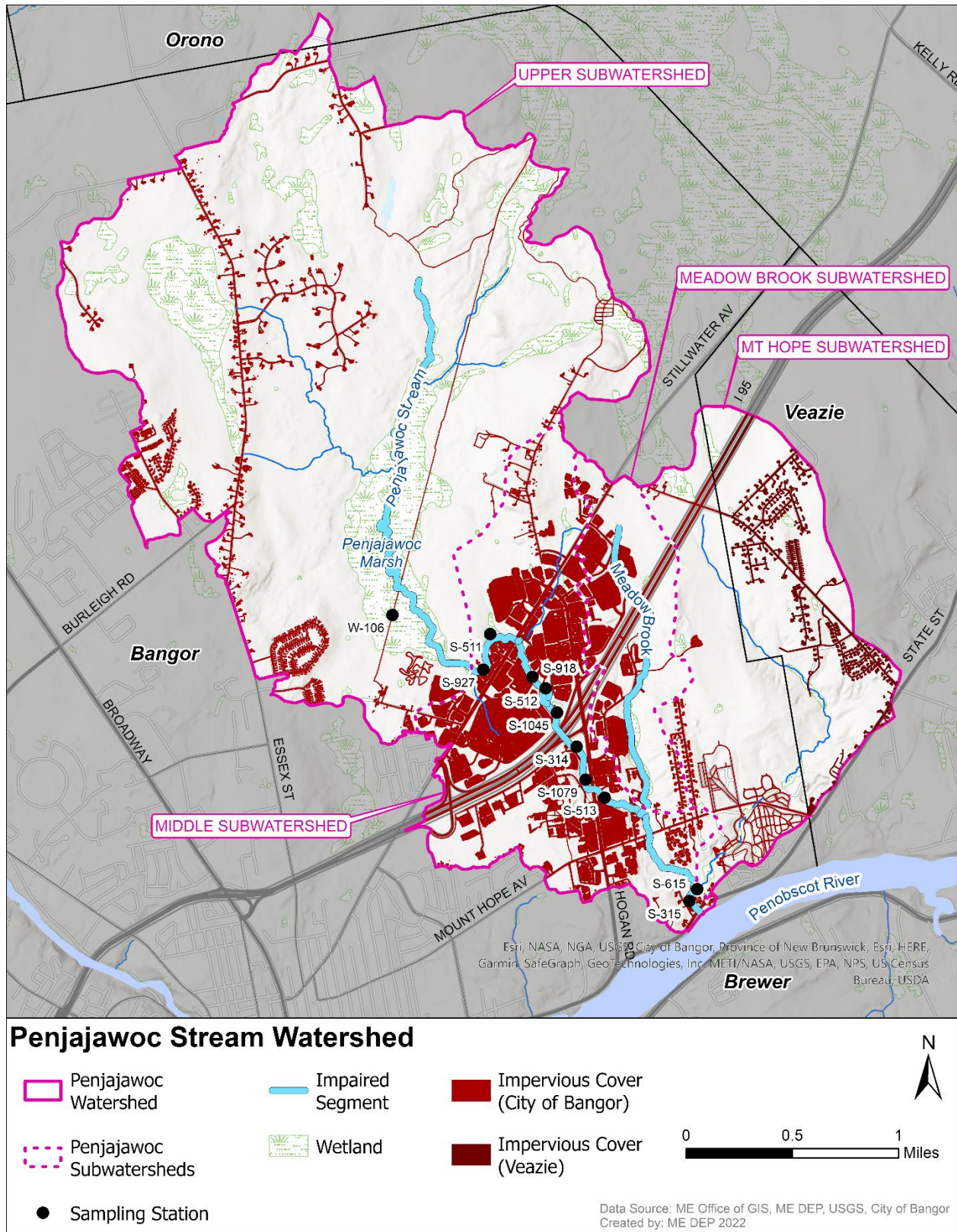
Increasing % IC in a watershed is linked to decreasing stream health (CWP, 2003). Because the impairment in Penjajawoc Stream and Meadow Brook is not caused by a single pollutant, % IC is used for this TMDL to represent the mix of pollutants and other impacts associated with excessive stormwater runoff. The Penjajawoc Stream watershed (including Meadow Brook) has an estimated % IC of **11%** (Figure 1). A TMDL is defined as  $TMDL = WLA + LA + MOS$ . DEP has found that in order to support Class B aquatic life use, the Penjajawoc Stream watershed needs to have the characteristics of a watershed with 9% IC (DEP, 2012). The IC TMDL has set an explicit Margin of Safety (MOS) for Class B waters at 1% IC, making 8% IC the combined Wasteload (WLA) and Load (LA) Allocation for the Penjajawoc Stream and Meadow Brook watersheds. This TMDL target of 9% is intended to guide the application of Best Management Practices (BMPs) and Low Impact Development (LID) techniques to reduce the *impact* of impervious surfaces, i.e. the effective IC. Ultimate success of the TMDL will result in Penjajawoc Stream and Meadow Brook's compliance with Maine's water quality criteria for aquatic life, dissolved oxygen, and habitat.

It should be noted that while the overall % IC for the Penjajawoc Stream watershed is only slightly higher than the TMDL % IC target for the watershed, the IC in the various subwatersheds within the overall Penjajawoc Stream watershed are not uniform (Figure 1). The Upper Subwatershed of Penjajawoc Stream is comprised largely of wetlands and other undeveloped land – much of it undevelopable or preserved – and has an estimated % IC of 3%. The Mt. Hope subwatershed, which is largely rural and drains the eastern section of the watershed, has an estimated % IC of 8%. However the Middle Subwatershed, where the Bangor Mall and other development along Stillwater Ave. are located, has an estimated % IC of 45%

---

<sup>1</sup> Bangor impervious data developed by James Sewall Company from ½ inch resolution aerial photography in November 2009. Data was updated in known changed areas in April 2014 by KAPPA mapping based on ¼ inch resolution photography provided by the Maine Geolibrary Board.

and the Meadow Brook subwatershed has an estimated % IC of 25%. Due to this variability, the whole watershed % IC value likely underestimates the effect of the imperviousness on the stream and the % IC values of the Middle and Meadow Brook subwatersheds likely overestimate the effect. It should be noted that while determining the % IC of the watershed and subwatersheds is part of the TMDL process, the path toward achieving water quality criteria will depend on locating and identifying the specific stressors to the aquatic community and addressing them where they occur.



**Figure 1:** Penjajawoc Stream Watershed Impervious Cover (City of Bangor, 2014 and updated Sanborn and State of Maine, 2007).

### Next Steps

The City of Bangor completed a Watershed-Based Management Plan (WBP) for Penjajawoc Stream, approved by DEP, in 2008. Following the approval of this WBP, six of the highest priority projects were implemented. In 2015, the City of Bangor drafted a WBP as an update to the 2008 plan and submitted it to the Maine DEP in 2017. This WBP was not approved because it did not address high chloride levels during baseflow conditions. The City of Bangor is currently working on updating the WBP. The development and implementation of the WBP is the primary strategy for implementing water quality improvements in Penjajawoc Stream. The strategy of WBPs includes locating and identifying specific stressors in the watershed and addressing them where they occur. This can include implementing appropriate Best Management Practices (BMPs) and Low Impact Development (LID) techniques to address the identified stressors. This TMDL does not mandate the removal of existing impervious cover or prevent future development. All future development will be governed by existing federal, state, and local regulations, including Maine Stormwater Rules.

In 2012, the City of Bangor passed an ordinance creating a stormwater utility. The purpose of the utility is to provide the municipality with funds for stormwater management throughout the City, including, infrastructure maintenance and installations, water quality improvements, and WBP development and implementation.

The City of Bangor is subject to the General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems (MS4s). The City anticipates revising and resubmitting the Penjajawoc Stream WBP as part of the 2022-2027 MS4 permit cycle. Following approval the WBP will be implemented. Additionally, the MS4 General Permit contains specific requirements for Urban Impaired Streams, which includes Penjajawoc Stream and tributaries. The MS4 Stormwater Management Plan (SMP) identifies three BMPs that will be implemented to meet the Urban Impaired Stream requirement of the 2022 MS4 General Permit. These BMPs include, an education campaign to raise citizens' awareness of Urban Impaired Streams in Bangor, inspection of publicly owned ditches within the right-of-way in Urban Impaired Stream watersheds, and implementation of structural BMPs in Urban Impaired Stream watersheds.

Future planning projects that will benefit both Penjajawoc Stream and Meadow Brook include:

- Update Watershed-Based Management Plan (including addition of high chloride levels in baseflow and a strategy for addressing this stressor).
- Implement Watershed-Based Management Plan recommendations.
- Implement the requirements of the 2022 MS4 permit and Stormwater Management Plan.

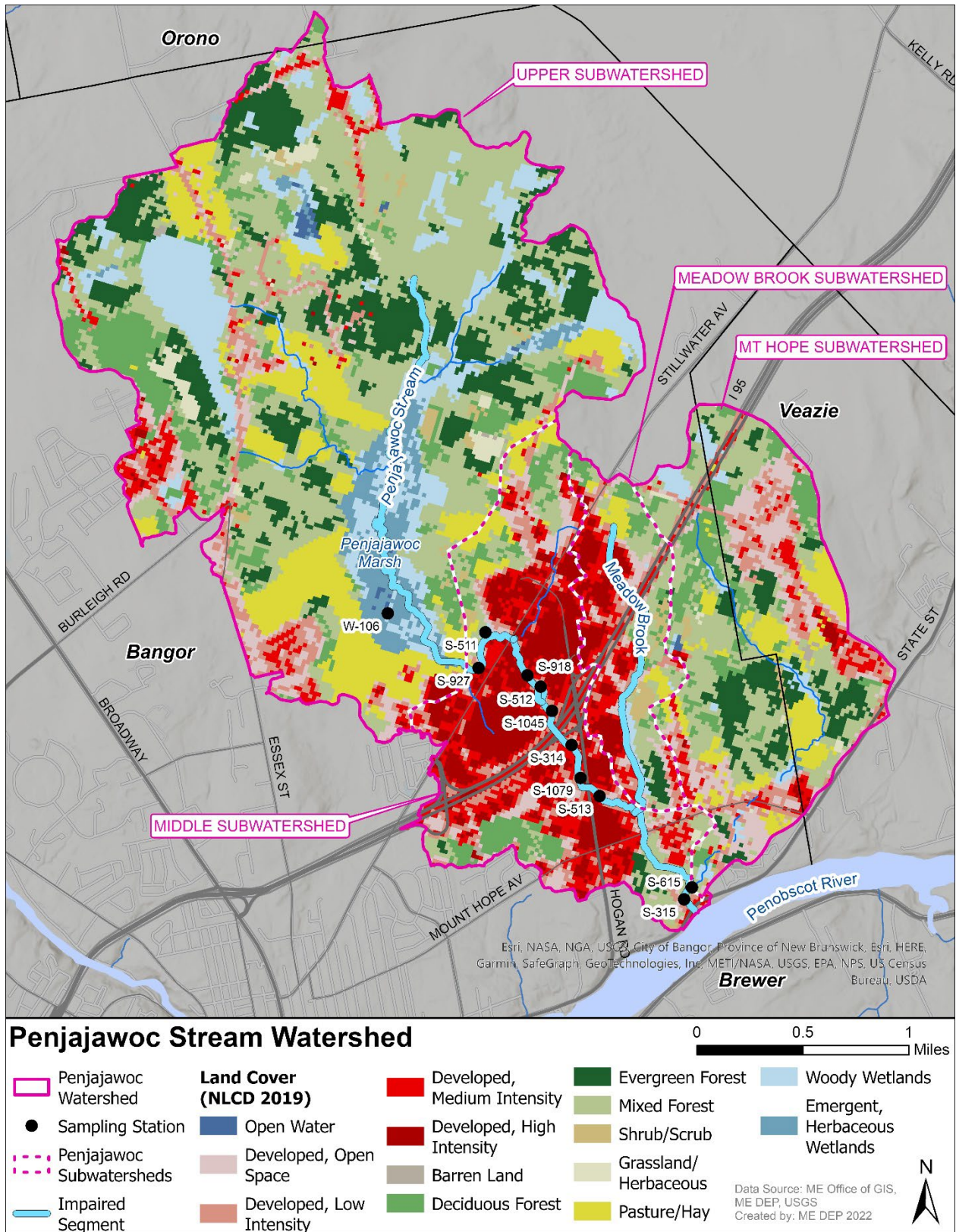


Figure 2. Penjajawoc Stream Watershed National Land Cover Database 2019 Land Cover.

## References

- BSA, 2008. Penjajawoc Stream Watershed Management Plan. BSA Environmental Consulting. August 29, 2008.
- Center for Watershed Protection (CWP), 2003. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1. Center for Watershed Protection, Ellicott City, MD. 142 pp.
- CH2MHILL, 2009. Penjajawoc Stream Watershed Analysis and Options for Refining Management Recommendations. Technical Memorandum for City of Bangor, June 26, 2009.
- City of Bangor, 2014. Impervious GIS layer. James Sewall Company 2009. Updated by KAPPA 2014.
- Davies, Susan P. and Leonidas Tsomides, 2002. Methods for Biological Sampling and Analysis of Maine's Rivers and Streams. Maine Department of Environmental Protection. Revised August, 2002. DEP LW0387-B2002.
- Maine Department of Environmental Protection (DEP), 2012. Maine Impervious Cover Total Maximum Daily Load (TMDL) for Impaired Streams. DEPLW-1239.  
[https://www.maine.gov/dep/water/monitoring/tmdl/2012/IC%20TMDL\\_Sept\\_2012.pdf](https://www.maine.gov/dep/water/monitoring/tmdl/2012/IC%20TMDL_Sept_2012.pdf)
- Maine Department of Environmental Protection (DEP), 2012. Maine Impervious Cover Total Maximum Daily Load (TMDL) for Impaired Streams. DEPLW-1239. Appendix 3: Public Comments, Frequently Asked Questions and DEP Responses to Public Comments.  
[https://www.maine.gov/dep/water/monitoring/tmdl/2012/IC%20Public%20Comments%20&%20FAQs\\_Appendix%203.pdf](https://www.maine.gov/dep/water/monitoring/tmdl/2012/IC%20Public%20Comments%20&%20FAQs_Appendix%203.pdf)
- Maine Department of Environmental Protection (DEP), 2022. 2018/2020/2022 Integrated Water Quality Monitoring and Assessment Report. Bureau of Water Quality, Augusta, ME.  
<https://www.maine.gov/dep/water/monitoring/305b/>
- NLCD, 2019. National Land Cover Database 2019 Land Cover U.S. Geological Survey (USGS), Earth Resources Observation and Science (EROS) Center, MRLC Project.
- Sanborn and State of Maine. 2007. Imperviousness change 2003-2007. Raster digital data.
- Stillwater Environmental Engineering, Inc., 2021. Municipal Separate Storm Sewer System (MS4) Stormwater Management Plan (SMP). For City of Bangor. March 25, 2021. MS4 General Permit Effective July 1, 2022.