PRESQUE ISLE BAY WATERSHED RESTORATION, PROTECTION, AND MONITORING PLAN

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1.0 INTRODUCTION

Figure 1. View of Presque Isle Bay looking west through the channel (photo courtesy of Don Benczkowski - DEP)

Presque Isle Bay is a 3,655 acre embayment located in northwestern Pennsylvania on the southern shore of Lake Erie (**Map 1**). The bay is 4.9 miles long, 1.8 miles wide, has an average depth of 13.1 feet, and connects to Lake Erie through a shipping channel maintained by the U.S. Army Corps of Engineers. Presque Isle Bay is formed to the north by Presque Isle State Park and to the south by the City of Erie and Millcreek Township **(Figure 1)**. Because Presque Isle State Park has a low impact on Presque Isle Bay and is managed under the *Presque Isle State Park Resource Management Plan*, it is excluded from the current plan.

Figure 2. Conversion of Liberty Pier from an industrial zone to a tourist attraction (top photo courtesy of Jerry Scrypzak)

The City of Erie, founded in 1792, grew around Presque Isle Bay. Like so many Great Lakes cities, Erie's history and bayfront are characterized by industrial and wastewater problems (**Table 1**). A transition of the city's bayfront began in the 1980s, as it transitioned from an industrial-dominated zone to one of tourism and recreation (**Figure 2**). As industry began to fade from the Erie area in the early 1980s, environmentally minded citizens banded together (today this group is known as the Presque Isle Bay Public Advisory Committee) with the common goal of restoring and protecting Presque Isle Bay. Their efforts ultimately lead to Presque Isle Bay being listed as the 43rd and final Area of Concern (AOC) under the Great Lakes Water Quality Agreement. To this day, the Presque Isle Bay Public Advisory Committee (PAC) (**Figure 3**) provides advice to the Pennsylvania Department of Environmental Protection (DEP) on the investigation and restoration of the Presque Isle Bay AOC.

In 1993, DEP published the first Remedial Action Plan (RAP) for the AOC. Based on existing data, the document identified chemicals of potential concern including ten heavy metals, nutrients, and polycyclic aromatic hydrocarbons (PAHs). The RAP also identified two of the 14 beneficial-use impairments (BUIs) listed under the Great Lakes Water Quality Agreement as present: fish tumors or other deformities, and restrictions on dredging activities; both of which were considered to be a result of the legacy of pollution to Presque Isle Bay. In 2002, due to a decreasing trend of tumors in brown bullhead and "natural capping" of contaminated sediment, Presque Isle Bay became the first U.S. AOC to be listed as an Area of Recovery, catalyzing a change in effort from remediation to monitoring (Boughton 2002). In 2005, a comprehensive sediment evaluation did not identify any "chemical hotspots" and found that the sediment was not toxic to aquatic life, sediment being deposited was "cleaner" than older sediment, and ecosystem health targets were being met. As a result, in July 2007, the U.S. Environmental Protection Agency approved the petition to delist the restrictions on dredging BUI.

Figure 3. Members of the Presque Isle Bay Public Advisory Committee

The continued improvement of Presque Isle Bay depends upon focused and coordinated efforts in the watershed to reduce pollution, protect and restore habitat and natural resources, and monitor the results.

The *Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan* (referred to as the *Plan*) is a blueprint for these efforts. The *Plan* summarizes a comprehensive GIS-based data collection, assessment, and analysis effort; and serves as a living document that provides a model to drive coordinated restoration, protection, and monitoring projects within the watershed.

2.0 WATERSHED ASSESSMENT

The Presque Isle Bay watershed drains a highly urbanized area (**Figure 4**) of approximately 26.22 square miles, including portions of Millcreek Township, City of Erie, Harborcreek Township, Summit Township, and Greene Township in Erie County, Pennsylvania (**Map 2**; **Table 2**). Tributaries of the bay include, from west to east, Scott Run, Unnamed Tributary One, Unnamed Tributary Two, Cascade Creek, Mill Creek, and its tributary Garrison Run (**Map 3**; **Table 3**). These tributaries comprise 90% of the bay's watershed; the remainder of the watershed (10%) is comprised of direct runoff to the bay (**Map 4**).

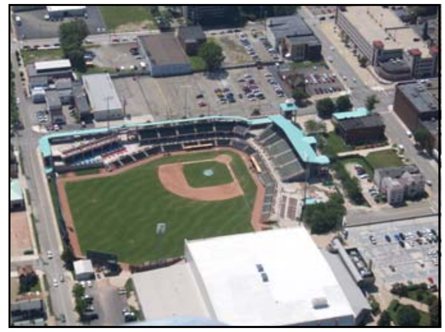

Figure 4. Highly urbanized area of the City of Erie (photo courtesy of Don Benczkowski)

Various universities, government agencies, and nonprofit organizations have conducted several chemical, physical, and biological assessments of the watershed in an attempt to characterize the impact of urbanization on the watershed. This section summarizes the most comprehensive and recent assessments. In addition, a GIS-based point source and nonpoint source assessment was conducted to further characterize the impact of urbanization on the watershed.

2.1 Chemical, Biological, and Physical Assessment

2.1.1 Pennsylvania 303(d) Assessment

Section 303(d) of the Clean Water Act requires that states develop impaired waters lists for all waters where required pollution controls are not sufficient to attain or maintain applicable water quality standards and designated uses (e.g. aquatic life, water supply, fish consumption, and recreational use data). As of April 2010, Scott Run, Cascade Creek, Mill Creek, and Garrison Run were listed on the Pennsylvania 303(d) list due to impairment of aquatic life. The aquatic life use in the four streams is considered impaired due to siltation from urban runoff.

Pennsylvania must develop a Total Maximum Daily Load (TMDL) for each water body on the 303(d) list. A TMDL identifies allowable pollutant loads to a water body from both point and nonpoint source pollution that will prevent violation of water quality standards. To date, TMDL's have not been developed for Scott Run, Cascade Creek, Mill Creek, or Garrison Run.

2.1.2 2002 Watershed Assessment

From 2000-2002, as part of initial watershed planning efforts funded by Pennsylvania's Growing Greener Program, the Erie County Conservation District (ECCD) worked with researchers from Mercyhurst College, Gannon University, and Penn State Behrend to conduct a physical, chemical, and biological assessment of Scott Run, Cascade Creek, Mill Creek, and Garrison Run. These assessments represent the most comprehensive effort to date to assess the health of the Presque Isle Bay watershed and determine where nonpoint source pollution problems exist, and provide baseline information for future monitoring efforts. Based on data from these assessments, Campbell *et al.* (2002) concluded that Garrison Run was the most severely degraded stream in the watershed, Cascade Creek sites also had consistently poor indications of water quality, and the Mill Creek sites above the Mill Creek Tube were found to be in better condition than the other sites. Results for the 2002 assessments are summarized in ***Sections 2.1.2.1 – 2.1.2.4*** and were used in the development of the GIS-based restoration prioritization model for the Presque Isle Bay watershed (***Section 4.0***).

2.1.2.1 Physical and Chemical Assessment

Diz and Johnson (2002) conducted a physiochemical assessment of 16 sites along Mill Creek, Cascade Creek, Garrison Run, and Scott Run. The study examined land use patterns, stream type and origin, riparian and in-stream features, and *in-situ* measurements of stream chemical and physical parameters. Habitat conditions were evaluated using a habitat assessment score, which scores 10 individual metrics based on condition. The maximum possible score for each metric is 20. The 10 individual metric scores are added to get a "Combined Habitat Assessment Score" and ranked as optimal (160-200), suboptimal (110-159), Marginal (60-109), or Poor (<60). Of the 15 sites assessed (**Figure 5**) by Diz and Johnson (2002), 0 were optimal, 11 were sub-optimal, 4 were marginal, and 0 were poor (**Map 5; Table 4**). Four of the Mill Creek locations (MC1, MC5, MC6, and MC8) had the most favorable habitat scores while the Garrison Run (GR) and Scott Run (SR) sites, Cascade Creek at Frontier Park (CC2), and Mill Creek above the Erie Zoo (MC2) received the lowest overall habitat scores.

Figure 5. Regional Science Consortium researcher Robert Wellington assessing the habitat of Unnamed Tributary One

Diz and Johnson (2002) assessed the streambed sediments for oil and grease and the metals zinc, nickel, lead, copper, and cadmium, which are commonly associated with runoff from urbanized areas (Paul and Meyer 2001; Pitt *et al.* 1995; Stenstrom *et al.*1984) (**Table 5**) and detected in urban stream sediments (Sutherland 2000; Horowitz 2008). Oil and grease concentrations were classified according to EPA standards, as: non-polluted (< 1,000 mg/kg), moderately polluted (1,000-2,000 mg/kg), and highly polluted (> 2,000 mg/kg). Of the 16 sites assessed by Diz and Johnson (2002) for oil and grease: four were non-polluted, three were moderately polluted, and nine were highly polluted (**Map 6; Table 6**).

Individual metal concentrations were compared to two toxicity thresholds, the low effect level (LEL) and severe effect level (SEL). The LEL implies a contaminant level such that the majority of benthic organisms would be able to conduct a complete life cycle; whereas, the SEL suggests the likelihood of pronounced disturbance of the sediment-dwelling community. A total of 16 sites were assessed for metals and classified as: < LEL, > LEL, or > SEL (**Maps 7-11; Table 7**). All 16 sites sampled had concentrations of one or more metals exceeding the LEL, most notably zinc and copper; 50% of the sites had concentrations exceeding the SEL for at least one metal; and only lead (31% of sites) and cadmium (100% of sites) were detected at concentrations below the LEL.

To assess metal contamination, metal concentrations were summed and ranked among the sites. As a result, two Cascade Creek sites on the upper portion of the West Branch (CC5 and CC6) and Garrison Run (GR) were found to be among the worst sites while Scott Run (SR) and three Mill Creek sites (MC3, MC4, and MC8) were among the sites with the lowest total metal concentrations. The differences in metal concentrations reflected the rural or urban area through which the stream flowed. The upper portion of Mill Creek, where lower concentrations were measured, is relatively undeveloped and retains a high portion of natural ground cover. However, Cascade Creek had less riparian cover than Mill Creek and runs through a more urban area. Generally, Diz and Johnson (2002) found that increasing heavy metal contamination correlated with decreasing width of the riparian zone.

Overall results from the physiochemical assessment indicated that the loss of streamside riparian habitat (**Figure 6**) was a major factor contributing to degraded water quality in the more developed areas of the Presque Isle Bay watershed (Campbell *et al*. 2002). Diz and Johnson (2002) concluded that the restoration of stream banks and riparian zones with natural vegetation (in already developed areas), and limiting construction activities in areas where these habitats are currently intact would be helpful to protect the streams in the watershed from pollution.

Figure 6. Loss of streamside riparian habitat along Cascade Creek

2.1.2.2 Fishery Assessment

Habitat degradation of urban watersheds has contributed to the decline and losses of North American freshwater fishes (Allan and Flecker 1993). Pyron *et al.* (2004) assessed the fisheries of Scott Run, Cascade Creek, Mill Creek, and Garrison Run for effects of urbanization using an Index of Biotic Integrity (IBI) score. The IBI included 12 metrics that collectively describe individual and assemblage-level attributes that reflect the surrounding habitat conditions (**Table 8**). IBI scores can range from a low of 12 to a high of 60. A total of 12 sites were assessed (**Figure 7**), with IBI scores ranging from a low of 12 (Garrison Run) to a high of 46 (Mill Creek). The 12 sites were categorized, as described by Yoder (1995), as either acceptable (IBI > 40) or impaired (IBI < 40). Only three sites were classified as acceptable and all were in Mill Creek (**Map 12; Table 9**). Pyron *et al.* (2004) concluded that the Mill Creek sites sampled appeared to have less urban impacts than the other streams in the Presque Isle Bay watershed. The low IBI scores for the Cascade Creek, Scott Run, and Garrison Run sites indicate negative impacts of industrial and urban development on these stream sections (Campbell *et al.* 2002).

Figure 7. DEP and Sea Grant staff assessing the fishery of Cascade Creek

2.1.2.3 Macroinvertebrate Assessment

Urbanization and resulting increases in impervious surfaces, loss of vegetation and riparian zones, sediment input, stream temperature increases, and increased contaminant input have all been suggested to negatively impact stream macroinvertebrate communities (Schuler 1994; Sponseller *et al.* 2001; Welte and Campbell 2003). Campbell (2002) assessed the benthic macroinvertebrate communities in Scott Run, Cascade Creek, Mill Creek, and Garrison Run using *EPA's Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (Barbour *et al.* 1999). A total of 16 sites were assessed by computing a Composite Index (CI) score based on an evaluation of six metrics, which allowed sites to be ranked according to the level of degradation indicated by the benthic community. Based on a statistical analysis of the scores, sites were categorized as: minimal biotic diversity, very poor, poor, slightly degraded, fair, good, very good, and optimum condition. Comparison of CI scores indicated that the benthic macroinvertebrate community of Mill Creek was in better condition than what was found in Cascade Creek, Garrison Run, and Scott Run (**Map 13; Table 10**).

The results generally confirm that developed portions of the watershed have the most severely degraded benthic macroinvertebrate communities. Campbell (2002) concluded that elements are in place that could support biological re-colonization of degraded areas of Mill Creek. Recovery of Cascade Creek, Scott Run, and Garrison Run may be more problematic as these streams are in watersheds that are highly developed and lack populations of aquatic insects that would be necessary to support biological restoration.

2.1.2.4 2002 Watershed Assessment Conclusions

One major point of concurrence among the physiochemical, fishery, and macroinvertebrate assessments is that Garrison Run is the most severely degraded stream in the Presque Isle Bay watershed. Cascade creek sites also produced consistently poor indications of water quality in all three assessments. The Mill Creek sites sampled above the Mill Creek Tube were generally found to be in better condition than other sites. All three assessments concluded that developed, urbanized areas within the watershed are associated with the more degraded portions of the stream.

2.1.3 Post-2002 Watershed Assessments

Watershed assessments conducted post-2002 primarily address suspended sediment and water quality in the streams flowing into Presque Isle Bay. The four assessments summarized in this section each focused on one or two of the tributaries to the bay and not the entire watershed. The assessments do provide valuable information for identifying and prioritizing areas within the watershed for restoration and protection.

2.1.3.1 Erie County Department of Health Assessment (2003)

In June and September 2002, the Erie County Department of Health (Wellington 2003) collected and analyzed suspended sediment from Cascade Creek during two separate storm events and the deposited sediment from the delta region of Cascade Creek. Samples were analyzed for metals, volatile organics, pesticides, and PCBs. The concentrations of these potential contaminants were compared to the Probable Effects Concentration (PEC), which represents a concentration above which adverse effects to aquatic life are expected to occur more often than not (MacDonald *et al.* 2000). None of the metals in suspended sediment from a June 2002 storm exceeded the PEC; however, the PEC was exceeded for zinc, nickel, lead, copper, chromium, cadmium, and arsenic during a September 2002 storm, which had a higher volume of rainfall. No exceedences for any of the contaminants were reported from the deposited sediment samples. The results from the September 2002 storm event indicate that there is the potential for significant concentrations of metals to enter Presque Isle Bay from the Cascade Creek watershed. However, these results only provide a snapshot into the potential for Cascade Creek to contribute pollutants to the bay.

2.1.3.2 Gannon University Assessment (2004)

In 2004, researchers from Gannon University modeled the peak flow and sediment transport of Mill Creek and Cascade Creek (Diz *et al.* 2004). The goal of the project was to model the hydrology and sediment transport of the streams using GIS-based tools (e.g. BASINS, SWAT, TR20 and TR55), and use resulting outputs from the tools to provide insight into problem areas which could become the focus of remediation and prevention efforts. As a result of the models, peak flows at the mouth of Mill Creek were found to range from 66 m^3/s for a 2-year storm event to 261 m^3/s for a 100-year storm, and 37 m^3/s and 130 m^3/s, respectively, for Cascade Creek. Peak flow in a stream represents the maximum volume of water being discharged during a precipitation event and typically intensifies with increased impervious surfaces. It was also determined that approximately 2,521 metric tons of sediment from the Mill Creek watershed and 108 metric tons of sediment from Cascade Creek are transported to Presque Isle Bay each year. Increased flows associated with stormwater runoff pose a direct threat to the aquatic organisms by modifying their physical habitat. Also, increased flows result in increased erosion, which causes increased sedimentation. The resulting sediment has the potential to carry pollutants; alter the stream form; fill the spaces between gravel and cobbles where aquatic invertebrates live; and scour organisms and clog their gills.

2.1.3.3 *Erie County Conservation District Lake Erie Tributary Assessment (2005)*

From May to October 2005, the Erie County Conservation District (Diz and Wellington 2006) conducted a water quality assessment of the streams flowing into Lake Erie along the Pennsylvania shoreline in order to identify possible nonpoint sources of pollution (**Map 14**). Included in the assessment of the 30 sites were Scott Run (one site), Cascade Creek (four sites), Mill Creek (two sites), and Garrison Run (one site). Measurements included temperature, conductivity, 5-day biological oxygen demand (BOD5), total organic carbon (TOC), total nitrogen (TN), total phosphorous (TP), total coliforms, and *E. coli* (**Table 11**). Each individual parameter was scored on a scale of 1 to 30 (lowest quality to highest quality), and scores for each ecologically important parameter were summed for each site resulting in a ranked score by site. The highest possible value was 240 and the lowest was 8. It is important to note that this ranking system allows for a comparison of sites among the streams; however, the system does not represent any regulatory methodology. The average total score of the 30 sites was 124, with a range of 58-173. Of the eight sites within the Presque Isle Bay watershed assessed by Diz and Wellington (2006), four were above the average and four were below the average (**Map 15; Table 12**).

Mill Creek (MC 1 and MC 2) and Garrison Run (GR) ranked near the bottom of every category of nonpoint source pollution. One site on Cascade Creek (CC 4) also scored poorly, the result of high levels of nitrogen and phosphorous and moderately poor rankings for physical factors (temperature and conductivity) and bacterial counts. In contrast, Scott Run (SR) scored well in all factors other than conductivity, which is likely the result of high sediment loads during storm events.

2.1.3.4 *Erie County Department of Health Assessment (2005)*

From June 2005 to May 2006, the Erie County Department of Health (Ebert 2006) analyzed various metal and PAH concentrations in suspended sediment collected at the mouths of Scott Run and Mill Creek. Chromium, nickel, copper, mercury, cadmium, lead, zinc, arsenic, and PAH (chrysene, pyrene, phenanthrene, fluroanthene, benzo(a)pyrene, benz(a)anthracene) concentrations in Scott Run and Mill Creek suspended sediment were assessed during a total of 14 and 12 storm events respectively. Other PAH compounds and semivolatiles were also measured. Results of the analysis are summarized in **Table 13**. While exceedances of PECs for metals and PAHs were observed in both Scott Run and Mill Creek suspended sediment, it is important to note there was difficulty obtaining enough suspended sediment for the analysis using an ISCO 6712 sampler (**Figure 8**). The assessment also included an analysis of stream-bed sediments from the mouths of Scott Run and Mill Creek for the same suite of metals and PAHs on four occasions between 2005 and 2006. No exceedences of the PEC were reported, suggesting that these areas of Scott Run and Mill Creek do not have metal and PAH concentrations sufficient to cause adverse effects to aquatic life.

Figure 8. ISCO 6712 sampler used to collect storm water from Mill Creek

2.2 *Point Source Assessment*

Point source pollution, commonly associated with facilities and/or locations with the potential to impact the watershed, refers to single, identifiable sources that discharge pollutants into the environment (**Figure 9**). While there are many federal (e.g. Clean Water Act and Clean Air Act) and state (e.g. Pennsylvania Clean Streams Law and Air Pollution Control Act) regulations in place to prevent these facilities and locations from impacting the watershed, it is important to document these facilities due to the fact that pollutants have the potential to be introduced into the environment through point sources (e.g. air emission, wastewater discharge, etc.). The GIS-based point source assessment data were created by digitizing information from *EPA Envirofacts Web site* and/or downloaded from the *Pennsylvania Spatial Data Access Web site*, and are summarized in *Sections 2.2.1 – 2.2.6*.

Figure 9. Potential sources of point source pollution

2.2.1 NPDES Facilities

The National Pollutant Discharge Elimination System (NPDES) program, mandated under the Clean Water Act and Pennsylvania Clean Streams Law, regulates municipal, commercial, or industrial facilities that directly discharge (or have the potential to discharge) pollutants into any surface water. Under the NPDES program, wastewater dischargers are required to have a permit establishing pollution limits, and specifying monitoring and reporting requirements. Permits regulate discharges with the goals of protecting public health and aquatic life, and assuring that every facility treats wastewater. There are 20 NPDES permitted facilities located within the Presque Isle Bay watershed (**Map 16**).

2.2.2 Toxic Release Inventory Sites

In 1987, The Toxics Release Inventory (TRI) program was created under the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 with the intention of empowering communities to hold companies accountable and make informed decisions about how toxic chemicals are to be managed. The TRI program contains information about more than 650 toxic chemicals that are being used, manufactured, treated, transported, or released into the environment. There are 38 TRI facilities within the Presque Isle Bay watershed (**Map 17**).

2.2.3 Large Quantity Hazardous Waste Generators

Large Quantity Generators (LQG) of hazardous waste, regulated under the Resource Conservation and Recovery Act (RCRA), generate 1,000 kilograms per month or more of hazardous waste, more than 1 kilogram per month of acutely hazardous waste, or more than 100 kilograms per month of acute spill residue or soil. There are 11 LQC facilities within the Presque Isle Bay watershed (**Map 18**).

2.2.4 Air Emission Facilities

Air emission facilities are regulated under the Pennsylvania Department of Environmental Protection's Air Quality Program. Sub-facilities regulated include: 1) Air Pollution Control Device - facility that removes one or more pollutants from an exhaust stream; 2) Combustion units are used to produce either electricity, steam, hot gases, or some combination of these; 3) Fuel Material Location - facility for storage of fuels shared by multiple combustion units, incinerators, or processes; 4) General Administrative Location - created automatically for every new air emission plant primary facility; 5) Incinerator - facility that destroys solid waste products using a variety of fuels; 6) Point of Air Emission - exact location or structure from which all other air emission plant sub-facilities exhaust their emissions; and 7) Process - facility that produces or modifies a product, and creates an air emission from either the materials used or a fuel consumed. There are 24 permitted air emission facilities within the Presque Isle Bay watershed (**Map 19**).

2.2.5 Land Recycling Cleanup Locations and Brownfields

The Pennsylvania Land Recycling Program (Act 2) encourages the voluntary cleanup and reuse of contaminated commercial and industrial sites. The Land Recycling Program allows an owner or purchaser of a Brownfield site to choose any one or combination of cleanup standards to guide the remediation. By meeting one or a combination of the background standards, the statewide health standard, or the site-specific standard, the remediator will receive liability relief for the property. Also, the Hazardous Sites Cleanup Act (HSCA) provides the DEP with the funding and authority to conduct cleanup actions at Land Recycling Cleanup Locations (LRCL) where hazardous substances have been released, and also provides DEP with enforcement authority to force the persons who are responsible for releases of hazardous substances to conduct cleanup actions or to repay public funds spent on a DEP-funded cleanup action. There are 15 LRCLs located within the Presque Isle Bay watershed (**Map 20**).

Brownfields are abandoned industrial or commercial sites available for redevelopment/reuse under the Pennsylvania Land Recycling Program (Act 2). There are six Brownfield sites located within the Presque Isle Bay watershed (**Map 21**).

2.2.6 Encroachment Locations

Encroachments to Pennsylvania's waterways are regulated under the Dam Safety and Encroachment Act of 1978. Specific encroachments include: stream enclosures, wetland impacts, bridges, culverts, pipelines, and outfall structures. There are 28 encroachment locations within the Presque Isle Bay watershed (**Map 22**).

2.3 Nonpoint Source Assessment

Nonpoint source pollution is pollution whose sources cannot be traced to a single point. This occurs when rainfall, snowmelt, or irrigation water moves over the land or through the ground, picks up pollutants, and deposits them into streams, lakes, and oceans; or introduces them into our ground water (**Figure 10**). Major types of nonpoint source pollution include pathogens, nutrients, toxic contaminants, and debris (Arnold and Gibbons 1996). In 2003, the National Pollutant Discharge Elimination System (NPDES) Phase II regulations were implemented with the intention of improving waterways by reducing the quantity of pollutants that storm water picks up and carries into storm sewer systems during storm events. Despite the NPDES Phase II program, nonpoint source pollution from storm water runoff continues to be the leading cause of water quality problems in the United States.

Figure 10. Storm water runoff entering Cascade Creek along the Bayfront Highway

The GIS-based nonpoint source assessment provides the framework for setting restoration and protection priorities within the Presque Isle Bay watershed, and establishes an information baseline for decision makers and watershed groups to make informed decisions regarding natural resource protection and restoration. The nonpoint source assessment documents the location of resources, the integrity of the resources, and their relationship to watershed quality. Nonpoint source assessment data are summarized in *Sections 2.3.1 – 2.3.8* and were used in the development of the GIS-based restoration and protection models for the Presque Isle Bay watershed (***Section 4.0***).

2.3.1 Imperviousness

Arnold and Gibbons (1996) define impervious surfaces as any material that prevents the infiltration of water into the soil. Imperviousness includes the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape (Schueler 1994). Impervious surfaces are a useful indicator to measure the impacts of land development on aquatic systems (Schueler 1994), as they not only indicate urbanization, but are major contributors to the environmental impacts of urbanization (Arnold and Gibbons 1996). Impervious surfaces are a critical contributor to the hydrologic changes that degrade waterways; are a major component of the intensive land uses that generate pollution; prevent natural pollutant processing in the soil by preventing percolation; and serve as an efficient conveyance system transporting pollutants into waterways (Arnold and Gibbons 1996). Specifically, imperviousness can be related to physical changes such as channel widening and incision, increased rates of erosion and sedimentation, and habitat degradation; chemical changes (via increased runoff) such as elevated levels of organic compounds, suspended and dissolved solids, nutrients, and heavy metals; and resulting biological changes such as alterations in community structures of aquatic organisms (Morse *et al.* 2003).

There is a strong relationship between the imperviousness of a watershed and the health of its receiving stream; generally, as impervious coverage increases, stream health decreases. Schueler (1994) divides urban streams into three management categories based on the general relationship between impervious cover and stream quality: 1) sensitive streams (1-10% impervious cover); 2) impacted streams (11-25% impervious cover); and 3) non-supporting streams (26-100% impervious cover). The classification system presented by Schueler was applied to the Presque Isle Bay watershed, and as a result, 23.3% of the Presque Isle Bay watershed is classified as sensitive, 0.60% as impacted, and 76.1% as non-supporting (**Map 23**). Areas within the Presque Isle Bay watershed with greater than 25% impervious surface should be restored, and areas with less than 10% impervious cover should be protected.

Roads, parking lots, and rooftops (i.e. buildings) are a major component of impervious surfaces. The combustion process of vehicles and wearing of vehicles, road construction and maintenance, road surface degradation, and application of road maintenance chemicals all contribute to pollutants in the environment (Bohemen and Janssen Van de Laak 2003). Specific pollutants associated with vehicle traffic and roads include nitrogen oxides, hydrocarbons, carbon monoxide, and fine particulate matter due to incomplete combustion; heavy metals, mineral oil, and PAHs from combustion processes, vehicle wear, leaking of oil and coolants, and corrosion; and herbicides, organic matter, and soil that fall from vehicles (Bohemen and Janssen Van de Laak 2003). Water that runs off a road surface carries many of these pollutants to the roadside and eventually into surface waters and groundwater. Within the Presque Isle Bay watershed, there are approximately 511 miles of roadways, with a density = 19.5 miles of roads/mi^2 (**Map 24**).

As the number of cars people own increases, the more parking lots become necessary; however, parking lots can adversely affect the environment and detract from community character (Gibbons 1999). Parking lots are designed to collect and concentrate large areas of storm water runoff, which can impact stream hydrography and water quality. Also, paved parking lots generate heat, raising the surrounding air temperatures as well as the temperature of the first flush of storm water which can have significant ecological impacts (Gibbons 1999). There are over 2,000 parking lots within the Presque Isle Bay watershed, comprising an area of 1.22 mi^2 or 4.7% of the watershed (**Map 25**). Areas within the watershed with greater than 25% parking lot cover should be restored, and areas with less than 10% parking lot cover should be protected.

Building rooftops can play an important role in the pathway that contaminants enter urban streams, as they serve as collectors of atmospheric particles and deliverers of contaminants to storm water runoff (Van Metre and Mahler 2003). Also, rooftops themselves can serve as a source of contamination through the leaching and disintegration of roofing materials. For example, metal roofs have repeatedly been shown to be a source of zinc, cooper, and cadmium (Van Metre and Mahler 2003). There are over 50,000 buildings within the Presque Isle Bay watershed, with a rooftop area of approximately 3.22 mi^2 or 12.2% of the watershed (**Map 26**). Areas within the watershed with greater than 25% building cover should be restored, and areas with less than 10% building cover should be protected.

2.3.2 Storm Sewers and Outfalls

Figure 11. Storm water outfall discharging directly into Cascade Creek

Polluted storm water runoff is commonly transported through Municipal Separate Storm Sewer Systems (MS4s) and ultimately discharged untreated into waterways. Municipalities within the Erie urbanized area (**Map 27**) are required to obtain NPDES phase II permits and develop a storm water management program to prevent harmful contaminants from being washed and/or dumped into the MS4; however, contaminants continue to enter the storm sewer system (**Figure 11**). When deposited into nearby waterways through MS4 discharges, pollutants can impair the waterways, thereby discouraging recreational use of the resource, contaminating drinking water supplies, and interfering with the habitat for fish, other aquatic organisms, and wildlife (EPA 2005). There are approximately 182 miles of storm sewers within the Presque Isle Bay watershed carrying polluted runoff, which discharge directly into streams or into Presque Isle Bay through 15 storm sewer outfalls (**Map 28**).

2.3.3 Land Use

Land use refers to how land is used by humans and land use decisions can have significant impacts on water quality. Intensity of land use can be categorized as low intensity (e.g. open space including forested lands, rangeland, agricultural land, and managed green space) or high intensity (e.g. residential, commercial, and industrial). When development occurs, the resulting alteration of the land can lead to changes in the way water is transported and stored. Impervious surfaces and compacted earth associated with development create a barrier to the infiltration of rainfall and snowmelt, resulting in decreased water quality; increased volume and velocity of runoff (**Figure 12**); increased frequency and severity of flooding; peak (storm) flows many times greater than in natural basins; loss of natural runoff storage capacity in vegetation, wetland, and soil; reduced groundwater recharge; and decreased based flow (Arnold and Gibbons 1994).

Figure 12. Increased volume of storm water entering Cascade Creek during a storm event

Residential land use is the dominant land use within the Presque Isle Bay watershed, comprising 40.47% of the watershed; followed by transportation at 18.14%, forest at 14.17%, commercial at 10.67%, intuitional/governmental/religious at 5.08%, rangeland at 4.81%, industrial at 2.80%, open urban/public at 2.30%, agriculture at 0.92%, water at 0.30%, transitional at 0.25%, and barren land at 0.09% (**Map 29; Table 14**). Descriptions of the various land use classifications are discussed in detail in Anderson *et al.* 1976. Using the intensity classification system described above, 77.16% of the Presque Isle Bay watershed is categorized as high intensity (residential, transportation, commercial, institutional, and industrial) and 22.84% is categorized as low intensity (forest, rangeland, open urban/public, agriculture, water, transitional, and barren land) (**Map 30**). Areas within the watershed with greater than 50% high intensity land use should be restored, and areas with less than 25% high intensity land use should be protected.

2.3.4 Wetlands

The Clean Water Act defines wetlands as those areas that are inundated or saturated by surface or ground water (hydrology) at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation (hydrophytes) typically adapted for life in saturated soil conditions (hydric soils). A survey conducted by U.S. Department of Agriculture found that urbanization was implicated in wetland loss in 96% of watersheds assessed in the United States and may account for 58% of the total wetland loss nationally (reviewed by Ehrenfeld 2000). This is important as wetlands play a vital role in regulating movement of water within watersheds (Werren *et al.* 2000). Wetlands store precipitation and surface water and release it into other surface and groundwater reserves and to the atmosphere, and in doing so, serve an important role in controlling water flow, regulating discharge of water from catchments, retarding flows and mitigating flood damage, and protect against erosion (Werren *et al.* 2000) (**Figure 13**). Fluctuating water levels within wetlands play a key role in nutrient cycling, availability, and export; sediment and organic matter accumulation, decomposition, and export; and metal adsorption and export. Wetlands also play an important role in regulating contaminant fluxes and mitigating their impacts. Mitch and Gosselink 2000 suggest that an optimum amount of wetlands be around 3-7% (average of 5%) in watersheds to optimize the landscape for their ecosystems values such as flood control and water quality enhancement.

Figure 13. Example of a well protected wetland

Based on data from the 2005 National Wetlands Inventory conducted by the United States Fish and Wildlife Service, the Presque Isle Bay watershed is comprised of 143 acres of wetlands, which is less than 1% of the watershed (**Map 31**). Areas within the watershed with wetlands present should be restored and protected.

2.3.5 Soils

For the purposes of hydrologic modeling, the SCS (Soil Conservation Service) curve number method (method for determining the amount of runoff from a rainfall event in a particular area) ranks nearly 8,500 different soils into four hydrologic soil types (Category A, B, C, and D) based on their hydrologic characteristics (Diz *et al.* 2004). Category A soils are sand, loamy sand, or sandy loam, and have low runoff potential and high infiltration rates even when thoroughly wetted. Category B soils are silt loam or loam, and have a moderate infiltration rate when thoroughly wetted. Category C soils are sandy clay loam, and have low infiltration rates when thoroughly wetted. Category D soils are clay loam, silty clay loam, sandy clay, silty clay, or clay, and have very low infiltration rates when thoroughly wetted.

According to the Pennsylvania soil survey (reported by Diz *et al*. 2004) of Erie County, Pennsylvania, there are three hydric soil groups found within the Presque Isle Bay watershed: Category B, C, and D (**Map 32**). Category B hydric soils are the dominant soil type within the Presque Isle Bay watershed, comprising 53.8% or 14.05 mi^2 of the watershed; followed by Category C soils at 39.7% or 10.37 mi^2 and Category D soils at 6.5% or 1.70 mi^2 (**Table 15**). Areas within the watershed with greater than 50% Category B soils should allow infiltration of storm water; therefore, best management practices which promote infiltration (e.g. porous pavement) should be implemented.

2.3.6 Slope

Disturbance of steep slopes along stream banks can result in erosion processes from storm water runoff and the subsequent sedimentation of surface waters, often leading to degraded water quality and loss of aquatic life (**Figure 14**). Other effects include soil loss, changes in natural topography and drainage patterns, increased flooding potential, further fragmentation of forest areas, and compromised aesthetic values. Because sloping terrains are prone to erosion if disturbed, Arendt

Figure 14. Steep slopes along Scott Run

(1999) suggests slopes over 25% should be avoided for clearing, re-grading, or construction, and slopes between 15-25% require special site planning and should also be avoided whenever possible. The vast majority of land within the Presque Isle Bay watershed is sloped less than 15%, and only a small fraction of land is sloped greater than 25% (**Map 33**). Areas within the watershed with greater than 25% percent slope should be restored and protected.

2.3.7 Riparian Buffers

Riparian buffers serve as a link between stream environments and their terrestrial surroundings. Because of their physical proximity, riparian ecosystems influence the structure of aquatic and upland terrestrial habitats and affect important functional processes in the stream channel (Osborne and Kovacic 1993). Riparian ecosystems have been widely accepted as a viable and useful tool for restoring and managing streams because of their ability to moderate stream temperatures; reduce sediment, pathogen, metal, pesticide, toxin, and nutrient input; provide important sources of organic matter to stream communities; provide important wildlife habitat; and stabilize stream banks (Osborne and Kovacic 1993; Klapproth and Johnson 2000). Wenger (1999), based on a review of over 140 articles and books, suggests that a 30 m (~100 ft) buffer is sufficient to trap sediments and nutrients, and provide habitat for many terrestrial wildlife species; however, suggested that some riparian tracts of 90 m (~300 ft) should be preserved to provide habitat for forest interior species. An assessment of the stream riparian buffers within the Presque Isle Bay watershed is provided below:

Figure 15. Scott Run riparian buffer

Figure 16. Unnamed Tributary One riparian buffer

Figure 17. Cascade Creek riparian buffer

Figure 18. Mill Creek riparian buffer

- Scott Run has the potential for 0.04 mi^2 of 30 m buffers and 0.12 mi^2 of 90 m buffers. The existing vegetated buffer for Scott Run is 0.04 mi^2 and includes 46% (0.02 mi^2) of the potential 30 m buffer, 27% (0.03 mi^2) of the potential 90 m buffer, while 19% (0.007 mi^2) of the existing vegetated buffer expands beyond 90 m (**Map 34; Figure 15**).
- Unnamed Tributary One and Two have the potential for 0.06 mi^2 of 30 m buffers and 0.15 mi^2 of 90 m buffers. The existing vegetated buffer for the Unnamed Tributaries is 0.16 mi^2 and includes 77% (0.04 mi^2) of the potential 30 m buffer, 56% (0.09 mi^2) of the potential 90 m buffer, while 46% (0.07 mi^2) of the existing vegetated buffer expands beyond 90 m (**Map 35; Figure 16**).
- Cascade creek has the potential for 0.16 mi^2 of 30 m buffers and 0.48 mi^2 of 90 m buffers. The existing vegetated buffer for Cascade creek is 0.15 mi^2 and includes 43% (0.07 mi^2) of the potential 30 m buffer, 24% (0.12 mi^2) of the potential 90 m buffer, while 22% (0.03 mi^2) of the existing vegetated buffer expands beyond 90 m (**Map 36; Figure 17**).
- Mill creek (not including the Mill Creek Tube) has the potential for 0.52 mi^2 of 30 m buffers and 1.47 mi^2 of 90 m buffers. The existing vegetated buffer for Mill Creek is 1.53 mi^2 and includes 74% (0.38 mi^2) of the potential 30 m buffer, 57% (0.84 mi^2) of the potential 90 m buffer, while 45% (0.69 mi^2) of the existing vegetated buffer expands beyond 90 m (**Map 37; Figure 18**).

- Garrison Run has the potential for 0.03 mi^2 of 30 m buffers and 0.08 mi^2 of 90 m buffers. The existing vegetated buffer for Garrison Run is 0.02 mi^2 and includes 51% (0.01 mi^2) of potential 30 m buffer, 23% (0.02 mi^2) of potential 90 m buffer, while 13% (0.003 mi^2) of the existing vegetated buffer expands beyond 90 m (**Map 38; Figure 19**).

Figure 19. Garrison Run riparian buffer

In general, Unnamed Tributary One and Two have the highest percentage of existing buffer within 30m (77%) and beyond 90 m (46%); Mill Creek and Unnamed Tributary One and Two have the highest percentage of existing buffer within 90m (57% and 56% respectively); Cascade Creek has the lowest percentage of existing buffer within 30m (43%); and Garrison Run has the lowest percentage of existing buffer within 90m (23%) and beyond 90m (13%) (**Table 16**). Areas within the watershed where less than 50% of the riparian buffer is vegetated should be restored, and areas where greater than 75% of the riparian buffer is vegetated should be protected.

2.3.8 Floodplains

Flood zones are geographic areas that the Federal Emergency Management Agency (FEMA) defines according to varying levels of flood risk, including high, moderate, and low risk (reviewed by Ward *et al.* 2008). High-risk areas are mapped based on 100-year flood events. A 100-year floodplain is the area adjacent to a stream that has a 1% probability of being flooded in any year (Holway and Burby 1990). In streams unaffected by human activities, floodplains often contain well-established, rooted vegetation to help absorb the force and volume of rising floodwaters, which serve to protect and stabilize stream banks from erosion (Ward *et al.* 2008). Vegetated floodplains also filter pollutants, shade and cool the stream, reduce floods by slowing down the velocity of floodwaters, and provide wildlife and recreational habitat. Impervious surfaces within floodplains impair a floodplains capacity to slow and absorb floodwaters and runoff, and increases the volume and velocity of runoff in stream channels; resulting in down cutting and widening of the stream channel (Ward *et al.* 2008). This may eventually lead to development of a new floodplain at a lower elevation as the stream channels begins to recover.

There are 0.37 mi^2 of assessed 100-year floodplains within the Presque Isle Bay watershed (**Map 39**), 80% (0.29 mi^2) of which are located within the Mill creek watershed and 20% (0.07 mi^2) are located within the Cascade creek watershed (**Table 17**). The 100-year floodplain for Mill creek is 73% (0.22 mi^2) vegetated and 27% (0.08 mi^2) developed (**Map 40**). The 100-year flood plain for Cascade Creek is 69% (0.05 mi^2) vegetated and 31% (0.02 mi^2) developed (**Map 40**). Development within the floodplains of Cascade Creek and Millcreek should be minimized, and areas where less than 50% of the floodplain is developed should be restored.

3.0 GOALS AND OBJECTIVES

The primary purpose of the *Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan* is to provide a framework for action that will ensure that the quality and quantity of water and sediment entering the bay will not cause adverse impacts to the ecosystem. The 2002 Watershed Assessment, GIS analysis, and supporting studies provide evidence that the Presque Isle Bay watershed has been impacted as a result of urbanization and that, restoration and protection efforts are feasible and can result in improvements to the watershed. Based on the data collected, developed, and assessed as part of the *Plan*, members of the Presque Isle Bay Watershed Planning Committee and Presque Isle Bay Public Advisory Executive Committee established the following goals and objectives:

Goal #1: Protect, restore, and enhance the quality of water resources within the Presque Isle Bay watershed. Objectives include:

- control and/or minimize the input of sediment, nutrients, pathogens, and storm water runoff-related contaminants to surface and ground waters;
- identify and correct any illicit discharges into tributaries of Presque Isle Bay (**Figure 20**); and
- promote the installation of oil/grit separators and debris separators to reduce the amount of oil and grease, and trash entering Presque Isle Bay and its watershed.

Figure 20. Pipe discharging into Cascade Creek during dry weather

Goal #2: Protect, restore, and enhance aquatic and terrestrial diversity and habitat within the Presque Isle Bay watershed. Objectives include:

- promote and maintain macroinvertebrate communities and naturally reproducing native fish populations;
- promote the restoration and protection of fish habitat in the tributaries of the watershed (**Figure 21**);
- restore riparian buffers along tributaries and protect existing riparian habitats; and
- identify opportunities to daylight enclosed portions of tributaries.

Figure 21. Brown trout collected in Cascade Creek post-streambank restoration

Goal #3: Reduce the impacts of storm water runoff on water quality and increase the natural filtering capacity of the Presque Isle Bay watershed. Objectives include:

- reduce the percentage of impervious cover within the sub-basins (i.e. Scott Run, Cascade Creek, Mill Creek, Garrison Run, and Unnamed tributaries) of the Presque Isle Bay watershed;
- install rain gardens, green roofs, pervious pavement, and other storm water reducing best management practices within the watershed (**Figure 22**); and
- increase the acreage of wetlands within the Presque Isle Bay watershed.

Figure 22. Grass parking lot at the Bayfront Center for Maritime Studies

Goal #4: Increase public awareness of and involvement in watershed restoration, protection, and monitoring activities, and incorporate watershed stakeholders into the decision making process. Objectives include:

- increase the public’s knowledge and awareness of environmental issues facing the watershed;
- utilize Pennsylvania Sea Grant’s Nonpoint Education for Municipal Officials (NEMO) program to encourage participation among the municipalities within the Presque Isle Bay watershed; and
- encourage local watershed organizations to apply for funding to implement restoration projects identified by the current plan.

4.0 Data Analysis

To address the goals and objectives of the *Plan* identified in *Section 3.0*, data collected as part of the 2002 watershed assessment (*Section 2.1.2*) and nonpoint source assessment (*Section 2.3*) were used to develop GIS-based restoration and protection prioritization models for the Presque Isle Bay watershed. The purpose of the models is to assist with the prioritization of actions within the numerous subareas of the Presque Isle Bay watershed. Generally, the models identified and ranked those subareas within the Presque Isle Bay watershed most in need of restoration and protection efforts. The models are the result of input provided by the Presque Isle Bay Watershed Planning Committee.

4.1 Subarea Delineation

Analysis subareas within the Presque Isle Bay watershed were delineated using the ArcGIS™ tool Geo WEPP (water erosion prediction project) developed by the Department of Geography at The State University of New York at Buffalo. Geo WEPP allows the delineation of sub-watersheds using digital elevation model (DEM) data. As a result of running Geo WEPP for the Presque Isle Bay watershed, over 1,000 subareas were identified. To consolidate the subareas into a more manageable base layer, the over 1,000 subareas were merged into 78 subareas using the Geoprocessing function of ArcGIS™ (**Maps 41-47**). It is important to note that the 78 subareas do not represent true sub-watersheds; as mapping true sub-watersheds would be difficult because of the altered stream networks and extensive storm sewer system, which do not necessarily follow traditional elevation data. However, Geo WEPP allowed the creation of functional management subareas for developing the restoration and protection prioritization models.

4.2 Restoration Prioritization Model

Data collected as part of the nonpoint source assessment and 2002 watershed assessment were used to develop the restoration prioritization models. Each parameter was defined by criteria developed by the Presque Isle Bay Watershed Planning Committee based on a review of relevant literature. The criteria correspond to a score between 0 and 5, with higher scores reflecting a higher priority for restoration (**Table 18**). The 18 parameters were evaluated in each of the 78 subareas within the Presque Isle Bay watershed using ArcGIS™ 9.2 software. Scores for each parameter were summed within each subarea, resulting in a total restoration score for each subarea ranging from a low of 12 in Mill Creek subarea 23 (MC 23) to a high of 76 in Cascade Creek subarea 7 (CC 7) (**Map 48**).

However, these scores were biased because not all subareas contained watershed assessment data or a complete set of nonpoint source assessment data. To compensate for this bias, the restoration prioritization model was adapted for three scenarios: 1) subareas with a daylit stream but no 2002 watershed assessment data; 2) subareas without a daylit stream; and 3) subareas with a daylit stream and 2002 watershed assessment data. For the three scenarios, higher scored subareas represent a higher restoration priority (red-orange colored subareas in **Maps 49-51**) in comparison to lower scored subareas (yellow-green colored subareas in **Maps 49-51**).

In *Scenario 1*, the total restoration score was based on a combined score of all nine nonpoint source assessment parameters, with scores ranging from 6-45 possible. The total restoration scores for the 33 subareas included in the *Scenario 1* analysis ranged from a low of 12 in Mill Creek subarea 23 (MC 23) to a high of 35 in Cascade Creek subarea 12 (CC 12) (**Map 49**; **Table 19**).

In *Scenario 2*, the total restoration score was based on a combined score of seven (buffer and floodplain data were excluded) of the nine nonpoint source parameters, with scores ranging from 6-35 possible.

The total restoration scores for the 31 subareas included in the *Scenario 2* analysis ranged from a low of 18 in Cascade Creek subarea 16 (CC 16) and Garrison Run subarea 1 (GR 1) to a high of 27 in Direct Runoff subarea 3 (DR 3) and Scott Run subarea 1 (SR 1) (**Map 50**; **Table 20**).

In *Scenario 3*, the total restoration score was based on a combined score of the nine nonpoint source parameters and nine 2002 watershed assessment parameters, with scores ranging from 6-90 possible. The total restoration scores for the 14 subareas included in the *Scenario 3* analysis ranged from a low of 36 in Mill Creek subarea 12 (MC 12) to a high of 76 in Cascade Creek subarea 7 (CC 7) (**Map 51**; **Table 21**).

4.3 Protection Prioritization Model

Data collected as part of the nonpoint source assessment were used to develop the protection prioritization model. Each parameter was defined by criteria developed by the Presque Isle Bay Watershed Planning Committee based on a review of relevant literature. The criteria correspond to a score between 0 and 5, with higher scores reflecting a higher priority for protection (**Table 22**). The nine nonpoint source parameters were evaluated in each of the 78 subareas within the Presque Isle Bay watershed using ArcGIS™ 9.2 software. Scores for each parameter were summed within each subarea (possible score range of 1-45), resulting in a total protection score for each subarea ranging from a low of 4 in Garrison Run subarea 10 (GR 10) to a high of 33 in Unnamed Tributary One subarea 2 (UN1 2) (**Map 52**; **Table 23**).

5.0 RECOMMENDED RESTORATION, PROTECTION, AND MONITORING ACTIONS

This section provides an overview of the historical restoration and protection recommendations for the Presque Isle Bay watershed as well as current recommendations resulting from the models presented in *Sections 4.2* and *4.3*.

5.1 Historical Restoration and Protection Recommendations

The historical recommendations are based on the assessments conducted by Campbell *et al.* 2002 and Diz *et al.* 2004. While the historical recommendations are general in nature, many of the historical recommendations do overlap with current recommendations.

Campbell *et al.* (2002) suggested the following remediation strategies for the Presque Isle Bay watershed:

- Restore natural riparian vegetation on stream banks and increase the width of buffer zones in all locations possible, especially in sites with already unstable banks and poorly developed riparian vegetation. In some cases, invasive plant species that inhabit the growth of ground cover vegetation should be replaced with native plants obtained from local plant stocks.
- Develop plans with major property owners and appropriate municipal officials to increase storm water retention in developed areas. Educate all parties regarding best management practices (BMPs) and assist as needed to obtain funding to finance construction and installation.
- Work with developers of Brownfield sites and appropriate municipal officials to encourage the installation of passive treatment systems such as wetlands for ubiquitous environmental contaminants in the watershed. Areas of the City of Erie along the railroad tracks would be good places to attempt this.

Diz *et al.* (2004) modeled the sediment transport of Mill Creek and Cascade Creek. Based on their findings, the authors made the following recommendations:

- Organize and execute an on-going education program in cooperation with existing environmental

groups, to inform and train the public in how their activities affect their environment;
- Encourage the use of BMPs at the source of runoff (e.g. parking lots, industrial areas, and residential areas) to minimize the first flush effect;
- Disconnect residential and commercial downspouts from the storm sewer system;
- Restore Cascade Creek within Frontier Park using natural stream channel design principles; and
- Promote the use of modern farming and conservation practices in the headwaters of Mill Creek to minimize the loss of soil from agricultural lands.

5.2 Restoration Recommendations

The current restoration recommendations are focused on addressing the goals and objectives identified in *Section 3.0*, and build upon the historical recommendations discussed in *Section 5.1*. Generally, restoration efforts within the Presque Isle Bay watershed should focus on:
- reestablishing fish and macroinvertebrate communities by restoring habitat;
- reducing chemical concentrations in the streambed sediment through the reduction of storm water runoff;
- restoration and expansion of existing riparian buffers;
- stabilization of highly erodible stream banks;
- restoration and expansion of existing wetlands;
- removal of impervious surfaces, such as unused parking lots;
- promoting storm water best management practices on all new and redevelopment projects (e.g. green roofs, porous parking lots, etc);
- separation of downspouts from the storm sewer system;
- installing rain gardens; and
- installing oil/grit separators in storm sewer grates.

For purposes of the current plan, specific restoration projects are identified for the top priority subareas identified by each scenario. General restoration efforts are recommended for those subareas out of the top priority range.

5.2.1 Scenario 1 Restoration Recommendations

In *Scenario 1*, the total restoration score was based on a combined score of all nine nonpoint source assessment parameters for the 33 assessed subareas. Restoration scores ranged from a low of 12 in Mill Creek subarea 23 (MC 23) to a high of 35 in Cascade Creek subarea 12 (CC 12). Restoration projects for the top two priority subareas identified in *Scenario 1* are listed below. In addition, general restoration recommendations for the other subareas are summarized in **Table 24**.

<u>Cascade Creek subarea 12 (CC 12) (score = 35)</u>: Restoration scores of 5 were given for six of the nine nonpoint source parameters within Cascade Creek subarea 12, including:
- land use (> 50% high intensity),
- impervious cover (> 25%),
- floodplains (< 50% vegetated),
- wetlands (wetland present),
- 30 m buffer (< 50% vegetated), and
- soils (> 50% Type B soils).

Cascade Creek subarea 12 drains a predominately industrial and residential area, and includes an 85 linear foot daylit segment of the Main Branch of Cascade Creek. Currently, there is a debris separator installed on Cascade Creek within this subarea (**Figure 23**). This debris separator should be regularly maintained to ensure proper function. Restoration efforts should focus on:

- the removal of any unused impervious surfaces;
- separation of downspouts draining industrial facilities and residential areas from the storm sewer system; and
- assessment and restoration of existing wetlands just south of the Chicago Railroad Line (**Map 53**).

Figure 23. Debris separator located on Cascade Creek in Cascade Creek subarea 12

Cascade Creek subarea 8 (CC 8) (score = 32): Restoration scores of 5 were given for five of the nine nonpoint source parameters with Cascade Creek subarea 8, including:

- land use (> 50% high intensity),
- impervious cover (> 25%),
- wetlands (wetland present),
- 30 m buffer (< 50% vegetated), and
- soils (> 50% Type B soils).

Cascade Creek subarea 8 includes approximately 5,358 feet of the West Branch of Cascade Creek, and drains a predominately residential, industrial, and commercial area. Restoration efforts should focus on:

- establishing a riparian buffer (**Figure 24**);
- separating commercial and residential down spouts from the storm sewer system;
- installing rain gardens in residential areas; and
- assessing and expanding existing wetlands (**Map 54**).

Figure 24. Impaired riparian buffer along Cascade Creek in Cascade Creek subarea 8

5.2.2 Scenario 2 Restoration Recommendations

In *Scenario 2*, the total restoration score was based on a combined score of seven (buffer and floodplain data were excluded) of the nine nonpoint source assessment parameters. Restoration scores ranged from a low of 18 in Cascade Creek subarea 16 (CC 16) and Garrison Run subarea 1 (GR 1) to a high of 27 in Direct Runoff subarea 3 (DR 3) and Scott Run subarea 1 (SR 1) for the 31 subareas assessed. None of the 31 subareas assessed under *Scenario 2* include a daylit stream; therefore, riparian buffer and floodplain restoration recommendations are not suggested. Restoration projects for the top two priority subareas identified in *Scenario 2* are listed below. In addition, general restoration recommendations for the remaining subareas are summarized in **Table 25**.

Direct Runoff subarea 3 (score = 27): Restoration Scores of 5 were given for four of the seven nonpoint source parameters, including:

- land use (> 50% high intensity),
- impervious cover (> 25%),
- wetlands (wetland present), and
- soils (> 50% Type B soils).

Direct Runoff subarea 3 drains a predominately residential area adjacent to Frontier Park and includes one direct storm water discharge to Presque Isle Bay (**Figure 25**). Restoration efforts should focus on:

- separating residential down spouts from the storm sewer system;

Figure 25. Storm water outfall located in Direct Runoff subarea 3

- installing rain gardens; and
- assessing and expanding existing wetlands (**Map 55**).

Scott Run subarea 1 (score = 27): Restoration scores of 5 were given for four of the seven nonpoint source parameters, including:
- land use (> 50% high intensity),
- impervious cover (> 25%),
- wetlands (wetland present), and
- soils (> 50% Type B soils).

Scott Run subarea 1 drains a predominately commercial and industrial land area, including Yorktown Center (**Figure 26**). Restoration efforts should focus on:
- separating commercial down spouts from the storm sewer system;
- installing oil/grit separators in storm sewer grates; and
- removing any unused impervious surfaces (**Map 56**).

Figure 26. Commercial area located in Scott Run subarea 1

5.2.3 Scenario 3 Restoration Recommendations

In *Scenario 3,* the total restoration score was based on a combined score of the nine nonpoint source assessment parameters and nine 2002 watershed assessment parameters. Scores ranged from a low of 36 in Mill Creek subarea 12 (MC 12) to a high of 76 in Cascade Creek subarea 7 (CC 7) for the 14 subareas assessed. Restoration projects for the top three priority subareas identified in *Scenario 3* are listed below. In addition, general restoration recommendations for the remaining subareas are summarized in **Table 26**.

Cascade Creek subarea 7 (CC 7) (score = 37): Restoration scores of 5 were given for six of the nine nonpoint source parameters and seven of the nine 2002 watershed assessment parameters, including:
- land use (> 50% high intensity),
- impervious cover (> 25%),
- floodplains (< 50% vegetated),
- wetlands (wetland present),
- 30 m buffer (< 50% vegetated),
- soils (> 50% Type B soils),
- oil and grease (highly polluted),
- zinc (> SEL),
- nickel (> SEL),
- lead (> SEL),
- copper (> SEL),
- fishery (impaired), and
- macroinvertebrates (very poor/minimal biological diversity).

Cascade Creek subarea 7 includes approximately 3,889 linear feet of the West Branch of Cascade Creek, which runs through a predominately industrial and commercial area. Restoration efforts should be directed in two areas: 1) the commercial and industrial area (Yorktown Centre and former Value City site) located north of the Chicago Railroad Line, south of West 12th Street, and west of Pittsburgh Avenue; and 2) the commercial area (West Erie Plaza) located north of West 12th Street, south of West 8th Street, and west of Pittsburgh Avenue (**Map 57**). A riparian buffer is essentially absent within this subarea and the stream is concreted as in runs through the West Erie Plaza. Restoration efforts should focus on:

- establishing a riparian buffer (**Figure 27**);
- re-vegetating the concrete stream channel along Cascade Creek (**Figure 28**);
- separating downspouts from the stream (**Figure 29)**; and
- assessing, remediating, and expanding wetlands.


Figure 27. Impaired riparian buffer along Cascade Creek in Cascade Creek subarea 7

Garrison Run subarea 2 (score = 67): Restoration scores of 5 were given for five of the nine nonpoint source assessment parameters and seven of the nine 2002 watershed assessment parameters, including

- land use (> 50% high intensity),
- impervious cover (> 25%),
- wetlands (wetland present),
- 30 m buffer (< 50% vegetated),
- soils (> 50% Type B soils),
- habitat (marginal),
- oil and grease (highly polluted),
- zinc (> SEL), nickel (> SEL),
- lead (> SEL),
- fishery (impaired), and
- macroinvertebrates (very poor/ minimal biological diversity).


Figure 28. Channelized section of Cascade Creek in Cascade Creek subarea 7

Garrison Run subarea 2 (adjacent to the Erie Wastewater Treatment Plant and Erie Coke Corporation) includes approximately 1,123 linear feet of Garrison Run, which runs through an open/wooded area; however, the subarea drains a predominately residential, commercial, and industrial area. Restoration efforts should focus on:

- reducing runoff from commercial/industrial areas, including removing any unused impervious surfaces;
- separating residential downspouts from the storm sewer system; and
- expanding and restoring the existing riparian and open/wooded habitat (**Map 58**).


Figure 29. Downspouts discharging into Cascade Creek in Cascade Creek subarea 7

Cascade Creek subarea 2 (score = 60): Scores of 5 were given for four of the nine natural resource parameters and three of the nine watershed assessment parameters, including

- land use (> 50% high intensity),
- impervious cover (> 25%),
- wetlands (wetland present),
- (> 50% Type B soils),
- nickel (> SEL),
- fishery (impaired), and
- macroinvertebrates (very poor/ minimal biological diversity).

Cascade Creek subarea 2 includes approximately 2,834 linear feet of the Cascade Creek (including the mouth of the stream), which drains a predominately residential area. Restoration efforts should focus on:

- the expansion and remediation of vegetated riparian buffers along the Bayfront Connector Highway (**Figure 30**),
- assessment and restoration of wetlands near the mouth of Cascade Creek, and


Figure 30. Riparian buffer along Cascade Creek in Cascade Creek subarea 2

- the separation of residential downspouts from the storm sewer system (**Map 59**).

5.3 Protection Recommendations

The current protection recommendations are focused on addressing the goals and objectives identified in *Section 3.0*. Open space protection is typically reserved for lands (e.g. forested and wetlands) not developed into residential, commercial, or industrial land uses. Forested lands are the third most dominant land use within the Presque Isle Bay watershed; however, 77.16% of the watershed is categorized as high intensity land use while only 22.84% is categorized as low intensity land use. Given the disproportionate intensity of land use, it is important to promote the expansion and protection of existing open space, forested land, and wetlands; especially, lands adjacent to stream corridors. Generally, protection efforts should focus on:

- subareas with less than 10% impervious cover;
- subareas with less than 25% high intensity land use;
- subareas with wetlands;
- subareas where the floodplain is greater than 75% vegetated; and
- subareas where the riparian buffer is greater than 75% vegetated.

The total protection score was based on a combined score of all nine nonpoint source assessment parameters. Protection scores ranged from a low of 4 in Garrison Run subarea 10 (GR 10) to a high of 33 in Unnamed Tributary One subarea 2 (UN1 2) for the 78 subareas assessed. For purposes of the current plan, specific protection projects are identified for the top two priority subareas and are listed below. In addition, general protection efforts for the remaining subareas are summarized in **Table 27**.

Figure 31. Forested area in Unnamed Tributary One subarea 2

Unnamed Tributary One subarea 2 (UN1 2) (score = 33): This subarea is < 25% high intensity land use, wetlands are present, and the riparian buffer is > 75% vegetated. A portion of this subarea is within the boundaries of Scott Park and is currently protected by Millcreek Township (**Figure 31**); however, the remainder of the subarea is owned by Erie Water Works (Sommerheim Water Treatment Plant) and privately owned (**Map 60**). Property owners within this subarea should be contacted in regard to conserving their properties.

Mill Creek subarea 17 (MC 17) (score = 32): This subarea is <25% high intensity land use, wetlands are present, the floodplain is > 75% vegetated, and the riparian buffer is > 75% vegetated. Protection efforts should focus on conserving existing wooded land, wetlands, riparian corridors, and vegetated floodplains (**Map 61; Figure 32**). Property owners within this subarea area, particularly those owning property within the riparian zone, should be contacted in regard to conserving their properties. In addition, any future residential development in this subarea should consider utilizing residential conservation design techniques.

Figure 32. Riparian buffer along Mill Creek in Mill Creek subarea 17

5.4 Monitoring Recommendations

Measuring the success of watershed restoration and protection efforts will rely heavily upon a long-term watershed monitoring plan. As previously mentioned, Diz *et al.* (2002), Campbell *et al.* (2002), and Pyron *et al.* 2004 provided a baseline chemical, physical, and biological assessment of the Presque Isle Bay watershed by assessing a total of 16 sites along Scott Run, Cascade Creek, Mill Creek, and Garrison Run. The long-term monitoring plan for the watershed includes re-sampling the sites assessed during the 2002 watershed assessment (Campbell *et al.* 2002) in addition to sampling the mouths of the streams (**Map 62**).

Each site should be assessed for sediment chemistry, fisheries, macroinvertebrate communities, and water quality every five years to track improvements. The sediment assessment should include metals, oil and grease, PAHs, PCBs, pesticides, nitrogen, and phosphorus. The water quality assessment should include temperature, dissolved oxygen, conductivity, 5-day biological oxygen demand, total organic carbon, total nitrogen, total phosphorus, and *E. coli*. The following sampling methodologies should be used to assess the physical, chemical, and biological conditions of the streams:

- Streambed sediment chemistry: Horowitz and Stephens (2008).
- Habitat conditions: http://www.epa.gov/owow/monitoring/rbp/wp61pdf/ch_05.pdf.
- Macroinvertebrate communities: http://www.epa.gov/owow/monitoring/rbp/
- Fisheries: Pyron *et al.* (2004).
- Water Quality: Diz and Wellington (2006).

5.5 Additional Recommendations

In addition to the restoration, protection, and monitoring recommendations detailed in *Sections 7.2-7.4*, the following actions are recommended to enhance the quality of the Presque Isle Bay watershed:

- Develop TMDLs for Scott Run, Cascade Creek, Mill Creek, and Garrison Run.
- Identify and correct illicit discharges to the streams within the Presque Isle Bay watershed.
- Identify and summarize all historical restoration and protection efforts within the watershed.
- Identify unused impervious surfaces within the watershed, including brownfields.
- Update municipal ordinances to allow for the separation of downspouts.

6.0 IMPLEMENTATION STRATEGY

The *Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan* was developed to serve as the framework for restoring and protecting water resources within the watershed, and to provide a model that can be adapted to other watersheds. The *Plan* serves as a living document, which can be updated as new information becomes available. Implementing the recommendations of the *Plan* will require a cooperative effort among governmental agencies, nonprofit organizations, municipal governments, and academia. Project partners should include:

- **Agencies**: Pennsylvania Department of Environmental Protection (DEP), Pennsylvania Fish and Boat Commission (PFBC), Pennsylvania Department of Conservation and Natural Resources (DCNR), Erie County Department of Health (ECDH), and Erie County Conservation District (ECCD).
- **Nonprofit Organizations**: Pennsylvania Sea Grant (PASG), Pennsylvania Lake Erie Watershed Association (PLEWA), Lake Erie Region Conservancy (LERC), Presque Isle Bay Public Advisory Committee (PAC), and S.O.N.S of Lake Erie (S.O.N.S), and Regional Science Consortium (RSC).
- **Municipal Governments**: Millcreek Township, City of Erie, Harborcreek Township, Summit Township, Greene Township, and Erie County Department of Planning (ECDP).
- **Academia**: Penn State Behrend, Gannon University, and Mercyhurst College.

The 10-year implementation strategy for the *Plan* is outlined in **Table 28**. It is important to note that as conditions and opportunities change, adaptive strategies should be implemented to take advantage of opportunities for watershed restoration or protection funding. To fund the implementation of the recommendations of the *Plan*, the following funding sources should be explored:

- Pennsylvania Department of Environmental Protection Growing Greener Program
- Pennsylvania Department of Conservation and Natural Resources Community Conservation Partnerships Program (C2P2)
- Pennsylvania Coastal Resources Management Program
- Pennsylvania Fish and Boat Commission Erie Access Improvement Grant Program
- U.S. Environmental Protection Agency Great Lakes Restoration Initiative
- Great Lakes Commission Great Lakes Basin Program for Soil Erosion and Sediment Control
- Great Lakes Protection Fund
- Water Resources Education Network (WREN) Grants
- National Fish and Wildlife Foundation

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APPENDIX A: TABLES

Table 1. History of the City of Erie

Time Period	History
Pre-War of 1812	Industry was dominated by saw milling, grain grinding, salt hauling, lumbering, shipbuilding, and blacksmithing.
1830s	Wool yards, tanneries, distilleries, paper mills, brickyards, lumber yards, and foundries were added to the City's list of industries (Lechner 1994)
1840s and 1850s	Additional foundries opened as well as metal works, machine shops, oilcloth manufacturers, paper mills, breweries, and gas works.
Late 1800s	Agriculture (grape culture and fruit production) and commercial fishing gained popularity. By the end of the 19th century, the City of Erie was the largest commercial fishing port on the Great Lakes; however, by the late 1950s the fishery had been depleted.
1900	The turn of the century saw improved infrastructure and transportation. In 1900, most of the business and manufacturing streets had been paved. At the same time, improvements were made to the harbor (Presque Isle Bay), allowing for increased imports and exports. The main export was coal, and by 1900, the bayfront had three large grain elevators, the Scott Coal Dock, ore docks, warehouses, and H.F. Blast Furnace (Lechner 1994).
1913	There were 464 industries in the City of Erie, including the largest boiler works and horse-shoe factory in the world.
World Wars	During WWI, Erie industry benefited from war efforts. However, in the 1930s the Great Depression set in and many of the wealth lost their companies and as a result, many of the work force lost their jobs. During WWII, many of the industries in the city ceased to help with the war efforts. Following the war, GIs returning to the Erie area strained the economy as manufacturers returned to normal production, and industrial activities and jobs declined (Lechner 1994).
1960s	Residents began moving to into suburban municipalities, looking for more space and prestigious neighborhoods. As a result, businesses in the City of Erie were abandoned and followed the sprawling trend.
1900-2000	As was common practice in the 18th and 19th centuries, much of the waste water from the City of Erie's industries and domestic sources was discharged directly to Presque Isle Bay. In the early 1890s, an intercepting sewer to divert sewage into Lake Erie was proposed; however, the improvements were not approved. As a result, a typhoid fever epidemic hit the City due to contaminated drinking water. In 1908, in response to the epidemic, the City extended its water supply into Lake Erie and constructed a water treatment plant. In the 1930s, construction began on the Erie Wastewater Treatment Plant (EWTP) with the construction of the first primary plant and outfall to Lake Erie; secondary treatment was constructed in 1954; and expansions and upgrades were completed in 1974. Despite these improvements, problems remained due to Combined Sewer Overflows (CSOs) to the Bay. In 1989, the City of Erie and Sewer Authority entered into a Consent Order with DEP. As a result, after spending nearly $100 million, upgrades to the City's waste water treatment, collection, and conveyance system were completed in 2000, and the number of CSOs has been reduced from 70 to 5 per year.

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Table 2. Municipalities located within the Presque Isle Bay watershed

Municipality	Percent of municipality within the water-shed (%)	Percent of watershed within the munici-pality (%)
City of Erie	74.79	54.59
Millcreek	30.63	36.97
Greene	4.54	6.52
Summit	1.44	1.30
Harborcreek	0.47	0.62

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Table 3. Stream length and sub-watershed area

Watershed/Stream	Stream Length (mi)*	Watershed Area (mi^2)	Percent Area of Presque Isle Bay Watershed (%)
Scott Run	1.18	0.68	2.6
Unnamed Tributary One and Two	1.79	0.44	1.7
Cascade Creek	4.75	7.01	26.7
Mill Creek	15.2	12.62	48.1
Garrison Run	0.79	2.86	10.9
Direct Runoff		2.61	10.0
Total	**24.33**	**26.22**	

* piped sections of the stream were not included in the length calculation.

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Table 4. Presque Isle Bay watershed habitat assessment

	Habitat Assessment Score*			
Site	Optimal	Sub-optimal	Marginal	Poor
SR			91	
CC 1		116		
CC 2			95	
CC 3		126		
CC 4		116		
CC 5				
CC 6		120		
MC 1		142		
MC 2			107	
MC 3		118		
MC 4		114		
MC 5		147		
MC 6		132		
MC 7		112		
MC 8		154		
GR			104	

* habitat assessment data were adapted from Diz and Johnson 2002

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Table 5. Sources of sediment-associated metals and oil and grease

Parameter	Source*
Cadmium	lubricating oils, diesel oils, tires, phosphate fertilizers, sewage sludge, insecticides, electroplating, pigments, batteries, electronics, paint, wear of tires and break pads coal and oil combustion, non-ferrous metal production, refuse incineration, and iron and steel manufacturing,
Copper	metal plating, bearing and brushing wear, moving engine parts, brake-lining wear, fungicides and insecticides, anti-foulants, corrosion of plumbing, algaecides, concrete and asphalt, rubber, phosphate fertilizers, sewage sludge, and treated lumber
Lead	Leaded gasoline (banned in 1995), automobile exhaust, tire wear, lubricating oil and grease, bearing wear, brake linings, rubber, concrete, paint manufacturing, battery manufacturing, insecticides, phosphate fertilizers, sewage sludge, paint, and glass making
Nickel	Diesel fuel and vehicle exhaust, lubricating oil, metal plating, brushing wear, brake lining wear, asphalt paving, phosphate fertilizers, storage batteries, stainless steel, batteries, and food production
Zinc	Vulcanization of rubber and tire wear, motor oil, grease, batteries, galvanizing, plating, air-conditioning ducts, pesticides, phosphate fertilizers, sewage sludge, transmission fluid, under coating, brake linings, asphalt, concrete, coal combustion, smelting operations, incineration and wood combustion, and roof shingles
Oil and Grease	Deliberate dumping, automobile emissions, chemical spills, and automobile crankcase drippings

* source data was derived from Horowitz 2008, Wheeler *et al. 2005, Sutherland 2000, Makepeace et al. 1995, and Stenstrom et al. 1984*

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Table 6. Presque Isle Bay watershed oil and grease analysis

	Oil and Grease*		
Site	Non-Polluted	Moderately-Polluted	Highly-Polluted
SR	x		
CC 1		x	
CC 2	x		
CC 3	x		
CC 4			x
CC 5			x
CC 6			x
MC 1			x
MC 2			x
MC 3			x
MC 4	x		
MC 5			x
MC 6			x
MC 7		x	
MC 8		x	
GR			x

* oil and grease data were adapted from Diz and Johnson 2002

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Table 7. Presque Isle Bay watershed metal analysis*

	[Zinc]			[Nickel]			[Lead]			[Copper]			[Cadmium]		
Site	<LEL	>LEL	>SEL	<LEL	>LEL	>SEL	<LEL	>LEL	>SEL	<LEL	>LEL	>SEL	<LEL	>LEL	>SEL
SR		x				x	x				x		x		
CC 1		x				x		x			x		x		
CC 2		x				x		x			x		x		
CC 3		x				x		x			x		x		
CC 4		x			x			x			x		x		
CC 5		x				x			x			x	x		
CC 6			x			x		x			x		x		
MC 1		x			x			x			x		x		
MC 2		x			x			x			x		x		
MC 3		x			x		x				x		x		
MC 4		x			x		x				x		x		
MC 5		x			x		x				x		x		
MC 6		x			x			x			x		x		
MC 7			x		x			x			x		x		
MC 8		x			x		x				x		x		
GR			x			x			x		x		x		

* all metal data were adapted from Diz and Johnson 2002

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Table 8. IBI scoring criteria for streams of the Presque Isle Bay watershed

	Scoring Criteria		
Category*	1	3	5
1. Total number of species	< 2	2 - 3	> 3
2. Number of darter/sculpin species	< 1	1 - 2	> 2
3. Headwater species	< 2	2 - 3	> 3
4. Number of minnow species	< 2	2 - 4	> 4
5. Number of sensitive species	< 1	1 - 2	> 3
6. Percent tolerant species	> 57%	34 - 57%	< 34%
7. Percent pioneering species	> 55%	30 - 55%	< 30%
8. Percent omnivores	< 1%	10 - 20%	> 20%
9. Percent insectivores	< 14%	14 - 26%	> 26%
10. Simple lithophil species	< 1.5	1.5 - 3	> 3
11. % DELT anomalies**	> 1.3	0.1 - 1.3	< 0.1
12. Fish numbers	< 50	51 - 110	> 110

* IBI criteria adapted from Pyron *et al. (2004)*

** DELT refers to Deformities, Erosions, Lesions, and Tumors

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Table 9. Presque Isle Bay watershed fishery assessment

	Index of Biotic Integrity (IBI)*	
Site	Acceptable	Impaired
SR		26
CC 1		37
CC 2		28
CC 3		
CC 4		28
CC 5		
CC 6		28
MC 1	46	
MC 2		38
MC 3		
MC 4		37
MC 5		29
MC 6	42	
MC 7		
MC 8	42	
GR		12

* fishery data was adapted from Pyron *et al. 2004*

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Table 10. Presque Isle Bay watershed macroinvertebrate assessment

Site	Average Composite Index Score*							
	Optimum	Very Good	Good	Fair	Slightly Degraded	Poor	Very Poor	Minimal Biological Diversity
SR						14.25		
CC 1							11.2	
CC 2							11	
CC 3							10	
CC 4							12	
CC 5							6.5	
CC 6							12.5	
MC 1						22		
MC 2					28			
MC 3						23.3		
MC 4					28			
MC 5				38.5				
MC 6						24.2		
MC 7					21.6			
MC 8					28.7			
GR								6

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Table 11. Ecological relevance of water quality parameters

Parameter	Ecological Relevance*
Temperature	The rates of biological and chemical processes are dependent on temperature and many aquatic organisms are required specific temperature ranges for their optimal health. If temperatures are outside the optimal range for extended periods of time, aquatic organisms can become stressed and die. Causes of temperature change include weather, removal of shading streambank vegetation (i.e. riparian buffer), impoundments (e.g. dams), discharge of cooling water, urban storm water, and groundwater inflows to the stream.
Conductivity	Conductivity is a measure of the ability of water to pass an electrical current. Conductivity is affected by temperature and by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations. Discharges to streams can change the conductivity depending on their make-up. For example, a failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; however, an oil spill would lower the conductivity.
Total Organic Carbon (TOC)	Total Organic Carbon (TOC) is a sum measure of the concentration of all organic carbon atoms covalently bonded in the organic molecules of a given sample of water. TOC does not identify specific organic contaminants; however, it does detect the presence of all carbon-compounds, thus identifying the presence of any organic contaminant. Sources of organic contaminants include storm water runoff (e.g. insecticides and herbicides), domestic and industrial waste water, and accidental spills.
5-day Biological Oxygen Demand (BOD5)	Biochemical oxygen demand (BOD) measures the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream and as a result aquatic organisms become stressed, suffocate, and die. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff.
Total Nitrogen (TN)	Total Nitrogen (TN) is an essential nutrient for plants and animals; however, an excess amount of nitrogen can result in low levels of dissolved oxygen and negatively alter various plant life and organisms. Sources of nitrogen include wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, runoff from animal manure and storage areas, and industrial discharges that contain corrosion inhibitors.
Total Phosphorus (TP)	Phosphorus is an essential nutrient for aquatic plants and animals. Phosphorus is a limiting nutrient; therefore, modest increase in phosphorus can lead to accelerated plant growth, algal blooms, low dissolved oxygen, and the death of fish and invertebrates. Sources of phosphorus include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic tanks, runoff from manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.
Total Coliforms and *E.coli*	Total coliforms and *E.coli are used as indicators of possible sewage contamination because they are commonly found in fecal matter. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic bacteria, viruses, and protozoans that also live in human and animal digestive systems. Total coliforms are a group of bacteria that are widespread in nature. All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil, and submerged wood. E. coli is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals.*

* All water quality parameter information was adapted from EPA's *Volunteer Stream Monitoring: A Methods Manual (EPA 1997)*

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Table 12. Ranking of water quality parameters for Lake Erie watershed stream sites*

Site	Water Quality Parameters**									
	Map 14 ID***	Temp	Cond	BOD5	TOC	TN	TP	Total Coli-form	*E. coli*	Total Score
Six Mile Creek	24	3	25	30	20	30	25	11	29	173
Lamson Run	7	7	24	20	22	29	26	28	17	173
Twenty Mile Creek	30	2	26	23	27	21	16	27	28	170
Scott Run (SR)	**14**	**29**	**4**	**27**	**15**	**16**	**20**	**29**	**30**	**170**
Elk Creek 3	5	12	28	13	13	28	24	30	16	164
Cascade Creek 3 (CC 3)	**17**	**27**	**5**	**19**	**28**	**12**	**18**	**25**	**27**	**161**
Seven Mile Creek	25	15	19	22	16	18	27	10	20	147
Crooked Creek	2	21	22	17	19	19	22	19	6	145
Raccoon Creek	1	22	21	16	5	22	12	26	21	145
Twelve Mile Creek	27	9	23	6	26	7	28	21	24	144
Four Mile Creek	23	8	14	3	17	24	30	22	22	140
Little Elk Creek	6	1	29	11	11	25	29	1	23	130
Cascade Creek 1 (CC 1)	**18**	**18**	**3**	**21**	**18**	**5**	**19**	**20**	**25**	**129**
Marshall Run	13	26	6	28	24	8	17	9	9	127
Cascade Creek 2 (CC 2)	**16**	**24**	**1**	**29**	**25**	**6**	**23**	**12**	**7**	**127**
Wilkins Run	12	20	10	24	14	11	11	23	13	126
Elk Creek 1	3	10	15	18	23	15	8	24	8	121
Eight Mile Creek	26	5	20	25	10	27	21	8	5	121
Godfrey Run	8	30	18	15	30	2	10	7	1	113
Baker Creek	29	11	27	26	7	26	1	3	12	113
Elk Creek 2	4	16	30	8	1	20	6	16	3	100
Walnut Creek 2	11	4	7	5	8	23	15	18	19	99
Garrison Run (GR)	**20**	**17**	**12**	**12**	**12**	**9**	**9**	**14**	**14**	**99**
Mill Creek (MC 2)	**21**	**13**	**11**	**2**	**21**	**14**	**14**	**5**	**15**	**95**
Trout Run	9	28	17	9	9	4	2	15	11	95
Walnut Creek 1 (WC 1)	10	19	13	14	6	17	3	17	4	93
McDanel Run	22	14	9	10	4	3	13	13	26	92
Cascade Creek 4 (CC 4)	**15**	**25**	**2**	**4**	**29**	**1**	**4**	**4**	**18**	**87**
Mill Creek 1 (MC 1)	**19**	**23**	**8**	**1**	**2**	**10**	**7**	**2**	**10**	**63**
Sixteen Mile Creek	28	6	16	7	3	13	5	6	2	58

* data were adapted from Diz and Wellington (2006)

** Temp = temperature; Cond = Conductivity; BOD5 = 5 day biological oxygen demand; TN = total nitrogen; TP = total phosphate. (higher score is higher quality)

*** Map ID refers to the sampling locations presented on Map 14

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Table 13. Exceedance of PECs in suspended sediment*

	Exceedances of PEC**	
Metal/PAH	Mill Creek (12 storm events)	Scott Run (14 storm events)
Chromium	0	0
Nickel	10	0
Copper	5	0
Mercury	0	0
Cadmium	0	0
Lead	11	1
Zinc	11	0
Arsenic	0	0
Chrysene	4	3
Pyrene	4	4
Phenanthrene	4	3
Fluroanthene	5	6
Benzo(a)pyrene	4	0
Benzo(a)anthracene	3	2

* data were adapted from Ebert (2006)

** represents the number of storm events that each metal/PAH, as measured in suspended sediment, exceeded the probable effects concentration (PEC)

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Table 14. Presque Isle Bay watershed land use

Intensity Classification	Land Use Class	Area (mi^2)	Percent of watershed (%)
High Intensity	Residential	10.59	40.47
	Transportation/Communications/Utilities	4.75	18.14
	Commercial	2.79	10.67
	Institutional/Govt/Religious	1.33	5.08
	Industrial	0.73	2.80
Low Intensity	Forest	3.71	14.17
	Rangeland	1.26	4.81
	Open Urban/Public	0.39	2.30
	Agricultural	0.37	0.92
	Water	0.08	0.30
	Transitional	0.07	0.25
	Barren	0.02	0.09

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Table 15. Hydric soil classification for the Presque Isle Bay watershed

Hydric Soil Class*	Runoff Potential	Area (mi^2)	Percent of watershed (%)
Category A	Low	0	0
Category B	Moderate	14.05	53.8
Category C	High	10.37	39.7
Category D	Very High	1.7	6.5

* Hydric soil classes adapted from Diz *et al. 2004*

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Table 16. Stream riparian buffer data for the Presque Isle Bay watershed

Stream	Existing buffer (mi^2)	Potential 100 ft buffer (mi^2)	Potential 300 ft buffer (mi^2)	Existing area w/in 100 ft (mi^2)	Percent of potential 100ft buffer w/ existing buffer	Existing area w/in 300 ft (mi^2)	Percent of potential 300ft buffer w/ existing buffer	Existing area outside 300 ft (mi^2)	Percent existing outside 300 ft
Scott Run	0.0396	0.0405	0.1217	0.0187	46	0.0322	27	0.0074	19
Unnamed Tributary One and Two	0.1581	0.0569	0.1521	0.0440	77	0.0861	56	0.0720	46
Cascade Creek	0.1503	0.1643	0.4803	0.0698	43	0.1167	24	0.0336	22
Mill Creek	1.5266	0.5219	1.4744	0.3849	74	0.8356	57	0.6910	45
Garrison Run	0.0224	0.0279	0.0844	0.0143	51	0.0194	23	0.0030	13

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Table 17. 100-year floodplains within the Presque Isle Bay watershed

Stream	Floodplain area (mi^2)	Floodplain area (%)	Floodplain vegetated (mi^2)	Floodplain vegetated (%)	Floodplain developed (mi^2)	Floodplain developed (%)
Cascade Creek	0.0739	20	0.0509	69	0.0230	31
Mill Creek	0.2948	80	0.2162	73	0.0786	27
Scott Run	-	-	-	-	-	-
Garrison Run	-	-	-	-	-	-
Unnamed Tribs	-	-	-	-	-	-
Total	**0.3687**	**-**	**0.2671**	**-**	**0.1016**	**-**

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Table 18. Restoration model criteria

Parameter	Score 0	1	3	5
Land use		< 25% high intensity	25-50% high intensity	> 50% high intensity
Impervious cover		0-10%	10-25%	> 25%
Parking lots		0-10%	10-25%	> 25%
Buildings		0-10%	10-25%	> 25%
Floodplains	no floodplain	> 75% vegetation	50-75% vegetated	< 50% vegetated
Wetlands	no wetland			wetland present
100' (30m) buffer	no 100' buffer	> 75% vegetated	50-75% vegetated	< 50% vegetated
Slope		0-15%	15-25%	> 25%
Hydric soils		> 50% Type D	> 50% Type C	> 50% Type B
Habitat	no assessment	optimal	sub-optimal	marginal
Oil and grease	no assessment	non-polluted	moderately-polluted	highly-polluted
Zinc	no assessment	< LEL	> LEL	> SEL
Nickel	no assessment	< LEL	> LEL	> SEL
Lead	no assessment	< LEL	> LEL	> SEL
Copper	no assessment	< LEL	> LEL	> SEL
Cadmium	no assessment	< LEL	> LEL	> SEL
Fishery (IBI)	no assessment	acceptable		impaired
Macroinvertebrate	no assessment	fair/slightly degraded	poor	very poor/minimal biological diversity

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Table 19. Total restoration scores for the Presque Isle Bay watershed subareas (*Scenario 1)*

Name	Map 49 ID	Parameters*									
		LU	IC	PL	Bldgs	FldP	WetL	Buff	Slope	Soil	T_NRI
Mill Creek subarea 23	MC 23	3	1	1	1	1	0	1	1	3	12
Unnamed Tributary One subarea 4	UN1 4	1	5	1	1	0	0	1	1	5	15
Unnamed Tributary One subarea 5	UN1 5	1	5	1	1	0	0	1	1	5	15
Mill Creek subarea 14	MC 14	1	5	1	1	0	5	1	1	1	16
Mill Creek subarea 22	MC 22	3	5	1	1	1	0	1	1	3	16
Mill Creek subarea 24	MC 24	3	5	1	1	1	0	1	1	3	16
Mill Creek subarea 13	MC 13	1	5	1	1	0	5	1	1	3	18
Mill Creek subarea 10	MC 10	5	5	1	3	0	0	1	1	3	19
Mill Creek subarea 17	MC 17	1	5	1	1	1	5	1	1	3	19
Garrison Run subarea 3	GR 3	3	5	1	1	0	0	3	1	5	19
Scott Run subarea 3	SR 3	5	5	1	1	0	0	3	1	5	21
Unnamed Tributary Two subarea 1	UN2 1	5	5	1	3	0	0	1	1	5	21
Garrison Run subarea 5	GR 5	5	5	1	3	0	0	1	1	5	21
Unnamed Tributary One subarea 2	UN1 2	1	5	1	1	0	5	1	3	5	22
Scott Run subarea 4	SR 4	5	5	3	3	0	0	1	1	5	23
Unnamed Tributary One subarea 3	UN1 3	5	5	1	3	0	0	1	3	5	23
Unnamed Tributary One subarea 6	UN1 6	5	5	3	3	0	0	1	1	5	23
Unnamed Tributary Two subarea 2	UN2 2	5	5	3	1	0	0	3	1	5	23
Unnamed Tributary Two subarea 3	UN2 3	5	5	1	3	0	0	3	1	5	23
Mill Creek subarea 16	MC 16	5	5	1	1	1	5	1	1	3	23
Mill Creek subarea 19	MC 19	5	5	1	1	1	5	1	1	3	23
Unnamed Tributary One subarea 8	UN1 8	5	5	1	1	0	5	1	1	5	24
Unnamed Tributary One subarea 7	UN1 7	5	5	1	3	0	0	3	3	5	25
Mill Creek subarea 11	MC 11	5	5	1	1	3	5	3	1	1	25
Cascade Creek subarea 3	CC 3	5	5	1	3	3	0	3	1	5	26
Scott Run subarea 5	SR 5	5	5	3	3	0	0	5	1	5	27
Cascade Creek subarea 9	CC 9	5	5	1	1	3	5	3	1	3	27
Cascade Creek subarea 10	CC 10	5	5	3	3	0	0	5	1	5	27
Cascade Creek subarea 6	CC 6	5	5	1	3	3	0	5	1	5	28
Mill Creek subarea 2	MC 2	5	5	1	1	0	5	5	1	5	28
Unnamed Tributary One subarea 1	UN1 1	5	5	3	3	0	5	3	1	5	30
Cascade Creek subarea 8	CC 8	5	5	3	3	0	5	5	1	5	32
Cascade Creek subarea 12	CC 12	5	5	1	3	5	5	5	1	5	35

* LU = land use; IC = impervious cover; PL = parking lots; Bldgs = buildings; FldP = floodplains; WetL = wetlands; Buff = 100' buffers; Slope = average watershed slope; Soil = hydric soils; T_NRI = total restoration score based on all nine nonpoint source assessment parameters.

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Table 20. Total restoration scores for the Presque Isle Bay watershed subareas (*Scenario 2)*

Name	Map 50 ID	Parameters*							
		LU	IC	PL	Bldgs	WetL	Slope	Soil	T_NRI
Cascade Creek subarea 16	CC 16	5	5	1	3	0	1	3	18
Garrison Run subarea 1	GR 1	5	5	1	3	0	1	3	18
Direct Runoff subarea 1	DR 1	1	5	1	1	5	1	5	19
Cascade Creek subarea 1	CC 1	5	5	1	3	0	1	5	20
Cascade Creek subarea 13	CC 13	5	5	1	3	0	1	5	20
Cascade Creek subarea 15	CC 15	5	5	1	3	0	1	5	20
Cascade Creek subarea 17	CC 17	5	5	1	3	0	1	5	20
Mill Creek subarea 3	MC 3	5	5	1	3	0	1	5	20
Mill Creek subarea 7	MC 7	5	5	1	3	0	1	5	20
Garrison Run subarea 6	GR 6	5	5	1	3	0	1	5	20
Garrison Run subarea 9	GR 9	5	5	1	3	0	1	5	20
Garrison Run subarea 10	GR 10	5	5	3	3	0	1	3	20
Garrison Run subarea 11	GR 11	5	5	1	3	0	1	5	20
Garrison Run subarea 12	GR 12	5	5	1	3	0	1	5	20
Garrison Run subarea 14	GR 14	5	5	1	3	0	1	5	20
Garrison Run subarea 16	GR 16	5	5	1	3	0	1	5	20
Cascade Creek subarea 4	CC 4	5	5	1	5	0	1	5	22
Cascade Creek subarea 14	CC 14	5	5	1	5	0	1	5	22
Mill Creek subarea 5	MC 5	5	5	3	3	0	1	5	22
Mill Creek subarea 6	MC 6	5	5	3	3	0	1	5	22
Garrison Run subarea 4	GR 4	5	5	1	5	0	1	5	22
Garrison Run subarea 15	GR 15	5	5	1	5	0	1	5	22
Direct Runoff subarea 5	DR 5	1	5	1	1	5	5	5	23
Mill Creek subarea 4	MC 4	5	5	3	5	0	1	5	24
Garrison Run subarea 8	GR 8	5	5	3	5	0	1	5	24
Garrison Run subarea 7	GR 7	5	5	1	3	5	1	5	25
Garrison Run subarea 13	GR 13	5	5	1	3	5	1	5	25
Direct Runoff subarea 2	DR 2	5	5	1	3	5	3	5	25
Direct Runoff subarea 4	DR 4	5	5	1	3	5	1	5	25
Scott Run subarea 1	SR 1	5	5	3	3	5	1	5	27
Direct Runoff subarea 3	DR 3	5	5	1	3	5	3	5	27

* LU = land use; IC = impervious cover; PL = parking lots; Bldgs = buildings; WetL = wetlands; Slope = average watershed slope; Soil = hydric soils; T_NRI = restoration score based on seven of the nine nonpoint source assessment parameters (excludes buffers and floodplains).

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Table 21. Total restoration scores for the Presque Isle Bay watershed subareas (*Scenario 3*)

	Parameters*																			
Map 51 ID	LU	IC	PL	Bldgs	FldP	WetL	Buff	Slope	Soil	T_NRI	Habitat	OandG	Zn	Ni	Pb	Cu	Cd	Fishery	Macros	T_charac	Total
MC 12	3	5	1	1	0	0	3	1	1	15	3	1	3	3	1	3	1	5	1	21	36
MC 15	5	5	1	1	1	0	1	1	3	18	3	5	3	3	1	3	1	0	0	19	37
MC 1	3	5	1	1	1	5	3	1	3	23	3	3	3	3	1	3	1	1	1	19	42
MC 18	3	5	1	1	1	5	1	1	1	19	3	5	3	3	1	3	1	5	1	25	44
MC 21	3	5	1	1	1	5	1	1	3	21	3	5	3	3	3	3	1	1	3	25	46
MC 8	5	5	1	3	3	0	3	1	3	24	3	5	3	3	3	3	1	1	3	25	49
MC 20	5	5	1	1	5	5	1	1	3	27	3	3	5	3	3	3	1	0	1	22	49
SR 2	5	5	1	1	0	5	5	1	5	28	5	1	3	5	1	3	1	5	3	27	55
MC 9	5	5	1	1	3	5	3	1	3	27	5	5	3	3	3	3	1	5	1	29	56
CC 11	5	5	3	5	5	0	5	1	5	34	3	1	3	5	3	3	1	0	5	24	58
CC 5	5	5	3	3	1	0	1	1	5	24	5	5	3	5	3	3	1	5	5	35	59
CC 2	5	5	1	3	1	5	3	1	5	29	3	3	3	5	3	3	1	5	5	31	60
GR 2	5	5	1	1	0	5	5	1	5	28	5	5	5	5	5	3	1	5	5	39	67
CC 7	5	5	3	3	5	5	5	1	5	37	3	5	5	5	5	5	1	5	5	39	76

* LU = land use; IC = impervious cover; PL = parking lots; Bldgs = buildings; FldP = floodplains; WetL = wetlands; Buff = 100' buffers; Slope = average watershed slope; Soil = hydric soils; T_NRI = restoration score based on nonpoint source assessment parameters; Habitat = habitat assessment; OandG = oil and grease; Zn = zinc; Ni = nickel; Pb = lead; Cu = copper; Cd = cadmium; Fishery = fishery assessment; Macros = macroinvertebrate assessment; T_charac = restoration score based on 2002 watershed assessment parameters; Total = total restoration score based on nonpoint source assessment and 2002 watershed assessment parameters.

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Table 22. Protection model criteria

Parameter	Score 0	1	3	5
Land use	> 50% high intensity	25-50% high intensity		< 25% high intensity
Impervious Cover	> 25%	10-25%		0-10%
Parking Lots	> 25%	10-25%		0-10%
Buildings	> 25%	10-25%		0-10%
Floodplains	no floodplain or < 50% vegetated	50-75% vegetated		> 75% vegetation
Wetlands	no wetland			wetland present
100' (30m) Buffer	no 100' buffer or < 50% vegetated	50-75% vegetated		> 75% vegetated
Slope		0-15%	15-25%	> 25%
Hydric Soils	> 50% Type D	> 50% Type C		> 50% Type B

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Table 23. Total protection scores for the Presque Isle Bay watershed subareas

Name	Map 52 ID	Parameters*									
		LU	IC	PL	Bldgs	FldP	WetL	Buff	Slope	Soil	T_NRI
Garrison Run subarea 10	GR 10	0	0	1	1	0	0	0	1	1	4
Cascade Creek subarea 11	CC 11	0	0	1	0	0	0	0	1	5	7
Mill Creek subarea 4	MC 4	0	0	1	0	0	0	0	1	5	7
Garrison Run subarea 8	GR 8	0	0	1	0	0	0	0	1	5	7
Scott Run subarea 5	SR 5	0	0	1	1	0	0	0	1	5	8
Cascade Creek subarea 10	CC 10	0	0	1	1	0	0	0	1	5	8
Cascade Creek subarea 16	CC 16	0	0	5	1	0	0	0	1	1	8
Mill Creek subarea 5	MC 5	0	0	1	1	0	0	0	1	5	8
Mill Creek subarea 6	MC 6	0	0	1	1	0	0	0	1	5	8
Garrison Run subarea 1	GR 1	0	0	5	1	0	0	0	1	1	8
Mill Creek subarea 8	MC 8	0	0	5	1	1	0	1	1	1	10
Cascade Creek subarea 4	CC 4	0	0	5	0	0	0	0	1	5	11
Cascade Creek subarea 14	CC 14	0	0	5	0	0	0	0	1	5	11
Garrison Run subarea 4	GR 4	0	0	5	0	0	0	0	1	5	11
Garrison Run subarea 15	GR 15	0	0	5	0	0	0	0	1	5	11
Cascade Creek subarea 1	CC 1	0	0	5	1	0	0	0	1	5	12
Cascade Creek subarea 13	CC 13	0	0	5	1	0	0	0	1	5	12
Cascade Creek subarea 15	CC 15	0	0	5	1	0	0	0	1	5	12
Cascade Creek subarea 17	CC 17	0	0	5	1	0	0	0	1	5	12
Mill Creek subarea 3	MC 3	0	0	5	1	0	0	0	1	5	12
Mill Creek subarea 7	MC 7	0	0	5	1	0	0	0	1	5	12
Garrison Run subarea 6	GR 6	0	0	5	1	0	0	0	1	5	12
Garrison Run subarea 9	GR 9	0	0	5	1	0	0	0	1	5	12
Garrison Run subarea 11	GR 11	0	0	5	1	0	0	0	1	5	12
Garrison Run subarea 12	GR 12	0	0	5	1	0	0	0	1	5	12
Garrison Run subarea 14	GR 14	0	0	5	1	0	0	0	1	5	12
Garrison Run subarea 16	GR 16	0	0	5	1	0	0	0	1	5	12
Scott Run subarea 1	SR 1	0	0	1	1	0	5	0	1	5	13
Scott Run subarea 4	SR 4	0	0	1	1	0	0	5	1	5	13
Unnamed Tributary One subarea 6	UN1 6	0	0	1	1	0	0	5	1	5	13
Unnamed Tributary Two subarea 2	UN2 2	0	0	1	5	0	0	1	1	5	13
Unnamed tributary Two subarea 3	UN2 3	0	0	5	1	0	0	1	1	5	13
Cascade Creek subarea 6	CC 6	0	0	5	1	1	0	0	1	5	13
Cascade Creek subarea 7	CC 7	0	0	1	1	0	5	0	1	5	13
Mill Creek subarea 10	MC 10	0	0	5	1	0	0	5	1	1	13
Mill Creek subarea 12	MC 12	1	0	5	5	0	0	1	1	0	13
Unnamed Tributary One subarea 1	UN1 1	0	0	1	1	0	5	1	1	5	14
Cascade Creek subarea 3	CC 3	0	0	5	1	1	0	1	1	5	14
Unnamed Tributary one subarea 7	UN1 7	0	0	5	1	0	0	1	3	5	15
Unnamed Tributary two subarea 1	UN2 1	0	0	5	1	0	0	5	1	5	17
Cascade Creek subarea 8	CC 8	0	0	5	1	0	5	0	1	5	17
Cascade Creek subarea 12	CC 12	0	0	5	1	0	5	0	1	5	17
Garrison Run subarea 3	GR 3	0	0	5	5	0	0	1	1	5	17

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Table 23 (continued). Total protection scores for the Presque Isle Bay watershed subareas

		Parameters*									
Name	Map 52 ID	LU	IC	PL	Bldgs	FldP	WetL	Buff	Slope	Soil	T_NRI
Garrison Run subarea 5	GR 5	0	0	5	1	0	0	5	1	5	17
Garrison Run subarea 7	GR 7	0	0	5	1	0	5	0	1	5	17
Garrison Run subarea 13	GR 13	0	0	5	1	0	5	0	1	5	17
Scott Run subarea 3	SR 3	0	0	5	5	0	0	1	1	5	17
Direct Runoff subarea 2	DR 2	0	0	5	1	0	5	0	1	5	17
Direct Runoff subarea 4	DR 4	0	0	5	1	0	5	0	1	5	17
Cascade Creek subarea 5	CC 5	0	0	1	1	5	0	5	1	5	18
Mill Creek subarea 11	MC 11	0	0	5	5	1	5	1	1	0	18
Unnamed Tributary One subarea 3	UN1 3	0	0	5	1	0	0	5	3	5	19
Cascade Creek subarea 9	CC 9	0	0	5	5	1	5	1	1	1	19
Mill Creek subarea 9	MC 9	0	0	5	5	1	5	1	1	1	19
Direct Runoff subarea 3	DR 3	0	0	5	1	0	5	0	3	5	19
Scott Run subarea 2	SR 2	0	0	5	5	0	5	0	1	5	21
Mill Creek subarea 2	MC 2	0	0	5	5	0	5	0	1	5	21
Garrison Run subarea 2	GR 2	0	0	5	5	0	5	0	1	5	21
Mill Creek subarea 15	MC 15	0	0	5	5	5	0	5	1	1	22
Mill Creek subarea 20	MC 20	0	0	5	5	0	5	5	1	1	22
Cascade Creek subarea 2	CC 2	0	0	5	1	5	5	1	1	5	23
Mill Creek subarea 22	MC 22	1	0	5	5	5	0	5	1	1	23
Mill Creek subarea 24	MC 24	1	0	5	5	5	0	5	1	1	23
Mill Creek subarea 1	MC 1	1	0	5	5	5	5	1	1	1	24
Unnamed Tributary One subarea 4	UN1 4	5	0	5	5	0	0	5	1	5	26
Unnamed Tributary One subarea 5	UN1 5	5	0	5	5	0	0	5	1	5	26
Unnamed Tributary One subarea 8	UN1 8	0	0	5	5	0	5	5	1	5	26
Direct Runoff subarea 1	DR 1	5	0	5	5	0	5	0	1	5	26
Mill Creek subarea 14	MC 14	5	0	5	5	0	5	5	1	0	26
Mill Creek subarea 13	MC 13	5	0	5	5	0	5	5	1	1	27
Mill Creek subarea 16	MC 16	0	0	5	5	5	5	5	1	1	27
Mill Creek subarea 18	MC 18	1	0	5	5	5	5	5	1	0	27
Mill Creek subarea 19	MC 19	0	0	5	5	5	5	5	1	1	27
Mill Creek subarea 21	MC 21	1	0	5	5	5	5	5	1	1	28
Mill Creek subarea 23	MC 23	1	5	5	5	5	0	5	1	1	28
Direct Runoff subarea 5	DR 5	5	0	5	5	0	5	0	5	5	30
Mill Creek subarea 17	MC 17	5	0	5	5	5	5	5	1	1	32
Unnamed Tributary One subarea 2	UN1 2	5	0	5	5	0	5	5	3	5	33

* LU = land use; IC = impervious cover; PL = parking lots; Bldgs = buildings; FldP = floodplains; WetL = wetlands; Buff = 100' buffers; Slope = average watershed slope; Soil = hydric soils; T_NRI = protection score based on nonpoint source assessment parameters.

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Table 24. Restoration recommendations (*Scenario 1*)

Subarea	Restoration Score	Restoration Action									
		Reestablish fish and macro communities	Reduce chemicals in stream-bed sediment	Stabilize highly erodible stream banks	Restore and expand riparian buffers	Restore and expand wetlands	Remove unused impervious surfaces	Disconnect downspouts from storm sewer system	Install raingardens	Install oil/grit separators	Incorporate BMPs in future development
MC 23	12										X
UN1 4	15										
UN1 5	15										
MC 14	16										X
MC 22	16										X
MC 24	16										X
MC 13	18					X					X
MC 10	19				X			X	X		
MC 17	19					X		X	X		X
GR 3	19				X						
SR 3	21				X		X	X	X		
UN2 1	21			X				X	X		
GR 5	21						X	X	X	X	
UN1 2	22			X		X					
SR 4	23			X							
UN1 3	23			X				X			
UN1 6	23							X	X		
UN2 2	23			X	X			X	X		
UN2 3	23			X	X			X	X	X	
MC 16	23					X		X	X		X
MC 19	23					X		X	X		X
UN1 8	24					X					
UN1 7	25			X	X			X			
MC 11	25				X	X		X	X		
CC 3	26			X	X			X	X		
SR 5	27				X		X	X	X	X	
CC 9	27				X	X		X	X		
CC 10	27				X		X	X	X	X	
CC 6	28				X		X	X	X	X	
MC 2	28				X	X					
UN1 1	30					X		X	X		

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Table 25. Restoration recommendations (*Scenario 2)*

Subarea	Restoration Score	Reestablish fish and macro communities	Reduce chemicals in stream-bed sediment	Stabilize highly erodible stream banks	Restore and expand riparian buffers	Restore and expand wetlands	Remove unused impervious surfaces	Disconnect downspouts from storm sewer system	Install raingardens	Install oil/grit separators	Incorporate BMPs in future development
		Restoration Action									
CC 16	18							X	X		
GR 1	18							X	X		
DR 1	19					X				X	
CC 1	20							X	X		
CC 13	20							X	X		
CC 15	20							X	X		
CC 17	20							X	X		
MC 3	20							X	X	X	
MC 7	20							X	X		
GR 6	20						X	X	X	X	
GR 9	20							X	X		
GR 10	20						X	X	X		
GR 11	20							X	X		
GR 12	20						X	X	X	X	
GR 14	20						X	X	X	X	
GR 16	20							X	X	X	
CC 4	22						X	X	X	X	
CC 14	22						X	X	X	X	
MC 5	22						X	X	X	X	
MC 6	22						X	X	X		
GR 4	22						X	X	X		
GR 15	22							X	X		
DR 5	23					X					
MC 4	24							X	X	X	
GR 8	24						X	X		X	
GR 7	25					X	X	X	X		
GR 13	25					X	X	X	X	X	
DR 2	25						X	X	X		
DR 4	25							X	X		

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Table 26. Restoration recommendations (*Scenario 3)*

Subarea	Restoration Score	Restoration Action										
		Reestablish fish communities	Reestablish macro community	Reduce chemicals in stream-bed sediment	Stabilize highly erodible stream banks	Restore and expand riparian buffers	Restore and expand wetlands	Remove unused impervious surfaces	Disconnect downspouts from storm sewer system	Install raingardens	Install oil/grit separators	Incorporate BMPs in future development
MC 12	36	X		X					X	X		X
MC 15	37			X					X	X		
MC 1	42			X			X		X	X	X	X
MC 18	44	X		X			X		X	X		X
MC 21	46		X	X			X		X		X	X
MC 8	49		X	X	X	X	X	X	X	X		
MC 20	49			X			X		X	X		X
SR 2	55	X	X	X	X	X	X				X	
MC 9	56	X		X	X	X	X		X	X		
CC 11	58		X	X	X	X		X	X		X	
CC 5	59	X	X	X	X	X	X		X	X		

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Table 27. Protection recommendations

Subarea	Protection Score	Protection Criteria: < 10% impervious cover	< 25% high intensity land use	Wetlands present	Floodplain is > 75% vegetated	Riparian buffer is > 75% vegetated	Property owners should be contacted	Priority should be placed on restoration efforts
GR 10	4							X
CC 11	7							X
MC 4	7							X
GR 8	7							X
SR 5	8							X
CC 10	8							X
CC 16	8							X
MC 5	8							X
MC 6	8							X
GR 1	8							X
MC 8	10							X
CC 4	11							X
CC 14	11							X
GR 4	11							X
GR 15	11							X
CC 1	12							X
CC 13	12							X
CC 15	12							X
CC 17	12							X
MC 3	12							X
MC 7	12							X
GR 6	12							X
GR 9	12							X
GR 11	12							X
GR 12	12							X
GR 14	12							X
GR 16	12							X
SR 1	13			X				X
SR 4	13					X	X	
UN1 6	13					X	X	
UN2 2	13							X
UN2 3	13							X
CC 6	13							X
CC 7	13			X			X	
MC 10	13					X	X	
MC 12	13							X
UN1 1	14			X				X

Table 27 continues on next page

Table 27 (continued). Protection recommendations

Subarea	Protection Score	Protection Criteria						
		< 10% impervious cover	< 25% high intensity land use	Wetlands present	Floodplain is > 75% vegetated	Riparian buffer is > 75% vegetated	Property owners should be contacted	Priority should be placed on restoration efforts
CC 3	14							X
UN1 7	15							X
UN2 1	17					X	X	
CC 8	17			X			X	
CC 12	17			X				X
GR 3	17							X
GR 5	17					X	X	
GR 7	17			X				X
GR 13	17			X				X
SR 3	17							X
DR 2	17			X				X
DR 4	17			X			X	
CC 5	18				X	X	X	
MC 11	18			X			X	
UN1 3	19					X	X	
CC 9	19			X				X
MC 9	19			X			X	
DR 3	19			X			X	
SR 2	21			X				X
MC 2	21			X				X
GR 2	21			X				X
MC 15	22				X	X	X	
MC 20	22			X		X	X	
CC 2	23			X	X			X
MC 22	23				X	X	X	
MC 24	23				X	X	X	
MC 1	24			X	X		X	
UN1 4	26		X			X	X	
UN1 5	26		X			X	X	
UN1 8	26			X		X	X	
DR 1	26		X	X			X	
MC 14	26		X	X		X	X	
MC 13	27		X	X		X	X	
MC 16	27			X	X	X	X	
MC 18	27			X	X	X	X	
MC 19	27			X	X	X	X	
MC 21	28			X	X	X	X	
MC 23	28	X			X	X	X	
DR 5	30		X	X			X	

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Table 28. 10-year implementation strategy

Action	Partners	Year 2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Conduct a watershed-wide physical, chemical, and biological assessment	PASG, PFBC, DEP, ECDH, RSC, Gannon , Penn State Behrend, Mercyhurst		X					X			
Develop TMDLs for Scott Run, Cascade Creek, Mill Creek, and Garrison Run	DEP, ECHD	X	X	X	X						
Identify all historical restoration and protection projects within the Presque Isle Bay watershed	DEP, PFBC, DCNR, ECDH, ECCD, PASG, PLEWA, LERC, PAC, S.O.N.S, Millcreek Twp, City of Erie, ECDP	X	X								
Identify unused impervious surfaces within the Presque Isle Bay watershed	PASG, Mercyhurst, ECDP		X	X							
Identify and correct illicit discharges	DEP, Millcreek Twp, City of Erie, Greene Twp, ECDP		X	X	X	X	X	X	X	X	
Implement restoration recommendations for Cascade Creek subarea 12 (*Scenario 1)*	PASG, DEP, ECCD, PLEWA, S.O.N.S, City of Erie, Mercyhurst	X	X	X	X						
Implement restoration recommendations for Cascade Creek subarea 8 (*Scenario 1)*	PASG, DEP, PFBC, ECCD, PLEWA, Millcreek Twp	X	X	X	X						
Implement restoration recommendations for Direct Runoff subarea 3 (*Scenario 2)*	PLEWA, City of Erie, ECCD	X	X	X	X						
Implement restoration recommendations for Scott Run subarea 1 (*Scenario 2)*	PASG, PLEWA, Millcreek Twp, ECCD	X	X	X	X						
Implement restoration recommendations for Cascade Creek subarea 7 (*Scenario 3)*	PASG, DEP, ECCD, PLEWA, Millcreek Twp, City of Erie	X	X	X	X						
Implement restoration recommendations for Garrison Run subarea 2 (*Scenario 3)*	PASG, PLEWA, City of Erie, PFBC, DEP, ECCD	X	X	X	X						
Implement restoration recommendations for Cascade Creek subarea 2 (*Scenario 3)*	PASG, PLEWA, City of Erie, PFBC, DEP, ECCD	X	X	X	X						
Implement protection recommendations for Unnamed Tributary One subarea 2	PASG, LERC, Millcreek Twp	X	X	X	X						
Implement protection recommendations for Mill Creek subarea 17	PASG, LERC, PFBC, Millcreek Twp	X	X	X	X						
Update the *Presque Isle Bay watershed restoration, protection, and monitoring plan*	PASG, DEP, ECCD					X					X
Implement the restoration and protection recommendations of the updated *Plan*	DEP, PFBC, DCNR, ECDH, ECCD, PASG, PLEWA, LERC, PAC, S.O.N.S, Millcreek Twp, City of Erie, Harborcreek Twp, Summit Twp, Greene Twp, ECDP, Mercyhurst College						X	X	X	X	

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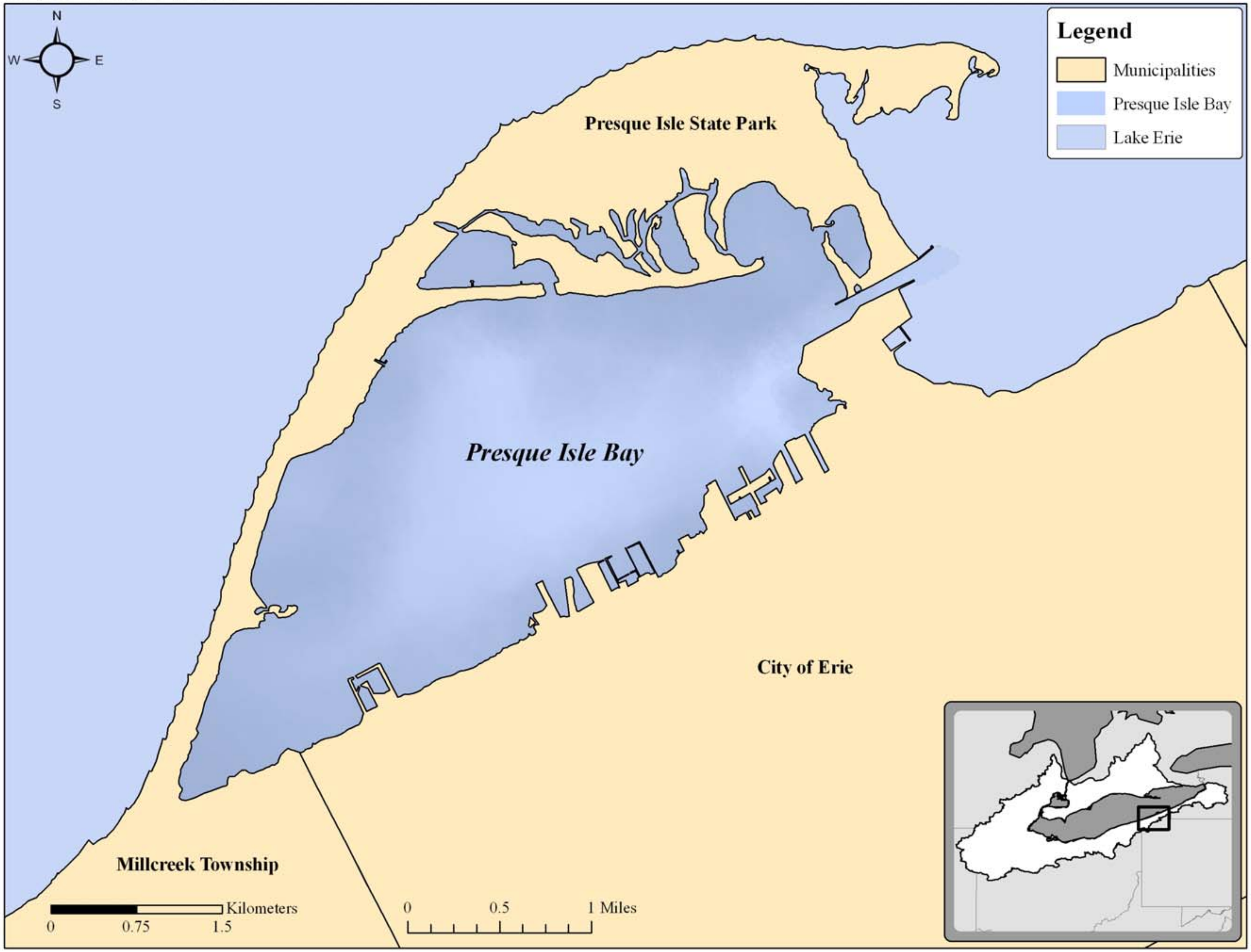
APPENDIX B: MAPS

Map 1: Presque Isle Bay



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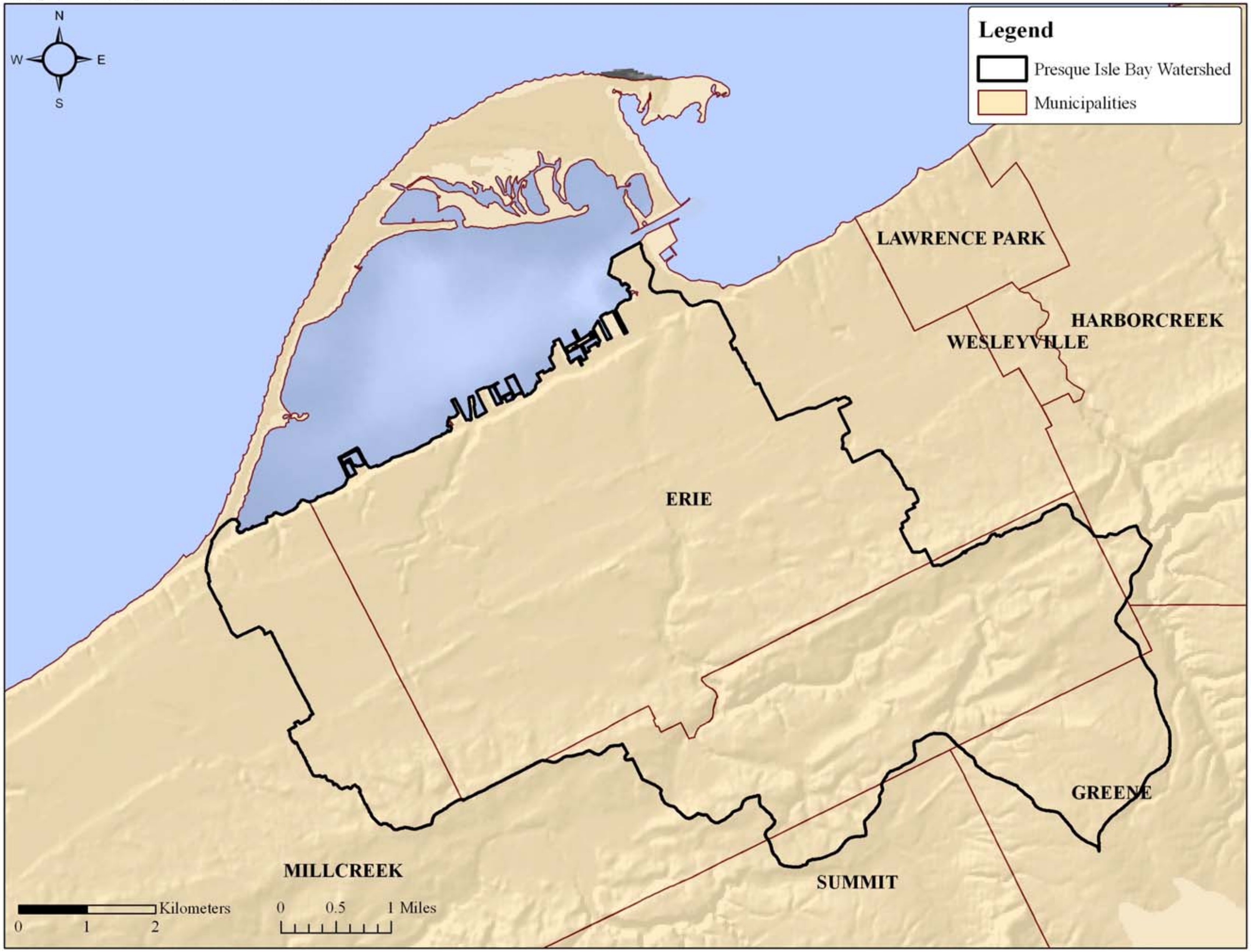
Map 2: Presque Isle Bay watershed



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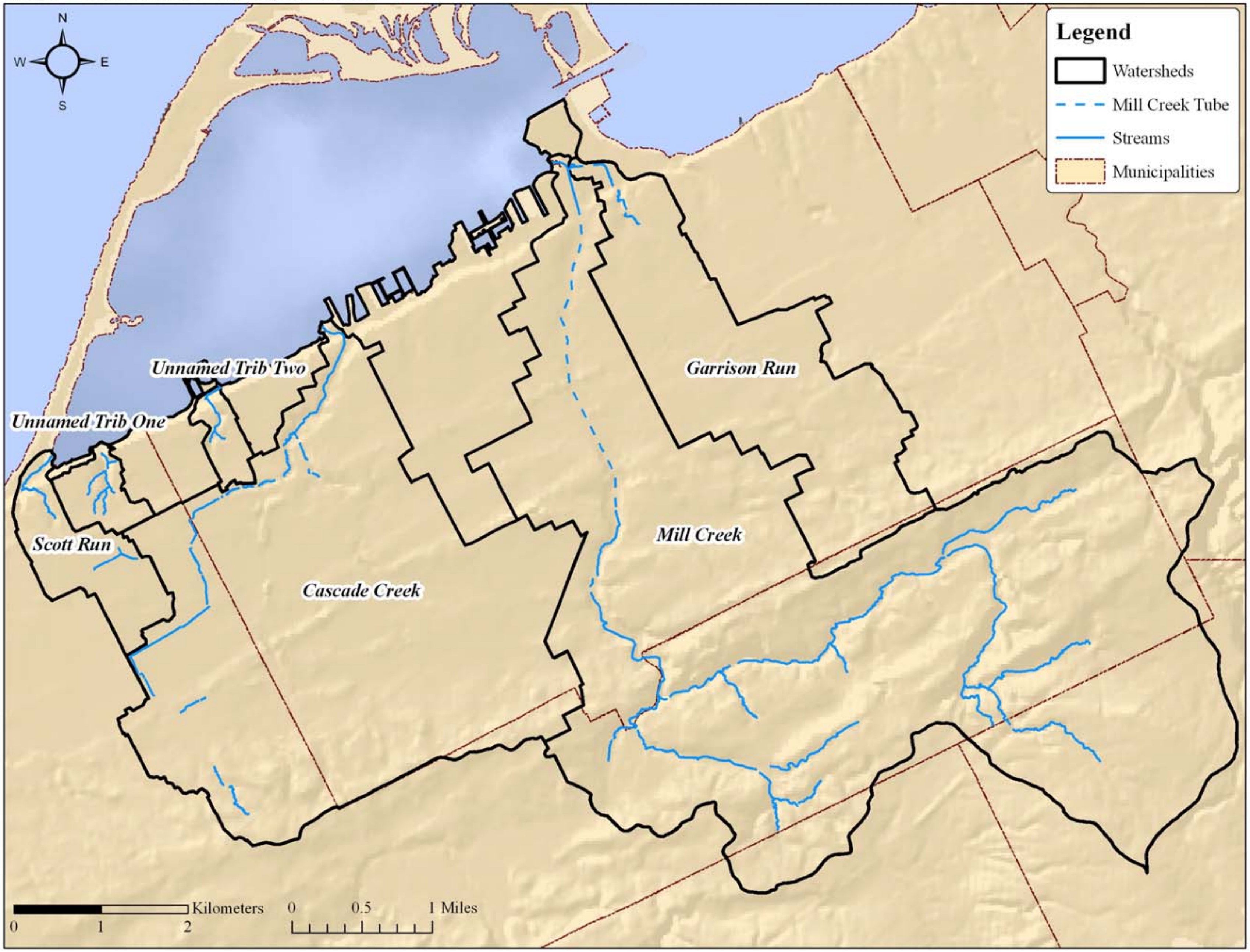
Map 3: Tributaries of Presque Isle Bay



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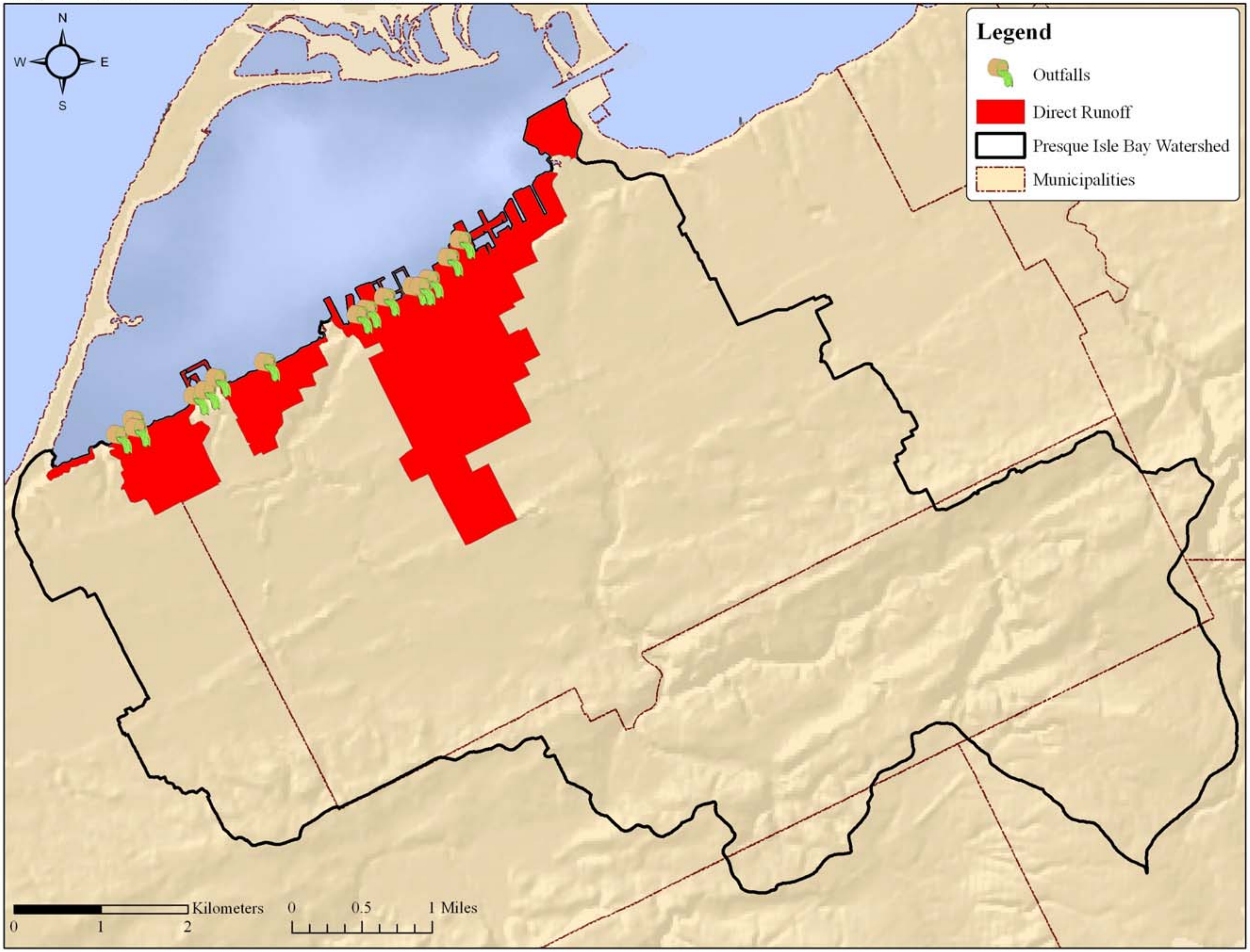
Map 4: Direct runoff to Presque Isle Bay



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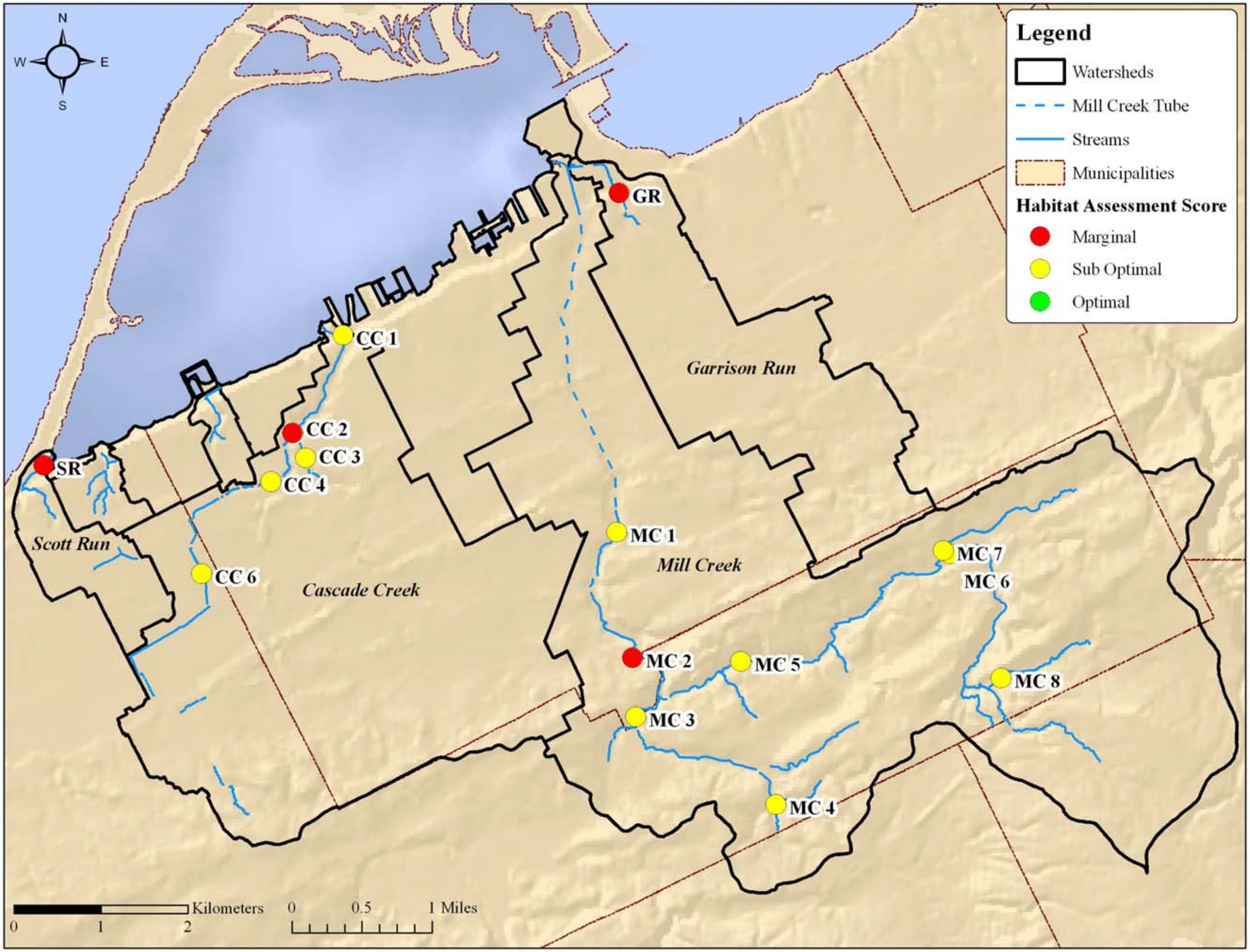
Map 5: Habitat assessment of the Presque Isle Bay watershed (Diz and Johnson 2002)



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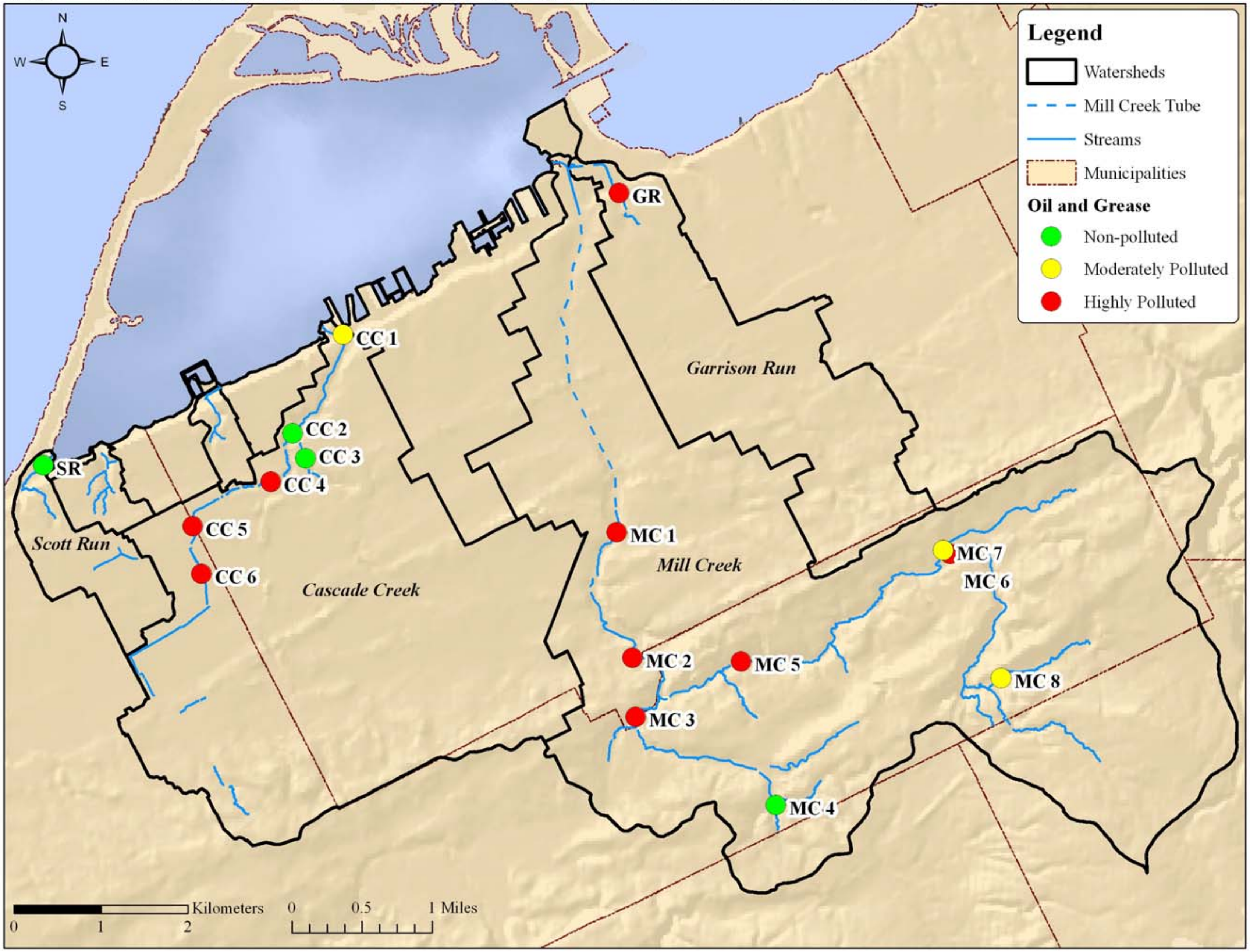
Map 6: Oil and grease assessment of the Presque Isle Bay watershed (Diz and Johnson 2002)



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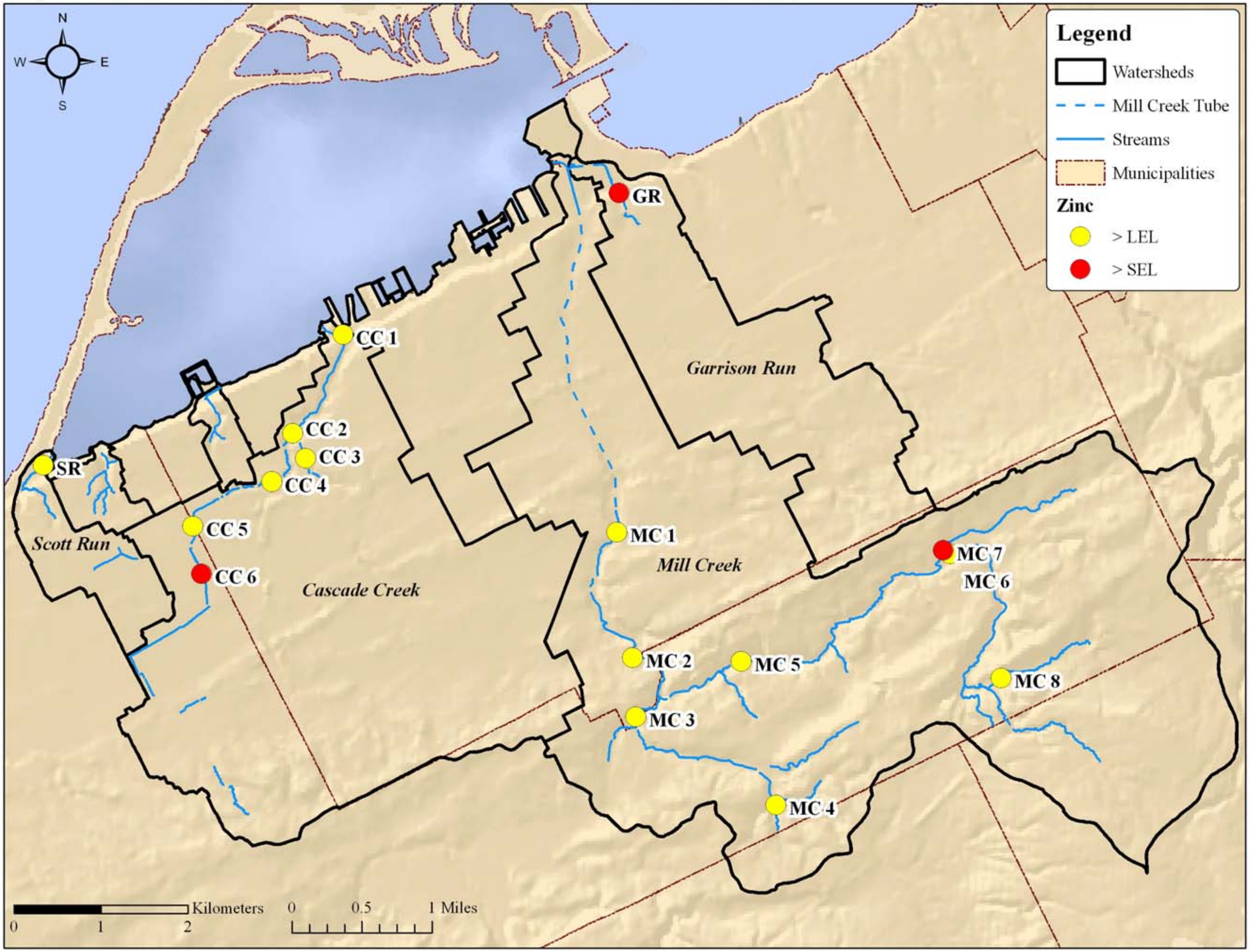
Map 7: Zinc assessment of the Presque Isle Bay watershed (Diz and Johnson 2002)



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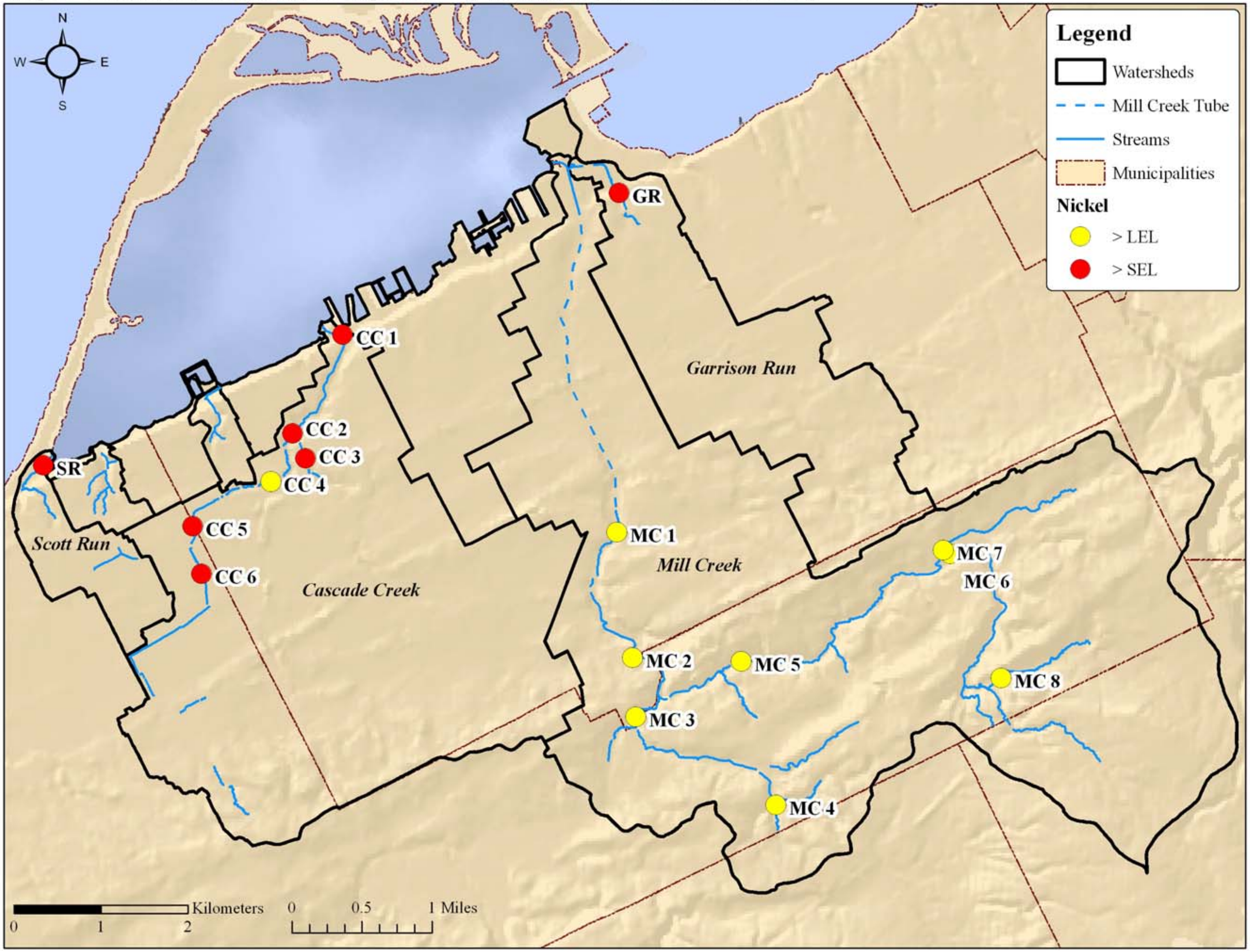
Map 8: Nickel assessment of the Presque Isle Bay watershed (Diz and Johnson 2002)



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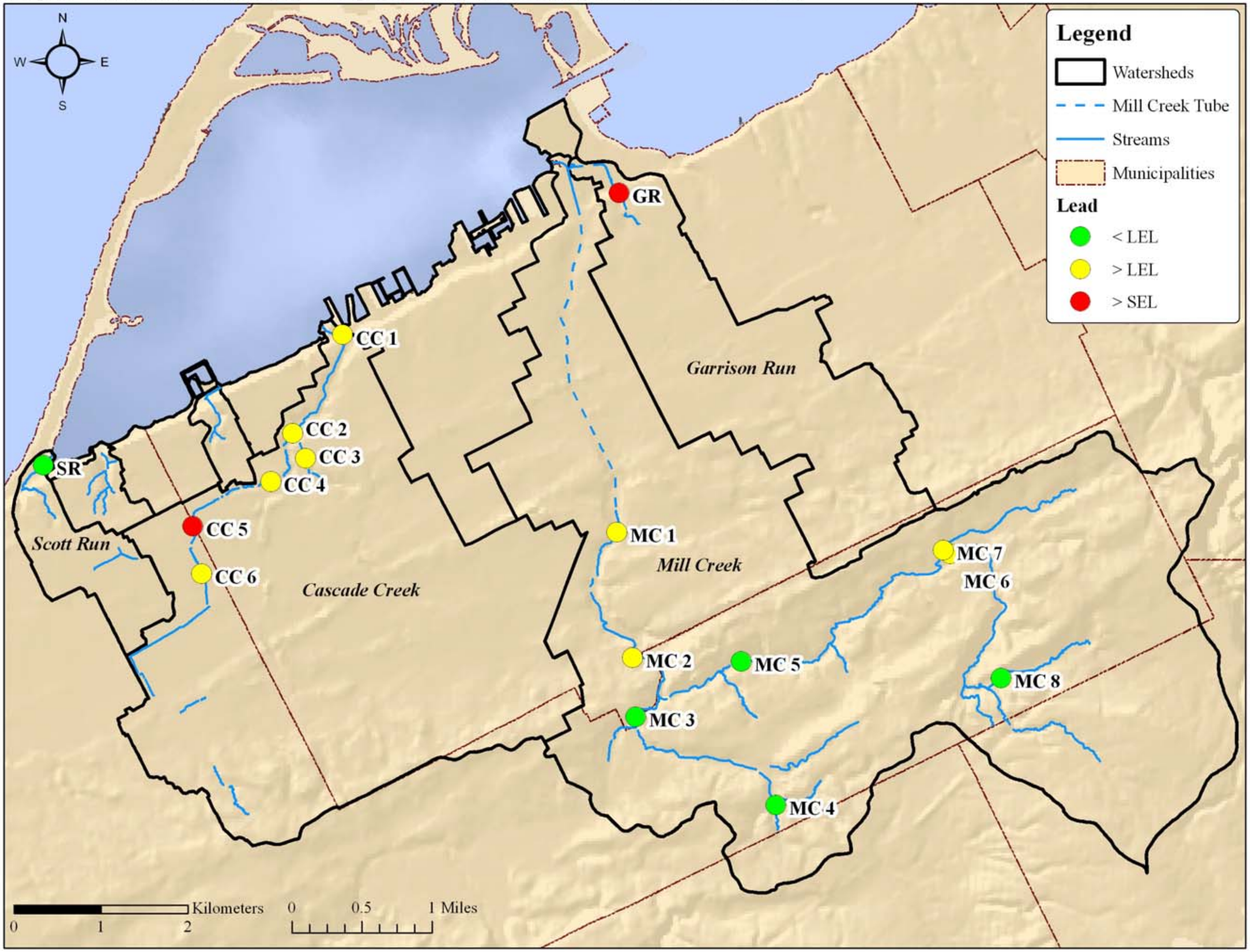
Map 9: Lead assessment of the Presque Isle Bay watershed (Diz and Johnson 2002)



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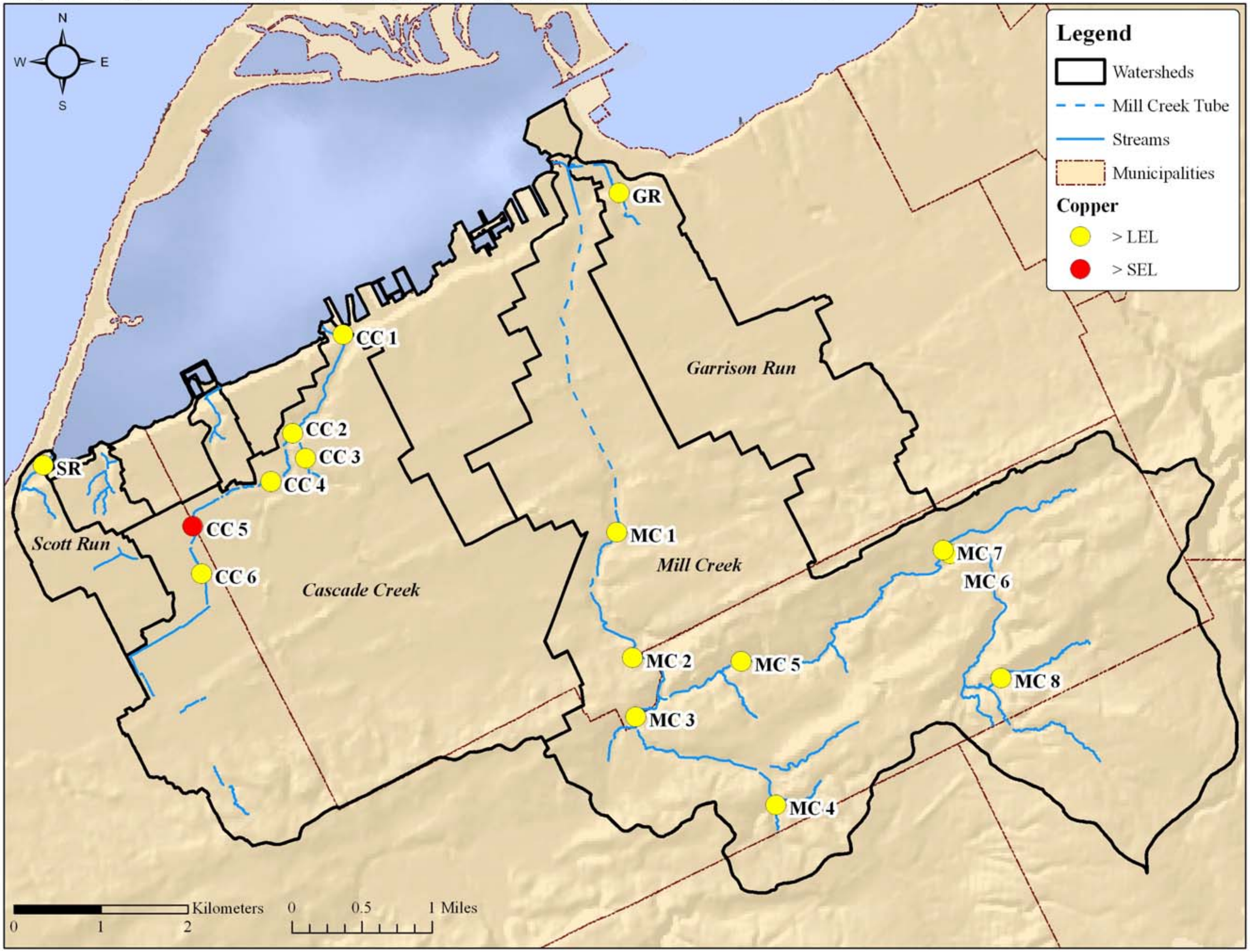
Map 10: Copper assessment of the Presque Isle Bay watershed (Diz and Johnson 2002)



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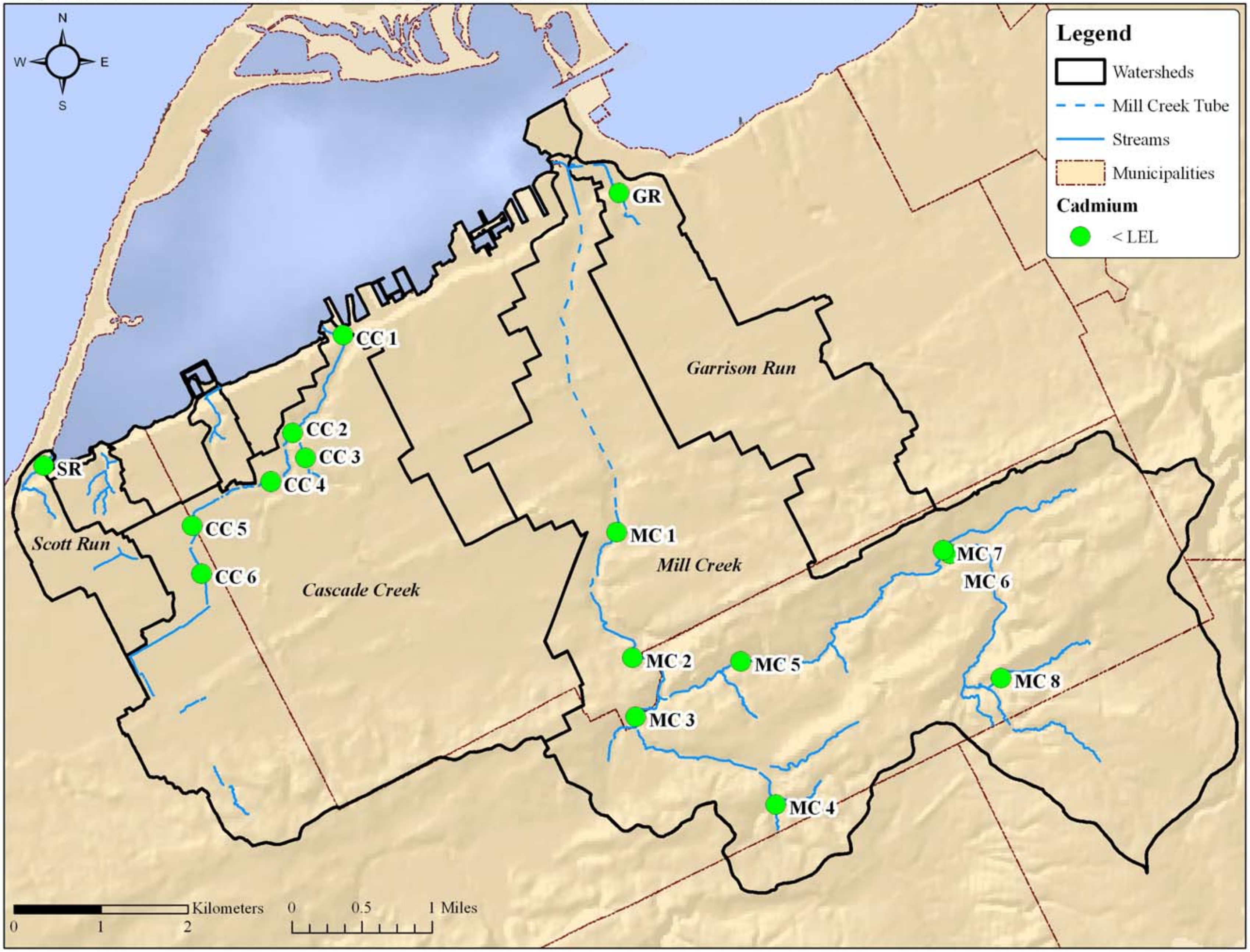
Map 11: Cadmium assessment of the Presque Isle Bay watershed (Diz and Johnson 2002)



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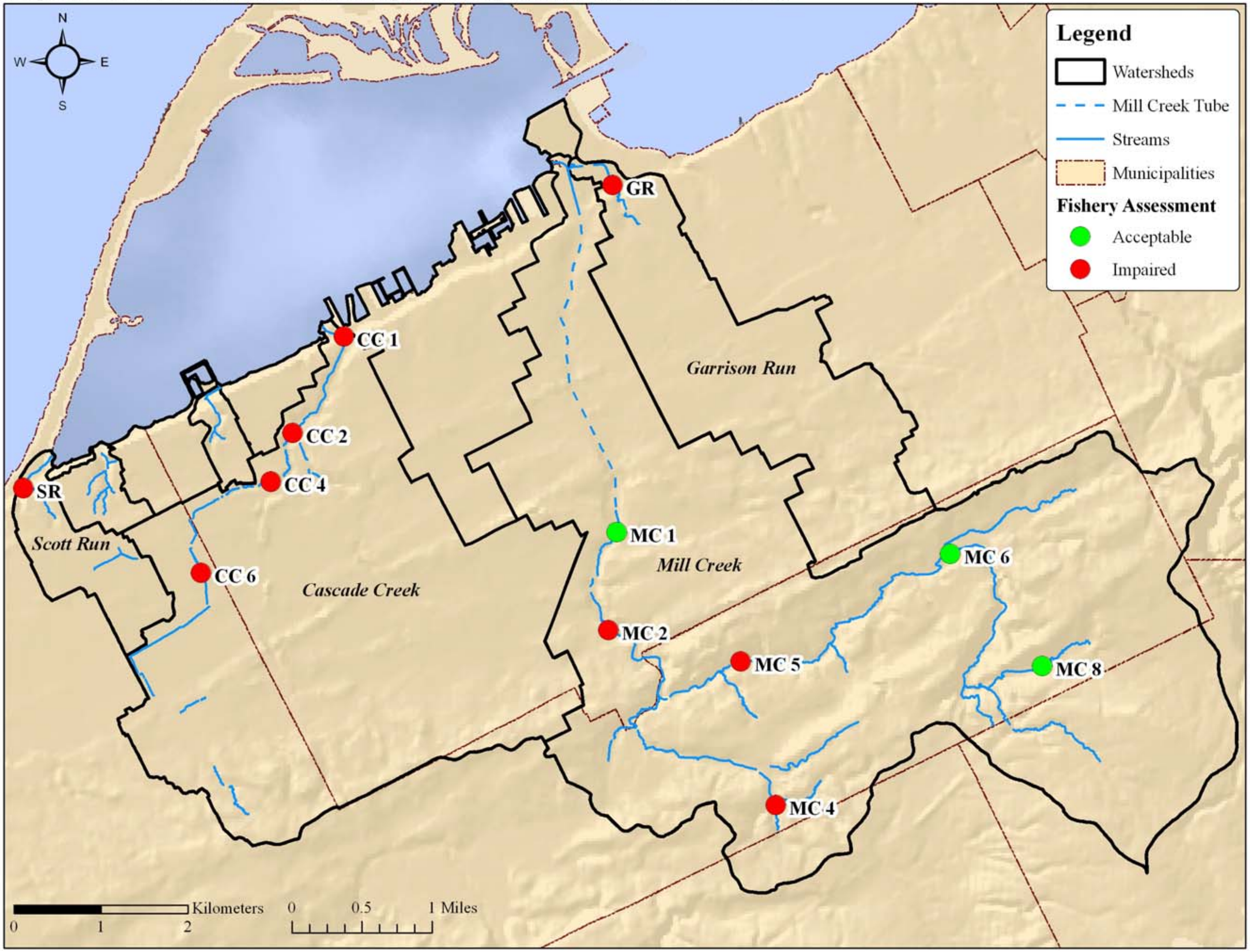
Map 12: Fishery assessment of the Presque Isle Bay watershed (Pyron et al. 2004)



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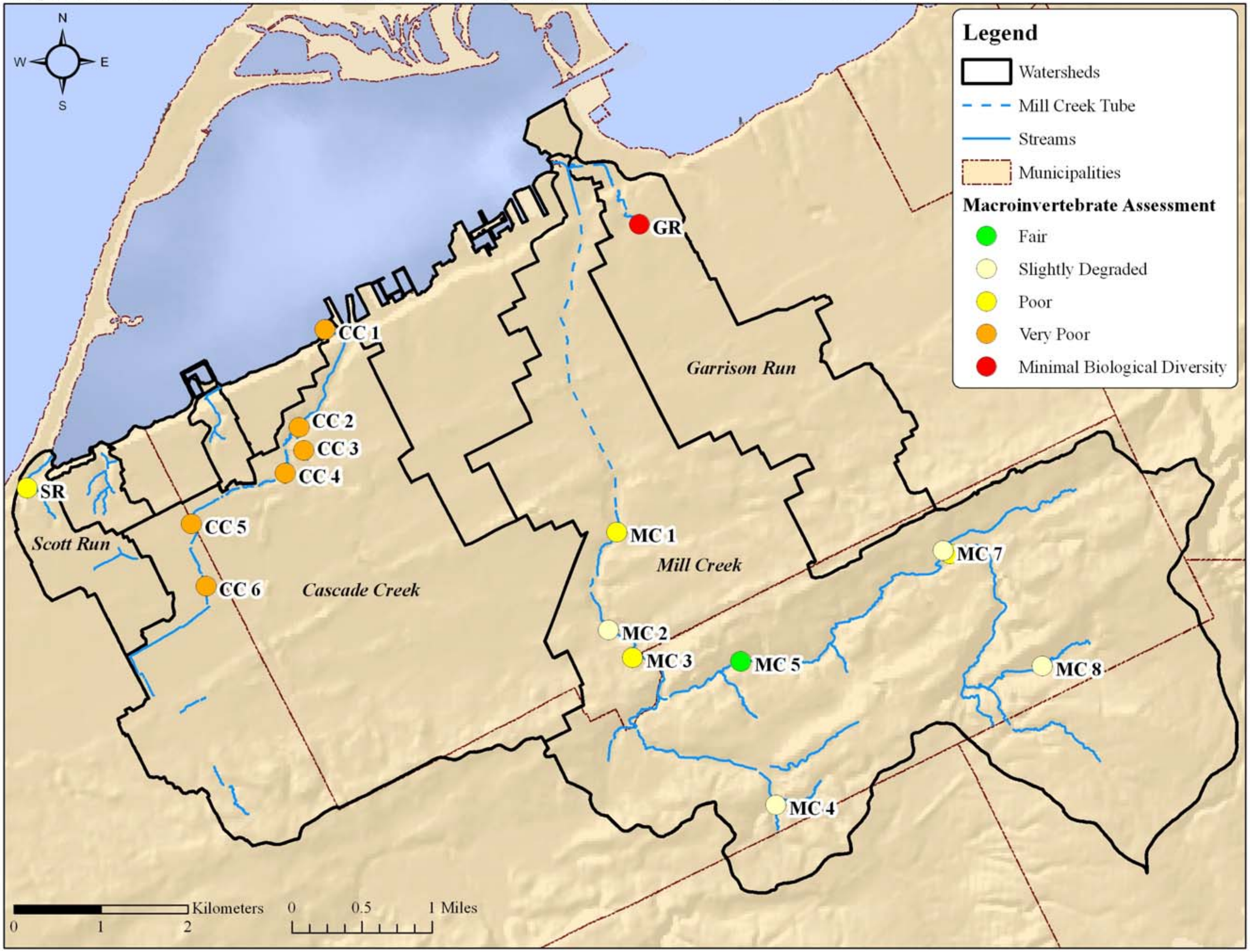
Map 13: Macroinvertebrate assessment of the Presque Isle Bay watershed (Campbell 2002)



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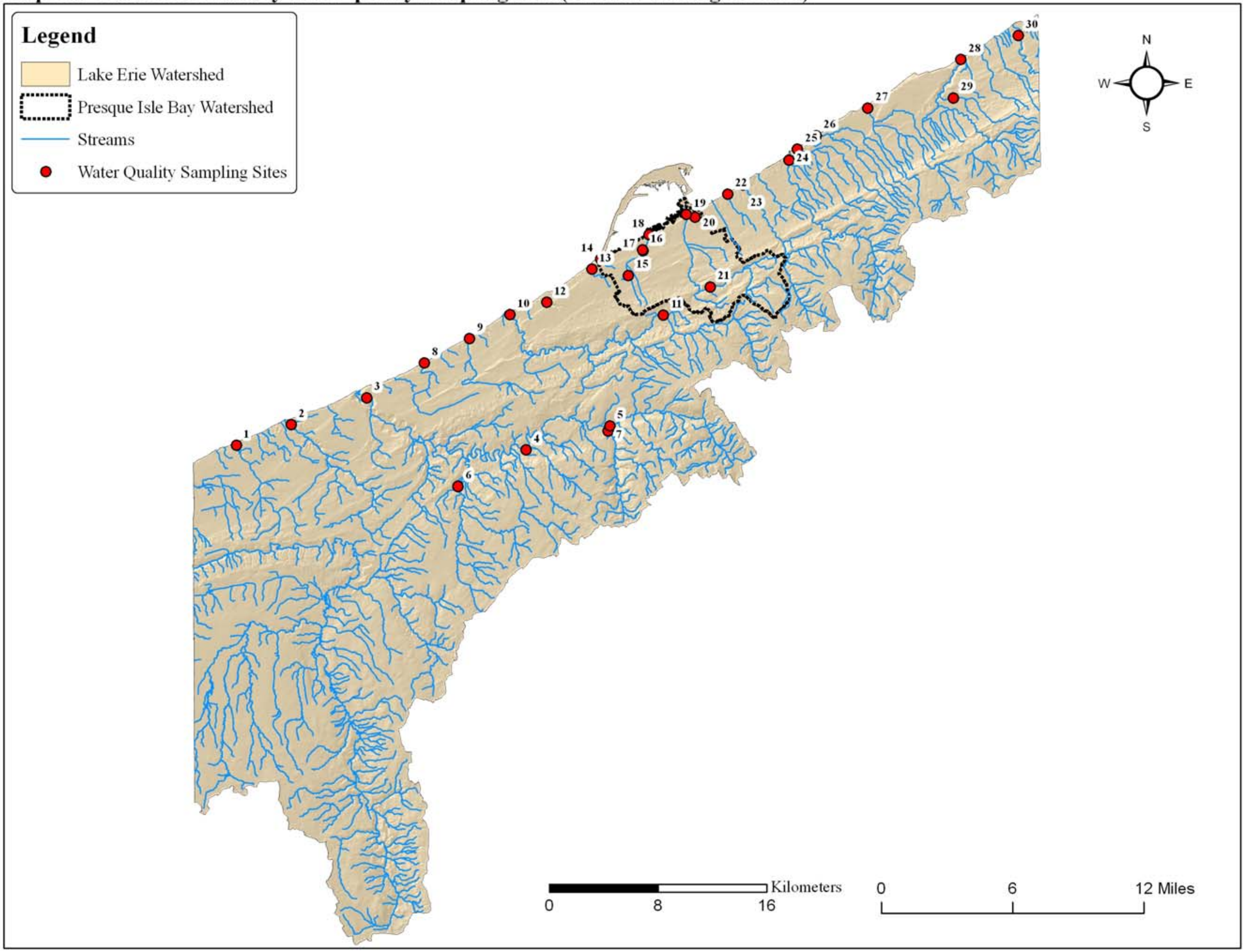
Map 14: Lake Erie tributary water quality sampling sites (Diz and Wellington 2006)



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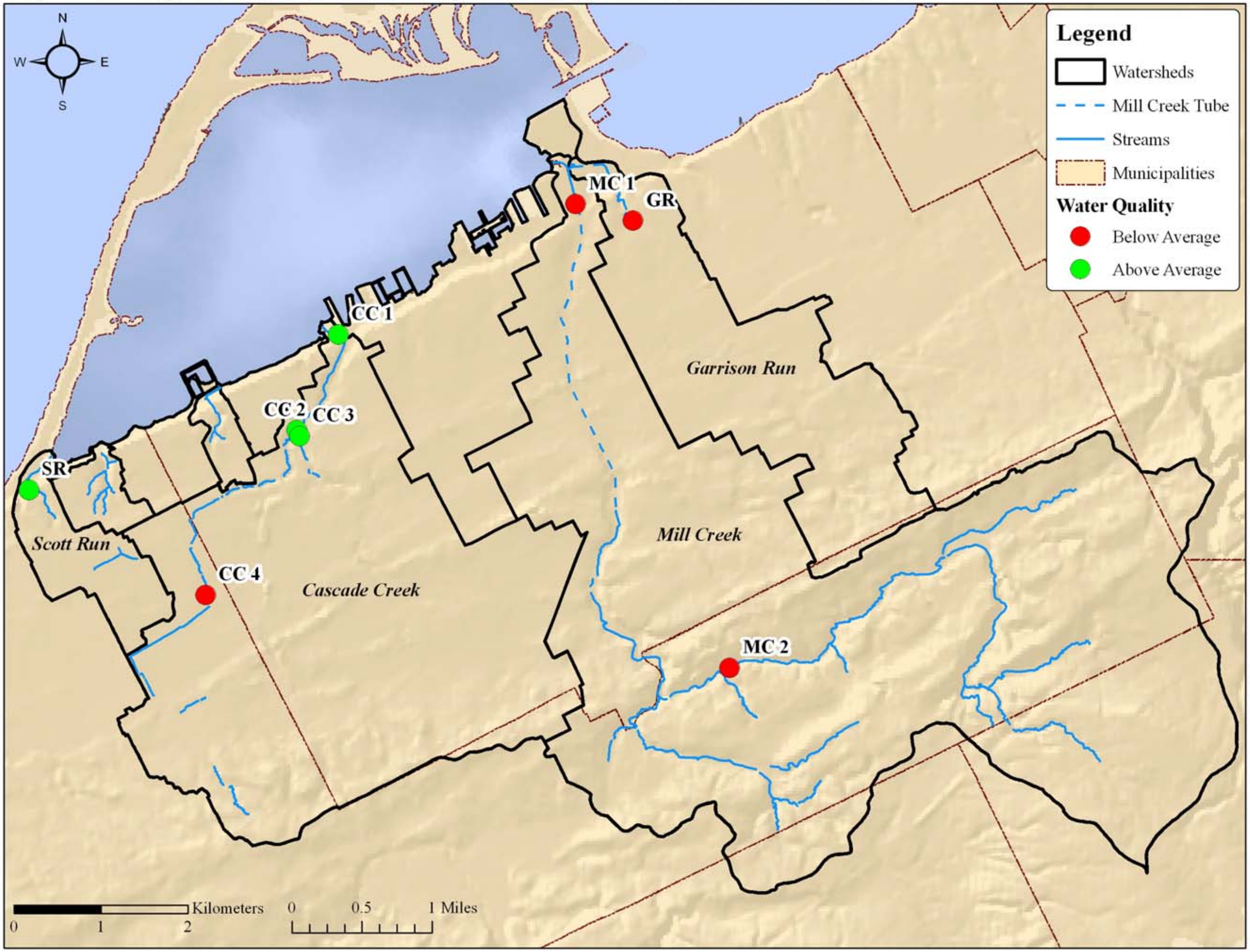
Map 15: Water quality assessment of the Presque Isle Bay watershed (Diz and Wellington 2006)



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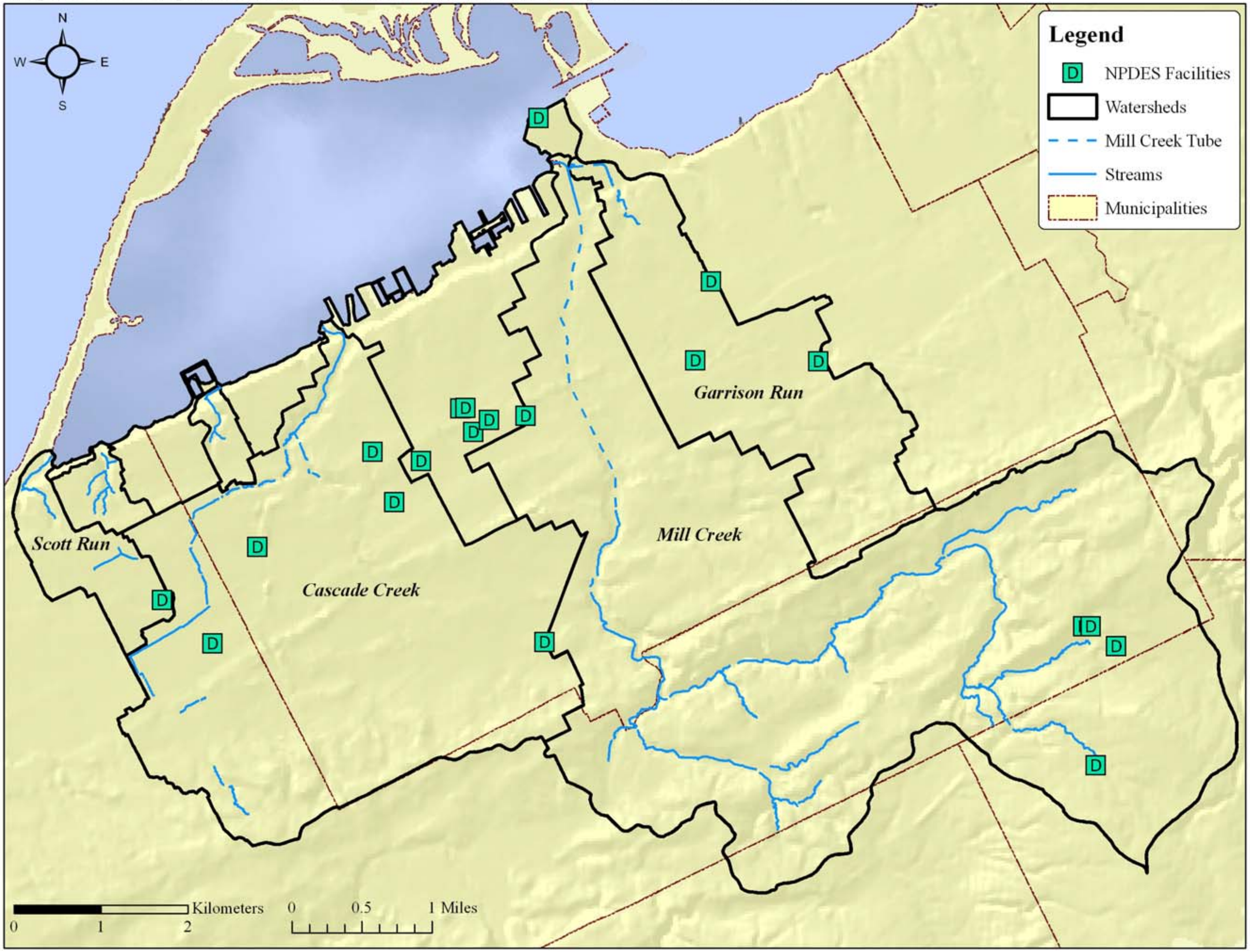
Map 16: NPDES permitted facilities located within the Presque Isle Bay watershed



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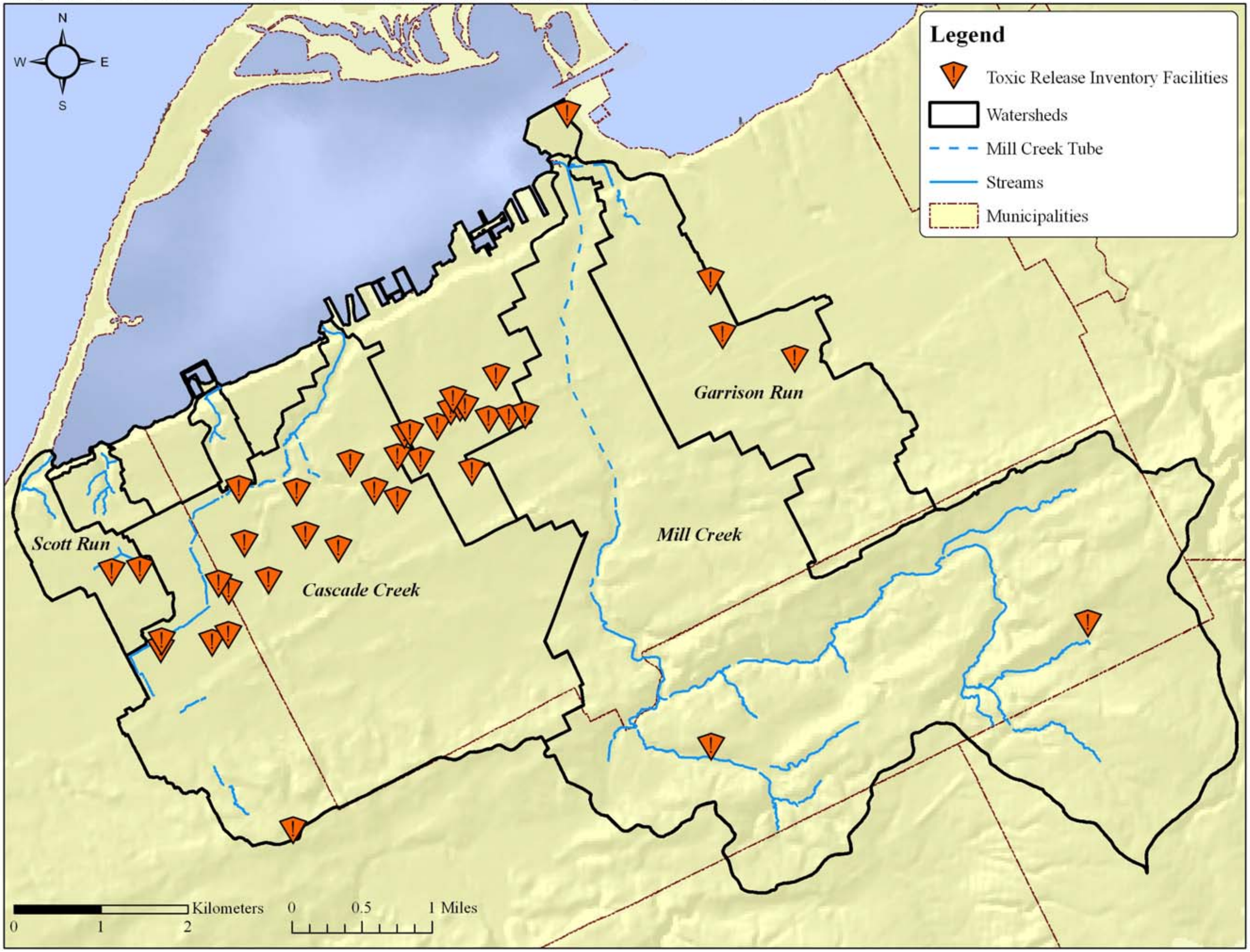
Map 17: Toxic release inventory facilities located within the Presque Isle Bay watershed



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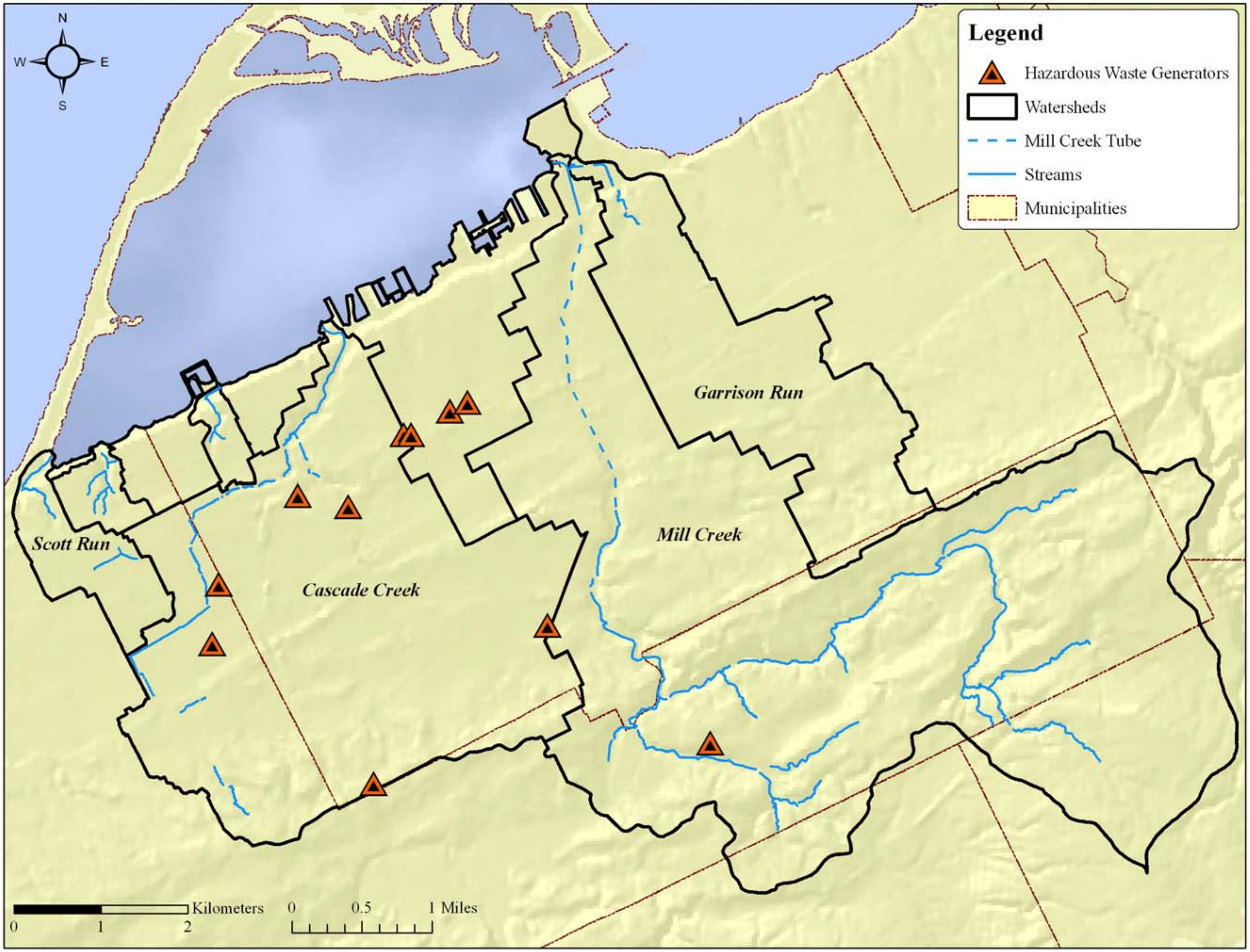
Map 18: Large quantity hazardous waste generators located within the Presque Isle Bay watershed



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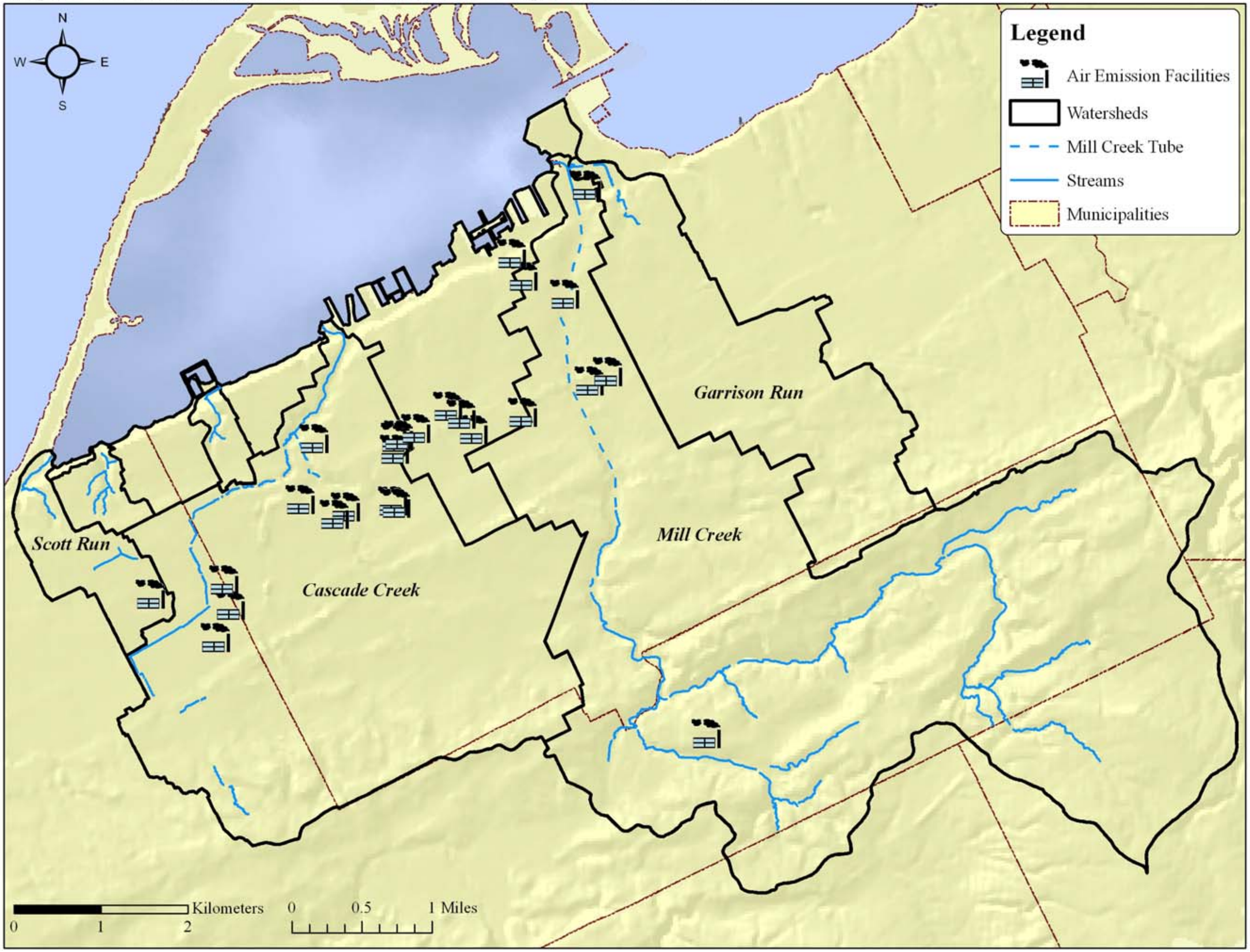
Map 19: Air emission facilities located within the Presque Isle Bay watershed



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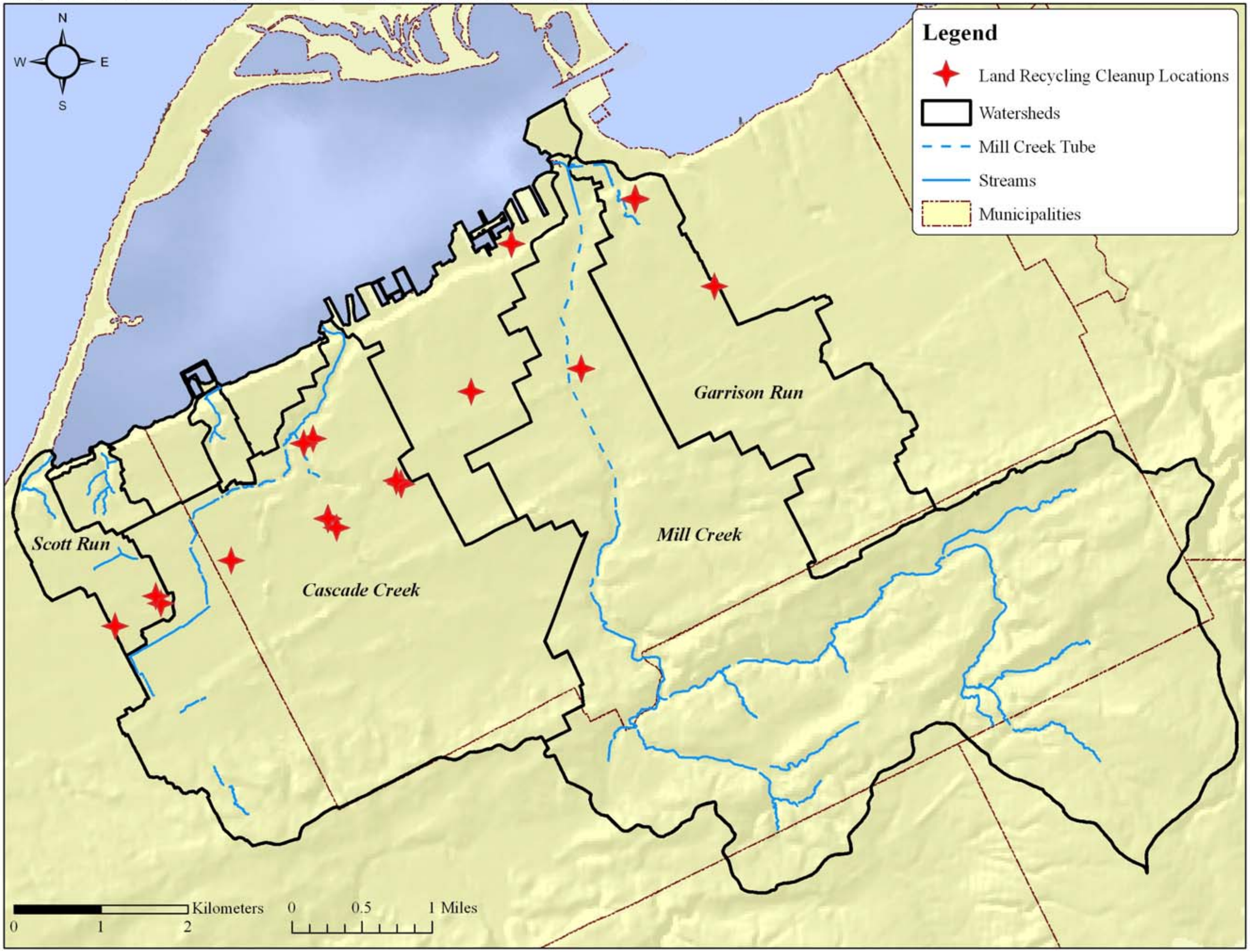
Map 20: Land recycling cleanup locations within the Presque Isle Bay watershed



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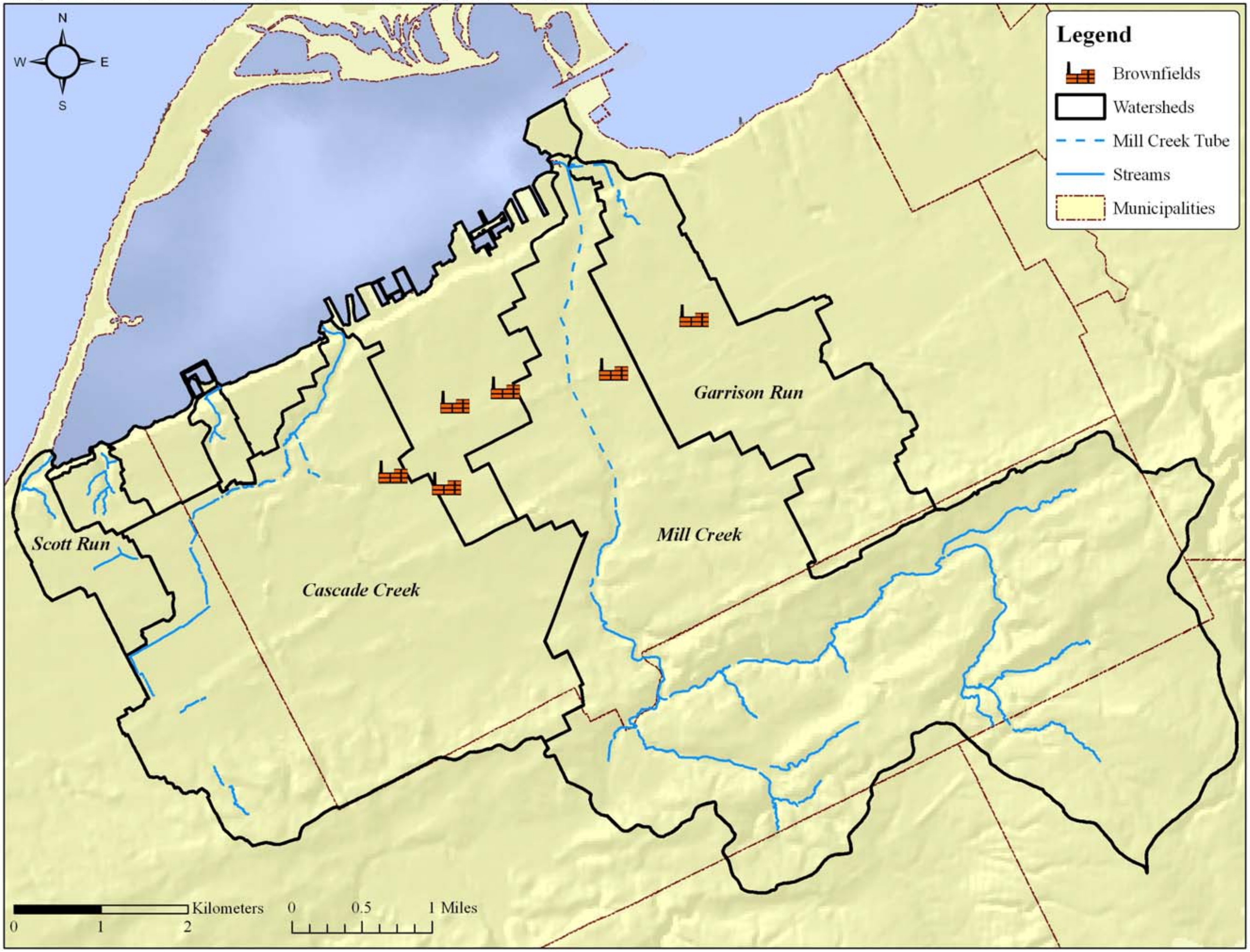
Map 21: Brownfields located within the Presque Isle Bay watershed



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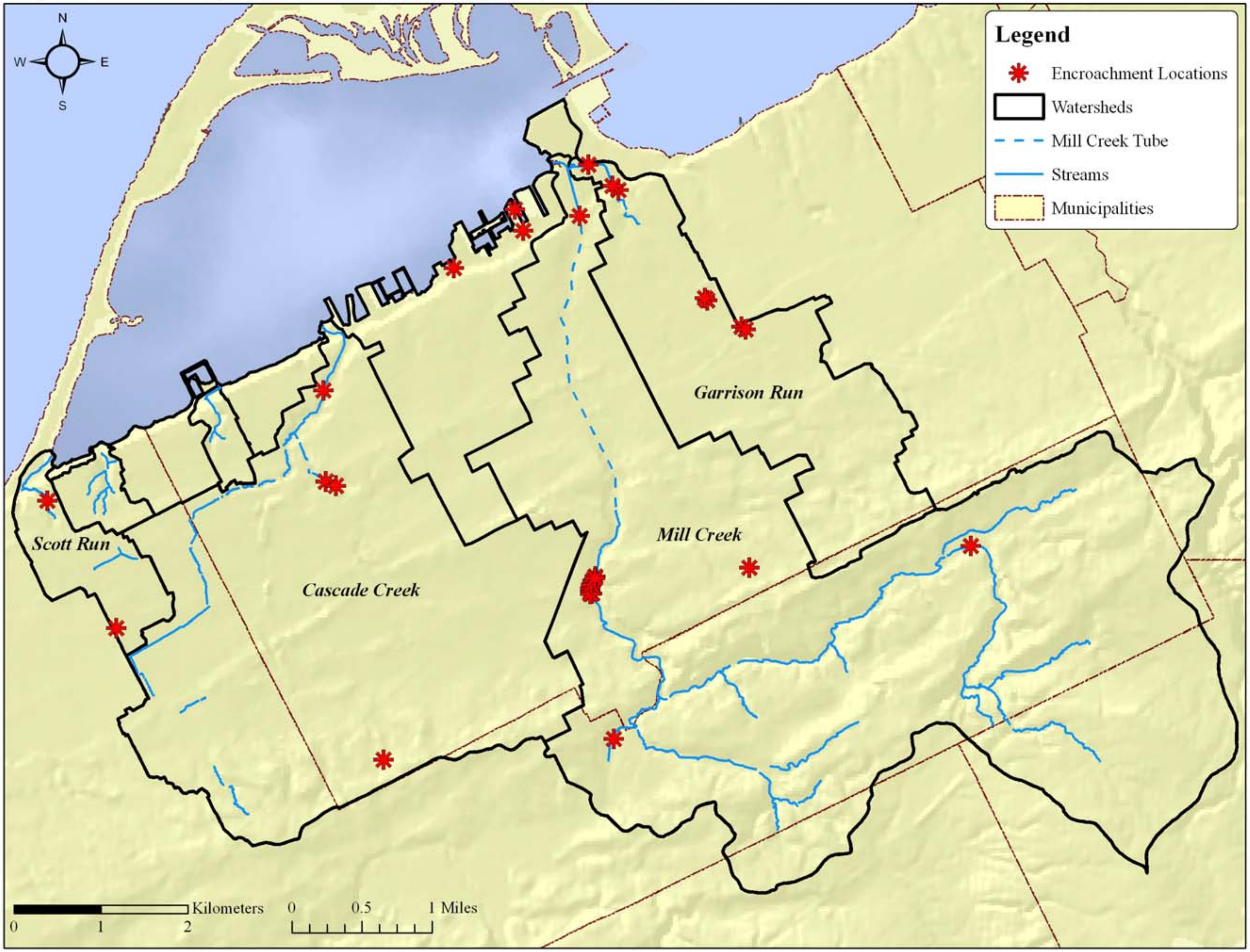
Map 22: Encroachment locations within the Presque Isle Bay watershed



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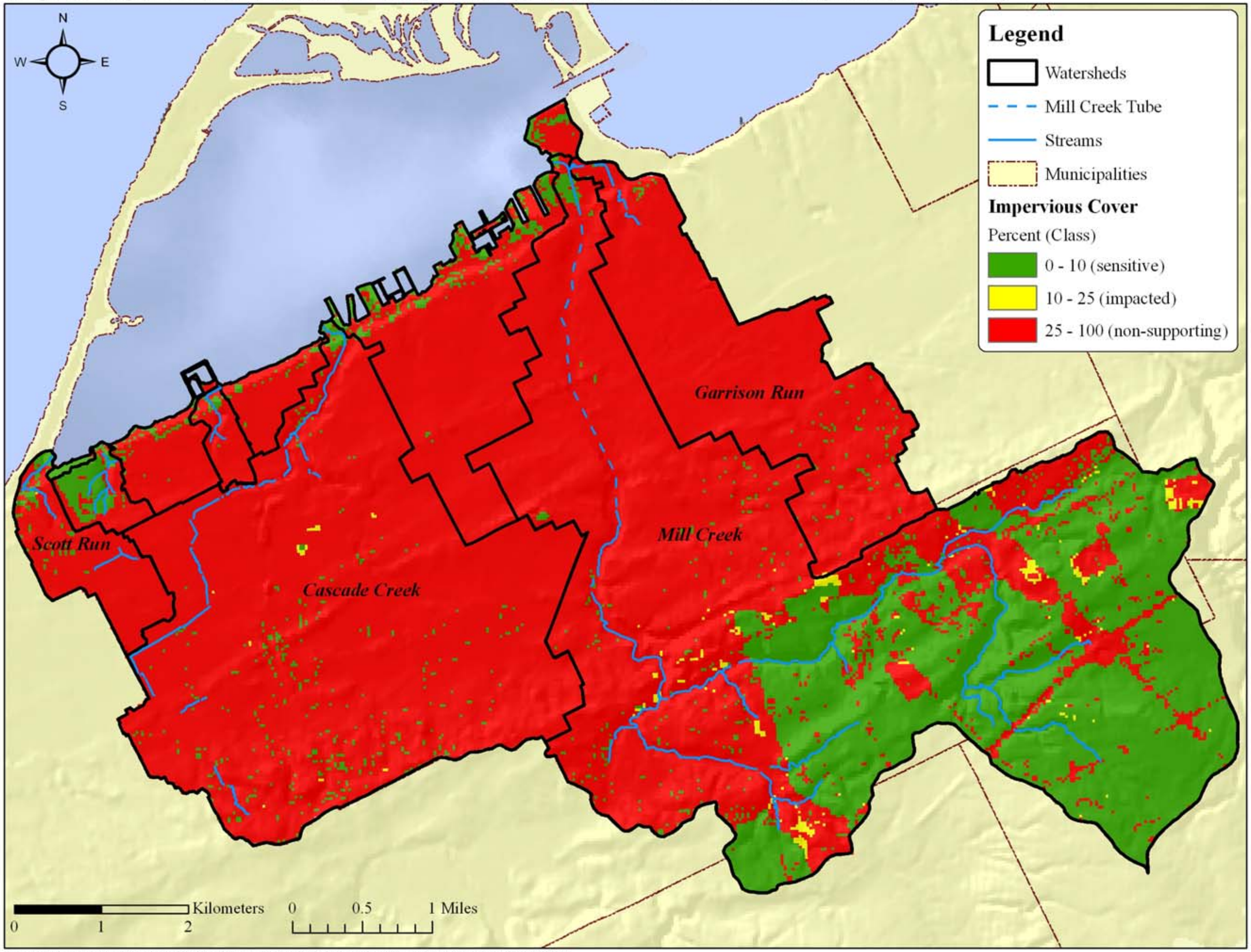
Map 23: Impervious cover within the Presque Isle Bay watershed classified according to Schueler (1994)



Impervious cover data was developed by Toby Carlson (Penn State University) and downloaded from PASDA.

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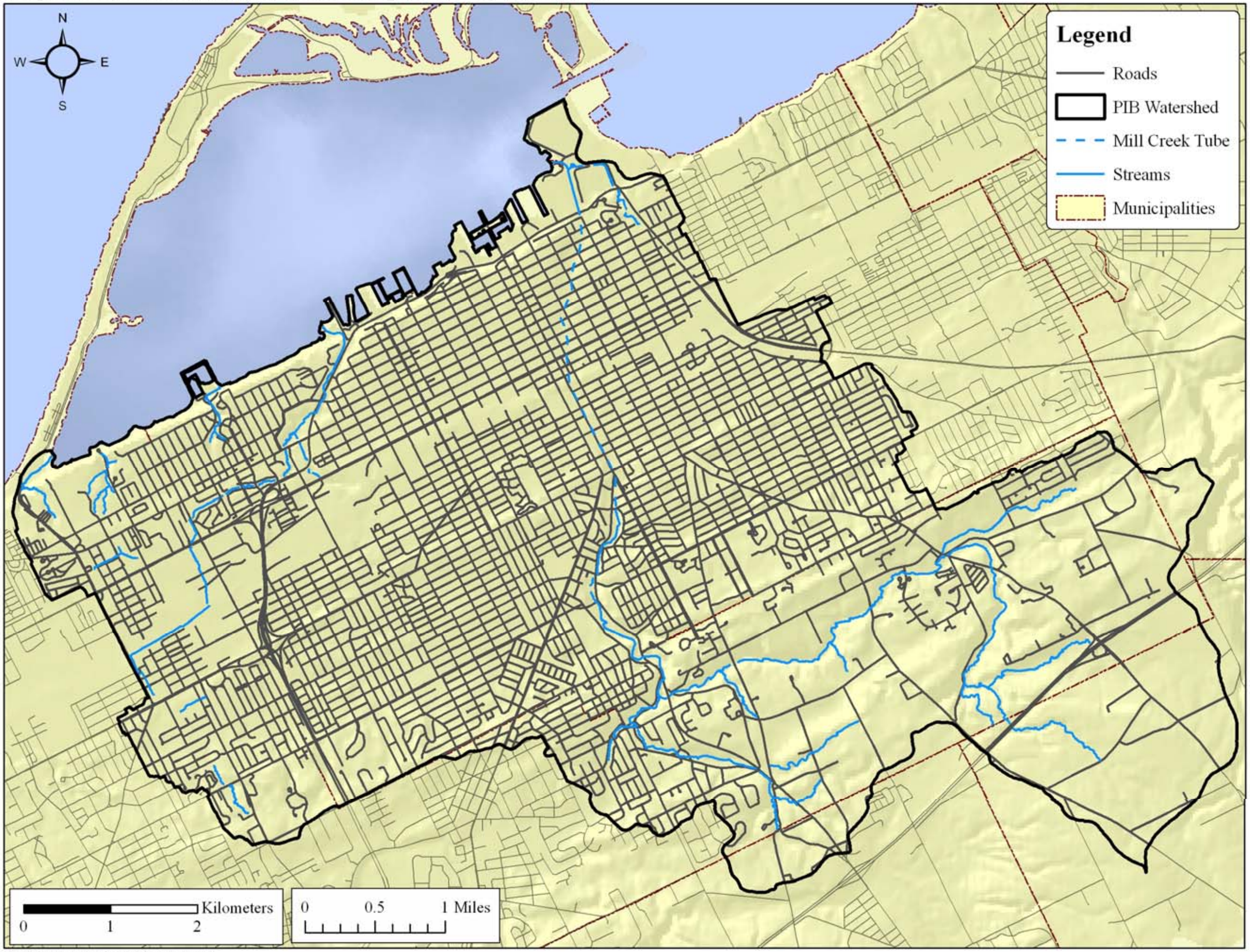
Map 24: Road network within the Presque Isle Bay watershed



Road data was dowloaded from PASDA

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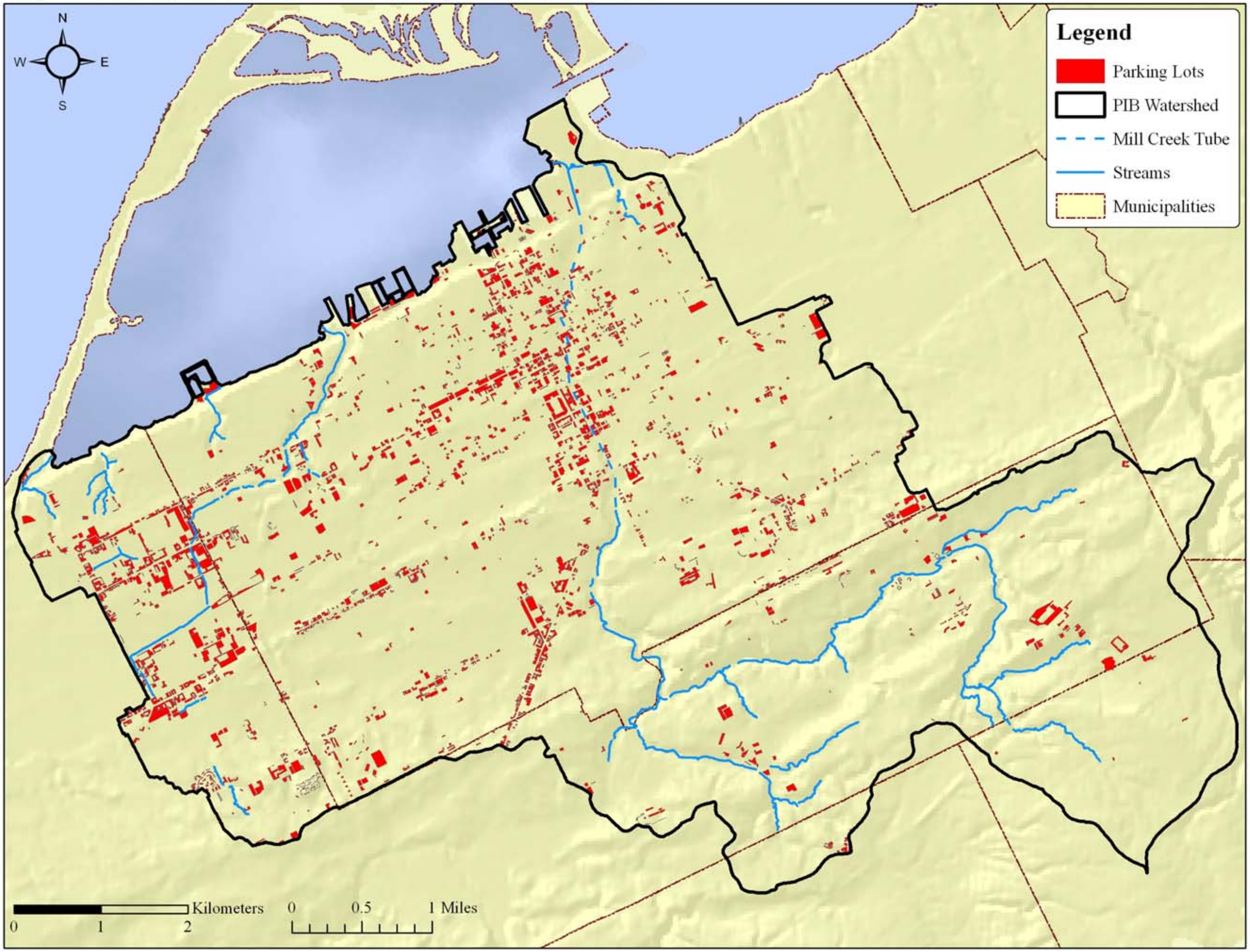
Map 25: Parking lots located within the Presque Isle Bay watershed



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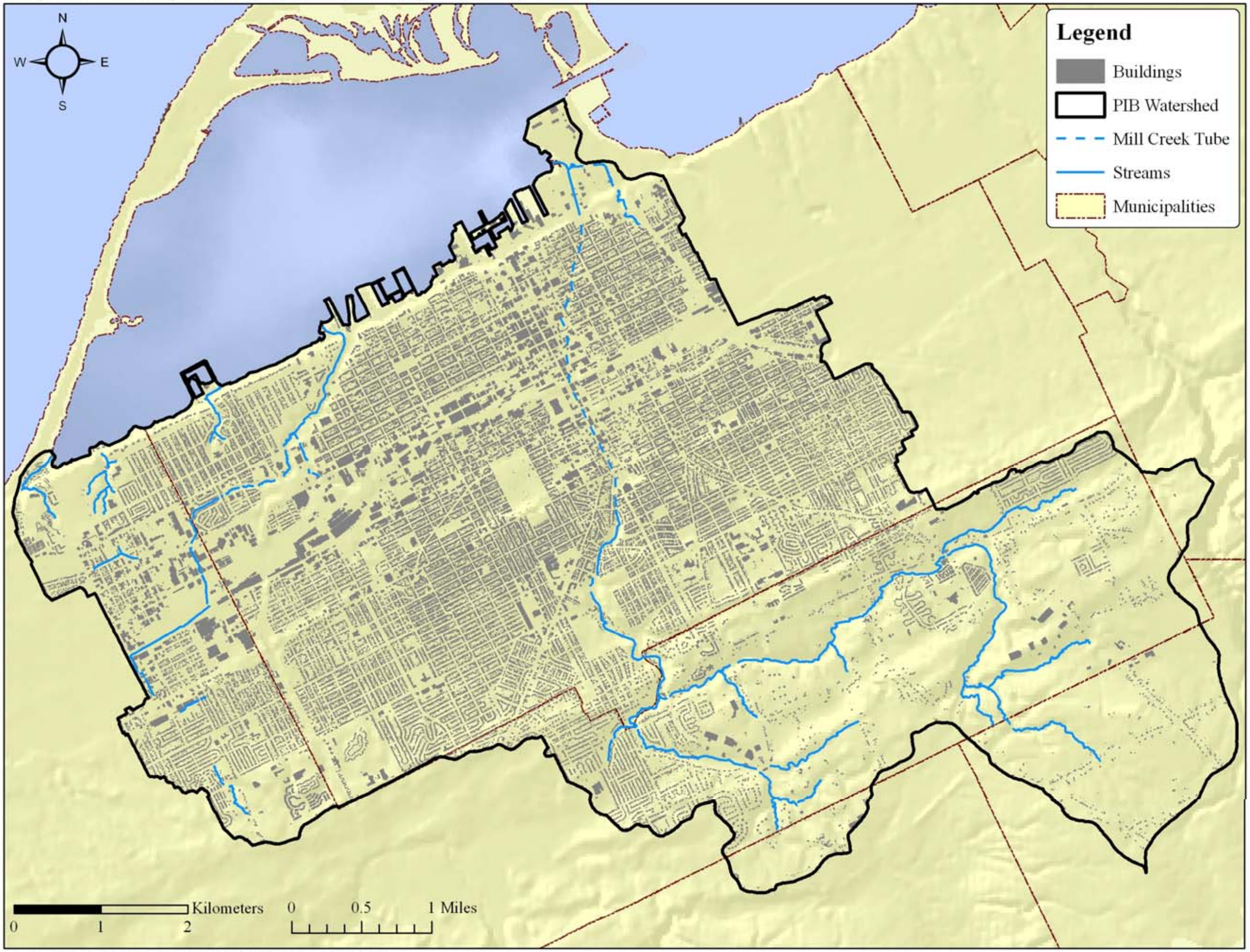
Map 26: Buildings located within the Presque Isle Bay watershed



Building data was obtained from the Erie County Department of Planning

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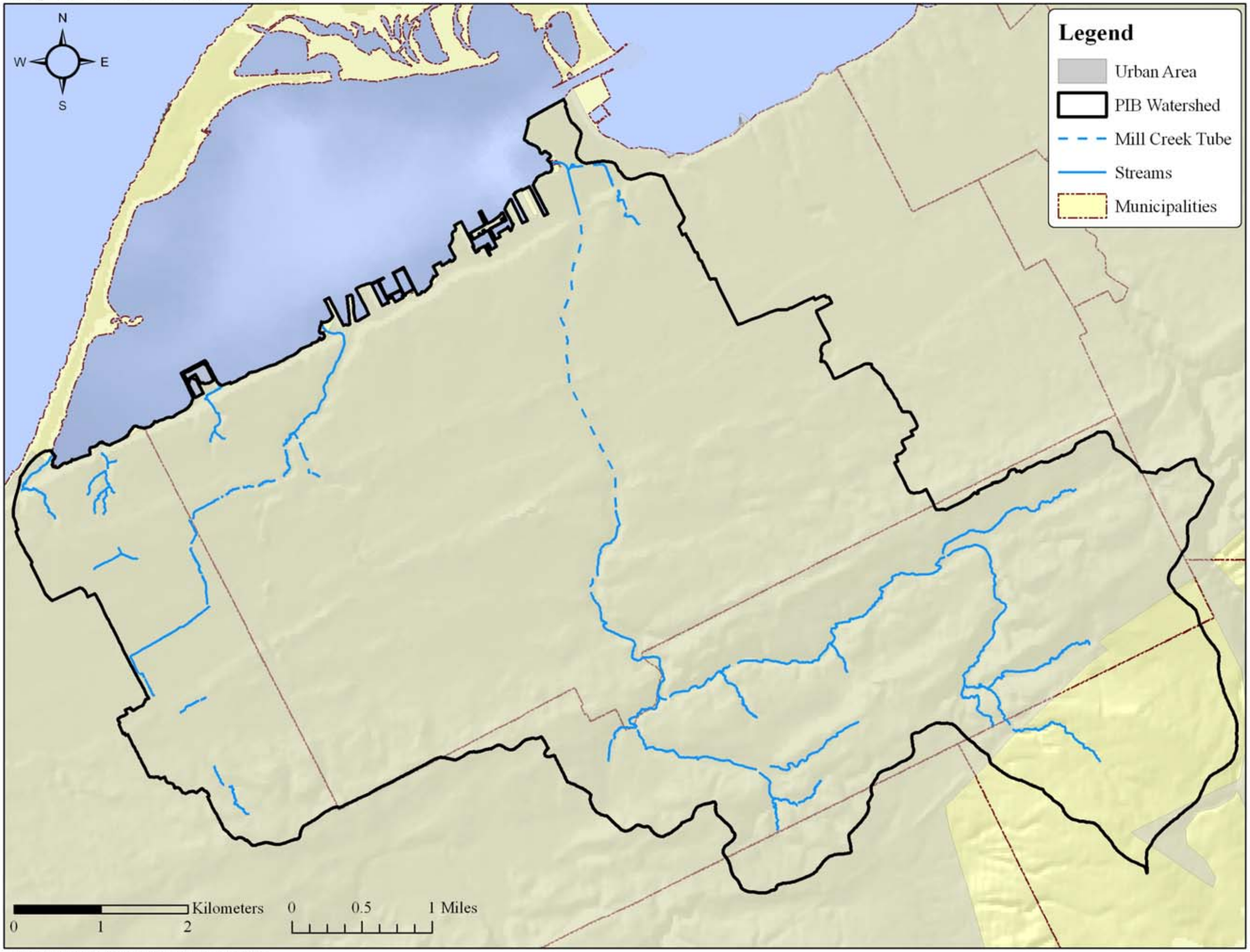
Map 27: Erie Urbanized Area



Urbanized area data was downloaded from PASDA

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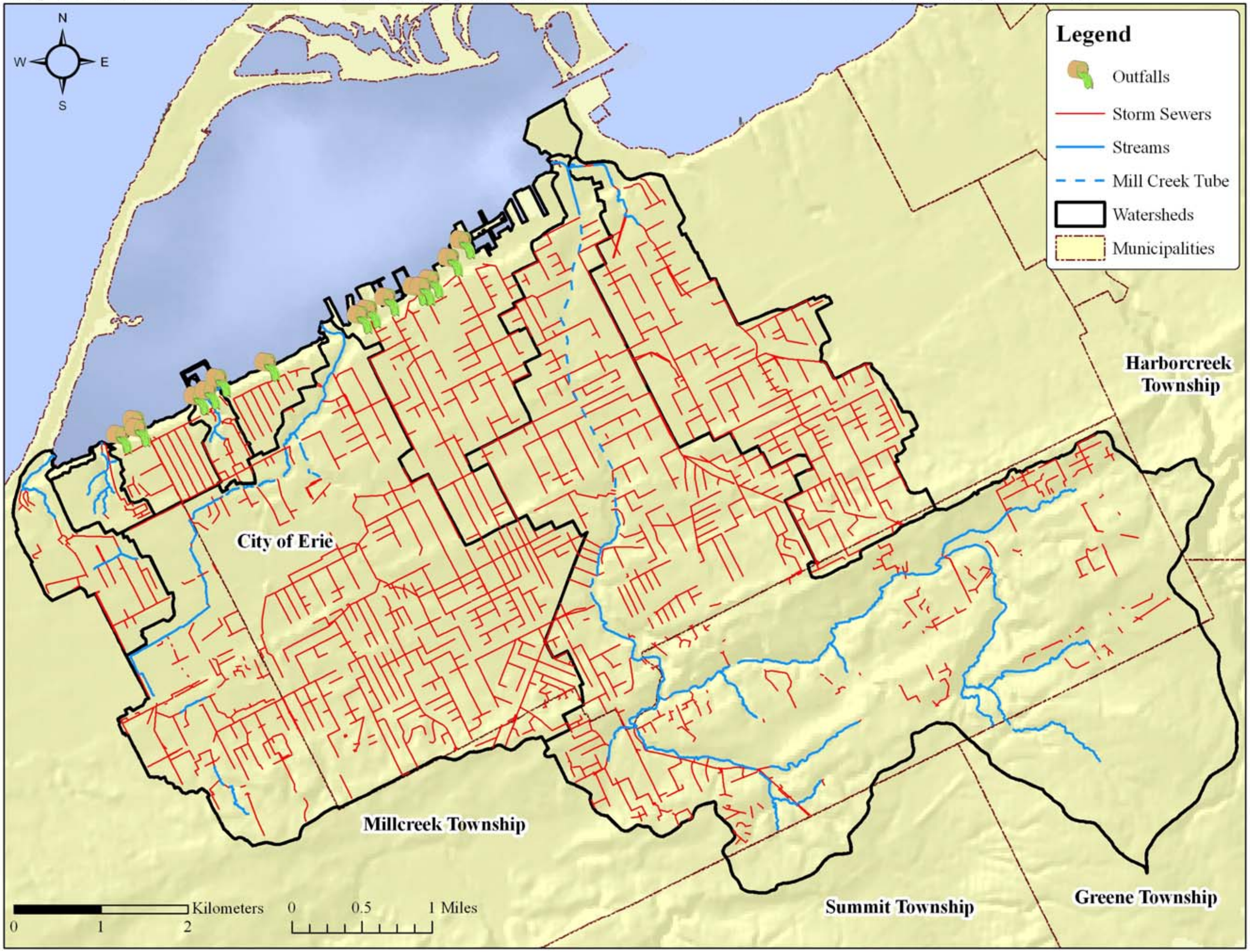
Map 28: Storm sewer system within the Presque Isle Bay watershed and storm water outfalls to Presque Isle Bay



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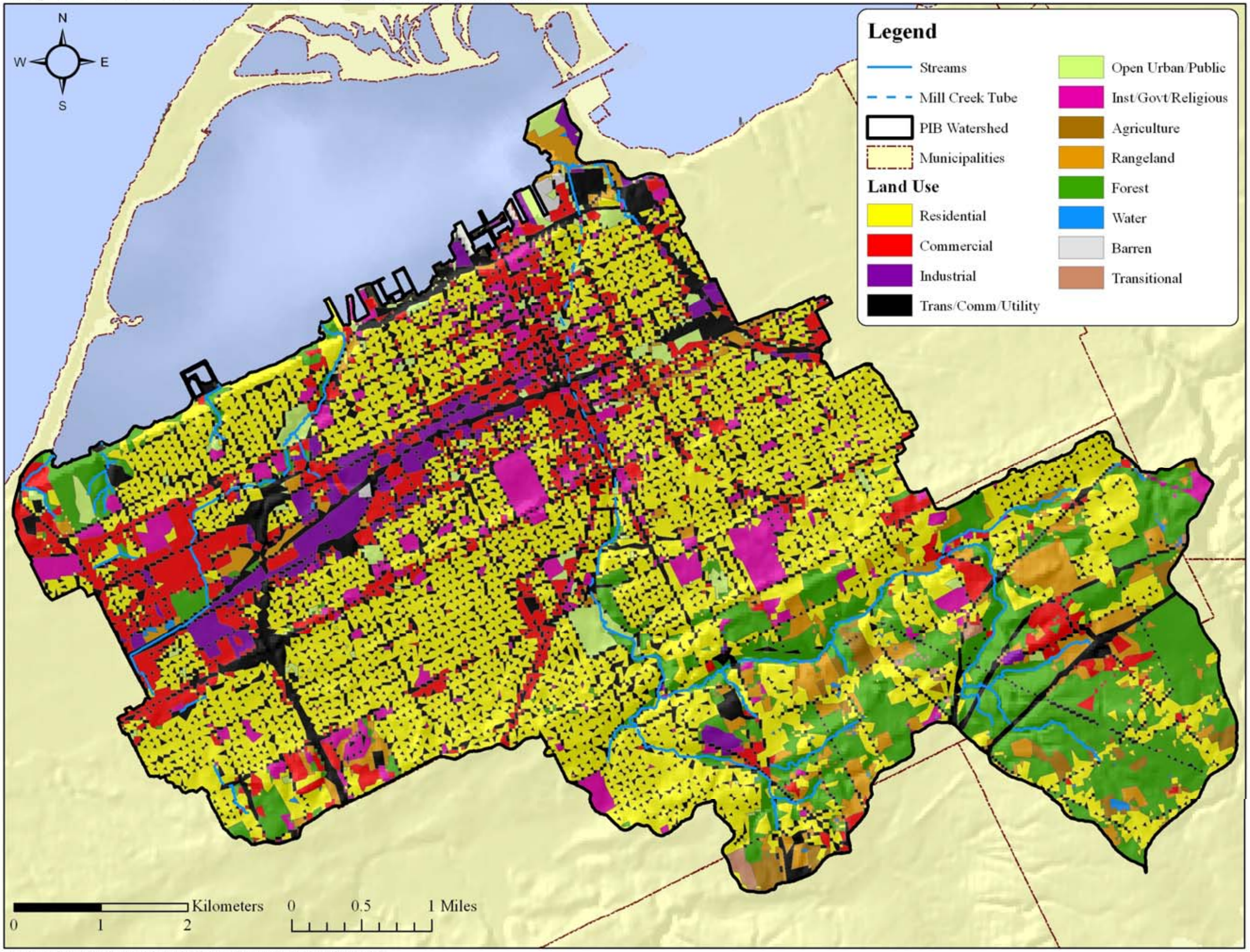
Map 29: Land Use within the Presque Isle Bay watershed



Land use data was obtained from the Erie County Department of Planning

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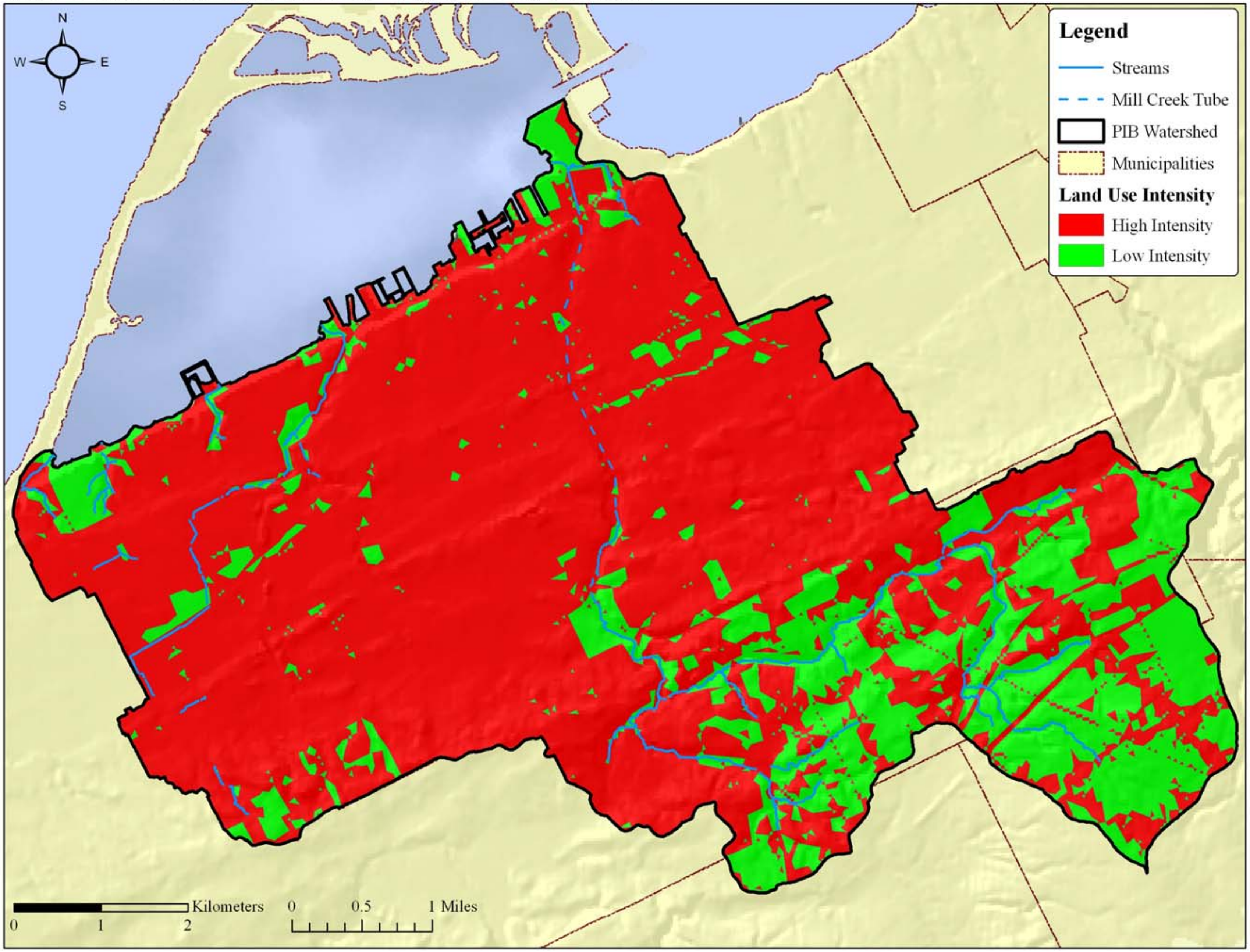
Map 30: Land Use intensity within the Presque Isle Bay watershed



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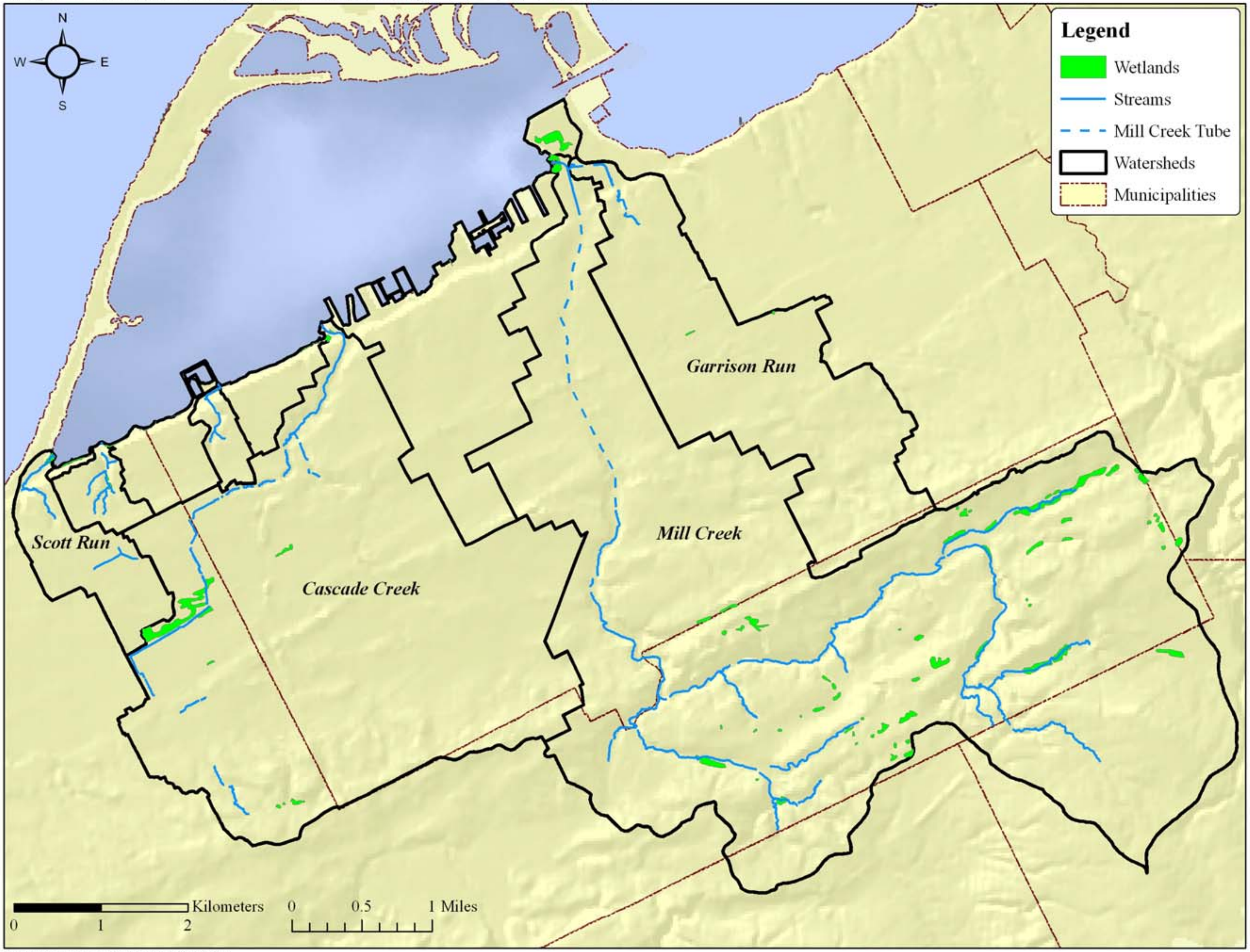
Map 31: Wetlands located within the Presque Isle Bay watershed



Wetland data was downloaded from PASDA

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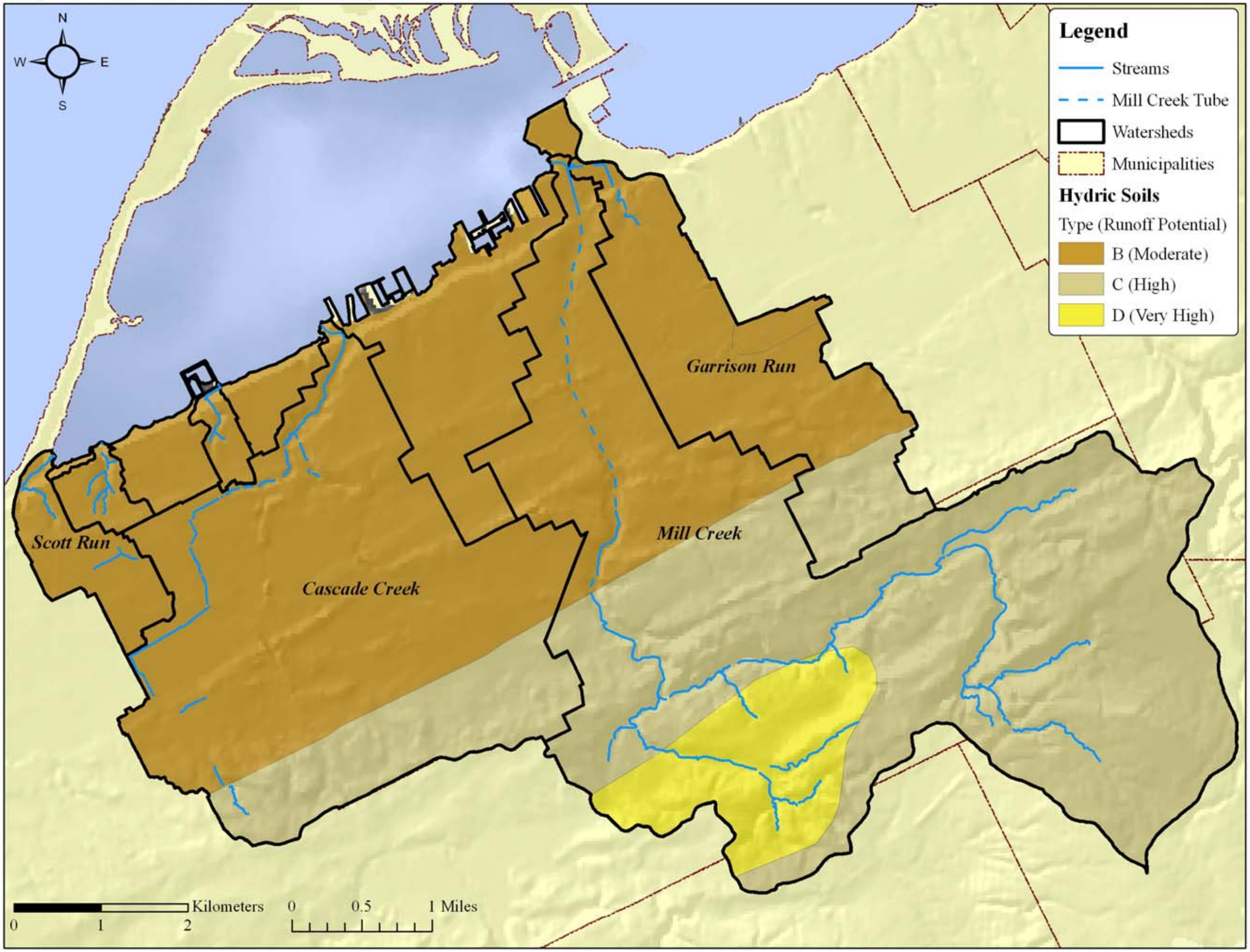
Map 32: Hydric soils within the Presque Isle Bay watershed



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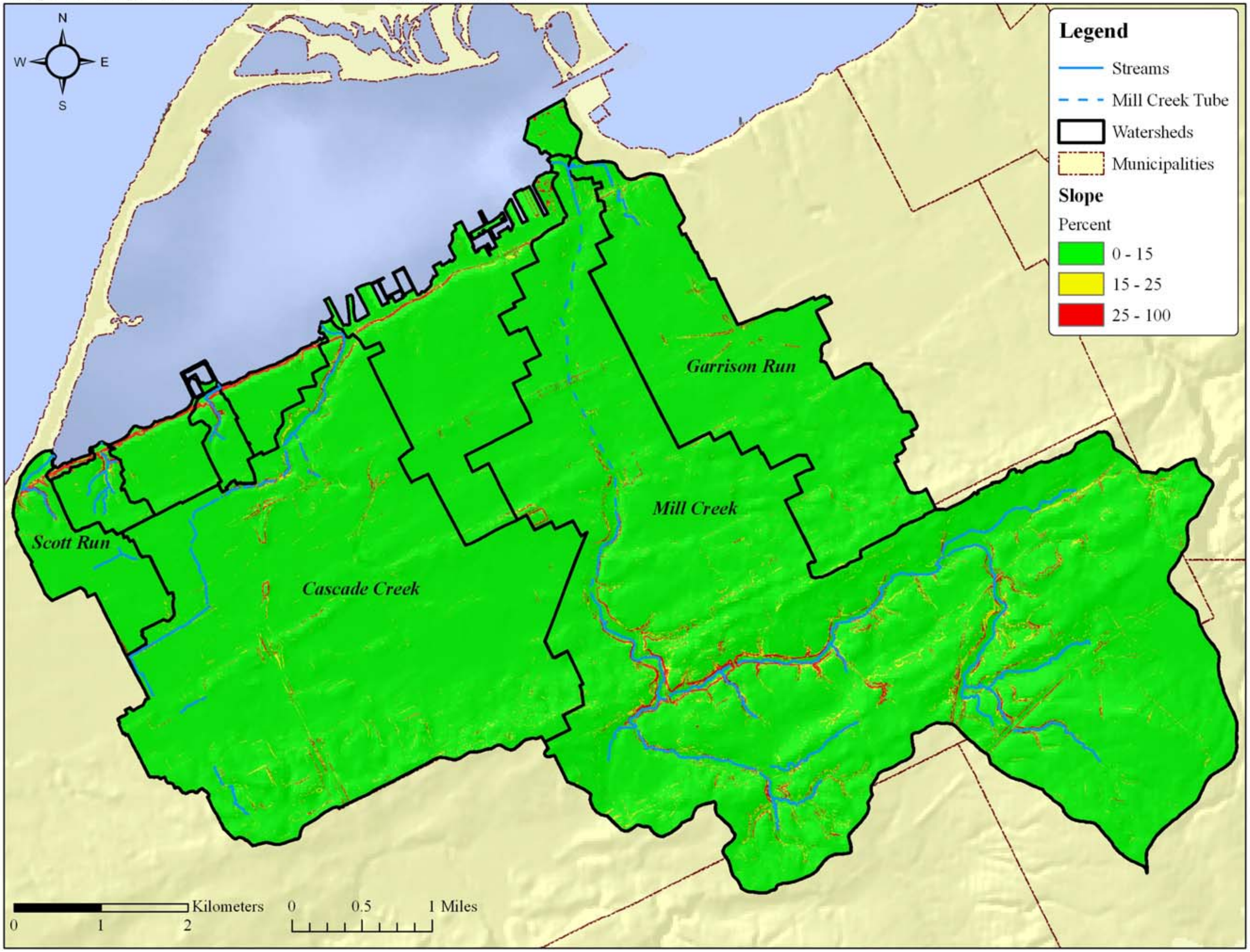
Map 33: Slope within the Presque Isle Bay watershed



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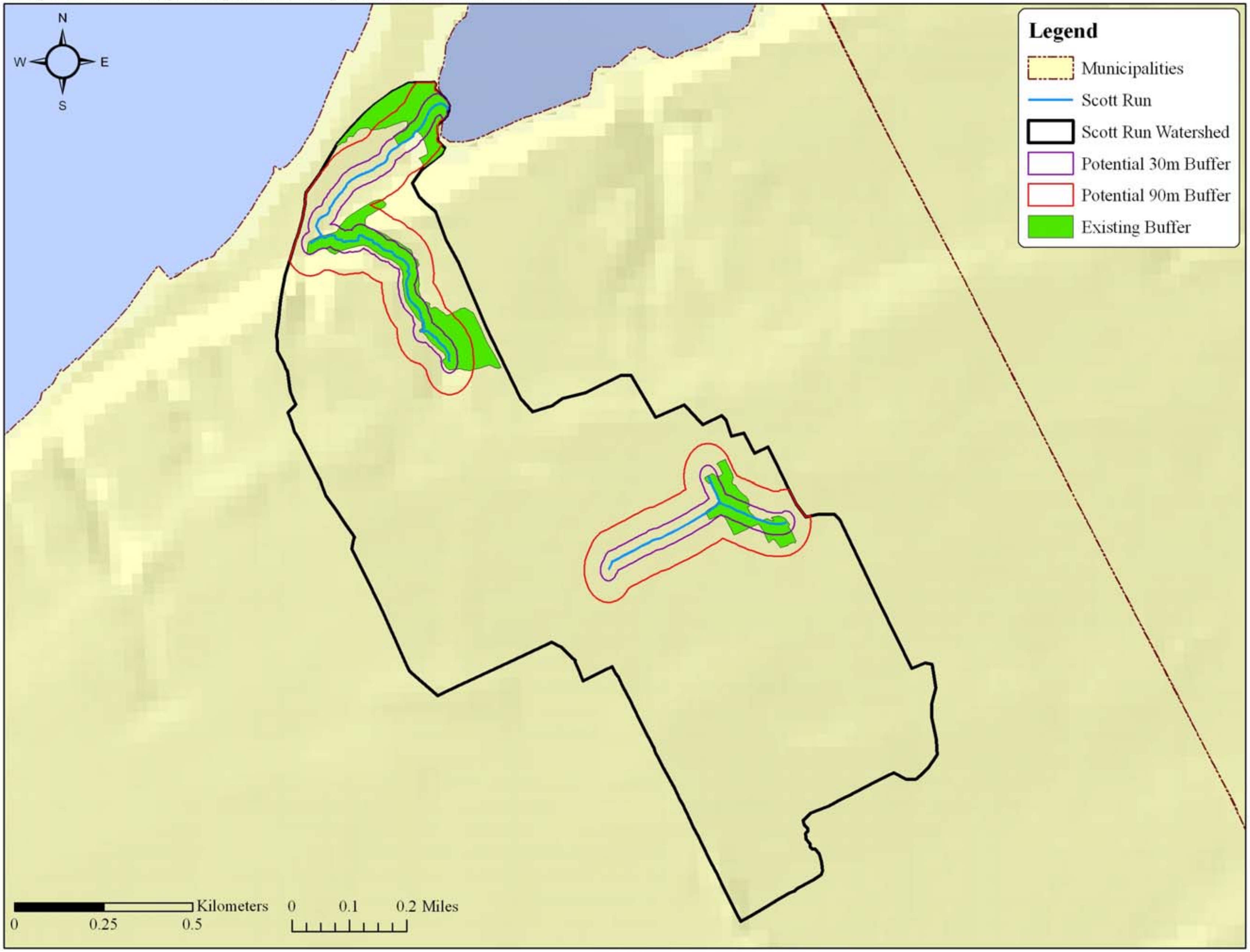
Map 34: Existing and potential riparian buffer for Scott Run



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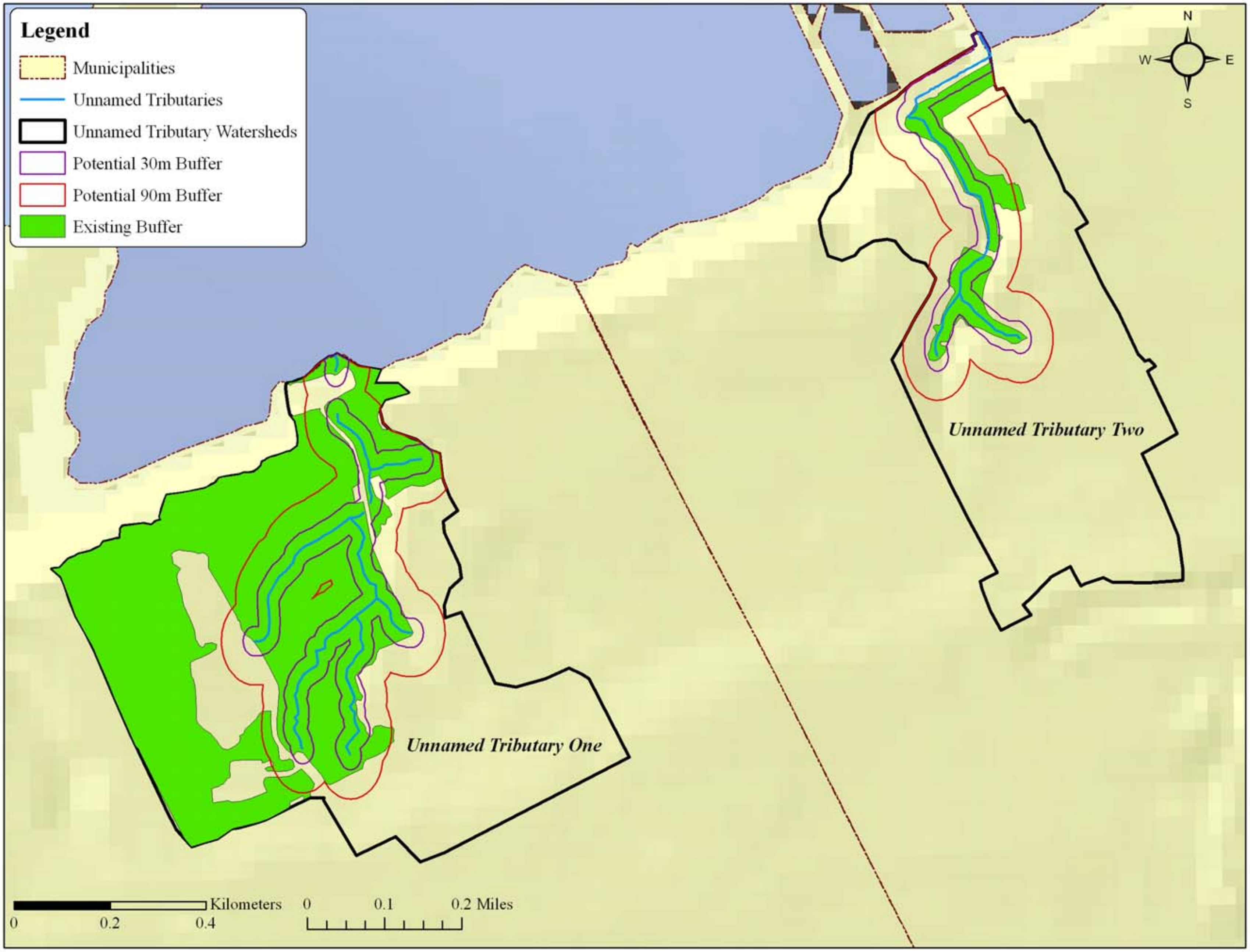
Map 35: Existing and potential riparian buffer for Unnamed Tributary One and Unnamed Tributary Two



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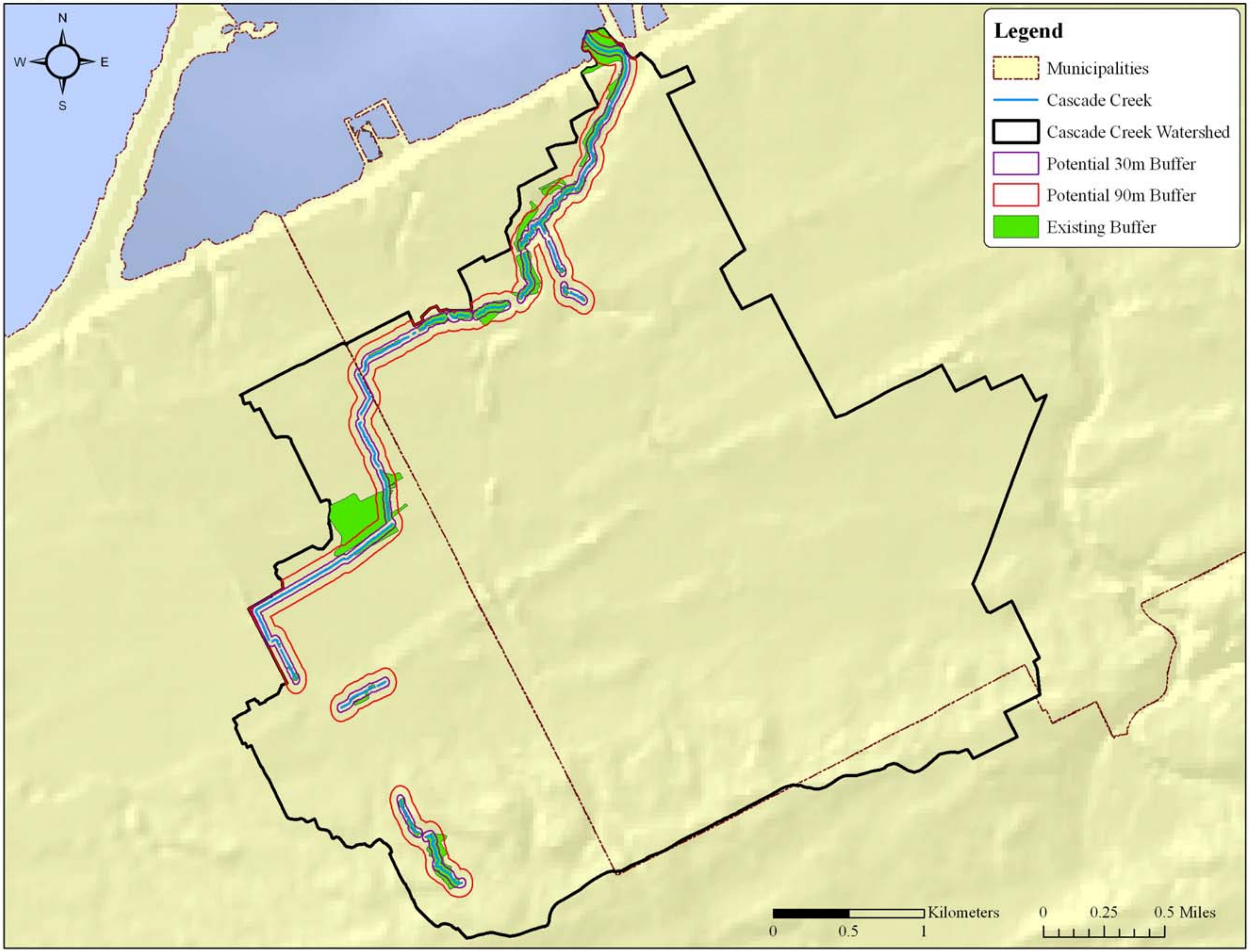
Map 36: Existing and potential riparian buffer for Cascade Creek



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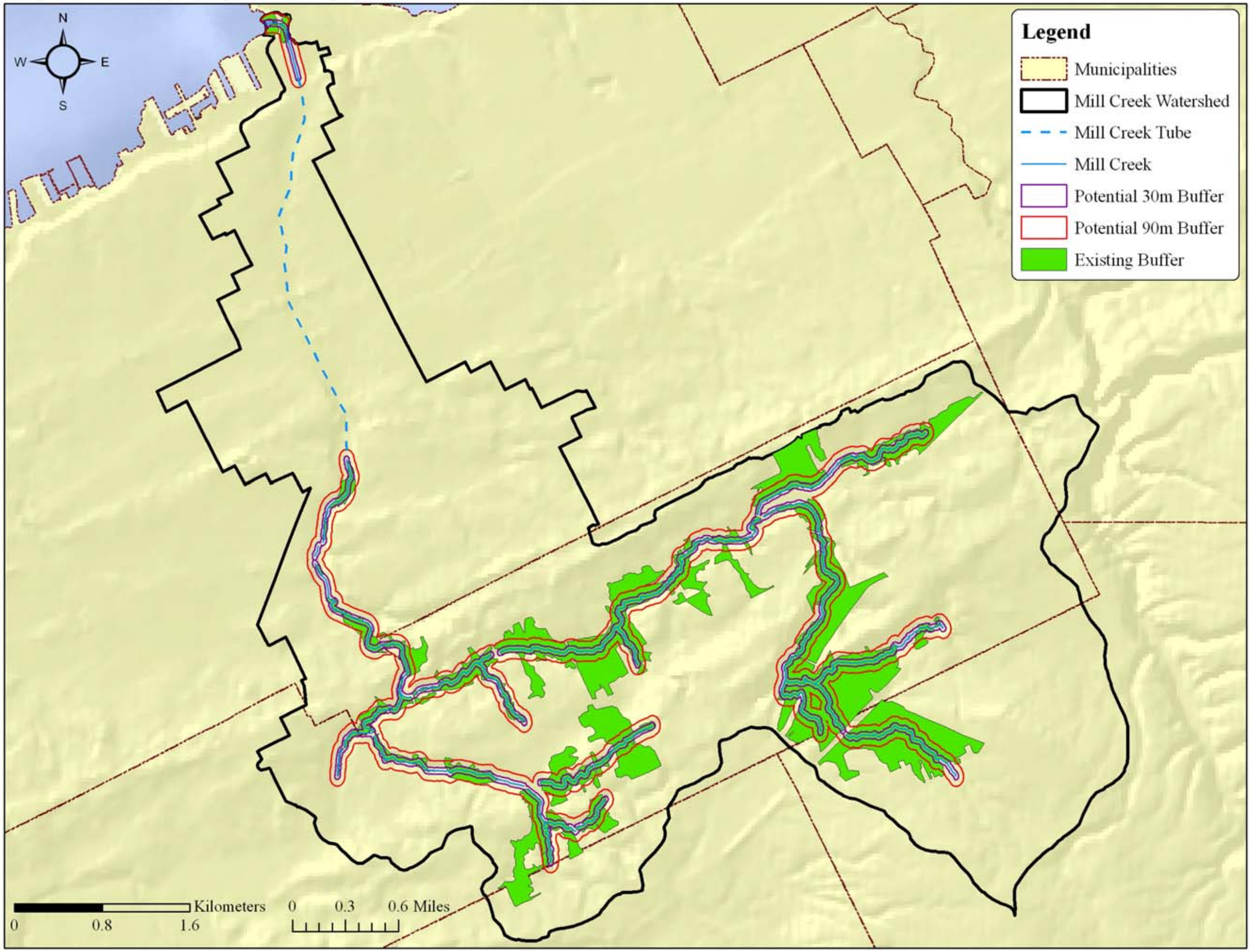
Map 37: Existing and potential riparian buffer for Mill Creek



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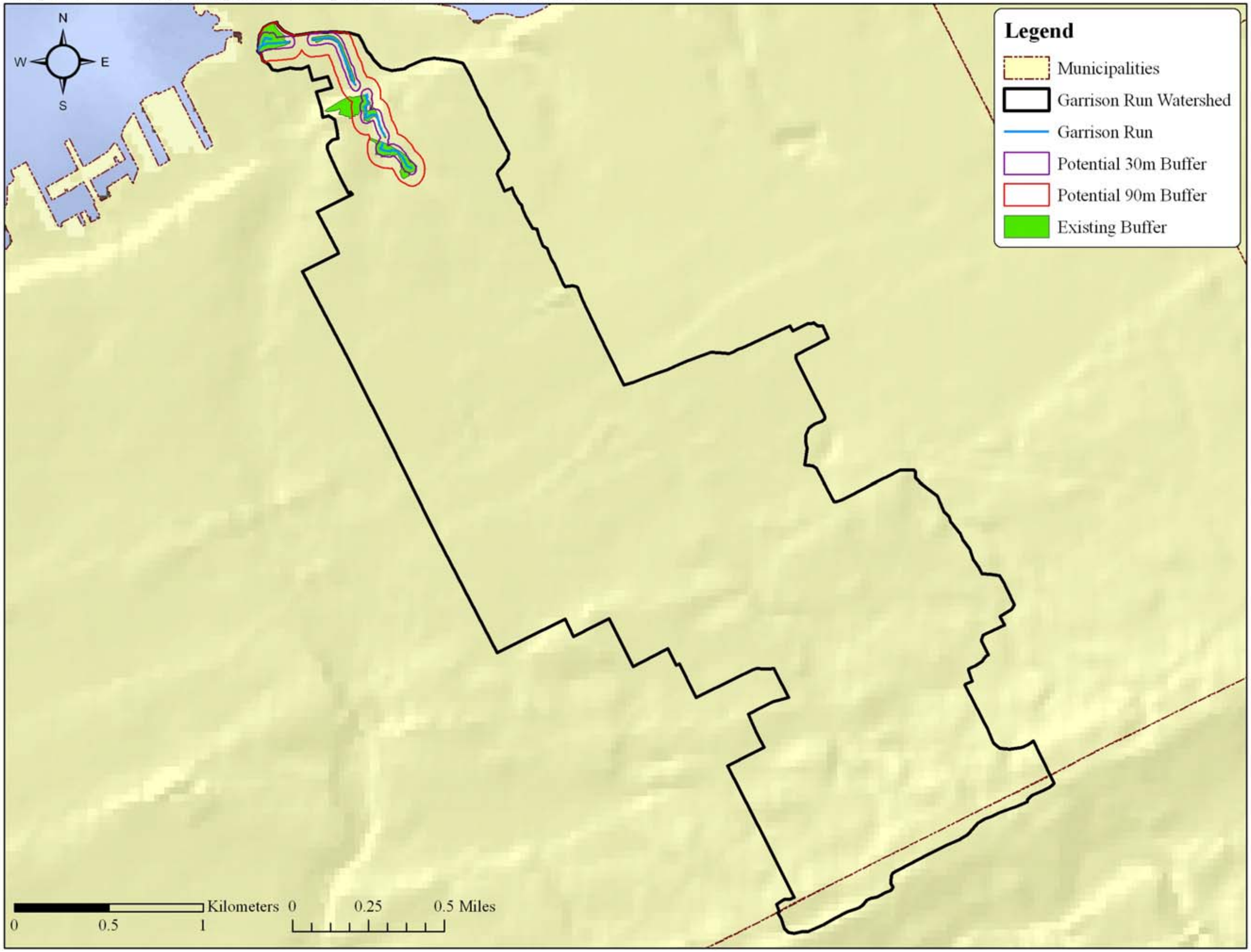
Map 38: Existing and potential riparian buffer for Garrison Run



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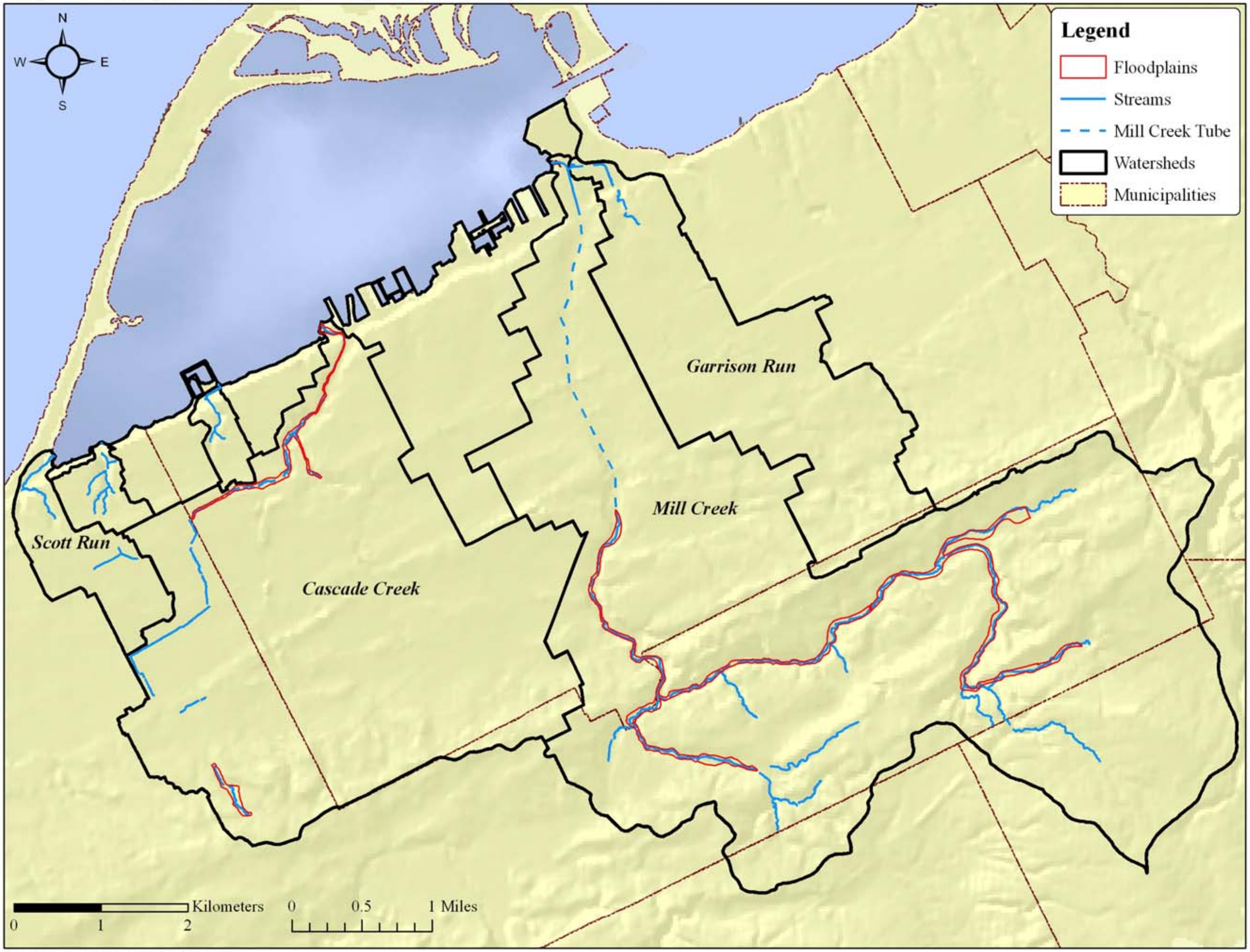
Map 39: Floodplains within the Presque Isle Bay watershed



Floodplain data was downloaded from PASDA

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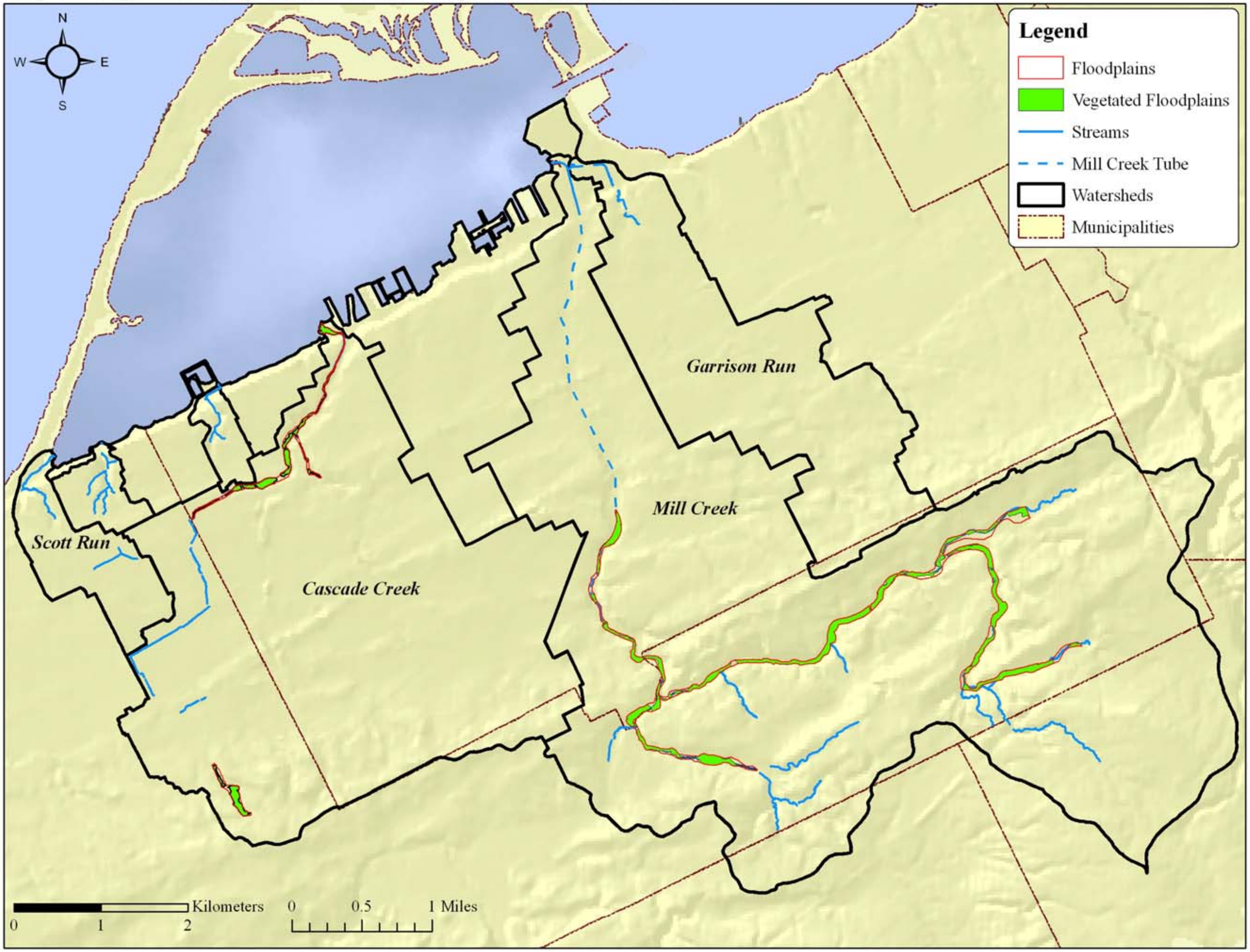
Map 40: Vegetated floodplains within the Presque Isle Bay watershed



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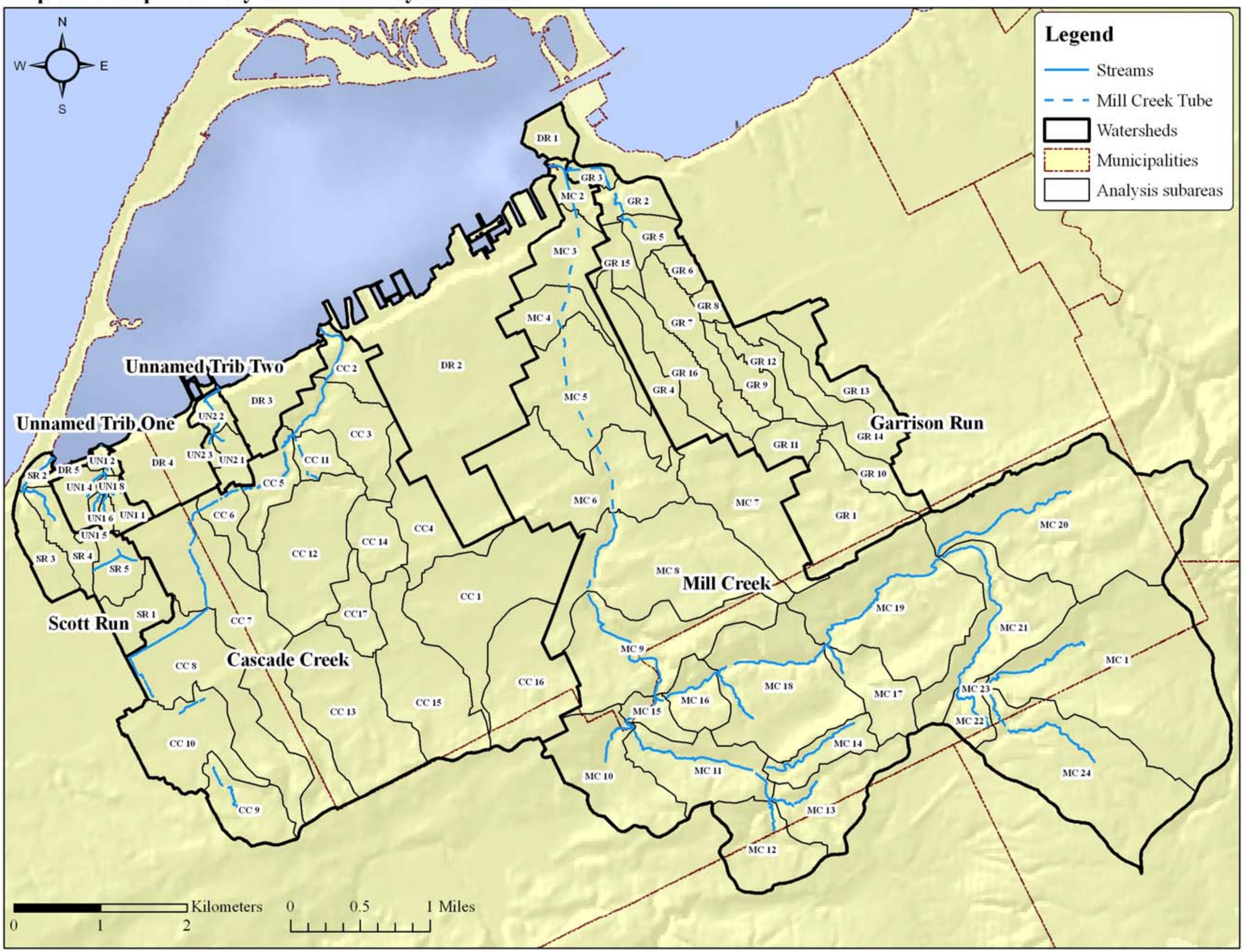
Map 41: Presque Isle Bay watershed analysis subareas



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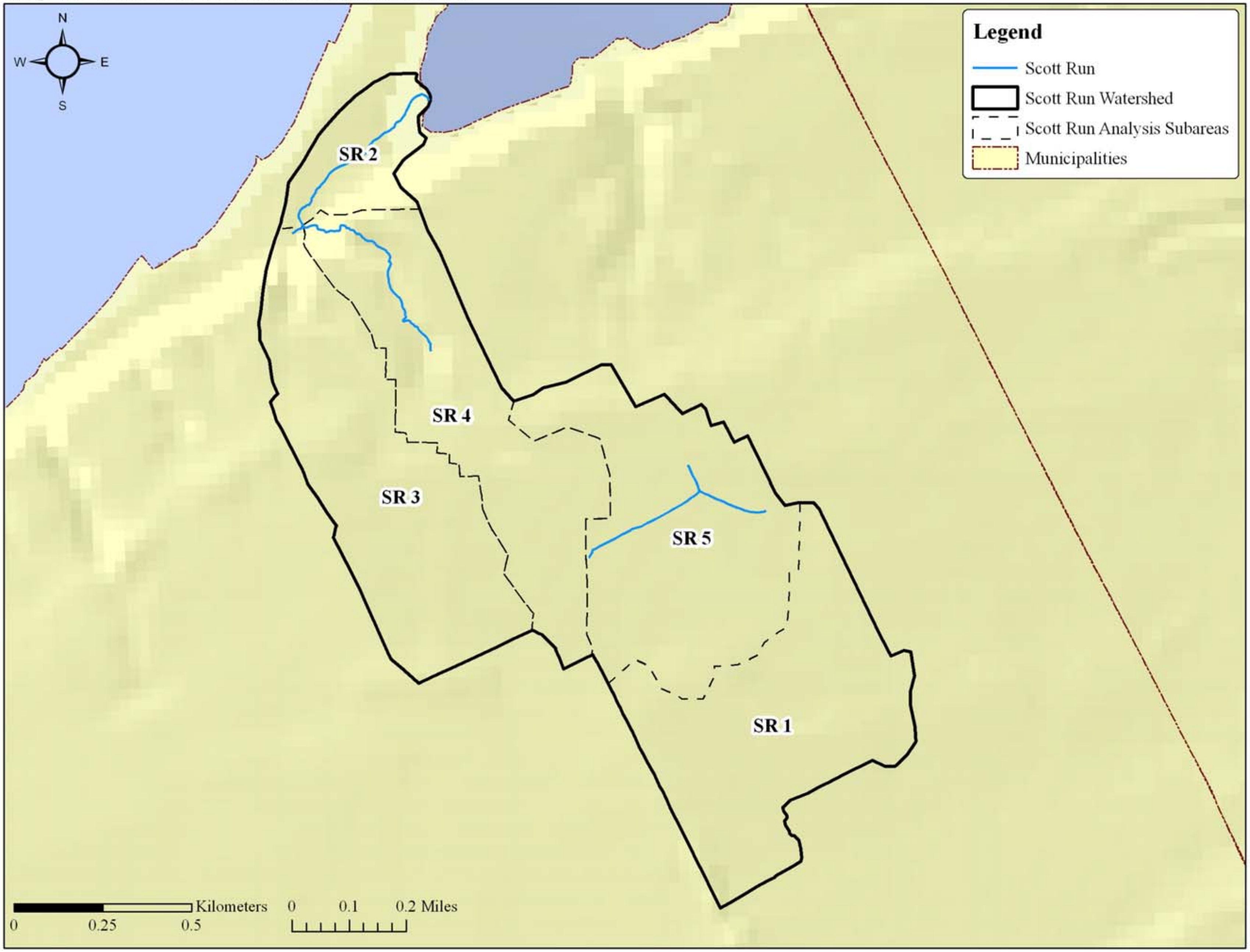
Map 42: Scott Run watershed analysis subareas



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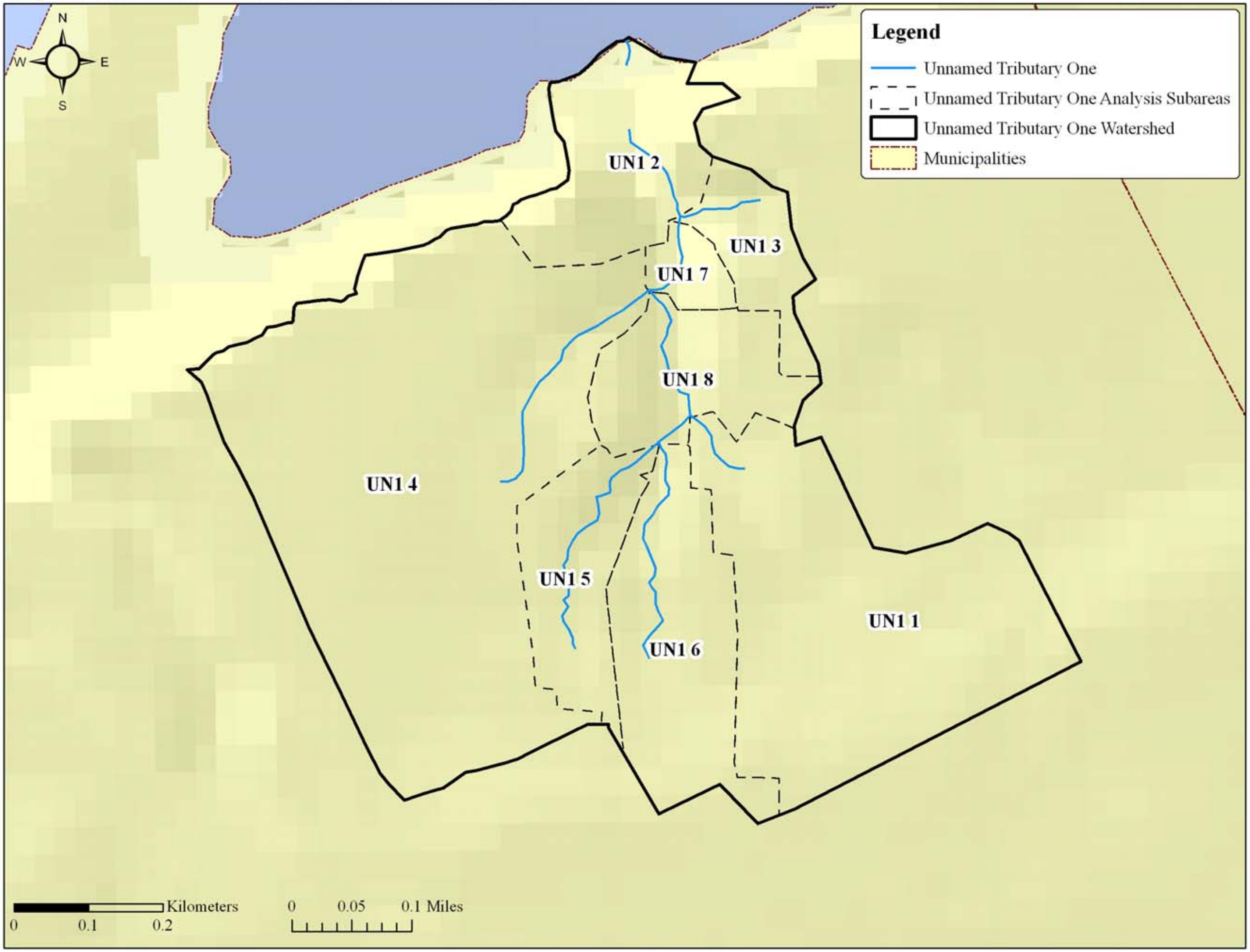
Map 43: Unnamed Tributary One watershed analysis subareas



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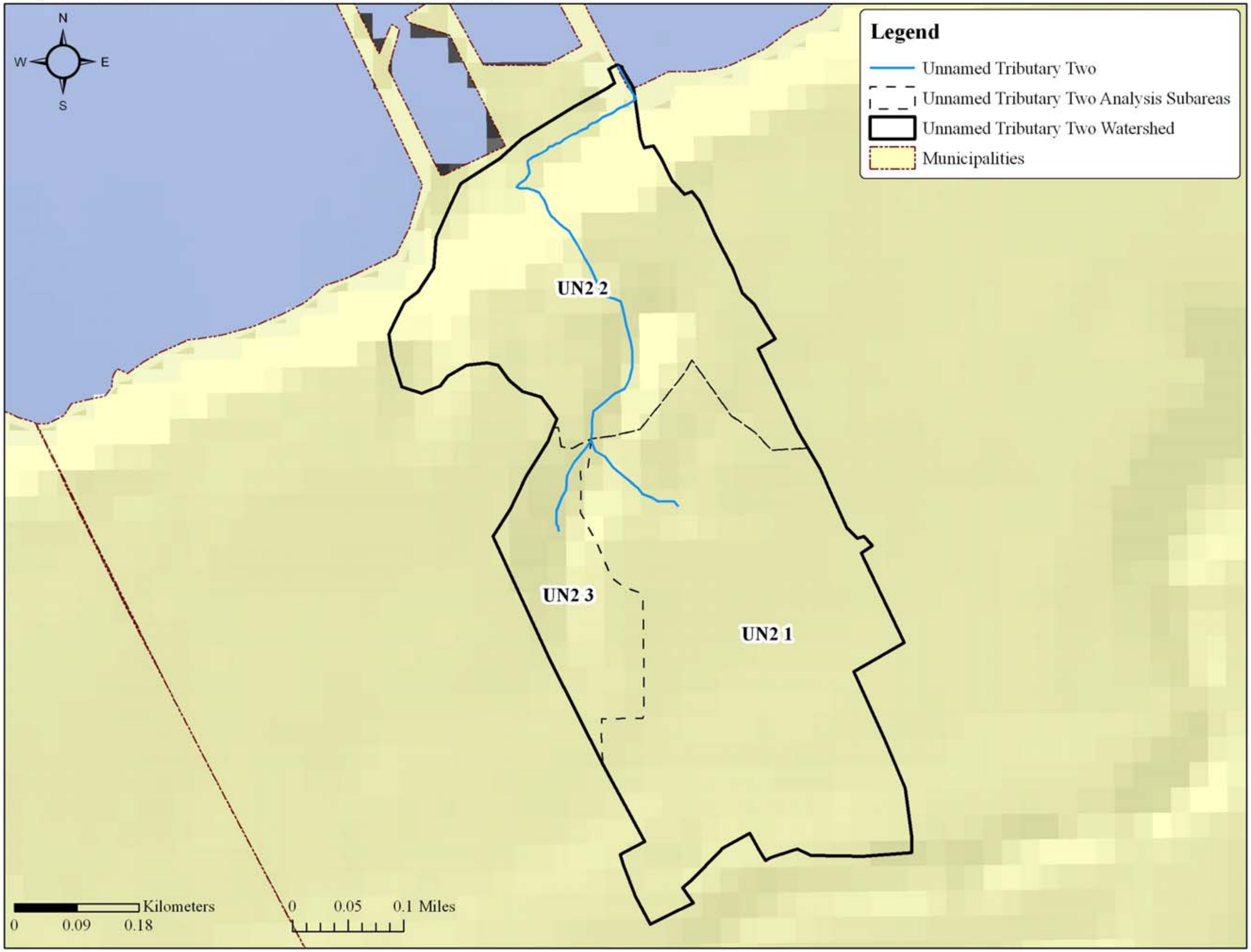
Map 44: Unnamed Tributary Two watershed analysis subareas



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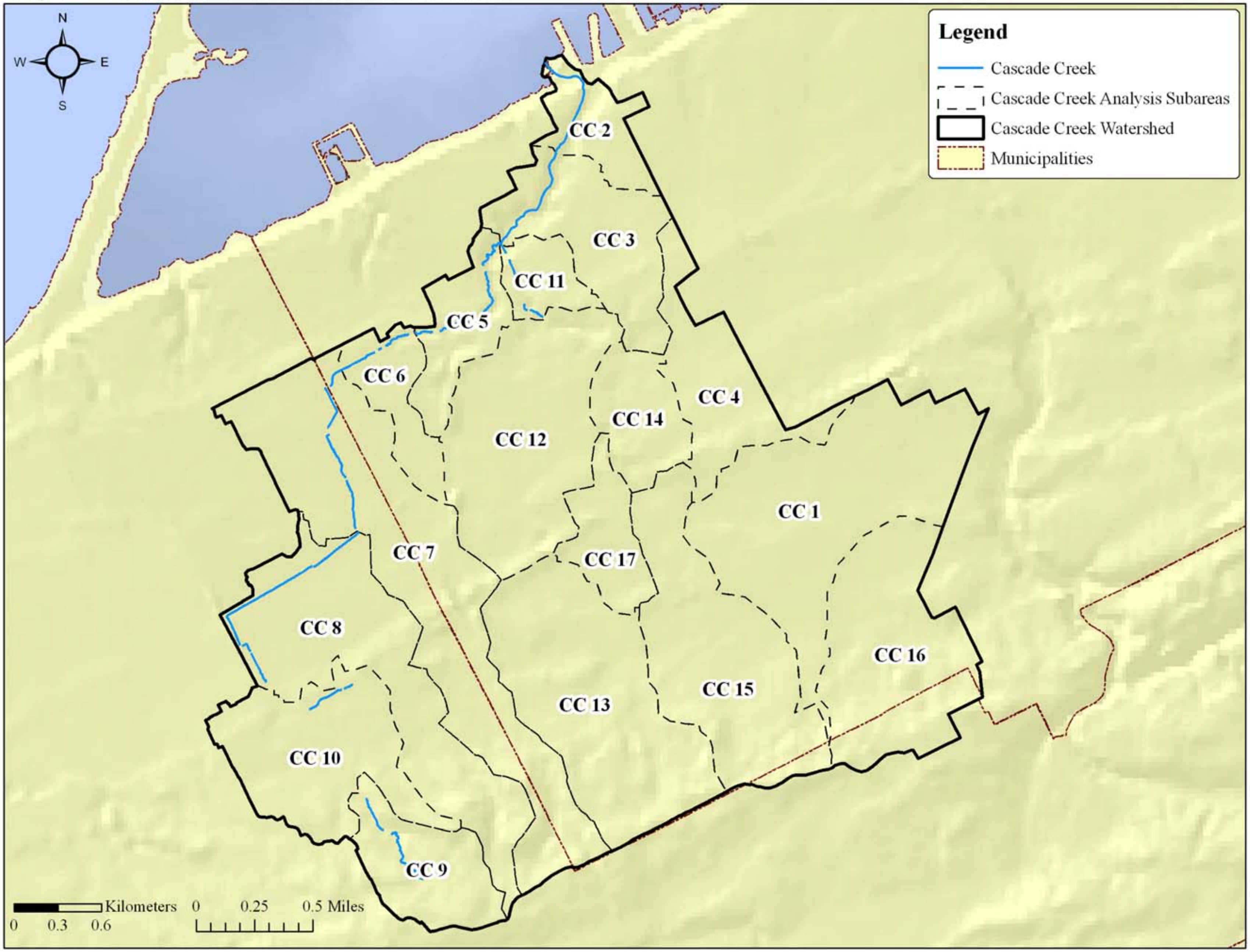
Map 45: Cascade Creek watershed analysis subareas



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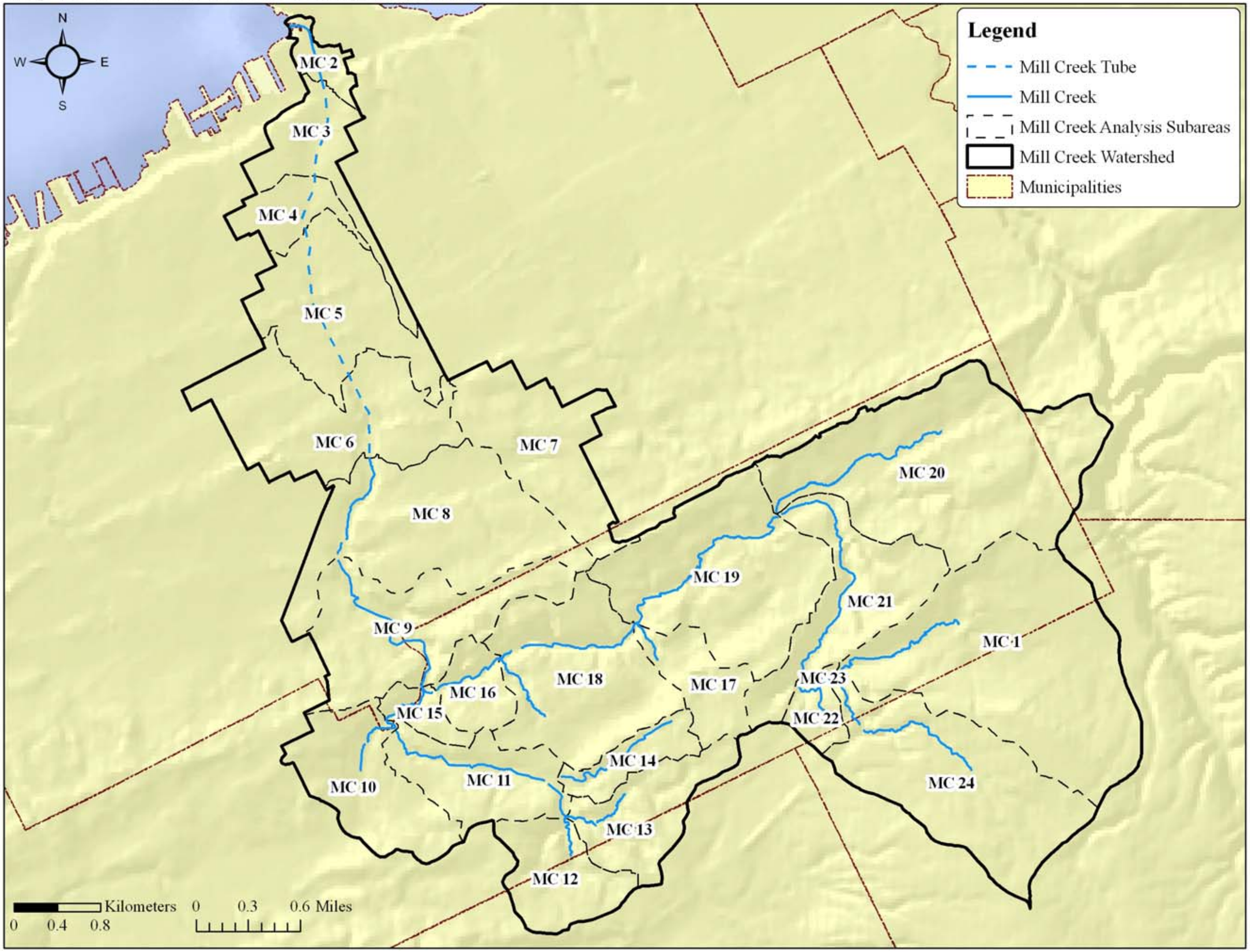
Map 46: Mill Creek watershed analysis subareas



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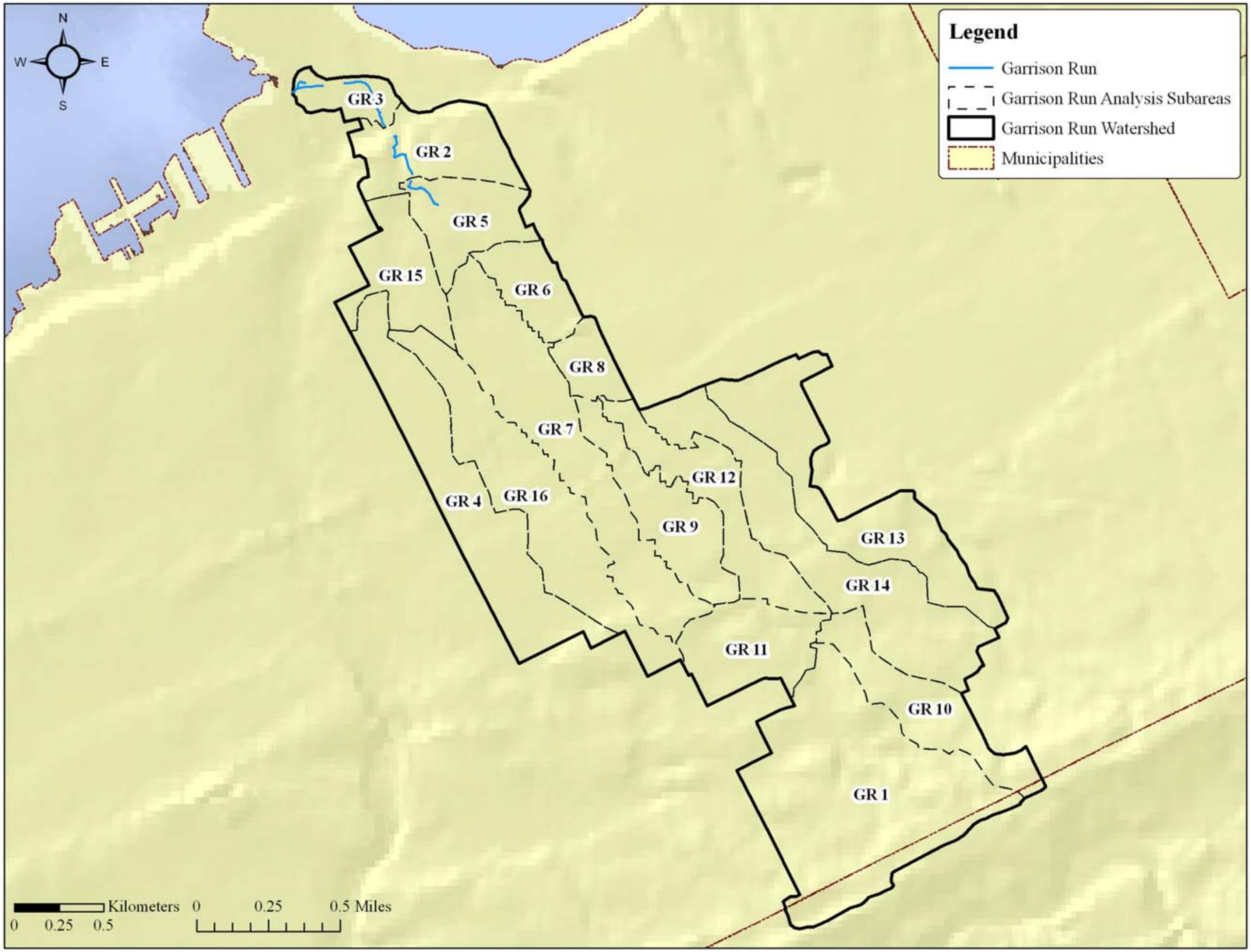
Map 47: Garrison Run watershed analysis subareas



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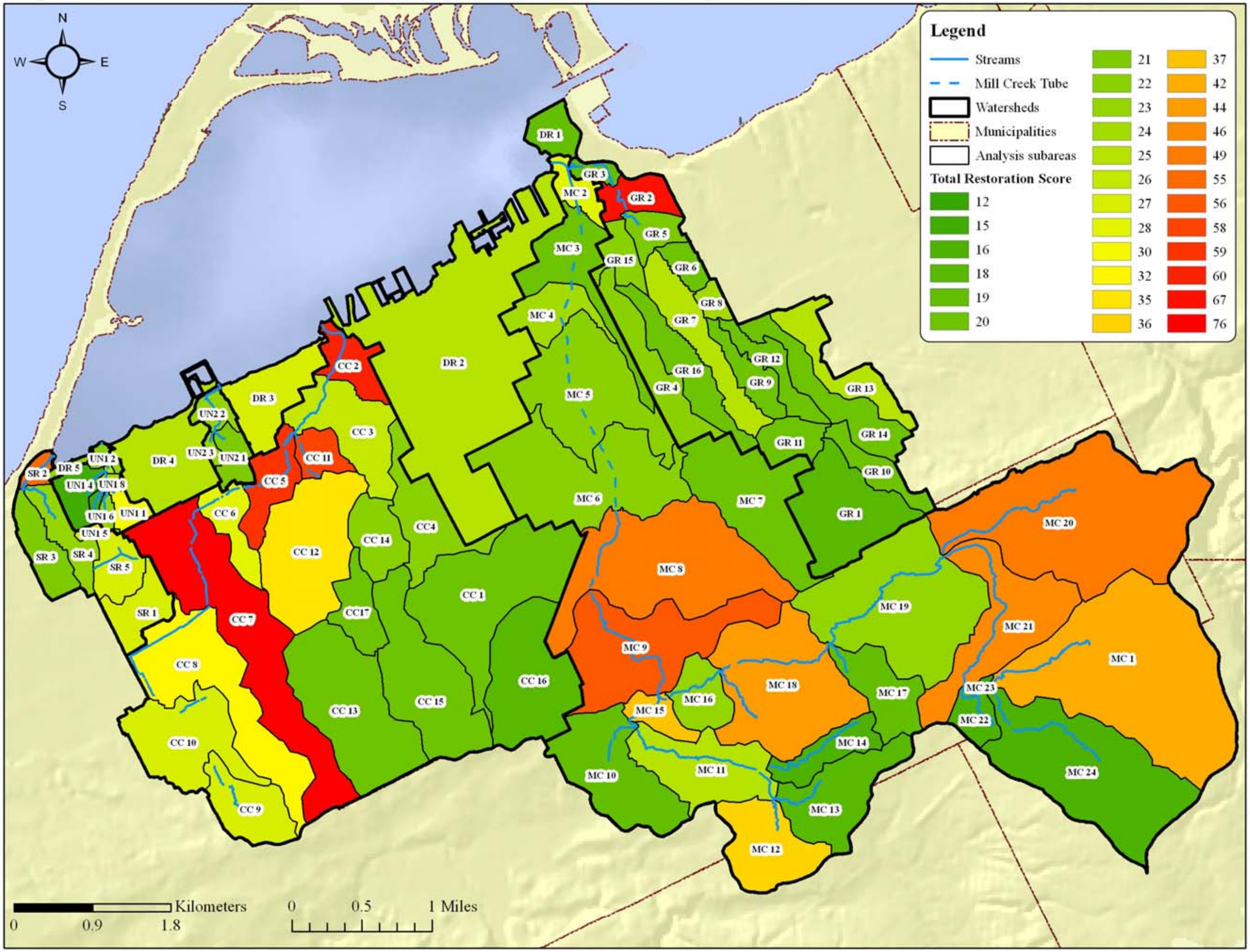
Map 48: Total restoration scores for the Presque Isle Bay watershed analysis subareas



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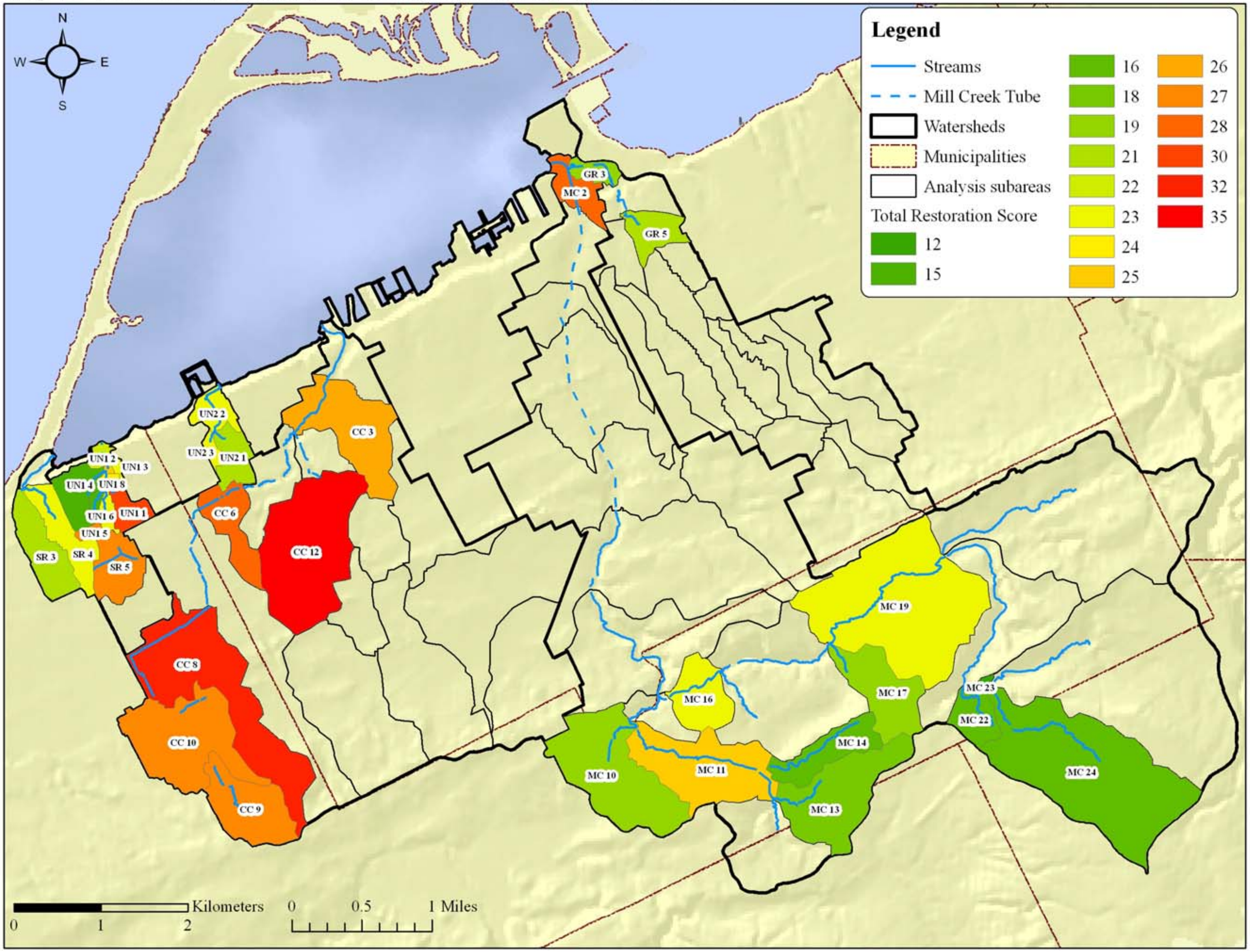
Map 49: Total restoration scores for the subareas assessed under Scenario 1



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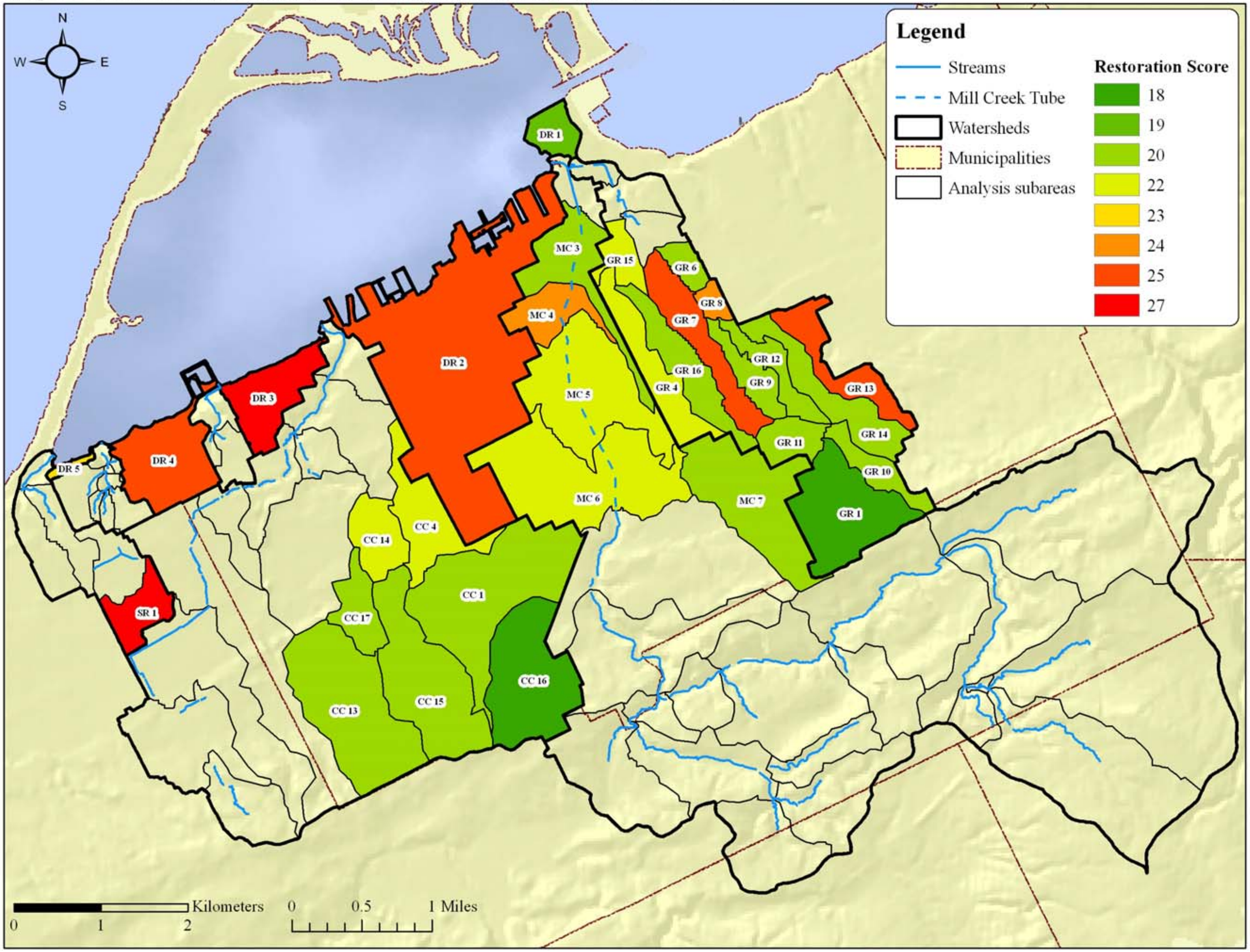
Map 50: Total restoration scores for the subareas assessed under Scenario 2



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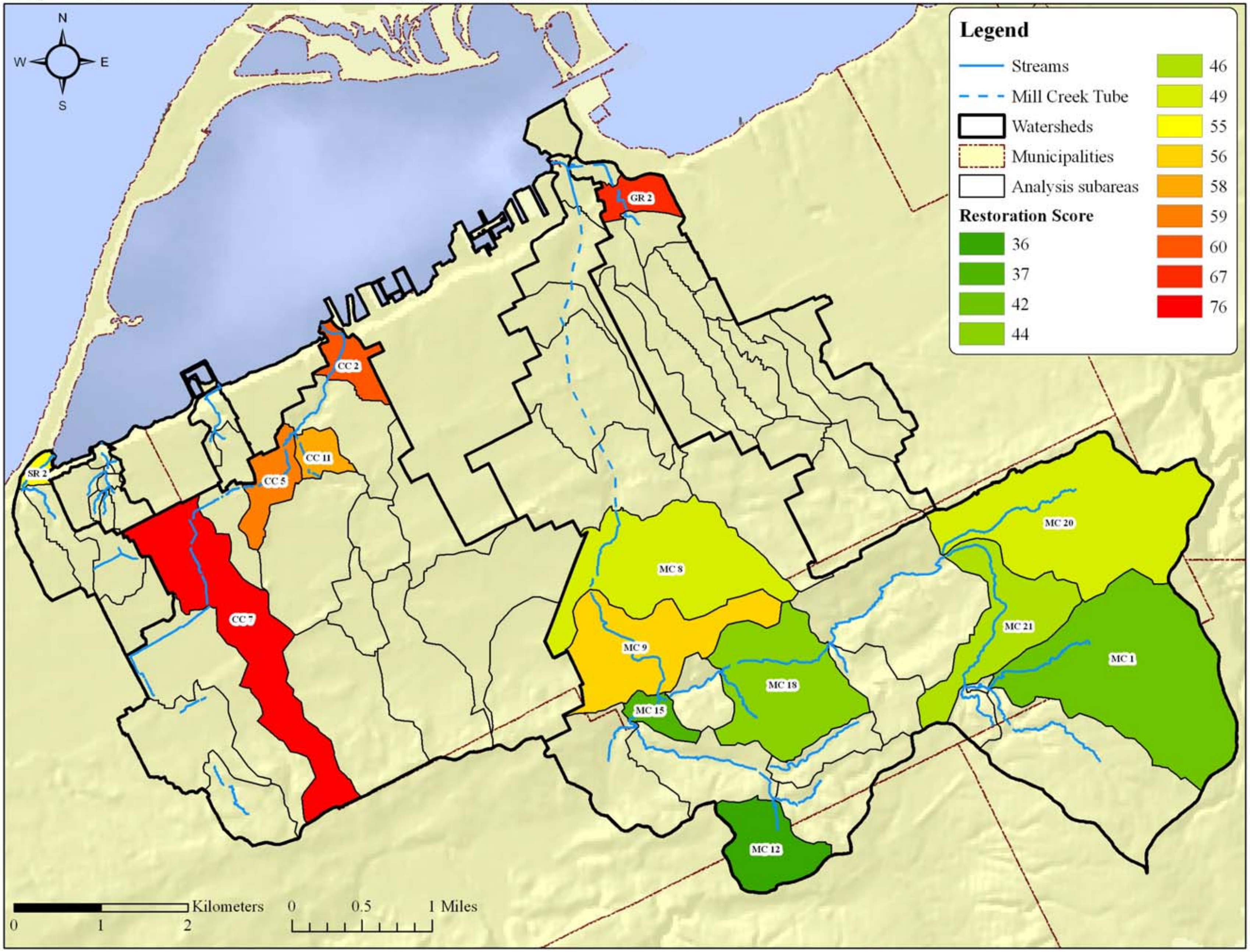
Map 51: Total restoration scores for the subareas assessed under Scenario 3



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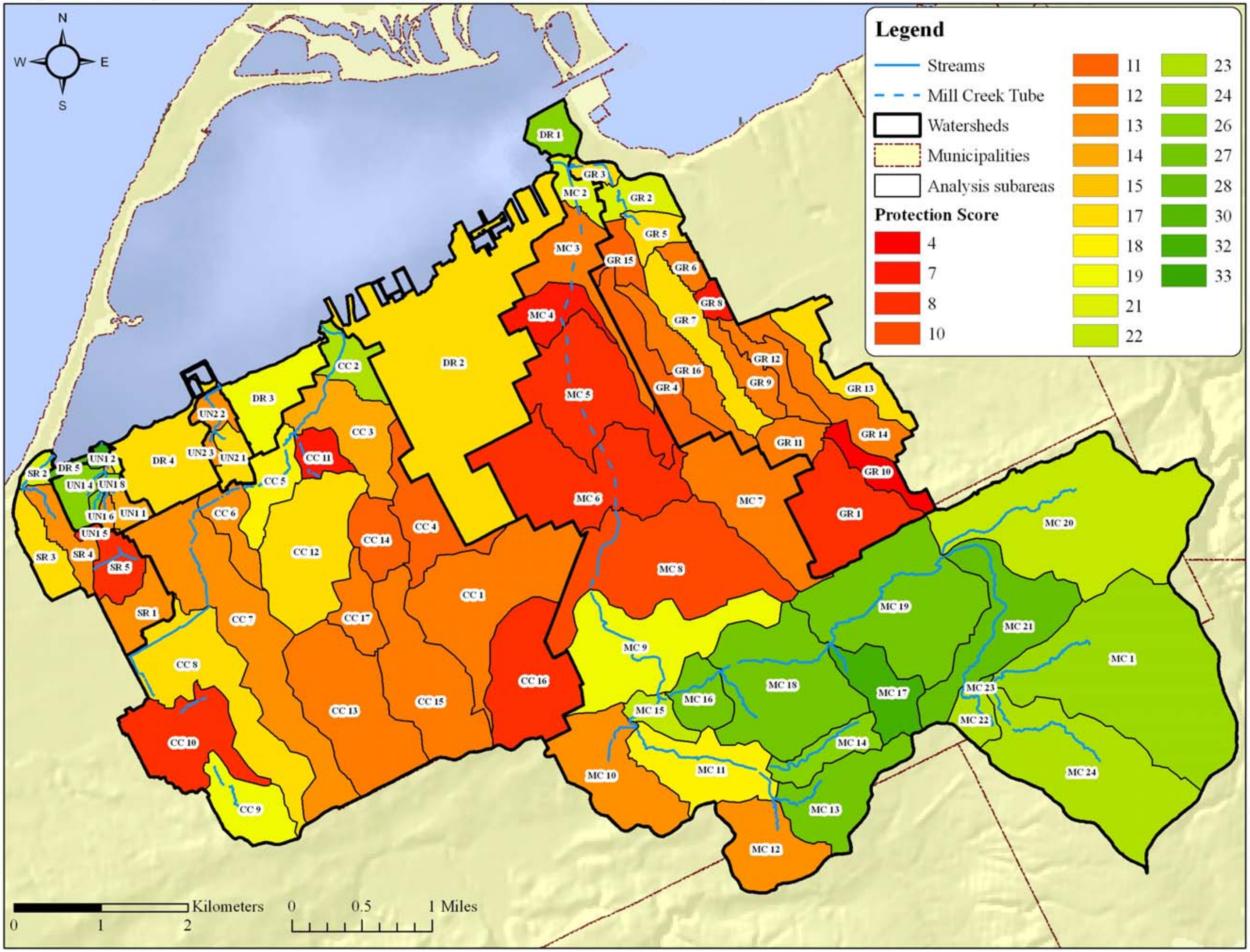
Map 52: Total protection scores for the Presque Isle Bay watershed analysis subareas



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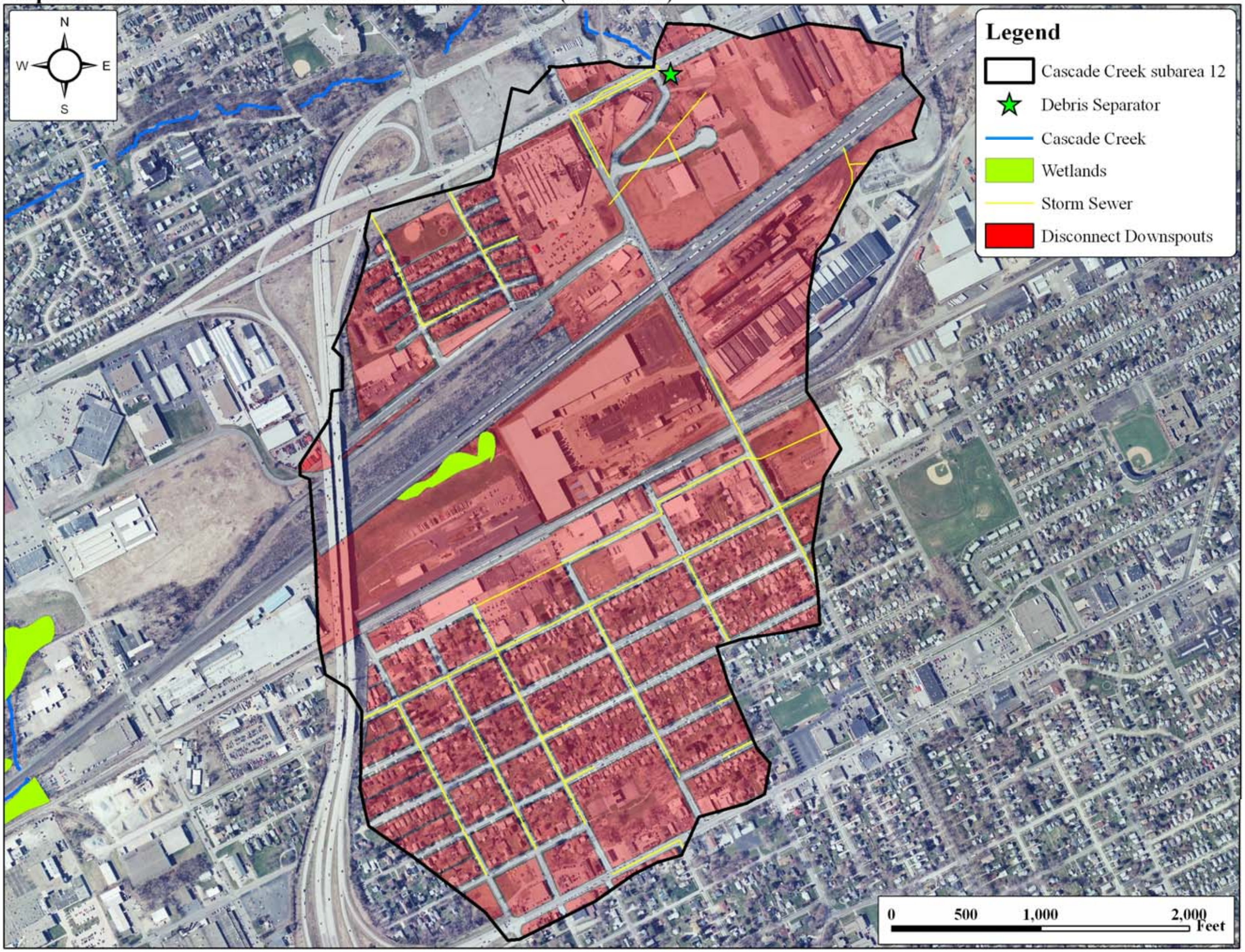
Map 53: Restoration focus for Cascade Creek subarea 12 (Scenario 1)



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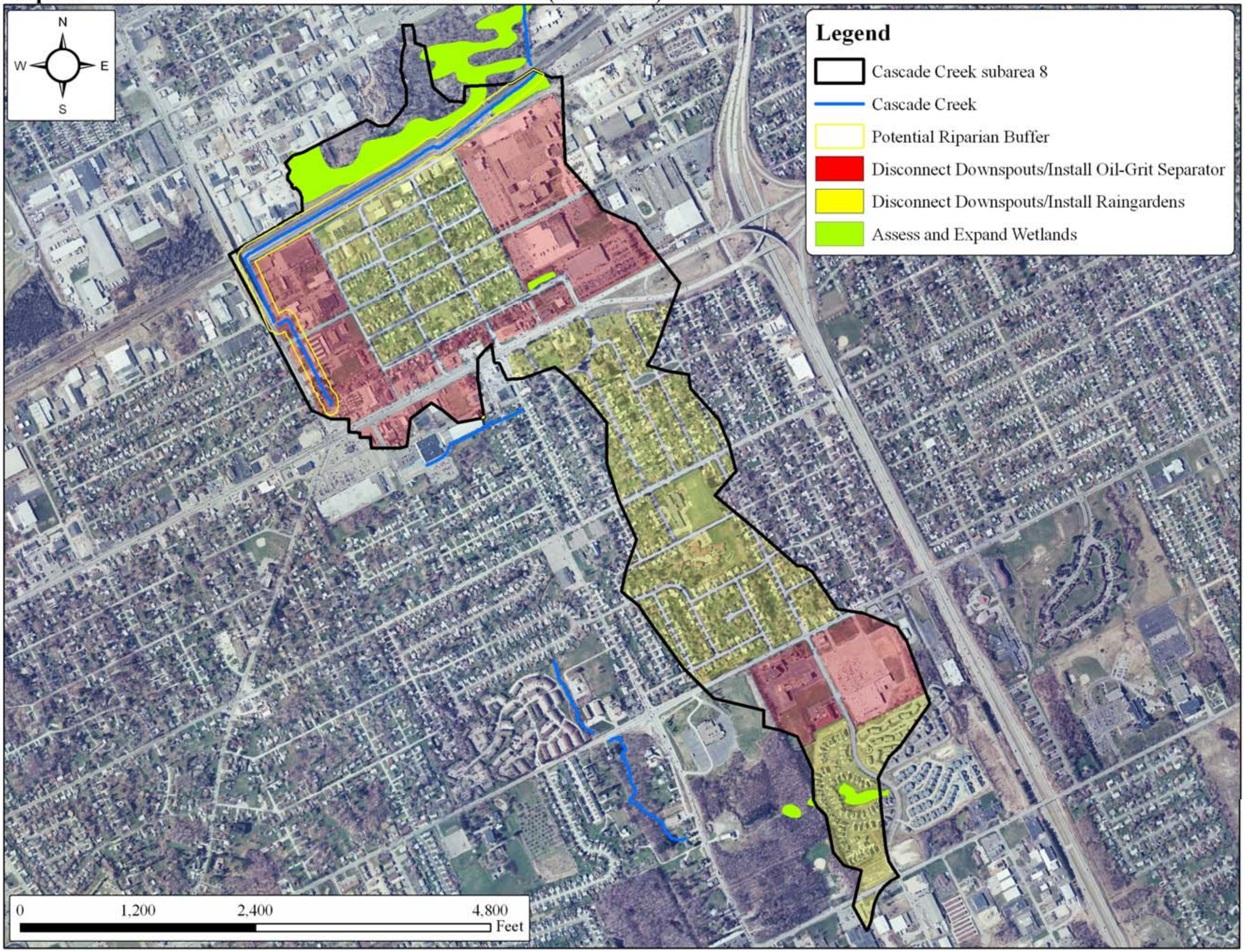
Map 54: Restoration focus for Cascade Creek subarea 8 (Scenario 1)



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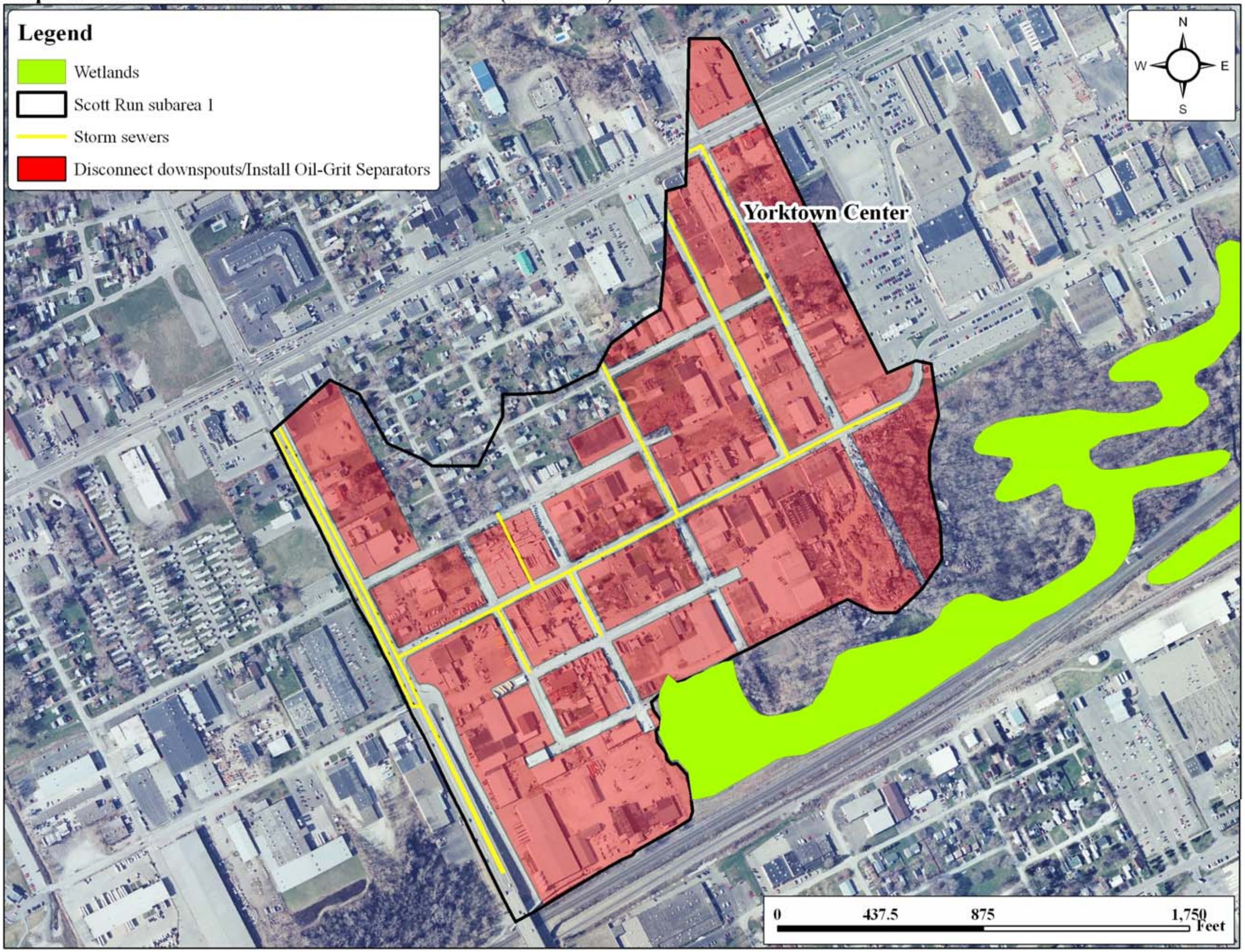
Map 55: Restoration focus for Direct Runoff subarea 3 (Scenario 2)

Map 56: Restoration focus for Scott Run subarea 1 (Scenario 2)



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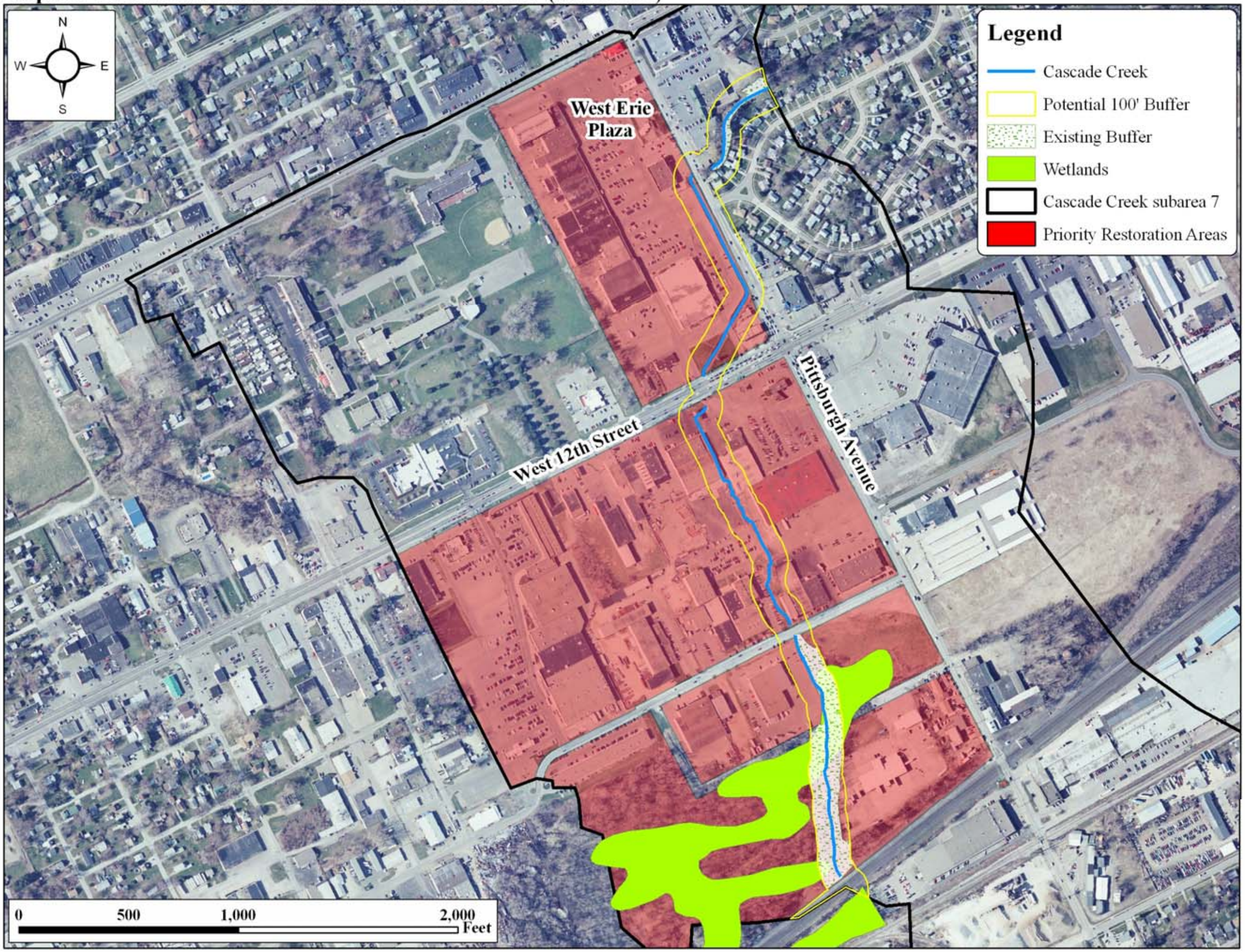
Map 57: Restoration focus for Cascade Creek subarea 7 (Scenario 3)



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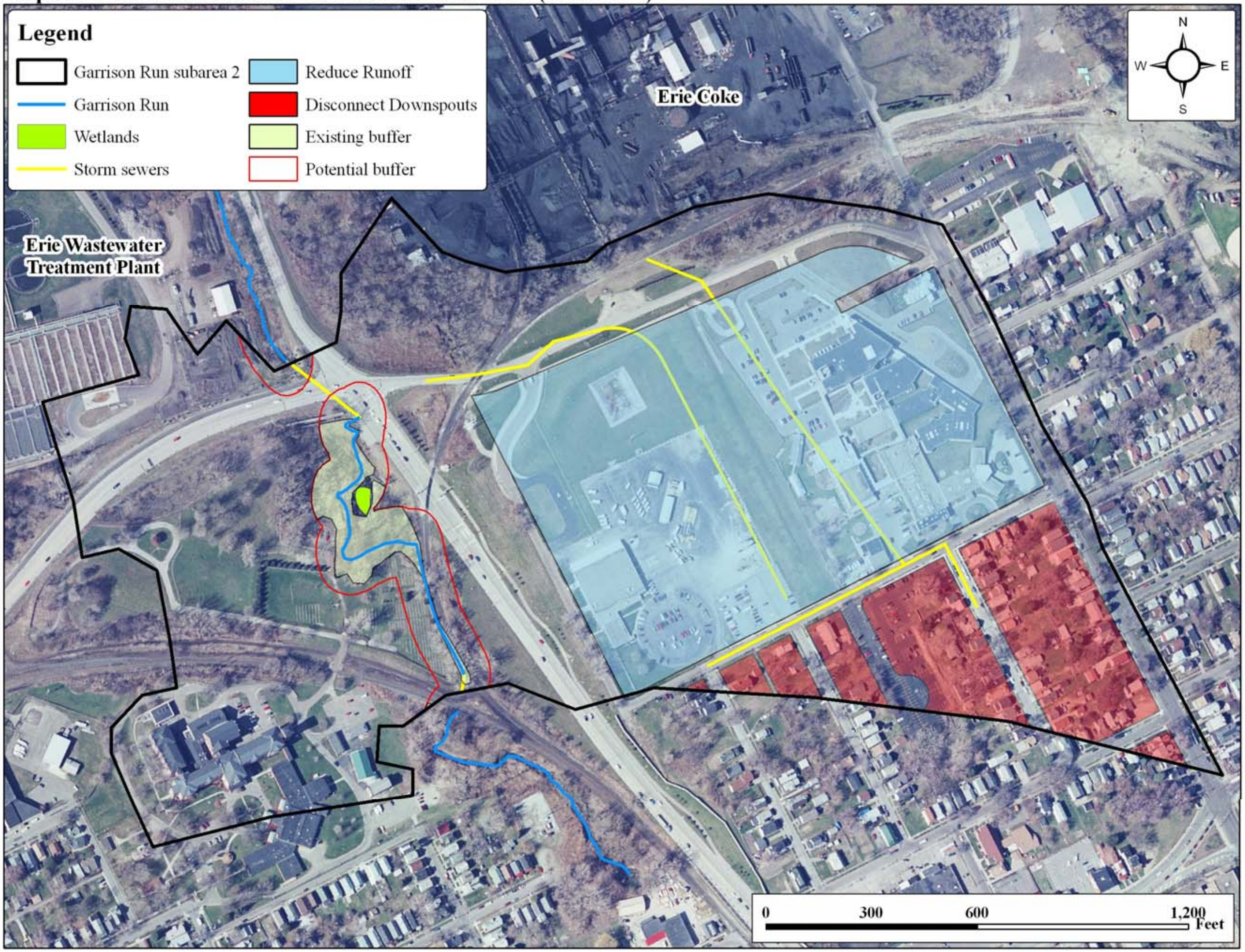
Map 58: Restoration focus for Garrison Run subarea 2 (Scenario 3)



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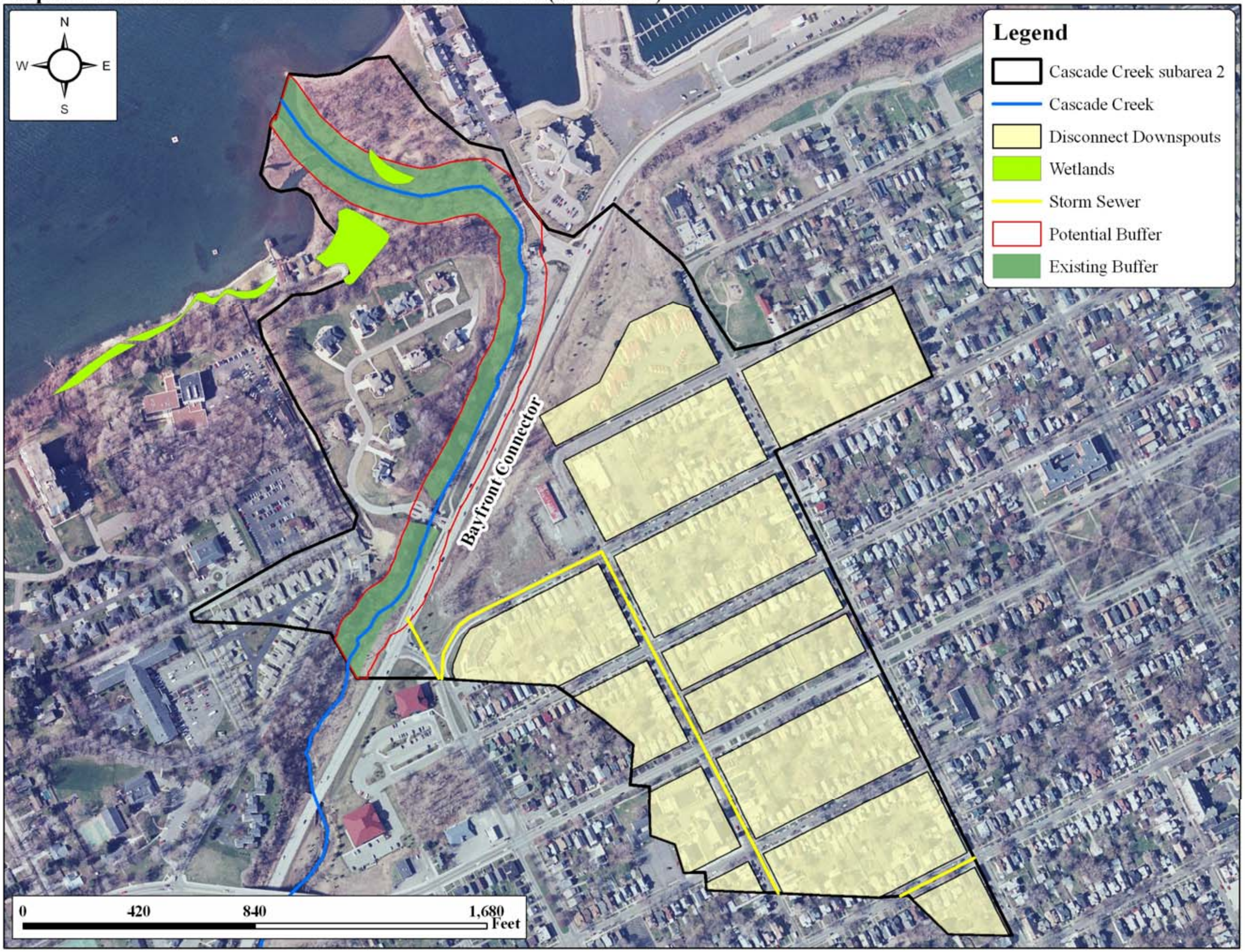
Map 59: Restoration focus for Cascade Creek subarea 2 (Scenario 3)



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Map 60: Protection focus for Unnamed Tributary One subarea 2

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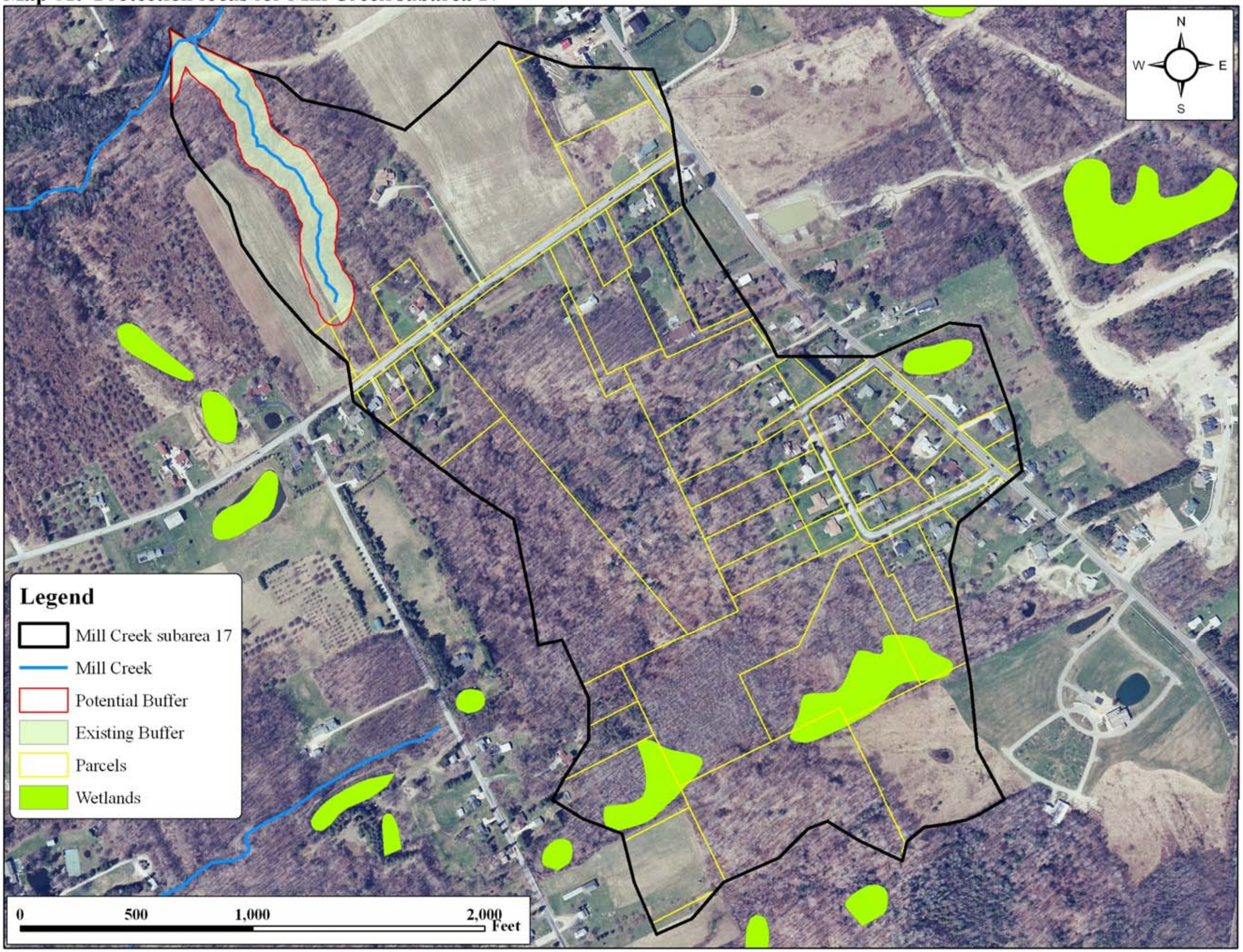
Map 61: Protection focus for Mill Creek subarea 17



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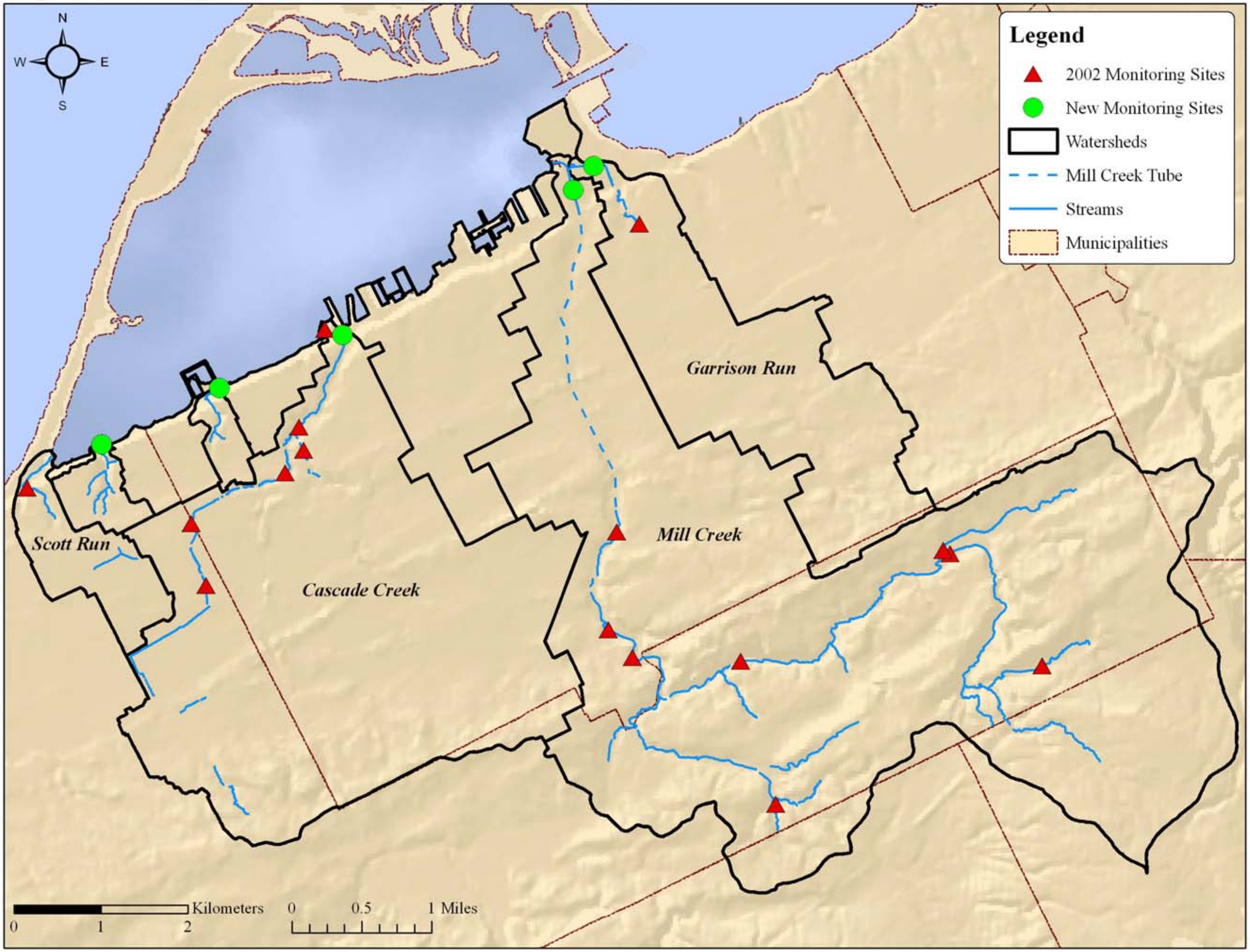
Map 62: Monitoring locations for the Presque Isle Bay watershed



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