Genesee – Finger Lakes Impervious Surface Scan

An Inventory of Impervious Surfaces in the Genesee – Finger Lakes Region

June 2011

GENESEE/FINGER LAKES Regional Planning Council

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A PDF version of this report along with access to all referenced GIS data can be found at the following web address:
http://gflrpc.org/ImperviousSurfaceScan.htm

GENESEE/FINGER LAKES
Regional Planning Council

Mission Statement
The Genesee/Finger Lakes Regional Planning Council will identify, define, and inform its member counties of issues and opportunities critical to the physical, economic, and social health of the region. G/FLRPC provides forums for discussion, debate, and consensus building, and develops and implements a focused action plan with clearly defined outcomes, which include programs, personnel, and funding.

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Executive Summary

The objective of the *Genesee – Finger Lakes Impervious Surface Scan* was to provide greater insight regarding the impacts of impervious cover (IC) on regional aquatic systems by providing a basic screening tool to watershed planners. Percentages of impervious cover (%IC) have been generated at the catchment level in urbanized areas of the Genesee – Finger Lakes region. %IC is mapped and reported in accordance with the standard %IC ranges as described by the Center for Watershed Protection. Information is represented in a series of thematic maps that identify various other geographic attributes and identifiers (political boundaries, watershed boundaries, adjacent waterbodies, etc.).

With the completed catchment-level %IC GIS geo-database in-hand, an intermediate-level GIS user can begin to investigate the impacts of impervious cover on water quality in the Genesee – Finger Lakes region with relative ease. It provides informed users with a useful screening tool that can be applied in a rapid watershed assessment process to prioritize geographic focus areas within a watershed, narrow down the scope of potential applicable planning and remediation projects, and quickly identify practical watershed restoration goals for areas with high levels of impervious cover.

Maps included in this report help to illustrate and describe the issue of IC to the general audience. The scale of analysis utilized – the catchment – is an ideal size for conducting a sub-watershed analysis. While these static maps and data clearly lack the full functionality and dynamics of a GIS, individuals with particular interest on a specific watershed or waterbody can begin to investigate the degree to which IC is present.

GIS Data Availability

The GIS geo-database associated with this project is available from G/FLRPC upon request. Contact gflrpc@gflrpc.org and reference *Impervious Surface Scan*.

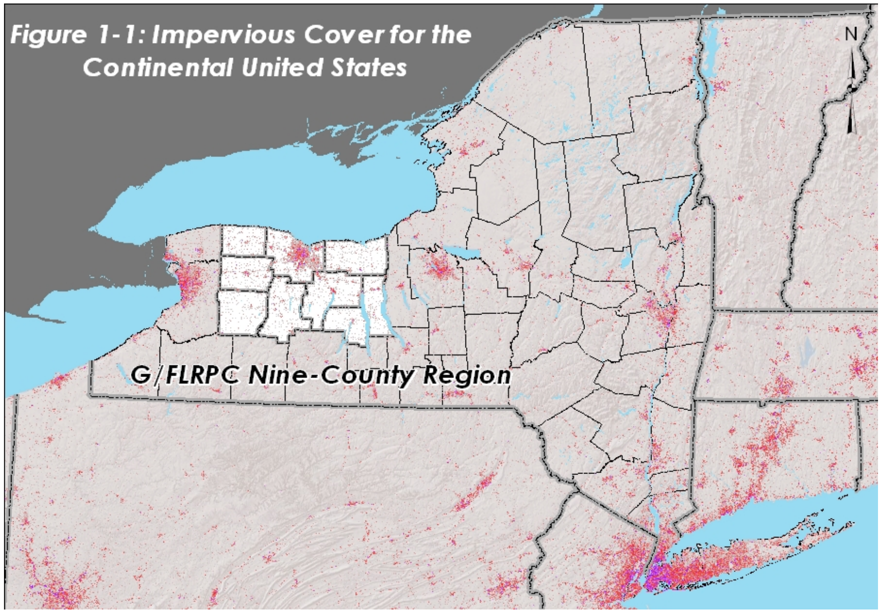
1.0 Introduction

The Center for Watershed Protection (CWP) defines impervious cover as "any surface in the urban landscape that cannot effectively absorb or infiltrate rainfall."[1] It is the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape. The impacts of impervious cover on aquatic systems are well-documented.[2] In 1994, CWP published the paper *The Importance of Imperviousness* which outlined the empirical evidence showing the relationship between impervious cover and stream quality. Among the conclusions drawn from that paper include:

- Impervious surfaces reduce infiltration of stormwater and increase stormwater runoff volumes and velocities;
- Impervious surfaces increase stream channel instability which, in turn, triggers a cycle of streambank erosion and habitat degradation;
- Impervious surfaces collect and accumulate pollutants deposited from the atmosphere, leaked from vehicles or derived from other sources and quickly directs those pollutants into receiving waterbodies in a concentrated fashion;
- Impervious surfaces along with other associated factors (such as decreased tree cover) amplify stream warming;
- Increases in impervious surfaces are associated with a decrease in the diversity, richness and composition of the aquatic insect community, such as marcroinvertebrates; and
- Levels of subwatershed imperviousness in excess of 10 to 15% can have a negative impact on the abundance and diversity of fish communities as well as the richness of both the wetland plant and amphibian community. (pages 1-8)

Impervious cover (IC) is therefore a key indicator of stream quality and watershed health. The CWP has integrated these research findings into a general watershed planning model, known as the Impervious Cover Model (ICM). The ICM predicts that most stream quality indicators decline when watershed IC exceeds 10%, with severe degradation expected beyond 25% IC. While the actual stream response to the level of IC will vary based on a variety of conditions (local topography and physiology, other prevailing land

Figure 1-1: Impervious Cover for the Continental United States



[1] Center for Watershed Protection. Impacts of Impervious Cover on Aquatic Systems. March 2003. page 139
[2] *Review of Key Findings of Recent Research Examining the Relationship of Urbanization on Aquatic Systems*. [Online] In *Stormwatercenter.net/*. Last viewed online 3/3/11 at http://www.stormwatercenter.net/monitoring%20and%20assessment/imp%20cover/impercovr%20model.htm

cover characteristics, stormwater practices, watershed history), IC has nonetheless been identified as a significant contributor to aquatic system decline and therefore a reliable indicator of urban hydrologic stress. [3]

1.1 Impervious Cover Applications to Watershed Analysis

CWP has conducted extensive research on the impacts of impervious cover on water quality. For example, Figure 1-2 illustrates the basic three-tiered threshold classification scheme of urban stream-quality potential based on watershed imperviousness levels.

Figure 1-2: Relationship between Urban Stream Quality and Impervious Cover

Urban Stream Quality	Level of Imperviousness
Stressed	1 – 10% Imperviousness
Impacted	11 – 25% Imperviousness
Degraded	>26% Imperviousness

In addition, CWP has identified a basic relationship between the level of impervious cover and the associated range of restoration practices and goals that may be feasible in different classification areas of IC.[4] These relationships are illustrated in Figures 1-3 and 1-4:

Figure 1-3: General Feasibility of Retrofit Practices at Different Levels of Subwatershed IC

Developed by the Center for Watershed Protection[5]

Restoration Practice	Subwatershed Impervious Cover			
	10 to 25%	25 to 40%	40 to 60%	60 to 100%
Storm Water Retrofit Practices				
Storage Retrofit	●	⊙	○	⊗
On-site Non-Residential Retrofits	●	●	⊙	○
On-site Residential Retrofits	●	●	⊙	○
Stream Repair Practices				
Stream Clean-ups	●	●	⊙	⊗
Stream Repairs	●	⊙	⊙	○
Comprehensive Restoration	⊙	○	○	⊗
Riparian Management Practices				
Site Preparation	●	⊙	○	⊗
Active Reforestation	●	●	⊙	⊗
Park/Greenway Plantings	●	⊙	⊙	⊗
Natural Regeneration	●	⊙	⊙	⊗
Riparian Wetland Restoration	●	⊙	○	⊗
Discharge Prevention Practices				
Illicit Sewage Connections	●	●	●	●
Other Illicit Connections	⊙	●	●	●
Failing Sewage Lines	●	●	●	●
Industrial and Transport Spills	⊙	●	●	●
Watershed Forestry Practices				
Land Reclamation	●	●	⊙	○
Upland Revegetation	●	●	⊙	○
Natural Area Remnant	●	●	⊙	○
Pollution Source Control Practices				
Residential Source Controls	●	●	●	⊙
Hotspot Source Controls	⊙	●	●	●
Municipal Practices and Programs				
Street and Storm Drain Cleaning	⊙	⊙	⊙	●
Best Practices for Redevelopment	●	●	●	●
Stewardship of Public Land	●	●	⊙	○
Municipal Stewardship Programs	●	●	●	●
Education and Enforcement	●	●	●	●

Key
● Technique is normally feasible and can be widely applied across subwatershed
⊙ Technique is often feasible, depending on subwatershed characteristics
○ Individual sites can be found, but widespread implementation across subwatershed is limited
⊗ Technique is generally not feasible in the subwatershed

[3] Center for Watershed Protection. *Impacts of Impervious Cover on Aquatic Systems*.
[4] CWP. *Urban Subwatershed Restoration Manual 1: Chapter 4: The Range of Subwatershed Restoration Practices*, pp 50 – 53.

[5] CWP. Urban Subwatershed Restoration Manual 1: Chapter 4 p 51. Chart is intended for general guidance only and should be verified with detailed field analysis.

Figure 1-4: General Ability to Meet Subwatershed Goals at Different Levels of IC
Developed by the Center for Watershed Protection[6]

Restoration Practice	Subwatershed Impervious Cover			
	10 to 25%	**25 to 40%**	**40 to 60%**	**60 to 100%**
Water Quality				
Reduce pollutants of concern	●	●	●	⊙
Prevent illegal discharges/spills	⊙	●	●	⊙
Meet water quality standards	●	⊙	○	⊗
Reduce sediment contamination	●	●	⊙	⊗
Allow water contact recreation	●	●	⊙	⊗
Protect drinking water supply	⊙	○	⊗	⊗
Biological				
Restore aquatic diversity	●	⊙	⊗	⊗
Restore wetlands/natural areas	●	⊙	⊙	⊗
Expand forest cover	●	●	●	⊙
Restore/reintroduce species	●	⊙	⊗	⊗
Improve fish passages	●	●	⊙	⊗
Enhance wildlife habitat	●	●	⊙	⊗
Remove invasive species	●	●	⊗	⊗
Keep shellfish beds open	⊙	⊗	⊗	⊗
Enhance riparian areas	●	●	⊙	○
Physical/Hydrological				
Increase groundwater recharge	●	⊙	⊙	⊗
Reduce channel erosion	●	⊙	⊗	⊗
Reclaim stream network	●	⊙	⊗	⊗
Reduce flood damage	●	●	⊙	○
Reconnect with floodplain	●	⊙	⊗	⊗
Restore physical habitat	●	○	⊗	⊗
Protect municipal infrastructure	●	●	⊙	⊙
Community				
Eliminate trash/debris	●	●	●	●
Create open space	●	●	●	⊙
Revitalize neighborhoods	●	●	●	●
Improve aesthetics/beautification	●	●	●	●
Increase citizen awareness	●	●	●	●
Improve recreation	●	●	●	●
Increase angling opportunities	●	●	⊙	⊗

Key
● Goal can often be achieved in many subwatersheds
⊙ Goal can be achieved in some subwatersheds depending on degree of treatment
○ Goal can possibly be achieved in unusual circumstances
⊗ Goal generally not achievable

All of the ranges illustrated in Figures 1-3 and 1-4 therefore provide useful categories for subwatershed planning, analysis and comparison.

1.2 Limitations of the Impervious Cover Model

CWP stresses that the ICM can often be over-simplified, misapplied and misunderstood. It is therefore important to point out that the ICM does have a number of limitations in its application to watershed planning. A selection of those limitations is provided below, as summarized by The Stormwater Manager's Resource Center (SMRC):

> **1. Scale effect.** The impervious cover model should generally only be applied to smaller urban streams from first to third order. This limitation reflects the fact that most of the research has been conducted at the catchment or subwatershed level (0.2 to 10 square mile area), and that the influence of impervious cover is strongest at these spatial scales. In larger watersheds and basins, other land uses, pollution sources and disturbances often dominate the quality and dynamics of streams and rivers.
>
> **2. Reference condition.** The simple [IC] model predicts ***potential*** rather than ***actual*** stream quality. Thus, the reference condition for a sensitive stream is a high quality, non-impacted stream within a given ecoregion or sub-ecoregion. It can and should be expected that some individual stream reaches or segments will depart from the predictions of the impervious cover model. For example, physical and biological monitoring may find poor quality in a stream classified as sensitive, or good diversity in a non-supporting one. Rather than being a shortcoming, these "outliers" may help watershed managers better understand local watershed and stream dynamics. For example, an "outlier" stream may be a result of past human disturbance, such as grazing, channelization, acid mine drainage, agricultural drainage, poor forestry practices, or irrigation return flows.

[6] CWP. Urban Subwatershed Restoration Manual 1: Chapter 4 p 53. Chart is intended for general guidance only and should be verified with detailed field analysis.

3. Statistical variability. Individual impervious cover/stream quality indicator relationships tend to exhibit a considerable amount of scatter, although they do show a general trend downward as impervious cover increases. Thus, the impervious cover model is not intended to predict the precise score of an individual stream quality indicator for a given level of impervious cover. Instead, the model attempts to predict the average behavior of a group of stream indicators over a range of impervious cover. In addition, the impervious cover thresholds defined by the model are not sharp breakpoints, but instead reflect the expected transition of a composite of individual stream indicators.

4. Measuring and projecting impervious cover. Given the central importance of impervious cover to the model, it is very important that it be accurately measured and projected. Yet comparatively relatively little attention has been paid to standardizing techniques for measuring existing impervious cover, or forecasting future impervious cover. Some investigators define impervious cover as "effective impervious area" (i.e., impervious area directly connected to a stream or drainage system) which may be lower than total impervious cover under certain suburban or exurban development patterns (Sutherland, 1995).

5. Regional adaptability. To date, much research used to develop the model has been performed in the mid-Atlantic and Puget Sound eco-regions. In particular, very little research has been conducted in western, midwestern, or mountainous streams. Further research is needed to determine if the impervious cover model applies in these ecoregions and terrains.

6. Defining thresholds for non-supporting streams. Most research has focused on the transition from sensitive streams to impacted ones. Much less is known about the nature of the transition from impacted streams to non-supporting ones. The impervious cover model projects the transition occurs around 25% impervious cover for small urban streams, but more sampling is needed to firmly establish this threshold.

7. Influence of BMPs in extending thresholds. Urban BMPs may be able to shift the impervious cover thresholds higher. The ability of the current generation of urban BMPs to shift these thresholds however, appears to be very modest according to several lines of evidence. First, a handful of the impervious cover/stream indicator research studies were conducted in localities that had some kind of requirements for urban best management practices; yet no significant improvement in stream quality was detected. Second, Maxted and Shaver (1996) and Jones, et al. (1996) could not detect an improvement in bioassessment scores in streams served by stormwater ponds.

8. Influence of riparian cover in extending thresholds. Conserving or restoring an intact and forested riparian zone along urban streams appears to extend the impervious cover threshold to a modest degree. For example, Steedman (1988) found that forested riparian stream zones in Ontario had higher habitat and diversity scores for the same degree of urbanization than streams that lacked an intact riparian zone. Horner, et al. (1996) also found evidence of a similar relationship. This is not surprising, given the integral role the riparian zone plays in the ecology and morphology of headwater streams. Indeed, the value of conserving and restoring riparian forests to protect stream ecosystems is increasingly being recognized as a critical management tool in rural and agricultural landscapes as well (CBP, 1995).

9. Potential for stream restoration. Streams classified by their potential for restoration (also known as restorable streams) offer opportunities for real improvement in water quality, stability, or biodiversity and hydrologic regimes through the use of stream restoration, urban retrofit and other restoration techniques.

10. Pervious areas. An implicit assumption of the impervious cover model is that pervious areas in the urban landscape do not matter much, and have little direct influence on stream quality. Yet urban pervious areas are highly disturbed, and possess few of the qualities associated with similar pervious cover types situated in non-urban areas. For example, it has recently been estimated that high input turf can comprise up to half the total pervious area in suburban areas (Schueler, 1995a). These lawns receive high inputs of fertilizers, pesticides and irrigation, and their surface soils are highly compacted.

> Although strong links between high input turf and stream quality have yet to be convincingly demonstrated, watershed planners should not neglect the management of pervious areas. Pervious areas also provide opportunities to capture and store runoff generated from impervious areas. Examples include directing rooftop runoff over yards, the use of swales and filter strips, and grading impervious areas to pockets of pervious area. When pervious and impervious areas are integrated closely together, it is possible to sharply reduce the "effective" impervious area in the landscape (Southerland, 1995).
>
> While there are some limitations to the application of the urban stream impervious cover model, impervious cover still provides us with one of the best tools for evaluating the health of a subwatershed. Impervious cover serves not only as an indicator of urban stream quality but also as a valuable management tool in reducing the cumulative impacts of development within subwatersheds.[7]

As stated under number 4 above, an important distinction needs to be made between *connected* and *disconnected* impervious surfaces (or *effective* versus *ineffective* IC). Connected impervious surfaces are those which are contiguous and tied directly to an adjacent waterbody *via* appurtenance or drainage network. Waters therefore flow from the impervious surface directly into a waterbody. Disconnected impervious surfaces, on the other hand, are those which have no direct connection to a waterbody, thereby allowing opportunity for stormwater infiltration and mitigation once the stormwater passes across the surface. The connected impervious surfaces are those associated with the most significant water quality concerns.

[7] *Limitations of the Impervious Cover Model.* [Online] In Stormwater Manager's Resource Center. Last viewed online 3/3/11 at http://www.stormwatercenter.net/monitoring%20and%20assessment/imp%20cover/impercovr%20model.htm

Two challenges in particular – (1) scale of analysis and (2) connected/disconnected surfaces – are significant issues of concern when conducting a regional impervious cover analysis.[8] While we feel that the issue of scale has been adequately addressed in this study by utilizing the catchment as the basic unit of analysis (further explanation under Section 2.1), the issue of connected versus disconnected impervious surfaces is one that remains. It is therefore recommended that this project be used as a starting point to addressing the issue of impervious surface impacts on water quality at the local level. Further analysis of these areas at the local level can begin to narrow down the scope of concern to the most problematic connected impervious surfaces.

1.3 Project Objectives

In an effort to provide greater insight regarding the impacts of IC on regional aquatic systems and to create a basic screening tool for watershed planners, Genesee/Finger Lakes Regional Planning Council (G/FLRPC) has conducted a scan of impervious cover throughout its nine-county region utilizing available land cover data provided by the Multi-Resolution Land Characteristics (MRLC) Consortium.

The primary objective of this project was to utilize available land cover data in an effort to ascertain the degree of imperviousness at a uniform and useful geographic level of analysis across the Genesee –

[8] Exum, Linda R., Sandra L. Bird, James Harrison and Christine A. Perkins. *Estimating and Projecting Impervious Cover in the Southeastern Un*ited States. Ecosystems Research Division, National Exposure Research Laboratory, US EPA, 2005 (page 5).

Finger Lakes region. By doing so, the final assessment can be used as a screening tool with a variety of applications, including stream protection and rehabilitation; watershed planning and management; stormwater management; and watershed education and outreach.

The results of this project will be used directly in G/FLRPC's own ongoing water quality program and planning projects, including watershed management plans in the Black Creek, Oatka Creek, and Seneca Lake watersheds as well as green infrastructure planning and implementation projects in nine municipalities in the G/FLRPC region.[9] Data were compiled utilizing a GIS in an effort to aid in data distribution to other interested watershed planning entities upon request.

[9] Refer to "Current Projects" at http://gflrpc.org/CurrentProjects.htm for more information

2.0 Impervious Cover Database Development

Impervious surfaces across the continental US are illustrated through a GIS raster layer in the 2006 National Land Cover Dataset (NLCD), available for download from the USGS website as of February 16, 2011 (see Figures 1-1, 2-3 & 2-4).[10] The data set can be used to compute impervious area as a percentage of total land in a specific geographic unit of analysis, referred to herein as % Impervious Cover (%IC). These values can then be classified into a range of user-defined categories for comparison and analysis (see Figures 1-2, 1-3 and 1-4 above).

Impervious cover of a geographic unit of analysis (generally a polygon representing a municipality, watershed, or other area of interest) can be derived through a variety of means, including spreadsheet calculations or with GIS extension tools. For the purposes of this study, analysis was conducted utilizing the basic data management tools for raster processing found in the ESRI ArcToolbox application available in ArcMap versions 8.0 and higher; no additional extensions or add-on tools were used. To determine %IC, the user is required to define a geographic unit of analysis and then "clip" the NLCD Impervious Cover raster file to that area. In this case, the average value of the mix of impervious cover cells in the clipped raster file is used to determine %IC. Statistics can then be derived from that clipped raster file through the Layer Properties "Source" tab; the value identified as the "mean" of the band of raster cells is synonymous with %IC. These data are then classified and stored as part of a geo-database for future use and analysis.

[10] NLCD 2006 description and data download http://www.mrlc.gov/nlcd_update.php. See Appendix for full reference and metadata.

2.1 Establishing a Geographic Unit of Analysis

Identifying a useful geographic unit of analysis under which to classify, store and report this information is an important consideration when conducting impervious surface analysis, particularly when attempting to draw any conclusions related to aquatic systems. The watershed provides a useful geographic unit of analysis, but one in which the watershed *scale* needs to be clearly defined. As stated on page 3 above, the Impervious Cover Model is strongest when applied at the catchment or subwatershed scale of analysis.

Watershed boundaries have been delineated in the United States using a cataloguing system referred to as hydrologic units.

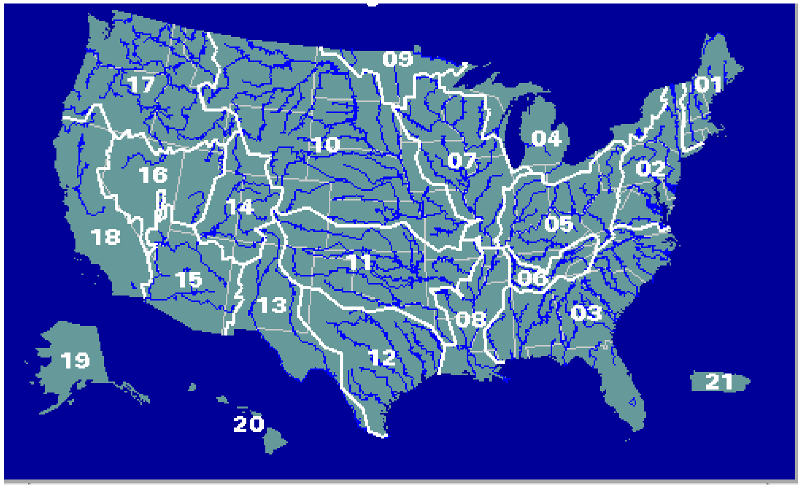


Figure 2.1: Hydrologic Unit Map of the United States. http://water.usgs.gov/GIS/huc.html

Hydrologic units are watershed boundaries organized in a nested hierarchy by size. They range in size from regions, to the smaller cataloging units (Hydrologic Unit Codes, or HUCs) which are roughly equivalent to a local watershed. The lowest-order (or smallest sized) HUC presently delineated for New York State by the USGS is the 12-digit HUC. Among the 184 12 digit HUCs that intersect the nine-county G-FL region, the average size was determined to be approximately 31 square miles in area (the smallest of which was approximately 11 square miles).

The 12 digit HUC boundary was therefore well above the standard scale preferred for application of the ICM. Therefore, a lower-order geographic boundary needed to be identified in order to conduct a proper analysis. ***Catchments*** were determined to be the optimum geographic unit of analysis for this study.

A catchment is defined as the land area that contributes runoff to a given hydrographic feature, such as a stream segment or a lake. Catchments were obtained for each 8 digit HUC that intersects the G-FL region utilizing catchment boundaries associated with the National Hydrography Dataset.[11] NHDPlus is an integrated suite of application-ready geospatial data sets that incorporate many of the best features of the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), the National Land Cover Dataset (NLCD), and the Watershed Boundary Dataset (WBD).

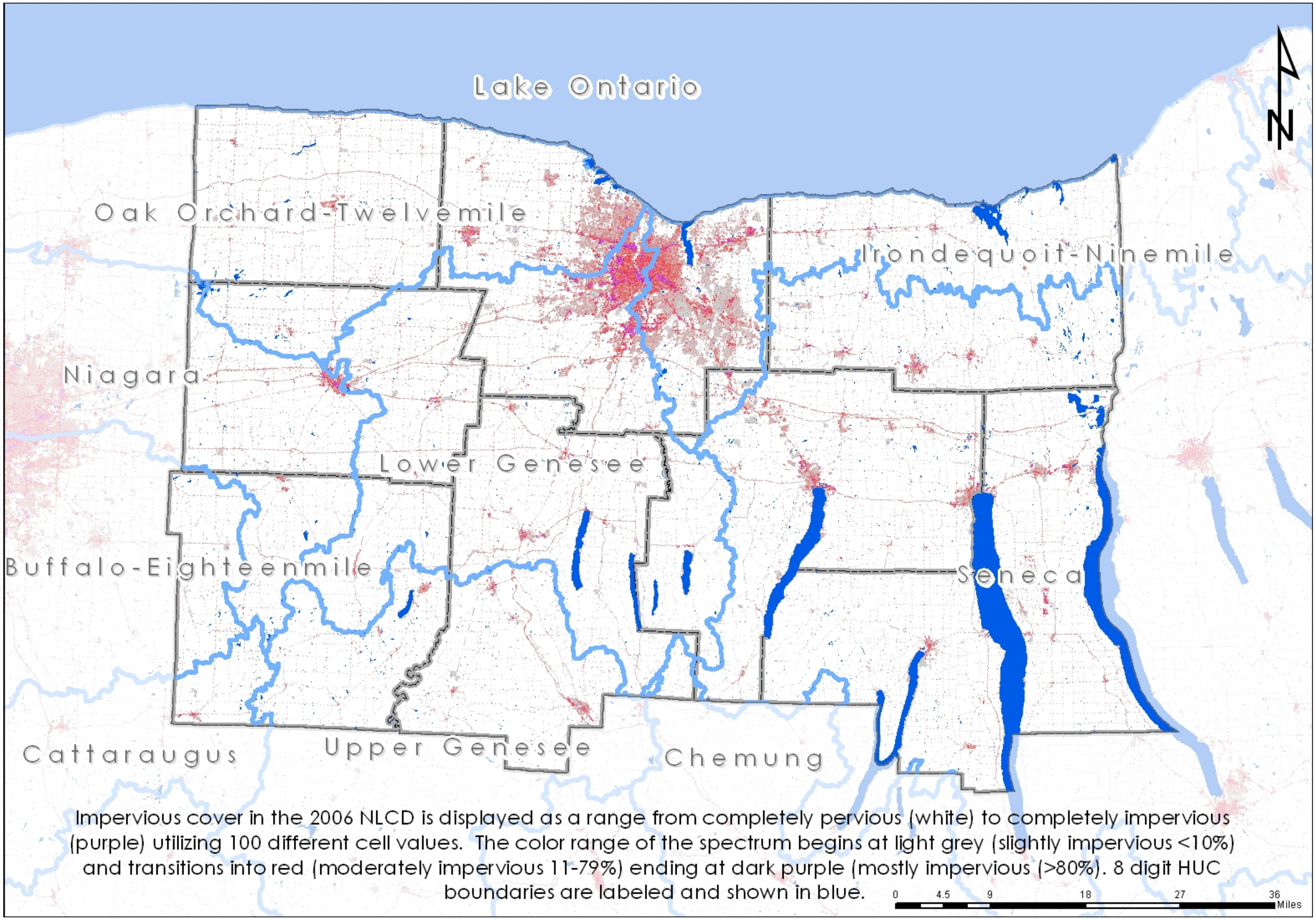
~Text continues on page 13~

Figure 2-2: 8 Digit HUCs and Associated Catchments that Intersect the G-FL Region

8 Digit HUC	Total # of Catchments within HUC boundary	Average Catchment Size (Sq. Miles)	# Catchments Intersecting the GFLRPC Region
Buffalo River – Eighteen Mile Creek	1,021	1.16	192
Cattaraugus River	628	1.44	107
Chemung River	941	2.07	33
Irondequoit – Nine Mile	918	1.24	768
Lower Genesee River	1,256	1.36	1,256
Niagara	1,017	1.24	534
Oak Orchard-Twelve Mile Creeks	1,238	1.35	771
Seneca	4,321	1.29	2,034
Upper Genesee River	1,464	1.56	773

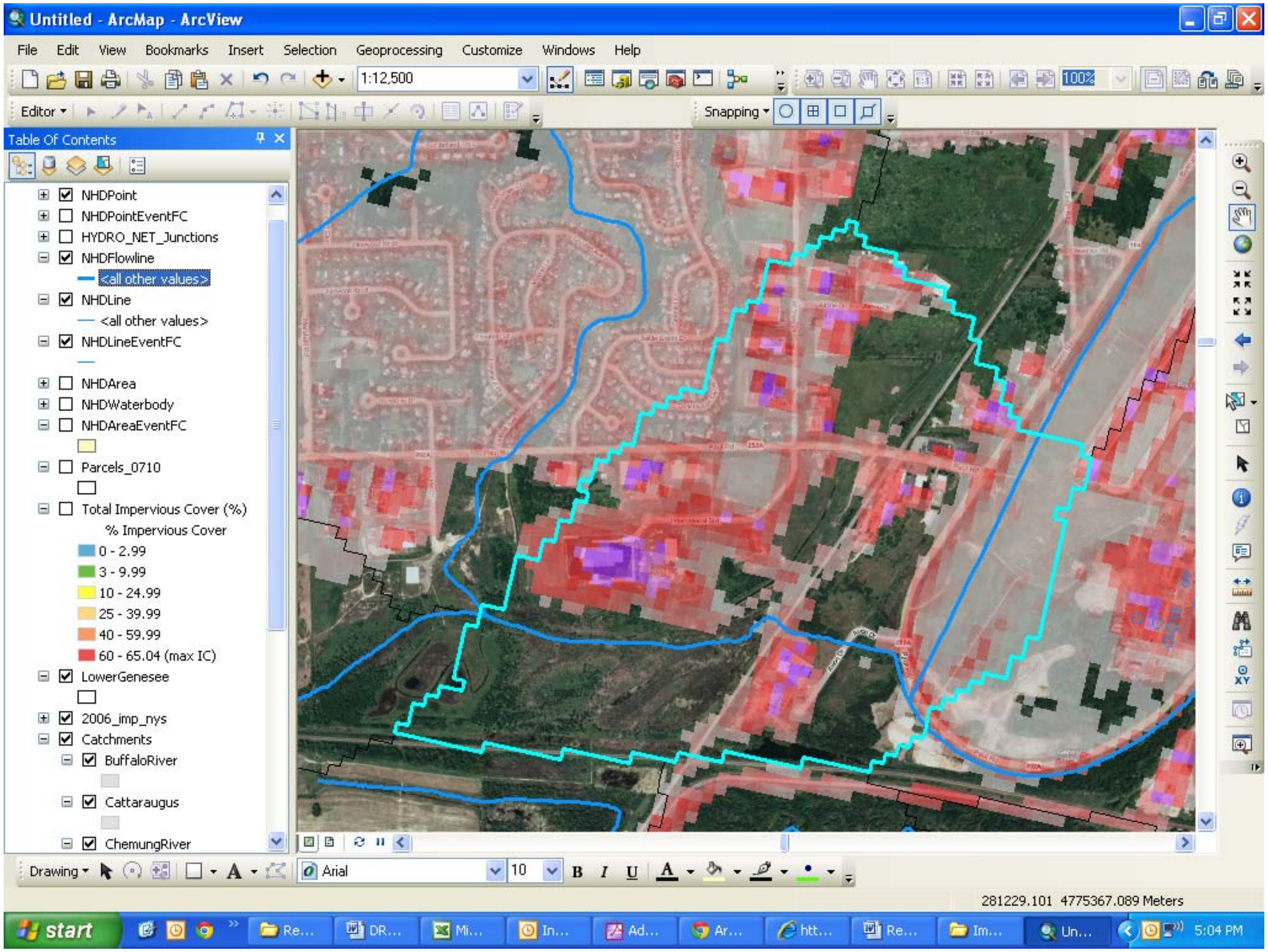
[11] NHDPlus Home. http://www.horizon-systems.com/nhdplus/index.php

Figure 2-3: 2006 National Land Cover Dataset (NLCD) Impervious Cover Layer in the G-FL Region



Impervious cover in the 2006 NLCD is displayed as a range from completely pervious (white) to completely impervious (purple) utilizing 100 different cell values. The color range of the spectrum begins at light grey (slightly impervious <10%) and transitions into red (moderately impervious 11-79%) ending at dark purple (mostly impervious (>80%). 8 digit HUC boundaries are labeled and shown in blue.

Figure 2-4: GIS Snapshot of the 2006 NLCD Impervious Surface Coverage over Orthophoto



Each transparent 30x30 meter grey/pink/purple cell has a unique value ascribed to it which represents a value within a range of impervious cover from one (least impervious) to 100 (completely impervious). The magenta boundary represents a catchment; %IC is the statistical average of all pixels within the catchment boundary area. Values of zero are clear and are typically bodies of water or forest, field or other agricultural or wild lands. Turf grasses, such as those found on residential yards, playing fields or golf courses, generally exhibit low levels of imperviousness (between zero and five percent) due to soil compaction. %IC for this catchment was determined to be 20.35%, although *effective impervious cover* may be much lower. This can only be determined through detailed analysis in the field.

Figure 2.5: Urbanized Area and 8-Digit HUCs in the G-FL Region

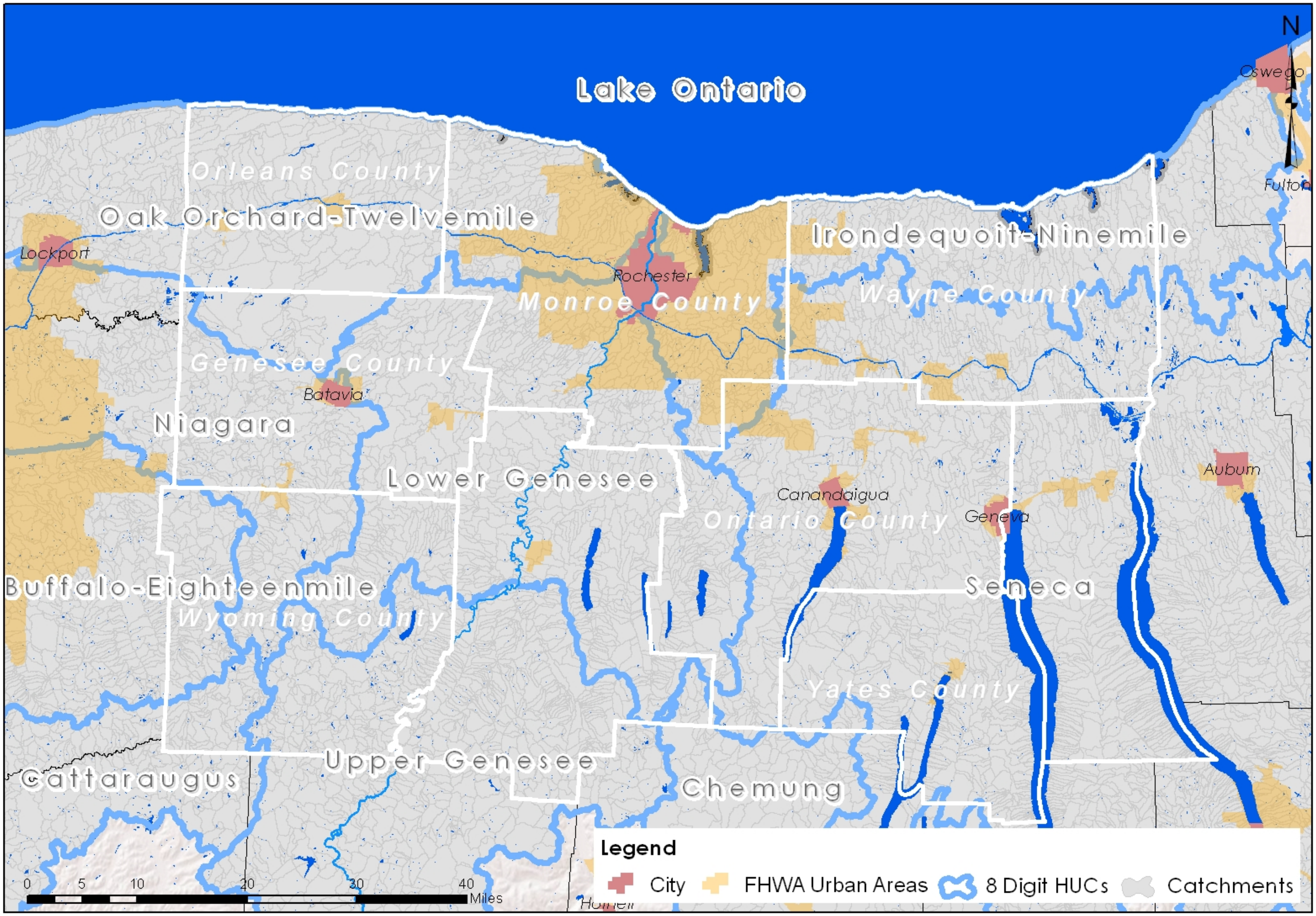
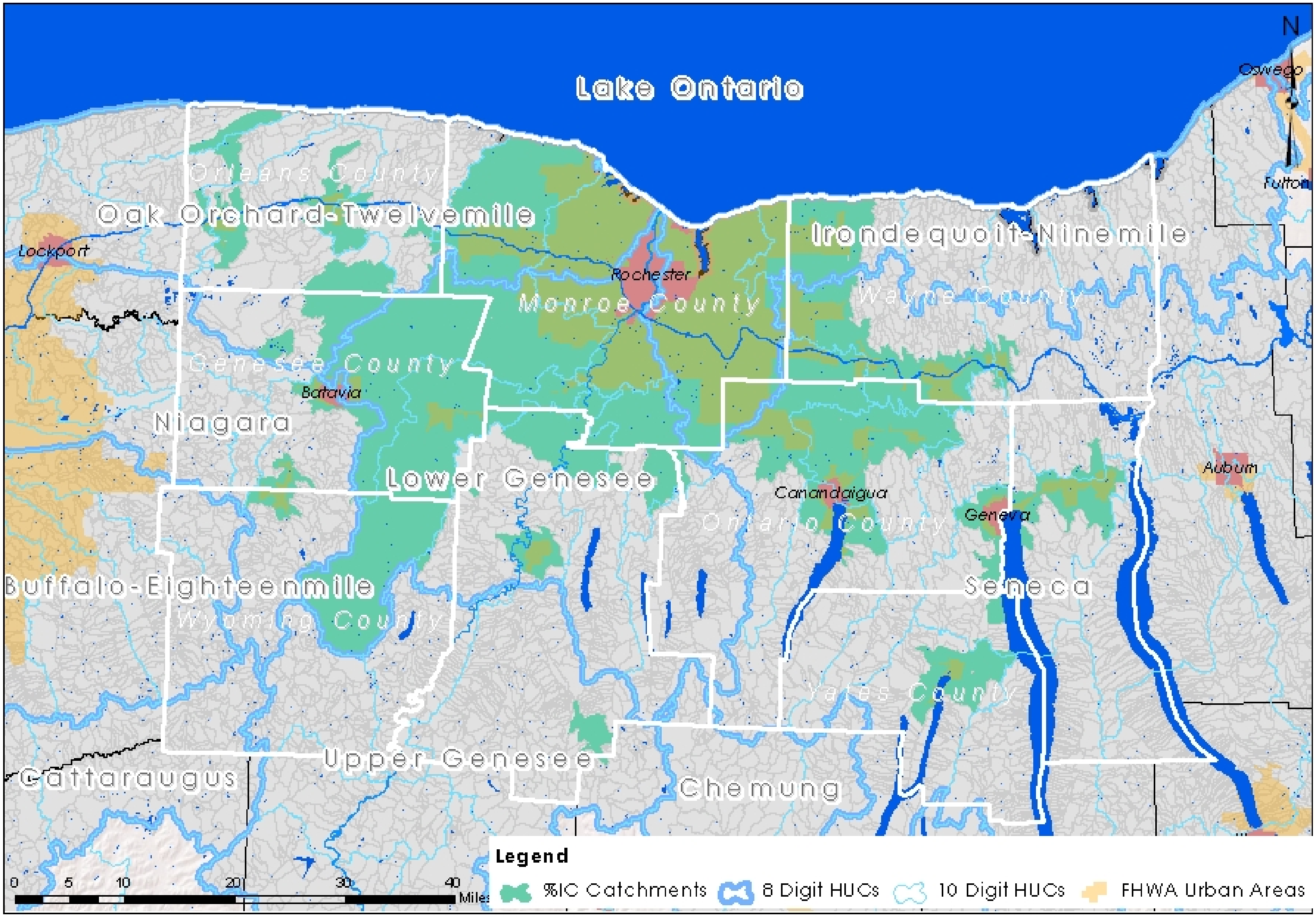


Figure 2.6: Catchments for which % Impervious Cover (%IC) was calculated



2.2 Focus on the Urbanized Area

Impervious surfaces generally do not exist at a high enough concentration outside of urbanized areas to produce seriously detrimental water quality effects – it is essentially an urban and suburban condition. In the Genesee – Finger Lakes region of New York State, impervious cover is most prevalent in the densely-populated City of Rochester and its surrounding suburbs. Outside of this urbanized area, the region is largely rural in character, interspersed with "urban clusters" that follow the major transportation corridors. A number of these urban clusters also exhibit levels of IC similar to those found within the traditional urbanized area, although on a much smaller scale. In an effort to focus the impervious cover analysis and limit the number of catchments that do not require further attention due to their obvious lack of impervious cover, catchments that intersect the Census-delineated Urbanized Area were identified and selected using the GIS (refer to Figure 2-5). Other catchments in specific geographic focus areas were selected for analysis regardless of their location in the Urbanized Area. These included the watersheds of the Black Creek and Oatka Creek, most incorporated villages, as well all regulated MS4's. In addition, catchments that were contiguous to other significant patches of impervious cover were selected to establish a uniform study area.

This process produced a total of 2,076 catchments for which the % Impervious Cover would be classified, stored and reported (see Figure 2-6). The average catchment size of this final group is .81 square miles. The maps in Section 3.0 display the results of this process.

Figure 2-7: Catchments within the Study Area

8 Digit HUC	Total # of Catchments where %IC was Calculated	Total Size of Area of Analysis (Sq. Miles)	Average Catchment Size (Sq. Miles)
Buffalo River – Eighteen Mile Creek	0	--	--
Cattaraugus River	0	--	--
Chemung River	0	--	--
Irondequoit – Nine Mile	461	271.2	.59
Lower Genesee River	723	645.3	.89
Niagara River	35	31.5	.90
Oak Orchard-Twelve Mile Creeks	361	312.2	.86
Seneca River	483	403.4	.84
Upper Genesee River	13	10.4	.80

2.3 Creating the Geo-database

As stated above, %IC is stored in a geo-database consisting of catchment boundaries and associated spatial reference data. This geo-database is the primary product of this study and acts as the source of %IC for all reporting and analysis. In addition to %IC, each catchment is provided with a unique object identification number, its area in size, and the associated 8-digit and 10-digit HUCs within which it lies. This allows the user to quickly sort through the 2,076 catchments and focus on the drainage area(s) of interest. The geo-database also contains the entire catalogue of HUCs (without %IC classification) for each watershed that intersects the G-FL region.

3.0 Impervious Cover in the Genesee-Finger Lakes Region

The following analysis looks at impervious cover at the catchment level utilizing the watershed as the primary area of focus. The following 8-digit drainage basins and associated 10-digit watersheds are reviewed herein (see also *Figure 3.2: Impervious Cover Analysis – Directory of Assessed Watersheds* on page 16):

- **Irondequoit – Nine Mile**
  - Figure 3.3: Fourmile Creek
  - Figure 3.4: Irondequoit Creek (North)
  - Figure 3.5: Irondequoit Creek (South)
- **Lower Genesee River**
  - Figure 3.6: Beards Creek
  - Figure 3.7: Black Creek
  - Figure 3.8: Genesee River
  - Figure 3.9: Honeoye Creek
  - Figure 3.10: Oatka Creek
- **Niagara River**
  - Figure 3.11: Upper Tonawanda Creek
- **Oak Orchard-Twelve Mile Creeks**
  - Figure 3.12: Greece Ponds (drains Northrup, Larkin, Round Pond & Slater Creeks)
  - Figure 3.13: Salmon Creek
  - Figure 3.14: Johnsons, Oak Orchard, & Sandy Creeks
- **Seneca Lake**
  - Figure 3.15: Mud Creek
  - Figure 3.16: Canandaigua Lake/Canandaigua Outlet/Flint Creek (three 10 digit HUCs included on one map)
  - Figure 3.17: Ganargua Creek/Erie Canal
  - Figure 3.18: Keuka Lake
  - Figure 3.19: Seneca Lake/River (two 10-digit HUCs included on one map)
- **Upper Genesee River**
  - Figure 3.20: Canaseraga Creek

%IC is illustrated in each watershed along with other relevant geographic features, such as municipal boundaries and major waterbodies. Catchments found to have %IC greater than 3% are labeled with their object identification number. Object identification numbers can be used to verify the exact level of impervious area that was measured for a particular catchment of interest. Full information for each specific catchment can be found in the attribute table of the impervious cover geo-database that was created for this report. The level of impervious cover is illustrated utilizing the following intervals:

Figure 3-1: Ranges of Impervious Cover Used in G-FL Maps

%IC Range	Representative Color
0 – 3%	
4 – 10%	
11 – 25%	
26 – 40%	
40 – 60%	
>60%	

In a number of instances, particularly in rural areas, only those areas within a watershed that showed significantly large or dense patches of impervious cover have been examined. Areas that were not examined are illustrated as an "Unassessed Catchment."

Figure 3.2: Impervious Cover Analysis – Directory of Assessed Watersheds

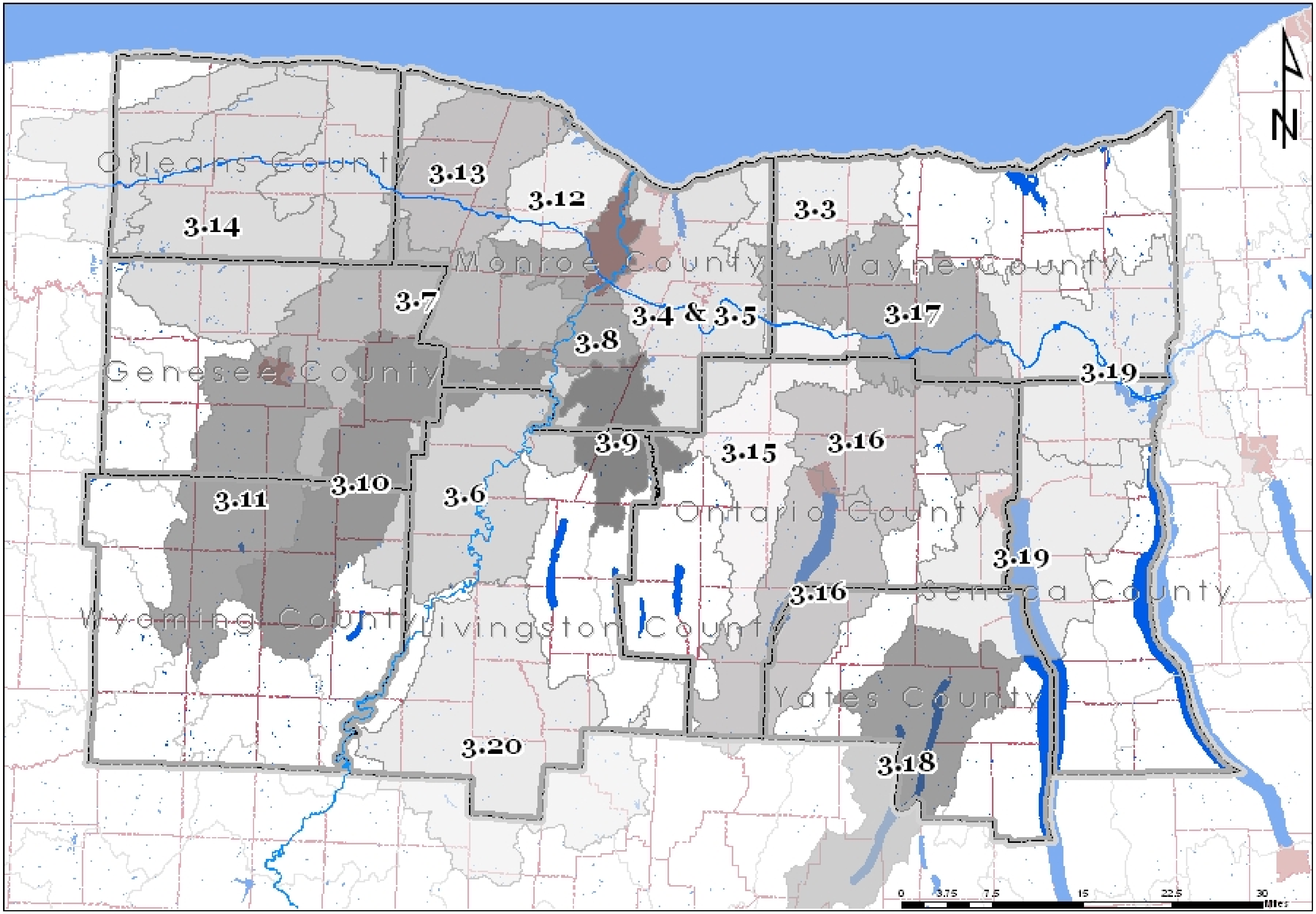


Figure 3.3: Fourmile Creek Watershed Impervious Cover

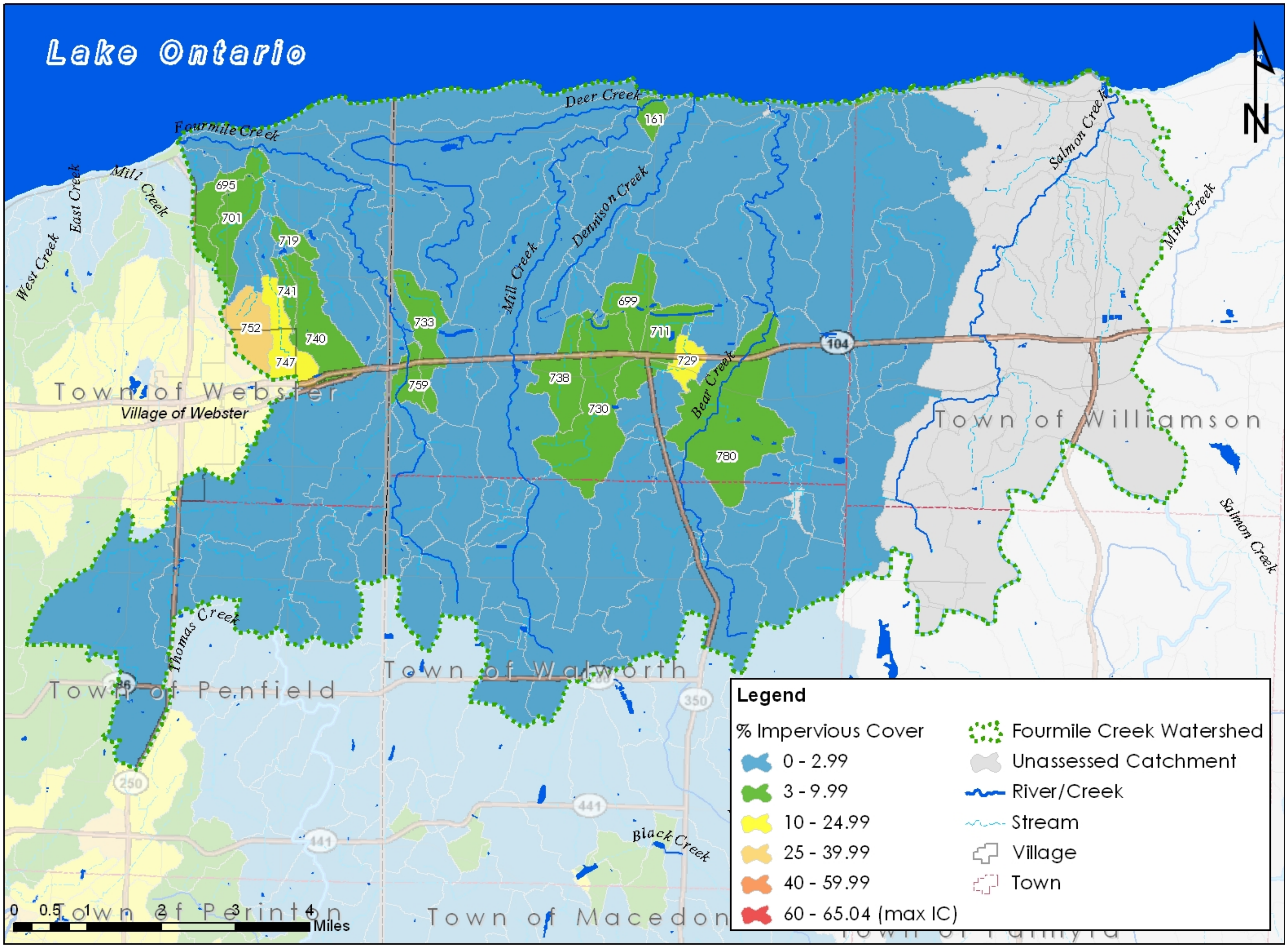


Figure 3.4: Irondequoit Creek Watershed (North) Impervious Cover

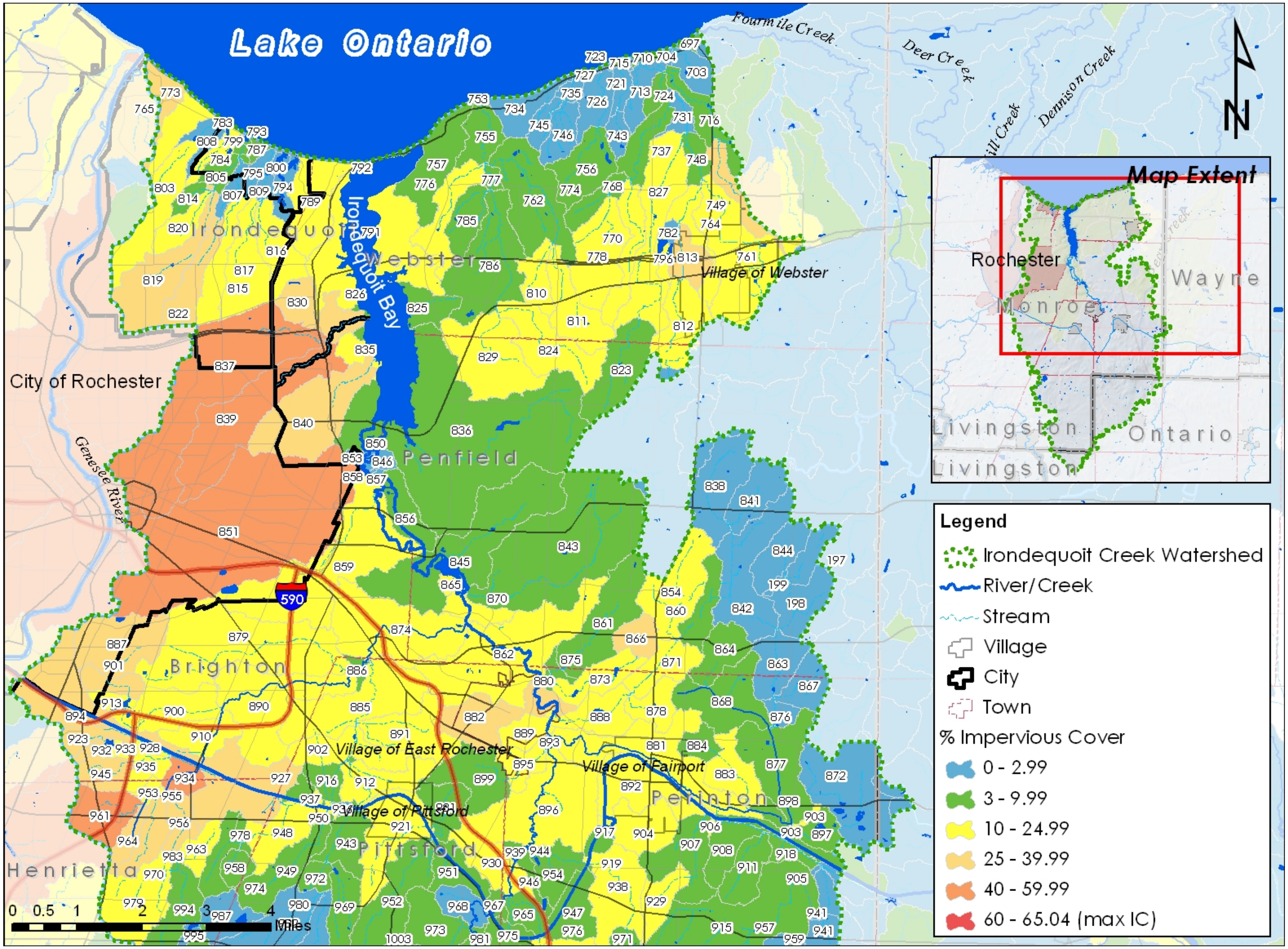


Figure 3.5: Irondequoit Creek Watershed (South) Impervious Cover

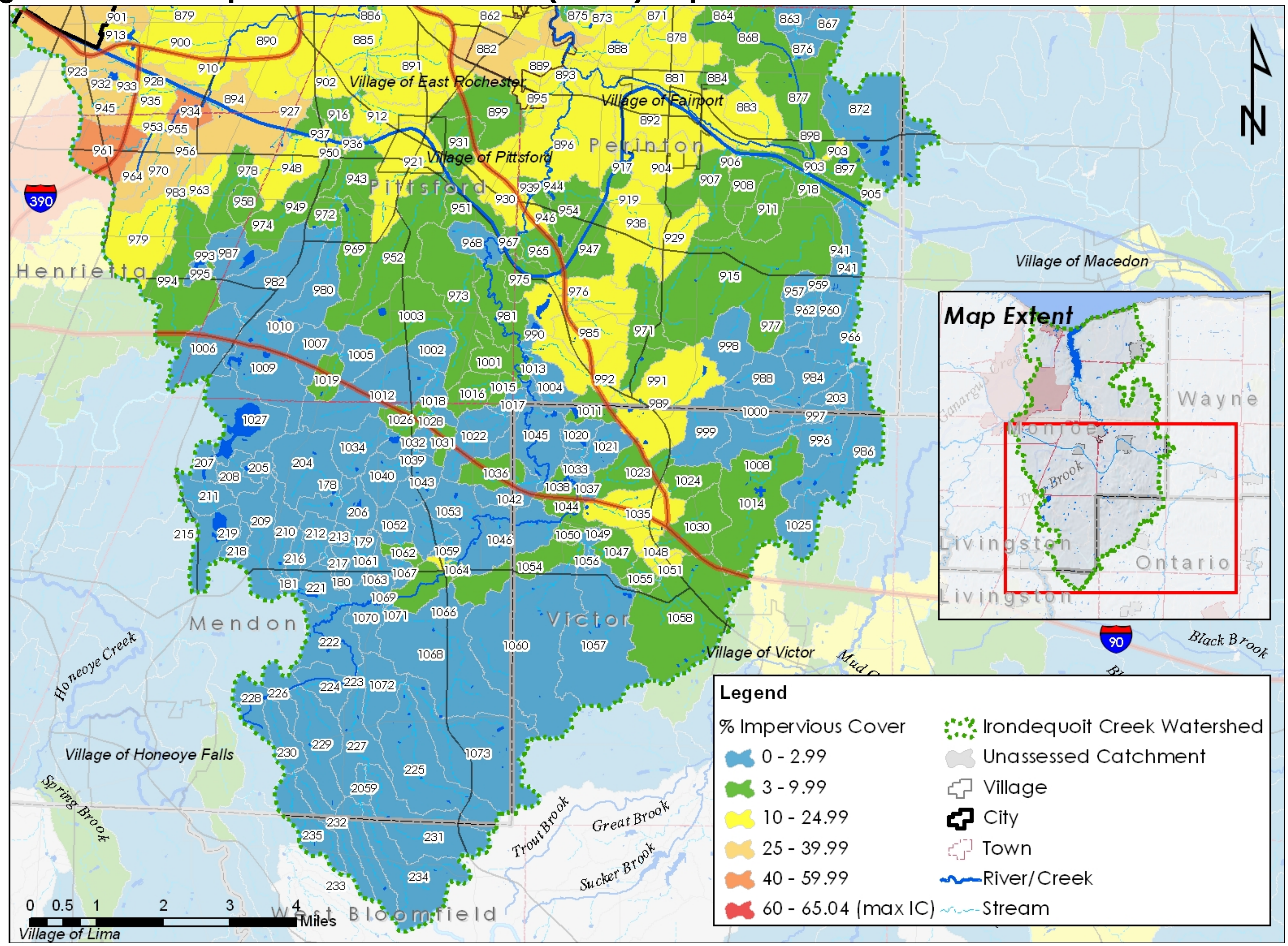


Figure 3.6: Beards Creek Watershed Impervious Cover

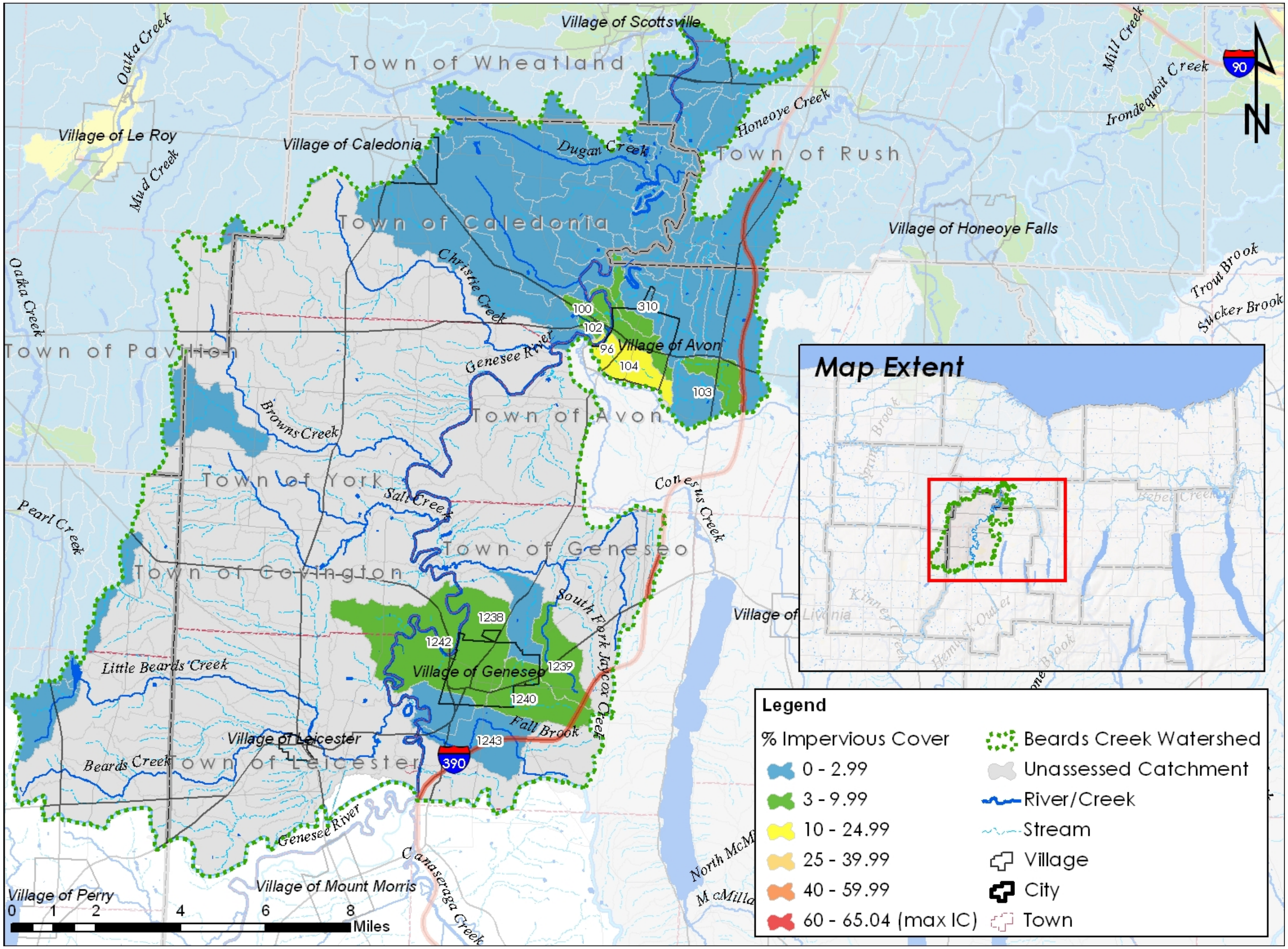


Figure 3.7: Black Creek Watershed Impervious Cover

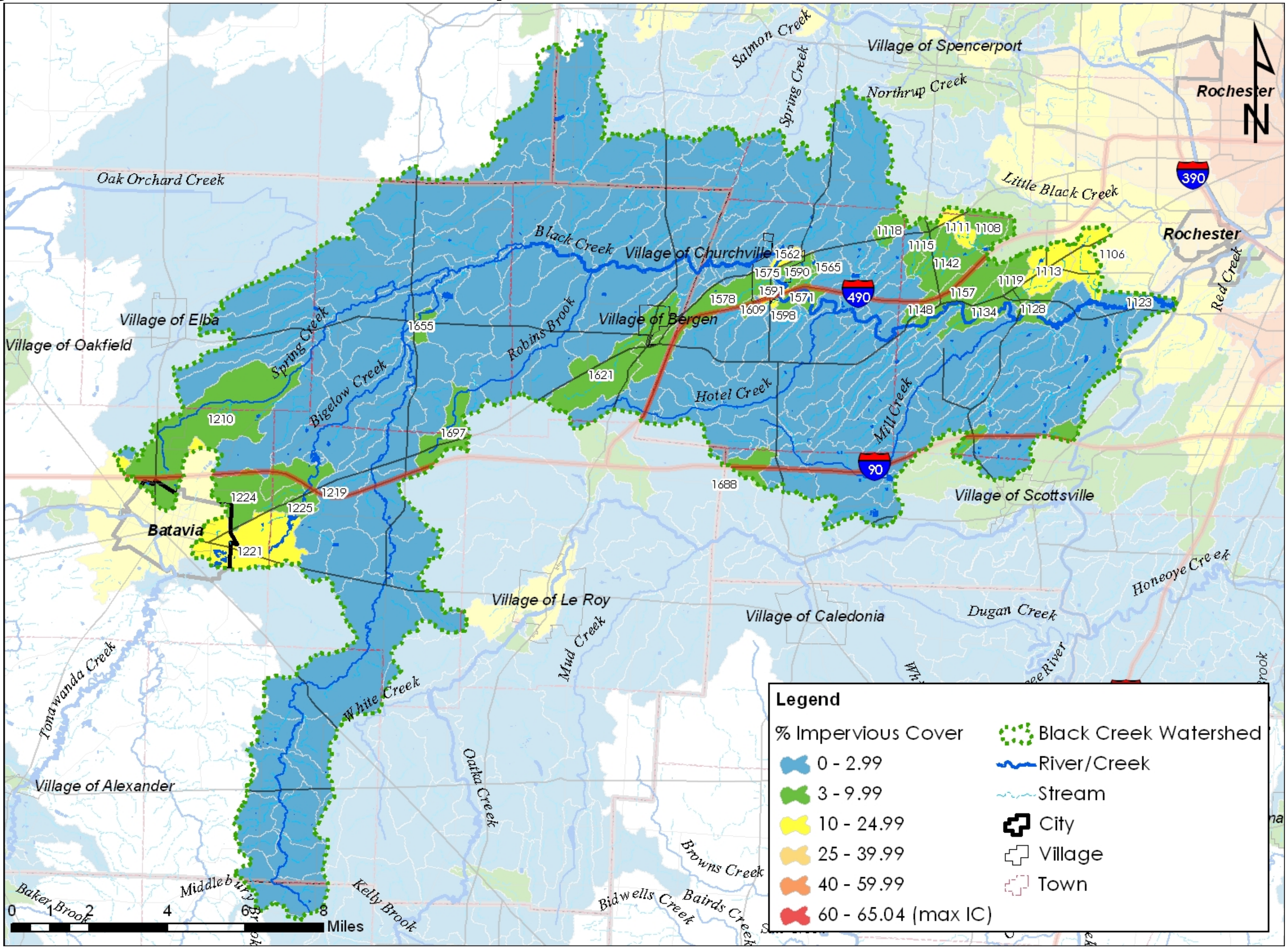


Figure 3.8: Genesee River Watershed Impervious Cover

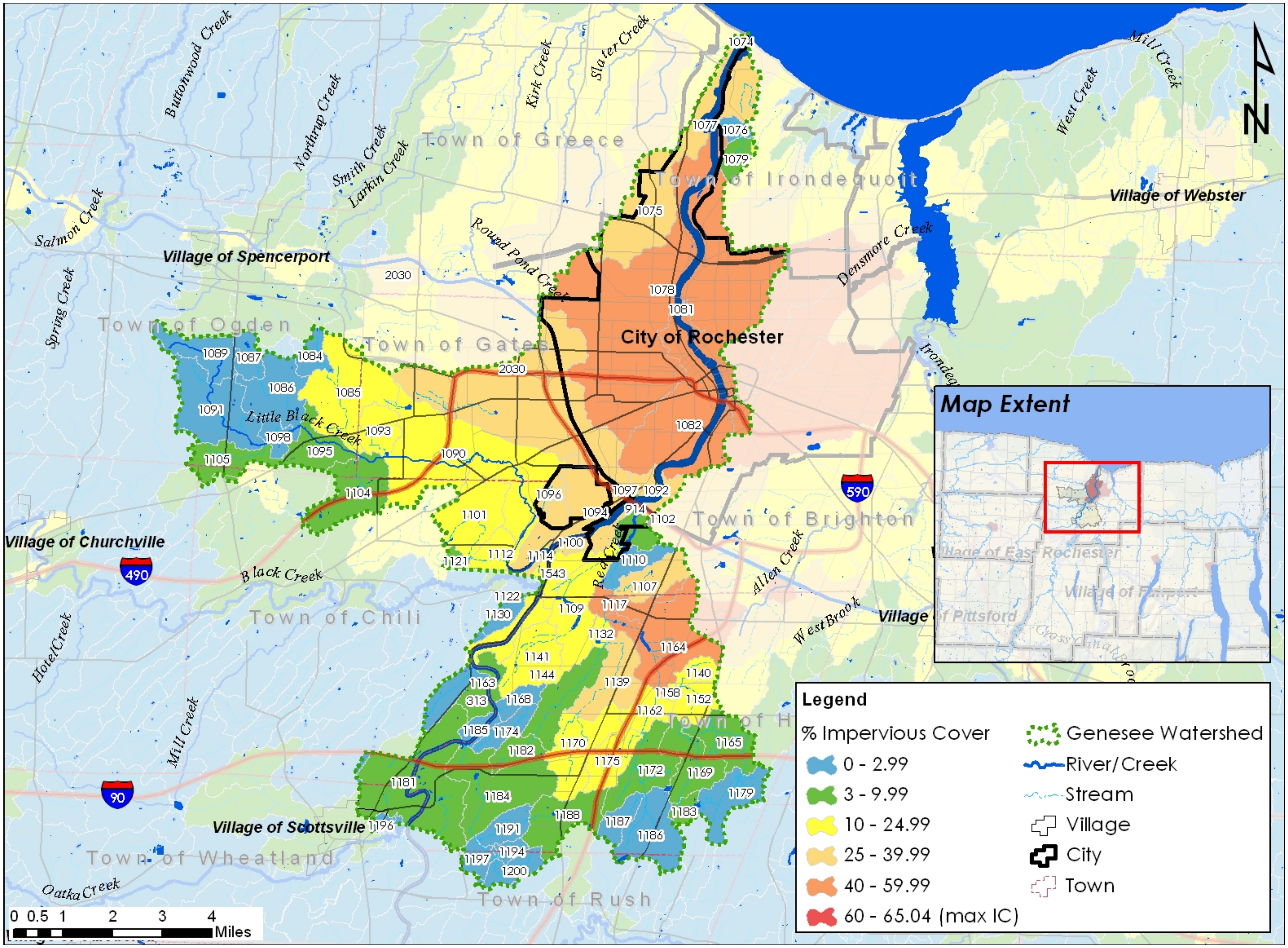


Figure 3.9: Honeoye Creek Watershed Impervious Cover

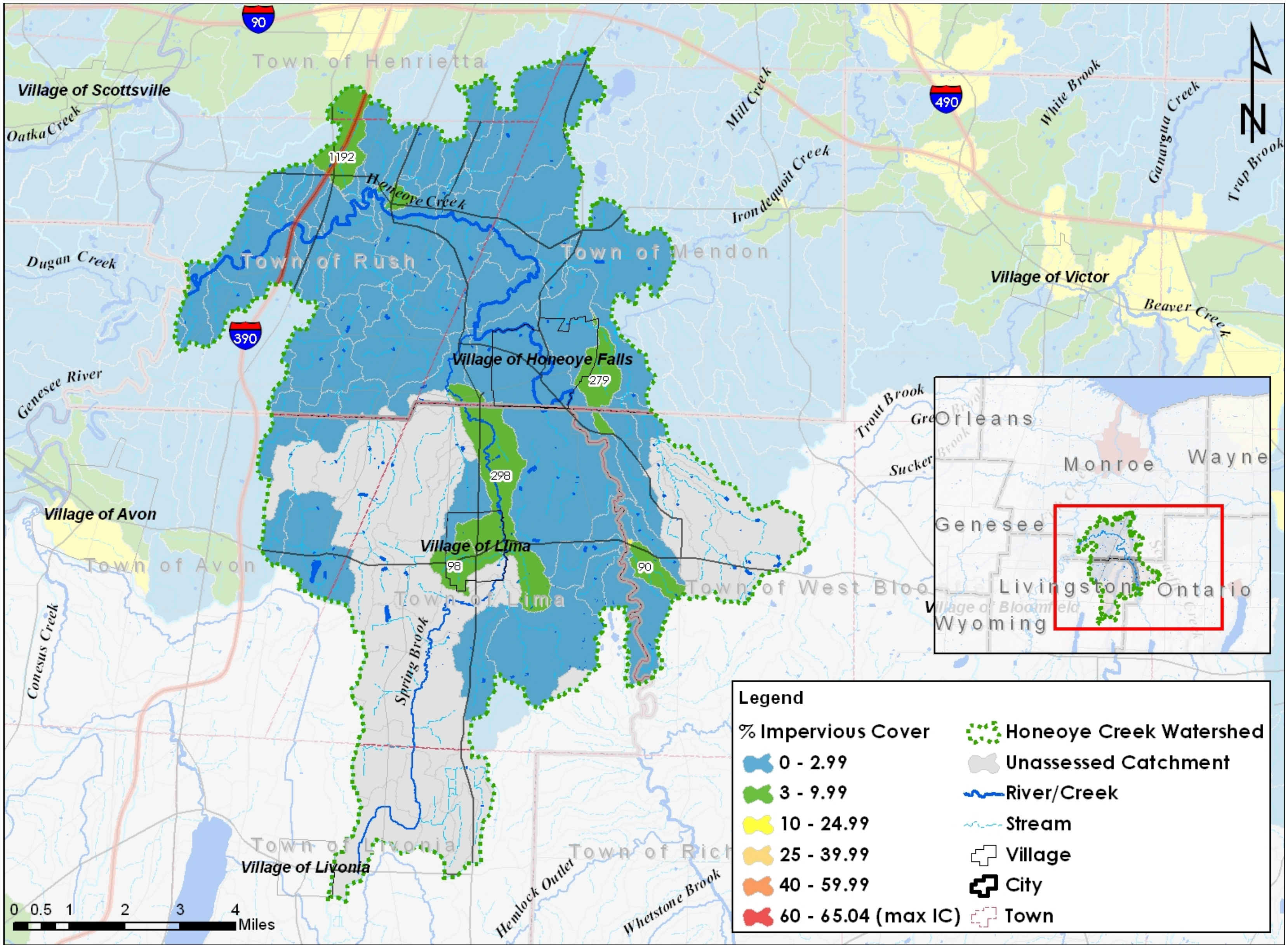


Figure 3.10: Oatka Creek Watershed Impervious Cover

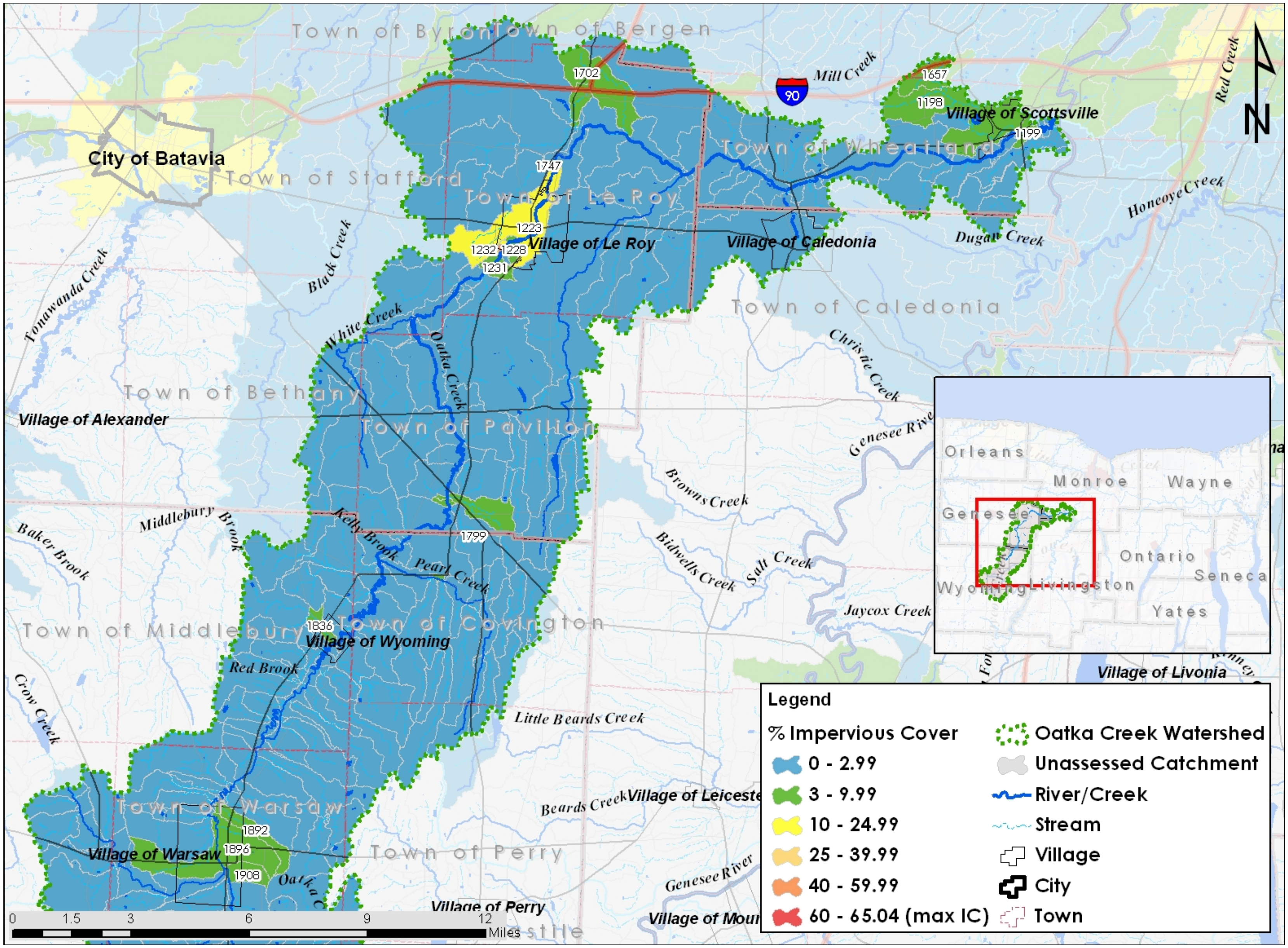


Figure 3.11: Upper Tonawanda Creek Watershed Impervious Cover

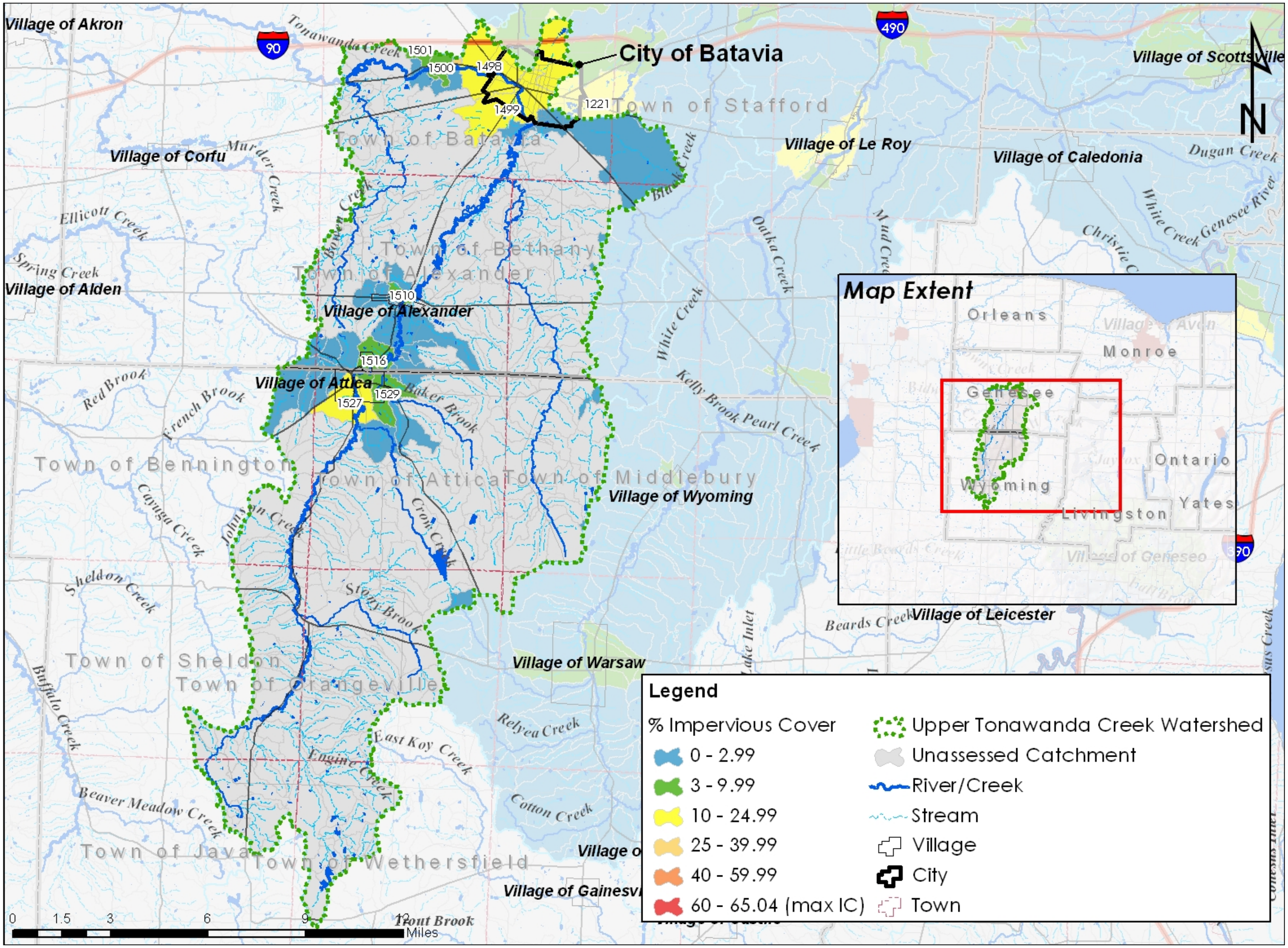


Figure 3.12: Greece Ponds Watersheds Impervious Cover

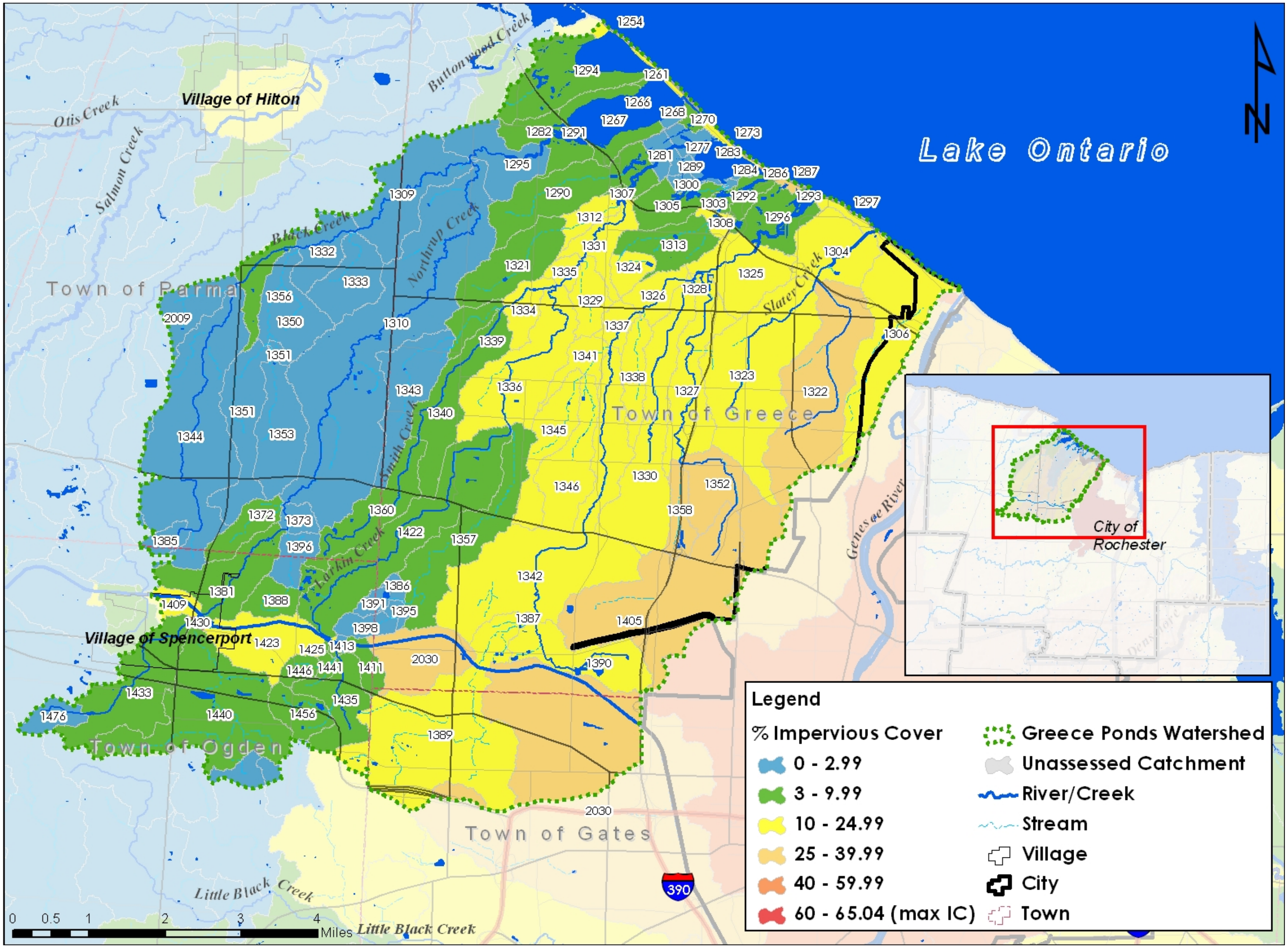


Figure 3.13: Salmon Creek Watershed Impervious Cover

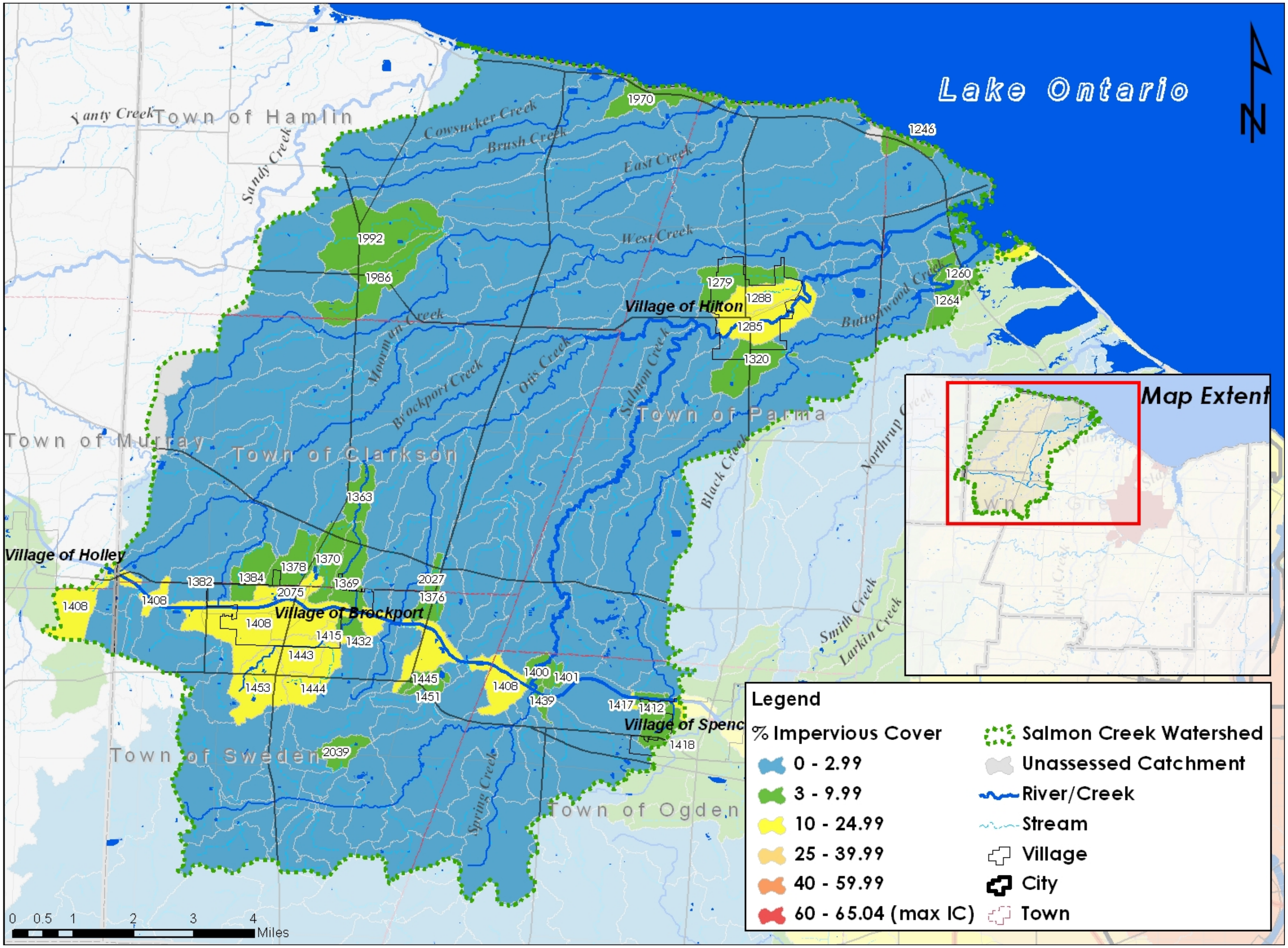


Figure 3.14: Johnsons Creek, Oak Orchard Creek, and Sandy Creek Watersheds Imp. Cover

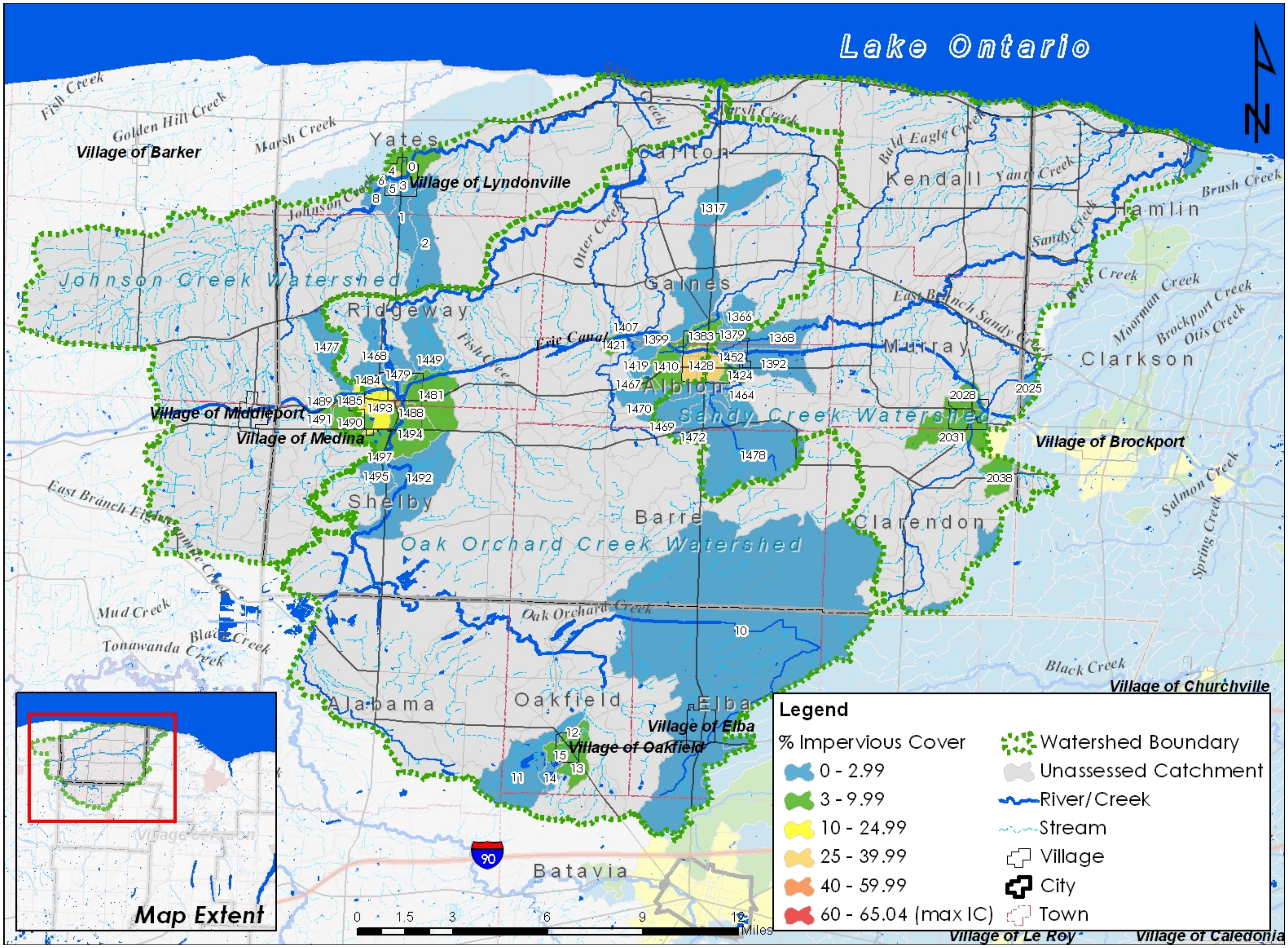


Figure 3.15: Mud Creek Watershed Impervious Cover

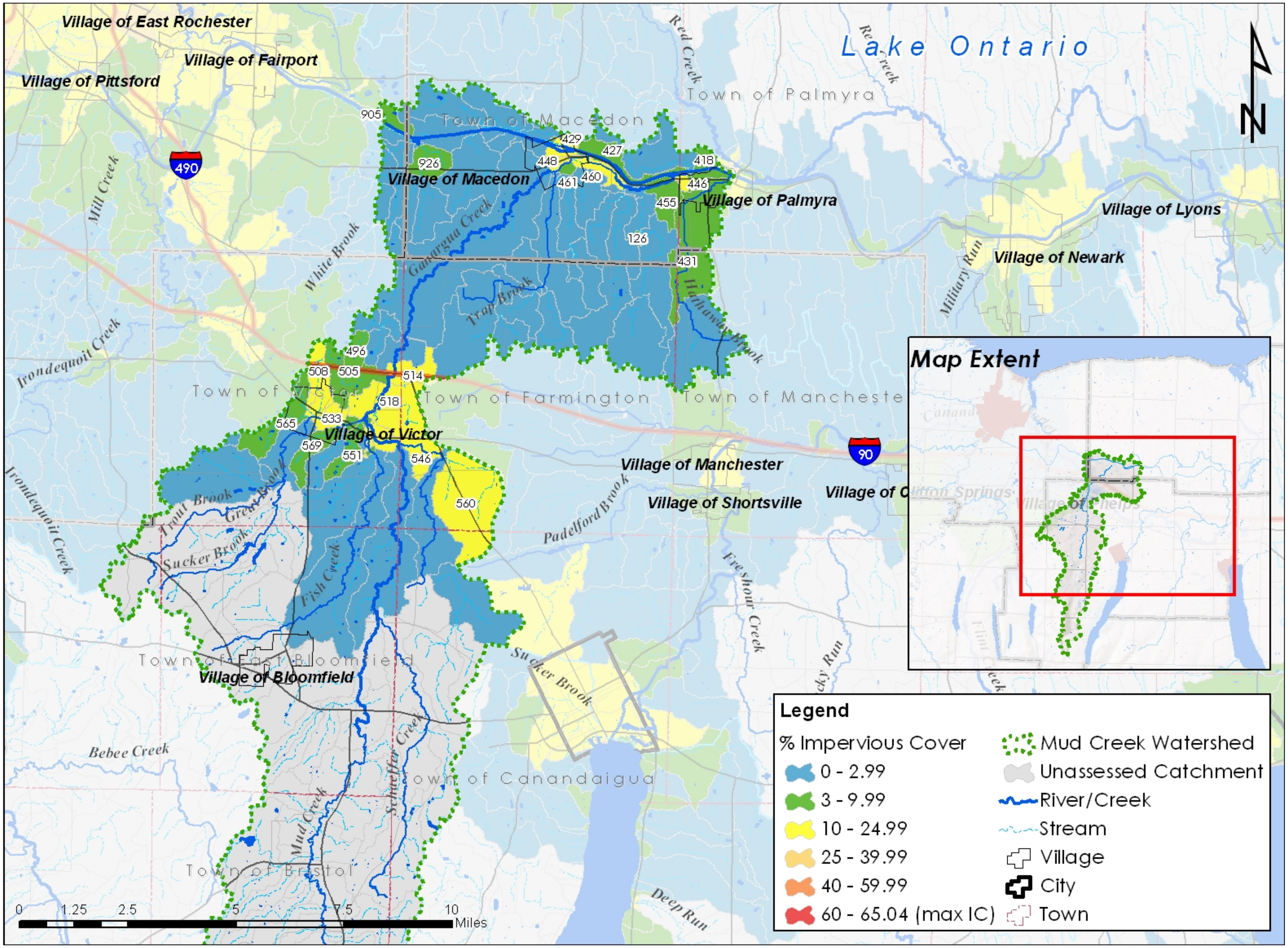


Figure 3.16: Canandaigua Lake & Outlet Watersheds Impervious Cover

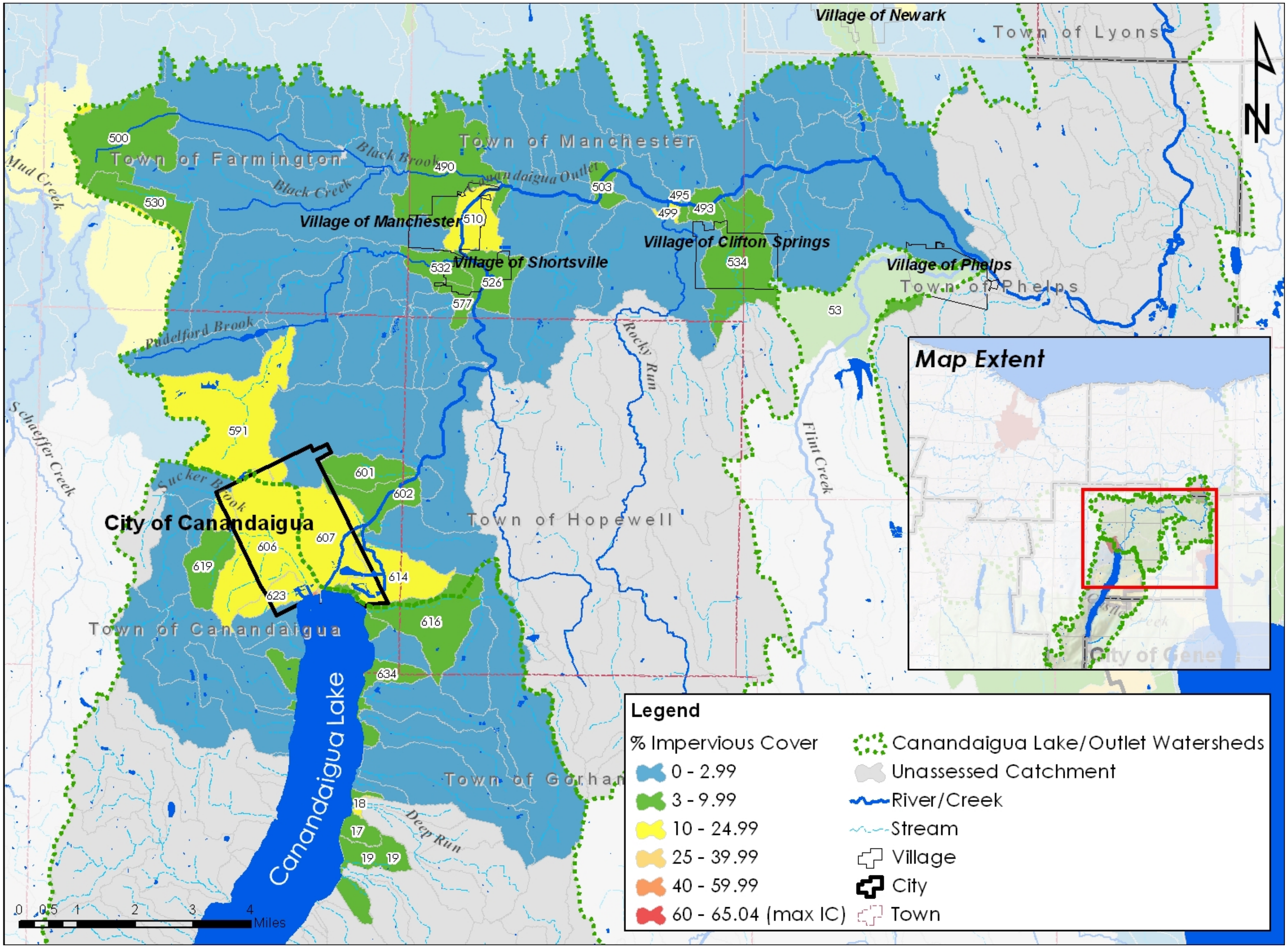


Figure 3.17: Ganargua Creek/Erie Canal Watershed Impervious Cover

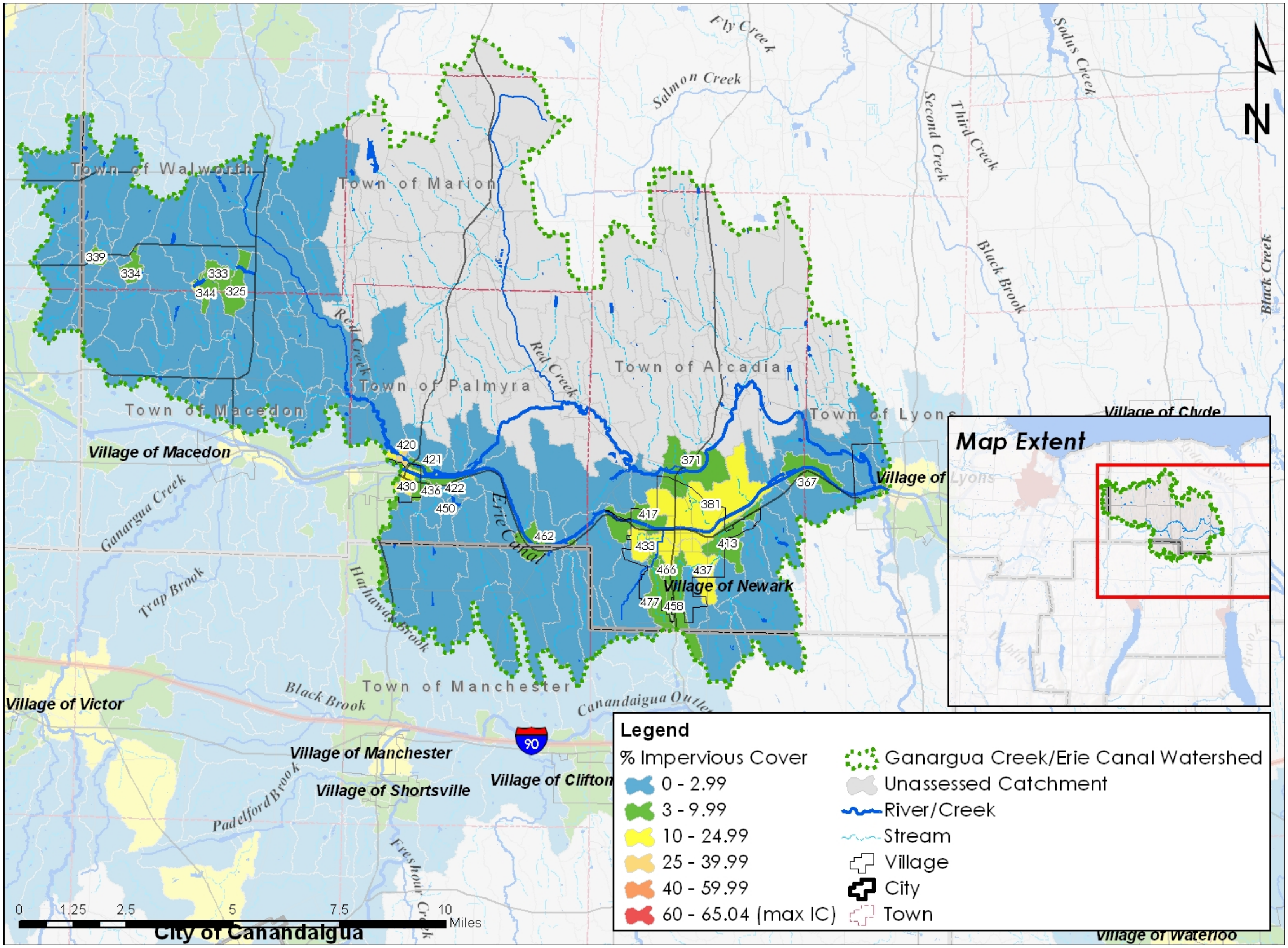


Figure 3.18: Keuka Lake Watershed Impervious Cover

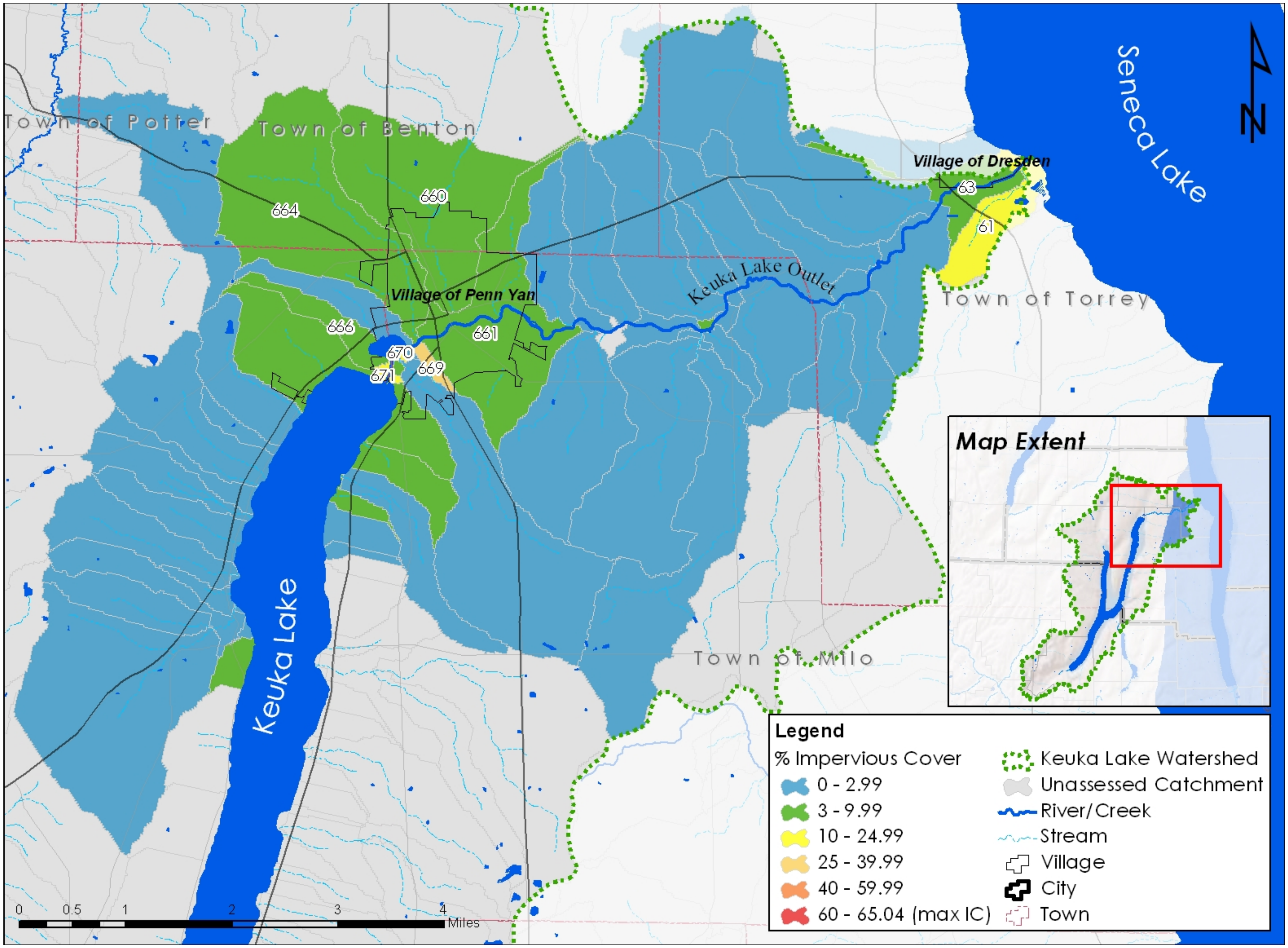


Figure 3.19: Seneca Lake/River Watershed Impervious Cover

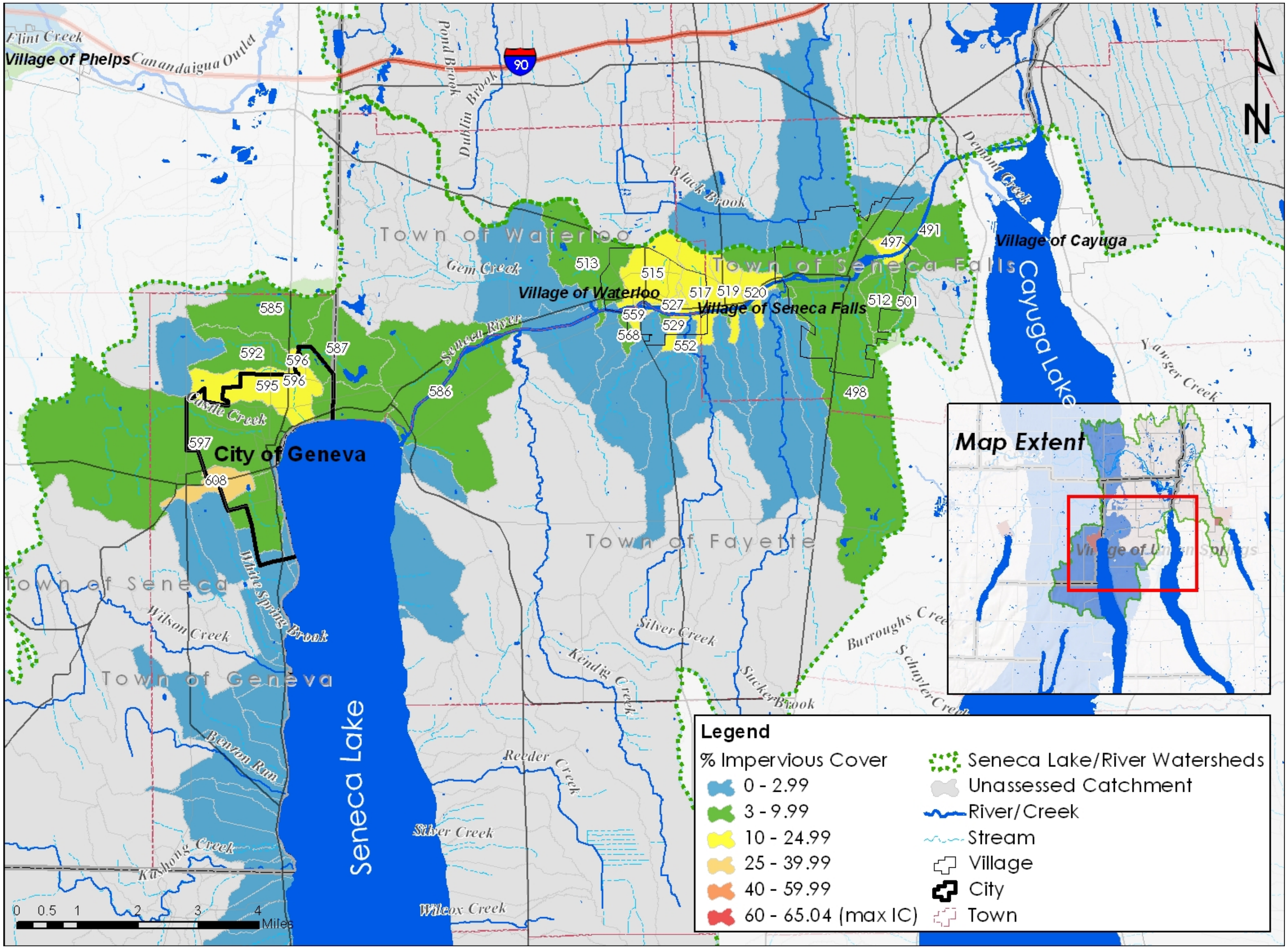
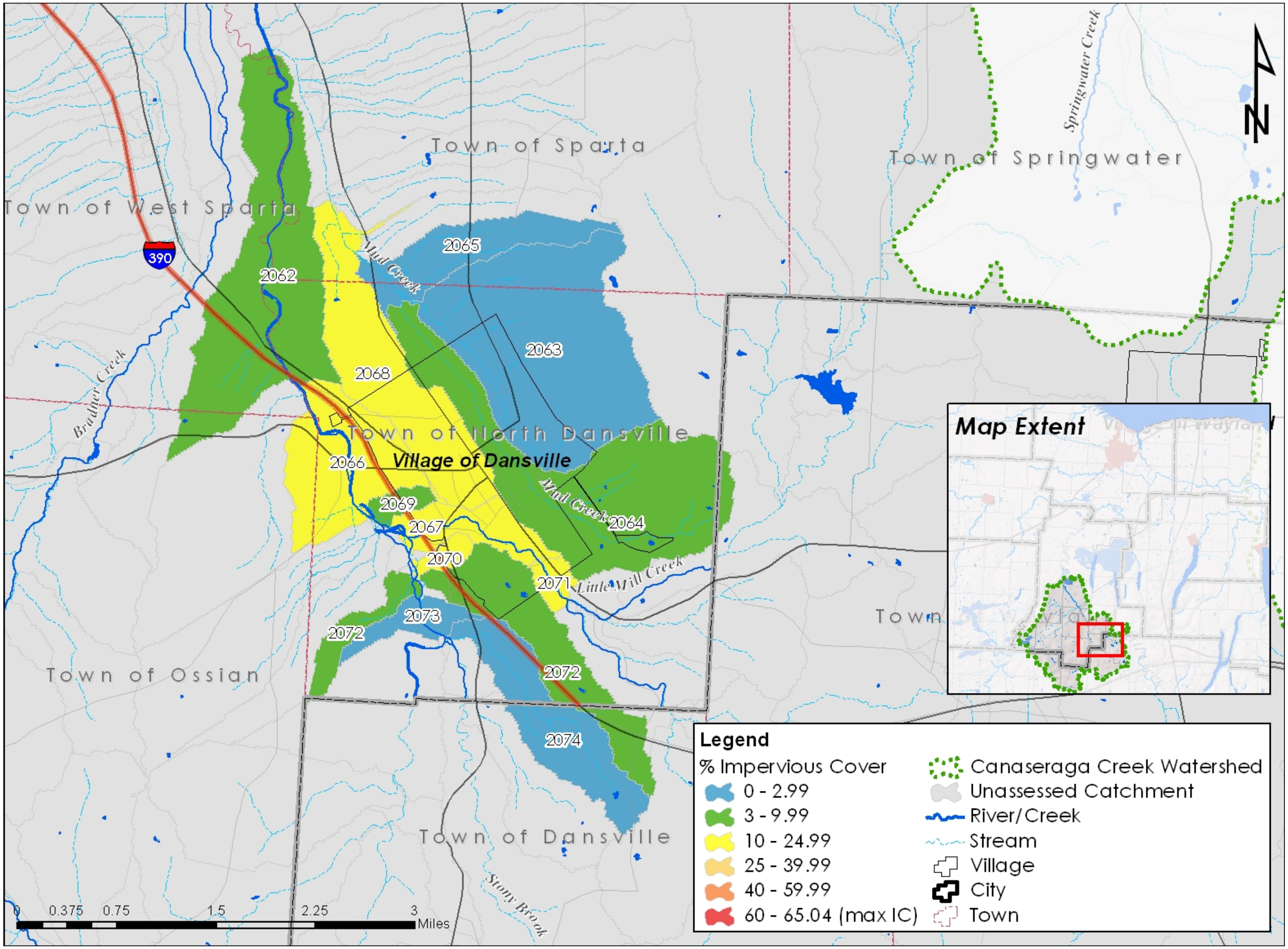


Figure 3.20: Canaseraga Creek Watershed Impervious Cover



4.0 Conclusions

A number of conclusions can be drawn regarding the applications of this regional scan of impervious surfaces.

The objective of the project was to provide greater insight regarding the impacts of IC on regional aquatic systems by providing a basic screening tool to watershed planners. As described in Section 1.1 of the report, impervious cover is a very useful indicator that can be used to measure the impacts of human development on local water quality and aquatic systems.

With the completed catchment-level %IC GIS geo-database in-hand, an intermediate-level GIS user can begin to investigate the impacts of impervious cover on water quality in the Genesee – Finger Lakes region with relative ease. It provides such users with a useful initial screening tool that can be applied in a rapid watershed assessment process to prioritize geographic focus areas within a watershed, narrow down the scope of potential applicable planning and remediation projects, and quickly identify practical watershed restoration goals for areas with high levels of impervious cover.

Maps included in this report help to illustrate and describe the issue of IC to the general audience. While these static maps and data clearly lack the full functionality and dynamics of a GIS, individuals with particular interest in a specific watershed or waterbody can begin to investigate the degree to which IC is present. The catchment is an ideal scale of analysis with which to conduct such an investigation.

The %IC GIS coverage is perhaps most useful to planners when applied as a preventive screening tool that can be used to identify those catchments that have not yet been heavily impacted by impervious cover. The scan can be used to identify catchments that may be approaching a hydrologic "tipping point" whereby impervious cover is about to inflict irreparable harm within the watershed.

Planners can utilize this information to consider actionable measures to protect a particular watershed or catchment of interest, such as watershed-based land use controls and practices. Examples of such approaches include:

- Encouraging infill development over "green field" development;
- Instituting Better Site Design/Low Impact Development practices;
- Basing lot coverage ratios on impervious surface area (as opposed to the structure footprint) within new developments;
- Mandating minimum stream setbacks and establishing adequate vegetated buffers near waterbodies.

Impervious Cover Scan Caveats

As described on page 5 of this report, the issue of connected versus disconnected impervious surfaces is an important one when attempting to measure or predict the degree to which impervious surfaces impact local water quality. Effective impervious cover – that is, the impervious portions of a subwatershed that are hydraulically connected to a drainage system or waterway – is a superior metric to %IC of a catchment or subwatershed.[12] The unit of analysis used in this report – the catchment – was on average .78 square miles in size, which is well within the ideal scale of analysis for a regional impervious cover assessment. Even so, significant variations in effective impervious cover could often be found when catchments were reviewed by eye on the GIS. Given that the scale of this project was regional in scope, the results were more than satisfactory. Neighborhood and subwatershed-scale planning and analysis, however, will require much closer scrutiny and inspection of impervious cover in order to plan for appropriate mitigation efforts.

Because %IC is essentially a statistical average of the mix of 30x30 meter cells that the GIS identifies within a catchment, significant IC variability may actually be present throughout the catchment. A large effective/connected impervious area could easily be present within a catchment with an overall low %IC value. This again underscores the importance of conducting a more detailed review of IC at the neighborhood-scale when developing a comprehensive watershed mitigation or protection strategy.

[12] *Methods for Estimating the Effective Impervious Area of Urban Watersheds.* [Online] In Stormwater Manager's Resource Center. Last viewed 3/13/11 at http://www.stormwatercenter.net/Library/Practice/32.pdf.

Data Sources and Notes

2006 National Land Cover Dataset (NLCD) Citation Information:

Title: NLCD 2006 Percent Developed Imperviousness
Originator: U.S. Geological Survey
Publication_Date: 20110216
Edition: 1.0
Geospatial_Data_Presentation_Form: remote-sensing image
Publication_Information:
  Publication_Place: Sioux Falls, SD
  Publisher: U.S. Geological Survey
Other_Citation_Details:

References:

(1) Homer, C., Huang, C., Yang, L., Wylie, B., & Coan M., (2004). Development of a 2001 National Land Cover Database for the United States. Photogrammetric Engineering and Remote Sensing, 70, 829 - 840.

(2) Jin, S., Yang, L., Xian, G., Danielson, P., Fry, J., and Homer C., (2011). A multi-index integrated change detection method for updating the National Land Cover Database (In Preparation).

(3) Nowak, D. J., & Greenfield, E. J., (2010). Evaluating the National Land Cover Database tree canopy and impervious cover estimates across the conterminous United States: A comparison with photo-interpreted estimates. Environmental Management, 46, 378 - 390.

(4) Wickham, J. D., Stehman S. V., Fry, J. A., Smith, J. H., & Homer, C. G., (2010). Thematic accuracy of the NLCD 2001 land cover for the conterminous United States. Remote Sensing of Environment, 114, 1286 - 1296.

(5) Xian, G., Homer, C., and Fry, J., (2009). Updating the 2001 National Land Cover Database land cover classification to 2006 by using Landsat imagery change detection methods. Remote Sensing of Environment, 113, 1133-1147.

(6) Xian, G., and Homer C., (2010). Updating the 2001 National Land Cover Database impervious surface products to 2006 using Landsat imagery change detection methods. Remote Sensing of Environment, 114, 1676-1686.

Attribute_Accuracy_Explanation:
This document and the described imperviousness map are considered "provisional" until a formal accuracy assessment is completed. The U.S. Geological Survey can make no guarantee as to the accuracy or completeness of this information, and it is provided with the understanding that it is not guaranteed to be correct or complete. Conclusions drawn from this information are the responsibility of the user.

Additional References

Arnold, C.L., Jr. and C.J. Gibbons. *Impervious Surface Coverage: The Emergence of a Key Environmental Indicator*. Journal of the American Planning Association 1996-62(2): 243-258.

Center for Watershed Protection. *Impacts of Impervious Cover on Aquatic Systems*. 2003

Center for Watershed Protection. *Urban Subwatershed Restoration Manual 1: An Integrated Framework to Restore Small Urban Watersheds. 2005.* Retrieved online 3/3/11 from http://www.cwp.org/categoryblog/92-urban-subwatershed-restoration-manual-series.html.

Exum, Linda R., Sandra L. Bird, James Harrison and Christine A. Perkins. *Estimating and Projecting Impervious Cover in the Southeastern Un*ited States. Ecosystems Research Division, National Exposure Research Laboratory, US EPA, 2005.

Glossary and Acronyms

CWP – Center for Watershed Protection:	The Center for Watershed Protection (CWP) works to protect, restore, and enhance our streams, rivers, lakes, wetlands, and bays. CWP creates viable solutions and partnerships for responsible land and water management so that every community has clean water and healthy natural resources to sustain diverse life. http://www.cwp.org/
GIS – Geographic Information System:	An integrated computer hardware, software, and data system used to capture, manage, analyze, and display all forms of geographically referenced information.
HUC – Hydrologic Unit Code:	The Hydrologic Unit Code system is a standardized watershed classification system developed by the USGS in the mid 1970s. Hydrologic units are watershed boundaries organized in a nested hierarchy by size.
IC – Impervious Cover:	The sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape that prevent or restrict the absorption of precipitation into the subsurface.
ICM – Impervious Cover Model:	A general watershed planning model that uses percent watershed impervious cover to predict various stream quality indicators. It predicts expected stream quality declines when watershed IC exceeds 10% and severe degradation beyond 25% IC.
%IC – Percent Impervious Cover:	A measurement of the average amount of impervious cover found within a defined geographic area.
NLCD – National Land Cover Dataset:	A hierarchical land cover classification scheme of 21 classes (a modified Anderson Land Cover Classification) developed and applied in a consistent manner across the entire United States. The spatial resolution of the data is 30 meters and mapped in the Albers Conic Equal Area projection, NAD 83. http://landcover.usgs.gov/natllandcover.php