Post Classification Change Detection of Four Lake Drainage Basins in the Pawtuxet Watershed between 1985 and 2010

Michael Yanchuk

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Introduction:

Water quality is important to protect, conserve, and improve for the well-being of human health and recreation, as well as wildlife and natural ecosystems. Many factors cause freshwater sources to decline due to various pollutants entering waterways. Nonpoint source pollutants, which are contaminants entering waterways indirectly collectively, contribute a large amount of sediment, nitrogen, phosphorus, etc (EPA, 2001). Some of the common sources are earth disturbances, such as housing construction projects and agriculture, and fertilizers/pesticides from homeowners and farming practices.

Long-term water quality monitoring programs can help to provide insight as to how waterways (lakes and ponds in our study) are improving or declining over time. One method of interest to our study is secchi disk depth, which provides a simple measure of water clarity by lowering the disk into the water and recording the depth at which it can't be seen due to water clarity. This method is an indicator of water quality because water clarity can be affected by a number of pollution factors related to nitrogen and phosphorus (Burns et al., 2005). Heightened nitrogen and phosphorus levels lead to heightened levels of chlorophyll, which leads to algae growth. Algae within a water column lower water clarity, which would be evident in the secchi depth reading (Burns et al., 2005).

Watershed Watch (WW) is a program within the Water Quality Program at URI that has been monitoring the waterways of Rhode Island for nearly 30 years. With protocols and Standard Operating Procedures developed, volunteers are responsible for water collection and delivery to the URI lab where samples are processed. Data records have existed in hardcopy and excel workbooks, which has recently been developed into a database for efficient data retrieval. Since 1988, 500+ water collection stations have been documented, with monitoring taking place between the months of April and November (WW Field SOP, 2005).

Determining landscape change through history can provide an important illustration of the response effects to a changing landscape. The above example of water quality is one way of documenting response effects of landscape change. The following study uses land use / land cover images that have been developed through supervised classification of 30-m Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) remote sensing data in Dr. Wang's laboratory for terrestrial remote sensing at the University of Rhode Island (Archetto and Wang). Due to interest in WW water quality monitoring data, which began in 1988, the 1985 and 2010 LULC image files will be used to quantify land use change between this time period.

Study Area:

The Pawtuxet watershed was chosen as the study area due to its various land use classifications. The watershed occupies roughly 60,000 ha from its headwaters in western Rhode Island to where it enters the Narragansett Bay North of Warwick. Appendix C provides an overview of the study area. Within its boundaries the Scituate Reservoir supplies ¾ of the Rhode Island's residents with drinking water, giving reason for concern for the amount of urban growth that has taken place in the past as well as preserving forested land for future generations. From 1985-2010, a decrease of 1,279 ha of deciduous forest and an increase in 870 ha urban development as interpreted through Landsat MSS and TM remote sensing post classification change detection (Archetto and Wang). A portion of the Pawtuxet watershed that is surrounding Providence has seen substantial growth within the past 50-100 years, but when was the bulk of urban expansion? Was there significant change from forest to urban land use within the past 30 years? These are questions which may indicate reasons for changing water quality in the lakes found within the Pawtuxet watershed's boundaries.

Nine HUC12 subwatersheds make up the Pawtuxet watershed: Moswansicut Pond, Barden Reservoir-Ponaganset River, Pocassett River, Scituate Reservoir, Pawtuxet River, North Branch Pawtuxet River, Headwaters of the South Branch Pawtuxet, South Branch Pawtuxet River, and Big River. Three of the above mentioned subwatersheds were represented in this study. Four lakes were chosen to delineate drainage basins and perform post classification change totals within the Pawtuxet watershed.

The four lakes were chosen due to the continuity demonstrated in water quality records between 1988 and 2012. Although this study represents only the post classification change detection process, the results will be used in future research involving a statistical relationship to water quality monitoring records. The four lakes:

Johnson Pond – Flat River Reservoir (WW15), Mashapaug/Spectacle Ponds (WW25), Carr/Tarbox Ponds (WW54), and Tiogue Lake (WW55) were determined because monitoring records spanned each year from 1988-2012. 24 other lakes were found to be monitored for a period of time within the Pawtuxet watershed, however the datasets had gaps between active monitoring years. Johnson Pond – Flat River Reservoir drainage basin was determined to be the largest area of the four watersheds delineated for the study. At 14,549 ha, forested land use is the most represented classification. Oppositely, the Mashapaug/Spectacle Pond watershed covers only 454 ha and is almost entirely urban land use. The Carr/Tarbox Pond watershed is similar in size (453 ha) and its predominant land use is forested. Tiogue Lake was determined to be 717 ha and has a mixed forest/urban land use.

Objective:

The objective of this study is to take a comparative look at land use change within lake drainage basins in the Pawtuxet HUC 10 watershed during the years of active Watershed Watch water quality monitoring (1985-2010).

Methods:

Each of the four lakes' watersheds was delineated in order to consider the amount of change that took place within the area of land that drains to each lake (Canham, 2004). This was done using Spatial Analyst extension of ESRI's ArcGIS 10.2 software. The watershed tool requires the input of a pour point and a flow accumulation raster in order to determine the delineated watershed. The flow accumulation raster was determined using a DEM layer to determine flow direction. The pour points were created as single point shapefiles representing the furthest downstream point to be considered within the watershed. Refer to Appendix D for an image of the pour points and flow accumulation layer. The output raster files were then converted to polygon in order to clip the land use rasters to watershed polygons using the raster clip tool. 1985 and 2010 land use images were clipped to each of the four watersheds, producing eight total images to represent change between 1985 and 2010 for each watershed. Refer to Appendix B for raster images.

Land use change was then quantified using ERDAS Imagine 9.3. Quantification was done using the mask tool to mask the 2010 urban classification which created image files representing all 1985 land use classifications that subsequently moved to urban in 2010. The addition of an 'Area' field allowed each land use classification in the masked output to be totaled for comparison during analysis.

Discussion:

A total of 771 ha were converted to urban land use between 1985 and 2010 within the Flat River Reservoir drainage basin. Deciduous Forest was the leading classification type to shift to urban landscape (437 ha). A total of 20 ha were converted to urban land use between 1985 and 2010 within the Mashapaug/Spectacle Pond drainage basin. Deciduous Forest was the leading classification type to shift to urban landscape (8 ha). A total of 13 ha were converted to urban land use between 1985 and 2010 within the Carr/Tarbox Pond drainage basin. Deciduous Forest was the leading classification type to shift to urban landscape (6 ha). A total of 93 ha were converted to urban land use between 1985 and 2010 within the Tiogue Lake drainage basin. Deciduous Forest was the leading classification type to shift to urban landscape (50 ha).

The total change in acres to urban can be found for each land use classification in Appendix A. For each watershed, total urban area was documented and ultimately subtracted from the total area of change in order to document land that changed to urban from another classification. This total was then compared to the total area of each watershed to create a percentage of change, shown below:

Johnson Pond - Flat River Reservoir		
	acres	ha
Total Urban	2995	1212
Change to Urban	1907	771
Total Area	35953	14549
Percent Change	5%	5%

Mashapaug/Spectacle Ponds		
	acres	ha
Total Urban	932	377
Change to Urban	51	20
Total Area	1123	454
Percent Change	5%	5%

Carr/Tarbox Ponds		
	acres	ha
Total Urban	41	16
Change to Urban	33	13
Total Area	1120	453
Percent Change	3%	3%

Tiogue Lake		
	acres	ha
Total Urban	853	345
Change to Urban	231	93
Total Area	1773	717
Percent change	13%	13%

It is important to consider that three of the watersheds were roughly the same size, and the fourth was 30 times larger in area. For this reason, percent change is useful as it is a factor of each watershed that doesn't take into account total area. Size may play a role in determining specific areas of change though. The larger watershed is speckled with small patches of urban growth, totaling only 5% of the entire watershed. For this study, varying sized watersheds did not present a problem because the interest was land use change for specific drainage areas. If the study is expanded in the future, it will be interesting to see if size plays a role in extrapolating predicted water quality response based on land use change.

As described in the "Study Area" section, dominant land use classification was different in each drainage basin. Mashapaug/Spectacle Ponds are located within a densely urban area that has been classified that way since before 1985, yet there was still 5% urban growth. Oppositely, Carr/Tarbox Pond watershed has little urban development and is mostly forested classification. Tiogue Lake displays forested land use with urban patches throughout and demonstrated the highest change between 1985 and 2010.

Conclusion:

The Common trend in change between 1985 and 2010 is that the leading classification type to be converted to urban land was deciduous forest in each of the four watersheds. Small percentages of each watershed were converted to urban between 1985 and 2010, however Tiogue Lake indicated 13% conversion in this time period. It will be interesting to compare water quality parameters to the results found in Tiogue Lake watershed, specifically secchi depth measurements may be a useful indicator of change in water clarity. A regression analysis may be a useful statistical approach to study change overtime, not only for secchi depth, but also chlorophyll and phosphorus concentrations. Refer to Appendix E for scatter plots of secchi measurements vs. date. Another approach that may be useful in furthering this study might be to mask all class types except forested types in order to see and quantify total forest (deciduous, coniferous, and mixed) that is decreasing with growth which may not be specific to urban land use.

References:

Archetto, Glenn and Y.Q. Wang. “Forty Years of Urbanization and Changing Landscapes in Rhode Island”. Department of Natural Resources Science University of Rhode Island. Kingston, Rhode Island 02881

Burns, Noel M., Rockwell, David C., Bertram, Paul E., Dolan David M., Ciborowzki, Jan J.H. “Trends in Temperature, Secchi Depth, and Dissolved Oxygen Depletion Rates in the Central Basin of Lake Erie, 1983-2002”. Journal of Great Lakes Research. Volume 31, 2005. Pages 35-49.

Canham, Charles D., Michael L. Pace, Michael J. Papaik. “A Spatially Explicit Watershed-Scale Analysis of Dissolved Organic Carbon In Adirondack Lakes”. Ecological Applications. 14(3), 2004.

United States Environmental Protection Agency. “Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures – Urban”. 2001

Watershed Watch Field Standard Operating Procedures. University of Rhode Island Watershed Watch. 2005.

Appendix A: Urban mask class attributes

Histogram	Class Names	Color	Red	Green	Blue	Opacity	Area
0			0	0	0	0	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
4896	URBAN		1	0	0	1	1088.85
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
376	URBAN GRASS		1	0.65	0	1	83.6205
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
341	AG		1	1	0	1	75.8367
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
4881	Deciduous Forest		0.51	0.82	0.61	1	1085.51
1226	Coniferous		0	0.39	0	1	272.656
0			0	0	0	1	0
0			0	0	0	1	0
1489	Mixed Forest		0.36	0.64	0.41	1	331.146
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
130	Brushland		0.82	0.7	0.55	1	28.9114
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0

Histogram	Class Names	Color	Red	Green	Blue	Opacity	Area
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
8	Water		0	0	1	1	1.77916
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
1	Herb Wetland		1	0.71	0.76	1	0.222395
129	Decid wetland		0.93	0.51	0.93	1	28.689
0	conif wetland		0.69	0.19	0.38	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
2			1	1	0.88	1	0.44479

Flat River Reservoir (WW15) urban mask attributes.
Area in acres.

Histogram	Class Names	Color	Red	Green	Blue	Opacity	Area
0			0	0	0	0	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
3963	URBAN		1	0	0	1	881.351
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
34	URBAN GRASS		1	0.65	0	1	7.56143
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
102	Deciduous forest		0.51	0.82	0.61	1	22.6843
18	Coniferous		0	0.39	0	1	4.00311
0			0	0	0	1	0
0			0	0	0	1	0
64	Mixed Forest		0.36	0.64	0.41	1	14.2333
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0

Histogram	Class Names	Color	Red	Green	Blue	Opacity	Area
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
6	Water		0	0	1	1	1.33437
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
1	Herb Wetland		1	0.71	0.76	1	0.222395
3	Decid wetland		0.93	0.51	0.93	1	0.667185

Mashapaug/Spectacle Ponds (WW25) urban mask attributes.
Area in acres.

Histogram	Class Names	Color	Red	Green	Blue	Opacity	Area
0			0	0	0	0	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
36	URBAN		1	0	0	1	8.00622
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
4	URBAN GRASS		1	0.65	0	1	0.88958
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0	AG		1	1	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
71	Deciduous Forest		0.51	0.82	0.61	1	15.79
39	Coniferous		0	0.39	0	1	8.67341
0			0	0	0	1	0
0			0	0	0	1	0
34	Mixed Forest		0.36	0.64	0.41	1	7.56143
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
4	Brushland		0.82	0.7	0.55	1	0.88958

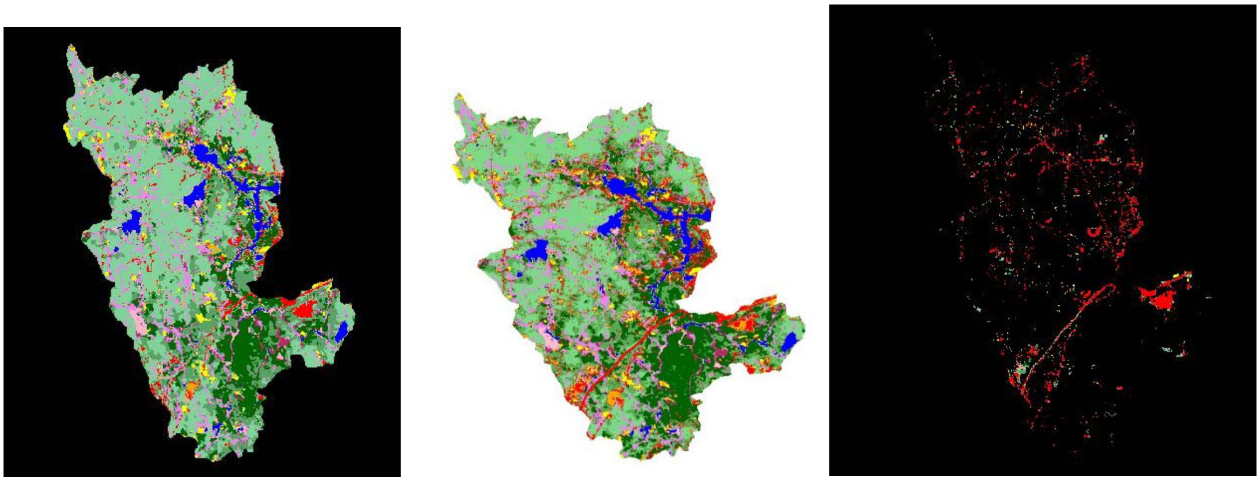
Carr/Tarbox Ponds (WW54) urban mask attributes. Area in Acres.

Histogram	Class Names	Color	Red	Green	Blue	Opacity	Area
0			0	0	0	0	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
2796	URBAN		1	0	0	1	621.816
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
94	URBAN GRASS		1	0.65	0	1	20.9051
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
14	AG		1	1	0	1	3.11353
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
569	Deciduous Forest		0.51	0.82	0.61	1	126.543
77	Coniferous		0	0.39	0	1	17.1244
0			0	0	0	1	0
0			0	0	0	1	0
265	Mixed Forest		0.36	0.64	0.41	1	58.9347
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
9	Brushland		0.82	0.7	0.55	1	2.00156
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0

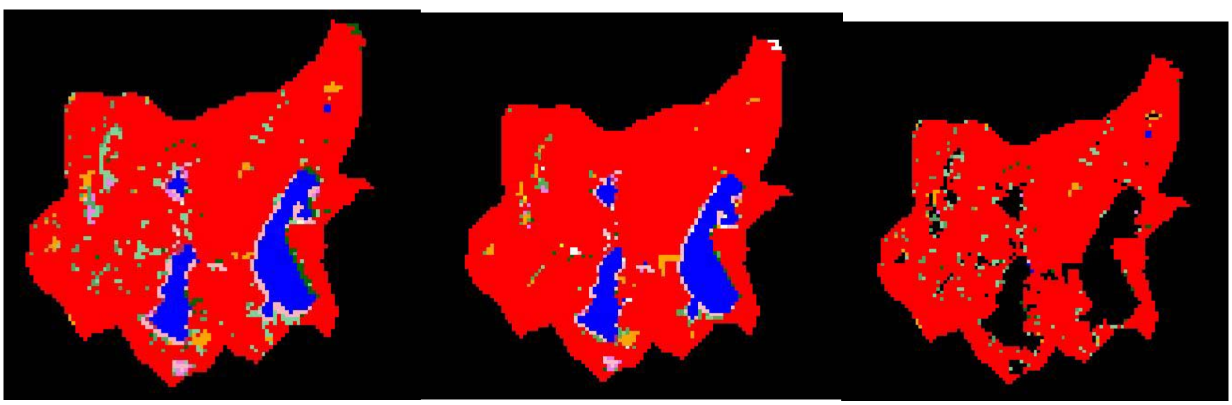
Histogram	Class Names	Color	Red	Green	Blue	Opacity	Area
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
2	Water		0	0	1	1	0.44479
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0	Decid Wetland		1	0.71	0.76	1	0
12	Conif Wetland		0.93	0.51	0.93	1	2.66874
0	Mixed Wetland		0.69	0.19	0.38	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
0			0	0	0	1	0
1			1	1	0.88	1	0.222395

Tiogue Lake (WW55) urban mask attributes. Area in acres.

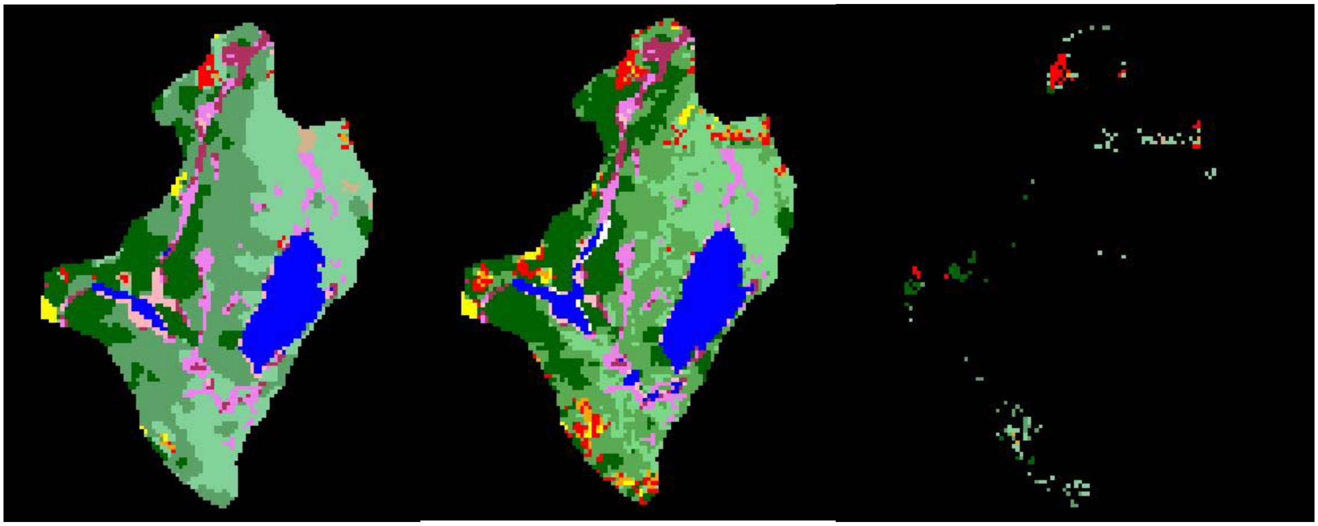
Appendix B: Land Use/Land Cover images



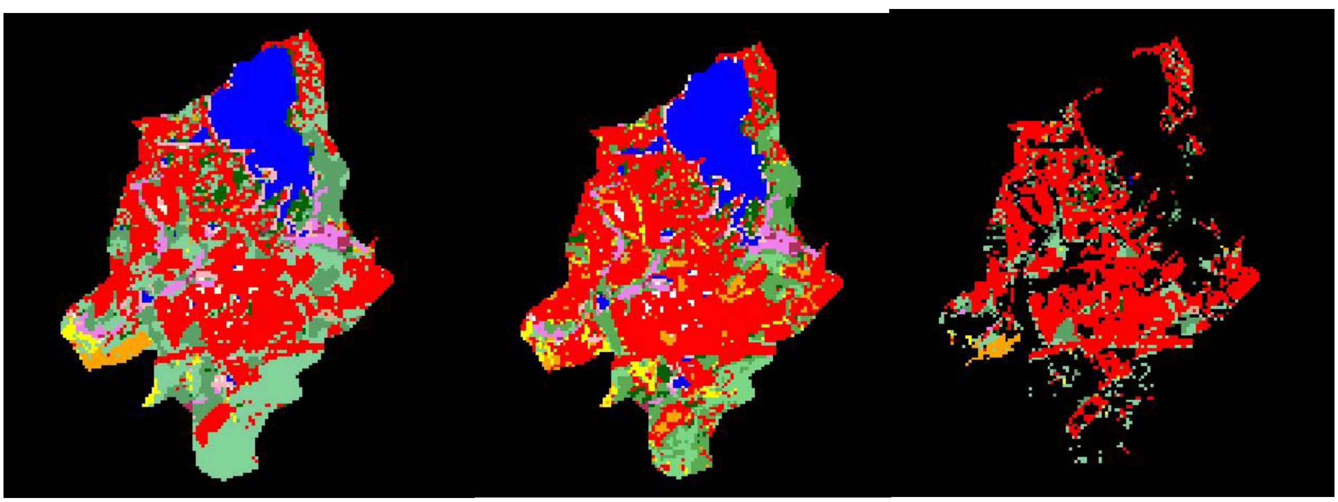
WW15: LULC 1985, 2010, and urban mask.



WW25: LULC use 1985, 2010, and urban mask.

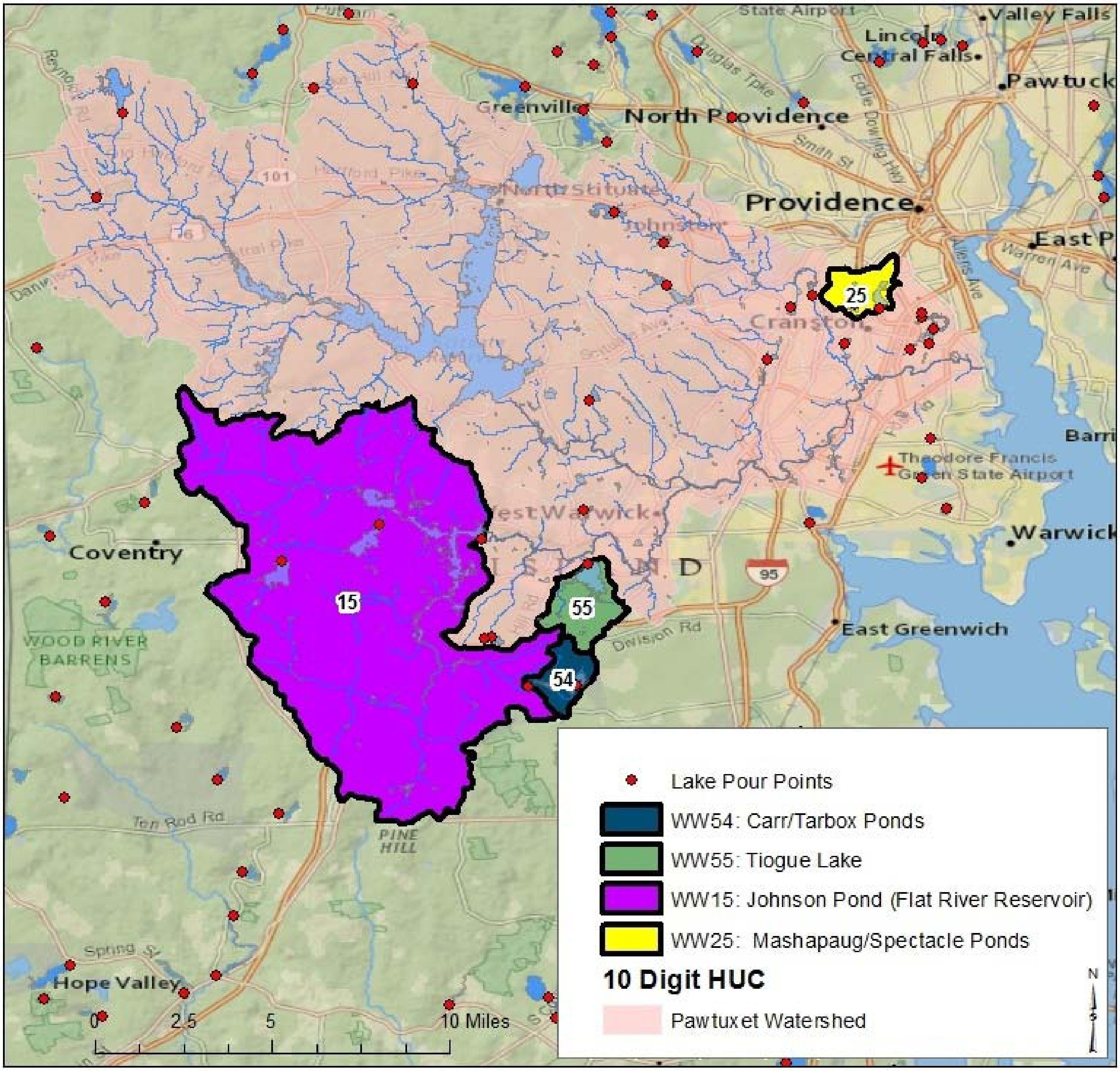


WW54: LULC 1985, 2010, and urban mask.

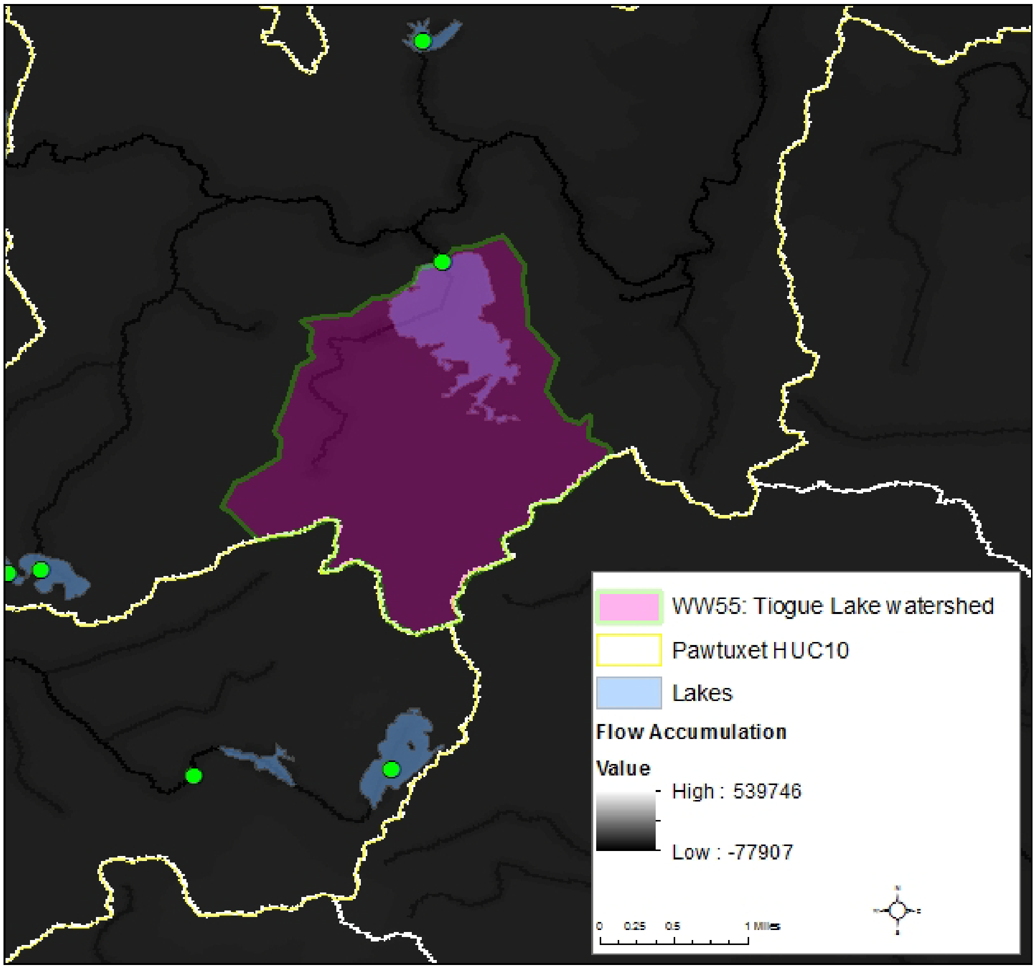


WW55: LULC 1985, 2010, and urban mask.

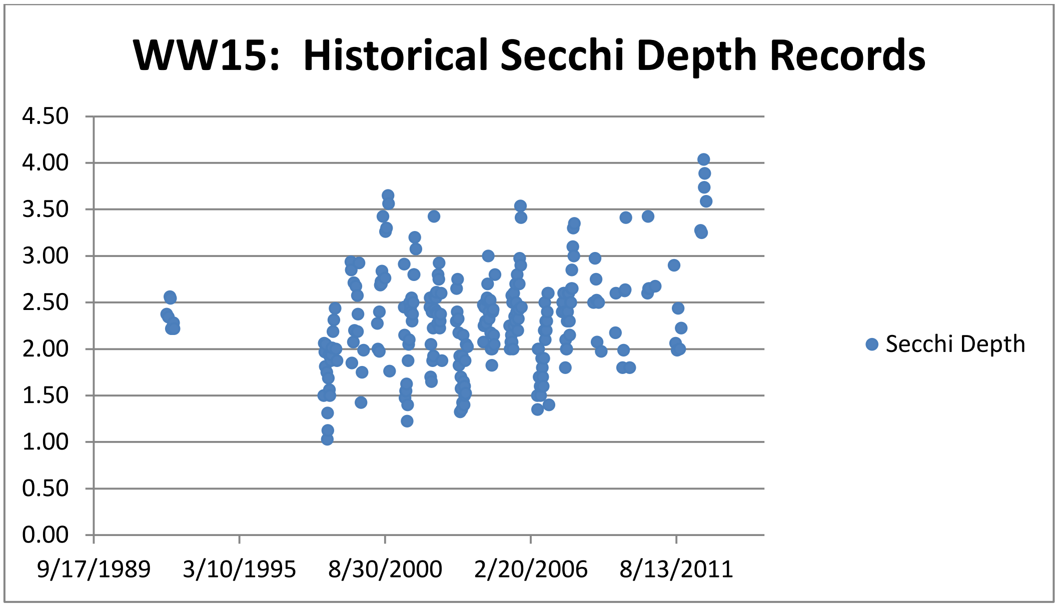
Appendix C: Study Area Overview

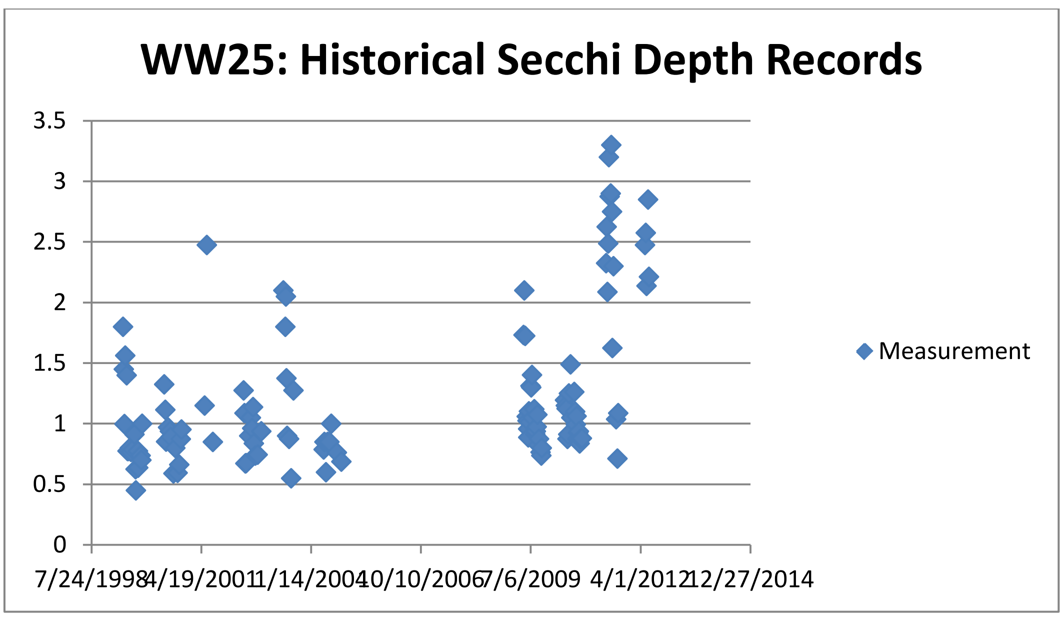


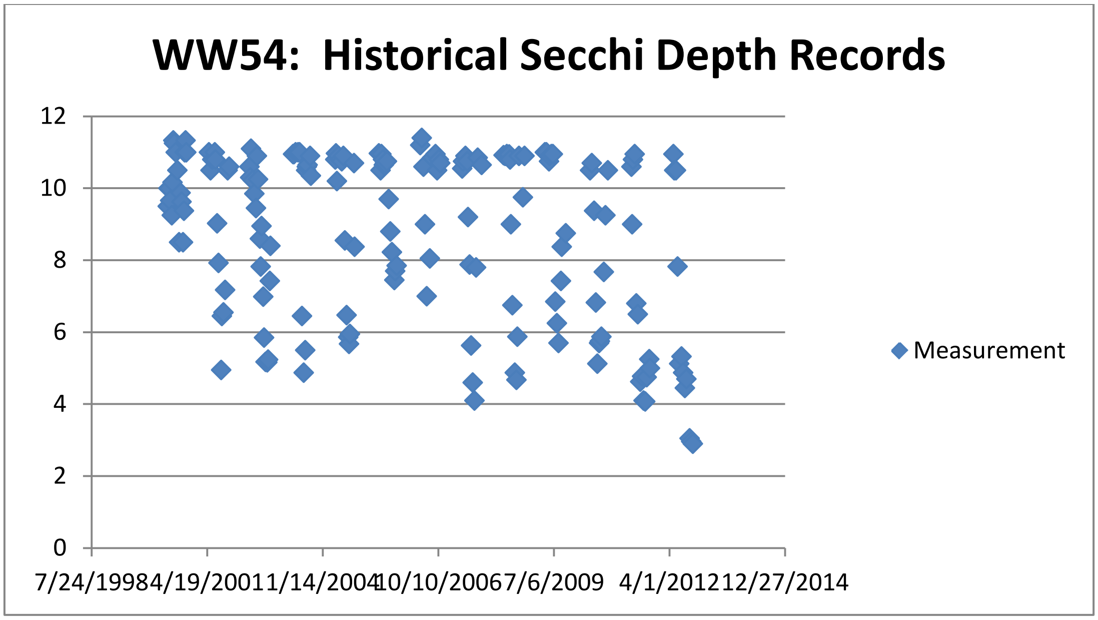
Appendix D: Watershed delineation required rasters and points

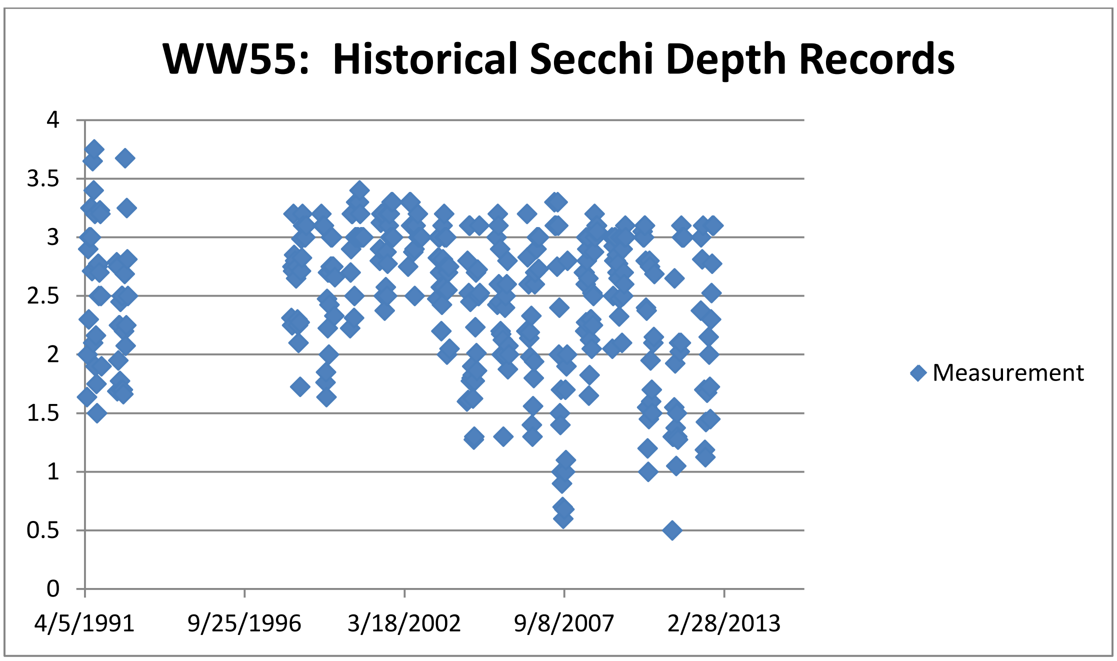


Appendix E: Secchi depth (m) records between 1988-2012






WW54: Historical Secchi Depth Records
12
10
8
6
4
2
0
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
Measurement


WW55: Historical Secchi Depth Records
4
3.5
3
2.5
2
1.5
1
0.5
0
4/5/1991
9/25/1996
3/18/2002
9/8/2007
2/28/2013
Measurement