SUBWATERSHED REPORT

1. Introduction

The *Black Creek Watershed Prioritization of Subwatersheds* provides a description of Black Creek's natural features such as hydrology, floodplains, and wetlands, along with consideration of water quality within the subwatersheds or stream segments. Some of the consideration of natural features and water quality were addressed in the *Black Creek Watershed Characterization Report*. Additional analysis has been done for this report. Additional water quality information has become available since that time with the work that was done by Mellissa Jayne Winslow in a thesis submitted to the Department of Environmental Science and Biology of the State University of New York College at Brockport, February 2012 entitled "*Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model*." The report acknowledges the United States Department of Agriculture for funding the project and the Research Foundation of SUNY and Dr. Joseph Makarewicz for the opportunity to work as a graduate assistant.

This *Black Creek Watershed Prioritization of Subwatersheds* is the second component of a comprehensive watershed management plan for the Black Creek watershed. The subwatershed prioritization includes:

- Description of the watershed and its constituent subwatersheds including population density, hydrology, floodplains, impervious cover, riparian cover, and wetlands;
- Description of the land use and land cover in the watershed and its constituent subwatersheds with agriculture as the primary land use and likely primary source of non-point source pollution;
- A prioritization of management practices that could reduce non-point source pollution from agricultural lands for each subwatershed
- Evaluation of existing water quality data, run-off characteristics and pollutant loadings; and
- Identification of pollution sources, sources of water quality impairment, and potential threats to water quality and watershed hydrology and ecology.

In addition to the subwatershed prioritization, subsequent project components will together comprise an overall strategy to protect and restore water quality and quantity within the Black Creek watershed. These components include:

- A community education and outreach program on water quality and quantity and watershed protection issues;
- Identification of management strategies and prioritization of projects and other actions for watershed protection and restoration;
- Identification of land and water use controls for water quality and quantity management and roles and responsibilities of governmental and non-governmental organizations; and
- An implementation strategy, including the identification of watershed wide and site specific projects and other actions necessary to protect and restore water quality.

This *Black Creek Watershed Prioritization of Subwatersheds* report is intended to facilitate these subsequent tasks by providing a description of the natural features of the watershed and subwatersheds and based on the characterization of the watershed, evaluate subwatersheds according to impairments and/or threats to water quality and habitat, and attempt to prioritize management practices that could reduce non-point source pollution, largely from agriculture given the nature of the watershed, for each subwatershed.

This project is being conducted simultaneously and in conjunction with watershed planning efforts for its neighboring watershed, the Oatka Creek watershed. While these two watersheds share many similar traits and while planning efforts are being conducted concurrently and under the same auspices in both watersheds, each watershed planning project is intended to function independently of the other. The outcomes of both watershed planning efforts will, wherever possible, identify methods and strategies to share responsibilities in the management of both watersheds.

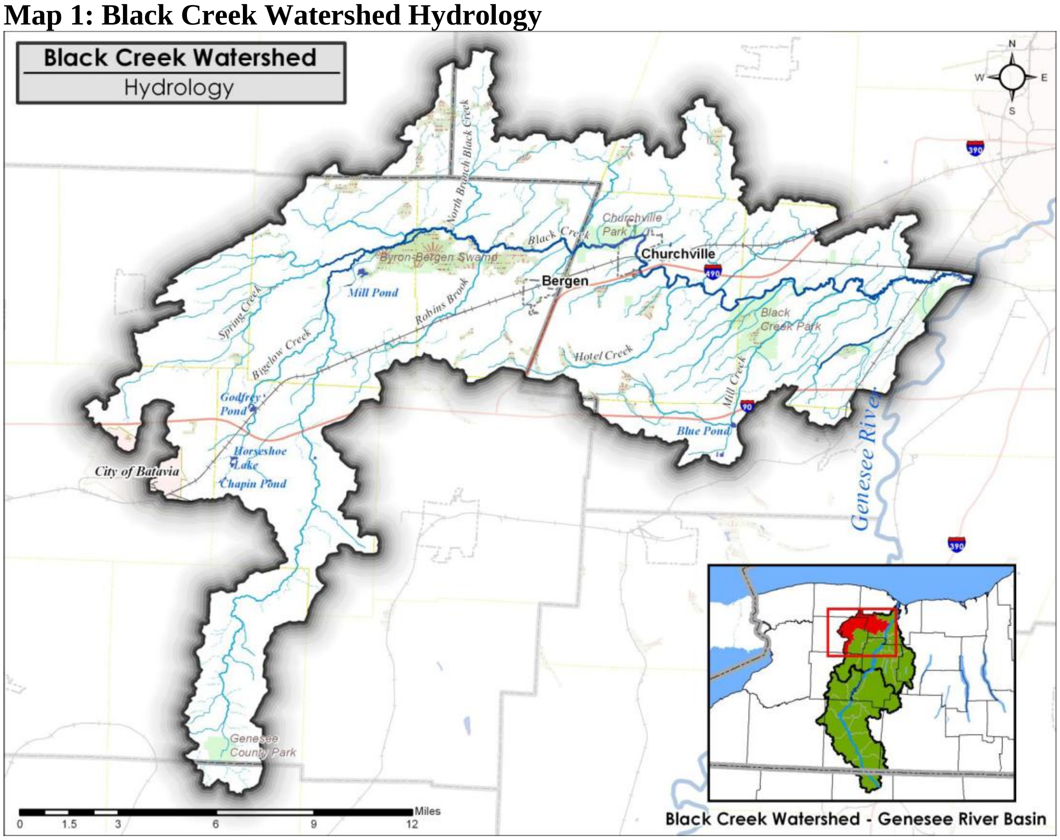
Project Advisory Committees for each of these two watersheds were formed in August of 2009 in order to guide preparation and eventual implementation of the completed watershed management plans. The committees are comprised of a variety of watershed stakeholders, including interested citizens, members of the Black Creek Watershed Coalition and the Oatka Creek Watershed Committee, municipal representatives, and representatives from a variety of public agencies and non-governmental and community-based organizations. These groups have been, and will continue to work together to develop joint water quality planning goals and implementation strategies wherever feasible, including leveraging resources and assets jointly whenever such efficiencies can be identified.

2. General Characteristics

Hydrology

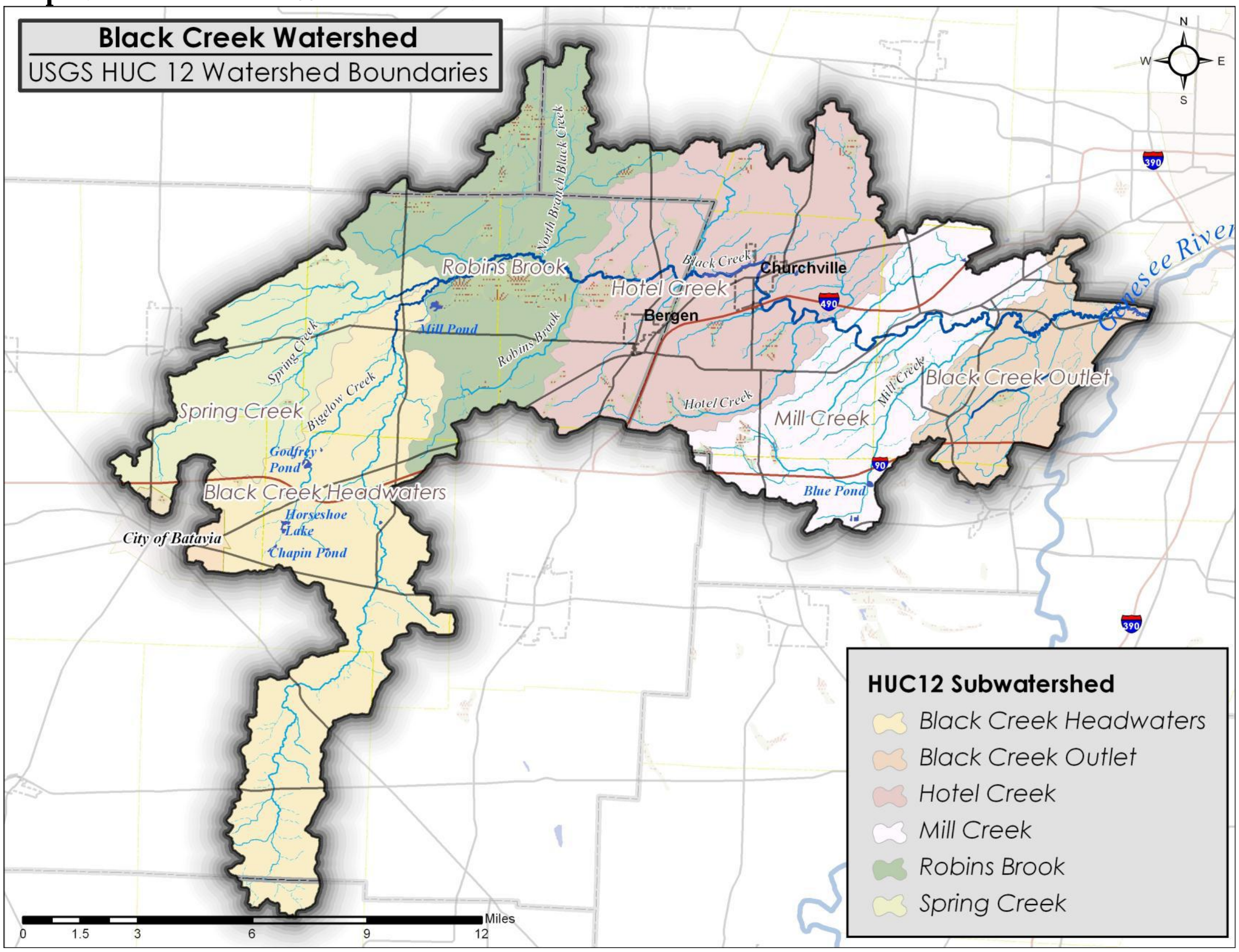
Hydrology is determined by a complex interaction between geology, groundwater, climate, physiography, and land cover. Perhaps the most distinctive trait that characterizes the hydrology of the Black Creek watershed is that it lies within an area of North America that has been largely influenced by prolonged periods of glaciation. The watershed lies in the "Eastern Great Lakes Lowlands", which is a series of low relief plains separated by higher relief escarpments. The escarpments and plains trend roughly east-west and slope gently from south to north. The influence of this topography on the hydrology of the Black Creek watershed is clearly visible in Map 1: Black Creek Watershed Hydrology as tributaries flow in a general north-easterly direction across the roughly "L-shaped" drainage area of the watershed.

Map 1: Black Creek Watershed Hydrology



The subwatersheds used in this report relate to Map 2: USGS HUC 12 Watershed Boundaries and the stream segments discussed can be seen in Figure 1: Streams and Corresponding Subwatersheds.

Map 2: USGS HUC 12 Watershed Boundaries



The following sections describe the hydrologic features and properties of the Black Creek watershed and how their function relates to watershed management.

The main stem of the Black Creek flows for 52.6 miles across the counties of Wyoming, Genesee, Orleans and Monroe until it meets the Genesee River in the Town of Chili (Monroe County) where it empties into the Genesee River. The headwaters of the Black Creek originate at approximately 1,150 feet above sea level in the northern portion of the Town of Middlebury in Wyoming County. The Creek begins as several small tributaries flowing north into Genesee County and coalescing at the Genesee County Park and Forest in the Town of Bethany. The Creek becomes a second-order stream shortly thereafter as smaller streams drain the highland areas of the watershed in the Town of Bethany. The Creek meets the Onondaga escarpment in the Town of Stafford (elev. ~850'), establishing Morganville Falls. Here the Black Creek drops approximately 100 feet in elevation over the course of a half-mile. It is after this point that the Black Creek completes its journey out of the northern foothills of the Alleghany Plateau and enters the rolling terrain typical of the Eastern Great Lakes Lowlands. After flowing a distance of approximately 20 miles from its headwaters, the Black Creek converges with Bigelow Creek (elev. ~620') and becomes a third-order stream. The Bigelow Creek subwatershed consists of a series of four ponds created primarily by small, privately-owned dams. Seven Springs Pond lies near the headwaters of

Bigelow Creek (elev. 823'), followed downstream by Chapin Pond (elev. 820'), Horseshoe Lake (elev. 778'), and Godfrey Pond (elev. 729').

Downstream of Bigelow Creek, a portion of Black Creek feeds Mill Pond (elev. 608'), located just east of Byron Center. Spring Creek meets Black Creek three miles below the convergence of Bigelow and Black Creek, establishing Black Creek as a fourth-order stream. Spring Creek originates just west of the Batavia Airport and north of the City of Batavia draining the rolling agricultural lands found through the Towns of Elba and Byron. After converging with Spring Creek, Black Creek begins to meander for approximately four miles through Bergen Swamp. Here the Creek is joined by the North Branch of the Black Creek (elev. ~570'), a small, meandering tributary that flows south draining large areas of fields and wetlands across the Towns of Clarendon, Sweden and northern Byron and Bergen.

Robins Brook meets the Black Creek on the eastern edge of Bergen Swamp. Slack water created by the Churchville Dam (elev. 565') begins near the Genesee and Monroe County line as the Black Creek runs through the Village of Churchville. Further downstream, Hotel Creek drains the lands adjacent to Interstates 90 and 490 in the Town of LeRoy and meets the Black Creek at Creek-mile point 38 (elev. ~549'). Mill Creek – the last significant tributary of the Black Creek watershed – meets with the Black Creek at Creek-mile point 45 (elev. ~525'). The Mill Creek watershed drains a portion of northern Wheatland and contains large portions of the active floodplain area within the Town of Chili.

At Creek-mile point 52, the Black Creek meets the Genesee River (elev. ~523') just north of the Ballantyne Bridge at the intersections of State Routes 383 and 252 in the Town of Chili. The Creek is known for having significant slack water and frequent flooding in this area, which is created by a combination of factors, both known and suspected. Large volumes of water from the Genesee River converge with the Black Creek Outlet, creating significant back-flow. This situation is suspected to be exacerbated by numerous man-made and natural obstructions on the Black Creek, but is generally thought to be caused primarily by back-water held by the Court Street Dam approximately 6 miles downstream on the Genesee River in the City of Rochester. The dam helps to maintain the levels of the Erie Canal during navigation season, which is often complicated by the high-volumes of water associated with the 2,500 mi^2 Genesee River drainage basin.

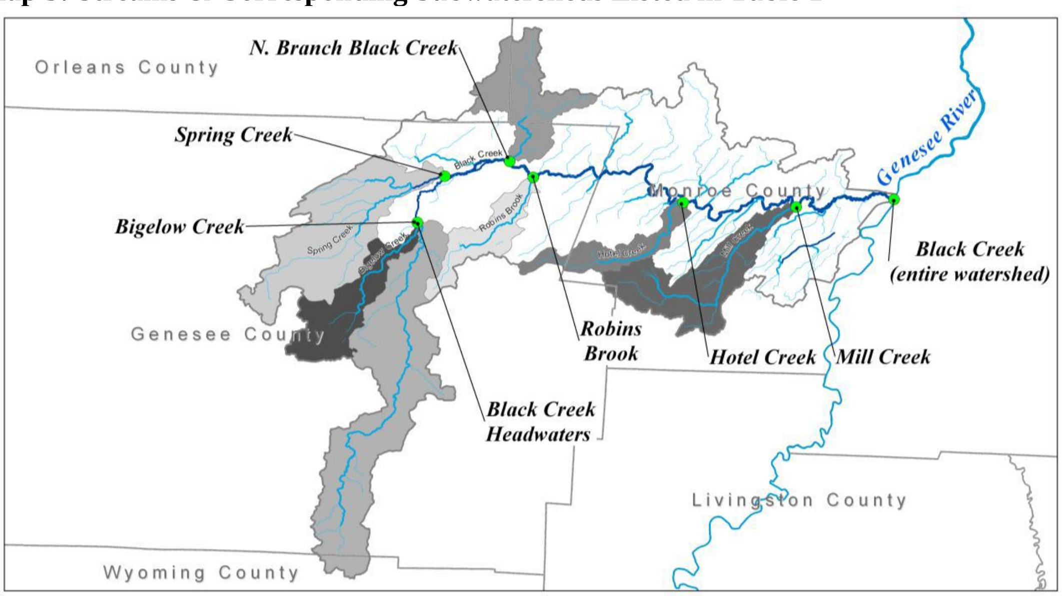
General flow statistics and other fundamental characteristics of the hydrologic network in the Black Creek have been summarized in Table 1. These data were derived from two primary sources – GIS analysis of the National Hydrography Dataset (NHD) and through the web-based USGS New York StreamStats GIS application. StreamStats allows users to obtain streamflow statistics, basin characteristics, and descriptive information for USGS data-collection stations and user-selected ungauged sites.[1] The program can estimate streamflow statistics for ungauged sites either on the basis of regional regression equations or on the basis of the known flows for nearby stream-gauging stations. All of the flow statistics provided in Table 1 are estimates which were derived through a combination of these approaches.

Table 1: Characteristics of Streams and Associated Subwatersheds in the Black Creek Watershed								
	Black Creek	**Black Creek Headwaters (Upstream of Bigelow Creek)**	**Bigelow Creek**	**Spring Creek**	**N. Branch Black Creek**	**Robins Brook**	**Hotel Creek**	**Mill Creek**
Drainage Area (Miles²)	**202**	32.60	12.90	22.10	11.80	6.90	6.21	14.8
Main Channel Stream Length (Miles)	**58.6**	23.10	10.70	13.90	9.50	8.19	10	12.9
Total Stream Network Length (Miles)*	**385.8**	56.80	12.10	39.90	22.60	10.7	11.7	29.3
Mean Annual Precipitation (inches)	**31**	33.60	32.80	32.40	29.90	30.6	30	29.9
Mean Annual Runoff (inches)	**11.1**	13.70	12.90	12.40	9.88	10.6	10	9.93
Basin Lag Factor (hours)	**6.91**	0.8	0.41	0.58	0.82	0.26	0.58	.98
Basin Storage**	**1.73**	0.32	1.8	1.02	2.48	0.81	0.35	2.05
Average basin slope (feet per mi.)	**135**	224	259	156	41.20	186	88.20	139
Minimum daily flow (cfs)	**15**	--	--	--	--	--	--	--
Maximum daily flow (cfs)	**45,700**	--	--	--	--	--	--	--
Average daily stream flow (cfs)	**1,677.7**	--	--	--	--	--	--	--
Mean Annual Flow (cfs)	**1,660**	--	--	--	--	--	--	--

*Stream lengths vary here from those listed in this section due to variations in calculation method. StreamStats includes braided channels and other intermittent stream reaches, creating greater stream lengths in some cases

**Percentage of total drainage area shown as lakes, ponds and swamps

Map 3: Streams & Corresponding Subwatersheds Listed in Table 1



The Black Creek Headwaters is the largest or second largest subwatershed in most categories based on Characteristics of Streams and Associated Subwatersheds in the Black Creek Watershed shown in Table 1, followed in large part by the other upper subwatershed, Spring Creek. This is an important consideration given the nature of the upper part of the Black Creek Watershed: largely agricultural (see Table 4) with steep slopes with a significant number of Section 303(d) Impaired/TMDL Waters (see Priority Waterbodies List (PWL) and Section 303(d) Listing sections below along with Map 5).

The downstream portions of the Black Creek Watershed, that of the Black Creek Outlet and Mill Creek subwatersheds are characterized by low relief, large floodplains (see Floodplain section below), more developed land cover (see Table 5), and outside of the City of Batavia, the highest population density as well as a high percentage of the 303d Impaired/TMDL Waters (see Priority Waterbodies List (PWL) and Section 303(d) Listing sections below along with Map 5).

The mid-section of the Black Creek Watershed, the Robins Brook and Hotel Creek subwatersheds are characterized by fairly high wetland concentration (see Table 3), floodplains (see Floodplain section below), and fairly low slope. This is largely agricultural and forested lands outside of the Village of Churchville and Bergen.

General Characteristics

Table 2: General Characteristics of the Subwatersheds of the Black Creek Watershed

	Black Watershed	Headwaters	Spring Creek	Robins Brook	Hotel Creek	Mill Creek	Black Creek Outlet
Total Area (acres)	129393.17	29628.13	14108.42	23462.37	32108.00	19828.51	10257.74
Total Area (square miles)	202.18	46.29	22.04	36.66	50.17	30.98	16.03
Impervious Cover (acres)	12903.51	3175.06	1204.69	952.27	2913.09	3393.00	1265.40
% Impervious Cover	9.97%	10.72%	8.54%	4.06%	9.07%	**17.11%**	**12.34%**
Forest Cover (acres)	14933.93	3276.69	1070.36	2021.97	4550.10	2833.47	1181.34
% Forest Cover	11.54%	11.06%	**7.59%**	**8.62%**	14.17%	14.29%	11.52%
Turf Cover (acres)	39318.33	10166.34	4472.49	5839.07	10014.67	5901.79	2923.98
% Turf Cover	30.39%	34.31%	31.70%	24.89%	31.19%	29.76%	28.51%
Riparian Cover (acres)	12063.36	2714.09	1410.6	2233.20	3148.53	2368.32	188.62
% Riparian Cover	9.32%	9.16%	10.00%	9.52%	9.81%	11.94%	**1.84%**
Wetlands (acres)	18503.22	1392.52	1086.348	6428.69	5008.85	2419.08	2195.16
% Wetlands	14.30%	**4.70%**	**7.70%**	27.40%	15.60%	12.20%	21.40%
Floodplains (acres)	12467.53	1275.01	311.59	3145.24	2819.85	883.70	4032.13
Public Lands (acres)	5277.08	576.21	0.00	1234.48	1263.72	1660.18	542.49
Population	52913.00	7882	3648	3449	10612	19725	7597
Density-Population[a]	261.72	170.26	165.48	94.08	211.53	**636.66**	**473.99**
Commercial Land	339	**132**	29	2	53	**101**	22
Industrial Land	30	**18**	0	0	6	5	1
Aquifers (acres)	9748.95	2018.56	32.66	0.00	3355.19	4244.82	97.72
Road Stream Crossings	115	**43**	11	5	**21**	**26**	9
SPDES	5	1	1	0	2	1	0
Large Parcels [b]	2331	**552**		397	**586**	328	209
[a]Density-Population/Square Miles							
[b] Large Parcel at least 10 acres							

Land Use and Land Cover

Land activities and water quality are inherently linked to one another. The type of activities that take place on the land will directly influence the quality and characteristics of the water that runs off of it. Understanding the characteristics of the land within a watershed area is therefore a central aspect of watershed planning. Land use characteristics such as public lands, commercial land, industrial land, developed open space, developed low intensity, developed medium intensity, developed high intensity, barren land, along with general agricultural land categories are listed in Tables 2 and 4.

Land Cover

Land cover refers to the type of features present on the surface of the earth. For example, agricultural fields, water, pine forests, and parking lots are all land cover types. Land cover may refer to a biological categorization of the surface, such as grassland or forest, or to a physical or chemical categorization such as concrete.

Land cover was assessed in the Black Creek watershed utilizing imagery associated with the National Land Cover Dataset. This dataset was developed by the Multi-Resolution Land Characteristics (MRLC) Consortium, a group of federal agencies who first joined together in 1993 (MRLC 1992) to purchase satellite imagery for the conterminous U.S. to develop the NLCD. In 1999, a second-generation MRLC consortium was formed to purchase three dates of satellite imagery for the entire United States (MRLC 2001) and to coordinate the production of a comprehensive land cover database for the nation called the National Land Cover Database (NLCD 2001). This database was once again updated utilizing new data from 2006.

A summary of 2006 NLCD data focusing on natural land cover categories by subwatershed is shown in Table 2 and can be seen in the Forest Cover (acres), % Forest Cover, Turf Cover (acres), % Turf Cover, Riparian Cover (acres), and % Riparian Cover categories.

Table 3: 2006 NLCD Natural Land Cover within the Black Creek Watershed

HUC 12 Subwatershed	**Subwatershed Area (Acres)**	***% Forest***	***% Wetland***	**Natural Cover Total**
Black Creek Headwaters Subwatershed	29,622.33	*11.1%*	***4.7%***	**15.7%**
Spring Creek Subwatershed	14,103.39	***7.6%***	***7.7%***	**15.3%**
Robins Brook Subwatershed	23,455.09	*8.6%*	*27.4%*	36.1%
Hotel Creek Subwatershed	32,102.70	*14.2%*	*15.6%*	29.8%
Mill Creek Subwatershed	19,826.50	*14.3%*	*12.2%*	26.5%
Black Creek Outlet Subwatershed	10,254.18	*11.5%*	*21.4%*	33.0%
Black Creek Watershed	**129,368.19**	***11.5%***	***14.3%***	**25.9%**

Over all this is a largely agricultural watershed. As the figures above indicate, natural cover is relatively low throughout the watershed, with the highest percent natural cover found in the Robins Brook and Black Creek Outlet subwatersheds. The highest percentage of natural cover is found in the Robins Brook subwatershed at 36.1%. Bergen Swamp is located in this watershed, which would explain this high degree of natural cover relative to other subwatersheds. Black Creek Outlet subwatershed similarly has a high percentage of natural cover relative to the entire watershed, which is found primarily in the Rural-Agricultural and Agricultural-Conservation zoning districts within the Town of Chili (which also corresponds with the floodplain area). A relatively low percent of the important categories of forest and wetland are found in the Spring Creek and Black Creek Headwaters subwatersheds. The Robins Brook subwatershed has a relatively low percent of forest cover as well. With the exception of the City of Batavia and some of the surrounding area this is likely due to the agricultural nature of these subwatersheds (see Table 4, 2006 NLCD Land Cover – Subwatersheds of the Black Creek Watershed, Pasture Hay and Cultivated Crops Categories) and overall, the watershed average natural cover percentage of 25.9% is again indicative of the watershed's intense agricultural character. A full explanation of 2006 NLCD categories and results by subwatershed is provided in Table 4 below.

Table 4: 2006 NLCD Land Cover – Subwatersheds of Black Creek Watershed

	Headwaters		Spring Creek		Robins Brook		Hotel Creek		Mill Creek		Outlet	
NLCD Category	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
11 - Open Water	113.20	0.4	6.89	0.0	28.02	0.1	46.04	0.1	59.82	0.3	21.79	0.2
21 - Developed, Open Space	2,073.83	7.0	676.53	4.8	733.01	3.1	2,022.46	6.3	2,254.86	11.4	940.51	9.2
22 - Developed, Low Intensity	856.22	2.9	374.07	2.7	204.16	0.9	766.82	2.4	872.45	4.4	235.74	2.3
23 - Developed, Medium Intensity	183.03	0.6	120.54	0.9	14.01	0.1	94.07	0.3	228.84	1.2	79.62	0.8
24 - Developed, High Intensity	67.16	0.2	27.80	0.2	0.44	0.0	27.80	0.1	38.47	0.2	7.34	0.1
31 - Barren Land	159.46	0.5	0.00	0.0	0.00	0.0	145.22	0.5	29.58	0.1	0.00	0.0
41 - Deciduous Forest	2,610.69	8.8	930.28	6.6	1,821.19	7.8	3,964.86	12.4	2,377.40	12.0	913.38	8.9
42 - Evergreen Forest	135.66	0.5	16.23	0.1	12.90	0.1	52.93	0.2	24.24	0.1	13.12	0.1
43 - Mixed Forest	530.19	1.8	122.32	0.9	187.70	0.8	532.86	1.7	431.00	2.2	253.75	2.5
52 - Shrub/Scrub	469.92	1.6	68.94	0.5	153.90	0.7	295.79	0.9	237.07	1.2	108.97	1.1
71 - Grass/ Herbaceous	51.37	0.2	10.01	0.1	43.37	0.2	93.85	0.3	75.61	0.4	23.80	0.2
81 - Pasture Hay	10,115.41	34.1	4,463.46	31.6	5,794.72	24.7	9,910.80	30.9	5,827.63	29.4	2,900.25	28.3
82 - Cultivated Crops	10,876.66	36.7	6,199.70	44.0	8,027.79	34.2	9,133.53	28.5	4,946.95	25.0	2,556.87	24.9
90 - Woody Wetlands	1,287.89	4.3	1,070.83	7.6	6,199.26	26.4	4,708.10	14.7	2,268.43	11.4	2,093.18	20.4
95 - Emergent Herbaceous Wetlands	91.63	0.3	15.79	0.1	234.63	1.0	307.57	1.0	154.12	0.8	105.86	1.0
Total	29,622.33		14,103.39		23,455.09		32,102.70		19,826.50		10,254.18	

Land Cover in the Riparian Zone

The land area directly adjacent to streams is considered to be among the most dynamic and sensitive components of a watershed and has a significant influence on water quality. A stream that is surrounded by tree cover and vegetation, for example, will benefit from the cooling effects of shade from the tree canopy above and bank stabilization bank from tree roots and other types of plant cover below. Detritus from surrounding plants will also be contributed to the stream as a source of nutrition and habitat for a variety of animals and organisms. Conversely, streams surrounded by impervious, hard, non-vegetative cover or agricultural cover will likely experience greater soil loss and more impacts from nonpoint source pollution.

In an effort to ascertain the level of natural cover within areas surrounding streams, a 300' buffer was created around each tributary within the watershed (150' linear distance perpendicular from the stream on both sides of the stream). The riparian buffer linear distance of 150' (45.72m) was selected in an effort to accommodate 30m² cells used by the NLCD raster grid. While correlations exist between various riparian buffer widths and specific ecological, chemical and stream morphological conditions, no such implications are made here with this selection of the 150' distance. Rather, the goal is simply to provide a snapshot of land cover in and around the riparian zone throughout the watershed.[2] Land cover analysis using the 2006 NLCD was conducted by subwatershed specifically in this 300' buffer zone. As the chart below indicates, nearly 16,000 acres of land was identified to be within this riparian area. Results of the land cover analysis are as follows:

Table 5: Analysis of Natural Land Cover within a 300' Buffer of All Streams, by Subwatershed					
HUC 12 Subwatershed	**Riparian Buffer Area (Acres)**	**% Forest**	**% Wetland**	**Natural Cover Total**	**% Impervious**
Black Creek Headwaters Subwatershed	3,110	*20.4%*	*19.6%*	**39.9%**	**<1%**
Spring Creek Subwatershed	1,579	*10.2%*	*26.5%*	**36.8%**	**<1%**
Robins Brook Subwatershed	**2,645**	***10.4%***	***55.2%***	**65.7%**	**<1%**
Hotel Creek Subwatershed	3,663	*18.1%*	*36.7%*	**54.9%**	**<1%**
Mill Creek Subwatershed	2,749	*17.9%*	*30.9%*	**48.7%**	**1.7%**
Black Creek Outlet Subwatershed	2,216	*11.3%*	*38.2%*	**49.5%**	**1.2%**
Black Creek Watershed	**15,962**	***12.3%***	***34.6%***	**46.9%**	**<1%**

It is again important to emphasize that NLCD land cover classification is generalized on a 30x30 meter scale (.22 acres). Random ground-truthing of NLCD land cover pixels against orthophotos generally reveals a diverse array of actual land cover types within a given NLCD 30x30 meter cell area. Results of this analysis are therefore estimates and should be viewed with a degree of caution.

As Table 5 illustrates, the percentage of natural cover in lands adjacent to stream corridors within the Black Creek watershed range between 36.8% in the Spring Creek subwatershed to 65.7% in the Robins Brook subwatershed, with an overall total average of 46.9% natural cover. The large proportion of natural cover in the Robins Brook subwatershed is to be expected due to the presence of the forested wetlands in the Bergen Swamp, a major natural feature of this area. Table 2 also includes the percentage of impervious cover by subwatershed, which is a good indicator of aquatic system health.[3] Impervious cover is very low throughout the riparian area across the entire Black Creek watershed, with the highest level of riparian area impervious cover found in the Mill Creek subwatershed at 1.7%.

Unabridged riparian area land cover figures are provided in Table 6 of this report and offer further insight regarding the range of land cover in this sensitive area of the Black Creek watershed. The remainder of land cover in the Black Creek watershed riparian area appears to be predominantly agricultural in nature, including pasture and cultivated crops. This is the predominant land cover in the Spring Creek subwatershed (58% hay and crops combined) and the Black Creek Headwaters subwatershed (51% hay and crops combined), while accounting for smaller, although not insignificant, proportions in the remaining subwatersheds.

Table 6: 2006 NLCD Land Cover – 150' Riparian Buffer Analysis within Subwatersheds of Black Creek Watershed												
	Headwaters		Spring Creek		Robins Brook		Hotel Creek		Mill Creek		Outlet	
NLCD Category	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**
11 - Open Water	30.2	1.0%	3.8	0.2%	8.5	0.3%	28.7	0.8%	16.9	0.6%	20.5	0.9%
21 - Developed, Open Space	155.5	5.0%	60.0	3.8%	66.7	2.5%	143.2	3.9%	147.4	5.4%	177.0	8.0%
22 - Developed, Low Intensity	25.4	0.8%	11.8	0.7%	9.8	0.4%	38.0	1.0%	51.8	1.9%	25.4	1.1%
23 - Developed, Medium Intensity	6.4	0.2%	4.2	0.3%	0	0	9.6	0.3%	23.4	0.8%	13.6	0.6%
24 - Developed, High Intensity	0	0%	0	0%	0	0%	3.1	0.1%	4.4	0.2%	0.4	0%
31 - Barren Land	0	0%	0	0%	0	0%	1.1	0.0%	6.9	0.3%	0	0%
41 - Deciduous Forest	472.8	15.2%	127.2	8.1%	234.4	8.9%	533.7	14.6%	373.2	13.6%	182.8	8.2%
42 - Evergreen Forest	10.7	0.3%	6.9	0.4%	1.8	0.1%	8.0	0.2%	7.1	0.3%	4.2	0.2%
43 - Mixed Forest	150.1	4.8%	27.6	1.7%	39.6	1.5%	122.8	3.4%	111.0	4.0%	62.9	2.8%
52 - Shrub/Scrub	79.8	2.6%	7.6	0.5%	16.2	0.6%	30.0	0.8%	26.0	0.9%	16.2	0.7%
71 - Grass/ Herbaceous	12.5	0.4%	0.0	0.0%	1.1	0.0%	4.9	0.1%	8.2	0.3%	5.3	0.2%
81 - Pasture Hay	**1116.0**	**35.9%**	**546.0**	**34.6%**	435.4	16.5%	904.0	24.7%	714.6	26.0%	407.0	18.4%
82 - Cultivated Crops	472.6	15.2%	368.7	23.4%	379.0	14.3%	518.6	14.2%	426.1	15.5%	474.6	21.4%
90 - Woody Wetlands	542.0	17.4%	407.4	25.8%	**1377.1**	**52.1%**	**1187.1**	**32.4%**	**768.6**	**28.0%**	**771.3**	**34.8%**
95 - Emergent Herbaceous Wetlands	36.5	1.2%	7.3	0.5%	75.8	2.9%	129.9	3.5%	62.9	2.3%	55.2	2.5%
Total	3110.4		1,578.6		2645.4		3662.8		2748.6		2216.4	

Impervious Cover

The Center for Watershed Protection (CWP) defines impervious cover as "any surface in the urban landscape that cannot effectively absorb or infiltrate rainfall."[4] 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.[5] 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 macroinvertebrates; 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.

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 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.

Impervious cover is obviously highest in urbanized areas within the watershed, such as the NE of the City of Batavia, Villages of Churchville and Bergen and the suburban are around the Towns of Riga and Chili.

The density of buildings and streets creates a high degree of impervious cover in these areas. Overall, the analysis indicates that IC is not a major concern throughout most of the Black Creek watershed when measured by this standard. Several large catchments near the Batavia area are indicating high %IC levels, but these are at the low-end of the 10 – 24.9% range; this is also the case in the area near the Towns of Riga and Chili. The Village of Churchville does have several small catchments with a high %IC with one small catchment measuring IC greater than 25%. Therefore, as Table 2 indicates, when prioritizing the subwatersheds for impervious cover, the highest percent of impervious cover in the Black Creek Watershed is in the downstream subwatersheds of Mill Creek and Black Creek Outlet. The ICM therefore provides a starting point for further research into how these areas affect local aquatic health.

Floodplains

The National Flood Insurance Program (NFIP) is a federal program that enables property owners to purchase affordable flood insurance. Before the NFIP, flood insurance was generally unavailable. The program is based on a partnership between communities and the federal government in which the community adopts floodplain management regulations to reduce flood risks and the federal government makes flood insurance available within the community.

The National Flood Insurance Program uses the 100-year flood as the standard on which to base its regulations. This is a national standard used by virtually every Federal and most state agencies, including New York State agencies, in the administration of their programs as they relate to floodplains. The technical and engineering methods involved in determining the magnitude of these floods are well established. Although the 100-year flood is the event estimated to have a one percent chance of being equaled or exceeded each year, there is no guarantee that a flood of this magnitude could not occur in less than 100 years or that one will necessarily occur in each 100 year period at a precise location.

Flood Insurance Rate Maps (FIRM) are produced by the Federal Emergency Management Agency and provide the official record of special flood hazard areas. While paper or flat FIRM maps are generally available online for every community in the Black Creek watershed, corresponding digital GIS data pertaining to the flood boundary are not available for every Black Creek watershed community through state or federal agencies. Furthermore, some portions of watershed communities have never been mapped by FEMA at all, creating significant and sometimes perplexing gaps in the floodplain record. (In order to create efficiencies in the mapping process, FEMA likely elected to skip certain areas which were not prone to frequent flooding or had low population density). Information provided by FEMA has therefore been combined with information created by local offices and agencies in an effort to create a comprehensive picture of the 100-year flood zone across the entire Black Creek watershed.

Map 4: Floodplains illustrates those areas estimated to be within the 100-year flood zone. While these boundaries are generally very close to the actual boundaries as indicated on official FIRM maps, some variation is evident from place to place. Maps and associated data are therefore for planning purposes only and should not be used to determine the level of flood hazard in any particular area.

Map 4: Floodplains

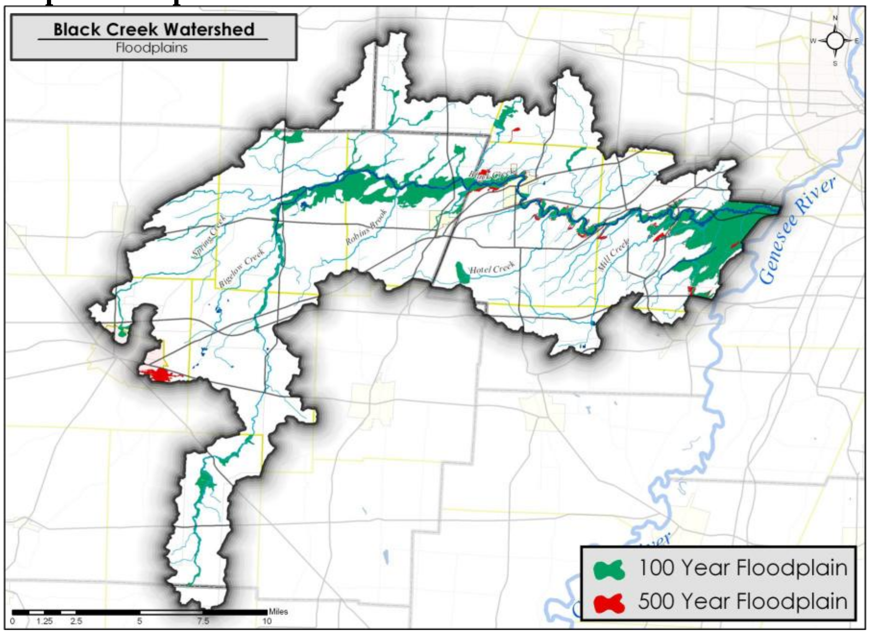


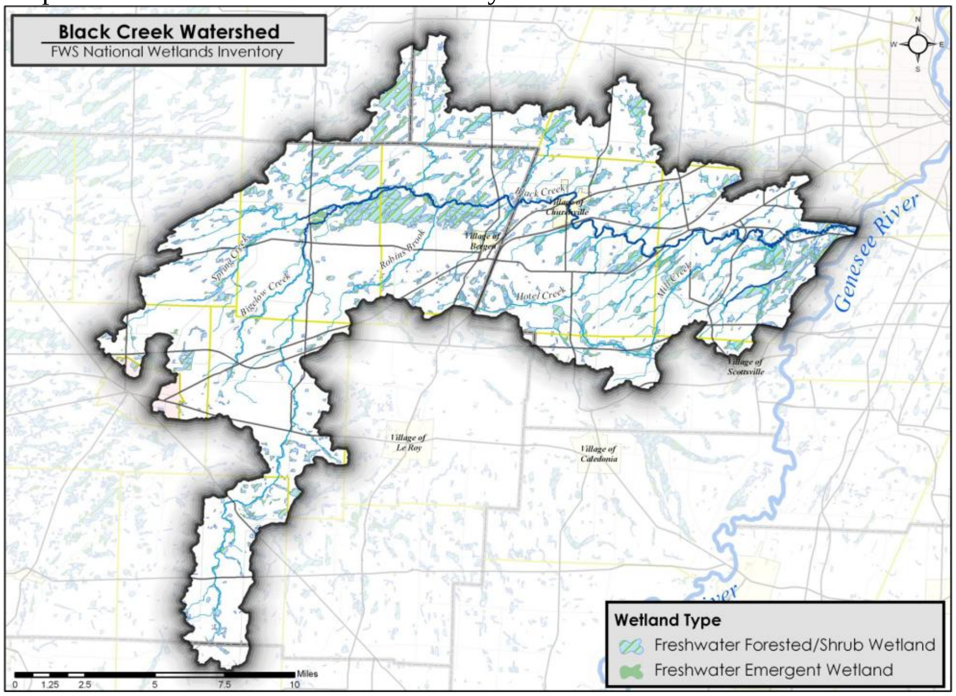
Table 7: Analysis of 100-Year Flood Zone in the Black Creek Watershed			
Subwatershed	**Acres at or below 100-year flood elevation**	**% of Subwatershed Area**	**% of Black Creek Watershed Area**
Black Creek Headwaters	1,263.7	4%	1%
Spring Creek	311.6	2%	0.2%
Robins Brook	2,339.0	10%	2%
Hotel Creek	2,819.9	9%	2%
Mill Creek	883.7	4%	1%
Black Creek Outlet	4,032.1	39%	3%
Black Creek Watershed	**11,650.0**	**--**	**9%**

Analysis of the 100-year base flood elevation (1% flood risk) indicated that 9% of the total land area within the Black Creek watershed is within this zone. The Black Creek Outlet subwatershed has the highest concentration of lands in the 100-year floodplain, with 4,032 acres accounting for approximately 39% of total subwatershed area. Full results of this analysis are provided in Table 7.

Wetlands

Significant areas of wetlands exist in the Black Creek watershed, particularly in the northern half of the watershed where a post-glacial lake once existed, likely contributing to the wetlands occupying the landscape there today. Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface.[6] Wetlands serve a number of important functions within a watershed, including sediment trapping, chemical detoxification, nutrient removal, flood protection, shoreline stabilization, ground water recharge, stream-flow maintenance, and wildlife and fisheries habitat.

Map 5: FWS National Wetlands Inventory



In 1986, the Emergency Wetlands Resources Act mandated that the US Fish and Wildlife Service complete the mapping and digitizing of the Nation's wetlands. The result is the Wetlands Geospatial Data Layer of the National Spatial Data Infrastructure. This digital data provides highly-detailed information on freshwater wetlands and ponds with numerous classifications and sub-classifications. Federal wetlands (referred to as the National Wetlands Inventory (NWI)) in the Black Creek watershed are illustrated on Map 5. A subwatershed analysis of the NWI geospatial information is provided in Table 8, US Fish and Wildlife Service National Wetlands Inventory for Black Creek Watershed. As indicated above a relatively low percent of wetlands are found in the Spring Creek and Black Creek Headwaters subwatersheds.

Table 8: US Fish and Wildlife Service National Wetlands Inventory for Black Creek Watershed

Subwatershed	Total Acreage	Freshwater Emergent Wetland	Freshwater Forested/ Shrub Wetland	Freshwater Pond	Lake	Other	Riverine
Black Creek Headwaters	2,608.1	*407.0*	*1,968.0*	*170.6*	*59.0*	*3.5*	*2,608.1*
Spring Creek	1,359.1	*147.2*	*1,155.8*	*52.1*	*0*	*4.0*	*0*
Robins Brook	5,864.7	*353.6*	*5,405.1*	*52.7*	32.9	*3.6*	*16.8*
Hotel Creek	5,276.1	*612.3*	*4,440.0*	*73.1*	*0*	*0*	*150.6*
Mill Creek	2,754.9	*359.5*	*2,228.0*	*112.7*	*0*	*0*	*54.6*
Black Creek Outlet	2,592.4	*367.4*	*2,097.2*	*41.3*	*0*	*4.3*	*82.1*
Black Creek Watershed	20,455.2	*2,247.0*	*17,294.1*	502.6	*91.9*	*15.4*	*304.2*

3. Water Quality

Priority Waterbodies List (PWL)

States must complete periodic assessments of water quality and habitat conditions in order to evaluate whether standards are met, and whether the designated uses are supported. In New York, surface waters exhibiting symptoms of degradation are placed on a Priority Waterbodies List (PWL), and categorized based on the severity of water quality and/or habitat degradation.

The most recently published Priority Waterbodies List (2003) evaluates 3 segments of Black Creek—upper, middle and lower Black Creek, each with its associated minor tributaries, and Bigelow Creek, a major tributary of the upper segment of the creek (Table 9).

Table 9: Priority waterbody listings (PWL) for segments of Black Creek and its tributaries (NYSDEC PWL 2003)

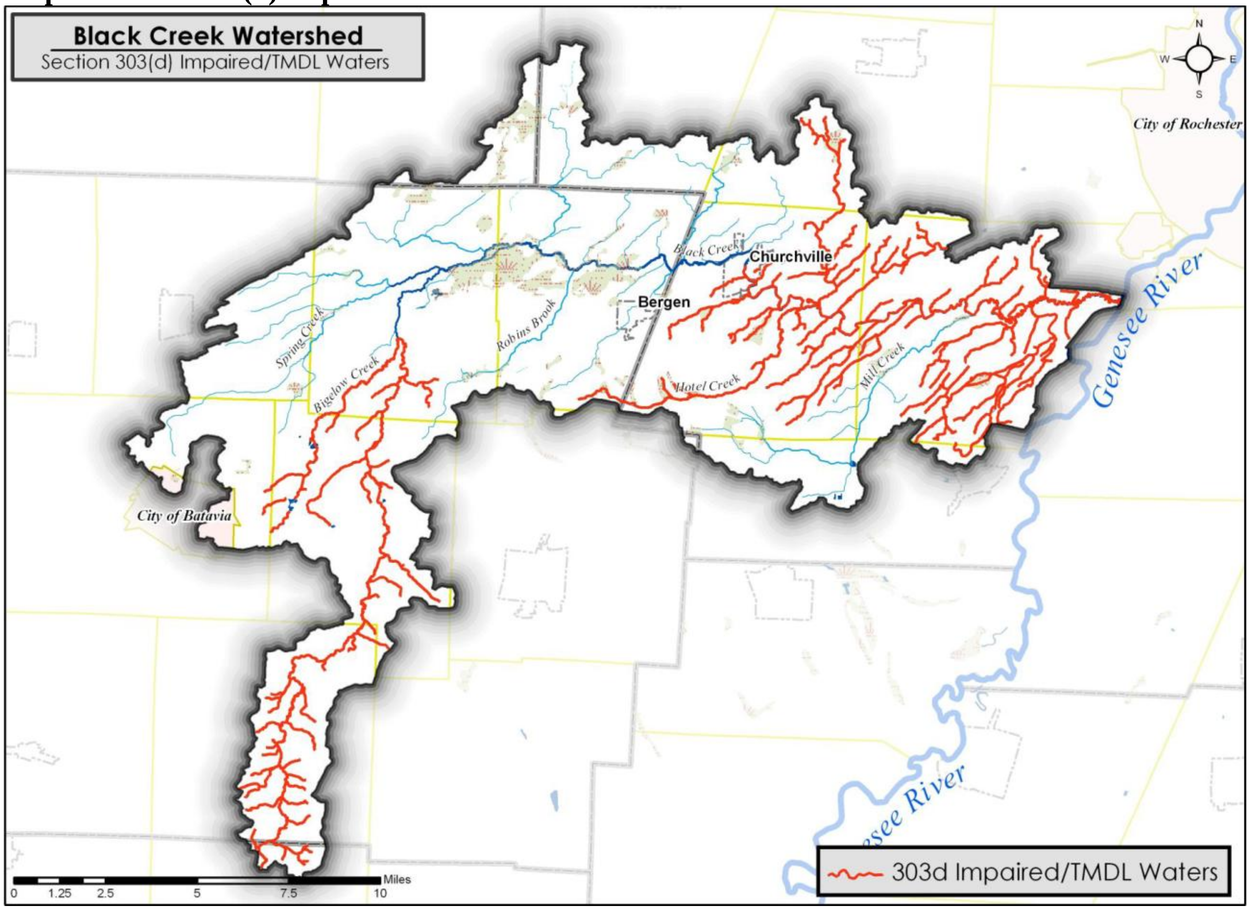
Black Creek Segment	**Use Impairment**	**Cause Source**	**Class**	**W B Category**
Upper Black Ck & Minor Tribs.	Aquatic life known to be **impaired** Recreation known to be **stressed**	nutrients agriculture; municipal	C	Impaired
Bigelow Creek and Tribs. (Trib. of upper Black Ck)	Aquatic life known to be **impaired** Recreation known to be **stressed**	nutrients agriculture	C	Impaired
Middle Black Ck & Minor Tribs.	Aquatic life known to be **stressed** Recreation known to be **stressed** Aesthetics known to be **stressed**	algal/weed growth; nutrients	C	Minor Impacts
Lower Black Ck & Minor Tribs.	Aquatic Life known to be **impaired** Recreation known to be **stressed** Aesthetics known to be **stressed**	nutrients agriculture/municipal	C	Impaired

Section 303(d) Listing

In New York, waterbodies with designated uses considered precluded or impaired are eligible for placement on the 303(d) list. This list is named for the section of the Clean Water Act requiring states, territories, and authorized tribes to assess water-quality conditions within their jurisdictions and compare the data to promulgated standards. The 303(d) list is a product of this assessment; water bodies are placed on the list when additional controls are needed to bring water quality into compliance with standards and criteria.

Based on review of the Final New York State (June 2010) 2010 Section 303(d) List of Impaired Waters Requiring a TMDL/Other Strategy (http://www.dec.ny.gov/docs/water_pdf/303dlistfinal10.pdf), Black Creek was listed in 2004 with impairment requiring Total Maximum Daily Load (TMDL) development for phosphorus from agriculture and municipal sources. The two segments noted are both Class C waters, and are designated as “Black Creek, Lower and minor tribs (0402-0033)” and “Black Creek, Upper and minor tribs (0402-0048)” (Map 6). Currently NYSDEC has no Total Maximum Daily Load (TMDL) standards for flowing waters.

Map 6: Section 303(d) Impaired/TMDL Waters



Macroinvertebrates

The community of animals living in a waterbody is a good indication of the qualities of the water, especially the qualities important for supporting organisms. In particular, evaluation of the community of invertebrate animals—largely insects—living on the bottom of a stream has been widely used as an indicator of water quality. These bottom-dwelling invertebrate animals, large enough to be seen without the aid of a microscope, are referred to as benthic macroinvertebrates. Some of these animals are sensitive to pollution, and since many of them live in the stream for a year or more, they integrate the condition of the water over time, unlike so-called "grab samples" for chemical analysis that represent only a snapshot of conditions. The NYSDEC, the USEPA and other environmental regulatory agencies publish standard techniques for using the community of benthic macroinvertebrates to assess water quality.

Table 10: NYSDEC preliminary analysis of the assessment of level of impact on water quality in Black Creek and tributaries from benthic macroinvertebrate data collected as part of the NY-DEC RIBS program, 14 September 2004 (provided by Peter Lent)				
	Black Creek North of Byron 200 m Upstream Rt 237 Bridge	**Black Creek Below Churchville 80m Downstream Burnt Mill Rd Bridge**	**Spring Creek North of Byron 20m Downstream RT 237 Bridge**	**Mill Creek Chili Center Immediately Above Stottle Rd Bridge**
Total Number in Sample	100	100	100	100
Number of Species in Sample	21	11	12	14
Biological Assessment Profile (BAP)	5.9	3.8	3.9	4.2
Overall Rating of Impact	SLIGHT	MODERATE	MODERATE	MODERATE

The benthic macroinvertebrate community of Black Creek and a number of its tributaries were scheduled for assessment in the NY-DEC Rotating Integrated Basin Studies (RIBS) program in 2004 and 2009, but those data have not yet formally been made available by the DEC. Table 10 includes a summary of the preliminary data analysis made available by DEC from their 2004 monitoring of Black Creek. Table F-2 in Appendix F of the 2012 Black Creek Watershed Characterization report (see http://www.gflrpc.org/Publications/BlackOatka/Characterization/BlackCreekWatershed/index.htm) includes a summary of the preliminary data from the 2004 study; additional explanation and detail is provided therein.

Water Quality Analysis

A consideration when prioritizing the Black Creek subwatersheds is the work that was done by Mellissa Jayne Winslow in a thesis submitted to the Department of Environmental Science and Biology of the State University of New York College at Brockport February 2012 entitled "*Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model*." The report acknowledges the United States Department of Agriculture for funding this project and the Research Foundation of SUNY and Dr. Joseph Makarewicz for the opportunity to work as a graduate assistant.

The Methods section of the *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report indicates the following:

> This study will assess the sources and sinks of sediment, nutrients, and bacteria in the Black Creek watershed and will evaluate its impact on the Genesee River. It will also determine what best management practices will be most effective at reducing the flux of sediments and phosphorus into the creek. Finally, it will identify a phosphorus concentration for Black Creek that is a reasonable water quality target from the point of view of watershed management.
>
> Specific objectives of the *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report are listed as follows:
>
> > *Objective 1:* Determine the contribution of Black Creek and its tributaries to the watershed and to the Genesee River using discharge measurements and water quality monitoring.

Objective 2: Employ the stressed stream analysis approach to evaluate the relative impact that point sources such as wastewater treatment plants and the surrounding land uses have on water chemistry of stream segments throughout Black Creek.

Objective 3: Develop and calibrate a hydrological model (Soil and Water Assessment Tool or SWAT) to determine the allocation of pollution fluxes from different parts of the watershed, evaluate the role that point sources and septic fields have at the watershed scale, and determine which BMPs will be most effective at reducing the load of phosphorus to a reasonable level.

The *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report indicates the following watershed-wide:

- Sources of these pollutants from the Black Creek watershed include improperly managed cropland and pastures, dairy manure application, and effluent discharges from wastewater treatment plants.
- The annual losses (June 2010 through May 2011) of total phosphorus (TP), total nitrogen (TN), and total coliform bacteria from the Black Creek watershed were 16.5 MT/yr, 349.4 MT/yr, and 7.0E15 CFU/yr, respectively, where most of the losses occurred in the upper portion of the watershed. Impacted tributaries (Bigelow Creek and Spring Creek) had the highest areal loads of nutrients and bacteria and were a focus for remediation. More than 70% of the TP load was found to be due to anthropogenic sources including but not limited to manure applications from Confined Animal Feeding operations, the Bergen wastewater treatment plant, and nonpoint agricultural practices throughout the watershed.
- Sediment loss, on the other hand, was the highest in the downstream reaches of Black Creek where 73% of the total sediment load (8,360.6 MT/yr) occurs due to excessive flooding and stream bank erosion during events. These findings were used to calibrate a SWAT model for Black Creek that simulated the impact of implementing several Best Management Practices (BMPs) to reduce phosphorus and sediment loads. Individual BMPs reduced TP loads from Black Creek at Lower BC anywhere from 0 to 28% and sediment 0 to 84%.
- A holistic approach to watershed remediation using a combination of several effective BMPs focusing on major contributors of phosphorus and sediment reduced TP 28% and total suspended solids (TSS) 73%. This remedial action plan, if implemented, can reach a water quality target of 65 μg P/L proposed by the Department of Environmental Conservation, which would reduce the annual TP concentration from 79.6 μg P/L to 38.3 μg P/L. This scenario can be used to determine an appropriate Total Maximum Daily Load for Black Creek that will help attain the ultimate goal of reducing the impairments of nearshore Lake Ontario.

As noted, the Black Creek watershed is dominated by agriculture and as such much of the issues evident in the evaluation and prioritization of the subwatersheds is based on that dominate land use.

Upper Subwatersheds

The Black Creek Headwaters is the largest or second largest subwatershed in most categories based on Characteristics of Streams and Associated Subwatersheds in the Black Creek Watershed shown in Table 1. This is an important consideration given the nature of the upper part of the Black Creek Watershed: largely agricultural (see Table 4) with steep slopes and a significant number of Section 303(d) Impaired/TMDL Waters (see Map 5).

The *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report indicates the following for the Upper Black Creek (including Black Creek Headwaters subwatershed)*:*

- The Upper BC subbasin, an agriculturally dominated segment, is losing TP and SRP at a higher rate than other main stem reaches.
- The results of areal load and an initial segment analysis through field work in the Black Creek watershed suggest that the Bigelow Creek subwatershed is a major contributor to the high phosphorus, sediment, and bacteria issues in Upper BC. Most of the phosphorus and sediment load is due to the large amount of agriculture (82%) in this area.
- In general, the most effective agricultural operations found through model simulations to reduce TP and TSS include buffer strips (24% reduction in TP, 43% reduction in TSS) and terracing (24% reduction in TP, 29% reduction in TSS).
- The sources within this segment that are of the highest concern are the large dairy farms in the headwaters of Black Creek as well as agriculture within the Bigelow Creek tributary. These farms located in the Upper Black Creek subbasin likely have a large impact on the water quality of downstream systems. However, Makarewicz and Lewis[7] have shown that proper management (buffer strips, no tillage farming, grassed waterways, erosion control weirs, construction of retention ponds and gully plugs, and total farm planning) of subwatersheds dominated by dairy cattle can lead to significant reductions of nutrient loss from watersheds in the Finger Lakes Region.
- The BCSWAT model was used to simulate potential management practices within the Upper Black Creek segment to reduce TP and TSS load. The most effective simulated agricultural BMPs to reduce the phosphorus load from the Upper BC segment were retiring all agriculture (41% reduction), grassed waterways (28% reduction), and conservation tillage (21% reduction) and to reduce sediment loss were buffer strips (62% reduction), conservation tillage (25% reduction), and contouring (25% reduction). Because these practices provide the largest reduction in sediment and phosphorus in this segment, they are the most appropriate options for agricultural management.
- Through segment analysis conducted in the field it was determined that nutrient losses in the Upper BC segment are highly influenced by the runoff from manure application fields of CAFOs in the headwaters (Fig. 54). Manure application areas are an important source of phosphorus because P applied to cropland (row crops and hay) through manure is often in excess of the growth requirements of the crop.[8] The amount of phosphorus in runoff is also relative to the history of manure applications and soil phosphorus buildup.[9] Therefore these BMPs (grassed waterways, conservation tillage, buffer strips, and contour farming) would be most applicable to the croplands where manure from the CAFOs is applied as fertilizer. Another option is to manage the effects of runoff from the corn silage that was found to contribute high concentrations of TP to Black Creek by either applying buffer strips, providing a better containment system, or moving the silage farther from the stream.
- Another option to reduce the loss of P and sediment from the watershed in the headwaters of Black Creek, other than applying cropland management practices, is to remove the application of manure as fertilizer from CAFO operations. In doing so, the impact on water quality due to the runoff of manure from croplands and the overall effect of CAFO operations would be eliminated from the watershed. If the manure produced by CAFOs in this area were used in another manner rather than as crop fertilizer, the phosphorus load to Upper BC could be reduced by 17%. Alternative manure disposal could include anaerobic digestion, liquid storage, or stacking which would reduce the nonpoint runoff of manure applied to cropland. This would be a quick and fairly cost effective fix to reduce the loss of TP from farmland. Dairy farm operations are the largest source of nutrients and sediments in the headwaters of Black Creek, and it is therefore important to investigate the possible management practices that will reduce their impact on water quality downstream. The storage of manure from these operations is a feasible solution to abate this large source of P.

Therefore, given the nature of this subwatershed and the type of agriculture the *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report recommended the following: a greater use of buffer strips and terracing to reduce TP and TSS; grassed waterways; conservation tillage; reduction in manure application; the use of better containment systems or moving the silage farther from the stream to reduce phosphorus loading; and buffer strips, conservation tillage, and contouring to reduce sediment loss. Alternative manure disposal could include anaerobic digestion, liquid storage, or stacking, which would reduce the nonpoint runoff of manure applied to cropland.

Middle Subwatersheds
The mid-section of the Black Creek Watershed, includes Spring Creek, Robins Brook, the North Branch Black Creek, and Hotel Creek.

The Spring Creek subwatershed is the largest or second largest subwatershed in most categories based on Characteristics of Streams and Associated Subwatersheds in the Black Creek Watershed shown in Table 1, followed in large part by the other upper subwatershed, the Black Creek Headwaters. This is an important consideration given the nature of the upper part of the Black Creek Watershed: largely agricultural (see Table 4) with relatively low forest cover (see Table 2), steep slopes, a significant number of Section 303(d) Impaired/TMDL Waters (see Map 5), and an overall macroinvertebrate impact rating of moderate (see Table 10).

The Robins Brook and the North Branch Black Creek is characterized by fairly high wetland concentration (see Table 3), floodplains, and fairly low slope. This too, is largely agricultural lands. The wetlands and floodplains should be considered with all potential development.

The Hotel Creek subwatershed is characterized by fairly high wetland concentration (see Table 3), floodplains , fairly low slope, a significant number of Section 303(d) Impaired/TMDL Waters (see Map 5), and an overall macroinvertebrate impact rating of moderate (see Table 10). The wetlands and floodplains should be considered with all potential development. This is largely agricultural and forested lands outside of the Village of Churchville and Bergen.

The *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report indicates the following for the Middle Subwatersheds (including Spring Creek):

- The Spring Creek subwatershed is a large source of nutrients (TN and nitrate in particular), sediment, and bacteria to Black Creek. This subwatershed is highly agricultural (96%) and the cropland in this area receives a dense application of manure from the four CAFOs in this area.[10] Elevated levels of TN, NO3 and total coliform together are indicators of animal waste in streams. Three CAFOs are suspected to be the cause of increased nutrients in the lower portion of Spring Creek, and another CAFO is likely contributing to high concentrations of nutrients and sediment in the headwaters.
- Using BCSWAT several management practices were used to simulate potential reductions in TP and sediment loss from the Spring Creek subbasin. The most effective management practices were buffer strips (TP 22% reduction), conservation tillage (TP 14% reduction, TSS 32% reduction), and grassed waterways (a natural or constructed channel lined with vegetation that provides safe water disposal from croplands (USDA NRCS 2007) (TP 43% reduction, TSS 65% reduction). Additionally, sequential reduction of fertilizer applications for nutrient management excluding manure from CAFOs (25%, 50%, 75%, and 100% reduction in fertilizer applied) achieved a reduction in TP ranging from 6 to 21%. However, significant reductions in the amount of fertilizer applied to croplands (100%) may have detrimental impacts on crop productivity and is not recommended.
- The Bergen WWTP is the largest point source in the watershed and was found to be a significant contributor of nutrients to Black Creek using stressed stream analysis techniques. If this WWTP was renovated to a tertiary treatment system (chemical addition, two-stage filtration) rather than a secondary treatment system, the TP load to the Middle BC site would be reduced 18%. If this source were to be shut down and pumped to the Van Lare plant in Monroe County for treatment, there would be a 19% reduction in the TP load at Middle BC and a 16% reduction at Lower BC. This action was

successfully used when the Churchville WWTP was closed in 2002 and its influence on Black Creek was eliminated.[11] (Note: the Bergen WWTP was updated to membrane filtration. The current NYSDEC discharge permit was renewed in August 2014 based on a phosphorus reduction goal of 1.0 mg/l by 2016 and a May-October seasonal average of 0.2 mg/l by 2024.)

The *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report indicated that the Spring Creek subwatershed is a large source of nutrients (TN and nitrate in particular), sediment, and bacteria to Black Creek. This subwatershed is highly agricultural and the cropland in this area receives a dense application of manure from the four CAFOs in this area. The modeling associated with the report used several management practices to simulate potential reductions in TP and sediment loss from this subwatershed. The most effective management practices were buffer strips, conservation tillage, and grassed waterways.

In the Hotel Creek subwatershed the *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report indicates that the Bergen WWTP is the largest point source in the watershed and was found to be a significant contributor of nutrients to Black Creek. A recommendation was to shut this WWTP down and pump the waste to the Van Lare plant in Monroe County for treatment.

Lower Subwatersheds
The downstream portions of the Black Creek Watershed, includes the Mill Creek subwatershed and the Black Creek Outlet.

The Mill Creek subwatershed is characterized by low relief, large floodplains, more developed land cover (see Table 5), and outside of the City of Batavia, high population density as well as a high percentage of the 303d Impaired/TMDL Waters (see Map 5). It has an overall macroinvertebrate impact rating of moderate (see Table 10). Given the nature of this subwatershed, it has a relatively high percent of impervious cover, which should be considered within land use regulation and control and potential development.

The Black Creek Outlet subwatershed is characterized by low relief, large floodplains, more developed land cover (see Table 5), and outside of the City of Batavia, high population density as well as a high percentage of the 303d Impaired/TMDL Waters (see Map 5). It has an overall macroinvertebrate impact rating of moderate (see Table 10). Given the nature of this subwatershed, it has a relative high percent of impervious cover, which should be considered within land use regulation and control and potential development.

The *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report indicated the following for the Lower Subwatersheds (including the Mill Creek and Black Creek Outlet subwatersheds):

- In the Mill Creek subwatershed, increases in TN and nitrate were found; this was first thought to be due to the golf course that runs along the stretch of Mill Creek between these two sites. The Mill Creek Golf Course is located in Churchville, NY, and covers 130 ha of land in the Mill Creek subwatershed. Golf courses generally impact nitrate-nitrogen levels more than orthophosphates from excess fertilization of greens and fairways.[12] Intensely managed golf courses can significantly increase nitrates in ground and surface water through leaching and runoff depending on the fertilizer application and soil percolation rates.[13] The clubhouse also has a septic system that discharges 3,308 gallons of treated effluent per day into a drainage ditch leading to Mill Creek. This permit contains seasonal effluent limits for biological oxygen demand, suspended solids, pH, ammonia, dissolved oxygen, and fecal coliform.[14]

- Additionally, a small farm exists in the Mill Creek subwatershed whose runoff is fed into Mill Creek from a small tributary. This is likely impacting water quality more than the Mill Creek Golf Course. High concentrations of TP, SRP, TN, nitrate, and TSS were found in drainage downstream of this farm on 15 March 2011 during an event period. These high concentrations are diluted by the main stem of Mill Creek but slightly raise nutrient and sediment concentrations within the creek. This farm is the suspected source of high nutrient, sediment, and bacteria levels found at Mill Creek although it is important to note that the Mill Creek Golf Course is a possible secondary source of nitrogen nearby.
- Within the Northeast Tributary elevated nutrient and sediment concentrations were found at the outlet. In the Northeast Tributary there is one Large CAFO, one medium CAFO, and one small horse farm that impact the stream. The medium CAFO is suspected as the source of high concentrations of nutrients and sediments found during an event period. The high concentrations of nutrients and sediments in conjunction with high levels of bacteria indicate the presence of fecal contamination in this area. The large CAFO pasture farm has approximately 1000 dairy cattle[15] and is a suspected source of TN, nitrate, and total coliforms. The small horse farm is likely the source of TSS and TP. This farm is sloped downward towards the stream and does not have any means to keep soil on the land. When the soil runs off into the water from this site, it will also increase phosphorus loading as well. Loss of phosphorus from soil due to surface runoff has a significant effect on water quality in receiving waters.[16]
- Several agricultural, wastewater, and stream bank management scenarios were simulated in the Lower BC segment using BCSWAT, and the percent reduction in TP and sediment was found. The most effective agricultural practices applied to croplands in Lower BC were buffer strips (17% reduced TP, 35% reduced TSS), conservation tillage (27% reduced TP, 39% reduced TSS), and grassed waterways (28% reduced TP, 50% reduced TSS). These BMPs would be most applicable to the small farm in the Mill Creek subwatershed, to the CAFO and small horse farm in the Northeast Tributary subwatershed, and to other farm fields, which were all found to be sources of nutrient and sediment losses. Applying structural BMPs to these areas would provide the greatest and most efficient reduction in P and sediment lost to Lower BC.
- The focus for management within this segment was on mechanisms to reduce sources of sediment because the areal TSS load was high (407.5 kg/ha/yr; Table 10), and a field erosion inventory identified the major source of sediment in this reach to be stream bank erosion. The results of a SWAT model analysis of erosion on this segment provide further evidence that stream bank erosion is the underlying cause of the high areal load of TSS in this area. A management scenario where the highly erodible areas above Lower BC were stabilized by simulating the application of vegetative cover and reducing the erodibility of stream banks caused a 71% reduction in the sediment load (Table 18).
- Although stabilizing stream banks in this area simulated a large reduction in sediment, there was only a small reduction in TP (2%). It is likely that the actual TP load from Black Creek will be reduced by a higher percentage by implementing stream bank stabilization techniques than is simulated by the model. In the future it would be beneficial to modelers and managers of watersheds to incorporate a mechanism into the SWAT model that would more accurately simulate the effect of implementing stream bank stabilization techniques on nutrient load.
- Once reductions in TP and sediment from BMPs were quantified the Black Creek SWAT model was then utilized to determine the management necessary to reach certain water quality targets proposed by the Department of Environmental Conservation. A target of 65-ug P/L was achieved at Lower BC by remediating impacted tributaries (Spring and Bigelow Creeks), applying buffer strips to agricultural areas near streams, utilizing alternative manure operations such as anaerobic digestion and manure storage for CAFOs in the watershed, upgrading the Bergen WWTP to tertiary treatment, and stabilizing erodible stream banks above Lower BC (Management Scenario 1; Table 12). The TP concentration was reduced from 79.6 ug P/L to 60.3 ug P/L and the TSS concentration from 30.6

mg/L to 8.7 mg/L. A more stringent water quality target of 45-ug P/L was achieved at Lower BC by utilizing all management used in Management Scenario 1 (Table 12) as well as buffer strips, conservation tillage, and grassed waterways applied to all croplands, by rerouting all effluent from Bergen WWTP and septic systems to an WWTP outside of the watershed, and by stabilizing all stream banks within Black Creek (Management Scenario 2; Table 12). The above described management scenario reduced the annual TP concentration to 38.3 ug P/L, well below the 45-ug P/L target. A target of 20-ug P/L is not attainable in Black Creek because it is below the natural state of the watershed (36.2 ug P/L). By meeting the 65-ug P/L target in the Black Creek watershed, the annual TP load to the Genesee River can be reduced by 27%; alternatively, reaching the 45-ug P/L target can reduce the annual TP load by 56%. In doing so, the impact that this area has on water quality as well as the beneficial use impairments in Lake Ontario will be greatly reduced.

Some of the water quality concerns expressed in the *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report for the Mill Creek subwatershed include the presence of a golf course and agricultural lands. Agriculture, and possibly the golf course, is the suspected source of high nutrient, sediment, and bacteria levels in this subwatershed.

The *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report indicated that streambank erosion was an issue in the Black Creek Outlet subwatershed and given that this is the downstream subwatershed of the Black Creek watershed, any improvements made upstream, especially to agricultural practices, would likely impact this subwatershed as well.

Summary

The following tables summarize the critical areas and potential remediation scenarios by subwatershed:

Table 11: Summary Table from the *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report of critical areas identified from initial stressed stream sampling from major tributary nodes and main stem sites on 15 June 2010 and 17 August 2010. Critical areas define those areas that should be further segmented to identify the source of nutrients, sediments, or bacteria. TP=Total Phosphorus, SRP=Soluble Reactive Phosphorus, TN=Total Nitrogen, TSS=Total Suspended Solids, Total Coli=Total Coliform Bacteria.

Critical areas identified from initial sampling:						
Site	**TP**	**SRP**	**TN**	**Nitrate**	**TSS**	**Total Coli**
Lower	X	X			X	
Middle	X	X			X	X
Upper	X	X			X	
Headwaters of Upper BC	X	X				
Main stem 2 (Robins)					X	
Main stem 3 (Mill)					X	
Spring Creek			X	X		X
Bigelow Creek	X	X				X
Mill Creek	X	X				X
Robin's Brook			X	X		
North Branch Tributary (Robins)			X	X		
Northeast Tributary (Hotel)	X	X	X			

Table 12: Outline of Management Practices from the *Water Quality Analysis of Black Creek Watershed: Identification of Point and Nonpoint Source Pollution and Loading Simulation Using the SWAT Model* report applied in remediation scenarios simulated by BCSWAT for impacted tributaries, Bigelow Creek and Spring Creek, and management scenarios to meet water quality targets of either 65-µg P/L or 45-µg P/L at the outlet of Black Creek. For each management scenario the BMPs that were applied are indicated (X). In the Bigelow and Spring Creek scenarios the BMPs indicated were only applied to those subwatersheds whereas the Management 1 and Management 2 scenarios were applied to the entire Black Creek watershed.

	Bigelow Creek	**Spring Creek**	**Black Creek Watershed**	**Black Creek Watershed**
Management Operation			Management Scenario 1: 65-µg P/L Target	Management Scenario 2: 45-µg P/L Target
Buffer Strips	X	X	X	X
Conservation Tillage	X	X		X
Grassed Waterways	X	X		X
Terracing	X			
Nutrient Management	X	X		
Alternative Manure Operations		X	X	X
Upgrade Bergen WWTP			X	
Re-routing Bergen WWTP				X
All Septic to Sewer Districts		X		X
Stream bank Stabilization				X
Stabilize Highly Erodible Areas			X	
Tributary Remediation			X	X

Endnotes

[1] *StreamStats*. [Online] In *USGS*. Retrieved 8/1/11 from http://water.usgs.gov/osw/streamstats/.

[2] For a comprehensive literature review of riparian buffer functions and benefits, see *Riparian Buffer Functions and Benefits*. [Online] In *Maryland Department of Natural Resources*. Retrieved 8/8/11 from http://www.dnr.state.md.us/irc/bibs/riparianbuffers.html

[3] For a comprehensive literature review of the association between impervious cover and aquatic system health, see *The Impervious Cover Model*. [Online] in *Center for Watershed Protection*. Retrieved 8/8/11 from http://www.stormwatercenter.net/monitoring%20and%20assessment/imp%20cover/impercovr%20model.htm .

[4] Center for Watershed Protection. Impacts of Impervious Cover on Aquatic Systems. March 2003. page 139

[5] *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

[6] *Classification of Wetlands and Deepwater Habitats of the United States*. [Online] In *US EPA*. Retrieved 12/23/10 from http://www.fws.gov/wetlands/_documents/gNSDI/ClassificationWetlandsDeepwaterHabitatsUS.pdf

[7] Makarewicz, J.C. and T.W. Lewis. 2009. Oak Orchard Creek watershed: The location of sources of pollution, annual loss of nutrients and soil to Lake Ontario, and a test of effectiveness of zone tillage as a best management practice. Technical report to the Orleans County Soil and Water Conservation District, Albion, NY.

[8] Santhi, C., J. Arnold, J. Williams, W. Dugas, R. Srinivasan, and L. Hauck. 2001. Validation of the SWAT model on a large river basin with point and nonpoint sources. Journal of the American Water Resources Association 37:1169-1186.

[9] Santhi, C., R. Srinivasan, J.G. Arnold, and J.R. Williams. 2006. A modeling approach to evaluate the impacts of water quality management plans implemented in a watershed in Texas. Environ. Model Softw. 21(8):1141-1157.

[10] personal communication: George Squires, Genesee County Soil and Water Conservation District

[11] personal communication: Charles L. Knauf, Monroe County Health Department

[12] Wong, J.W.C., C.W. Chan, and K.C. Cheung. 1998. Nitrogen and phosphorus leaching from fertilizer applied on golf course: lysimeter study. Water, Air, and Soil Pollution 107: 335-345.

[13] Shuman, L.M. 2001. Phosphate and nitrate movement through simulated golf green. Water, Air, and Soil Pollution 129: 305-318.

[14] New York State Department of Environmental Conservation. 2010b. Environmental notice bulletin SPDES renewals. [Online.] Available at: http://www.dec.ny.gov/enb/20071212_spdes.html. Accessed 12 November 2010.

[15] personal communication: Tucker Kautz, Monroe County Soil and Water Conservation District

[16] McDowell, R.W. and A.N. Sharpley. 2001. Approximating phosphorus release from soils to surface runoff and subsurface drainage. Environmental Quality 30: 508-520.