Baseline Watershed Assessment
Tankerhoosen River Watershed

Friends of the Hockanum River
Linear Park of Vernon, Inc.

In Association With:

Town of Vernon
North Central Conservation District
Rivers Alliance of Connecticut
Hockanum River Watershed Association
Belding Wildlife Trust

Vernon, CT

April 2008

FUSS & O'NEILL
Disciplines to Deliver

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1.0 INTRODUCTION

The Friends of the Hockanum River Linear Park of Vernon, Inc. (the "Friends") has retained Fuss & O Neill to prepare a Watershed Management Plan for the Tankerhoosen River watershed. The Watershed Management Plan will be developed through a collaborative effort with a Technical Advisory Committee consisting of the Friends, the Town of Vernon (Planning Department and Conservation Commission), the North Central Conservation District, the Hockanum River Watershed Association, Rivers Alliance of Connecticut, and the Belding Wildlife Trust. The first part of the plan will consist of an assessment of existing condition in the watershed, an evaluation of pollutant sources in the watershed to prioritize watershed protection and restoration strategies, as well as prioritization of action items that could be adopted by governmental agencies and private groups to protect and improve the health of the Tankerhoosen River watershed. The recommended plan will be developed to address the priorities and issues identified in previous phases of the plan development, with participation by the Technical Advisory Committee.

2.0 BACKGROUND

The Tankerhoosen River watershed is a small but very important 12.85 square-mile sub-regional basin within the Hockanum River watershed (Figure 1-1). Approximately 70% of the watershed is located within the Town of Vernon, with the remaining portions within the Towns of Tolland, Bolton, and Manchester (Table 1-1).

Table 1-1: Distribution of Municipalities in the Tankerhoosen River Watershed

Town Name	Town Acreage	Acreage in Watershed	% of Town in Watershed	% of Watershed
Manchester	17,408	461	2.7	5.6
Vernon	11,904	5,572	46.8	67.9
Tolland	25,856	1,547	5.9	18.6
Bolton	9,920	646	6.5	7.9
Totals	65,088	8,226		100.0

A basic profile of the watershed is provided in Table 1-2. Later sections of this document provide more detailed information on these watershed characteristics.

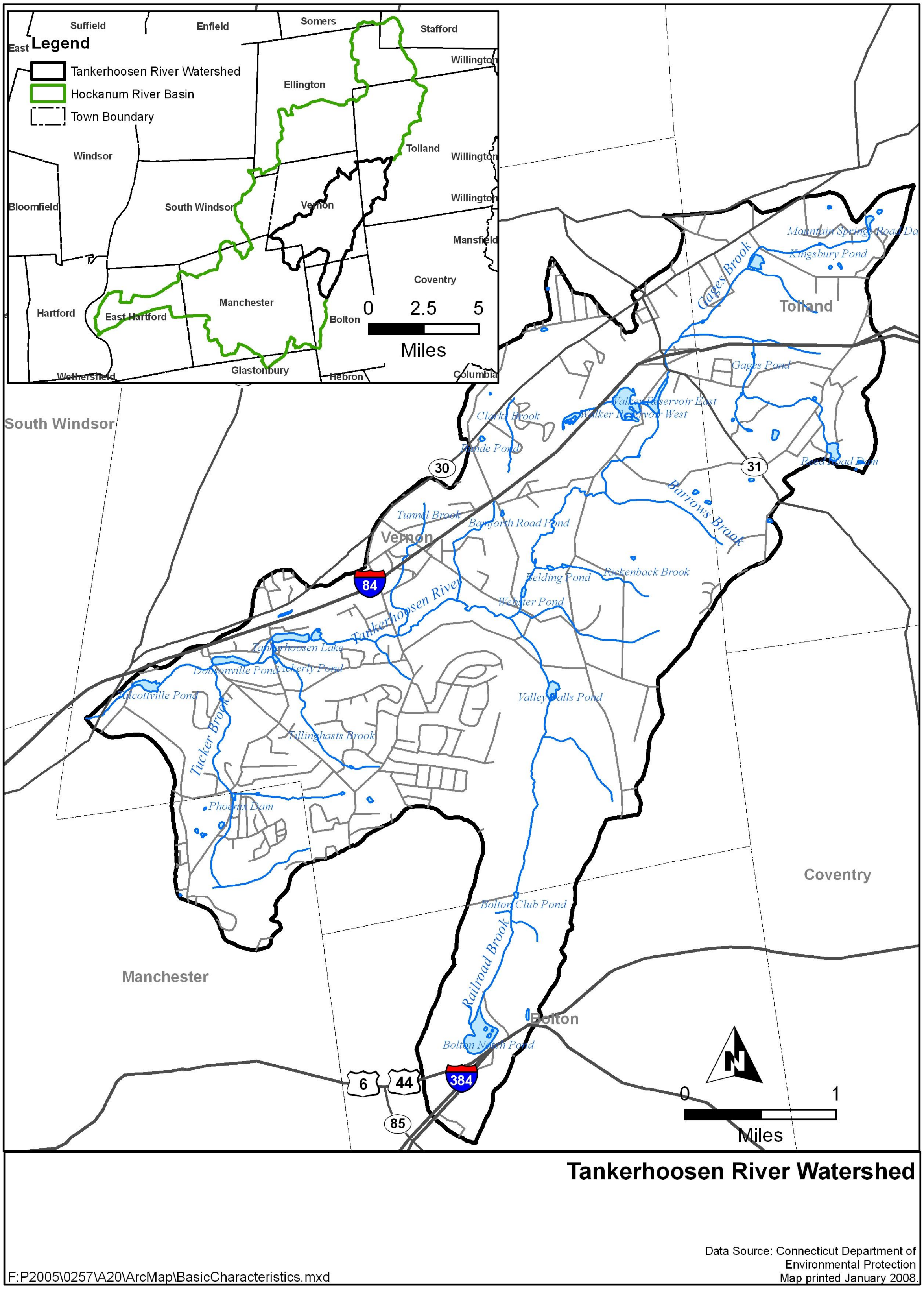


Figure 1-1: Tankerhoosen River Watershed

Table 1-2: Profile of the Tankerhoosen River Watershed

Area	C 12.85 square miles (8,226 acres)
Stream Length	C approximately 17.2 miles
Subwatersheds	C 10 subwatersheds
Jurisdictions	C 4 towns and cities
Water Quality	C 2006 DEP Impaired Waters List for habitat for fish and other aquatic life
Current Impervious Cover	C 9.8%
Subwatersheds Selected for Detailed Assessment based on Vulnerability Assessment	C Clarks Brook C Gages Brook C Gages Brook South Tributary C Lower Tankerhoosen River C Walker Reservoir
Subwatersheds Selected for Detailed Assessment based on Restoration Potential	C Clarks Brook C Gages Brook C Lower Tankerhoosen River C Middle Tankerhoosen River C Tucker Brook
Major Transportation Routes	C Interstates 84 and 384 C U.S. Routes 6 and 44 C State Routes 30 and 31
Significant Natural and Historic Features	C Belding Wildlife Management Area C Valley Falls Park C Northern Connecticut Land Trust C Bolton Notch Pond C Walker Reservoir C Talcottville Historic District

The high water quality (classified as A) in the upper regions of the Tankerhoosen River sustain a significant natural resource of the State of Connecticut – the Belding Wild Trout Management Area, which is one of only two such wild trout areas east of the Connecticut River. The importance of these small, high quality watersheds to the downstream health of the larger river basins, and therefore to Long Island Sound, is well recognized. Of utmost importance to these high quality watersheds is protection of the headwaters regions.

The headwaters region of the Tankerhoosen River is bisected by Interstate 84. Recent development pressure in this headwaters region at the Exit 67 interchange in Vernon poses a major threat to the long-term health of the watershed. Further stresses on the headwaters have been created by development of an industrial park in Tolland through which a key headwater stream flows, as well as the presence of the highway itself, which continues to generate increasing traffic loads from development along the I-84 corridor. There has also been declining water quality in the lower reaches of the Tankerhoosen River in recent years. The lower region of the watershed is classified as "B", and was cited as impaired in the DEP's most recent "List of Connecticut Waterbodies Not Meeting Water Quality Standards".

The importance of protecting the pristine upper region of the Tankerhoosen is recognized by both local and state agencies. The 2000-2004 State Plan of Conservation and Development identifies the riverway as a proposed preservation and conservation area. The Vernon Open Space Plan proposes a greenway plan of 2000 preserved acres along the Tankerhoosen. Most recently, the Nature Conservancy has identified several key watersheds in the state that it considers particularly important to the future protection of Long Island Sound, including the Tankerhoosen River watershed. The need for local decision-makers to give utmost consideration to the environmental consequences of development proposals that would impact the River, has been expressed by The Nature Conservancy (TNC) and by the Connecticut Department of Environmental Protection (DEP).

To address these very real and immediate threats, the Friends began a watershed assessment for the Tankerhoosen River in March 2007. The objective of this initial assessment was to describe and understand the overall health, quality and flow of waters within the watershed and to identify potential threats to water quality in the watershed. The assessment included water quality monitoring and natural resource inventories to begin establishing baseline conditions against which future monitoring can be measured. The next step in the watershed planning process is to develop a comprehensive management plan that will provide guidance to local decision-makers and to serve as an educational tool and reference document for those interested in protection of the Tankerhoosen River.

3.0 DEVELOPMENT OF THE BASELINE ASSESSMENT

The initial task in developing a Watershed Management Plan for the Tankerhoosen River is to develop an understanding of baseline, or existing conditions in the watershed. To accomplish this, the following tasks were completed:

- Reviewed existing watershed data, studies, and reports;
- Compiled and analyzed available Geographic Information System (GIS) data for the watershed;
- Consulted with the Technical Advisory Committee, the watershed municipalities, and the regional planning agency regarding available land use information, mapping, and land use planning regulations;
- Identified and delineated subwatershed within the over Tankerhoosen River watershed; and
- Conducted a comparative subwatershed analysis to prioritize watershed field inventories and management plan recommendations.

The results of this watershed inventory are presented in this document, including a description of current watershed conditions for the following categories:

- Geological and historical perspective;
- Natural resources including hydrology, water quality, wetlands and watercourses, fish and wildlife resources and habitat;
- Watershed modifications including dams, water supply, wastewater discharges, and regulated sites; and
- Land use and land cover.

In addition, the results of a comparative subwatershed analysis are also presented.

4.0 GEOLOGIC AND HISTORICAL PERSPECTIVE

4.1 Geology

The State of Connecticut is comprised of three distinct geologic units divided longitudinally across the state. These three units are known as the Western Uplands, the Central Valley, and the Eastern Uplands. The Western and Eastern Uplands are comprised of metamorphic rocks – rocks subjected to intense heat and pressure of the Earth's interior – while the Central Valley is a younger unit comprised of sedimentary rocks. The Central Valley began forming about 225 million years ago when the super-continent Pangaea began to break apart. A large rift formed a long, narrow valley through the middle of the state, eventually filling with sediments from the eroding hills to the east and west (presently known as the Eastern and Western Uplands). The sediments were compacted into soft, easily eroded, red and brown sandstones through which the Connecticut Rivers flows.

The Tankerhoosen River watershed is almost entirely within the Eastern Uplands. The westernmost portion of the watershed is located within the Central Valley. The boundary between the Central Valley and the Eastern Uplands is located near the Vernon-Manchester town line and known as the Bolton Range. The Bolton Range was formed as a result of the different rates of erosion of the less resistant sediments of the Central Valley creating an abrupt rise into the resistant rocks of the Eastern Uplands.

Drastic changes in the surficial geology have occurred within Connecticut since the formation of these geologic regions. Above the sandstone of the Central Valley and the metamorphic bedrock of the Eastern Uplands lie extensive glacial deposits, or "glacial till," left as the large glaciers receded. Melting glacier ice formed rivers which sorted glacial till into layers of sand and gravel, or "stratified drift." The Tankerhoosen River flows through hills of glacial till in the steep Eastern Uplands and then drops into the stratified drift of the Central Valley (Bell, 1985).

4.2 Population and Industry

Beginning about 10,000 years ago, as the last glacial ice retreated from New England, Native American populations settled Connecticut and the areas along the Tankerhoosen River. The river was used by Native Americans as a source of fish and a travel route to the Connecticut River (Hockanum River Watershed Association, 1998). The Podunks of East Hartford and Manchester, the Nipmucks of Ellington and Tolland were among the tribes that farmed corn in the fertile river floodplains of the Tankerhoosen River. In addition to agriculture, the tribes used the land within the watershed for hunting, gathering, and fishing.

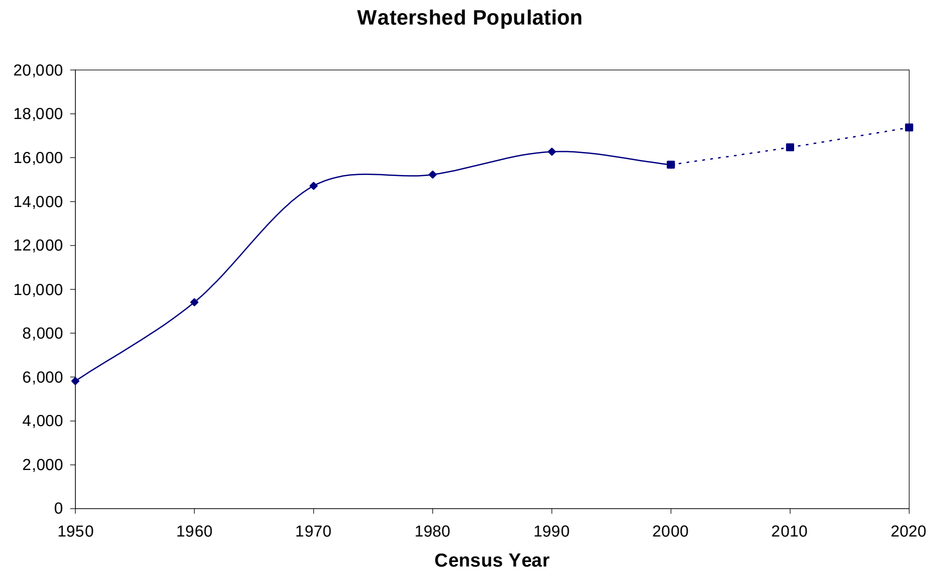
European settlers brought a marked change in land use to Connecticut. Land was cleared and agriculture was the primary use through the Revolutionary War era. However, the availability of more fertile lands in western New York, northern Ohio, and Pennsylvania led to the great migration of Connecticut farmers during the 1800s. Those who stayed worked in the many factories that arose along the rivers and streams, and manufacturing became a major economic force (Gibbons et al., 1992).

The Tankerhoosen River was no exception to the development patterns across Connecticut. From the headwaters at Gages Brook, the elevation drop of the Tankerhoosen River was ideally suited to power a wide variety of mills. During the eighteenth and nineteenth centuries, several mills associated with the textile, cotton-wool, energy, and paper industries were built near these waterfalls and in other areas in the watershed. The Talcottville Historical District is located in southwestern portion of the Tankerhoosen River watershed near the confluence with the Hockanum River. One of the first cotton mills in America was built by Peter Dobson in the early 1800's in Talcottville. The mill burned down in 1909, not to be rebuilt. Peter Dobson is also famous for early observations that ice may have played a role in the erosion and transport of rock in the region.

The town of Vernon was also an active transportation center during the early part of the twentieth century. The Vernon Depot was part of the Hartford, Providence & Fishkill Railroad, running seven times a day with connections to Rockville. The Keystone Arch on Tunnel Road (also known as the Keystone Tunnel) was constructed circa 1850 to allow trains to traverse Tunnel Road without disrupting street traffic toward Vernon Center. The 108-foot long tunnel is constructed of 30 arches, each of which consists of a center keystone with nine stones forming the curves on either side. The tunnel is considered by historians to be a fine piece of historic architecture and as a monument to the integrity and skilled workmanship of its builders.

Valley Falls was the site of the first industry in Vernon, a sawmill, in 1740. Valley Falls Park hosted a small mill complex for flaxseed oil and cotton between 1850 and 1877. Beginning in the mid-1800s until the mid-1900s the property was converted into farmland for producing corn, hay, oats, butter, and cheese. In 2001, the historic farmhouse and six outbuildings were purchased by the Friends of Valley Falls, Inc. to ensure preservation of the historical complex. Alternate forms of manufacturing power put most of the mills out of business by the late 1950s. Dozens of the mill buildings and their associated dams remain an integral component of the river.

Rapid population growth in the post-war era of the 1950s and 1960s slowed significantly as developable land became scare (see Figure 4-1). Today, the population of the Tankerhoosen River watershed is approximately 16,000 which is more than double the population of the watershed in the 1950s. Commercial and residential development has occurred in the watershed since the 1970s, with a continued decline in industrial uses. Significant commercial development along the major transportation corridors and residential development in the watershed has increased watershed impervious coverage and contributed to degraded water quality in portions of the Tankerhoosen River and its tributaries. Numerous historical impoundments within the watershed also continue to serve as barriers to fish passage along the Tankerhoosen River and its tributaries.



Source: Connecticut Population Projections, Series 95.1, Office of Policy and Management, September 1995

Figure 4-1: Population Trends in the Tankerhoosen River Watershed

4.3 Recreation Resources

The Tankerhoosen River provides many opportunities for recreational activities, such as fishing, swimming, and limited boating. Along the river, there are both town and state lands that are preserved for parks, wildlife sanctuaries and rail-trails. Recreational activities in these areas include hiking, biking, cross-country skiing, ice skating, nature observation, and aesthetic enjoyment.

Some of the prominent recreational centers in the watershed include the Walker Reservoir East, the Belding Wildlife Management Area, Valley Falls Park, the Rails-to-Trails, and Phoenix Mill Park. Each of these areas provides parking, picnicking, and trails for walking and cross-country skiing. The Belding Wildlife Management Area was the location of the first Class I Trout Management Area in Connecticut. Recreational areas that also have historical significance include the Dobsonville Pond and Talcottville Pond. Additionally, the area associated with the confluence of the Tankerhoosen and Hockanum Rivers includes a privately owned recreational facility and is the starting point for the annual Manchester Canoe and Kayak Race.

4.4 Watershed Restoration Efforts

The Connecticut River Watch Program (CRWP), a volunteer water quality monitoring, protection, and improvement program for the Connecticut River and its tributaries, is working closely with the Hockanum River Watch Program (HRWA) and North Central Conservation District to develop and support a community-based river monitoring and assessment program in the Tankerhoosen River watershed. The CRWP monitoring program has included stream walk surveys and rapid bioassessments (cost-effective biological survey techniques) along the Tankerhoosen River, as well as other areas of the larger Hockanum River watershed.

The Connecticut DEP also conducts routine ambient water quality and benthic monitoring at approximately twelve locations along the Hockanum and Tankerhoosen Rivers. The data assist in documenting the chemical and biological quality of surface waters within the watershed and will be used to support the development of a Total Maximum Daily Load (TMDL), which will address sources of water quality impairment in the Hockanum and Tankerhoosen Rivers.

Baystate Environmental Consultants, Inc. (BEC) conducted a feasibility study in 2002 for the dredging of Tankerhoosen Lake and subsequently prepared a Watershed Management Plan for Tankerhoosen Lake in 2004. The plan identified watershed factors that have directly affected or have the potential to affect the water quality and overall health of Tankerhoosen Lake. The project recommended a Town-wide approach for reducing the quantity of pollutants, specifically sediment and nutrients, reaching Tankerhoosen Lake. BEC personnel conducted field observations of the major contributing watercourses and impoundments in the Tankerhoosen Lake watershed to identify point sources of sediment and nutrients as well as nonpoint source pollutants. BEC recommended that the Town of Vernon require the implementation of stormwater best management practices (BMPs) that maximize to the extent practicable, the removal of total suspended solids and nutrients. In addition to the lake dredging project recommended in the feasibility study, BEC also recommended several structural and nonstructural elements, including a sediment trap at the inlet of Tankerhoosen Lake, installation of deep sump catch basins at key locations, maintenance of cross-culverts and drainage structures, and grass swales and vegetated filter strips. None of the BEC recommendations has been implemented to date.

5.0 NATURAL RESOURCES

5.1 Hydrology

The Tankerhoosen River watershed is 12.85 square-miles, with the majority of the watershed (approximately 70 percent) located within the Town of Vernon (Figure 1-1). Gages Brook and its associated southern tributary comprise the headwaters region of the watershed, eventually flowing into Walker Reservoir East. Gages Brook is located in the northwest portion of the Town of Vernon and within the western portion of neighboring Tolland. A few small impoundments are located within the Gages Brook watershed. The brook receives drainage from the I-84 corridor near the Vernon-Tolland town boundary. In Tolland, Gages Brook flows through an industrial park and residential areas.

Walker Reservoir is no longer an active public water supply but rather a recreational resource that attracts hikers, fisherman, and ice skaters. The Tankerhoosen River, which is a moderately sized (16 feet wide) upland stream, originates at the outlet of Walker Reservoir East and bisects the Town of Vernon on the south side of Interstate 84. The river flows southwest for approximately five miles to the Hockanum River in the Talcottville section of Vernon.

Barrows Brook, Rickenback Brook, and several other small tributaries drain the eastern portion of the upper Tankerhoosen River watershed between Walker Reservoir and the confluence with Railroad Brook near Webster Pond. Barrows Brook is the furthest upstream tributary to the Tankerhoosen River and flows through undeveloped, privately owned land. Rickenback Brook flows east to west through a relatively undeveloped portion of Vernon and discharges to the Tankerhoosen River approximately 0.4 miles upstream of the river's confluence with Railroad Brook. Portions of this brook are within the Belding Wildlife Refuge and have been established for catch and release trout fishing (BEC, 2004).

Railroad Brook drains the southern portions of the watershed, beginning at Bolton Notch Pond in Bolton and flows north through Valley Falls Park and the Belding Wildlife Refuge before joining the Tankerhoosen River. Valley Falls Pond is located along Railroad Brook within the confines of the Valley Falls Park property. Railroad Brook flows through primarily undeveloped land and discharges to the Tankerhoosen River approximately 1.6 miles upstream of Tankerhoosen Lake (BEC, 2004).

Clarks Brook and Tunnel Brook join the Tankerhoosen River in the middle portion of the watershed prior to the river's confluence with the DEP-owned Tankerhoosen Lake, the first of three DEP-owned run-of-river ponds. Clarks Brook originates north of I-84 and drains primarily industrial/commercial and undeveloped land within the Town of Vernon. Clarks Brook discharges to the Tankerhoosen River approximately 0.5 miles upstream of the river's confluence with Tunnel Brook. Tunnel Brook is located in the central portion of Vernon, flowing north to south and crossing the I-84 corridor. The brook empties into the Tankerhoosen River approximately 0.65 miles upstream of the inlet to Tankerhoosen Lake (BEC, 2004).

Dobsonville Pond is located just downstream of Tankerhoosen Lake. Tucker Brook, which drains the southeastern portion of the watershed and a residential section of the Town of Manchester, joins the Tankerhoosen River immediately upstream of Dobsonville Reservoir dam. Further downstream is Talcottville Pond and the confluence with the Hockanum River near the Vernon/Manchester town line.

Overall the Tankerhoosen River is comprised of a large percentage of first and second order (i.e., headwater) streams according to the Strahler Stream Order classification system. Stream hydrology and water quality in headwater streams are important components of ecosystem health because they are a critical food source for the entire river, influence downstream conditions, and support biodiversity.

Ten subwatersheds within the Tankerhoosen River watershed have been delineated for the purposes of this assessment. The subwatershed delineations are based on the CTDEP local basin delineations, modified slightly based on surface water hydrology and grouped accordingly to facilitate assessment and development of watershed management plan recommendations. Figure 5-1 depicts the subwatersheds identified in this assessment, and Table 5-1 summarizes the basic characteristics of the identified subwatersheds.

Table 5-1: Tankerhoosen River Subwatersheds

Subwatershed	Acronym	Area (acres)	Area (square miles)
Bolton Notch Pond	BNP	344	0.54
Clarks Brook	CB	647	1.01
Gages Brook	GB	695	1.09
Gages Brook South Tributary	GBST	680	1.06
Lower Tankerhoosen River	LTR	321	0.50
Middle Tankerhoosen River	MTR	1,578	2.46
Railroad Brook	RB	1,208	1.89
Tucker Brook	TB	934	1.46
Upper Tankerhoosen River	UTR	1472	2.30
Walker Reservoir	WR	347	0.54
Tankerhoosen River Watershed		8,226	12.85

The Tankerhoosen River Watershed is located in an area with a temperate and humid climate. Based on historical climate information available from the NOAA National Weather Service weather station in Harford/Bradley International Airport in Windsor Locks, Connecticut, precipitation is generally well-distributed throughout the year with the wettest conditions in August and November and driest in February (worldclimate.com for Harford/Bradley International Airport, Hartford County). In Windsor Locks, the mean annual precipitation over a 41-year period of record is 44.4 inches, and the 24-hour average temperature ranges from a high of 73.6°F in July to a low of 24.6°F in January.

Generally, the designated 100-year floodplain of the Tankerhoosen River is confined along a narrow corridor (<500 feet wide) surrounding the river. The entire length of the Tankerhoosen River is within the Federal Emergency Management Agency (FEMA) designated 100-year floodplain, with the exception of a small reach near the river's headwaters, between Reservoir Road and Fish and Game Road. The lower reach of Railroad Brook (below Valley Falls Pond including the pond) is also within the 100-year floodplain. Walker Reservoir West and East and portions of Gages Brook also lie within the designated 10-year floodplain (BEC, 2004).

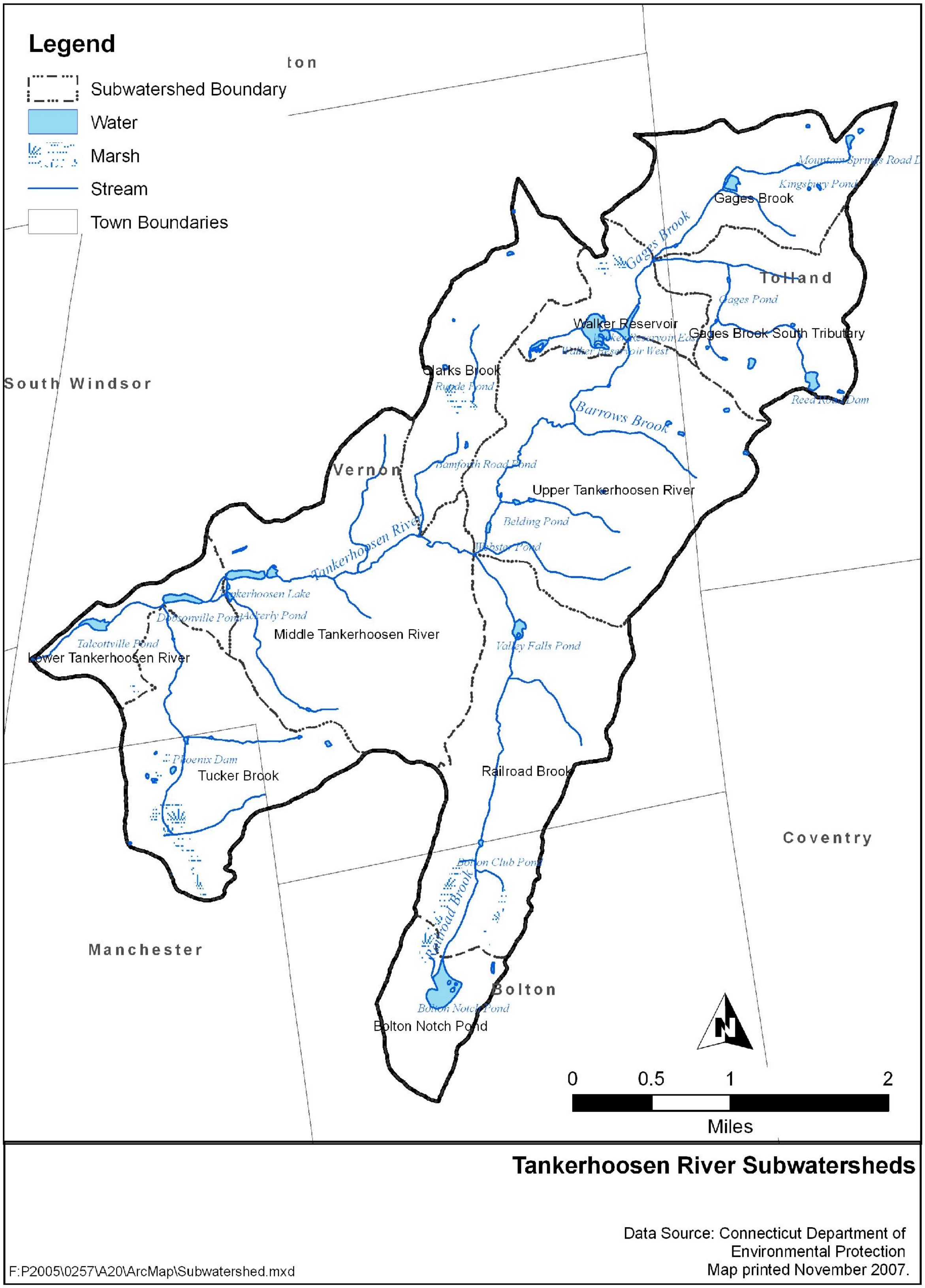


Figure 5-1: Tankerhoosen River Subwatersheds

5.2 Water Quality

5.2.1 Classifications and Impairments

The Federal Clean Water Act (CWA) was developed to protect the nation's surface waters. Through authorization of the CWA, the United States Congress declared as a national goal "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water wherever attainable". Connecticut Water Quality Standards are established in accordance with Section 22a-426 of the Connecticut General Statutes and Section 303 of the CWA. The Water Quality Standards are used to establish priorities for pollution abatement efforts. Based on the Water Quality Standards, Water Quality Classifications establish designated uses for surface and ground waters and identify the criteria necessary to support these uses. The Water Quality Classification system classifies inland surface waters into four different categories ranging from Class AA to D. Table 5-2 summarizes the Connecticut Surface Water Quality Classifications.

Table 5-2: Connecticut Inland Surface Water Quality Classifications

Designated Use	Class AA	Class A	Class B	Class C	Class D
Existing/proposed drinking water supply	●				
Potential drinking water supply	●	●			
Fish and wildlife habitat	●	●	●	Class C and D waters may be suitable for certain fish and wildlife habitat, certain recreational activities, industrial use, and navigation	
Recreational use	●	●	●		
Agricultural and industrial use	●	●	●		

Source: DEP Surface Water Quality Standards, December 17, 2002

Figure 5-2 depicts the Water Quality Classifications of surface waters in the Tankerhoosen River watershed. Surface waters throughout the Tankerhoosen River watershed are classified as Class A with the exception of the Tankerhoosen Lake, Dobsonville Pond, and Talcottville Pond which are classified as Class B/A.

The CWA (Federal Clean Water Act) requires states to:

1. Adopt Water Quality Standards,
2. Assess surface waters to evaluate compliance with Water Quality Standards,
3. Identify those waters not currently meeting Water Quality Standards, and
4. Develop Total Maximum Daily Load (TMDL) analysis and other management plans to bring water bodies into compliance with Water Quality Standards.

A portion of the Tankerhoosen River does not meet Water Quality Standards for at least one of the designated uses. The impaired segment consists of the lower 1.51 miles of the Tankerhoosen River from its confluence with the Hockanum River to Tankerhoosen Lake. The impaired uses include habitat for fish, other aquatic life, and wildlife. The causes and sources of impairment in the lower reaches of the Tankerhoosen River have not been identified and are currently listed as "unknown." TMDLs provide the framework to restore impaired waters by establishing the maximum amount of a pollutant that a water body can assimilate without adverse impact to aquatic life, recreation, or other public uses. The *2006 List of Connecticut Waterbodies Not Meeting Water Quality Standards* includes a priority ranking system for development of a TMDL specific to the contaminants in each impaired segment: high (H), medium (M), low (L), or under study (T). DEP has identified the impaired segment of the Tankerhoosen River as a high priority for development of a TMDL to restore the impairment. Table 5-3 summarizes the location and nature of the impairment.

Table 5-3: Tankerhoosen River Watershed Impaired Waters

Location Description	Waterbody Segment Length	Impaired Designated Use	Use Support	Cause	TMDL Priority	Potential Source
From mouth at Hockanum River , upstream to Tankerhoosen Lake	1.51 miles	Habitat for Fish, Other Aquatic Life and Wildlife	P	Impairment Unknown	H	Source Unknown

Source: DEP, 2006
H – high priority for which there is assessment information that suggests that a TMDL may be needed to restore the water quality impairment.
P – partially supporting

5.2.2 Tankerhoosen River Watershed Water Quality Monitoring Study

A water quality monitoring study was conducted in October and November 2006 to establish current baseline water quality conditions in the watershed, identify water quality impacts, and begin to develop a water quality database for the watershed (Fuss & O'Neill, 2007). Chemical water quality monitoring and biological assessments were conducted during dry and wet weather conditions. Samples were collected from fourteen locations throughout the watershed on four occasions (Figure 5-2). A variety of parameters were measured including pH, temperature, dissolved oxygen, and conductivity, which all reported values within normal ranges. These results indicate that the water quality of the watershed is generally good. However, some of the measured parameters including turbidity, metals, nitrogen, phosphorus, and bacteria highlighted some of water quality issues in the watershed. A brief discussion of the water quality parameters and identified issues is provided below:

Turbidity

Based on the wet weather monitoring results, excessive turbidity is a water quality issue in the Tankerhoosen River and its tributaries, particularly Gages Brook (Figure 5-3). Stream channel erosion and stormwater runoff from impervious surfaces and construction sites are potential sources of the observed turbidity during large precipitation events such as the August 2006 wet weather monitoring event, although it is difficult to attribute the turbidity excursions to a particular source. During the August 2006 wet weather monitoring event, turbidity measurements generally exhibited a declining trend from upstream to downstream within the watershed. Elevated levels of indicator bacteria (total coliform and *E. coli*) were measured at all monitoring locations during the October 2006 wet weather monitoring event, suggesting stormwater runoff and other non-point sources (pet waste, waterfowl, septic systems, etc.) as likely contributors of elevated pathogen levels in the Tankerhoosen River and its tributaries.

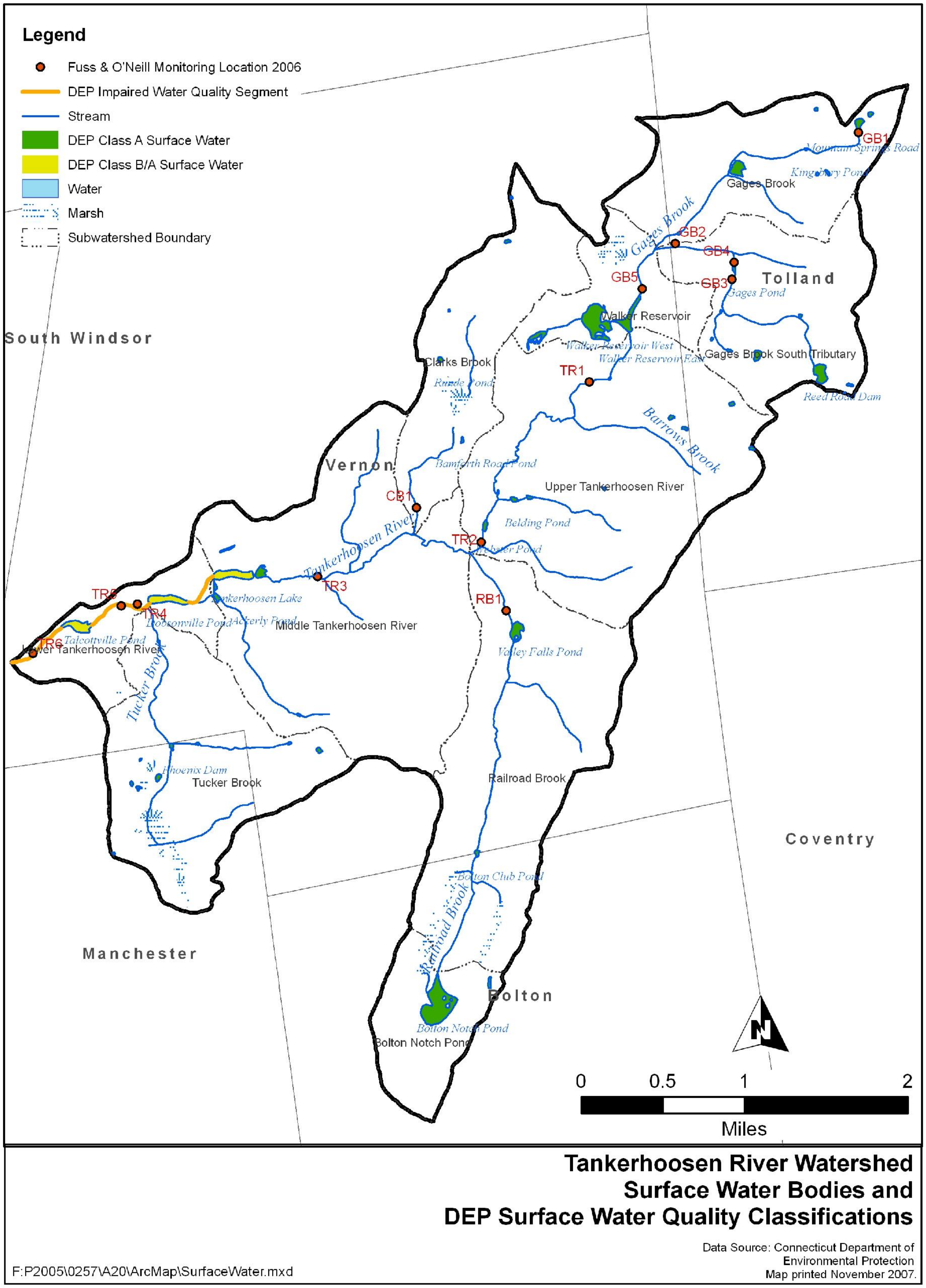


Figure 5-2: DEP Water Quality Classifications

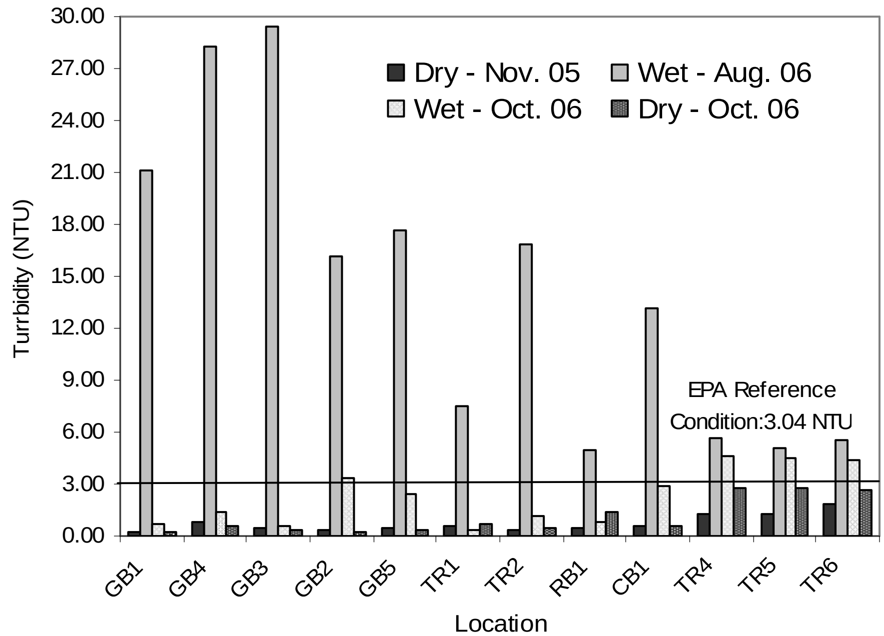


Figure 5-3: Turbidity – Tankerhoosen River Watershed

Metals

The monitoring data suggest a wet weather source of metals to Gages Brook (Figure 5-4 and Figure 5-5). Results from the August 2006 monitoring event indicate a wet weather source of metals close to the I-84 crossing of Gages Brook, as the dissolved copper concentration was consistently below detection limits at the Gages Brook headwaters monitoring location (GB1) and in excess of the chronic aquatic life criterion at several of the downstream Gages Brook locations. The highest wet weather lead concentration was measured in the Gages Brook monitoring location immediately downstream of I-84, which further suggests that highway runoff is a likely source of metals to Gages Brook. Exceedances of the CT WQS for lead were also measured along the Tankerhoosen River at the Fish and Game Road. (TR1) and Bolton Road (TR2) monitoring locations. Elevated dissolved copper and lead concentrations were also measured at the Clarks Brook monitoring location. The data suggest that metals are a potential source of impairment in Gages Brook, Clarks Brook, and the Tankerhoosen River during wet weather. The November 2005 results also indicate dry weather sources of dissolved copper to Gages Brook between the headwaters monitoring location (GB1) and the monitoring location behind the Tolland Agricultural Center (GB2).

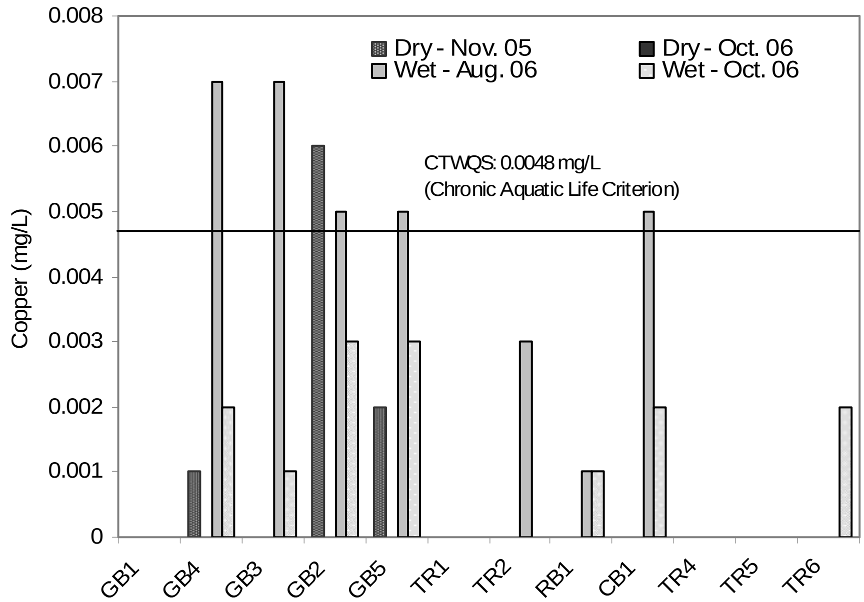


Figure 5-4: Dissolved Copper – Tankerhoosen River Watershed

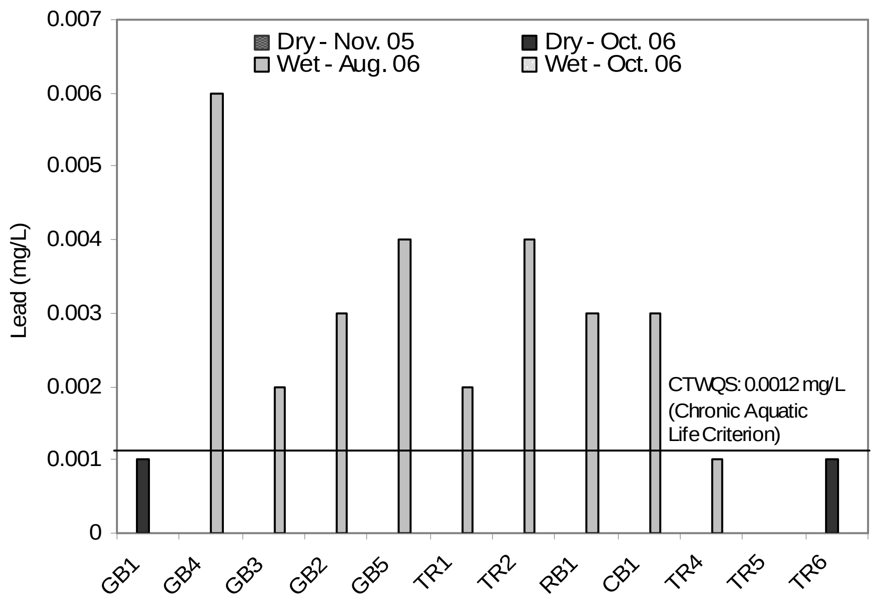


Figure 5-5: Lead – Tankerhoosen River Watershed

Nitrogen & Phosphorus

Many of the monitoring locations exceeded the EPA recommended Total Nitrogen criterion for rivers in Ecoregion XIV of 0.71 mg/L (Figure 5-6). Nitrogen concentrations were consistently higher at the Gages Brook monitoring locations than the other monitoring locations in both wet and dry weather.

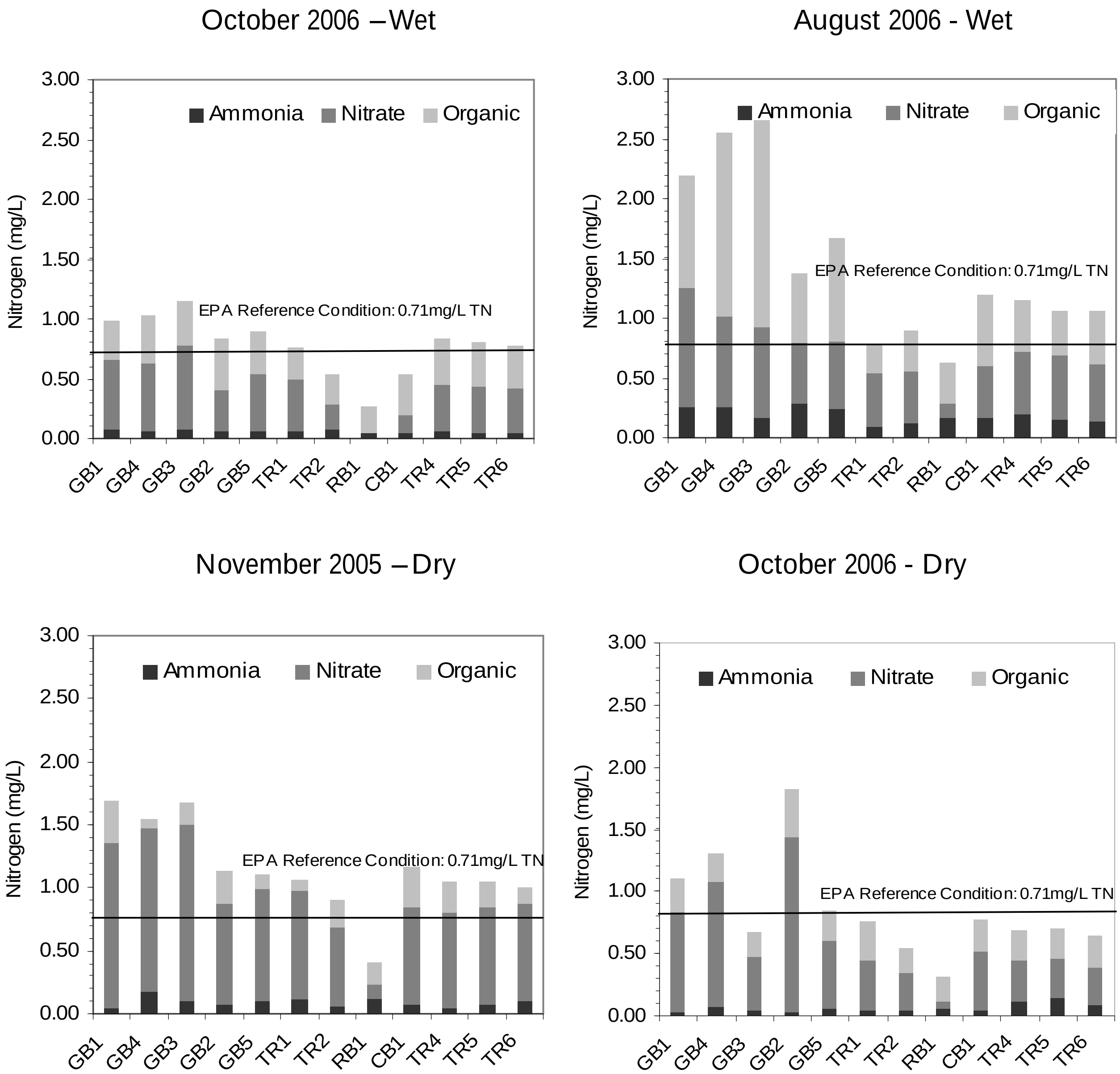


Figure 5-6: Nitrogen Species – Tankerhoosen River Watershed

Phosphorus concentrations measured during the wet and dry weather events significantly exceeded the CT WQS and EPA criterion at most locations (Figure 5-7). The elevated phosphorus levels are an indicator of potential organic enrichment and algal growth in water bodies along the Tankerhoosen River and its tributaries, which could impair aquatic life support and contact recreation under certain conditions.

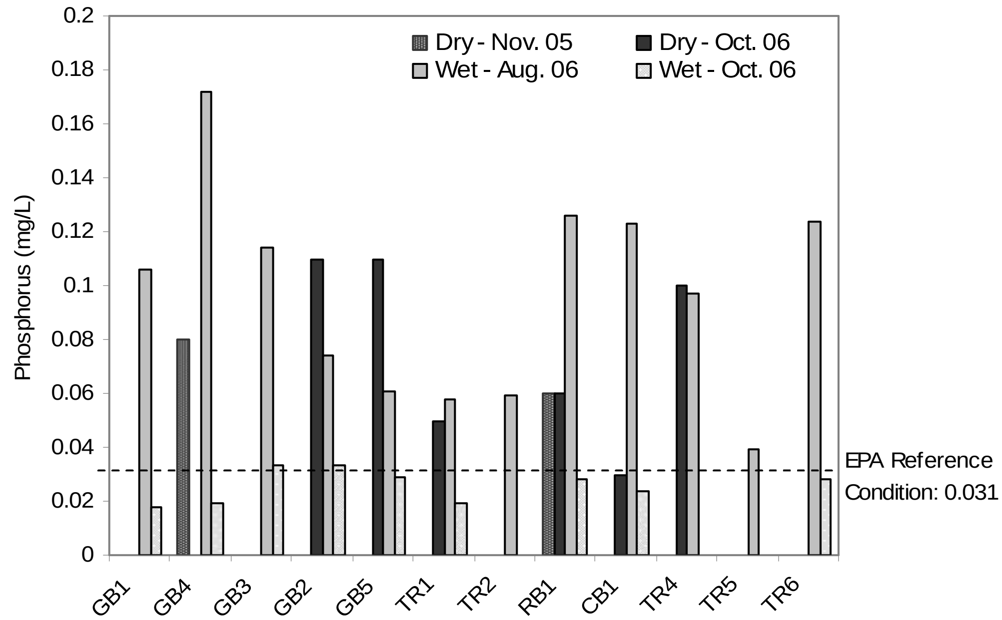


Figure 5-7: Phosphorus – Tankerhoosen River Watershed

Indicator Bacteria

Elevated levels of indicator bacteria (total coliform and *E. coli*) were measured at all monitoring locations during the October 2006 wet weather monitoring event, suggesting stormwater runoff and other non-point sources (pet waste, waterfowl, septic systems, etc.) as likely contributors of elevated pathogen levels in the Tankerhoosen River and its tributaries. Dry weather indicator bacteria concentrations were much lower than wet weather. Natural sources of indicator bacteria such as waterfowl or wildlife may have contributed to several dry weather exceedances of the CT WQS for total coliform at the Gages Brook monitoring location behind the Tolland Agricultural Center and at the Tankerhoosen River monitoring location just upstream of Fish and Game Road.

Bioassessment Results

The 2006 bioassessment data (RBV and Fuss & O Neill data collectively) vary considerably by site, but generally indicate very good water quality at most of the monitoring locations, with the exception of the lower Tankerhoosen River near the confluence with the Hockanum River and downstream of Dobsonville Pond. This finding is consistent with previous impairments identified in the lower reaches of the Tankerhoosen River by the CTDEP. Despite the water quality issues identified in Gages Brook, Clarks Brook, and in certain reaches of the Tankerhoosen River (i.e., heavy metals, turbidity and suspended solids, and potential nutrient enrichment), the 2006 bioassessment data indicate little or no impairment to the benthic communities at the monitored locations.

5.3 Wetlands

Generally, 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. Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. Wetlands and buffer zones between watercourses and developed areas help to preserve stream water quality by filtering pollutants, encouraging infiltration of stormwater runoff, and protecting against stream bank erosion.

Wetlands in Connecticut are designated by soil classification. Figure 5-8 depicts the extent and distribution of wetland soils in the Tankerhoosen River watershed based on Natural Resources Conservation Service soil classifications. Figure 5-8 also depicts wetland mapping available from the U.S. Fish & Wildlife Service National Wetlands Inventory. Wetlands soils comprise 11.3% of the overall watershed (approximately 926 acres), while 4% of the watershed area (approximately 320 acres) is mapped as freshwater emergent wetlands or freshwater forested/shrub wetlands. The concentration of wetland soils is generally higher in the undeveloped portions of the watershed. Mapped wetland soils are generally located in riparian and floodplain areas along the Tankerhoosen River and its major tributaries. Table 5-4 summarizes wetland soils coverage by subwatershed.

Table 5-4: Wetland Soils Coverage in the Tankerhoosen River Subwatersheds

Subwatershed Name	Wetland Soils Area (acres)	Percent of Subwatershed
Bolton Notch Pond	20	5.8 %
Clarks Brook	101	15.5 %
Gages Brook	111	15.9 %
Gages Brook South Tributary	34	5.1 %
Lower Tankerhoosen River	7	2.3 %
Middle Tankerhoosen River	188	11.9 %
Railroad Brook	136	11.3 %
Tucker Brook	109	11.7 %
Upper Tankerhoosen River	193	13.1 %
Walker Reservoir	27	7.6 %
Tankerhoosen River Watershed	926	11.3%

Several potential vernal pools are also located within the Tankerhoosen River Watershed. A "classic" high-quality vernal pool was identified by Mr. Ed Pawlak of the Connecticut Association of Wetland Scientists, who developed a draft definition of the term "vernal pool." In April of 2007, the Bolton Conservation Commission offered a hike to this vernal pool. Additionally, the Connecticut River Coastal Conservation District selected the Bolton Conservation Commission for a 2006 Special Merit Award. The award was given in recognition of the commission's ongoing interest, in leadership and dedication in maintaining the community-based Blackledge River monitoring program in partnership with the Connecticut River Watch Program.

In 1993, a comprehensive survey of plant life was conducted in the 1,400-acre watershed from Valley Falls Park in Vernon to Bolton Notch State Park in Bolton (Sexton, 1993). A total of 345 species representing 82 families were identified. A small band of marble exists a short distance north and south of the cut at Bolton Notch. A plant species unique to this area includes the Yellow Lady's Slipper. Marble is rare east of the Connecticut River and supports additional plants preferring more basic soil including the purple cliff-brake and maidenhair fern (Sexton, 1993).

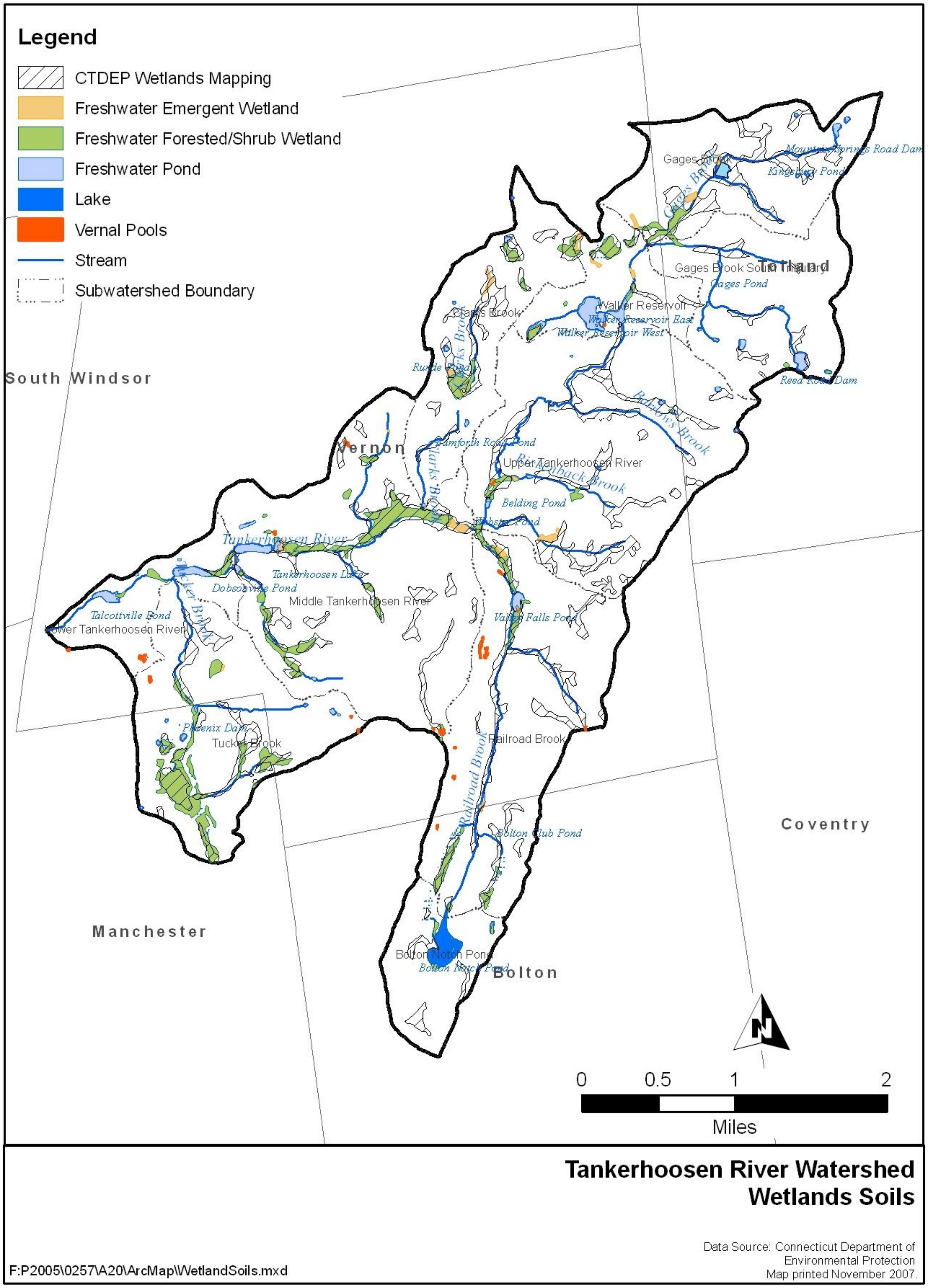


Figure 5-8: Wetland Soils – Tankerhoosen River Watershed

5.4 Fish and Wildlife Resources

Portions of the Tankerhoosen River have abundant habitats supportive of a variety of fish and wildlife. Various waterbodies, wetlands, and upland areas provide habitat to fish, mammals, amphibians, and birds.

Particularly notable is the 282-acre Belding Wildlife Management Area located in the central portion of the Tankerhoosen River watershed. The Belding Wildlife Management Area is a significant natural resource of undeveloped land owned by the State of Connecticut and managed by the DEP. A 1.4-mile section of the Tankerhoosen River within the Belding Wildlife Management Area is managed as a Class 1 Wild Trout Management Area and is one of only two such areas in eastern Connecticut. This section of stream is characterized by natural reproduction sufficient to produce robust populations of native brook trout (up to 8-10 inches) and wild brown trout (up to 10-11 inches) exhibiting above average growth rates (DEP correspondence, 2003).

Areas in the Tankerhoosen River watershed that provide significant habitat are summarized in Table 5-5. These areas provide habitat for some of the most valuable or unique natural resources or ecosystems in their respective communities. Other open space areas are described in the Land Use and Land Cover section of this report.

Table 5-5: Areas Providing Habitat for Valuable or Unique Natural Resources

Town	Natural Resource
Vernon	• Vernal Pools on Box Mountain Road • Tancanhoosen LLC Parcel • Talcottville Gorge • Belding Wildlife Management Area • Belding Wild Trout Management Area • Valley Falls Park • Rambling Ridge Property • Northern Connecticut Land Trust Properties
Tolland	• Tolland and Charter Marshes
Bolton	• Freja Park • Bolton Notch State Park

Source: Hockanum River – State of the Watershed Land Use Questionnaire, North Central Conservation District, 2005

Freja Park is a 21-acre, wooded town-owned area located west of Bolton Notch Pond. Freja Park serves as a gateway for the 1,400-acre Bolton Notch/Valley Falls watershed area. The town of Bolton originally acquired the property in 1968, but the park suffered from abuse and neglect. Beginning in March 1998, restoration efforts have been underway including numerous Earth Day Clean-up events with the help of volunteers, Boy Scouts, Conservation Commission members. A total of over two tons of litter have been removed from the park.

The following sections summarize the various fish and wildlife species that have been documented to exist in the Tankerhoosen River watershed, as well as endangered, threatened, and special concern species.

5.4.1 Fisheries

The Tankerhoosen River historically hosted large runs of many andromadous fish species. Development of the river with dams from 1700 to the 1920s created barriers to fish migration, which extirpated the salmon run and severely limited the upstream habitat for shad and river herring. Despite these obstacles, the Tankerhoosen River and its tributaries support a variety of fish species as detailed in Table 5-6.

The Tankerhoosen River is a cold water stream starting only a short distance below Walker Reservoir. The generally cold water temperatures in the Tankerhoosen are the result of extensive spring water inputs (DEP correspondence, 2008).

As indicated previously, the Belding Wild Trout Management Area in the upper portions of the Tankerhoosen River watershed is a Class 1 Wild Trout Management Area with self-sustaining native trout populations that rank among the best of their kind in the state. Portions of the remainder of the Tankerhoosen River are stocked annually by the DEP Inland Fisheries Division. Valley Falls Park Pond is stocked in the spring and winter with about 4,400 rainbow trout and generates between 7,500-8,000 angler hours of fishing annually. Walker Reservoir, upstream of the Belding Wildlife Management Area, is stocked each spring with over 1,800 adult brown and rainbow trout (DEP correspondence, 2003).

Table 5-6: Fish Species

	Bolton Notch Pond	Gages Brook	Lower Tankerhoosen River	Middle Tankerhoosen River	Upper Tankerhoosen River	Railroad Brook
American Eel				X	X	X
Brown Bullhead	X					X
Black Crappie	X				X	
Blacknose Dace		X		X	X	X
Brook Trout		X		X	X	X
Brown Trout			X	X	X	X
Bluegill	X		X	X	X	X
Chain Pickerel	X		X	X		
Common Shiner				X	X	X
Creek Chub				X	X	
Fallfish				X	X	
Fathead Minnow		X				
Golden Shiner	X			X	X	
Longnose Dace				X	X	
Largemouth Bass		X	X	X	X	X
Pumpkinseed Sunfish	X	X	X	X	X	X
Rainbow Trout				X	X	X
Rockbass			X			
Smallmouth Bass			X			
Tessellated Darter			X	X	X	

White Sucker		X		X	X	X
Yellow Perch	X			X		X
Tiger Trout					Stocked in Pond	
Golden Trout					Stocked in Pond	

5.4.2 Birds

Bird surveys were conducted in 2004 at the Tancanhoosen LLC property, within Valley Falls Park, and at various Town of Vernon properties, including areas around Walker Reservoir East and on the Connecticut Light & Power line site.

Eighty bird species were detected during the 2004 surveys. Seventy four species were counted during standardized bird counts at 24 count points, and 6 more were detected as incidental observations. The greatest number of species occurred at Walker Reservoir, while the former gravel pit on the Tancanhoosen LLC property contained the most uncommon birds. Prairie warbler, field sparrow, brown thrasher and eastern towhee were detected on the Tancanhoosen LLC property throughout the breeding season. Populations of these species are declining and brown thrasher is on Connecticut's list of Species of Special Concern. These birds are dependent on early successional habitats such as grassland and shrubland. These habitat types have been lost to reforestation and human development. The gravel pit is at an early successional stage with open, grassy habitat and short, scattered pine trees. This site will eventually revert to a forested habitat unless actively managed to maintain early successional habitat. Once the site is reforested, early successional species will disappear from this site (Seymour, 2004).

The Tankerhoosen River watershed also supports a wide range of bird of species. Surveys performed in 2003 and 2004 reported evidence of great blue heron, wood duck, willow flycatcher, hermit thrush, black-throated blue warbler, broad-winged hawk, hairy woodpecker, pileated woodpecker, olive-sided flycatcher, yellow-throated vireo, red-breasted nuthatch, blue-gray gnatcatcher, Nashville warbler, pine warbler, blackpoll warbler, blackburnian warbler, cerulean warbler, worm-eating warbler, and Canada warbler. European starling and house sparrow, two introduced invasive species, were also identified (Seymour, 2004). A complete species list is provided in Appendix A.

During 1999, a bird survey was completed to determine the species diversity and the relative abundance of breeding landbirds within Freja Park and Bolton Notch State Park (Comins, 1999). Of the total 55 species were recorded, 51 were likely nesting species and four were probably non-nesting visitors or migrants. An additional fourteen species were not recorded on the survey, but were identified as likely to occur during the nesting season. Another twenty-nine species have reasonable possibility of occurring in the nesting season from time to time or could be attracted to the area. Two Connecticut State Species of Special Concern were recorded; six species were listed as National Audubon Society Watch List High Conservation Priority species in Connecticut were recorded; an additional six species not listed as watch species were listed by Partners in Flight as High Conservation Priority Species in Connecticut; fourteen species that were uncommon nesters in the Hartford area were recorded (Comins, 1999). See report for additional listing of specific species.

5.4.3 Amphibians & Reptiles

Amphibian and reptile surveys were conducted in 2004 within the Tankerhoosen River watershed, including the Belding Wildlife Management Area, Barrows Brook, and Railroad Brook. Some of the species identified included Northern redback salamander, Northern two-lined salamander, Spotted salamander, American toad, Northern spring peeper, Gray treefrog, Wood frog, Green frog, Pickerel frog, Painted turtle, and Garter snake. The most abundant amphibian species detected during this study was the northern redback salamander. A complete list of the identified amphibian and reptile species is included as Appendix A. A previously undocumented vernal pool was discovered between Reservoir Road and Walker Reservoir West. Additional vernal pools were identified on Bolton Road and above Valley Falls Park (Seymour, 2004).

5.4.3 Threatened and Endangered Species

The DEP Natural Diversity Data Base (NDDB) maintains information on the location and status of endangered, threatened, and special concern species in Connecticut. Figure 5-9 displays the generalized areas of endangered, threatened, and special concern species in the Tankerhoosen River watershed. The areas represent a buffered zone around known species or community locations. The locations of species and natural community occurrences depicted on the NDDB mapping are based on data collected over the years by the Environmental and Geographic Information Center's Geologic and Natural History Survey, other units of the DEP, conservation groups, and the scientific community. Approximately ten such areas were identified throughout the watershed. Because new information is continually being added to the Natural Diversity Database and existing information updated, the areas are reviewed on an annual basis by the DEP. Areas can be removed or added based upon the results of the review.

Table 5-7: Endangered, Threatened, and Special Concern Species

Common Name	Scientific Name	Status
Flora		
Climbing fern	*Lygodium palmatum*	Special Concern
Sphagnum	*Sphagnum pulchrum*	--
Beaked sedge	*Carex rostrata*	--
Leatherleaf	*Chamaedaphne calyculata*	--
Fauna		
Eastern pearlshell	*Margaritifera margaritifera*	Special Concern
Brown thrasher	*Toxostoma rufum*	Special Concern
Southern bog lemming	*Synaptomys cooperi*	Special Concern
Wood turtle	*Clemmys insculpta*	Special Concern
Purple martin	*Progne subis*	Threatened
Eastern box turtle	*Terrapene c. carolina*	Special Concern
Habitats		
Medium fen	--	--
Subacidic rocky summit/outcrop	--	--

Source: DEP Natural Diversity Data Base, 2008.

- "Endangered Species" means any native species documented by biological research and inventory to be in danger of extirpation (local extinction) throughout all or a significant portion of its range within Connecticut and to have no more than five occurrences in the state.
- "Threatened Species" means any native species documented by biological research and inventory to be likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range within Connecticut and to have no more than nine occurrences in the state.
- "Species of Special Concern" means any native plant or any native nonharvested wildlife species documented to have a naturally restricted range or habitat in the state, to be at a low population level, to be in such high demand by man that its unregulated taking would be detrimental to the conservation of its population, or has become locally extinct in Connecticut.

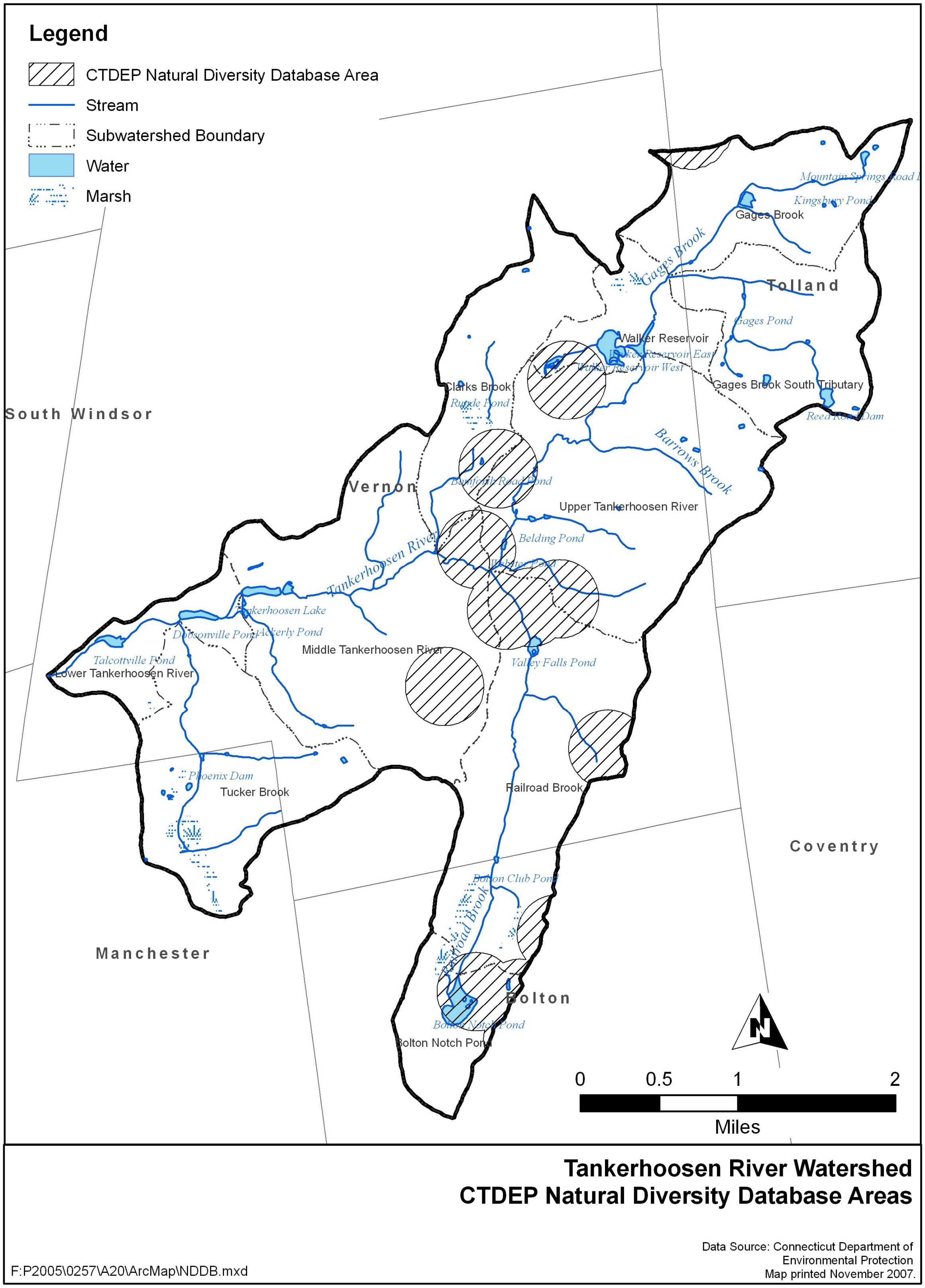


Figure 5-9: CTDEP Natural Diversity Database Areas – Tankerhoosen River Watershed

6.0 WATERSHED MODIFICATIONS

6.1 Dams, Impoundments, & Water Supply

The historical industrial use of the Tankerhoosen River and its major tributaries has left behind many small dams and impoundments. Most of this infrastructure is no longer used for power generation, and many of these impoundments currently provide aquatic and wildlife habitat and recreational opportunities. Many of the dams in the watershed are also an impediment to fish migration.

According to the DEP Dam Safety Regulations, the hazard classification of a dam is based on the damage potential from failure of the structure. Figure 6-1 shows the location and hazard classification of the identified dams within the watershed. Some of the dams which no longer serve an integral function to industry or public use have fallen into disrepair and pose a potential hazard to downstream properties.

Table 6-1 lists the major drinking water supplies within the Tankerhoosen River watershed which are regulated under the DEP Water Diversion program.

Table 6-1: Major Drinking Water Supplies

Name	Name of Diversion	MGD	Town
Connecticut Water Company	Vernon Well #1	0.1728	Vernon
	Vernon Well #2	0.1728	Vernon
	Vernon Well #3	0.1440	Vernon
	Vernon Well #4	0.1728	Vernon
	Vernon Well #5	0.4320	Vernon
Manchester Water Department	New Bolton Well Field, Well #1,2,3	Various	Bolton

The DEP, with Cooperation from the Connecticut Water Company, has identified two preliminary (Level B) Aquifer Protection Areas associated with these wells within the Tankerhoosen River watershed, as shown in Figure 6-2. Aquifer Protection Areas are designated around active well fields in sand and gravel aquifers that serve more than 1,000 people. Level B mapping identifies the general area of aquifer contribution/recharge based primarily on topography. The watershed communities are required to establish land use regulations for these areas to limit potential contamination to public groundwater supplies. Private groundwater supply wells are also prevalent throughout areas of the watershed that are not served by public water supplies.

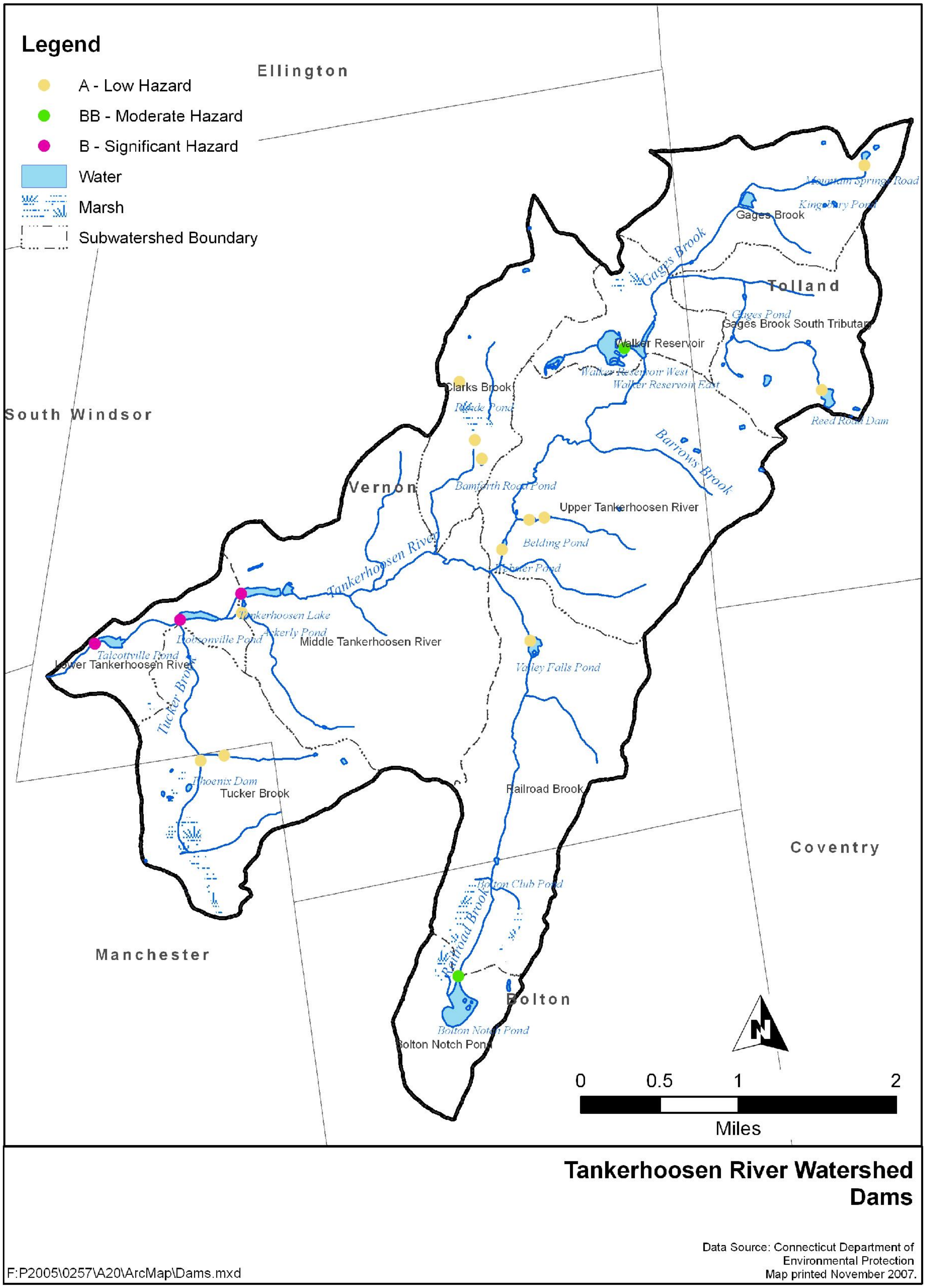


Figure 6-1: CTDEP Regulated Dams – Tankerhoosen River Watershed

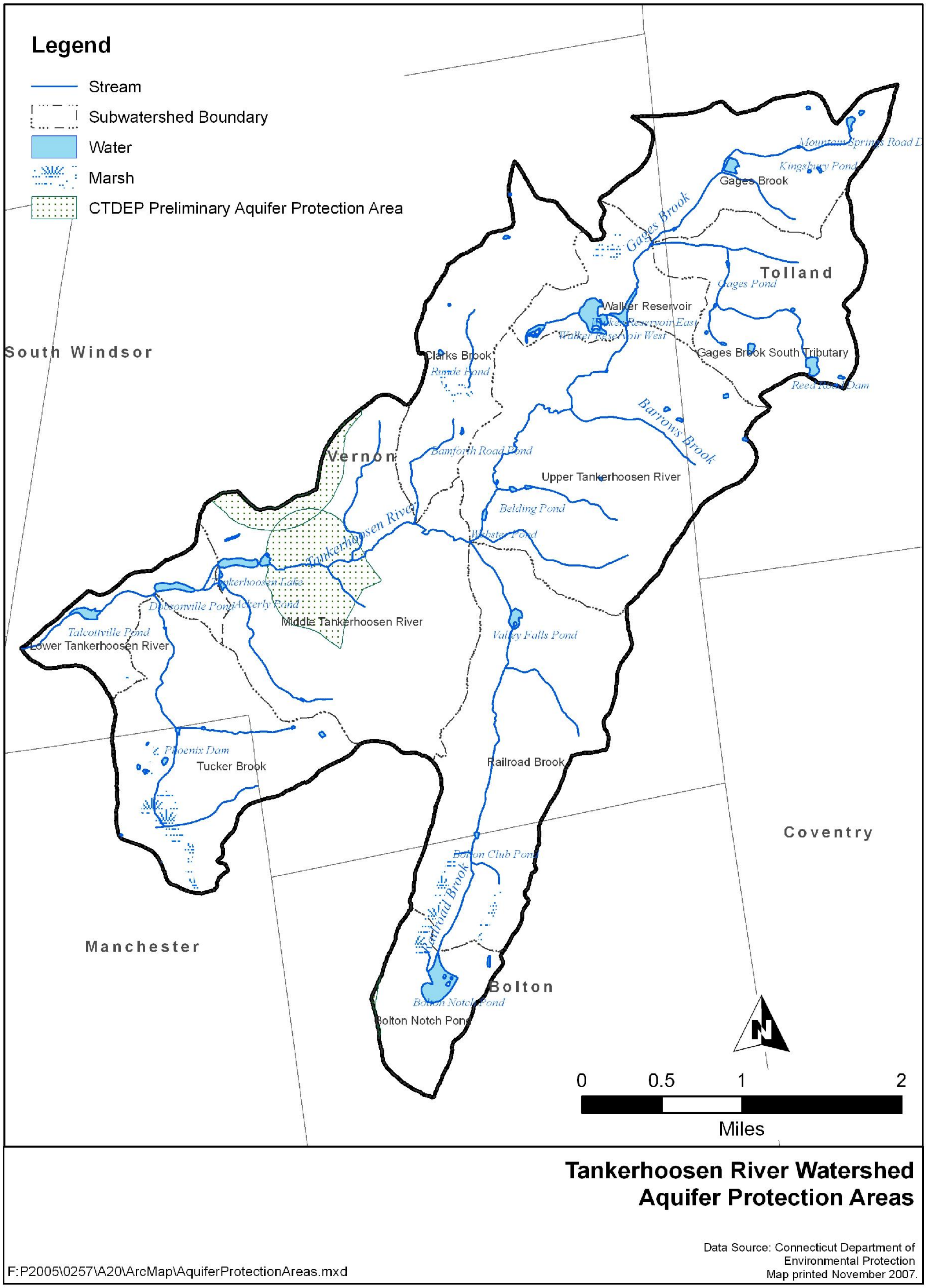


Figure 6-2: CTDEP Aquifer Protection Areas – Tankerhoosen River Watershed

6.2 Wastewater Discharges

As summarized in Table 6-2, there are number of industrial, commercial, and municipal facilities in the Tankerhoosen River Watershed with surface water discharges regulated under the National Pollutant Discharge Elimination System (NPDES) permit program, which is administered by the Connecticut DEP. The facilities listed in Table 6-2 have either permitted wastewater or stormwater discharges to surface waters. The majority of these facilities are located in Vernon. There are no municipal wastewater treatment plants located within the Tankerhoosen River watershed.

Table 6-2: NPDES Regulated Facilities

Town	Facility	Location	Permit Number
Vernon	Carpenter's Mobil	447 Hartford Turnpike	GVS000915
	Company 1 Firehouse	724 Hartford Turnpike	GVM000592
	Connecticut Golfland	95 Hartford Turnpike	GPL000108
	First Student	25 Whitney Ferguson Road	GSI001217
	Motiva Enterprises LLC	444 Hartford Turnpike	GGR001404
	Moore's Automotive	1245 Hartford Turnpike	GVM000806
	Mount Vernon Apartments	1120 Hartford Turnpike	GVS000863
	Oakland Meadows	1158 Hartford Turnpike	GSN001098
	Tighitco, Inc.	101-77 Industrial Park Road	GSI001599
	Vernon Maintenance	37 Campbell Avenue	GVS000988 GSI000074
	VMS Construction Company	120 Bolton Road	GVM000980
Bolton	Transportation Facility	326 Boston Turnpike	GSI001179
	Hull's Autobody	299-301 Boston Turnpike	GVM000800
Tolland	Dari Farms	Gerber Drive	GSN000814
	Mr. Sparkle Car Wash	157 Hartford Turnpike	GVM000646
	Connecticut Light & Power Co.	45 Tolland Stage Road	GVS001027
	Gerber Scientific Inc.	24 Industrial Park Road West	GSI000914
	Standard Register Co.	259 Hartford Turnpike	GPP000152 GPH000345
	CNC Software Inc.	671 Old Post Road	GSN000070
	Belvedere Ridge	601 Old Post Road	GSN001308

Source: DEP December 2007

Figure 6-3 depicts sewer service areas in the watershed. Areas outside of the mapped sewer service areas are presumed to be on individual sewage disposal (i.e., septic) systems. Approximately 23% of the overall Tankerhoosen River watershed area is served by municipal sanitary sewers.

6.3 Regulated Sites

Historical and current industrial and commercial development within the Tankerhoosen River watershed poses a potential threat to surface water and groundwater supplies in the watershed. Illegal waste disposal, improper use and disposal of chemicals such as used oil, pesticides, and herbicides, and chemical spills are potential sources of contaminants from industrial and commercial facilities. As summarized in the following table, several hazardous waste generators and other regulated sites are located within the watershed. These facilities are located in both Vernon and Tolland in the central and upper portions of the watershed.

Table 6-3: Summary of Regulated Sites

Site Type	Number of sites	
	Vernon	Tolland
Hazardous Waste Generator	5	6
Air Emissions	1	2
CERCLA Site	1 (1 on Final NPL)	0

Source: epa.gov/region1/superfund/sites/precision, accessed Nov. 2007.

There is one site that is listed as potential hazardous waste site that EPA has evaluated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), otherwise known as "Superfund." This site, Precision Plating Corporation, is located in the Hillside Industrial Park in Vernon and is currently on the Final National Priorities List (NPL). Chromium contaminated groundwater at the site is being remediated under the direction of the DEP.

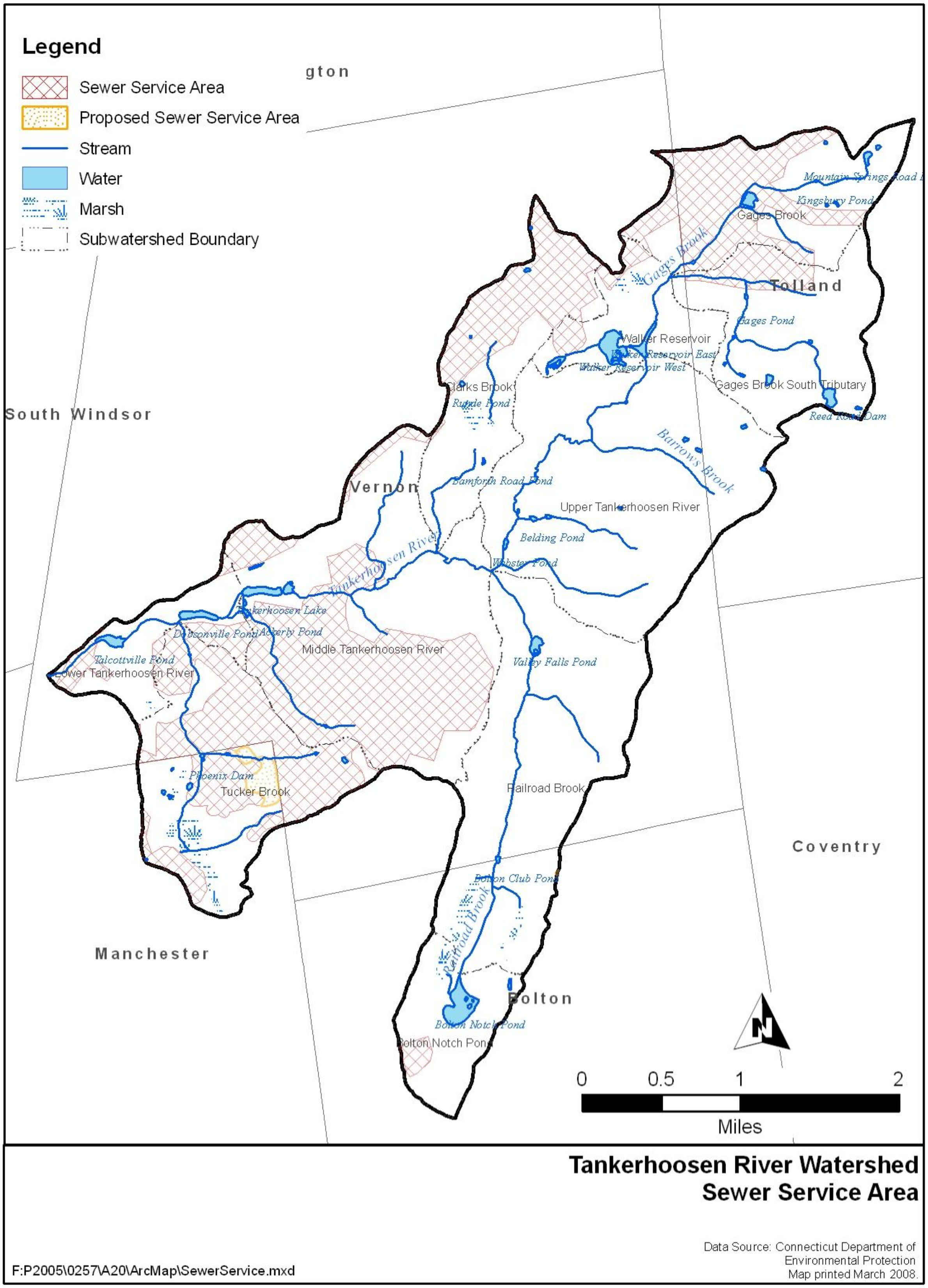


Figure 6-3: Sewer Service Areas – Tankerhoosen River Watershed

7.0 LAND USE AND LAND COVER

The type and distribution of land use within a watershed have direct impact on nonpoint sources of pollution and water quality. This section describes the land use and land cover patterns in the Tankerhoosen River watershed.

7.1 Current Conditions

7.1.1 Land Use

Figure 7-1 depicts general land use patterns in the Tankerhoosen River watershed. The data in Figure 7-1 are parcel-based land use categories for the watershed communities, provided by the Capital Region Council of Governments (CRCOG). The land uses in the watershed include 20 land use categories (Table 7-1). Approximately 60% of the watershed consists of developed land uses, with single-family residential comprising the largest percentage (40%). Highway and other road right-of-ways comprise approximately 9% of the watershed area. Approximately 30% is classified as resource/recreation land use, which includes committed and uncommitted open space. Major portions of the riparian areas adjacent to the Tankerhoosen River and its tributaries are located within resource/recreation areas. Areas in the northern portion of the watershed are more commercialized and have a greater retail and industrial use, with commercial, retail, and industrial land uses comprising approximately 4% of the watershed area. The majority of the commercial, industrial, and retail areas are located in headwater regions adjacent to the major transportation corridors of I-84/Route 30 and I-384.

Table 7-1: Current Land Use – Tankerhoosen River Watershed

Land Use Type	Acres	Percent of Watershed
Agriculture	103	1 %
One Family	3160	38 %
Two Family	48	<1 %
Three Family	2	<1 %
Multi Family	39	<1 %
Condominium	165	2 %
Group Quarters	12	<1 %
Commercial	110	1 %
Retail	88	1 %
Mixed Use	3	<1 %
Industrial	183	2 %
Government/Non-Profit	102	1 %
School	26	<1 %
Cemetery	22	<1 %
Health/Medical	6	<1 %
Resource/Recreation	2398	29 %
Undeveloped	851	10 %
Right-of-way	770	9 %
Water	77	<1 %
Unknown	61	<1 %

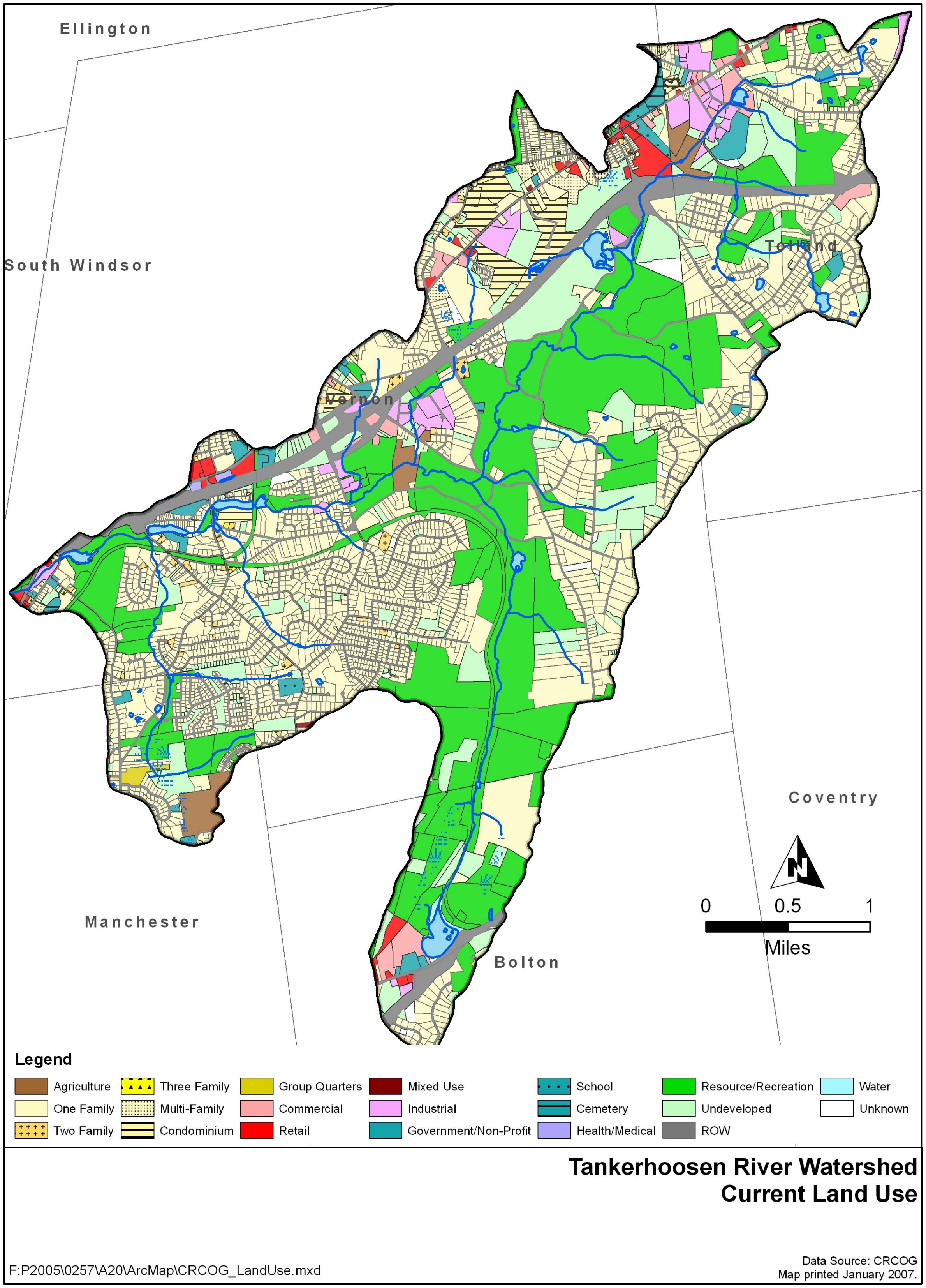


Figure 7-1: Current Land Use – Tankerhoosen River Watershed

In the Tankerhoosen River watershed, several tracts of potentially developable land have been permanently preserved as "committed" open space. Committed open space parcels in the Town of Vernon and the Town of Bolton were identified through available land use mapping and confirmed by members of the Technical Advisory Committee and the Bolton Conservation Commission. Committed open space parcels in Tolland and Manchester were determined through available mapping from each Town's Plan of Conservation and Development (POCD) and from the Connecticut Office of Policy and Management Municipal Plans of Conservation and Development. In general, the committed open space areas include deeded open space that is privately owned, parcels owned by land trusts, land owned by the State of Connecticut as well as parks owned by the Town of Vernon and Town of Bolton, including the Hop River State Park Trail, Valley Falls Park, Freja Park, and Bolton Notch State Park. This land is protected against future development and is generally located in the central and southern portion of the watershed. Figure 7-2 identifies the committed open space land in the watershed.

In addition, several parcels within the watershed are designated for agricultural or forestry use under Public Act 490. While development is not prohibited on this land, this program reduces the tax burden on this land, thereby relieving some of the pressure to develop the land and allows it to continue to serve as open space.

7.1.2 Zoning

Figure 7-3 depicts the zoning designations in the Tankerhoosen River watershed. The data in Figure 7-3 are also parcel-based and provided by CRCOG. The majority of the Tankerhoosen River watershed is zoned for residential uses. Commercial and industrial zones associated with the I-384 and I-84 corridors are located in the southern and northern portions of the watershed, respectively.

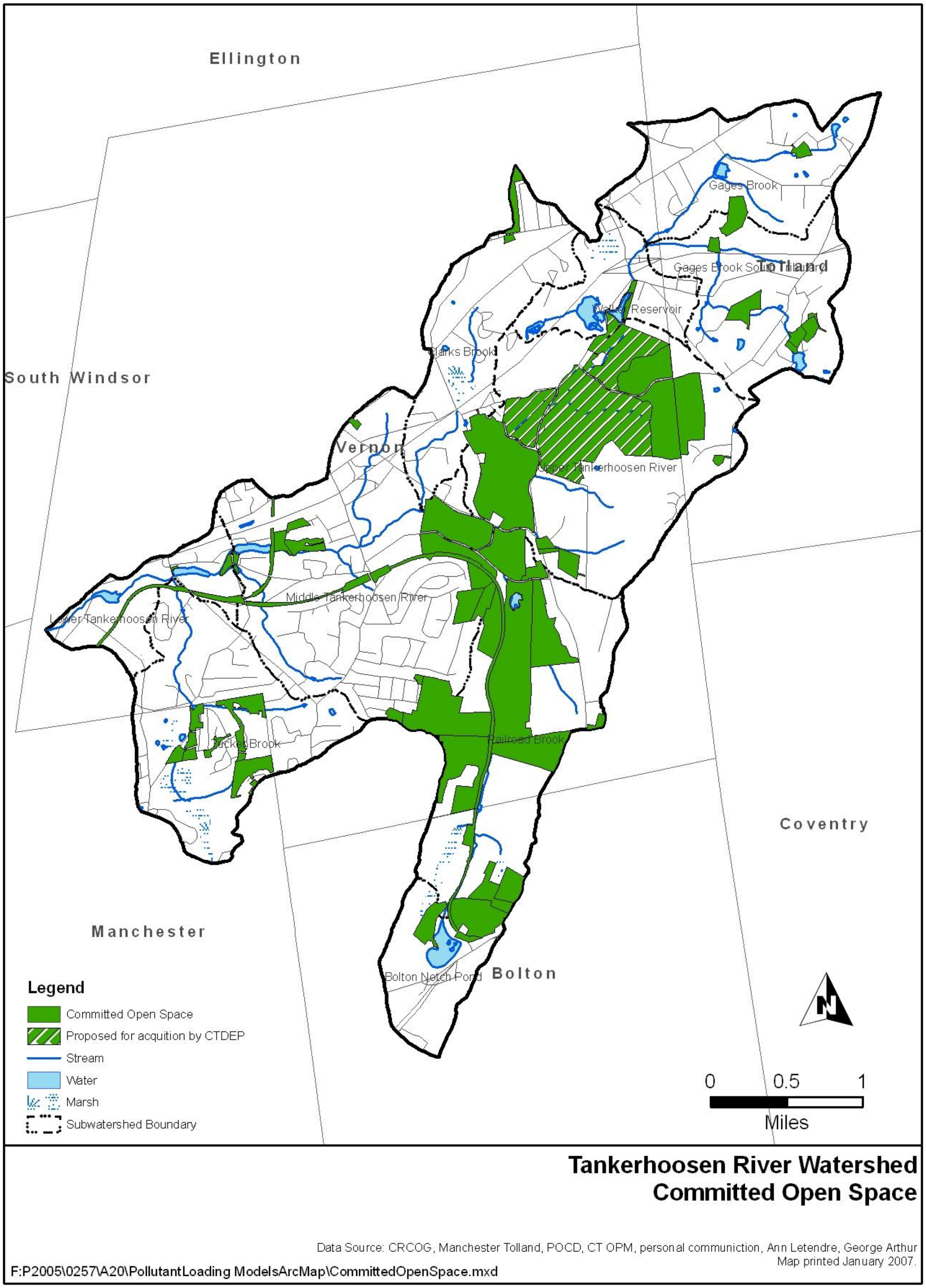


Figure 7-2: Committed Open Space – Tankerhoosen River Watershed

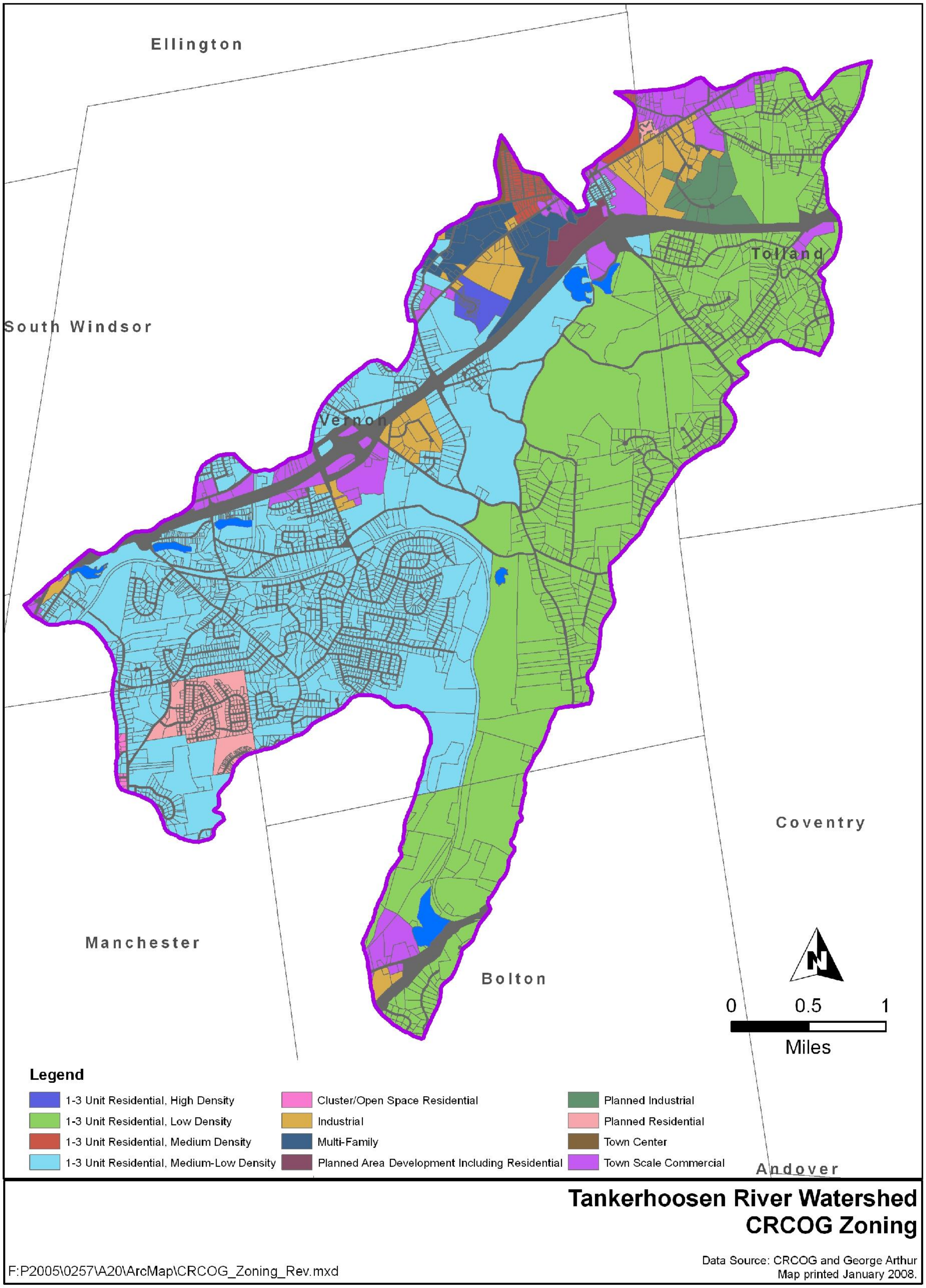


Figure 7-3: Zoning – Tankerhoosen River Watershed

7.1.3 Land Cover

Figure 7-4 depicts the general land cover in the Tankerhoosen River watershed. Data shown in Figure 7-4 are land cover categories derived from 2002 Landsat satellite imagery with ground resolution of 30 meters. The land cover data in the watershed are summarized into ten categories (Table 7-2). These ten categories are those used in the Connecticut Land Cover Map Series and are described following the table (University of Connecticut Center for Land Use Education and Research).

Table 7-2: Land Cover – Tankerhoosen River Watershed

Land Cover Type	1985		2002		Relative Percent Change[1]	Relative Rate of Change[2]
	Acres	Percent of Watershed	Acres	Percent of Watershed		
Barren	91	1 %	162	2 %	1%	78%
Coniferous Forest	454	6 %	430	5 %	-1%	-5%
Deciduous Forest	4581	56 %	4085	50 %	-6%	-11%
Developed	1793	22 %	2201	27 %	5%	23%
Forested Wetland	192	2 %	175	2 %	0	-9%
Non-forested Wetland	2	< 1 %	19	<1 %	0	912%
Other grasses and agriculture	551	7 %	603	7 %	0	9%
Turf and grass	448	5 %	447	5 %	0	0%
Utility Right of Way	19	< 1 %	17	<1 %	0	-12%
Water	95	2 %	88	1 %	1%	-7%

[1]Calculation = % land cover 2002 - % land cover 1985
[2]Calculation = (acres land cover 2002 – acres land cover 1985) / acres land cover 1985

Land Cover Type	1985		2002		Relative Percent Change[1]	Relative Rate of Change[2]
	Acres	Percent of Basin	Acres	Percent of Basin		
Barren	91	1	162	2	1%	78%
Coniferous Forest	454	6	430	5	-1%	-5%
Deciduous Forest	4581	56	4085	50	-6%	-11%
Developed	1793	22	2201	27	5%	23%
Forested Wetland	192	2	175	2	0	-9%
Non-forested Wetland	2	< 1	19	<1	0	912%
Other grasses and agriculture	551	7	603	7	0	9%
Turf and grass	448	5	447	5	0	0%
Utility Right of Way	19	< 1	17	<1	0	-12%
Water	95	2	88	1	1%	-7%

[1]Calculation = % land cover 2002 - % land cover 1985
[2]Calculation = (acres land cover 2002 – acres land cover 1985) / acres land cover 1985
Source: University of Connecticut's Center for Land Use Education and Research (CLEAR)

- Barren – Mostly non-agricultural areas free from vegetation, such as sand, sand and gravel operations, bare exposed rock, mines, and quarries. Also includes some urban areas where the composition of construction materials spectrally resembles more natural materials. Also includes some bare soil agricultural fields.

- Coniferous Forest – Includes Southern New England mixed softwood forests. May include isolated low density residential areas.
- Deciduous Forest – Includes Southern New England mixed hardwood forests. Also includes scrub areas characterized by patches of dense woody vegetation. May include isolated low density residential areas.
- Developed – High density built-up areas typically associated with commercial, industrial and residential activities and transportation routes. These areas contain a significant amount of impervious surfaces, roofs, roads, and other concrete and asphalt surfaces.
- Forested Wetland – Includes areas depicted as wetland, but with forested cover. Also includes some small watercourses due to spectral characteristics of mixed pixels that include both water and vegetation.
- Non-forested Wetland – Includes areas that predominantly are wet throughout most of the year and that have a detectable vegetative cover (therefore not open water). Also includes some small watercourses due to spectral characteristics of mixed pixels that include both water and vegetation.
- Other Grasses and Agriculture – Includes non-maintained grassy areas commonly found along transportation routes and other developed areas and also agricultural fields used for both crop production and pasture.
- Turf & Grass – A compound category of undifferentiated maintained grasses associated mostly with developed areas. This class contains cultivated lawns typical of residential neighborhoods, parks, cemeteries, golf courses, turf farms, and other maintained grassy areas. Also includes some agricultural fields due to similar spectral reflectance properties.
- Utility – Includes utility rights-of-way. This category was manually digitized on-screen from rights-of-way visible in the Landsat satellite imagery. The class was digitized within the deciduous and coniferous categories only.
- Water – Open water bodies and watercourses with relatively deep water.

Forest Cover

Forested areas are the predominant land cover type in the Tankerhoosen River watershed. Approximately 55% of the watershed consists of deciduous and coniferous forests, primarily in the central and southern portions of the watershed. Table 7-3 compares the total acres and percent forest cover by subwatershed. The percent forest cover in each subwatershed ranges from approximately 31% in the Walker Reservoir subwatershed to approximately 86% in the Railroad Brook subwatershed. Based on a literature threshold values documented in several studies (CLEAR, 2007), watershed forest cover of 65% or greater is the minimum needed for a healthy aquatic invertebrate community. Only two of the ten subwatersheds, Railroad Brook and the Upper Tankerhoosen River, exceed the threshold value of 65%. Based on a recommendation of the American Forests organization, 40% forest cover is a reasonable threshold goal for urban areas. All but two subwatersheds, Clarks Brook (34.8 %) and Walker Reservoir (31.3 %), both of which are located in the northern and most developed portion of the watershed, meet this goal.

Table 7-3: Forest Cover – Tankerhoosen River Watershed

Subwatershed Name	Forest Cover in Subwatershed (acres)	Percent Forest Cover in each Subwatershed	Developable Forest Cover in Subwatershed (acres)	Percent of Forest Cover that is Developable
Bolton Notch Pond	171	49.6 %	41	24.0 %
Clarks Brook	226	34.8 %	70	30.9 %
Gages Brook	314	45.2 %	134	42.6 %
Gages Brook South Tributary	395	58.1 %	171	43.3 %
Lower Tankerhoosen	149	46.6 %	82	54.9 %

River				
Middle Tankerhoosen River	625	39.6 %	122	19.6 %
Railroad Brook	1043	86.3 %	346	33.2 %
Tucker Brook	374	40.0 %	119	31.8 %
Upper Tankerhoosen River	1110	75.4 %	278	25.0 %
Walker Reservoir	109	31.3 %	54	49.2 %
Tankerhoosen River Watershed	4515	54.9 %	1416	31.4 %

Table 7-3 also includes a comparison of the amount of forest cover in each subwatershed that could potentially be developed in the future (i.e., "developable"). Refer to Section 7.2.1 for a discussion of the determination of "developable" areas and watershed buildout scenario. The percent of forest cover that is developable for each subwatershed ranges from approximately 20% in the Middle Tankerhoosen River subwatershed and up to approximately 55% in the Lower Tankerhoosen River subwatershed. These results suggest that future development within the watershed has the potential to significantly reduce forest cover and, in some subwatersheds, to below recommended thresholds.

Riparian Vegetation

Riparian, or streamside, corridors are critical areas important to stream stability, pollutant removal, and wildlife habitat. These areas are also sometimes called "buffer" areas, but are not to be confused with regulatory review zones, which are often also called buffers (CLEAR 2007). A stream walk survey of the Tankerhoosen River conducted in 1999 revealed that riparian buffers of 100 feet are common between the river and developed areas. However, some areas along the lower reaches of the Tankerhoosen River were identified as having stream buffers of less than 25 feet, according to the results of a 2000 stream walk survey of the Tankerhoosen River.

In order to assess the status and of the riparian corridors in the Tankerhoosen River watershed, the acreage of forest cover within the riparian area (defined as a 200-foot buffer on both sides of streams and a 200-foot buffer from waterbody shorelines) was calculated for each of the ten subwatersheds based on the 2002 Center for Land Use Education and Research (CLEAR) forest land cover classes (coniferous and deciduous forest). The results are provided below in Table 5-5:

Table 5-5: Forest Cover in Riparian Areas in the Tankerhoosen River Subwatersheds

Subwatershed Name	Forest Cover in 200-foot Riparian Corridor (acres)	Percent of 200-foot Riparian Corridor that is Forested
Bolton Notch Pond	19	34.9 %
Clarks Brook	42	46.3 %
Gages Brook	85	61.4 %
Gages Brook South Tributary	93	62.3 %
Lower Tankerhoosen River	31	35.8 %

Middle Tankerhoosen River	99	41.8 %
Railroad Brook	167	87.2 %
Tucker Brook	92	51.8 %
Upper Tankerhoosen River	216	80.7 %
Walker Reservoir	21	23.1 %
Tankerhoosen River Watershed	866	58.3%

Forest cover within the 200-foot riparian corridor for the overall Tankerhoosen River Watershed is nearly 60%, although the amounts vary considerably by subwatershed. Railroad Brook (87.2%) and the Upper Tankerhoosen River (80.7%) subwatersheds have the highest percentage of forest cover within the 200-foot riparian corridor. Walker Reservoir (23.1%) and Bolton Notch Pond (34.9%) have the lowest percentage of forest cover within the 200-foot riparian corridor. These results indicate that large portions of the watershed streams and waterbodies are well-protected by intact riparian forest cover, although several subwatersheds have significantly lower riparian forest cover.

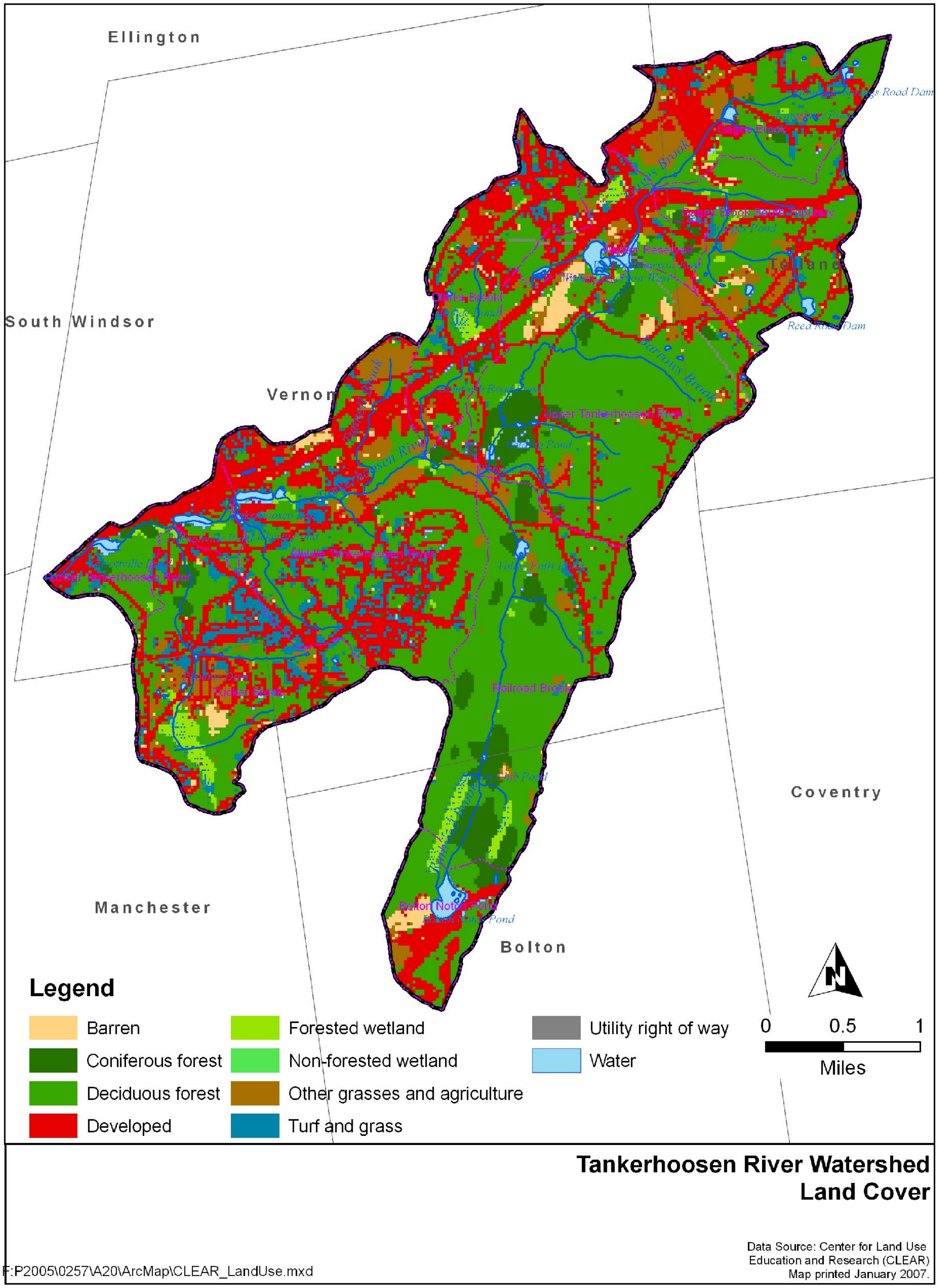


Figure 7-4: Land Cover – Tankerhoosen River Watershed

Developed Areas

Developed areas are also a dominant land cover type in the Tankerhoosen River watershed. Approximately 27% of the watershed consists of commercial, industrial, residential, and transportation land cover types (i.e. "developed" category) that follow the major transportation corridors, regional retail and commercial areas, and population centers. Approximately 7% of the watershed consists of other grass and agriculture, although only a small portion of this (approximately 1%) consists of land in active agricultural use.

A comparison of watershed land cover data between 1985 and 2002 (Table 7-2) shows a moderate increase in watershed development during this period (5% increase in developed cover types) and a corresponding loss of coniferous (1% decrease) and deciduous forest (6% decrease).

7.1.4 Impervious Cover

Impervious cover has emerged as a measurable, integrating concept used to assess the overall condition of a watershed. Numerous studies have documented the cumulative effects of urbanization on stream and watershed ecology (Center for Watershed Protection, 2003; Schueler et al., 1992; Schueler, 1994; Schueler, 1995; Booth and Reinelt, 1993, Arnold and Gibbons, 1996; Brant, 1999; Shaver and Maxted, 1996). Research has also demonstrated similar effects of urbanization and watershed impervious cover on downstream receiving waters such as lakes, reservoirs, estuaries, and coastal areas.

The correlation between watershed impervious cover and stream indicators is due to the relationship between impervious cover and stormwater runoff, since streams and receiving water bodies are directly influenced by stormwater quantity and quality. Although well-defined imperviousness thresholds are difficult to recommend, research has generally shown that when impervious cover in a watershed reaches between 10 and 25 percent, ecological stress becomes clearly apparent. Between 25 and 60 percent, stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases (NRDC, 1999). Watershed imperviousness in excess of 60 percent is generally indicative of watersheds with significant urban drainage. Figure 7-5 illustrates this effect. These research findings have been integrated into a general watershed planning model known as the impervious cover model (ICM) (CWP, 2003). The ICM has also been confirmed locally in Connecticut by the CTDEP, which has determined a statewide impervious cover threshold of 12 percent for aquatic life impairment (Belucci, CTDEP, 2007).

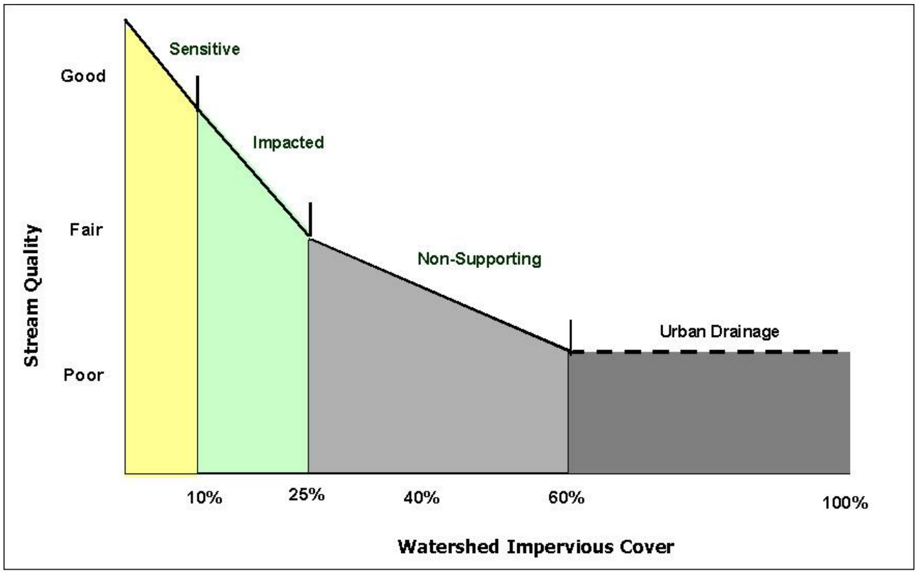


Figure 7-5: Relationship Between Watershed Imperviousness and Stream Health

Source: www.cwp.org

A GIS-based impervious cover analysis was performed for the Hockanum River watershed and including the Tankerhoosen River watershed by staff from the Department of Natural Resources Management and Engineering at the University of Connecticut (Civco, 2005). The satellite-derived land cover data described previously were used in the analysis. This technique, known as "direct impervious surface modeling", extracted impervious surface data directly from 2002 Landsat imagery to estimate the amount of impervious surface within each pixel. The DEP GIS basin layer was used to calculate the percent of imperviousness by basin. Figure 7-5 graphically summarizes the results of this analysis.

The overall imperviousness of the Tankerhoosen River watershed is estimated at approximately 9.7%. This level of impervious cover is slightly below the CTDEP aquatic life impairment threshold of approximately 12%, where ecological stress and stream impacts become apparent. As shown in Figure 7-6, impervious cover in much of the central and southern portions of the watershed (Upper Tankerhoosen River and Railroad Brook watersheds) is less than 5%, consistent with the high percentage of forest cover and conservation land in these areas. The headwater tributaries of the Tankerhoosen River, specifically Gages Brook, are estimated to have approximately 11.5% impervious cover, while localized subwatershed areas around Bolton Notch Pond, Walker Reservoir, and Dobsonville Pond have impervious cover near or above 20%.

Table 7-4: Percent Impervious Cover – Tankerhoosen Watershed

Subwatershed	Percent Impervious Cover
Bolton Notch Pond	16.6 %
Clarks Brook	17.2 %
Gages Brook	11.5 %
Gages Brook South Tributary	11.3 %
Lower Tankerhoosen River	15.8 %
Middle Tankerhoosen River	12.9 %

Railroad Brook	1.7 %
Tucker Brook	8.1 %
Upper Tankerhoosen River	4.5 %
Walker Reservoir	19.9 %
Total	9.7 %

The results of this analysis provide an initial diagnosis of potential stream and receiving water quality within the watershed study area. The analysis method and ICM are based on several assumptions and caveats, which limits its application to screening-level evaluations. Some of the assumptions of the ICM include:

- Requires accurate estimates of percent impervious cover, which is defined as the total amount of impervious cover over a subwatershed area. The resolution of the land cover data used in the evaluation is relatively coarse, although sufficient for a screening-level analysis.

- Predicts potential rather than actual stream quality.

- Does not predict the precise score of an individual stream quality indicator but rather predicts the average behavior of a group of indicators over a range of impervious cover.

- The 10 percent and 25 percent thresholds are approximate transitions rather than sharp breakpoints.

- The ICM has not been validated for lakes, reservoirs, aquifers, and estuaries.

- Does not currently predict the impact of watershed best management practices (treatment or non-structural controls).

- Does not consider the geographic distribution of the impervious cover relative to the streams and receiving waters. Effective impervious cover (impervious cover that is hydraulically connected to the drainage system) has been recommended as a better metric, although determining effective impervious cover requires extensive and often subjective judgment as to whether it is connected or not.

- Impervious cover is a more robust and reliable indicator of overall stream quality beyond the 10 percent threshold. The influence of impervious cover on stream quality is relatively weak compared to other potential watershed factors such as percent forest cover, riparian community, historical land use, soils, agriculture, etc. for impervious cover less than 10 percent.

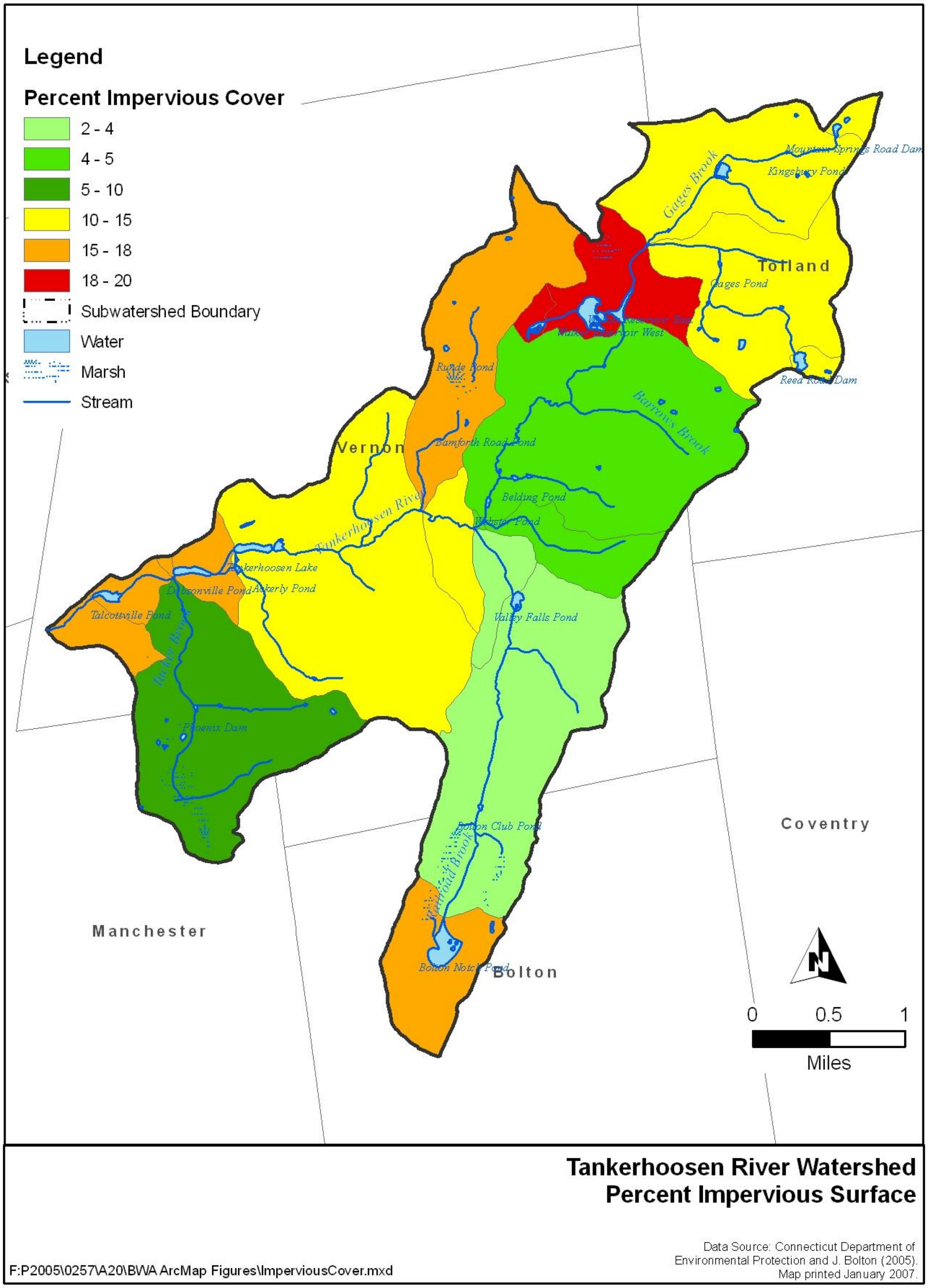


Figure 7-6: Current Impervious Cover – Tankerhoosen River Watershed

7.2 Future Conditions

A watershed buildout analysis was also conducted as part of this assessment to assist in the identification of subwatersheds with the highest restoration potential as well as the greatest vulnerability. The purpose of the analysis is to estimate the future land use and impervious cover conditions of the watershed as a result of maximum development allowed by the current zoning within the watershed.

7.2.1 Land Use

Watershed lands that could be developed in the future (i.e., "developable" land) were subdivided into two categories, based on the CRCOG parcel-based land use data:

- New Development - areas that are currently undeveloped and could become new developments in the future. Land designated as "new development" includes those parcels that are designated as "undeveloped" and "resource/recreation" in the CROCG land use data and not identified as committed open space.

- Redevelopment - areas that are currently underdeveloped and could be redeveloped with a higher intensity land use in the future. Land designated for "redevelopment" were limited to single-family residential parcels in the CRCOG land use data that could be subdivided and/or redeveloped in the future.

Areas having the following physical and/or regulatory constraints were also removed from consideration for future development or redevelopment: water bodies, wetland soils, and soils whose slope characteristics defined by NRCS exceed 15% (i.e., steep slope soils). Resulting fragments of land smaller than ¼-acre in size for new development and 3 acres in size for redevelopment were also removed from the analysis. Table 7-5 and Figure 7-7 summarize the amount of developable land by subwatershed, including the new development and redevelopment categories.

Table 7-5: Developable Land – Tankerhoosen Watershed

Subwatershed	New Development (acres)	New Development Percent in Subwatershed	Redevelopment (acres)	Redevelopment Percent in Subwatershed
Bolton Notch Pond	49	14.3 %	11	3.2 %
Clarks Brook	57	8.8 %	52	8.1 %
Gages Brook	129	18.5 %	72	10.3 %
Gages Brook South Tributary	123	18.1 %	102	15.0 %
Lower Tankerhoosen River	91	28.5 %	17	5.4 %
Middle Tankerhoosen River	127	8.0 %	141	8.9 %
Railroad Brook	212	17.6 %	172	14.3 %
Tucker Brook	122	13.1 %	89	9.5 %
Upper Tankerhoosen River	238	16.1 %	150	10.2 %

Walker Reservoir	108	31.3 %	13	3.8 %
Total	1257	15.3 %	820	10.0 %

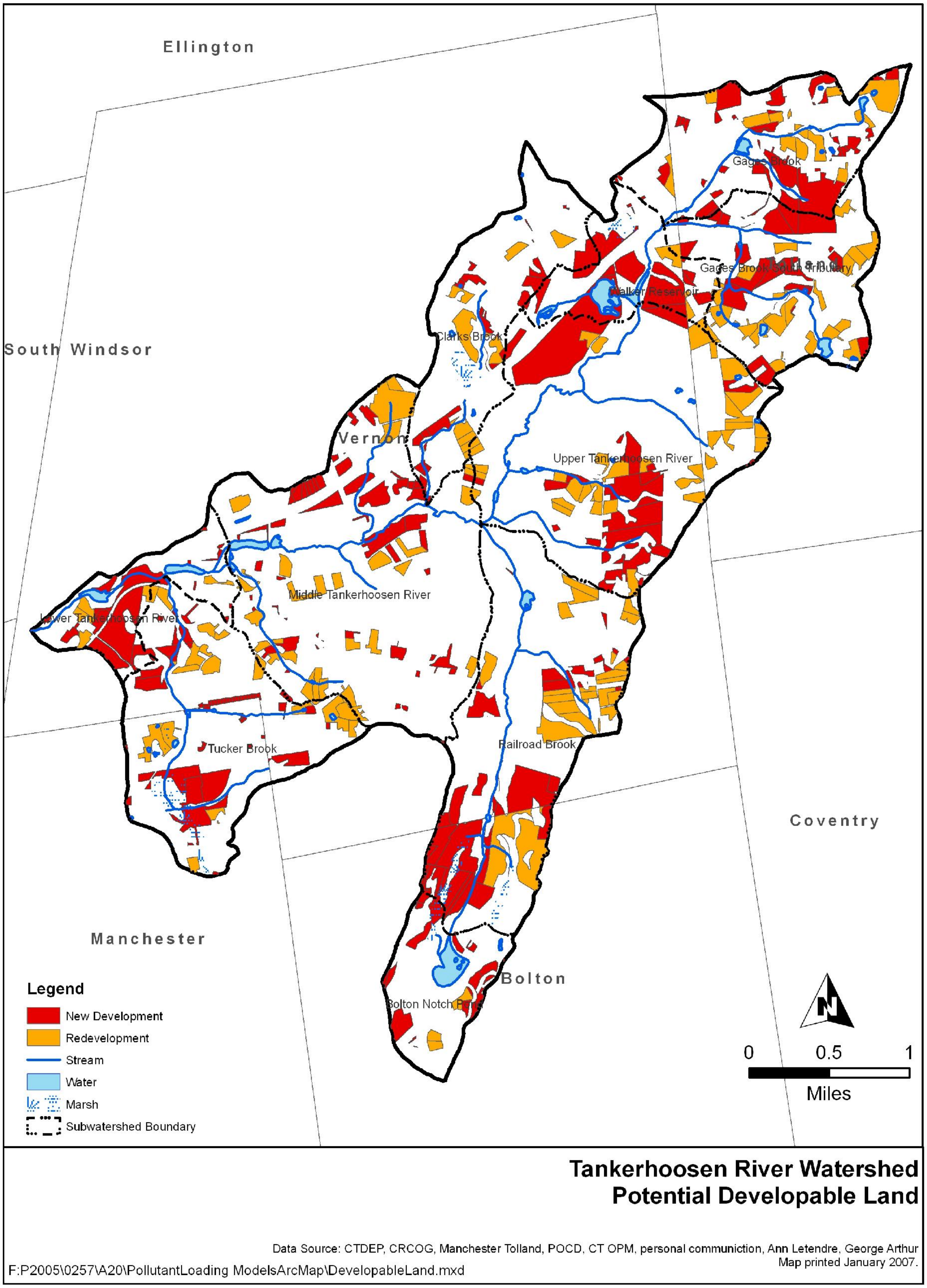


Figure 7-7: Developable Land – Tankerhoosen River Watershed

The future land use buildout scenario was estimated by assigning new land uses to developable areas (See Section 7.2.1), while maintaining the existing land uses for developed and unbuildable land (wetland soils, steep slope soils, etc.). The developable areas were assigned a future land use based on maximum degree of development allowed by the existing zoning category. Table 7-6 presents the future land use category assigned to each developable parcel based on the zoning category. This analysis assumes development of Act 490 parcels consistent with the underlying zoning and does not account for future zone changes or future land development regulatory changes.

Table 7-7: Assigned Future Land Use Category

Zoning Category	Assigned Future Land Use
1-3 Unit Residential, High Density	Condominium
1-3 Unit Residential, Medium Density	Three Family
1-3 Unit Residential, Medium-Low Density	Two Family
1-3 Unit Residential, Low Density	One Family
Cluster/Open Space Residential	One-Family
Industrial	Industrial
Multi-Family	Multi-Family
Planned Area Development Including Residential	Mixed Use
Planned Industrial	Industrial
Planned Residential	Multi-Family
Town Center	Mixed Use
Town Scale Commercial	Commercial

The results of the buildout analysis are summarized in Table 7-8, which compares acreage of existing and future land use in the watershed. The most significant potential land use change is in the residential land use categories, which is predicted to increase by approximately 15% watershed-wide. The area of resource/recreation and undeveloped land is predicted to decrease by approximately 15% watershed-wide, while commercial and industrial land are predicted to increase by approximately 3%.

Table 7-8: Existing and Future Land Use – Tankerhoosen Watershed

Land Use Type	$Acres_{Existing}$	Percent of $Basin_{Existing}$	$Acres_{Future}$	Percent of $Basin_{Future}$	Relative Percent Change
Agriculture	103	1 %	89	1 %	0
One Family	3160	38 %	3415	42 %	4%
Two Family	48	<1 %	811	10 %	10%
Three Family	2	<1 %	3	<1 %	0
Multi Family	39	<1 %	60	1 %	1%
Condominium	165	2 %	177	2 %	0
Group Quarters	12	<1 %	12	<1 %	0
Commercial	110	1 %	206	3 %	2%
Retail	88	1 %	88	1 %	0
Mixed Use	3	<1 %	33	<1 %	0

Industrial	183	2 %	270	3 %	1%
Government/Non-Profit	102	1 %	102	1 %	0
School	26	<1 %	26	<1 %	0
Cemetery	22	<1 %	14	<1 %	0
Health/Medical	6	<1 %	6	<1 %	0
Resource/Recreation	2398	29 %	1787	22 %	-7%
Undeveloped	851	10 %	233	3 %	-7%
Right-of-way	770	9 %	770	9 %	0
Water	77	<1 %	77	<1 %	0
Unknown	61	<1 %	46	<1 %	0

7.2.2 Impervious Cover

The watershed buildout analysis was used in conjunction with the existing conditions impervious cover analysis (Section 7.1.3) to estimate future impervious cover in the Tankerhoosen River subwatersheds. To complete this analysis, impervious cover was included as a parameter in the pollutant load model described in Section 8.1. Each urban land use type was assigned an impervious cover coefficient based on literature values (see Table 8-2). Land use data for both existing and buildout conditions were then entered into the model to determine the change in impervious cover for each subwatershed. The predicted change in impervious cover was then added to the existing impervious cover estimates described in Section 7.1.3 to estimate future impervious cover.

Table 7-9 presents estimates of existing and future impervious cover by subwatershed. The shaded cells in the table highlight the subwatersheds in which future impervious cover is predicted to approach or exceed either the "sensitive" (10% to 12%) or "impacted" (25%) threshold values as described by the Impervious Cover Model.

Table 7-9: Percent Impervious Cover – Existing and Future Conditions

Subwatershed	Existing Percent Impervious Cover	Future Percent Impervious Cover	Percent Change ($IC^{Future} - IC^{Existing}$)
Bolton Notch Pond	16.6 %	18.9 %	2.3 %
Clarks Brook	17.2 %	20.6 %	3.4 %
Gages Brook	11.5 %	14.2 %	2.7 %
Gages Brook South Tributary	11.3 %	13.5 %	2.2 %
Lower Tankerhoosen River	15.8 %	23.0 %	7.2 %
Middle Tankerhoosen River	12.9 %	15.5 %	2.6 %
Railroad Brook	1.7 %	3.4 %	1.7 %
Tucker Brook	8.1 %	10.3 %	2.2 %
Upper Tankerhoosen River	4.5 %	4.7 %	0.2 %
Walker Reservoir	19.9 %	29.13 %	9.2 %
Total	9.87 %	12.47 %	2.6 %

It is significant to note that, based on this analysis, the overall impervious cover in the Tankerhoosen River watershed is predicted to increase from less than 10% to greater than

12%, which is considered impacted (see Figure 7-5). The largest change in impervious cover is predicted in the Walker Reservoir subwatershed, where imperviousness could increase from approximately 20%, or "impacted," to approximately 29%, or "non-supporting." Additionally, the impervious cover in Gages Brook and the associated Gages Brook South Tributary subwatersheds, both of which are important headwater streams, is predicted to cross the state-wide 12% sensitive threshold value.

Another useful metric was developed by Goetz et al. (2003) for the Chesapeake Bay region, which combines subwatershed impervious cover and tree cover within the 100-foot stream buffer. Each of the subwatersheds within the Tankerhoosen River Basin was analyzed with regard to the combined impervious cover/riparian zone metric, which is summarized in the following matrix by Goetz et al. (2003).

Stream Health	% Watershed Impervious Cover	% Natural Vegetation in 100-ft Stream Buffer
Excellent	< = 6%	>=65%
Good	6-10%	60-65%
Fair	10-25%	40-60%
Poor	> 25%	<40%

Natural vegetation was determined using the CLEAR land cover data and included the deciduous forest, coniferous forest, forested wetland, and non-forested wetland categories. The following table presents the results from the combined impervious cover/riparian zone metric.

Table 7-10: Impervious Cover/Riparian Zone Metric – Existing and Future Conditions

Subwatershed	Existing		Future	
	% Watershed Impervious Cover	% Natural Vegetation in 100-ft Stream Buffer	% Watershed Impervious Cover	% Natural Vegetation in 100-ft Stream Buffer
Bolton Notch Pond	16.6 %	40.4 %	18.9 %	39.8 %
Clarks Brook	17.2 %	51.9 %	20.6 %	38.0 %
Gages Brook	11.5 %	59.5 %	14.2 %	50.1 %
Gages Brook South Tributary	11.3 %	69.6%	13.5 %	40.2 %
Lower Tankerhoosen River	15.8 %	42.7 %	23.0 %	26.0 %
Middle Tankerhoosen River	12.9 %	49.7 %	15.5 %	41.8 %
Railroad Brook	1.7 %	89.4 %	3.4 %	73.7 %
Tucker Brook	8.1 %	65.5 %	10.3 %	49.6 %
Upper Tankerhoosen River	4.5 %	84.6 %	4.7 %	76.3%
Walker Reservoir	19.9 %	41.2 %	29.13 %	31.8 %

Overall, most of the Tankerhoosen River subwatersheds are currently categorized as "fair" to "good" based on the riparian zone metric published by Goetz et al. (2003), while several of the key headwater streams, including Railroad Brook and the Upper Tankerhoosen River, fall into the highest category. Comparison between the existing and future ratings indicates that four of the ten subwatersheds (Clarks Brook, Gages Brook South Tributary, Lower Tankerhoosen River, and Tucker Brook) are predicted to experience a decline in stream health as a result of future development and, in particular, development within the riparian corridor.

8.0 POLLUTANT LOADING

A pollutant loading model was developed using the land use/land cover data described in Section 7.0. The model was used to compare existing nonpoint source (NPS) pollutant loads from the watershed to projected future pollutant loads that would occur under a watershed buildout scenario. It is important to note that the results of this screening-level analysis are intended for the purposes of comparing existing and future conditions and not to predict future water quality. This section summarizes the methods and results of the analysis, which are presented in greater detail in Appendix B.

The Spreadsheet Tool for the Estimation of Pollutant Load (STEPL), Version 4.0, was used for this analysis. This model was developed for US EPA by Tetra Tech in EPA Region 5 and has since been modified for use in other areas of the country. The model calculates watershed pollutant loads for sediment and nutrients based on land use-related pollutant sources, including urban runoff, septic system failures, stream bank erosion, and agricultural activities. The model also allows simulation of best management practices (BMPs) and Low Impact Development (LID) practices to reduce pollutant loads.

Data obtained as part of the Land Use/Land Cover analysis presented in Section 7.0 were used to generate model inputs. Several other model parameters were specified for each pollutant and subwatershed, including:

- Event Mean Concentrations (EMCs), which are literature values for the mean concentration of a pollutant in stormwater runoff for each land use, and
- Curve Number (CN), which is a measure of the runoff potential of the land surface and is a function of soil type, cover condition, and slope.

The model was applied to each subwatershed to estimate pollutant loads for each subwatershed under existing land use and future land use scenarios, as described in Section 7.0. The existing and future pollutant loads were compared to assess anticipated changes in loads for each subwatershed. Table 8-1 presents the results of this analysis. Results are shown in terms of increase in pollutant loading rate (the mass of pollutant to be discharged from each acre of land in a watershed) and percent increase in pollutant load (based on the total pollutant discharge from each of the watersheds).

Table 8-1: Projected Pollutant Loading Rate and Load Increases

	Loading Rate Increase (Load Increase per Acre, mass [lb or ton]/ac-yr)				Load Increase (%) (Total for Each Watershed)			
Watershed	N	P	BOD	Sediment	N	P	BOD	Sediment
Bolton Notch Pond (318 ac)	0.66	0.10	2.7	0.012	9.6%	8.0%	10.9%	7.7%
Clarks Brook (647 ac)	0.91	0.13	3.9	0.017	14.1%	12.9%	16.1%	11.7%

Watershed	Loading Rate Increase (Load Increase per Acre, mass [lb or ton] / ac-yr)				Load Increase (%) (Total for Each Watershed)			
	N	P	BOD	Sediment	N	P	BOD	Sediment
Gages Brook (695 ac)	1.29	0.19	5.6	0.027	19.4%	17.0%	21.5%	16.7%
Gages Brook South Tributary (680 ac)	0.73	0.11	3.1	0.014	12.2%	10.2%	14.1%	10.5%
Lower Tankerhoosen River (306 ac)	1.31	0.10	6.3	0.022	20.0%	8.9%	27.6%	14.7%
Middle Tankerhoosen River (1570 ac)	0.63	0.07	3.1	0.008	10.6%	7.6%	14.2%	5.8%
Railroad Brook (1203 ac)	0.89	0.06	4.3	0.015	56.8%	20.3%	69.8%	46.4%
Tucker Brook (934 ac)	0.67	0.04	3.3	0.012	14.1%	5.3%	18.0%	9.4%
Upper Tankerhoosen River (1472 ac)	0.24	0.05	1.1	0.003	9.3%	11.1%	11.2%	6.0%
Walker Reservoir (322 ac)	1.86	0.28	8.6	0.036	25.8%	23.3%	34.6%	21.6%
Total (8149 ac)	0.77	0.09	3.5	0.013	16.0%	11.4%	19.9%	12.0%

Several of the subwatersheds are predicted to experience significantly higher increases in pollutant loads and loading rates under a watershed buildout scenario. These include:

- *Gages Brook*. The existing conditions pollutant load model indicates that this subwatershed is characterized by both relatively high total pollutant loads and pollutant loading rates, with approximately 70% urban land use, the largest amount of industrial land use, and the second-highest commercial land use composition in the entire watershed. The buildout condition of this watershed is projected to result in a 19% increase in urban land use with a corresponding decrease in forest; and the new urban land is likely to consist of new residential and industrial development. As such, relatively large loads and loading rate increases may occur.

- *Lower Tankerhoosen River.* The existing conditions pollutant load model for this subwatershed predicts relatively small loads (since the watershed area is small) and moderate loading rates. Under a buildout scenario, this subwatershed is projected to result in more than a 20% increase in nitrogen and BOD loads. The resulting loading rates for these parameters are projected to be the second highest of the Tankerhoosen River subwatersheds.

- *Railroad Brook.* The projected buildout pollutant loadings in this subwatershed for nitrogen and BOD are anticipated to increase by approximately 57% and 70%, respectively. Significant increases are also anticipated in phosphorus and sediment loads. Currently, the Railroad Brook sub watershed is heavily forested, with comparatively little development. Several large tracts of land within this subwatershed are potentially available for future development, especially in Bolton and South Vernon, which makes this watershed vulnerable to potentially significant pollutant load increases.

- *Walker Reservoir.* The existing conditions pollutant loading model suggests that this subwatershed has some of the highest levels of pollutant loads within the overall Tankerhoosen River watershed. Potential land use changes in this subwatershed include significant areas of new residential and mixed-use development, much of which is located adjacent to Walker Reservoir. These changes are predicted to result in the greatest increases in pollutant loading rates for all of the parameters evaluated.

9.0 COMPARATIVE SUBWATERSHED ANALYSIS

A Comparative Subwatershed Analysis was performed for the Tankerhoosen River subwatersheds to identify the subwatersheds with the greatest vulnerability and restoration potential. Subwatershed "metrics" were used to conduct this analysis. Metrics are numeric values that characterize the relative vulnerability and restoration potential of a subwatershed. The results of this analysis will be used to prioritize field assessment efforts in future phases of this study and to guide plan recommendations.

The analysis involves a screening level evaluation of selected subwatershed metrics that are derived by analyzing available GIS layers and other subwatershed data sources. The basic approach used to conduct the Comparative Subwatershed Analysis consisted of:

1. Delineation of subwatershed boundaries and review of available metric data.
2. Selection and calculation of metrics that best describe subwatershed vulnerability and restoration potential. (The metrics used to rank subwatershed vulnerability were selected separately from the metrics used to rank subwatershed restoration potential.)
3. Developing weighting and scoring rules to assign points to each metric.
4. Computing aggregate scores and developing initial subwatershed rankings.

Subwatersheds with higher aggregate "vulnerability" scores are more sensitive to future development and should be the focus of watershed conservation efforts to maintain existing high-quality resources and conditions. Subwatersheds with higher aggregate "restoration potential" scores are more likely to have been impacted and have greater potential for restoration to improve upon existing conditions. This approach enables watershed planners to allocate limited resources on subwatershed where restoration and conservation efforts have the greatest chances of success. The subwatersheds used in this analysis are those identified in <u>Section 5.1</u> of this document.

The following sections describe the metrics used and the rationale for their selection, how the various metrics were calculated, and the results of the evaluation. Available GIS and other data were used to compute the value of each metric.

Table 9-1: Summary of Subwatershed Vulnerability Metrics

Subwatershed Metric	How Metric is Measured	Indicates Higher Vulnerability Potential When	Metric Points
1. Impervious Cover Change	% increase in impervious cover in subwatershed	Increase in IC is high, suggesting greater development potential and stream impacts	Award 1 pt for each 1% increase in impervious cover
2. Impervious Cover Threshold	Comparison of current and future IC relative to ICM threshold	Predicted IC crosses "impacted" (12%) threshold, development could result in significant stream impacts	Award 5 pts for each exceedance of the 12% threshold
3. Stream Order	% of subwatershed consisting of 1st or 2nd order streams	Subwatershed consists of more lower order streams, vulnerability of headwater streams for habitat and water quality protection	Award 6 pts if 100% of streams are 1st and 2nd order; 4 pts if 50% are 1st and 2nd order; 2 pts if 33% are 1st and 2nd order; 0 pts if 0% are 1st and 2nd order
4. Pollutant Loading	% increase in pollutant loading in subwatershed	Increase in pollutant loading is high, suggesting water quality impacts from future development	Award 1 pt for each pollutant loading parameter > 10% and 3 pts for each parameter >20%
5. Industrial/ Commercial Land	% of subwatershed as industrial or commercial land	Industrial/commercial land is high, greater potential for water quality impacts from pollutant hot spot	Award 1 pt for each 2% of subwatershed classified as industrial or commercial/retail
6. Forest Cover	% of subwatershed with developable forest cover	Area of developable forest cover is high, potential for significant future reductions in forested land	Award 1 pt for each 5% of subwatershed with developable forest cover
7. Stream Corridor Forest Cover	% of stream corridor that is forested	Corridor forest cover is high, potential for significant future reductions in forested riparian areas if public ownership of corridor is low	Add 1 pt for each 10% increase in forest cover
8. Public Ownership of Stream Corridor	% of stream corridor that is publicly owned	Public ownership is low (see metric 7)	Add 1 pt for each 10% reduction of stream corridor in public ownership
9. Road Crossings	number of road crossings / square mile	Number of road crossings is high, greater potential for direct stormwater discharges from roadways	<1 = 0pts; 1 to 5 = 1 pts; 5 to 8 = 3 pts; 9 to 12 = 5 pts; 13-15 = 7pt; >15 = 10 pts
10. Developed Areas with Septic	% of subwatershed served by septic	Area served by septic is high, indicating potential for pollutant loadings from failing septic systems	Award 1 pt for each 5% of subwatershed area served by septic
11. Drinking Water Resources	Acreage of developable land within a public drinking water supply area	Area of developable land is high, greater potential for impacts to sensitive surface and groundwater drinking water supplies	Award 3 pts for each subwatershed within an aquifer protection area

9.1 Priority Subwatersheds for Conservation

The results of the subwatershed vulnerability analysis are summarized in Table 9-2.

Table 9-2: Results of Subwatershed Vulnerability Analysis

Subwatershed	Impervious Cover Change	Impervious Cover Threshold	Stream Order	Pollutant Loading	Industrial/ Commercial Land	Developable Forest Cover	Stream Corridor Forest Cover	Public Ownership of Stream Corridor	Road Crossings	Developed Areas Served by Septic	Drinking Water Resources	Total
Bolton Notch Pond	2	10	6	1	7	2	3	3	0	5	0	41
Clarks Brook	3	10	6	4	7	2	5	5	1	4	0	47
Gages Brook	3	5	6	6	11	4	6	6	3	5	0	55
Gages Brook South Tributary	2	5	6	4	1	5	6	5	3	5	0	42
Lower Tankerhoosen River	7	10	0	7	2	5	4	5	7	5	0	53
Middle Tankerhoosen River	3	10	2	2	2	2	4	5	3	3	3	38
Railroad Brook	2	0	6	12	0	6	9	0	5	1	0	40
Tucker Brook	2	0	6	2	0	3	5	6	3	2	0	28
Upper Tankerhoosen River	0	0	4	2	0	4	8	3	3	3	0	27
Walker Reservoir	9	10	4	4	2	3	2	5	10	6	0	56

As shown in Table 9-2, the following subwatersheds are considered most vulnerable to future development impacts and should be given highest priority for conservation efforts to maintain existing resource conditions:

- Clarks Brook,
- Gages Brook,
- Gages Brook South Tributary,
- Lower Tankerhoosen River,
- Walker Reservoir.

Table 9-3: Summary of Subwatershed Restoration Potential Metrics

Subwatershed Metric	How Metric is Measured	Indicates Higher Restoration Potential When	Metric Points
1. Existing Impervious Cover	% impervious cover in subwatershed	Current impervious cover is low, suggesting range of possible sites for storage retrofits and stream repairs	<10% = 10 pts; 10 to 15% = 5 pts; >15% = 1 pt
2. Publicly-owned land	% of subwatershed that is publicly owned	Public land ownership is high, providing range of potential sites for restoration practices	Award 1 pt for each 2.5% of subwatershed in public ownership
3. Industrial Land	% of subwatershed that is industrial land	Industrial land is high, suggesting potential for source controls, discharge prevention, and on-site retrofits	Award 1 pt for each 2% of subwatershed classified as industrial
4. Forest Cover	% forest cover in subwatershed	Forest cover is low, suggesting potential for upland and riparian reforestation	<35% = 7pts; 36 to 50% = 5 pts; 50 to 70% = 3 pts; >70% = 1pt
5. Wetland Cover	% of subwatershed that is wetlands	Wetland cover is high, suggesting potential for wetland and riparian restoration	Award 1 pt for each 2% of subwatershed area
6.Development Potential	% of developable land in subwatershed	No more development is expected; stable conditions increase feasibility of stream repairs and storage retrofits	30 to 35% = 1pts; 25 to 30% = 4 pts; 20 to 25% = 7 pts; 15 to 25% = 10pt
7. Stream Density	stream miles / square mile	Stream density is high, suggesting greater feasibility of corridor practices	Award 1 pt for each 10% increase in stream density from watershed average of 1.3 stream miles / square mile
8. Stream Corridor Forest Cover	% of stream corridor that is forested	Corridor forest cover is low, suggesting feasibility of riparian reforestation and stream repairs	Add 1 pt for each 10% reduction in forest cover
9. Public Ownership of Corridor	% of stream corridor that is publicly owned	Public corridor ownership is high, suggesting greater feasibility of corridor practices	Add 1 pt for each 10% of stream corridor in public ownership
10. Road Crossings	number of road crossings / square mile	Number of road crossings is high, suggesting greater potential for stream repairs, culvert modifications	<1 = 0pts; 1 to 5 = 1 pts; 5 to 8 = 3 pts; 9 to 12 = 5 pts; 13-15 = 7pt; >15 = 10 pts
11. Developed Areas with Septic	% of subwatershed that is served by septic	Area served by septic is high, suggesting greater potential for septic system upgrades	Award 1 pt for each 5% of subwatershed area served by septic
12. Water Quality Impairments	number of water quality impairments / square mile	Number of water quality impairments is high, suggesting regulatory need to focus on WQ improvements	Award 3 pts for each water quality impairment identified

9.2 Priority Subwatersheds for Restoration

The results of the subwatershed restoration potential analysis are summarized in Table 9-4.

Table 9-4: Results of Subwatershed Restoration Potential Analysis

Subwatershed	Existing Impervious Cover	Publicly-owned Land	Industrial Land	Forest Cover	Wetland Cover	Development Potential	Stream Density	Stream Corridor Forest Cover	Public Ownership of Stream Corridor	Road Crossings	Developed Areas Served by Septic	Water Quality Impairments	Total
Bolton Notch Pond	1	1	1	5	3	10	0	6	6	0	5	0	38
Clarks Brook	1	10	5	7	8	10	0	4	11	1	4	0	60
Gages Brook	5	12	6	5	8	4	10	3	12	3	5	6	79
Gages Brook South Tributary	5	3	0	3	3	1	14	2	9	3	5	9	57
Lower Tankerhoosen River	1	6	1	5	1	1	15	5	11	7	5	6	64
Middle Tankerhoosen River	5	6	1	5	6	10	5	5	10	5	3	0	61
Railroad Brook	10	0	0	1	6	1	9	0	0	5	1	0	34
Tucker Brook	10	10	0	5	6	7	11	4	11	1	2	0	66
Upper Tankerhoosen River	10	3	0	1	7	4	12	1	6	3	3	3	52
Walker Reservoir	1	10	1	7	4	1	0	7	9	10	6	0	55

As shown in Table 9-4, the following subwatersheds should be given highest priority for restoration potential to improve upon existing conditions:

- Clarks Brook,
- Gages Brook,
- Lower Tankerhoosen River,
- Middle Tankerhoosen River,
- Tucker Brook.

Based on the CSA results, the following subwatersheds are recommended for detailed assessment and planning:

- Clarks Brook,
- Gages Brook,
- Gages Brook South Tributary,
- Lower Tankerhoosen River,
- Middle Tankerhoosen River,
- Tucker Brook,
- Walker Reservoir.

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APPENDIX A

APPENDIX A

FLORA OF BELDING WMA.

Club Mosses
Club-moss family (Lycopodiaceae)
Tree club moss (*Lycopodium obscurum*)

Ferns
Bracken Fern Family (Dennstaedtiaceae)
Hay-scented fern (*Dennstaedtia punctilobula*)
Bracken fern (*Pteridium aquilinum*)

Wood fern family (Dryopteridaceae)
Sensitive fern (*Onoclea sensibilis*)
Spinulose wood fern (*Dryopteris spinulosa*)
Christmas fern (*Polystichum acrosticoides*)
Rock polypody (*Polypodium virginianum*)

Royal fern family (Osmundaceae)
Cinnamon fern (*Osmunda cinnamomea*)
Interrupted fern (*Osmunda claytoniana*)
Royal fern (*Osmunda regalis*)

Maidenhair Fern family (Pteridaceae)
Maidenhair fern (*Adiantum pedatum*)

Marsh Fern family (Thelypteridaceae)
New York fern (*Thelypteris noveboracensis*)

Gymnosperms
Pine family (Pinaceae)
Eastern white pine (*Pinus strobes*)
Eastern red cedar (*Juniperus virginiana*)
Red pine (*Pinus resinosa*)
Pitch pine (*Pinus rigida*)
Eastern hemlock (*Tsuga Canadensis*)
Norway spruce (*Picea abies*)

Angiosperms (Flowering plants)

Magnolia family (Magnoliaceae)
Tulip tree (*Liriodendron tulipifera*)

Laurel family (Lauraceae)
Northern spicebush (*Lindera benzoin*)
Sassafras (*Sassafras albidum*)

Barberry family (Berberidaceae)
Japanese barberry (*Berberis thunbergii*)

Buttercup family (Ranunculaceae)
Wood anemone (*Anemone quinquefolia*)
Rue anemone(*Thalictrum thalictroides*)
Goldthread (*Coptis groenlandica*)
Kidneyleaf buttercup (*Ranunculus abortivus*)
American pokeweed (*Phytolacca Americana*)

Buckwheat family (Polygonaceae)
Arrow-leaf tearthumb (*Polygonum sagittatum*)

Witch-hazel family (Hamamelidaceae)
Witchhazel (*Hamamelis virginiana*)

Plane-tree family (Plantanaceae)
American sycamore (*Platanus occidentalis*)

Beech family (Fagaceae)
Black oak (*Quercus velutina*)
Red oak (*Quercus rubra*)
White oak (*Quercus alba*)
Scarlet oak (*Quercus coccinea*)
American chestnut (*Castanea dentata*)
American beech (*Fagus grandifolia*)

Birch family (Betulaceae)
Speckled alder (*Alnus rugosa*)
Black birch (*Betula lenta*)
Gray birch (*Betula populifolia*)
Paper birch (*Betula papyrifera*)
Yellow birch (*Betula alleghaniensis*)

Bayberry family (Myricaceae)
Sweetfern (*Comptonia peregrina*)

Walnut family (Juglandaceae)
Pignut hickory (*Carya glabra*)
Shagbark hickory (*Carya ovata*)

(Hypericaceae)
St. John's wort (*hypericum perforatum*)

Wintergreen family (Pyrolaceae)
Shinleaf (*Pyrola elliptica*)
Spotted wintergreen (*Chimaphila maculata*)

Indianpipe (*Monotropa uniflora*)
Pinesap (*Monotropa hypopithys*)

Heath family (Ericaceae)
Eastern teaberry (*Gaultheria procumbens*)
Black huckleberry (*Gaylussacia baccata*)
Mountain laurel (*Kalmia angustifolium*)
Pinxter flower (*Rhododendron nudiflorum*)
Highbush blueberry (*Vaccinium corymbosum*)
Lowbush blueberry (*Vaccimium angustifolium*)

Primrose family (Primulaceae)
Starflower (*Trientalis borealis*)
Whorled loosestrife (*Lysimachia quadrifolia*)

Violet family (Violaceae)
Common blue violet (*Viola papilionaceae*)
Northern white violet (*Viola pallens*)
Sweet white violet (*Viola blanda*)
Field violet (*Viola arvensis*)

Willow family (Salicaceae)
Quaking aspen (*Populus tremuloides*)

Cucumber family (Cucurbitaceae)
Bur cucumber (*echinocystis lobata*)

Elm family (Ulmaceae)
American elm (*Ulmus americana*)

Rose family (Rosaceae)
White meadowsweet (*Siriea latifolia*)
Steeplebush (*Spirea tomentosa*)
Blackberry (*Rubus allegheniensis*)
Raspberry (*Rubus occidentalis*)
Multiflora Rose (*Rosa multiflora*)
Strawberry (*Fragaria virginiana*)
Black cherry (*Prunus serotina*)
Apple (*Prunus malus*)

Pea family
Hop clover (*Trifolium aureum*)
Red clover (*Trifolium pretense*)
Cow vetch (*Viccia cracca*)

Maple family
Sugar maple (*Acer saccharum*)
Red maple (*Acer rubrum*)

Cashew family (Anacardiaceae)
Staghorn sumac (*Rhus typhina*)
Poison ivy (*Toxicodendron radicans*)

Touch-me-not Family (Balsaminaceae)
Spotted touch-me-not (*Impatiens capensis*)

Milkwort family (Polygalaceae)
Fringed polygala (*Polygala paucifolia*)
Field milkwort (*Polygala sanguinea*)

Staff-tree family (Celastraceae)
Winged euonymus (*Euonymus alatus*)
Asiatic bittersweet (*Celastrus orbiculatus*)

Holly family (Aquifoliaceae)
Winterberry (*Ilex verticillata*)

Oleaster family (Eleagnaceae)
Autumn olive (*Eleagnus umbellate*)
Russian olive (*Eleagnus angustifolium*)

Grape family (Vitaceae)
Virginia creeper (*Parthenocissus quinquefolia*)
Fox Grape (*Vitis labrusca*)

Dogwood family (Cornaceae)
Silky dogwood (*Cornus amomum*)

Ginseng family (Araliaceae)
Ginseng (*Panax quinquefolium*)
Dwarf ginseng (*Panax trifolium*)

Carrot family (Apiaceae)
Queen Anne's Lace (*Daucus carota*)

Honeysuckle family (Caprifoliaceae)
Tartarian Honeysuckle (*Lonicera tatarica*)
Elderberry (*Sambucus canadensis*)
Maple-leaved viburnum (*Viburnum acerifolium*)
Arrowwood (*Viburnum dentatum*)

Aster family (Asteraceae)
Yarrow (*Achillea millefolium*)
New York Aster (*Aster novi-belgii*)
Oxeye daisy (*Chrysanthemum lleucanthemum*)
Bull thistle (*Cirsium vulgare*)

Joe-Pye weed (*Eupatorium maculata*)
Black-eyed Susan (*Rudbeckia hirta*)
Rough-stemmed goldenrod (*Solidaga rugosa*)
Common dandelion (*Taraxacum officinale*)
Pineapple weed (*Matricaria matricarioides*)
Horseweed (*Erigeron canadensis*)

<u>Bedstraw family</u> (Rubiaceae)
Bluets (*Houstonia caerulea*)
Partridgeberry (*Mitchella repens*)

<u>Dogbane family</u> (Apocynaceae)
Periwinkle (*Vinca minor*)
Common milkweed (*Asclepias syriaca*)

<u>Nightshade family</u> (Solanaceae)
Bittersweet nightshade (*Solanum dulcamara*)
Jimsonweed (*Datura stramonium*)

<u>Olive family</u> (Oleaceae)
White ash (*Fraxinus americana*)

<u>Figwort family</u> (Scrophulariaceae)
Blue toadflax (*Linaria canadensis*)
Butter-and-eggs (*Linaria vulgaris*)
Monkey flower (*Mimulus ringens*)
Common mullein (*Verbascum thapsus*)
Thyme-leaved speedwell (*Verbascum serpyllifolia*)

<u>Mint family</u> (Lamiaceae)
Heal-all (*Prunella vulgaris*)
Wild mint (*mentha arvensis*)

<u>Melanthium family</u> (Melanthiaceae)
False hellebore (*Veratrum nigrum*)

<u>Trillium family</u> (Trilliaceae)
Purple trillium (*Trillium erectum*)
Nodding trillium (*Trillium cernuum*)

<u>Lily family</u> (Liliaceae)
Canada Mayflower (*Maianthemum canadense*)
False Solomon's seal (*Smilacina racemosa*)
Smooth Solomon's seal (*Polygonatum biflorum*)
Trout lily (*Erythronium americanum*)
Indian cucumber root (*Medeola virginiana*)

<u>Catbrier family</u> (Smilaceae)

Greenbrier (*Smilax rotundifolia*)

Orchid family (Orchidaceae)
Nodding ladies' tresses (*Spiranthes cernua*)
Pink lady's slipper (*Cypripedium acaule*)
Rattlesnake plantain (*Goodyera pubescens*)

Asparagus family (Asparagaceae)
Asparagus (*Asparagus officinalis*)

Spiderwort family (Commelinaceae)
Asiatic dayflower

Rush family Juncaceae
Canadian rush (*Juncus canadensis*)
Common rush (*Juncus effusus*)
Poverty rush (*Juncus tenuis*)

Sedge family (Cyperaceae)
Yellow nutsedge (*Cyperus esculentus*)
Fringed sedge (*Carex crinita*)
Greater bladder sedge (*Carex intumescens*)
Shallow sedge (*Carex lurida*)
Pennsylvania sedge (*Cares pensylvanica*)
Tussock sedge (*Carex stricta*)
Green bulrush (*Scirpus atrovirens*)
Wool grass (*Scirpus cyperinus*)
Panicled bulrush (*Scirpus microcarpus*)
Fox sedge (*Carex vulpinoidea*) - Metzler

Grass family (Poaceae)
Orchard grass (*Dactylis glomerata*)
Crabgrass (*Digitaria sanguinalis*)
Witch grass (*Panicum capillare*)
Reed canary grass (*Phalaris arundinaceae*)
Green foxtail (*Setaria viridis*)
Velvet grass (*Holcus lanatus*) – Metzler
Timothy (*Phleum pretense*) – Metzler
Cheatgrass (*Bromus tectorum*) – Metzler
Sweet vernal grass (*Anthoxanthum odoratum*) - Metzler

Water plantain family Alismataceae
Arrowhead (*Sagittaria latifolila*)

Arum family (Araceae)
Skunk cabbage (*Symplocarpus foetidus*)
Jack-in-the-pulpit (*Arisaema triphyllum*)

Cat-tail family (Typhacea)
Common cattail (*Typha latifolia*)

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INVERTEBRATES
Annelids
Earthworm (*Oligochaeta*)
Leech (*Hirudinea*)

Crustaceans
Crayfish (*Decapoda*)

Molluscs
Pea clam (*Sphaeriidae*)
Eastern pearlshell (*Margaritifera margaritifera*)
Eastern elliptio (*Elliptio complanata*)
Lymnaid snail (*Pseudosuccinea columella*)
Planorbid snail (*Helisoma*)

Insects
Mayflies (Ephemeroptera)
Drunella (*Ephemerellidae*)
Flat-head mayfly (*Heptageniidae:Epeorus*)
Stenonema (*Heptageniidae*)
Baetidae

True flies (Diptera)
Midge (*Chironomidae*)
Dance fly (*Empididae*)
Sand fly (*Psychodidae*)
Black fly (*Simuliidae*)
Crane fly (*Tipulidae*)
Phantom crane fly (*Ptychopteridae :Bittacomorpha clavipes*)

Stoneflies (Plecoptera)
Chloroperlidae
Glossosomatidae
Nemouridae
Peltoperlidae
Perlidae
Perlodidae

Caddisflies (Trichoptera)

Chimarra
Hydropsychidae
Lepidostoma
Limnephilidae
Philopotamidae
Rhyacophila

<u>Dobsonflies and fishflies</u> (Megloptera)
Corydalus
Nigronia

<u>Beetles</u> (Coleoptera)
Predaceous diving beetle (*Dytiscidae*)
Water beetle (*Elmidae*)
Water scavenger beetle (*Hydrophilidae*)
Water penny beetle (*Psephenidae*)
Scarab beetle (*Scarabaeidae*)
Green tiger beetle (*Cicindela sexguttata*)
Burying beetle (*Nicrophorus arbicollis*)

ODONATA
<u>Damselflies</u>
River jewelwing (*Calopteryx maculata*)
Ebony jewelwing (*Calopteryx aequibilis*)
Elegant spreadwing (*Lestes inaequalis*)
Fragile forktail (*Ischnura posita*)

<u>Dragonflies</u>
Brown darner (*Boyeria vinosa*)
Common green darner (*Anax junius*)
Spangled skimmer (*Libellula cyanea*)
Yellow-legged meadowhawk (*Sympetrum vicinum*)
Banded-winged meadowhawk (*Sympetrum semicinctum*)
Cherry-faced meadowhawk(*Sympetrum internum*)
Clubtail (Gomphidae)

Lepidoptera

<u>Butterflies</u>

Peck's skipper (*Polites peckius*)
Crossline skipper (*Polites origenes*)
Delaware skipper (*Anatrytone logan*)
Tiger swallowtail (*Papilio glaucus*)
Spicebush swallowtail (*Papilio Troilus*)
Cabbage butterfly (*Pieris rapae*)
Clouded sulphur (*Colias philodice*)
Small copper (*Lycaena phlaeas*)
Eastern tailed blue (*Everes comyntas*)
Spring azure (*Celastrina "ladon"*)
Red-spotted purple (*Limenitis arthemis*)
Great spangled fritillary (*Speyeria cybele*)
Pearl crescent (*Phyciodes tharos*)
Monarch (*Danaus plexippus*)
Viceroy (*Limenitis archippus*)

<u>Moths</u>

Garden tortrix (*Ptycholoma peritana*)
Lesser maple spanworm moth (*Itame pustularia*)
Blurry chocolate angle (*Semiothisa transitaria*)
Minor angle (*Semiothisa minorata*)
Four-spotted angle (*Semiothisa quadrinotaria*)
White spring moth (*Lomographa vestaliata*)
Lesser grapevine looper moth (*Eulithis diversilineata*)
Greater grapevine looper moth (*Eulithis gracilineata*)
Sweetfern geometer (*Cylophora pendulinaria*)
Cross-lined wave (*Calothysanis amaturaria*)
Red twin spot (*Xanthorhoe ferrugata*)
White-striped black (*Trichodezia albovittata*)
Brown bark carpet (*Horisme intestinata*)
Black-rimmed prominent (*Pheosia rimosa*)
Painted lichen moth (*Hypoprepia fucosa*)
Clymene moth (*Haploa clymene*)
Harnessed moth (*Apantesis phalerata*)
Pink-shaded fern moth (*Callopistria mollissima*)
Copper underwing (*Amphipyra pyramidoides*)
Common pinkband (*Ogdoconta cinereola*)
Eight-spotted forester (*Alypia octomaculata*)
Pink-barred lithacodia (*Lithacodia carneola*)
Decorated owlet (*Pangrapta decoralis*)
Spotted grass moth (*Rivula propinqualis*)
American idia (*Idia americalis*)
Common idia (*Idia aemula*)
Early zanclognatha (*Zanclognatha cruralis*)

Morbid owlet (*Chytolita morbidalis*)
Dark-spotted palthis (*Palthis angulalis*)

FISH
American Eel (*Anguilla rostrata*)
Bluegill (*Lepomis macrochirus*)
Brook Trout (*Salvelinus fontinalis*)
Blacknose Dace (*Rhinichthys atratulus*)
Brown Trout (*Salmo trutta*)
Chain Pickerel (*Esox Niger*)
Fallfish (*Semotilus corporalis*)
Golden Shiner (*Notemigonus crysoleucas*)
Longnose Dace (*Rhinichthys cataractae*)
Largemouth Bass (*Micropterus salmoides*)
Rainbow Trout (*Oncorhynchus mykiss*)
Tessellated darter (*Etheostoma olmstedi*)
White Sucker (*Catostomus commersoni*)
Yellow Perch (*Perca flavescens*)

AMPHIBIANS
American toad (*Bufo americanus*)
Gray treefrog (*Hyla versicolor*)
Northern spring peeper (*Pseudacris c. crucifer*)
Bullfrog (*Rana catesbeiana*)
Green frog (*Rana clamitans melanota*)
Pickerel frog (*Rana palustris*)
Wood frog (*Rana sylvatica*)
Northern Redback salamander (*Plethodon cinereus*)
Spotted salamander (*Ambystoma maculatum*)
Northern two-lined salamander (*Eurycea bislineata*)
Red-spotted newt (*Notophthalmus v. viridescens*)

REPTILES
Painted turtle (*Chrysemys picta*)
Eastern box turtle (*Terrapene c. carolina*)
Eastern milk snake (*Lampropeltis t. triangulum*)
Eastern garter snake (*Thamnophis s. sirtalis*)

Thraupidae
Scarlet Tanager (*Piranga olivacea*)
Emberizidae
Eastern Towhee (*Pipilo erythrophthalmus*)
Chipping Sparrow (*Spizella passerina)*
White-throated sparrow (*Zonotrichia albicollis*)
Song Sparrow (*Melospiza melodia*)
Dark-eyed junco (*Junco hyemalis*)
Cardinalidae
Northern Cardinal (*Cardinalis cardinalis*)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)
Indigo Bunting (*Passerina cyanea*)
Icteridae
Red-winged Blackbird (*Agelaius phoeniceus*)
Common Grackle (*Quiscalus quiscula*)
Brown-headed Cowbird (*Molothrus ater*)
Baltimore Oriole (*Icterus galbula*)
Fringillidae
American Goldfinch (*Carduelis tristis*)

MAMMALS
Short-tailed shrew (*Blarina brevicauda*)
Red-backed vole (*Clethrionomys gapperi*)
Meadow vole (*Microtus pennsylvanicus*)
Deer mouse (*Peromyscus leucopus*)
Jumping mouse (Zapodidae)
Chipmunk (*Tamiasciurus hudsonicus*)
Gray squirrel (*Sciurus carolinensis*)
Red squirrel (*Tamiasciurus hudsonicus*)
Muskrat (*Odontra zibethicus*)
Porcupine (*Erethizon dorsatum*)
Eastern cottontail rabbit (*Sylvilagus floridanus*)
Gray fox (*Urocyon cinereoargenteus*)
Raccoon (*Procyon lotor*)
Short-tailed weasel (*Mustela erminae*)
Fisher (*Martes pennanti*)
Striped skunk (*Mephitis mephitis*)
White-tailed deer (*Odocoileus virginianus*)

BIRDS

Ciconiiformes

Great Blue Heron (*Ardea herodias*)
Turkey Vulture (*Cathartes aura*)

Falconiformes

Red-tailed Hawk (*Buteo jamaicensis*)
Broad-winged hawk (*Butea platypterus*)
Cooper's hawk (*Accipiter cooperii*)
Sharp-shinned hawk (*Accipiter striatus*)

Gallifomes

Wild Turkey (*Meleagris gallopavo*)

Charadriiformes

American woodcock (*Scolopax minor*)
Killdeer (*Charadrius vociferus*)

Columbiformes

Mourning Dove (*Zenaida macroura*)

Cuculiformes

Yellow-billed cuckoo (*Coccyzus americanus*)

Strigiformes

Barred Owl (*Strix varia*)
Great horned owl (*Bubo virginianus*)

Apodiformes

Chimney Swift (*Chaetura pelagica*)

Coraciiformes

Belted Kingfisher (*Ceryle alcyon*)

Piciformes

Downy Woodpecker (*Picoides pubescens*)
Hairy woodpecker (*Picoides villosus*)
Red-bellied Woodpecker (*Melanerpes carolinus*)
Pileated woodpecker (*Dryocopus pileatus*)
Yellow-shafted Flicker (*Colaptes auratus*)

Passeriformes

Tyrannidae

Eastern Wood-Pewee (*Contopus virens*)
Eastern Phoebe (*Sayornis phoebe*)
Great Crested Flycatcher (*Myiarchus crinitus*)
Olive-sided flycatcher (*Nuttallornis borealis*)
Eastern Kingbird (*Tyrannus tyrannus*)

Vireonidae

Red-eyed Vireo (*Vireo olivaceus*)
Warbling Vireo (*Vireo gilvus*)
Yellow-throated vireo (*Vireo flavifrons*)

Corvidae

Common raven (*Corvus corax*)
American Crow (*Corvus brachyrhynchos*)
Blue Jay (*Cyanocitta cristata*)

Hirundidae
Tree Swallow (*Iridoprocne bicolor*)
Barn Swallow (*Hirundo rustica*)
Paridae
Black-capped Chickadee (*Poecile atricapillus*)
Tufted Titmouse (*Baeolophus bicolor*)
Sittidae
Red-breasted Nuthatch (*Sitta carolensis*)
White-breasted Nuthatch (*Sitta Canadensis*)
Certhiidae
Brown creeper (*Certhia familiaris*)
Troglodytidae
Carolina Wren (*Thryothorus ludovicianus*)
House Wren (*Troglodytes aedon*)
Turdidae
Eastern Bluebird (*Sialia sialis*)
Swainson's thrush (*Catharus ustulatus*)
Veery (*Catharus fuscescens*)
Wood Thrush (*Hylocichla mustelina*)
American Robin (*Turdus migratorius*)
Mimidae
Gray Catbird (*Dumetella carolinensis*)
Northern Mockingbird (*Mimus polyglottos*)
Brown Thrasher (*Toxostoma rufum*)
Bombycillidae
Cedar Waxwing (*Bombycilla cedrorum*)
Parulidae
Blue-winged Warbler (*Vermivora pinus*)
Nashville warbler (*Vermivora ruficapilla*)
Northern parula (*Parula americana*)
Yellow Warbler (*Dendroica petechia*)
Chestnut-sided warbler (*Dendroica pensylvanica*)
Yellow-rumped warbler (*Dendroica coronata*)
Black-throated green warbler (*Dendroica virens*)
Pine Warbler (*Dendroica pinus*)
Prairie warbler (*Dendroica discolor*)
Palm warbler (*Dendroica palmarum*)
Blackpoll warbler (*Dendroica striata*)
Blackburnian warbler (*Dendroica fusca*)
Cerulean warbler (*Dendroica cerulean*)
Black-and-white warbler (*Mniotilta varia*)
American redstart (*Setophaga ruticilla*)
Ovenbird (*Seirus aurocapillus*)
Louisiana waterthrush (*Seiurus motacilla*)
Common Yellowthroat (*Geothlypis trichas*)
Canada warbler (*Wilsonia canadensis*)

APPENDIX B

Pollutant Loading Analysis
Tankerhoosen River Watershed
Baseline Assessment

1.0 INTRODUCTION

A pollutant loading analysis was performed for the Tankerhoosen River watershed in support of the Baseline Watershed Assessment to assess the potential for increases in nonpoint source (NPS) pollutant loads. The model was used to compare existing nonpoint source (NPS) pollutant loads from the watershed to projected future pollutant loads that would occur under a watershed buildout scenario. The predicted change in pollutant loadings in each of the subwatersheds was then examined to assess their relative vulnerability to future development.

2.0 MODEL DESCRIPTION

A pollutant loading model was developed using the land use/land cover data described in Section 7.0 of the Baseline Watershed Assessment report (Fuss & O Neill 2008). The model was used to compare pollutant loadings from the watershed under existing land use conditions to future pollutant loadings under a watershed buildout scenario. It is important to note that the results of this screening-level analysis are intended for the purposes of comparing existing to future conditions and not to predict future water quality.

The Spreadsheet Tool for the Estimation of Pollutant Load (STEPL), Version 4.0, was used for this analysis. This model was developed for US EPA by Tetra Tech in EPA Region 5 and has since been modified for use in other areas of the country. The model calculates watershed pollutant loads based on land use-related pollutant sources, including urban runoff, septic system failures, stream bank erosion, and agricultural activities. The model also allows simulation of best management practices (BMPs) and Low Impact Development (LID) practices to reduce pollutant loads.

The focus of the Tankerhoosen watershed pollutant loading model was future development of presently undeveloped land and re-development of developed land with higher-intensity land uses (See Section 7.2 of Fuss & O Neill 2008), since these are likely sources of increased pollutant loads. Agricultural NPS pollutant loadings were not considered in the analysis since agricultural land comprises a very small percentage of the land uses within the watershed.

The pollutants modeled in this analysis are the default pollutants contained in the STEPL model: total phosphorus, total nitrogen, biological oxygen demand, and total suspended solids. These pollutants are the major parameters of concern in environmental systems.

Nitrogen and phosphorus are nutrients that promote the growth of algae and plants in water. When this biomass dies and settles to the bottom of water bodies, its decomposition consumes oxygen which is needed by other organisms for survival. Nitrogen is generally present in relatively small quantities compared to other nutrients in salt water systems, such as Long Island Sound, so limiting its concentration limits the growth of algae. In fresh water systems, such as the stream and impoundments in the Tankerhoosen River watershed, phosphorus is the nutrient that is relatively scarce and thus limits algal growth.

Biological oxygen demand (BOD) is a measure of the amount of oxygen that a pollutant consumes as it decomposes (e.g., one pound of BOD consumes one pound of oxygen). A given BOD loading to a water body effectively consumes an equivalent amount of oxygen from that water body, making it unavailable to aquatic organisms.

Total suspended solids (TSS) is a measure of both biodegradable and mineral sediment. Its discharge to a water body results in turbidity and sedimentation. TSS may also have secondary effect; biodegradable TSS exerts a BOD load, and mineral TSS can be associated with particulate phosphorus.

3.0 MODEL PARAMETER SELECTION

STEPL uses algorithms that calculate nutrient and sediment loads from different land uses to determine watershed pollutant loadings. The user specifies several model parameters for each land use in the watershed that are used to estimate runoff quantity and pollutant levels. These parameters include:

- Event Mean Concentrations (EMCs), which are literature values for the mean concentration of a pollutant in stormwater runoff for each land use, and
- Curve Number (CN), which is a measure of the runoff potential of the land surface and is a function of soil type, cover condition, and slope.

The model uses these parameters to estimate the runoff quantity and pollutant loading using data specific to each subwatershed, supplied by the user, as well as default climate data for the subject county In addition to these parameters, the model includes percent impervious surface values for each land use. As part of this project, the model was modified to accept user-specified impervious surface values for each land use.

A literature review was conducted to determine EMCs values for use in the study. STEPL includes default EMC values for each land use within the watershed. Since comparison between existing and proposed watershed conditions is the focus of this project, EMC values were selected to reflect the relative difference in NPS pollutant characteristics between the existing and future land use. Table 1 shows EMC values from several sources for the pollutants of interest.

Table 1. Runoff Event Mean Concentrations (EMCs)

Source	Pollutant	Land Use										
		Cropland	Open Space	Commercial	High Density Residential	Institutional	Industrial	Low Density Residential	Forest	Transport	Vacant	Units
STEPL	N	1.9	1.5	2	2.2	1.8	2.5	2.2	0.2	3	1.5	mg/L
	P	0.3	0.15	0.2	0.4	0.3	0.4	0.4	0.1	0.5	0.15	mg/L
	BOD	4	4	9.3	10	7.8	9	10	0.5	9.3	4	mg/L
	TSS	-	70	75	100	67	120	100	-	150	70	mg/L
NSQD	N*	-	1.2	2.2	2	-	2.1	-	-	2.3	-	mg/L
	P	-	0.25	0.22	0.3	-	0.26	-	-	0.25	-	mg/L
	BOD	-	4.2	11.9	9	-	9	-	-	8	-	mg/L

Source	Pollutant	Land Use										
		Cropland	Open Space	Commercial	High Density Residential	Institutional	Industrial	Low Density Residential	Forest	Transport	Vacant	Units
	TSS	-	51	43	48	-	77	-	-	99	-	mg/L
NURP	N*	-	1.5	1.75	2.6	-	-	-	-	-	-	mg/L
	P	-	0.1	0.201	0.38	-	-	-	-	-	-	mg/L
	BOD	-	-	9.3	10	-	-	-	-	-	-	mg/L
	TSS	-	70	57	101	-	-	-	-	-	-	mg/L
WTM	N*	-	-	2	2	-	-	2	-	2	-	mg/L
	P	-	-	0.26	0.26	-	-	0.26	-	0.26	-	mg/L
	BOD	-	-			-	-		-		-	mg/L
	TSS	-	-	55	55	-	-	55	-	55	-	mg/L
BEC	N*	-	-	13.7	13.7	-	10.6	10.0	-	-	-	kg/ha/yr
	P	-	-	2.7	2.7	-	2.6	1.9	-	-	-	kg/ha/yr
	BOD	-	-			-			-	-	-	kg/ha/yr
	TSS	-	-	748.0	748.0	-	802.5	456.0	-	-	-	kg/ha/yr
Selected	N*	1.9	1.5	2.2	2	1.8	2.5	1.8	0.2	3	1.5	mg/L
	P	0.3	0.15	0.4	0.2	0.3	0.4	0.3	0.1	0.5	0.15	mg/L
	BOD	4	4	10	9.3	7.8	9	7.8	0.5	9.3	4	mg/L
	TSS	-	70	100	75	67	120	67	-	150	70	mg/L

See References for Source Information

The majority of selected values were obtained from STEPL, with adjustments to ensure consistency with other sources. These adjustments include exchanging the multi-family and commercial values, since development included in the multi-family category is assumed to be less intensive in the Tankerhoosen watershed (See Section 4.0) than typical, and since the default commercial sediment EMC value was lower than sediment levels of other less sediment-intensive land uses. Similarly, since the single-family land use category selected for the watershed includes only large lot residential areas, the selected EMCs for these areas were reduced to Institutional land use levels.

As part of this project, the impervious surface coefficients in STEPL were adjusted for use in generating existing and proposed impervious surface estimates. The default factors, literature values for factors, and selected factors are presented in Table 2.

Table 2. Impervious Surface Coefficients

	Impervious Cover Coefficients		
Land Use	STEPL	NEMO[1]	Selected
Commercial	0.85	0.205 - 0.557	0.50
Industrial	0.70	0.264 - 0.557	0.40
Institutional	0.50	-	0.30
Transportation	0.95	0.433	0.43
Multi-family	0.75	0.09 - 0.39	0.24
Single-family	0.30	0.065 - 0.12	0.10
Vacant (developed)	0.70	-	0.41
Open Space	0.01	0.001 - 0.094	0.01

[1]*Sleavin et al. (2000) and Prisloe et al. (2003)*

The STEPL model also includes input parameters related to failing septic systems in the watershed. Parameters include the typical population per household and septic system failure rate. Default values were used for the typical population per household and septic system failure rate due to the limited availability of local data.

4.0 MODEL INPUT DATA

Land use/land cover data that is described in Section 7.0 of the Baseline Watershed Assessment was adapted for integration into the STEPL model. Data was prepared in this manner for both the existing conditions and future conditions (watershed buildout) pollutant loading scenarios. STEPL allows fewer land use categories than contained in the land use/land cover data obtained from other sources, so several data categories were combined for use in the model. Table 3 summarizes the assignment of STEPL land use categories for each of the land use/land cover data categories.

Table 3. Source Data - STEPL Category Correlation

Data Category	STEPL Category
Agriculture	Cropland
Cemetery	Open Space (urban)
Commercial	Commercial (urban)
Condominium	Multi-family (urban)
Government/Non-Profit	Institutional (urban)
Group Quarters	Institutional (urban)
Health/Medical	Institutional (urban)
Industrial	Industrial (urban)
Mixed Use	Commercial (urban)
Multi-Family	Multi-family (urban)
One Family	Multi- or Single-family (urban)
Resource/Recreation	Forest
Retail	Commercial (urban)
ROW	Transportation (urban)
School	Institutional (urban)
Three Family	Multi-family (urban)
Two Family	Multi-family (urban)
Undeveloped	Forest
Unknown	Vacant - Developed (urban)
Water	Not Considered

STEPL defines urban land uses differently from agriculture and forest. All urban land uses are lumped into a single land use category, and urban land cover characteristics are distinguished based on land use subcategories, which include commercial, industrial, institutional, transportation, multi-family residential, single-family residential, urban cultivated, vacant (developed), and open space land uses. Since the source land use data included many residential land use categories and STEPL only provides two residential categories, residential uses for all but the largest single-family residential parcels was included in the multi-family category. The Tankerhoosen River watershed has large areas of rural-residential land use with parcel sizes of greater than 2 acres. As such, parcels smaller than two acres were considered to be high density residential and parcels larger than two acres were considered low density residential. Table 4 summarizes the composition of single-family residential land use based on parcel size ranges.

Table 4. Composition of Single-Family Residential Land Use Based on Parcel Size

Watershed	0 - 22k sf	22k sf - 2 ac	2 - 5 acres	> 5 acres
Bolton Notch Pond	3.2%	49.7%	47.1%	0.0%
Clarks Brook	21.4%	36.0%	18.0%	24.6%
Gages Brook	11.4%	37.8%	25.4%	25.4%
Gages Brook South Tributary	0.9%	47.4%	33.6%	18.1%
Lower Tankerhoosen River	21.4%	43.9%	34.4%	0.3%
Middle Tankerhoosen River	13.6%	60.3%	15.7%	10.5%
Railroad Brook	0.2%	45.9%	53.7%	0.2%
Tucker Brook	22.0%	54.4%	11.1%	12.6%
Upper Tankerhoosen River	1.0%	79.9%	18.8%	0.3%
Walker Reservoir	17.0%	43.2%	24.0%	15.7%

Septic system data is also required for the STEPL model. Sewer service area GIS data from Connecticut DEP was used to screen out developed parcels in the Tankerhoosen watershed; parcels located completely outside of mapped sewer service areas were assumed to be served by septic systems. The resulting number of developed parcels without sewer service were divided into residential systems (single-family through multi-family systems) and other developed systems (including condominiums, industrial, commercial, and institutional systems). The residential systems were assumed to have similar characteristics and the other developed systems were assumed to be approximately 5 times the size of the residential systems, on average (this factor was estimated based on the total land area feeding these systems and an estimated intensity of use).

Hydrologic Soil Group (HSG) data are also required by the model. This data, which is available from the U.S. Natural Resource Conservation Service (NRCS), describes the infiltration characteristics of most soils in the county. Identifiers for the soil groups range from Type A soils, including sands and other soils that are very well drained and result in little runoff, to Type D soils, which are poorly drained, often being compacted, having high clay content and high groundwater levels. Soils data were compiled for each subwatershed and assimilated into an average HSG value. Each subwatershed was found to have Type B soil characteristics, on average, with the exception of the Gages Brook subwatershed, which was found to have Type C soil characteristics.

5.0 CURRENT POLLUTANT LOADINGS

5.1 Input

The following land use data were entered into the STEPL spreadsheet to create an existing conditions pollutant loading model. These inputs were reduced form the data presented in Section 7.1 of the Baseline Watershed Assessment. In general, agricultural land use (i.e. cropland) was the least common of the non-urban uses. In most subwatersheds, urban uses dominate, although forests compose more than half of the land area in the Railroad Brook and Upper Tankerhoosen River watersheds.

Table 5. Land Use Input Data

Watershed	Land Use Area (ac)				Land Use Area Composition		
	Urban	Cropland	Forest	Total	Urban	Cropland	Forest
Bolton Notch Pond	183.9	0.0	134.7	318.6	58%	0%	42%
Clarks Brook	533.3	3.6	110.5	647.4	82%	1%	17%
Gages Brook	485.8	28.2	181.5	695.5	70%	4%	26%
Gages Brook South Tributary	491.3	5.7	183.3	680.3	72%	1%	27%
Lower Tankerhoosen River	179.4	0.0	127.1	306.5	59%	0%	41%
Middle Tankerhoosen River	1185.5	22.6	362.4	1570.5	75%	1%	23%
Railroad Brook	377.6	0.0	825.3	1202.8	31%	0%	69%
Tucker Brook	648.8	43.0	241.8	933.5	69%	5%	26%
Upper Tankerhoosen River	519.2	0.0	952.6	1471.9	35%	0%	65%
Walker Reservoir	192.2	0.0	129.8	322.0	60%	0%	40%

Table 6 presents the composition of the urban land use areas listed in Table 5. In general, residential land use is the most prevalent in the urbanized areas, although transportation corridors are the predominant urban land use in the Bolton Notch Pond and Lower Tankerhoosen River watersheds, and comprise greater than 20% of urban land use in three of the ten watersheds.

Table 6. Urban Land Use Composition

Watershed	Urban Land Use Composition (%)							
	Com.	Ind.	Inst.	Trans.	Dense Res.	Rural Res.	Vacant	Open Space
Bolton Notch Pond	25.5	2.1	5.7	29.4	17.6	15.7	4.0	0.0
Clarks Brook	4.2	11.9	0.3	13.9	49.7	18.6	1.4	0.0
Gages Brook	13.7	16.7	8.8	7.7	27.5	25.0	0.0	0.6
Gages Brook South Tributary	2.4	0.0	4.0	19.7	35.4	37.9	0.6	0.0
Lower Tankerhoosen River	4.3	4.1	9.8	32.6	30.6	14.1	2.0	2.5
Middle Tankerhoosen River	2.7	1.9	1.8	17.9	55.8	18.5	1.0	0.4
Railroad Brook	0.0	0.0	0.0	4.5	43.4	50.7	1.4	0.0
Tucker Brook	0.3	0.0	4.5	11.9	63.9	19.3	0.1	0.0
Upper Tankerhoosen River	0.0	0.0	0.7	13.6	66.9	15.1	3.3	0.4
Walker Reservoir	6.3	2.7	0.0	37.8	39.4	11.5	2.3	0.0

Table 7 presents the total estimated number of septic systems in the Tankerhoosen River watershed, determined using the methods described in Section 4.0. Septic systems are assumed to be present at lots not included in or abutting the sewer service area shown in the Baseline Watershed Assessment report. As discussed in Section 4.0, "other" septic systems includes septic systems for land uses other than single-family and multi-family residential land uses, such as condominiums, group quarters, commercial, industrial parcels. These systems are assumed to serve an equivalent population of 5 times a residential system on average. Note that these septic system estimates and are intended only for estimating increases in NPS pollutant loads and should not be used for other purposes.

Table 7. Estimated Number of Septic Systems

Watershed	Number of Septic Systems		
	Residential	Other	Equivalent Total
Bolton Notch Pond	43	2	53
Clarks Brook	108	8	148
Gages Brook	81	1	86
Gages Brook South Tributary	236	4	256
Lower Tankerhoosen River	43	1	48
Middle Tankerhoosen River	169	7	204
Railroad Brook	76	0	76
Tucker Brook	98	0	98
Upper Tankerhoosen River	198	3	213
Walker Reservoir	42	2	52

5.2 Results

Table 8 presents total estimated loadings of total nitrogen, total phosphorus, BOD, and TSS for each subwatershed, as well as the loading rate for each subwatershed. In terms of total existing loads, the largest loads of pollutants originate in the Middle Tankerhoosen River, Gages Brook, Gages Brook South Tributary, Clarks Brook, and Tucker Brook subwatersheds. As such, pollutants from these areas are likely to have the largest effect on water quality in the Tankerhoosen River.

Since some of these watersheds are large compared to others, it is useful to look at the data in terms of the loading rate, which is the load of pollutant per unit land area. A high loading rate indicates dense pollutant sources, which suggests that implementation of best management practices (BMPs) in these areas would be more effective in reducing pollutant loads. Pollutant loading rates are relatively uniform between many of the watersheds. Outstanding loading rates include those from Railroad Brook and the Upper Tankerhoosen River, which are significantly lower than rates from other subwatersheds, and those from the Walker Reservoir, which are significantly elevated compared to loads from other subwatersheds. The highlighting in Table 8 identifies subwatersheds with high (orange), moderate (yellow), and low (green) pollutant loadings.

Table 8. Estimated Existing Pollutant Loads

Watershed	N	P	BOD	Sediment	N	P	BOD	Sediment
	lb/yr	lb/yr	lb/yr	t/yr	lb/ac-yr	lb/ac-yr	lb/ac-yr	t/ac-yr
Bolton Notch Pond (318 ac)	2175	385	7895	51	6.8	1.2	24.8	0.2
Clarks Brook (647 ac)	4157	669	15686	92	6.4	1.0	24.2	0.1
Gages Brook (695 ac)	4640	787	18084	115	6.7	1.1	26.0	0.2
Gages Brook South Tributary (680 ac)	4062	720	14877	89	6.0	1.1	21.9	0.1
Lower Tankerhoosen River (306 ac)	2009	343	6987	47	6.6	1.1	22.8	0.2

Watershed	N lb/yr	P lb/yr	BOD lb/yr	Sediment t/yr	N lb/ac-yr	P lb/ac-yr	BOD lb/ac-yr	Sediment t/ac-yr
Middle Tankerhoosen River (1570 ac)	9364	1473	34764	216	6.0	0.9	22.1	0.1
Railroad Brook (1203 ac)	1890	359	7451	40	1.6	0.3	6.2	0.0
Tucker Brook (934 ac)	4481	699	17014	118	4.8	0.7	18.2	0.1
Upper Tankerhoosen River (1472 ac)	3868	683	14562	82	2.6	0.5	9.9	0.1
Walker Reservoir (322 ac)	2312	390	7965	54	7.2	1.2	24.7	0.2
Total (8149 ac)	38960	6509	145286	903	4.8	0.8	17.8	0.1

- *Bolton Notch Pond*. Although this subwatershed is the second smallest in the study area, it is characterized by the second highest nitrogen loading rate, is tied for the highest phosphorus and sediment loading rate, and has the third highest BOD loading rate. These high values reflect the large composition of commercial land use (approximately 26%) and transportation land use (approximately 29%) in the subwatershed.

- *Gages Brook*. This watershed is characterized by both relatively high total pollutant loads and pollutant loading rates. This watershed is 70% urban land, and has the highest industrial land use composition and second-highest commercial land use composition.

- *Middle Tankerhoosen River*. This watershed has moderate pollutant loading rates. Although it is the largest subwatershed in the study area, it also has total pollutant loads that are approximately twice as high as those of other large subwatersheds.

- *Walker Reservoir*. Although the Walker Reservoir subwatershed is similar in size to the Bolton Notch Pond subwatershed, its pollutant loading rates for nitrogen, phosphorus, and sediment are significantly higher. These loading rates reflect the highly urbanized nature of this subwatershed, which also has the highest percentage of transportation land use.

5.3 Discussion

The sources of pollutants in the watershed are generally associated with urban land use, as presented in Table 9. Note that urban areas are estimated to account for between 80% and 95% of the NPS pollutant load in the watershed, although urban uses comprise only 59% of the total watershed land use area (See Table 5)

Table 9. Pollutant Source by Land Use

Source	N Load	P Load	BOD Load	Sediment Load
Urban	91.9%	81.5%	93.1%	88.6%
Cropland	1.9%	2.6%	1.0%	7.8%
Forest	2.3%	6.7%	1.5%	3.6%
Septic	3.9%	9.2%	4.3%	0.0%
Total	100.0%	100.0%	100.0%	100.0%

By subdividing the urban pollutant loads into the distinct urban categories that were included in the model (See Table 10), it is apparent that transportation land use accounts for the largest NPS pollutant loads in the watershed, with higher-density residential use being the second largest source of pollutant loads. Higher-density residential land use is a significant source since it is the predominant land use in the watershed (See Table 6). Transportation use is a significant source since it has the highest pollutant EMCs, and commercial uses are a significant source for the same reason (See Table 1).

Table 10. Pollutant Loads and Sources for Urban Categories

Urban Land Use	N Load	P Load	BOD Load	Sediment Load	N Load	P Load	BOD Load	Sediment Load
	lb/year	lb/year	lb/year	tons/year	%	%	%	%
Commercial	2242	408	10191	51	6%	8%	8%	6%
Industrial	1898	304	6834	46	5%	6%	5%	6%
Institutional	1061	177	4596	20	3%	3%	3%	2%
Transportation	17400	2900	53938	435	49%	55%	40%	54%
Dense Residential	9890	989	45990	185	28%	19%	34%	23%
Rural Residential	2970	495	12871	55	8%	9%	10%	7%
Vacant	297	30	792	7	1%	1%	1%	1%
Open Space	39	4	103	1	0%	0%	0%	0%

6.0 FUTURE POLLUTANT LOADINGS

6.1 Input

Future land use estimates, presented in Table 11, were used in the STEPL model to simulate a watershed buildout scenario. Also summarized in Table 11 is the predicted "increase" in urban land use for each subwatershed. These model inputs were derived form the data presented in Section 7.2 of the Baseline Watershed Assessment report. Much of the future developed area in the watershed is currently forested, such that the increase in urban area for each subwatershed includes a corresponding reduction in forested land.

Table 11. Land Use Input Data

Watershed	Land Use Area (ac)			Land Use Composition)			Urban Increase
	Urban	Cropland	Forest	Urban	Cropland	Forest	
Bolton Notch Pond	233.3	0	85.3	73%	0%	27%	15%
Clarks Brook	590.4	2.4	54.6	91%	0%	8%	9%
Gages Brook	614.4	28.2	52.9	88%	4%	8%	19%
Gages Brook South Tributary	614.3	5.7	60.3	90%	1%	9%	18%
Lower Tankerhoosen River	270.7	0	35.8	88%	0%	12%	30%
Middle Tankerhoosen River	1312.5	10.1	247.9	84%	1%	16%	8%
Railroad Brook	589.9	0	612.9	49%	0%	51%	18%
Tucker Brook	771.2	43.0	119.3	83%	5%	13%	13%
Upper Tankerhoosen River	746.1	0	725.7	51%	0%	49%	15%
Walker Reservoir	296.4	0	25.7	92%	0%	8%	32%

Table 12 summarizes a break-down of the urban land uses presented in Table 5. Much of the future development and redevelopment is anticipated in areas that are currently zoned for residential uses. As such, residential land use is likely to become a larger percentage of urban land use in many of the subwatersheds.

Table 12. Urban Land Use Composition

Watershed	Urban Land Use Composition (%)							
	Com.	Ind.	Inst.	Trans.	Dense Res.	Rural Res.	Vacant	Open Space
Bolton Notch Pond	20.2	6.5	4.5	23.2	16.0	26.6	3.1	0.0
Clarks Brook	6.0	15.2	0.3	12.6	57.1	7.6	1.3	0.0
Gages Brook	15.6	16.8	7.0	6.1	23.2	30.8	0.0	0.5
Gages Brook South Tributary	2.6	3.5	3.2	15.7	30.3	44.2	0.5	0.0
Lower Tankerhoosen River	3.5	2.7	6.5	21.6	59.8	2.8	1.3	1.6
Middle Tankerhoosen River	5.9	1.7	1.6	16.1	67.5	6.0	0.9	0.4
Railroad Brook	0.0	0.0	0.0	2.9	86.1	10.1	0.9	0.0
Tucker Brook	0.2	0.0	3.8	10.0	81.5	4.4	0.1	0.0
Upper Tankerhoosen River	0.0	0.0	0.5	9.5	33.9	55.0	0.9	0.3
Walker Reservoir	15.1	3.7	0.0	24.5	36.9	19.8	0.1	0.0

Table 13 presents the total estimated number of existing and future septic systems in the Tankerhoosen River watershed, determined using the methods described in Section 4.0. Septic systems are assumed to be present at lots not included in or abutting the sewer service area shown in the Baseline Watershed Assessment report. As discussed in Section 4.0, "other" septic systems includes septic systems for land uses other than single-family and multi-family residential land uses, such as condominiums, group quarters, commercial, industrial parcels. These systems are assumed to serve an equivalent population of 5 times a residential system on average.

Table 13. Estimated Number of Septic Systems

Watershed	Existing Equivalent Total	Future Residential Systems	Other Future Systems	Future Equivalent Total
Bolton Notch Pond	53	8		61
Clarks Brook	148	3	9	196
Gages Brook	86	5		91
Gages Brook South Tributary	256	14	1	275
Lower Tankerhoosen River	48	4		52
Middle Tankerhoosen River	204	11	9	260
Railroad Brook	76	26		102
Tucker Brook	98	6		104
Upper Tankerhoosen River	213	19		232
Walker Reservoir	52	7	1	64

6.2 Results

Table 14 presents projected future pollutant loads under a watershed buildout scenario. An increase in pollutant loads is predicted in all subwatersheds. The Railroad Brook subwatershed is predicted to have the highest increase in nitrogen, BOD, and sediment loads. Large increases are also predicted in nitrogen, phosphorus, and BOD in the Middle Tankerhoosen River subwatershed. The largest phosphorus increases are predicted in the Gages Brook subwatershed.

Table 14. Projected Future Pollutant Loads and Load Increases

	Total Future Load				Projected Load Increase			
	N	P	BOD	Sediment	N	P	BOD	Sediment
Watershed	lb/yr	lb/yr	lb/yr	t/yr	lb/yr	lb/yr	lb/yr	t/yr
Bolton Notch Pond (318 ac)	2384	416	8752	54	209	31	857	4
Clarks Brook (647 ac)	4745	756	18205	103	588	87	2519	11
Gages Brook (695 ac)	5538	921	21973	134	898	134	3888	19
Gages Brook South Tributary (680 ac)	4559	793	16976	98	497	73	2099	9
Lower Tankerhoosen River (306 ac)	2410	374	8916	53	401	31	1929	7
Middle Tankerhoosen River (1570 ac)	10357	1585	39700	229	993	112	4936	13
Railroad Brook (1203 ac)	2964	432	12652	59	1074	73	5201	19
Tucker Brook (934 ac)	5111	736	20084	129	630	37	3071	11
Upper Tankerhoosen River (1472 ac)	4228	759	16194	87	360	76	1632	5
Walker Reservoir (322 ac)	2909	481	10718	66	598	91	2754	12
Total (8149 ac)	45207	7252	174172	1011	6248	743	28886	109

Table 15 presents the projected future pollutant loads in terms of the projected load increase based on existing loads (percent increase) and loading rate increase for each subwatershed. These criteria were selected to determine the most significant changes in watershed loadings since they control for the existing load quantities (percent increase) and watershed size (rate increase). The highlighting in Table 15 identifies areas with the high (orange), moderate (yellow), and low (green) pollutant loadings or loading rates in the Tankerhoosen River watershed.

Table 15. Projected Pollutant Loading Rate Increases and Load Increases

	Projected Future Loading Rate Increase				Projected Load Increase			
	N	P	BOD	Sediment	N	P	BOD	Sediment
Watershed	lb/ac-yr	lb/ac-yr	lb/ac-yr	lb/ac-yr	lb/yr	lb/yr	lb/yr	t/yr
Bolton Notch Pond (318 ac)	0.66	0.10	2.7	0.012	9.6%	8.0%	10.9%	7.7%
Clarks Brook (647 ac)	0.91	0.13	3.9	0.017	14.1%	12.9%	16.1%	11.7%
Gages Brook (695 ac)	1.29	0.19	5.6	0.027	19.4%	17.0%	21.5%	16.7%
Gages Brook South Tributary (680 ac)	0.73	0.11	3.1	0.014	12.2%	10.2%	14.1%	10.5%
Lower Tankerhoosen River (306 ac)	1.31	0.10	6.3	0.022	20.0%	8.9%	27.6%	14.7%
Middle Tankerhoosen River (1570 ac)	0.63	0.07	3.1	0.008	10.6%	7.6%	14.2%	5.8%
Railroad Brook (1203 ac)	0.89	0.06	4.3	0.015	56.8%	20.3%	69.8%	46.4%
Tucker Brook (934 ac)	0.67	0.04	3.3	0.012	14.1%	5.3%	18.0%	9.4%

Watershed	Projected Future Loading Rate Increase				Projected Load Increase			
	N	P	BOD	Sediment	N	P	BOD	Sediment
	lb/ac-yr	lb/ac-yr	lb/ac-yr	lb/ac-yr	lb/yr	lb/yr	lb/yr	t/yr
Upper Tankerhoosen River (1472 ac)	0.24	0.05	1.1	0.003	9.3%	11.1%	11.2%	6.0%
Walker Reservoir (322 ac)	1.86	0.28	8.6	0.036	25.8%	23.3%	34.6%	21.6%
Total (8149 ac)	0.77	0.09	3.5	0.013	16.0%	11.4%	19.9%	12.0%

Several of the subwatersheds are predicted to experience significantly higher increases in pollutant loads and loading rates under a watershed buildout scenario. These include:

- *Gages Brook*. The existing conditions pollutant load model indicates that this subwatershed is characterized by both relatively high total pollutant loads and pollutant loading rates, with approximately 70% urban land use, the largest amount of industrial land use, and the second-highest commercial land use composition in the entire watershed. The buildout condition of this watershed is projected to result in a 19% increase in urban land use with a corresponding decrease in forest; and the new urban land is likely to consist of new residential and industrial development. As such, relatively large loads and loading rate increases may occur.

- *Lower Tankerhoosen River.* The existing conditions pollutant load model for this subwatershed predicts relatively small loads (since the watershed area is small) and moderate loading rates. Under a buildout scenario, this subwatershed is projected to result in more than a 20% increase in nitrogen and BOD loads. The resulting loading rates for these parameters are projected to be the second highest of the Tankerhoosen River subwatersheds.

- *Railroad Brook.* The projected buildout pollutant loadings in this subwatershed for nitrogen and BOD are anticipated to increase by approximately 57% and 70%, respectively. Significant increases are also anticipated in phosphorus and sediment loads. Currently, the Railroad Brook sub watershed is heavily forested, with comparatively little development. Several large tracts of land within this subwatershed are potentially available for future development, especially in Bolton and South Vernon, which makes this watershed vulnerable to potentially significant pollutant load increases.

- *Walker Reservoir.* The existing conditions pollutant loading model suggests that this subwatershed has some of the highest levels of pollutant loads within the overall Tankerhoosen River watershed. Potential land use changes in this subwatershed include significant areas of new residential and mixed-use development, much of which is located adjacent to Walker Reservoir. These changes are predicted to result in the greatest increases in pollutant loading rates for all of the parameters evaluated.

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