Restoring Water Quality in the Lake Memphremagog Basin:
Clyde River Phase I and II Stream Geomorphic Assessments

Final Report for the 2006 River Corridor Grant

Melissa Dyer, Fritz Gerhardt, and Jayson Benoit

April 1, 2008

NORTHWOODS
STEWARDSHIP CENTER

Mission

The NorthWoods Stewardship Center is a multi-disciplinary organization with a mission to foster long-term stewardship of human and natural communities. Through education and action, the Center strives to improve the region's natural resources while cultivating new generations of land stewards.

Founded in 1989 as the Vermont Leadership Center, the organization began by offering educational programs to local schools from its wooded site in the heart of Vermont's Northeast Kingdom. In 1995, the Vermont Leadership Center received its 501(c)(3) non-profit status and broadened its scope of service to three program areas: Education, Ecosystem Management and Conservation Service. In 2004, the Center changed its name to the NorthWoods Stewardship Center to better reflect its multidisciplinary programs as well as its multi-state service area. Today, NorthWoods is a dynamic organization that serves Northern Forest communities through environmental education, land management, conservation science, conservation service, and outdoor recreation programs.

NorthWoods is rooted in education, and NorthWoods' Education programs offer local and regional youth a wide array of hands-on learning experiences specifically designed to teach participants a land ethic and empower them with the knowledge and motivation necessary to take responsible action on behalf of themselves, their communities, and the natural world.

Through its Land Management offerings, NorthWoods is in a unique position to demonstrate and teach sustainable land management to landowners and land managers throughout the Northern Forest region.

Our Conservation Science efforts use research and monitoring to increase our understanding of humans and the natural environment in the Northern Forest by evaluating the health of Northern Forest ecosystems and assessing the impacts of local and regional human activities on these magnificent ecosystems.

NorthWoods' Northeast Kingdom Conservation Service Corps represents our steadfast commitment to the next generation of land stewards. The Kingdom Corps utilizes hands-on conservation work as a tool for teaching young people about the human and natural communities in which they live while working on projects that protect the environment, improve recreational opportunities, and ultimately strengthen our local communities.

Finally, through Outdoor Recreation, NorthWoods seeks to bring people in closer contact with the wonders of their natural environment while enjoying hikes through the woods, paddling down the Clyde River, or skiing or snowshoeing through the snowy woods.

Today NorthWoods Stewardship Center is poised to broaden our reach from local to regional communities while continuing the programs that we do best: learning stewardship through ecological research and monitoring; teaching stewardship through educational and recreational offerings for students of all ages; and doing stewardship through demonstration forestry, landowner assistance, and the Northeast Kingdom Conservation Service Corps. For further information on NorthWoods Stewardship Center, visit our website at www.northwoodscenter.org.

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fostering stewardship of human and natural communities

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1.0 Executive Summary

The Clyde River Stream Geomorphic Assessment is part of an on-going partership between the NorthWoods Stewardship Center and the State of Vermont to identify sources of nonpoint source pollution in the four main Vermont tributaries draining into Lake Memphremagog, a lake receiving high nutrient and sediment loads. Located in northeastern Vermont, the Clyde River Watershed encompasses 144 square miles of land noted for its remoteness and wildness. Although recognized for their natural beauty, relatively intact wetlands, and abundant recreational and fishing opportunities, the Clyde River, its tributaries, and associated lakes also face a number of water quality threats resulting from a variety of sources within the watershed. While it is important to address these threats, it is equally important to identify and prevent degradation of areas with excellent water quality.

In streams, water quality is influenced by inputs from the watershed as well as the health of the stream itself. A stable stream with a healthy floodplain is less likely to contribute to nonpoint sources of sediment and nutrients than a stream undergoing rapid change and adjustments due to heavy channel or floodplain alterations. To identify areas of nonpoint source pollution, we completed Phase 1 Stream Geomorphic Assessments on 83 miles of the Clyde River and its tributaries; from these, 17.5 miles were chosen for more detailed Phase 2 Stream Geomorphic Assessments.

The results of these assessments indicate that many streams in the Clyde River Watershed are in good or reference condition. However, there are areas in the watershed which have lost their protective riparian buffers, are receiving inputs of sediment and nutrients from urban and agricultural development, and are eroding and sending nutrients downstream. The Phase 2 reaches most profoundly affected by these stressors were rated in fair or poor condition and totaled 1.6 stream-miles.

The Phase 2 assessments highlighted several potential stream restoration sites, including reaches in Newport (reach M01), West Charleston (reach M08), East Charleston (reaches M15, M16 and an unnamed tributary to M15), and the lower reach of Cold Brook in Brighton (reach T4.01). These reaches contain areas of actively eroding streambanks and significant areas without riparian buffers. These reaches would benefit from buffer enhancement projects such as tree or shrub plantings.

The stream geomorphic assessments also highlighted many streams of reference or near-reference condition. Many of these areas contain high quality floodplain forests, wetlands, or other natural communities which filter out inputs from the surrounding watershed and allow the streams to meander and flood naturally, depositing sediments and reducing flood danger to downstream areas. Maintaining these areas in their current condition would be an essential strategy in preserving the good water quality, excellent habitat, and aesthetics so typical of the Clyde River Watershed. Landowner education and outreach regarding the many benefits of maintaining streamside vegetation will be a crucial component of this strategy.

Of the four principal Vermont tributaries to Lake Memphremagog, the Clyde River is the largest has the best water quality overall. However, water quality generally decreases and sediment loads increase as one travels downstream. This is a result of cumulative inputs throughout the watershed. Implementing restoration projects on degraded reaches and maintaining the other reaches in a healthy and natural condition will be essential in conserving and improving water quality, aesthetics, and aquatic habitat in the Clyde River Watershed.

2.0 INTRODUCTION

2.1 PROJECT BACKGROUND AND MEMPHREMAGOG WATERSHED DESCRIPTION

Water quality is important to both natural and human communities. Surface waters - such as streams, rivers, lakes, and ponds - provide and support a great diversity of natural communities and organisms. Water is essential for human life, as well as all other forms of life, as surface and ground waters provide drinking water and support agricultural and industrial production. Surface waters also provide an important source of recreation, whether for swimming, boating, fishing, hunting, nature-viewing, or other outdoor activities. Finally, besides being important for maintaining ecosystem health, water quality serves as a valuable indicator for measuring ecological health.

Water quality throughout the world faces a number of major threats on both local and global scales. At regional and global scales, water quality is threatened by global climate change, atmospheric deposition (e.g. acid precipitation and sulfur and nitrogen deposition), and invasive species. At the more local and landscape scales, water quality is threatened by poor agricultural and forestry practices, urban and suburban development, and loss of wetlands and other shoreline habitats. Furthermore, surface waters can provide habitat for aquatic organisms that serve as vectors for diseases that dramatically impact human health.

This project continues our efforts to assess and identify threats to water quality and to plan and implement protection and restoration projects in the Lake Memphremagog Basin. The Lake Memphremagog Basin is located in the Northeast Kingdom of Vermont and the Eastern Townships of Quebec and is a tributary watershed of the St. Francis River, which ultimately flows into the St. Lawrence River. Lake Memphremagog currently faces a number of imminent threats to water quality, including high sediment and nutrient loads, high phosphorus and mercury levels, excessive algal growth and eutrophication, and invasions of priority exotic species (State of Vermont 2006a, Simoneau 2004). Lake Memphremagog and South Bay are listed by the State of Vermont as impaired surface waters needing a total maximum daily load (TMDL) due to high phosphorus levels, nutrient enrichment, and excessive algal growth (State of Vermont 2006a). The Southern Basin of the lake is fed by three major tributaries that lie entirely within Vermont (Black, Barton, and Clyde Rivers) and one smaller tributary that straddles the Vermont / Quebec border (John's River). All four tributaries have been identified as priority surface waters outside the scope of Clean Water Act Section 303(d). Parts of the Clyde and John's Rivers are listed by the State of Vermont as needing a TMDL (Part A) due to high phosphorus levels, nutrient enrichment, excessive algal growth, and elevated levels of mercury. All four tributaries are also listed as needing further assessment (Part C). All surface waters in the Lake Memphremagog Basin are Class B waters, except the watersheds feeding an unnamed reservoir in Derby, May Pond in Barton, Island Pond in Brighton, an unnamed tributary of the Black River, an unnamed tributary of the Clyde River, and Lightning Brook in Brighton (all Class A2 waters) and all waters located above elevations greater than 2,500 feet (Class A1 waters)(State of Vermont 2006b).

During 2005 and 2006, the NorthWoods Stewardship Center sampled water quality in the four principal Vermont tributaries to Lake Memphremagog (Gerhardt 2005, Dyer and Gerhardt 2007) for nitrogen, phosphorus, and sediment (overall results are summarized below in Figure 1). All watersheds contained areas of high phosphorus and sediment levels (color-coded in yellow, orange, or red in Figure 1). These results indicated that water quality was best in the Clyde River, intermediate in the Barton and Black Rivers, and poorest in the John's River, where very high levels of phosphorus, sediment, and nitrogen were observed. These levels originate from many point and nonpoint sources located throughout the Lake Memphremagog Basin.

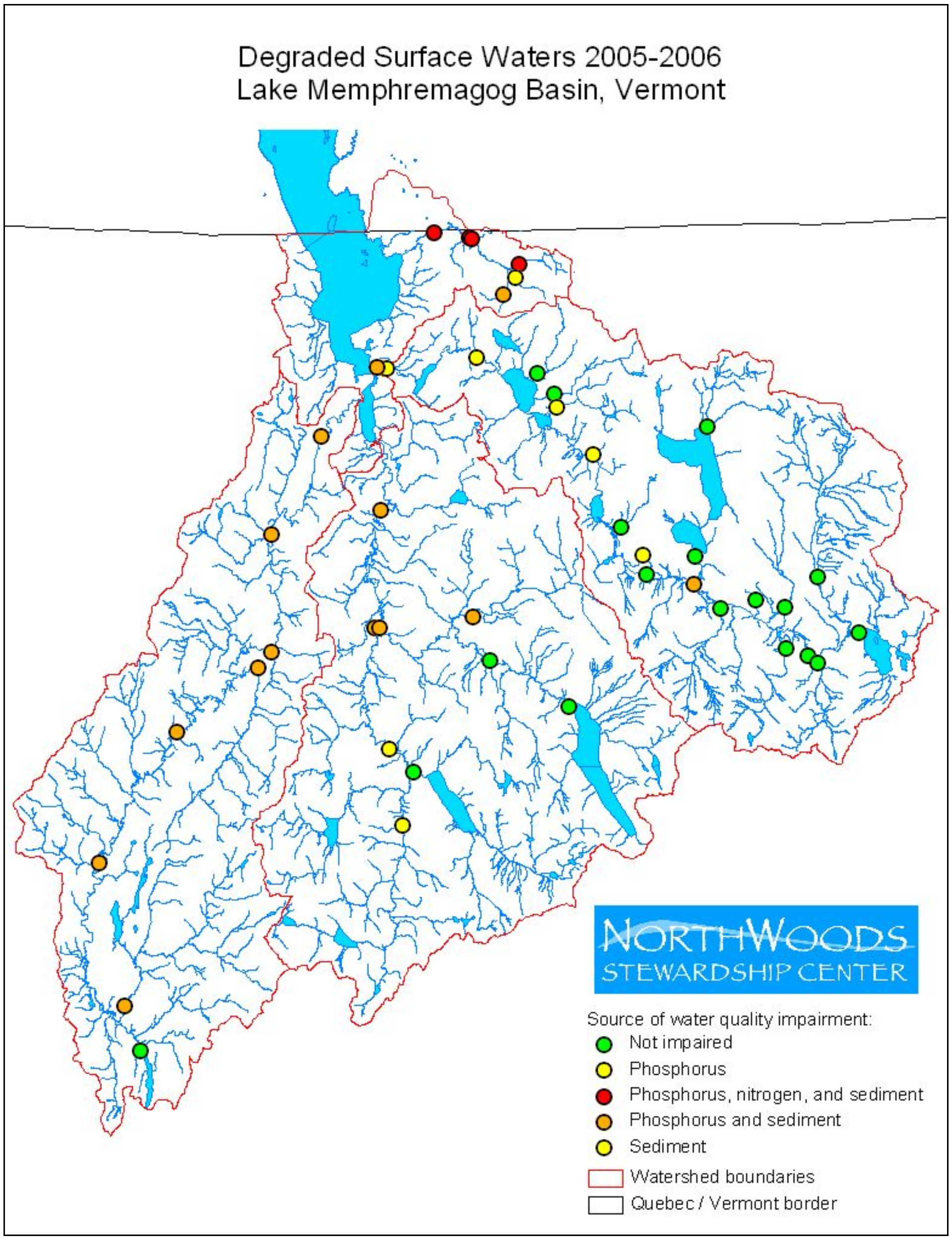


Figure 1. *Summary of water quality results in the four main Vermont tributaries to Lake Memphremagog, 2005-2006. Starting clockwise from the top are the John's, Clyde, Barton, and Black River Watersheds.*

Nonpoint source pollution (NPS) originates from a number of sources, including agriculture (non-irrigated crop production, specialty crop production, pastureland, feedlots, and manure lagoons), silviculture (harvesting, residue management, forest management, and road construction and maintenance), construction (highways, roads, and bridges and land development), urban runoff (storm sewers, combined sewers, and surface runoff), resource extraction, exploration, and development (surface mining, mill tailings), land disposal (wastewater, landfills, on-site wastewater systems, hazardous waste, and septage disposal), hydromodification (channelization, dam construction, flow regulation and modification, bridge construction, removal of riparian vegetation, stream bank modification and destablization, and draining and filling of wetlands), and other sources (atmospheric deposition, waste storage and storage tank leaks, highway maintenance and runoff, spills, recreational activities, upstream impoundment, and salt storage sites).

In addition to impairing water quality in Lake Memphremagog and its tributaries, pollutants from these sources could also impair the aesthetics, aquatic life, and recreational opportunities of the Lake Memphremagog Basin. Lake Memphremagog and its tributaries currently support a wide array of recreational opportunities, economic benefits, and ecological functions. Water bodies in the basin are used extensively for boating, swimming, fishing, hunting, and nature viewing. Lake Memphremagog and the Clyde River are important links in the Northern Forest Canoe Trail, which extends 744 miles (1,191 km) from Old Forge, New York through Vermont, Quebec, and New Hampshire to Fort Kent, Maine. Water bodies in this basin also provide drinking water, hydroelectric power, and disposal of treated wastewater; and their associated wetlands serve important flood control and water filtration functions. These wetlands also support a number of rare species and significant natural communities, which contribute greatly to regional biodiversity.

2.2 PROJECT GOALS

This project focused on assessing the health and stability of the Clyde River and several of its tributaries in order to identify the sources of phosphorus and other nutrient and sediment inputs into Lake Memphremagog, as well as the lakes which are part of the Clyde River system. For three years, NorthWoods Stewardship Center sampled water quality in the Clyde River Watershed (Heiser et. al. 2004, Gerhardt 2005, Dyer and Gerhardt 2007). During two of these years, sampling was expanded to include all four principal Vermont tributaries to Lake Memphremagog. These efforts identified many areas of sediment and nutrient enrichment. To begin identifying sources of these nutrients, we then completed Phase 1 Stream Geomorphic Assessments on 36 reaches in the Clyde River Watershed (Gerhardt and Dyer 2006). The Phase 1 assessments were initial evaluations of the river corridor and its watershed through aerial photographs, topographic maps, and GIS databases. The current project continues this effort and consisted of Phase 2 Stream Geomorphic Assessments of several priority reaches identified in 2006 and involved detailed field surveys and measurements of selected reaches by wading or canoeing. Phase 1 assessments were also completed on additional reaches. Collectively, the maps and data generated from these assessments allowed us to evaluate the overall condition and stability of the Clyde River and its tributaries, their roles in delivering nutrients and sediment to downstream locations, and the degree to which humans have impacted in-stream and adjacent riparian habitats.

3.0 BACKGROUND WATERSHED INFORMATION

3.1 GEOGRAPHIC SETTING

3.1.1 Clyde River Watershed Description

The Clyde River (Waterbody ID VT17-04) drains an area of 144 mi^2 extending from the river's headwaters in the Towns of Brighton and Morgan to its mouth at the City of Newport (Figure 2). The watershed includes several large tributary watersheds, most notably the Pherrins River (20 mi^2) and Echo and Seymour Lake Outlets (26 mi^2). Numerous large lakes are found within the watershed, including Seymour Lake (1777 acres), Lake Salem (788 acres), and Island Pond (608 acres). The Clyde River has been identified as being a high priority for further assessment and monitoring (Parts C, E, and F; State of Vermont 2006a). Identified threats include 1) elevated levels of mercury in walleye (*Stizostedion vitrium*) in the Lower Clyde River; 2) elevated levels of sediment, nutrients, and *Escherichia coli* caused by agricultural runoff throughout the watershed; and 3) flow regimes altered by hydroelectric and other dams and water withdrawal along the Clyde River and its tributaries. In addition, several priority exotic species have invaded the Clyde River Watershed. Clyde Pond and Lakes Derby and Memphremagog are currently infested by Eurasian milfoil. Small but rapidly expanding populations of purple loosestrife *(Lythrum salicaria)*, common reed *(Phragmites australis)*, and Japanese knotweed *(Polygonum cuspidatum)* occur throughout the watershed but are most abundant in the lower watershed in and around Lake Memphremagog.

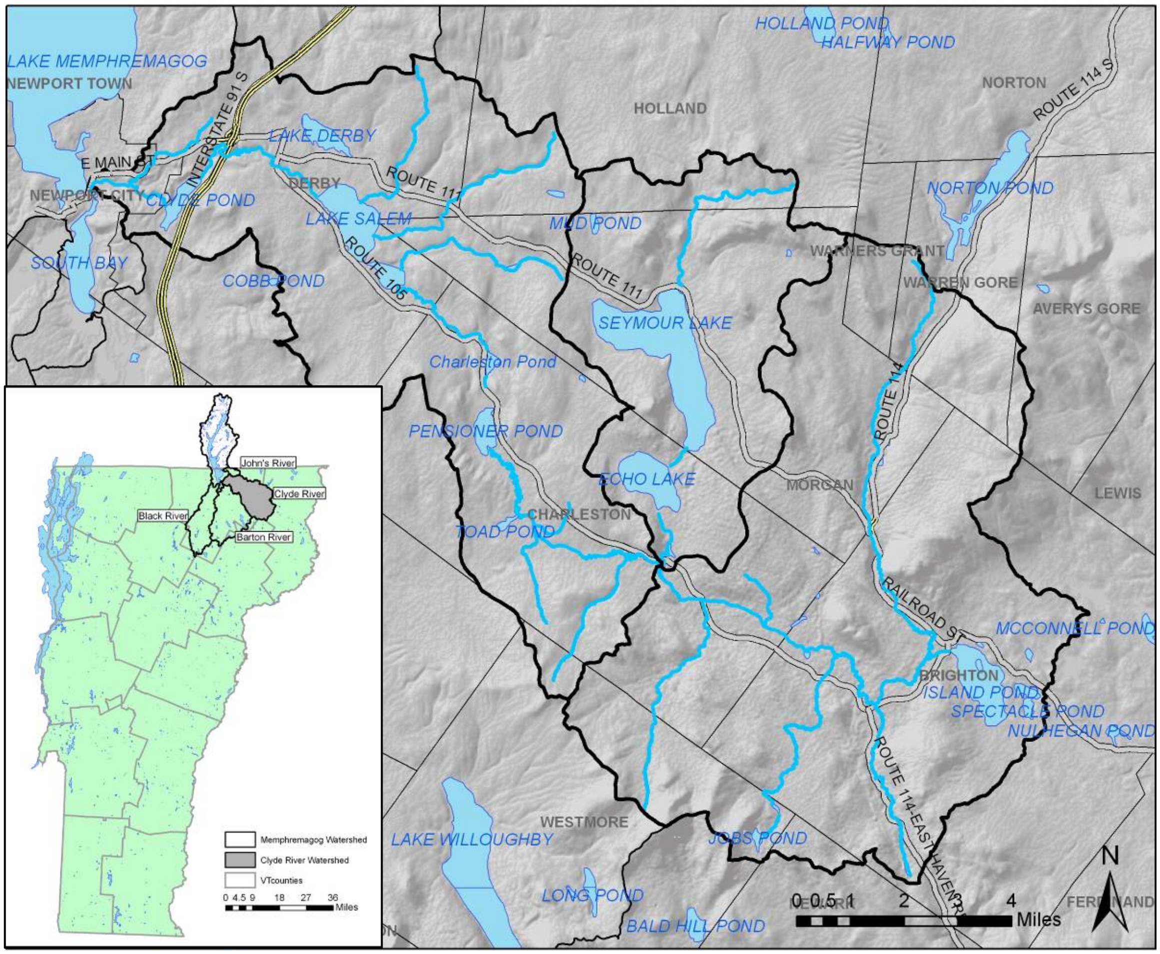


Figure 2. *Map of the Clyde River Watershed, one of the four principal Vermont tributaries to Lake Memphremagog (see inset). The watershed is separated into three distinct sub-basins: the Upper, Lower, and Seymour Lake Watersheds (black lines).*

3.1.2 Political Jurisdictions

The Clyde River Watershed lies mainly within Orleans and Essex counties in northeast Vermont, including all or portions of the towns of Brighton, Charleston, Derby, Holland, Morgan, Newport, Newark, and Westmore. The mainstem originates in Brighton; then travels through Charleston, Derby, and Newport before emptying into Lake Memphremagog (Figure 2).

3.1.3 Land Use History and Current General Characteristics

Onkawbegok: "at the chain of connected lakes" (Abenaki name for the Clyde River) (Nelson 2003)

Although located in one of the more remote parts of the state, the Clyde River watershed has a long history of human land use, with a range of resulting impacts on stream health. Spear points and other archaeological evidence point to early use of the Clyde River valley by Paleo-Indians more than 10,000 years ago. The valley remained an important east-west travel corridor and by roughly 4,000 years ago supported permanent Native American villages at Lake Memphremagog. At the time of colonization by the first Euro-Americans, bands of Western Abenaki were utilizing ponds and streams throughout the watershed for seasonal hunting and fishing activities. Despite this long period of early use, overall impact upon stream health is thought to have been minor due to a low population density and the largely subsistence hunting and gathering economy.

Euro-American settlement of the watershed came later than in other parts of Vermont, beginning in the Derby area with the completion of the Hinman Settler Road in 1793 and spreading gradually eastward. In the late 1790s, Surveyor General James Whitelaw coined the name Clyde River while laying out town boundaries in the upper watershed in honor of the River Clyde in his native Scotland. Settlements along the main stem of the Clyde were in place by the 1820s, with clearing and development emanating outward from the fertile floodplain soils and sites with greatest water power potential. Populations and the acreage of cleared land skyrocketed, peaking between 1870 and 1900. By 1900 over 80% of Orleans County had been cleared of its forest, while poorer soil areas of the upper Clyde River watershed had been cleared of roughly 55% of their forest (Benoit and Marvin unpublished, U.S. Census).

Though observers of the time made little mention of it, streams throughout the watershed were likely adversely impacted by land use activities throughout the last half of the 19th century. In addition to increased stream inputs and resulting pollution from the cleared landscape, the streams themselves were at the heart of the period's industry and likely received many of the effluents from this production. Water powered mills in Derby, West Charleston, East Charleston, and other parts of the watershed were used for tanning hides, milling lumber and grains, and processing dairy products and wool. In 1870 a starch factory in East Charleston village produced 78 tons of starch from 14,000 bushels of locally-grown potatoes, while a factory on lower Mad Brook produced another 53 tons (Benoit and Marvin unpublished, U.S. Census).

Logging and lumber production in the watershed were also intensive during the late 19th century, with improved milling technologies and transportation fueling productivity and demand. As one example of this intensity, at least eight sawmills were in operation during this time within 3 km of the NorthWoods Stewardship Center (in the upper part of the watershed). As a part of these operations, logs were frequently stockpiled along streams and on millponds and lake ice for transport downstream in the spring. One example appears in a May 12, 1879 newspaper reference to an upcoming drive of 100,000 feet of logs from the south end of Lake Seymour to a sawmill at the outlet of Echo Lake (Benoit and Marvin unpublished, *Orleans County Monitor*).

After 1900 industry gradually moved away from the streams when new technology allowed more efficient energy from steam and later electricity. Farmland was also gradually abandoned and reclaimed by forest, most rapidly in the upper part of the watershed. As an example, 3,000 acres surrounding the NorthWoods Stewardship Center in Charleston were approximately 55% open land in 1890, 25% open in 1943, and only 12% open in 1999 (Benoit and Marvin unpublished).

The November 1927 flood, which resulted when 6-10 inches of rain fell on already-saturated soils, came at a time when much of the Clyde River watershed was still deforested, or in the early stages of reforestation. Photographs from this event and aerial photography from the 1940s suggest that the flood significantly impacted some valleys in the watershed and transported large volumes of sediment downstream. This is an important consideration when interpreting the effects of today's stressors on a stream's condition, as these historic hydrologic impacts are probably still felt today even though forests now dominate the landscape.

Today nearly 69% of the Clyde River Watershed is forested. The upper watershed remains mostly forested with urban development focused along a few village locations, most notably Island Pond, East Charleston, and around Seymour and Echo Lakes. The fertile river valleys contain several small farms but still remain mostly forested. The lower watershed contains a higher population density; agricultural land use occurs heavily throughout this region and urban land use is very concentrated in Derby and Newport as well as West Charleston and around Lake Salem. These land uses impact the Clyde River and tributaries today by decreasing soil infiltration, increasing sediment inputs, and increasing peak flood levels.

3.2 GEOLOGIC SETTING

The Clyde River Watershed straddles two distinct biophysical regions, draining from the western flanks of the Northeastern Highlands to the Lake Memphremagog lowlands of the Northern Vermont Piedmont. Elevations in the watershed range from 700 feet at Lake Memphremagog in Newport to 3,315 feet at Bald Mountain in Westmore.

Bedrock in 54% of the watershed (mainly the lower half), is metamorphosed limestone, schist, and phyllite of the Gile Mountain and Waits River Formations. This rock was derived from muds, silts and marine organisms that accumulated along an ancient shoreline and were later compressed by a collision of continents about 380 million years ago. The result is a calcium-rich rock that weathers relatively easily, providing some buffering capacity to acid inputs from precipitation, decomposition, and other sources (Benoit 1999).

Most of the remaining watershed lies over granitic bedrock (gabbros, diorites, and granites) that were intruded as magma into the surrounding metamorphic rock about 360 million years ago. Comprised largely of quartz and feldspar, this bedrock is highly resistant to weathering and is non-calcareous.

The glaciers that receded from the region roughly 13,000 years ago influenced the landscape by scouring the watershed's lakes (most notably Lake Seymour), exposing bedrock at higher elevations, and through the types and patterns of sediments that were deposited. As a result, upland areas of the watershed are characterized by a combination of loose and compacted glacial till, while valleys contain a combination of alluvial and lake deposits, as well as ice contact features such as kames, eskers, and kettleholes. Lacustrine and outwash deposits are concentrated mainly in the lower half of the watershed, which was occupied circa 12,000 years ago by a proglacial Lake Memphremagog that was approximately 300 feet deeper than the current lake (Stewart and MacClintock 1969).

3.3 GEOMORPHIC SETTING

3.3.1 Description and Mapped Location of the Assessed Reaches

Prior to conducting Stream Geomorphic Assessments, the Clyde River Watershed was divided into 235 reaches and subwatersheds using topographic maps and aerial photographs (Gerhardt and Dyer 2006). The mainstem of the Clyde River was divided into 20 distinct reaches; each reach represented a section of stream with physical attributes that distinguish it from reaches immediately upstream and downstream. These attributes included valley width, adjacent land use, impoundments, channel sinuosity, width, and slope. Of these 235 reaches, 83 received Phase 1 Assessments and 11 reaches received Phase 2 Assessments (Figure 3).

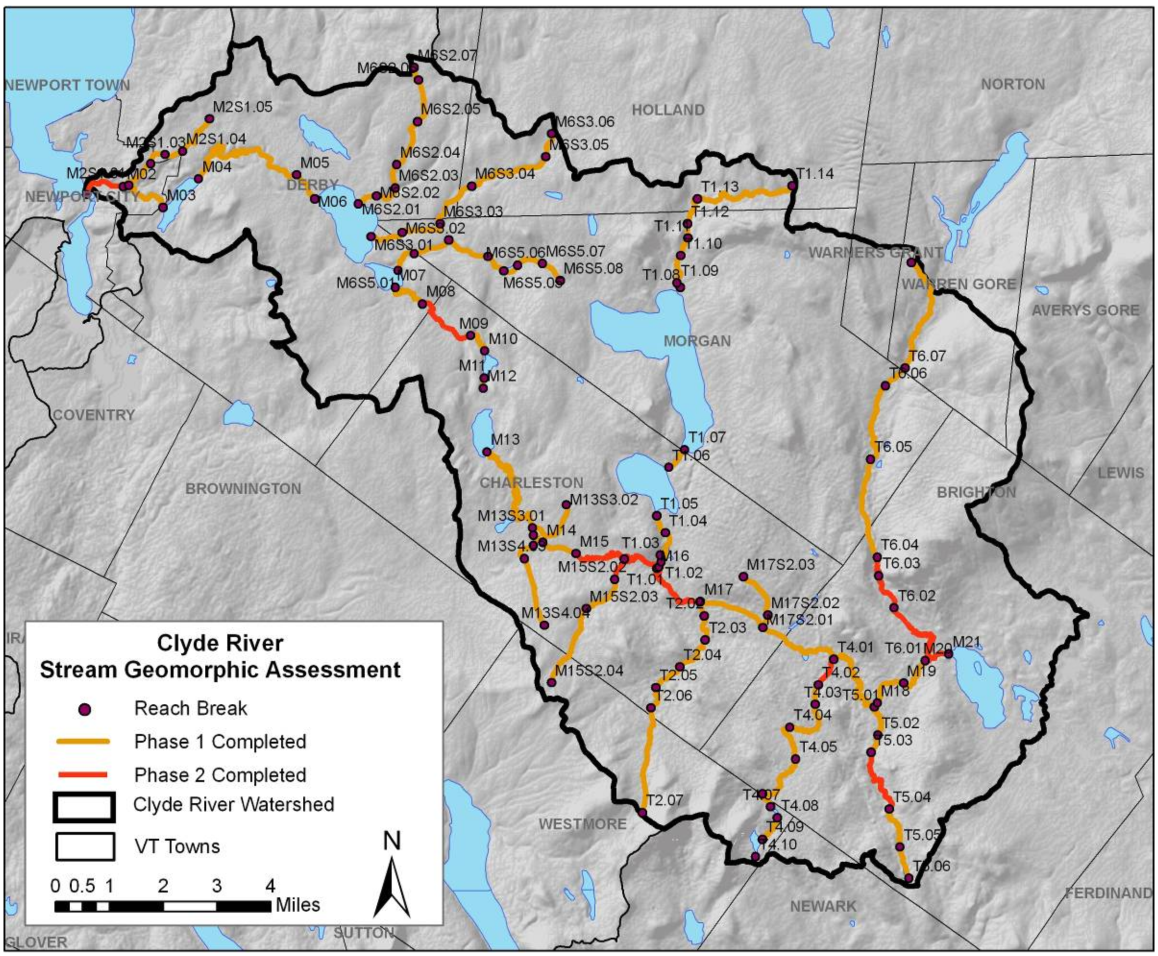


Figure 3. *Assessed and numbered reaches in the Clyde River Watershed. Phase 1 Assessments were completed on 83 reaches (totaling 81 river miles); Phase 2 Assessments were completed on 11 reaches (totaling 17.5 river miles).*

3.3.2 Longitudinal Profile, Alluvial Fans, and Natural Grade Controls

Dropping only 40 feet in elevation from its beginning at Island Pond (Reach M21) to Pensioner Pond (Reach M12), the Clyde River is a slow, low gradient river snaking its way through broad valleys, vast wetlands, and floodplain forests. The river receives inputs from numerous cold-water mountain tributaries during this 11.8 mile (16.5 river miles) stretch, most notably the Pherrins River (Reach T6), Oswegatchie Brook (T5), Cold Brook (T4), Webster Brook (not assessed), Mad Brook (T2), and outflows from Seymour and Echo Lakes (T1).

Below Pensioner Pond and the Great Falls Dam above West Charleston, the river changes dramatically, cascading over several bedrock ledges before entering Charleston Pond. Below Charleston Dam, the Clyde becomes a whitewater river, encountering more small bedrock ledges, flowing over cobble and boulder stream beds, and finally leveling off downstream of West Charleston village. The river elevation drops 140 feet from Pensioner Pond (Reach M12) to West Charleston (Reach M09), a distance of only 0.68 river miles, excluding the pond lengths.

After West Charleston village, the Clyde River transitions again to a low-gradient river, meandering through fields and forests before entering Little Salem Pond and Lake Salem (Reach M06). The river elevation drops 40 feet in these 1.7 miles (2.3 river miles). After exiting these lakes, the Clyde again changes to a fast-flowing and high-gradient river, traveling through a confined valley within the town of Derby and dropping 80 feet in 3.6 miles (3.9 river miles) between Lake Salem and Clyde Pond (Reach M03).

Upon leaving Clyde Pond, the river passes over the Clyde Pond Hydroelectric Dam and becomes a fast and cascading stream, dropping 190 feet in only 1.1 miles before leveling off in Newport and entering Lake Memphremagog.

The Clyde River flows through five lakes along its course. Its flows are affected by three man-made grade controls: Great Falls Dam below Pensioner Pond, Charleston Dam at Charleston Pond, and the Clyde Pond Dam in Newport. Salem Lake and Little Salem Pond are undammed, but all of these ponds and lakes capture sediment originating from upstream sources. These lakes were not assessed, as they fell outside the scope of the Stream Geomorphic Assessment.

3.3.3 Valley and Reference Stream Data

Using topographic maps and windshield surveys, data were collected describing the valley setting for each reach, which often determined the type of stream found there (Table 1). Stream types were assigned based on the Rosgen stream classification system (Appendix B). For example, meandering C and E stream types were found in the sandy, broad valleys of the upper watershed. These areas receive sediment from the many tributaries entering there. The river reacts to these sediment inputs by developing meanders and sand bars and, during flood events, depositing alluvium on the broad floodplains. Faster, cascading A and B stream types were found in the confined and sloping valleys that were more prevalent in the lower watershed. Here sediment transport was the dominant regime; transported sediment deposits in the broad valleys and lakes encountered on the way to the river’s mouth at Lake Memphremagog.

Table 1. Valley and channel characteristics for the main stem of the Clyde River (characteristics for the other assessed tributaries are displayed in Appendix C. Lake and pond reaches are excluded.

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type	Reference Stream Bedform
M01	85	0	1.05	Narrow	E	Dune-Ripple
M02	116.6	3.22	1	Narrowly Confined	A	Step-Pool
M04	115.2	0.34	1.09	Narrow	C	Riffle-Pool
M05	113.8	0.66	1	Semi-Confined	B	Plane Bed
M07	104.2	0.4	1.5	Very Broad	C	Dune-Ripple
M08	83(A); 91(B)	0.28	1.23	Very Broad	C	Riffle-Pool
M09	102.9	2.43	1	Narrowly Confined	B	Riffle-Pool
M11	102	7.17	1	Narrowly Confined	A	Cascade
M13	101.3	0.05	1.91	Very Broad	E	Dune-Ripple
M14	97.5	0	1	Narrow	C	Dune-Ripple
M15	39.5	0	1.54	Very Broad	E	Dune-Ripple
M16	37	0	1.33	Very Broad	E	Dune-Ripple
M17	77.2	0	1.3	Very Broad	C	Dune-Ripple
M18	60	0	1.08	Broad	C	Dune-Ripple
M19	58.8	0.39	1.31	Very Broad	C	Dune-Ripple
M20	35.5	0	1	Very Broad	C	Dune-Ripple

3.4 ECOLOGICAL SETTING

Through its influence upon nutrient availability and elevation, bedrock in the watershed has led to a somewhat predictable gradient in the distribution of natural community types. At the lower elevation, more enriched areas of the lower watershed, Northern Hardwood Forest forms the matrix community type. Rich Northern Hardwood is not uncommon in this area and community types with more southern affinities, such as Mesic Red Oak- Hardwood Forest and Buttonbush Swamp can be encountered. Nevertheless, human impact through agriculture and development has replaced or altered many of the natural communities in this area, including the formerly extensive wetlands at the mouth of the Clyde River.

Northern Hardwood Forest is also widespread in the upper half of the watershed, but a shorter growing season, higher elevations and more acidic bedrock introduce Lowland Spruce-Fir Forest and Montane Yellow Birch- Red Spruce Forest as other matrix community types. Natural communities here are less fragmented than in the lower part of the watershed, though widespread logging has altered species composition and successional stages in many areas. Uncommon wildlife species attracted to the more northerly habitat types of the upper watershed include Bicknell's thrush *(Catharus bicknelli)*, rusty blackbird *(Euphagus carolinus)*, boreal chickadee *(Poecile hudsonicus)*, and black-backed woodpecker *(Picoides arcticus)*. Common mammal species that benefit from the intact habitats here include black bear *(Ursus americanus)*, bobcat *(Felix rufus)*, fisher *(Martes pennanti)*, moose *(Alces alces)*, river otter *(Lutra canadensis)*, and beaver *(Castor canadensis)*.

The most notable natural communities and species of the watershed, however, are concentrated along the Clyde River itself, particularly in the extensive wetland complexes and low-gradient riverine communities found between Island Pond and Pensioner Pond. Uncommon and/or exceptional quality community types found in this area include Black Ash Floodplain Forest, Northern White Cedar Swamp, Sweet Gale Shoreline Swamp, Intermediate Fen, Riverine Floodplain Forest, Black Spruce Swamp, and Shrub Swamp (Engstrom et al. 1999). The flora of these wetland complexes include a diversity of rare species, most notably mare's tail *(Hippuris vulgaris)*, creeping sedge *(Carex chordorrhiza)*; nodding trillium *(Trillium cernuum)*, swamp fly honeysuckle *(Lonicera oblongifolia)*, mountain fly-honeysuckle *(Lonicera caerula* var. *villosa)*, bog willow *(Salix pedicellaris)*, water bur-reed *(Sparganium fluctuans)*, shining rose *(Rosa nitida)*, and common arrow-grass *(Triglochin maritimum)* (Engstrom et al. 1999). State-listed bird species that have regularly utilized the wetlands of the upper Clyde River during 1998-2007 breeding seasons include the bald eagle *(Haliaeetus leucocephalus)*, sora *(Porzana carolina)*, pied-billed grebe *(Podilymbus podiceps)*, and northern harrier *(Circus cyaneus)* (NorthWoods Stewardship Center, unpublished data).

Although diverse and apparently largely intact today, the wetlands of the upper Clyde River watershed are bordered or approached in many areas by agricultural fields, roads, and development and are currently minimally protected. As noted by Engstrom et al. (1999), *"Of greatest importance is protection of the water quality and maintenance of a natural hydrologic regime on the river and in the wetlands"*.

Aquatic ecosystems throughout the watershed also host several obligate taxa, whose populations rely upon healthy stream conditions and moderate sediment loads. One example is freshwater mussels, five species of which were observed in a 1998 survey of the Clyde River (Engstrom et al. 1999). A state-endangered sixth species, the cylindrical papershell *(Anodontoides ferussacianus)*, was noted in a 1928 survey of the Clyde, but was not found in the 1998 inventory. The watershed also supports a renowned cold-water fishery that includes the native brook trout *(Salvelinus fontinalis)* and lake trout *(Salvelinus namaycush)*. Fish stocking for recreational purposes, which began as early as 1860 in the watershed, has added landlocked Atlantic salmon *(Salmo salar)*, smallmouth bass *(Micropterus dolomieu)*, rainbow trout *(Oncorhynchus mykiss)*, brown trout *(Salmo trutta)*, and walleye *(Stizostedion vitrium)*. The introduction of hydroelectric dams to the lower Clyde River in the 1940s caused a crash in the salmon population and it has not fully recovered, even following the removal of the lower dam (Newport "Number 11") in 1996 (State of Vermont 1991).

Due to their sensitivity to water temperature, water quality, and competition from warm-water fish species, brook trout populations can serve as an indicator of changes in these conditions within a watershed (EBTJV 2006). A recent study by the Eastern Brook Trout Joint Venture identified the upper Clyde River subwatershed as among only 14% of watersheds in Vermont with intact brook trout populations (>90% of habitat occupied). The lower subwatershed, on the other hand, exhibited greatly reduced populations, with <50% of suitable habitat occupied.

4.0 METHODS

4.1 PHASE 1 ASSESSMENTS

The Stream Geomorphic Assessments were completed using protocols established by the Vermont Agency of Natural Resources (Vermont ANR; State of Vermont 2007b). The Phase 1 assessments were preliminary evaluations of selected reaches and sub-watersheds through three types of sources: remote sensing, current existing surveys, and brief "windshield" surveys. Phase 1 tributaries were chosen to correlate with water chemistry sample points conducted by NorthWoods Stewardship Center from 2004 through 2006 (Heiser et al. 2004, Gerhardt 2005, Dyer and Gerhardt 2007). Most of the Phase 1 Assessment was completed in ArcView 3.2 (ESRI, Redlands, California) from the following data layers (additional details about the data collected and their sources are found in Appendix A):

<u>Remote Sensing Data:</u>
1:24,000 USGS topographic maps (1988)
1:62,500 USGS topographic maps (1925, 1953)
1:5,000 Aerial orthophotographs (1962, 1999)
1:80,000 Infrared aerial photographs (1977)
1:5,000 Vermont Hydrography Data Set
Land use – land cover maps (1990s)

<u>Existing Survey Data:</u>
NRCS digital soil survey maps (2005)
Vermont Significant Wetland Inventory maps (2006)
National Wetlands Inventory maps (1975-1978)

All streams within the Clyde River Watershed represented in the Vermont Hydrography Data Set (VHD) were divided into individual reaches and sub-watersheds (Figure 3). We then used the Stream Geomorphic Assessment Tool (SGAT), a GIS extension developed by the Vermont ANR, to automatically associate all existing survey data with each individual sub-watershed. The data associated with each sub-watershed included the following:

Reach number and length
Valley length and width
Soil properties
Stream corridor land cover / land use
Watershed size
Geologic materials
Sub-watershed land cover / land use

Through evaluation of new and old topographic maps and aerial photographs as well as brief field visits, we described the following stream types and conditions:

Stream type / stream bed material
Valley side slopes
Stream migration
Presence of alluvial fans
Ground water inputs
Depositional features

Meander belt width and wavelength

In addition, we collected data describing human-caused modifications to the streams and their corridors:

Grade controls (dams)	Land use
Channel straightening	Riparian buffer width
Bridges and culverts	Floodplain encroachments
Dredging / gravel mining history	Development

All data were entered and archived in the Vermont ANR Data Management System (DMS) database. The DMS integrated all of the data and assigned impact ratings to each reach based on the degree of channel and floodplain modifications, and the degree to which the streams appeared to be responding to these modifications. These ratings were summed to calculate the overall reach condition rating, predicted adjustment scores, and reach sensitivities. This process highlighted reaches that warranted more detailed Phase 2 field assessments in order to further understand river processes and potential sediment sources. The complete DMS datasets are available to the public at https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm.

Due to the nature of the stream geomorphic data collection process, several Phase 1 parameters were not evaluated due to the remote location of some streams. In some instances a reach was not accessible from a road; in other instances only a small portion of a reach was viewable. Examples of such parameters included channel bedform, bed material, and ice and debris jam potential. In these instances NE (not evaluated) was written in the appropriate field in this report and in the DMS.

4.1.2 PHASE 2 ASSESSMENTS

The Phase 2 assessments consisted of in-depth mapping and evaluation of selected reaches and involved wading or canoeing entire reaches. Reaches were selected based on results of the Phase 1 assessment, with preference towards reaches that could potentially benefit from restoration or protection projects. The data collected included sketch maps, photographs, channel and floodplain measurements to document the condition of the stream itself and its adjacent floodplain. The following features were measured and mapped in the field:

Bank erosion	Beaver dams
Channel straightening	Debris jams
Bank armoring	Stormwater inputs
Floodplain development	Stream migration
Bridges and culverts	Grade controls
Floodplain encroachments	Channel cross-sections
Riparian buffer width	Pebble counts

Stream health was rated based on its geomorphic condition and its habitat condition. These ratings were based on the field measurements listed above and upon other characteristics, including sediment deposition and erosion patterns, channel evolution stage, and degree of floodplain access. All of these features were mapped with the SGAT extension and are presented in the following pages of this report. Like the Phase 1 data, the complete datasets are available to the public in the DMS database.

4.2 QA/QC SUMMARY

This project was completed in accordance with an approved Quality Assurance Project Plan developed in conjunction with Staci Pomeroy of the Vermont DEC. As part of this plan, all GIS layers and data entered into the DMS were checked through the appropriate Quality Assurance procedures specified in the Stream Geomorphic Assessment Protocol Handbook (State of Vermont 2007b). In addition, DMS data were checked for blank fields and conflicting Phase 1 and Phase 2 data by NorthWoods' staff. These data were checked again by Staci Pomeroy. QA/QC documentation are included in Appendix D.

5.0 RESULTS AND DISCUSSION

The Clyde River Watershed was divided into 235 numbered reaches and sub-watersheds. Of these, 36 were initially chosen for a Phase 1 Assessment, including the entire main stem of the Clyde River, the Pherrins River, Mad Brook, and Oswegatchie Brook (Gerhardt and Dyer 2006). This project expands upon this previous work to include 45 additional Phase 1 reaches. A summary of the Phase 1 results are listed in Appendix C and, for many reaches, are described in more detail in Gerhardt and Dyer (2006). Eleven of these reaches were chosen for a more detailed Phase 2 assessment based upon the adjacent land use, riparian buffer condition, or field visits. The lengths of assessed reaches totaled 83 river miles for Phase 1 and 17.5 river miles for Phase 2.

5.1 IDENTIFICATION OF HYDROLOGIC AND SEDIMENT REGIME STRESSORS IN THE WATERSHED

5.1.1 Hydrologic Regime Stressors

Land Cover / Land Use

Natural land cover types (e.g. forests, wetlands) play important roles in watersheds by storing and filtering run-off, trapping sediment, reducing peak flood levels, and maintaining base flows during summer. Deforestation and urban and agricultural development increase rainwater and snowmelt runoff by decreasing the amount of natural vegetation to naturally filter water and sediment. Additionally, urban lands contain large amounts of impervious surfaces where stormwater will quickly run off into adjacent drainages rather than slowly percolate through the soil, resulting in higher peak flood levels in addition high nutrient and sediment inputs. These levels can trigger a channel to enlarge and incise due to consistently high stormwater runoff. Combined with historic channel straightening, these land uses are likely responsible for the channel enlargement and incision observed on the Clyde River reach M08 downstream of West Charleston village and several tributaries in the upper watershed. Today agricultural and urban land use is concentrated in the lower Clyde Watershed, particularly downstream of West Charleston (Figure 4). The upper watershed remains mostly forested except for the village of Island Pond and portions of the Clyde River valley. Nearly 69% of the Clyde Watershed was forested, while agricultural and urban land uses comprised 18.1 and 8.6%, respectively (Table 2). Wetlands covered 2.9% of the watershed, mainly occurring along the Clyde and Pherrins Rivers in the upper watershed.

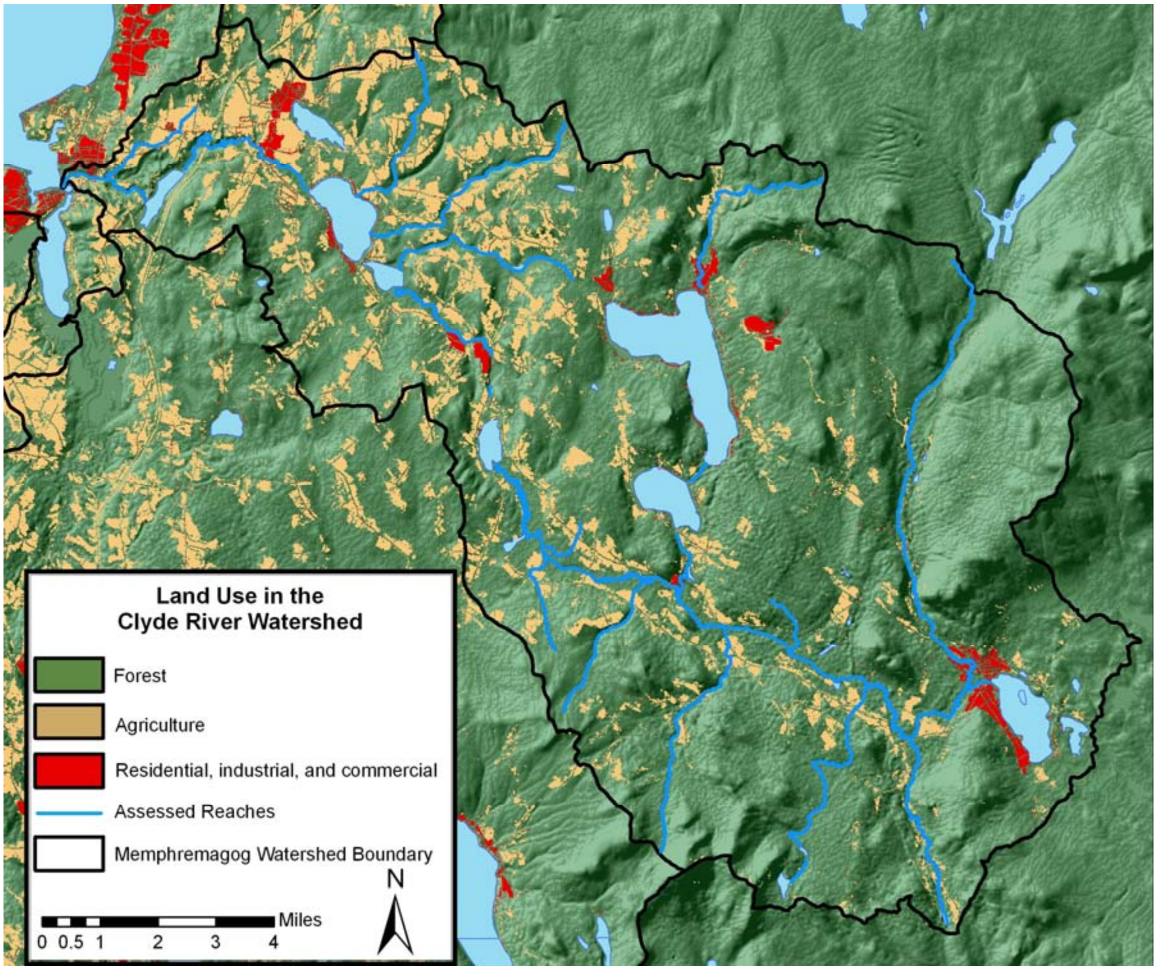


Figure 4. *Land Use in the Clyde River Watershed, showing agricultural land (uses include hay, crops, and pasture) and urban land (includes residential, industrial, and commercial).*

Table 2. Summary of Land Uses in the Clyde River Watershed

Land Use	Percentage of Watershed	
Mixed coniferous-broadleaf forest	30.8%	Forested or brush: 68.9%
Broadleaf forest (generally deciduous)	25.0%	
Coniferous forest (generally evergreen)	12.2%	
Brush or transitional between open and forested	0.9%	
Forested wetland	1.0%	Wetland: 2.9%
Non-forested wetland	1.9%	
Row crops (not including orchards and berries)	9.7%	Agriculture: 18.1%
Hay/rotation/permanent pasture	8.4%	
Other agricultural land	<0.1%	
Residential	5.6%	Urban: 8.6%
Commercial, services, and institutional	0.1%	
Industrial	<0.1%	
Transportation, communication, and utilities	2.8%	
Outdoor and other urban and built-up land	0.1%	
Barren land	<0.1%	Other: 1.3%
Water	1.3%	

Land use was also evaluated within stream corridors to further capture potential effects on runoff rates, erosion rates, and factors influencing the floodplains. A stream corridor was delineated for all assessed reaches in order to define the strip of land most influential to and most influenced by the river. Widths of stream corridors ranged from 100 feet to several hundred feet on either side, depending on valley and channel characteristics. For example, a straight stream in a steep and confined valley would have a narrower corridor than a meandering stream in a flat, broad valley. Figure 5 depicts areas in the Clyde watershed with high urban or agricultural land uses within the stream corridor. For this project, high land use was defined as having 10% or more of the stream corridor used for urban or agricultural purposes. High agricultural land uses were scattered throughout the watershed but were most concentrated in the lower watershed. Urban land use was low in most of the tributaries, although corridors along the main stem in Island Pond, West Charleston, Derby, and Newport contained very high urban land uses.

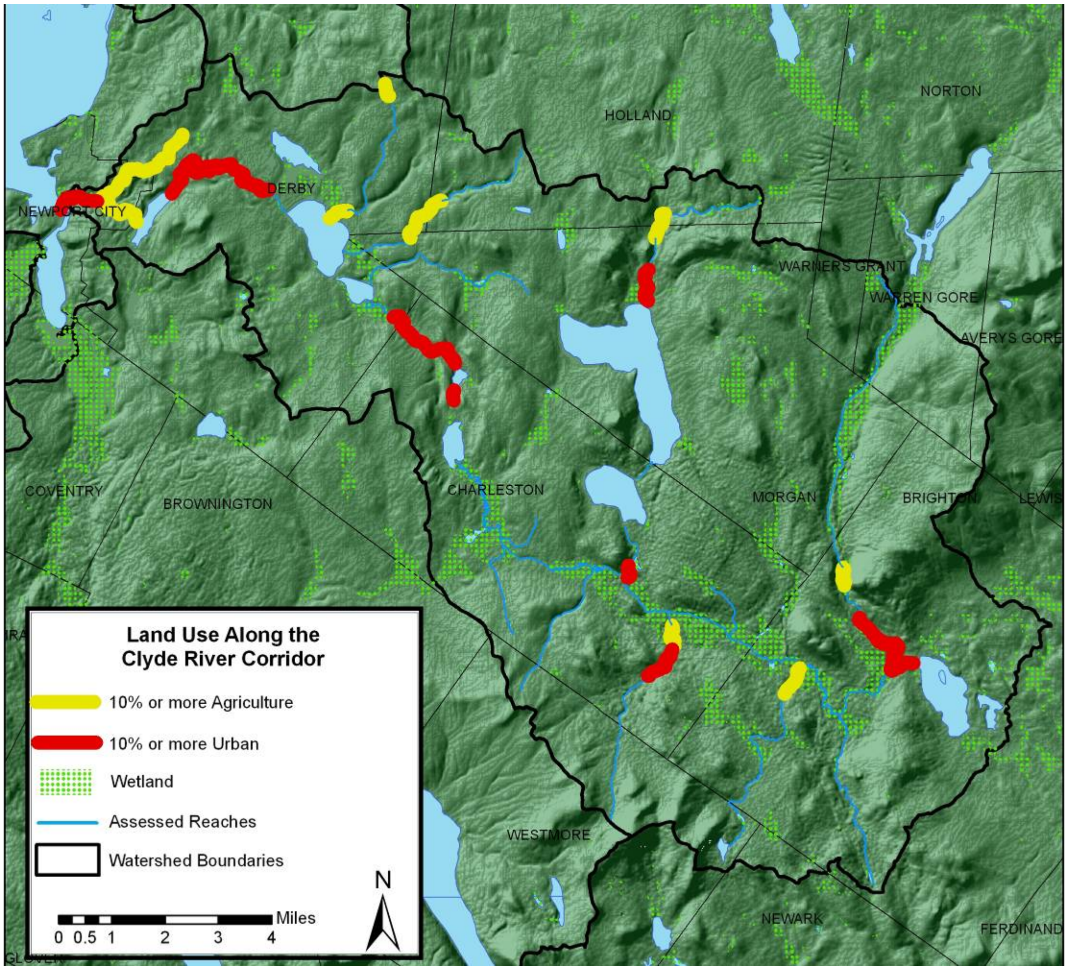


Figure 5. *Land use along the corridors of the Clyde River and its tributaries.*

Dams and Stormwater Inputs

The Clyde River is used intensively for generation of hydroelectric power. While providing a clean source of power, damming a river dramatically impacts a stream's ecology and geomorphology by altering both stream flows and sediment loads. Fish passage is impossible without fish ladders and water is diverted from the stream, resulting in stretches where flow levels are too low to sustain aquatic life. There are five dams currently existing in the Clyde River watershed (Figure 6). Four are owned by Citizen's Utilities, Inc.: Clyde Pond Dam (Newport), Charleston Pond Dam (Charleston), and the Echo Lake and Seymour Lake Dams. The Barton Village Electric Department operates the Great Falls Dam at Pensioner Pond (Charleston). A sixth dam located in the City of Newport (Newport #11) was removed in 1996 in an effort to restore salmon spawning habitat that was destroyed by diverting the river for hydroelectric power. Only two diversion dams are currently producing electricity: the Great Falls Dam and the Clyde Pond Dam.

Stormwater inputs were documented in the Phase 2 assessment in order to determine whether a reach may be responding to periodic high water flows during rain events. Reaches receiving large stormwater inputs may erode and enlarge to accommodate those sudden high flows. Stormwater inputs were infrequently encountered in the Clyde watershed with the exception of reach M01 in Newport (Figure 6). This reach received inputs from 17 sources; however, it did not show signs of channel degradation from these flows.

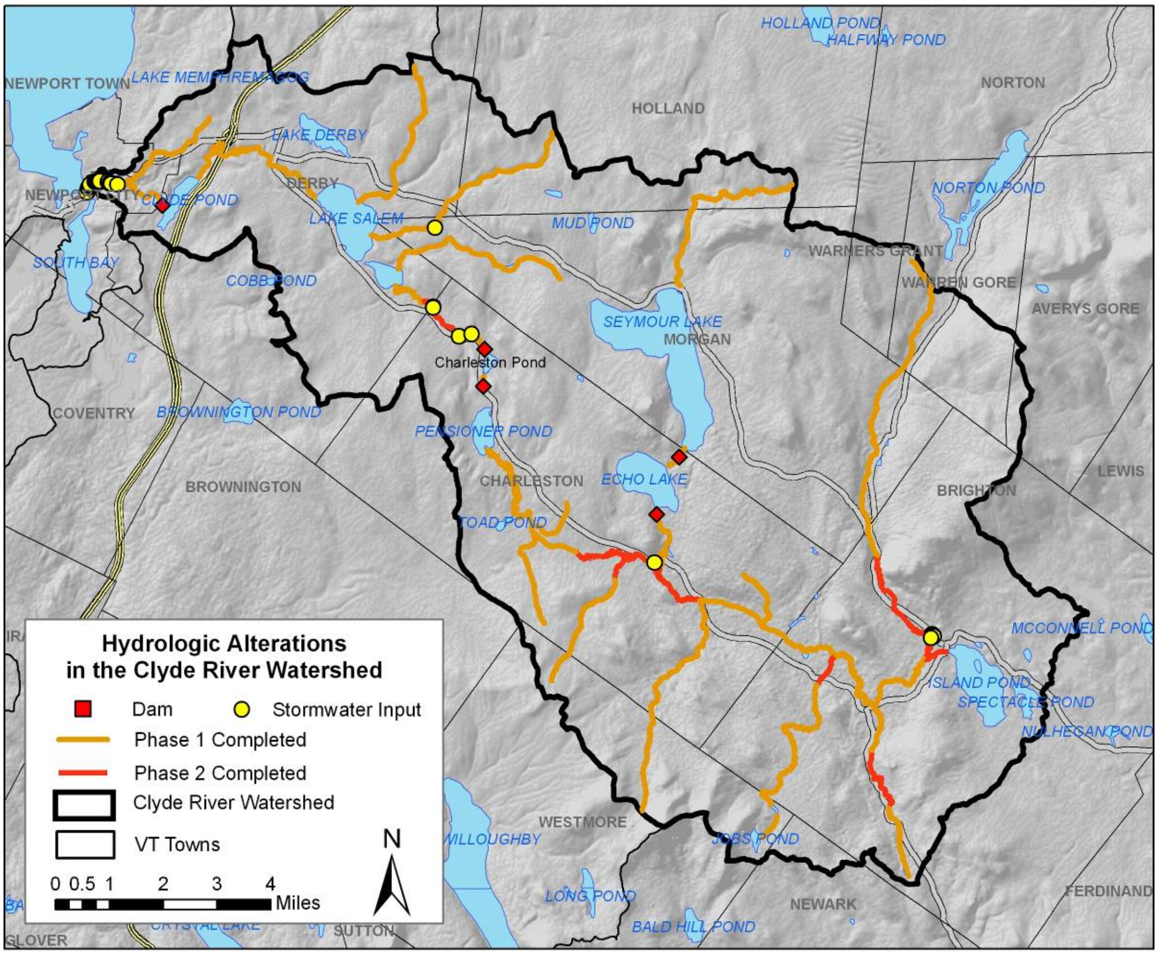


__Figure 6.__ Existing dams and stormwater inputs in the Clyde River Watershed.

5.1.2 Sediment Regime Stressors

<u>Channel Slope Modifiers</u>

Many land uses are incompatible with the meandering and ever-changing nature of rivers. Rivers and streams are often straightened, armored, dredged, bermed, or encroached upon to protect property investments or to make floodplains available for other land uses. Channel straightening and bank armoring remove or alter natural meanders, while undersized bridges and culverts act as channel constrictions, forcing the stream to flow faster through a narrow area. These channel alterations directly affect the stream by increasing its slope and power, resulting in areas of bed and bank erosion.

Floodplain encroachments such as roads, railroads, and berms exist as raised surfaces that cut off sections of floodplain that were normally utilized by the stream to migrate and deposit flood-related sediment. A stream that has access to a wide floodplain is also able to dissipate more energy when the floodwaters spread out over a large area, which decreases flood damage to downstream areas. Encroachments were mapped if they fell within the stream corridor, even if they did not occur immediately adjacent to a stream. This is because streams move and meander over time; a stream that is currently near but not immediately against a floodplain encroachment could migrate closer in the future, especially if that stream is rapidly adjusting to a stressor.

Figure 7 shows slope modifiers found along the Clyde River and assessed tributaries. Collectively, these modifications indicate the potential for increased erosion, channel incision, and decreased channel stability. The majority of channel straightening occurred in urban and agricultural areas, especially the broad, flat valleys adjoining the main stem of the Clyde River and the tributaries flowing into this valley. Floodplain encroachments occurred repeatedly throughout the watershed, but like the channel straightening, did not consistently impact the Clyde River and its tributaries for long distances. Bank armoring was rarely encountered with the exception of reach M01 in Newport.

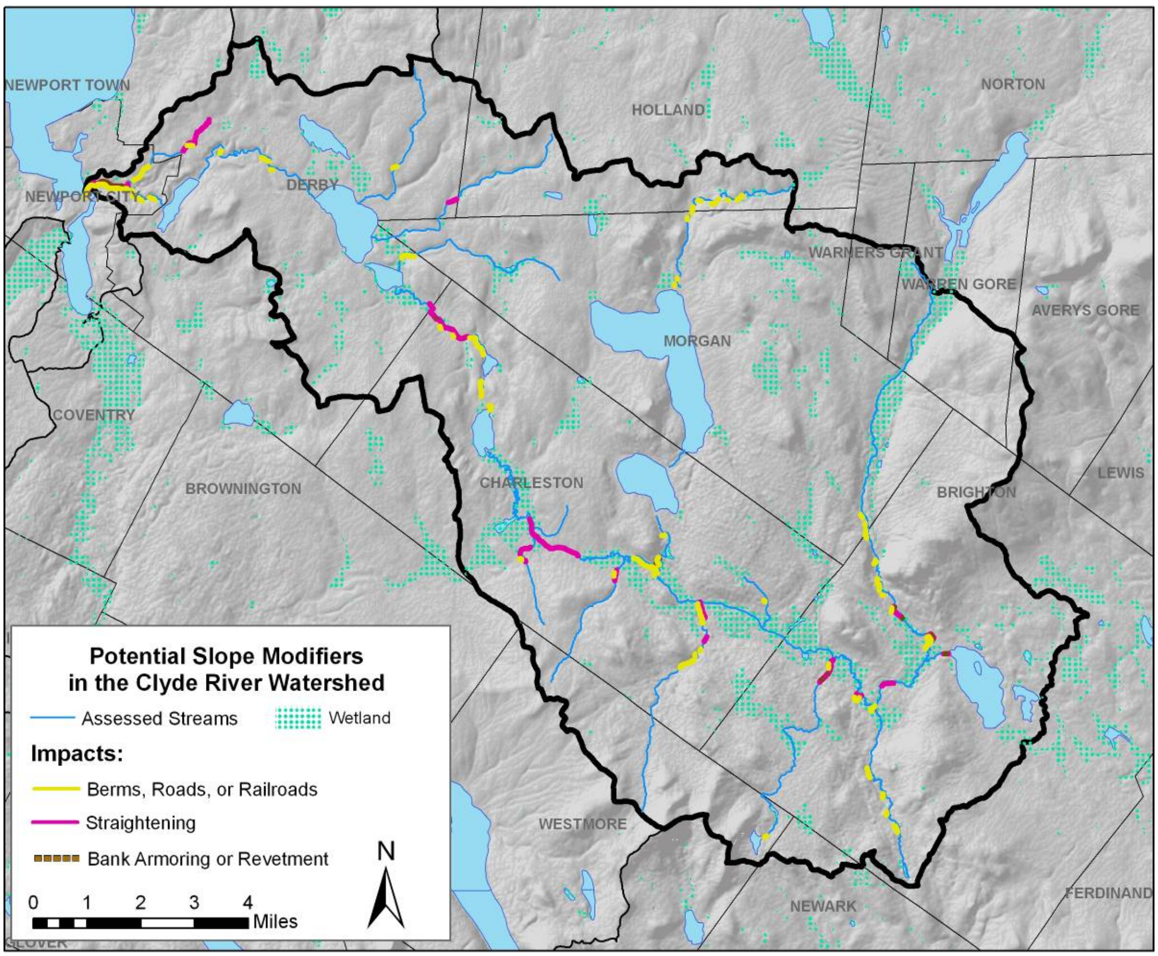


Figure 7. *Slope modifiers in the Clyde River Watershed, including floodplain encroachments (berms, roads, and railroads) and channel straightening.*

Table 3 shows the widths of all bridges and culverts measured in the Phase 2 assessments. Of the 17 structures listed, only five were appropriately sized for the channel. The remaining 12 bridges and culverts functioned as channel constrictions, altering the channel slope and flow regimes, and in many cases creating localized areas of erosion, scour pools and sediment deposition. In some instances, the stream was no longer aligned with the constriction due to migration in the vicinity of the undersized structure. These are areas where the stream could undermine the bridge or culvert during high flows; these are also areas where floodwaters could flow over and around the bridge, causing property damage and erosion.

Table 3. Channel and floodplain constrictions found during Phase 2 assessments of the Clyde River Watershed.

Reach	Type	Constriction Width (ft)	Channel Width (ft)	Channel Constriction?	Floodplain Constriction?	Problem Associated With Bridge
M01	Bridge	120	117	No	Yes	Alignment
M01	Bridge	66	117	Yes	Yes	None
M01	Bridge	120	117	No	Yes	None
M01	Bridge	63	117	Yes	Yes	Deposition Below, Scour Above
M15S2.01C	Bridge	12	18	Yes	Yes	Deposition Above, Scour Below, Alignment
M16	Bridge	70	37	No	Yes	Deposition Below
T4.01B	Bridge	15	27	Yes	Yes	Deposition Above, Scour Below, Alignment
T4.01B	Bridge	15	27	Yes	Yes	None
T5.03B	Bridge	6	24	Yes	Yes	Deposition Below, Scour Above
T5.03D	Culvert	4	24	Yes	Yes	Deposition Above, Scour Below
T5.03E	Culvert	4	24	Yes	Yes	Deposition Above, Scour Below, Alignment
T6.01A	Bridge	22	23	Yes	Yes	Scour Above, Scour Below
T6.01A	Bridge	22	23	Yes	Yes	Deposition Below, Scour Above
T6.02	Bridge	24	48	Yes	Yes	Deposition Above, Deposition Below, Scour Above
T6.02	Bridge	60	48	No	Yes	Alignment
T6.02	Bridge	115	48	No	No	None
T6.03	Bridge	27	47	Yes	Yes	Scour Above ,Scour Below

Erosion and Migration Features

Streams naturally meander and migrate over time. In its upper watershed, the Clyde River lies in an unconfined valley comprised of sands and gravels. It forms a meandering, sinuous pattern that is essential for the dissipation of energy and storage of sediment. Sediment erosion occurs in the outside meander bends, where the water flows fastest and contains the most energy. When the current slows, such as when it flows around the inside of a meander bend, it loses energy and its ability to transport sediment.

The sediment is then deposited and eventually forms bars. As they form, these bars push the flow of water to the outside of the bend, further exaggerating erosion of the outer banks. Unless there is a large change in the hydrology or sediment inputs from upstream, the bars continue to grow slowly to become the new floodplain.

This process is a natural part of stream evolution as it responds to varying flow levels and sediment inputs over time. In the absence of human influences, this process is normally quite slow, although some streams located on alluvial fans, at the base of very steep valleys, or are subject to extensive beaver activity are naturally dynamic. Streams that exhibit excessive migrations (such as avulsions, neck cut-offs, and flood chutes) and widespread erosion may be responding to a variety of stream channel or watershed stressors occurring either within the reach or upstream.

Numerous migration and erosion features were noted by comparing historic and current aerial photographs in Phase 1 as well as additional features noted during the detailed Phase 2 field assessments (Figure 8). Many migration features were observed in tributaries of the upper watershed where beaver activity amongst the alder swamps led to multiple flood chutes, ponds, and backwaters. Some channel avulsions and impending neck cut-offs were observed, but the erosion associated with these was very isolated and small in scale. Larger and more persistent areas of erosion were observed in some tributaries as they passed through the agricultural fields in the Clyde River valley and in areas of the main stem where the combination of land use and erodible stream banks enabled this process. A majority of the banks surveyed during the Phase 2 assessments were in stable condition; 12% of the river banks surveyed were actively eroding.

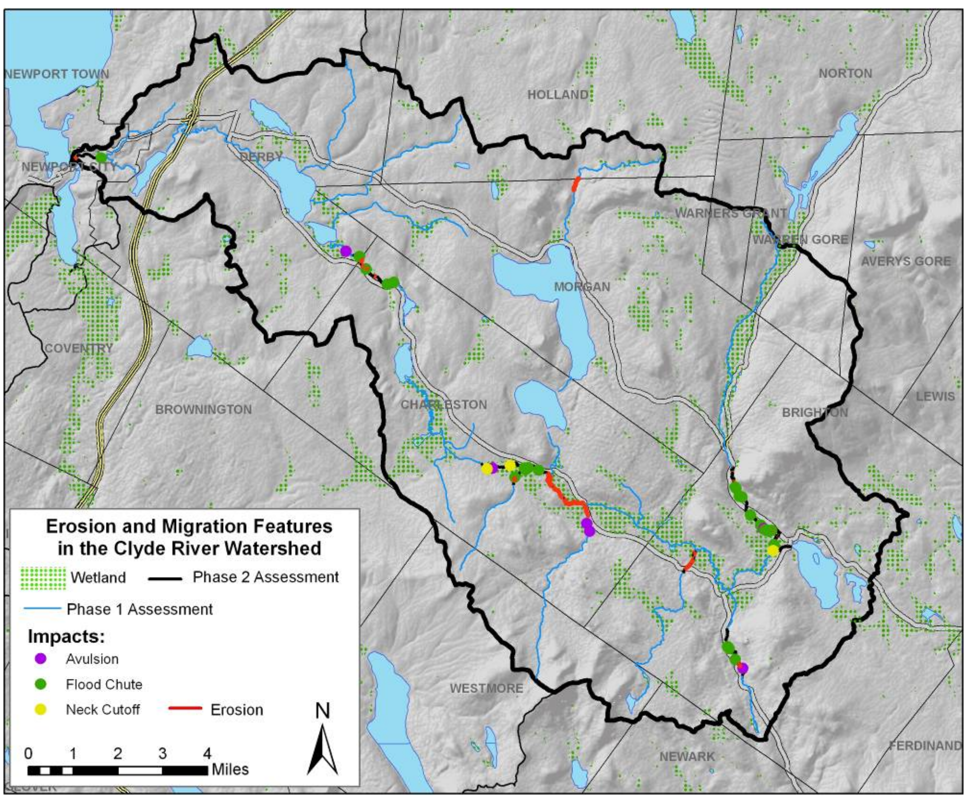


Figure 8.*Erosion and migration features for all Phase 2 reaches in the Clyde River Watershed.*

Riparian Buffer Conditions

Riparian buffers are the naturally vegetated land that lies between stream banks and lands altered for other uses. Buffers are integral parts of stable streams and healthy floodplains and are essential for healthy riparian ecosystems. During high precipitation events, they slow stream velocity, reduce peak flood levels, and allow streams to deposit sediments and nutrients on the floodplain rather than carrying them downstream. A wide buffer (e.g. >100 feet) will also filter most urban and agricultural runoff and reduce sediment and nutrient inputs to the streams. Ample trees and shrubs growing along the channel stabilizes stream banks, reduces erosion, and enhances aquatic habitat by providing organic debris to the channel and sheltering the stream from excessive sun.

Most of the Clyde River and its tributaries were surrounded by more than 25 feet of buffer (Figure 9). However, many areas did not have adequate riparian buffers, especially in urban areas and where tributaries crossed the fertile fields of the Clyde River valley. Additionally, much of reach T1 lacks an adequate riparian buffer, especially upstream of Seymour Lake. These areas often exhibited unstable banks and evidence of increased sediment loads, and are good candidates for streambank restoration projects.

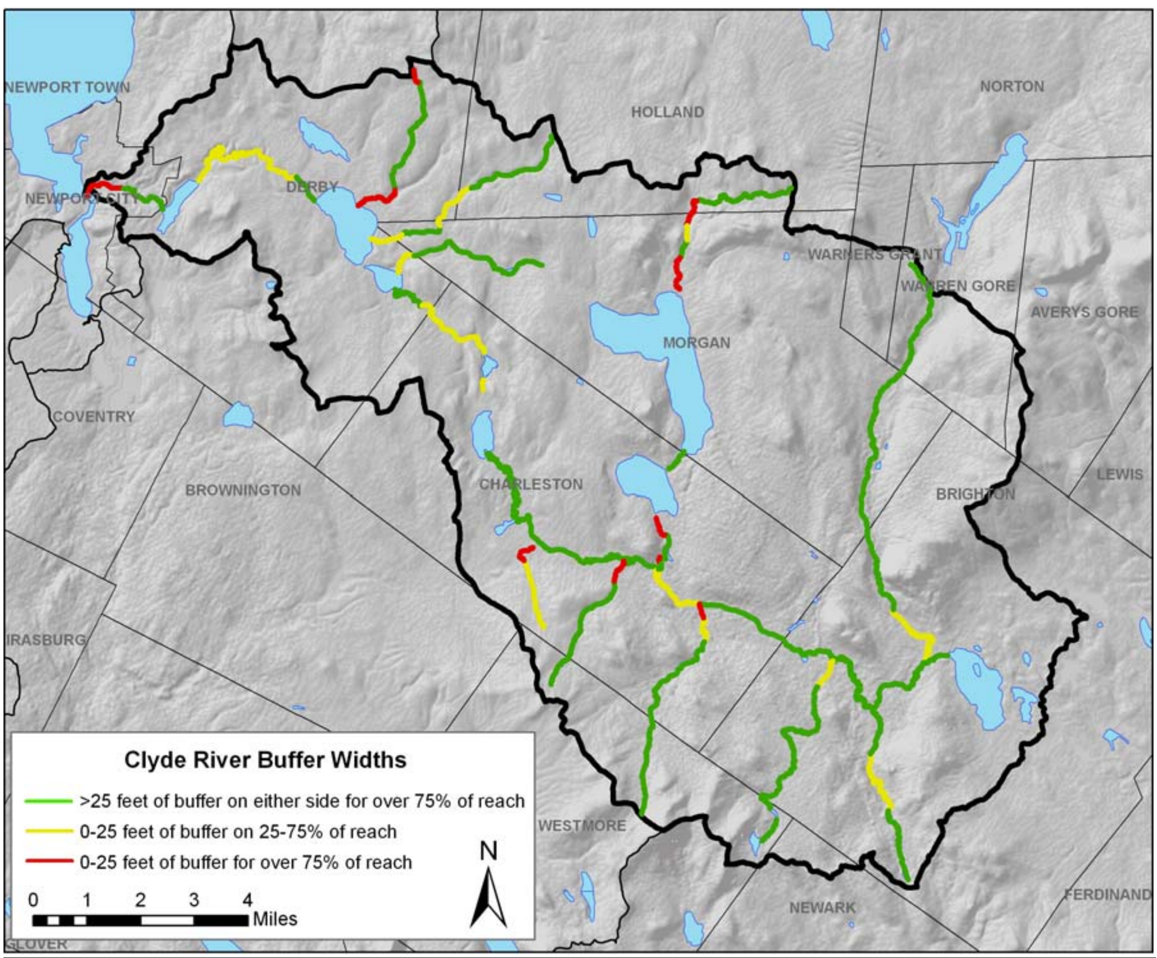


Figure 9. *Riparian buffer conditions for all assessed reaches in the Clyde River watershed.*

5.2 CURRENT GEOMORPHIC CONDITIONS AND STREAM SENSITIVITIES

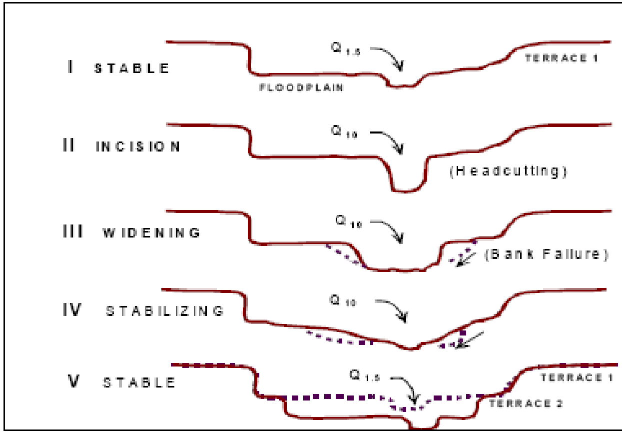
5.2.1 Geomorphic Condition Ratings and Channel Evolution Stage

Figure 11 depicts the stream geomorphic conditions found throughout the Clyde River Watershed, as found in the Phase 1 and Phase 2 Stream Geomorphic Assessments. Current channel evolution stages are also shown for Phase 2 reaches. Based on the intensity of channel and floodplain modifications, as well as the overall stream condition observed during the field assessments, reaches conditions were defined as reference, good, fair, and poor. Vermont ANR Stream Geomorphic Assessment Protocols describe these conditions below (State of Vermont 2007b):

> **"In Regime: A stream reach in *reference and good* condition that** is in dynamic equilibrium which may involve localized, *insignificant to minimal change* to its shape or location while maintaining the fluvial processes and functions of its watershed over time and within the range of natural variability.
>
> **In Adjustment: A stream reach in *fair* condition that** has experienced *major change* in channel form and fluvial processes outside the expected range of natural variability; and may be poised for additional adjustment with future flooding or changes in watershed inputs that could change the stream type.
>
> **Active Adjustment and Stream Type Departure: A stream reach in *poor* condition that** is experiencing extreme adjustment outside the expected range of natural variability for the reference stream type; likely exhibiting a new stream type; and is expected to continue to adjust, either evolving back to the historic reference stream type or to a new stream type consistent with watershed inputs and boundary conditions."

Since European settlement, watersheds and stream channels have undergone extensive modifications such as deforestation, development, channel straightening, and bank armoring. These actions function to increase peak flow levels, increase stream power, and decrease sediment storage. This has led to decreased floodplain function and increased erosion and flood damage. When stream channels or floodplains are modified, the stream adjusts to maintain equilibrium with its flows and sediment loads.

There are five stages in channel evolution depicted in Figure 10. Streams in stable condition that are not out of balance due to in-stream or upstream stressors are in Stage I. These streams are in good to reference condition and have the ability to regularly flood in order to disperse sediment and energy. Reaches in fair or poor condition are currently evolving to regain balance; these streams will be in various stages of channel evolution. Streams in Stage II have eroded their beds and may have lost the ability to access their floodplains. These reaches have increased power, increased ability to erode, and decreased ability to store sediment within the reach. Instead, much of the sediment may be sent downstream to affect downstream reaches or lakes. In Stages III and IV, the stream is widening and migrating as it re-establishes meanders and a new floodplain at a lower elevation. Erosion may be severe at these stages as the stream attempts to re-establish its equilibrium. Finally, Stage V represents a new equilibrium and a re-established floodplain at a lower elevation.



In regime, reference to good condition, insignificant to minimal adjustment.

Fair to poor condition, major to extreme channel degradation.

Fair to poor condition, major to extreme widening and aggradation.

Fair to good condition, major reducing to minor aggradation, widening, and planform adjustments

In regime, reference to good condition, insignificant to minimal adjustment.

Figure 10. *Channel evolution processes (State of Vermont 2007b); Stages I and V represent equilibrium conditions, and Stages II, III, and IV represent the channel degradation, widening, aggradation, and planform adjustments occurring as the stream adjusts to regain equilibrium.*

Most assessed reaches in the Clyde River watershed were stable and in good to reference condition (Figure 11). Although some reaches rated in good condition contained areas of erosion and unstable banks, they lacked the widespread instability resulting from extensive modifications to the channel and watershed. Four reaches were in fair condition, and one reach was in poor condition. These reaches were unstable, have lost floodplain function, and may be responsible for sending large amounts of sediment and nutrients downstream.

5.2.2 Stream Sensitivity Ratings

Streams react differently to human and natural disturbances depending on a variety of factors. Streams that are in a reference, or equilibrium, condition are more likely to withstand a disturbance than those which are undergoing major adjustments. Different types of streams are more sensitive to stressors than others, depending on their confinement, bed materials, slope, etc. For example, a steep, confined stream with a stream bed composed primarily of boulders will be very resistant to change. In contrast, an incised stream lying in a broad valley comprised of very erodible sand will be extremely sensitive to any floodplain or channel modifications. The assigned stream sensitivities listed in Figure 11 intend to capture both the inherent sensitivity of the stream and the effects of their current geomorphic condition on its sensitivity. For example, many reaches in the Clyde River valley are naturally highly sensitive to stressors. This is because these reaches travel through a valley dominated by erodible sands and fine gravels. When these reaches are undergoing adjustment (are rated in fair or poor geomorphic condition), their sensitivities to stressors become very high or extreme.

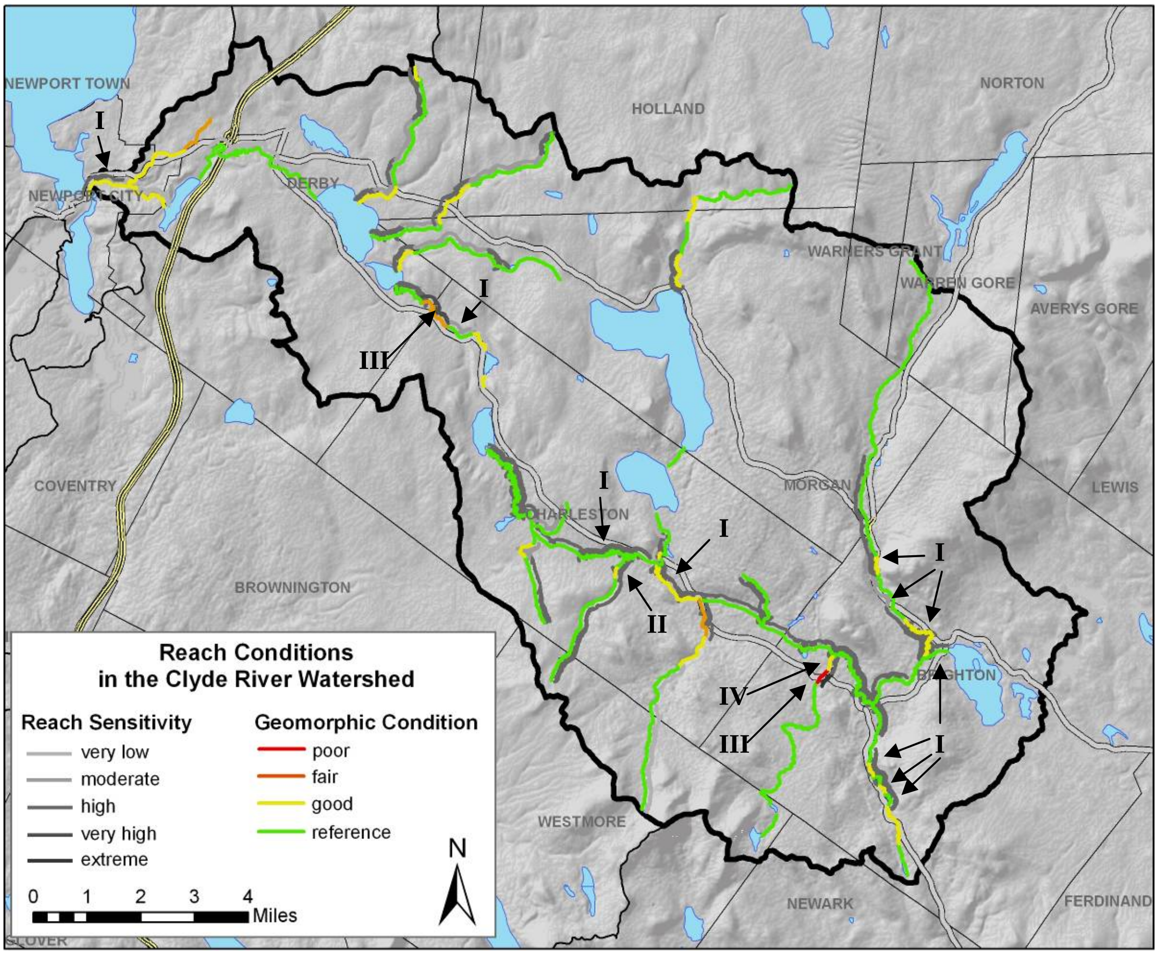


__Figure 11.__ Map of geomorphic conditions and reach sensitivities in the Clyde River watershed. Stages of channel evolution are in black.

5.3 RESULTS AND DISCUSSION OF PHASE 2 FIELD SURVEYS

The results of the Phase 2 field surveys are summarized in the following pages. In the accompanying figures, the field measurements and locations of other features are overlaid on 2003 aerial photographs (USDA 2003). For stream type descriptions, see Appendix B.

<u>Clyde River Reach M01</u> –Clyde St. Bridge to Lake Memphremagog (Newport)

Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

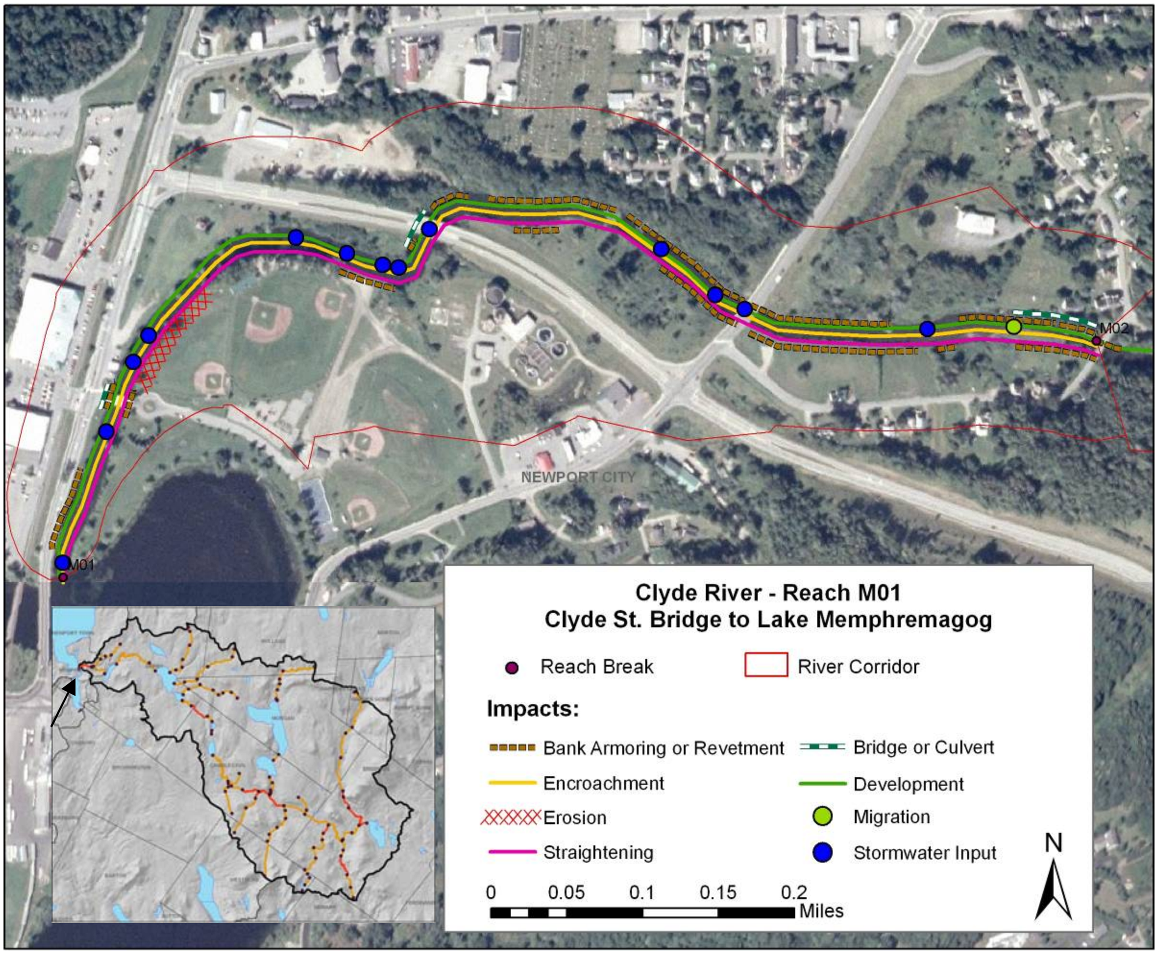


***Figure 12**. Phase 2 results for Clyde River Reach M01 in Newport.*

Reach M01 comprised 4,619 feet (0.87 miles) of the Clyde River, starting at the Clyde Street Bridge and ending at Lake Memphremagog (Figure 12). Formerly traveling through a wetland (according to 1928 USGS topographic maps), this highly-modified and slow-moving reach now travels along Gardner Park, a wastewater treatment plant, and a residential area. The entire reach was straightened; both existing and failing older rip-rap were observed along one or both banks for 46% percent of the reach. Floodplain access was limited in some areas due to road encroachments; however, flows are regulated by the Clyde Pond Dam, located approximately one mile upstream. Erosion was infrequent and minimal, probably due to the rip-rap and regulation of flows upstream.

As would be expected with a river located in such an urban area, this reach is subject to increased runoff due to numerous stormwater inputs and impervious surfaces in the highly developed river corridor. The dominant riparian buffer width was less than 25 feet along most of the reach. Grass was mowed up to the streambank along Gardner Park. Because the river and floodplain are so extensively altered there are no areas to deposit or filter incoming sediment and nutrients; instead they flow directly into the channel and into Lake Memphremagog. These inputs could be reduced by establishing natural, woody vegetation along the banks and in the numerous field drainages that empty into the river.

Clyde River Reach M08 Segment A – Downstream of West Charleston to approximately one mile upstream of Little Salem pond

Current Stream Type: C plane-bed, gravel
Reference Stream Type: C riffle-pool, gravel
Geomorphic Condition: Fair
Channel Evolution Stage: III (widening)
Habitat Condition: Fair
Stream Sensitivity: Very High

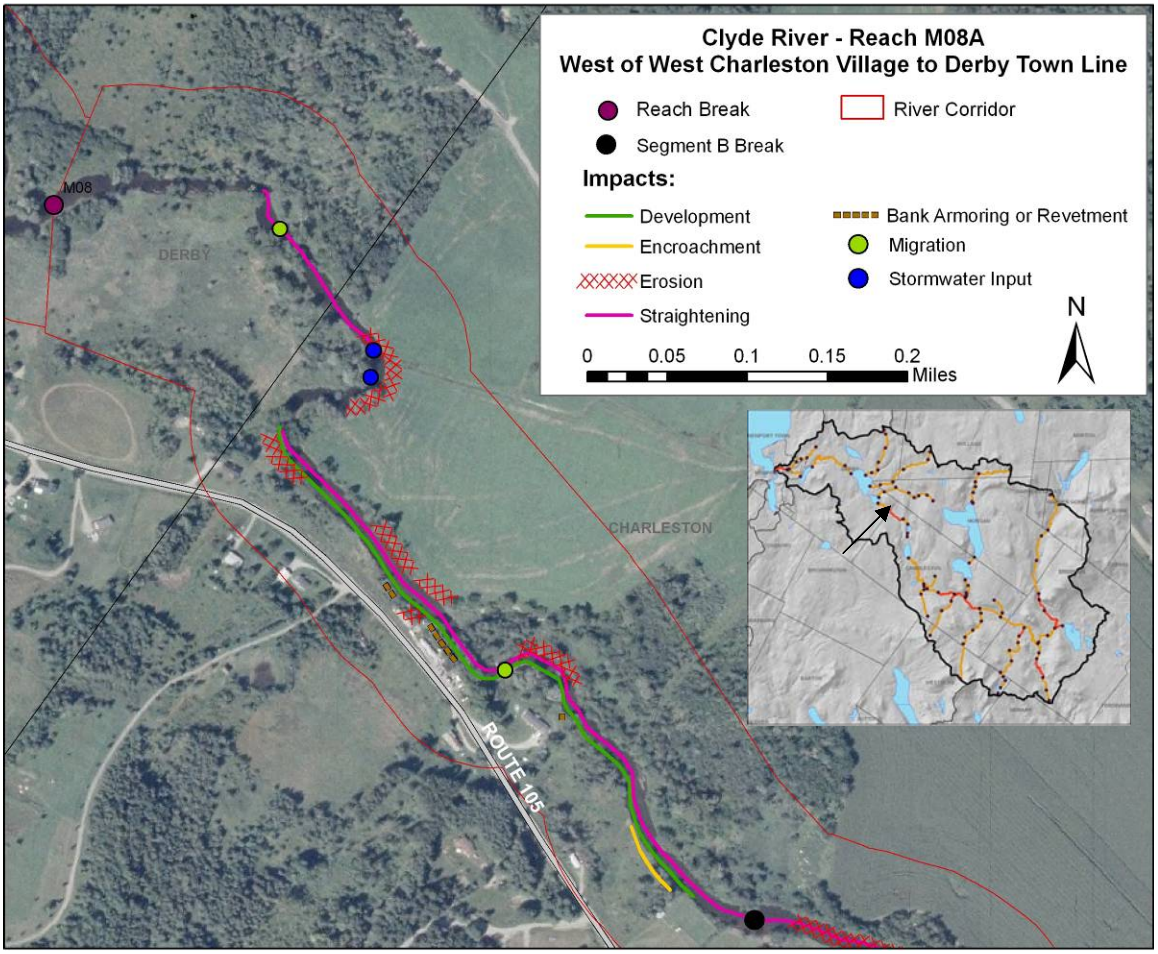


Figure 13. *Phase 2 results for Clyde River Reach M08A in West Charleston.*

Reach M08A comprised 4,283 feet (0.81 miles) of the Clyde River, beginning downstream of West Charleston village and paralleling Route 105. Though this segment lies in a very broad valley comprised of small gravels and sands, plane-bed features were observed. These stream bed features were atypical for this valley setting and suggests that the channel has undergone an evolution process. Unlike most of the Clyde, this reach was slow and shallow overall. Because of the reach's valley characteristics, slope, and bed materials, it was most likely a riffle-pool bedform in its reference condition. Historic straightening along 70% of this reach has resulted moderate channel incision and elimination of the diverse riffles, bars, and pools one would expect in this setting.

Segment A was rated to be in fair geomorphic condition due to anticipation of further channel evolution as the river slowly redevelops gravel bars and meanders. The river does run up to its extremely steep valley wall here at the rip-rapped section along Route 105 (Figure 13); however severe erosion of the valley wall was not observed. Aggradation was the dominant adjustment process observed; normal bed features such as riffles and pools were replaced by soft sands and fine gravels building up on the stream bed.

Currently about 1200 feet of the right bank lacks a riparian buffer; pastured land comes to within 25 feet of the stream. Restoration efforts along this reach should include establishment of an unmanaged corridor as a priority, as this reach is likely to migrate in future years as it re-establishes equilibrium.

Clyde River Reach M08 Segment B – Along farm, downstream of Fontaine Road Bridge

Reference Stream Type: C plane-bed, cobble
Geomorphic Condition: Reference
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: Moderate

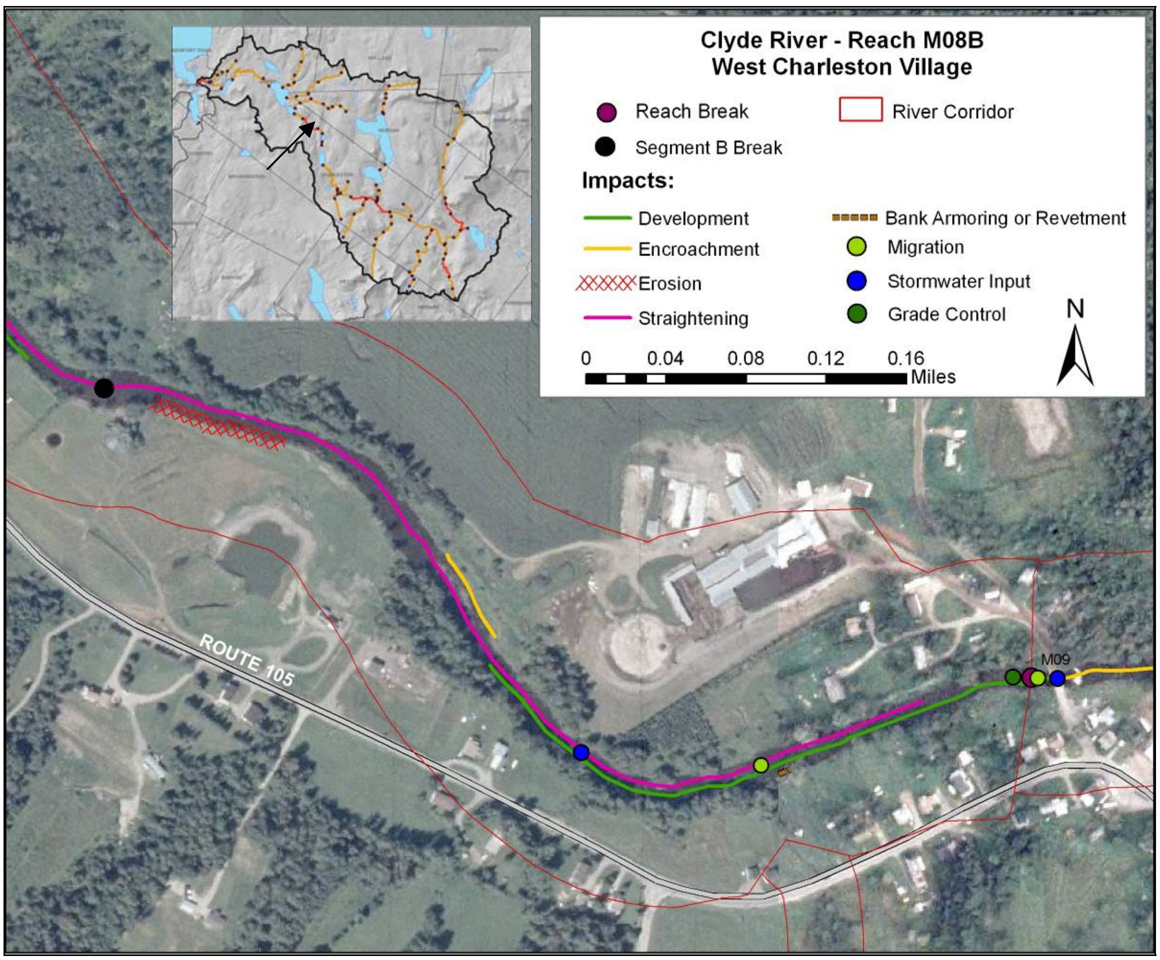


Figure 14. *Phase 2 results for Clyde River Reach M08B in West Charleston.*

Reach M08B comprised 2,800 feet (0.53 miles) of the Clyde River and served as a transition between the steep, high velocity cascades seen in reach M09 and the slow, flat water of reach M08A. This segment (Figure 14) began in a residential area and then ran along a dairy farm on the right side; lawns and sparse development were observed on the left side. The river ran against its valley wall at the beginning of the segment and again at its first bend, but the walls were comprised of boulders so significant erosion from these areas is unlikely. Habitat condition was good; many benthic macroinvertebrates were observed in the quick waters and cascades thanks to the prevalence unsedimented cobbles on the stream bed. Much of the vegetation on the left bank in the residential land was mowed up to the river's edge. Landowner education and the promotion of landscaping designed to protect water quality could benefit this reach as well as many other areas in the Memphremagog Watershed.

Clyde River Reach M15 – Twin Bridges Road to Center School Road (East Charleston)

Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Reference
Channel Evolution Stage: I (stable)
Habitat Condition: Reference
Stream Sensitivity: High

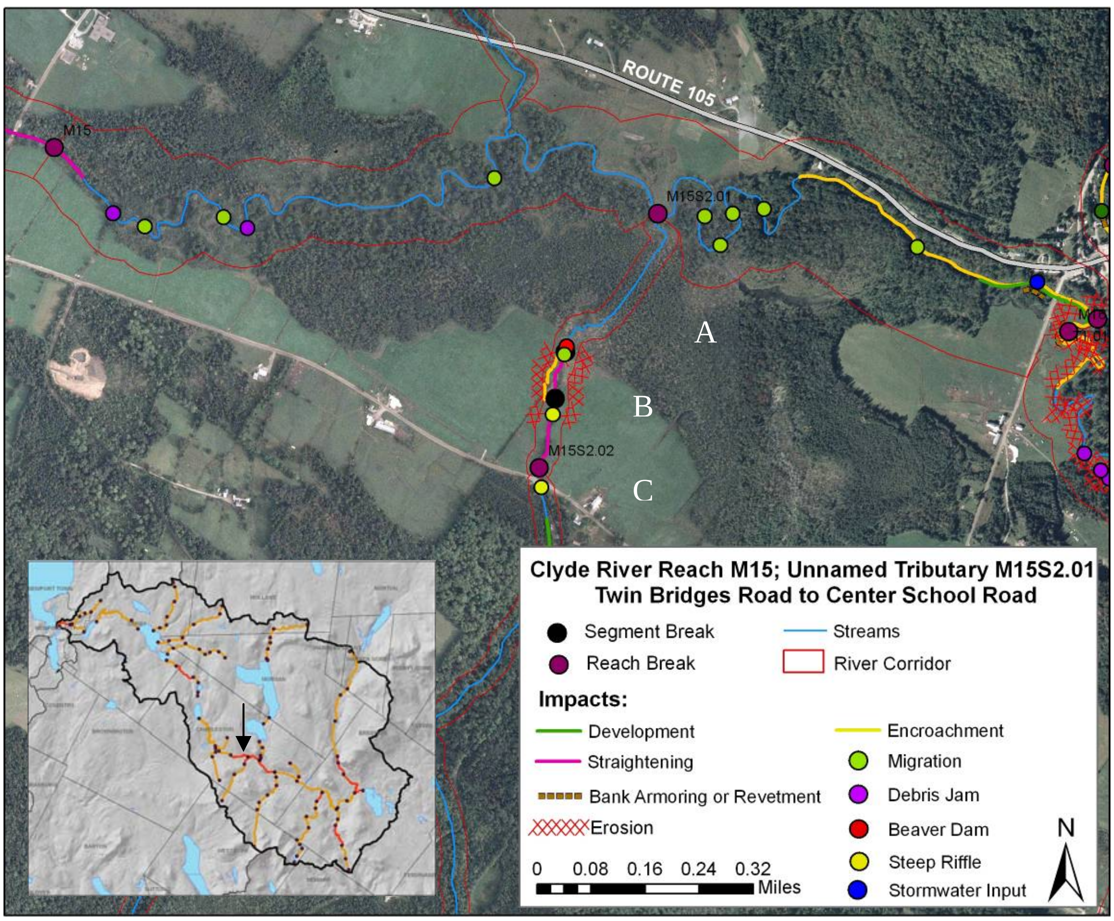


Figure 15. *Phase 2 results for Clyde River Reach M15 and an Unnamed Tributary Reach M15S2.01 in East Charleston.*

Reach M15 comprised 13,413 feet (2.54 miles) of the Clyde, beginning in a wooded pasture at East Charleston Village and ending near Center School Road (Figure 15). Reach M15 was a highly sinuous E stream type with bed and bank materials comprised entirely of sand and silt. This is a very beautiful section of the Clyde, meandering through silver maple *(Acer saccharinum)* forests and abundant wetlands in its very broad valley. Channel alterations were almost non-existent and Route 105 encroached upon only a small part of the broad and frequently accessed floodplain. Most of the river corridor is forested. Fallow field and agricultural land uses comprised only a minor portion of the land use. Abandoned channels and backwaters were frequently encountered. Most migration features were flood chutes; two neck cut-offs and one channel avulsion were in progress. This reach was in reference geomorphic condition due to the stability of the river. Aquatic habitat was in reference condition as well: A forested corridor, large amounts of woody debris and detritus, and highly variable stream depths make this reach excellent fish and wildlife habitat.

Reach M15 contains good examples of some of the unique and important natural communities common on the Clyde River. Here the river meanders through floodplain forests dominated by silver maple, black ash *(Fraxinus nigra)*, northern white cedar *(Thuja occidentilis)*, and yellow birch *(Betula alleghaniensis)*. Northern white cedar swamps also occur along various locations. The floodplain forests along Reach M15 are among the best examples in Vermont and contain several rare and uncommon plant species, including nodding trillium *(Trillium cernuum)*, yellow lady's-slipper *(Cypripedium calceolus)*, and meadow willow *(Salix petiolaris)* (Engstrom et al. 1998). In addition, these forests have a huge contribution to the quality of aquatic habitat in the area. Conservation and protection of these special areas should be a priority in this reach and other reaches, especially those upstream of Pensioner Pond.

<u>Unnamed Tributary – Reach M15S2.01 Segments A-C</u> – Hudson Road to Clyde River

Segment A – not assessed because it forms multiple channels through cedar forest.

Segment B
Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

Segment C
Reference Stream Type: E plane-bed, gravel
Geomorphic Condition: Good
Channel Evolution Stage: II (degrading)
Habitat Condition: Fair
Stream Sensitivity: High

Reach M15S2.01 was a small tributary to Reach M15 of the Clyde River (Figure 15), draining a forested and mountainous area before entering a hay field in the river valley. This small reach began at Hudson Road in East Charleston and traveled 2,493 feet (0.47 miles) before joining the Clyde River.

Segment C was chosen for Phase 2 assessment because the upper portion had recently been straightened; the streambed was dredged and those materials were piled along the banks (a process known as windrowing). This process increased the velocity and slope of this channel, causing degradation and moderate incision of the channel bed. A steep riffle was noted downstream of this area, marking the beginning of a portion of stream that must handle an increased sediment load. The hay field was mowed to the very edge of the stream. Buffers were almost non-existent; some of the streambanks had only bare soil and mowed grass on top of them.

Segment B rapidly changed to a sandy, dune-ripple stream type. Most of this segment was bermed; a portion of the berm was eroding near the end of the segment. Erosion was occurring on both stream banks, likely due to the increased flows and sediment originating upstream, but was not severe because the banks were still relatively vegetated.

Reach M15S2 is one of several streams which have been altered extensively as they crossed the Clyde River valley. Although these mountain streams are smaller, they still serve as important fish habitat and need the shading and stabilization that streamside vegetation provides. In these instances, landowner education and revegetation projects would restore and enhance water quality and aquatic habitat.

Clyde River Reach M16 – VT Route 105 Bridge to Twin Bridges Road (East Charleston)

Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

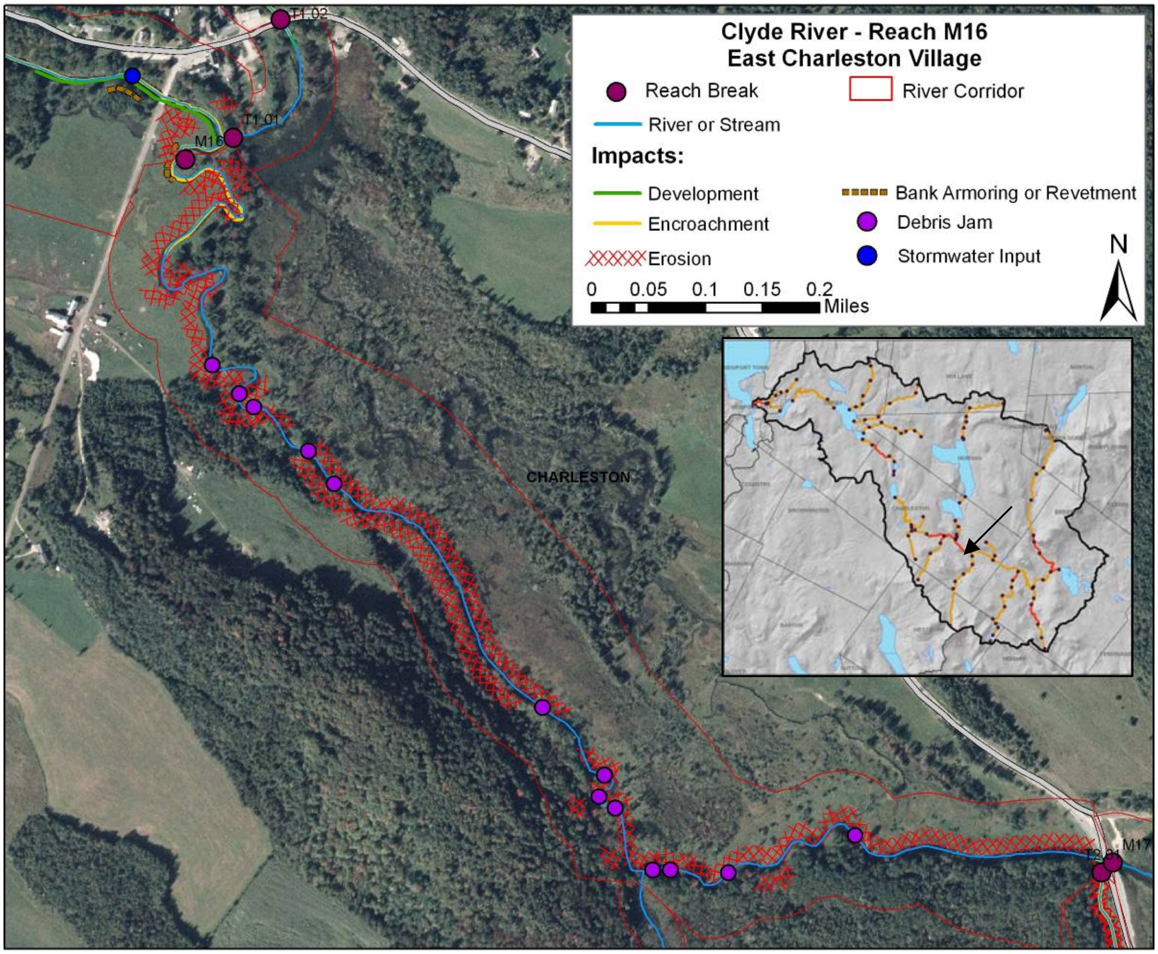


Figure 16. *Phase 2 results for Clyde River Reach M16 in East Charleston.*

Comprising 8,043 feet (1.52 miles) of the Clyde River, Reach M16 begins at a popular fishing spot at its confluence with Mad Brook and ends at its confluence with the Echo and Seymour Lake outlets upstream of Twin Bridges Road in East Charleston. This sandy and sinuous E-type stream traveled along silver maple forests, abundant wetlands, and accesses its broad floodplain several times per year. One notable aspect of this river was the amount of woody debris in the stream: At the time of this assessment, 240 downed logs and 13 debris jams were counted. While causing many localized areas of erosion, this debris also contributed to habitat quality in the reach by providing fish cover and the multitude of highly variable pools present.

Grazing evidence was observed throughout both sides of the riparian corridor, including the tops of the banks, but was much more concentrated in the lower portion of the reach. Because most of the reach was pastured, woody vegetation had not established itself along much of the stream banks. Bank erosion was observed throughout most of this reach but was minor in scale until the downstream third.

When obtaining landowner permission to access the river, the owner mentioned the rapid lateral movement of this river across his pasture near Twin Bridges Road. Cattle fencing, establishment of alternate water sources for cattle, restoration of streamside buffers and revegetation of the frequently flooded riparian corridor would be essential to any restoration project along this reach.

Clyde River Reach M20 – Island Pond to Pherrins River Confluence

Reference Stream Type: C dune-ripple, sand
Geomorphic Condition: Reference
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

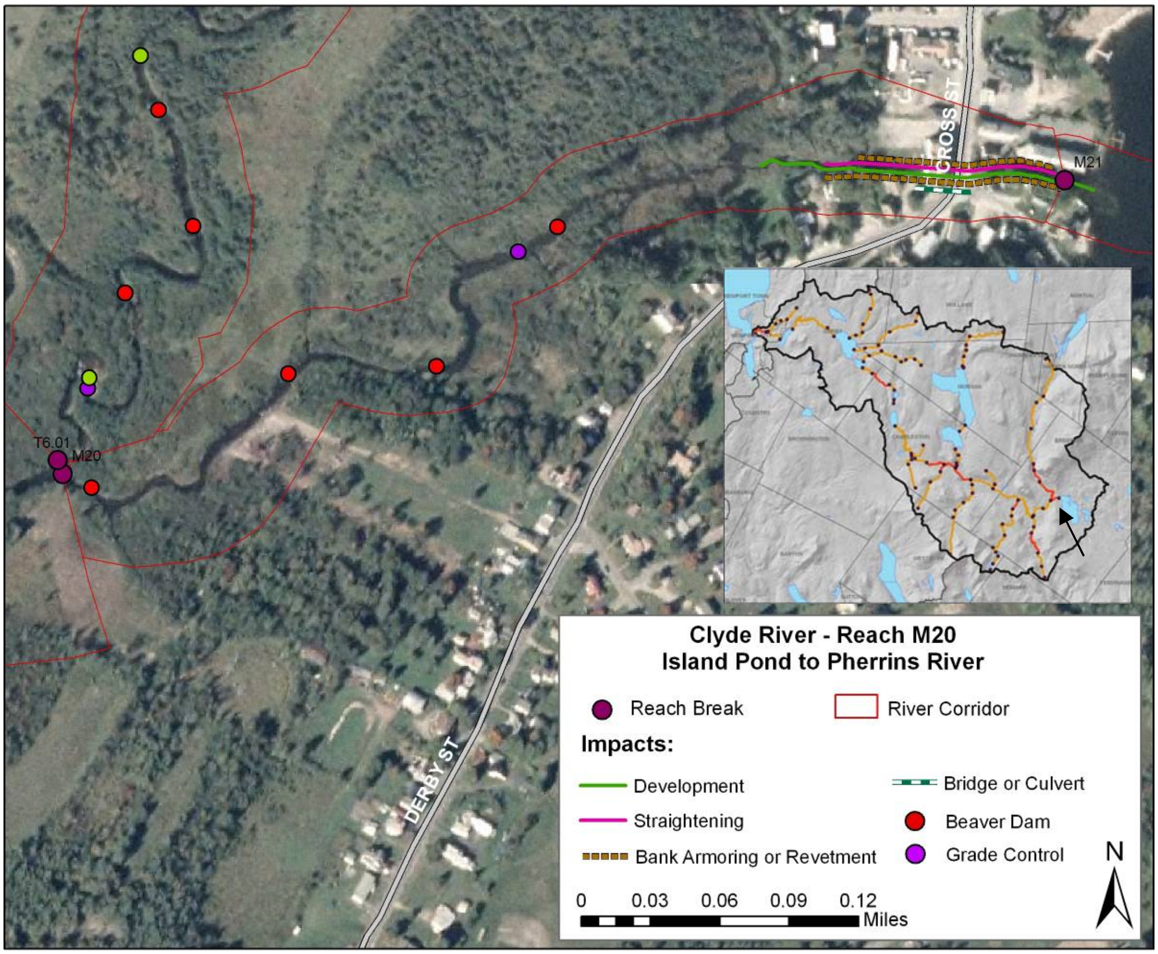


Figure 17. *Phase 2 results for Clyde River Reach M20 in Brighton.*

Reach M20 is the start of the Clyde River from its source at Island Pond to the Pherrins River confluence (Figure 17). This 2,767 foot (0.52 miles) reach was highly channelized at its origin but after traveling beneath the Clyde River Hotel it quickly became the slow, dune-ripple type stream typical of much of the upper Clyde River, dividing up into multiple channels and pools among cattails before becoming a single channel passing through alder swamps and over several beaver dams. A few changes in the corridor were noted since the initial Phase 1 assessment (Gerhardt and Dyer 2006): A field along the right corridor that was managed in the 1999 aerial photos had grown fallow, and a large lawn had been cleared to the bank on the left side. Beavers had impacted 800 feet of the reach and large amounts of detritus were prevalent throughout. Submerged aquatic vegetation was present throughout the reach, as were many fish.

Reach M20 was in reference geomorphic state due to the lack of observed channel adjustments and minimal alterations of its riparian corridor. Because fine sands and silts dominate the stream bed and banks, this reach is highly sensitive to any man-made or natural stressors.

Conservation of the riparian corridor should be a priority here. Currently the stream has ample buffer to filter out runoff from the adjacent development, but this pattern could change in the future without ample landowner education and outreach. This reach could also benefit from a volunteer clean-up effort; a lot of trash was found in the river in Island Pond and in the wetlands just downstream of the village.

Pherrins River Reach T6.01A and B – Confluence with Clyde River to its third crossing at VT Route 114

Segment A:
Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Segment B:
Reference Stream Type: C plane-bed, boulder
Geomorphic Condition: Reference
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: Very low

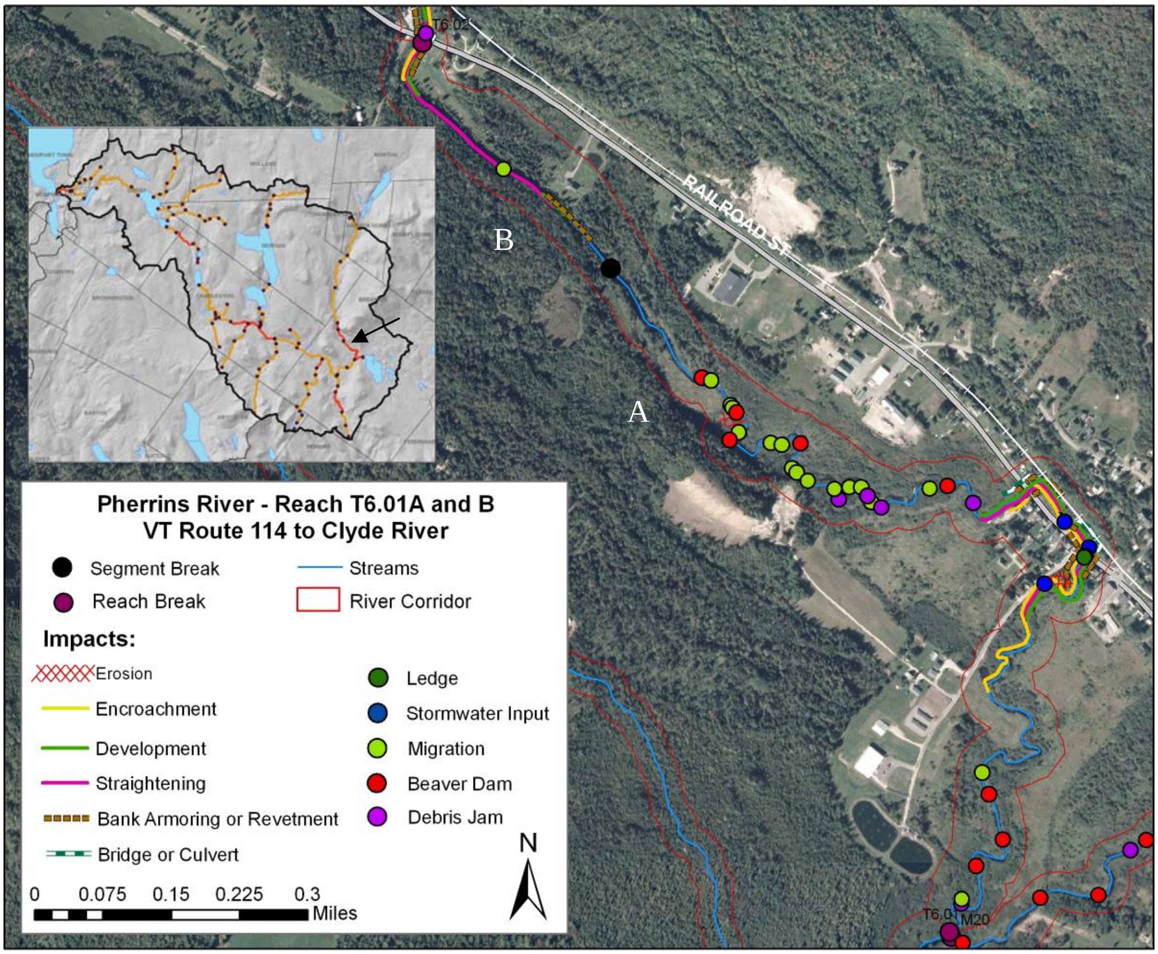


Figure 18. *Phase 2 results for Pherrins River Reach T6.01 in Brighton.*

Reach T6.01 was the first reach of the Pherrins River, beginning at VT Route 114 near an iron railroad bridge, meandering through the village of Island Pond, and ending at its confluence with the Clyde River (Figure 18). The reach was broken into two segments due to differences in stream types.

Segment A was 8,587 feet (1.63 miles) in length and was a meandering, E-type stream traveling through a very broad alder-dominated floodplain. The upper portion of the segment was very dynamic: 13 flood chutes and two avulsions were counted as it passed through and around beaver dams and debris jams. The middle portion of this stream passed through residential and commercial development where it was armored in places and straightened for 16% of the reach. Here the river was altered to make two very sharp turns before passing under two undersized bridges under Route 114. In this area, the river's floodplain was encroached upon on both sides: the highway on one side and a railroad on the other. The combinations of these factors cause flooding to occur several times each year in this area. From here, the river returned to its normal meandering state in what was a managed field in the 1999 aerial photos but has now grown fallow. Any restoration efforts in this area would need to address the undersized bridges on Route 114 that could fail in the event of a large flood. In addition, conservation of the river corridor should be emphasized since the river floods several times per year.

Segment B comprised 1,871 feet (0.35 miles) of the Pherrins River. Although traveling through a flat and very broad valley, the channel exhibited plane-bed features and a bed substrate dominated by boulders. Although some channel alterations were observed, this was assumed to be the reference stream type due to the increased valley slope, the lack of channel degradation, and the resistant bed materials encountered in this segment. Lawns were mowed to the riverbank for some of the left side, but coniferous forest dominated the buffer for over 100 feet on both sides along most of the reach.

Pherrins River Reach T6.02 – End of alder wetland to VT Route 114

Reference Stream Type: C plane-bed, cobble
Geomorphic Condition: Reference
Channel Evolution Stage: I (stable)
Habitat Condition: Reference
Stream Sensitivity: Moderate

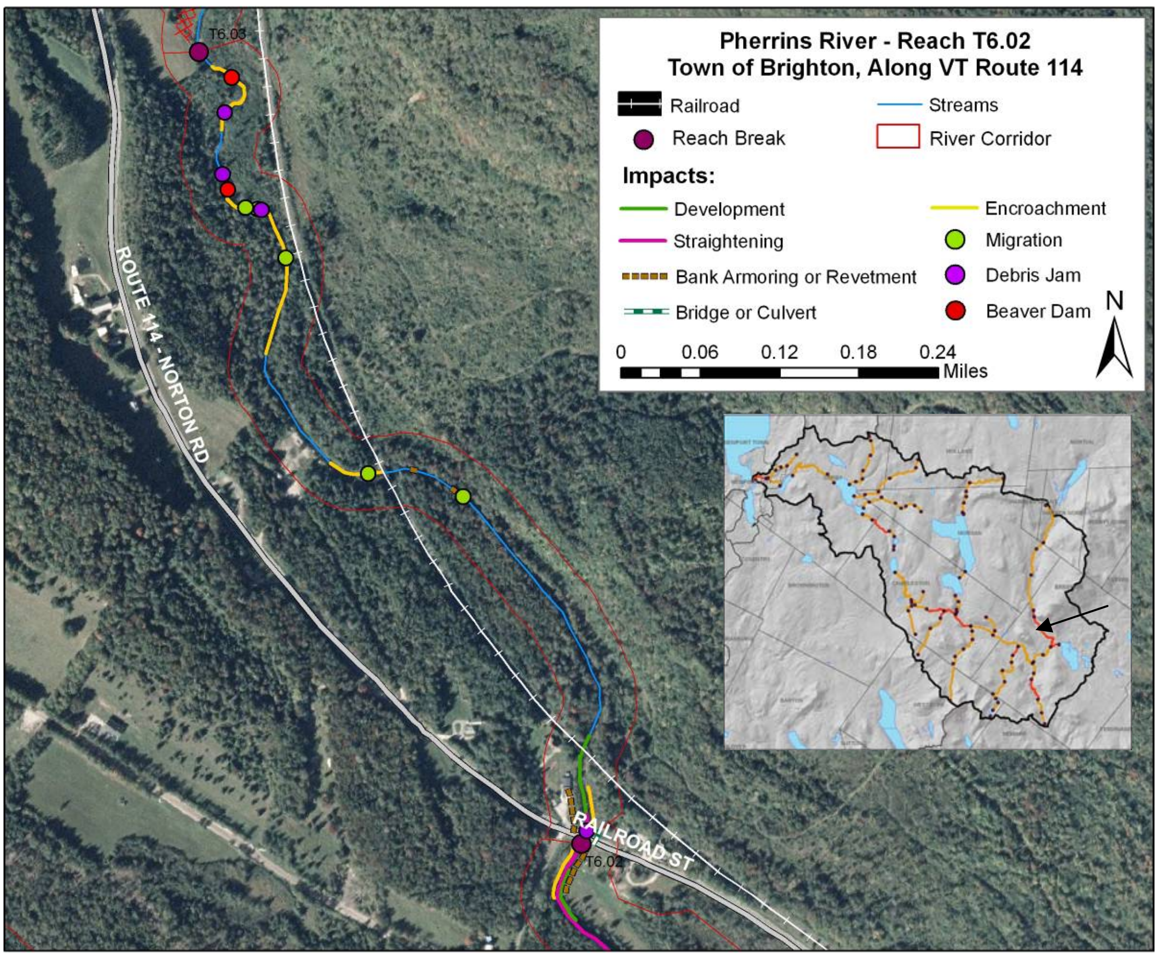


Figure 19. *Phase 2 results for Pherrins River Reach T6.02 in Brighton.*

Reach T6.02 comprises 4,205 feet (0.80 miles) of the Pherrins River. This beautiful and shaded reach began in an alder-dominated wetland, then traveled through cedar forest in a semi-confined valley (Figure 19). The upstream portion began in an area heavily impacted by beavers, with two beaver dams and several debris jams. Then it transitioned to a plane-bed stream where large, unembedded cobbles and boulders dominated the stream bed. Two floodplain encroachments were found on the upstream half of the reach: one large berm along the left bank against the railroad, and another smaller berm along the right bank. These never overlapped, so the river could access at least one side of the floodplain at high flows. Due to its stability, a completely forested corridor, and infrequent channel and floodplain modifications, this reach was in reference geomorphic condition. Excellent habitat characteristics were noted throughout this portion of the Pherrins River, which is a popular fishing area for Brook Trout.

Pherrins River Reach T6.03 – VT Route 114 to end of alder wetland

Reference Stream Type: E dune-ripple, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

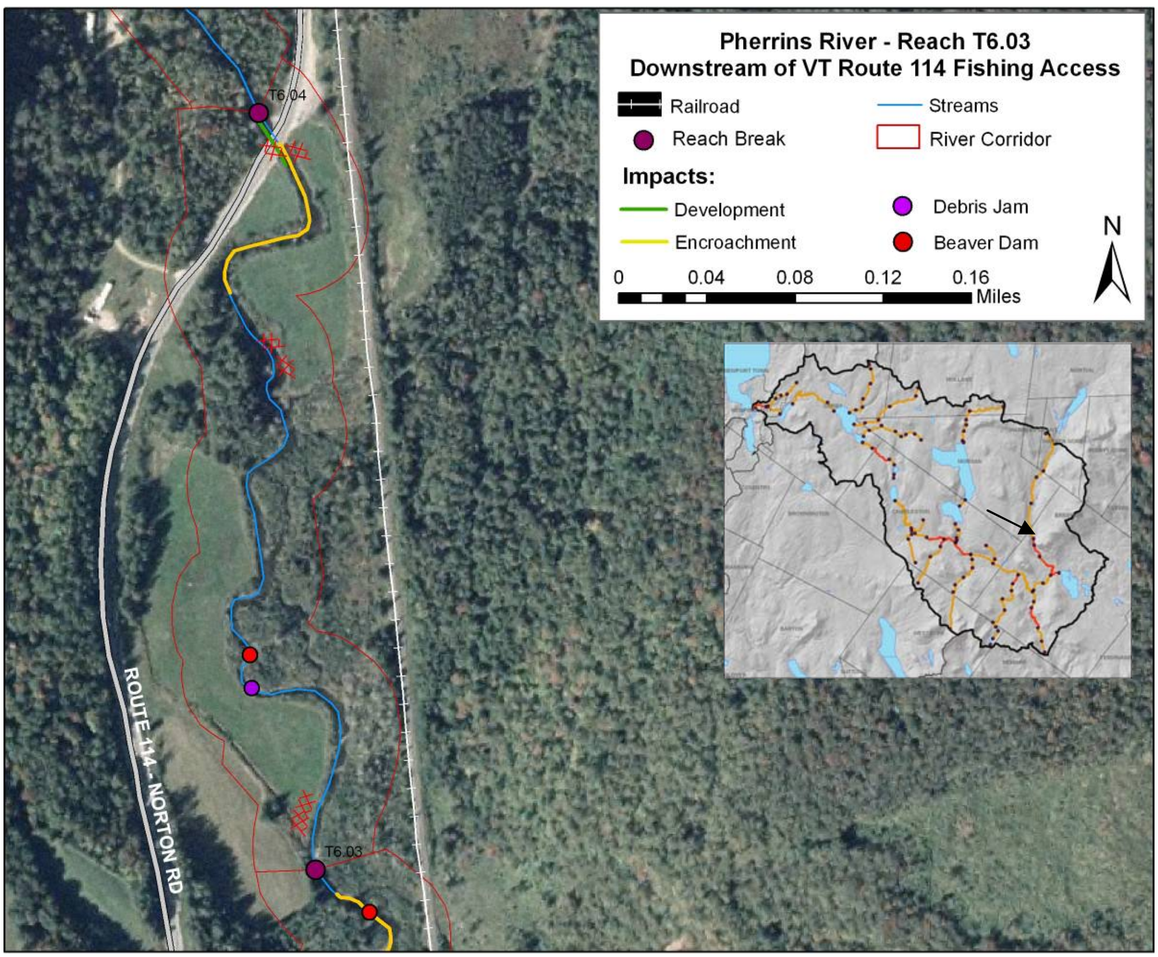


Figure 20. *Phase 2 results for Pherrins River Reach T6.03 in Brighton.*

Reach T6.03 traveled through 2,358 feet (0.45 miles) of the Pherrins River from a fishing access at Route 114 to the end of a horse pasture (Figure 20). The entire reach meandered through alder wetland with heavy beaver activity. Water levels were high and slow throughout most of this reach due to a beaver dam located about 1,500 feet downstream. Some erosion and a large scour pool existed around the Route 114 bridge which acted as a channel constriction, but erosion elsewhere in the reach was minimal. This reach, a popular trout fishing spot, receives fresh water inputs from many small tributaries and adjacent wetlands. Habitat conditions were in good, but not reference condition due to land use practices along the stream corridor.

At the time of the field assessment, about half of the riparian corridor was used as a horse pasture. However, the corridor is no longer managed for that purpose and has been set aside so that natural vegetation could be restored. In 2007, employees of NorthWoods Stewardship Center planted completed 800 trees and shrubs on 4.1 acres and installed 500 feet of fencing to protect and restore this frequently flooded area. Efforts such as this project protect water quality by allowing rivers to flood and deposit sediment over natural land cover types.

<u>Cold Brook Reach T4.01A, B</u> – Upstream of VT Route 105 to Clyde River confluence

Segment A:
Reference Stream Type: E dune-ripple, fine gravel
Geomorphic Condition: Good
Channel Evolution Stage: IV (stabilizing)
Habitat Condition: Fair
Stream Sensitivity: High

Segment B:
Current Stream Type: G riffle-pool, coarse gravel
Reference Stream Type: E riffle-pool, gravel
Geomorphic Condition: Poor
Channel Evolution Stage: III (widening)
Habitat Condition: Fair
Stream Sensitivity: Extreme

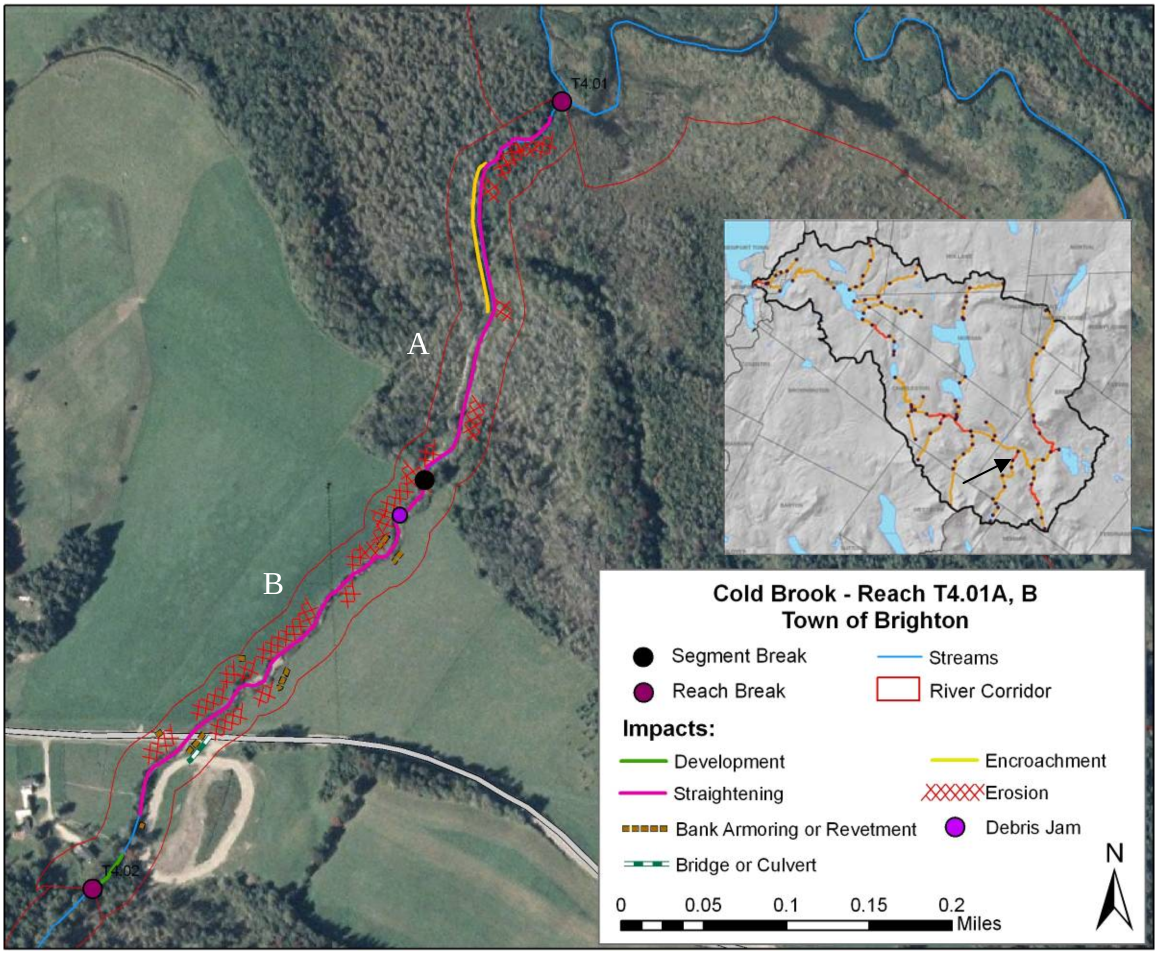


Figure 21. *Phase 2 results for Cold Brook Reach T4.01 in Brighton.*

Cold Brook Reach T4.01 lies in the flat and very broad Clyde River valley after cascading through a narrowly confined valley (Figure 21). It is 3,205 feet in length (0.61 miles).This reach was divided into two segments due to stark differences in land uses and differing existing stream types.

Reach A travels through a cedar forest during its 1,418 foot (0.27 miles) course. Although the adjacent land is not currently farmed or developed, 100% of this segment shows signs of historic straightening. A berm still exists along the left bank for approximately one third of its length. This segment is in better shape than segment B; however slight channel incision (incision ratio is 1.5), and extensive historic straightening limit the sediment storage capacity of this stream. Nine small sand bars were present along its length but a very large delta bar exists where this tributary meets the Clyde River, large enough to divert a formerly canoeable portion of the Clyde. Sediment measurements on the bed and bars are roughly equal, further confirming that this segment sends most of the sediment generated both upstream and in-reach into the Clyde River, rather than storing it within the reach. The channel incision appeared historic: bankfull depths were measured from newly established terraces observed inside the channel. The stream is currently migrating laterally across the floodplain to regain its natural sinuosity.

Reach B first travels along a fenced field, then through a cornfield during its 1,787 foot (0.34 miles) course. This segment lies in a very broad valley dominated by sands and fine gravels. In its reference condition, this stream was most likely a sinuous E stream type. Both current and historic channel straightening have resulted in a highly incised and entrenched G stream type that is unable to flood, disperse its energy and deposit sediment during high flows. Bankfull depths that were measured from newly established terraces inside the channel indicate an incision ratio of 3.3. Sediment measurements on the bed and bars are equal, again indicating that sediment is being transported downstream rather than being stored within the segment. Little to no buffer was the dominant condition on both sides of this channel. Bank failures were common; corn was falling into the stream in several places. Frequent areas of bank erosion indicate the stream was widening and attempting to regain sinuosity as it establishes a new floodplain. The bridge at VT Route 105 is undersized; an ice jam formed during winter 2007 that caused the brook to flood the highway, run through the unvegetated field, and rejoin the channel downstream.

Cold Brook drains a mountainous watershed, starting at Job’s Pond in Westmore and joining the Clyde River in Brighton. This tributary travels through wetlands through a portion of its course and receives water inputs from many tributaries. Most of the watershed is forested with the exception of Reach T4.01. Temperature and water chemistry samplings near reach T4.02 indicate this tributary would provide excellent fish habitat (Dyer and Gerhardt 2007). It is clear that this reach sends excessive sediment into the Clyde River. Boulders were piled along eroding banks in some places along the reach, but these attempts only focus the erosion to downstream portions as this tributary attempts to re-establish a floodplain at a lower elevation. Any restoration project on this reach would likely require land to be set aside on both sides of the stream to allow it to naturally regain its stability. This reach is also a good candidate for a riparian buffer planting.

Oswegatchie Brook Reach T5.03 Segments A-C
Segment A: From intersection of Newark Road and VT Route 114 to hay field
Geomorphology not evaluated due to extensive beaver activity

Segment B: From beginning to end of hay field along VT Route 114
Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Segment C: Braided portion that veers away from VT Route 114
Geomorphic condition not evaluated due to extensive beaver activity

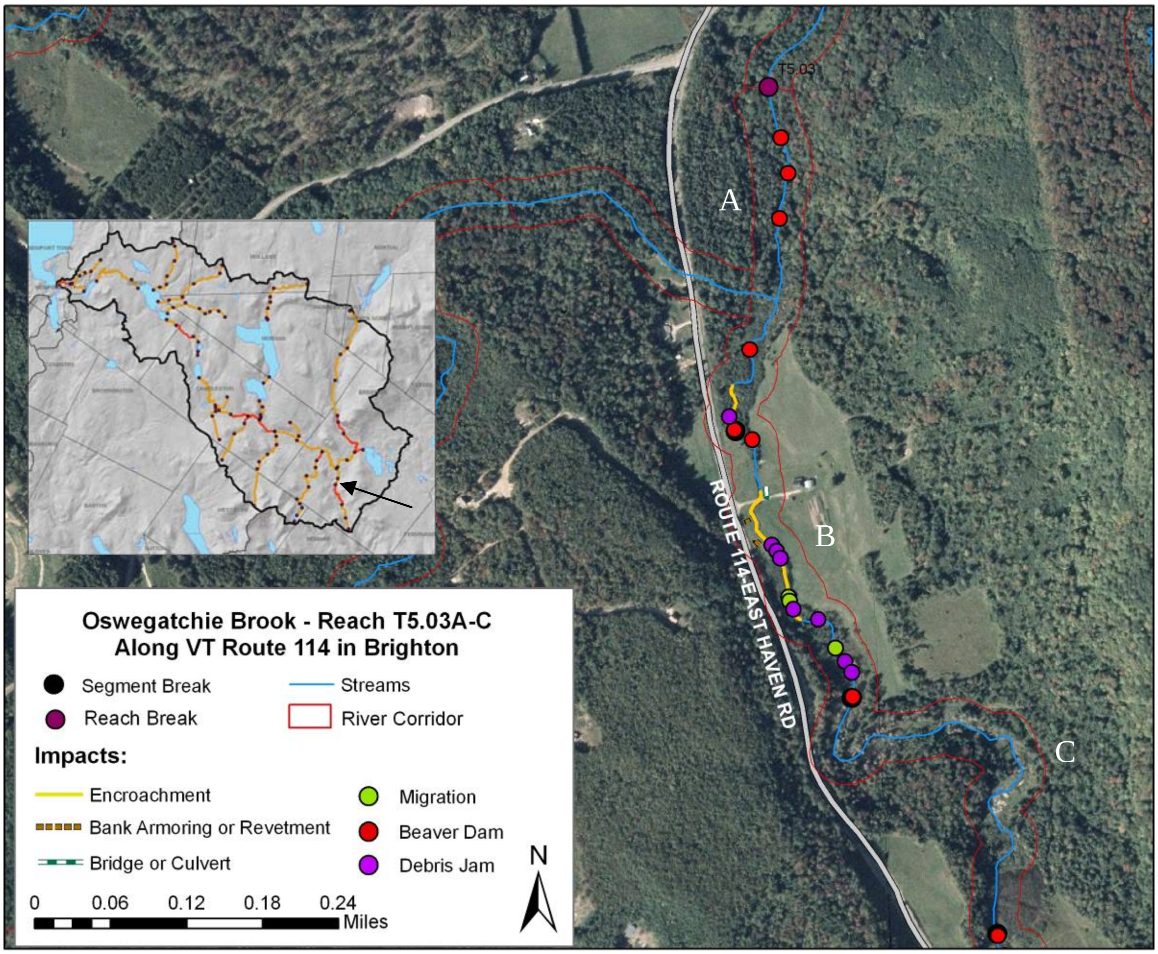


Figure 22. *Phase 2 results for Oswegatchie Brook Reach T5.03, Segments A-C in Brighton.*

Oswegatchie Brook (T5) is a cold-water tributary in the Upper Clyde Watershed that begins at Sukes Pond and travels along VT Route 114 until it meets the Clyde River near the junction of VT Routes 114 and 105. Lying entirely within the Town of Brighton, this tributary is currently managed as a brook trout fishery. Most of the watershed is forested but the valley along Route 114 is mixture of managed fields, fields reverting to forest, and forest. Reach T5-03 was chosen because Phase 1 assessment revealed land use as more intensive in this section than along the remainder of the tributary. Phase 2 assessments revealed this to be a dynamic tributary, alternating between heavy beaver activity and a ripple-dune system meandering through alder-dominated wetlands and mixed coniferous and deciduous forests. For this reason, T5-03 was divided into six segments (Figures 22 and 23). Segments A, C, and F were not evaluated because beavers had altered the stream so extensively.

Reach T5-03A was a completely shaded section of 1,604 feet (0.30 miles), surrounded by coniferous forest and consisted of a series of beaver ponds, waterfalls, and wetlands. Land use in this area had changed recently; about 900 feet of forest had been cleared into the riparian corridor. Still, over 100 feet of buffer remained the dominant condition in this segment. Because of the extensive beaver activity within the reach, most Phase 2 steps were not applicable towards this reach.

Segment T5-03B traveled through a hayfield throughout its 1,394 foot (0.26 miles) length. This segment appeared historically straightened, as it lies within an unconfined and sandy valley, exhibits low sinuosity, and has occasional areas of failed bank armoring. The banks were consistently lined with alders, but the dominant width of riparian buffer remained less than 25 feet. Organic debris was prevalent throughout the segment, including seven debris jams which provided a diversity of pools and fish cover. Overall, this segment was in good geomorphic condition; evidence of channel adjustments were found but these were mostly a result of the debris and beaver activity.

Segment T5-03C traveled through a wooded area for 2,092 feet (0.40 miles); however, geomorphic conditions could not be assessed because the segment was highly impacted by beaver activity.

Oswegatchie Brook Reach T5.03 Segments D-F –
Segment D: From end of alder swamp to confluence with McKinney Brook
Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Segment E: McKinney Brook to braided portion in forest
Reference Stream Type: E riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Segment F: Braided portion that veers toward VT Route 114
Geomorphology not evaluated due to extensive beaver activity

Figure 23. *Undersized and perched culvert on Oswegatchie Brook Reach T5.03, Segment E*

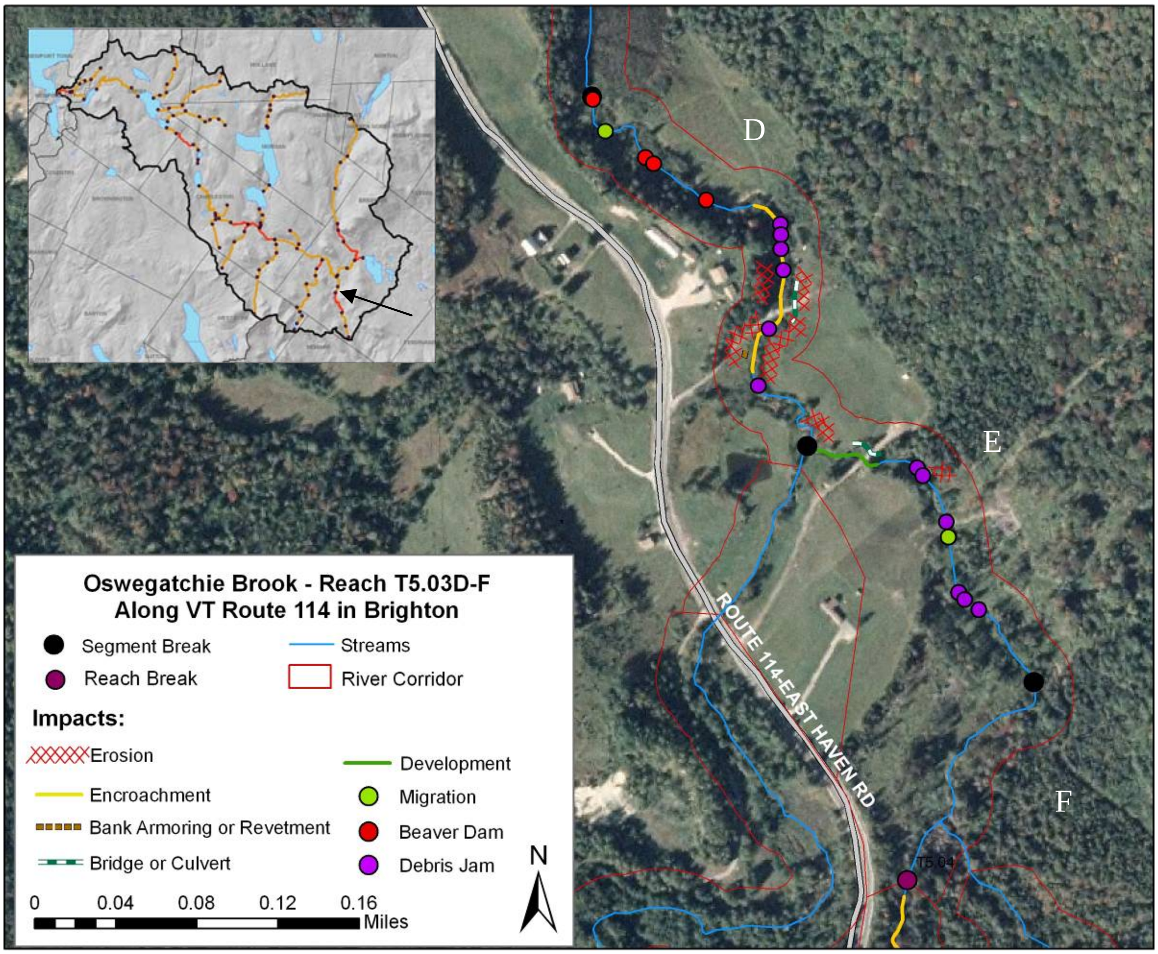


Figure 24. *Phase 2 results for Oswegatchie Brook Reach T5.03, Segments D-F in Brighton.*

Segment D traveled through a broad valley and flowed through several beaver dams and many debris jams as it meandered through the alder wetlands. Its length was 1,427 feet (0.27 miles). Its valley wall lies very close to the channel for much of the left corridor; the right corridor was dominated by hay field and bare ground (due to a dirt road, which is eroding into the stream). An undersized culvert was found mid-segment and was the cause of bank erosion in its vicinity, including a scour pool downstream of and sediment deposition upstream of the culvert. This segment was very similar to segment B. The dominant buffer condition was less than 25 feet wide, but the banks were consistently lined with alders that stabilized the banks and filled the stream with organic debris.

Segment E exhibited riffle-pool features as it traveled 1,668 feet (0.32 miles) through a broad and mostly forested valley. Like much of Oswegatchie Brook, this portion was filled with debris jams, which provide excellent habitat for aquatic species. However, a very undersized and misaligned culvert caused sediment deposition upstream and a large scour pool downstream (Figure 23). The culvert was perched about one foot above the water level and could be responsible for impeding fish movement throughout the reach at certain flow levels. With the exception of this issue, the segment was in reference geomorphic condition.

5.4 RECOMMENDATIONS AND NEXT STEPS

The Clyde River is a valued and treasured resource, and currently has the best water quality of the four main Vermont tributaries to Lake Memphremagog. Most of the river and its tributaries are in good or reference geomorphic condition, only 1.6 stream-miles were in fair or poor condition. Any future development and land management in the watershed should be planned carefully to maintain and improve the current values and aesthetics that landowners and visitors in the watershed enjoy today.

Gauging landowner interest in restoration programs would be the first step in restoring degraded stream reaches. There are several programs that will help landowners cover costs of setting aside buffers along streams, such as the Conservation Reserve Enhancement Program (CREP), the Environmental Quality Incentives Program (EQIP), and the Wildlife Habitat Incentives Program (WHIP). These programs can help cover costs of planting buffers, restoring stream corridors, building fences, and providing alternate water sources for livestock. Perhaps the best method for protecting the health of streams and rivers in the Clyde River Watershed is widespread outreach and education that includes the benefits of maintaining riparian buffers.

Another valuable tool in protecting water resources are town plans which emphasize the protection of water resources for the long-term. The Clyde River mainly travels through the towns of Brighton, Charleston and Derby before emptying into Lake Memphremagog. Brighton has a town plan which encourages buffer areas and controls development near wetlands, streams, and ponds. The town of Derby will vote on a new town plan in late spring of 2008 to replace the former one, which expired in spring of 2007. If approved, this plan will allow for the creation of a conservation commission, mapping of important wetland and riparian areas, and updated zoning regulations aimed at maintaining buffer areas and preserving the health and integrity of lakeshores, riparian areas, and wetlands. Currently, the town of Charleston does not have a town plan or zoning bylaws. This should be a priority, as many of the most pristine portions of the Clyde and its tributaries lie in this town.

5.5 EDUCATION AND OUTREACH

The success of this and other projects depend a great deal on education and outreach with the goal of informing and involving as many stakeholders as possible. We incorporated this assessment and into several outreach programs oriented at informing the local community. These included a public outreach meeting and participation at Memphremagog Watershed Association and Memphremagog Watershed Council meetings, lectures at Sterling College, a newspaper article, and a field day with a teen research camp. The public outreach meeting included an overview of the River Management Program by Shayne Jaquith of Vermont DEC and a presentation of results of the Clyde River Stream Geomorphic Assessment by Melissa Dyer of the NorthWoods Stewardship Center to the Memphremagog Watershed Council. The audience included members of the Memphremagog Watershed Association; representatives from state, city, and non-profit agencies; members of the public; and the press. We also actively participated in watershed meetings in an effort to contribute our findings to the public knowledge. We held two lectures at Sterling College’s Watershed Science class to teach basics of the stream geomorphic assessment using examples and lessons from the Clyde River. We wrote an article for the *Caledonian-Record* newspaper, based out of St. Johnsbury, to educate and inform the public of the importance of protecting our streams and floodplains. Finally, we involved participants of NorthWoods' teen research camp to collect stream measurements on the Clyde and Pherrins Rivers and taught how the health of these rivers affects water quality. We will continue to develop collaborations with as many stakeholders as possible to protect and restore water quality and aquatic habitat in the Lake Memphremagog Basin.

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Glossary

Aggradation – Accumulation of sediment on the channel bed.

Alluvial – Refers to sediment materials deposited by a river or stream.

Avulsion – A change in a stream's course caused by the stream breaking through the banks and forming a new channel.

Basin – see Watershed

Degradation –Process of scouring of the channel bed due to changes in flow rates or sediment loads.

Entrenched – Having little space to flood. A stream's entrenchment is represented by its entrenchment ratio (the width of the floodprone area divided by the width of the channel).

Erosion – The loosening and transport of soil and other particles. Erosion is a natural process but can be accelerated by human activities, such as vegetation removal and stream channel alteration.

Flood chute – An area outside the main channel that a stream accesses during high flows. These areas may become the future location of the channel as the stream migrates.

Floodplain – The area adjacent to a stream that becomes inundated with water during high flows. This land is built of sediment originating from flooding of the stream. Floodplains have important roles in reducing sediment transport and stream power during floods.

Incision – The process by which a river erodes its channel bed to a lower level than existed previously.

Incision ratio – The lower floodplain height divided by the depth of the channel at bankfull. A stable stream in reference condition would have an incision ratio of 1, meaning that degradation of the channel bed has not occurred. A stream which has undergone degradation of the channel bed would have an incision ratio greater than 1. The higher the ratio, the less likely a stream can access its floodplain.

Neck Cutoff – The narrow strip of land that exists between two meanders migrating closer to one another; eventually, the channel may break through this strip of land and the old channel will form an oxbow.

Nonpoint source pollution – Pollution that does not originate from a single location or source (for example, a drainage pipe) but rather from many sources spread out across the landscape (for example, runoff from agricultural fields).

Planform – The shape and pattern that a stream forms on a landscape.

Riffle – A section of stream characterized by fast, shallow water flowing over coarser bed materials, such as cobbles and boulders

Riparian buffer – A strip of natural vegetation growing along a waterbody which serves to reduce erosion, filter sediment and pollutants, and enhance aquatic biodiversity.

Sensitivity – A measure of how likely a reach would react to human or natural stressors to the watershed or the reach itself. This takes into account the current geomorphic condition of the reach and the composition and erodibility of its bed and bank materials.

Sinuosity – A measure of how meandering a stream is. Sinuosity is displayed as a ratio of the length of the river divided by the length of its valley.

Stream corridor – The area of land adjacent to a stream that influences and is influenced by that stream. During the Phase 1 and Phase 2 assessments, this corridor is at least 100 feet on either side of the stream.

Tributary – A body of water, such as a stream, that flows into another body of water.

Watershed (or basin) – A region drained by all of the rivers and streams flowing into a lake, river, or ocean. The relative size of a watershed and the human alterations to that watershed greatly affect the quality of the water in the waterbody into which it drains.

Appendix A. Phase 1 Project Metadata.

Parameter	**Source**
Alluvial fan	1:24K topos
Bank armoring and revetments	Not Evaluated
Bank erosion - relative magnitude	Field observation
Dominant bed form and material	Field observation
Belt width	1:5K NHD, 1:5K orthos
Berms and roads	1:24K topos, 1:5K orthos
Bridges and culverts	1:24K topos, 1:5K NHD & orthos
Channel length	SGAT automated
Channel straightening	1:24K topos, 1:5K NHD & orthos
Confinement type	1:24K topos
Corridor land use - land cover data	Land use - land cover (1990s statewide)
Corridor soil data	NRCS soil survey maps – (updated 2005)
Debris and ice jam potential	Field obs. at access point along reach
Depositional features	1:5K orthos
Dredging and gravel mining history	Interviews - DEC, NRCS
Downstream and upstream elevations	1:24K topos
Flow regulations and water withdrawals	1:24K topos, 1:5K NHD & orthos
Grade controls	1:24K topos, field observation
Latitude and Longitude	SGAT automated
Meander centerline	1:24K topos, 1:5K NHD
Meander migration and channel avulsion	1:5K orthos (1990s & 1970s), other aerial photographs
Historic corridor land use - land cover	Not Evaluated
Historic watershed land use - land cover	Not Evaluated
Reach breaks	1:24K topos, 1:5K NHD
Riparian buffer width	1:5K orthos
River corridor development	1:24K topos, 1:5K orthos
Stream type	1:24K topos
Towns that reaches are in	1:24K topos
Valley length	SGAT automated
Valley side slopes	1:24K topos, soils slope data
Valley walls	1:24K topos
Valley width	SGAT automated
Groundwater and small tributary inputs	1:24K topos, 1:5K NHD, NWI maps
Wavelength	1:5K NHD, 1:5K orthos
Watershed delineations	1:24K topos, 1:5K NHD
Watershed land use - land cover data	Land use - land cover (1990s statewide)

Appendix B: Summary of Rosgen Stream Classifications and Descriptions of Channel Bed Forms

Rosgen Stream Classifications (Rosgen 1994)

Stream Type	Sinuosity	Slope (%)	Features
A	Low	>10	Steep, entrenched, high energy/debris transport stream. Contain vertical steps, deep scour pools, waterfalls
B	Low to moderate	4-10	Moderately entrenched, dominated by riffles, pools infrequent. Stable bed and banks
C	High	<2	Low gradient, meandering, alluvial channels with broad and well defined floodplains. Exhibit point bars and riffle-pool characteristics
D	Variable	<4	Braided, very wide channels with eroding banks, in broad valleys with abundant sediment supply
E	Very high	<2	Low gradient, highly sinuous channel with very broad and alluvial floodplain
F	High	<2	Entrenched stream in highly weathered, low gradient material. Laterally unstable, high bank erosion. Riffle-pool characteristics
G	Low to moderate	2-4	Entrenched stream in narrow valley or deeply incised in alluvial or colluvial materials. Unstable, high bank erosion rates

Descriptions of Channel Bed Forms (State of Vermont 2007b)

Bed Forms	Description
Cascade	Generally occur in very steep channels, narrowly confined by valley walls. Characterized by longitudinally and laterally disorganized bed materials, typically bedrock, boulders, and cobbles. Small, partial channel-spanning pools spaced < 1 channel width apart common.
Step-Pool	Often associated with steep channels, low width/depth ratios and confining valleys. Characterized by longitudinal steps formed by large particles (boulder/cobbles) organized into discrete channel-spanning accumulations that separate pools, which contain smaller sized materials.
Plane Bed	Occur in moderate to high gradient and relatively straight channels, have low width/depth ratios, and may be either unconfined or confined by valley walls. Composed of sand to small boulder-sized particles, but dominated by gravel and cobble substrates. Channel lacks discrete bed features (such as pools, riffles, and point bars) and may have long stretches of featureless bed.
Riffle-Pool	Occur in moderate to low gradient and moderately sinuous channels, generally in unconfined valleys, and has well-established floodplain. Channel has undulating bed that defines a sequence of bars, pools, and riffles. Pools spaced every 5 to 7 channel widths in a self-formed (alluvial) riffle-pool channel.
Dune-Ripple	Usually associated with low gradient and highly sinuous channels. Dominated by sand-sized substrates. Channel may exhibit point bars or other bedforms forced by channel geometry. Typically undulating bed does not establish distinct pools and riffles.
Bedrock	Lack a continuous alluvial bed. Some alluvial material may be temporarily stored in scour holes, or behind obstructions. Often confined by valley walls.
Braided	Multiple channel system found on steep depositional fans and deltas. Channel gradient is generally the same as the valley slope. Ongoing deposition leads to high bank erosion rates. Bed features result from the convergence/divergence process of local bed scour and sediment deposition. Unvegetated islands may shift position frequently during runoff events. High bankfull widths and very low meander (belt) widths.

Appendix C: Phase 1 Valley and Channel Characteristics for Clyde River and its Tributaries, Impact and Sensitivity Scores

Clyde River - M

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
M01	85	0	1.05	Narrow	E	Dune-Ripple	19	Fair	High
M02	116.6	3.22	1	Narrowly Confined	A	Step-Pool	11	Good	Very Low
M04	115.2	0.34	1.09	Narrow	C	Riffle-Pool	7	Good	Very Low
M05	113.8	0.66	1	Semi-Confined	B	Plane Bed	3	Reference	Not Evaluated
M07	104.2	0.4	1.5	Very Broad	C	Dune-Ripple	7	Reference	High
M08	83(A), 91(B)	0.28	1.23	Very Broad	C	Riffle-Pool	17	Fair	Very High
M09	102.9	2.43	1	Narrowly Confined	B	Riffle-Pool	13	Good	Very Low
M11	102	7.17	1	Narrowly Confined	A	Cascade	10	Good	Not Evaluated
M13	101.3	0.05	1.91	Very Broad	E	Dune-Ripple	9	Reference	High
M14	97.5	0	1	Narrow	C	Dune-Ripple	9	Reference	High
M15	40	0	1.54	Very Broad	E	Dune-Ripple	9	Reference	High
M16	37	0	1.33	Very Broad	E	Dune-Ripple	10	Good	High
M17	77.2	0	1.3	Very Broad	C	Dune-Ripple	6	Reference	High
M18	60	0	1.08	Broad	C	Dune-Ripple	8	Reference	High
M19	58.8	0.39	1.31	Very Broad	C	Dune-Ripple	5	Reference	Not Evaluated
M20	35.5	0	1	Very Broad	C	Dune-Ripple	14	Fair	High

Unnamed Tributary to Reach M02

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
M2S1.01	14.4	5.29	1	Semi-Confined	B	Not Evaluated	9	Good	Not Evaluated
M2S1.02	13.5	1.64	1.23	Very Broad	C	Not Evaluated	7	Good	Not Evaluated
M2S1.03	10.7	2.07	1.01	Broad	C	Not Evaluated	6	Good	Not Evaluated
M2S1.04	10.3	1.29	1.09	Very Broad	C	Not Evaluated	11	Fair	Not Evaluated

Greens Brook - M6S2

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
M6S2.01	23.2	1.07	1.12	Very Broad	C	Dune-Ripple	7	Good	High
M6S2.02	23.1	2.1	1	Semi-Confined	B	Riffle-Pool	7	Good	Moderate
M6S2.03	13.4	5.47	1	Narrowly-Confined	A	Riffle-Pool	4	Reference	High
M6S2.04	12.8	2.17	1	Semi-Confined	B	Step-Pool	3	Reference	Moderate
M6S2.05	10	1.56	1	Narrow	C	Riffle-Pool	3	Reference	High
M6S2.06	2.7	5.48	1	Narrowly-Confined	A	Step-Pool	6	Good	High

Orcutt Brook – M6S3

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
M6S3.01	22.7	0.65	1.15	Very Broad	C	Riffle-Pool	4	Reference	High
M6S3.02	22	3.45	1	Semi-Confined	B	Step-Pool	4	Reference	Moderate
M6S3.03	20.9	1.38	1	Narrow	C	Step-Pool	7	Good	High
M6S3.04	18.6	1.78	1.03	Narrow	B	Riffle-Pool	2	Reference	Moderate
M6S3.05	8.6	0.75	1.12	Narrow	C	Riffle-Pool	3	Reference	High

Coche Brook - M6S5

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
M6S5.01	24.8	1.09	1.11	Very Broad	C	Riffle-Pool	7	Good	High
M6S5.02	24.3	2.81	1	Narrowly-Confined	B	Step-Pool	3	Reference	Moderate
M6S5.03	23.5	2.14	1	Semi-Confined	B	Riffle-Pool	3	Reference	Moderate
M6S5.04	18.4	0	1.09	Very Broad	C	Dune-Ripple	2	Reference	High
M6S5.06	13.6	0.67	1.1	Very Broad	C	Dune-Ripple	2	Reference	Not Evaluated
M6S5.07	11.2	3.12	1	Narrowly-Confined	B	Step-Pool	1	Reference	Not Evaluated

Unnamed Tributaries to Reach M13

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
M13S3.01	9.4	2.98	1	Broad	B	Riffle-Pool	3	Reference	Moderate
M13S4.02	13.6	0	1.44	Very Broad	C	Plane Bed	11	Good	Moderate
M13S4.03	12.8	7.35	1	Narrowly-Confined	A	Plane Bed	4	Reference	High

Unnamed Tributary to Reach M15

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
M15S2.01	17.9	0.88	1.11	Very Broad	E	Riffle-Pool	16	Fair	High
M15S2.02	17.6	6.82	1	Narrowly-Confined	A	Step-Pool	4	Reference	High
M15S2.03	15.1	5.26	1	Narrowly-Confined	A	Step-Pool	1	Reference	High

Lang Brook – M17S2

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
M17S2.01	11.6	0	1.35	Very Broad	C	Dune-Ripple	1	Reference	High
M17S2.02	10	5.38	1	Narrowly-Confined	A	Step-Pool	3	Reference	High

Outflow From Echo and Seymour Lakes, Including Unnamed Tributary to Seymour Lake – T1

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
T1.01	54.6	0	1	Very Broad	C	Riffle-Pool	6	Reference	Moderate
T1.02	54.6	2.68	1	Narrowly-Confined	A	Cascade	11	Good	Very Low
T1.03	54.5	1.17	1.24	Very Broad	C	Dune-Ripple	3	Reference	High
T1.04	53.5	0.96	1.02	Semi-Confined	B	Step-Pool	6	Reference	Very Low
T1.06	49.9	1.22	1	Semi-Confined	B	Not Evaluated	2	Reference	Not Evaluated
T1.08	23.4	0	1.41	Very Broad	C	Dune-Ripple	9	Good	High
T1.09	21.3	1.23	1.1	Very Broad	C	Riffle-Pool	6	Good	High
T1.10	20.9	6.13	1	Narrowly-Confined	A	Not Evaluated	1	Reference	Not Evaluated
T1.11	19.9	1.39	1	Broad	C	Not Evaluated	2	Reference	Not Evaluated
T1.12	19.7	1.16	1.16	Broad	C	Not Evaluated	14	Good	Not Evaluated
T1.13	14.6	4.01	1.07	Narrow	C	Not Evaluated	2	Reference	Not Evaluated

Mad Brook – T2

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
T2.01	30.4	0	1	Very Broad	C	Dune-Ripple	15	Fair	High
T2.02	30.4	0.63	1.27	Very Broad	C	Riffle-Pool	16	Good	High
T2.03	30.2	3.98	1	Narrowly-Confined	A	Step-Pool	6	Reference	Not Evaluated
T2.04	28	2.99	1	Semi-Confined	B	Step-Pool	4	Reference	Very Low

T2.05	26.1	4.23	1	Narrowly-Confined	A	Step-Pool	1	Reference	Not Evaluated
T2.06	16.3	8.01	1	Narrowly-Confined	A	Cascade	1	Reference	Very Low

Cold Brook – T4

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
T4.01	26.9	0.62	1.02	Very Broad	E	Riffle-Pool	19	Fair	High
T4.02	26.3	10.44	1	Narrowly-Confined	A	Cascade	1	Reference	Not Evaluated
T4.03	26.1	2.04	1.01	Semi-Confined	B	Not Evaluated	1	Reference	Not Evaluated
T4.04	24.7	1.8	1.09	Narrow	C	Not Evaluated	1	Reference	Not Evaluated
T4.05	21.9	2.19	1.06	Narrow	B	Not Evaluated	3	Reference	Not Evaluated
T4.06	13.1	2.2	1.02	Very Broad	C	Not Evaluated	2	Reference	Not Evaluated
T4.08	11.7	6.21	1.07	Narrow	C	Not Evaluated	4	Reference	Not Evaluated

Oswegatchie Brook – T5

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
T5.01	27.8	0.5	1.34	Very Broad	C	Dune-Ripple	8	Reference	High
T5.02	24.6	2.96	1	Narrowly-Confined	B	Step-Pool	1	Reference	Not Evaluated
T5.03	24.4	0.98	1.22	Very Broad	E	Dune-Ripple	10	Good	High
T5.04	14.4	3.44	1	Narrowly-Confined	B	Step-Pool	8	Good	Not Evaluated
T5.05	8.9	0.59	1	Very Broad	C	Dune-Ripple	7	Reference	Not Evaluated

Pherrins River – T6

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type[1]	Reference Stream Bedform[1]	Impact Score[2]	Phase 1 Reach Condition	Phase 1 Reach Sensitivity
T6.01	49.2	0.19	1.48	Very Broad	E	Dune-Ripple	17	Good	High
T6.02	48	0.48	1.14	Narrow	C	Plane Bed	8	Reference	Moderate
T6.03	47.4	0.85	1.27	Very Broad	E	Dune-Ripple	13	Good	High
T6.04	46.9	0.19	1.03	Broad	C	Riffle-Pool	3	Reference	High
T6.05	43.7	0.42	1.23	Very Broad	C	Dune-Ripple	7	Reference	Not Evaluated
T6.06	24.7	0.72	1.07	Broad	C	Dune-Ripple	5	Reference	Not Evaluated
T6.07	24.3	2.78	1.14	Very Broad	C	Riffle-Pool	5	Reference	Not Evaluated

1. See Appendix B for summary of stream types and bedforms
2. Impact Scores range from 0 (not impacted) to 32 (highly impacted) and indicate how much the reach is impacted by land use, instream modifications, and floodplain modifications.

NorthWoods Stewardship Center

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