Restoring Water Quality in the Lake Memphremagog Basin:
River Corridor Plan for the Black River

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Table of Contents

<u>List of Tables and Figures</u>

<u>List of Tables</u>

<u>List of Figures</u>

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1. Summary

The Black River Stream Geomorphic Assessments are part of an on-going partnership between the **NorthWoods Stewardship Center** and the **State of Vermont** to identify non-point pollution sources in the four main Vermont tributaries draining into Lake Memphremagog. These assessments aim to evaluate river stability and the condition of the adjacent landscape in order to determine the degree to which certain river reaches are impacting water quality as well as aquatic habitat. Unstable reaches may be a source of higher sediment inputs into a river. Furthermore, unstable reaches and the accompanying erosion result in increased property damage during high flows, due to rapid adjustment of the channel position. This river corridor plan presents and interprets the Phase 1 and Phase 2 geomorphic assessment data for the entire Black River mainstem and many of its major tributaries in order to identify unstable river reaches, identify exemplary reaches, and identify factors driving the conditions of these tributaries. Finally, this plan offers specific recommendations for prioritizing restoration efforts and for long term management of the river and its corridor - for the improvement of water quality and fish and wildlife habitats.

Phase 1 assessments were completed along the entire Black River (49 river-miles) as well as Stony Brook, Ware Brook, Lords Creek, Lamphear Brook, McCleary Brook, Rogers Branch, and Whitney Brook (40 river-miles). From these, we selected for Phase 2 assessment reaches that appeared most likely in need of restoration. We completed Phase 2 field assessments along ten reaches of the Black River (14 river-miles) and ten tributary reaches (totaling nine river-miles) along Stony Brook, Ware Brook, Lords Creek, Lamphear Brook, McCleary Brook, Rogers Branch, and Whitney Brook.

The majority of the Black River is a sinuous, low-gradient river with abundant and frequently inundated wetlands adjacent to the river channel. In fact, this watershed contains the highest proportion of wetlands of the four major Memphremagog tributaries, at over 6% of the watershed area. The majority of the river corridor consists of natural land cover, which sometimes extends for several hundred feet on either side of the river, however there are also sections where agricultural uses occur up to the river’s edge. Natural land cover types cover nearly 76% of the watershed, while 19% of the watershed is used for agriculture and less than 5% is urban land. Because much of the river is located far from roads and other development, impacts to the channel are largely concentrated in areas where agricultural use occurs near the corridor.

In our Phase 1 assessments, we found ten miles (20%) of the Black River mainstem to be in reference condition. All reference condition reaches were located either in the headwaters area upstream of Craftsbury, or in the lowest sections of the river in the vicinity of South Bay WMA and its extensive wetlands. Good condition reaches occupied 14 miles (29%). These reaches tended to have minor instability due to alterations to the channel corridor, such as removal of riparian vegetation, straightening, or stream bank armoring. Finally, 22 miles (45%) were in fair condition and three miles (6%) were in poor condition. These reaches tended to be straightened along most of their lengths,

lacked vegetated buffers, and were either in an active process of channel adjustment or were highly likely to change position in the near future.

Our Phase 1 analyses found the main tributaries of the Black River to be in better shape than the mainstem on average, with 19 miles (48%) in reference condition and eight miles (20%) in good condition. Reference conditions were again found most consistently in the forested upper headwaters regions of these streams. Within the tributaries, fair conditions were encountered on Lord's Creek , Stony Brook, and in the lowest reach of Roger's Branch, with a total of 13 miles (33%) in fair condition. The only reach assessed as poor was 0.3 miles long (< 1%) and was located within an active gravel pit area along Stony Brook.

The Phase 2 assessments - though focusing on areas of concern and therefore including no reference condition reaches - did result in "upgraded" condition rankings for many of the reaches ranked in Phase 1 as in poor or fair condition. Overall, the Phase 2 surveys along the mainstem found eleven miles (79%) in good condition, three miles (21%) in fair condition, and no reaches in poor condition. The tributary findings were nearly identical proportionately, with seven miles (78%) in good condition, two miles (22%) in fair condition, and no reaches in reference or poor condition.

Often the geomorphic state of a reach impacts the condition of the in-stream habitat, while land uses within the river corridor affect habitat along the adjacent riparian zone. During Phase 2 assessments, we evaluated habitats along each of the ten mainstem and ten tributary reaches. All of the mainstem assessed reaches had habitat conditions that were either good (eight miles - 57%) or fair (six miles - 43%). The assessed tributaries had slightly more degraded habitat conditions, with 4.1 miles (46%) being good, 4.7 miles (53%) fair, and 0.1 miles (1%) poor. Reaches rated as having fair or poor habitat condition exhibited higher bank instability and increased sediment deposition affecting the streambed, as well as decreased riparian vegetation. No reaches were in reference condition; in part because we prioritized reaches with impacted riparian zones for the Phase 2 assessments.

Summary Recommendations

Located in a rural watershed, the Black River and its tributaries are relatively lightly influenced by development; one exception being gravel mining operations along Stony Brook. The primary impacts today are from agricultural use within the river corridor, which is much reduced from historic levels, and which is offset in many areas by vegetated riparian buffers. Still, a number of areas do require active restoration - and other intact wetlands and forest within the riparian corridor merit protection to maintain the outstanding habitat and water quality benefits that they provide. Along the mainstem, nearly six miles of river bank currently lack a minimal vegetated buffer (>25 feet wide), while over 15 miles of tributaries lack this minimal buffer. Areas where lack of buffer coincides with stream sensitivity should be prioritized for re-planting efforts. These occur in short sections along the Black River mainstem (reaches M05,M20, and M24), as well as the lower reaches of Ware Brook, McCleary Brook, Rogers Branch, and Whitney Brook, but more extensively in reach M29 and along Lords Creek and Stony Brook.

Several buffer planting projects in 2010 began to address these needs and should continue in the future, as funding and other resources allow. In addition, many extensive wetland natural communities exist along or near the river, including cedar swamps, alluvial shrub swamps, oxbows, beaver ponds, floodplain forests, and others. These habitats harbor many uncommon plant and animal species and should be the focus of larger-scale conservation efforts. Finally, invasive species such as purple loosestrife *(Lythrum salicaria)*, tartarian honeysuckle *(Lonicera tatarica)*, and Japanese knotweed *(Polygonum cuspidatum)* threaten these wetlands. Control of these species should be a priority, as they currently exist in manageable densities along much of the Black River.

A more complete summary of the priority needs identified in this study, and resulting recommendations can be found on page 66.

2. INTRODUCTION

2.1 PROJECT BACKGROUND AND MEMPHREMAGOG WATERSHED DESCRIPTION

This project continues our multi-year effort to identify water quality threats within the Lake Memphremagog Watershed. Our goal is to prioritize and implement watershed protection and restoration projects, with the intention of improving water quality and riparian habitat. Lake Memphremagog is shared between the Eastern Townships of Quebec, Canada and the tri-county Northeast Kingdom of Vermont in the United States. Approximately 73% of the lake lies in Quebec, while about 71% of the lake's watershed lies in Vermont. The southern portion of the lake is fed by three main tributaries (Barton, Black, and Clyde Rivers) located in Vermont and one smaller tributary that straddles the Vermont/Quebec border (Johns River). These rivers flow north into Lake Memphremagog, which drains north via the Magog River to the St. Francis River and ultimately the St. Lawrence River.

A valued resource for its scenery, recreation, aquatic habitat, and other values, Lake Memphremagog nevertheless faces a number of threats to water quality. Concern over sediment and nutrient inputs and the resulting eutrophication have motivated groups on both sides of the border to address non-point sources of pollution throughout the watershed. In particular, these groups are concerned with phosphorus, which is considered a limiting nutrient in the lake, and sediments, which tend to bind and transport the phosphorus. Blue-green algae (cyanobacteria) blooms, caused by high nutrient inputs such as phosphorus, have occurred in the lake. Lake Memphremagog is listed by the State of Vermont as an impaired surface water requiring a phosphorus total maximum daily load (TMDL) due to nutrient enrichment and excessive algal growth (State of Vermont 2008).

Non-point pollution sources stem from multiple dispersed locations throughout the watershed and from a variety of landscapes. Precipitation flows over and through these landscapes carrying sediment, phosphorus and other nutrients, pesticides, metals, and other contaminants into nearby waterways. All land cover types contribute phosphorus to some degree, though some contribute more than others. Examples of non-point sources include agricultural fields, forests, wetlands, construction sites, roads, urban stormwater, waste disposal, streambank erosion, atmospheric deposition, and septic systems. Even natural land cover types that normally contribute low amounts of phosphorus can become significant contributors, such as when improper logging practices are used.

During 2005 and 2006, the NorthWoods Stewardship Center sampled water quality in the four Vermont tributaries to Lake Memphremagog (Gerhardt 2005, Dyer and Gerhardt 2007) for nitrogen, phosphorus, and sediment. The results indicated that water quality, in respect to these nutrients, was poorest in the Johns River and best in the Clyde River. The Black and Barton Rivers were similar in water quality, though average nutrient and sediment levels were slightly higher on the Black. These results were also shown during tributary monitoring completed by the Vermont Agency of Natural Resources in 2008 (Quebec-Vermont Steering Committee 2008), where mean phosphorus concentrations were 39, 53, and 19 parts-per-billion for the Barton, Black, and Clyde Rivers, respectively, when measuring from the downstream-most bridges.

More research has since been completed to monitor water quality along the Johns River, its tributaries, and the small tributaries that drain into Lake Memphremagog, in order to pinpoint non-point pollution sources and the effects of a manure pit upgrade along Crystal Brook, a major Johns River tributary (Gerhardt 2009 and 2010). In 2010, water quality sampling at six sites along the Black River mainstem and 15 tributary locations identified elevated phosphorus levels along most of the Black River itself and on Shalney Brook, Stony Brook, Brighton Brook, and upper Lords Creek (Gerhardt 2011).

In 2006, the NorthWoods Stewardship Center began an effort to identify sediment sources through Stream Geomorphic Assessments conducted along the major tributaries within the Memphremagog Watershed. During these assessments, we followed protocols developed by the Vermont Department of Environmental Conservation to analyze these tributaries both on a watershed-scale and a stream reach-scale. To date, we have completed these assessments along the Barton, Clyde, and Johns Rivers and this document presents the results of the most recent assessments on the Black River. These studies have identified areas that are likely contributors of significant amounts of sediment to the tributaries and to Lake Memphremagog. They have also highlighted areas that are in excellent condition and that may require protection to preserve water quality and valuable riparian habitat. The information gathered from these studies has been presented during several public meetings and has been used to guide a number of restoration projects in the watershed.

2.2 PROJECT GOALS

The goal of the project described in this report was to identify potential sources of nutrients and sediment into the Black River and its tributaries by assessing the current health and stability of the river and its waterways. Additionally this project was intended to help direct management efforts of the river and its floodplain. We have identified specific areas of river and adjacent landscape which merit conservation due to the benefits provided to water quality. We have also identified specific areas requiring restoration in order to improve water quality and aquatic habitat. The information gathered during this project guided the development and implementation of two buffer planting projects in 2010 along the Black River, and is currently being employed by several regional conservation partners to identify new project sites for 2011.

3. BACKGROUND WATERSHED INFORMATION

3.1 GEOGRAPHIC SETTING

3.1.1 Black River Watershed Description

The Black River Watershed lies within the Memphremagog Watershed in northern Vermont. The Black River drains an area of approximately 135 mi^2 and begins on a southerly course from its headwaters in Albany, paralleling the Creek Road into Craftsbury. The river then turns 180-degrees to flow north through Craftsbury, Albany, Irasburg, and Coventry (Figure 1) before emptying into Lake Memphremagog’s South Bay. It distantly parallels Routes 14 and 5 for most of its course through a wide, level, and alluvial valley that is bound by the Lowell Mountains to the west and the hills of Albany and Craftsbury to the east. The river is fed by many smaller tributary watersheds that drain the Lowell Mountains, the largest of which are listed here in a north to south order: Stony Brook (6 mi^2), Ware Brook (4 mi^2), Brighton Brook (9 mi^2), Lamphear Brook (5 mi^2), McCleary Brook (3 mi^2), Shalney Branch (3 mi^2), Rogers Branch (3 mi^2), and Seaver Branch (4 mi^2). The river also receives large inputs from tributaries draining the south-western portion of the watershed: Whitney Brook (14 mi^2) and Lord's Creek (16 mi^2). One lake and many ponds occur in the watershed: Lake Elligo (174 acres), Little Hosmer Pond (180 acres), Great Hosmer Pond (140 acres), Duck Pond (9 acres), Mud Pond (35 acres), Page Pond (16 acres), Heart Pond (6 acres), Hartwell Pond (16 acres), Potters Pond (5 acres), Griggs Pond (6 acres), Walker Pond (18 acres), Smith Pond (8 acres), and Sargent Pond (6 acres).

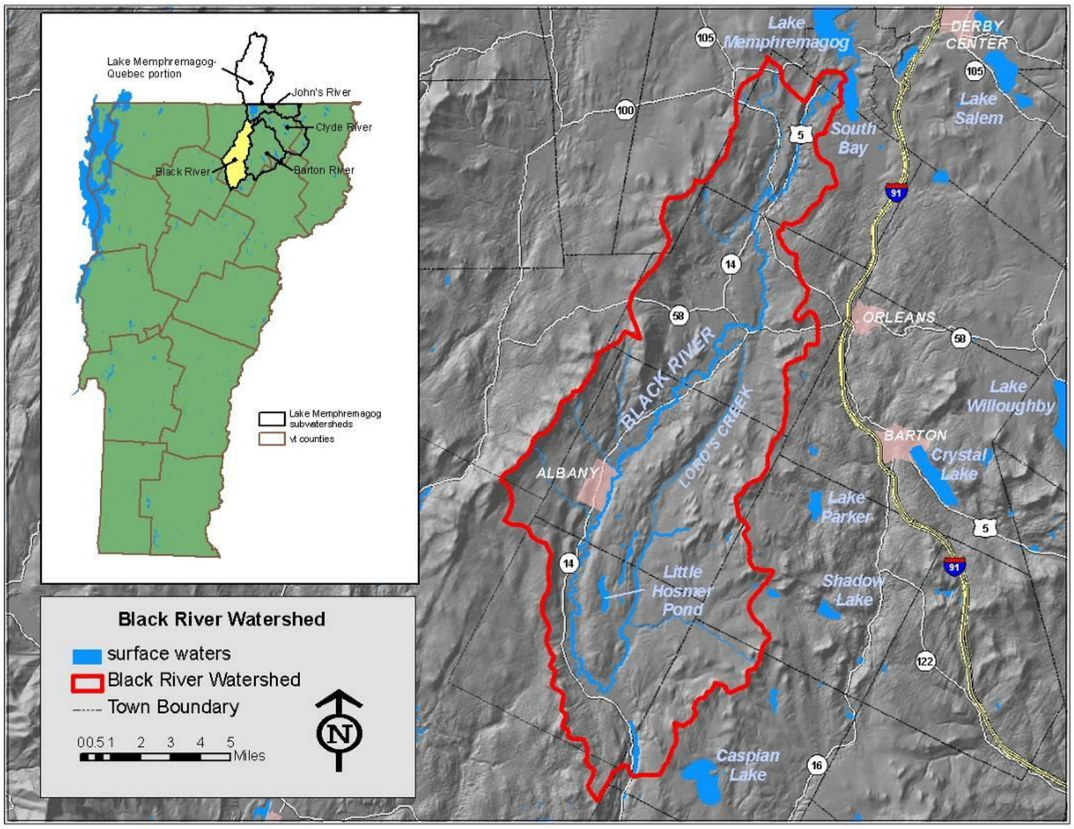

__Figure 1.__ Location of the Memphremagog and Black River Watersheds.

3.1.2 Political Jurisdictions

The Black River Watershed lies mostly within Orleans County; with the southern tip extending into Lamoille County. The river's mainstem flows through the towns of Craftsbury, Albany, Irasburg, Coventry, and Newport, and the watershed also includes small portions of Greensboro, Glover, Lowell, Eden, and Wolcott. The mainstem and its tributaries cross mostly private land, though the State of Vermont owns some shoreline. The northern six miles of the river cross the South Bay Wildlife Management Area.

3.1.3 Land Use History

Changing land use patterns within the Black River watershed, particularly during the past two centuries, have resulted in the most significant impacts to the river and its tributaries since the glaciers and provide useful context for understanding the conditions that exist today.

Prior to 1790, most human use in the watershed was by relatively small bands of Native Americans of the Western Abenaki tribe. Permanent villages existed on Lake Memphremagog for several thousand years, with mostly short term use of the watersheds extending from the lake for hunting, small-scale agriculture, and travel. The landscape at this time was largely a mixed virgin forest, dominated by beech, sugar maple, red spruce and other late-successional tree species on the side slopes. In the valleys, softwood swamps and hardwood floodplain forests were interspersed with beaver meadows and open wetland communities.

The first Euro-American settlement in the valley was at Craftsbury in 1778, and the floodgate for settlement opened in 1799 with the completion of the Bayley-Hazen military road from Newbury to Hazen's Notch, via Craftsbury and Albany. The Hinman Settler Road, completed in 1793, followed a south-north route just east of the Black River watershed, further hastening settlement.

Census records for Albany, Craftsbury, Irasburg, and Coventry plot a population explosion in the first half of the 19th century – from 18 people in 1791 (all in Craftsbury), to 263 in 1800 (all towns), to a high of 4,682 in 1860 (US Census Bureau 2003). Although the population began a slow century-long decline in 1860, and has never rebounded to 1860 levels, land clearing continued for several decades after the population maximum.

During the early 1800's Craftsbury became a major center of commerce for all the surrounding towns. By 1868 the town had five 5 sawmills, 3 churches, 1 academy, 1 woolen factory, 7 stores, 2 grist-mills, 1 hulling-mill, 5 blacksmith-shops, 3 wheelwright-shops, 1 tannery, 1 tin-shop, 5 shoe-shops, 2 harness shops and 3 hotels (Hemenway 1877). Similar development occurred during this time in Albany, Irasburg, and Coventry.

Production of potash and pearl ash from the burning of hardwood trees was the primary industry for the area during the late 18th and early 19th century. This was the major commodity that settlers could trade for their life necessities, as farms were still at the subsistence level.

During the mid 1800's farmland began to be used more for agricultural commodity crops - such as potatoes, Indian corn, and wheat - and for sheep grazing. After the sheep market crashed, diary cows replaced sheep as the primary type of livestock. The number of farms and total acres of cleared land peaked in 1900, with over 80% of Orleans County cleared of its original forests. This clearing was most pronounced in the fertile valleys, and was accompanied over the next century by the manipulation of streams and rivers, in the form of drainage of wetlands and channel straightening, to increase the amount of accessible farmland. Although the number of farms dropped steadily after 1900, acreage per farm increased, so that Orleans County remained >70% open land until 1959. After this time, total acres in agricultural production began a steady decline that continues today. Active farmland now comprises 30% of the land in Orleans County and 19% of the total acreage in the Black River Watershed (USDA 2000, 2007). Aerial photography from 1963 and recent years (1999, 2008, and 2009) provides excellent documentation of the return of native vegetation to portions of the valley, and of areas with continued impacts on the river channel and river corridor (NRCS 1963, VCGI 2011).

Though less well documented than farming, logging has also been a significant land use in the watershed, with some long-lasting impacts in the river corridor. Extensive removal of forest cover leads to more overland runoff, resulting in increased frequency of flooding events and the flushing of sediments and nutrients from upland areas into streams and rivers. The effects of this use can be most dramatically seen at the lower end of the Black River, around its outlet into South Bay. Past study of the vegetation and substrates in this area have shown that what is now primarily shrub swamp was once an extensive conifer swamp on peat soils, dominated by tamarack, and northern white cedar, with black and/or white spruce and white pine also occurring (Lloyd and Scarth 1922, Engstrom et al 1999). Based on multiple lines of evidence, including 8-16 inches of silty muck overlying a deep peat layer, investigators have surmised that these forests were destroyed by flooding and sedimentation that resulted from the clearing of upland forests throughout the watershed in the late 19th century. Dams installed at Magog (Quebec) in 1882 and 1914 may have also had some effect, though this is thought to have been secondary to the logging impact.

3.2 GEOLOGIC SETTING

The Black River Watershed straddles two biophysical regions: the Northern Green Mountains and the Northern Vermont Piedmont, with Route 14 roughly following their shared boundary. The boundary between these biophysical regions occupies a fault line between bedrock of two distinct types and origins. West of this line lies older, somewhat acidic metamorphic bedrock that was formed during the Cambrian and Ordivician Periods, roughly 540-443 million years ago. Originating as sediments laid down in an ancient proto-Atlantic Ocean, these rocks were metamorphosed when tectonic plates converged during the Taconic Orogeny (mountain-building event) 445 million years ago, resulting in the phyllites, schists, gneisses and quartzites found today. Small pieces of the earth’s mantle and crust were mixed into the eastern portion of this mass and now appear as localized deposits of serpentine, asbestos and talc (Thompson and Sorenson 2000).

East of the fault line are younger metamorphic rocks, mainly phyllites, schists, and crystalline limestones, that formed in the Silurian and Devonian Periods, 443-354 million years ago, during a second mountain-building period known as the Acadian Orogeny. Known collectively as the Waits River Formation, these rocks originated from near-shore sediments that included the remains of marine organisms, resulting in higher amounts of calcium carbonate. Because calcium is often a limiting nutrient for plants, soils derived from this easily-weathered bedrock are known as some of the best in the state for growing crops and forests.

Granitic bedrock appears in small scattered patches throughout the watershed, including at Allen Hill west of Orleans village and at the north end of the Lowell Range. Part of the New Hampshire Series of plutons, these rocks were intruded from the earth’s mantle into the metamorphic “ceiling” near the end of the Acadian Orogeny and have emerged from the earth’s surface gradually through subsequent erosion of the softer overlying metamorphic rock.

Surficial features associated with the most recent glacial period (the Wisconsin) are also found throughout the watershed, with the greatest diversity of types occurring along the main Black River valley downstream of Craftsbury (Figure 2). At glacial maximum approximately 18,000 years ago, the Laurentide Ice Sheet covered the region with up to 4,000 feet of ice, laden with sediments of all sizes. By 13,000 years ago the ice sheet had receded to the Canadian border, but then stagnated during a cooler period, periodically surging and receding within the northern Vermont region. By approximately 12,000 years ago melting had again begun in earnest and the resulting meltwaters were dammed by the ice sheet to the north, creating an extensive proglacial Lake Memphremagog that was 300 feet deeper than the current lake level (Stewart and

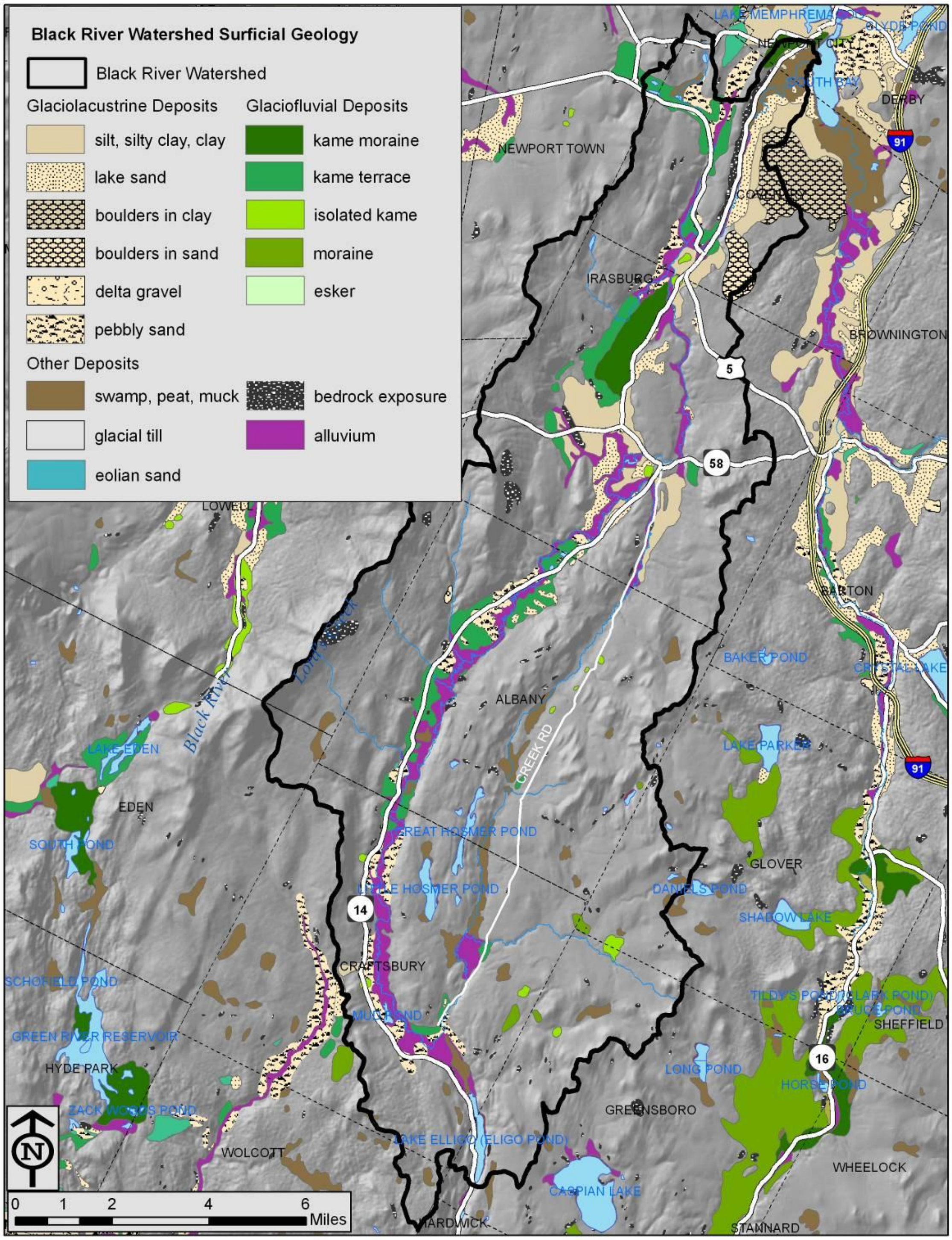

__Figure 2__. Surficial geology map of the Black River Watershed. Note the extensive alluvial deposits, especially as compared with the Barton River (right) (Source: VCGI 2010).

MacClintock 1969). At its greatest extent this lake reached the 1,000 foot elevation contour in the Black River watershed, inundating the current headwaters south of Elligo Pond and into the adjacent Lamoille River watershed to the south.

During the various phases of the glacier's retreat, the proglacial Lake Memphremagog, and the post-glacial wet climate, sediment deposits were laid down in patterns guided by the underlying topography. Upland areas, which represent nearly 80% of the watershed, were cloaked mainly in glacial till deposits. These unsorted materials are now often found as lodgement or dense basal till overlain by ablation till. Lodgement till was formed by the compressive action of the ice sheet and can act as an impermeable layer in the soil profile. Ablation till is loose material that was dropped directly out of the melting ice. The glacier also scraped some upland areas free of soil, resulting in over 1,300 acres of exposed or shallow bedrock across the watershed, including the long ridge west of route 5 between Coventry and Newport.

Valley sediments were transported and deposited in water and as a result tend to be sorted by particle size, reflecting the speed of the water that carried them. Ice contact features were formed during the glacier's retreat and include eskers, kames, and kame terraces. Kame terraces were created when sand and gravel outwash was deposited in meltwater lakes between the receeding glacier ice and the higher valley walls. These features occur mainly in the wider valleys of the watershed, including along the Black River valley downstream of the Seaver Branch, south of lower Ware Brook, and along Stony Brook. Albany Village and part of the village of Craftsbury occupy kame terraces. The watershed's many gravel pits also take advantage of the sorted gravels found in these ice-contact deposits.

Lake deposits associated with the ice-dammed former Lake Memphremagog are also common along the Black River valley from Elligo Pond north to Newport and three miles up Lord's Creek. These sediments are largely clays, silts, and sands, but include ice-rafted boulders in some areas. The former lake sediments are 8/10 of a mile wide just below Craftsbury and over 1.5 miles wide at the Route 14/ Route 58 junction northwest of Irasburg village.

Smaller glacial features, including recessional moraines and kames, occur sporadically in the watershed, most notably in the southeastern region east of Craftsbury. Many swamp areas formed on silt deposits accumulated during past wet climate periods. These include much of the upper portion of the Black River (upstream of Craftsbury), as well as the Black River outlet area at South Bay. Recent (post glacial) alluvium dominates closest to the Black River and its main tributaries, occupying as much as a quarter mile of the valley in some locations, such as northeast of Albany Village.

3.3 GEOMORPHIC SETTING

3.3.1 Description and Location of the Assessed Reaches

For the purposes of this study, the river and most of its tributaries were divided into 224 reaches and sub-watersheds using topographic maps and aerial photographs. Each reach represents a section of river or stream with physical attributes that distinguish it from reaches immediately upstream and downstream. These attributes include valley width, valley slope, channel width, and channel sinuosity. Tributaries which received Phase 1 assessments are shown in blue in

Figure 4. Phase 2 reaches were chosen based on the Phase 1 results. Preference was given to reaches that could potentially benefit from restoration and conservation projects. Stream reaches characterized by bedrock gorges, very steep terrain, or ongoing beaver influence, were excluded from consideration for Phase 2 assessments because the unique dynamics under these conditions make the information provided by Stream Geomorphic Assessment less relevant. Several sections initially flagged for Phase 2 consideration were later excluded when access permission was not obtained. Ten Black River reaches between Craftsbury and Coventry received Phase 2 field assessments, as did selected reaches along Stony Brook, Ware Brook, Lords Creek, Lamphear Brook, McCleary Brook, Rogers Branch, and Whitney Brook. Phase 2 reaches are shown in gold in Figure 4.

3.3.2 Longitudinal Profile, Alluvial Fans, and Natural Grade Controls

Of the three main tributaries to Lake Memphremagog, the Black River has the least elevation change, and the slowest average flow rates. While several sections drop quickly in elevation, the river is more characteristically slow and meandering through a flat, broad, and wet alluvial valley. An elevation profile for the Black River is show in Figure 3.

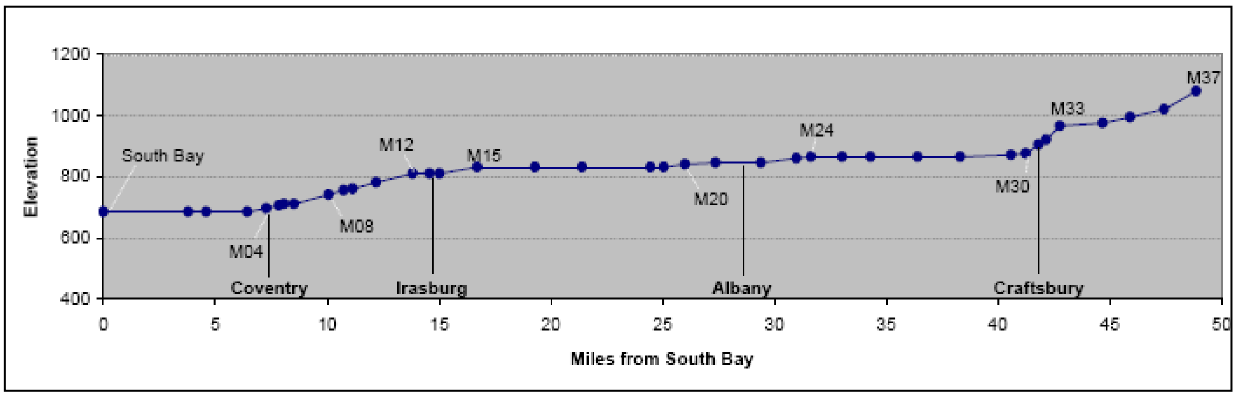

Figure 3. *Elevation profile for the Black River, from its mouth at South Bay to its headwaters. Selected reaches and town centers are labeled in black.*

Interestingly, the mainstem of the Black River originates in Albany, very close to the headwaters of its major tributary, Lord's Creek. Both streams originate from a wetland complex along Creek Road; the Black River initially flowing south and Lord's Creek north. Page Pond Road itself crosses the divide between these watersheds.

The Black River continues south through a series of wetlands and beaver ponds in a narrow forested valley until its confluence with Whitney Brook, at the upstream end of Reach M34. The main channel is inconspicuous here, as beaver activity has resulted in a network of channels of similar size. The river descends 105 feet over this four-mile section, which is entirely Class 2 wetland mapped by the Vermont Significant Wetland Inventory, and which is isolated from roads and other development. After Whitney Brook, the river channel becomes more defined, meandering in a very broad valley through abandoned farm fields for the next two miles. The valley narrows dramatically upon reaching the Creek Road (Reach M33), and the river cascades over a five foot waterfall. After this brief gorge, the valley widens slightly and the river quickens over boulders and pools while passing through Craftsbury Village (Reach M31). The river descends 90 feet in elevation during this 1.5 mile section.

After Craftsbury Village, the river enters a broad, alluvial valley paralleled by Route 14. This is the dominant setting for the next 41 miles to South Bay. After the Lake Elligo outlet, the river makes a 180-degree turn and flows northerly. Its flow is consistently slow and meandering through extensive wetlands and both abandoned and active agricultural fields. In some areas (M25 and M26), the river becomes pond-like with barely discernable flow. Only 60 feet of elevation are lost over the next 27.4 miles as the river continues north through the towns of

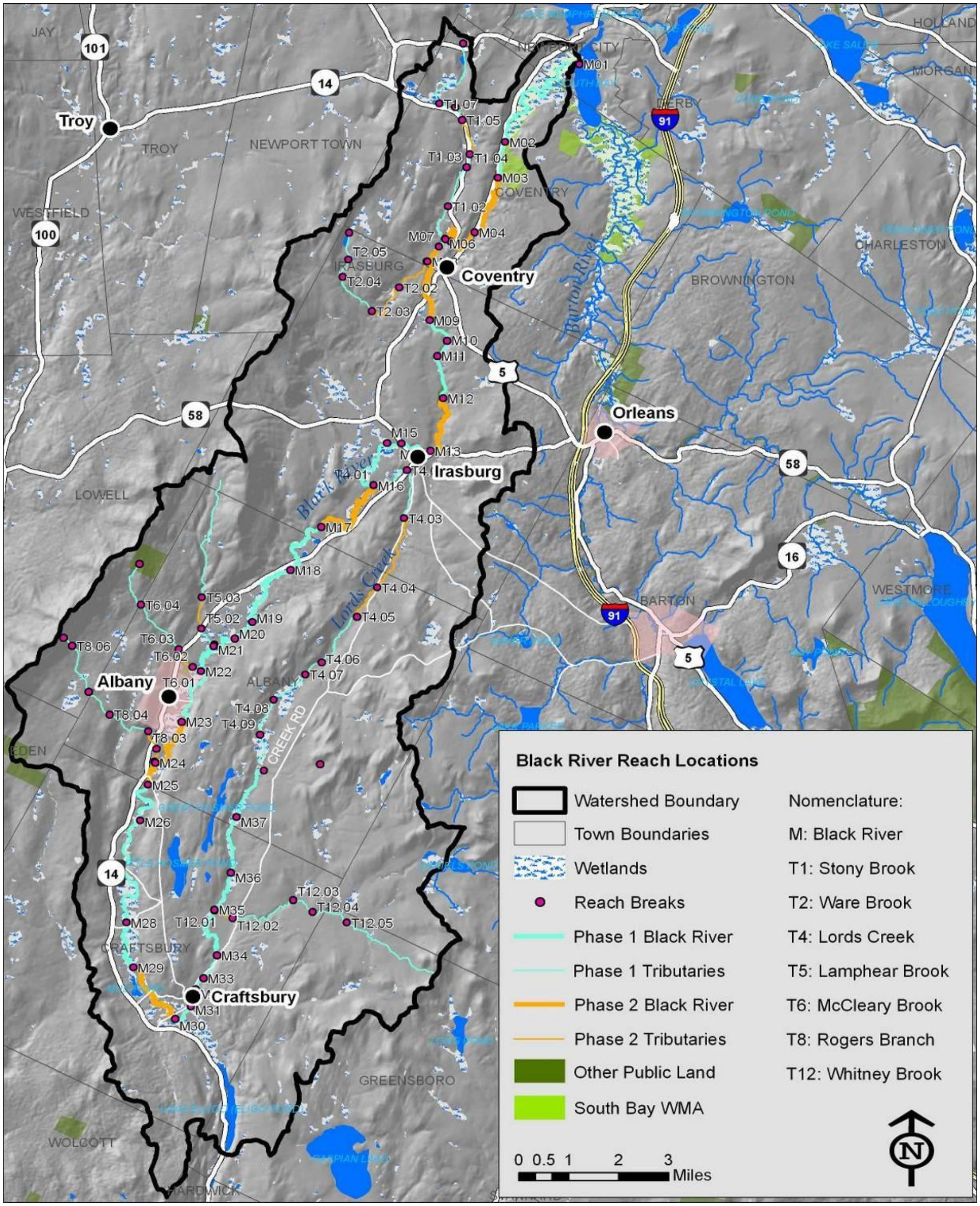

__Figure 4:__ Numbered reaches and assessed status of the Black River and its major tributaries

Craftsbury, Albany, and Irasburg (Reaches M30 through M14).

In the center of Irasburg (Reach M13), the valley constricts and steepens enough to result in a brief whitewater section for 0.75 miles, flowing over small bedrock outcrops before the gradient lessens again near Covered Bridge Road. For the next 1.6 miles (Reach M12), the river flows relatively swiftly and meanders through farm fields and narrow forested corridors.

The next 2.0 miles (Reaches M11 through M09) comprise the Black River's longest high-gradient section. The isolated valley here runs between two very steep hillsides and is very narrow in places. Despite this constricted valley setting, the slope is gentle, there are no bedrock outcrops, and the river forms easy rapids over large boulders interspersed with straight, flat sections. After Reach M09, the valley widens to a broader setting in Reaches M08 and M07, and the river flows through agricultural fields for the next 2.0 miles until Coventry Falls.

Reach M06 comprises a brief (0.2 mile) and significant constriction of the valley at Coventry Falls - located just downstream of a USGS gaging station (Figure 5). Here the channel splits into two falls, one side with two drops totaling seven feet, and the other side with one six foot drop. A large pool lies below the falls.

The next 0.6 mile section, between Coventry Falls and a subsequent unnamed falls (Reach M05), follows an interesting course as it flows directly toward a steep valley wall before changing direction 180-degrees and plummeting over an 11- foot waterfall. After the waterfall, the river quickly transitions to a sandy and slow-flowing channel, passing amidst abandoned fields for 2.7 miles (M04 and M03), and then through floodplain forest (M02 and M01) for 4.6 miles, before

Figure 5. *Coventry Falls in Reach M06.*

ending at Lake Memphremagog's South Bay. The river descends approximately ten feet in elevation during these final four reaches.

3.3.3 Valley and Reference Stream Data

Using topographic maps and windshield surveys, data were collected to describe the valley setting and slope for each assessed reach (Table 1). Stream types were assigned based on the Rosgen stream classification system (Appendix B), where variables such as channel slope, valley slope, valley width, and sinuosity were evaluated, as these variables determine the type of stream found in a given location. Each reach was assigned a letter classification from A through G. As described in the previous section, much of the river flows through a very flat alluvial valley, where the river floods wide areas and deposits fine sediments on the adjacent floodplain. In this setting, the meandering E and C stream types dominate. In other areas where the valley is narrow; B type streams occur. These reaches contain narrow floodplains, with widths less than 2x the channel width. A single A-type stream exists in the upper watershed - where the river flows through a brief gorge. The floodplain in this reach is either very limited or non-existent.

Table 1. Valley and channel characteristics for the assessed reaches on the mainstem and tributaries of the Black River. Shaded rows delineate reaches which have had a Phase 2 Assessment.

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type*	Bedform	Streambed Substrate
M01	113	< 2	1.52	Very Broad	E	Dune-Ripple	Sand
M02	112	< 2	1.00	Narrowly-Confined	B	Dune-Ripple	Sand
M03	81	< 2	1.38	Broad	E	Dune-Ripple	Silt
M04	78	< 2	1.10	Semi-Confined	E	Dune-Ripple	Sand
M05	102	< 2	2.03	Broad	C	Dune-Ripple	Sand
M06	108	< 2	0.98	Narrowly-Confined	B	Plane Bed	Cobble
M07	64	< 2	1.04	Very Broad	C	Riffle-Pool	Gravel
M08	87	< 2	1.12	Broad	C	Riffle-Pool	Gravel
M09	105	< 2	1.07	Narrow	C	Plane Bed	Cobble
M10	104	< 2	1.00	Narrowly-Confined	B	Plane Bed	Boulder
M11	104	< 2	1.06	Semi-Confined	B	Plane Bed	Cobble
M12	102	< 2	1.25	Broad	C	Riffle-Pool	Gravel
M13	101	< 2	1.09	Semi-Confined	B	Riffle-Pool	Cobble
M14	75	< 2	1.09	Broad	C	Dune-Ripple	Sand
M15	97	< 2	1.40	Broad	C	Dune-Ripple	Sand
M16	46	< 2	1.58	Very Broad	E	Dune-Ripple	Sand
M17	45	< 2	1.39	Broad	E	Dune-Ripple	Sand
M18	87	< 2	2.01	Broad	E	Dune-Ripple	Sand
M19	85	< 2	1.15	Narrow	C	Dune-Ripple	Sand
M20	85	< 2	1.98	Very Broad	E	Dune-Ripple	Sand
M21	82	< 2	2.10	Broad	E	Dune-Ripple	Sand
M22	80	< 2	1.50	Broad	E	Dune-Ripple	Sand
M23	46	< 2	1.46	Very Broad	E	Dune-Ripple	Gravel

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type*	Bedform	Streambed Substrate
M24	46	< 2	1.14	Very Broad	E	Dune-Ripple	Gravel
M25	72	< 2	1.58	Very Broad	E	Dune-Ripple	Sand
M26	71	< 2	1.16	Very Broad	C	Dune-Ripple	Sand
M27	70	< 2	1.63	Very Broad	E	Dune-Ripple	Sand
M28	68	< 2	1.89	Very Broad	E	Dune-Ripple	Sand
M29	38	< 2	1.50	Very Broad	E	Dune-Ripple	Sand
M30	54	< 2	1.38	Very Broad	C	Dune-Ripple	Sand
M31	54	< 2	1.00	Semi-Confined	C	Step-Pool	Boulder
M32	54	< 2	1.13	Broad	C	Riffle-Pool	Cobble
M33	53	< 2	1.00	Narrowly-Confined	A	Bedrock	Bedrock
M34	53	< 2	1.58	Broad	E	Dune-Ripple	Sand
M35	26	< 2	1.33	Very Broad	C	Not Evaluated	Not Evaluated
M36	23	< 2	1.23	Very Broad	C	Not Evaluated	Not Evaluated
M37	18	< 2	1.14	Very Broad	C	Not Evaluated	Not Evaluated
T1.01	30	<2	1.14	Very Broad	C	Dune-Ripple	Sand
T1.02	28	<2	1.02	Very Broad	C	Dune-Ripple	Sand
T1.03	26	<2	1.01	Broad	C	Riffle-Pool	Sand
T1.04A	26	<2	1.12	Very Broad	E	Riffle-Pool	Cobble
T1.04B	26	<2	1.12	Very Broad	C	Riffle-Pool	Cobble
T1.05	18	<2	1.06	Very Broad	C	Dune-Ripple	Sand
T1.06	17	2.6	1.10	Very Broad	C	Riffle-Pool	Sand
T1.07	17	<2	1.10		C	Dune-Ripple	Sand
T2.01	14	<2	1.28	Very Broad	E	Riffle-Pool	Gravel
T2.02A	22	<2	1.46	Very Broad	E	Riffle-Pool	Gravel
T2.02B	22	<2	1.46	Very Broad	E	Riffle-Pool	Gravel
T2.03	19	4.9	1.06	Narrowly-Confined	A	Plane Bed	Cobble
T2.04	9	3.2	1.11	Semi-Confined	B	Plane Bed	Gravel
T2.05	7	<2	1.03	Very Broad	C	No Data	Silt
T4.01	44	<2	1.65	Very Broad	C	Dune-Ripple	Silt
T4.02	44	<2	1.12	Narrow	B	Riffle-Pool	Sand
T4.03A	31	<2	1.50	Very Broad	E	Riffle-Pool	Gravel
T4.03B	31	<2	1.50	Very Broad	E	Ripple-Pool	Gravel
T4.04A	35	<2	1.30	Broad	C	Riffle-Pool	Gravel
T4.04B	35	<2	1.30	Very Broad	E	Riffle-Pool	Sand
T4.05	33	<2	1.37	Very Broad	C	Dune-Ripple	Sand
T4.06	28	<2	1.10				
T4.07	23	<2	1.17	Very Broad	C	Dune-Ripple	Silt
T4.08	17	<2	1.18	Very Broad	C	Dune-Ripple	Silt

Reach	Channel Width (ft)	Channel Slope (%)	Sinuosity	Valley Type	Reference Stream Type*	Bedform	Streambed Substrate
T4.09	14	<2	1.16	Very Broad	C	Dune-Ripple	Silt
T5.01	26	<2	1.31	Very Broad	C	Dune-Ripple	Sand
T5.02	26	2.1	1.07	Very Broad	C	Riffle-Pool	Cobble
T5.03	24	4.6	1.08	Narrowly-Confined	A	Step-Pool	Cobble
T6.01	20	<2	1.38	Very Broad	C	Dune-Ripple	Sand
T6.02A	20	2.0	1.13	Very Broad	C	Riffle-Pool	Gravel
T6.02B	33	2.0	1.13	Very Broad	C	Riffle-Pool	Gravel
T6.02C	30	<2	1.13	Very Broad	C	Plane-Bed	Gravel
T6.03	19	5.3	1.04	Narrowly-Confined	A	Step-Pool	Cobble
T6.04	13	9.2	1.07	Narrowly-Confined	A	Step-Pool	Cobble
T8.01	21	<2	1.01	Very Broad	C	Riffle-Pool	Gravel
T8.02	20	<2	1.13	Very Broad	C	Riffle-Pool	Gravel
T8.03	20	5.6	1.08	Narrowly-Confined	A	Step-Pool	Cobble
T8.04	17	5.1	1.03	Narrow	A	Step-Pool	Cobble
T8.05	15	4.0	1.09		A	Plane Bed	Gravel
T8.06	4	33.4	1.04	Narrowly-Confined	A	Cascade	Boulder
T12.01A	41	<2	1.17	Very Broad	C	Riffle-Pool	Gravel
T12.01B	41	<2	1.17	Very Broad	E	Riffle-Pool	Gravel
T12.02	41	<2	1.19	Narrow	B	Riffle-Pool	Gravel
T12.03	29	2.2	1.13		B	Riffle-Pool	Gravel
T12.04	29	2.4	1.15	Narrow	B	Riffle-Pool	Gravel
T12.05	19	3.9	1.10	Narrowly-Confined	A	Step-Pool	Cobble

*** See Appendix B for stream type descriptions**

3.4 ECOLOGICAL SETTING

The Black River Watershed occupies both the Northern Green Mountains and the Northern Vermont Piedmont biophysical regions, with elevations ranging from 682 ft at the South Bay of Lake Memphremagog to 2,535 ft in the Lowell Mountains. Microclimate extremes can vary widely within the watershed, as evidenced by a range in average annual precipitation from 48 inches in the highlands of the Lowell Range, to 37 inches near Newport (Schultz et al.1979).

Most of the watershed is relatively low in elevation and average temperatures tend to be milder than in other parts of the Northeast Kingdom, particularly at the lower reaches of the watershed near Lake Memphremagog. This relatively mild climate, in combination with fertile calcium-rich soils, has encouraged agricultural activity and subsequent fragmentation of the landscape.

The Lowell Mountains, which form the western border of the watershed, feature largely unfragmented forest and have been identified as an important potential linkage for wildlife movement between the Green Mountains and the large swaths of state and federally protected land in Essex County. Recently, the Lowell Mountain ridgeline has been proposed to be developed for wind energy.

The watershed includes a wide diversity of natural community types, with the dominant matrix type being Northern Hardwood Forest. Rich Northern Hardwood Forest is not uncommon in cove, toe slope, and some side slope areas, due to mineral enrichment (primarily calcium) present in the bedrock and soils. The most significant natural communities identified to date, however, are located in the wetlands, and include many unique and high quality examples harboring a variety of rare plant species. These were most recently catalogued in a Lake Memphremagog watershed wetland ecological inventory conducted by the Vermont Nongame and Natural Heritage Program (Engstrom et al 1999), which provided much of the information summarized here.

Extending across roughly 650 acres, the complex of wetlands along the lower Black River (mostly within the South Bay Wildlife Management Area), include some of the most extensive and highest quality natural communities in the watershed – and in the state. A few examples include riverine floodplain forest, red maple-northern white cedar swamp, buttonbush swamp, sedge meadow, sweet gale shoreline shrub swamp, and river mud shore. A state-endangered sedge species and several other uncommon plants occur here, though the extent and diversity of the complex are the greatest source of its overall value and ecological benefits.

Other highly significant wetland communities are found in various locations along the Black River mainstem, including near Great Hosmer Pond, at various locations in the Craftsbury area, and in the Albany area. Found within this mix of northern white cedar swamp, alder shrub swamp, silver maple floodplain forest, oxbow sedge meadow, alluvial shrub swamp, and red maple-black ash swamp are such rarities as the state endangered marsh valerian and mare's tail, the rare nodding trillium, the state-threatened fairy-slipper orchid, and uncommon breeding birds such as three-toed and black-backed woodpeckers, Tennessee warbler, and rusty blackbird.

For 27 miles between Irasburg and Craftsbury, the Black River floodplain forms a nearly continuous wetland complex that was encroached upon by agricultural fields in the past, and that still contains some active agricultural usage. This area appears to be inundated with flood waters at least once per year. During the summer of 2009 (a wet year), this area was flooded well into the beginning of July. Agricultural use was much more prevalent historically than it is today, and several areas appear to be transitioning from former fields. Between Irasburg and the Route 14 bridge several miles to the south, the river's floodplain is highly impacted by agriculture, with large patches of very scenic floodplain forest interspersed with oxbows. Upstream of Route 14 bridge, the river meanders through a wide floodplain comprised of silver maple floodplain forest, extensive alder shrub swamps, scattered cedar swamps, and oxbows in various stages of succession. It is possible that, due to the former agricultural use in the area, many of the alder wetlands are successional in nature and will eventually grow into floodplain forest.

The floodplain near the Albany/Craftsbury town line is highly impacted by agricultural practices, however upstream of the town line the floodplain is very wet, the river very sluggish, and the landscape is fallow and transitioning from its agricultural past. Upstream of North Craftsbury Road, the floodplain is dominated by a mixture of wet sedge meadows and alder swamps. Some of the sedge meadow is pastured. Several beaver ponds exist and this region is adjacent to Mud Pond. Again, it is very possible that these community types are in transition between their former agricultural uses and eventual floodplain forest.

Upstream of Black River Road, the wetlands have been drained and converted to agriculture. Small portions of silver maple floodplain forest exist, indicating the former natural state of this region. The next wetland complex occurs upstream of Whitney Brook. These upper, isolated reaches of the Black River, are impacted by beaver activity and flooded in many areas. The forest adjacent to this area is primarily cedar swamp and shrub swamp.

4. METHODS

4.1 PHASE 1 ASSESSMENT

The Stream Geomorphic Assessments were completed using protocols established by the Vermont Agency of Natural Resources (State of Vermont 2007). The Phase 1 assessments were preliminary evaluations of selected reaches and sub-watersheds through three types of sources: remote sensing, other survey datasets, and brief "windshield" surveys. Most of the Phase 1 Assessment was completed using the following data layers (additional details about the data collected and their sources are in Appendix A):

1:24,000 USGS topographic maps (1988)
1:62,500 USGS topographic maps (1928, 1953)
1:5,000 Aerial orthophotographs (1974, 2003)
1:5,000 Vermont Hydrography Data Set
Land use – land cover maps (1990s)
Vermont Significant Wetland Inventory maps (2006)
National Wetlands Inventory maps (1975-1978)
Natural Resource Conservation Service Soil Maps (1990s)

Significant streams (generally >0.25 miles in length) within the Black River Watershed represented in the Vermont Hydrography Data Set (VHD) were divided into individual reaches and sub-watersheds. 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 reach and sub-watershed included the following:

Reach number and length
Valley length and width
Stream corridor land cover / land use
Predicted channel width
Sub-watershed area
Sub-watershed land cover / land use
Channel slope and valley slope

Through evaluation of new and old topographic maps and aerial photographs as well as field visits, we evaluated the following features:

Stream type / stream bed material	Presence of alluvial fans
Valley side slopes	Ground water inputs
Stream migration	Depositional features
Meander belt width and wavelength	Grade controls

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

Land use / land cover	Historic land use / land cover
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. These data sets were reviewed by River Management staff and any needed changes were noted in the DMS. The complete DMS datasets are available to the public at https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm.

4.2 PHASE 2 ASSESSMENT

The Phase 2 assessments consisted of in-depth mapping and evaluation of the river and involved wading or paddling entire reaches. The data collected included sketch maps, photographs, channel profiles, 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:

Streambank erosion	Beaver dams
Channel straightening	Debris jams
Streambank armoring	Stormwater inputs
Floodplain development	Stream migration
Bridges and culverts	Grade controls
Floodplain encroachments	Channel profile
Riparian buffer width	

The river's geomorphic condition was rated 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. Additionally, we evaluated the aquatic and riparian habitat for each reach. The conditions of the following habitat-related features were evaluated in the field:

Riparian buffer width	Riffle frequency
Streambed substrate embeddedness	Streambank stability
Pool variability and depths	Channel flow status
Velocity/depth patterns	Epifaunal Substrate and fish cover
Channel Alteration	Sediment deposition

All of the features were mapped with the SGAT extension and are presented in the following pages of this report. Like the Phase 1 data, the complete Phase 2 datasets are available to the public in the DMS database.

4.3 QA/QC SUMMARY

This project was completed in accordance with an approved Quality Assurance Project Plan developed in conjunction with River Management Program (RMP) staff. 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 2007). In addition, DMS data were checked for blank fields and conflicting Phase 1 and Phase 2 data by NorthWoods' staff and RMP staff.

5. RESULTS AND DISCUSSION

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 such as forests and wetlands play important roles in watersheds by storing and filtering run-off, trapping sediment, reducing peak flood levels, and maintaining base flows during summer. The loss of these natural land cover types can affect watersheds in several ways. Deforestation and urban and agricultural development increase rainwater and snowmelt runoff by decreasing the amount of natural vegetation available to naturally filter water and sediment. Urban lands also contain impervious surfaces which quickly shed stormwater into adjacent drainages rather than slowly percolating it through the soil. The result is higher peak flood levels as well as high nutrient and sediment inputs. Consistently high stormwater runoff can cause a channel to enlarge, erode, and incise to accommodate high flows. Additionally, agricultural practices which rely on tilling increase the amount of bare soil which is susceptible to eroding during precipitation events or during the annual spring melt.

The Black River Watershed contains 75.9% natural land cover (Table 2, Figure 6). This category includes the land areas that are forested, transitioning to forest, wetlands, and surface waters. One interesting aspect of the Black River is the consistent wetland cover along the river. Wetlands comprise 6.4% of the watershed and are found along most of the river (except for approximately nine miles between Irasburg and Coventry) and in a large complex in South Bay

WMA. As a comparison, the Barton and Clyde Watersheds only contain 3.5% and 2.9% wetland cover, respectively, and the total wetland cover in Vermont is 5% (State of Vermont 1999). While some wetlands in the Black River watershed have been ditched and drained, and some are currently used for agricultural purposes, most exist as extensive wet meadows, alluvial shrub wetlands, cedar swamps, and silver maple floodplain forests.

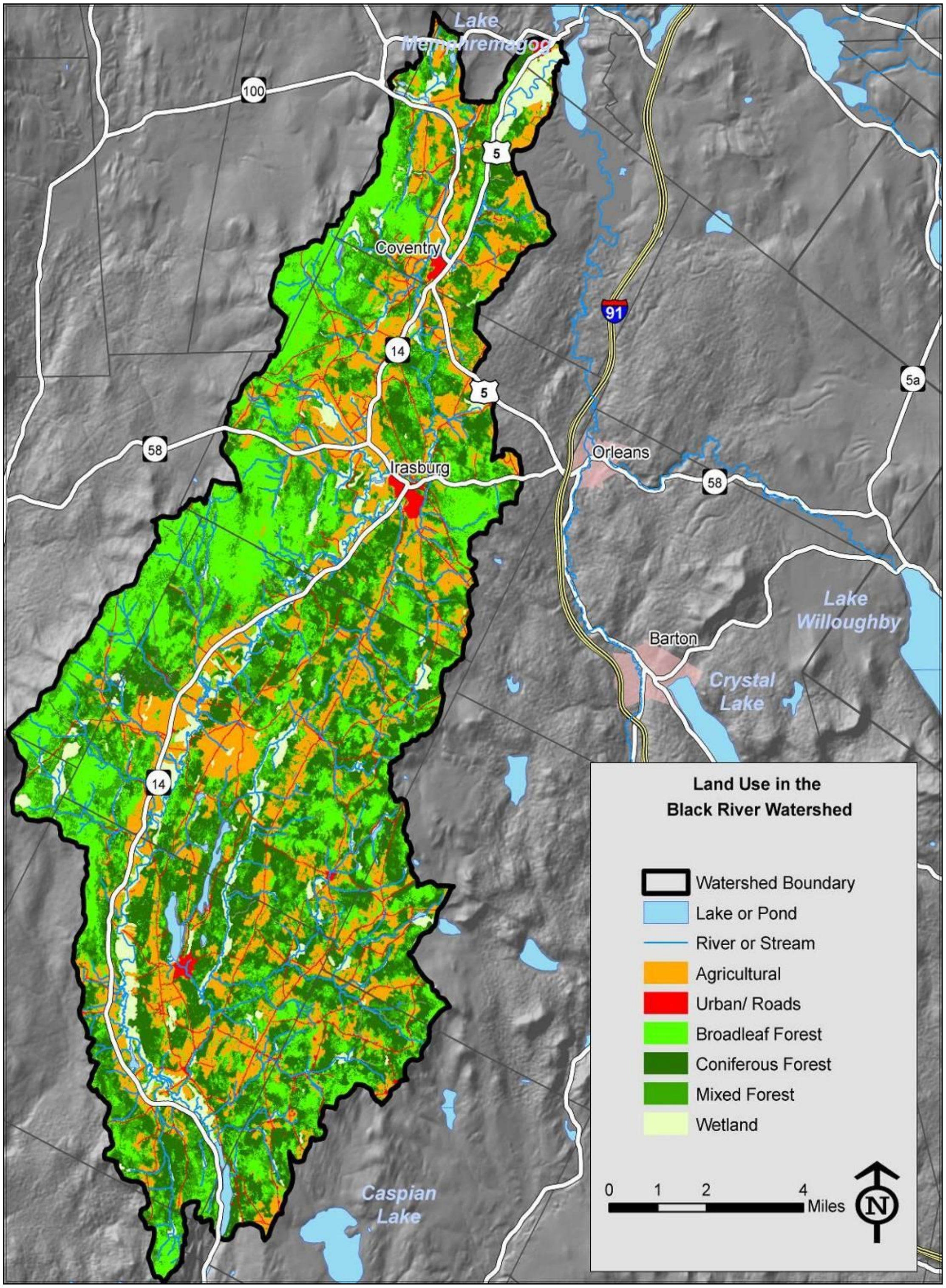

Figure 6. *Land Use in the Black River Watershed (Source: VCGI 2002).*

Forested land occupies the majority of the watershed area, nearing 66%, and forest types are split between deciduous, mixed, and coniferous. The Lowell Mountains constitute the largest tract of intact forested land in the watershed, while the remainder of the watershed consists of forests fragmented by agricultural fields and roads. Agricultural land uses amount to 19.4% of the total land cover, owing to the gentle topography that dominates much of the watershed (excluding the Lowell Mountains) and the fertile soils originating from nutrient-rich bedrock and alluvial deposits. Agriculture is split between pasture and hay fields (9.2%), which do not involve tilling of the soil, and row crops (10.2%) such as corn, which generally does involve tilling. Agricultural land use in the Black River Watershed totals 19.4% - slightly lower than the 20.9% of total land in Vermont that is currently in agricultural use (USDA 2007).

Urban areas, which include transportation, communication, and utility infrastructure; and residential, urban, and commercial lands, occupy a much smaller proportion of the watershed (4.7%). The Black Watershed contains the lowest concentration of urban lands of the four Memphremagog tributaries; the Clyde is the most urbanized at 8.6%, the Johns contains 8.5%, and the Barton Watershed contains 5.5%. The majority (3.8%) of the urban land in the Black Watershed is in the form of roads. The watershed is quite rural and contains several small town centers; most notably Coventry, Irasburg, Albany, Craftsbury Common, and Craftsbury Center. Residential development in these areas and scattered elsewhere in the watershed accounts for 0.8% of the land cover. Only a fraction of a percent of the land cover is devoted to commercial or industrial uses.

Table 2. Summary of Land Uses in the Black River Watershed (source: VCGI 2002)

Land Use	**Percentage of Watershed**	
Broadleaf forest (generally deciduous)	23.9%	Forested or brush: 65.8%
Mixed coniferous-broadleaf forest	22.2%	
Coniferous forest (generally evergreen)	19.4%	
Brush or transitional between open and forested	0.3%	
Forested wetland	4.6%	Wetland: 6.4%
Non-forested wetland	1.8%	
Hay/rotation/permanent pasture	9.2%	Agriculture: 19.4%
Row crops (not including orchards and berries)	10.2%	
Other agricultural land	0.1%	
Transportation, communication, and utilities	3.8%	Urban: 4.7%
Residential	0.8%	
Industrial	<0.1%	
Commercial, services, and institutional	0.1%	
Outdoor and other urban and built-up land	0.1%	
Water	3.7%	Other: 3.7%
Barren land	<0.1%	

Stormwater Inputs, Road Densities, and Urban Land Cover

To determine areas that may be responding to hydrologic stressors, we calculated the proportion of urban land within the overall watershed and the individual subwatersheds (Figure 7). Stormwater inputs noted in the field assessments, such as field and road ditches, tile trains, and urban stormwater inputs, are also shown. High road densities, urban land densities, and stormwater inputs can lead to channel enlargement due to sudden pulses of high water flows during rain events. These features move water quickly away from land surfaces and into stream channels.

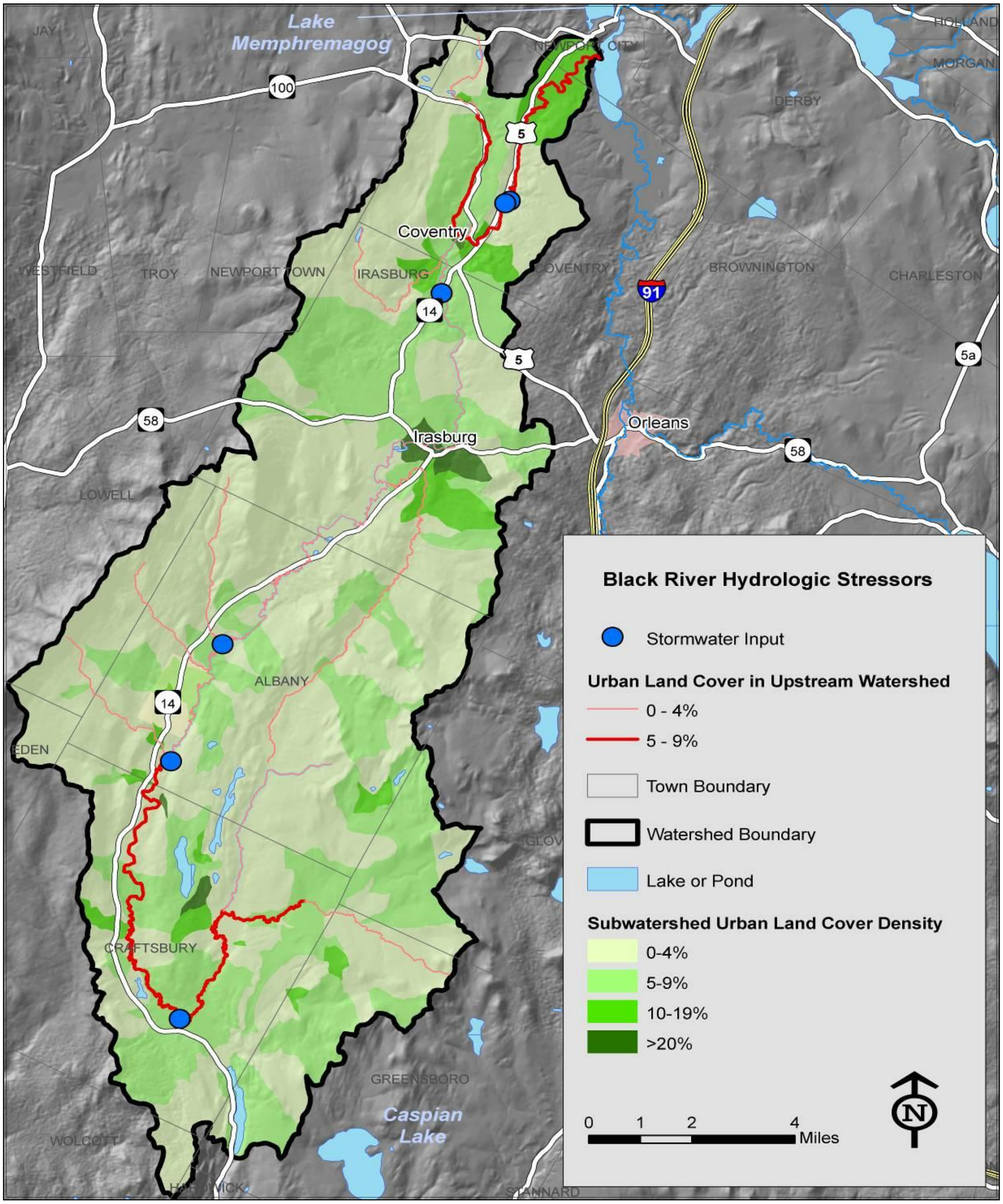

Figure 7. *Hydrologic stressors in the Black River Watershed.*

Despite paralleling Routes 14 and 5 for most of its length, the Black River is relatively removed from urban impacts as a whole. The river flows near the four small town centers of Craftsbury, Albany, Irasburg, and Coventry, but its passage through urban landscapes is brief. Between Irasburg and Craftsbury Route 14 occupies kame terraces and glacial lake deposits at the base of the Lowell Mountains along the west edge of the Black River valley, while the river itself occupies the eastern edge. In this section, the river is often 1000' from the highway. After flowing through Irasburg, it occupies a remote valley before flowing through Coventry. After Coventry, the river closely parallels Route 5 for several miles, but then veers away to South Bay. Because of its distance from town roads and highways, urban development along the river corridor is quite limited. As a result, stormwater inputs were uncommon during the field assessments and mostly consisted of occasional field and road ditches.

The Black River Watershed lies in a rural region; urban lands comprise 4.7% of the total watershed area. As stated in the previous section, most of the urban land is transportation infrastructure, with a small percentage as residential lands. Figure 7 displays the proportion of urban lands within each sub-watershed as shaded polygons, and also displays the cumulative urban land cover upstream of each stream reach as colored lines. Most of the impervious surfaces are scattered in low densities throughout the watershed. Higher densities are concentrated in Craftsbury, where the Black River is shaded dark red to indicate that upstream urban land cover approaches 5%. Very low impervious surface densities are in Albany, but high densities in three sub-watersheds exist in Irasburg. These sub-watersheds contain over 25% urban land cover, where there is both high residential use and a high road density that accompanies this use. One small sub-watershed in Coventry contains 53% urban land. In this area, both Stony Brook and the Black River upstream watersheds approach 5% urban land cover.

5.1.2 Sediment Regime Stressors

Channel Slope Modifiers

Many land uses conflict with the meandering and ever-changing nature of rivers. Rivers and streams are often straightened, dredged, and bermed to protect property investments or to make floodplains available for other land uses. Channel straightening and bank armoring remove or alter natural meanders, resulting in faster and more powerful flows. Similar results can occur when river sediments are dredged from the stream bed. These channel alterations directly affect the stream by increasing its slope and power, resulting in a higher sediment transport capacity and higher rates of erosion. Floodplain encroachments, such as roads, railroads, and berms, cut off sections of floodplain that are naturally utilized by the stream for gradual migration and deposition of flood-related sediments. These features can increase channel slope by eliminating the stream's ability to dissipate energy during flood stage, increasing flood damage to downstream areas. Many rivers have incised (eroded the stream bed) because of these alterations, further increasing the river's power during high flows. Additionally, the sediment transported by these reaches is deposited in downstream reaches, which in turn must adjust to inputs of the newly deposited sediments.

Certain man-made and natural features may decrease the slope of the channel as well. Grade controls including bedrock ledges, waterfalls, and beaver dams serve as natural barriers to increases in channel slope. Undersized bridges and culverts can cause a localized reduction in the channel slope. These aggradational areas can cause the river to form sharp meanders where flood flows are backed up.

Slope modifiers along the Black River mainstem and major tributaries are displayed in Figure 8;

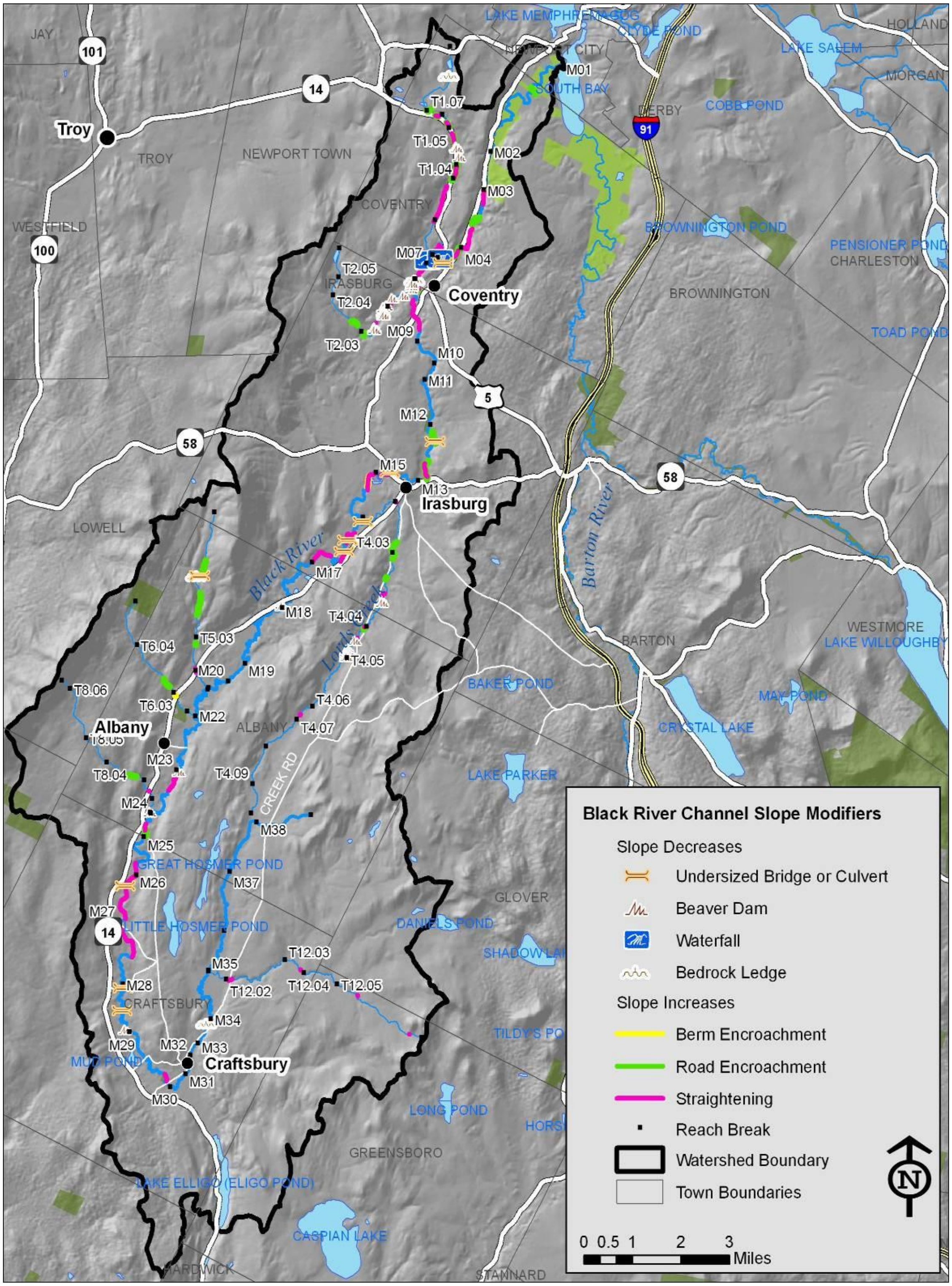

Figure 8. Slope modifiers along the Black River mainstem and assessed

these features were mapped if they fell within the Black River's corridor between Coventry and Craftsbury (M03-M29), or along the assessed tributaries. Undersized bridges and abutments were found throughout the river's length but were mainly concentrated (and had their greatest impact) on Reach M16, southwest of Irasburg. Several of these constrictions caused areas of bank erosion and sediment deposition immediately upstream, but most caused large areas of scour and deposition downstream, as a result of the velocity gained by water flowing through the narrow passages. Natural grade controls were concentrated in the Coventry area, where two waterfalls and one ledge were located. One ledge was also located in the upper watershed in Craftsbury.

Additionally, three active beaver dams were found along the slow, meandering portion of the river between Craftsbury and Irasburg, along with many more breached dams and debris jams.

Straightening was observed along 7.6 miles of the Black River, or about 16% of the assessed mileage. Straightening was most prevalent in Coventry and Irasburg where the river flowed through drier land that was more suitable for agriculture, but it also occurred along several miles of wetlands in north Craftsbury. The river's flow was slow and pond-like in Craftsbury, and during our 2009 survey the adjacent floodplain was inundated well into July. For these reasons, it appeared unlikely that this portion of the river will erode and regain its natural sinuosity in the near future. The straightened portions of the river in Irasburg and Coventry behaved differently. One of these reaches was incised (Reach M07), and several of these reaches contained areas of actively eroding riverbank and areas of new sediment deposition where the river was regaining a natural meandering profile. Less straightening (2.5 total miles or 6% of the assessed mileage) was found on the tributaries, the majority of this along Stony Brook.

Floodplain encroachments are fairly uncommon along the Black River. Those that were found were scattered along various sections of the river in Irasburg and Coventry. Most were road encroachments, though about 10% were from berms in the floodplain. Encroachments never occurred along both sides of the floodplain and left a broad area of floodplain on one side for the river to access. Only two miles of the Black River's floodplain was encroached upon, or about 4% of the assessed mileage.

Along the assessed tributaries, 2.7 miles of encroachments were found (6.8% of the total miles). These were almost entirely roads paralleling the stream within its floodplain on one side. They were encountered on all of the assessed tributaries except Whitney Brook, with the most substantial amounts concentrated on Stony Brook, Lamphear Brook, and Lords Creek.

<u>Sediment Load Indicators</u>

Indicators and sources of the sediment load within the Black River watershed are displayed in Figure 9. Agricultural land use is an important source of sediment and nutrients on a watershed scale because of the bare ground created by tilling crops, manure that is spread on fields, or to a lesser extent, runoff from pastured land. The percentage of land devoted to crop, hay, pasture, and other agricultural uses is shown in Figure 9 for each sub-watershed. Overall agricultural use in the watershed is 19.4%, and the use is concentrated in areas with the gentlest topography. Most of the larger tributaries originate in the Lowell Mountains where agricultural use is low, but use becomes high in the lower reaches of those tributaries as they near the Black River. Percentage of land in agricultural use in these four sub-watersheds is lower than the average for the overall watershed, at 3% for Lamphear Brook, 8% for McCleary Brook, 9% for Rogers Branch, and 12% for Ware Brook. Three tributaries contain agricultural use along much of their length and in a high proportion of their subwatershed - Lord's Creek (21%), Whitney Brook (21%), and Stony Brook (27%).

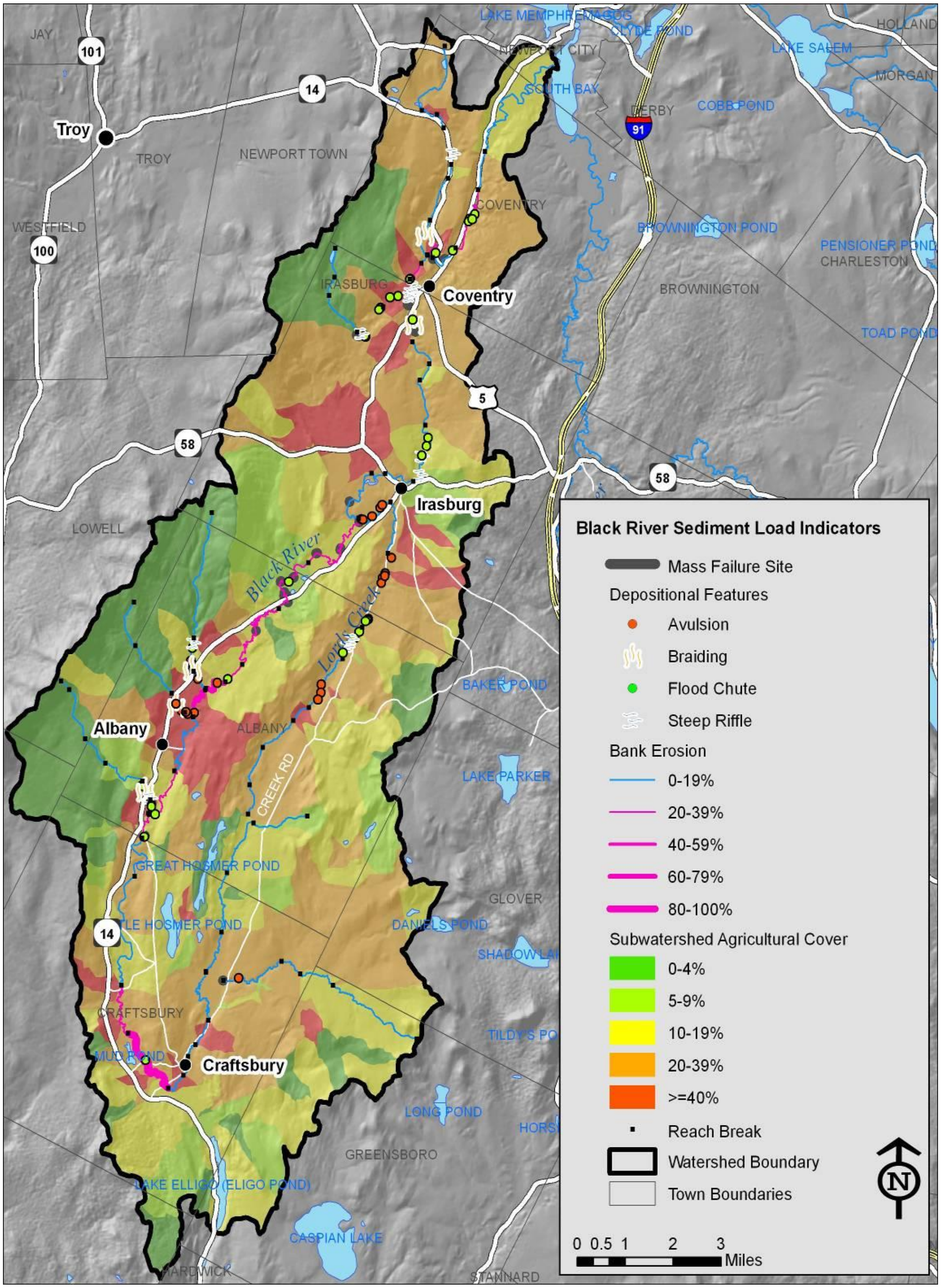

Figure 9. *Sediment load indicators along the Black River.*

Agricultural land along the Black River itself is more variable. Of the 38 sub-watershed reaches along the mainstem, two sub-watersheds contain low to moderate agricultural use (<10%). Twelve reaches contain high agricultural use (10-19%), eighteen contain very high agricultural use (20-39%), and six contain extreme agricultural use (40-50%). These concentrations in land use tend to be fairly evenly-distributed along the river's mainstem.

Figure 10. *Example of a mass failure site, located along Reach M16.*

Streams naturally erode, move, and deposit sediment as a response to varying flow levels and sediment inputs over time. Some river reaches are naturally unstable, such as those located on alluvial fans or at the base of very steep valleys. Others become unstable when human induced stressors, such as increased urban runoff, decreased stabilizing vegetation, dredging, straightening, etc, cause the river to react,. Thus, the river bed and banks can be a source of sediment as well. These sources were mapped during the 36 miles of "windshield" assessments from Coventry to Craftsbury (Reaches M03 through M29), and during Phase 2 surveys.

Along the Black River mainstem we found 22% of the banks eroding on either side – this in contrast to our 2007 survey of the Barton River mainstem that found that 52% of nearly 23 miles of river banks were eroding (Dyer 2008). Along many reaches of the Black River, riverbank erosion was only infrequently observed. Of the 27 surveyed reaches, 14 contained erosion rates of 0-19% of the reach length. The majority of these reaches occurred along the extensive wetlands downstream of Craftsbury as well as the swift, isolated, higher-gradient reaches in Irasburg. Ten of the reaches contained erosion rates of 20-39% of the reach length; these reaches were located along the fields and floodplain forests upstream of Lords Creek as well as the old fields downstream of Coventry. Three reaches contained erosion rates higher than 40%. Reach M29 was eroding the most, at 82% of the reach. This section of the Black River flowed entirely through pastures and hay fields, was not fenced off, and contained no stabilizing vegetation along its banks. Reaches M20 and M21 had erosion rates at 62% and 52%, respectively, and flowed through abandoned agricultural fields.

Mass failure sites (Figure 10) occur when a river erodes a hillside, and can be another significant source of sediment into the river channel. Seventeen mass failures were mapped along the Black River mainstem; ten of these located in three reaches upstream of Irasburg village (between the village and the Route 14 crossing), and five scattered near the Irasburg/Coventry town line. The remainder were located in Albany and Craftsbury. All of these mass failures occurred in fine gravel or sandy soils.

In addition to sources of sediment to the river channel, depositional features and channel adjustments are also displayed in Figure 9 for Reaches M03 through M29 and the assessed tributaries. These features can serve as indicators of a river's sediment load as it adjusts to high sediment inputs, and include steep riffles, channel avulsions, braiding, and flood chutes. Our data show that most of the Black River reaches are exhibiting signs of a large sediment load. The two reaches with the most depositional features per mile are Reaches M04, located upstream of the Route 5 crossing in Coventry, and M23, located upstream of the Rogers Branch confluence.

5.1.3 Channel Constrictions and Stream Crossings

Bridges and culverts that are narrower than the stream channel may decrease channel stability by causing excessive deposition upstream of the structure and increasing stream velocity and erosive energy downstream of the structure. This often results in localized areas of sediment deposition, erosion, fish passage problems, and ice and debris jams. In some cases, the stream constriction may increase the risk of flooding and property damage by forcing the river to flow around or over the bridge during high flows.

Figure 11: *Old abutment on Reach M16. Note narrow constriction, upstream scour pool, and resulting erosion downstream.*

Table 3 shows the widths of the bridges and other channel constrictions measured in the Phase 2 assessments and the during the Phase 1 windshield surveys. We found many stream crossings acting as channel constrictions along the Black River. Three of these constrictions were old bridge abutments that no longer serve as stream crossing structures. These abutments force the river through a passage that, in these cases, was less than half of the river's bankfull width. They are adversely affecting the river and would be excellent candidates for removal, particularly the abutments on Reach M16 (Figure 11). Bridges were the majority of the channel constrictions along the Black River, while undersized culverts were more commonly encountered on the tributaries. Eight of the 13 bridges were narrower than the channel width, however not all of the bridges appeared to affect the river. Where the river was affected, common features included large and deep scour pools (where water movement was swift), streambank erosion, and sediment deposition either upstream or downstream of the constriction.

Table 3. Summary of channel constrictions found during Phase 2 assessments of the Black River and its tributaries.

Reach	Road Name	Type	Bridge Span (ft)	Channel Width (ft)	% of Stream Width	Length of River Affected (ft)	Comments/ Problem Associated With Constriction
M03	Hi-Acres Rd	Bridge	62	75	83	0	None
M03	Route 5	Bridge	96	81	119	0	None
M04	Route 14	Bridge	140	78	179	0	800' of rip-rap on either side of bridge
M06	Heermanville Rd	Bridge	75	65	115	0	None
M08	Covered Bridge Rd	Covered Bridge	69	87	79	0	None – river is straightened past this point
M08	Route 14	Bridge	130	87	149	0	None – most of reach has been straightened
M08	N/A	Bedrock Outcrop	46	87	53	300	Deposition and channel braiding upstream of constriction
M12	Private	Covered Bridge	43	102	42	230	8' deep pool and mid-channel bar downstream of bridge
M16	N/A	Old Abutment	20	46	43	225	Causing large scour pool, mid-channel bar, and erosion downstream
M16	N/A	Old Abutment	21	46	46	160	Scour pool below, erosion upstream
M16	Farm Rd	Bridge	27	46	59	120	Large, >12' deep scour pool downstream, scour of bridge footers, low clearance
M16	Private	Bridge	18	46	39	Unknown	Erosion upstream and scour pool downstream of old wooden farm bridge
M22	Water St.	Bridge	40	46	87	0	None
M24	Wyllie Hill Rd.	Bridge	41	46	89	0	None
M28	N/A	Old Abutment	12	38	32	70	Scour pool downstream
M28	Post Rd.	Bridge	34	38	89	150	Scour pool downstream
M29	Cemetery Rd.	Bridge	38	38	100	0	None
T1.04	Nadeau Park Rd	Culvert	9	14	64	0	None- but undersized for channel
T1.04	Route 14N	Culvert	6	14	43	107	Scour pool and side bars downstream

Reach	Road Name	Type	Bridge Span (ft)	Channel Width (ft)	% of Stream Width	Length of River Affected (ft)	Comments/ Problem Associated With Constriction
T2.01	Snowmobile	Bridge	24	14	171	0	None- but washed off footers (will fail)
T2.01	Chilafoux Rd	Culvert	6	14	43	0	None- but undersized
T2.01	Hill and Dale Rd	Culvert	8	14	57	171	Side bars and sharp stream angle upstream
T2.02	Back Coventry Rd	Culvert	10	21	48	200	Side and mid-channel deposition and scour pool downstream
T2.02	Back Coventry Rd	Culvert	6	21	29	168	Side bars up and down stream and scour pool downstream
T4.03A	Creek Rd	Bridge	61	31	197	113	Some bank erosion upstream and side bars up and downstream
T4.03A	Farm Bridge	Bridge	13	31	42	0	None
T4.03A	Farm Rd	Culvert	8	31	29	Unknown	Scour pool and undermining downstream, deposition upstream
T4.03A	Labounty Rd	Culvert	12	31	39	180	Scour pool and deposition downstream; some bank erosion up and downstream
T4.04A	Creek Rd	Bridge	18	33	55	275	Deposition up and downstream
T4.04A	Chamberlin Hill Rd	Bridge	20	33	61	Unknown	Scour pool downstream and undermining footers; mid-channel deposits upstream
T4.04B	Farm Field Rd	Culvert	6	33	18	Unknown	Scour pool and some bank erosion downstream; sharp bend in upstream approach
T5.01	Route 14	Culvert	24	34	71	570	Some bank erosion upstream and sediment deposits up and downstream
T5.02	Shutteville Rd	Culvert	9	34	26	Unknown	Large scour pool downstream, mid-channel deposits up and downstream
T6.02C	Route 14N	Bridge	16	30	53	104	Scour pool downstream (undermining footers); bank erosion and side bars up and downstream
T6.02B	Farm Rd	Bridge	30	30	100	Unknown	None
T6.02B	Snowmobile	Bridge	19	30	63	Unknown	Side deposits and some bank erosion up and downstream
T8.02	Route 14	Culvert	12	31	39	108	Scour pool causing undermining, some bank erosion downstream; downstream rip-rap failing

5.2 CURRENT GEOMORPHIC CONDITIONS

5.2.1 Geomorphic Condition Ratings and Channel Evolution Stage

Since Euro-American settlement, watersheds and stream channels have undergone extensive modifications through deforestation, development, channel straightening, bank armoring, and other impacts. In many streams, these actions have led to increased peak flow levels, increased stream power, and decreased sediment storage. Subsequent consequences have included 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 12. Streams in stable or equilibrium condition are Stage I. These streams are in reference or good condition and have the ability to regularly access their floodplain, where they disperse sediment and energy. Reaches in fair or poor condition are currently evolving to regain stability; these streams will be in various stages of channel evolution. Stage II streams have incised 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 other 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 equilibrium. Finally, Stage V represents a new equilibrium and a re-established floodplain at a lower elevation.

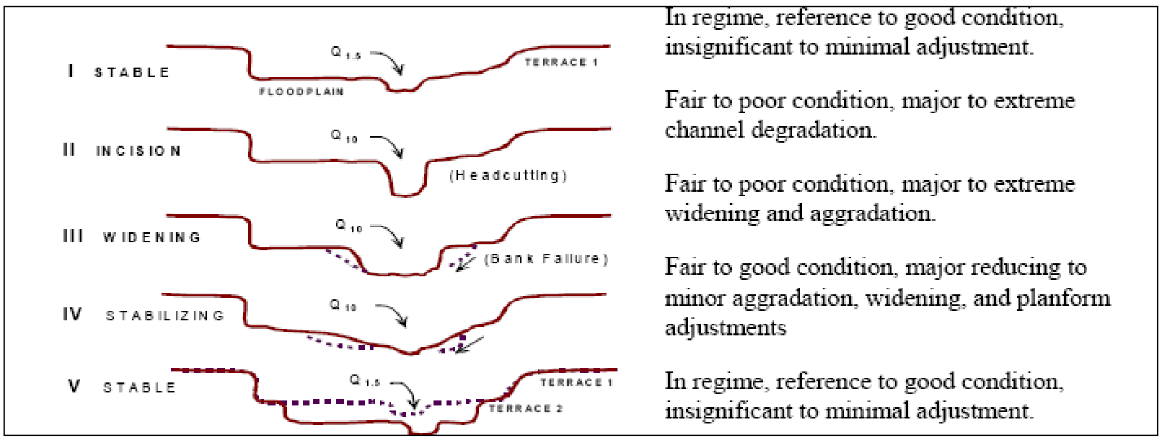

Figure 12: *Channel evolution processes (State of Vermont 2007); Stages I and V represent equilibrium conditions, and Stages II, III, and IV represent the channel degradation, widening, aggradation, and planform adjustments occurring as the stream adjusts to regain equilibrium.*

Figure 13 depicts the geomorphic conditions found along the Black River and its tributaries during our Phase 1 and Phase 2 assessments. Channel evolution stages were determined during the Phase 2 assessments. Based on the intensity of channel and floodplain modifications, as well as the overall stream condition observed during the field assessments, reach conditions were defined as reference, good, fair, or poor. Vermont ANR Stream Geomorphic Assessment Protocols describe these conditions as follows (State of Vermont 2007):

> **"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."

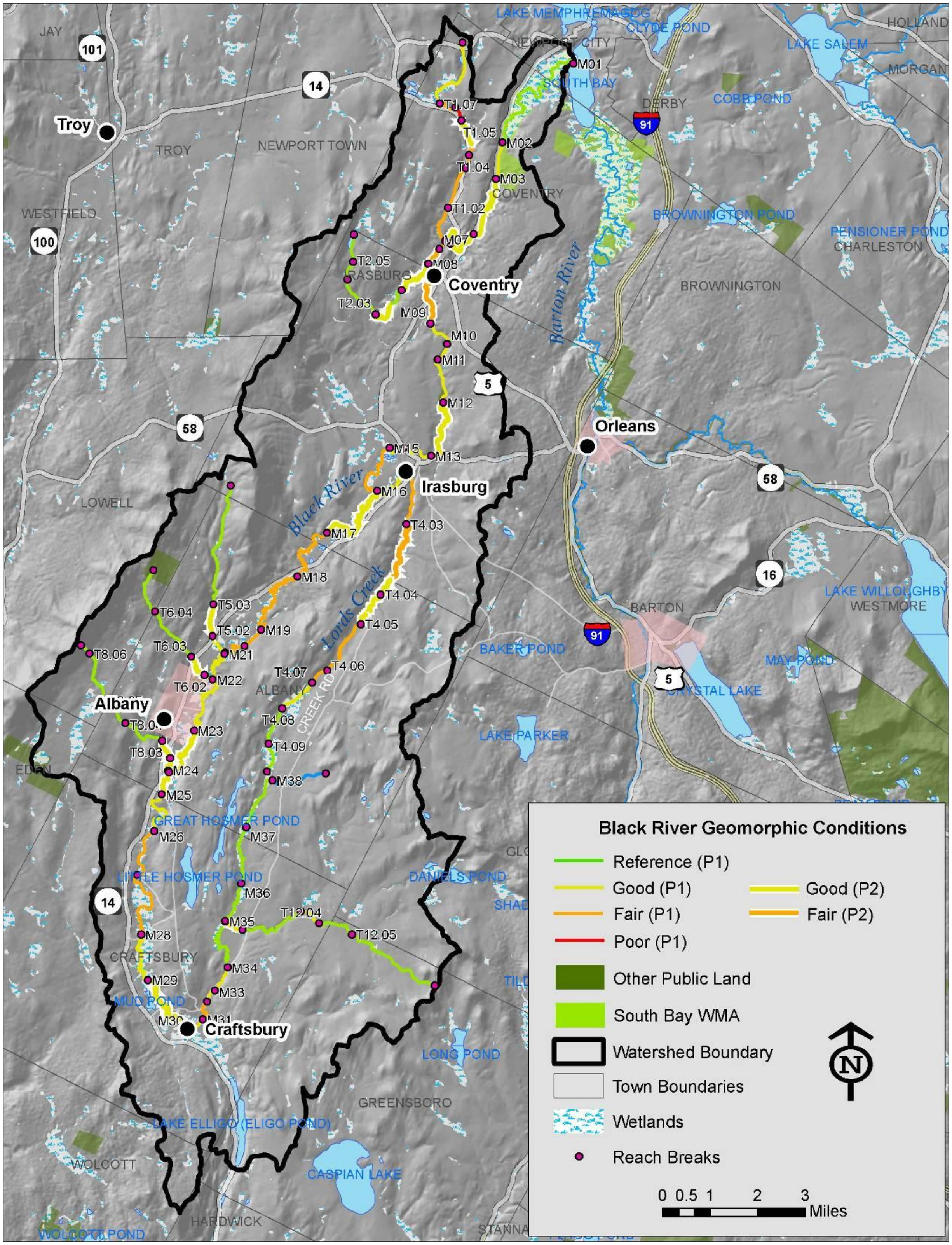

Figure 13. *Map of geomorphic conditions found during Phase 1 and 2 assessments .*

Along the Black River, our Phase 1 assessments identified 10 river-miles (20% of the total assessed miles) as in reference condition. These reaches were stable, well-connected with their floodplains, and lacked significant alterations to the channel or floodplains. The mainstem reaches in good condition totaled 14 miles (29%) and were less stable than the reference reaches. Finally, 22 miles (45%) were in fair condition and three miles (6%) were in poor condition; these reaches having higher impacts due to historic channel alteration - such as straightening - or current land use activities (generally agriculture).

Our Phase 1 analyses of the main Black River tributaries found these to be in better shape than the mainstem on average, with 19 miles (48%) in reference condition and eight miles (20%) in good condition. Reference conditions were again found most consistently in the forested upper headwaters regions of these streams. Within the tributaries, fair conditions were encountered on Lord’s Creek , Stony Brook, and in the lowest reach of Roger’s Branch, with a total of thirteen miles (33%) in fair condition. The only reach assessed as poor was 0.3 miles long (< 1%) and was located in an active gravel pit area along Stony Brook (T1.05).

Phase 2 field assessments targeted the more degraded reaches, and therefore recorded no reference level conditions. In our Phase 2 work along the mainstem, we found twelve miles (86%) to be in good condition, two miles (14%) in fair condition, and no reaches in poor condition. The Phase 2 tributary findings were slightly worse than along the mainstem, with seven miles (78%) in good condition, two miles (22%) in fair condition, and no reaches in reference or poor condition.

The two mainstem reaches ranked as fair in the Phase 2 assessments (M07 and M08) were straightened for a significant portion of their lengths, and one had incised. All but one of the Black River reaches (Reach M07) were in Stage I of channel evolution, meaning that they were in relatively stable condition and had no significant channel adjustments. Reach M07 was incised and appeared to be in stage IV of channel evolution, as it had significant areas of streambank erosion and was developing small gravel bars which will eventually form the new floodplain.

Among the tributaries, the only reach with a fair geomorphic condition in the Phase 2 assessments was in the lower-mid portion of Lord’s Creek (T4.03 segment A). This section passes through unbuffered farmland, with livestock accessing the stream in various places, and the streambanks here are eroding in many areas. It is important to note that additional reaches along Stony Brook and Lords Creek that were ranked as in fair or poor condition in Phase 1, could not be accessed for the Phase 2 surveys. These reaches were T1.01, T1.02, T1.03, T1.04A, T1.06, T4.02, T4.05, and T4.06.

5.2.2 Summary of Watershed-Scale and Reach-Scale Stressors

Both watershed-scale and reach-scale stressors are summarized in Table 4. These are the stressors that have influenced the geomorphic condition for each Phase 2 reach along the Black River mainstem. This table summarizes characteristics of each reach’s hydrologic regime, watershed-scale or upstream sediment inputs, stream power, and bank resistance. Urban and crop cover were summarized for each reach on the sub-watershed scale. Depositional features included mid-channel bars, steep riffles, delta bars, flood chutes, avulsions, and braiding.

Table 4: Summary of Watershed and In-stream Stressors for Phase 2 Reaches (Black River mainstem only)

	Watershed-Scale Stressors**		**Reach-Scale Stressors****	
River Segment (Existing Stream Type, CES, RGA score*)	**Hydrologic (urban land cover, stormwater inputs, wetland loss)**	**Sediment Load (depositional features, erosion, cropland, migration, mass failure)**	**Stream Power (Increase: straightening, encroachments; Decrease: deposition, migration)**	**Boundary Resistance (Increase: bank armoring, grade controls; decrease: erosion, reduced vegetation)**
M03 (E6, I, Good)	Increased flows: • Two stormwater inputs (road ditches)	Increased load: • Extreme (26%) cropland in sub-watershed • High (21%) bank erosion	Increased power: • High (28%) straightening	Decreased resistance: • High (21%) bank erosion • Reduced woody riparian vegetation
M04 (E5, I, Good)	Increased flows: • High (16%) urban land cover in sub-watershed	Increased load: • High (13%) cropland in sub-watershed • Abundant depositional features (>5/mile) • Low (8%) bank erosion • Two mass failure sites	Increased power: • High (40%) straightening Decreased power: • Abundant depositional features (>5/mile)	Decreased resistance: • Low (8%) bank erosion • Reduced woody riparian vegetation Increased resistance: • High (25%) bank armoring • One waterfall
M05 (C5, I, Good)	Increased flows: • Moderate (5%) urban land cover in sub-watershed	Increased load: • Extreme (45%) cropland in sub-watershed • Several depositional features (3-5/mile) • High (28%) bank erosion	Increased power: • High (72%) straightening Decreased power: • Several depositional features (3-5/mile)	Decreased resistance: • High (28%) bank erosion • Reduced woody riparian vegetation
M07 (C4, IV, Fair) Incision Ratio: 1.57	Increased flows: • Moderate (9%) urban land cover in sub-watershed	Increased load: • High (17%) cropland in sub-watershed • Several depositional features (3-5/mile) • High (21%) bank erosion	Increased power: • High (93%) straightening Decreased power: • Several depositional features (3-5/mile)	Increased resistance: • High (17%) bank armoring Decreased resistance: • High (21%) bank erosion • Reduced woody riparian vegetation

	Watershed-Scale Stressors**		Reach-Scale Stressors**	
M08 (C4, I, Fair)	Increased flows: • Moderate (7%) urban land cover in sub-watershed • One stormwater input (road ditch)	Increased load: • High (16%) cropland in sub-watershed • Several depositional features (3-5/mile) • Moderate (18%) bank erosion • Two mass failure sites	Increased power: • High (59%) straightening Decreased power: • Several depositional features (3-5/mile) • Braiding	Increased resistance: • Moderate (8%) bank armoring • Bedrock ledge in reach Decreased resistance: • Moderate (18%) bank erosion • Reduced woody riparian vegetation
M12 (C4, I, Good)	Increased flows: • Moderate (6%) urban land cover in sub-watershed	Increased load: • Moderate (9%) cropland in sub-watershed • Several depositional features (3-5/mile) • Low (6%) bank erosion	Increased power: • High (44%) floodplain encroachments • Moderate (18%) straightening Decrease: • Several depositional features (3-5/mile)	Decreased resistance: • Reduced woody riparian vegetation
M16 (E5, I, Good)	No Significant Stressors	Increased load: • Moderate (8%) cropland in sub-watershed • High (20%) bank erosion • Multiple migration features • Two mass failure sites	Increased power: • High (26%) straightening Decrease: • Multiple migration features	Decreased resistance: • High (20%) bank erosion • Reduced woody riparian vegetation
M23 (E4, I, Reference)	Increased flows: • One stormwater input (tile drain) • Some wetland loss	Increased load: • Moderate (5%) cropland in sub-watershed • High (39%) bank erosion • Few depositional features (1-2/mile)	Increased power: • High (30%) straightening Decrease: • Few depositional features (1-2/mile)	Decreased resistance: • High (39%) bank erosion • Reduced woody riparian vegetation (grazing)

	Watershed-Scale Stressors**		Reach-Scale Stressors**	
M24 (E5, I, Good)	No Significant Stressors	Increased load: • Moderate (9%) cropland in sub-watershed • High (21%) bank erosion • Multiple depositional features (>5/mile) • One mass failure site	Increased power: • High (21%) straightening Decrease: • Multiple depositional features (>5/mile)	Increased resistance: • High (21%) bank armoring Decreased resistance: • High (21%) bank erosion • Reduced riparian vegetation (mowing)
M29 (E5, I, Good)	Increased flows: • Moderate (6%) urban land cover in sub-watershed • Stormwater inputs (tile drain, field ditch) • Wetland loss	Increased load: • Moderate (9%) cropland in sub-watershed • High (82%) bank erosion • Few depositional features (1-2/mile)	Increased power: • Moderate (7%) straightening Decreased power: • Few depositional features (1-2/mile)	Decreased resistance: • High (82%) bank erosion • Significant loss of riparian vegetation

*For Stream Type descriptions, see Appendix B. Stream type lettering is followed by the dominant stream bed material: 1 = bedrock, 2 = boulder, 3 = cobble, 4 = gravel, 5 = sand; CES = Channel Evolution Stage (Figure 12); RGA Score = Rapid Geomorphic Assessment Score

** Urban land cover, crop land cover, straightening, bank erosion, encroachments, and bank armoring were listed if they exceeded 5% of the reach length..

5.3 RESULTS AND RECOMMENDATIONS FROM PHASE 2 FIELD SURVEYS

The results of the Phase 2 field surveys are described in the following pages for each assessed reach. Stream types given include the dominant bedform and substrate. In the accompanying figures, the locations of observed features are overlaid on 2003 (mainstem) or 2008 (tributaries) aerial photographs. The reach descriptions refer to left and right banks, which are determined when facing downstream. For an explanation of stream types, see Appendix B. Management recommendations are in bold.

Black River Mainstem Reaches:

Black River Reach M03 – *South Bay WMA to Route 5 Crossing*
Reference Stream Type: E dune-ripple, silt
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

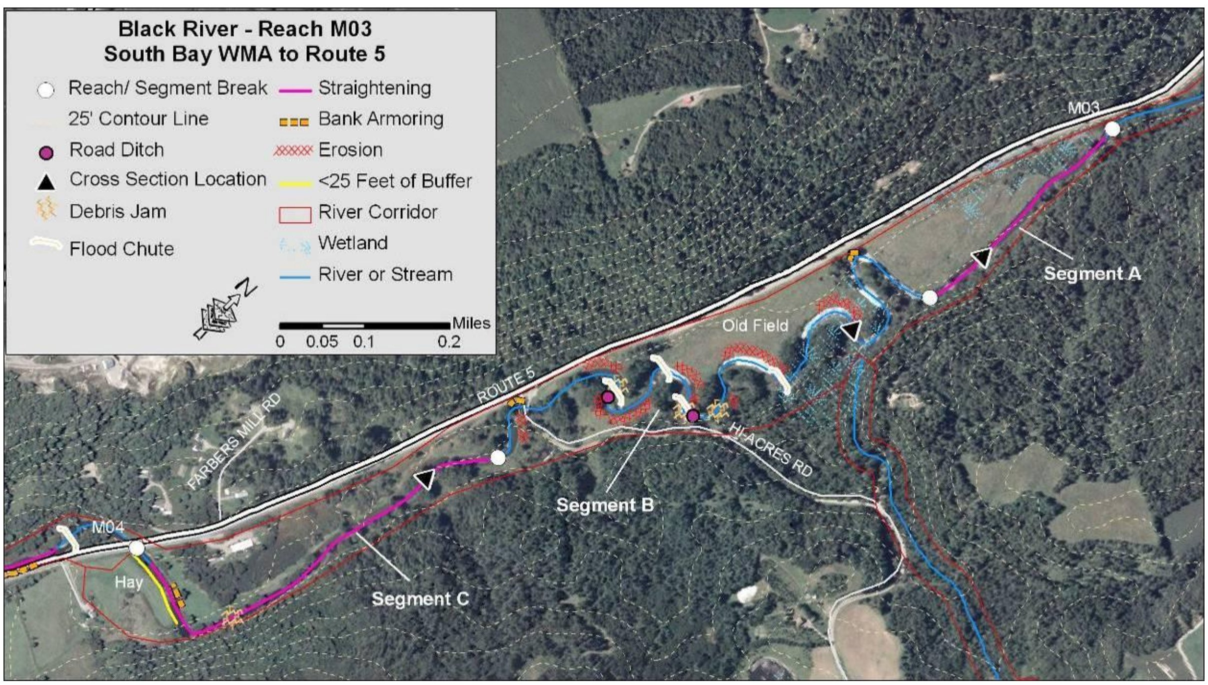

Figure 14: *Results for Black River Reach M03.*

Reach M03 (Figure 14) parallels Route 5 for its entire length, beginning near the Route 5 bridge a short distance downstream of Coventry village and ending 1.8 miles downstream as the river flows close to the highway. Half of this reach is within South Bay WMA, starting from Hi-Acres road and continuing downstream. The reach was segmented after initial surveys, due to historic straightening in the beginning and ending segments. Segment A is at the lower end of the reach. In segment C the river is shallow and flows straight mainly along the valley wall (right bank). The landscape along the left corridor consists of scattered silver maple trees with an ostrich fern understory along the fringes of a fallow field, while the steep right bank hillside contains many seeps among a hemlock forest. Downstream of Hi-Acres Road (segment B), the river meanders through fallow fields, and becomes slower, deeper, and more silted. Along this portion of the river, the riverbanks are covered by herbaceous plants (mostly grasses) with occasional silver maple and willow trees, particularly along the right side. Most outside bends are eroding, however in most instances the erosion appeared older and may be slowing.

The reach contains good aquatic habitat. Where present, the large silver maples provide ample large woody debris and detritus. The large logs and branches also provide scour pools and habitat complexity. Deep pools were frequently encountered; one pool measured over 15 feet in depth where the river flowed against a bedrock slope. In terms of re-establishing a forested buffer, **passive restoration would be a good management approach for this reach.** If the adjacent fallow fields (in the South Bay Wildlife Management Area) were allowed to become re-forested, this reach would become excellent habitat, dominated by silver maple floodplain forest and cattail marshes.

We noted two freshly-dug ditches from Hi-Acres Road draining directly into the Black River (Figure 15). These ditches were discharging silt into the river (during a dry period). A good management approach would be to **encourage road crews and landowners to use erosion control techniques,** such as seeding, erosion matting, or gravel along new ditches, particularly those that are dug through silty soils.

Figure 15. *Freshly-dug road ditch emptying into Reach M03.*

Black River Reach M04 – *Route 5 to first falls above Coventry*
Current Stream Type: E dune-ripple (riffle-pool is sub-dominant), sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

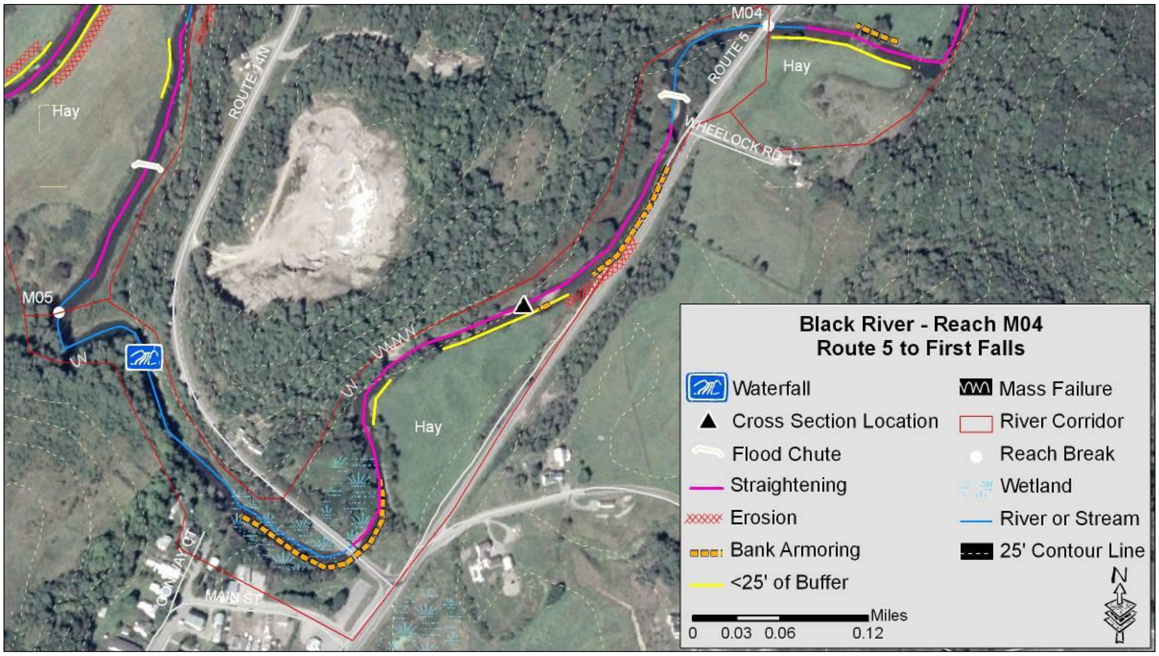

Figure 16: *Phase 2 results for Black River reach M04.*

Reach M04 (Figure 16) begins at the second of two waterfalls in Coventry and ends at the Route 5 crossing, approximately 0.5 miles downstream of the intersection of Route 14 and Route 5. This 0.8 mile reach is initially a swift, cobble-bed river near the 11-foot waterfall (Figure 17) but transitions to a slower river with a sandy bed. The channel shows many signs of historic alteration, with approximately 40% straightened and 25% lined with rip-rap. The areas that were rip-rapped are deep and slow flowing, but the areas lacking rip-rap are shallow and contain very soft, new sediment deposition. These areas are also wide, and contain mid-channel bars – indicating that the river's planform will change, though probably quite slowly.

Aquatic habitat is in fair condition. The reach flows along a hay field for about half its length. This area lacks natural riparian vegetation, as the field is mowed close to the river and there is little shade and few sources of debris. Elsewhere, the river flows through floodplain forest with large silver maples, occasional box elder, and an ostrich fern understory. A small portion of this field is eroding due to sediment deposition mid-

Figure 17: *Waterfall at upstream end of Reach M04.*

channel. Sediment deposition is common along the non-armored streambeds. Much of the channel bed consists of uniform, freshly-deposited sands and silts. Management of this reach should consider the historic straightening and current aggradational nature of the reach, and that the river is slowly attempting to regain natural meanders in this area.

A wider buffer should be established along the hay field to provide shade to the river, better riparian habitat, and to give the river room to re-form natural meanders. Additionally, existing populations of invasive tartarian honeysuckle *(Lonicera tatarica)* occur between the waterfall and the Route 14 crossing, and scattered purple loosestrife plants *(Lythrum salicaria)* are found throughout the reach and **should be removed.**

<u>Black River Reach M05</u> – *180-Degree Turn in Coventry*
Reference Stream Type: C dune-ripple (riffle pool is sub-dominant), sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

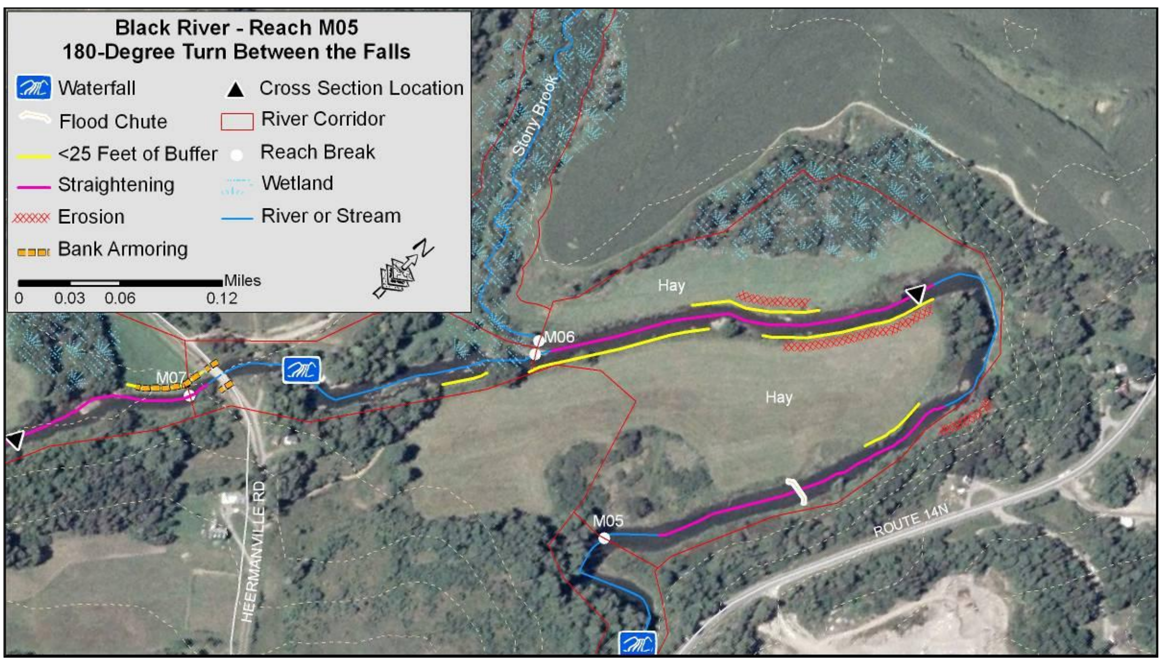

Figure 18: *Results for Black River Reach M05.*

Reach M05 (Figure 18) follows an interesting path after its origin at Stony Brook, flowing first straight toward the steep valley wall, then making a 180-degree turn while continuing to flow against the valley wall. Furthermore, the river makes this sharp bend prior to hitting the steep valley wall; however the water was too deep and murky during our visit to determine if this section had been armored to protect the hillside. Because it flows straight through an unconfined valley, most of the reach was likely straightened for agricultural purposes long ago, and it now lacks the natural sinuosity one would expect in this landscape. Reach M05 is not in reference geomorphic condition because of the anticipated channel adjustments brought on by the extensive straightening. The riverbanks are eroding in the first half of the reach, where flow is fastest, as the river adjusts to regain its natural sinuosity. Along the downstream half of the reach, the river flows against bedrock and is stable and unlikely to change quickly.

Habitat is only in fair condition due to alterations of the channel planform and alterations to the riparian corridor. The historic straightening of this channel has created a uniform stream bed in the upstream half of the reach, and pools were not observed until after the cross section location. Approximately 1,700 feet of riverbank also lacks a riparian buffer (Figure 19), and in the areas where mowing is not adjacent to the riverbank, only herbaceous vegetation is present. As a result, some benefits provided by woody vegetation are absent, such as ample woody debris in the channel and shade and cover along the riverbanks. Additionally, scattered purple loosestrife plants are found in this reach, as well as garbage thrown from Route 14. Management priorities in reach M05 include **re-establishing the riparian buffer through plantings of native trees and shrubs** and **removal of the invasive plants and garbage.**

Figure 19. *Hay fields along Reach M05 (facing upstream).*

Black River Reach M07 – *Heermanville Road to Ware Brook Confluence*
Reference Stream Type: C riffle-pool (plane bed is sub-dominant), gravel
Geomorphic Condition: Fair
Channel Evolution Stage: IV (aggrading)
Habitat Condition: Fair
Stream Sensitivity: Very High

Reach M07 (Figure 20) is 0.4 miles in length and flows between Ware Brook and Coventry Falls - a 7-foot waterfall occupying a brief but interesting constriction of the river valley. This reach has been artificially straightened in the past, as evidenced by its straight path through a wide and flat valley. Both historic (failed) and existing rip-rap is present, and both riverbanks exhibit signs of old erosion that has since stabilized. The reach is incised (incision ratio 1.6); a cross sectional measurement of the channel was taken at a lower terrace formed by an eroded riverbank that had stabilized (Figure 21). Because of the significant man-made alterations to the channel, and subsequent downcutting of the channel bed, the reach has been rated in fair geomorphic condition.

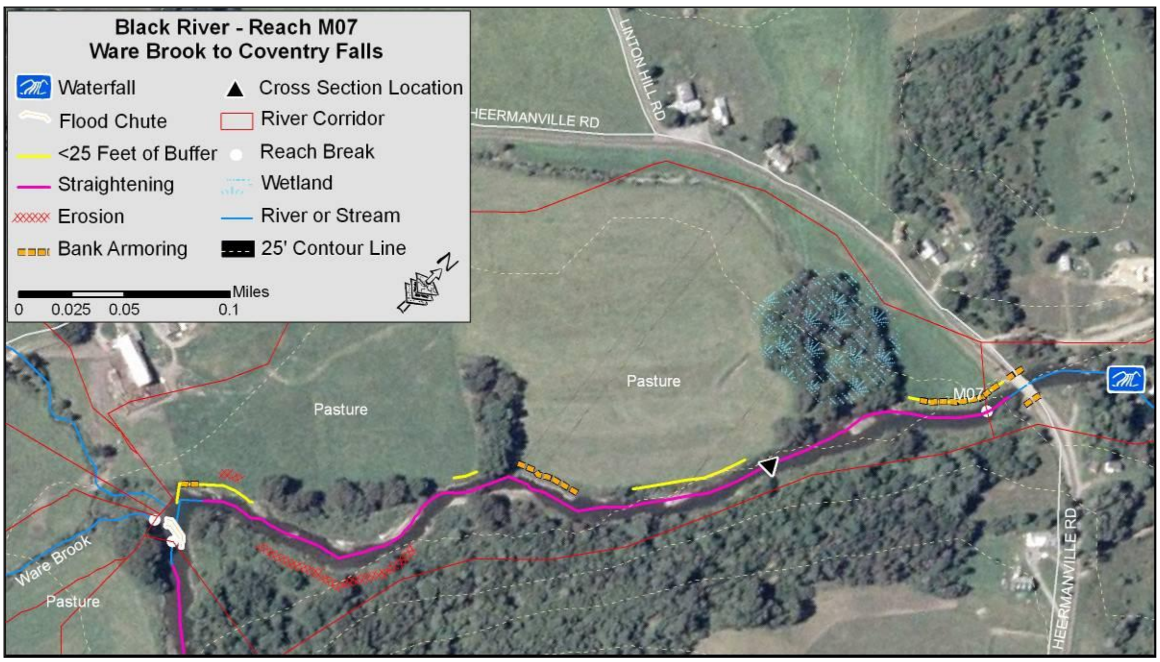

Figure 20: *Results for Black River Reach M07.*

Habitat is also in fair condition; as the reach is clearly receiving and reacting to fine sediment deposition. The dominant substrate of coarse gravels is approximately 35% embedded with finer silts and sands. Additionally, the channel bed is characterized by uniform plane-bed features, rather than the diverse riffles and pools that would naturally occur in this setting. As a result, portions of the streambed are fairly wide and shallow. Riparian vegetation is intact along the entire right corridor, and the upstream portion of the left corridor (Figure 22), but is lacking downstream. Instead, herbaceous vegetation dominates the left side, particularly where fences are placed close to the riverbank.

Future management actions should include **re-establishing a riparian buffer along the left bank** and **fence set-back**. A **corridor easement coupled with buffer planting** here would allow the river to re-establish natural meanders gradually while also improving habitat conditions.

Figure 21: *New, vegetated terrace (dashed line) used to determine the bankfull height on Reach M07.*

Figure 22: *The upstream portion of Reach M07, depicting the healthy riparian corridor in this area.*

Black River Reach M08 – *Upstream of Ware Brook*
Reference Stream Type: C riffle-pool (dune-ripple is sub-dominant), gravel
Geomorphic Condition: Fair
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: Very High

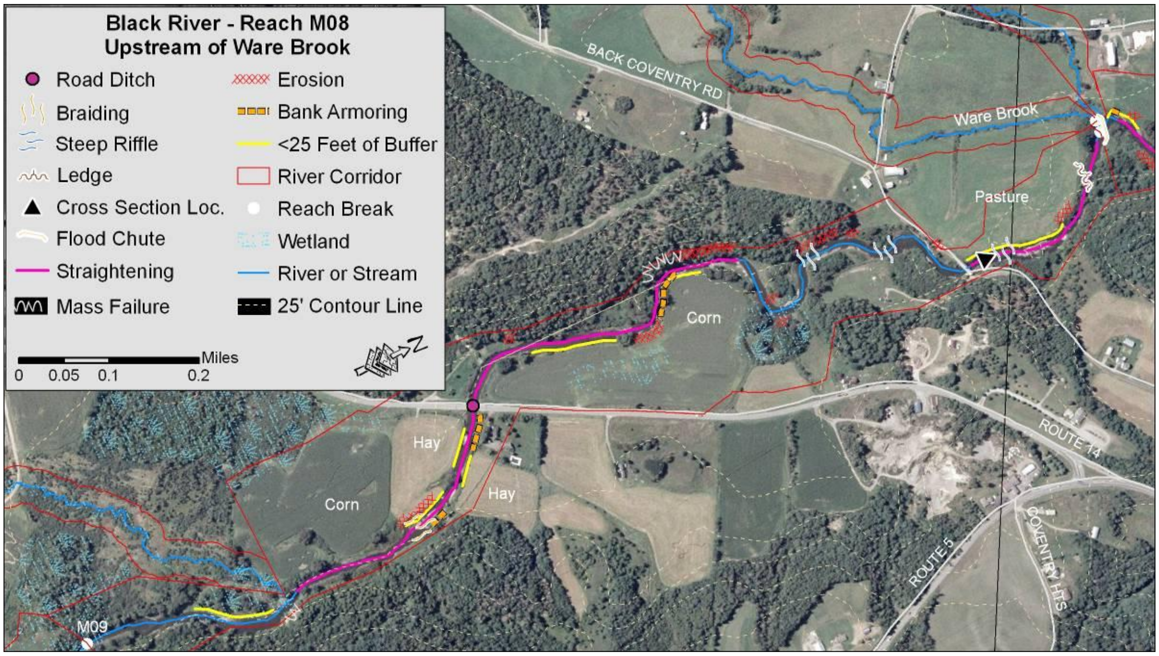

***Figure 23**. Results for Black River Reach M08.*

Reach M08 begins at the Ware Brook confluence and ends near the terminus of an interesting narrow and forested valley. This reach totals 1.5 miles in length and is a transition between the two miles of confined, transport-type reaches with gentle rapids upstream and the slow, sand-dominated reach downstream. As an unconfined section with a gentle slope, Reach M08 serves as a depositional area for the sediment carried from upstream. Several significant sediment sources were identified along these upstream reaches and the upper portion of Reach M08 including; a 4' wide gully, recent logging in the river corridor, a mass failure site, and an eroding logging road. In addition, 59% of the reach was straightened historically to facilitate agriculture along the river. Thus, this portion of the river is attempting to regain natural meanders while simultaneously accepting sediment inputs from upstream and within the reach. This is most obvious at a braided section near the Route 14 crossing, where the river has formed two islands that split the river into three channels. The left riverbanks are collapsing into the river and it is possible that the left channel will become dominant in the future. There is also a flood chute along the left side. This particular location is likely affected because a bedrock outcrop on the right riverbank is slowing flows along the right channel and causing the carried sediment to deposit at this location. Furthermore, the outcrop is preventing erosion along the right bank and causing the left bank to be the most affected.

After the Route 14 crossing, the river continues through a straightened section then, due to an armored riverbank, turns to flow against the valley wall (which is eroding into the river). Further downstream, the river flows at sharp angles into its banks. Three steep riffles, a mid-channel bar, and an island are present. The channel is very wide and shallow in this section (Figure 24), indicating another area of aggradation. The reach is rated in fair geomorphic condition because of its aggradational nature and the anticipated adjustments that the reach will experience as it transitions from a straight channel to a more meandering one.

Reach M08's geomorphic condition and past alterations to the channel affect the condition of its habitat as well, which is rated in fair condition. Pools are uncommon because much of the reach is wide, shallow, and affected by sediment deposition. Trees and other woody riparian vegetation are uncommon overall, though the river flows for a time adjacent to a nicely forested hillside (hemlock, white pine, and yellow birch), and portions of the right corridor include small patches of silver maple forest. Woody debris is rare in the channel, and much of the reach lacks shading vegetation. Scattered purple loosestrife plants are found along the river as well. Management recommendations are to **remove the purple loosestrife** and to **re-establish riparian buffers along the 2,300 feet** of unbuffered bank. **Corridor easements** along the straightened sections would also beneficial to allow the river to regain its natural meanders.

Figure 24. *Very wide portion of Reach M08, featuring a well-buffered corridor.*

<u>Black River Reach M12</u> – *Paralleling Covered Bridge Rd to Irasburg*
Reference Stream Type: C riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Reach M12 flows alongside the Covered Bridge Road, which is located approximately 0.5 miles west of the center of Irasburg (Figure 25). The reach totals 1.6 miles in length and flows between patches of silver maple floodplain forest and pasture. Located downstream of a narrow and cascading portion of river, it is rated in good geomorphic condition because upstream and in-reach stressors are minimal. Approximately 1,500’ of the reach is straightened, but this straightening was completed long ago. A covered bridge that is only 42% of the river’s width impacts about 230’ of river downstream of the bridge. The bridge impact includes an 8-foot deep scour pool and mid-channel sediment deposition. It appears that the reach is affected by sediment deposition, as multiple indicators of deposition are found. These include three flood chutes, three mid-channel bars, and two steep riffles. A small portion of the river’s banks are eroding.

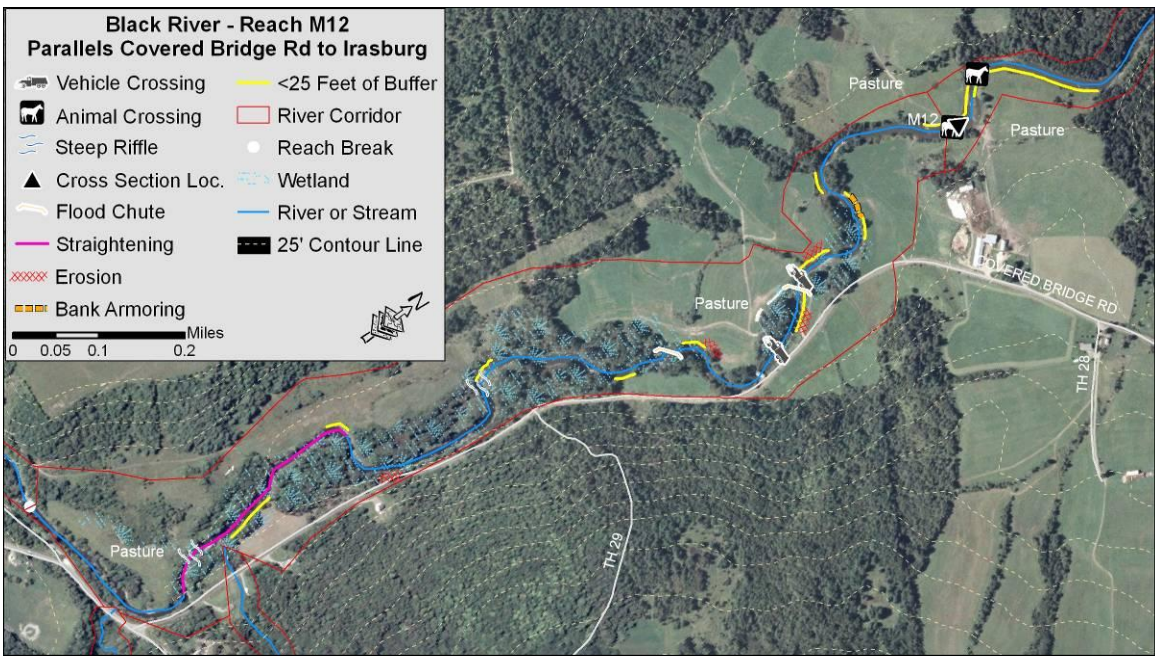

Figure 25. *Phase 2 results for Reach M12.*

Habitat is also in good condition. The majority of the upstream half of the river corridor contains a wide riparian buffer; though **fencing should be set back along parts of the downstream half of the reach and part of Reach M11**. Fencing is adequate along much of the corridor, though some is located closer than 25’ from the riverbank. **A wider natural buffer should be re-established** to introduce woody vegetation on the bare exposed riverbanks and to connect the good habitat found upstream with the excellent habitat located in downstream reaches. The upstream portion of M12 contains large willows and silver maples that lean into the channel, providing a source of shade to some sections. The reach contains a mix of deep pools and frequent riffles, though some areas are affected by sediment deposition (Figure 26). The coarse gravels that comprise the majority of the streambed material are approximately 60% embedded with fine sediments. Also, **a large patch of Japanese knotweed is located along Covered Bridge Road and should be removed.** This is one of only a few knotweed infestations encountered during the 2009/2010 Black River surveys.

Figure 26. *Sediment deposition along Reach M12.*

<u>Black River Reach M16</u> – *Lords Creek to Hill near Potters Pond*
Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Reach M16 (Figure 27) meanders for 2.6 miles upstream of the Lords Creek confluence through fields and interesting floodplain forests. This reach lies near the start of the wide and gently sloping valley that extends from Irasburg to Craftsbury, where the river meanders through extensive shrub and forested wetlands for approximately 27 miles. Several factors keep Reach M16 from being a reference reach. Approximately 26% of the reach was straightened to maximize agricultural use in the river corridor. Because most of the fields adjacent to the straightening are no longer utilized, it is likely that the river will re-establish meanders in these areas. Also, two bridges and two old abutments are much narrower than the channel, ranging between 39 and 59% of the channel width. In particular, the abutment near the Lord's Creek confluence appear to be exacerbating erosion of a 15' high bank downstream of the constriction, causing mid-channel deposition and erosion of the left riverbank (Figures 11, 29). **Removal of the abandoned abutments should be at least a long-term goal.** Riverbank erosion is present along the reach in patches - where the riverbanks retain only herbaceous vegetation and in the

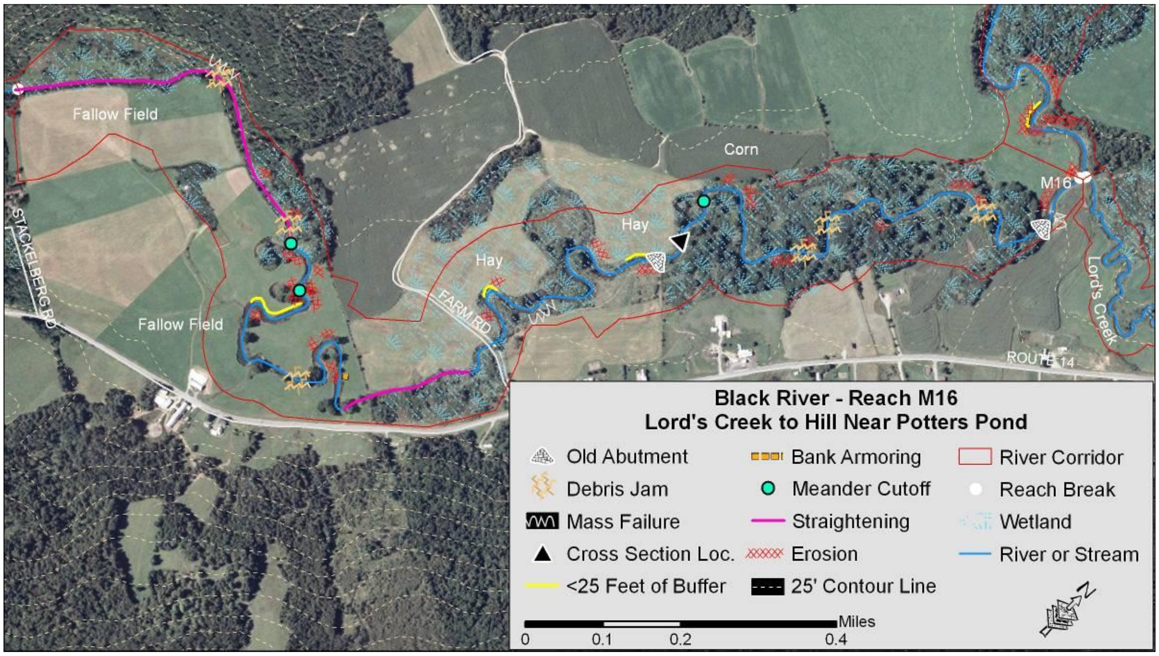

Figure 27. *Phase 2 results for Reach M16.*

Figure 28. *Reach M16, as photographed in 1962 after leaf drop, showing a mostly unforested corridor and a multitude of old oxbows.*

vicinity of debris jams. Active erosion is present along 20% of the reach, while many banks exhibit old erosion that has since stabilized. Interestingly, despite the meandering nature of the river and the very wet landscape, the corridor was once cleared for agriculture, and was in fact unforested as recently as 1962 (Figure 28). Three meanders have cut off since 1962 and the floodplain forest has re-established upstream of the Lords Creek confluence.

Habitat is in good condition; though channel straightening, streambank instability, and the lack of riparian vegetation are negatively affecting fish and wildlife habitat along the upstream half of the reach. Most of the fields in this section are fallow and wet, and will grow into floodplain forest if left unmanaged. Large basswood trees and occasional silver maple and butternut trees grow in patches along this section; otherwise shrubs dominate the riverbanks – including speckled alder, dogwood, and elderberry. The downstream half of the reach contains excellent riparian habitat where the silver maple floodplain forest has grown back and is providing shade and woody debris. Several oxbows are found along the reach. Large woody debris is plentiful throughout and provides in-stream habitat complexity.

A mix of passive and active restoration is needed for this reach. As mentioned previously, a **passive restoration** approach would be useful along the straightened portion of the reach, where fields are fallow and scattered shrubs and trees are already present along the riverbank. **Corridor easements** would make passive restoration more economically feasible, while also allowing the river the time and space to regain its natural meanders. Active restoration through a **buffer planting is needed** along the meandering portions further downstream where more active erosion is occurring and where the riverbanks only contain herbaceous vegetation. Also, a large patch of **tartarian honeysuckle** was found just below the straightened section and **should be removed** to prevent its further spread along the bare riverbanks downstream. Combined, these approaches will re-establish the forested wetlands and connect the habitat upstream of the Lord's Creek confluence with the extensive and high-quality habitat located upstream.

Figure 29. *Wide scour pool, eroding riverbanks, and mid-channel deposition downstream of an old abutment on Reach M16.*

Black River Reach M23 – *Shalney Branch to Rogers Branch*
Reference Stream Type: E dune-ripple, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

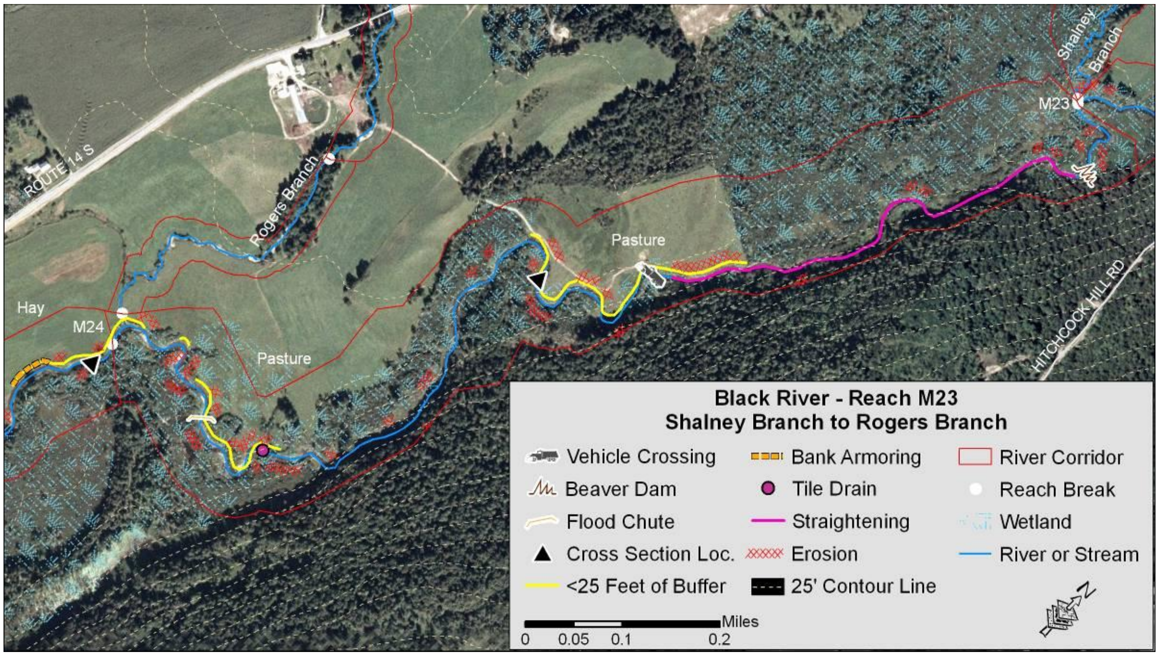

Figure 30. *Phase 2 results for Reach M23.*

Reach M23 (Figure 30) flows for 1.6 miles between the Shalney and Rogers Branches, which originate in the Lowell Mountains. The reach mainly meanders through alder-dominated wetlands and pasture, but also flows along the base of a steep hillside off the right riverbank. Reach M23 is in good geomorphic condition. Thirty percent of the reach is straightened where the river appears pushed against the right valley wall. Approximately 36% of the river lacks a riparian buffer on the left bank, where the buffer width is less than 5 feet along most of the portions highlighted in yellow in Figure 30. The lack of stabilizing vegetation and localized sediment inputs from the Rogers Branch are contributing to the river eroding along many outside bends, and **re-establishment of the riparian buffer should be a priority**.

Habitat is in good condition; with on-going sediment deposition, riverbank instability, historic straightening, and the lack of riparian buffer along the left corridor (Figure 30) keeping it from achieving reference condition. This reach is heavily influenced by beaver activity, with one active dam, one breached dam, and extensive sign throughout. Wood turtles, bobcat and mink sign were also observed. Given the very wet nature of the corridor, the landscape is naturally an alluvial shrub swamp, dominated by speckled alder. The river does flow against the valley wall for a time amid a mixed forest of hemlock, cedar, and deciduous tree species. At times the river flows against bedrock and here it has gouged deep pools into the riverbed. **Improved fencing is needed along the left corridor**, as cattle are currently accessing the river and having clear detrimental effects on the riverbank vegetation and stability.

Figure 31. *The pastured left corridor along Reach M23. The natural alluvial shrub wetland is visible along the right corridor, bordered by mixed forest.*

Black River Reach M24 – *Rogers Branch to Seaver Branch*
Reference Stream Type: E dune-ripple, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

Reach M24 flows for 0.7 miles between the Rogers and Seaver Branches (Figure 32), and is in good geomorphic condition. At the Seaver Branch confluence, deposited sediments are constricting the river's flow, forcing water to accelerate through a narrow channel. From here the river flows against the valley wall, eroding the hillside where it is not armored. After this point, the reach flows straight amid agricultural fields. About 21% of the reach is straightened, and an additional 21% was recently armored to reduce erosion of the hayfield along the left bank. As a result, flows are deflected to a portion of the reach located in the shrub wetland, where eroding riverbanks, an eroding point bar, and a diagonal bar were observed. At the diagonal bar, river flows are focused directly at a riverbank. This portion of the river will likely change position in the near future.

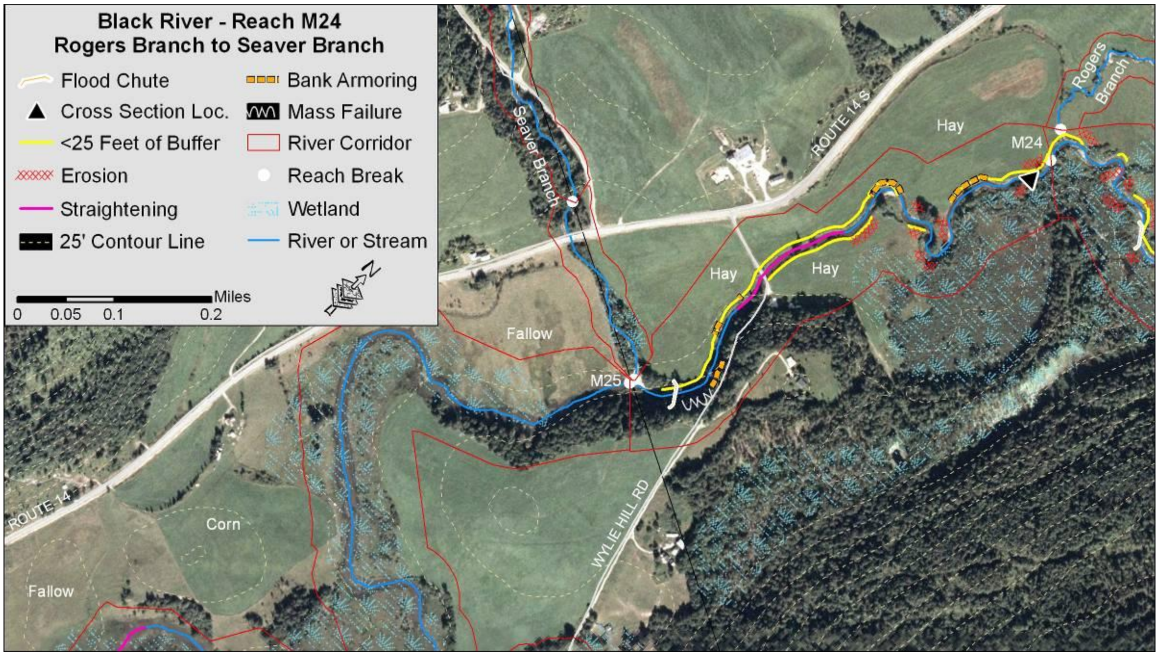

Figure 32. Phase 2 results for Reach M24. A portion of slow, pond-like M25 is also shown.

Habitat is in fair condition, due to the intensive alteration of the river and the adjacent landscape. Many of the hayfields adjacent to the reach were formerly wetlands. Most of the left riverbank and a portion of the right riverbank are mowed to the very edge, eliminating any natural vegetation. Because of the lack of riparian vegetation, important habitat features are absent, such as woody debris in the river and streambank shading. Also, alteration of the channel itself has changed the morphology of the reach by eliminating natural meanders and the diverse pools and streambed features that often accompany a meandering reach. If possible, **riparian buffers should be re-established** and the fields that were formerly wetlands should be converted back to native wetland vegetation, providing a continuous naturally vegetated corridor with adjacent areas and greatly enhancing wildlife habitat along the reach. Several small patches of **Japanese knotweed** (an invasive exotic plant) are present and **should be removed**.

Black River Reach M29 – *Mud Pond Outlet to Lake Elligo Outlet*
Reference Stream Type: E dune-ripple, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

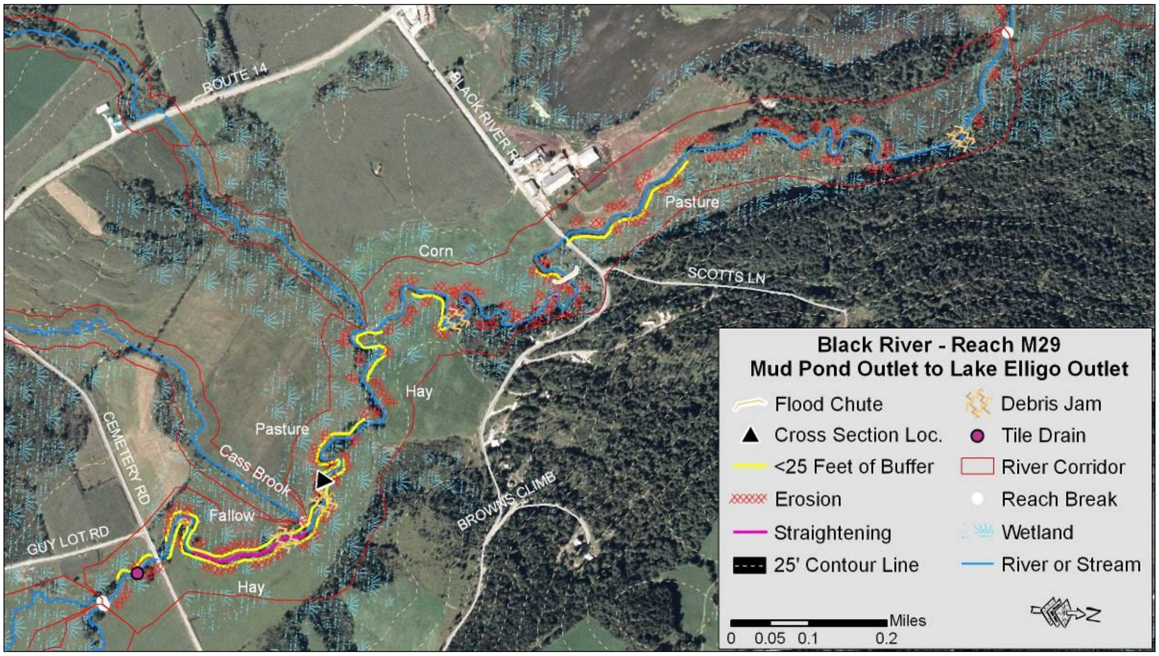

Figure 33. *Phase 2 results for Reach M29.*

Located in Craftsbury, Reach M29 flows for 2.3 miles between the Mud Pond outlet and the Lake Elligo Outlet (Figure 33). A majority of the river valley was formerly wetland, but now exists as wet pasture or has been ditched and is utilized for growing hay or corn. Though direct human-caused modifications to the channel are minimal (mainly straightening along 7% of the reach), impacts from land uses along the corridor are evident. Tributaries entering the reach have been straightened and several field ditches also enter the river. Sediment deposition is occurring at the Lake Elligo outlet and at the Cass Brook confluence. About 82% of the riverbanks between Cemetery Road and Black River Road are eroding due to limited or non-existent bank vegetation along both sides, as is the case along the right bank downstream of Black River Road. Despite these stressors, the reach is in good geomorphic condition. The river is clearly migrating, however the rate is slow - in part due to the slow flows here, and also because of the more stable clays that make up the lower riverbanks.

Because of the intensive adjacent land uses, habitat is only in fair condition. Most of what had been floodplain forest or shrub wetland has since been drained and converted to agricultural fields. Most of the riverbanks, particularly those between Cemetery and Black River Road, are completely devoid of natural vegetation. Though Figure 33 displays areas with <25' of riparian buffer in yellow, most of these areas actually contain less than 5 feet of buffer (Figure 34). The non-forested areas not highlighted in yellow only contain an herbaceous buffer. Because of these conditions, the corridor lacks cover for wildlife, vegetation to shade the river, and woody vegetation to stabilize the riverbanks. There is also a fair amount of sediment deposition in the reach as evidenced by the many sand bars observed and the soft, newly-deposited sediments present on the streambed. Compared with the remainder of the river, **this reach is a top priority for restoration**. Fencing exists along both sides of the riverbanks, but is in disrepair and falling into the river as the banks erode. Cattle are able to access the river where the fencing has failed. **Restoration of this reach is recommended and should include upgraded or repaired fences as well as plantings of native trees and shrubs along all un-vegetated or grassy riverbanks**, as seed sources in the area are limited. Restoration of this area also would connect well with an existing restoration site located upstream, and the existing natural forests and wetlands downstream.

Figure 34 *Unbuffered stream bank along Reach M29.*

Black River Tributaries:

Stony Brook Reach T1.04 Segment B – *Between Nadeau Park Road and VT Route 14*
Reference Stream Type: E plane bed, cobble
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: Moderate

Reach T1.04 on Stony Brook flows for approximately 0.9 miles along VT Route 14 (Figure 35). Segment A includes the portion of the reach located downstream of Nadeau Park Road (~1490 ft) and was not assessed due to restricted access by the property

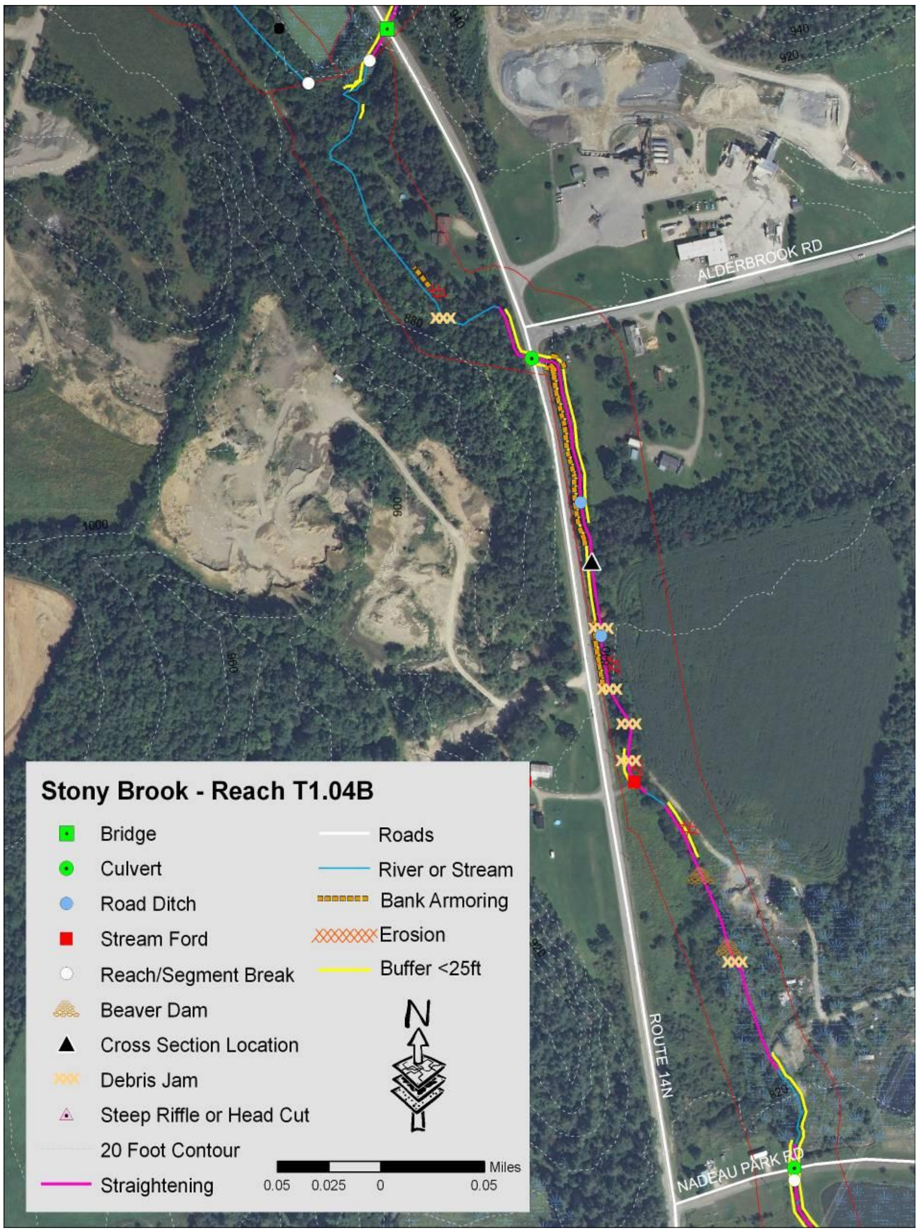

Figure 35. *Phase 2 results for Reach T1.04B.*

owner. Based on aerial photos and observations from a nearby road, the segment appears to flow through a shrubby wetland. An artificial pond is located adjacent to the stream within the stream corridor, and the pond's dam may serve as minor encroachment to the stream. Route 14N also encroaches on the stream's corridor for a short distance near the downstream end of the segment.

Segment B includes the portion of the reach located between Route 14N (upstream of Alderbrook Road) and Nadeau Park Road (~3372 ft), and this segment was the subject of our Phase 2 assessment. The culvert at Nadeau Park Road creates a slight channel constriction, but appears to have minimal impact on the stream, as there is no obvious scour or deposition, and the cobble substrate in the culvert is consistent with the stream bed upstream and downstream of the culvert. Most of the section between Nadeau Park Road and Route 14N (south of Alderbrook Rd.) has been straightened. The road encroaches on the corridor for more than 1,000 feet, with rip rap revetment along the road edge for most of this distance. The river is slightly incised in this reach with an incision ratio of 1.5. The dominant buffer width is <25 feet along most of the segment, with road along the right bank and cornfield/development along the left bank. The cornfield edge would be a good site for a **buffer planting**, to reduce sediment runoff from the field.

The culvert at Route 14 south of Alderbrook Road strongly constricts the channel (the 5.5 foot culvert attempting to accommodate a 14 foot wide channel). At the downstream end of the culvert, the stream encounters a sharp bend, but little erosion is evident. The stream exits the culvert at a slight (0.4') drop to the water's surface, creating 2' deep scour hole. This culvert may serve as an obstruction to migrating aquatic organisms and would be a **good candidate for an Aquatic Organism Passage retrofit project**, when the town is able to undertake a culvert upgrade. Upstream from this culvert the river flows through a mostly forested corridor with some development along the left bank and gravel pits located about 400' west of the left bank.

Reaches T1.05 and T1.06 were not assessed during this study, due to access permission complications, however they pass between several gravel pits and may be significant sources of sediment and phosphorus. **These reaches should be considered high priority sites for future geomorphic assessments in the watershed.**

<u>Ware Brook Reach T2.01</u> –*Black River confluence to just upstream of Hill and Dale Rd.*
Reference Stream Type: E riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

This reach runs approximately 5,929 feet through cropland and pasture. Buffer width is <25' for most of the reach and cows are present in the stream corridor, but are prevented from accessing the stream in most areas by electric fencing. In areas where cows do have access, bank trampling is minimal. Most outside stream bends show signs of active erosion and this reach would be a good candidate for a **buffer planting project**.

Two culverts are present in the reach, one at Hill and Dale Road and one at Chilafoux Road. Both are channel constrictions but they do not appear to have a major detrimental impact on the stream at this time. There is also a VAST snowmobile bridge just upstream of Chilafoux Road that has washed off of its footers. The bridge is still supported by the river banks but it is likely to fail in the near future. **The bridge is unsafe and should be repaired and repositioned on its footers or removed.**

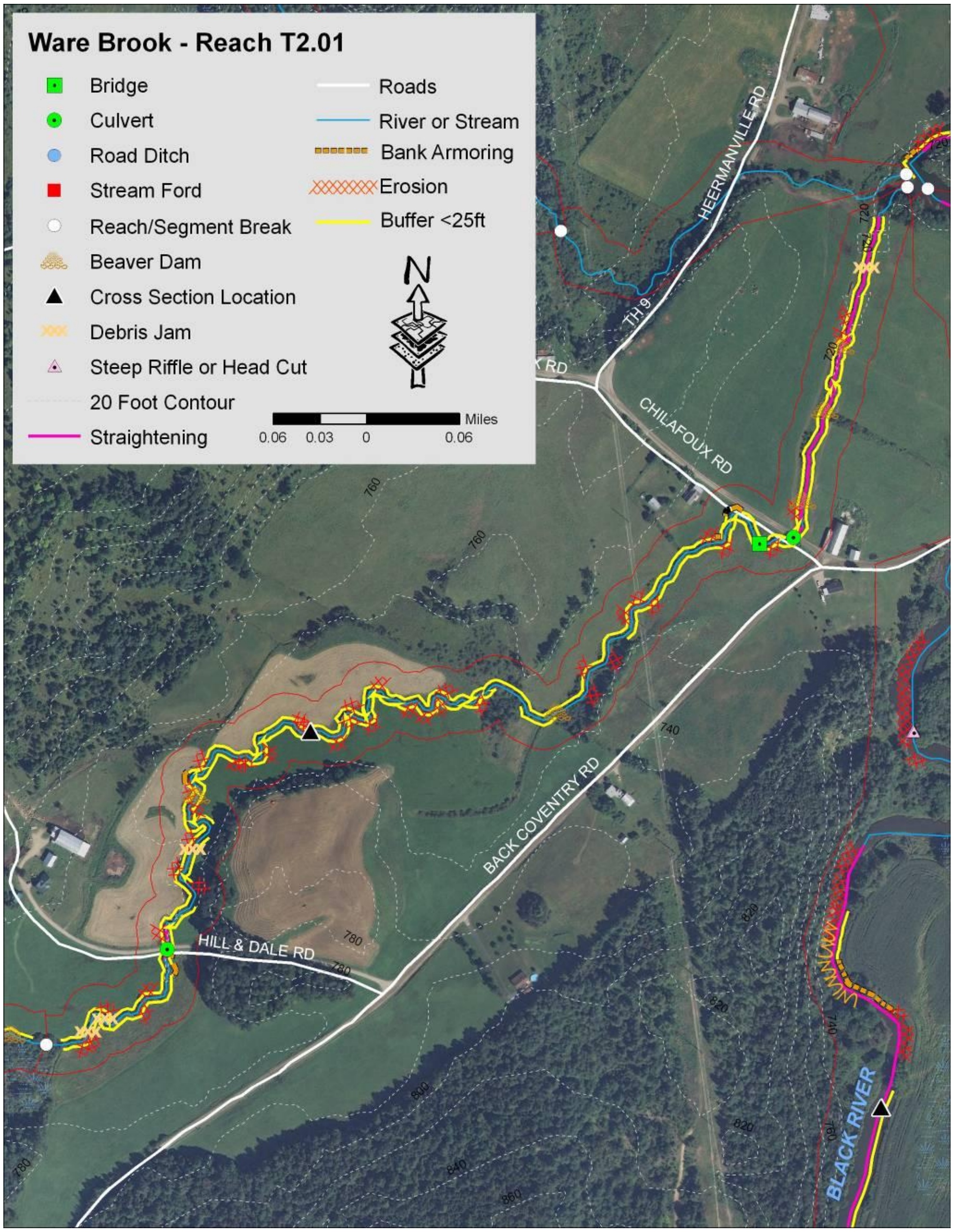

Figure 36. Phase 2 results for Reach T2.01.

Ware Brook Reach T2.02 Segment B – *Between and near Back Coventry Road crossings*
Reference Stream Type: E riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Reach T2.02 extends 1.3 miles from roughly 500 feet upstream of Hill Dale Road to just upstream of an un-named pond northwest of Back Coventry Road. The stream passes through mostly abandoned field and shrub growth and adjacent to a gravel pit and cropland.

The downstream segment (A) of 3,145 feet crosses sedge and shrub dominated beaver wetlands to a point about 275 feet downstream of the lowest crossing of Back Coventry Road. The river channel becomes difficult to discern here as it splits and passes amongst the sedge hummocks. Several beaver dams are present in the lower portion of the segment. These conditions are not appropriate for Phase 2 assessments and this segment was therefore excluded.

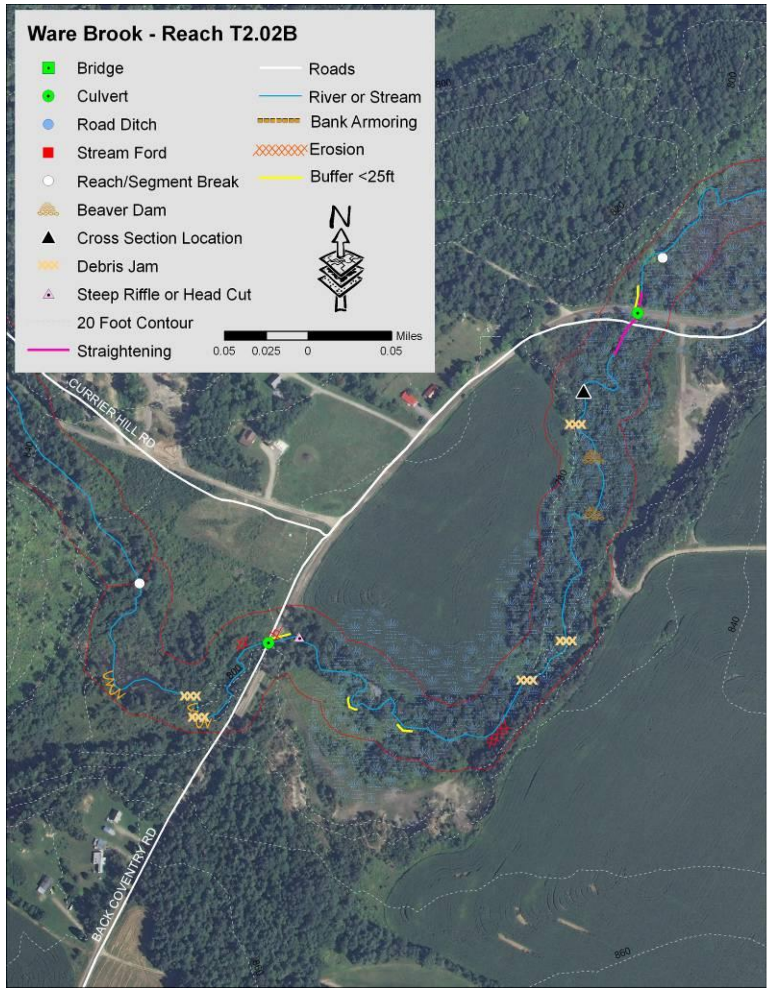

Figure 37. *Phase 2 results for Reach T2.02B*

Segment B extends 4,175 feet, from 275 feet downstream of the lowest Back Coventry Road crossing to 1,000 feet upstream of the upper crossing of this road. The river corridor is forested and development is absent (except for the two road crossings).

Cornfields occur just outside of the forested buffer on both sides of the river and a gravel pit is located approximately 250 feet east of the river just upstream of the lower crossing with Back Coventry Road. Channel constricting culverts are present at both locations where the river intersects with Back Coventry Road and deep (>4 foot) scour pools are present at the downstream end of each culvert. A steep riffle and flood chutes below the uppermost culvert further indicate that this structure is undersized and negatively impacting the stream. This culvert also appears likely to obstruct the movements of aquatic organisms during times of low flow and would be a good candidate for an **Aquatic Organism Passage retrofit project**.

Lords Creek Reach T4.03 Segment A – *Lowest crossing of Creek Rd to one half mile above Labounty Rd*

Reference Stream Type: E riffle-pool, gravel
Geomorphic Condition: Fair
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: Extreme

Reach T4.03 was segmented due to the smaller substrate size and greater impacts from livestock in segment A. Segment A includes the section of stream from the lowermost crossing with Creek Road to a point 2,600 feet upstream of Labounty Road.

This segment flows almost entirely through cow pasture and hayfields. Buffer width is <25' through most of the reach. Erosion is present on most outside bends and avulsions also occur. There is some evidence of historic channel straightening, but many of the revetments appear to have failed over time. Cows have complete access to the stream in pasture sections and severe bank trampling has resulted. This is most severe in the section downstream of the confluence with T4.03S1.01. **This segment should be considered a high priority site for a buffer planting project and efforts should also be made to restrict cow access to the stream.** The USDA Conservation Reserve Enhancement Program (CREP) offsets the cost to farmers for measures that enhance water quality, and would be a good match for this site.

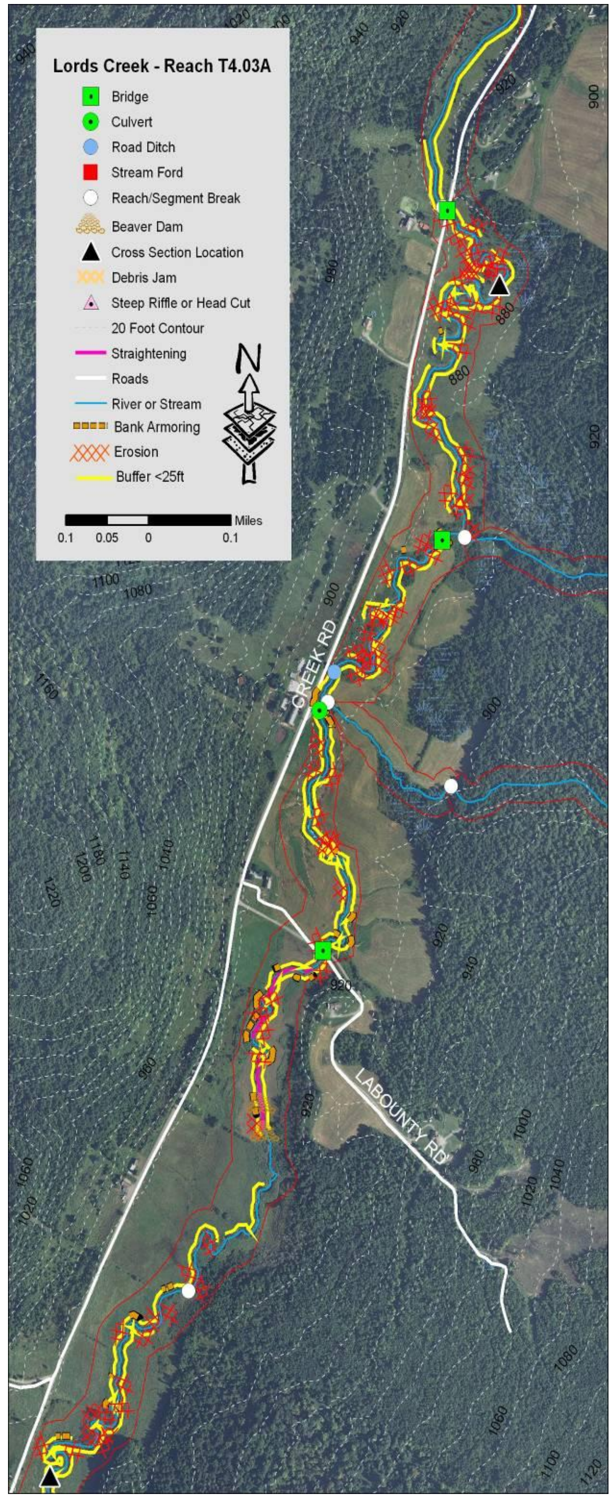

Figure 38. *Phase 2 results for Reach T4.03A*

A culvert located near the farm buildings about 1,700 feet downstream of Labounty Road serves as a channel constriction, with upstream deposition and downstream scour resulting. This culvert is likely a migration barrier for aquatic organisms during most flow levels, and would be an appropriate **Aquatic Organism Passage retrofit project**. An unusual number (8-10) of dead fish of multiple species (minnows, suckers, and trout- thought to be brown trout) were also encountered in this segment, though the cause of this mortality was unclear.

Lords Creek Reach T4.03 Segment B – *One half mile above Labounty Rd to confluence with Beaver Brook*

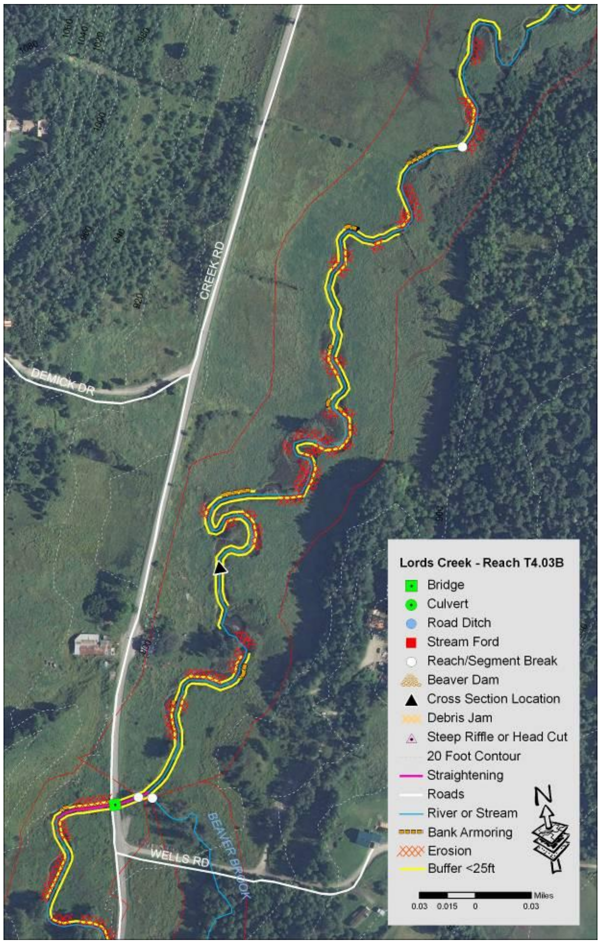

Figure 39. *Phase 2 results for Reach T4.03B*

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

Segment B is 3,082 feet long and encompasses the section of stream from the uppermost crossing with Creek Road downstream to a point 2,600 feet above Labounty Road.

The stream flows through pasture for most of the segment, with little to no vegetated buffer between the bank edge and the open pasture. Erosion is present on most outside bends. The pasture in this segment is not as heavily used as in segment A and bank trampling is minimal. This segment would be a good location for a **buffer planting project** and should be considered a medium to high priority for this work.

Lords Creek Reach T4.04 Segment A – *2nd Creek Rd crossing to next upstream tributary confluence (T4.04S1)*

Reference Stream Type: C riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Reach T4.04 was segmented during Phase 2 due to differences in channel dimensions and substrate size between the two sections. Segment A includes 3,551 feet of Lords Creek, from the stream's uppermost crossing of Creek Road to the confluence with stream T4.04S1. This segment flows through cow pasture for 1,000 feet upstream from the Creek Road, and the banks here are very trampled from cows continually accessing the stream channel. This section would benefit greatly from a **buffer planting**, if the cows were also restricted from entering the stream (**fencing**).

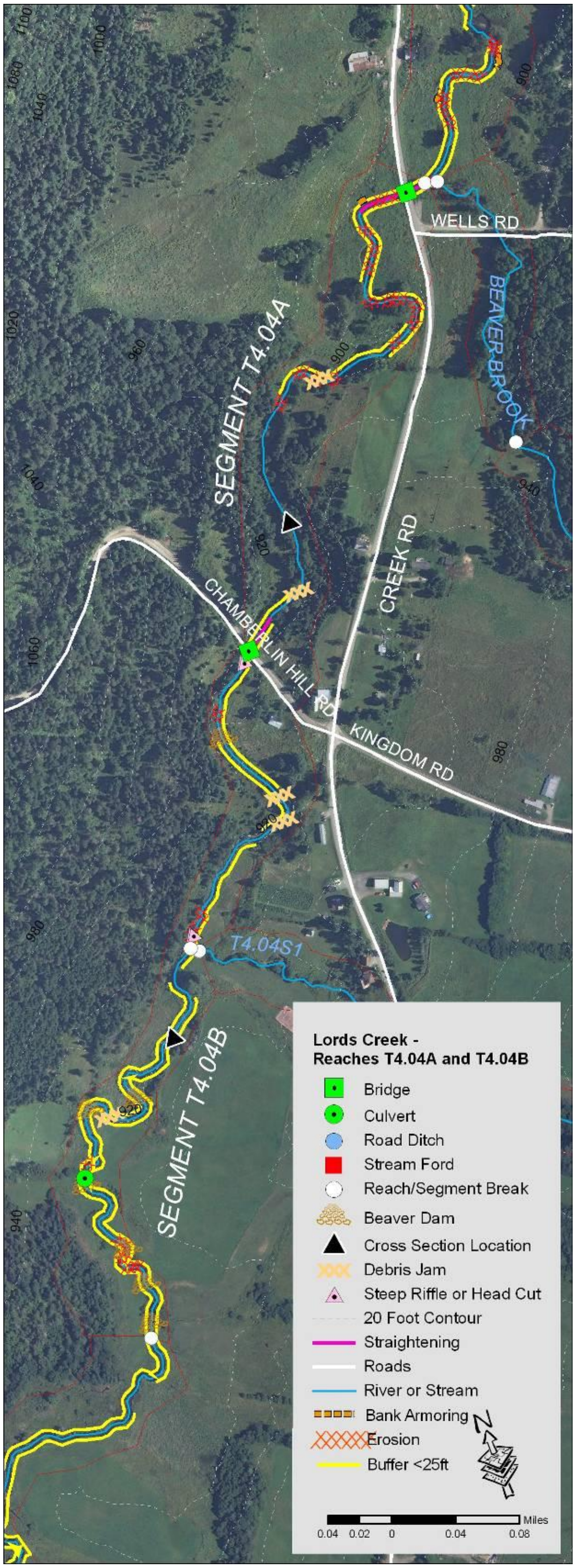

Figure 40. *Phase 2 results for Reach T4.04A & B*

Continuing upstream from the pasture, the stream flows through a mostly forested area until reaching the bridge at Chamberlain Hill Road. Between this bridge and the upstream end of the segment, the left river corridor is mostly forested while the right corridor consists mostly of residential areas and pasture.

<u>Lords Creek Reach T4.04 Segment B</u> – *T4.04S1 confluence to 2,000 ft upstream*
Reference Stream Type: E riffle-pool, sand
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

Segment B includes the section of Lords Creek from the confluence with T4.04S1 to a point 1,976 feet upstream of that confluence. This segment flows mostly through hayfield and pasture and some erosion is present along the outside bends, though most bends appear to be fairly stable. Several beaver dams were also found here. This segment would be a **good candidate for a buffer planting project** and should be considered a medium to high priority for this work.

Lamphear Brook Reach T5.02 – *Rte 14 to ~600 ft upstream of Shuteville Rd*
Reference Stream Type: C riffle-pool, cobble
Geomorphic Condition: Good
Channel Evolution Stage: II (incising)
Habitat Condition: Good
Stream Sensitivity: Moderate

This 3,932 foot long reach extends from Route 14 north to a point 630 feet upstream of Shuteville Road.

The right corridor in this reach is mostly forested with some meadow areas and residential development. The left corridor includes a mix of forest, cornfield, and pasture.

Stream banks are fairly stable through most of the reach, with little erosion evident. Several large bar deposits are present on the inside of meander bends. A large debris jam is located 500 feet upstream of Route 14, and channel braiding has resulted for a short distance downstream.

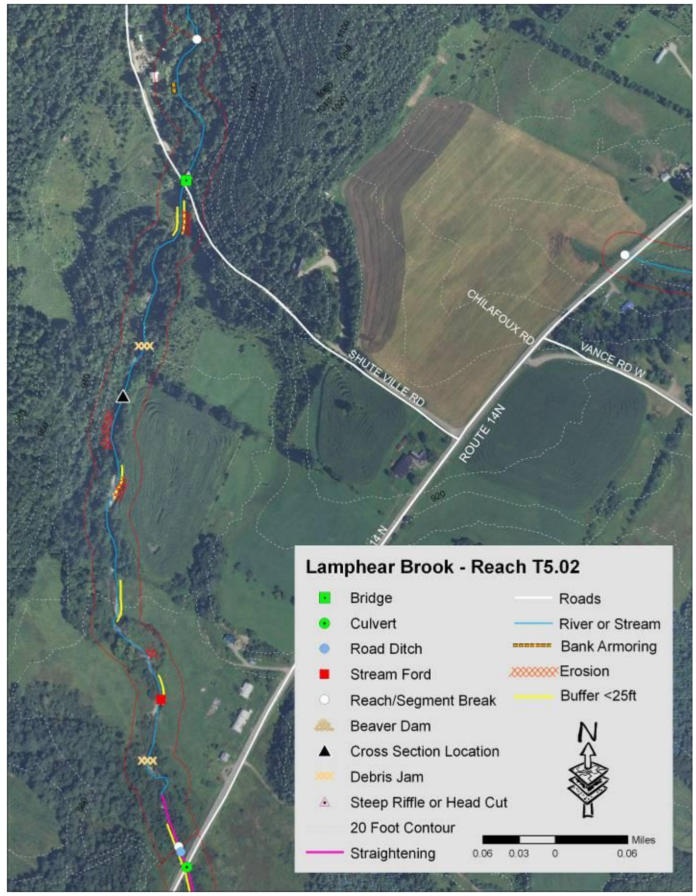

Figure 41. *Phase 2 results for Reach T5.02*

The culvert at Shuteville Road is a channel constriction that is causing both deposition upstream and a very large scour pool downstream. The stream exits the culvert in a freefall drop, which very likely presents a barrier to the movement of most aquatic organisms during low flows. This culvert would be a good candidate for an **Aquatic Organism Passage retrofit project**.

Planting of a riparian buffer of native woody vegetation along the edge of the cornfield would help to reduce sediment inputs to the stream and would eventually increase bank stability. Buffer planting in areas of cornfield and pasture in this reach that currently have <25 feet of buffer would be beneficial, but should be considered a medium priority watershed-wide.

McCleary Brook Reach T6.02 Segment A – *1,500 feet upstream of Black River confluence to point 1,850 feet downstream of Rte 14* (NOT ASSESSED)
Reference Stream Type: C riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

Reach T6.02 was segmented during Phase 2 as a result of widely varying flow conditions. Segment A is 715 feet long and extends from 1,850 feet to 2,565 feet downstream from Route 14. This segment flows through a shrubby wetland and the channel becomes very indistinct. As a result, this segment was not assessed. The stream appears to continue to cross shrubby wetlands on through reach T6.01, to the confluence with the Black River.

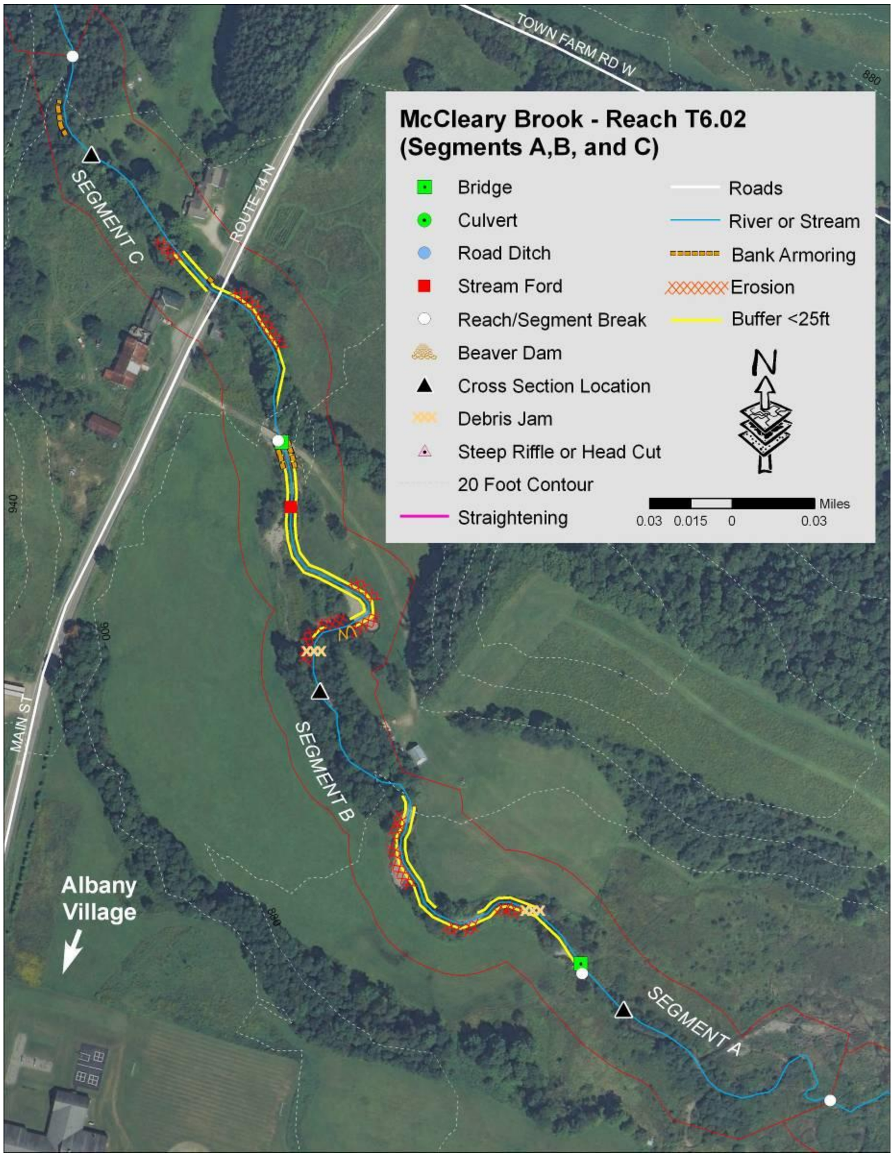

Figure 42. *Phase 2 results for Reach T6.02 (segments A-C)*

<u>McCleary Brook Reach T6.02 Segment B</u> – *Upper edge of wetland between Black River and Route 14 to 320 feet downstream of Route 14*
Reference Stream Type: C riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

Segment B is 1,530 feet long and extends from the upper shrubby wetland edge 1,850 feet downstream of Route 14 to a point roughly 300 feet downstream of this highway. This section of stream was completely dry at the time of the Phase 2 assessment. The stream corridor here consists mainly of hayfields and meadow, with some small patches of forest. Several areas lack a naturally vegetated buffer and, where it is absent, extensive erosion has occurred. **Re-establishing a vegetated buffer** would reduce runoff and help to stabilize banks within this reach and should be considered a medium to high priority.

McCleary Brook Reach T6.02 Segment C –
From 320 ft downstream to 500 ft upstream of Rte 14
Reference Stream Type: C plane bed, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

Segment C extends from 320 feet downstream of Route 14 to a point 550 feet upstream of the highway. The stream through most of this section is bordered by a small patch of forest, with some residential development encroaching into the corridor on both sides just upstream of Route 14. Small areas of erosion, absent buffer, and bank armoring are present, but no significant impacts were noted. Judging by the close width/depth ratio, this segment may fluctuate between a C and an E stream type and **additional cross-sections** should be done prior to active restoration projects to confirm the stream type in the project area.

Rogers Branch Reach T8.01 – *Black River to 950 ft downstream of Rte 14*
Reference Stream Type: C riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

Reach T8.01 includes the 1,890 foot section of stream from the confluence with the Black River to a point 950 feet downstream of Route 14. The majority of the reach is unbuffered as it passes through active pasture and hayfield, though a small forested area encompasses most of the corridor near the upstream end of the reach. In the unbuffered section, most outside bends are actively eroding and large point bars have developed on the inside bends. A **buffer planting project** in this area would help to stabilize the stream banks and to mitigate sediment and nutrient inputs from the adjacent fields and should be considered a high priority. As a farm parcel, this site may also be a good match for a federal cost share program such as CREP. A small snowmobile bridge in serious disrepair is located near the lower end of the reach and is tilted and sagging into the stream. Beavers previously built a dam beneath the bridge, which appears to have caused the stream to overtop the bridge during times of high water. **This bridge should be repaired or removed.**

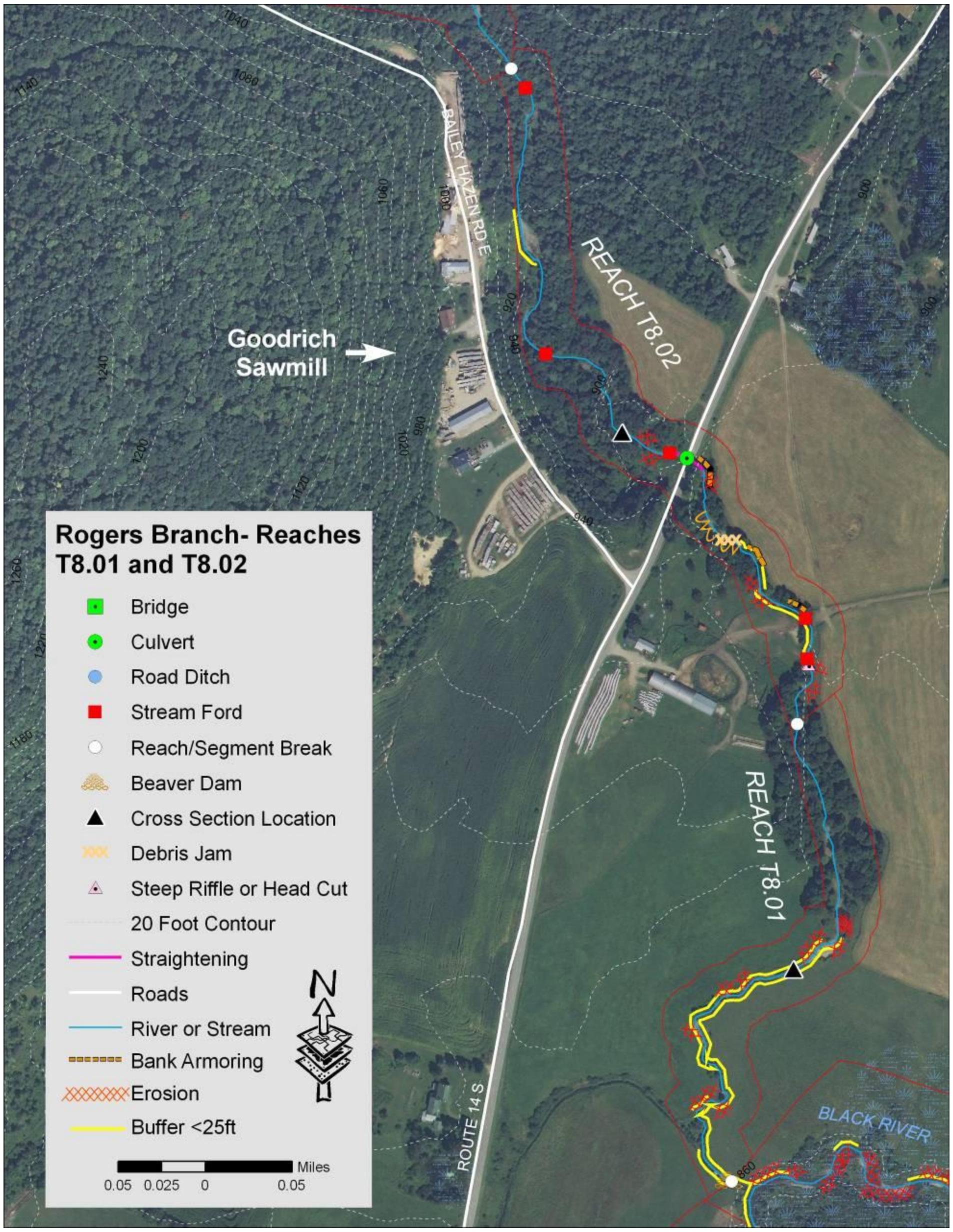

Figure 43. *Phase 2 results for Reaches T8.01 and T8.02*

<u>Rogers Branch Reach T8.02</u> – *Both sides of Route 14*
Reference Stream Type: C riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High

Reach T8.02 extends from 950 feet downstream of Route 14 to point 1,440 feet upstream of the highway. The corridor here is mostly forested, with several sections also including active pasture and hayfield. Erosion is present on many, but not all, outside bends. There is one very large (138 foot long x 33 foot high) mass failure, located along the right bank just downstream of Route 14, which may have been influenced in part by upstream rip-rap installed to direct the stream flow away from the hayfield as it exits the culverts at Route 14. This pair of culverts also forms a channel constriction, and likely presents a barrier to the upstream movement of aquatic organisms at all but the highest flows. At the time of our Phase 2 fieldwork in 2010 there was a 1.5 foot drop along a cascade from the culvert outlet to the stream surface below. This site should be considered as a possible **Aquatic Organism Passage retrofit project**.

Cows currently have access to the stream below Route 14, but this is limited to two fords, and cows are unlikely to exert a major impact on overall bank stability within the reach. The Goodridge Lumber Mill occupies a high bench off the right bank and parallels the stream along most of its length upstream of Route 14. There is a steep forested buffer of at least 100 feet between the stream and the mill, except for one unforested section 196 feet in length, where it is possible that the stream may receive direct runoff from the mill. Through much of the reach there is an abundance of garbage along the stream corridor, including old barrels, scrap metal, and other large items. This reach would be a good candidate for a **stream cleanup effort**.

Whitney Brook Reach T12.01 Segment A – *Black River to 1,832 feet upstream*
Reference Stream Type: E riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Fair
Stream Sensitivity: High

Segment A includes the section of stream from the Black River confluence to a point 1,832 feet upstream from the confluence. This segment flows between two corn fields for nearly its entire length. Buffer width is minimal throughout the segment and is non-existent in several locations. Bank erosion is occurring in the corn field areas and rapid stream migration at one location in the upper portion of the reach will soon isolate one section of field from another. This area should be considered a high priority for a buffer planting project, which would help to reduce the input of sediments and nutrients from the field to the stream and possibly prevent loss of access for the farmer to the distant section of field. A project that includes both **planting a buffer** with natural woody vegetation and **establishing a long-term corridor easement** would be most beneficial. This project should be considered a high priority in the watershed.

Whitney Brook Reach T12.01 Segment B – *Upper end of segment A to 600 feet downstream of the Creek Rd.*
Reference Stream Type: C riffle-pool, gravel
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: High
Segment B of Reach T12.01 extends from the upper end of segment A (1,832 feet upstream of the Black River confluence) an additional 1,130 feet upstream, to a point

roughly 600 feet downstream of the Creek Road. The upper end of this segment has a forested buffer, but this rapidly diminishes downstream as the stream flows between corn and hay fields. There is some erosion on the outside bends in this area, but the banks are fairly stable. **Localized buffer plantings** to increase woody vegetation within the stream corridor would be beneficial here and should be considered a medium priority.

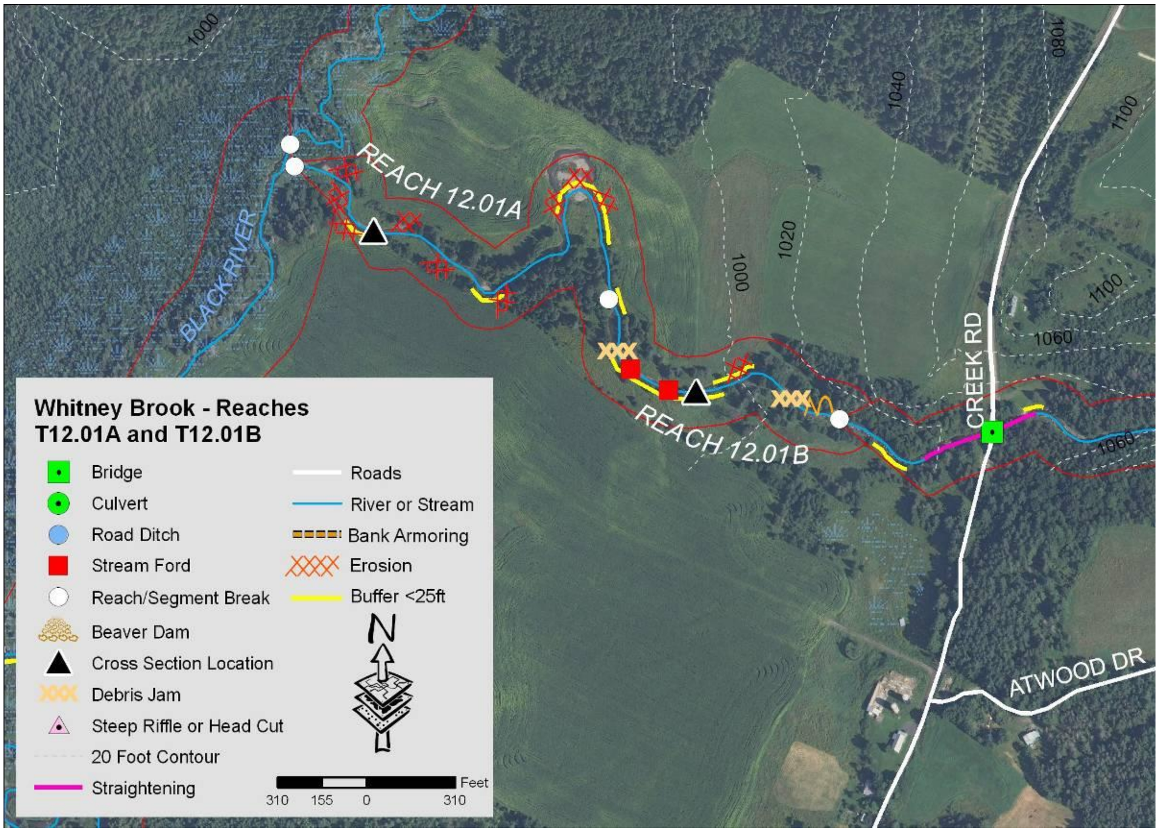

Figure 44. *Phase 2 results for Reaches T12.01A and B*

Recommendations / Next Steps

Like many river systems across the state, the Black River is undergoing a gradual process of adjustment, following several centuries of direct alteration and other land-use related impacts. Many areas of the river corridor within this relatively undeveloped watershed are returning to natural forest or shrub cover without active intervention, but other sections continue to be impacted by land use practices in or near the river corridor, structures such as bridges and culverts, and the introduction of invasive plants. These impacts compromise the wildlife habitat values of the river and riparian corridor, cause expensive loss of topsoil and property, and pollute downstream water bodies – as evidenced by continued elevated levels of phosphorus and suspended solids at various locations along the mainstem and several major tributaries (Gerhardt 2011).

Detailed Stream Geomorphic Assessments have provided a 2009/2010 snapshot of the status of the entire mainstem and many tributaries, in terms of the adjustment process and current impacts. Because resources of time and money are limited, a goal of this study was to identify specific priority restoration needs and opportunities within the watershed – to maximize the benefits gained from a necessarily limited number of projects.

A summary of suggested projects and their relative priorities is given in Table 5. Specific circumstances and locations for these projects are outlined in more detail in the reach descriptions provided in the previous section, or (for bridges and culverts) in Table 3. A partial list of potential resources for funding, expertise, contract labor, or volunteer support is provided in Appendix C. It is also important to recognize that Table 5 is intended as a guide only, and that new information should be continuously sought to update and augment these project suggestions. As one example, recent water quality sampling identified water quality issues originating from Brighton Brook and Shalney Brook – both tributaries that were not included in our Phase 2 assessments (Gerhardt 2011). Further assessments will be needed to identify and rank project needs and opportunities in these areas and to gauge the impacts of ongoing restoration efforts throughout the watershed.

Table 5: Recommended Project Priorities
Note that landowner permission and – in some cases- permits from the State of Vermont or other agencies will be required prior to undertaking these projects.

Reach/ Segment	Project Needed	Extent	Priority[1]	Notes
M03	Passive Management (allow reforestation of stream buffer)	4,800 ft	medium	South Bay WMA
M03	Road ditch stabilization	2 ditches	high	Hi-Acres road
M04	Invasive plant removal	moderate	high	honeysuckle/ loosestrife
M04	Buffer planting	700 ft	medium	
M05	Buffer planting	1,700 ft	high	
M05	Invasive plant removal	low	high	loosestrife
M05	Trash removal- stream corridor	low	medium	
M07	Buffer planting/ fence set back	750 ft	medium	
M07	Corridor easement	750 ft	medium	
M08	Invasive plant removal	low	high	loosestrife
M08	Buffer planting	2,300 ft	medium	
M08	Corridor easement	2,300 ft	medium	
M12	Invasive plant removal	low	high+	Japanese knotweed
M12	Buffer planting/ fence set back	2,300ft /? ft	medium(!)	
M16	Invasive plant removal	low	high	large honeysuckle patch
M16	Buffer planting	1,000 ft	high	
M16	Corridor easement	5,700 ft	high	
M16	Old abutment and old farm bridge removal	2 abutments/ 1 bridge	medium	Figure 11
M23	Buffer planting/ fence repair	2,800 ft	high	cows accessing river
M24	Invasive plant removal	low	high+	Japanese knotweed
M24	Buffer planting/ corridor easement	3,600 ft	high (!)	restore wetland habitat
M28	Old abutment removal	1 abutment	medium	
M29	Buffer planting/ fence repair	5,200 ft	high+	2,500 ft of this planted in 2010 @ Cemetery Rd
T1.02	Buffer planting	5,150 ft	medium(!)	based on Phase 1 only
T1.04B	Buffer planting	1,050 ft	medium	cornfield
T1.04B	Culvert retrofit (Aquatic Organism Passage (AOP) project)	1 culvert	medium	Rte 14 south of Alderbrook Rd

Reach/ Segment	Project Needed	Extent	Priority[1]	Notes
T1.05	Phase 2 assessment (gravel pit area)	1,790 ft	high	contact info-Appendix C
T1.06	Phase 2 assessment (gravel pit area)	2,220 ft	high	contact info-Appendix C
T2.01	Buffer planting	10,500 ft	medium	
T2.01	Snowmobile bridge repair/ removal	1 bridge	medium	Upstream of Chilafoux Rd
T2.01	Culvert retrofit (AOP project)	1 culvert	medium	Hill and Dale Rd
T2.02B	Culvert retrofits (AOP projects)	2 culverts	high	Back Coventry Rd crossings (2)
T4.03A	Buffer planting/ fencing	20,800 ft	high	possible CREP
T4.03A	Culvert retrofits (AOP projects)	2 culverts	high/ medium	at farm buildings downstream of Labounty Rd/ and Farm Rd
T4.03B	Buffer planting	4,500 ft	medium (!)	
T4.04A	Buffer planting/ fencing	2,000 ft	high (!)	
T4.04B	Buffer planting	4,000 ft	medium	
T4.04B	Culvert retrofit (AOP project)	1 culvert	medium	Farm Rd
T5.01	Culvert retrofit (AOP Project)	1 culvert	medium	Route 14
T5.02	Culvert retrofit (AOP Project)	1 culvert	high	Shuteville Rd
T5.02	Buffer planting	650 ft	medium	corn field edge
T6.02B	Buffer planting	1,300 ft	medium	
T6.02B	Bridge removal/ retrofit	1 bridge	medium	Snowmobile bridge
T6.02C	Additional cross sections (to determine stream type)		medium	before restoration work
T6.02C	Bridge replacement	1 bridge	medium	Route 14
T8.01	Buffer planting	2,400 ft	high	possible CREP project
T8.01	Repair or remove broken bridge	1 bridge	medium	snowmobile
T8.02	Culvert retrofit (AOP Project)	2 culverts	medium	Route 14 (double culvert)
T8.02	Trash removal – stream corridor	medium	medium	
T12.01A	Buffer planting/ corridor easement	650 ft	high	eroding corn field edge
T12.01B	Buffer planting	600 ft	medium	

[1] For *buffer plantings*, priority is based on stream sensitivity ranking ("high" priority = high or greater sensitivity and significant existing erosion). All invasive plant removal was ranked as a high priority due to the short term opportunity to control these species before populations become unmanageable. Other priorities levels were based on the extent of impact observed during Phase 2 assessments.

! – indicates elevated (>20 :g/l)total phosphorus levels measured in this reach, or within approximately 1 mile downstream of the reach, in 2010 (Gerhardt 2011).

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(VCGI) Vermont Center for Geographic Information. 2010. “GeologicSurficial_SURFICIAL62K” statewide GIS layer.

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.

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.

River (or stream) corridor – The area of land adjacent to a stream that influences and is influenced by that stream. As delineated in Vermont's Phase 1 and Phase 2 Stream Geomorphic Assessments, this corridor is at least 100 feet on either side of the stream.

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.

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)
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 containing assessed reaches	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 2007)

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: Partial List of Watershed Resources

Beck Pond LLC
Scientific research organization that partners with public agencies and non-profit organizations to conduct scientific research that increases our understanding of and informs on-the-ground actions to protect and restore the natural environment of northern New England and adjacent Canada. Has completed various studies of water quality in the Lake Memphremagog watershed. Contact Fritz Gerhardt at fgerhardt@newarkvt.net.

Memphremagog Watershed Association (MWA)
Promotes awareness and enhancement of the natural resources of the Lake Memphremagog Watershed, including water quality. Provides educational workshops and volunteer support for water quality monitoring, stream assessments, buffer planting, and river clean up efforts. Visit online at http://www.lakememphremagog.org/.

NorthWoods Stewardship Center
The NorthWoods Stewardship Center is a regional nonprofit organization whose mission is to connect people and nature through research, education and action. Since 1995, NorthWoods has planted over 30,000 trees on streambank restoration projects across the region and has conducted water quality sampling and stream geomorphic assessments throughout the Lake Memphremagog watershed. Visit online at www.northwoodscenter.org or contact by phone at 802-723-6551.

Natural Resources Conservation Service (NRCS)
Source for historic aerial photography, GIS mapping, and technical assistance in various issues relating to farms and natural resources. Also administers a variety of programs that support projects related to Best Management Practices and wildlife habitat enhancement (CRP, EQIP, WRP, WHIP). Offices in Newport and St. Johnsbury. Contact Linere Silloway at 802-334-6090 ext. 24.

Vermont Agency of Natural Resources (ANR)
Stream Geomorphic Assessment Data Management System
Online access to SGA results by watershed. https://anrnode.anr.state.vt.us/SGA/default.aspx

Vermont Association of Conservation Districts (VACD) – with county-level Natural Resource Conservation Districts (NRCDs)
Free support to landowners and agricultural producers. Offers technical, financial, and educational assistance for working with state and federal programs. Agricultural Resource Specialists (contact Sarah Damsell at 802-334-8325 x 20) provide farmers with environmental assessments of farm operations, manure management, water sampling, and information about funding to implement suggested changes. For other assistance, including buffer planting opportunities, contact Orleans County District Manager Dayna Cole at 802-334-8325.

Vermont Center for Geographic Information (VCGI)
On-line clearinghouse for a wide range of digital data for Vermont, including GIS data files and aerial photography. Includes an interactive natural resources map viewer. Visit online at http://www.vcgi.org/.

Vermont Department of Environmental Conservation- Water Quality Division
Ben Copans- Watershed Coordinator 802-751-2610

Coordinates and/or supports a variety of watershed awareness and enhancement efforts, including development of a Lake Memphremagog Watershed Plan.

Vermont Clean and Clear Program
A VT DEC program that since 2004 has supported hundreds of water quality projects throughout the state, including the SGA work summarized in this report, and Black River watershed buffer planting projects planned for 2011.
Website: http://www.anr.state.vt.us/cleanandclear/index.htm

Calkins Sand and Gravel
Chris Martel General Manager (2010). Permission and employee assistance required to access Stony Brook parcels (Reaches T1.05 and T1.06). (802)626-5755.

NorthWoods Stewardship Center

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