Miller's Run River Corridor Plan

Lyndon, Wheelock and Sheffield, VT
October 2009

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Acknowledgements

Funding for the Phase 2 stream geomorphic assessment of the Miller's Run River was provided by River Corridor Grants, managed by the Vermont Department of Environmental Conservation. Field work for the study took place during the summer of 2007 with assistance from the River Management Staff, Jared Carrano, Staci Pomeroy and Lauren Moore. Thank you to the streamside landowners for providing access to the river.

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1.0 Executive Summary

This corridor plan is part of a larger effort to conduct stream geomorphic assessments and analysis in the Upper Passumpsic River Watershed, including the Miller' Run, and the East and West Branches of the Passumpsic River. Initial geomorphic assessments took place on the East Branch Passumpsic in 2003, following a major flood in 2002 that inundated the town of Lyndon and caused extensive damage. As of 2008, we have completed and updated assessments on all three major tributaries. Assessment results are presented in this report and include an analysis of stream stressors and departures, and stream sensitivity. This overview provides the context for a more detailed reach by reach analysis as well as preliminary identification of river restoration and protection needs and opportunities. Recommendations for restoration and protection projects are outlined and prioritized in Chapter 6. Particular attention is given to those projects that will enhance sediment and floodwater attenuation, restore the river to a condition of equilibrium, and reduce river corridor erosion and other flood related hazards throughout Lyndon and downstream communities. Otherwise, preliminary projects are generally intended to improve water quality, enhance habitat and restore the Miller's Run River to equilibrium conditions.

The clearest and most consistent pattern of channel adjustment occurring along the Miller's Run River is historic channel incision coupled with current aggradation. This adjustment sequence has resulted in reduced floodwater storage capacity along the river corridor and increased sediment loads within the channel. Historic incision means that over time, the Miller's Run has been degrading its channel bed and losing access to its floodplain. Floodwater within an incised river cannot overtop the channel banks and spill onto the floodplain, thus a tremendous amount of high velocity flow and power is contained in the channel leading to additional channel degradation. The containment of this powerful flow results in increased erosion and inundation hazards along the Miller's Run and its receiving rivers. Floodwater storage on the Upper Passumpsic tributaries is critical to attenuating floodwater on the Passumpsic River main stem. Incised tributaries will simply channel floodwater to downstream rivers instead of storing them while flows in the channel recede.

Compounding historic channel incision on the Miller's Run is current aggradation or infilling of the channel as evidenced by steep riffles (sediment deposits building in the channel), and enlarged bars (sediment deposits along the edge of the stream). This aggradation process is fueled by erosion of the high unstable banks that have resulted from historic channel incision (see widening in figure 1). The natural tendency of an incised stream is to widen and create new floodplain at a lower elevation that is accessible to flood flows (see stabilizing in figure 1). The enlarged depositional bars seen on the Miller's Run are re-vegetating, becoming new floodplain and the stream is repositioning itself to be able to deposit sediment and store floodwater on this new floodplain.

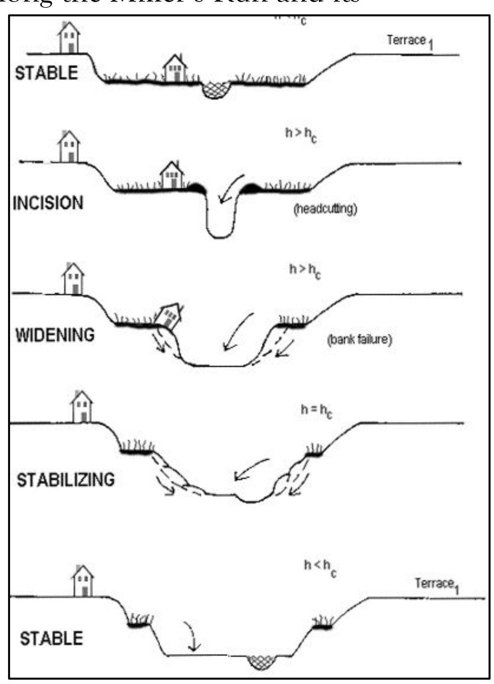


Figure 1: Schumm Channel Evolution Model (ANR, 2009)

While this natural process is occurring on the Miller's Run, it is happening very slowly, and is impeded by investments along the river that require protection from the erosive processes of channel evolution. Route 122 follows the Miller's Run and at times is preventing these processes from occurring and further causing increased channel incision. Encroachment from development and agricultural land uses are also limiting factors in the discussion of natural channel evolution as well as flood and sediment attenuation. These variables will need to be weighed out as we continue to address the Upper Passumpsic Watershed and the role it plays with problem flooding on the main stem.

2.0 Project Background and Overview

Phase 1 stream geomorphic assessment on the Miller's Run took place in 2004 by the Caledonia County Natural Resources Conservation District, and was updated to meet the parameters of the current protocol in 2007. In addition, *The Passumpsic River Flood Mitigation Study* was prepared for the town of Lyndon by Gomez and Sullivan Engineers, P.C. in November of 2006. This study came about as a result of frequent flooding in the town of Lyndon, particularly the flood in June of 2002. The study was intended to assist the town of Lyndon in understanding the reasons for the flooding and outline recommendations for structural and nonstructural alternatives.

The Flood Mitigation Study discussed the need for more information on the upper main tributaries into Lyndon; the Miller's Run River, as well as the East and West Branches of the Passumpsic River. At the time of the study, some Phase 2 information was available for the East Branch Passumpsic, and the study noted increased incision and decreased floodwater storage from the East Branch contributing to problem flooding in Lyndon. It was unknown what impact the West Branch and Miller's Run were having on the Passumpsic main stem, and more information was necessary to fully explore the tributary impacts and potential for flood attenuation. (G&S, 2006).

The following are recommendations from The Flood Mitigation Study (G&S 2006)

- *Using the East Branch Phase 2 geomorphic assessment, along with some follow-up field work, estimate the storage capacity on the East Branch. Quantify how much storage capacity could be gained in those areas where the East Branch currently can not access its floodplain. Quantify the overall floodplain storage capacity and the benefit relative to curtailing flooding in Lyndon.*

- *Work with the Vermont Rivers Management department to conduct geomorphic assessments on the other major tributaries- West Branch and Miller Run- to determine if these rivers can access their floodplains. Conduct the same evaluations described above for the East Branch, including quantifying the floodplain storage capacity that could be made available.*

- *It is recommended that first geomorphic studies be conducted on Miller Run and the West Branch to a) determine the river's stability, b) identify floodplains that provide key attenuation assets and c) compute he total belt width along each river that would define the river corridor. It is recognized that some floodplains are already occupied by houses or roads, thus emphasis should be placed on floodplains that remain relatively undeveloped.*

This study provides guidance and purpose for this Phase 2 stream geomorphic assessment of Miller's Run and presents pertinent research questions. Flood storage and floodplain evaluation of the Miller's Run are key foci in understanding the tributaries' impact on the Passumpsic River main stem and flooding considerations.

The Federal Emergency Management Agency (FEMA) conducted a Flood Insurance Study (FIS) for the town of Lyndon in 1977, which was updated in 1988. As part of the study, FEMA delineated 100-year, 500 year and floodway boundaries, which assume varying degrees of flooding in any given year. A 100-year flood assumes a 1% chance of flood inundation within the delineated boundary in any given year. A floodway, more specifically, indicates the area of the floodplain within which any filling would result in an increase to the elevation of the 1% chance flood and with that carries more development restrictions.

A series of restoration projects utilizing various trial technologies were conducted at 38 sites along the Miller's Run River in 1994, and were re-assessed by the Caledonia County NRCD in 2003 in a report entitled *Miller's Run Improvement Project: A Ten Year Evaluation*, funded by the Connecticut River Joint Commissions. The restoration projects involved the goals of bank stabilization, establishing vegetative buffers and improving water quality and habitat. Techniques including tree revetments, un-rooted willow and other shrub plantings, brush rolls, fascines, log vanes, fencing and bioengineering field trials were employed to stabilize and re-vegetate sections of the Miller's Run River. In general, the 2003 evaluation showed bank stabilization at lower gradient sites to be successful. Many sites, however, were characterized by the river currently accessing the opposite bank from where the treatments took place, rendering the previous 'bank work' to be more of a streamside buffer. In some places the treatments were in excess of 75' away from the edge of the river and the far end of an existing gravel bar. Sediment transport is noted as a factor in this occurrence and more notably the importance of integrating fluvial geomorphology with riparian conservation projects. (Gemmett, 2004)

Phase 2 stream geomorphic assessments took place on reaches T201 through T208 of the Miller's Run covering 11.8 miles of river channel. Reaches T205 and T207 are step pool systems that flow through the villages of Wheelock and Sheffield, respectively, and were excluded from the study, totaling 6 reaches that were assessed.

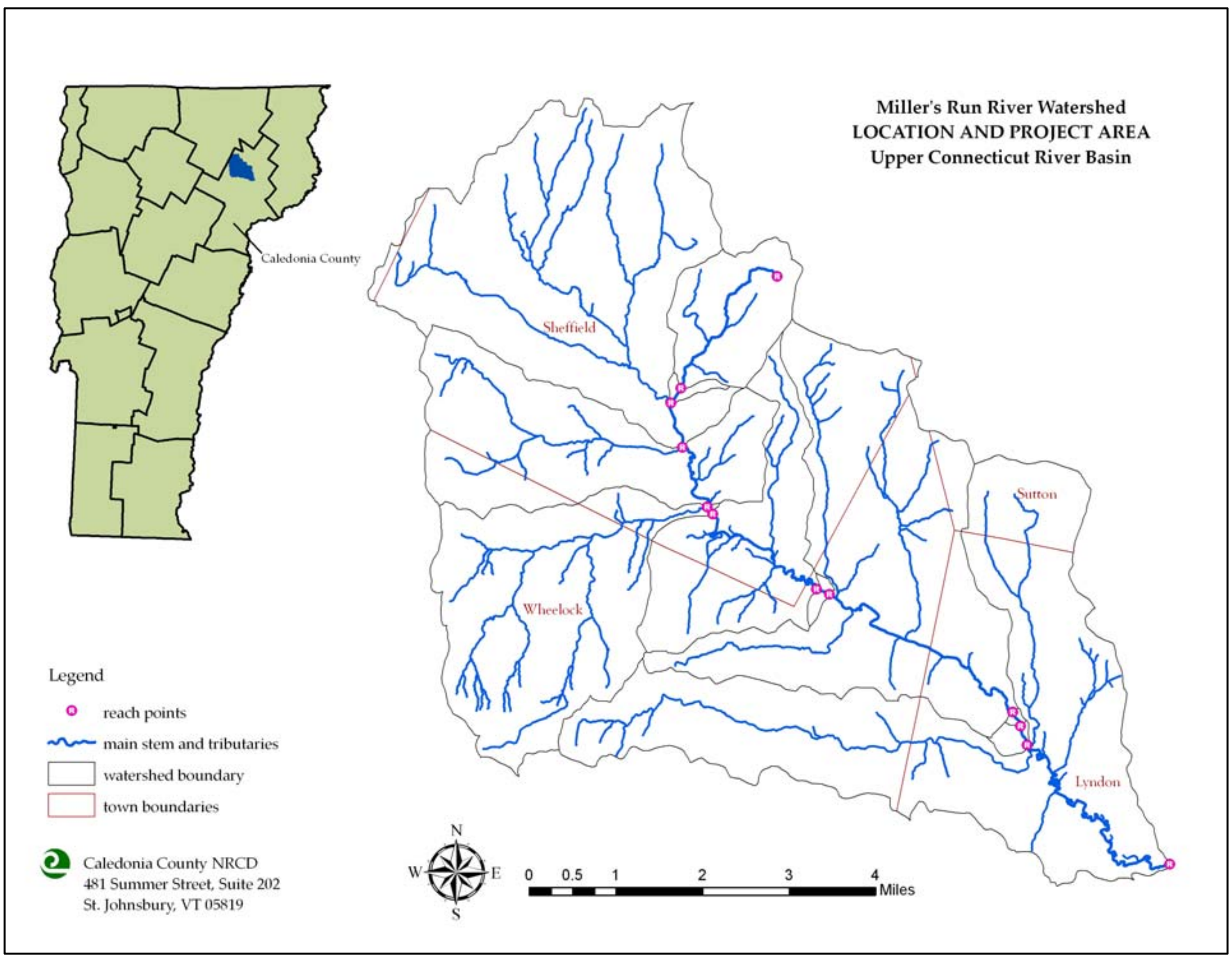
3.0 Background Watershed Information

3.1 Geographic Setting

The Miller's Run River is a major tributary of the Passumpsic River, a 507 square mile watershed and one of the largest tributaries of the Northern Connecticut River. The Passumpsic River passes through seven hydroelectric stations over 34 miles, meanders around Nine Mile Islands and empties into the Connecticut River. The main stem of the Passumpsic River begins approximately 1.5 miles upstream from the mouth of the Miller's Run, at the confluence of the East and West Branches of the Passumpsic in Lyndon, VT.

The Miller's Run River drains 48.5 square miles. Originally known as Miller Run, the river was named for the number of early sawmills and gristmills, taking advantage of the water resources and power. The two fastest flowing sections of river are in the villages of Sheffield and Wheelock, which both originated as mill towns (SHS, 1993). Vermont Route 122, built in 1813, follows the course of the Miller's Run along its steep eastern flank. Interstate 91 was built in 1973 and also follows the river's corridor and crosses the river with two 75' bridge abutments at a northwest/southeast direction. The rest of the watershed is mountainous and forested. The watershed has a history of heavy agricultural land use which reached its peak around the year 1850. Currently only about 11% of the watershed is in agriculture, though the river's wider, flat valleys are generally still in agricultural production.

Figure 2. Location and Project Area Map of the Miller's Run Watershed



3.2 Political Jurisdictions

Project reaches are located in the towns of Lyndon, Wheelock and Sheffield, Vermont. The drainage area also includes a very small portion of the town of Sutton. Headwaters originate on the eastern side of the town of Sheffield.

3.3 Geologic Setting

Towns of Sheffield, Wheelock and Lyndon of the Lyndonville quadrangle lie within the Connecticut River Valley between the Green Mountains and the White Mountains of New Hampshire. The area encompasses two main sedimentary formations, the Gile Mountain formation at the headwaters, and the Waits River formation beginning near Sheffield village and downstream. The Gile Mountain to Waits River contact is gradual and varying but is generally characterized by a change from the rigid and resistant quartzite and schist of Gile Mountain, to the more easily weathered limestone of the Waits River Formation. The highest point of elevation in this quadrangle is Wheelock Mountain at 2783 feet, which rests south of the Miller's Run main stem. (Doll, 1965)

The bedrock falls in the villages of Sheffield and Wheelock are outcrops of Barton River lithologies, primarily composed of limestone. Pleistocene glaciation along the main stem from Wheelock village downstream resulted in a considerable number of kame moraines and various glaciofluvial deposits. This surficial geology lends itself to observable micro-topography, as well as gravel and sand deposits along the main stem. (Doll, 1965)

The soils of the Miller's Run watershed correspond to the geologic setting. Glaciofluvial till and alluvial soils along the wide, flat valleys characterize the majority of the main stem. The bedrock outcrops in the villages are followed by coarser sediment downstream, which decreases to finer sediment as the valley decreases in slope.

Table 1. Miller's Run River Dominant Soil Characteristics By Reach

Reach ID	Dominant Soil Type	%Dom	Parent Material	Flooding	Hydro Group	Drainage Class	Hydric
T201	Charles silty loam	46	silty alluvium	frequent	C	poorly drained	yes
T202	Podunk fine sandy loam	17	loamy alluvium/ sandy alluvium	occasional	B	moderately well drained	no
	Charles silty loam	35	silty alluvium	frequent	C	poorly drained	yes
T203	Roundabout silt loam	46	silty glaciolacustrine	none	C	poorly drained	yes
T204	Podunk fine sandy loam	21	loamy alluvium/ sandy alluvium	occasional	B	moderately well drained	no
	Buckland fine sandy loam	15	loamy basal till	none	C	moderately well drained	no
T205	Podunk fine sandy loam	34	loamy alluvium/ sandy alluvium	occasional	B	moderately well drained	no
T206	Rumney fine sandy loam	24	loamy alluvium/ sandy alluivium	frequent	C	poorly drained	yes
	Podunk fine sandy loam	20	loamy alluvium/ sandy alluvium	occasional	B	moderately well drained	no

Reach ID	Dominant Soil Type	%Dom	Parent Material	Flooding	Hydro Group	Drainage Class	Hydric
T207	Vershire Lombard complex	56	loamy till	none	C	well drained	no
T208	Moosilauke very fine sandy loam	61	sandy/gravelly glaciofluvial	none	C	poorly drained	yes

3.3 Geomorphic Setting

The Millers' Run River was divided into 11 reaches for the purpose of the geomorphic assessment, with a total of six reaches assessed in Phase 2. Reaches are homogeneous sections of stream, with breaks located where there are visible changes in physical aspects of the stream and valley such as channel confinement, sinuosity and/or hydrologic characteristics such as tributary inputs. During the Phase 1 assessment of the Miller's Run River, the remote sensing phase, preliminary reference stream types are determined based on the confinement, slope and other characteristics that are outlined below. Table 2 outlines the reference characteristics of the stream reaches as recorded in Phase 1.

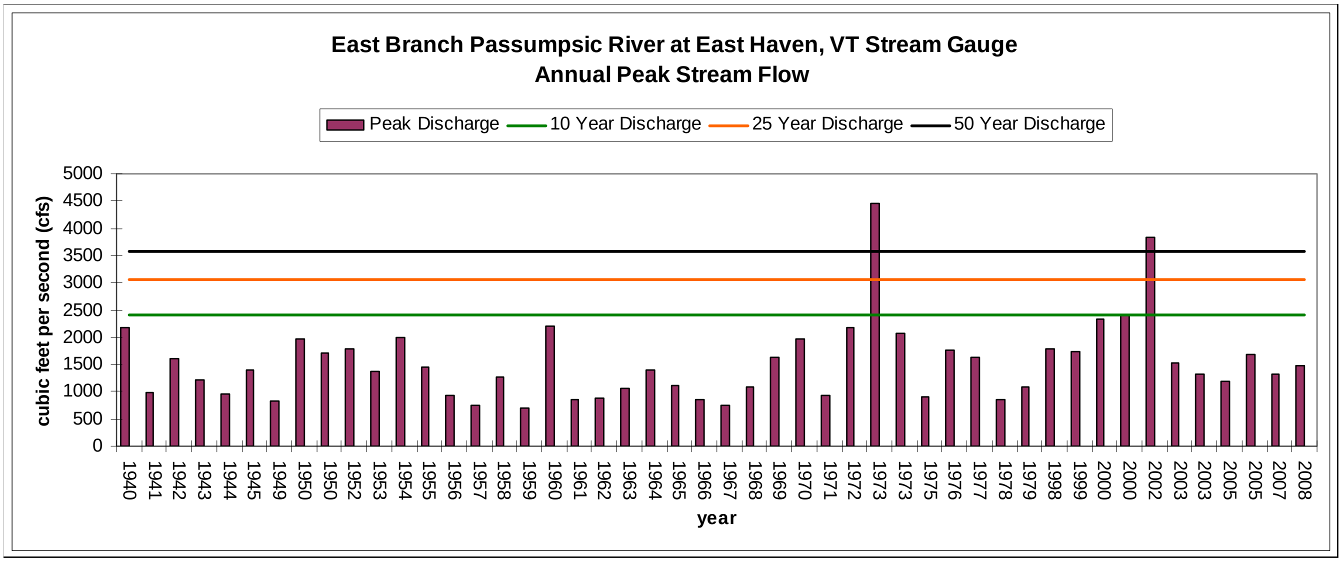
Table 2. Miller's Run River Reference Stream Characteristics

Reach ID	Drainage Area (sq mi)	Valley Width (ft)	Valley Type	Channel Width (ft)	Channel Length (ft)	Channel Slope %	Sinuosity	Reference Stream Type	Channel Bed Form
T201	46.66	1200	Very Broad	45.5	23,452	0.03	1.95	E	Dune-Ripple
T202	35.24	962	Very Broad	62.8	1263	1.58	1.19	C	Plane Bed
T203	35.11	200	Semi-confined	62.7	1038	Gentle gradient	1.21	B sub-c	Plane Bed
T204	35.08	815	Very Broad	62.7	16,778	0.23	1.19	C	Riffle Pool
T205	26.45	70	Narrowly Confined	55.4	879	6.03	1.01	A	Step Pool
T206	26.37	1262	Very Broad	55.3	12,364	0.53	1.43	C	Riffle Pool
T207	51.9	1092	Very Broad	51.9	600	3.33	1.00	C	Plane Bed
T208	45.1	1050	Very Broad	45.1	5930	0.99	1.57	C	Riffle Pool
T209	38.5	312	Broad	38.5	3127	2.53	1.09	C	Plane Bed
T210	1.98	73	Narrow	17.7	1171	5.04	1.06	B	Plane Bed
T211	1.89	N/A	Narrowly Confined	17.3	11,513	7.69	1.00	A	Cascade

3.4 Hydrology and Flood History

The United States Geological Survey (USGS) collects data from river gauging stations throughout Vermont. The nearest USGS gage to the Miller's Run is located on the East Branch Passumpsic in East Haven, where the flow is not impacted by any upstream impoundments, thus reflecting an unregulated stream flow. While basin characteristics of the Miller's Run differ from the East Branch (e.g drainage area and slope), insight can be drawn from the East Branch gage in determining annual peak flows and how they relate to the flooding history of the Upper Passumpsic watershed. The period of record for the East Branch gage is not continuous, with a prominent break in record from 1979 to 1997.

Figure 3: Annual peak steamflows at the USGS stream gage 01133000
East Branch Passumpsic near East Haven, VT (http://nwis.waterdata.usgs.gov/nwis/)



The largest flood measured on record from the East Branch gauging station was in 1973, with the second highest and most recent flood in 2002. According to interviews with Vermont DEC, the 2002 flood caused extensive damage throughout Lyndon and downstream to St. Johnsbury, including property damage, power outages, as well as road and business closures. The photo on the left shows the Passumpsic River main stem near the confluence of the East and West Branches and the Miller's Run River. This is an area of frequent flooding and sediment accumulation, which is additionally challenged by development and transportation routes. As we examine the Upper Passumpsic watershed, it is clear that these three tributaries are critical components in the discussion of flood attenuation in Lyndon.

Figure 4: Photo by Kenneth Mason: 2002 Passumpsic River main stem flooding near junction of Rte 114 and Rte 5 in Lyndon and Miller's Run confluence

3.5 Ecological Setting

The northern end of the Upper Passumpsic River Watershed is generally part of the Northeastern Highlands biophysical region, an area generally more similar to New Hampshire and Quebec than the rest of Vermont. This area is characterized by colder climate, granite bedrock, rugged terrain and large deposits of sand and gravel in the river valleys. While this characterization holds true for most of the upper East Branch Passumpsic River, the Millers' Run River valley makes a transition to Northern Vermont Piedmont. This biophysical region is slightly warmer and drier then the Highlands, and is characterized by granite only in higher elevations, with more easily weathered glacial till everywhere else. (Thompson and Sorenson, 2000) The region features Northern Hardwood and hemlock forests, though extensive clearing for agriculture in the 1800s did alter this composition to more mixed forests. This region offers a wide variety of wildlife habitat with little fragmentation, particularly favoring species that require more extensive core habitats.

Riparian habitat within the corridor around the Miller's Run was classified during the Phase 2 geomorphic assessment as "poor" habitat, which is largely due to the stream lacking buffers and diversity of substrate. The ecology of the corridor has been significantly altered by human land use and agriculture. The river valley generally lacks habitat connectivity in the corridor, but does provide small and occasional pockets of riparian habitat. In-stream habitat is largely impacted by increased thermal temperatures and excess fine sediments, though woody debris does provide occasional habitat opportunities.

4.0 Research Methods

4.1 Stream Geomorphic Assessment Protocols

Fluvial geomorphology functions to explain the interrelationships between flowing water, sediment and various land forms. Understanding how streams interact with their environment is the central focus of the Vermont Agency of Natural Resources comprehensive stream geomorphic assessment protocols. With the ultimate goal of resolving or avoiding conflicts between river systems and human investments, the stream assessment protocols provide comprehensive physical and habitat data of a watershed and stream system that can be utilized for long term planning and restoration practices. Excerpted from the Vermont Agency of Natural Resources (VT ANR, 2007), the stream geomorphic assessment program objectives are:

1) To create a data collection protocol for the physical assessment of streams and rivers that is scientifically sound and produces repeatable results, so that data can be compared not only within a watershed but between watersheds and regions.

2) To create a state GIS and database system of fluvial geomorphic data that is accessible to users inside and outside the Agency of Natural Resources.

3) To create a method for predicting stream channel and flood plain evolution in Vermont that will technically support the resolution of river/land use conflicts and allow for sound land use practices and planning at the watershed scale.

4) To create a river assessment methodology that will help lay people understand how human activities over time within a watershed can be conducted in a manner that is both ecologically and economically sustainable.

Stream geomorphic assessments are divided into two phases. The phase 1 assessment, the remote sensing phase, is a preliminary analysis from existing studies, maps, aerial photos and "windshield surveys" of the watershed. Phase 2 involves in-stream data collection, cross section surveys and a more detailed and comprehensive analysis of the streams' adjustment patterns, as well as physical and habitat characteristics. Both phases function in tandem with a spatial database of the watershed and an online data management system (DMS) at https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm.

4.2 Quality Assurance and Quality Control

Vermont's River Management Program conducted quality assurance/quality control (QA/QC) checks on the Miller's Run data in December of 2008. The QA/QC tools were developed by the VT ANR and are partially built into the online database management system. The spatial (GIS) database of the watershed and uploaded spatial data are also reviewed through the QA/QC process. Geomorphic assessment data was initially collected on the Miller's Run in 2004, prior to some significant changes in the SGA protocol. Current parameters of the protocol would require inclusion of the Miller's Run tributaries into the spatial database and as a component of the Phase 1 data collection. Because the Arcview project was created prior to this expansion, only the main stem of the Miller's Run is included in the spatial data and project.

5.0 Departure Analysis and Stressor Identification

5.1 Hydrologic Regime Stressors

The timing, volume and duration of flow events throughout the year and over time determine the hydrologic regime of a watershed (VT ANR 2007). The following description from VT Agency of Natural Resources River Corridor Planning Guide explains hydrologic regime and stressors.

> The hydrologic regime may be influenced by climate, soils, geology, groundwater, watershed land cover, connectivity of the stream, riparian, and floodplain network, and valley and stream morphology. The hydrologic regime, as addressed in this section, is characterized by the input and manipulation of water at the watershed scale and should not be confused with channel and floodplain "hydraulics," which describes how the energy of flowing water affects reach-scale physical forms and is affected by reach-scale physical modifications (e.g., bridges modify channel and floodplain hydraulics). When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. Where hydrologic modifications are persistent, the impacted stream will adjust morphologically (e.g., enlarging when stormwater peaks are consistently higher) and often result in significant changes in sediment loading and channel adjustments in downstream reaches.

Analysis of land cover and land use is useful in understanding hydrologic stressors. Historic deforestation has had prominent impacts on hydrologic regimes statewide by altering the flow and ability of land to absorb the volume of water during a storm event. Precipitation on open land has a far greater tendency to create erosion and concentrated flows of runoff and associated sediment, as opposed to forested land that has a much greater capacity to store water and hold sediment in place (VT ANR, 2007). Land use/land cover for the Miller's Run is summarized below in Table 3. There is a significant difference between the watershed coverage as compared to the stream corridor, most notably, the clear concentration of agricultural land along the stream. Agriculture is the most prominent land use within the river corridor.

Table 3: Miller's Run River Corridor and Watershed Land Cover/Land Use

Watershed Land Cover/Use Type	% Cover	Corridor Land Cover/Use Type	% Cover
Forested	78%	Forested	37%
Agriculture	11.5%	Agriculture	39%
Wetland and Water	5.5%	Wetland and Water	15.5%
Residential/Commercial/Industrial	1%	Residential/Commercial/Industrial	3%
Transportation	4%	Transportation	5.5%

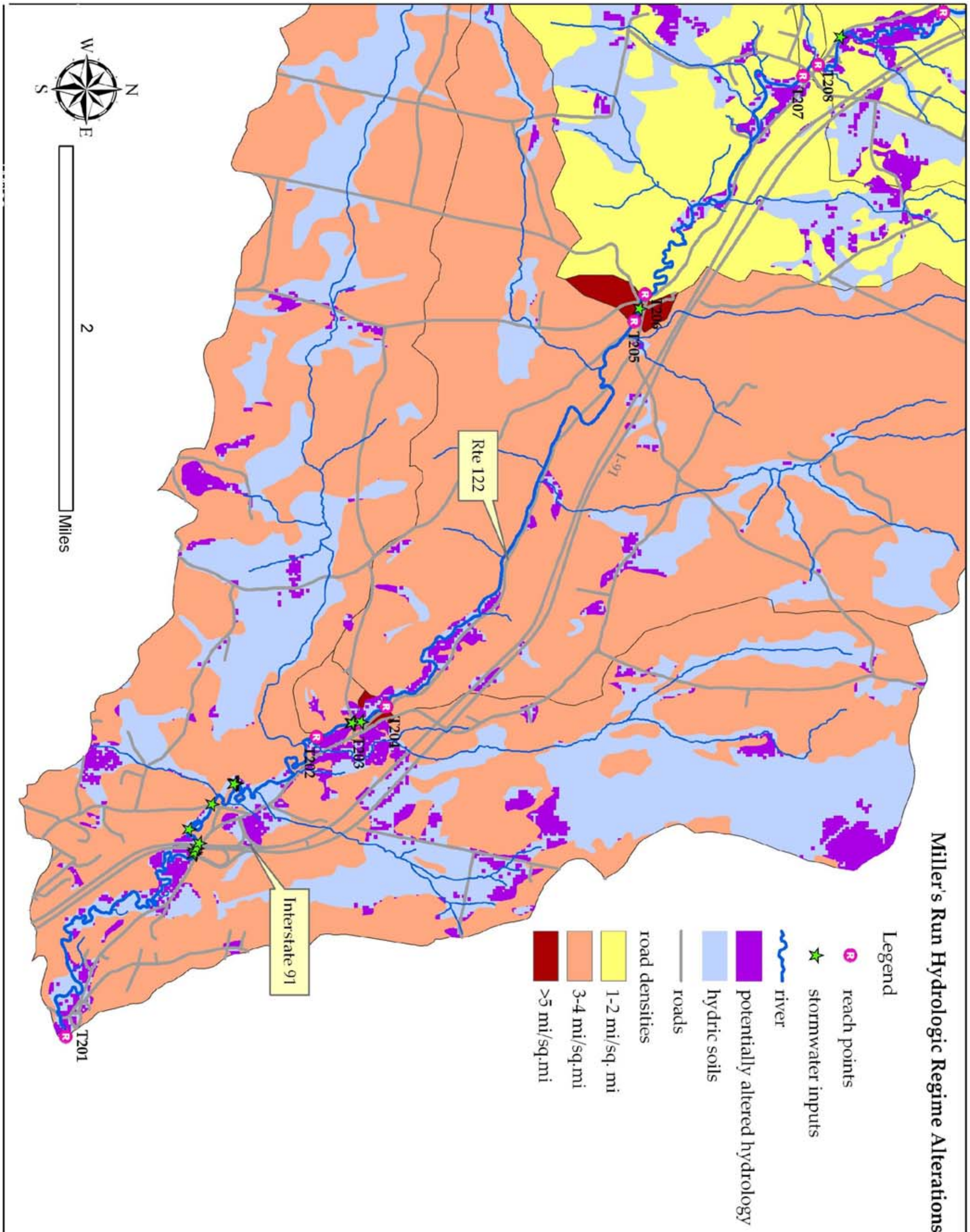
Agricultural land use in the Miller's Run watershed peaked in the mid-1800s (SHS, 1993), and today makes up approximately 11% of the watershed However, 39% of the stream corridor, mostly in the wider alluvial valleys, is dominated by agricultural land, 22% of which is tilled land. In Figure 5, agricultural and urban land uses were correlated with hydric soils, and where they overlap is referred to as 'potentially altered hydrology.' To begin this discussion, it is important to note that there are many research questions regarding the impacts of streamside agricultural land use that have not been addressed during this geomorphic assessment. The impacts of agriculture in a stream corridor are dependent on many factors, including micro-topography, slope, buffers, soil type and bank resistance, for example. Additionally, the impacts of streamside agriculture may also range from water quality issues, to hydrologic alterations, to sediment regime alterations. These variables were not specifically addressed during this assessment, but it was revealing to examine this a bit more closely due to the high levels of agricultural land use in the Miller's Run stream corridor. The focus of this discussion is the potential for agricultural and urban land uses to decrease floodwater storage capacity in the stream corridor. It can be argued that a floodplain forest or wetlands would slow, store and absorb more water than agricultural lands, partly due to hydraulic roughness created by vegetation and root mass but also due to micro-topography which may include small depressions in the landscape that would store and absorb water. Clearing and tilling a streamside field may reduce these opportunities and thereby alter the hydrologic regime of the watershed. This is difficult to quantify, but Figure 5 provides a visual context for this discussion by showing where agriculture and urban land uses intersect with hydric soils, and the potential in these areas for decreased water storage and absorption capacity.

The second most significant hydrologic stressor in the Miller's Run watershed is roads. Roads, road densities and stormwater inputs are mapped on Figure 5. Road densities are based on the number of miles of road per square mile of a reach's subwatershed. Road densities provide a broad context for road impacts, however the data are somewhat skewed based on the size of the reach. In a 1997 report entitled *The Miller's Run Stream Habitat Improvement Project*, which chronicled the series of bank stabilization projects that were completed between 1994 and 1997 on the Miller's Run, a number of landowner interviews were summarized and shed light into some of the hydrologic alterations on the Miller's Run. The following excerpt from the report explains:

> Anecdotal information collected from individuals who grew up in the [Miller's Run River] valley, indicate that the building of the interstate highway had a major impact on the stream. Runoff from storms that once soaked into wooded hills is now concentrated into a small number of tributaries. Wetland areas, which were destroyed for the interstate, are no longer there to act as sponges or filters soaking up storm water and capturing silt. In at least one pasture below the highway, what was a seasonal feeder stream is now running year round. In addition, housing development in the stream corridor has increased rapidly. These factors have had the overall effect of speeding the runoff from a storm into Millers Run so that a greater volume of water now tries to move through the channel in a shorter time period. People in the valley say that a storm which took hours to affect the stream in the past, will now cause high water very quickly. The stream has responded by trying to widen its channel to carry the higher peak flow. Floods are much more frequent now, leaving development along the stream vulnerable. (Dedham, 1997)

The Interstate and Route 122 are mapped on Figure 5, and provide a visual context for this discussion. Route 122 follows the entire stream corridor and has a broad impact on the stream's hydrology. Stormwater inputs are mapped on Figure 5 but there are likely more drainage culverts than were recorded during this assessment passing under Route 122. This network of roads and stormwater inputs have the ultimate effect of concentrating runoff during storm events, and further reducing opportunities for water to be distributed across the landscape, stored and absorbed. Instead, stormwater that may have otherwise been accommodated along the corridor or within the watershed is channelized and delivered more efficiently to the main stem. This could potentially increase flood flows downstream.

Figure 5: Hydrologic Regime Alterations



5.2 Sediment Regime Stressors

The sediment regime is the quantity, size, transport, sorting and distribution of sediments (VT ANR 2007). Stressors to this regime result from alterations to stream power and sediment supply. The following description from VT Agency of Natural Resources River Corridor Planning Guide explains sediment regime and stressors.

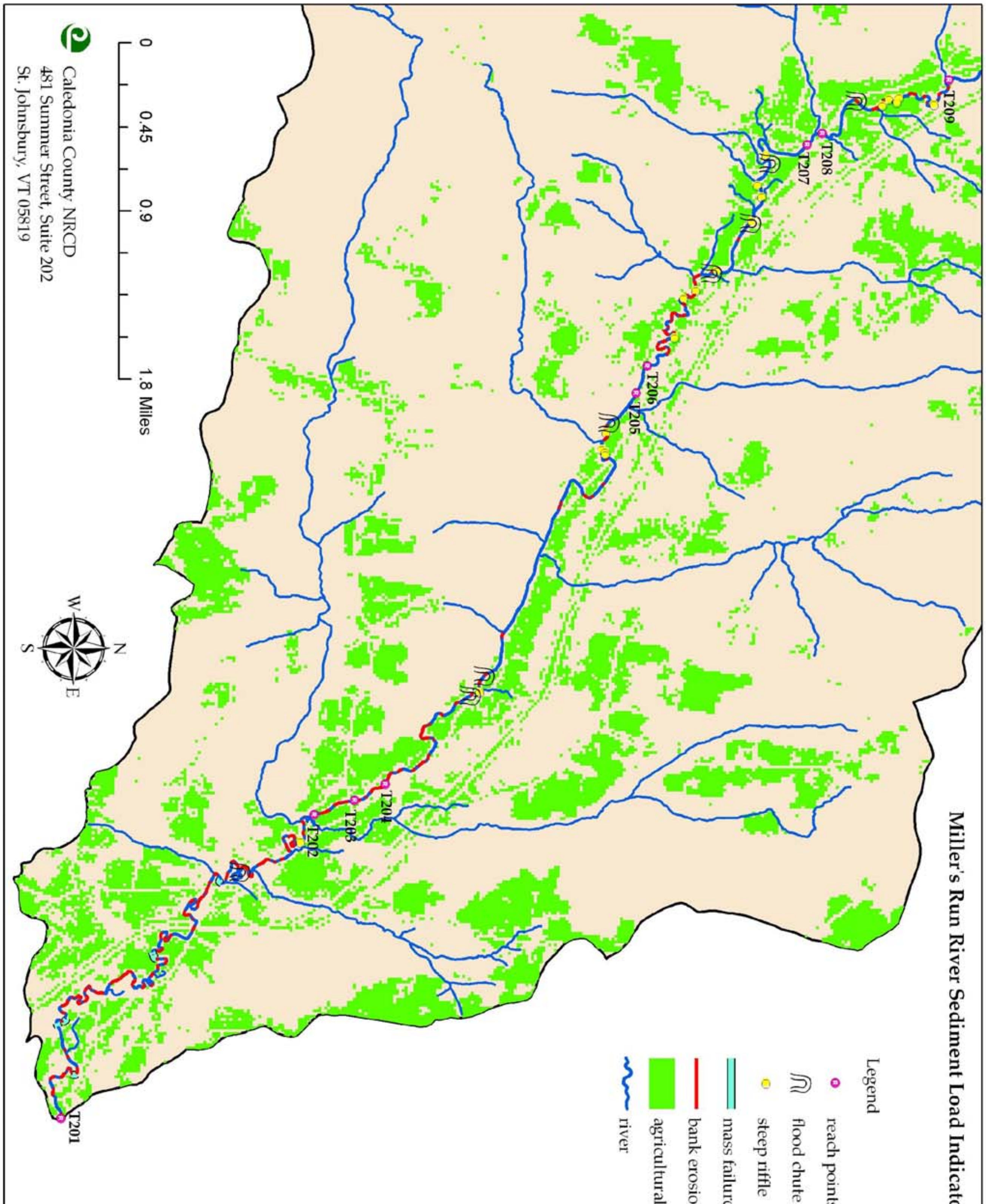
> The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and valley, floodplain and stream morphology. Understanding changes in sediment regime at the reach and watershed scales is critical to the evaluation of stream adjustments and sensitivity. The sediment erosion and deposition patterns, unique to the equilibrium conditions of the stream reach, and create and maintain habitat. In all but the most dynamic areas (e.g., alluvial fans), they provide for relatively stable bed forms and bank conditions.

Sediment regime stressors for the Miller's Run watershed are mapped on Figure 6 and include agricultural lands, erosion, as well as depositional and migration features such as steep riffles and flood chutes. Erosion impacts are greater than 20% in all assessed reaches except T208. The erosion data shows a significant amount of lateral migration occurring on the wider alluvial valleys of the Miller's Run, which is consistent with a stream that is in stages III and IV of the channel evolution process.

Streamside tilled land is vulnerable to precipitation and channel overflow, and with the addition of lacking buffers, are likely to result in a significant increase of sediment inputs and runoff into the Miller's Run River. As discussed in the previous section, agricultural land makes up 39% of the stream corridor and is found along these wide valleys. On Reach T206, where agricultural land use is heavy, we see a concentration of steep riffles, flood chutes and erosion. Additionally, a recent avulsion occurred on T206 at an area referred to as 'clay bank.' Prior to this avulsion, this area was characterized by a deep meander bed in the stream accessing a 60' tall saturated clay bank, and was thought to be the single greatest source of sediment into the Miller's Run regime (more detail and photos of the avulsion in Chapter 6.5). Another excerpt from the 1997 report *The Miller's Run Stream Habitat Improvement Project* reads: "A saturated clay bank located just below the town of Sheffield has been slumping into the stream for at least 50 years and is probably the biggest single contributor to sedimentation in the stream." (Dedham, 1997 p. 8)

This sediment enters the transport reach (cascade falls) in T205, and at the upstream end of Reach T204 shows some sediment deposition, largely due to alignment and sizing problems at the bridge on Route 122. Just after the bridges the stream begins a long, straightened transport section with some opportunities for sediment deposition towards its downstream end. Reaches T203 and T202 are the final transport reaches before Reach T201. This reach is particularly sinuous and showing erosion, mass failures and aggradation, as is the downstream end of Miller's Run before the confluence and high flooding area of the Passumpsic River main stem. Miller's Run River shows clear and consistent historic incision and current aggradational processes throughout most of its reaches. High erosion, high agricultural land use, roads, undersized bridges and narrow to non-existent buffers in locations are contributing to large amounts of sediment accumulations within the river channel, particularly in Reach T201.

Figure 6: Sediment Regime Stressors



5.3 Channel Slope and Depth Modifiers

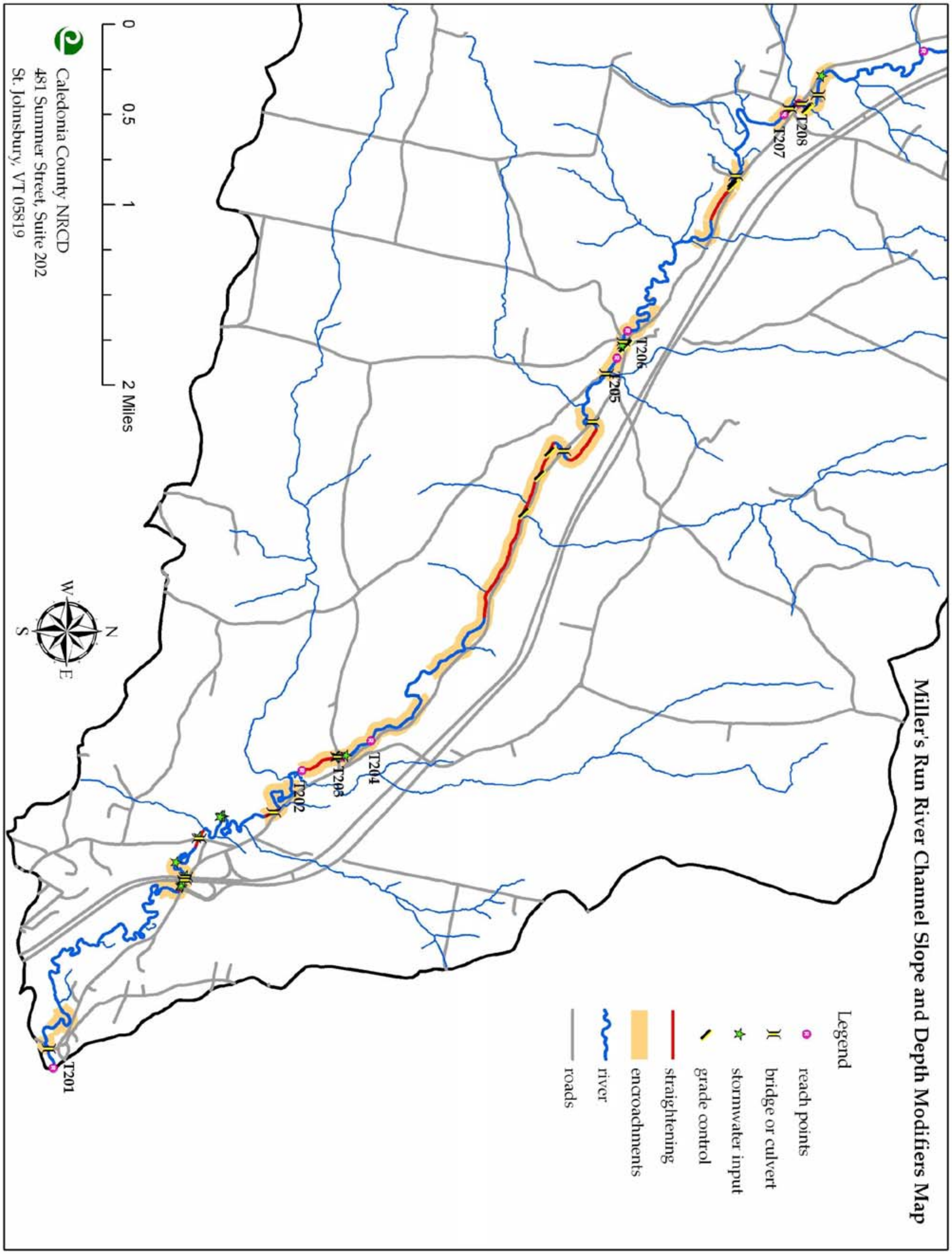
The two primary factors influencing the amount of shear stress (the extent of power within a channel and its corresponding ability to erode) generated by river flow are channel slope and flow depth. Changes to these factors and the resulting change in shear stress within the channel affect the rivers ability to transport sediment. Historic channel modifications and manipulations are significant in influencing channel geometry and floodplain access. Channel straightening increases channel slope and leads to increased sediment transport, bed erosion and incision ratios. Loss of floodplain access leads to heightened flow depths and subsequent shear stresses during times of high flows. Slope decreases occur from channel constrictions such as bridges and other structures, which often cause unnatural meander bends upstream due to an accumulation of sediment at the point of constriction.

Streamside encroachments such as roads, development or agriculture are often associated with dredging and berming of the stream channel, which increase the depth of a stream and raise the height of the floodplain. These practices will confine the stream to its channel and cut off access to the floodplain and the opportunity to store floodwaters in its natural location. While this may provide temporary protection from flood inundation at this point of the stream, floodwaters that would otherwise be stored on the floodplain are transported downstream creating increased fluvial erosion hazards and subsequent downstream inundation.

Channel slope and depth modifiers for the Miller's Run watershed have been mapped on Figure 7, which shows straightening, encroachment, grade controls, bridges and stormwater inputs. Reaches T204 and T202 have greater than 20% straightening, while the rest of the assessed reaches have more moderate levels of straightening (5-10%) or lower. Encroachments are shown and include both roads and development, though the majority of the encroachment is caused by Rte 122 and is causing an associated high impact rating for encroachment for most of the watershed.

Reach T204 shows the greatest level of channel slope and depth modification. At the upstream end of the reach, a large amount of sediment has been deposited due to constriction from the bridge on Route 122, where the river is directed to the opposite valley wall, then quickly redirected under a second bridge. The river is then straightened and confined against the valley wall, limiting access to its valley and floodplain, and resulting in an increase in slope and depth of the channel. The other prominent straightened section showing a significant increase in depth and slope can be seen on Reach T202, where the river was straightened to accommodate agriculture on its left bank. Due to these factors, historic incision is prevalent throughout the Miller's Run.

Figure 7. Channel Slope and Depth Modifiers

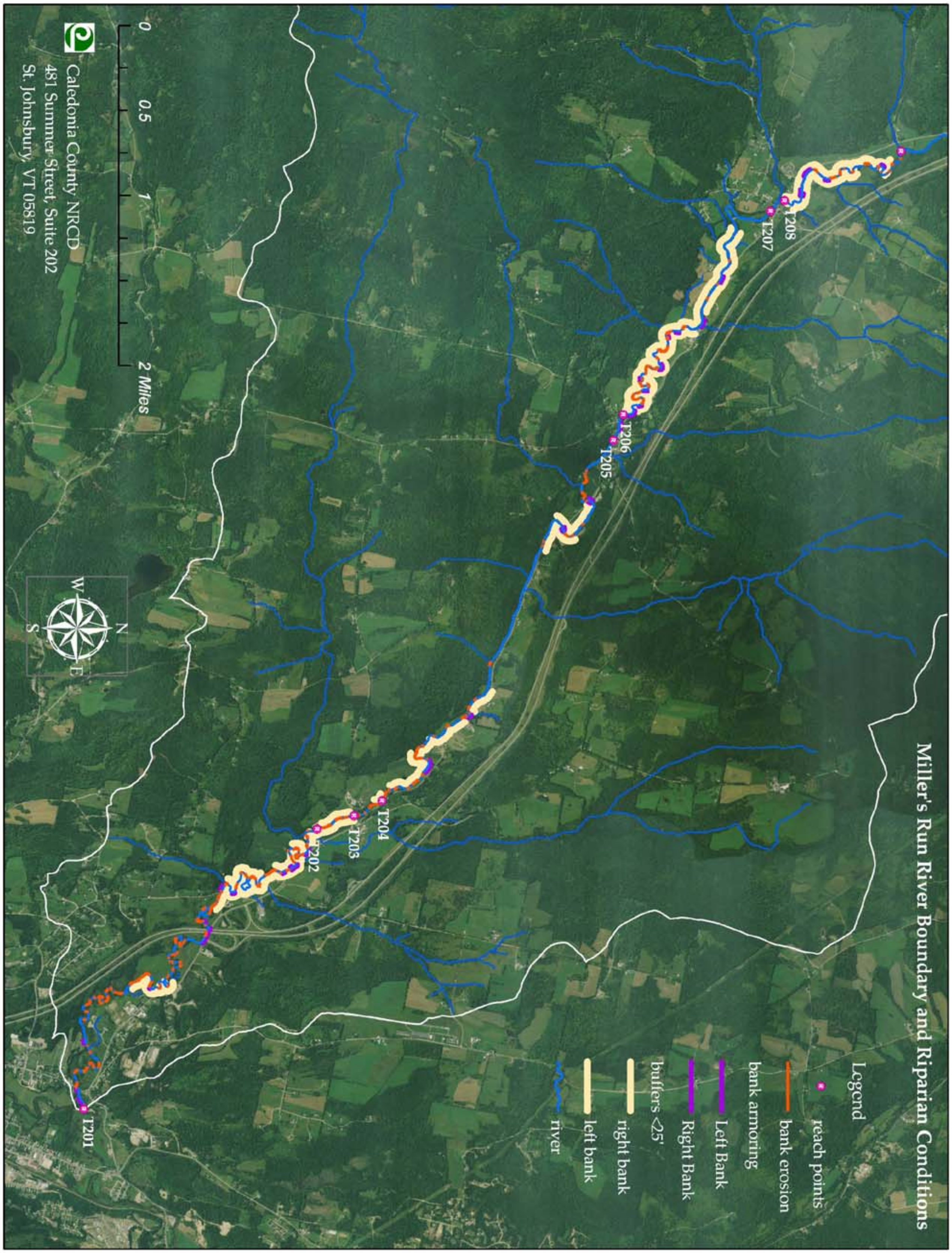


5.4 Channel Boundary and Riparian Condition Modifiers

Examining the boundary and riparian conditions provides insight into the ability of the channel to adjust. Buffer composition and bank material determine the amount of resistance that is present and impacting planform change. Channel armoring, for example, is a common channel boundary modifier and is intended to increase the banks resistance to planform change. Vegetated buffers also provide boundary resistance, and removal of the riparian buffer will increase the tendency of lateral movement of the channel. Bed substrate composition also impacts the resistance of the channel bed, and human made structures such as weirs and dams, or natural grade controls will increase the bed's boundary resistance.

Boundary and riparian conditions are mapped on Figure 8 and include bank armoring, erosion, and buffer information. Buffers widths less than 25 feet are demarcated on the map. As discussed previously with Sediment Regime Stressors in section 5.2, erosion is noted as high impact throughout all assessed reaches on the Miller's Run. Agricultural use on the flat alluvial valleys along with low buffer widths and non-cohesive bank material (recorded on all reaches) contribute to low boundary resistance and high lateral migration along most of the Miller's Run. The exceptions to this are where the stream is straightened and confined against the valley wall by Rte 122 in Reach T204, along small sections of Reach T201, and the two village cascade falls. Bank armoring is noted as "low" for the majority of the assessed reaches.

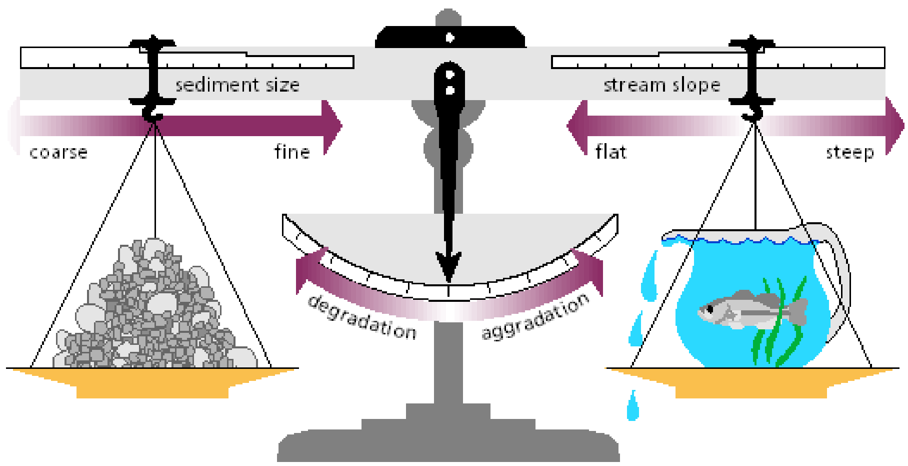
Figure 8: Channel Boundary and Riparian Conditions



5.5 Sediment Regime Departure Analysis

The balance of stream power and sediment are the defining elements to stream equilibrium (Leopold 1994). Rivers are in constant adjustment as they work to deal with an uneven distribution of power or sediment (disequilibrium), typically caused by stressors or modifications to channel geometry or watershed inputs. This concept of balance has been widely documented by Lane (1955) and his depiction of a scale to show the elements of dynamic equilibrium at work. See Figure 9 below. Streams are naturally adaptive to minor changes in stream power or sediment, however, land use changes and other management practices can create major changes in these inputs making the state of dynamic equilibrium more difficult to achieve. A river management practice or land use decision that works against the physical processes of this balance will undoubtedly be a continuing source of conflict.

Figure 9: Lane's Balance (1955).



The analysis of sediment regime departure is a useful method for understanding the context of stream disequilibrium and channel evolution. The VT ANR River Corridor Planning Guide (2007) has developed a methodology for understanding reference and existing sediment regime types. Sediment regimes are summarized below in Table 4.

Table 4. A Summary of Sediment Regimes (VT ANR, 2007)

Sediment Regime	Narrative Description
Transport	Steeper bedrock and boulder/cobble cascade and step-pool stream types; typically in more confined valleys, do not supply appreciable quantities of sediments to downstream reaches on an annual basis; little or no mass wasting; storage of fine sediment is negligible due to high transport capacity derived from both the high gradient and/or natural entrenchment of the channel.
Confined Source and Transport	Cobble step pool and steep plane bed streams; confining valley walls, comprised of erodible tills, glacial lacustrine, glacial fluvial, or alluvial materials; mass wasting and landslides common and may be triggered by valley rejuvenation processes; storage of coarse or fine sediment is limited due to high transport capacity derived from both the gradient and entrenchment of the channel. Look for streams in narrow valleys where dams, culverts, encroachment (roads, houses, etc.), and subsequent channel management may trigger incision, rejuvenation, and mass wasting processes.

Unconfined Source and Transport	Sand, gravel, or cobble plane bed streams; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to entrenchment or incision and associated bed form changes; these streams are not a significant sediment supply due to boundary resistance such as bank armoring, but may begin to experience erosion and supply both coarse and fine sediment when bank failure leads to channel widening; storage of coarse or fine sediment is negligible due to high transport capacity derived from the deep incision and little or no floodplain access. Look for straightened, incised or entrenched streams in unconfined valleys, which may have been bermed and extensively armored and are in Stage II or early Stage III of channel evolution.
Fine Source and Transport & Coarse Deposition	Sand, gravel, or cobble streams with variable bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to vertical profile and associated bed form changes; these streams supply both coarse and fine sediments due to little or no boundary resistance; storage of fine sediment is lost or severely limited as a result of channel incision and little or no floodplain access; an increase in coarse sediment storage occurs due to a high coarse sediment load coupled with the lower transport capacity that results from a lower gradient and/or channel depth. Look for historically straightened, incised, or entrenched streams in unconfined valleys, having little or no boundary resistance, increased bank erosion, and large unvegetated bars. These streams are typically in late Stage III and Stage IV of channel evolution.
Coarse Equilibrium (in = out) & Fine Deposition	Sand, gravel, or cobble streams with equilibrium bed forms; at least one side of the channel is un-confined by valley walls; these streams transport and deposit coarse sediment in equilibrium (stream power—produce as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance); storage of fine sediment as a result of flood-plain access for high frequency (annual) floods. Look for unconfined streams, which are not incised or entrenched, have boundary resistance (woody buffers), minimal bank erosion, and vegetated bars. These streams are Stage I, late Stage IV, and Stage V of channel evolution.

Figure 10 displays the reference sediment regime type, which is largely determined by valley confinement and slope. Most reaches on the Miller's Run, except for T201 which is an e-type stream and the excluded cascade falls in the villages, were determined to be C-type streams in Phase 1. C-type streams are generally in a broader valley with adequate access to their floodplains. Figure 11 shows the existing sediment regime type, and the clearest departure is from a Coarse Equilibrium & Fine Deposition (CEFD) regime to a Fine Source and Transport and Coarse Deposition (FST&CD) condition. The reference CEFD regime generally means that the stream is depositing and transporting sediment in equilibrium. A departure from this regime to the FST& CD regime is largely the result of historic incision, low channel boundary resistance and loss of access to the floodplain. Because of these conditions, the stream is no longer able to store fine sediments on the floodplain, and thereby transports an excess of fine and coarse sediments to downstream reaches, resulting in large sandy bars. Reach T201 is a clear example of this departure.

Figure 10: Reference Sediment Regime

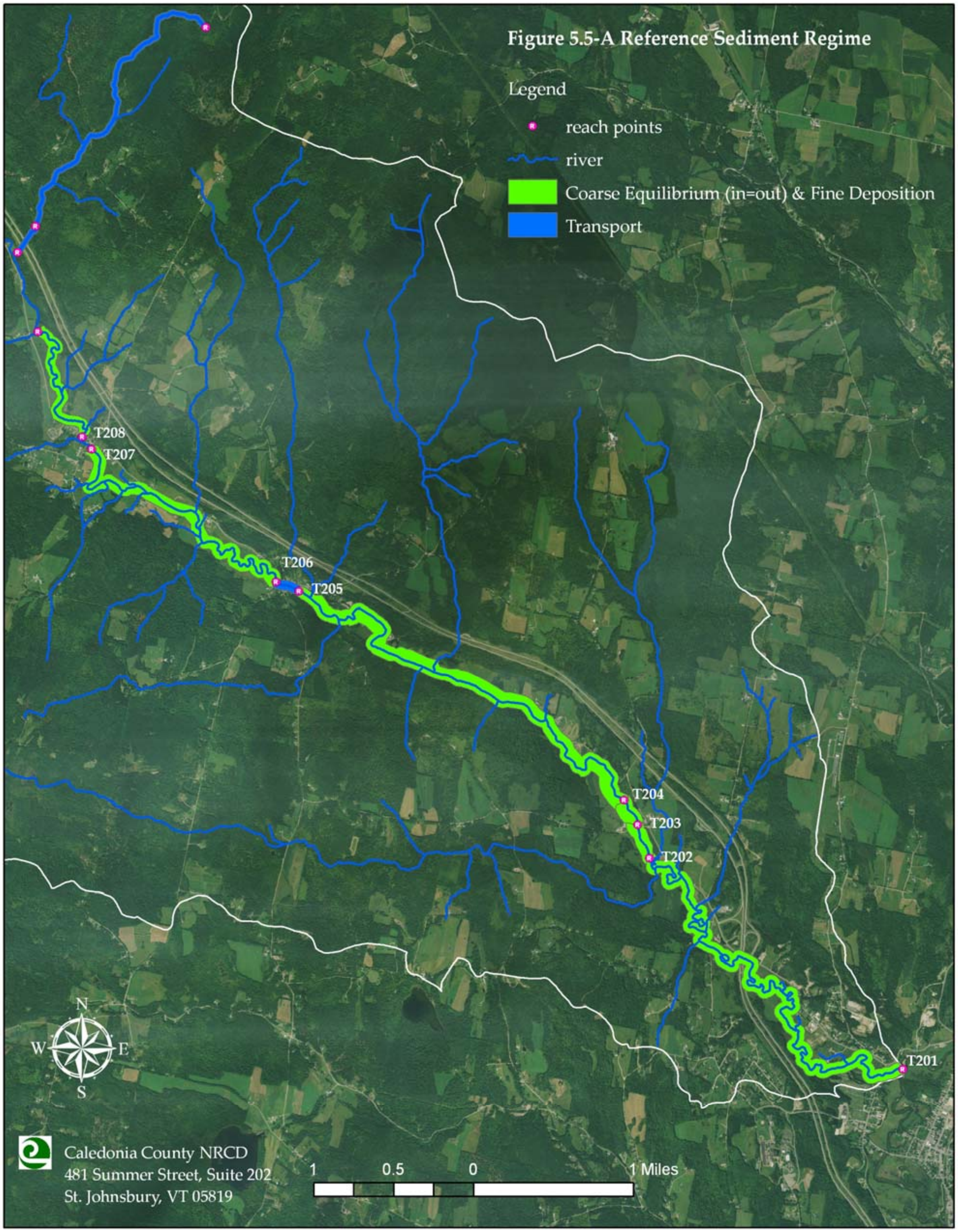
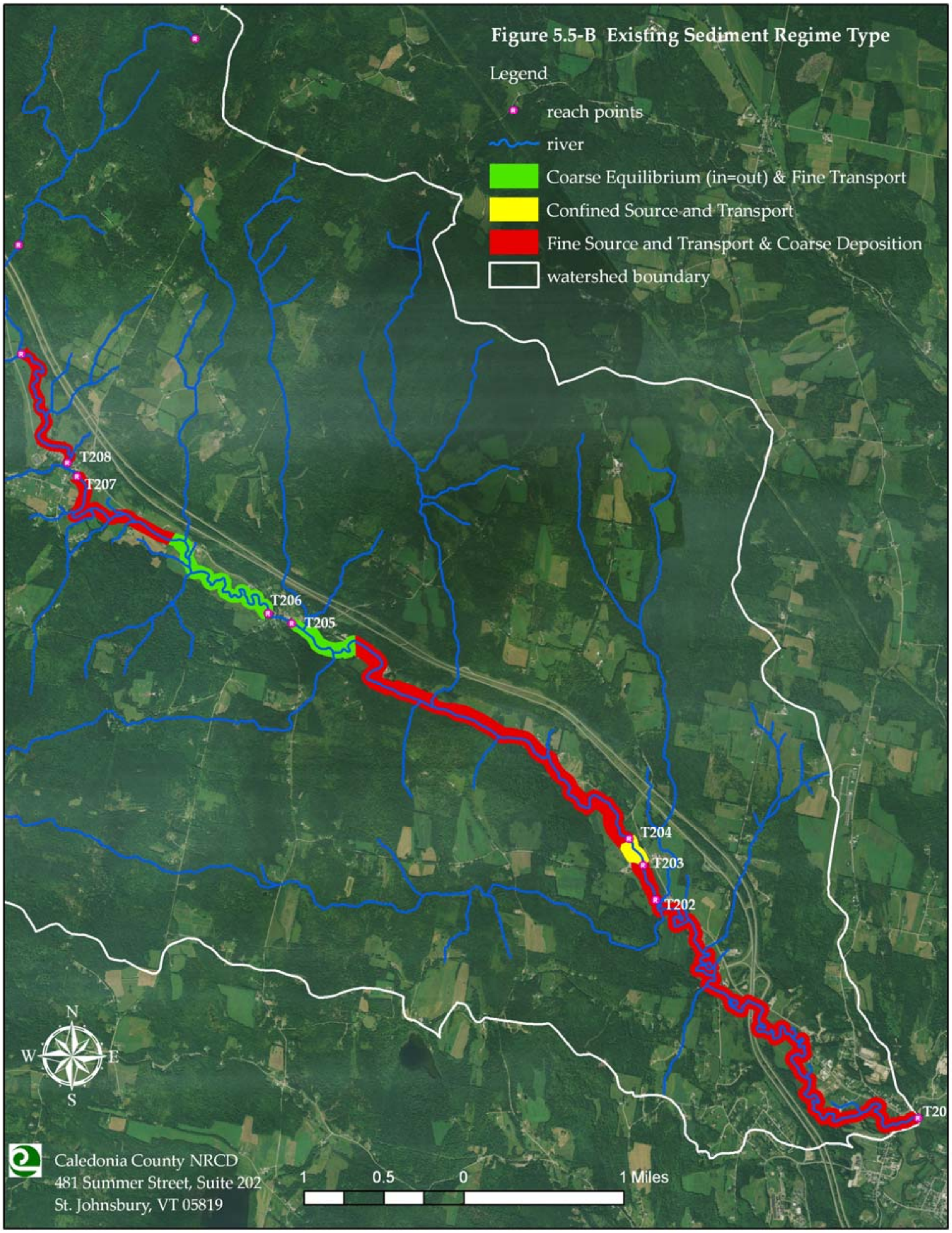


Figure 11: Existing Sediment Regime



5.6

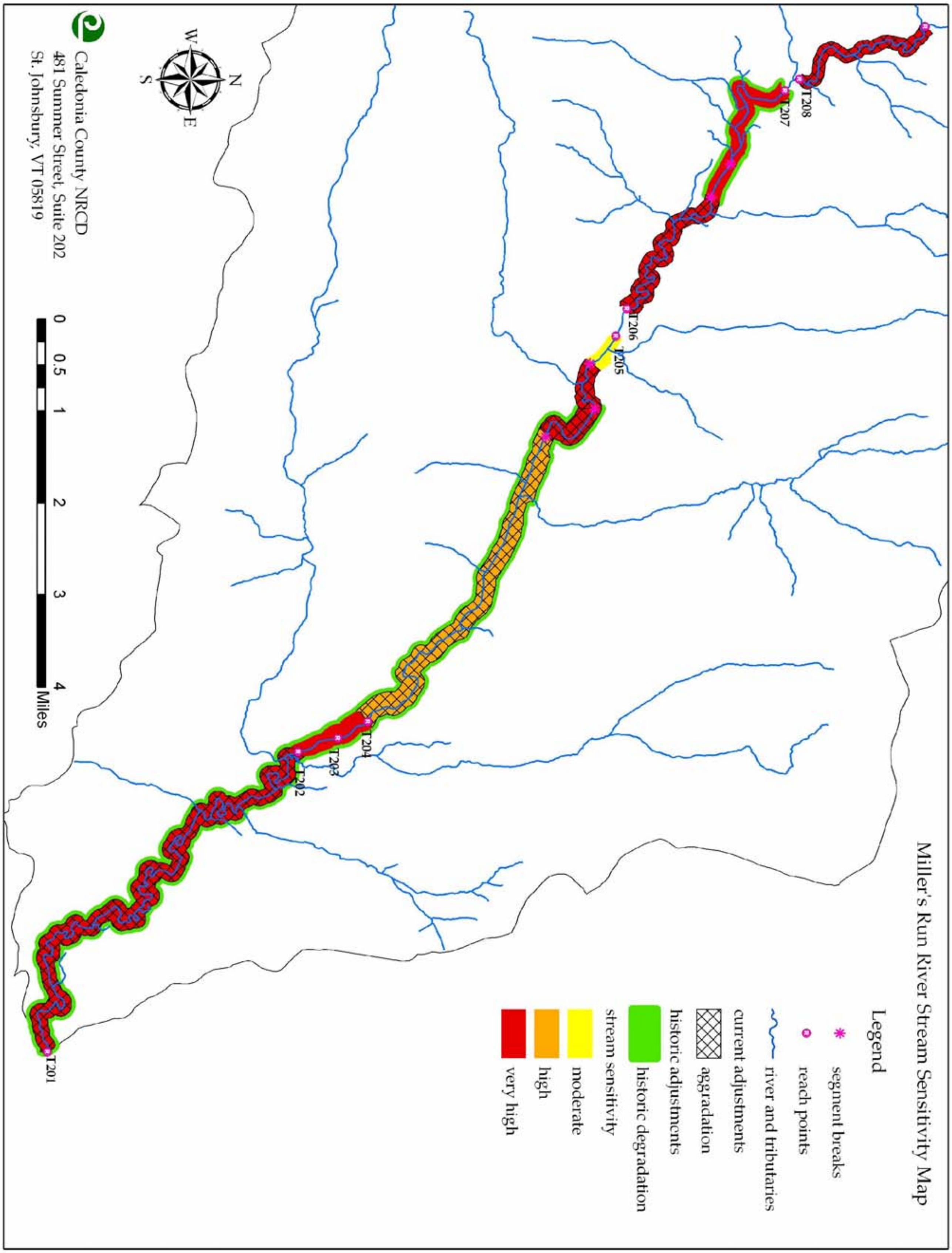
Stream Sensitivity Analysis

An examination of a stream's sensitivity provides a context to better understand a channel's adjustment processes and the ability of the channel to respond to changes. As explained by the VT Agency of Natural Resources Stream Geomorphic Assessment Protocols (VT ANR 2007):

> Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor. Assigning a sensitivity rating to a stream is done with the assumption that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened when human activities alter the setting characteristics that influence a stream's natural adjustment rate including boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive. (VT ANR Section 5.2)

High levels of erosion and aggradation, coupled with historic degradation on the Miller's Run River, have rendered much of the stream channel as very highly sensitive. Figure 12 maps the sensitivity ratings for each assessed reach, and additionally shows current and historic channel adjustments. Reach T201, the mouth of the Miller's Run, is extremely sinuous, erosive and has high levels of sediment throughout. This entire reach is very sensitive which indicates that it is in a rapid state of change and is very responsive to stressors and changes in the stream channel. Sensitivity upstream from this reach to T204, continues to have high or very high sensitivity, often with current aggradation. Historic channel degradation is consistent throughout much of the stream channel, accounting for high incision ratios with lacking floodplain access, while the current adjustment is consistently aggradation, with associated steep riffles, depositional bars and flood chutes.

Figure 12: Miller's Run Stream Sensitivity



6.0 Preliminary Project Identification

A primary goal of stream geomorphic assessments is to inform management of streams towards equilibrium conditions. In the previous chapter, we examined the Miller's Run departure from equilibrium and its sensitivity ratings to provide a context by which we can then select priority projects that will produce the greatest benefits to the stream channel. The following chapter indentifies preliminary projects on a reach by reach basis. Projects are listed by priority at the end of the chapter and it should be noted that social constraints have not been considered as limiting factors for any project. "Left bank" and "right bank" descriptions are referenced looking downstream. A geomorphic description of the reach is listed followed by potential projects and their priority.

6.1 Preliminary Project Identification: Reach T201 – Mouth to near Hubbard Hill Road Bridge

Reach T201 is a long, sinuous reach extending for over 23,000 feet with many oxbows. The valley length of the reach is almost half the channel length, making the sinuosity ratio 1.95. The reach was classified as an E-type stream with sand substrate and a dune-ripple bed form situated in a very broad valley. There are C-type stream features throughout the reach, but a low width to depth ratio, low gradient and fine sediment accumulations throughout the reach resulted in the E-type classification. Land use ranges from agriculture to fallow land, with some residential development in the corridor towards the mouth. Lateral migration is occurring throughout the entire reach, with oxbows, erosion, debris jams, and mass failures present. The current adjustment patterns include aggradation and widening. The selected cross section for this reach had an incision ratio of 1.85, though other cross section data taken on this reach averaged around 1.35 with higher entrenchment ratios. The selected data brings the stream type close to a G, which would be a departure consistent with the high incision ratio, though the existing numbers still support the E-type stream classification.

Figure 13: Reach T201 showing fine sediment accumulation, low gradient and debris jam

Figure 14: Reach T201 showing mass failure and lateral migration

This reach includes the confluence with the Passumpsic River main stem, and an area of frequent flooding. Reach T201 is in Stage III of channel evolution, characterized by widening and regaining access to its floodplain after a period of historic incision. Current aggradation and fine sediment accumulation are considerable on this reach, and additionally on the Passumpsic River main stem. The low gradient and meander patterns of the Miller's Run and Passumpsic River at this location are very similar, each stream taking on large amounts of sediment and showing similar sinuosity. This is a striking difference from the nearby confluences with the East and West Branches of the Passumpsic River, approximately 1.5 miles upstream on the Passumpsic River main stem, which have steeper gradients and are contributing greater levels of stream power and floodwater volume than the Miller's Run. Additional factors on this reach include roads, development and an adjacent cemetery, which is on a terrace along the right bank of the Miller's Run, but could be threatened by erosion hazards posed during flood events. A historic covered bridge crosses the Miller's Run near the mouth, and the bridge is often overtopped by water during flood events. The bridge is a channel constriction with alignment and bed scour problems.

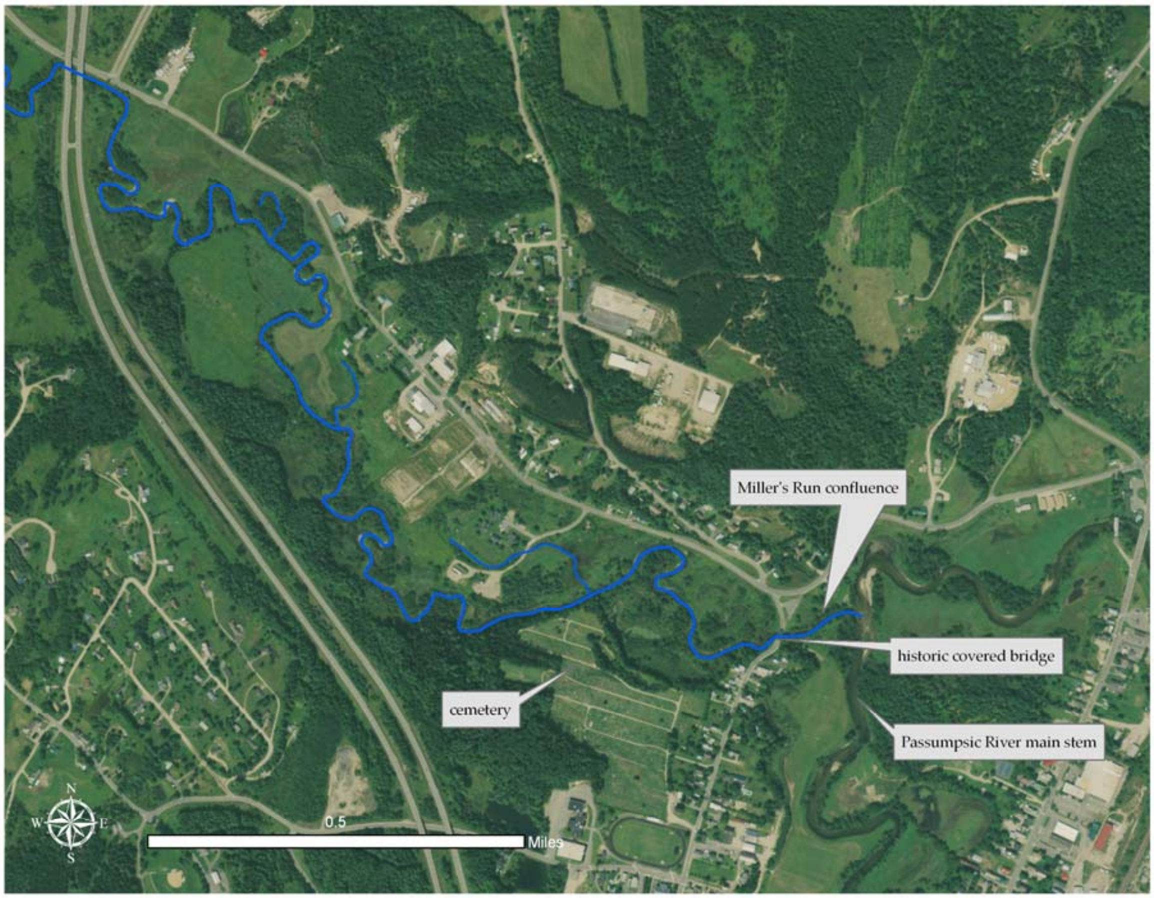


Figure 15: Photo showing the downstream end of Reach T201 and the Miller's Run River confluence with the Passumpsic River main stem. Both streams are very sinuous and flood frequently. Additional characteristics include roads, development, a historic covered bridge and a streamside cemetery.

Additional key features of Reach T201 include:

- Five bridge crossings, two of which are Interstate 91, the most actively managed section of the reach. The stream abuts Route 122 as it crosses under the Interstate and is straightened and armored along the left bank.
- The two upstream bridge crossings are both channel constrictions and areas of conflict with the potential for debris jam. The bridge pictured on the right shows potential for erosion hazards and structural failure with the footing.

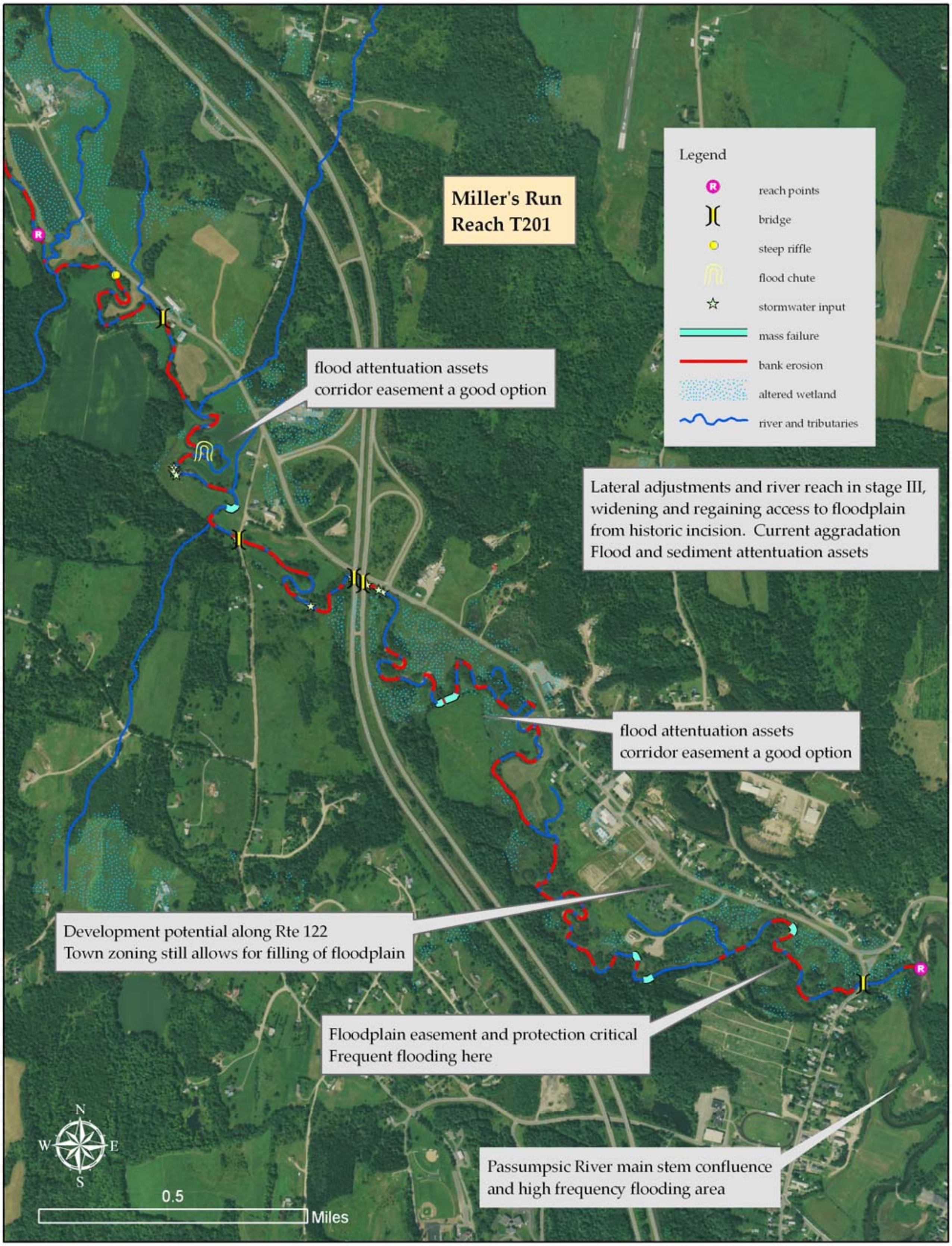
Figure 16: Farm bridge on Miller's Run Reach T201 showing potential for bridge footing failure

- Lateral adjustment evident from erosion data
- Six mass failures on reach
- Old channel beds in valley
- Development potential along Route 122
- Dominant buffer width is 0-25' on left bank, 26-50' on right bank with herbaceous plants as dominant buffer species
- There are nine stormwater inputs (5 road ditches, 4 tile drains)
- Tributaries are rejuvenating
- Dominant corridor land use agriculture on left bank, shrubs/saplings on right bank
- Stream sensitivity very high in fair geomorphic condition

Table 5: Preliminary Project Identification Reach T201

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T201	Update Floodway Zoning	Very High	High	Yes	Floodway boundaries on the Miller's Run should be updated and digitized to accommodate the changes in the river since the last update in 1988. The exploration of Fluvial Erosion Hazard (FEH) mapping is highly recommended.
T201	Protect River Corridor	Very High	High	Yes	Very valuable flood attenuation assets on this reach. Area is prone for potential development along Route 122. Extremely necessary to look at options with town and landowners concerning Fluvial Hazard Zoning or floodplain easements.
T201	Re-establish buffers	High	Moderate	Yes	Due to lateral migration and incision ratio, either a belt width planting or natural regeneration through easements. Conservation Reserve Enhancement Program (CREP) possible for agricultural land
T201	Replace existing bridge structures	Moderate	Low	Yes	Two upstream bridges may require attention due to undersized structures. Interstate bridges fine. Covered bridge is historic and often inundated with floodwater. Potential for financial assistance for covered bridge from state programs.
T201	Expand floodplain access	Moderate	Moderate	Yes	Due to elevated incision ratios, and the necessity of increasing floodwater storage capacity, a consideration of floodplain excavation to increase access is recommended. Would require further study.

Figure 17: Preliminary Project detail for Reach T201 Map



6.2 Preliminary Project Identification: Reach T202
Along farm field just downstream of Hubbard Hill Bridge

Reach T202 is short reach that extends for just over 1200 feet. The reach is entirely straightened and shows evidence of dredging. Agricultural land use flanks the left bank with cropland as the dominant land use. There is a strip of hayed land between the cropland and the stream, with a few shrubs along the stream but generally no buffer. There is a berm along the left bank that extends for nearly the entire length of the reach. The top of the berm is almost 9' from the thalweg. The right bank is characterized by a gravel mining operation along the right bank corridor. There is just over 900 feet of erosion on the reach, which is characterized by slumping of saturated bank (see figure 6.1.2-A below). This reach is working to regain access to its floodplain through lateral migration. Sand is the dominant substrate, and the reach keyed out to an F-type stream with an entrenchment ratio of 1.3. This is a departure from the reference stream type of the reach, which was a C-type stream in a very broad valley. The historic dredging, straightening and berming of the reach prohibited access to the floodplain, caused incision of the stream channel and the stream-type departure. The incision ratio was recorded as 1.6 for the reach, however the incision is historic and the stream is now in stage III channel evolution characterized by aggradation, widening and regaining access to the floodplain.

Figure 18: Photo showing right bank of Miller's Run Reach T202 with slumping banks. The gravel operation is along the corridor on this side of the river

Additional characteristics of Reach T202 include:

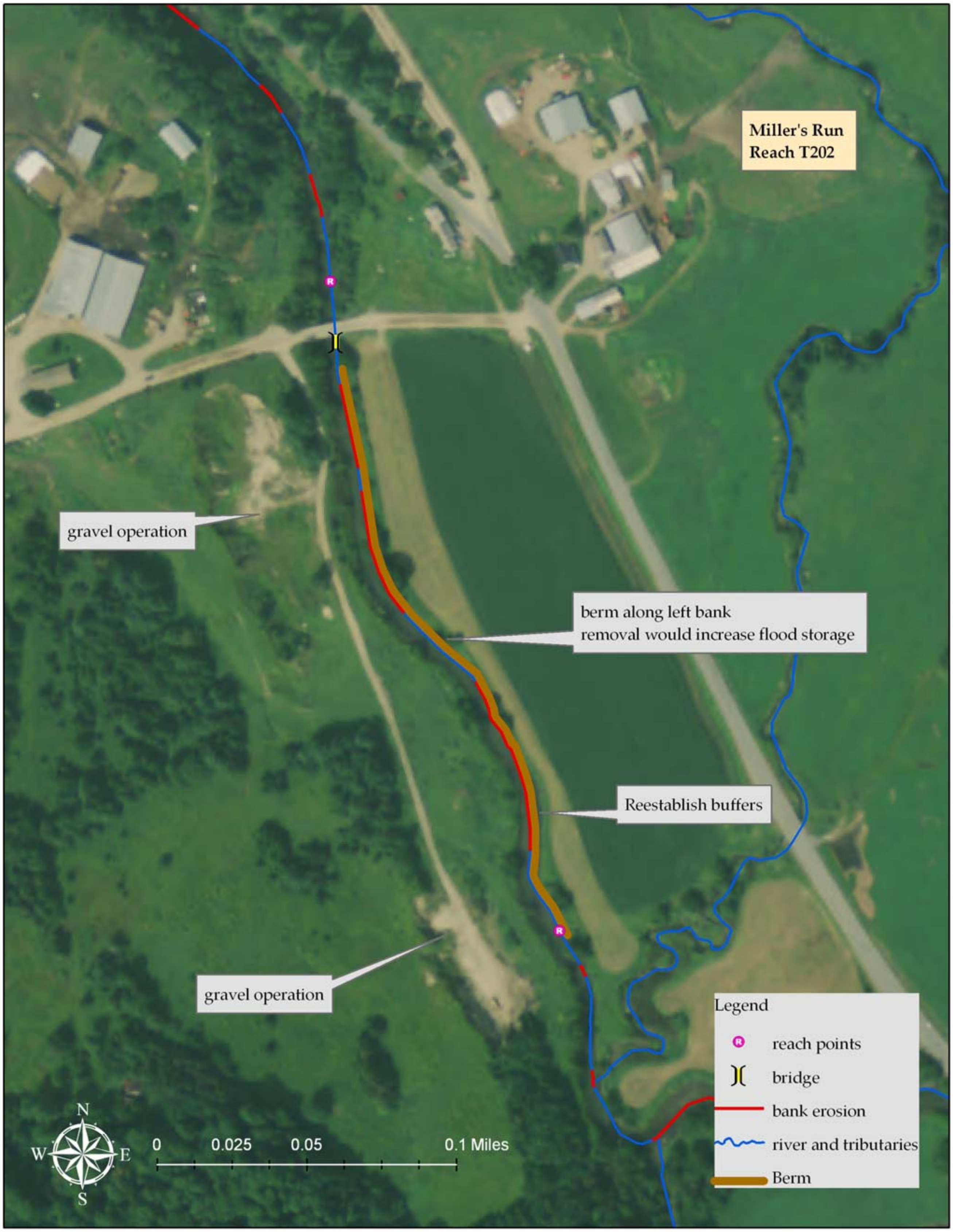
- Hubbard Hill bridge undersized with associated stream bed scour downstream
- Stream sensitivity very high
- Habitat condition of fair
- Bed form is plane bed, with some pools and woody debris in pools
- Dominant buffer width 0-25' on both sides

Figure 19: Hubbard Hill Bridge on Reach T202, channel constriction and associated scour

Table 6: Preliminary Project Identification Reach T202

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T202	Remove berm	High	High	Yes	The removal of the berm at this location would decrease incision from >2.0' to 1.6 and offer flood attenuation potential. Agricultural land use would be compromised and landowner would likely need compensation
T202	Reestablish buffers	High	High	Yes	Gravel pit operation continues to move away from the river as material is used. Good potential for buffer installation on this side. Farm field on left bank also lacking buffer.
T202	Replace bridge structure	Low	Low	Yes	Bridge is a channel constriction but has good height to accommodate flows.
T202	Expand floodplain access	Low	Low	Yes	Due to elevated incision ratios, and the necessity of increasing floodwater storage capacity, a consideration of floodplain excavation to increase access is recommended. Would require further study.
T202	Protect River Corridor	Low	Low	Yes	This is a short reach but in an area with significant hydrologic alterations. Protecting the corridor along with the above practices should be considered.

Figure 20: Preliminary Project Details Reach T202 Map



6.3 Preliminary Project Identification: Reach T203 Upstream of Hubbard Hill Bridge

Reach T203 is a short, semi-confined reach extending 1038 feet. There is a dairy farm along the right bank corridor, situated on a terrace uphill from the stream valley and the opposite left corridor is occupied by Route 122. The reach was classified as a B subclass c stream type in Phase 1, but due to historic incision has departed to an F-type stream with and entrenchment ratio of 1.2. Current adjustments include aggradation and widening. The dominant bed material is gravel with plane bed form, with sand dominated, non-cohesive banks. Dominant buffer widths are >100 on the right bank and 51-100 on the left, with only a small un-buffered section on the upstream end of the left bank. Dominant land use if forested, with the road and the dairy farm making up the sub-dominant land uses.

Figure 21: Miller's Run Reach T203 cross section. Photo showing aggrading gravel-dominant plane bed stream, in a semi-confined valley

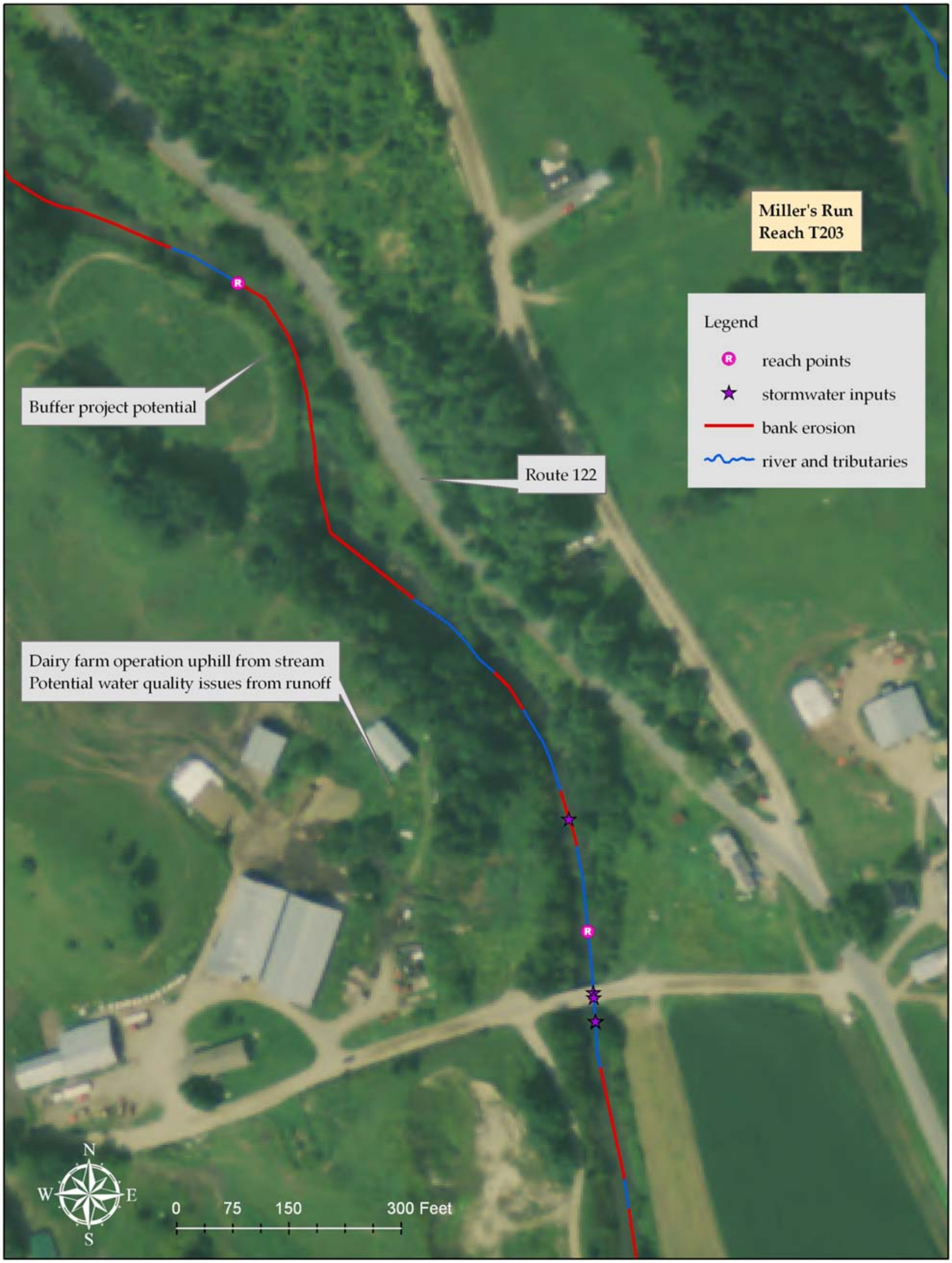
Other key characteristics of Reach T203 include:

- One mid-channel bar and one side bar
- 1 field ditch
- Potential for barnyard runoff and related water quality issues
- No bridges or culverts
- Moderate erosion
- Invasive plants for bank vegetation
- Channel evolution in stage III, widening
- Geomorphic condition of fair
- Very high sensitivity rating
- Habitat condition of fair

Table 7: Preliminary Project Identification Reach T203

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T203	Protect River corridor	low	low	yes	Low priority project area due to confinement. Some potential water quality issues from road and farm could be addressed
T203	Restore buffers	low	low	yes	Low priority but good buffer project potential on upstream right bank
T203	Address potential water quality issues	low	low	yes	Some potential for agricultural runoff into stream should be considered. Various federal programs could provide assistance with this.

Figure 22: Miller's Run Reach T203 Preliminary Project Details



6.4 Preliminary Project Identification: Reach T204: From the base of Wheelock Village falls to 1000' upstream of Hubbard Hill Bridge

Reach T204 is 16,788 feet long and was divided into 4 segments. Segments are described separately beginning at the downstream end of the reach. Reach T204-A extends for 10,936 feet from the T203 reach break upstream to near the Rte 122 bridges south of Wheelock village. Upon further examination of this segment, it could easily be divided into two segments as the planform changes mid-segment. The upstream half of the segment is straightened and pinned along the valley wall on the right bank by Rte 122 on the left. The straightening extends for approximately one mile, until the lower half of the segment where the stream pulls away from the road and develops sinuosity. Overall, the segment classifies as a B-type stream with gravel substrate. Cross section data varied from C to B to F-type streams throughout, however the entire stream was generally entrenched with small pockets of floodplain access, and a cross section was selected with a 2.36 entrenchment ratio but classified as a B-type stream. This was a stream type departure due to historic incision from a C to a B type stream. Similar to other reaches, this reach also shows current aggradation and widening and stream evolution in stage III. The lower end of the segment is the first opportunity upstream from the floodway of the Miller's Run mouth and Reach T201 for flood and sediment attenuation to occur. The entrenchment and incision ratio of 1.5 is concerning as this particular section could provide good attenuation assets with increased floodplain access.

Additional characteristics of Reach T204-A include:

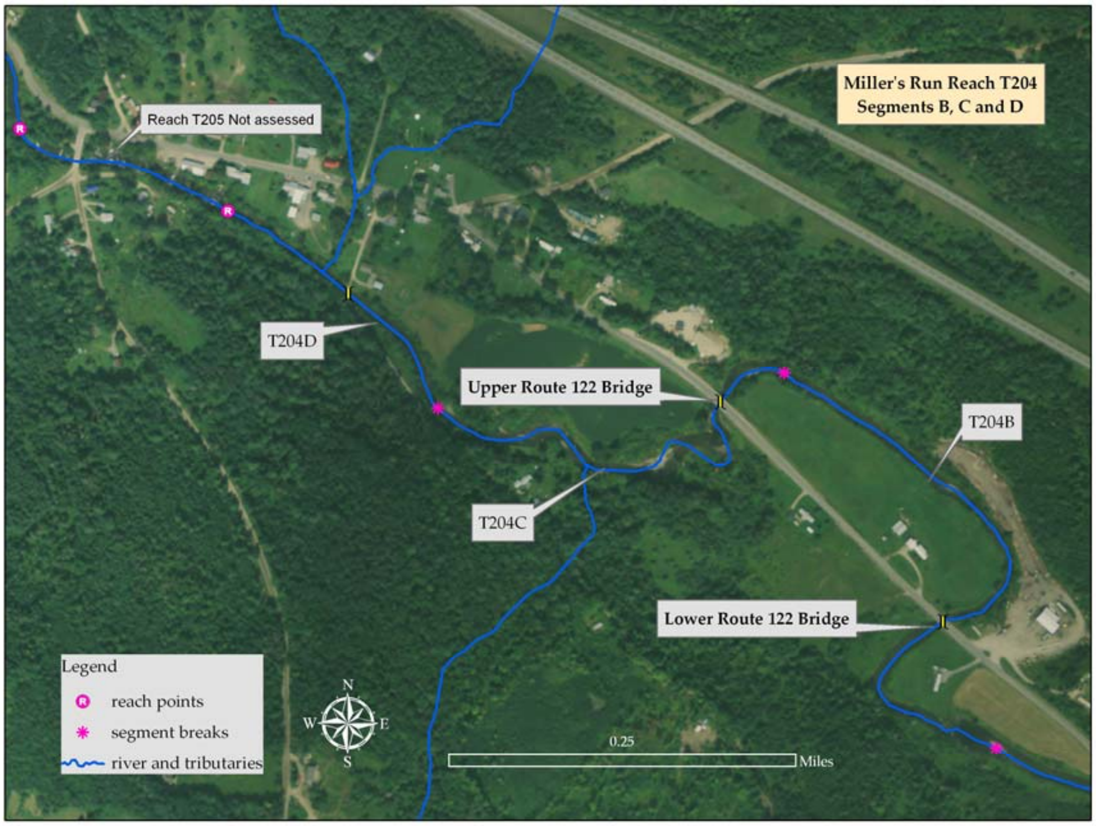
- Riprap in most locations is failing
- Three channel spanning ledges with pools in upstream part of segment
- Stream sensitivity is high and geomorphic condition is fair
- Habitat conditions are fair
- Stream bed form is plane bed, was riffle pool by reference
- There are 12 depositional bars recorded, with 1 steep riffle and two flood chutes
- Dominant land use along the left bank cropland with Rte 122 as subdominant
- Dominant land use along the right bank is forest with hayland as subdominant
- Moderate erosion noted, mainly in the lower more sinuous section of the segment

Figure 23: Photo showing reach T204-A with valley wall on right and Rte 122 on left. Lateral movement is minimal.

Figure 24: Photo showing cross section of Reach T204-A farther downstream. Increased lateral movement and gravel substrate, but still relatively entrenched

Reaches T204 B, C and D make up the upstream end of the reach and extend from the base of Wheelock falls to downstream of the Rte 122 bridges. The bridges are a significant stressor to the Miller's Run, and though the segments are short, they help illustrate the various impacts seen at locations upstream and downstream of the bridges. For the purpose of the discussion, these bridges will be referred to as the upper (upstream) Rte 122 Bridge, and the lower Rte 122 Bridge.

Figure 25: Reach T204 Upstream Segment Locations



Beginning upstream, T204D begins at the base of the Wheelock village falls and extends for 1042' to the segment break. The segment has been historically straightened to accommodate development, but it is reasonably stable with little erosion. It is classified as a C-type stream with cobble dominated substrate. The straightening has changed the bed form from its reference riffle pool form to plane bed. The incision ratio was recorded at 1.2, and because of the apparent stability of the channel, it was classified in stage I channel evolution (though arguably could be approaching stage II). There is one bridge that is a channel constriction with scour noted upstream of the bridge.

Additional characteristics of T204-D include:

- Dominant land use on left corridor is 'residential,' right corridor is forested
- One point bar recorded and no other depositional features
- Dominant buffer width on left is 0-25', right is >100
- Entrenchment ratio is 3.4
- No stormwater inputs
- Evidence of dredging

Reach T204C is a 1700' segment surrounding the upper Rte 122 Bridge. The section was segmented due to the impacts of the bridge, and the resulting changes seen in channel dimensions, sinuosity and substrate. The upper Rte 122 Bridge is recorded as 90' wide and the Millers' Run has a bankfull width of 58'. However, the channel is armored underneath the bridge (see Figure 6.1.4-C below); therefore the channel does not have access to the full 90' and is constricted. In addition, Route 122 and its bridges run parallel with the valley of the Miller's Run, which necessitates the stream to cross under the bridge at nearly a perpendicular angle to its river valley. The stream is funneled from one side of the valley to the other, and the alignment and constriction of the bridge is causing backwater, sediment deposition and large meander bends upstream. The stream type is still a C-type stream on this segment, though with gravel dominated substrate (due to finer sediment accumulation upstream of the bridge). There are a number of steep riffles, one flood chute and two mid-channel bars which provides some sediment attenuation assets. There is no incision but clear aggradation and planform adjustments. It was determined the reach is in stage IV channel evolution, and is working to rebuild a new floodplain.

Figure 26: Photo showing Reach T204C upstream of bridge on Rte 122 and its new and old floodplains.

Figure 27: Photo showing Reach T204C and the upstream Bridge on Rte 122. Sediment accumulation upstream of the bridge is visible here, as well as the alignment issues of the bridge itself. While the bridge is 90' wide, riprap constricts the channel width.

Figure 28: Photo showing the lower Rte 122 Bridge on Reach T204B. Channel upstream of the bridge is straightened the bridge is a channel constriction and long term area of conflict.

Other characteristics of Reach T204C include:

- Dominant land use on left bank is agricultural, right bank is forested with residential sub-dominant
- Dominant buffer width on left bank is 0-25', right bank >100
- Stream sensitivity is Very High
- Geomorphic condition is Fair
- Habitat condition is Fair
- Sedimented riffles are present
- Gravel and fine sediment accumulations, bars have become floodplains

Reach T204-B extends for 3100' and encompasses the stream surrounding the lower Rte 122 Bridge. Upstream of the bridge, the segment is extensively straightened and held against the valley wall on its left bank before it makes a sharp turn across the river valley to cross under the bridge. The stream was classified as a C-type stream with gravel substrate and is noted as having historic incision and a current incision ratio of 1.6. The stream bed appears to be aggrading though it was determined the segment was still in stage II channel evolution. There is deposition upstream of the bridge, and scour below the bridge, indicating that the bridge is acting as a channel constriction and is undersized. The width of this bridge is recorded as 33', which is smaller than the segment's bankfull width of 44'.

Management and land use surrounding this segment is intense, with a logging operation along the left bank of the stream as it pulls away from the valley wall, and hayland and a residence along the right bank. Encroachment seems to have the potential to expand, particularly along the right bank which would continue to force the river against the valley wall. At the downstream end of the segment is a grade control with a very deep pool at its foot. The depth of the pool was greater than we could measure in the field. The downstream segment continues to be straightened for about a mile. Aside from the sediment accumulation upstream of the upper Rte 122 Bridge on segment T204-C, nearly this entire reach transporting sediment which could be contributing to the high accumulations of sediment on the lower reaches and have an impact on flooding there.

Other characteristics of the Reach T204B include:

- Entrenchment ratio of 3.57
- Bed form is plane bed
- Stream sensitivity is very high
- Geomorphic condition is fair
- Habitat conditions are fair
- Dominant buffer width on both sides is 0-25'
- One delta bar
- Dredging evidence present
- No stormwater inputs

Table 8: Preliminary Project Identification Reach T204

River Segment	Project	Reach Priority	Watershed Priority	Completed Independent of Other Practices	Next Steps and other project notes
T204A	Protect River Corridor	High	High	Yes	The lower end of this segment has flood and sediment attenuation assets and should be protected to provide more opportunities. Bank armoring is discouraged at the downstream end of the segment in order to facilitate stream processes here. The rest of the segment is straightened and will require long term management
T204B		Moderate	Moderate	Yes	Increased encroachment would require long term management and force the river to be kept against the valley wall. Drawing back land use activities along the river in order for it to reclaim its valley would be beneficial. Continued armoring is discouraged.
T204C		Moderate	Moderate	Yes	Constriction at bridge causing upstream sediment accumulation and meander bends. Protecting corridor important to accommodate planform changes due to bridge
T204A	Install River Buffers	Moderate	Moderate	Yes	Lower end of segment would benefit from belt width plantings
T204B		High	High	Yes	Buffer plantings on this segment would help protect corridor and allow stream to reclaim some of its valley
T204	Assess Bridge Constrictions	Very High	Very High	Yes	Bridges having significant impact on stream and requiring long term conflict management. Stream would benefit from a larger channel width at bridges by drawing back riprap or widening bridge opening to minimize constriction.

Figure 29: Preliminary Project Details Reach T204-A Map

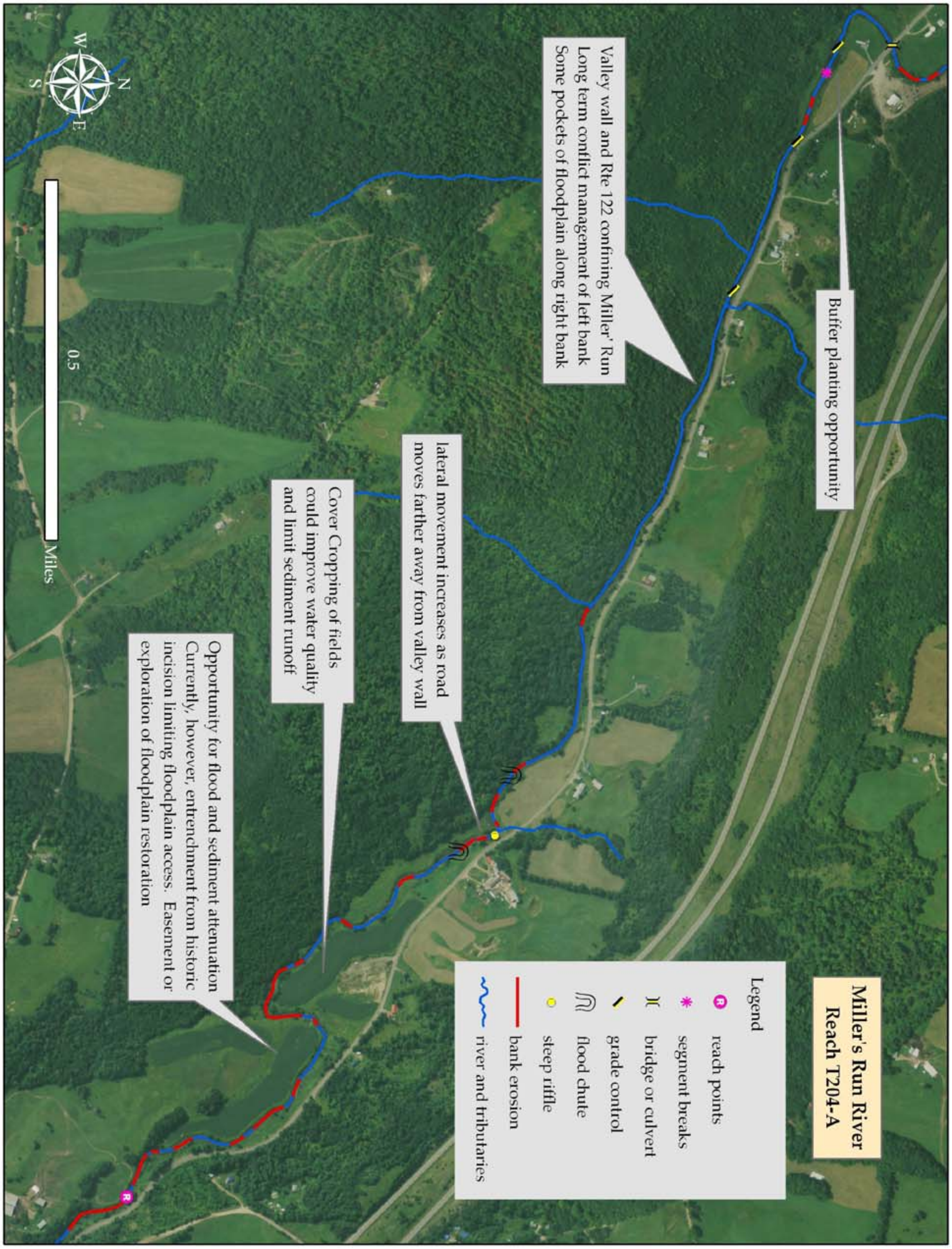
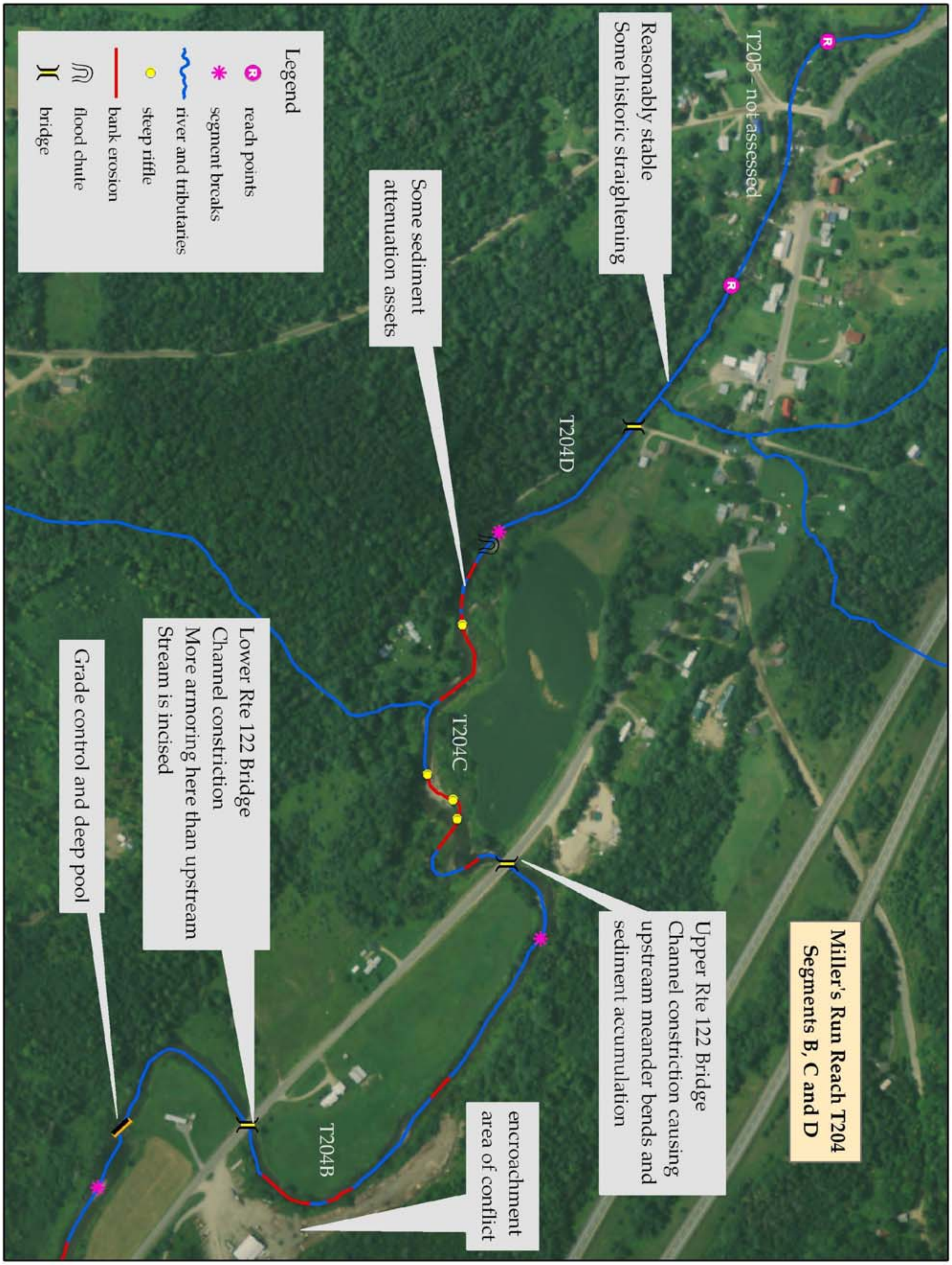


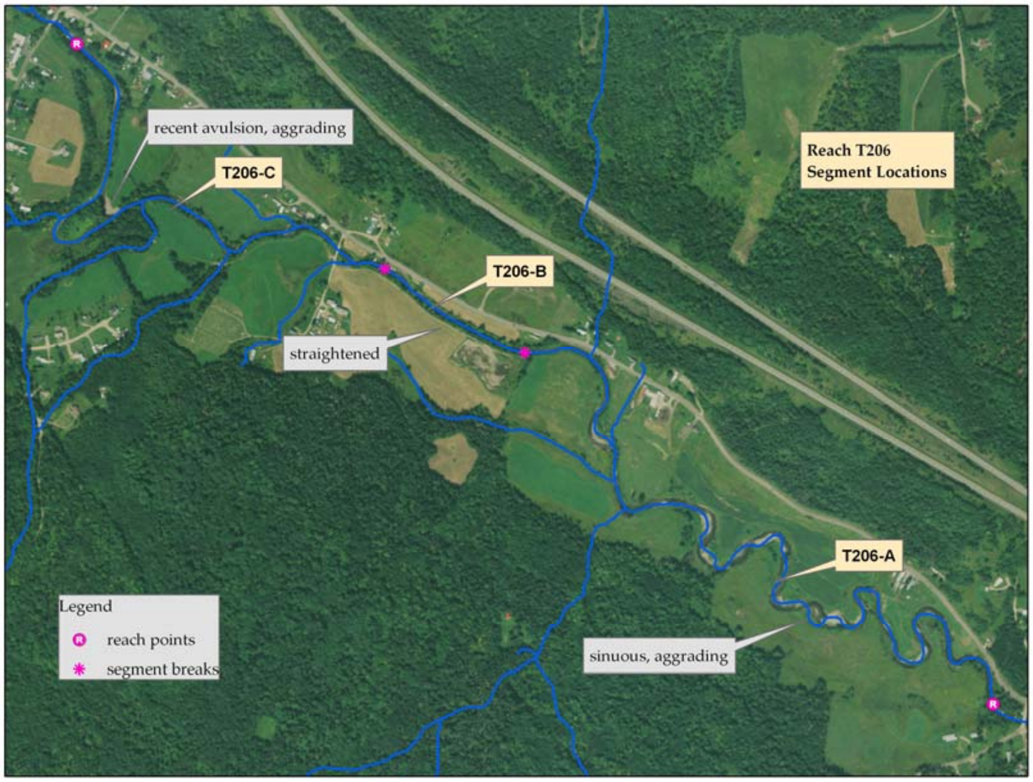
Figure 30: Preliminary Project Details Reach T204 C, C & D Map



6.5 Preliminary Project Identification: Reach T206 – Between Sheffield and Wheelock villages

Reach T206 extends for 12,264' and was divided into three segments. The lower segment, Reach T206A is situated in a wide flat agricultural valley and shows high sinuosity and lateral migration. The middle segment, Reach T206B is a short straightened section and T206C is aggrading and had a recent avulsion. Each segment is described in more detail separately.

Figure 31: Reach T206 Segment Locations



Reach T206 A is 6970' long and is situated upstream of Wheelock village and its bedrock falls. With a grade control at the downstream end of the reach, the steam is depositing sediment and moving laterally across its wide valley. Land use surrounding the stream is dominated by agriculture, with tillage along the left corridor and hayland on the right. There is erosion throughout the segment, particularly on the outside of meander bends, and bank armoring is noted sporadically but is failing in most locations. The upstream segment is straightened and transporting sediment. Depositional features are significant, with 27 depositional bars recorded. New floodplain is developing throughout the segment and it was determined that the segment is in stage III channel evolution with planform changes and widening noted as the current adjustments. T206-A is classified as a C-type stream with gravel dominated substrate. Flood and sediment attenuation on this segment may provide some protection for Wheelock village downstream.

Other characteristics of T206-A include:

- No incision located at cross-section, but tall eroding banks are noted throughout
- Bed form is plane bed, riffles seen are sedimented

- Entrenchment ratio is 5.3
- One stream ford recorded
- Geomorphic condition is fair, due to aggradation
- Stream sensitivity is very high
- Habitat conditions are poor

Figure 32: Reach T206-A showing aggradation, mid channel bars and significant lateral migration across the valley

Figure 33: Photo showing Reach T206-A, erosion and high banks with little resistance. Dominant land use is agriculture.

Reach T206-B is a short, historically straightened segment that extends for 1614'. The straightening appears to be the contributing factor to a high incision ratio and stream type departure from a C-type stream to an F-type stream with a 1.2 entrenchment ratio. Field notes indicate that bankfull indicators were difficult to isolate, so a margin of error should be considered. The general adjustment patterns indicated by the existing data are reasonable, however, as the straightening has certainly led to bed degradation and the stream losing access to its floodplain. The segment is flanked on its left corridor by Rte 122, with agricultural land use on the right. Dominant buffer width on both sides of the stream is 0-25'. There is a gravel pit on the downstream end of the segment along the right bank. The segment is transporting sediment which can be seen depositing in the downstream segment (T206-A), which is showing high levels of aggradation and lateral migration.

Other characteristics of Reach T206-B include:

- Bed form is plane bed, no sinuosity
- Gravel dominated substrate, but a good mixture with 32% cobble and some boulders
- Geomorphic condition is fair
- Stream sensitivity is high
- Habitat conditions are fair
- Channel evolution determined to be in stage III, incision is historic but stage III is still in very early stages of widening.

Reach T206-C is 3780' long and extends from the base of the bedrock falls in Sheffield village to ledges at the downstream end of the segment. The segment is aggrading with coarser, cobble sized sediment and there are several cobble bars noted throughout. Reach T206-C is largely characterized by a significant avulsion that occurred approximately 10 years ago. The stream had formerly had a sharp meander bend that was actively eroding a 60' tall steep and unstable clay bank. The site was a major source of sediment for the Miller's Run, and in the mid-1990s, various restoration projects took place on the clay bank to help provide drainage and stabilization. During an evaluation of the restoration projects ten years later in 2004, a neck cut off has since occurred and the stream was no longer accessing the clay bank. The increase in stream power has clearly transported fine sediments that were previously stored, and coarser sediments are now exposed and comprising most of the channel's bars and new floodplain.

Figure 34: Reach T206-C Channel Avulsion

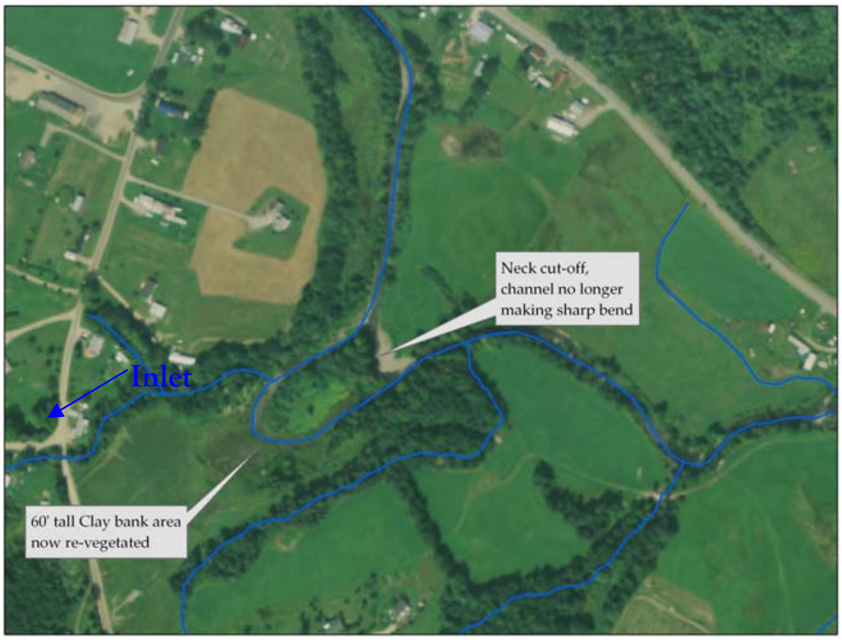


Figure 35: Photo taken in 2003 showing former channel on Reach T206-C. An avulsion occurred sometime before this photo was taken and a small amount of water is still accessing the old channel.

Figure 36: Photo taken in 2007 looking up into former inlet to the clay bank area that is no longer accessed by the river. Area has re-vegetated and fine sediments are transporting.

Other characteristics of T206-C include:

- Incision ratio of 1.5
- Entrenchment ratio of 3.8
- C-type stream with cobble dominated substrate
- Stage III channel evolution
- 8 depositional bars and 1 island recorded
- No stormwater inputs
- Dominant land use is hayland on right and left corridors
- Dominant buffer width is 0-25' on both banks
- Geomorphic condition is fair
- Stream sensitivity is very high
- Habitat condition is fair
- One bridge with alignment problems, and channel constriction

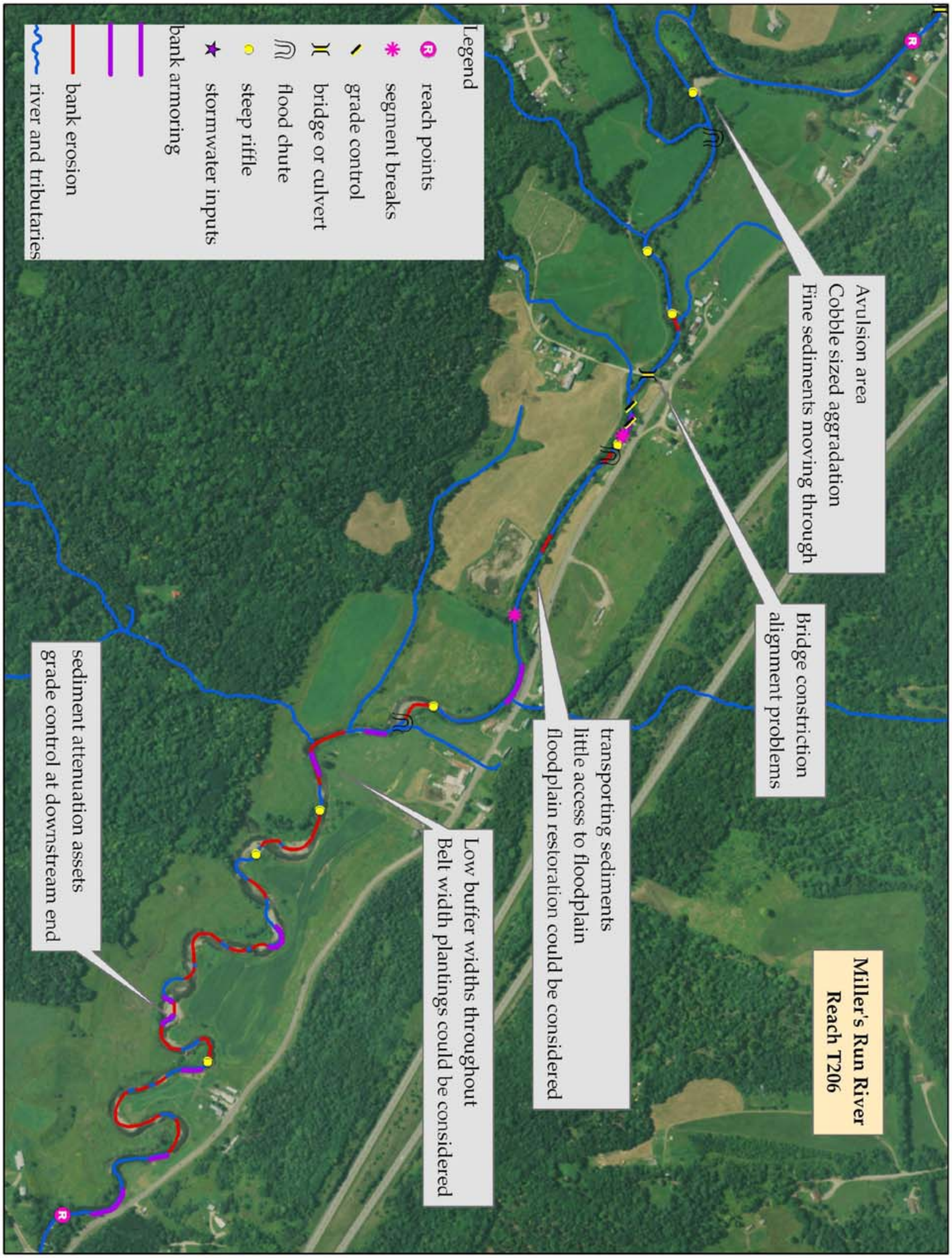
Table 9: Preliminary Project Identification Reach T206

River Segment	Project	Reach Priority	Watershed Priority	Independent of Other Practices	Next Steps and other project notes
T206A	Protect River Corridor	High	High	Yes	This segment has sediment attenuation assets and good access to its floodplain. With the amount of lateral movement and erosion, it would be wise to protect the corridor to accommodate these adjustments.
T206B T206C		Moderate	Moderate	Yes	Some of these segments have been straightened and the river is cut off from its floodplain. Allowing it to return to its natural state and re-gain access would ease adjustments downstream and provide additional attenuation assets.
T206 A, B, and C	Install River Buffers	High	High	Yes	The entire reach would benefit from planting, particularly segment A with a belt width planting.
T206 A	Cover Crop	High	Moderate	Yes	Cover cropping tilled land would provide greater water & soil quality protection and reduce sediment runoff into the stream

	Project	Reach	Watershed	Independ	Next Steps and

River Segment		Priority	Priority	ent of Other Practices	other project notes
T206B	Restore Floodplain	Low	Low	Yes	Some additional floodwater storage and sediment attenuation could be achieved through restoration of floodplain access, perhaps at gravel pit location.
T206C	Assess Bridge Constriction	Low	Low	Yes	Sizing and alignment of bridge should be considered when opportunity arises

Figure 37: Preliminary Project Details Reach T206



6.6 Preliminary Project Identification Reach T208

Reach T208 is upstream of Sheffield village, and its bedrock falls which was not assessed (Reach T206). This reach was not segmented though incision ratios increase at the downstream end as it nears the village. The majority of this reach is situated on a wide flat valley with agricultural use on both sides of the river. The downstream end nears Route 122 and encounters development and ledge as is flows into Sheffield village. The reach is a C-type stream with gravel dominated substrate. Aggradation is the current and dominant adjustment pattern with 10 point bars and 8 diagonal bars recorded, and channel braiding in one location. It is noted that there is good floodplain access throughout the reach (entrenchment ratio is over 15), however the incision ration is 1.6 but is not impeding the river from accessing its floodplain. The stream is moving laterally across its valley with high sinuosity and moderate erosion on the outside meander bends. The dominant buffer width is 0-25', however there are small pockets of bank and buffer vegetation consisting primarily of Japanese Knotweed, an invasive species. This reach provides good floodwater storage upstream of Sheffield village. The sediment accumulation and aggradation is largely due to upstream transport reaches and the grade control at the downstream end of this reach.

Figure 38: Miller's Run Reach T208 showing aggradation

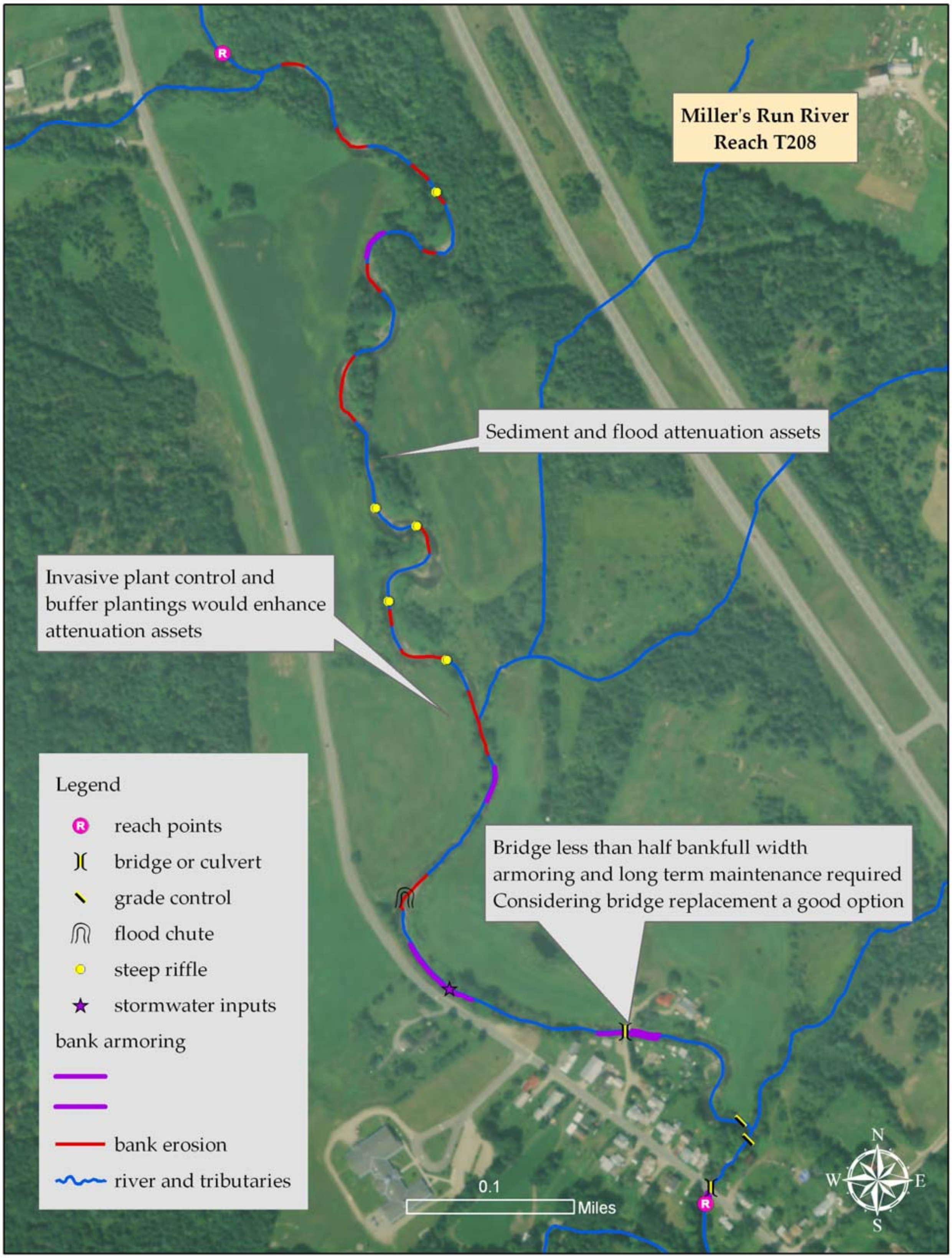
Other characteristics of Reach T208 include:

- Two bridges on reach, both channel constrictions, the upstream bridge more serious and becoming a long-term area of conflict
- Channel evolution in Stage III, aggradation and widening
- Geomorphic condition is fair (due to aggradation)
- Stream sensitivity is very high
- Habitat condition is fair
- Ledges at downstream end of reach
- 1 stormwater input
- Tillage and hayland along stream

Table 10: Preliminary Project Identification Reach T208

River Segment	Project	Reach Priority	Watershed Priority	Independent of Other Practices	Next Steps and other project notes
T208	Protect River Corridor	High	Moderate	Yes	Reach provides good floodwater storage and sediment attenuation upstream of Sheffield Village.
T208	Address Invasive Plants	Moderate	Moderate	Yes	Japanese knotweed growth is rampant through this reach and is not providing good habitat or bank stability. Because of its location upstream in the watershed it has a high potential of spreading downstream.
T208	Install buffers	High	Moderate	No	Restoring native vegetation and a wider buffer would enhance the attenuation assets of this reach. Invasive plant eradication should take place first. Agricultural fields a good candidate for federal programs.
T208	Assess Bridge Constriction	Moderate	Moderate	Yes	Upstream bridge opening is less than half of the bankfull width. The area around the bridge is armored and the stream will continue to cause bed scour and long term maintenance. Widening the channel width of the bridge should be considered.

Figure 39: Preliminary Project Details Reach T208 Map



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