Phase 2 Stream Geomorphic Assessment
Mettowee River Watershed
Rutland & Bennington Counties, Vermont
November 2007

Falls below Mach's Market, Pawlet, Vt (Flower Brook, Reach M05T3.01)

Prepared by

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TABLE OF CONTENTS

APPENDICES

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Field work was conducted with the assistance of Hilary Solomon, representing the Poultney-Mettowee Watershed Partnership. Technical support was provided by Shannon Hill of the Vermont Department of Environmental Conservation, Water Quality Division. South Mountain Research & Consulting is grateful for the volunteer efforts of Peg Underwood, Louise Sobing, and John Underwood who also assisted with field work.

Many thanks are extended to the riparian landowners who granted permission to cross their property to access the river. Historical accounts of past flood events and channel management activities were also generously offered by many local representatives.

EXECUTIVE SUMMARY

Phase 2 stream geomorphic assessments were completed in 2005 and 2006 in the Vermont portion of the Mettowee River watershed to provide a geologic and geomorphic context for the streambank erosion and water quality issues documented in the river over the past several years by Poultney-Mettowee Watershed Partnership and others.

Geomorphic data will be used to inform future management strategies for the river corridor by watershed stakeholders including landowners; towns of Pawlet, Wells, Rupert and Dorset; and resource agencies, such as the Poultney Mettowee Watershed Partnership, Poultney Mettowee Natural Resources Conservation District, US Department of Agriculture, and Vermont Agency of Natural Resources. For a given reach or segment, the geomorphic condition helps to define the short-term compatibility and long-term sustainability of various restoration or conservation projects and future land use or channel management activities.

Assessments were completed on 25 reaches (36.9 river miles) of the Mettowee River main stem and major tributaries in 2005 and 2006, following protocols published by the Vermont Agency of Natural Resources (VTANR, 2005, 2006). Seven reaches along the main stem and Flower Brook in Pawlet and Rupert townships were assessed in 2005. An additional 18 reaches along the main stem, Flower Brook, Beaver Brook, Sykes Hollow Brook, Scallop Brook, Wells Brook, and Indian Brook were assessed in 2006.

Various watershed-scale and channel-level disturbances, noted through field investigation and historical data review, have served as stressors to the Mettowee River main stem and tributaries. Channel disturbances along the assessed river reaches have included:

- Apparent and reported channelization;
- Channel armoring (rip-rap);
- Berming;
- Historic floodplain encroachment by roads, railroads, and residential and commercial development;
- Historic impoundments, including (1) the former Lackey Dam on the main stem just downstream of School Street bridge crossing; (2) the former grist mill dam downstream of Mach's Market; and (3) the current mill pond dam upstream of the Arch Bridge (Rt. 133/30) in center Pawlet.
- Reported gravel extraction, dredging and berming: (1) through Pawlet Village upstream of the Mill Dam; and (2) along the main stem near the Pawlet / Rupert border in response to the flood events of 1938 and 1973.
- Undersized private and public bridges and in-stream culverts, serving as flow constrictors at bankfull flow or higher-magnitude flood events;
- Active stream crossings (fords) and direct access by cattle to the river;
- Minimal or absent riparian buffers along portions of the study reaches.

Watershed-level disturbances to the Mettowee River and tributaries have included:

- Historic (mid-1880s) deforestation of the watershed which could be expected to lead to increased runoff and sediment mobilization;
- High-magnitude flood events, including a reasonably large flood event on 17 December 2000 (20- to 40-year storm magnitude), and larger floods of 1973, 1938 and 1927.

The Mettowee River and tributary channels are responding to these past disturbances through adjustment of their dimensions (cross section geometry), planform (position in the landscape), and profile (slope). Adjustments have occurred to varying degrees, as dependent on multiple factors (including channel sediment types, vegetative cover type and density, presence of grade controls, etc.). Most reaches are experiencing minor to moderate degrees of aggradation, widening and planform adjustments.

Opportunities for river restoration and conservation have been identified based on the Phase 2 geomorphic assessment results. A preliminary project listing forms the basis for follow-on project development and planning activities which can be carried out by watershed stakeholders.

1.0 INTRODUCTION

Stream geomorphic assessments were completed on 25 reaches (36.9 river miles) of the Mettowee River main stem and major tributaries in 2005 and 2006, following protocols published by the Vermont Agency of Natural Resources (VTANR, 2005, 2006). Objectives of the Phase 2 geomorphic assessments were to:

- determine the geomorphic condition of targeted reaches, and identify active vertical and lateral adjustment processes;
- identify current and historic channel and watershed stressors; and
- evaluate the sensitivity of reaches to future channel and watershed stressors given their current geomorphic condition and inherent vulnerability (e.g., valley setting, slope, streambed and streambank sediments, vegetative buffer conditions);

Assessment data were entered into the online Data Management System (DMS), a custom database of geomorphic data developed and maintained by the Vermont Water Quality Division. This summary report has been prepared by South Mountain Research & Consulting (SMRC) of Bristol, Vermont under contract to the Poultney-Mettowee Natural Resource Conservation District (PMNRCD).

Assessment results will be used by watershed stakeholders (e.g., landowners, towns, Poultney Mettowee Watershed Partnership (PMWP), VT Department of Environmental Conservation Water Quality Division (VTDEC WQD), Natural Resources Conservation Districts) to:

- support restoration and conservation project planning and design;
- plan for future development which is compatible with adjusting river channels;
- support the evaluation of Vermont rivers for listing or de-listing of waters pursuant to Part G, State of Vermont List of Priority Surface Waters Outside the Scope of Clean Water Act, Section 303(d) of the Federal Clean Water Act (VTDEC WQD, 2006a); and
- understand water quality and temperature monitoring trends in the river.

2.0 BACKGROUND

Phase 2 assessments were undertaken in the Mettowee River watershed to provide a geologic and geomorphic context for the streambank erosion and water quality issues documented in the river over the past several years.

Since 1999, ongoing temperature monitoring has identified thermal stresses to the Mettowee River, and Flower Brook and Indian Brook tributaries (PMWP, 2005a). Fish kills have been recorded during extreme temperature conditions in past Summers (VTDEC WQD, 2004a). Based on this monitoring data from PMWP and others, the State of Vermont has listed 8.2 miles of the Mettowee River main stem upstream of the Vermont / New York border as impaired as a result of elevated temperature (VTDEC WQD, 2004b). Contributing causes include "loss of riparian vegetation" and "close proximity of agricultural uses". Portions of Flower Brook and Indian Brook (tributary that joins the Mettowee in New York) have also been identified as thermally impacted (VTDEC WQD, 2004a). Thermal monitoring studies conducted in 2001 recorded higher temperatures in the Flower Brook than in the Mettowee main stem (VTDEC WQD, 2004a).

Long term water quality monitoring at the mouth of the Mettowee River has identified elevated phosphorous levels and sedimentation (VTDEC WQD, 2005). Phosphorous loading from the Mettowee to Lake Champlain exceeds target levels outlined in the Lake Champlain Phosphorous TMDL (LCBP, 2005). Eroding streambanks have been identified as a contributing nonpoint source of phosphorous in rivers and streams of Vermont (VTANR, 2001; DeWolfe *et al.*, 2004).

The Poultney-Mettowee Watershed Partnership is currently undertaking an expanded water quality monitoring program to better define the degree and extent of phosphorous in the watershed, and to monitor for *E.coli* and other parameters in the Mettowee River and its tributaries. Results of Summer 2005 sampling will be summarized in a report available in the Winter of 2005/2006. These water quality results can be evaluated within the context of streambank erosion sites, buffer conditions and reach-level channel adjustment processes identified in this assessment.

2.1 Geographic Setting

The Mettowee River drains an approximately 211 square mile area of land located in Rutland and Bennington Counties of Vermont and Washington County, New York (Figure 1). The Mettowee River joins the Champlain Canal just south of Whitehall, New York. The canal accepts drainage from the Poultney River on the north side of Whitehall, and waters then flow northerly to the southern extent of Lake Champlain.

This study focused on the Vermont portion of the Mettowee watershed which is nearly 135 square miles in area, or 64% of the total watershed. Seven river reaches along the Mettowee main stem and Flower Brook tributary in Pawlet and Rupert townships were assessed in 2005. Eighteen additional reaches along the Mettowee main stem, Sykes Hollow Brook, Scallop Brook, Flower and Beaver Brooks, Wells Brook and Indian River were assessed in 2005.
The assessed reaches were located in eight Vermont towns (Figure 2):

- Rutland County: Pawlet, Wells, Danby, Tinmouth, Poultney, and Middletown Springs
- Bennington County: Rupert and Dorset

2.2 Regional Geologic Setting

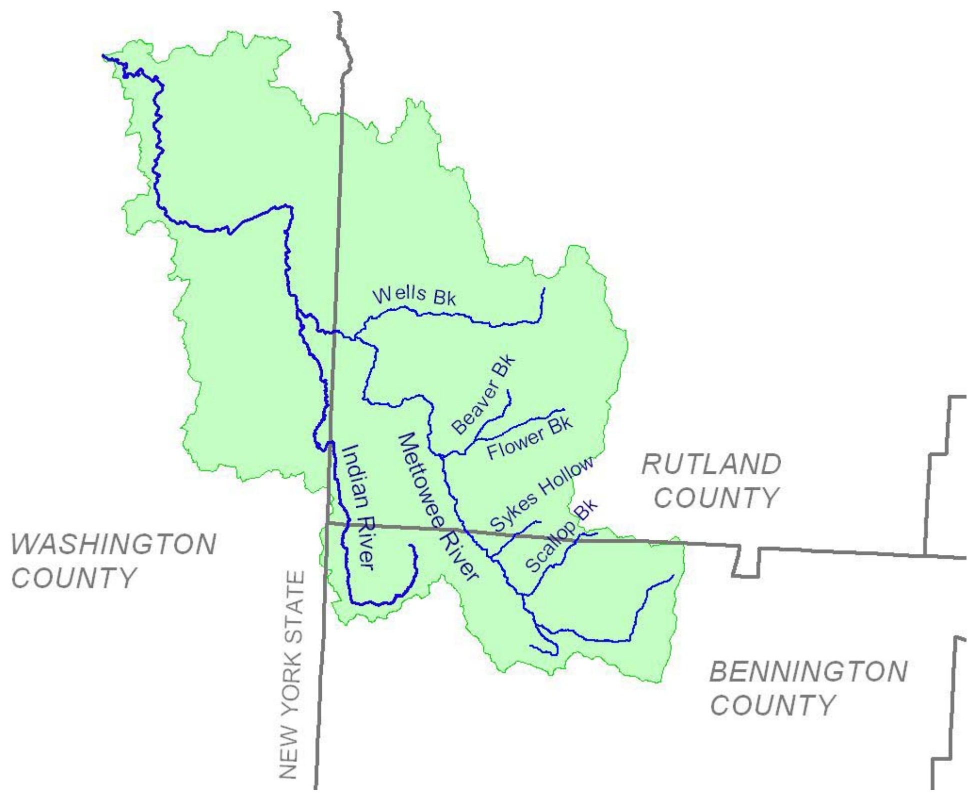
The Mettowee River watershed is located in the Taconic Mountain physiographic province, a wide band of elevated terrain trending north-south from the Lake Bomoseen area to eastern New York and western Massachusetts. The Taconic province is positioned between the narrow Vermont Valley and the higher-elevation Green Mountains to the east and the broad Champlain Valley to the north and northwest. Elevations within the Mettowee River watershed range from 2,260 feet in the headwaters on the western flanks of Dorset Mountain, to 395 feet at the Vermont / New York border, to approximately 110 feet at the confluence with the Champlain Canal.

In recent geologic time (from 20,000 to 13,200 years before present) this landscape was occupied by advancing and retreating glaciers, with ice up to a mile or more in thickness above the present land surface in the Champlain Valley to the north. Glacial tills now blanket much of the upper bedrock-controlled slopes and headwaters of the watershed. As glaciers melted and receded, deposits of water-washed boulders, cobbles, gravel and sand (kame terraces) built up along the ice margins in the Mettowee Valley, particularly on the eastern portions of the valley (Doll, 1970). While earlier glacial advances covered all of Vermont, the final glacial advance (Burlington ice sheet) is believed to have extended only part way into the Mettowee watershed to the vicinity of Pawlet (Stewart & MacClintock, 1969). Associated with this last glacial advance, an ice dam formed near Pawlet and created a temporary high-elevation lake in the present day Mettowee valley between Pawlet and East Dorset (Behling, 1966; Stewart & MacClintock, 1970). Lake-bottom silts and clays are present in this portion of the Mettowee Valley, overlain by more recent alluvial sands, gravels and cobbles associated with the Mettowee River and its tributaries (Stewart & MacClintock, 1969; Doll, 1970).

As the global climate warmed and the glaciers receded, a large fresh-water lake inundated the Champlain Valley. At its highest stage, Lake Vermont's shoreline extended to the vicinity of Middletown Springs in the Mettowee watershed (Stewart & MacClintock, 1969). Deltaic gravels are mapped along a margin thought to be coincident with this highest elevation of Lake Vermont, downstream of the bedrock gorge below the Route 153 (Williams Bridge) crossing (Doll, 1970).

Figure 1a. (left) Location of Mettowee River Watershed within Vermont.

Figure 1b. (below) Location of Mettowee River Watershed within Rutland & Bennington Counties, of Vermont and Washington County of New York.



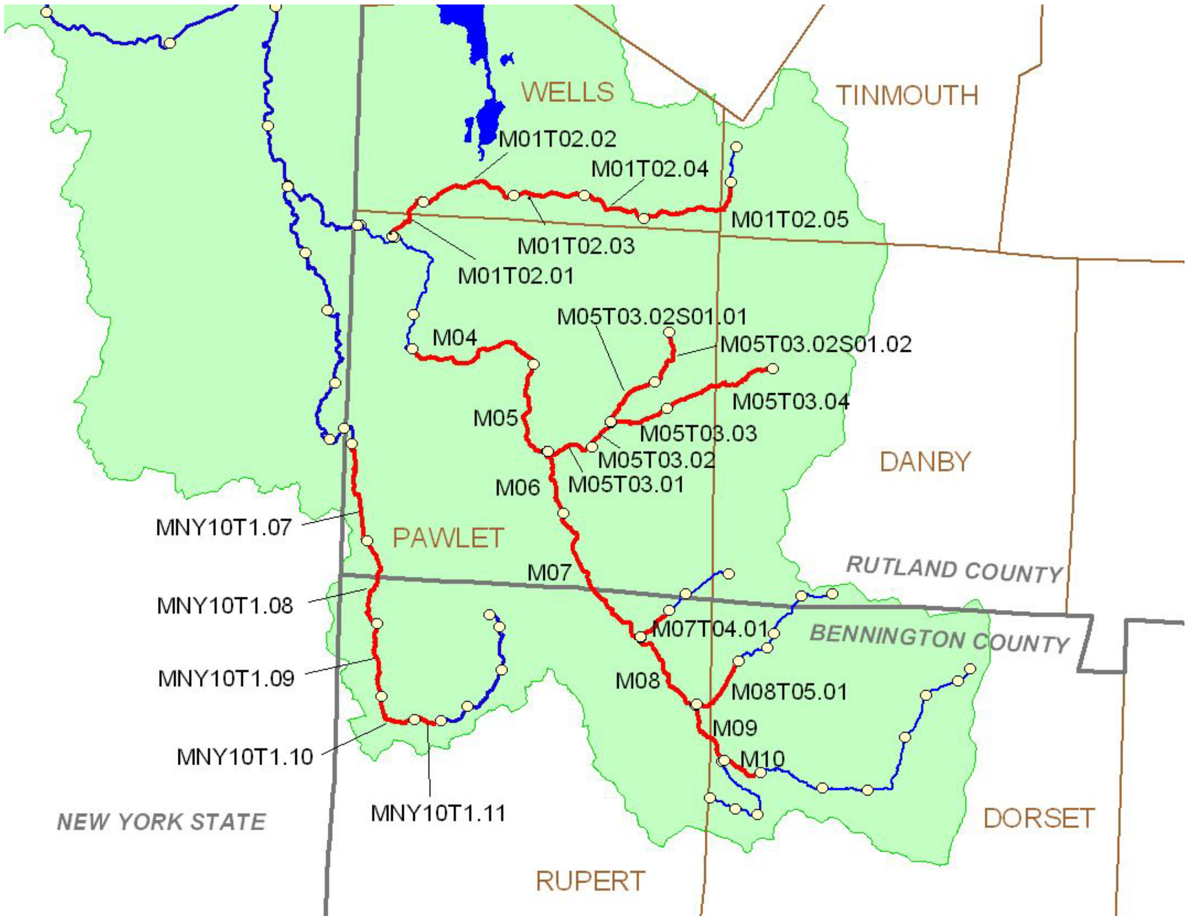


Figure 2. Location of Phase 2 reaches along Mettowee River main stem and major tributaries assessed in 2005 and 2006 (highlighted in red).

Lake Vermont waters receded in stages as natural dams in southern Vermont and New York gave way. From approximately 12,800 to 10,200 years before present, marine waters filled the valley from the St. Lawrence Seaway as the rate of rise in ocean water levels far exceeded the rate of rise, or isostatic rebound, of the land surface now relieved of its glacial burden (Stewart and MacClintock, 1969; Cronin, 1977; Wagner, 1972; Connally and Calkin, 1972). The maximum elevation of these brackish waters is not believed to have extended into the present-day Mettowee River watershed (Wagner, 1972). Champlain Sea waters had receded from the greater Champlain Valley by approximately 10,000 years before present, as the rate of land rise began to outpace the rate of sea-level rise. River systems, including the Mettowee River, then went to work moving sediments left in the wake of the glaciers, and further eroding the Taconic Mountains. The surrounding landscape continues in this erosion phase today.

2.2.1 Bedrock Geology

In general, the bedrock geology of the Mettowee River watershed consists of folded and faulted slates and phyllites of Cambrian and Ordovician age (Shumaker, 1967). These rocks originated as sedimentary mudstones deposited in an ancient sea (450 to 550 million years old). They were later compressed and altered under elevated temperature and pressure conditions during the Taconic mountain building event and subsequent regional deformations to form metamorphic slates and phyllites. In the process of Taconic mountain-building, older Cambrian and Ordovician rocks were folded and thrust over younger Ordovician limestones and marbles. Later, regional stresses caused further folding and faulting of the Taconic mass.

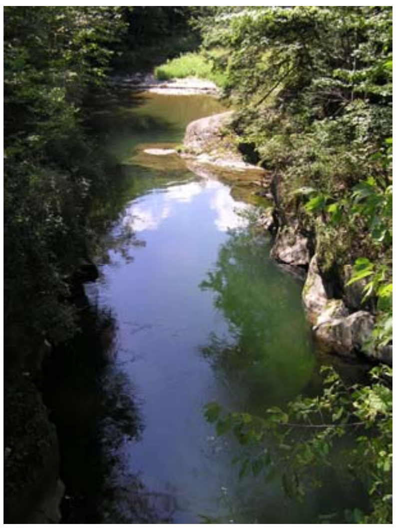


Figure 3. (M03) Bedrock gorge beneath Route 153 crossing at the Williams Bridge. This channel-spanning exposure of bedrock serves as a vertical grade control for the Mettowee River channel.

The underlying bedrock geology of the watershed influences the Mettowee River in many ways. The topography of the watershed is a direct result of the characteristics of the underlying bedrock. Phyllite and slate members that are more resistant to weathering, and those which comprise thrust sheets, form the uplands of the watershed as in the area of Dorset, Tinmouth, and Woodlawn Mountains. The valley bottoms of the Mettowee main stem and its major tributaries, like the Wells Brook and Flower Brook, have formed where the lithology and fractures of the bedrock cause it to be more erodible. The folded and faulted structure of the underlying bedrock is reflected by the asymmetric shape of the Mettowee drainage basin. The Mettowee River receives its runoff predominantly from southern and western facing mountain slopes.

Frequent bedrock exposures influence the channel position and profile in the watershed. Bedrock exposures along the valley walls control the lateral position of the river channel. Locations of channel-spanning bedrock offer vertical grade control, preventing possible downward erosion of the channel in response to regional or local stressors (at least over the 10- to 100-year time spans on which this study is focused). Within the study area there are two main gorges. One forms the bedrock falls under the arch bridge (Rt. 30/133) in the center of Pawlet village. A second bedrock gorge is located at the William's Bridge (Rt. 153) near the intersection with River Road (Figure 3).

2.2.2 Surficial Geology

Glacial activity has influenced the surficial sediments and soil types which are present in the Mettowee River watershed today (see Figure 4). Upland slopes are dominated by shallow- to moderate-thickness glacial till deposits overlying bedrock. The river valleys of the Mettowee main stem and its major tributaries, such as the Flower Brook, are occupied by kame moraine and kame terraces along the eastern and northern valley edges, with alluvium adjacent to and underlying the channel. Kame terrace deposits are comprised of sands, gravels, and cobbles deposited by meltwaters of receding glaciers in temporary high-level lakes formed at the margin between stagnating ice blocks and the adjacent mountain slopes. These ice contact deposits are typically non-cohesive and have moderate to high erodibilities when exposed in stream banks and beds. Review of the NRCS soil survey coverage for the watershed confirms that soil types in the upland portions of the watershed are dominated by soils of the till-derived Taconic-Macomber-

Hubbardton and Dutchess-Bomoseen-Pittstown Associations. The valleys are dominated by sandy loams the of the Hinckley-Warwick-Windsor association consistent with alluvial, glacio-fluvial or glacial lake origins (Ferguson, 1998; USDA, 1998; USDA, 1995; USDA, 2005).

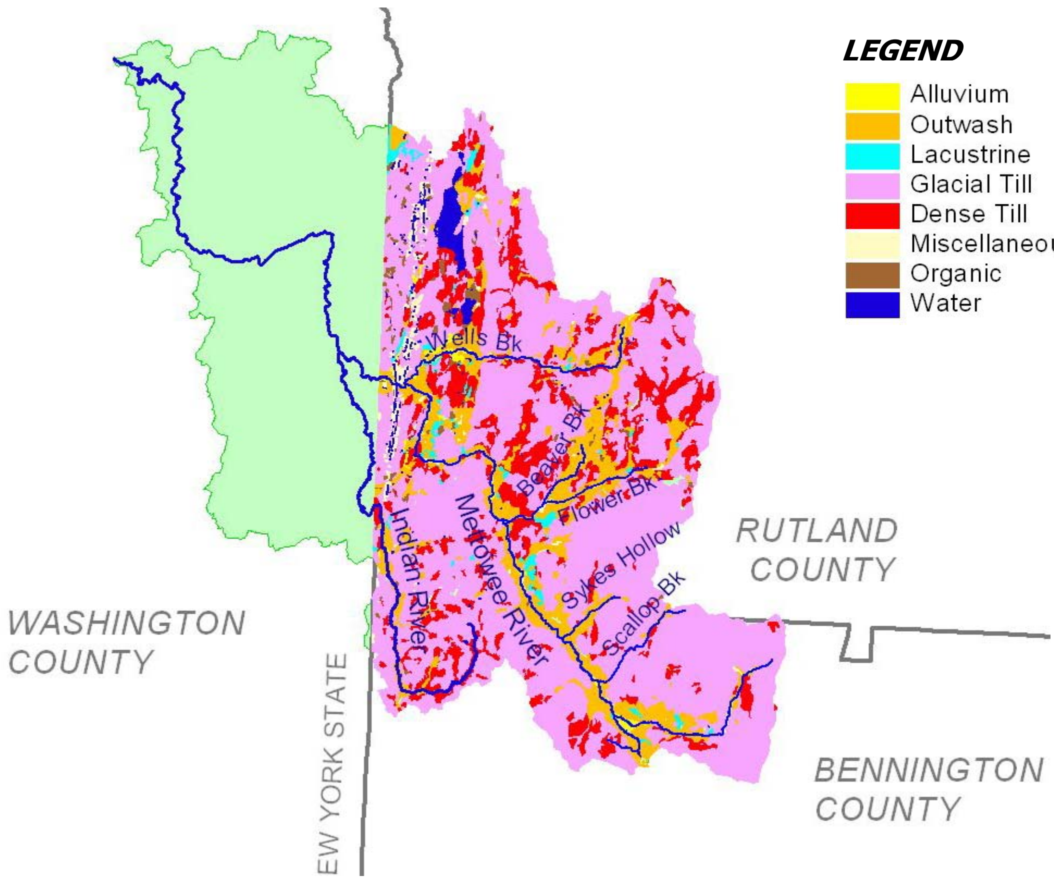


Figure 4. Soils types in the Vermont portion of the Mettowee River watershed, classified by parent material (USDA, 2005; USDA, 1998; USDA, 1995).

2.3 Geomorphic Setting

Figure 5 illustrates the Vermont portion of the Mettowee main stem and its main tributaries in longitudinal profile. Generally, valley and river channel slopes become shallower as one progresses downstream toward the Vermont/ New York border. Relief in the watershed varies from highest elevations of 2,260 feet at the upper extent of M08T05 and 1,880 feet at the upstream end of the main stem near Dorset Peak, to a low elevation of approximately 395 feet near the Vermont / New York border. The upper reaches of the main stem and tributaries on steeper slopes are generally in narrow, "V" shaped valleys on the forested slopes of Dorset and Tinmouth Mountains. Velocities are high, and these reaches have sufficient power to carry large gravels, cobbles, and occasional boulders. As the stream channels flow out into the Mettowee River valley near East Rupert, slopes become significantly shallower, and the river has more of a meandering, sinuous pattern. The reduction in stream energy given by the reduction in slope, means that the river is no longer able to carry all of its sediment, and there is a tendency for that sediment to accumulate at this point of transition. These are natural locations for a river to meander and split into multiple, braided channels in response to the reduced energy and sediment transport capacity. Often, sediment accumulated over hundreds of years will form an alluvial fan - for example, through the community of East Rupert.

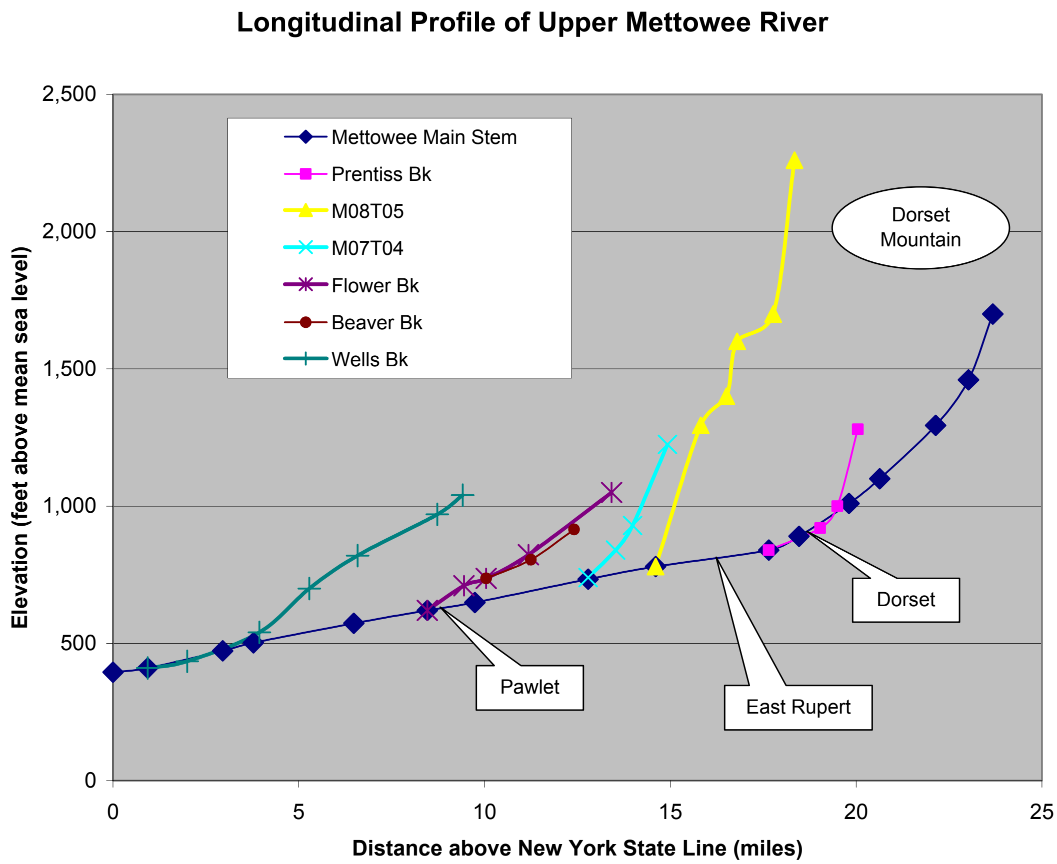


Figure 5. Longitudinal profile of Mettowee River main stem (Vermont portion) and major tributaries.

In separate Phase 1 Stream Geomorphic Assessments, the Mettowee River watershed and the Indian River watershed were delineated into geomorphic reaches using remote sensing methods supported by windshield surveys. Geomorphic reaches were defined based on variation in valley confinement, slope, and sinuosity. The reader is referred to the Phase 1 summary reports prepared by Poultney Mettowee Watershed Partnership for details of the Phase 1 assessments (PMWP, 2005a; PMWP, 2005b).

The Vermont portion of the Mettowee River watershed (upstream from the New York border) was delineated into a total of 39 reaches during the Phase 1 process (see Table 1). Symbols in Figure 2 denote the downstream reach breaks. Main-stem reaches were identified with an "M". Major tributary reaches were denoted with a "T"; minor tributaries with an "S". Reach lengths ranged from 1,532 ft (0.3 mile) to 16,075 ft (3.0 miles), with an average length of 1.2 miles (PMWP, 2005a).

Table 1. Reach Delineation in the Mettowee River Watershed (Vermont portion).

Tributary Identification	Name	Drainage Area (sq mi)	Channel Length (mi)	Number Reaches
M	Mettowee River	113.8	24	16
M01T02	Wells Brook	32.6	8.5	6
M05T03	Flower Brook	18.9	5.0	4
M05T03.02S01	Beaver Brook (trib to Flower Bk)	5.2	2.4	2
M07T04	Unnamed trib to Mettowee River (sykes)	4.5	2.1	3
M08T05	Unnamed trib to Mettowee River (scallop)	2.6	3.7	5
M09T06	Prentiss Brook	1.7	2.4	3

Source: PMWP, 2005a (accessed through DMS)

The New York portion of the Mettowee River main stem (downstream from the New York border) was delineated into a total of 11 reaches during the Phase 1 process (see Table 2). Symbols in Figure 2 denote the downstream reach breaks. New York main-stem reaches were identified with an "MNY". Major tributary reaches were denoted with a "T"; minor tributaries with an "S". The Indian River joins the Mettowee River in New York reach MNY10 and was identified as major tributary MNY10T1. Fifteen reaches were delineated on the Indian River ranging in length from 1,873 ft (0.35 mile) to 11,091 ft (2.1 miles), with an average length of 1.2 miles (PMWP, 2005b).

Table 2. Reach Delineation in the Indian River Watershed (VT and NY).

Tributary Identification	Name	Drainage Area (sq mi)	Channel Length (mi)	Number Reaches
MNY	Mettowee River (reaches in New York State)	210.9	20.5	11
MNY10T1	Indian River (reaches in NY and VT)	37.1	17.5	15

Source: PMWP, 2005b (accessed through DMS)

Based on the channel and watershed stressors identified through remote sensing, windshield surveys and limited historical research during the Phase 1 Geomorphic Assessment, seven reaches along the main stem and Flower Brook in Pawlet and Rupert townships were prioritized for Phase 2 Stream Geomorphic Assessments in 2005 (see Figure 2, Table 3). An additional 18 reaches along the main stem, Flower Brook, Beaver Brook, Sykes Hollow Brook, Scallop Brook, Wells Brook, and Indian Brook were selected for Phase 2 in 2006. Targeted reaches were those expected to demonstrate higher degrees of channel adjustment and sensitivity based on their topographic setting and provisional identification of past and current watershed and channel disturbances.

Table 3. Reaches selected for Phase 2 Stream Geomorphic Assessments on Mettowee River main stem and major tributaries, Vermont.

Tributary	Reach	Drainage Area (sq mi)	Reach Length (miles)	Year Assessed
Mettowee River	M04	71.2	2.7	2005
	M05	68.4	2.0	2005
	M06	43.8	1.3	2005
	M07	40.9	3.0	2005
	M08	27.7	1.8	2006
	M09	21.9	1.3	2006
	M10	13.6	0.8	2006
Wells Brook	M01T02.01	32.6	1.1	2006
	M01T02.02	16.2	1.9	2006
	M01T02.03	14.3	1.3	2006
	M01T02.04	11.6	1.3	2006
	M01T02.05	6.6	2.1	2006
Flower Brook	M05T03.01	18.9	1.0	2005, 2006
	M05T03.02	17.4	0.6	2005
	M05T03.03	12.0	1.1	2005
	M05T03.04	11.6	2.2	2006
Beaver Brook	M05T03.02S01.01	5.2	1.2	2006
	M05T03.02S01.02	3.9	1.2	2006
Unnamed (Sykes Hollow)	M07T04.01	4.5	0.7	2006
Unnamed trib (Scallop)	M08T05.01	2.6	1.2	2006
Indian River	MNY10T1.07	15.8	2.1	2006
	MNY10T1.08	11.2	1.8	2006
	MNY10T1.09	6.2	1.5	2006
	MNY10T1.10	4.3	1.0	2006
	MNY10T1.11	2.3	0.5	2006
		Total River Miles:	**36.9**	

2.4 Hydrology

The United States Geological Survey (USGS) operates two main flow gages on the Mettowee River (see Figure 6).

- Station #04280350 is located mid-way along the main stem at the Betts Bridge Road crossing (Reach M04), and measures flow from an approximate drainage area of 70.5 square miles (or 33% of the total watershed). This station has daily flow records dating back to 1985, or approximately 22 years. The maximum peak flow recorded during this period was 7,080 cubic feet per second (cfs) on 17 December 2000; the corresponding daily mean flow for this date was 2,860 cfs.

- Station #04280450 is located in New York State downstream of Granville. The upstream drainage area of this gage is 167 square miles, or approximately 79% of the total watershed. This gage has been in continuous operation approximately 17 years, since 1990. The maximum recorded peak flow during this time period was 13,100 cfs on 17 December 2000. Peak flow records for this station also contain isolated events recorded prior to 1990, including a peak flow of 14,500 cfs on 14 March 1977.

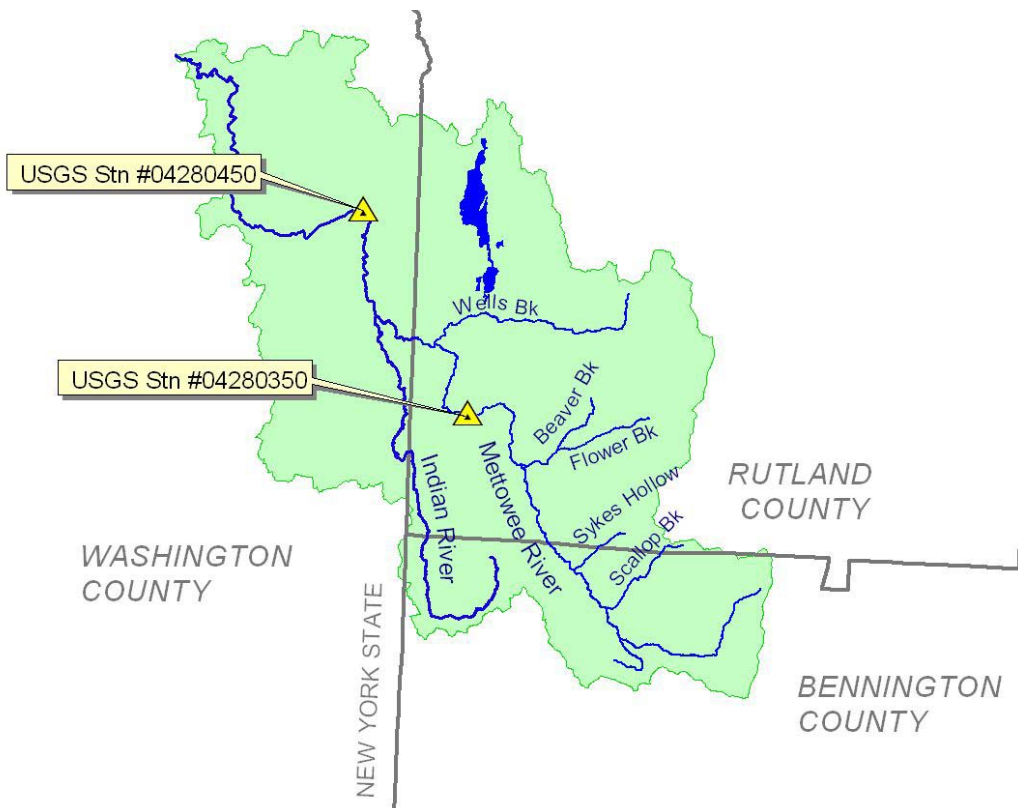


Figure 6. Location of USGS Gaging Stations in Mettowee River Watershed.

From a relatively limited period of record existing for each gaging station, and relying on relationships established for other regional gaging stations with longer periods of record, the USGS (Olson, 2002) has estimated the approximate magnitude of peak flows for each gaging station (Table 4). Note that USGS uses the "Mettawee" spelling for the river.

Table 4. Estimated flood magnitudes for Mettowee River watershed

	USGS Stn #	4280450	4280350
	USGS Description	Mettawee River near Middle Granville, NY	Mettawee River near Pawlet, VT
	USGS Period of Record	1990 - 2007	1985 - 2007
	Upstream Dr. Area (sq mi)	167	70.5
	Geomorphic Reach	MNY08	M04
Magnitude	**Data Source**	**Discharge (cfs)**	
$Q_{1.5}$	*(VTDEC, 2001)*	4,227	1,680
Q_2	*(Olson, 2002)*	4,560	2,040
Q_5		7,810	3,400
Q_{10}		10,400	4,480
Q_{25}		14,100	6,060
Q_{50}		17,100	7,380
Q_{100}		20,500	8,850
Q_{500}		29,400	12,900

From the actual records for these two gages, it can be seen that the Mettowee River has experienced a few moderate floods in the previous 20 years (see Figure 7). The 17 December 2000 flood equates to an estimated 20- to 40-year magnitude event.

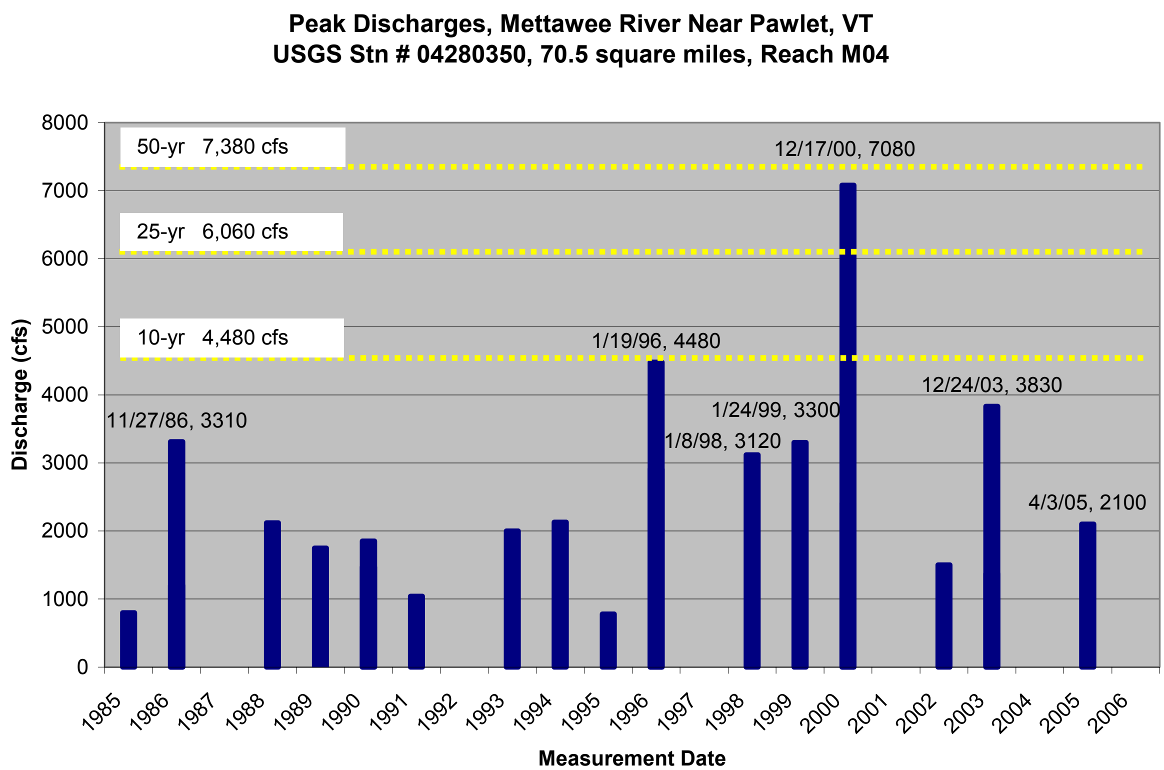


Figure 7. Recorded Peak Flows for Mettowee River, Betts Bridge Gage Station #04280350 (compared to estimated flood peaks after Olson, 2002)

For comparison, the bankfull flow (that event which can be expected to occur once every one to two years) is estimated to be 1,680 cfs at the Betts Bridge gage location (Stn #04280350).

Phase 2 Stream Geomorphic Assessments were completed between 5 July 2005 and 5 August 2005 and between 29 August and 26 October 2006. Flows measured at the Betts Bridge gage during these two time periods ranged from a minimum of 25 cfs to a maximum of 260 cfs based on certified and provisional data available from USGS (USGS, 2006). A few rain storms did occur throughout the assessment period, resulting in "blips" on the hydrograph in Figure 8 (Weather Underground, 2006). Overall, however, flows on the Mettowee during the 2005 and 2006 assessment periods can be considered to represent base flow conditions.

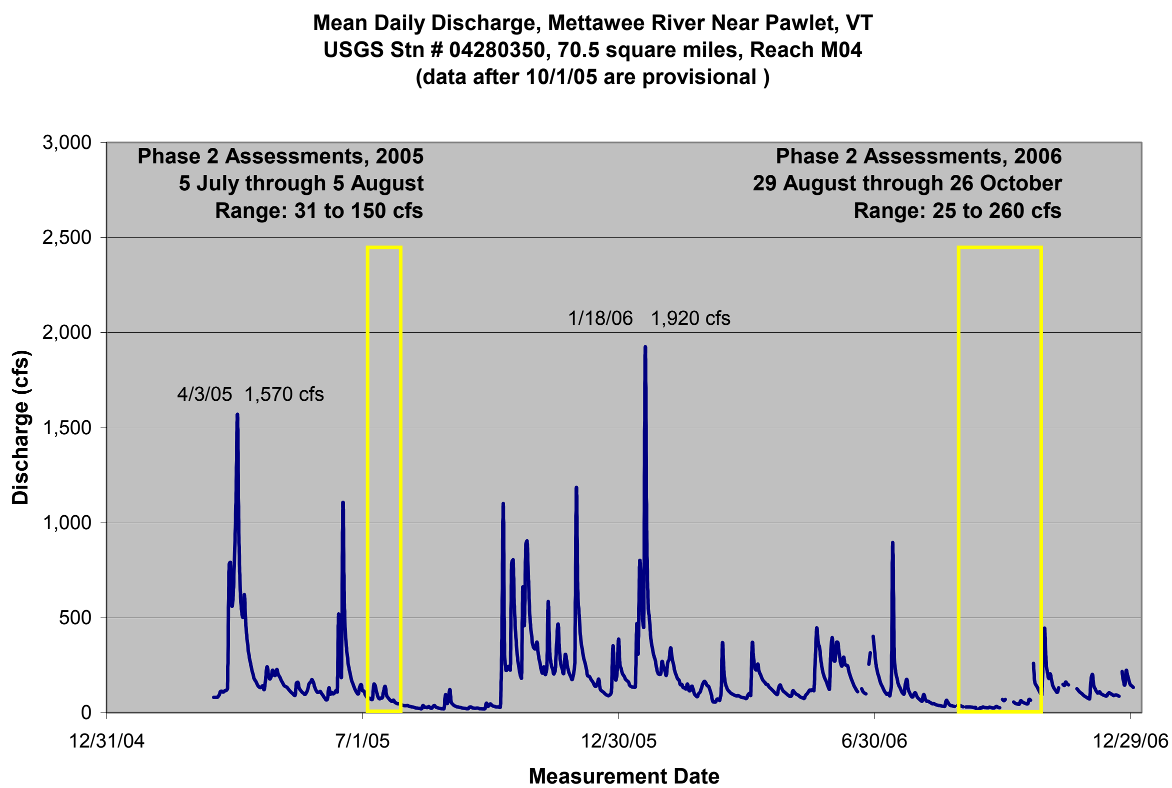


Figure 8. Provisional Daily Mean Discharges for Mettowee River, Betts Bridge Gage Station #04280350, during Phase 2 Stream Geomorphic Assessments, 2005 and 2006.

2.5 Flood History

Flood events can serve as a stressor to the river network leading to localized or systemic channel adjustments. Available historic data and USGS flow data were reviewed to identify flood events of significance over the last century in the Mettowee River watershed (Table 5). Limited historical review included review of annual town reports for the Town of Pawlet, Pawlet history books, State-wide flood publications, and interviews with local citizens. The 1927 flood was the highest flood on record in the State of Vermont.

Table 5. Notable flood events in Mettowee River watershed

Notable Flood Dates	Data Source
1913	USGS, 1990
1927	Pawlet Bi-Centennial Committee, 1975; USGS, 1990
1936	USGS, 1990
1938	USGS, 1990; Stone, 2005
1973, Jun 30-Jul 1	Mach, 2005; Stone, 2005 VTDEC WQD, 1999
1996, Jan	VTDEC WQD, 1999; USGS, 2006;
2000, Dec 17	Waite, 2005; USGS, 2006

3.0 ASSESSMENT METHODOLOGY

Stream geomorphic assessments conducted in the Mettowee River watershed utilized protocols published by the Vermont Agency of Natural Resources and available at: http://www.vtwaterquality.org/rivers/htm/rv_geoassesspro.htm. Reaches assessed in 2005 utilized the 2005 version of the protocols, while reaches assessed in 2006 followed the 2006 version of the protocols. Reference is made to these protocols for a description of specific methods followed to complete Phase 2 Stream Geomorphic Assessments and Bridge and Culvert Assessments.

3.1 Phase 2 Stream Geomorphic Assessment

Phase 2 Stream Geomorphic Assessment protocols are field procedures for geomorphic and habitat assessment. Reach-specific and cross-section data gathered during Phase 2 identify the present geomorphic condition of the river reach and the dominant process(es) of adjustment (i.e., degradation, widening, aggradation and/or planform adjustment). Phase 2 results, along with Phase 1 assessment results, define the natural and anthropogenic disturbances to the watershed and channel over time and the composite response or adjustment of the channel to these stressors.

Assessments were completed during the following time frames:

- 2005 reaches – 5 July 2005 and 5 August;
- 2006 reaches – 29 August and 26 October.

In accordance with protocols, specific features were digitized in ArcView© 3.x. For the 2005 reaches, features were documented in shape files. For 2006 reaches, features were referenced to the Vermont Hydrography Dataset (VHD), using the Feature Indexing Tool, a component of the Stream Geomorphic Assessment Tool (SGAT).

During Phase 2 assessments, specific features and present channel positions were located using a Garmin™ eTrex Vista global positioning system (GPS) unit. Pictures were recorded with an Olympus™ C-765 ultra-zoom, 4.0-megapixel digital camera.

Phase 2 assessment data were entered into the online Data Management System (DMS) maintained by the VTDEC WQD. Phase 2 reach summary reports, standard output from the DMS, are compiled in Appendix A.

Bridge and culvert crossing structures were encountered during Phase 2 assessments. Structure spans, clearance and width measurements were conducted at each structure. The span of each minor and major crossing was compared to measured or predicted bankfull widths (VTDEC WQD, 2006b), to determine if the structure was a constrictor of flows at the bankfull stage or the flood-prone-width elevation (10-year to 50-year flood) for completion of Phase 2 Step 4.8 (Constrictions). The work scope for reaches assessed in 2006 included bridge and culvert assessments completed in accordance with Appendix G of the VTANR protocols. Appendix B provides a summary of the structures assessed and the assignment of a VTrans Structure Number (where necessary) which enables storage of bridge and culvert data in the DMS. Appendix C provides the Bridge & Culvert Assessment reports – standard output from the Structures database in the DMS.

3.2 Phase 1 Updates

For the Mettowee River and tributary Phase 2 reaches assessed in 2005 and 2006, Phase 1 assessment data were reviewed and verified during field work as per VTANR protocols. Necessary corrections or updates were documented on Phase 1 summary sheets for each reach (see original field data sheets). As appropriate, GIS shape files were corrected or updated (using the Feature Indexing Tool), as well as the Phase 1 data in the DMS.

Phase 1 parameters updated, included:

- presence of alluvial fans (Phase 1 Step 3.1);
- presence and location of bedrock or other grade controls (Phase 1 Step 3.2)
- steepness of valley side slopes (Phase 1 Step 3.4);
- width of riparian buffers (Phase 1 Step 4.3);
- groundwater inputs (Phase 1 Step 4.4);
- revetment lengths and locations (Phase 1 Step 5.3);
- channel straightening (Phase 1 Step 5.4);
- location and lengths of berms and roads (Phase 1 Step 6.1);
- location and lengths of development (Phase 1 Step 6.2);
- occurrence of depositional bars and bedforms (Phase 1 Step 6.3);
- occurrence of channel avulsions, neck cut-offs, flood chutes (Phase 1 Step 6.4);
- erosion lengths and heights (Phase 1 Step 7.2);
- occurrence of, or potential for, ice/debris jams (Phase 1 Step 7.3)

The above features are more comprehensively inventoried for the study reaches during field assessments, than they are able to be during a Phase 1 which is accomplished through remote sensing and limited windshield surveys.

3.3 Quality Assurance / Quality Control

Assessments were carried out in compliance with the VTANR Programmatic QAPP (VTANR, 2003). Select features were geo-located using the Feature Indexing Tool of SGAT (v.4.53). Data were entered into the VTANR web-based Data Management System (DMS) https://anrnode.anr.state.vt.us/ssl/sga/index.cfm

For the 2006 reaches, Phase 2 data were reviewed against standard DMS Phase 2 quality control checks (X.1 through X.4), and then submitted to the River Management Section for a quality assurance review. Quality assurance documentation is contained in Appendix D for the 2006 reaches.

The following considerations and limitations apply to the Phase 2 data for the Mettowee River watershed:

- Where applicable, reaches were segmented using the Segmentation Tool contained in SGAT (v. 4.53). Segmentation was necessary to:
  - Capture subreaches of a stream type (after Montgomery & Buffington, 1997; and Rosgen, 1996) that was different than the reference stream type of the overall reach;
  - Identify sections of a reach that were of distinctly different geomorphic condition;
  - Identify sections of a reach undergoing a different channel management or land use;
  - Isolate in-stream wetlands; and
  - Define bedrock channel sections, defined as "gorges" by protocols;
- The Segmentation Tool within SGAT automates the calculation of segment lengths. Elevation data for the downstream and upstream segment breaks were interpolated from USGS 7.5-Minute topographic maps. Segment lengths and elevations are presented in Appendix E, along with channel gradients calculated for each segment. Segment slopes were factored into the stream-type designation for each segment. Occasionally, a subreach of alternate stream type was identified based on the calculation of segment slopes (e.g., in reaches M08T05.01, M05T03.01, M05T03.02S01.02, and MNY10T1.11). The elevation data for the downstream and upstream ends of the overall reach were originally developed in the Phase 1 assessment of the Mettowee River and Indian River watersheds (PMWP, 2005). During this Phase 2, reach break elevations were occasionally updated as a result of field-based observations. Accordingly, channel and valley gradient calculations were updated. In no case did these updates result in a change in stream type (slope) for the overall reach (see Appendix E).
- Select Phase 2 features (including, grade control locations, stormwater inputs, streambank erosion, revetment locations, and more) were geo-located using the Feature Indexing Tool (FIT) in SGAT (for 2006 reaches only). Using FIT, these features are indexed to the available Vermont Hydrography Dataset (VHD) for the Mettowee River basin. In many cases, surface waters depicted on the VHD were significantly offset from their actual position on 1994 orthophotos available for the study area. Additionally, in some cases, the actual channel position has moved from its 1994 position as a result of channel management activities (e.g., straightening) or natural channel migrations. These cases were revealed by comparison of the 1994 orthophotos with the 2003 aerial imagery (NAIP, 2003), or by review of 2005 and 2006 channel positions recorded with a hand-held GPS receiver. Thus, locations and lengths of features indexed to the VHD should be considered approximate. Waypoint logs and sketch maps contained on the Project CD provide more insight into the recorded locations of these features.

4.5 Indian River (MNY10.T1)

Indian River drains a 37.1-square-mile subwatershed in the southwestern portion of the Mettowee River watershed (see Figure 69). This tributary joins the Mettowee River main stem just northwest of Granville, NY.

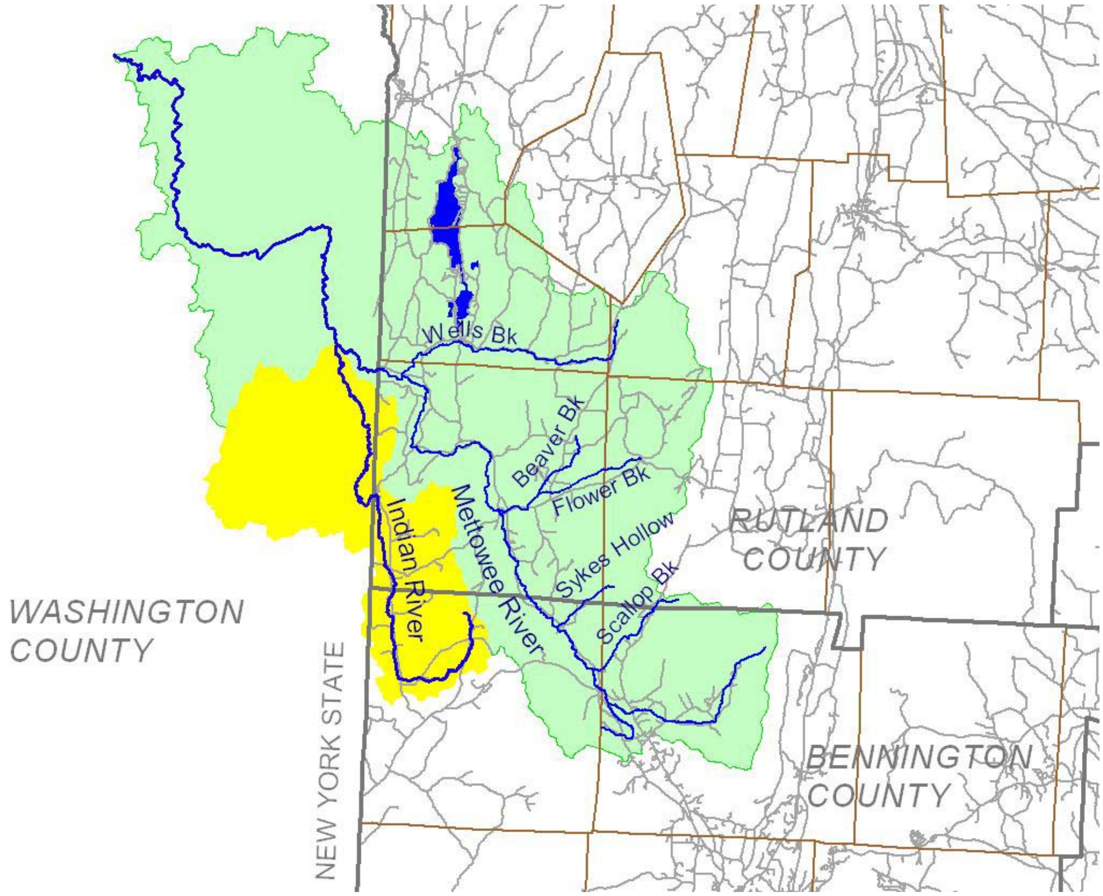


Figure 69. Indian River subwatershed of the Mettowee River watershed. (See Figure 2 for identification of towns and individual reaches).

At 37.1 square miles in area, the Indian River tributary watershed accounts for about 17.6% of the 211-square-mile Mettowee River watershed. Since a large portion of the Indian River watershed is located in New York State, and comparable land cover/land use coverages were not available for the New York portion of the Mettowee River watershed, land cover/land use estimates were not available in the Phase 1 Stream Geomorphic Assessment for the entire Indian River subwatershed. Upstream of reach MNY10T1.10, the Indian River is wholly contained within Vermont. In this upstream end of the subwatershed, approximately 60.1% of the subwatershed is in forest cover; 24.7% is in agricultural use; 10.2% is developed; and the remainder is water or wetlands.

Five reaches of the Indian River were selected for Phase 2 field-based assessment in 2006: MNY10 T1.11 through T1.07. These reaches comprise a 6.9-mile length of the tributary extending from northwestern Rupert downstream to the village of West Pawlet. Results are summarized in Table 10.

Table 10. Results of Phase 2 Geomorphic Assessments, Indian River Tributary reaches completed in 2006.

Indian River (MNY10T1)

Reach	Seg-ment	Channel Length (ft)	Channel Slope (%)	Drainage Area (sq mi)	Stream Type	Incision Ratio	RHA Condition	RGA Condition	Adjustment	Stream Type Departure?	Channel Evolution Stage	Sensitivity
MNY10T1.11	B	616	***4.9***		B3a-S/P	1.0 (RAF)	0.645 Fair	0.79 Good	Min PF	No	I (F)	Moderate
	A	2,205	***2.3***	2.3	C3b-S/P	1.9 (RAF)	0.69 Good	0.58 Fair	Mod PF	No	IV (F)	High
MNY10T1.10	B	3,103	***1.9***		C3c-S/P	1.6 (RAF)	0.60 Fair	0.61 Fair	Mod PF	No	IV (F)	High
	A	2,337	***1.7***	4.3	C4c-R/P	1.0 (RAF)	0.72 Good	0.71 Good	Mod PF	No	IV (F)	High
MNY10T1.09	C	4,319	***1.4***		F3c-PB	2.2 (HEF)	0.60 Fair	0.59 Fair	Min PF / Aggr	C to F	II (F)	Extreme
	B	2,712	***0.8***		C4c-R/P	1.0 (RAF)	0.72 Good	0.66 Good	Mod PF / Aggr	No	I (F)	High
	A	758	***0.9***	6.2	F4c-PB	2.2 (HEF)	0.52 Fair	0.55 Fair	None	C to F	II (F)	Extreme
MNY10T1.08	B	5,328	***1.2***		F4c-R/P	2.0 (HEF)	0.69 Good	0.61 Fair	Min PF	C to F	IV (F)	Extreme
	A	4,126	***0.9***	11.2	F4c-R/P	2.3 (RAF)	0.49 Fair	0.48 Fair	Min PF / Aggr	C to F	II (F)	Extreme
MNY10T1.07	E	4,815	***0.6***		F4c-R/P	2.5 (HEF)	0.46 Fair	0.55 Fair	Min PF / Aggr	C to F	II (F)	Extreme
	D	1,159	***0.3***				Not Assessed - Wetland					
	C	2,213	***0.2***		C4c-R/P	1.0 (RAF)	0.67 Good	0.73 Good	Mod PF / Wid	No	I (F)	High
	B	1,430	***0.3***		C4c-PB	1.8 (HEF)	0.46 Fair	0.61 Fair	None	No	II (F)	Very High
	A	1,473	***0.2***	15.8	C4c-R/P	1.0 (RAF)	0.57 Fair	0.61 Fair	Mod PF / Wid	No	I (F)	Very High

Notes / Abbreviations:
Channel Slope: Values in italic bold have been updated since the Phase 1 SGA, due to field-truthing and/or segmentation.
Stream Type: S/P = Step/Pool; R/P = Riffle/Pool; R/D = Ripple/Dune; PB = Plane Bed; Casc = Cascade; Ref = Reference
Incision Ratio: RAF = Recently Abandoned Floodplain; HEF = Human-elevated Floodplain (following protocols, VTANR, 2007).
Condition: RHA = Rapid Habitat Assessment; RGA = Rapid Geomorphic Assessment (VTANR, 2006).
Adjustment: PF = Planform Adjustment; Aggr = Aggradation; Wid = Widening; Deg = Degradation; NM = Not Measured.
Channel Evolution Stage: F = F-stage model; D = D-stage model (see Appendix C of protocols, VTANR, 2006).

MNY10T1.11

This half-mile reach of Indian River begins just upstream of the farmstead at the end of Lewis Road in the town of Rupert. It flows to the west parallel with Lewis Road extension, and ends approximately 650 feet downstream of the Lewis Road / Suncrest Road crossing (Figure 70). At the upstream end of the reach, Indian River is transitioning out of a Semi-Confined to Narrowly-Confined valley setting of steep gradient (5.6% in reach MNY10T1.12) into a Semi-Confined to Narrow valley of moderate gradient (2.8% overall gradient of reach MNY10T1.11). USDA mapping indicates that soils in the Indian River valley at this location have a glacio-fluvial origin. The upper third of the reach has a cobble, B-step/pool reference stream type, while the downstream two-thirds of the reach appear to have a Cb-step/pool reference stream type due to the lesser degree of channel confinement. Given the slight variation in reference stream type and an apparent difference in incision status of the channel, reach T1.11 was segmented as depicted in Figure 70.

Figure 70. Segmentation of Indian River reach MNY10T1.11.
(Flow is from picture right to picture left).

Segment B

Segment B of reach MNY10T1.11 is a short segment (616 feet) with a confined setting (Narrowly-Confined to Semi-Confined) and somewhat steeper slope (4.9%) than the remainder of the reach, comprising a section of alternate reference stream type, or subreach. Valley width ranges from an estimated 30 to 80 feet through Segment B, averaging 40 feet (or approximately 2 times the measured channel width). A cobble-dominated step/pool bedform is evident.

Encroachments along the segment are minor. A short cobble berm is present along the RB near the downstream end of the segment on approach to a farm road crossing (in the next segment). Some farm equipment and debris were noted along the top of the RB terrace within 50 to 100 feet distant from the channel. Livestock pasture occupies the LB corridor and beyond. At present, a fence prevents direct access to the Indian River; however, some closely-cropped vegetation along the LB area suggests that livestock recently may have had access to the channel. Some degree of straightening is possible given the linear planform of the channel upstream of the farm road crossing.

LB buffer widths are most often 5 feet or less in width, but are occasionally up to 25 feet; vegetation is herbaceous. RB vegetation consists of a mix of herbaceous (near-bank) and shrubs/sapling, with the occasional deciduous tree on the nearby terrace and side slope providing a limited RB canopy. Many unembedded boulders and cobbles within the bankfull channel margins provide for some epiphaunal substrates, although pool depths are limited. Overall, habitat was rated in "Fair" condition by the RHA, with a score on the cusp with a "Good" rating.

A cross section performed mid-segment confirmed a B3a-step/pool stream type. A very minor degree of incision (historic) was suggested by the measurement of a 1.04 incision ratio. However, it is also possible that bankfull elevation was slightly underestimated. No signs of active incision were noted in the segment. Generally, the segment was in a minor state of adjustment. Very few depositional bars were evident. The segment was rated in "Good" condition following the RGA; a sensitivity of "Moderate" was assigned as the corresponding rating for a cobble-dominated B stream type in minor adjustment.

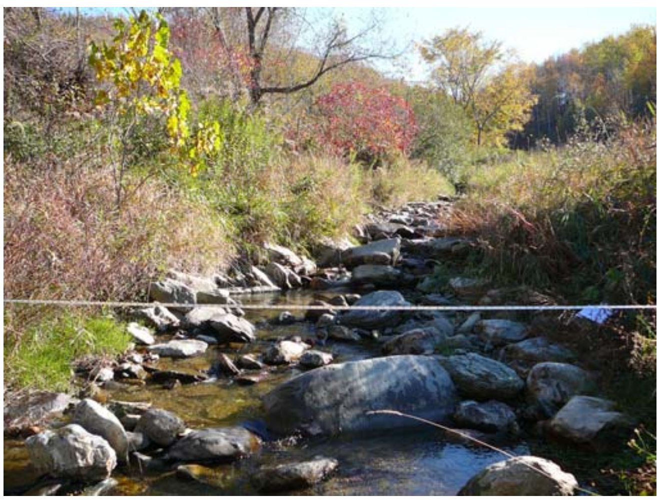


Figure 71. Cross section site in Segment B of Indian River reach MNY10T1.11. View upstream, 16 October 2006.

Given the confined setting and moderate gradient, Segment B would appear to be functioning as a transport-dominated reach. Stability has been afforded by the erosion-resistant cobbles and boulders in the bed and banks. As vegetation is permitted to re-establish over time along the near-bank areas and within the buffer, trees will offer additional channel stability, as well as shading, detritus, and LWD for riparian habitats.

Segment A

Segment A is a 2,205-foot section of reach MNY10T1.11 which comprises a majority of the reach length. This segment extends from the farm road crossing downstream along the Lewis Road extension, crosses under the Lewis Road / Suncrest Road bridge, and ends at the downstream reach break approximately 650 feet downstream of the bridge. Valley widths range from 40 to 150 feet along Segment A, averaging 120 feet (or approximately 5 to 6 times the measured channel width). Near the downstream end of the segment, valley widths are slightly reduced by the Lewis Road, but not substantially enough to change the valley type or unconfined status of the channel. A cobble C-step/pool reference stream type is suggested by the valley setting; an estimated 2.3% segment gradient indicates a "b" subclass slope modifier. The slope of Segment A is notably less than upstream Segment B (4.9%); a greater percentage of gravel was noted in the stream bed of Segment A with distance downstream. Two exposures of channel-spanning bedrock were noted immediately downstream of the farm road crossing at the upstream end of the reach.

Encroachments along the segment include nearby hay fields (along LB) and adjacent corn fields (along RB). The upstream end of the segment has an appearance of fallow pasture with perhaps 2 to 3 years herbaceous and shrub/sapling growth. Straightening is inferred along a majority of the segment, given the linear planform and close encroachment of agricultural fields. The age of deciduous trees along the near-bank areas of some channel sections indicate that straightening occurred historically.

The farm road crossing at the upstream end of the segment consists of two corrugated steel culverts, side-by-side: one 4-foot diameter and one 3.6-foot diameter. These are reinforced by laid-up stone headers. Fragments of concrete immediately downstream of the crossing suggest a former crossing structure. A representative for the landowner contacted on the assessment date indicated that this crossing had washed out and been replaced in the past year (perhaps as a result of the January 2006 flood event). The combined span of the two structures (7.6 feet) is undersized with respect to the reference and measured bankfull widths (18.9 ft and 19.1 feet, respectively). A second bridge crossing by the Lewis Road / Suncrest Road near the downstream end of the segment is also a bankfull constrictor. Despite their status as bankfull constrictors, minimal evidence of local scour or deposition issues was noted at either of these crossings. The farm crossing has been replaced only recently; it may take additional time for potential scour or deposition issues to develop at this crossing.

Figure 72. Cross section site in Segment A of Indian River reach MNY10T1.11. View upstream, 16 October 2006.

Evidence of active incision was not observed in Segment A. Varying degrees of historic incision were noted given the degree of vertical separation of the channel bed from the surrounding floodplain. The channel appears to have good access to a narrow floodplain in the upstream 450 feet (through fallow pasture). As the Indian River continues downstream, however, the degree of incision increases. A cross section performed approximately 500 feet downstream of the farm road crossing (Figure 72), indicated an incision ratio of 1.8, and an entrenchment ratio of 2.45. Several of the trees along both banks in this riffle section are curved at the base, appearing to record a history of leaning toward the channel (during a past event of active bank collapse), then recovering to grow straight upward (as the channel banks stabilized).

Continuing downstream the channel occasionally has access to a small pocket of incipient floodplain at a slightly lower elevation than the surrounding floodplain (cultivated by corn and hay). Moderate planform adjustment in this downstream half of the segment is suggested by the presence of several unvegetated mid-channel, point, and side bars; one vegetated island which bifurcates the channel; and several flood chutes. Aggradation and widening are localized, and considered minor over the full segment length.

The channel then becomes moderately incised again just upstream of the Lewis Road/Suncrest Road bridge crossing, with evidence of a low-profile berm along LB. Downstream of the bridge, the segment regains access to a narrow floodplain.

Thus, overall, Segment A appears to be moderately entrenched due to historic incision in response to straightening and localized berming. Incision appears to have been moderated by the presence of relatively coarse (and erosion-resistant) sediments in the bed and banks, and presence of channel-spanning bedrock near the upstream end of the segment. This is also a location of reduced valley slope, and it is possible that aggradation has offset potential incision and widening in response to historic channelization. Segment A was rated in "Fair" condition, geomorphically, with an associated "High" sensitivity rating.

Habitat conditions are compromised somewhat by the history of channelization and limited width of buffers. However, ample recruitment of LWD and detritus is contributing to recovery of the reach through forced riffles and pools. Habitat conditions were rated as "Good" following the RHA.

Segment A has a high recovery potential. Provided that future management of the channel does not include continued straightening, berming, and armoring, the channel will continue to develop the incipient floodplain through active meander migration and extension. Continued aggradation, and planform adjustments are to be expected in this location of valley slope reduction. This can be a strategic reach for sediment (and possibly nutrient) attenuation downstream of active and fallow pastures and corn and hay fields which likely receive periodic applications of fertilizers and/or manure. It would be important to refrain from development within the corridor surrounding the river channel to avoid potential erosion hazard losses and support the channel's return to a more balanced profile, gradient and sinuosity. This will help to minimize streambank erosion and sediment and nutrient mobilization in the long term.

MNY10T1.10

This one-mile reach of Indian River begins approximately 650 feet downstream of the Lewis Road / Suncrest Road crossing and flows to the west, along crop fields, through pasture and near residential homes to cross under Route 153 before turning toward the north to flow in a broad valley (Figure 73). The overall reach gradient is 1.8%. Within the reach, the Indian River is transitioning from a cobble-dominated, step/pool channel in a semi-confined valley setting (upstream reach) to a lesser-gradient, gravel-dominated riffle/pool stream type in a broad, unconfined valley setting. This transition in valley setting is combined with a change in stream gradient from 5.6% and 2.8% in MNY10T1.12 and MNY10T1.11, respectively, to 1.2% in MNY10T1.09. USDA soil survey mapping indicates that soils in the Indian River valley at this location have a glacio-fluvial origin.

Topographic contours in the upstream half of reach MNY10T1.10 are suggestive of an alluvial fan feature that probably involved more active sediment deposition in earlier post-glacial environments (1,000s of years before present). A braided channel (D stream type) might be expected as the reference stream type in this setting under more intense hydrologic and sediment regimes. A reference stream type of C is likely more appropriate under present sediment and hydrologic regimes.

Evidence of significant channel management was observed along reach MNY10T1.10, including armoring, berming and inferred channelization to constrain lateral movement of the channel. Several occurrences of channel-spanning bedrock were also observed which may have moderated the potential for vertical channel adjustments. Given an apparent difference in incision status of the channel, reach T1.10 was segmented as depicted in Figure 73.

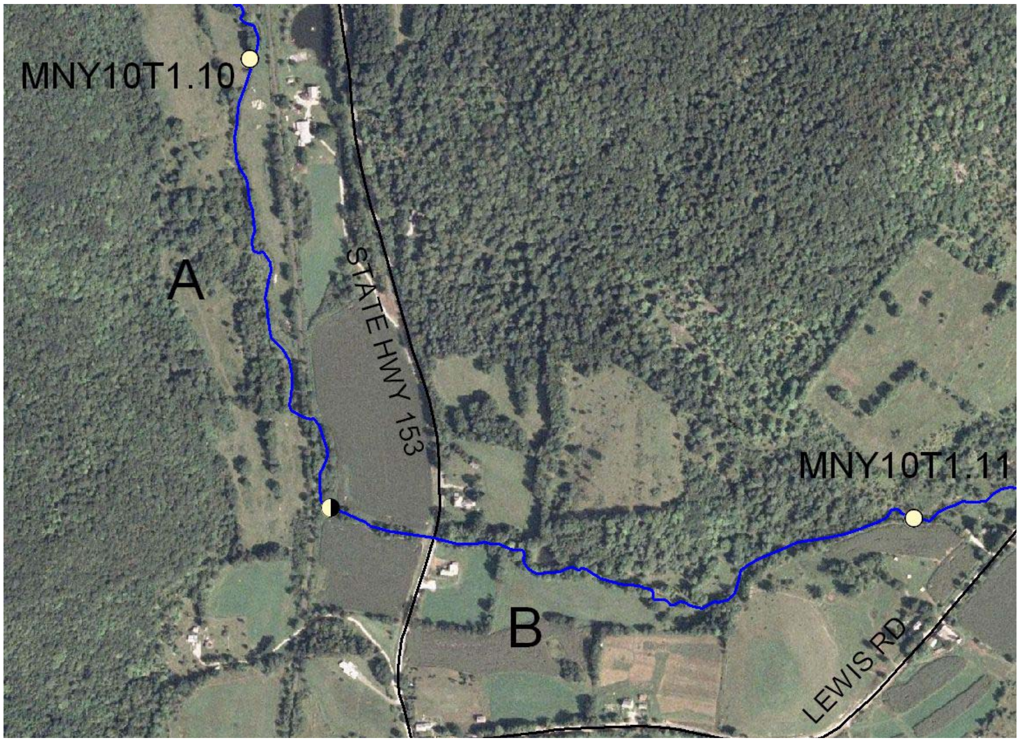


Figure 73. Segmentation of Indian River reach MNY10T1.10. (Flow is from picture right to picture left).

Segment B

Segment B of reach MNY10T1.10 is approximately 3,103 feet in length and extends from the upstream reach break to the vicinity of the former Delaware & Hudson railroad (now a rail trail) where the channel turns to the north. The valley width and available floodplain vary considerably through the segment, but the channel has a predominantly unconfined valley setting. Generally, valley width increases with distance downstream. Channel gradient was observed to decrease somewhat within the segment, especially downstream of the Route 153 bridge. Channel bed materials are dominated by cobbles. Bedform is transitional between step/pool and riffle/pool; however, pools are generally shallow in depth, and a plane bed form was visible on occasion.
Several occurrences of low-profile channel-spanning bedrock were observed in the upstream and middle portions of the segment. Bedrock was also observed providing lateral grade control along the RB upstream of the Route 153 bridge.

Bedrock along the RB is contributing to a low sinuosity in Segment A. However, close encroachment by crop and hay fields, armored banks and occasional LB and RB berms indicate that channelization has also occurred. Fill material along a constructed pond also serves as a berm along RB. A small shed was observed in the LB corridor approximately 600 feet upstream of the Route 153 bridge crossing. Residences on either side of the channel at the bridge crossing are located just outside of the corridor.

Two bridges were observed in Segment B: a footbridge consisting of two wooden planks near the constructed pond, and the Route 153 bridge crossing. Measured spans of these bridge crossings indicate them to be constrictors of the bankfull flow. No significant deposition or scour features were observed local to these structures.

Two cross sections were completed in Segment B. Varying degrees of historic incision were indicated by these cross sections, but each confirmed the reference stream type of cobble-dominated C-step/pool channel. The upstream cross section indicated a degree of historic incision (1.9) that was localized in extent. A pocket of RB floodplain was available at this cross section at highest flood stages; the LB was the high bank and the top of bank had been further elevated above the channel by placement of field stones that effectively berm the channel along the margins of a corn field.

Proceeding downstream, the channel has more floodplain access (2 to 4 times channel width). For approximately 500 feet mid-segment the Indian Brook flows through a pasture area where cattle have direct access to the stream. The stream has ample floodplain access through this pastured section. Former channel positions were observed in both the LB and RB corridors, indicating recent avulsions. GPS waypoints collected on the assessment date (28 September 2006) indicate that the current channel position is offset to the northeast from the planform indicated on the 1994 orthophotograph coverage. Trees are largely absent along both banks, and grasses are closely cropped in the near-bank areas. Low-bank erosion is present, exacerbated by trampling action of livestock.

Downstream of the pasture area, the Indian Brook flows alongside a constructed pond in the RB corridor. A 6-inch PVC intake pipe was observed in the channel approximately 200 feet upstream of the pond. Fill material surrounding the southern side of the pond forms a RB berm along the channel margins. A pipe outlet at the western end of the pond conveys pond overflow to the Indian Brook; this outlet was indexed as a stormwater input.

A second cross section was performed between the pond and the Route 153 bridge crossing, in an area of inferred historic channelization. This cross section indicated historic incision (IR = 1.6) and limited floodplain access along the RB. A rock wall running parallel to the stream is elevated above the floodplain and serves as a berm to the flood prone width.

Figure 74. (a) Indian River flows through a pasture area for approximately 500 feet, where livestock have direct access to the channel. Several flood chutes and recently abandoned channels are visible in the pasture area, such as the former channel position along the left valley wall (b) as depicted on 1994 orthophotos.
Segment M10NYT1.10-B, View downstream, 28 September 2006.

Downstream of the Route 153 crossing, the channel has a linear planform and is closely encroached upon by corn fields within the LB and RB corridors. Channel armoring is present for discrete lengths along both banks, and a low-relief berm is apparent for short sections along both banks. The segment break occurs just upstream of the location where Indian Brook turns sharply to the north and begins to flow parallel to the former railroad.

Based on the absence of indicators of active incision, the degree of incision recorded along Segment B is inferred to be the result of historic degradation following channelization, armoring and berming. Vertical adjustments were probably moderated by the presence of shallow and exposed bedrock in the channel bed, so that the channel has not fully lost connection to its floodplain but is moderately entrenched. Incision may also have been offset by aggradation in this location of local slope reduction. Lateral adjustments are constrained in many locations along RB by the presence of bedrock. Where the channel is unconstrained by bedrock, armoring, berms or woody vegetation (e.g., in the mid-segment pastured area), planform adjustments are active (e.g., flood chutes and recent avulsions). Elsewhere, the degree of planform adjustment is minor. Absence of significant widening was supported by the low width/depth ratios measured at both cross sections (24.5 and 18.5), and the relative absence of mid-channel bars, coincident scour along both banks, or leaning trees. Indicators of aggradation were also minor to absent; embeddedness was measured in the 0-to-25% quadrant; depositional bars were minor in extent. Overall, Segment B was rated in "Fair" condition by the RGA, and a "High" sensitivity was assigned.

Habitat was rated in "Good" condition following the RHA. Factors contributing to less than optimal habitat conditions included the degree of historic channelization, relative scarcity of deep pools or submerged logs for epifaunal substrates. Outside of the pastured and closely-cultivated areas, stream banks are densely vegetated by shrubs/saplings and relatively young-growth forest. More mature trees are present upstream of the Route 153 bridge; however, buffer widths are limited (15 to 50 feet wide).

Segment B of reach MNY10T1.10 appears to have a high recovery potential, assuming that future channel management choices do not include re-channelization, buffer removals, or further channel and floodplain encroachments. Historic channelization along agricultural fields has left the channel moderately entrenched and formerly converted a naturally aggradational setting (local slope reduction) to a transport-dominated setting. In recent years, the channel has regained some degree of sinuosity (and associated potential for sediment storage and flow attenuation along channel margins). Increased sediment and flow attenuation potential could be realized by refraining from future channel manipulations and supporting a return to a more balanced profile, dimension and planform. Cattle exclusion and buffer restoration along the currently pastured section of channel would reduce mobilization of sediments and nutrients.

Segment A

Segment A of reach MNY10T1.10 is approximately 2,337 feet in length and extends from the vicinity of the railroad bridge to the north along Route 153 to the reach break in the vicinity of a farmstead with a pond. The natural valley setting is greater than 10 times the channel width ("Very Broad") in this segment. A bedrock-controlled steep valley wall constrains the left (west) side of the valley. The right valley wall is a very subtle drainage divide between the Indian River and a parallel tributary at the western edge of Route 153. The adjacent RB side slope is classified as "Flat (0 to 3%)" by protocols. A reference stream type of C-riffle/pool is suggested by the topographic setting.

The former Delaware & Hudson railroad is located along the LB corridor upstream of the bridge crossing and along the RB corridor downstream of the crossing (a majority of the segment). The exact construction date of this railroad is unknown, but it is depicted on the 1897 USGS topographic map of the reach, as well as the Beers Atlas (1869) and Walling maps (1856), indicating that the construction date was prior to the late 1800s. Today, this railroad is no longer in service and the corridor is utilized as a "greenway" or rail trail. The railroad encroaches on the Indian River, reducing the available valley width. While the confinement is increased somewhat from "Very Broad" to "Broad", the channel is still considered unconfined.

Figure 75. Rail trail crossing of Indian Brook in Segment A, reach MNY10T1.10. View to the north, 6 October 2006.

Some degree of channelization is inferred along Segment A in the vicinity of the railroad crossing and where adjacent crop uses encroach upon the channel. However, bedrock was observed along the LB in several locations along the segment, and contributes to the linear planform. Three separate occurrences of channel-spanning bedrock were also recorded.

The upper two-thirds of the segment indicate good floodplain access and a moderate sinuosity where the channel is not flowing along LB bedrock exposures. A cross section completed in this section confirmed a gravel-dominated C-riffle/pool stream type, consistent with reference stream type. An incision ratio of 1.0 indicated good access to the surrounding floodplain (which had been reduced somewhat by a short-length, RB berm along corn fields. At very high flood stages this berm would be overtopped and the channel would have access to another more than 100 feet of floodplain in the RB corridor. With distance downstream, the channel was observed to pull away from the railroad berm and a broader floodplain was available to the channel. In the downstream 600 feet of the segment, the channel was "pinned" along exposed bedrock at the LB and was somewhat incised below a RB hay field. Straightening is inferred in this section, given the linear planform, close encroachment of the hay field, and partly-entrenched status of the channel. An old abutment was noted in this section west of a farmstead along Route 153. A wooden bridge was also observed in the same general location as well as two equipment fords. The abutment span and bridge span were each undersized with respect to the channel width.

A moderate degree of planform adjustment was indicated by the presence of flood chutes and low-level scour on the outside of meander bends. Minor to moderate aggradation was indicated by the presence of diagonal bars, and a few steep aggradational riffles. No significant indicators of channel widening were observed; the measured width/depth ratio at the cross section site was 22.4.

Wide forested buffers were present along much of the LB. Tree buffers were limited in width along the RB due to encroachment by hay and crop fields and the railroad berm, locally. A reasonable diversity of pool/riffle habitat and mix of epiphaunal substrates (submerged logs, unembedded cobbles) were observed. Overall, habitat was rated in "Good" condition by the RHA.
Segment A of MNY10T1.10 was rated in "Good" geomorphic condition by the RGA, as it is showing minor to moderate adjustment in response to limited historic channelization and encroachments. Exposures of channel-spanning bedrock (in this segment and in the downstream reach) and lateral bedrock constraints appear to have moderated the potential for channel incision and widening.

MNY10T1.09

This 1.5-mile reach of Indian River begins near a farmstead with a pond along the west side of Route 153 and flows to the north, along the former D&H railroad through hay and crop fields to the vicinity of the intersection of Perkins Road with Route 153. The overall reach gradient is 1.2%. Within this reach, the Indian River is flowing through sediments of glacio-fluvial origin (USDA, 1998; USDA, 2005). Several occurrences of channel-spanning bedrock were observed; and the channel flows along a bedrock-controlled left valley wall in several locations, which has contributed to the linear planform. A reference gravel-dominated riffle/pool stream type is expected in this very broad, unconfined valley setting.

Significant floodplain encroachments by the railroad along RB, and evidence of channel management (straightening, inferred dredging, armoring, berming), were observed along reach MNY10T1.09. Given an apparent difference in incision status of the channel, reach T1.09 was segmented as depicted in Figure 76.

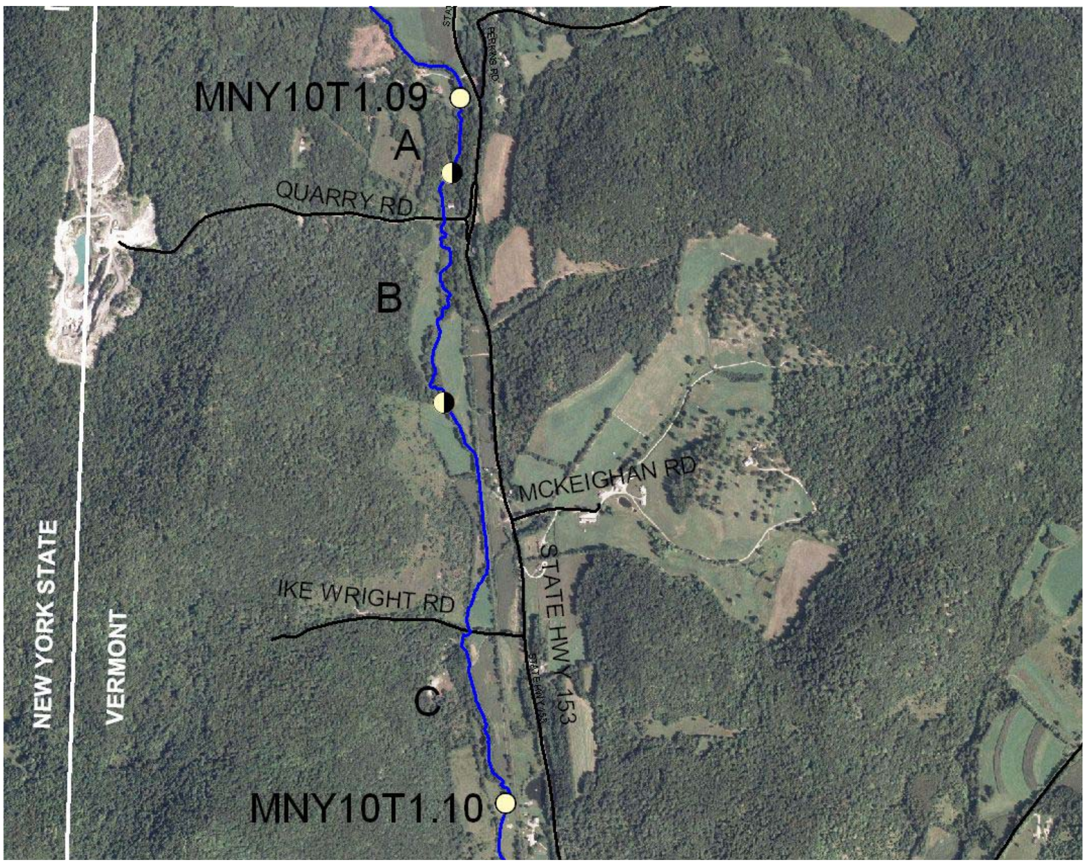
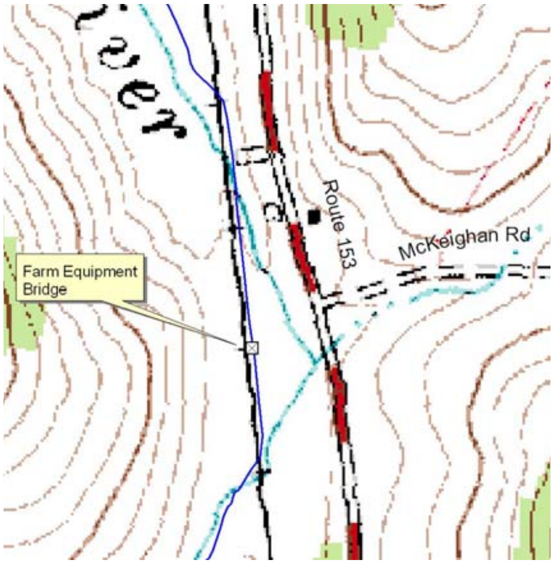
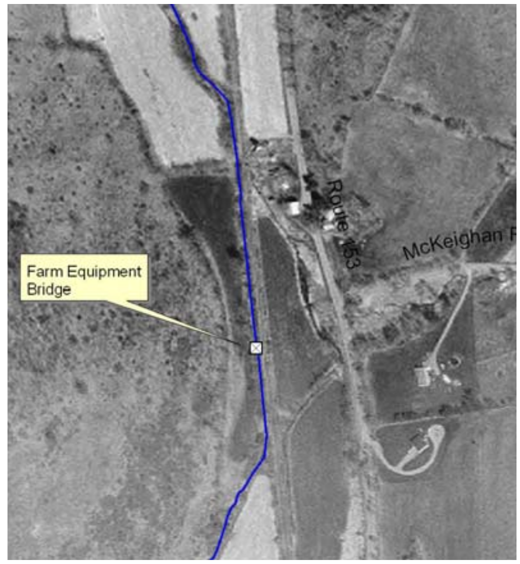


Figure 76. Segmentation of Indian River reach MNY10T1.09.
(Flow is from bottom to top of picture).

Segment C

Segment C of reach MNY10T1.10 is 4,319 feet long and extends from the upstream reach break to the mid-point of the reach. The former railroad encroaches on the floodplain throughout. Near the downstream half of the segment, the channel appears to have been moved and channelized (and possibly dredged) to flow along the west side of the D&H railroad (see Figure 77). Straightening is also inferred in the upstream half of the segment, due to the linear planform and close encroachment of corn and hay fields along the RB. Short lengths of low-profile berms are also present along RB along these fields.





(a) (b)

Figure 77. Review of 1967 topographic map (a) and 1994 orthophotograph (b) suggests that the position of the Indian River was shifted to the west side of the railroad, and the confluence of a right-bank tributary (along McKeighan Road) was thus shifted to the northwest, at some time between these two dates. (Downstream end of Segment C, reach MNY10T1.09).

Two bridge crossings were observed: one new driveway bridge crossing (steel I-beams and concrete decking) upstream of the Ike Wright Road crossing; and one farm road crossing downstream in the channelized section along the railroad. Measured bridge spans were undersized with respect to the bankfull width; however, deposition or scour features associated with these bridges were not substantial. The Ike Wright Road crossing is currently a ford; it is unknown if a bridge or culvert was previously located at this crossing. Evidence of recent stormwater and sediment runoff to the channel was evident from LB and RB at this ford crossing. Just upstream of this crossing, a tributary junction bar ("delta") was observed from a LB tributary that was dry on the assessment date. A brief walk up this tributary revealed a washout of a gravel road crossing uphill from the Indian River.

The overall degree of channel incision in Segment C was observed to increase from the upstream reach break to where the channel has been modified to flow directly alongside the D&H Railroad (Figure 76). A cross section completed in the upstream end of the segment indicated an IR = 1.8; a cross section in the channelized section downstream of Ike Wright Road indicated a IR = 2.2. Conservatively, the entire segment was classified as having lost connection to its floodplain, resulting in a stream type departure – from a C4-riffle/pool to F3c-plane bed.

Six separate occurrences of channel-spanning bedrock were recorded through Segment C. Bedrock also constrains the channel along the LB for much of the reach, contributing to the linear planform. In the downstream half where the Indian River was recently channelized, the river is pinned between bedrock on the LB and the high berm and armoring of the railroad bed along RB.

Figure 78. Cross section site in Segment C, Indian Brook, reach MNY10T1.09.
View to the north (downstream), 6 October 2006.

While gravels appeared to dominate the channel bed through a majority of the reach, a cobble-sized D50 was measured by pebble count techniques in the straightened section. It is possible that finer sands and gravels have been winnowed from the channel bed in this straightened section, resulting in a D50 in the cobble category. It is also possible that the dominance of cobbles has resulted from the placement (and subsequent collapse) of rip-rap along the RB through this section.

Segment C scored in "Fair" condition for habitat following the RHA. Factors contributing to a less than optimal score, included the substantial channel modifications, related plane-bed morphology, and minimal buffer widths.

No signs of active incision were observed through Segment C. It is likely that lateral and vertical bedrock controls have moderated the degree of incision and widening. Evidence of aggradation and planform adjustment was minor in degree, also. A few mid-channel bars and one steep riffle were observed, often localized to debris jam sites or channel-spanning bedrock exposures. Three small flood chutes were recorded in the segment. Overall, the segment was rated in "Fair" condition, due to the stream type departure resulting from historic channelization and incision. Given the stream type departure, a sensitivity of "Extreme" was assigned, following protocols.

Historic channelization has left the channel entrenched and converted a sinuous planform with opportunities for sediment attenuation into a more transport-dominated setting with limited potential for sediment, flow and nutrient attenuation. Frequent bedrock exposures in the bed and LB are offering stability to the entrenched channel. Armoring along the RB appears to have provided sufficient erosion resistance in recent flood events. However, this segment remains vulnerable to catastrophic erosion during a major flood event given its entrenched status.

Segment B

Segment B of reach MNY10T1.09 is approximately 2,712 feet long and extends from the middle of the reach to approximately 450 feet downstream of the Quarry Road culvert. As with upstream Segment C, the valley setting is very broad and has been encroached upon somewhat by the former D&H railroad grade along the RB. While the valley type is changed by this encroachment from "Very Broad" to "Broad", the reference C stream type, and unconfined setting of the channel remain unchanged. One occurrence of channel-spanning bedrock was observed downstream of the Quarry Road crossing. Wetlands are mapped contiguous to the channel for approximately 1,000 feet south (upstream) of Quarry Road (NWI, VSWI).

Straightening is inferred in discrete sections: in the upstream half of the segment between crop fields, and in vicinity of the Quarry Road culvert crossing near the downstream end of the segment. An abandoned commercial building encroaches along the RB immediately downstream of the Quarry Road crossing.

The Quarry Road culvert crossing is undersized with respect to the bankfull width. A span of 5.0 feet was measured at the main culvert. A secondary overflow culvert with a span of 3.0 feet is present along the LB margins of the channel elevated above the main channel. This overflow culvert was dry and obscured by some debris (leaves, branches) on the date of assessment. RB armoring downstream of the culvert was failing in spots.

Buffer widths were reasonable along both banks (generally greater than 50 feet). Near-bank areas were dominated by deciduous trees and shrub/saplings. Active meander extension was observed in a couple of locations where tree buffers were minimal to absent along LB corn fields or RB hay fields. Recruitment of LWD, detritus and organic matter was observed. Submerged logs are contributing to bar formation and riffle/pool diversity. Three large turtles were encountered in the segment. Habitat was ranked as "Good" following the RHA.

Unlike upstream Segment C, the channel has ample access to the surrounding floodplain. An incision ratio of 1.0 was measured at the cross section site approximately 650 feet upstream of the Quarry Road crossing. Channel measurements indicated a gravel-dominated C-riffle/pool stream type, consistent with reference stream type. No indications of active incision were observed. Channel widening is minimal, based on the absence of low-level scour or collapsing banks along both banks simultaneously in a riffle section and supported by the relatively low width/depth ratio measured at the cross section site (24.9). Minor to moderate aggradation and planform adjustments are suggested by the presence of multiple unvegetated, mid-channel, side, point and diagonal bars, channel bifurcations around vegetated islands, and several minor flood chutes. Meander extension is suggested the moderate degree of streambank erosion along the outside of meander bends. The RGA yielded a score of "Good", with a corresponding sensitivity rating of "High".

Overall, Segment B is a depositional segment exhibiting signs of active aggradation and planform adjustments downstream of an entrenched and transport-dominated segment. This segment and its channel-contiguous wetlands can offer important flow, sediment and nutrient attenuation functions in the watershed, downstream of some intensively modified channel sections with close agricultural encroachments. With landowner willingness, this segment of the Indian River may be a good candidate for conservation.

Segment A

Segment A of reach MNY10T1.09 is a short section where the channel returns to an entrenched condition in a straightened profile alongside the former D&H railroad. Lengths of channel armoring were present along both banks. The railroad grade at the RB was observed at 4 to 7 feet above the channel bed, while the LB ranged from 3 to 5 feet above the channel bed. Visual estimates suggested an incision ratio over 2, and an available floodplain between 1.5 and 3 times the channel width, constituting a stream type departure from C to F. Channel dimensions were very similar to those measured in Segment C; therefore values from this upstream segment were applied to Segment A. Channel bed materials were dominated by gravels; pebble count data from Segment B were applied to Segment A in the DMS.

MNY10T1.08

This 1.8-mile reach of Indian River begins near the intersection of Perkins Road with Route 153 and extends nearly to the Sawmill Road crossing. Sediments of glacio-fluvial origin (USDA, 1995; USDA, 2005) are mapped in the valley. The overall reach gradient is 1.1%. The drainage area of the Indian River watershed nearly doubles in size from the upstream to downstream ends of reach T1.08, largely due to the acceptance of two prominent RB tributaries, near the mid-point of the reach, which drain Rupert Mountain, Highgo Hill and Rock Hill to the east. Several occurrences of channel-spanning bedrock were observed in reach T1.08, mostly in the upstream half. The channel flows along a bedrock-controlled left valley wall in several locations, which has contributed to the linear planform in the upstream half of the reach. A reference gravel-dominated riffle/pool stream type is expected in this very broad, unconfined valley setting.

Significant floodplain encroachments by the railroad along RB, and evidence of channel management (straightening, inferred dredging, armoring, berming), were observed along reach MNY10T1.08. Given differences in channel management, as well as incision status of the channel and slight differences in valley confinement, reach T1.08 was segmented near the Pawlet/Rupert town line (also the Rutland/Bennington County line) as depicted in Figure 79.

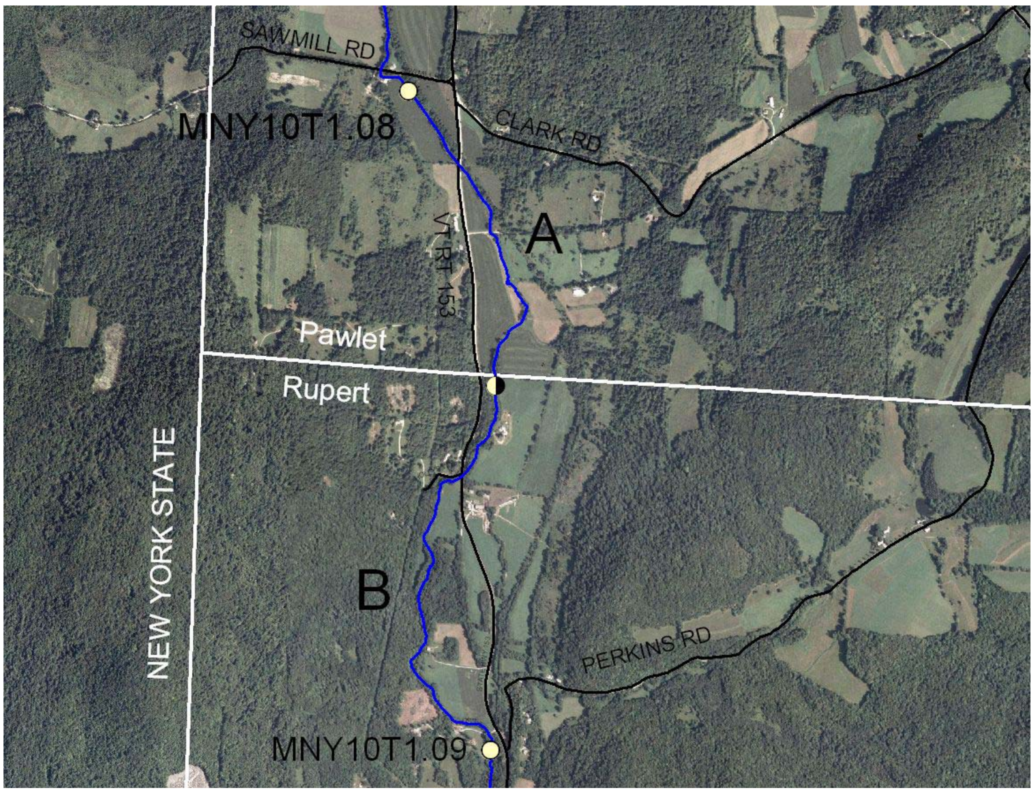


Figure 79. Segmentation of Indian River reach MNY10T1.08 (Flow is from picture bottom to top).

Segment B

Segment B of reach MNY10T1.08 is just over a mile (5,328 feet) in length and extends from the upstream reach break to the mid-point of the reach near the Rupert/Pawlet town line. The valley width varies within Segment B from 250 to 700 feet wide. This valley has been reduced only slightly at the upstream extent of the segment, by the rail trail and by Route 153, but not enough to change the valley type (Broad to Very Broad), or the reference stream type (C-riffle/pool). This characterization does not include the brief 280-foot long section of bedrock gorge mid-reach, where bedrock walls define a narrowly-confined valley approximately 60 feet wide. This section would be characterized as a B1b-cascade stream type. However, since the section represents such a small percentage of the overall reach, this area was typed as a single point of grade control classified as a "waterfall" by protocols. In addition to this short gorge section, four other occurrences of channel-spanning bedrock were observed in Segment B.

Figure 80. Short section of bedrock gorge within Segment B of Indian Brook, reach MNY10T1.08 was classified as a single point of "waterfall" grade control.
View to the north (downstream), 11 October 2006.

Recent and historic residential development encroaches somewhat on the stream corridor through Segment B. Crop and hay fields are also present in discrete sections along the RB. Some degree of channelization is inferred along these fields, which are further protected by low-profile berms and rip-rap armoring along the RB. However, LB exposures of bedrock are also contributing to a linear planform in these sections. A small hay field is present along LB just downstream of the bedrock gorge. Higher-profile gravel berms (and possible windrowing of the channel) were observed in this area.

Four bridge and culvert crossings and one pair of old laid-up stone abutments were observed in the segment. All five structures were determined to be undersized with respect to the bankfull and flood prone widths. Minor deposition and scour issues were identified associated with a few of the structures (see DMS). Points of stormwater (and fine sediment) runoff were observed from a LB driveway at the upstream end of the segment, and at the downstream end of the segment. Just downstream of a timber footbridge and upstream of the bedrock gorge, a small dam or possible ford of fine gravel and sand was observed to have been recently breached by flow in the channe (Figure 81)l. Sediments were observed deposited in downstream pools and on downstream bars.

Wide, forested buffers are maintained along a majority of the LB. Tree buffer widths are very narrow along the RB due to close proximity of agricultural fields, and near-bank vegetation is limited by the prevalence of stream armoring. Nevertheless, woody debris is providing some pool/ riffle diversity in a channel otherwise dominated by runs. Habitat conditions were rated as "Good" following the RHA.

Figure 81. Small dam or possible ford of fine gravel and sand recently breached by flow in the channel within Segment B of Indian Brook, reach MNY10T1.08. View upstream, 11 October 2006.

Outside of the bedrock gorge section, assessors noted a degree of vertical separation of the channel bed from the floodplain along the RB (the LB is most often coincident with the steep, bedrock-controlled left valley wall). Historic incision is inferred based on the absence of features that would suggest active incision. Channel degradation is consistent with a history of channelization and berming in this segment. At a cross section site in the upstream half of the segment, the measured incision ratio (1.96) and entrenchment ratio (1.43) suggest a stream type departure from the reference C-riffle/pool form. Interpreted literally the measured dimensions would describe a Bc-riffle/pool stream type. With consideration of the (+/-) 0.2 units for entrenchment ratio, permissible under protocols, the channel could also be classified as an F stream type. Elsewhere in the segment (outside of the bedrock gorge), visual observations suggest that IR ranges from 1.6 to greater than 2, while the floodplain available to the channel ranges from approximately 1.5 times channel width to 4 times channel width. The channel appears to have established an incipient floodplain at a lower-elevation than the surrounding, recently-abandoned floodplain. Frequent bedrock exposures in the bed and LB are offering stability to this new floodplain.

In consideration of the above discussion, a stream type of F4c-riffle/pool was assigned to Segment B. This classification is a conservative one, and may overstate the loss of floodplain connection in many parts of the segment. Signs of widening, aggradation and planform adjustment within the segment were negligible. The segment scored in "Fair" condition following the RGA; an "Extreme" sensitivity rating was assigned due to the stream type departure.

Historic channelization has left the channel entrenched and converted a sinuous planform with opportunities for sediment attenuation into a more transport-dominated setting with limited potential for sediment, flow and nutrient attenuation. Frequent bedrock exposures in the bed and LB are offering stability to entrenched channel. And armoring along the RB appears to have erosion resistance to recent flood events. However, this segment remains vulnerable to catastrophic erosion during a major flood event given its entrenched status.

Segment A

Segment A of reach MNY10T1.08 is approximately 4,126 feet in length and extends from the Rupert / Pawlet town line to the downstream reach break near the Sawmill Road crossing. The natural valley width within Segment A varies from 350 to 650 feet wide. Encroachments by the former D&H railroad along RB and by Route 153 along LB have reduced the natural valley width available to the channel. These encroachments are enough to change the valley type (from Very Broad to Broad); however, the reference stream type (C-riffle/pool) and confinement status (unconfined) have not been changed.

Sediments of glacio-fluvial origin are mapped in this broad valley. Two occurrences of channel-spanning bedrock (one "waterfall" and one "ledge") were observed mid-segment, just upstream of the Edwards Lane bridge crossing.

Crops (corn) and hay fields are developed in the floodplain alongside both banks of Segment A for a majority of the length. A narrow tree buffer is maintained along much of the segment, in the upstream and downstream ends – often 5 to 25 feet in width, but sometimes less and sometimes over 50 feet wide. In the middle of the segment a minimal herbaceous buffer is present and the channel canopy is open. The railroad serves as a berm along RB downstream of the Edwards Lane crossing. Upstream of this crossing, fill material was observed in the corridor which occasionally serves as a berm to either left or RB. Fill material possibly represents a new road which is being constructed parallel to the channel. In one location a meander of the channel had been removed, and filled with slate to straighten the channel (post-2003). Armoring is present along both LB and RB in various locations. Typically, where rip-rap is absent, the stream bank was observed to be eroding.

Habitat conditions were rated as "Fair" following the RGA. Limited tree buffer widths contribute to a less than optimal rating. Algae growth was abundant in this section adjacent to crop fields, in stark contrast to the upstream segment, where bank and channel canopies provide more shading, and agricultural encroachments are less pronounced. Pools are scarce in Segment A, and are mostly filled by fine gravels. The extensive history of channelization, berming, and armoring has also reduced the morphological diversity.

In the upstream extent of the segment and for the majority of the downstream half where the channel is present alongside the rail road grade, the channel is entrenched with incision ratios greater than 2.0. An abbreviated cross section performed near the downstream reach break was selected to represent the overall segment condition; this site indicated an F4c-riffle/pool stream type representing a departure from the C-riffle/pool reference stream type. A complete cross section and pebble count conducted approximately 400 feet upstream of the Edwards Lane crossing indicated moderate floodplain access (IR=1.25). However, this was a localized occurrence; this cross section site is within 250 feet upstream of a bedrock grade control which may be inducing localized aggradation and moderating the potential for channel incision. Overall, Segment A has very limited floodplain access due to inferred historic incision resulting from straightening and channel and floodplain encroachments.

No signs of active incision were observed. Evidence of widening is minor and localized. Width/ depth ratios measured at cross section sites in the segment ranged from 14.7 to 22.5. Coincident LB and RB erosion was observed in one short 30-foot section near the upstream end of the segment. Evidence of minor aggradation and planform adjustment included several low-profile mid-channel and diagonal bars, as well as erosion on most outside bends, and several small flood chutes which appear active at higher flows. The reach was rated in "Fair" geomorphic condition following the RGA. An "Extreme" sensitivity rating was assigned, given the stream type departure from C to F.

MNY10T1.07

This 2.1-mile reach of Indian River begins just upstream of the Sawmill Road crossing and flows to the north to end approximately 0.5 mile upstream of the village of West Pawlet. The overall reach gradient is 0.4%. Like the upstream reaches, the Indian River flows through sediments of glacio-fluvial origin in this reach. In contrast to the upstream reaches, channel-spanning bedrock was not encountered in reach T1.07, nor was bedrock observed to provide lateral grade controls. A reference gravel-dominated C-riffle/pool stream type is expected in this very broad, unconfined valley setting.

Significant floodplain encroachments have occurred historically along the RB; the former Delaware & Hudson railroad was constructed in the mid-1850s and much of the Indian River was channelized, dredged, and armored to flow in a straight channel along the west side of the railroad. Agricultural land uses have also encroached within the left and right corridors of the reach. The reach was segmented as depicted in Figure 82, to capture differences in channel management and incision status of the channel as well as to isolate a beaver-impounded in-stream wetland area (Segment D).

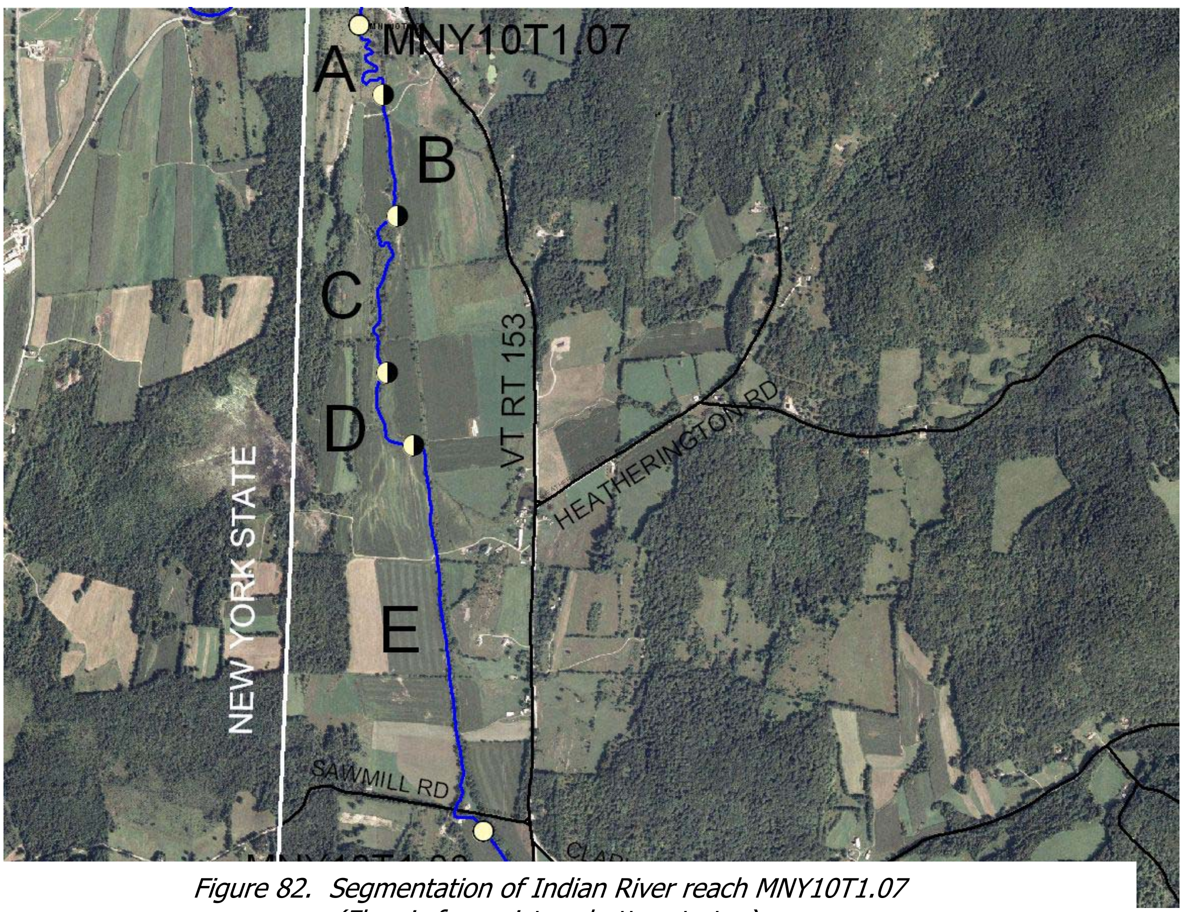


Figure 82. Segmentation of Indian River reach MNY10T1.07
(Flow is from picture bottom to top).

Segment E

Segment E of reach MNY10T1.07 is approximately 4,815 feet in length and extends from the upstream reach break to the approximate mid-point of the reach at a beaver-impounded wetland. The Indian River is flowing through a very broad valley in this section ranging from 1,200 to over 2,500 feet wide. The Dry Brook tributary joins the Indian River within this segment, draining uplands from the east. To the west is a low-lying drainage divide which separates the Indian Brook watershed from wetlands at the upstream extent of the Black Creek watershed in New York state. A 300-foot section of dry channel with a few isolated pools was observed in this segment of Indian Brook on the assessment date.

Historically, the river has been channelized to flow along the immediate west side of the former D&H railroad. The armored bank of the railroad is elevated above the floodplain and serves as a berm to the channel, preventing floodplain access to the east. The available floodplain is reduced to a width between 900 and 1,300 feet. While this encroachment represents a significant floodplain reduction, the valley type ("Very Broad"), confinement status (unconfined), and reference stream type (C-riffle/pool) remain unchanged.

Crop and hay fields encroach on the channel throughout most of the segment length. A narrow buffer of herbaceous cover with sparse deciduous trees is maintained along both banks (perhaps 5 to 15 feet in width). The railroad (a considerably elevated berm) separates the river from agricultural fields in the RB corridor. Until very recently, a berm was present along LB for the majority of Segment E, ranging in height from 1 to 2 feet above the adjacent floodplain. This berm was removed in the Spring of 2007 in a project directed by the VTDEC River Management Section. Consequently, this berm has not been indexed using FIT for this assessment report. (see Appendix D page D19 for more details. Two farm roads cross the channel via bridges constructed of timber decking on steel I-beams. These bridge spans are undersized with respect to the bankfull width. The Sawmill Road bridge also crosses within Segment E near the upstream (southern) end of the reach. This concrete bridge crossing is also a bankfull constrictor and the river approaches the crossing at a pronounced angle. RB rip-rap upstream of the bridge alongside Sawmill Road appears newly installed. Evidence of recent bar and channel dredging was also apparent upstream of the bridge. A newly-poured concrete abutment at the bridge suggests that the bridge height was recently raised. Collectively, these observations suggest that the Sawmill Road bridge was the site of recent flood or debris jam damages.

Figure 83. Sawmill Road bridge crossing in Segment E of Indian Brook, reach MNY10T1.07. View downstream, 11 October 2006.

Habitat conditions were rated in "Fair" condition by the RHA. Historic channel alterations have significantly reduced variability in bed morphology and flow patterns, and reduced available epiphaunal substrates. There are very few pools or submerged logs and very few unembedded boulders to provide refuge for fish or invertebrates. Buffer widths are minimal along both banks, and offer limited shading, detritus, and LWD.

The Indian River is incised below the surrounding floodplain in Segment E (Figure 84). Channel entrenchment is enhanced by the presence of the railroad / berm along the RB (and the LB berm prior to its removal in early 2007). While the channel occasionally had LB floodplain access at highest flow stages (channel incision ratios ranging from 1.8 to 2.5), the channel was fully entrenched along most of the segment length. A very subtle riffle/pool bedform was present, although pools were generally filled by fine sediments. An F4-riffle/pool stream type was assigned, which represents a stream type departure from the reference C-riffle/pool stream type.

Figure 84. View upstream from farm bridge crossing in Segment E of Indian Brook, reach MNY10T1.07. Rail trail constrains channel on right bank (picture left). 13 October 2006.

No indicators of active incision were observed in Segment E. Likewise, excessive channel widening was not evident; a width/depth ratio of 18.3 and 25 were measured in segment cross sections. Streambank sediments were a mix of silt, sand, and gravel, and displayed a cohesive nature, generally. These cohesive sediments along with channel armoring may be moderating the potential for channel widening. A minor degree of aggradation was suggested by the presence of multiple low-profile side bars, and a few transverse bars. Steep riffles were present associated with debris jams and localized streambank erosion. Minor active planform adjustment is also suggested by the presence of multiple small flood chutes; the historically straightened planform appeared very similar on the 1994 and 2003 aerial photos. Overall, Segment E rated in "Fair" condition following the RGA.

At this time, the segment appears to be stable in its modified form. Historic channel manipulations likely converted a reference meandering form with opportunities for sediment deposition and flow attenuation into a highly entrenched, transport-dominated channel with little geomorphic and instream habitat diversity. This transport-dominated reach also has the effect of translating erosional energies and sediments to downstream reaches.

Despite its seemingly stable form, Segment E remains susceptible to catastrophic erosion in a very large flood event, given the entrenched status. It would be prudent to limit future encroachments within the stream corridor to protect public safety and reduce fluvial erosion losses, and avoid costly channel management efforts in protection of these investments. Further study could evaluate the feasibility of various active geomorphic and engineering techniques to restore reference planform, profile and dimensions in this segment (e.g., lower the elevation of the rail trail to increase floodplain connection to the east. In the long term, such measures could accelerate a return to dynamic equilibrium in the channel, and reduce impacts to downstream segments, by creating more opportunities for sediment and flow attenuation along the corridor. The benefits of such active geomorphic measures would need to be evaluated in light of the costs, risks, compatibility with existing land uses by riparian landowners, and potential short-term consequences for sediment and nutrient mobilization.

Segment D

Segment D of reach MNY10T1.07, consists of wetland area where flow is impounded by multiple beaver dams. The segment is approximately 1,159 feet in length. While wetlands are not mapped in this location on either the National Wetlands Inventory or Vermont Significant Wetlands Inventory coverages, USDA soil survey mapping does indicate hydric soils along the channel in Segment D (and downstream Segment C) (USDA, 1995; USDA, 2005).

The somewhat linear planform of the channel depicted on 1994 and 2003 photos, and the close encroachment of crop fields, suggest historic channelization. The railroad berm is approximately 500 feet to the east of the channel through this segment. Presence of the railroad/berm reduces the valley available to the floodplain, but the valley type ("Very Broad"), confinement status (unconfined), and reference stream type (C-riffle/pool) remain unchanged. Tree and scrub/shrub buffers are somewhat wider in this segment than in surrounding segments (generally over 50 feet wide).

Beaver dam impoundments are forcing depositional bars and inducing some meander extension and avulsions. On the assessment date, flow was diffuse and multithread, and impounded waters were extending into adjacent corn fields along the RB. At the point where the channel transitioned from wetlands back to a single-thread riffle/pool channel, nick points were observed in the multi-thread channels. These appeared to be locations where the stream bed had eroded through a cohesive surface layer of silt. Streambank erosion in a RB meander bend immediately downstream (in Segment C) revealed a vertical profile of imbricated sand and gravel stream sediments overlying very dense silt ("hardpan").

A reference C-riffle/pool channel is suggested by the unconfined setting, shallow gradient (estimated 0.3%), and the moderately sinuous planform. Since Segment D is dominated by wetlands, Steps 2, 5, 6 RHA and 7 RGA and were not completed.

Figure 85. Segment D of Indian River reach MNY10T1.07 is in an area of mapped hydric soils where the channel is impounded by multiple beaver dams. View downstream toward the north, 13 October 2006.

Segment D is actively providing sediment and flow (and possibly nutrient) attenuation functions within the Indian River corridor. Although short in length, this segment is a strategic conservation segment for preservation of these flow and sediment attenuation functions, given its location downstream of intensively channelized and managed stream sections with close encroachment by crop and hay uses. Greater buffer widths between the wetlands and adjacent agricultural fields would offer increased water quality protection from sediments and nutrients.

Segment C

Segment C of reach MNY10T1.07 is approximately 2,213 feet long. Within this segment, the Indian River flows through a very wide valley over sediments of glacio-fluvial origin. While wetlands are not mapped in this location on either the National Wetlands Inventory or Vermont Significant Wetlands Inventory coverages, USDA soil survey mapping does indicate hydric soils along the channel in Segment C (USDA, 1995; USDA, 2005).

The railroad/berm is approximately 100 to 400 feet to the east of the channel through this segment. Presence of the railroad/berm reduces the valley width surrounding the channel, but the valley type ("Very Broad") and confinement status (unconfined) remain unchanged. A reference C-riffle/pool channel is suggested by the unconfined setting, shallow gradient (estimated 0.2%), and the moderately sinuous planform. One breached beaver dam was observed at the upstream end of the segment, suggesting that this segment may have been impounded in the recent past with conditions similar to those observed in upstream Segment D.

Other than the railroad, encroachments within the corridor of this segment are relatively minor. Historic channelization is inferred due to the somewhat linear planform of the channel depicted on 1994 and 2003 photos, and the relative proximity of crop fields.

A cross section completed mid-segment, confirmed a gravel-bed C-riffle/pool stream type. The channel has regained some measure of sinuosity (more than depicted by the VHD). However, riffles are short in length, and meander amplitude is notably less than regime. The channel has good access to a moderately wide floodplain (IR = 1.0; ER = 5.6).

Herbaceous and scrub/shrub buffers are somewhat wider in this segment than in the upstream segments (often over 100 feet wide). The occasional mature deciduous tree was observed, particularly along the outer edge of the buffers. While channel canopies are open, permitting direct sun exposure to the channel, the channel appears narrower and deeper than in other nearby reaches. Limited shading is offered by dense herbaceous vegetation along the near-bank areas. Some recruitment of LWD was observed (DJs = 2 and LWD = 9). These are providing limited refuge and epiphaunal substrates for riparian organisms. The history of channelization appears to have resulted in minimal pool/riffle diversity in localized sections. However, where the channel has regained some sinuosity and meander bends are pronounced, deep pools were evident along the outer edge of meander bends. Habitat conditions were rated in "Good" condition following the RHA.

Despite an apparent history of channelization, evidence of active incision was not observed in the segment, and good connection to the surrounding floodplain suggests the absence of historic incision. Similarly, evidence of channel widening was also minimal. A low width/depth ratio (17.6) was measured at the channel cross section. Coincident erosion along both banks was observed, but was localized to a short straight section near the downstream end of the segment. The cohesive nature of streambank soils, as well as the well-developed natural buffer vegetation may have moderated the potential for incision and widening in this segment. It is also possible that historic aggradation induced by beaver impoundments in the reach may have offset historic incision.

Present evidence of major aggradation was not observed. A few low-profile mid-channel bars, and two diagonal bars were present; several of these were associated with the breached beaver dam. Moderate planform adjustment is indicated by the presence of several flood chutes. Extension of several of the meander bends is evident from comparison of the 1994 to 2003 planforms. Overall, Segment C was rated in "Good" geomorphic condition following the RGA.

This segment is a high-recovery reach, providing that further channel manipulations and encroachments are avoided in the future. The channel is actively storing fine sediments. As sinuosity grows over time, the channel planform will contain additional point bars and depositional areas for attenuation of sediments. Good connection to the floodplain in this section will support flow (and possibly nutrient) attenuation. Although short in length, this segment could offer significant flow and sediment attenuation functions – particularly if corridor protection along this reach could be granted in conjunction with wetland restoration in the immediately upstream Segment D. Together, these segments are strategic in the overall reduction of sediment and nutrient mobilization in the Indian River, given their location downstream of several miles of intensively channelized and managed stream sections with close encroachment by crop and hay uses.

Segment B

Within Segment B of reach MNY10T1.07 the Indian River returns to flow directly along the west side of the railroad / berm. This is a short section approximately 1,430 feet long, and extends to a pasture nearly at the downstream end of the reach.

As with upstream segments, the armored bank of the railroad is elevated above the floodplain and serves as a berm to the channel, reducing the width of the available floodplain. The valley width has been reduced from more than 1,400 feet to approximately 350 to 600 feet. However, the valley type ("Very Broad"), confinement status (unconfined), and reference stream type (C-riffle/pool) remain unchanged.

Crop fields (corn) encroach on the channel throughout most of the segment length; a livestock pasture is present at the downstream end of the segment. A narrow buffer of shrub/sapling and deciduous trees (typically 5 to 15 feet in width) is maintained along both banks. One farm road crosses the channel over a bridge constructed of wooden decking and beams. The span of this bridge (20.4 feet) is undersized with respect to the reference bankfull width (44 feet) and upstream measured bankfull width (27.9 feet). Old rip-rap is present along a majority of the RB along the railroad; a section of newly-installed rip-rap was observed upstream of the bridge crossing, suggesting recent bank failure. Armoring is present is isolated sections along LB.

Habitat conditions were rated in "Fair" condition by the RHA. Historic channel alterations have significantly reduced variability in bed morphology and flow patterns, and reduced available epiphaunal substrates. Pools are absent and there are very few submerged logs or unembedded boulders to provide refuge for fish or invertebrates. Buffer widths are minimal along both banks, but do offer some shading, detritus, and LWD.

The railroad effectively cuts off access to the RB flood plain, and the Indian River is partly entrenched below the LB floodplain. Occasional pockets of LB floodplain are available where historic widening has created an incipient floodplain perhaps 1.5 to 3 times the channel width. Visual estimates suggested incision ratios ranging from 1.2 to 1.6. Riffles and pools were generally absent; a plane bed form dominates. Segmentation of this short section of the reach was not anticipated on the field date, and an abbreviated cross section performed in the segment did not include sufficient data to serve as the segment cross section. However, a cross section performed in upstream Segment E (in a localized area of greater floodplain access) was very similar to conditions encountered in Segment B. Channel dimensions of this upstream cross section were deemed representative of conditions in Segment B (for the sole purpose of categorizing stream type and informing stream condition and sensitivity). These data were therefore applied to Segment B in the DMS. Stream type was categorized as gravel-bed, C-plane bed. A degree of channel entrenchment exists but generally not sufficient to constitute a stream type departure.

No indicators of active incision were observed in Segment B, suggesting that the degree of entrenchment is the result of historic incision and inferred dredging during (or following) construction of the railroad. Likewise, active channel widening was not evident. Streambank sediments were a mix of silt, sand, and gravel, and displayed a cohesive nature, generally. These cohesive sediments along with channel armoring may be moderating the potential for channel widening. Only three low-profile side bars, and one mid-channel bar were observed in the segment, indicating negligible aggradation. A couple of flood chutes indicated minor active planform adjustment; the historically straightened planform appeared very similar on the 1994 and 2003 aerial photos. Overall, Segment B rated in "Fair" condition following the RGA.

At this time, Segment B appears to be stable in its modified form (although recent installation of RB armoring indicates the potential for occasional high-bank failures). Historic channel manipulations have converted a reference meandering form with opportunities for sediment deposition and flow attenuation into a moderately-entrenched, transport-dominated channel with little geomorphic and instream habitat diversity. This transport-dominated reach also has the effect of translating erosional energies and sediments to downstream reaches.

Despite its seemingly stable form, Segment B remains susceptible to catastrophic erosion in a very large flood event, given the partly entrenched status. It would be prudent to limit future encroachments within the stream corridor to protect public safety and reduce fluvial erosion losses, and avoid costly channel management efforts in protection of these investments. Further study could evaluate the feasibility of various active geomorphic and engineering techniques to restore reference planform, profile and dimensions in this Segment (possibly involving lowering of the railroad grade). Such efforts, in the long term, could accelerate a return toward dynamic equilibrium in the channel, and reduce impacts to downstream segments, by creating more opportunities for sediment and flow attenuation along the corridor. The benefits of such active geomorphic measures would need to be evaluated in light of the costs, risks and potential consequences.

Segment A

Segment A of Indian River reach MNY10T1.07 consists of the downstream 1,473 feet of the reach. Sediments mapped in the channel vicinity are hydric, and of glacio-fluvial origin (USDA, 1995; USDA, 2005). The valley walls are approximately 600 feet apart and begin to "pinch down" to create a semi-confined channel in the next downstream reach.

The railroad / berm is present within the RB corridor (between 10 and 190 feet distant from the channel). The railroad encroachment reduces the natural valley width somewhat (from "Very Broad" to "Broad" classification), but the confinement status (unconfined) and reference stream type (C-riffle/pool) remain unchanged. The full segment length flows through an active livestock pasture. Grasses are closely cropped throughout the floodplain. Some stream bank erosion has resulted from direct trampling action.

Habitat conditions are compromised by the absence of naturally-vegetated buffers, substantial streambank erosion, and minimal epiphaunal substrates. Direct livestock access to the channel is presumed to have contributed sediments and nutrients to the channel.

An apparent concrete dam structure is present at the upstream end of the reach (see Figure 86). Two vertical concrete walls are located perpendicular to the channel with an approximate control height of 4.1 feet above the channel thalweg. The concrete structures appear to be positioned to accommodate wooden flashboards. The structure is not impounding water at present. The original purpose of this structure is not known, but it may historically have been utilized to impound water for livestock. The distance between the two concrete walls is approximately 14 feet, and it is expected that this structure would constrict bankfull flows or higher-stage flood flows.

Figure 86. Possible dam structure at upstream end of Segment A of Indian River reach MNY10T1.07. View downstream through pasture, 13 October 2006.

Downstream of the structure the channel no longer flows directly alongside the railroad grade. Instead the channel meanders broadly through silt-rich cohesive sediments. A few of the meanders are highly tortuous and neck cutoffs may be imminent. Evidence of a recent neck cutoff (post-1994 and pre-2003) is apparent from review of aerial photographs. Planform adjustment in the form of meander extensions and meander translation is active; the current planform (measured with a GPS receiver on the assessment date) is even more sinuous than represented on the 2003 aerial photo.

A cross section performed mid-segment confirmed a gravel-bed C-riffle/pool stream type, consistent with reference. The channel has ample connection to the surrounding floodplain (IR = 1.0). Evidence of active incision was not noted. Moderate widening is suggested by a measured width/depth ratio of 35.6; direct cattle access to the channel appears to be causing some localized overwidening. A minor degree of aggradation is suggested by somewhat enlarged point bars, and two mid-channel bars. Overall, the segment was rated in "Fair" geomorphic condition; a "Very High" sensitivity was assigned.

5.0 Summary and Discussion

Phase 1 and Phase 2 assessment results have begun to characterize the watershed and channel stressors to the Mettowee watershed over time, and the spatial and temporal variability in adjustment processes which together have resulted in the present day geomorphic conditions. These interpretations can be used by watershed stakeholders to identify possible consequences of land use and watershed management decisions on future geomorphic condition of the river to minimize erosion and flooding hazards and to optimize water quality and aquatic habitats.

5.1 Watershed and Channel Stressors

Various watershed-scale and channel-level disturbances have served as stressors to the Mettowee River main stem and tributaries (Table 11). These stressors have been identified through direct observation, limited historical research, anecdotal accounts from landowners and local citizens, as well as remote sensing. This is not a comprehensive list, but it begins to characterize the degree of natural and anthropogenic disturbance to the watershed, that has caused variable and overlapping adjustment responses in the channel.

Channel and watershed disturbances that exceed thresholds for change can upset the dynamic equilibrium of stream systems. Imbalance in the channel affects the sediment transport capacity of the stream system, and has significant consequences for erosion hazards, water quality and riparian habitats. Equilibrium can be disturbed locally and result in channel adjustments that are limited in magnitude and extent (for example, scour at an undersized culvert crossing). Alternately, the disturbance (or an overlapping combination of disturbances) can be of sufficient size, duration, or frequency to cause substantial channel adjustments that result in a system-wide imbalance extending far upstream and downstream through the river network.

Such imbalances, whether localized or systemic, interfere with the river's ability to efficiently convey its water and sediment loads. These interruptions are either expressed as a sediment transport deficiency where sediment accumulates in the channel (which itself may lead to further imbalances - e.g., flow widens and splits to erode streambanks on either side, or flow may avulse or jump its banks in a flood event). Alternately, the imbalance can be expressed as an increased sediment transport capacity. For example, a channel that has been straightened, dredged, armored and bermed has a local increase in channel slope, which creates higher flow velocities, and an increased power to erode the streambed. The channel bed is scoured and this condition often leads to further channel adjustments including streambank collapse and widening.

Sediment transport capacity of the channel can be inferred from the geomorphic features observed during field work and from the stressors catalogued in Table 11. Even a qualitative understanding of these processes can help to identify and prioritize appropriate management strategies for the river that will facilitate a return toward a more balanced (dynamic equilibrium) condition.

5.2 Dominant Adjustment Processes and Reach Sensitivity

The Mettowee River and tributary channels are responding to stressors through adjustment of their dimension, planform, and profile. Adjustments have occurred to varying degrees, as dependent on multiple factors (including channel sediment types, vegetative cover type and density, presence of grade controls, etc.). The relative magnitude of these channel adjustment processes, together with the topographic, geologic, and vegetative setting define the sensitivity of each reach /segment to continuing and future stresses.

Table 11. Summary of Watershed and Channel Stressors in Study Area Reaches / Segments. Mettowee River Watershed, 2005 and 2006 Stream Geomorphic Assessments.

Reach / Segments	Watershed			Channel - Reach Scale							Channel - Site Scale				
	Deforestation in 1800s	Transportation Networks (1700s, 1800s)	Flood events	Channelization / Straightening	Dredging	Berming	Bank Armoring	Floodplain Encroachment	Loss of Forested Buffers	Impoundment (dam)	Gravel extraction	Bankfull-constricting Bridge / Culvert	Other Bankfull Constrictor	Direct Pasturing by Livestock	Ford
Main Stem															
M10-D				√			√	√	√			√			
M10-C				√			√		√						√
M10-B				√		√	√		√						
M10-A							√	√	√						
M09				√			√	√	√			√			√
M08				√		√	√	√	√			√			√
M07-B				√		√	√	√	√			√	√		√
M07-A				√		√	√	√	√		√	√	√		√
M06-B				√			√	√	√				√		
M06-A				√			√	√		√(H,B)		√			
M05							√	√	√					√	√
M04						√	√	√				√			√
Scallop & Sykes Hollow Brooks															
M08T05.01-B				√		√									
M08T05.01-A				√		√	√	√	√			√			
M07T04.01				√		√	√	√				√			√
Flower & Beaver Brooks															
M05T03.04							√	√							√
M05T03.03				√			√	√	√			√		√	√
M05T03.02							√					√			
M05T03.01-C				√	√	√	√	√	√		√	√	√		
M05T03.01-B						√	√	√	√	√	√	√	√		
M05T03.01-A							√	√	√						
M05T03.02S01.02-E							√	√				√			√
M05T03.02S01.02-D													√		
M05T03.02S01.02-C							√	√				√			
M05T03.02S01.02-B								√	√			√		√	√
M05T03.02S01.02-A															
M05T03.02S01.01-D															
M05T03.02S01.01-C				√		√	√	√	√			√		√	
M05T03.02S01.01-B				√		√	√	√	√			√			
M05T03.02S01.01-A							√	√							√

Table 11. (Continued) Summary of Watershed and Channel Stressors in Study Area Reaches/Segments. Mettowee River Watershed, 2005 and 2006 Stream Geomorphic Assessments.

Reach / Segments	Watershed			Channel - Reach Scale							Channel - Site Scale				
	Deforestation in 1800s	Transportation Networks (1700s, 1800s)	Flood events	Channelization / Straightening	Dredging	Berming	Bank Armoring	Floodplain Encroachment	Loss of Forested Buffers	Impoundment (dam)	Gravel extraction	Bankfull-constricting Bridge / Culvert	Other Bankfull Constrictor	Direct Pasturing by Livestock	Ford
Wells Brook															
M01T02.05				√			√	√	√			√		√	√
M01T02.04				√			√	√	√		√	√			√
M01T02.03				√			√	√				√	√		√
M01T02.02-E				√			√	√	√				√		√
M01T02.02-D				√	√	√	√	√	√			√	√		
M01T02.02-C				√			√	√	√			√			√
M01T02.02-B				√	√	√	√		√				√		√
M01T02.02-A				√			√	√	√			√			√
M01T02.01							√	√		√(H,B)		√			
Indian River															
MNY10T1.11-B				√		√	√		√						
MNY10T1.11-A				√		√	√	√	√			√			
MNY10T1.10-B				√		√	√	√	√			√		√	
MNY10T1.10-A				√		√	√	√	√			√	√		√
MNY10T1.09-C				√	√	√	√	√	√			√			√
MNY10T1.09-B				√			√	√	√			√			
MNY10T1.09-A							√	√	√						
MNY10T1.08-B				√		√	√	√	√			√	√		√
MNY10T1.08-A				√		√	√	√	√			√			√
MNY10T1.07-E				√	√	√	√	√	√			√			√
MNY10T1.07-D				√			√								
MNY10T1.07-C				√			√	√							
MNY10T1.07-B				√	√		√	√	√			√			
MNY10T1.07-A							√	√	√	√(H,B)			√	√	

Notes: √ (H) = historic stressor; √ (m) = minor condition; √ (B) = breached

Note that data for 2005 reaches in red text are provisional – not yet QA-approved by the VTDEC River Management Section.

The sensitivity classification is intended to identify "the degree or likelihood that vertical and lateral adjustments (erosion) will occur, as driven by natural and/or human-induced fluvial processes" (VTANR guidance, 1 July 2007). Inherent in the stream sensitivity rating are:

- the natural sensitivity of the reach given the topographic setting (confinement, gradient) and geologic boundary conditions (sediment sizes) – as reflected in the reference stream type; and

- the enhanced sensitivity of the reach given by the degree of departure from reference (or dynamic equilibrium) condition – as reflected in the existing stream type classification and the condition (Reference, Good, Fair to Poor) rating of the Rapid Geomorphic Assessment).

Generally speaking, those channels with steeper gradients in confined valleys carrying coarser sediment loads (boulders, cobbles) and showing good vertical grade controls (e.g., channel-spanning bedrock) are considered to be more stable and less susceptible to vertical and lateral adjustments that may present conflicts with human investments in the corridor. In contrast, the low- to moderate-gradient (less than 2%) channels dominated by gravels or sands, and absent of grade controls tend to be more susceptible to future adjustments in response to current and future channel and watershed stressors.

Sensitivities of the study area reaches/segments as defined in VTANR protocols (2006) are presented in Figure 87. For the most part, this Phase 2 purposely targeted lower-gradient, (reference C-stream-type) reaches in the watershed that would be expected to exhibit higher sensitivity, and which have current constraints within the river corridor. Therefore, it is not unexpected that study area reaches were defined as having sensitivities at the high end of the scale.

Exceptions to this generalization were the following **Moderate** and **Very Low** sensitivity segments and reaches. These segments are afforded greater stability by erosion resistance of materials in the channel bed and banks, and are less susceptible to lateral and vertical adjustments:

- three bedrock gorge subreaches which were afforded stability by the underlying bedrock which were assigned a Very Low sensitivity - Scallop Brook (M08T05.01-B), Flower Brook (M05T03.01-B), and Beaver Brook (M05T03.02S01.02-D); and

- two steeper-gradient, semiconfined, cobble and boulder segments which had RGA scores (0.74 and 0.79, respectively) in the Good quardrant and were assigned a Moderate sensitivity - M01T02.03 (Wells Brook) and MNY10T1.11-B (Indian River).

In contrast, segments exhibiting a pervasive stream type departure (as compared to reference stream type) were assigned an **Extreme** sensitivity. Typically, these reaches/segments have lost access to their floodplains becoming entrenched within their banks, as a result of historic channelization and/or dredging. Occasionally, entrenchment has been exacerbated by road or railroad encroachments or sediment berms close to the channel. None of the segments exhibited signs of system-wide active incision; incision was characterized as "historic" following protocols. One reach Dominant adjustment processes observed in these segments included minor to moderate widening, planform adjustment and aggradation; RGA scores ranged from 0.33 (Poor) to 0.64 (Fair). Generally, these moderate- to lower-gradient (< 2.6%), cobble and gravel channels showed stream type departures from C (or Cb) reference stream type to an entrenched F stream type (there was also one example of a Cb to B departure). Watershed segments / reaches classified in the Extreme sensitivity category due to a stream type departure included the following:

- Main stem segments M10-D, M10-B, and M06-A;
- Sykes Hollow Brook reach M07T04.01;
- Flower Brook segment M05T03.01-C;
- Wells Brook segments M01T02.02-D and M01T02.02-C; and
- Indian River segments MNY10T1.09-C, MNY10T1.09-A, MNY10T1.08-B, MNY10T1.08-A, and MNY10T1.07-E.

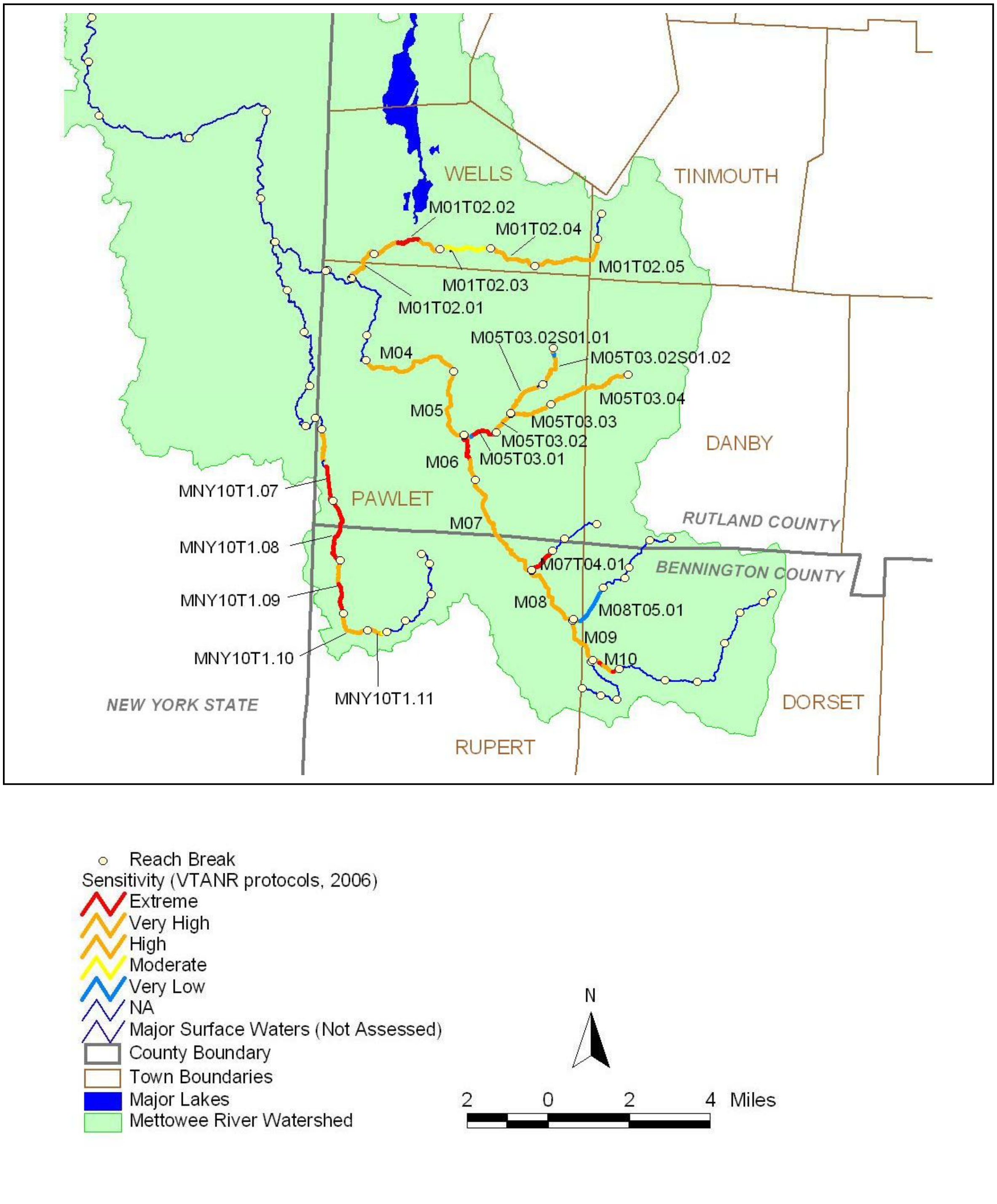


Figure 87. Reach / Segment Sensitivity
Mettowee River Watershed, 2005 and 2006 Stream Geomorphic Assessments.

The remaining assessed segments/reaches, were unconfined, lower-gradient (generally <2%), gravel- and sand-dominated channels that were assigned a **High** or **Very High** sensitivity as prescribed in VTANR protocols. They exhibited moderate to minor adjustments, and consequently were rated in Fair or Good condition (RGA scores ranging from 0.36 to 0.80). Some indicated a minor to moderate degree of historic incision, but none had lost complete access to their floodplain. Often lateral and vertical adjustments appear to have been moderated by the presence of exposed or shallow bedrock or forested buffers.

Three segments were not assessed or assigned a Sensitivity classification due to the dominance of wetlands: Beaver Brook segments M05T03.02S01.02-A and M05T03.02S01.01-D and Indian River segment MNY10T1.07-D.

Figure 87 shows that the Indian River tributary in Rupert and Pawlet has a greater length of segments classified in the Extreme sensitivity category than the other major tributaries of the Mettowee River. Other Extreme sensitivity segments are located in the village of Wells on the Wells Brook and in the village of Pawlet on sections of the main stem and Flower Brook. An additional section of Extreme sensitivity channel is located along the Sykes Hollow Brook in a low-density residential area of Rupert.

6.0 PRELIMINARY PROJECT IDENTIFICATION

Landowners, Pawlet community members, and resource agencies, including Poultney Mettowee Watershed Partnership, Poultney Mettowee NRCD, the Natural Resources Conservation Service, and Vermont Agency of Natural Resources, can use geomorphic data to inform future management strategies for the river corridor. For a given reach or segment, the active adjustment processes, degree of departure from reference, and sensitivity ranking will define the short-term compatibility and long-term sustainability of various restoration or conservation options and future land use or channel management activities.

The preliminary identification and prioritization of corridor restoration and protection projects and practices outlined below has been informed by:

- stream sensitivity data (Section 5.2);
- qualitative observations of sediment transport and attenuation characteristics (summarized for each reach in Sections 4.1 through 4.5); and
- preliminary departure analysis contained in Sections 4.1 and 4.5.

This provisional listing follows the outline of management actions identified in the *Step-Wise Procedure for Identifying Technically Feasible River Corridor Restoration and Protection Projects* included in VTANR guidance (1 June 2007 draft). Per VTANR guidance, the listed approaches can be classified under three broad management approaches:

> <u>Active Geomorphic:</u> Restore or manage rivers to a geomorphic state of dynamic equilibrium through an **active** approach that may include the removal or reduction of human-placed constraints or the construction of meanders, floodplains, and bank stabilization techniques. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.
>
> <u>Passive Geomorphic</u>: Allow rivers to return to a state of dynamic equilibrium through a **passive** approach that involves the removal of constraints from a river corridor thereby allowing the river, utilizing its own energy and watershed inputs to re-establish its meanders, floodplains, and self maintaining equilibrium condition over an extended time period. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.
>
> <u>Active-Passive Combination</u>: Use a sequenced combination of active and passive approaches to accommodate the varying constraints that typically occur along a project reach.
> *(VTANR, 2007; 1 June draft)*

The work scope for this Phase 2 Assessment has not included public outreach or analysis to determine the technical, financial and social feasibility and relative priorities of these listed project opportunities. Instead, this listing will form the basis for future project development and implementation efforts in the context of watershed, community, and corridor planning projects. A few of these projects (e.g., buffer plantings) can be considered for immediate implementation, independent of other watershed projects, and will require only minimal feasibility analysis and project development activities. Other identified projects may require further evaluation and efforts to conduct alternatives analyses, conduct landowner outreach and negotiations, and identify potential stakeholders and funding sources.

Watershed stakeholders which may look to this data for guidance include (but are not necessarily limited to):

- landowners,
- towns of Pawlet, Rupert, Dorset, and Wells,
- Poultney-Mettowee Natural Resources Conservation District,
- Poultney-Mettowee Watershed Partnership,

- VT Department of Environmental Conservation, Water Quality Division –
    - River Management Section and
    - Wetlands Section,
- Vermont Agency of Agriculture,
- Vermont Department of Transportation,
- Vermont Land Trust,
- Vermont River Conservancy,
- Northern Vermont Resource Conservation and Development Council (Better Back Roads),
- US Fish and Wildlife, and
- US Department of Agriculture, Natural Resources Conservation Service.

Note that Appendix F contains a listing of specific project opportunities for the Mettowee and tributary reaches assessed in 2006. This listing was developed based on previous River Management Section guidance (VTDEC RMS, 2003; VTDEC RMS, 2005b). This previous guidance has now been superseded by newer guidance:

- *VTANR River Corridor Planning Guide to Identify and Develop River Corridor Protection and Restoration Projects* (1 June 2007 draft).

Nevertheless, the project listings in Appendix F may provide additional detail in support of this Section 6 and future watershed and corridor planning efforts.

6.1 Protecting River Corridors

Protection of river corridors is an essential element to all passive and active geomorphic restoration and conservation projects. River corridor protection can support multiple objectives:

- **Dynamic Equilibrium** - Preserve (or support a return to) reference sinuosity, slope, and channel dimensions through active or passive geomorphic approaches. Refrain from future channel management, such as channelization, dredging, berming, armoring.

- **Floodplain Access** – Preserve or restore a channel's access to its surrounding floodplain in bankfull and higher flow events through active or passive geomorphic approaches. Refrain from future channel management, such as channelization, dredging, berming, armoring.

- **Sediment Attenuation** – Preserve, restore, or enhance the storage of sediments (from in-reach or upstream sources) within the channel margins, floodplain, and channel-contiguous wetlands.

- **Flow Attenuation** – Preserve, restore, or enhance the storage and detainment of flood flows through overbank flooding, increased channel length (sinuosity), increased channel roughness (e.g., buffers), and inundation of channel-contiguous wetlands.

- **Avoidance** – Refrain from developments and infrastructure in the corridor to minimize future fluvial erosion losses

Under a passive geomorphic approach, the river channel is allowed to freely meander within the area defined as the belt-width-derived river corridor. For a reach that is already close to reference condition or exhibiting only minor adjustments, preserving a river corridor will ensure the river's ability to continue to meander through the valley unconstrained by human infrastructure. In turn, human investments in the landscape will be protected from future channel adjustments. For a reach that has seen significant channel management in the past, and has lost some degree of floodplain connection and some measure of its sinuosity and balanced planform and profile, the channel is allowed to adjust unimpeded to a more sinuous, meandering planform closer to regime conditions. During ongoing adjustments, the river will re-establish greater floodplain access (where access has been lost) and adjust channel dimensions for optimum conveyance of its water and sediment loads. Restoring channel equilibrium will reduce instream production of sediment and nutrients and enhance sediment and nutrient attenuation over the long term.

Under an active geomorphic approach, protection of the river corridor will prevent future channel management that might unravel constructed features of a recently restored reach.

Lower priority reaches for river corridor protection include "wooded corridors experiencing very little threat from encroachment and less sensitive reaches not playing a significant flow or sediment load attenuation role in the watershed (1 June 2007, VTANR guidance)". Of the Mettowee River reaches assessed, this would include the:

- three bedrock gorge subreaches which were afforded stability by the underlying bedrock which were assigned a Very Low sensitivity –
    - Scallop Brook (M08T05.01-B),
    - Flower Brook (M05T03.01-B),
    - Beaver Brook (M05T03.02S01.02-D).
- two steeper-gradient, semiconfined, cobble and boulder segments which were assigned a Moderate sensitivity -
    - M01T02.03 (Wells Brook) and
    - MNY10T1.11-B (Indian River).

Highest priority reaches for river corridor protection include "highly sensitive reaches critical for flow and sediment attenuation from upstream sources or sensitive reaches where there is a major departure from equilibrium conditions and threats from encroachment (1 June 2007, VTANR guidance)". Limited term or permanent corridor easements are possible mechanisms for corridor protection, with the willingness of landowners.

Table 12. High-priority River Corridor Protection Sites, Mettowee River waterhsed

Rationale	Tributary	Reach / Segment	Town
Protection Upstream of Constrained / Altered Reaches Reduction of streambank erosion, improved floodplain access and enhanced sediment and flow attenuation in these reaches upstream of village areas of Pawlet and Wells, will reduce sediment production and delivery in the long-term to downstream segments which are constrained by the topographic setting and floodplain encroachments and are unable to adjust their dimensions, planform, and profile in response to excess sediment and water loads delivered from upstream.	Flower Brook	Protection of M05T03.03 and M05T03.02 to reduce impacts to M05T03.01	Pawlet
	Wells Brook	Protection of M01T02.04 and M01T02.05 to reduce impacts to M01T02.02	Wells
Sediment attenuation areas - preservation and enhancement. At present, land uses contiguous to many of these locations do not appear to be in conflict with channel adjustment processes. These sites are high-priority	Mettowee River main stem	M07-A (upstream extent M05 near the mid-section M04 downstream of Betts Bridge Road	

candidates for outreach and eventual conservation with the willingness of landowners.		crossing	
	Flower Brook	M05T03.02 (entire reach)	Pawlet
Reduction of Fluvial Erosion Hazards Corridor protection in these reaches, enabled by FEH mapping and zoning, can:			
(a) Inform residents of FEH hazards in already densely populated areas	Flower Brook	M05T03.01 (Pawlet village)	Pawlet
	Wells Brook	M01T02.02 (Wells village)	Wells
(b) reduce future fluvial erosion hazards along highly "sensitive **reaches where there is a major departure from equilibrium** conditions and threats from encroachment" (VTANR, 2007)	Mettowee River main stem	M10-D M10-B M06-A	Dorset Dorset Pawlet
	Sykes Hollow	M07T04.01	Rupert
	Flower Brook	M05T03.01-C	Pawlet
	Wells Brook	M01T02.02-D M01T02.02-C	Wells Wells
	Indian River	MNY10T1.09-C MNY10T1.09-A MNY10T1.08-B MNY10T1.08-A MNY10T1.07-E	Rupert Rupert Rupert Pawlet Pawlet
(c) reduce future fluvial erosion hazards along reaches at **alluvial fans or points of marked valley slope reduction** that contributes to increased sediment aggradation and planform adjustment. Carefully manage land use changes in the upstream watershed to reduce the potential for increases in sediment or flows that may induce channel adjustments in the subject reach/segment.	Mettowee River main stem	M10-D	Dorset
	Scallop Brook	M08T05.01-A	Rupert
	Sykes Hollow	M07T04.01	Rupert
	Flower Brook	M05T03.01-A	Pawlet
	Wells Brook	M01T02.02	Wells
	Indian River	MNY10T1.10-B	Rupert

6.2 Planting Stream Buffers

Forested riparian buffers serve to improve water quality and contribute to greater flow and sediment attenuation in the floodplain. They will also help to restore and maintain dynamic equilibrium of the channel by increasing resistance to boundary shear stresses along the channel margins. Tree buffers will provide the additional benefits of organic matter, detritus, and LWD recruitment for aquatic and riparian habitats, as well as increased shading to reduce river temperatures. Connectivity of buffer areas from reach to reach along a river network is also supportive of mammalian terrestrial habitats by providing wildlife corridors. The column heading "Loss of Forested Buffers" in Table 11 (Section 5.1) highlights the Mettowee River reaches which would benefit most from buffer plantings. Highest priority should be given to highest sensitivity reaches (see Figure 87).

Associated with buffer restoration in select watershed reaches is the exclusion of livestock to reduce channel trampling and allow trees and other native species to re-vegetate the channel margins. Opportunities for livestock exclusion in the Mettowee River watershed were noted on the following reaches / segments:

Table 13. Livestock Exclusion Opportunities in the Mettowee River Watershed

Tributary	Reach / Segment	Town
Mettowee main stem	M05	Pawlet
Flower Brook	M05T03.03	Pawlet
Beaver Brook	M05T03.02S01.02-B	Pawlet
	M05T03.02S01.01-C	Pawlet
Wells Brook	M01T02.05	Wells
Indian River	MNY10T1.10-B	Rupert
	MNY10T1.07-A	Pawlet

6.3 Stabilizing Stream Banks

Streambank stabilization can be considered in "laterally-unstable, [but vertically stable] reaches where human-placed structures are at high risk and not taking action may result in increased risk of erosion, to not only the structure, but lands that would provide the opportunity to establish a buffer (1 June 2007 draft VTANR guidance)".

Any bank stabilization project should be considered in the broader context (both in time and space) for the channel adjustment processes such management will set in motion and for the consequences to upstream and downstream reaches.

Table 14. Potential Bank Stabilization Sites in the Mettowee River Watershed

Tributary	Reach / Segment	Town	Description
Mettowee main stem	M04	Pawlet	Streambank stabilization may be warranted at the landslide failure site along LB in the mid-section of this reach to protect the residence located within 50 feet of the top of bank (see Section 4.1). Further site investigation would be required to confirm local channel dynamics and the causes of the mass failure.
	M08	Rupert	Further evaluate possible imminent hazard of further streambank erosion in vicinity of the mobile home through landowner outreach / site reconnaissance (see Section 4.1).

6.4 Arresting Head Cuts and Nick Points

Head cut sites were noted in two assessed reaches/segments of the Mettowee River watershed:

- Wells Brook segment M01T02.02-E (see Section 4.4) - this head cut was thought to represent a localized phenomenon related to the recent breaching of a debris jam and meander migration and does not appear to respresent an indication of system-wide active incision. This is a location of valley slope reduction and high bed load; aggradational processes and planform adjustments are the dominant adjustment processes. It is expected that this head cut site will aggrade naturally in the short term. Therefore, no active measures are proposed to arrest this head cut site.

- Sykes Hollow reach M07T04.01 (see Section 4.2) - Signs of active incision were observed in the upstream third of the reach. Multiple head cuts were present in this vicinity, along with high-bank erosion and significant vertical separation of the channel from the adjacent LB floodplain (IR = 4.6 measured at one cross section site). The upstream extent of active incision appears to coincide with the location of a former vehicle crossing. A temporary gravel road crosses the brook at this location and leads to the north toward a newly-developed (post-1994) residential property that is currently accessed by the other private driveway bridge crossing. Within 100 feet and 850 feet upstream, respectively, are two separate occurrences of channel-spanning bedrock which should serve to limit the potential for further upstream migration of incision. Since the bedrock grade controls are located within one meander wavelength (14 x bankfull width) of this channel, no active measures are proposed to arrest this series of head cuts. This reach is further addressed under Section

6.5 Removing Berms / Other Constraints to Flood & Sediment Load Attenuation

Removing berms or other constraints to the full meander expression and floodplain connection of a river channel may accelerate a return to dynamic equilibrium in the channel, and reduce impacts to downstream segments, by creating more opportunities for sediment and flow attenuation along the corridor. Further study is necessary to evaluate the feasibility of various active geomorphic and engineering techniques. The benefits of such projects would need to be evaluated in light of the costs and potential short-term consequences in terms of sediment and nutrient mobilization, and risk to infrastructure and public safety.

Table 15. Higher-priority Potential Berm Removal Sites, Mettowee River watershed.

Rationale	Tributary	Reach / Segment	Town
Restore Floodplain Access and Remove Constraints to full Meander Expression for Increased Flow and Sediment Load Attenuation			
(a) Evaluate the feasibility of lowering rail trail elevation where the former railroad grade presently constrains the channel and limits floodplain access (as well as incidental berms along opposite bank)	Indian River	MNY10T1.10-A MNY10T1.09-C MNY10T1.09-A MNY10T1.08-A MNY10T1.07-E MNY10T1.07-B	Rupert Rupert Rupert Pawlet Pawlet Pawlet
(b) Evaluate the feasibility of active geomorphic measures (e.g., lowering elevation of near-bank areas) where berms/armoring presently constrain the channel and limit floodplain access. Accompanied by corridor protection (see Section 6.1)	Scallop Brook	M08T05.01-A	Rupert
	Sykes Hollow	M07T04.01-A	Rupert
	Wells Brook	M01T02.02-B	Wells

6.6 Removing / Replacing Structures

Human-placed structures which span and "constrain the vertical and lateral movement of the channel and/or result in a significant constriction of the floodplain" can be considered for removal or replacement to support dynamic equilibrium of the channel.

6.6.1 Dams

One existing impoundment is present on the assessed reaches of the Mettowee River – the mill pond and dam at the top of the bedrock gorge through Pawlet village on Flower Brook (segment M05T03.01-B). A dam and mill pond (in varying configurations) have existed at this location for more than 200 years (since the late 1700s). This dam effectively raises the control height of the bedrock gorge by several feet. The mill dam and pond function to trap significant volumes of sediment at this location. Ongoing adjustment processes in Flower Brook are centered on the control elevation of this dam. The stability of this control feature and its effects on the Flower Brook upstream and downstream of the gorge are partly dependent on the structural integrity of the dam itself. The role that this dam structure plays as a grade control is also dependent on the decision of private landowners to maintain the Mill Pond dam in its present configuration and elevation. This structure is serving as a local base level control at an elevation several feet above the bedrock falls. If a catastrophic flood event were to breach the dam, or if future landowner were to propose dam removal, there would be a substantial change in both the flow regime and sediment regime for the Flower Brook associated with this drop in control height and reduction in sediment storage. The resultant impacts to upstream reaches of Flower Brook and downstream reaches of Flower Brook and Mettowee main stem would be significant and difficult to predict.

Segment M05T03.01-C is in a state of dis-equilibrium related to overlapping channel adjustments in response to historic and ongoing channel management and corridor encroachments. This segment is receiving sediments from instream erosion, avulsions, and mass failures as well as from upstream reaches that are undergoing active adjustments. A net reduction in sediment transport capacity is evident. However, the ability of this reach to adjust its slope, planform, and dimensions in response to these excess sediments is hampered by a combination of natural topography and human infrastructure. The valley is narrow and local base levels are fixed at the bedrock falls (and mill dam) at the downgradient extent. Roads and residential and municipal development have encroached significantly on the valley. The observed reduction in channel capacity appears to be the net effect of historic berming, armoring, and channelization practices to protect these human investments, accompanied by aggradation from instream and upstream sediment sources.

It is generally conceded that active management of the Flower Brook channel will continue in this segment to protect existing investments in the corridor, including the volunteer fire department building, various residences along both LB and RB, commercial properties (e.g., former Locker building), Route 133, and bridge crossings. The mill dam and pond at the downstream extent of the reach will continue to store sediments produced from streambank erosion in M05T03.01-C and upstream Flower Brook reaches. There will be a continual need for periodic dredging of sediments from the mill pond at the downstream extent of the segment. Considered over multi-generation time scales, continued channel management and maintenance of the mill pond dam may or may not be sustainable. Costs of continued channel maintenance, mill pond dredging, and bridge and road reinforcements are significant; recovery from erosion damage after major flood events can be catastrophic to a landowner or small community.

At the least, the town of Pawlet and landowners should consider limiting future development and floodplain filling within the Flower Brook corridor, to reduce flooding and streambank erosion losses. Continued channel management, such as armoring or channelization, should be considered in the broader context (both in time and space) for the channel adjustment processes such management will set in motion and for the consequences to upstream and downstream reaches of the Flower Brook. A corridor planning project recommended for Flower Brook reaches could help to increase public awareness and reduce sediment delivery to Segment M05T03.01-C and the mill pond (see Section 6.1).

If future plans involve rehabilitation or removal of the mill dam, or if a future flood events leads to damage to the structure, any changes in control height and sediment trapping functions of this mill dam area should be reevaluated in light of the resultant changes to flow and sediment regime in the Flower Brook, upstream and downstream of this location.

6.6.2 Bridges and Culverts

Several bridge and culvert crossings were encountered during this study. Their status as either a bankfull or flood-prone-width constrictor is addressed under Step 4.8 of the Phase 2 assessment (see Appendix A). Additional bridge and culvert assessment data are provided in Appendices B and C. These data can be utilized by the town road crews and regional planning commissions when establishing schedules and budgets for crossing rehabilitation and replacement.

In general, the geomorphic context should be considered when designing new and rehabilitated structures.

- New or replacement bridges should ideally have openings which pass the bankfull width to flood-prone-width without constriction.

- Bridges and culverts should be designed to cross the river without creating channel approaches at an angle to structures. Such sharp angles can lead to undermining of fill materials and structural components.

- The historic channel migration pattern of the river should be considered when installing new or replacement crossing structures, and when constructing new roads, driveways, and buildings.

- Planned build-out for watershed communities and resultant channel enlargement (from increased percent imperviousness) should be considered when designing new or replacement bridges and crossing structures.

- Divert road ditch runoff to side-slopes where energy can be dissipated, stormwaters can infiltrate, and sediment / detritus loads can be deposited on the land and not directly to streams.

6.7 Restoring Incised Reaches

Further study could evaluate the feasibility of various active geomorphic and engineering techniques to restore incising reaches which could accelerate a return to dynamic equilibrium of the channel, and reduce impacts to downstream segments, by creating more opportunities for sediment and flow attenuation along the corridor. The benefits of such active geomorphic measures would need to be evaluated in light of the costs, risks and potential short-term consequences in terms of sediment and nutrient mobilization.

Based on the Phase 2 geomorphic assessments in the Mettowee River watershed to date, one possible candidate is the section of active incision on Sykes Hollow Brook reach M07T04.01 (see Section 4.2). Further, more detailed geomorphic assessments (Phase 3) and an alternatives analysis would be required to evaluate:

- The history of incision and causal factors (e.g., increased peak flows, gravel extraction, channel manipulations, other);
- The feasibility of controlling the stressor(s) that resulted in the incision;
- The feasibility of restoring equilibrium channel dimensions, slope and profile;
- The feasibility of removing corridor constraints to floodplain access and full meander expression;
- Landowner willingness to participate in a potential restoration project.

6.8 Restoring Aggraded Reaches

Further study could evaluate the feasibility of various active geomorphic and engineering techniques to restore aggraded reaches which could accelerate a return to dynamic equilibrium of the channel, by restoring equilibrium of sediment transport processes. The benefits of such active geomorphic measures would need to be evaluated in light of the costs, risks and potential short-term consequences in terms of sediment and nutrient mobilization.

Based on the Phase 2 geomorphic assessments in the Mettowee River watershed to date, one possible candidate site has been identified:

- Wells Brook segments M01T02.02-C / -B (see Section 4.4) – where constriction of the channel by berms / armoring in downstream segment B appears to have contributed to accelerated aggradation and lateral adjustments immediately upstream in Segment C.

Further, more detailed geomorphic assessments (Phase 3) and an alternatives analysis would be required to:

- Confirm the causal factors;
- Evaluate feasibility of controlling upstream sources of sediments that are contributing to the problem;
- Evaluate feasibility of restoring equilibrium channel dimensions, slope and profile;
- Evaluate feasibility and consequences of removing corridor constraints to floodplain access and full meander expression;
- Understand landowner willingness to participate in a potential restoration project.

6.9 Other Related Projects

6.9.1 Controlling Sources of Sediment –

Flower Brook reach M05T03.04 There are significant sources of fine sediment along the valley margins of this reach from gullies that have developed on ephemeral tributaries. Conduct landowner outreach and site reconnaissance to evaluate the driving forces for gully formation on the tributaries and evaluate the feasibility of possible gully stabilization techniques and/or sediment attenuation measures to reduce sediment mobilization to the Wells Brook. Preserve sinuosity and floodplain access along Flower Brook, enhance sediment/flow attenuation functions, through passive geomorphic measures (possible limited term or permanent corridor easement).

6.9.2 Restoration of Channel-Contiguous Wetlands

Table 16. Wetland Restoration Sites, Mettowee River watershed.

Rationale	Tributary	Reach / Segment	Town
Restore Channel-contiguous wetlands and hydrologic connection to channel for Increased Flow and Sediment Load Attenuation	Beaver Brook	M05T03.02S01.01-C	Pawlet
	Wells Brook	M01T02.01 (strategic location just downstream of the Mill Brook confluence)	Wells / Pawlet
	Indian River	MNY10T1.07-D	Pawlet

7.0 RECOMMENDATIONS

7.1 Corridor Planning Projects

Corridor planning projects should be undertaken in the following locations to identify landowner-approved restoration and conservation projects that will protect the river corridor and generally support the restoration or preservation of dynamic equilibrium. Public and private benefits associated with dynamic equilibrium of the river include reduced fluvial erosion hazards, and improved water quality and instream and riparian habitats.

Recommended Corridor Planning Projects, Mettowee River Watershed

Tributary	Reach / Segment	Town
Mettowee main stem	M08 – M04	Rupert and Pawlet
Flower Brook	M05T03.04 – M05T03.01	Pawlet (and Danby)
Wells Brook	M01T02.05 – M01T02.01	Wells (and Pawlet, Tinmouth)
Indian River	MNY10T1.09 – MNY10T1.07	Rupert and Pawlet

Phase 2 geomorphic assessment data can be used to define a Fluvial Erosion Hazard corridor overlay district for consideration in town zoning regulations. Currently, funding and technical resources are available to the watershed towns for such planning processes through the Governor's Clean and Clear Action program.

A Wells Brook and Flower Brook corridor planning process could be considered a high priority as a means to communicate the potential for erosion hazards particularly along the highly-populated reaches in Wells village and Pawlet village. Moreover, projects and practices that could be effective in avoiding or reducing excess sedimentation and flows from upstream reaches to these communities might reduce erosion hazard risks in these village areas.

At the same time, the Indian River and Mettowee main stem corridors could be considered high priorities since development is much more sparse along these river sections at this time. This condition offers a strategic opportunity for corridor protection that will help landowners and these communities avoid erosion hazards in the future.

7.2 Project Development / Implementation

With the appropriate local, regional, state and federal partners, the individual projects outlined in Section 6.0 should be implemented, pending available funding. In addition to the financial and technical resources which may be available from the relevant partner organizations, River Corridor Grant funds available from the VTDEC Water Quality Division are an important source of funding for high-priority projects.

7.3 Buffer Restoration

Buffer plantings should be implemented in the watershed, with landowner approval, to support dynamic equilibrium conditions, reduce erosion, and improve water quality (including thermal) and riparian habitats (see Section 6.2 for locations). Technical and financial resources are currently available from various regional, state and federal agencies for buffer plantings. In addition to the agricultural resource agencies of and programs listed under Section 7.3 for lands in agricultural use, the following agencies / programs can provide resources to landowners and towns for buffer plantings.

- Vermont Department of Environmental Conservation (Vermont Watershed Grant Program, Nonpoint Source Management Grant [Section 319] Program, River Corridor Grant Program)

- USDA Natural Resources Conservation Service (Wildlife Habitat Incentives Program)

- US Fish & Wildlife (Partners Program)

7.4 Water Quality

Restoration and preservation of geomorphic equilibrium in the Mettowee River and its tributaries will contribute to water quality improvements and reduced sediment loading in the long term. In the short term, resources in this watershed can be directed toward preventing sediments and nutrients from entering the tributaries and main stem of the Mettowee River at their source. This can be accomplished on multiple fronts:

1. Address increased flows to the Mettowee River from drainage ditches, erosional gullies, and stormwater runoff.

    a. In the residential, commercial and municipal arenas, stormwater flows can be managed through compliance with state regulations. The towns of Wells, Pawlet, Rupert and Dorset can consider local ordinances to provide more stringent controls on stormwater runoff and which could apply to smaller developments and road / driveway installations that may not be subject to state stormwater regulations.

    b. Road maintenance practices to mitigate for stormwater and sediment runoff to the Mettowee River and tributaries may include: stabilization of road surfaces (different gravel materials), improvement of roadside ditches (excavation, stone lining and/or seeding and mulching), alternative grading practices (turnouts, check-basins); re-orientation of culvert crossings; protection of culvert headers; and gully stabilization. Technical and financial resources are available to the towns through the Better Back Roads program (Northern Vermont Resource Conservation and Development Council) as well as the VT Department of Transportation.

    c. In agricultural settings, increased flows from drainage tiles, ditches and erosional gullies can be addressed through design and retrofitting of tile networks to provide for energy dissipation at tile outlets; gully stabilization; and consideration of crop rotation or alternative farming practices that reduce the need for drainage tiles. Considerable technical and financial resources are available to farmers to implement these practices (see below).

2. Exclude livestock from direct access to stream channels (see Section 6.2). Livestock exclusion (fencing) can be accompanied by provisions for alternative water sources and installation of stabilized livestock crossings. Technical and financial resources are available to farmers to implement these practices (see below).

3. Implement changes in cropping practices to reduce direct runoff of fine sediments (and nutrients) to drainage ditches, surface swales, and the Mettowee River and tributary channels. Possible measures include crop rotation, filter strips, grass buffers, cover cropping, interseeding, and no-till options in the fall of the year. At a minimum, improved compliance

with current agricultural regulations, including Accepted Agricultural Practices (AAPs), Large Farm Operation (LFO) rules, and Medium Farm Operations (MFO) rules, will begin to address reduction in sediment and nutrient mobilization from agricultural sources.

Substantial technical and financial resources are currently available to farmers from various regional, state and federal agencies to implement the above changes in farming practices. Resource agencies and programs include, but are not necessarily limited to:

- Vermont Agency of Agriculture
  - Conservation Reserve Enhancement Program
  - Best Management Practices cost-share program
  - Integrated Crop Management cost-share program
  - Nutrient Management Plan incentive grants

- Vermont Natural Resources Conservation Districts
  - Agricultural Resource Specialists

- USDA Natural Resources Conservation Service
  - Agricultural Management Assistance
  - Conservation Reserve Program
  - Environmental Quality Incentives Program

4. Address possible stormwater contributions to thermal impacts in the Flower Brook (M05T03.01-B) in the vicinity of the mill dam and gorge. The high concentration of stormwater inputs and the diversion for power generation should be more closely monitored to determine the potential contribution of elevated temperatures to the Flower Brook. There is a high concentration of paved road surfaces and roof tops immediately contiguous to this segment and in the catchment areas for the observed stormwater drainage structures. Mitigating the thermal heating affects associated with these stormwater drainage systems could reduce the elevated temperatures in Flower Brook -although it should be noted that other factors (e.g., absence of shade-providing buffers) in upstream reaches are also contributing to this problem.

7.5 Additional Geomorphic Assessment Tasks

Pending available funding, geomorphic data for the seven 2005 reaches (Mettowee River main stem, reaches M07 through M04; and Flower Brook reaches M05T03.03 through M05T03.01) should be revised to bring into compliance with 2007 protocols and quality-assured.

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APPENDIX A

Phase 2 Stream Geomorphic Assessment
Reach Summary Reports

APPENDIX B

Assignment of VTrans Structure Numbers to Bridges and Culverts

Fifty-eight (58) bridge, arch and culvert crossing structures were encountered during Phase 2 assessments on the Mettowee River watershed in 2006. Structure spans, clearance and width measurements were conducted at each structure. A full Bridge & Culvert Assessment was completed at 48 of the structures, following Appendix G (April, 2005) of the VTANR geomorphic assessment protocols. The remaining 10 structures were simple wooden footbridges (and one abandoned pair of abutments spanned by two small steel beams, with no apparent road remaining). These ten structures were not associated with any transportation corridor; therefore a full Bridge & Culvert Assessment was not completed at these structures.

A listing of all the crossing structures encountered is provided in Table B-1. A shape file provided on the Project CD includes the location of each of these structures. Span information was entered into Step 4.8 (Constrictions) of the Phase 2 database of the VTANR web-based Data Management System (DMS) under the appropriate reach and segment records. The Bridge and Culvert Assessment information has been entered into the structures database in the VTANR web-based DMS.

Determine VTrans Structure Number

To enable data entry into the structures database of the DMS, a unique VTrans Structure Number must be entered for each bridge or culvert structure. Twentyone (21) of the structures already had a VTrans Structure Number assigned. For each of the remaining structures, a unique VTrans Structure Number was assigned during this project. The assignment of the VTrans Structure Number followed guidance provided in the Addendum to Appendix G. Methods are summarized below.

Review Existing Resources

For each crossing structure, the following ArcView™ shape files were reviewed to determine whether or not a VTrans Structure Number had already been assigned.

VTrans Structure Number
TransStructures_TRANSTRUC
VT Bridges and Culverts – transportation structures available from the Vermont Center for Geographic Information (www.vcgi.org). Post date: 9 November 2005

Consisting of four separate tables:

1) BC_LocalInventoryTable,
2) BC_VTransInventoryTable_Primary,
3) BC_VTransInventoryTable_Secondary, and
4) BC_VTransInventoryTable_Other.

The twenty-one structures with existing VTrans Structure Numbers were contained in either the "LocalInventoryTable" or the "VTransInventoryTable_Primary".

Table B-1. Identification of crossing structures encountered during Phase 2 assessments in 2006, with an indication of which structures were assessed by Appendix G of VTANR Protocols (*N/A = Not Available*).

Field Map #	Reach	Road	Route	Town	Structure Type	Bridge-Length or Culvert-Diam.(ft)	Bridge & Culvert Assessment?
1	M01T02.05	VT Route 133	VT-133	Tinmouth	Bridge	16.0	Yes
2	M01T02.05	Wells Brook Road	TH 27	Tinmouth	Culvert	12.5	Yes
3	M01T02.05	footbridge	N/A	Wells	Bridge	12.0	No
4	NM	Farm Road, Class 4	TH 5	Wells	Culvert	5.9	Yes
5	M01T02.05	Wells Brook Road	TH 5	Wells	Culvert	13.5	Yes
6	M01T02.05	trail	N/A	Wells	Bridge	16.2	Yes
7	M01T02.05	driveway	N/A	Wells	Bridge	21.0	Yes
8	M01T02.05	driveway	N/A	Wells	Bridge	17.7	Yes
9	M01T02.05	trail	N/A	Wells	Bridge	28.0	Yes
10	M01T02.05	Wells Brook Road	TH 5	Wells	Bridge	14.1	Yes
11	M01T02.04	Tunket Road	TH 30	Wells	Culvert	16.5	Yes
12	M01T02.04	footbridge	N/A	Wells	Bridge	49.2	No
13	M01T02.04	footbridge	N/A	Wells	Bridge	36.8	No
14	M01T02.04	footbridge	N/A	Wells	Bridge	21.8	No
15	M01T02.04	footbridge	N/A	Wells	Bridge	28.4	No
16	M01T02.03	Private Road	N/A	Wells	Bridge	26.2	Yes
17	M01T02.03	driveway	N/A	Wells	Bridge	27.8	Yes
18	M01T02.03	farm road	N/A	Wells	Bridge	24.7	Yes
19	M01T02.03	driveway	N/A	Wells	Bridge	29.3	Yes
20	M01T02.02	South Street	TH 2	Wells	Bridge	28.1	Yes
21	M01T02.02	farm road	N/A	Wells	Bridge	27.4	Yes
22	M01T02.02	VT Route 30	VT-30	Wells	Bridge	34.0	Yes
23	M01T02.01	VT Route 149	VT-149	Pawlet	Bridge	31.0	Yes
24	M10	VT Route 30	VT-30	Dorset	Bridge	33.8	Yes
25	M09	VT Route 30	VT-30	Dorset	Bridge	25.5	Yes
26	M09	VT Route 30	VT-30	Rupert	Bridge	25.6	Yes
27	M09	farm road	N/A	Rupert	Bridge	24.8	Yes
28	M08	equipment crossi	N/A	Rupert	Bridge	21.0	Yes
29	M08	Connaway Rd	Class 8	Rupert	Bridge	24.5	Yes
30	M08T05.01	VT Route 30	VT-30	Rupert	Culvert	9.0	Yes
31	M07T04.02	Sykes Hollow Rd	TH 7	Rupert	Culvert	12.6	Yes
32	M07T04.01	Private Driveway	N/A	Rupert	Bridge	23.4	Yes
33	M07T04.01	VT Route 30	VT-30	Rupert	Bridge	13.0	Yes
34	M05T03.02S01.02	Abandoned	N/A	Pawlet	Bridge	9.0	No
35	M05T03.02S01.02	Kelly Hill Rd	TH 14	Pawlet	Culvert	9.2	Yes
36	M05T03.02S01.02	footbridge	N/A	Pawlet	Bridge	8.0	No
37	M05T03.02S01.02	footbridge	N/A	Pawlet	Bridge	10.0	No
38	M05T03.02S01.01	VT Route 133	VT-133	Pawlet	Arch	14.1	Yes
39	M05T03.02S01.01	Andrus Road	TH 35	Pawlet	Culvert	5.7	Yes
40	MNY10T1.11	farm road	N/A	Rupert	Culvert	7.6	Yes
41	MNY10T1.11	Lewis Road	TH 11	Rupert	Bridge	17.6	Yes
42	MNY10T1.10	footbridge	N/A	Rupert	Bridge	16.4	No
43	MNY10T1.10	VT Route 153	TH 1	Rupert	Bridge	16.0	Yes
44	MNY10T1.10	railroad	N/A	Rupert	Bridge	13.0	Yes
45	MNY10T1.10	farm road	N/A	Rupert	Bridge	19.7	Yes
46	MNY10T1.09	farm road	N/A	Rupert	Bridge	26.9	Yes
47	MNY10T1.09	farm road	N/A	Rupert	Bridge	16.8	Yes
48	MNY10T1.09	Quarry Road	Class 8	Rupert	Culvert	5.0	Yes
49	MNY10T1.08	private driveway	N/A	Rupert	Bridge	24.8	Yes
50	MNY10T1.08	footbridge	N/A	Rupert	Bridge	30.4	No
51	MNY10T1.08	VT Route 153	TH 1	Rupert	Bridge	22.1	Yes
52	MNY10T1.08	private driveway	N/A	Rupert	Culvert	9.9	Yes
53	MNY10T1.08	Edwards Lane	Class 8	Pawlet	Bridge	22.5	Yes
54	MNY10T1.08	VT Route 153	TH 1	Pawlet	Bridge	26.8	Yes
55	MNY10T1.07	Sawmill Road	TH 22	Pawlet	Bridge	14.5	Yes
56	MNY10T1.07	farm road	N/A	Pawlet	Bridge	19.4	Yes
57	MNY10T1.07	farm road	N/A	Pawlet	Bridge	19.8	Yes
58	MNY10T1.07	farm road	N/A	Pawlet	Bridge	20.4	Yes

Assignment of VTrans Structure Number to remaining structures

As per the Addendum to Appendix G of the VTANR protocols pertaining to Bridge & Culvert Assessments, the assignment of a VTrans Structure Number is based upon the structure size, type, and location. Refer to the Addendum for more details. Table B-2 provides a summary of the component elements of the VTrans Structure Number assigned to each structure.

VTrans Structure Number = <STRUCTYPE><ROUTE#><NUM><CTCODE><SYSFLAG>

<STRUCTYPE>

Under this project, the span measured at each structure was used to determine the <STRUCTYPE> value. For culverts, the span equates to the "culvert width" parameter noted on the B&C assessment form. The span value was used to categorize whether the structure was a Long, Short, or Ultra Short structure, as defined in the table below. The span, together with the identification of the structure as either a Town, State or Private structure, defined the value (code) assigned under <STRUCTYPE>.

Code	Structure Type	Description
10	Town Long	>= 20 feet
20	State Long	>= 20 feet
30	State Short	< 20 feet >= 6 feet
40	Town Short	< 20 feet >= 6 feet
50	State Ultra Short	< 6 feet
60	Town Ultra Short	< 6 feet
70	Other	e.g., private bridges, culverts

<ROUTE#>

The route number of the road crossing the bridge or culvert structure was determined from a review of the attribute data for VTrans road center line shape file (TransRoad_RDS obtained from www.vcgi.org on 3 June 2006; post date 24 October 2005). A majority of the structures encountered in this project were private crossings on farm roads, driveways, railroads, or recreational paths, and no corresponding state or town route number was available. A value of "0000" was entered as the <ROUTE#> element for these structures.

<NUM>

Typically, the number assigned under this category is an approximate 911 address for the structure, determined from review of the E911 sites data overlain on the VTrans road network. However, since a majority of the structures encountered in this project were private crossings on farm roads, driveways, or recreational paths, and no corresponding road network coverage was available, a 911-type address could not be readily developed. Therefore, the value substituted for the <NUM> component, was the Field Map # prefixed by the appropriate number of zeros to bring the total number of digits to four.

<CTCODE>

From a review of the attribute data for VTrans road center line shape file (TransRoad_RDS), the VTrans County/Town code for the watershed towns are as follows:

Dorset	3015	Rupert	3045
Pawlet	1070	Tinmouth	1120
		Wells	1130

<SYSFLAG>

The system flag denotes whether the structure is a town system structure (1), a state system structure (2), or a private system structure (3). For this project, it was assumed that a state system structure is one located on a state highway, and a town system structure is one located on a town highway (as depicted on the town highway maps for watershed towns. A private system structure was assumed to be one located on a private driveway, private road, path or railroad.

Table B-2. VTrans Structure Number Assignment, Mettowee River watershed bridges and culverts.

									Derivation of Vtrans Structure Number as per Addendum to Appendix G.					
Field Map #	Reach	Road	Route	Town	Structure Type	Bridge-Length or Culvert-Diam.(ft)	Bridge & Culvert Assessment?	Existing VTrans Structure Number [a]	STRUCTYPE	ROUTE#	NUM	CTCODE	SYSFLAG	Assigned VTrans Number
1	M01T02.05	VT Route 133	VT-133	Tinmouth	Bridge	16.0	Yes	300139000511241						
2	M01T02.05	Wells Brook Road	TH 27	Tinmouth	Culvert	12.5	Yes	70002701121124X						
3	M01T02.05	footbridge	N/A	Wells	Bridge	12.0	No		70	0000	0003	1130	3	700000000311303
4	NM	Farm Road, Class 4	TH 5	Wells	Culvert	5.9	Yes		60	0005	0004	1130	1	600005000411301
5	M01T02.05	Wells Brook Road	TH 5	Wells	Culvert	13.5	Yes		40	0005	0005	1130	1	400005000511301
6	M01T02.05	trail	N/A	Wells	Bridge	16.2	Yes		70	0000	0006	1130	3	700000000611303
7	M01T02.05	driveway	N/A	Wells	Bridge	21.0	Yes		70	0000	0007	1130	3	700000000711303
8	M01T02.05	driveway	N/A	Wells	Bridge	17.7	Yes		70	0000	0008	1130	3	700000000811303
9	M01T02.05	trail	N/A	Wells	Bridge	28.0	Yes		70	0000	0009	1130	3	700000000911303
10	M01T02.05	Wells Brook Road	TH 5	Wells	Bridge	14.1	Yes	401126000611261						
11	M01T02.04	Tunket Road	TH 30	Wells	Culvert	16.5	Yes	401126001611261						
12	M01T02.04	footbridge	N/A	Wells	Bridge	49.2	No		70	0000	0012	1130	3	700000001211303
13	M01T02.04	footbridge	N/A	Wells	Bridge	36.8	No		70	0000	0013	1130	3	700000001311303
14	M01T02.04	footbridge	N/A	Wells	Bridge	21.8	No		70	0000	0014	1130	3	700000001411303
15	M01T02.04	footbridge	N/A	Wells	Bridge	28.4	No		70	0000	0015	1130	3	700000001511303
16	M01T02.03	Private Road	N/A	Wells	Bridge	26.2	Yes		70	0000	0016	1130	3	700000001611303
17	M01T02.03	driveway	N/A	Wells	Bridge	27.8	Yes		70	0000	0017	1130	3	700000001711303
18	M01T02.03	farm road	N/A	Wells	Bridge	24.7	Yes		70	0000	0018	1130	3	700000001811303
19	M01T02.03	driveway	N/A	Wells	Bridge	29.3	Yes		70	0000	0019	1130	3	700000001911303
20	M01T02.02	South Street	TH 2	Wells	Bridge	28.1	Yes	101126000811261						
21	M01T02.02	farm road	N/A	Wells	Bridge	27.4	Yes		70	0000	0021	1130	3	700000002111303
22	M01T02.02	VT Route 30	VT-30	Wells	Bridge	34.0	Yes	200015008211262						
23	M01T02.01	VT Route 149	VT-149	Pawlet	Bridge	31.0	Yes	200154000211142						
24	M10	VT Route 30	VT-30	Dorset	Bridge	33.8	Yes	200015005802032						
25	M09	VT Route 30	VT-30	Dorset	Bridge	25.5	Yes	200015006002032						
26	M09	VT Route 30	VT-30	Rupert	Bridge	25.6	Yes	200015006202102						
27	M09	farm road	N/A	Rupert	Bridge	24.8	Yes		70	0000	0027	3045	3	700000002730453
28	M08	equipment crossi	N/A	Rupert	Bridge	21.0	Yes		70	0000	0028	3045	3	700000002830453
29	M08	Connaway Rd	Class 8	Rupert	Bridge	24.5	Yes		70	0000	0029	3045	3	700000002930453

Table B-2. (continued) VTrans Structure Number Assignment, Mettowee River watershed bridges and culverts.

Field Map #	Reach	Road	Route	Town	Structure Type	Bridge-Length or Culvert-Diam.(ft)	Bridge & Culvert Assessment?	Existing VTrans Structure Number [a]	Derivation of Vtrans Structure Number as per Addendum to Appendix G.: STRUCTYPE	ROUTE#	NUM	CTCODE	SYSFLAG	Assigned VTrans Number
30	M08T05.01-A	VT Route 30	VT-30	Rupert	Culvert	9.0	Yes	300015006302101						
31	M07T04.02	Sykes Hollow Rd	TH 7	Rupert	Culvert	12.6	Yes	400210002702101						
32	M07T04.01	Private Driveway	N/A	Rupert	Bridge	23.4	Yes		70	0000	0032	3045	3	700000003230453
33	M07T04.01	VT Route 30	VT-30	Rupert	Bridge	13.0	Yes	300015065A02101						
34	M05T03.02S01.02	Abandoned	N/A	Pawlet	Bridge	9.0	No		70	0000	0034	1070	3	700000003410703
35	M05T03.02S01.02	Kelly Hill Rd	TH 14	Pawlet	Culvert	9.2	Yes	401114001911141						
36	M05T03.02S01.02	footbridge	N/A	Pawlet	Bridge	8.0	No		70	0000	0036	1070	3	700000003610703
37	M05T03.02S01.02	footbridge	N/A	Pawlet	Bridge	10.0	No		70	0000	0037	1070	3	700000003710703
38	M05T03.02S01.01	VT Route 133	VT-133	Pawlet	Arch	14.1	Yes	300139000411141						
39	M05T03.02S01.01	Andrus Road	TH 35	Pawlet	Culvert	5.7	Yes	401114003011141						
40	MNY10T1.11	farm road	N/A	Rupert	Culvert	7.6	Yes		70	0000	0040	3045	3	700000004030453
41	MNY10T1.11	Lewis Road	TH 11	Rupert	Bridge	17.6	Yes	400210003202101						
42	MNY10T1.10	footbridge	N/A	Rupert	Bridge	16.4	No		70	0000	0042	3045	3	700000004230453
43	MNY10T1.10	VT Route 153	TH 1	Rupert	Bridge	16.0	Yes	400210000902101						
44	MNY10T1.10	railroad	N/A	Rupert	Bridge	13.0	Yes		70	0000	0044	3045	3	700000004430453
45	MNY10T1.10	farm road	N/A	Rupert	Bridge	19.7	Yes		70	0000	0045	3045	3	700000004530453
46	MNY10T1.09	farm road	N/A	Rupert	Bridge	26.9	Yes		70	0000	0046	3045	3	700000004630453
47	MNY10T1.09	farm road	N/A	Rupert	Bridge	16.8	Yes		70	0000	0047	3045	3	700000004730453
48	MNY10T1.09	Quarry Road	Class 8	Rupert	Culvert	5.0	Yes		70	0000	0048	3045	3	700000004830453
49	MNY10T1.08	private driveway	N/A	Rupert	Bridge	24.8	Yes		70	0000	0049	3045	3	700000004930453
50	MNY10T1.08	footbridge	N/A	Rupert	Bridge	30.4	No		70	0000	0050	3045	3	700000005030453
51	MNY10T1.08	VT Route 153	TH 1	Rupert	Bridge	22.1	Yes	200131001202102						
52	MNY10T1.08	private driveway	N/A	Rupert	Culvert	9.9	Yes		70	0000	0052	3045	3	700000005230453
53	MNY10T1.08	Edwards Lane	Class 8	Pawlet	Bridge	22.5	Yes		70	0000	0053	1070	3	700000005310703
54	MNY10T1.08	VT Route 153	TH 1	Pawlet	Bridge	26.8	Yes	200131000611142						
55	MNY10T1.07	Sawmill Road	TH 22	Pawlet	Bridge	14.5	Yes	401114002111141						
56	MNY10T1.07	farm road	N/A	Pawlet	Bridge	19.4	Yes		70	0000	0056	1070	3	700000005610703
57	MNY10T1.07	farm road	N/A	Pawlet	Bridge	19.8	Yes		70	0000	0057	1070	3	700000005710703
58	MNY10T1.07	farm road	N/A	Pawlet	Bridge	20.4	Yes		70	0000	0058	1070	3	700000005810703

Notes:
a Source of Vtrans Structure Number is "TransStructures_TRANSTRUC" data obtained from VCGI (www.vcgi.org), post date: 9 Nov 2005.

APPENDIX C

Bridge & Culvert Assessment Reports

(2006 Reaches)

APPENDIX D

Quality Assurance Documentation

Mettowee River Watershed

MEMORANDUM

TO: Kristen Underwood, SMRC
FR: Leslie Fernandes, VT ANR River Management
DATE: May 28, 2007
RE: Mettowee River Phase 2 2006 QA Report

South Mountain Research & Consulting Services (SMRC) appreciates the opportunity to clarify data limitations, enhance data accuracy, and maximize the utility of the Mettowee River Phase 2 (2006) data set. This response to VT River Management Section QA Review Comments has been completed by Kristen L. Underwood, PG, on 11/7/2007. SMRC comments are in blue text following each step below. Corrections made to original field data sheets (Field Notes, RGA, RHA) as a result of this QA review have been made in red. Applicable updates have been made to the Phase 1 and Phase 2 data in the VTDEC Data Management System (DMS) and to the summary report which accompanies this data.
Responses from Shannon Pytlik contained in an 11/14/2007 email are noted below in orange text preceded by "SP – 11/14/2007".

General Comments:

Sub class slope

You don't need to enter a sub class slope if it is the same as the stream type. For example if you have a C stream type you do not need a "c" as a sub class slope. In this situation the sub class slope should be none. $\mathbf{C}_{\mathbf{NONE}}$

Noted. The subclass slope has been corrected to "None" for reaches/segments in this category.

CEM / CES

Many of your reaches and sub-reaches have an incision ratio equal to 1 and you put a F-stage CEM and a CES of I, which makes sense, but these reaches also have a lot of aggradation and often some plan form adjustments. To me this sounds like a D-stage CEM with a CES of IId.

As appendix C states;

> *In D-stage channel evolution, the dominant, active adjustment processes is **aggradation**, widening, and plan form change. In some situations, the stream may not experience any degradation because its bed is significantly more resistant to erosion than its banks.*

Is it possible that while the bed is neither clay nor bed rock that this is still in stage D?

I am open to more discussion on the CEM / CES and have requested that River Management Section hold some training on the topic to better clarify their expectations for this step in the protocols. Generally speaking, I feel that the D-stage CEM may be more applicable than the F-stage CEM for many tributary reaches and some main stem reaches of the Mettowee River (even when bedrock or clay is not readily apparent in the channel bed) where lateral channel adjustments dominate and active incision is absent and historic incision is minimal to negligible. The first paragraph of the description under D-stage Channel Evolution Process (Appendix C of protocols) seems to support this interpretation, as you quoted above. However, since the May 2007 revision to Appendix C specifically states (in bold lettering at the top of the page) to "Only use the D stage CEM where the stream has no opportunity to incise.", I classified these reaches in F-stage CEM.

Comments specific to assignment of CEM / CES appear under each reach/segment in the text below, where applicable.

Also, I would like to offer the following general comments on assignment of CEM and CES.

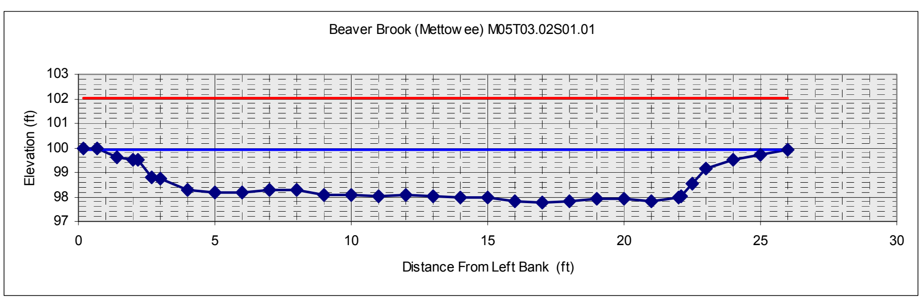
General Comments

SMRC has assigned channel evolution model (CEM) and channel evolution stage (CES) because it is a requirement of completing the protocols. However, speaking generally, SMRC would like to note the high uncertainty and subjectivity inherent in assigning both CEM and CES to segments based on the results of Phase 2 assessments from one date. Inferring a possible evolution of channel adjustments based on one discrete and limited set of observations and measurements from one snapshot in time, with limited knowledge of the historic channel and watershed stressors, is at best theoretical. A trend cannot be definitively assigned on the basis of one set of data.

A channel evolution model can begin to characterize a theory of the possible sequence of channel adjustments in response to a known or inferred stressor(s). However, lateral and vertical adjustments in river systems are much more complex than a single CEM can express. Vertical and lateral grade controls to channel adjustment often exist, soils of highly variable erodibility and cohesive strength can be present along the corridor in the stream bed and banks, vertical layering of lithologies can exist, variable riparian vegetation conditions may exist, all of which constrain channel adjustments in response to a given stressor to varying degrees. In addition, the majority of rivers have experienced multiple stressors (of varying types, magnitude, duration, and periodicity) to multiple locations (of varying extent), especially over recent centuries of human habitation. Channel adjustments in response to these multiple stressors are translated upstream and downstream (as constrained by the various boundary conditions). Process lag times, threshold relationships, and cumulative effects (Jacobson et al., 2001) operating over broader spatial and temporal scales determine how the system responses to stressors will overlap and manifest themselves in a specific channel morphology at a specific watershed location at a given time. In other words, the present condition and dimensions of a given segment are the manifestation of these dynamic channel adjustment processes in response to variable stressors, integrated over time and space.

Cross Sections

In general cross sections do not go far enough into the valley to show the relationship between the river and its recently abandoned floodplain. (e.g. M05T03.02S01.01-A While this cross section shows a great detail for the stream channel itself, it is unknown if this sub-reach has access to the RAF?)



When the cross sections do not extend far enough into the valley, River Management does not know whether the river is doing this

Or this?

Generally, I do have cross section measurements that extend beyond the left pin and right pin areas (these are recorded on the field data sheets, which I realize that you did not have a copy of at the time of your QA review). In the past, I have tended not to include the floodplain / valley wall measurements in the cross section spreadsheet, since they tend to "dwarf" the cross section profile itself, and it is hard to see the detail of the bankfull channel features (e.g., benches).

Wells Brook

M01T02.01
CEM/CES
See general comments D_{IId}?

I classified this reach with a D-stage CEM in CES of "I", so I agree with you on the CEM (D-stage). Since the reach has multiple exposures of channel-spanning bedrock, it would appear that the statement in Appendix C of the protocols ("Only use the D stage CEM where the stream has no opportunity to incise.") would not necessarily preclude application of the D-stage CEM.

However, I would disagree with a "IId" CES. While the reach is undergoing moderate aggradation (rated in the "Good" quadrant) and planform adjustment ("Fair" quadrant), I would not classify the reach as "extremely depositional" or "braided", resulting in a C to D stream type departure, as is indicated under the description of a D_{IId} CES in Appendix C. Nor would I classify the reach in a D_{IIc} CES, given the low width/depth ratio (16.8) and absence of other features that might suggest channel widening. The reach has good connection to a broad floodplain (IR = 1.0). Therefore, I classified it in D_I CES.

M01T02.02

M01T02.02A
CEM / CES
The river is incised (incision ratio 1.23) and you have it as a CEM F stage I, but there is also a lot of aggradation (21 bars in less than a mile of river), with 3 steep riffles and some flood chutes. Should it be stage III or IV?

Overall, I classified the degree of vertical separation of the channel from the surrounding floodplain as historic incision.

I would like to classify the reach as D-stage (perhaps IIc) since the historic incision has not resulted in a full loss of floodplain connection, and because aggradation, widening and planform adjustment are the dominant processes. However, the May 2007 revision to Appendix C of the protocols specifically states to "Only use the D stage CEM where the stream has no opportunity to incise." This channel segment has erodible materials in the bed and bank, and no apparent bedrock grade controls. Therefore, I assigned an F-stage CEM – with a CES of I. A CES of F[II] or F[III] does not seem appropriate, given that the channel has not completely lost connection with its floodplain (IR >2) – a condition seemingly implied by the stream type departure to a B, G, or F stream type specified under the descriptions for these Stages. The degree of historic incision is relatively minor. Therefore, I am inclined to leave the CES classification of F[I] unchanged.

Please also see the discussion above under *General Comments: CEM/CES*.

M01T02.02B
Riparian Corridor
For the sub dominant riparian corridor you note that the right bank is "Residential", if this is the case I would expect to see some "Development" (1.3) entered for this segment.

It is my understanding that Residential land use classified under Step 3.3 includes lawn areas incidental to residential buildings. Whereas, "Development" classified under Step 1.3 is limited to buildings, crossing structures, cemeteries and other permanent to semi-permanent infrastructure that would encroach on, or fill, the floodplain and constrain lateral or vertical channel adjustments. Within the corridor for Segment M01T02.02B, there are mowed lawns associated with residential homes located outside of (to the north of) the corridor. These mowed lawns were classified as residential land use under Step 3.3.

Erosion

In your report for segment B (pg. 44 paragraph 4) you indicate that there is erosion on both sides ("…low erosional scour along both banks"), yet in your data set (DMS and FIT) you do not mark any erosion for the right bank?

The report actually states: " A very minor degree of widening is indicated by low erosional scour along both banks. However, channel armoring appears to provide sufficient resistance to erosion." The scour was manifest as scarring of the moss and lichens on large angular rip-rap – mostly intact. No significant bank erosion was noted. As noted in the protocols (Step 3.1) "Phase 2 bank erosion assessment should attempt to quantify active and accelerated erosion, and not the background erosion that occurs at a more natural (slower) rate. For example, you may assess a channel where both banks show exposed soil throughout the reach, which may indicate minor erosion typical of natural stream processes. This minor bank erosion should not be considered in your assessment…". Therefore, no streambank erosion was indexed with the FIT in these areas.

<u>M01T02.02C</u>

Riparian Corridor

For the sub dominant riparian corridor you note is "Shrubs/Sapling", yet in step 1.3 you have 789 feet of development. This is a length that would cover over 30% of one side of the segment. Is it possible to assume that at least one side should have "Residential" as the sub dominant corridor?

The 789 feet of development is comprised of:

LB	barns	138 ft
RB	Residential	588 ft
Both Banks	Farm bridge	63 ft

If barns are grouped as residential (since there is no agricultural category other than crops/hay), the LB corridor contains a 201-ft length of residential development, or 8% of the 2,424-foot segment C. The RB corridor contains a 651-ft length of residential development, or 27% of the 2,424-ft segment.

It is my understanding that characterization of the dominant and subdominant land use in the riparian corridor under Step 3.3 looks at the full land area within the Phase 2 corridor. While residential use was identified within the RB corridor along a significant ***length*** of the channel (27%), the residential land cover does not comprise a substantial percentage of the ***area*** of the corridor, enough to be identified as a Subdominant land use within the RB corridor.

Sub Class Slope

In section 2.14 you indicate a stream type of F. According to the phase 2 handbook and F stream has a sub class slope of <2%. The slope of this reach is 1.02% and therefore it should have a sub class slope of "None". F_{NONE}

(And the Phase 2 estimated slope of the segment is 1.2% - also less than 2%.) OK, I will change the subclass slope to "None".

M01T02.02D

Sub Class Slope
In section 2.14 you indicate a stream type of F. According to the phase 2 handbook and F stream has a sub class slope of <2%. The slope of this reach is 1.02% and therefore it should have a sub class slope of "None". $\mathbf{F_{NONE}}$
(And the Phase 2 estimated slope of the segment is 1.4% - also less than 2%.) OK, I will change the subclass slope to "None".

M01T02.02E
CEM / CES
The river is incising (incision ratio 1.79) this makes it a stage F, but there is also a lot of aggradation (16 bars in less than a mile of river), with 3 steep riffles, some flood chutes and an avulsion. Is it in CES III?

Steep Riffles and Head cuts
You have 3 steep riffles and 2 head cuts, what was the river doing? Where some of these localized around channel constrictions?

Channel degradation (Historic?)
You marked channel degradation as historic, yet you have 2 head cuts?

The above three questions can be addressed, in part, by text contained in the reach summary in the Phase 2 report:

> *The degree of incision noted within the segment (visual observations indicated IRs from 1.5 to 2.0) is consistent with past channelization. Incision is believed to be historic in nature - at least in the upstream half of the segment.*
>
> *Some indications of localized, active incision were observed near the downstream end of the segment in the vicinity of a recent (post-2003) channel avulsion near a very large debris jam. Two short, very steep riffles (possibly head cuts) were observed within 75 feet upstream of the avulsion site. Significant aggradation was also noted in this location as evidenced by enlarged point and mid-channel bars of cobble and gravel sediments with steep bar faces. This small avulsion site was apparently induced by aggradation of sediments and debris just upstream from a channelized and entrenched channel section (Segment B) that has been historically maintained with berms and armoring.*
>
> *Evidence of localized widening was observed in the segment, including erosional scour at the base of both banks in a riffle section mid-segment. Otherwise, adjustment processes in the segment were dominated by planform adjustment (active flood chutes, meander extension, and the small avulsion site) and aggradation, which increased in intensity with distance downstream.*

Available data are not sufficient to state with certainty that incision is active or historic. If active incision is occurring at the avulsion site near the downstream end of the reach, it would appear to be very localized in nature and related to the sudden breaching of the debris jam. It could also be related to recent flooding in the area (December 2000 and December 2003). Minor to moderate planform adjustment and aggradation are the dominant adjustment processes segment-wide. And, in fact, aggradation may be overlapping with (moderating the effects of) the localized active incision. This is a valley setting marked by sudden slope reduction where aggradational tendencies would be expected due to a slope-controlled reduction in sediment transport capacity. Overall, I classified the degree of vertical separation of the channel from the surrounding floodplain as historic incision.

I would like to classify the reach as D-stage (perhaps IIc) as the historic incision has not resulted in a full loss of floodplain connection, and because aggradation and planform adjustment are the dominant processes. However, the May 2007 revision to Appendix C of the protocols specifically states to "Only use the D stage CEM where the stream has no opportunity to incise." This channel segment has erodible materials in the bed and bank, and no apparent bedrock grade controls. Therefore, I assigned an F-stage CEM – with a CES of II. Upon further reflection, a CES of F[II] (or for that matter, F[III]) does not seem appropriate, given that the channel has not completely lost connection with its floodplain (IR >2) – a condition seemingly implied by the stream type departure to a B, G, or F stream type specified under the descriptions for these Stages. Therefore, I have revised the segment classification to an F[I] CES.

Please also see the discussion above under *General Comments: CEM/CES*.

<u>M01T02.03</u>

CEM/CES

See general comments D_{IId}?

This reach was classified with a D-stage CEM, in CES I. Frequent channel-spanning bedrock was indexed throughout the reach. Thus, the reach overall could be characterized as a "stream [that] has no opportunity to incise" (protocols Appendix C, May 2007) at least over time scales of 10s to 100s of years. So, I felt that a D-stage CEM was appropriate. However, I would not agree with an assignment of channel evolution stage "IId".

Stage IId of the D-stage CEM is suggested for a channel that is "extremely depositional… braided… and erod[ing] banks and terrace side slopes", with an associated Stream Type Departure to a D stream type. This description is not consistent with the features and conditions observed in reach M01T02.03. This reach exhibited a very minor degree of aggradation and planform adjustment (both rated in the "Good" quadrant of the RGA). The measured stream type was consistent with the reference stream type (B3-S/P). Therefore, I am inclined to leave the CES as D[I].

<u>M01T02.04</u>

Good

<u>M01T02.05</u>

Valley Width

Your valley width is 100ft. You claim that this is estimated. 100ft is a small enough distance that it could have been measured.

The valley width was, in fact, measured – at waypoint 153, XS-2 (97 ft) and waypoint 166 (227 ft). Based on these field measurements, and upon GIS measurements, the valley width appears to vary between 50 and 300 feet, but average about 100 feet in width. Since the valley width varies along the 2.1-mile length of the reach (sometimes Narrowly Confined, sometimes Narrow, but dominantly Semi-confined), I elected to characterize the valley-wall value of 100 ft as "Estimated" – or in other words representing an average condition for the reach overall.

SP – 11/14/2007 - If you measure the valley width you should select "measured" instead of estimated. We understand that all reaches and/or segments have some variability. The "measured" versus "estimated" is intended to capture the way the data was collected, not the variation of the widths.

Bridge and Culvert

Phase 1 has 9 bridges and Culverts. Phase 2 has 8 bridges and culverts. Was one missed, if not update phase 1.

Nine (9) bridges and culverts were encountered along this reach during the 2006 Phase 2 assessment, and were indexed using the FIT. The FIT upload file from 29 April 2007 contains 9 crossing structures, and both the Phase 1 and Phase 2 data sets show 9 structures, as I view them in the DMS on 11/5/2007. I know that back in April / May, there were some issues with how FIT data was uploading and being stored in the DMS. Perhaps a FIT/DMS bug was the source of the apparent conflicting Phase 1 / Phase 2 bridge and culvert data identified above in May 2007.

CEM/CES

Multiple mass failures/ over 1,500 ft of bank erosion/ 113 bars/ 18 Flood Chutes and more. See general comments D_{IId}?

As the reach is more than 2 miles in length, the noted 1500+ feet of stream bank erosion represents only 7% (LB) and 8% (RB) of the reach length. The prevalent depositional bars and multiple flood chutes are reflected in the "Fair" scores assigned to the Aggradation and Planform Adjustment categories of the RGA. These are the dominant adjustment processes for the reach.

The channel appeared to have good access to a Narrow to Semi-confined floodplain (IR_{RAF} = 1.0), constrained only very minimally by human encroachments (roads). One occurrence of channel-spanning bedrock "ledge" was noted in the upstream portion of the reach. Otherwise, channel bed and bank materials appear susceptible to erosion (e.g., incision). Since the May 2007 revision to Appendix C of the protocols specifically stated to "Only use the D stage CEM where the stream has no opportunity to incise.", I classified this reach in the only other available CEM - F-stage (F[I]). (See also discussion above under *General Comments: CEM/CES*).

Mettowee River

<u>M10</u>

<u>M10A</u>

CEM/CES

See general comments D_{IId}?

Stage IId of the D-stage CEM is suggested for a channel that is "extremely depositional… braided… and erod[ing] banks and terrace side slopes", with an associated Stream Type Departure to a D stream type. This description is not consistent with the features and conditions observed in segment M10A. This segment exhibited a minor degree of aggradation and planform adjustment (both rated in the "Good" quadrant of the RGA). The measured stream type was consistent with the reference stream type (C4-R/P).
The May 2007 revision to Appendix C of the protocols specifically states to "Only use the D stage CEM where the stream has no opportunity to incise." There were no occurrences of channel-spanning bedrock in the segment. The channel has the potential to incise. Therefore, the D-stage CEM is not applicable.

An CES of F[I] was assigned. The channel has access to its floodplain, and has not incised. These values were inadvertently missed during data entry and have been added to the DMS.

(See also discussion above under *General Comments: CEM/CES*).

Corridor / Riparian

In 3.3 of Phase 2 the dominant riparian corridor is Residential, but in section 1.3 there is only 133ft (10%) of development.

It is my understanding that Residential land use classified under Step 3.3 includes lawn areas incidental to residential buildings. Whereas, "Development" classified under Step 1.3 is limited to buildings, crossing structures, cemeteries and other permanent to semi-permanent infrastructure that would encroach on, or fill, the floodplain and constrain lateral or vertical channel adjustments. The LB corridor for Segment 10A is dominated by landscaped lawns, a driveway, and a pond (post-1994, pre-2003 development) associated with a residential home (which comprises the 133 ft of indexed "development" under Step 1.3). These areas were classified as residential land use under Step 3.3.

M10B

Riffle / Step Spacing

Step 2.11 is entered as zero. Please enter a number

This parameter is "Not Applicable" in Segment M10-B. A plane bed form dominates the segment. There are no riffles to speak of.

M10D

Straightening

Your notes indicate that there has been historic straightening, yet for section 5.5 "straightening" you have "No"?

This was an oversight during feature indexing. Thank you for picking that up. I have revised the FIT files and uploaded to the DMS.

Cross Section

Please enter a cross section for M10D.

This was an abbreviated cross section. Segmentation was not fully anticipated in the field. It has been entered in the cross section spreadsheet and uploaded to the DMS.

M09

Corridor / Riparian

In section 1.3 Development is 676ft (13%), yet in section 3.3 it is not considered to be sub-dominant?

Development-One Side in reach M09 is recorded as 280 ft (4%); Development-Both Sides is recorded as 596 ft (9%). It is my understanding that characterization of the dominant and subdominant land use in the riparian corridor under Step 3.3 looks at the full land area within the Phase 2 corridor. While residential use was identified within the LB and RB corridors along significant ***lengths*** of the channel, the residential land cover does not comprise a substantial percentage of the ***area*** of the corridor, enough to be identified as a Subdominant land use within the either corridor.

Please note – it would helpful if Phase 2 protocols (Step 3.3) would define the % of land area within the corridor that constitutes a "Subdominant" land use. Would it be a land use that comprises a minimum of 25% of the corridor area? (I think this was a value published in earlier versions of the protocols). Based on visual estimation from an orthophoto-base reach map, it becomes really difficult to discern a "Subdominant" land use that comprises less than 15% of the corridor area.

M08

CEM/CES

This was left blank? See general comments D_{IId}?

Stage IId of the D-stage CEM is suggested for a channel that is "extremely depositional… braided… and erod[ing] banks and terrace side slopes", with an associated Stream Type Departure to a D stream type. This description is not consistent with the features and conditions observed in reach M08. This reach exhibited a minor to moderate degree of aggradation and planform adjustment (both rated in the "Good" quadrant of the RGA). The measured stream type was consistent with the reference stream type (C4-R/P). While the number of mid-channel bars (4), point bars (21), side bars (8) and diagonal riffles (13) appears somewhat high, when normalized to the reach length (9,606 feet), this is not an extreme number of depositional bars. The reach has not become braided. Riffle/pool bedform persists, and has not become replaced by plane bed features. There are occasional deep pools. Depositional features are typically less than half bankfull stage in height. The thalweg is lined up with the planform. Streambank erosion is estimated at 13% of the LB and 8 % of the RB.

The channel has good access to its floodplain, despite some degree of historic straightening and berming. It is possible that past tendencies toward incision were offset by aggradation from upstream sediment sources. It is also possible that natural armoring of the streambed caused lateral adjustments to dominate over vertical adjustments. I would like to choose a D-stage CEM for this reason. However, the May 2007 revision to Appendix C of the protocols specifically states to "Only use the D stage CEM where the stream has no opportunity to incise." There were no occurrences of channel-spanning bedrock in the segment. Thus, the channel has the potential to incise.

A CES of F[I] was assigned. These values were inadvertently missed during data entry and have since been added to the DMS.

(See also discussion above under *General Comments: CEM/CES*).

Cross Section

The cross section is missing much detail, is there a reason for this?

The cross section (at waypoint 336) chosen to represent the reach under Step 2 was one of four cross sections completed in the reach. It is stored under Segment D. As I review this cross section, there is reasonable detail – measurements conducted every one to two feet along the tape, capturing the BKFL, LEW, TW, REW, and multiple benches. It is missing the LVW and RVW for reasons discussed under "General Comments" above. The original field data sheet (which I realize that you may not have had at the time of your review), notes that the valley setting at the site is several 100 feet wide. The floodplain along the left and right corridors is mostly level extending to the valley wall. Route 30 cuts across the RB corridor and is somewhat elevated above the floodplain. The channel flows along a LB terrace, so the LFPW was measured at approximately 4 feet distant from the LPIN. This four feet added to the 48.5 feet width of the bankfull channel and a paced estimate of 250 feet along the RB corridor to a terrace = the 302 feet estimated for floodprone width.

Scallop Brook

<u>M08T5.01</u>

Channel Bars

Phase 1 section 6.3 has "point" entered for bar type. Phase 2 has both point and side. Please update phase 1.

OK, Phase 1 data has been updated.

> <u>M08T5.01B</u>
>
> *Valley Width*
>
> Valley with was entered as 35ft with a determination of estimated. I would think that a width of 35 feet was probably measured?

Since the valley width varies along the length of the segment, I elected to characterize the value of 35 ft as "Estimated" – or in other words representing an average condition for the segment overall. Also, not all of

the segment was accessed, since the segment was classified as a gorge – another reason that the noted VW should be considered approximate.
SP – 11/14/2007 - If you measure the valley width you should select "measured" instead of estimated. We understand that all reaches and/or segments have some variability. The "measured" versus "estimated" is intended to capture the way the data was collected, not the variation of the widths.

Skyes Hollow

M07T04.01

Grade Control
P1 has ledge for a grade control. P2 has none, but notes indicate the presence of "channel spanning Bedrock" this would be a ledge, no? This may be a DMS issue since the grade control appears to be in the FIT file. We tried to check if it was in the actual dbf file you uploaded to the DMS, but the file you uploaded on April 29, 2007 does not have data for reach M07T04.01 in it.
This is a DMS issue (as of April/May 2007). It appears to have been resolved in the intervening months, as a notation of "Ledge" now appears in the Phase 1 record for this reach.

Cross Section
Where was the cross section taken (please send your cross section location points)
A cross section shape file is stored on the Project CD.

Segmentation
Upon field examination we noticed that this reach seems to change near Rt. 30, this could possibly be a new segment? The downstream section looks like it is highly incised and un-entrenched. The upstream looks naturally entrenched and confined.
The reach flows on sediments of glaciofluvial origin. The upstream 2/3 may be on a post-glacial alluvial fan feature that overlaps glacio-fluvial deposits. Detailed surficial mapping is not available for this area. Certainly, this reach is located at a significant reduction in slope from the upstream reach M07T04.02. A braided channel (D stream type) might be expected as the reference stream type in this setting under more intense hydrologic and sediment regimes.
A laterally adjusting reference stream type of C is likely more appropriate under present sediment and hydrologic regimes.

My best estimate (working from Phase 1 and Phase 2 data alone) is that the reference valley setting is unconfined (in contrast to what you have suggested above – that the "upstream looks naturally entrenched and confined"). While the brook is "pinned" along the bedrock-controlled right valley wall in the upstream third of the reach, there appeared to be a broad (recently-abandoned) floodplain extending several 10s of feet into the left-bank corridor. If the channel were not incised below this floodplain, there would be a sufficiently wide flood prone width, such that the reference Entrenchment Ratio would be >2.2. For this reason, I assigned a Cb reference stream type to the reach. Perhaps additional field work would be warranted in this area to better clarify the reference and existing stream types.

Sediments in the bed and banks of this reach are highly erodible (unconsolidated sands, gravels, cobbles, occasional boulders). Incision appears active in the mid-portion of the reach as evidenced by tall, undercut and eroding banks, measured incision ratios of 4.6 and 3.5, and presence of head cuts. The upstream end of the reach is probably isolated from headward migration of these nick points by the presence of channel-spanning bedrock.

There is a reduction in slope as the tributary approaches the Route 30 crossing. Review of the topographic map (see map next page) suggests a slope less than 2% (a "c" subclass slope), and an unconfined reference valley setting. This downstream section could be classified as a subreach of alternate reference stream type (i.e., a subreach of C4-riffle/pool in a reach that is otherwise classified with a reference stream type of C3b-riffle/pool). Based only on one abbreviated cross section in this downstream section, the degree of incision appears somewhat reduced (IRRAF = 1.6) as compared to upstream cross sections. However, berms have enhanced the degree of channel entrenchment (IRHEF >1.6). Also, incision appears historic in nature in this downstream section, based on absence of head cuts and actively eroding banks.

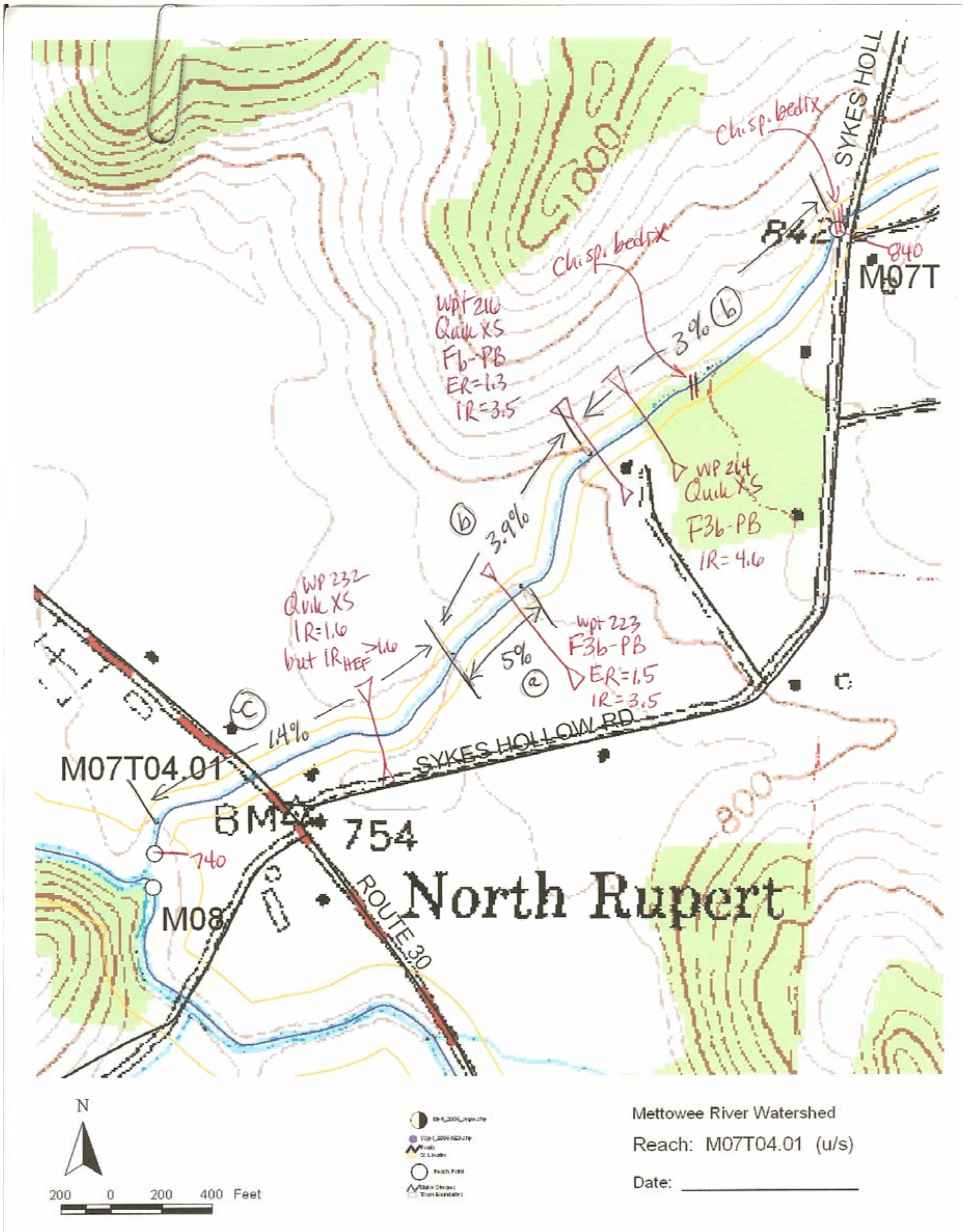
Overall, reach M07T04.01 has lost connection to its floodplain resulting in a stream type departure from C to F. I agree with you that segmentation of this reach would better characterize the subtle change in reference stream type imparted by the slope reduction, as well as the difference in the nature of channel entrenchment between the two sections of the reach: Upstream 2/3 - active incision and recent abandonment of the floodplain (accompanied by some berms); Downstream 1/3 - historic incision and partial loss of connection with the floodplain enhanced locally by berms which result in a "human-elevated-floodplain". To support segmentation, I would need to return to the field to conduct cross sections and pebble counts in the downstream 1/3 of the reach. "Lumping" the reach characteristics may slightly overstate the sensitivity (and hazard classification) of the downstream 1/3 of the reach which has marginally greater floodplain access (in a greater-than-bankfull flow) than the upstream 2/3 of the reach, and does not appear to be actively incising. However, dimensions of the Fluvial Erosion Hazard corridor would be the same for each segment – i.e., buffered at 3 times the channel width.

CEM / CES

There seems to be a lot of aggradation, maybe the stream is in Stage III of even IV or maybe the segmentation mentioned above will resolve this?

Observation of active incision features confirms the "opportunity to incise" that according to protocols necessitates classification in the F-stage CEM. Even though channel-spanning bedrock is present near the upstream end of the reach, Appendix C of the protocols specifies that "If the stream has incised and has now hit bedrock or clay…you would still use the F stage CEM."

A minor to moderate degree of aggradation, planform adjustment and widening are occurring; these processes were rated in the "Good" quadrant of the RGA for the overall reach. However, active incision (mid-reach) is the dominant condition (rated in the "Poor" quadrant of the RGA), which prompted me to place the reach in CES F[II].


SYKES HOLL
Chisp. bedrx
R42
840
M07T
Chisp. bedrx
wpt 216
Quik XS
F6-PB
ER=1.3
IR=3.5
3%
3.9%
WP 214
Quik XS
F3b-PB
IR=4.6
WP 232
Quik XS
IR=1.6
5%
wpt 223
F3b-PB
ER=1.5
IR=3.5
1.4%
SYKES HOLLOW RD
M07T04.01
BM
754
740
M08
ROUTE 30
North Rupert
800
1000
N
200 0 200 400 Feet
Mettowee River Watershed
Reach: M07T04.01 (u/s)
Date:

Flower Brook

M05T03.04

CEM / CES

There seems to be a lot of aggradation with some plan form change (multiple mass failures, multiple gullies, 48 bars, multiple steep riffles, multiple debris jams, and 17 flood chutes). Yes, this is a long segment at 11,820ft, but still this is a lot of widening and deposition. Is stream in Stage III of even IV?

I agree there are many depositional and flood chute features, and the rating of the aggradation and planform adjustment processes in the "Fair" category of the RGA reflect these conditions – as well as the overall RGA score of 0.50. This stream is receiving excess sediments from within the reach and upstream reaches; it has responded by forming depositional bars, widening (marginally) and shifting its planform. Some degree of historic incision is apparent (IR = 1.5). However, aggradational and planform processes are more dominant than degradation. Therefore, I would like to classify this reach in CES D-IIc. However, the May 2007 revision to Appendix C of the protocols specifically states to "Only use the D stage CEM where the stream has no opportunity to incise." Occurrences of channel-spanning bedrock in this 2-mile reach were few and far between. The channel has the opportunity to incise between bedrock occurrences, and protocols state that "If the stream has incised and has now hit bedrock or clay…you would still use the F stage CEM."

Therefore, I originally classified the stream in CES F[I]. If I classify the reach in F[III] or F[IV] as you suggest above. However, the description under F-stage CEM in Appendix C would seem to imply that the channel previously moved through CES F[II], losing access to its floodplain and undergoing a stream type departure. An incision ratio greater than 2 seems to be implied by the description under CES F[II] in Appendix C, which suggests that a channel in this evolution stage is now a B, G, or F stream type. If channels with incision ratios greater than 1 but less than 2 can be classified in CES F[II], then the descriptive text under Stage II (page C-1 of the protocols) should include a C stream type, in addition to the B, G, and F stream types listed in parentheses.

I am not convinced that reach M05T03.04 underwent historic incision to the degree that resulted in a stream type departure. I think it may have evolved from a C3-riffle/pool channel with IR = 1.0 to a C3-riffle/pool channel with IR = 1.5, with aggradation and planform change now dominating. Coarsening of the bed (natural pavement) may have resisted increased shear stress from (for example) flood event flows; in any case, erosional energies appear now to be expressed laterally rather than vertically. I have changed the CES to F[IV], assuming that the
F-stage channel evolution process model can be applied to reaches that have not undergone a vertical stream type departure (incision greater than 2.0) in Stage II.

(See also discussion above under *General Comments: CEM/CES*).

Beaver Brook

M05T03.02S01.01

M05T03.02S01.01A

CEM/CES

See general comments D_{IId}?

This segment was classified with an F-stage CEM, in CES I. Stage IId of the D-stage CEM is suggested for a channel that is "extremely depositional… braided… and erod[ing] banks and terrace side slopes", with an associated Stream Type Departure to a D stream type. This description is not consistent with the features and conditions observed in Segment M05T03.02S01.01A. This segment exhibited minor aggradation and planform adjustment (as reflected in the "Good" quadrant ratings for each process in the RGA).

Some channel-spanning bedrock was indexed in the segment. The channel has opportunity to incise between bedrock exposures – therefore it should be classified with an F-stage CEM, according to Appendix C of the protocols (May 2007). The channel has good access to its floodplain (IR=1.0) and no apparent indications of active or historic incision. The measured stream type was consistent with the reference stream type (C4-R/P). Therefore, it was classified as F[I]. (See also discussion above under *General Comments: CEM/CES*).

M05T03.02S01.01B

Corridor / Riparian

In section 1.3 Development is 126ft (12%), yet in section 3.3 it is not considered to be sub-dominant?

Please see comments under M01T02.02C, M10A, M09

M05T03.02S01.02

M05T03.02S01.02C

Corridor / Riparian

In section 1.3 Development is 155ft (12%), yet in section 3.3 it is not considered to be sub-dominant?

Please see comments under M01T02.02C, M10A, M09

CEM/CES

See general comments D_{IId}?

This segment was classified with an F-stage CEM, in CES I. Stage IId of the D-stage CEM is suggested for a channel that is "extremely depositional… braided… and erod[ing] banks and terrace side slopes", with an associated Stream Type Departure to a D stream type. This description is not consistent with the features and conditions observed in Segment M05T03.02S01.02C. This segment exhibited minor aggradation, widening, and planform adjustment (as reflected in the "Good" quadrant ratings for each process in the RGA).

No channel-spanning bedrock was indexed in the segment. The channel has opportunity to incise – therefore it should be classified with an F-stage CEM, according to Appendix C of the protocols (May 2007). The channel has good access to its floodplain (IR=1.0) and no apparent indications of active or historic incision. The measured stream type was consistent with the reference stream type (C4-R/P). Therefore, it was classified as F[I].

(See also discussion above under *General Comments: CEM/CES*).

M05T03.02S01.02E

Why Not assessed

It seems like this 373 foot reach was not assessed. If this is the case please provide a reason. If this is not the case please fill in the blanks for Step 2.

This segment was assessed for all steps other than Step 2.0. This 373-foot piece of the reach was created when the bedrock gorge immediately downstream was delineated by segmenting, after the field season was over. Since a cross section had not been completed in this 373-foot length, Step 2.0 could not be filled in. However, visual characteristics indicate a reference and existing stream type consistent with downstream Segment C (C4-R/P).

I could have selected "Not Assessed" for this segment, but all the other data recorded for this segment (bridge, bedrock grade controls, erosion, revetments, vegetation, etc.) would be lost (at least in the DMS). I could "lump" this 373 feet in with the downstream gorge (Segment D). Or I could assign Administrative Judgement data. Please advise.
SP – 11/14/2007 - For reach M05T03.02S01.02E I would characterize it as C if that is similar.

Cross Section

There is no cross section for this reach. I know that with our current excel template you can only enter cross sections for A, B, C or D, but if you have this information, please enter it in section D and make a note indicating that this is actually the cross section for E.

See above.

CEM/CES

Without a cross section there can be no predictions of the CEM or CES.

Understood. See above.

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Indian River Watershed

MEMORANDUM

TO: Kristen Underwood, SMRC
FR: Shannon Pytlik, VT ANR River Management
DATE: June 19, 2007
RE: Indian River Phase 2 2006 QA Report

South Mountain Research & Consulting Services (SMRC) appreciates the opportunity to clarify data limitations, enhance data accuracy, and maximize the utility of the Indian River Phase 2 (2006) data set. This response to VT River Management Section QA Review Comments has been completed by Kristen L. Underwood, PG, on 11/8/2007. SMRC comments are in blue text following each step below. Corrections made to original field data sheets (Field Notes, RGA, RHA) as a result of this QA review have been made in red. Applicable updates have been made to the Phase 1 and Phase 2 data in the VTDEC Data Management System (DMS) and to the summary report which accompanies this data.
Responses from Shannon Pytlik contained in an 11/14/2007 email are noted below in orange text preceded by "SP – 11/14/2007".
A subsequent comment from Kristen Underwood is noted below in fuscia text preceded by "SMRC – 11/26/2007".

General Comments:
I tried to look up the B&C data and it looks like it wasn't entered for the Indian River.
These structures were entered May 2007 and are present in the "Mettowee" structures database in the DMS. Based on March 2007 email correspondence, we decided not to have a separate Indian River structures database but instead include all of the Mettowee River watershed structures (including Indian River) in one Structures database.

The cross section notes are not consistent with the guidance provided in Appendix A. It is impossible for us to keep track of every consultant's individual preference for labeling features on either the maps or the cross sections. Therefore we provide guidance for keeping the abbreviations consistent between the assessments. It is impossible for me to discern from these notes what the features are within the cross section, therefore reducing my ability to use the data in the future.
I have edited cross sections to use abbreviations consistent with those noted on the Cross-Section Worksheet (July 2007) in the Phase 2 protocols. Revised spreadsheets have been uploaded to the DMS.

In general the cross sections do not extend far enough into the valley to determine the relationship between the stream channel, RAF and adjacent floodplain. I many cases the RAF and floodprone width are not even shown in the cross section. Generally, I do have cross section measurements that extend beyond the left pin and right pin areas (these are recorded on the field data sheets, which I realize that you may not have had a copy of at the time of your QA review). In the past, I have tended not to include the floodplain / valley wall measurements in the cross section spreadsheet, since they tend to "dwarf" the cross section profile itself, and it is hard to see the detail of the bankfull channel features (e.g., benches). In future assessments (beginning with the 2007 field season), I have included the floodplain and valley wall points within the spreadsheet.

T1.11 A – In notes *within* should be *with* in last sentence. Thank you for catching this typo. The cross section does not show the floodpalin. How far does the right terrace go into the valley? My notes indicate that there is a subtle terrace approximately 30 ft north of the RBF point, which defines the RB flood prone width. The flood prone width value of 53 ft = 21.67 ft (bankfull width) + 1 ft (from LBF) + 30 ft (from RBF).

What is LBBIS, TBIS, BBIS, LBBIS, RTerr-mi and RBBIS?

TBIS = Top of Break In Slope
BBIS = Bottom of Break In Slope
LBBIS = Left-bank Bottom of Break In Slope
RBBIS = Right-bank Bottom of Break In Slope
RTerr = Right Terrace

Please change these and use the abbreviation in the protocol . We have no way of going back and knowing what these features are in your cross section. Understood. See note under General Comments.

Page 66 of the report notes "evidence of active incision was not observed in Segment B", but it is in the segment summary for Segment A? I don't know if this is intentional or a typo. This is a typo and has been corrected. This sentence (under the section for Segment A) should read "evidence of active incision was not observed in Segment **A**".

T1.11 B – If stream type is B and slope range matches the ST than sub class slope should be none. Understood. Actually, as I rechecked this I noted that my estimate (from the topographic map) of the segment slope (4.9%) would classify as an "a" sub class slope since it is in the range from 4 to 10%. I have changed the subclass slope from a "b" to an "a" in the DMS (Step 2.14 and Step 2.15).

T1.10 B – Why is the CEM D and stage of IIc? Based on the data I would say it should be F II or III.
Generally speaking, I feel that the D-stage CEM may be more applicable than the F-stage CEM for many tributary reaches and some main stem reaches of the Mettowee River (even when bedrock or clay is not readily apparent in the channel bed) where lateral channel adjustments dominate and active incision is absent and historic incision is minimal to negligible. The 2006 version of Apppendix C of the protocols stated that "In D-stage channel evolution, the dominant, active adjustment processes is aggradation, widening, and plan form change. In some situations, the stream may not experience any degradation because its bed is significantly more resistant to erosion than its banks." Therefore, I originally assigned a CES of D[IIc]. The segment has multiple channel-spanning bedrock exposures, offering vertical grade control. Incision appears historic in nature (IR=1.6). The dominant adjustment process is moderate planform adjustment, accompanied by very minor aggradation and widening. A C-step/pool stream type is evident, consistent with reference stream type, and the channel has not undergone a vertical stream type departure. These conditions appear consistent with the description on page C3 of the protocols Appendix C.

However, in a subsequent May 2007 revision to Appendix C a statement was added in bold lettering at the top of page C3 to: "Only use the D stage CEM where the stream has no opportunity to incise. If the stream has incised and has now hit bedrock or clay and is currently widening, you would still use the F stage CEM". Is the latter statement why you are suggesting F[II] or F[III], for this segment?

A CES of F[II] or F[III] does not necessarily seem appropriate, given that the channel has not completely lost connection with its floodplain (IR >2) – a condition seemingly implied by the stream type departure to a B, G, or F stream type specified under the descriptions for these Stages on page C1 of the Appendix. If channels with incision ratios greater than 1 but less than 2 can be classified in CES F[II] or F[III], then the descriptive text under these stages (page C-1 of the protocols) should include a C stream type, in addition to the B, G, and F stream types listed in parentheses.

I am not convinced that reach T1.10B underwent historic incision to the degree that resulted in a vertical stream type departure – given the presence of relatively shallow channel-spanning bedrock. I think it may have evolved from a C3-step/pool channel with IR = 1.0 to a C3-step/pool channel with IR = 1.6, with planform change now dominating. Erosional energies appear now to be expressed laterally rather than vertically. I have changed the CES to F[IV], assuming that the
F-stage channel evolution process model can be applied to reaches that have not previously undergone a vertical stream type departure (incision greater than 2.0) in Stage II.

I am open to more discussion on the CEM / CES and have requested that River Management Section hold some training on the topic to better clarify their expectations for this step in the protocols. Also, I would like to offer the following general comments on assignment of CEM and CES.

General Comments

SMRC has assigned channel evolution model (CEM) and channel evolution stage (CES) because it is a requirement of completing the protocols. However, speaking generally, SMRC would like to note the high uncertainty and subjectivity inherent in assigning both CEM and CES to segments based on the results of Phase 2 assessments from one date. Inferring a possible evolution of channel adjustments based on one discrete and limited set of observations and measurements from one snapshot in time, with limited knowledge of the historic channel and watershed stressors, is at best theoretical. A trend cannot be definitively assigned on the basis of one set of data.

A channel evolution model can begin to characterize a theory of the possible sequence of channel adjustments in response to a known or inferred stressor(s). However, lateral and vertical adjustments in river systems are much more complex than a single CEM can express. Vertical and lateral grade controls to channel adjustment often exist, soils of highly variable erodibility and cohesive strength can be present along the corridor in the stream bed and banks, vertical layering of lithologies can exist, variable riparian vegetation conditions may exist, all of which constrain channel adjustments in response to a given stressor to varying degrees. In addition, the majority of rivers have experienced multiple stressors (of varying types, magnitude, duration, and periodicity) to multiple locations (of varying extent), especially over recent centuries of human habitation. Channel adjustments in response to these multiple stressors are translated upstream and downstream (as constrained by the various boundary conditions). Process lag times, threshold relationships, and cumulative effects (Jacobson et al., 2001) operating over broader spatial and temporal scales determine how the system responses to stressors will overlap and manifest themselves in a specific channel morphology at a specific watershed location at a given time. In other words, the present condition and dimensions of a given segment are the manifestation of these dynamic channel adjustment processes in response to variable stressors, integrated over time and space.

SP – 11/14/2007 - I recognize that there has been some confusion about the CEM in the past. We hoped that the 2007 protocol revisions would clear things up, but you apparently still have some issues with the consistency in Appendix C. We could further clarify this, but we are not doing any revisions to the protocol, except the new habitat protocol, this year. It takes an entire year for the revisions to trickle their way down into the DMS, SGAT, etc and we wind up working out the bugs long after. We can't keep up with the revisions every year, especially now that we are losing staff. I think a training is a great idea and I hope to have one in the Spring.

What is TBIS, BBIS and LP in the cross section notes?

- TBIS = Top of Break In Slope
- BBIS = Bottom of Break In Slope
- LP = Left Pin

Is cross section B2 on segment A or B? I am confused because cross section C3 is for segment B, which is fine but the notes for B2 don't specify where that cross section is.

Cross section A1 (waypoint 79) is on Segm A and its data was entered in Step 2 for that segm.

Cross section B2 (waypoint 40) is on Segm B and its data was entered in Step 2 for that segm.

Cross section C3 (waypoint 12) is actually on Segm B (supplemental for that segment) – indicates a stream type consistent with cross section B2 (C3-S/P) but with a locally higher incision ratio (1.9).

I have added notes in the cross section spreadsheets, where needed, to make this clearer. Revised spreadsheets have been uploaded to the DMS.

SMRC – 11/26/2007
T1.10 B –
The same logic as discussed under the topic of CEM/CES for segment T1.10A would apply here to segment T1.10B. Therefore, SMRC changed the CEM/CES to IV (F) – subject to the same limitations as discussed above.

T1.09 C Neat comparison of old topo and ortho!

T1.08 – Three cross section in the spreadsheets, yet only two segments in the DMS. Can you out in the notes of the spreadsheet which segment the cross sections represents?

Reach CS-1 (waypoint 291) is on Segm A and its data was entered in Step 2 for that segm.

Reach CS-2 (waypoint 271) is on Segm A (supplemental CS for that segment) – indicates a stream type consistent with reference (C4-PB; IR=1.25) but not representative of the segment as a whole.

Reach CS-3 (waypoint 217) is on Segm B and its data was entered in Step 2 for that segm.

I have re-arranged the cross section order in the Excel workbook and added notes in the cross section spreadsheets, where needed, to make this clearer. Revised spreadsheets have been uploaded to the DMS.

T1.07 E – There actually was another berm on the left bank of this segment, about 2-3 feet higher than the adjacent floodplain. We just paid to remove it on the Consider Bardwell Farm and the belt width corridor is now enrolled in a CREP contract with FSA/VT Ag. I am surprised you did not catch this in your cross section, where was the cross section? The berm extends almost the entire length of the left bank in this segment and into Segment D it is on both the right and left bank.

In the past, the landowner has had a difficult time with flood chutes through the field to the west of the Indian River, downstream of the farm bridge crossing. The berm on the left bank had some gaps (just south of the farm bridge) where the river would break through and flood and severely erode the field. The escaped water would return to the Indian River downstream in Segment D. We removed the berm hoping to alleviate some of the pressure built up in the stream and allow the stream to flood and deposit sediment within the floodplain. The CREP contract area will be taken out of corn production and seeded and includes all prior flood chutes.

Interestingly, I have been to this site multiple times, during different times of the year, and never seen the area flooded the way the picture indicates in segment D. I did notice some drastic changes in the location and planform of the stream in Segment D, but did not know it was attributed to beaver activity. Every time I have been on the site the water levels have been low and there has been no evidence of beaver dams, that I could see form the banks anyway. I have walked the site with the landowner at least three times and he has never mentioned beavers. Maybe he doesn't know? It is very interesting to find out what caused this drastic channel movement since I was wondering…..

Due to the drastic adjustments of the stream there are currently head cuts migrating up through Segment D. The bed where the stream is currently located is much higher than the old bed and I am hopeful that the head cut will work itself out within segment D and stabilize the segment at the old bed elevation and not migrate up.

Prior to these recent massive avulsions, NRCS had a contract with the farmer who uses the land on the Consider Bardwell farm and they had planned to give the farmer "bonus points" for nutrient management toward a larger contract to rip-rap the one bend in the stream. Two years later after working with NRCS to get the rip-rap stipulation out of the contract the bend is high and dry and the stream is at least 50-100 feel west of the prior location.

OK I got side tracked, back to QA!

It is good to hear this information. I am disturbed that we did not notice a berm along left bank that was 2 to 3 feet higher than the floodplain along the entire length of Segment E. We certainly noticed the even higher berm along right bank which is the railroad grade. I indexed this as Encroachment: Railroad rather than berm. I did index a left-bank berm in two distinct locations (Line Impact Numbers 462 (90 ft long) and 488 (72 ft long)).

We did actually capture a left-bank berm at two additional measurement locations within the segment:

- At waypoint 321 (see cross section C3 in the spreadsheet; notes point out that this is actually Segment E). At this location, the berm was approximately 1.4 feet above the LB floodplain (corn field).
- At waypoint 319 (see Waypoint / Photo Log page 2 of 9) I did quick measurement of bank heights and a cross section sketch at a riffle to track incision / entrenchment. The railroad grade was at 7 feet above the thalweg on RB; the left top of bank was at 4.5 feet above the thalweg, and the ground surface sloped down and away from the channel to the adjacent corn field.

In hindsight, I should have indexed a section of left-bank berm connecting these two points, but missed this.

In other locations along the left bank we did not note a left-bank berm. Perhaps it was because we were generally down in the channel (where left top of bank ranged from 4.5 to maybe 6 feet above the streambed), and our view of the floodplain was obscured. Also, buffer vegetation may have obscured the berm from our view in some locations. Sometimes, features that might be identified as a low-profile berm (less than 0.5 foot) are actually relief features created by the relative lowering of the adjacent fields due to compaction from repeated cultivation. From my vantage point down in the entrenched channel, I may have mistaken a more prominent, purposeful berm feature for this kind of relief feature. Also, this experience points to the value of multiple site visits. As you stated you had walked the segment (up on the floodplain, I imagine) three separate times with the landowner, keying specifically on the left-bank berm.

I would like to correct the FIT data for this segment. Shall I note a 2-foot high berm along the left bank for the entire segment length? to reflect the conditions at the time of the Phase 2 assessment? Or should I reflect current conditions and delete the two short segments of berm that I had indexed, since the berm has apparently been removed. Has the berm been removed along the entire length of Segment E? or just to the limits of the landowner's property? Was the berm removed just to the floodplain elevation or was the top of left bank lowered to an elevation below the adjacent LB floodplain?

SP – 11/14/2007 - As for the berm on the Consider Bardwell Farm, we removed it from the farm bridge down to where the stream shoots off west away from the rail road berm. I think it is OK to not index it, since it has been removed. .

APPENDIX E

Reach Segmentation

Note: *Highlighted segment slope indicates a subclass slope category different than the overall reach slope (subreach).*

Reach	Segment	Feature	Point	Total Reach Length (ft)	Segment Lengths (ft)	Elevation (ft)	Segment Slopes	Reach Slope	Comparison to Phase 1 Slope: Elevation (ft)	Comparison to Phase 1 Slope: Reach Slope
Main Stem										
M10		d/s end reach				840			840	
	A	segment break	A/B		1,134	853	1.1%			
	B	segment break	B/C		597	858	0.8%			
	C	segment break	C/D		1,579	870	0.8%			
	D	u/s end reach		4,299	990	890	2.0%	1.2%	890	1.16%
M07		d/s end reach				649			649	
	A	segment break	A/B		8,140	683	0.4%			
	B	u/s end reach		16,075	7,935	734	0.6%	0.5%	734	0.5%
M06		d/s end reach				620			620	
	A	segment break	A/B		3,750	638	0.5%			
	B	u/s end reach		6774	3,024	649	0.4%	0.4%	649	0.4%
Scallop Brook										
M08T05.01		d/s end reach				780			780	
	A	segment break	A/B		996	810	3.0%			
	B	u/s end reach		6,406	5,410	1294	8.9%	8.0%	1294	8.02%
Flower Brook										
M05T03.01		d/s end reach				620			620	
	A	segment break	A/B		1,170	640	1.7%			
	B	segment break	B/C		550	678	6.9%			
	C	u/s end reach		5,217	3,497	705	0.8%	1.6%	710	1.7%

Note: *Highlighted segment slope indicates a subclass slope category different than the overall reach slope (subreach).*

Reach	Segment	Feature	Point	Total Reach Length (ft)	Segment Lengths (ft)	Elevation (ft)	Segment Slopes	Reach Slope	Comparison to Phase 1 Slope: Elevation (ft)	Comparison to Phase 1 Slope: Reach Slope
Beaver Brook										
M05T03.02S01.02		d/s end reach				805			805	
	A	segment break	A/B		1,156	825	1.7%			
	B	segment break	B/C		2,724	845	0.7%			
	C	segment break	C/D		1,268	865	1.6%			
	D	segment break	D/E		618	912	7.6%			
	E	u/s end reach		6,139	373	915	0.8%	1.8%	915	1.79%
M05T03.02S01.01		d/s end reach				737			737	
	A	segment break	A/B		2,177	765	1.3%			
	B	segment break	B/C		1,506	782	1.1%			
	C	segment break	C/D		1,969	803	1.1%			
	D	u/s end reach		6,356	704	805	0.3%	1.1%	805	1.07%
Wells Brook										
M01T02.02		d/s end reach				435			435	
	A	segment break	A/B		1,936	443	0.4%			
	B	segment break	B/C		1,835	458	0.8%			
	C	segment break	C/D		2,424	488	1.2%			
	D	segment break	D/E		1,000	502	1.4%			
	E	u/s end reach		10,250	3,056	540	1.2%	1.0%	540	1.02%
Indian River										
MNY10T1.11		d/s end reach				860			860	
	A	segment break	A/B		2,205	910	2.3%			
	B	u/s end reach		2,822	616	940	4.9%	2.8%	940	2.83%
MNY10T1.10		d/s end reach				760			760	
	A	segment break	A/B		2,337	800	1.7%			
	B	u/s end reach		5,440	3,103	860	1.9%	1.8%	860	1.84%

Note: *Highlighted segment slope indicates a subclass slope category different than the overall reach slope (subreach).*

									Comparison to Phase 1 Slope	
Reach	Segment	Feature	Point	Total Reach Length (ft)	Segment Lengths (ft)	Elevation (ft)	Segment Slopes	Reach Slope	Elevation (ft)	Reach Slope
MNY10T1.09		d/s end reach				670			670	
	A	segment break	A/B		758	677	0.9%			
	B	segment break	B/C		2,712	700	0.8%			
	C	u/s end reach		7,789	4,319	760	1.4%	1.2%	760	1.16%
MNY10T1.08		d/s end reach				570			570	
	A	segment break	A/B		4,126	607	0.9%			
	B	u/s end reach		9,454	5,328	670	1.2%	1.1%	670	1.06%
MNY10T1.07		d/s end reach				525			525	
	A	segment break	A/B		1,473	528	0.2%			
	B	segment break	B/C		1,430	532	0.3%			
	C	segment break	C/D		2,213	537	0.2%			
	D	segment break	D/E		1,159	540	0.3%			
	E	u/s end reach		11,091	4,815	570	0.6%	0.4%	570	0.41%

APPENDIX F

Opportunities for Geomorphically-Compatible River Corridor Management

	Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
1	**M10-D, -B** Mettowee River Un-STD	**various properties - southwest of Route 30, Dorset** Historic channelization along commercial development and agricultural fields has resulted in entrenched channel along a majority of these segments. Route 30 bridge is a bankfull constrictor. Minimal width buffers along ag fields.	Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through passive geomorphic measures (increased width of woody buffers, possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from developments in the corridor to prevent future fluvial erosion losses. Increase buffer widths along ag fields to reduce sediment and nutrient inputs.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
2	**M10-C** Mettowee River Un-MOD	**various properties - southwest of Route 30, Dorset** Historic channelization along agricultural fields has resulted in moderately entrenched channel. Regaining some sinuosity and building an incipient floodplain. High recovery segment that could offer sediment and flow attenuation downstream of an entrenched and more intensely modified segment.	Support a return to reference sinuosity, enhance sediment/flow attenuation functions, and continue to improve floodplain access through passive geomorphic measures (possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from developments in the corridor to prevent future fluvial erosion losses. Increase buffer widths along ag fields to reduce sediment and nutrient inputs.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
3	**M10-A** Mettowee River EQ-Min	**various properties - southwest of Route 30, Dorset** Close to reference sinuosity and good floodplain access. Some residential encroachment (armoring, absent tree buffers) in upstream end. Channel-contiguous wetlands mapped by NWI, VSWI. Short segment that can continue to offer sediment and flow attenuation downstream of entrenched and more intensely modified segments.	Preserve sinuosity and floodplain access, enhance sediment/flow attenuation functions, through passive geomorphic measures (possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from developments in the corridor to prevent future fluvial erosion losses.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
4	**M09** Mettowee River Un-MOD	**various properties - along Route 30, Dorset / Rupert** Channel has regained some limited sinuosity and has good access to the floodplain (with localized exceptions) following historic channel management to facilitate residential, commercial, agricultural and transportation encroachments. Three bankfull constricting bridge crossings. Small pockets of channel-contiguous wetlands mapped by NWI, VSWI. Serving a limited sediment attenuation role.	Support a return to reference sinuosity, enhance sediment/flow attenuation functions, and enhance floodplain access through passive geomorphic measures (possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from developments in the corridor to prevent future fluvial erosion losses. Increase buffer widths along ag fields and commercial nursery/greenhouse to reduce sediment and nutrient inputs.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC

	Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
5	**M08** Mettowee River EQ-Min	**various properties - along Route 30, Dorset / Rupert** Channel has regained some limited sinuosity and has good access to the floodplain (with localized exceptions) following historic channel management to facilitate and protect residential, agricultural and transportation encroachments. Two bankfull-constricting bridge crossings. Small pockets of channel-contiguous wetlands mapped by NWI, VSWI. Serving a limited sediment attenuation role.	Support a return to reference sinuosity, enhance sediment/flow attenuation functions, and enhance floodplain access through passive geomorphic measures (possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from developments in the corridor to prevent future fluvial erosion losses. Increase buffer widths along ag fields to reduce sediment and nutrient inputs. **Further evaluate possible imminent hazard of further streambank erosion in vicinity of the mobile home through landowner outreach / site reconnaissance.**	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - st, lt	High	Low	High	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
6	**M08T05.01-A** Scallop Brook Un-MOD	**various properties - crosses Route 30, Rupert** Historic channelization along agricultural fields and LB residential property has resulted in moderately entrenched channel in a setting of marked slope reduction (upstream segment is very steep bedrock gorge). Route 30 box culvert is a bankfull constrictor. Minimal width tree buffers along ag fields.	Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through passive geomorphic measures (increased width of woody buffers, possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from further developments in the corridor to prevent future fluvial erosion losses. Increase buffer widths along ag fields to reduce sediment and nutrient inputs. Carefully manage land use changes in the upstream watershed to reduce the potential for increases in sediment or flows that may induce channel adjustments in the subject reach/segment. Evaluate the feasibility of active geomorphic measures (e.g., lowering elevation of near-bank areas where berms/armoring presently constrain the channel and limit floodplain access).	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
7	**M07T04.01** Sykes Hollow Brook Un-Incis (STD)	**various properties - northwest of Sykes Hollow Road, Rupert** Historic channelization along agricultural fields and residential properties has resulted in fully entrenched channel in a setting of marked slope reduction ("alluvial fan"). Bedrock offers some vertical and lateral grade control. One short segment of recent incision/widening is bounded by channel-spanning bedrock. Two bankfull-constricting bridges. Recent small avulsion site upstream of one bridge. Minimal width tree buffers along ag fields. Significant mobilization of sediment to the Mettowee River. **High erosion hazard potential.**	Refrain from further developments in the corridor to prevent future fluvial erosion losses. Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through passive geomorphic measures (increased width of woody buffers, possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Increase buffer widths along ag fields to reduce sediment and nutrient inputs. Evaluate the feasibility of active geomorphic measures (e.g., lowering elevation of near-bank areas where berms/armoring presently constrain the channel and limit floodplain access). Work with the town and landowners re: planning measures and strategies to reduce future FEH hazards.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	High	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC

	Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
8	**M01T02.05** Wells Brook EQ-Min	**various properties - along Wells Brook Road, Tinmouth & Wells** Good sinuosity and floodplain access overall. Some limited straightening inferred at crossings and along a LB hay field near the downstream end of the reach. Limited encroachments by residential, agricultural and transportation investiments in the corridor. Nine bankfull-constricting state, town and private bridge and culvert crossings - localized instability at some. Offering some sediment and flow attenuation.	Preserve sinuosity and floodplain access, enhance sediment/flow attenuation functions, through passive geomorphic measures (possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from developments in the corridor to prevent future fluvial erosion losses. Replace undersized crossings with structures of wider span at next opportunity.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS BBR VRC
9	**M01T02.05** Wells Brook EQ-Min	**Horse pasture - upstream half of reach Wells Brook Road, Wells** Horse pasture with direct access to the channel.	Livestock exclusion (fencing), accompanied by provision for alternative water source and installation of stabilized livestock crossing(s) where appropriate. Increased buffer widths along corn fields downstream of Route 153. Restoration of woody buffers within the geomorphically defined corridor.	SR - st NR - st	High	Low	High	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners
10	**M01T02.04** Wells Brook EQ-Min	**various properties - along Wells Brook Road, Tinmouth & Wells** Good sinuosity and floodplain access overall. Some limited straightening inferred at crossings and along a LB hay field near the downstream end of the reach. Limited encroachments by residential, agricultural and transportation investiments in the corridor. Nine bankfull-constricting state, town and private bridge and culvert crossings - localized instability at some. Offering some sediment and flow attenuation.	Preserve sinuosity and floodplain access, enhance sediment/flow attenuation functions, through passive geomorphic measures (possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from developments in the corridor to prevent future fluvial erosion losses. Replace undersized crossings with structures of wider span at next opportunity.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS BBR VRC

	Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
11	**M01T02.04** Wells Brook EQ-Min	**various properties - along Wells Brook Rd / East Wells Rd, Wells** Historic channelization along town roads and agricultural fields & residential properties has resulted in moderately entrenched channel with limited floodplain access. Naturally-armored bed and human-armored banks, and limited tree buffers have moderated the potential for incision / widening. Bedrock offers some vertical and lateral grade control. Reach appears fairly stable but remains susceptible to sudden erosion in a high flood event. Three bankfull-constricting footbridges and one culvert. Minimal width herbaceous buffers along ag fields.	Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through passive geomorphic measures (increased width of woody buffers, possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from further developments in the corridor to prevent future fluvial erosion losses. Increase buffer widths along ag fields to reduce sediment and nutrient inputs.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
12	**M01T02.03** Wells Brook EQ-Min	**various properties - along East Wells Road, Wells** Good sinuosity and floodplain access overall in a semi-confined moderately steep cobble channel with frequent bedrock grade controls. Some limited straightening inferred at crossings. Limited encroachments by residential and transportation investiments in the corridor. Four bankfull-constricting private bridges and one old abutment. Remains of three (previously washed out bridges) within the reach. Naturally transport-dominated reach.	Replace undersized crossings with structures of wider span at next opportunity.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	BBR Town VTDEC RMS
13	**M01T02.02-E, C, A** Wells Brook Un-MOD	**various properties - along East Wells Rd & Route 30, Wells** Historic channelization along agricultural fields & residential/commercial properties has resulted in moderately entrenched channel with limited floodplain access. Minimal width tree and scrub/shrub buffers. Segments are actively adjusting - in some cases lateral adjustments are conflicting with adjacent land uses. Segments are gaining some measure of sinuosity and capacity to store sediments. **Moderate erosion hazards to nearby driveways, roads and residential properties as channel adjusts.**	Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through passive geomorphic measures (increased width of woody buffers, possible limited term or permanent corridor easement; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from further developments in the corridor to prevent future fluvial erosion losses. Increase buffer widths along ag fields to reduce sediment and nutrient inputs. **Work with the town and landowners to communicate erosion hazard risk and develop strategies for managing the risks.**	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	High	Unknown	Town VTDEC RMS USDA-WHIP USFW - Partners USDA - CRP, EQIP VTAA - CREP, BMPs

	Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
14	**M01T02.02-D, B** Wells Brook Un-Min	**various properties -** **crossing South Street & south of Rt 30, Wells** Historic channelization/berming/armoring along agricultural fields & residential/commercial properties has resulted in moderately to fully entrenched channel with limited floodplain access. Minimal width tree and scrub/shrub buffers. Segments have been actively maintained (armored, bermed) in the linear, entrenched planform. **High erosion hazard potential** along Segment D to nearby driveways, roads, bridge and residential properties in future flood.	Refrain from further developments in the corridor to prevent future fluvial erosion losses. **Work with the town and landowners to communicate erosion hazard risk and develop strategies for managing the risks.** In case of Segment B, evaluate feasibility of active geomorphic measures to restore floodplain access.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	High	Unknown	Town VTDEC RMS USDA-WHIP USFW - Partners USDA - CRP, EQIP VTAA - CREP, BMPs
15	**M01T02.01** Wells Brook EQ-Min	**various properties -** **west of Rt 30, north/south of Rt 149, Wells** Good sinuosity and floodplain access overall. Bedrock offers some lateral and vertical grade control. Channel-contiguous wetlands are mapped within the reach. Some encroachment by agricultural fields; revegetating buffers. One bankfull-constricting state bridge crossing (Rt 149) - but in vicinity of bedrock controls. Reach is providing some sediment and flow attenuation. Large "delta" of sediment at the confluence with Mettowee River.	Preserve sinuosity and floodplain access, enhance sediment/flow attenuation functions, through passive geomorphic measures (possible limited term or permanent corridor easement; possible wetland restoration / conservation; refrain from future channel management, such as channelization, dredging, berming, armoring). Refrain from developments in the corridor to prevent future fluvial erosion losses.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
16	**M01T02.01** Wells Brook EQ-Min	**Historic neck cutoff / forested wetland** **west of Rt 30, north of Rt 149, Wells** Short section of apparently straightened channel contiguous with mapped forested Class II wetland (VSWI).	Conduct landowner outreach and site reconnaissance to evaluate feasibility of possible wetland restoration / conservation project. Restoring meanders through the wetland may increase capacity for sediment / flow / nutrient attenuation at a strategic location just downstream of the Mill Brook confluence.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	High	Unknown	VTDEC WS VTDEC RMS USDA-WHIP, SRP USFW - Partners VRC

	Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
17	**M05T03.04** Flower Brook Un-MOD	**various properties -** **north of Danby/Pawlet Rd, Danby/Pawlet** Good sinuosity and floodplain access overall. Bedrock offers some lateral and vertical grade control. Minimal encroachments; ample forested buffers. Reach is providing some sediment and flow attenuation. Active planform adjustments and aggradation. Flood-related sediments working through reach. Mass failures and moderate streambank erosion contributing in-reach sediments. **Significant fine sediment sources along valley margins from gullies that have developed on ephemeral tributaries.**	**Conduct landowner outreach and site reconnaissance to evaluate the driving forces for gully formation on the tributaries and evaluate the feasibility of possible gully stabilization techniques and/or sediment attenuation measures to reduce sediment mobilization to the Wells Brook.** Preserve sinuosity and floodplain access along Flower Bk, enhance sediment/flow attenuation functions, through passive geomorphic measures (possible limited term or permanent corridor easement).	EQ - lt FP - lt SA - lt SR - lt NR - lt	Unknov	Mod	High	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
18	**M05T03.02S01.02-B** Beaver Brook EQ-Min	**Pasture with direct cattle access downstream of Kelly Hill Rd, Pawlet** Pasture with direct cattle access.	**Livestock exclusion** (fencing), accompanied by provision for alternative water source and installation of stabilized livestock crossing(s) where appropriate. Increased buffer widths within the geomorphically defined corridor.	SR - st NR - st	High	Low	High	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners
19	**M05T03.02S01.01-C** Beaver Brook EQ-Min	**Horse pasture - upstream half of segment\ upstream of Rt 133, Pawlet** Horse pasture with direct access to the channel.	**Livestock exclusion** (fencing), accompanied by provision for alternative water source and installation of stabilized livestock crossing(s) where appropriate. Increased buffer widths within the geomorphically defined corridor.	SR - st NR - st	High	Low	High	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners
20	**M05T03.02S01.01-C** Beaver Brook EQ-Min	**Mapped wetlands - prior converted upstream / downstream of Rt 133, Pawlet** Wetlands mapped contiguous with the channel (NWI, VSWI). Channel has been historically channelized along crop fields and pasture.	Conduct landowner outreach and evaluate the feasibility and benefits / consequences of possible **wetland restoration** to enhance flow/nutrient attenuation potential along the Beaver Brook.	EQ - lt FP - lt SA - lt FA - lt SR - lt NR - lt	Unknov	Mod	High	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
21	**MNY10T1.11-A** Indian River Un-Mod	**Lewis property -** **Lewis Rd, Rupert** Historic channelization along agricultural fields has left the channel moderately entrenched and	Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through restoration of woody buffers, and possible limited term or	EQ - lt FP - lt SA - lt SR - lt NR - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS

Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
	formerly converted a naturally aggradation setting (local slope reduction) to a transport dominated setting. Channel is actively adjusting its planform, and locally aggrading and widening - at times in conflict with adjacent ag fields. One of two undersized crossings have washed out recently.	permanent corridor easement. Refrain from future channel management, such as channelization, dredging, berming, armoring. Refrain from developments in the corridor to prevent future fluvial erosion losses.	AV - lt					VRC

	Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
22	**MNY10T1.10-B** Indian River Un-Mod	**various properties - north of Lewis Rd, Rupert** Historic channelization along agricultural fields has left the channel moderately entrenched and formerly converted a naturally aggradation setting (local slope reduction) to a transport dominated setting. Channel is actively adjusting its planform, and locally aggrading and widening. Two undersized bridge crossings. **Direct pasturing** for 500 feet of channel mid-segment is contributing sediments and nutrients to the Indian River.	**Livestock exclusion** (fencing), accompanied by provision for alternative water source and installation of stabilized livestock crossing(s) where appropriate. Increased buffer widths along corn fields downstream of Route 153. Restoration of woody buffers within the geomorphically defined corridor. Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through restoration of woody buffers, and possible limited term or permanent corridor easement. Refrain from future channel management, such as channelization, dredging, berming, armoring. Refrain from developments in the corridor to prevent future fluvial erosion losses.	EQ - lt FP - lt SA - lt SR - st, lt NR - st, lt AV - lt	High	Low	High	Unknown	USDA - CRP, EQIP VTAA - CREP USDA-WHIP USFW - Partners VTDEC RMS VRC
23	**MNY10T1.10-A** Indian River Un-Mod	**various properties - west of Route 153, Rupert** Limited historic channelization along the railroad and agricultural fields has left the channel moderately entrenched. Channel is actively adjusting its planform, and has a good degree of floodplain access in much of the segment. Two bridge crossings and one former abutment are bankfull constrictors. Minimal buffers along right-bank corn and hay fields.	Increased buffer widths along ag fields. Restoration of woody buffers within the geomorphically defined corridor. Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through restoration of woody buffers, and possible limited term or permanent corridor easement. Refrain from future channel management, such as channelization, dredging, berming, armoring. Refrain from developments in the corridor to prevent future fluvial erosion losses. **Evaluate the feasibility of lowering rail trail elevation where the former railroad berm presently constrains the channel and limits floodplain access.**	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP USDA-WHIP USFW - Partners VTDEC RMS VRC
24	**MNY10T1.09-C, -A** Indian River Un-STD	**various properties - west of Route 153, Rupert** Historic channelization along the railroad and agricultural fields has resulted in entrenched channel along a majority of the segment. Bedrock offers lateral and vertical grade control along the entrenched channel moderating further incision. Two bridge crossings are bankfull constrictors. Some stormwater and sediment runoff from fords. Minimal buffers along right-bank corn and hay fields.	Increased buffer widths along ag fields. Restoration of woody buffers within the geomorphically defined corridor. Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through restoration of woody buffers, and possible limited term or permanent corridor easement. Refrain from future channel management, such as channelization, dredging, berming, armoring. Refrain from developments in the corridor to prevent future fluvial erosion losses. **Evaluate the feasibility of lowering rail trail elevation where the former railroad berm presently constrains the channel and limits floodplain access.**	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
25	**MNY10T1.09-B** Indian River EQ-Min	**various properties - west of Route 153, Rupert** Equilibrium channel with reasonably-wide naturally vegetated buffer along both banks. Channel-contiguous wetlands may offer flow, sediment and nutrient attenuation function.	Preserve equilibrium channel offering instream and riparian habitat functions and values, sediment, flow and nutrient attenuation functions. **Possible corridor and wetland conservation easements**. Improve Quarry Road grading and base material to reduce stormwater and sediment runoff direct to the stream. Replace culvert crossing with structure of wider span at next opportunity.	EQ - lt FP - lt EC - st, lt	High	Low	High	Unknown	USDA-WHIP USFW - Partners VTDEC RMS VTDEC WS VRC TNC BBR

	Reach / Segment; Condition	Site Description	Project Description	Objectives Addressed short-term (ST) long-term (LT)	Technical Feasibility	Cost	Priority	Landowner Approval	Potential Partners - Programs
26	**MNY10T1.08-B** Indian River Un-STD	**various properties - west of Route 153, Rupert** Limited historic channelization along agricultural fields has left the channel entrenched in many sections. Channel is gradually building an incipient floodplain at lower elevation. Frequent bedrock exposures offer stability to the entrenched channel and its incipient floodplain. Four bridge/ culvert crossings and one former abutment are bankfull constrictors. Minimal buffers along right-bank ag fields.	Increase buffer widths along ag fields. Restore tree buffers within the geomorphically-defined corridor. Support a return to reference sinuosity, restore sediment attenuation function of the reference meandering planform, and restore floodplain access through possible limited term or permanent corridor easement. Refrain from future channel management, such as channelization, dredging, berming, armoring. Refrain from developments in the corridor to prevent future fluvial erosion losses.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP USDA-WHIP USFW - Partners VTDEC RMS VRC
27	**MNY10T1.08-A** Indian River Un-STD	**various properties - west of Route 153, Pawlet** Historic channelization along agricultural fields and the railroad has resulted in channel entrenchment. Two bridge crossings are bankfull constrictors. Minimal herbaceous buffers along ag fields.	Increase buffer widths along ag fields. Restore tree buffers within the geomorphically-defined corridor. Support a return to reference sinuosity and improved floodplain access, to restore sediment attenuation function of the reference meandering planform. Possible limited term or permanent corridor easement. Refrain from future channel management, such as channelization, dredging, berming, armoring. Refrain from developments in the corridor to prevent future fluvial erosion losses. **Evaluate the feasibility of lowering rail trail elevation where the former railroad berm presently constrains the channel and limits floodplain access.**	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	Mod	Unknown	USDA - CRP, EQIP VTAA - CREP, BMPs USDA-WHIP USFW - Partners VTDEC RMS VRC
28	**MNY10T1.07-E** Indian River Un-STD	**various properties - west of Route 153, Pawlet** Historic channelization along the railroad and agricultural fields has resulted in entrenched channel along a majority of the segment. Three bridge crossings are bankfull constrictors. Minimal buffers along left-bank corn and hay fields.	Increase buffer widths along ag fields. Restore tree buffers within the geomorphically defined corridor. **Evaluate the feasibility of lowering rail trail elevation where the former railroad berm presently constrains the channel and limits floodplain access.** Support a return to reference sinuosity, restore sediment attenuation function, and restore floodplain access through restoration of woody buffers, and possible limited term or permanent corridor easement. Refrain from future channel management, such as channelization, dredging, berming, armoring. Refrain from developments in the corridor to prevent future fluvial erosion losses.	EQ - lt FP - lt SA - lt SR - lt NR - lt AV - lt	High	Low	High	Likely	USDA - CRP, EQIP VTAA - CREP, BMPs VTDEC RMS USDA-WHIP USFW - Partners VRC Land Trust
29	**MNY10T1.07-D** Indian River Not Assessed Beaver-impounded	**various properties - west of Route 153, Pawlet** Hydric soils mapped coincident with the channel. Beaver dams presently impounding the channel such that waters have inundated the margins of nearby corn field. Restoration of channel-contiguous wetlands may offer flow, sediment and nutrient attenuation function.	Evaluate the feasibility of a wetland restoration project to enhance riparian habitat values, and sediment, flow and nutrient attenuation functions. Possible limited-term or permanent easements. Increase buffers along the wetlands to reduce nutrient, sediment impacts to the wetland and Indian River.	EQ - lt FP - lt EC - st, lt	High	Low	High	Likely	USDA-WRP, WHIP USFW - Partners VTDEC RMS VTDEC WS VRC TNC