Phase 2 Stream Geomorphic Assessment
Upper Otter Creek Watershed

Reaches: M22 – M26
Rutland & Clarendon, Rutland County, Vermont

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TABLE OF CONTENTS

APPENDICES

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Field work was conducted with the assistance of Hilary Solomon, representing the Rutland Natural Resources Conservation District. Technical support was provided by Shannon Hill of the Vermont Department of Environmental Conservation, Water Quality Division.

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

In November 2005, Phase 2 stream geomorphic assessments were completed on 5 reaches (14.2 river miles) the Upper Otter Creek main stem between Wallingford village and Rutland City. Assessments were conducted to provide a geologic and geomorphic context for the streambank erosion and water quality issues documented in the river over the past several years.

Geomorphic data will be used to inform future management strategies for the river corridor by watershed stakeholders including landowners, Clarendon and Rutland townships, the Rutland Natural Resources Conservation District (RNRCD), Rutland Regional Planning Commission, VT Department of Environmental Conservation Water Quality Division (VTDEC WQD), and others. Knowledge of the geomorphic condition will help to define the short-term compatibility and long-term sustainability of various restoration or conservation projects and future land use or channel management activities.

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

- Inferred and reported channelization;
- Channel armoring (rip-rap);
- Berming;
- Historic floodplain encroachment by roads, a railroad and minor development;
- Undersized bridges (and old abutments), serving as flow constrictors at bankfull flow or higher-magnitude flood events; and
- Minimal or absent riparian buffers along portions of the study reaches.

Recent watershed-level disturbances to the Upper Otter Creek have included:

- High-magnitude flood events, including the recent floods of 1987 and 1973;
- Inferred increases in upland development which can accelerate runoff and sedimentation to the tributaries draining to the Upper Otter Creek main stem;
- Accelerated delivery of sediment and flows from major tributaries (Mill River and Cold River), which appear to be undergoing significant adjustments in response to intensive channel management, based on cursory observations during windshield surveys.

Despite the apparent history of channel management in the study area between Wallingford and Rutland City, the Otter Creek channel appears fairly stable and is not exhibiting excessive adjustments, or a substantial departure from reference conditions. Cross section measurements (and frequent overbank flooding conditions) demonstrate excellent floodplain access throughout the five reaches. No signs of channel incision were noted during assessments. Presence of erosion-resistant ancient lake silts and clays at depth below a veneer of more erodible alluvial sands may account for the lack of expected channel incision.

Minor degrees of aggradation, widening and planform adjustment were noted in the study area. Adjusting areas do not appear to be the result of system-wide imbalances; instead they are largely coincident with locations of:

- undersized bridges or old abutments;
- areas of absent buffers;
- and debris jams in areas of beaver activity.

The relative magnitude of channel adjustment processes, together with the topographic, geologic, and vegetative setting define the sensitivity of each reach to continuing and future stresses. The study area reaches were classified as having High sensitivity. The High sensitivity of the five reaches is imparted by the inherent sensitivity factors of a shallow-gradient, broad-valley setting and highly erodible (alluvial) sands along the channel margins. The inherent sensitivity of the geologic setting means that these study reaches are still vulnerable to future changes in sediment production or hydrology from upstream and upwatershed sources. Future stressors could easily "tip the balance" for the Otter Creek main stem. Of particular concern is the current geomorphic condition of the Mill River and Cold River, and the accelerated sediment production and delivery resulting from active adjustments in these tributaries.

Given the current geomorphic condition and sensitivity of the Upper Otter Creek reaches, a passive geomorphic approach to river management is appropriate, involving:

- long-term management and preservation of the river corridor - protecting the floodplain from future development and filling, and refraining from channel management activities that tend to cause a channel to become disconnected with its floodplain;
- preservation and enhancement of forested riparian buffer areas along the channel margins; and
- geomorphic assessment of the Mill River and Cold River tributaries and implementation of appropriate restoration and conservation techniques to reduce sedimentation and attenuate flows.

1.0 INTRODUCTION

Phase 2 geomorphic and habitat assessments were completed in November 2005 on 5 reaches (14.2 river miles) of the Otter Creek main stem following protocols published by the Vermont Agency of Natural Resources (VTANR, 2005). 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 results will be used by watershed stakeholders (e.g., landowners, Clarendon and Rutland townships, the Rutland Natural Resources Conservation District (RNRCD), Rutland Regional Planning Commission, VT Department of Environmental Conservation Water Quality Division (VTDEC WQD), and others to:

- provide a watershed and river-network context for site-specific restoration and conservation projects (i.e., understand if the river is actively degrading, aggrading, widening, or shifting its planform in the areas upstream and downstream of a proposed project site);
- support site-specific channel restoration design and planning;
- understand water quality monitoring trends in the river;
- 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.

The assessment also included a review of increased overbank flooding conditions reported by residents in the study area and potential contributing causes related to channel conditions or land use changes in the watershed draining to the study area.

This summary report has been prepared by South Mountain Research & Consulting (SMRC) of Bristol, Vermont under contract to the Rutland Natural Resources Conservation District.

2.0 BACKGROUND

Phase 2 geomorphic assessments were undertaken along the Otter Creek main stem to provide a geologic and geomorphic context for the streambank erosion and water quality issues documented in the river over the past several years.

2.1 Geographic Setting

The Otter Creek drains a 1,100-square-mile area of land located primarily in Rutland and Addison Counties of Vermont (Figure 1a) before joining the southern portion of Lake Champlain at Fields Bay and Porter Bay in the town of Ferrisburg. For management purposes, the Otter Creek basin is split near the Addison / Rutland County line into the Lower and Upper Otter Creek watersheds. The Lower Otter Creek watershed (Addison County) contains approximately 611 square miles and the Upper Otter Creek watershed (Rutland County) drains approximately 487 square miles. This study focused on five reaches of the Upper Otter Creek main stem located in the towns of Clarendon and Rutland (Figure 1b). These five reaches extend 14.2 miles from the village of Wallingford north to Rutland City.

Approximately 81% of the Otter Creek watershed upstream of Rutland City is in forested use; 7% in agriculture; 6.7% is developed; and the remainder is covered by surface waters or wetlands (RRPC *et al.*, 2005). While agricultural and developed uses comprise a relatively small percentage of the overall watershed area, these activities tend to be concentrated along the valleys of the Otter Creek and its tributaries.

2.2 Regional Geologic Setting

The Upper Otter Creek watershed from Wallingford north to Rutland is located in the Vermont Valley physiographic province. This north-south trending narrow valley, an extension of the Champlain Valley province, is positioned between the Taconic Mountains to the west and the higher-elevation Green Mountains to the east.

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 bedrock slopes of the valley side walls 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 at the eastern valley wall. These kame deposits are now the site of sand and gravel quarries along the slopes of the Green Mountains elevated above the present-day Otter Creek valley in locations such as East Clarendon at the foothills of Bald Mountain, and at the base of Round Hill and Bear Mountain (Stewart, 1972).

As the global climate warmed and the glaciers receded, a large fresh-water lake inundated the Champlain Valley and the Vermont Valley provinces. At its highest stage, Lake Vermont waters extended southward into the present-day Otter Creek valley to the vicinity of South Wallingford (Stewart & MacClintock, 1969). The Otter Creek valley is filled with sands and silts deposited over hundreds of years in this ancient lake. Rivers carried sands and gravels eroded from the

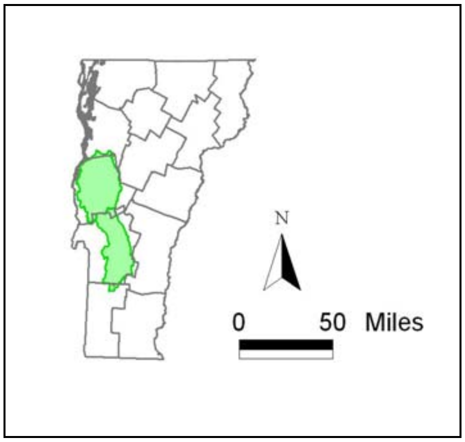
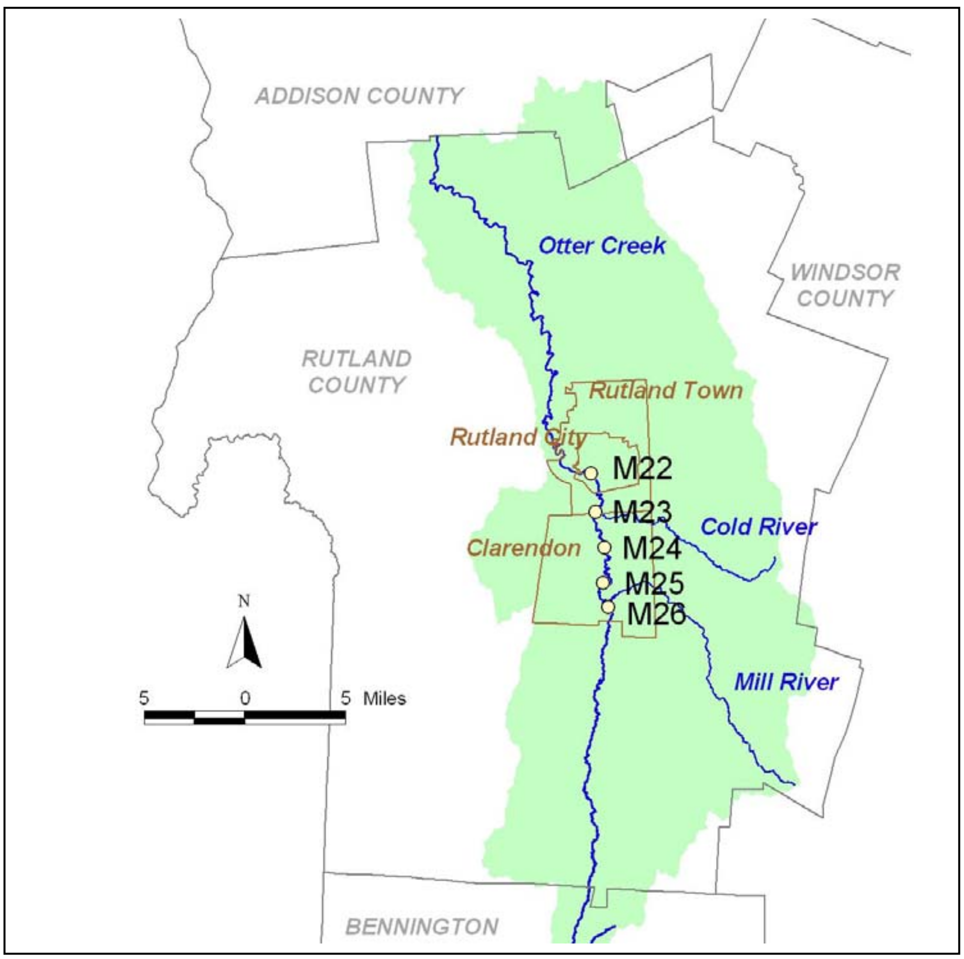


Figure 1a. (left)
Location of Otter Creek Watershed within Vermont.

Figure 1b. (below) Location of Upper Otter Creek main stem reaches assessed in November 2005.



recently-glaciated headwaters to the margins of the lake, particularly along the eastern shores at the foot of the Green Mountains. Deltas of these sands and gravels extended out into the lake; these delta deposits formed, for example, at the confluence of the ancient Mill River and Cold River (Stewart & MacClintock, 1969; Stewart, 1972).

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 Otter Creek 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 Otter Creek, then went to work moving sediments left in the wake of the glaciers, and further eroding the Taconic and Green Mountains. The surrounding landscape continues in this erosion phase today. A thin veneer of alluvium from the recent Otter Creek now blankets the lake sands and deltaic gravels in the greater Otter Creek valley.

2.2.1 Bedrock Geology

The Otter Creek valley in the area of the five assessed reaches is flanked by the Taconic Mountains to the west and the Green Mountains to the east. The Taconic Mountains consist of folded and faulted slates and phyllites of Cambrian and Ordovician age (Shumaker, 1967). The Green Mountains to the east are formed by gneisses, phyllites and schists of PreCambrian, Cambrian and Ordovician age. The rock types which make up the Taconic and Green Mountains are more resistant to erosion than the dolomitic and limestone marbles that underlie the Otter Creek valley (Stewart, 1972).

A narrowing of the Otter Creek valley at Center Rutland is caused by the constraints of exposed bedrock. A series of shallow bedrock falls (Meads Falls) is located here; two dams are constructed at the falls (Center Rutland dam, Ripley Mills dam). The upstream end of the study area is also marked by exposed bedrock in the vicinity of Wallingford village. 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).

2.2.2 Surficial Geology

Glacial activity has influenced the surficial sediments and soil types which are present in the Otter Creek watershed today. Upland slopes are dominated by shallow- to moderate-thickness glacial till deposits overlying bedrock. Kame terrace deposits are located along the eastern valley wall at the approximate elevation of East Clarendon. 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 channels. The Mill and Cold Rivers transport these kame gravels to the Otter Creek valley floor and deposit them in alluvial fans which now overlie the delta deposits that formed here during the Lake Vermont era several thousand years ago.

The Otter Valley itself is filled with glacial and post-glacial deposits several tens to hundreds of feet in thickness. A seismic profile completed at a location between the Cold River and Rutland City indicates that the Otter Creek valley is filled with more than 175 feet of sediments: 100 feet of till, overlain by 50 to 85 feet of lake silts and clays, blanketed by lake sands and recent alluvial sands and silts (Stewart, 1972).

2.3 Geomorphic Setting

In the Phase 1 Stream Geomorphic Assessment, the Upper Otter Creek watershed was delineated into 28 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 report for further details (RRPC *et al.*, 2005).

Based on the channel and watershed stressors identified through remote sensing, windshield surveys and limited historical research during the Phase 1 assessment, five contiguous reaches along the main stem were prioritized for Phase 2 Stream Geomorphic Assessments in 2005 (see Figure 2). The five reaches are located in the towns of Clarendon and Rutland (see Figure 3). Two of the five reaches accept drainage from the Mill River and Cold River.

Elevations along the assessed portion of Otter Creek range from 175 feet above sea level near Wallingford to 160 feet near Rutland City. The overall slope along this 14.2 mile section of the Otter Creek is 1.1 feet per mile (RRPC *et al.*, 2005).

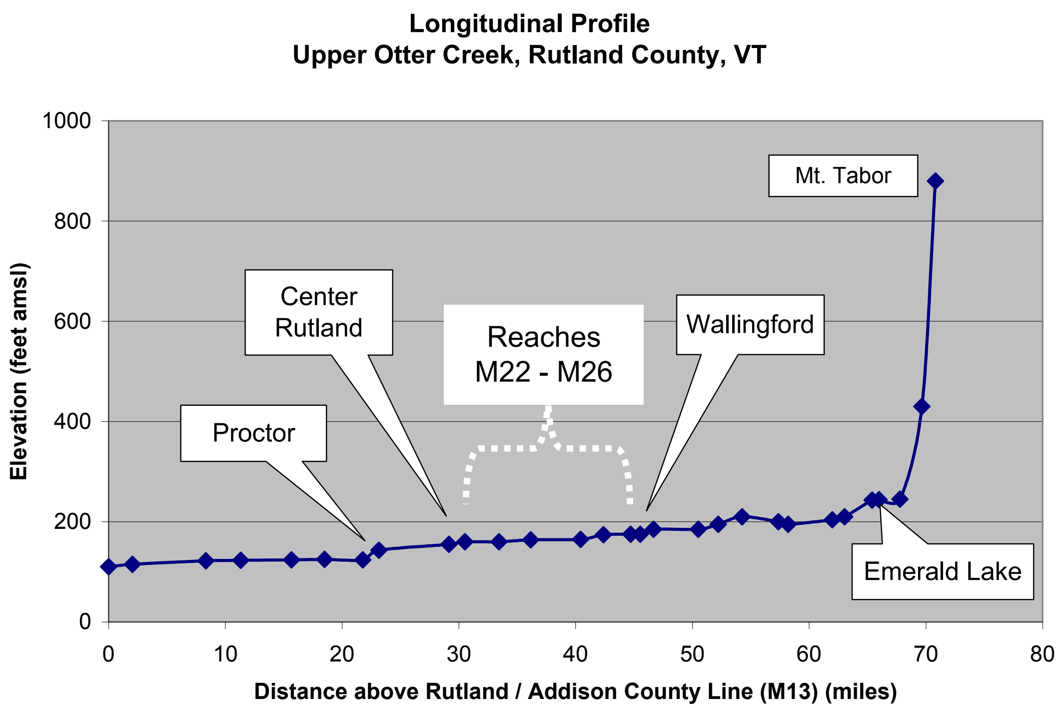
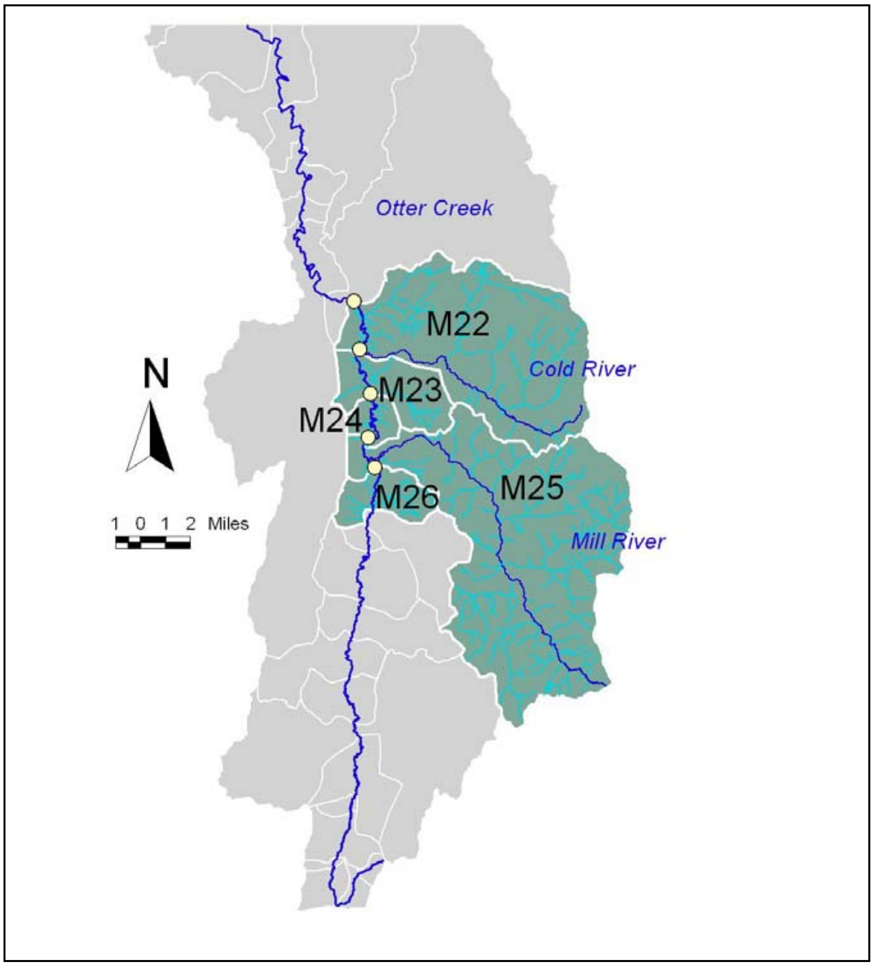


Figure 2. Longitudinal Profile of Upper Otter Creek Main Stem.



Reach	Channel Length (ft)	Channel Slope (%)	Total Upstream Drainage Area (sq mi)
M26	12,278	0.01	110.1
M25	10,369	0.09	183.7
M24	22,541	0.00	186.9
M23	14,331	0.03	196.6
M22	15,383	0.00	244.9

Figure 3. Location of reaches selected for Phase 2 Stream Geomorphic Assessments on Upper Otter Creek main stem, Clarendon & Rutland, Vermont.

2.4 Hydrology

The United States Geological Survey (USGS) operates a flow gage on the Otter Creek just downstream of the assessed reaches (see Figure 4).

- Station #04282000 is located approximately 200 feet downstream of the Center Rutland dam and 500 ft upstream of the Business Route 4 bridge (Reach M21). The gage measures flow from an approximate drainage area of 308 square miles (or the upper 35% of the Otter Creek watershed). This station has daily flow records dating back to 1928, or approximately 77 years. The maximum peak flow recorded during this period was 13,700 cubic feet per second (cfs) on 22 September 1938; the corresponding daily mean flow for this date was 10,100 cfs (USGS, 2006). This gaging station was not operational during the flood of 1927, the highest flood on record for the state of Vermont (USGS, 1990).

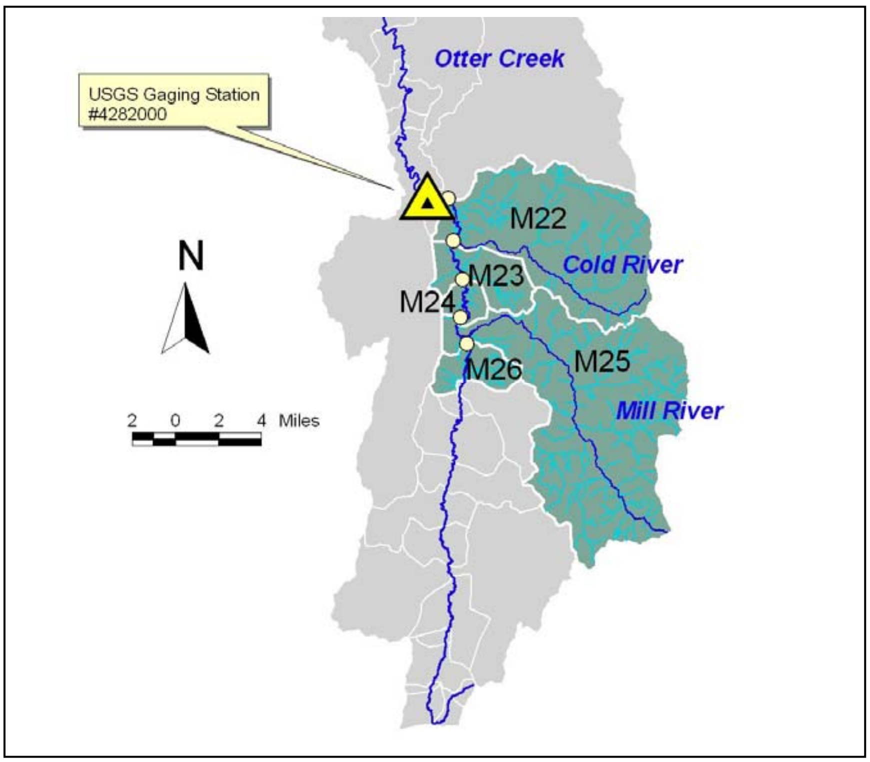


Figure 4. Location of USGS Gaging Station #4282000
Otter Creek at Center Rutland, VT.

From 77 years of record existing for this gaging station, USGS (Olson, 2002) has estimated the approximate magnitude of peak flows for the Center Rutland station (Table 1).

Table 1. Estimated flood magnitudes for Upper Otter Creek main stem

	USGS Stn #	4282000
	USGS Description	Otter Creek at Center Rutland, VT
	USGS Period of Record	1928 - present
	Upstream Dr. Area (sq mi)	308
	Geomorphic Reach	M21
Magnitude	**Data Source**	**Discharge (cfs)**
Q_2	*(Olson, 2002)*	5,370
Q_5		7,490
Q_{10}		8,890
Q_{25}		10,700
Q_{50}		12,000
Q_{100}		13,300
Q_{500}		16,300

From the actual record for this gage, it can be seen that the Otter Creek has experienced a few large floods in the previous 77 years (see Figure 5). The September 1938 flood was a 100-year magnitude event, while the more recent flood events of 1987 and 1973 were estimated as 25-year events.

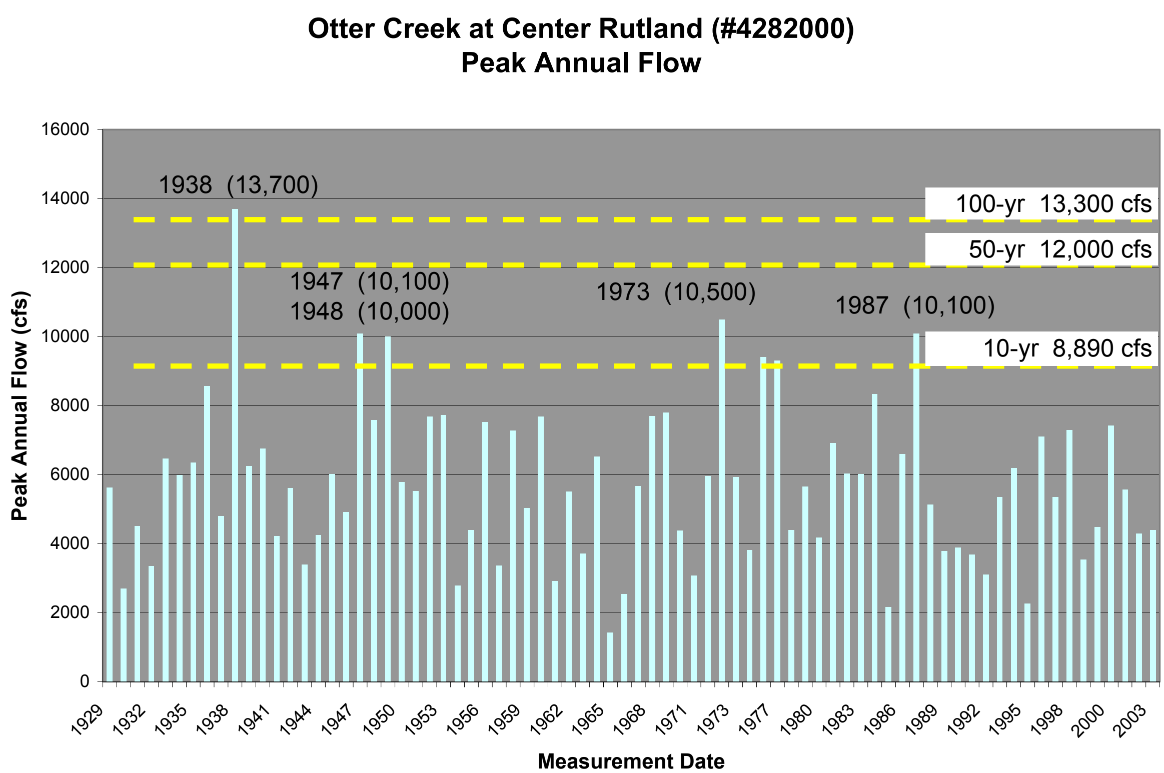


Figure 5. Recorded Peak Flows for Otter Creek at Center Rutland Gage Station #04282000 (compared to estimated flood peaks after Olson, 2002)

Phase 2 Stream Geomorphic Assessments were completed between 5 November 2005 and 29 November 2005. Daily mean flows measured at the Center Rutland gage during this time period ranged from a minimum of 742 cfs to a maximum of 2,190 cfs based on provisional data available from USGS (USGS, 2006). October and November of 2005 were wet months with repeated rain storms. Assessments were conducted between near-bankfull flow events during moderate flow conditions. Ideally, assessments would be conducted during low-flow events, and the high-water-level conditions encountered during assessment work obscured certain streambank and bed features below water level. Assessment data were supplemented by field observation data recorded during a fall of 2004 buffer assessment (Solomon, 2005). Flows in the fall of 2005 can be compared to flows in fall of the previous year on Figure 6.

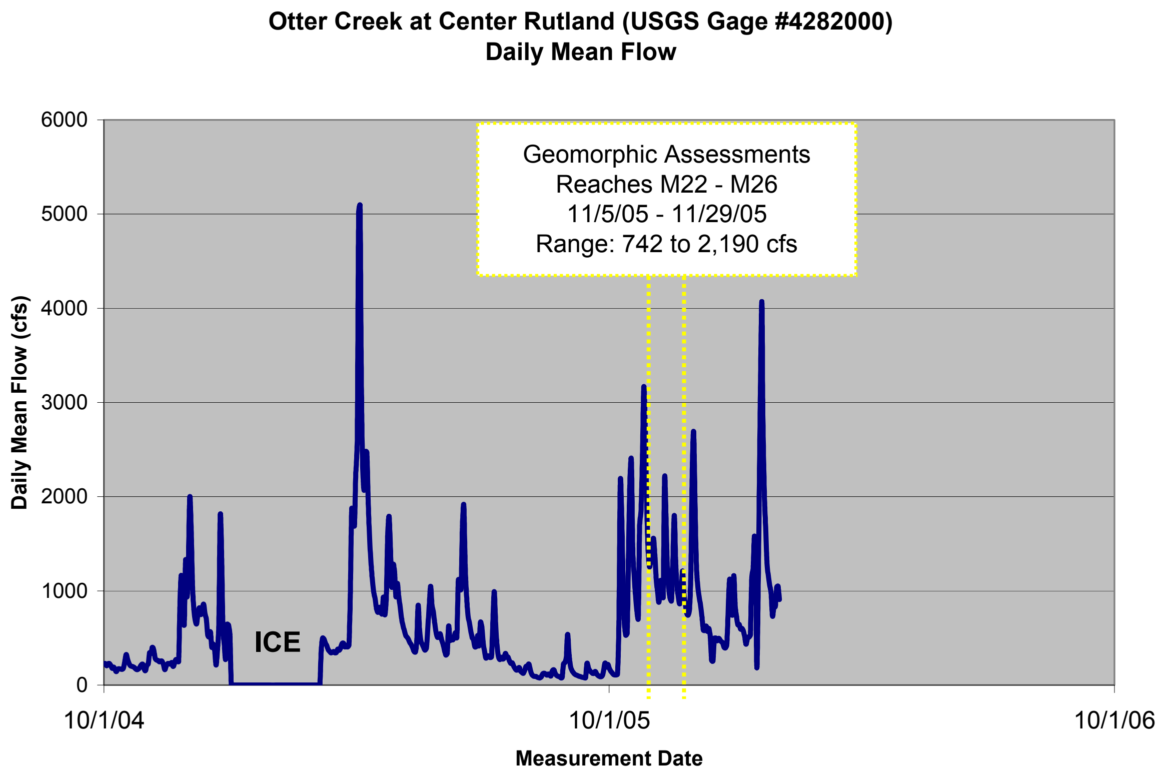


Figure 6. Provisional Daily Mean Discharges for Otter Creek, Center Rutland Gage Station #04282000, during Phase 2 Stream Geomorphic Assessments, 11/5/2005 through 11/29/2005.

3.0 ASSESSMENT METHODOLOGY

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 human disturbances to the watershed and channel over time and the composite response or adjustment of the channel to these stressors. Reference is made to VTANR Stream Geomorphic Assessment protocols (VTANR, 2005) for the specific assessment methods.

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.

In accordance with protocols, specific features were digitized in ArcView© 3.x shape files, including cross section locations, grade control locations, and others. Phase 2 assessment data were entered into the online Data Management System (DMS) maintained by the Vermont Department of Environmental Conservation, Water Quality Division.

Assessments were performed under a programmatic Quality Assurance Project Plan (QAPP) generated by the Vermont Water Quality Division, River Management Section (VTDEC WQD, 2003).

4.0 PHASE 2 ASSESSMENT RESULTS

Detailed Phase 2 assessment results are tabulated in Appendix A, the standard report output from the online Data Management System for Phase 1 & 2 stream geomorphic assessment data. Major channel and geographic features are noted on orthophotograph base maps of each reach in Appendix B. Orthophotograph coverage for the study area is dated 1994. Results for the five main stem reaches are summarized below in Table 2 from upstream (M26) to downstream (M22).

Table 2. Results of Phase 2 Geomorphic Assessments, Upper Otter Creek Main Stem

Otter Creek Main Stem - Clarendon, Rutland

Reach	Seg-ment	Channel Length (ft)	Channel Slope (%)	Drainage Area (sq mi)	Stream Type	RHA Condition	RGA Condition	Adjustment	Stream Type Departure?	Sensitivity
M26	B	2,330	--	--	C4-R/P	0.66 Good	0.71 Good	Aggrad, Wid, PF (local)	No	High
	A	9,948	0.01	110.1	E4-PB	0.56 Fair	0.70 Good	Aggrad, PF (minor)	No	High
M25	--	10,369	0.09	183.7	E5-PB	0.63 Fair	0.69 Good	Wid, PF (minor)	No	High
M24	--	22,541	0.00	186.9	E5-PB	0.63 Fair	0.69 Good	PF (meand migr)	No	High
M23	--	14,331	0.03	196.6	E5-R/D	0.64 Fair	0.80 Good	Wid, PF (minor)	No	High
M22	--	15,383	0.00	244.9	E5-R/D	0.68 Good	0.85 Ref	None (meand migr)	No	High

Abbreviations:
S/P = Step/Pool; R/P = Riffle/Pool; R/D = Ripple/Dune; PB = Plane Bed; Casc = Cascade; Ref = Reference
RHA = Rapid Habitat Assessment; RGA = Rapid Geomorphic Assessment (VTDEC, 2005).
PF = Planform Adjustment; Aggrad = Aggradation; Wid = Widening; NM = Not Measured.

The five assessed reaches extend through a broad and gentle-gradient alluvial valley between the bedrock-controlled valley pinch-points in Wallingford and Rutland City. Where alluvial fans (and ancient delta deposits) at the locations of the Mill River confluence (M25) and the Cold River confluence (M22) join the valley from the east, the Otter Creek main stem is positioned along the west valley wall.

The valley setting suggests a reference stream type of E5-dune/ripple. Field measurements generally confirmed this stream type. A plane-bed form was noted on occasion in the upper reaches; however, high water levels and minor turbidity limited visual observations during the assessment dates. A subreach of M26 exhibited C-stream type conditions where the channel transitioned out of the narrow bedrock-controlled valley of upstream reach M27.

Floodplain encroachment by residential and commercial development along the river valley is relatively minor, limited primarily to the valley edges. Agricultural crops, fields and pastures are prevalent within the river corridor. Woody buffers are absent in select locations along the channel margins. Encroachment by roads and a railroad has constrained the valley width somewhat in the upstream reach, M26.

A history of channelization in some sections is suggested by the linear planform extending for distances greater than 20 times the channel width. Straightening is also suggested by lower than regime meander belt widths (particularly, reaches M22, M23, and M25) measured during the Phase 1 assessment (RRPC *et al.,* 2005). Straightening was inferred along four of the five reaches (Table 3). This channelization, where it occurred, appears to pre-date the 1940s, since the Otter Creek today has much the same planform (position in the valley) as is visible on 1940s and 1960s aerial photographs.

Table 3. Percent Straightening along Upper Otter Creek main stem

Reach	% Straightening
M26	33%
M25	60%
M23	56%
M22	72%

Source: RRPC *et al.,* 2005

Berms were observed along short lengths of two reaches (M22: 250 ft and M24: 60 ft). Armoring (rip-rap) was noted to a minor degree in each of the five reaches, ranging from 4% to 17% of the reach. It should be noted, however, that the high water conditions during assessments may have prevented observation of some channel armoring. Armoring is noted by an alternating black and white line on reach maps in Appendix B.

Buffers consisting of mature trees with occasional shrubs were dominantly 5 to 25 feet in width along the five study area reaches. There were intermittent sections of streambank without woody buffers, where active streambank erosion and sloughing were typically noted. Table 4 lists lengths of erosion recorded with a GPS along left bank (LB) and right bank (RB), facing downstream. Erosion is noted by a red stippled line on reach maps in Appendix B.

Table 4. Erosion measured along Upper Otter Creek main stem reaches, November 2005 geomorphic assessment.

Reach	Bank	Erosion Length (ft)	Reach Length (ft)	Reach Percent (%)
M26	LB	1,574	12,278	12.8%
	RB	2,248		18.3%
M25	LB	3,730	10,369	36.0%
	RB	3,198		30.8%
M24	LB	7,045	22,541	31.3%
	RB	7,624		33.8%
M23	LB	2,830	14,331	19.7%
	RB	4,199		29.3%
M22	LB	984	15,383	6.4%
	RB	1,726		11.2%

Figure 7. Bank erosion noted typically along channel sections without tree buffers.

Despite the apparent history of channelization in the study area between Wallingford and Rutland City, the Otter Creek channel appears fairly stable and is not exhibiting excessive adjustments, or a substantial departure from reference conditions. Cross section measurements indicate excellent floodplain access throughout the five reaches. No signs of channel incision were noted during assessments.

Presence of less erodible lake silts and clays at depth below a veneer of more erodible alluvial sands may account for the lack of expected channel incision. The tendency for channel incision in response to past channelization may also have been offset by aggradation from in-stream and up-watershed sources.

Minor degrees of aggradation, widening and planform adjustment were noted in the study area. These are natural and ongoing processes in a self-adjusting alluvial channel like the Otter Creek. An equilibrium or balanced condition of the channel does not imply that a channel remains in one fixed position over time. Rivers are continuously adjusting their position in the landscape, their slope, and channel dimensions in response to continuously fluctuating volumes of water, sediment and debris. Rather, the concept of dynamic equilibrium implies that a channel will have the capacity to move the sediments and water loads supplied to it, with no net change in average planform characteristics, average slope, or average channel dimensions over time.

The channel widening, aggradation, and plan form adjustments observed along the Upper Otter Creek study area do not appear to be the result of system-wide imbalances. Rather, accelerated channel adjustments are localized in nature and appear to be largely coincident with locations of:

- undersized bridges or old abutments;
- areas of absent buffers;
- and debris jams in areas of beaver activity.

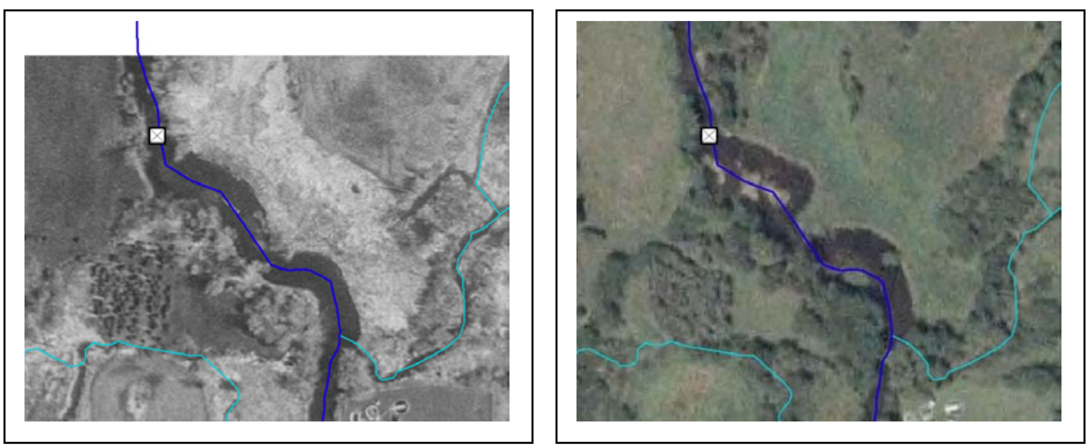
Eight bridge crossings and four old abutment pairs of laid-up stone were encountered on the 14.2 river miles assessed (Table 5). Eight of these structures are bankfull constrictors, meaning that they have a narrower span than the width of the bankfull channel measured at the closest upstream or downstream crossing. One bridge near the upstream end of reach M26 is unusually constricting, measuring only 34% of the bankfull width. Sediments have accumulated upstream of this constricting bridge crossing forming a series of mid-channel bars. Flows in the channel are diverted around the sediment bars and have accelerated meander extensions on the north side (right bank) of the channel (Figure 8).

Table 5. Crossing structures and old abutments encountered along Upper Otter Creek main stem, November 2005 geomorphic assessment. (in order from upstream to downstream)

Reach	Type	Road	Approx. Span (ft)	Constriction Status
M26	bridge	Farm Road	24	BKFL
M26	old abutment	None	NM *	BKFL
M26	old abutment	None	45	BKFL
M26	collapsed steel bridge	None	NM *	BKFL
M25	old abutment	None	43	BKFL
M24	steel bridge	Walker Mountain	85	BKFL
M23	steel bridge	Alfrecia Road	117.8	FPW
M23	iron bridge	Farm Road	67	BKFL
M22	steel bridge	Route 4 Highway	NM **	FPW
M22	steel bridge	Route 4 Highway	NM **	FPW
M22	old abutment	None	60	BKFL
M22	steel bridge	River Street	190	FPW

Abbreviations:
BKFL = span narrower than bankfull width measured at adjacent cross sections
FPW = span narrower than floodprone width measured at adjacent cross sections
NM = Not Measured

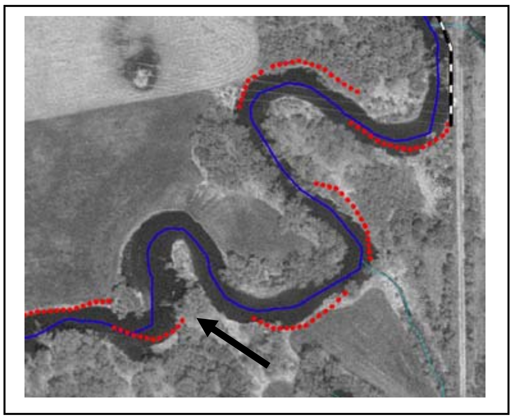
Notes:
** Constriction status inferred from abutments positioned jutting into the channel.*
** Constriction status inferred from visual observation and GIS measurement.*



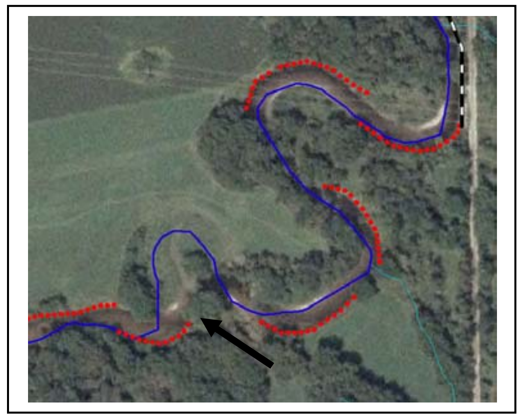
(a) 1994 *(b) 2003*

Figure 8. M26. Site of undersized bridge span causing upstream sedimentation, and accelerated meander migration. (Flow direction is to the northwest – from bottom right to upper left on the images.)

Accelerated meander extension was noted at several locations along the Upper Otter Creek valley, coincident with gaps in the woody riparian buffer. Occasionally, a meander will grow and move until the bend becomes too tortuous for the river to pass through, and the neck of the meander will be cut off in the next flood event (or a series of flood events). Comparison of the 1994 orthophotos with 2003 aerial imagery revealed a few examples of recent and pending neck cutoffs in the study area (see Figure 9). Where possible, these gaps in the buffer can be filled in by tree and shrub plantings. As the shrubs and trees establish themselves, the root systems will hold the erodible alluvial soils along the channel margins and offer roughness elements to slow the erosive power of the river; streambank erosion will be reduced and nutrient and sediment loading to the river will be reduced over the long term.



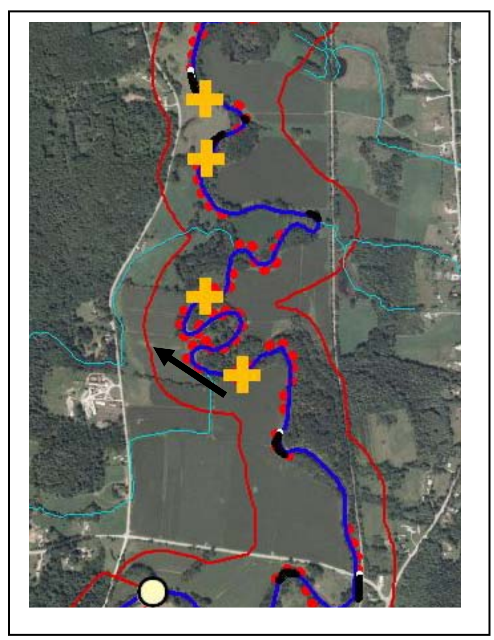
(a) 1994



(b) 2003

Figure 9. M24. Site of neck cutoff occurring between 1994 and 2003 (at arrow). (Flow direction is to the northeast – from bottom left to upper right on the images.)

Figure 10. (above). Active beaver chews in reach M24 downstream (north) of the Walker Mountain Road are coincident with high density of Large Woody Debris in the channel. Orange crosses on base map (right) are locations of channel-spanning debris jams encountered in November 2005.



Habitat conditions assessed by the Rapid Habitat Assessment (Step 6 of Phase 2 protocols) for the five reaches of the Upper Otter Creek main stem ranged from Fair to Good. Those reaches in Fair condition were at the high end of Fair, on the cusp with Good.

A reasonable diversity of pools and epiphaunal substrates was observed. Woody buffers, although narrow (5 to 25 ft) and not continuous, were prevalent along the reaches. The trees offer large woody debris and detritus to the channel, providing organic matter to fish and other aquatic organisms. Incorporation of large woody debris in the channel margins also provides local scour pools and substrates for epiphaunal growth.

5.0 Summary and Discussion

Phase 1 and Phase 2 assessment results have begun to characterize the watershed and channel stressors to the Upper Otter Creek main stem reaches 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 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 Upper Otter Creek main stem between Wallingford and Rutland City (Table 6). 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 human disturbance to the watershed, that has caused variable and overlapping adjustment responses in the channel.

Table 6. Summary of Watershed and Channel Stressors in Study Area Reaches. Upper Otter Creek Watershed, 2005 Stream Geomorphic Assessment.

Stressors	M22	M23	M24	M25	M26
Watershed					
deforestation in 1800s					
Road / Railroad Networks (1700s, 1800s)					
Flood events (1927, 1938, 1947, 1948, 1973, 1987)	→	→	→	→	→
Sediment contributions from Mill and Cold Rivers					
Upland development					
Channel - Reach Scale					
Channelization / Straightening	√	√		√	√
Dredging					
Berming	√		√		
Bank Armoring	√	√	√	√	√
Floodplain Encroachment	√	√	√	√	√
Loss of Forested Buffers	√	√	√	√	√
Impoundment (dam)					
Channel - Site Scale					
Gravel extraction					
Undersized Crossing Structure/ Abutments	√	√		√	√
Ford					

5.2 Dominant Adjustment Processes and Reach Sensitivity

Rivers respond to stressors through adjustment of their dimensions, planform, and profile. Adjustments occur to varying degrees, depending on many 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 to continuing and future stresses.

Sensitivities of the study area reaches as defined in VTANR protocols (2005) are presented in Table 7.

Table 7. Reach Sensitivity, Upper Otter Creek Watershed, 2005 Stream Geomorphic Assessments.

Tributary	Reach	Sensitivity
Upper Otter Creek Main Stem	M26	High
	M25	High
	M24	High
	M23	High
	M22	High

The High sensitivity of the five reaches is imparted by the inherent sensitivity factors of a shallow-gradient, broad-valley setting and highly erodible (alluvial) sands along the channel margins. Were these type E channels exhibiting more significant channel adjustments leading to a moderate or severe departure from expected reference conditions, they would have been classified as having Very High or Extreme sensitivity. Since the reaches were not exhibiting major adjustments or system-wide imbalances, and they were in Good to Reference condition, they have been classified as having High sensitivity to future channel and watershed stressors.

The inherent sensitivity of the geologic setting means that these study reaches are still vulnerable to future sediment or hydrologic changes from upstream and upwatershed sources. Future stressors could easily "tip the balance" for the Otter Creek main stem. Of particular concern is the current geomorphic condition of the Mill River and Cold River tributaries. Excessive sediment contributions and an apparent reduction in sediment transport capacity are noted in the vicinity of the Mill River confluence with the Otter Creek (Figure 11).

Figure 11. Excessive sedimentation in the Mill River near the confluence with Otter Creek in reach M22.

5.3 River Corridor Management Strategies

Landowners, community members, and resource agencies, including the Rutland 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. There are a variety of potential management strategies that are appropriate for the Upper Otter Creek main stem between Wallingford and Rutland, based on the present geomorphic condition and sensitivity of these reaches. These strategies define a passive geomorphic approach to corridor management.

A passive geomorphic approach involves long-term management and preservation of the river corridor. Floodplain access for the river can be maintained by protecting the corridor from future development and filling, and refraining from channel management activities that tend to cause a channel to become disconnected with its floodplain (e.g., channelization, dredging, berming). The channel is allowed to adjust unrestrained to a more sinuous, meandering planform closer to regime conditions. Through lateral adjustments, the river will continue to adjust its slope and channel dimensions for optimum conveyance of its water and sediment loads. Generally speaking, the river can achieve a sustainable and balanced planform, profile and channel geometry more successfully and much more cheaply than humans engaged in a series of active channel restoration projects.

Preservation of sediment attenuation areas along the river network is an important element in the passive geomorphic approach. In the case of the Upper Otter Creek main stem, the focus on developing sediment attenuation areas would be most effective in the upland watershed areas draining to the Otter Creek valley. In particular, along the Cold River and Mill River networks. Several wetland areas and valley settings contiguous to these tributaries have been preliminarily identified through remote sensing for the potential role they could serve in sediment and nutrient attenuation. With the willingness of landowners, these sites may be good candidates for conservation, particularly where existing land uses do not appear to be in conflict with channel adjustment processes. These potential sites are compiled in Appendix E; this list is provisional and requires ground-truthing and landowner outreach to determine if these sites would in fact be effective attenuation areas.

Within a passive geomorphic approach, preservation and enhancement of forested riparian buffer areas along the channel margins should continue to be pursued. Buffers serve to improve water quality through filtering and nutrient uptake. Forested buffers offer roughness elements to the channel margins and near bank areas, helping to dissipate the erosive energies of flood waters and contributing to greater flow and sediment attenuation in the floodplain. Thus, buffers will help to restore and maintain dynamic equilibrium of the channel by increasing resistance to shear stresses along the channel boundaries. Tree buffers will provide the additional benefits of organic matter, detritus, and LWD to aquatic and riparian habitats. Connectivity of buffer areas from reach to reach along a river network also provides for wildlife corridors, thereby supporting mammalian terrestrial habitats.

6.0 RECOMMENDATIONS

To protect and enhance the current condition of the Upper Otter Creek main stem, and to minimize future stressors to the Creek, efforts on several fronts can be undertaken. The following recommendations are offered based upon the results of this Phase 2 Stream Geomorphic Assessment:

1) Gaps in the wooded riparian buffers along the channel margins should be continue to filled and improved. Willing landowners can receive technical and financial assistance working with partners such as the Rutland NRCD, Partners for Wildlife Program (US Fish & Wildlife), Natural Resources Conservation Commission (CRP, CREP, EQIP), VT Agency of Agriculture, Wallingford Conservation Commission and others.

2) Contingent upon landowner(s) willingness, an alternatives analysis should be completed to investigate the cost-benefit of removing the undersized bridge at the upstream end of reach M26 just downstream of the Wastewater Treatment Facility. It is unknown what current function this bridge provides, or whether its removal or replacement would impose undue burden on the landowner(s). The bridge is a constrictor of flows and appears to be causing localized channel instabilities resulting in significant streambank erosion and loss of adjacent agricultural lands. Depending on the nature of the project, technical and financial assistance may be available from partner agencies including Natural Resources Conservation Commission (CRP, CREP, EQIP), VT Agency of Agriculture, Partners for Wildlife Program (US Fish & Wildlife), and/or the VTDEC River Management Section.

3) Geomorphic principles should be considered in community planning on several fronts both in Clarendon and Rutland, but more importantly in up-watershed communities such as Wallingford, Mount Holly and Shrewsbury:

    a. Development – future development in upstream communities should utilize best management practices to reduce sedimentation during construction phases. Development should incorporate low impact design features to minimize stormwater runoff to receiving streams.

    b. Bridge and Culvert crossings - In future, new or replacement crossing structures over the Otter Creek and its tributaries, should ideally be sized to have openings which pass the bankfull channel without constriction. Ongoing vertical and lateral adjustments of channels should be considered when installing new or replacement crossing structures, and when constructing new roads, driveways, and buildings.

    c. Road Maintenance - Road ditch runoff should be divert to side-slopes where energy can be dissipated, stormwaters can infiltrate, and sediment loads can be deposited on the land and not directly to streams. Substantial technical and financial resources are now available to towns for training, capital budget planning, and road maintenance projects through the Better Backroads Programs http://www.anr.state.vt.us/cleanandclear/bbroads.htm

4) Phase 1 and 2 geomorphic assessments on the Cold and Mill Rivers should be undertaken to understand the current geomorphic condition and adjustment processes ongoing in these major tributaries. To date, the condition of the Otter Creek main stem in reaches receiving theses discharges does not appear to be in significant adjustment. However, the Otter Creek main stem remains highly sensitive to potential changes in or imbalances of sediment and hydrologic loading from these major tributaries.

5) Wetland areas contiguous to the channel and other low-gradient in-channel areas in the upland tributary watersheds draining to the Upper Otter Creek main stem should be identified and further assessed to determine the possible functions they may serve for sediment and nutrient attenuation. Significant financial and technical resources are now available to support landowners who would be willing to evaluate possible wetland restoration and conservation projects in these locations.

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APPENDIX A

Phase 2 Stream Geomorphic Assessment Results

Project: Upper Otter Creek

Phase 2 Reach Summary

March 1, 2006

Stream: **Upper Otter Creek** Reach # **M26** Segment: **B** Completion Date: **November 4, 2005**

Organization: **Rutland NRCD** Observers: **KLU, HS** Rain: **Yes**

Segment Length (ft): **2,330** Segment Location: **Upstream 2330 feet of reach M26 extending from approximately 700 feet upstream to 1500**

Step 1. Valley and Floodplain

1.1 Watershed Zone **Response**

1.2 Alluvial Fan **No**

1.3 Corridor Encroachments

Length (ft)	Left	Right
Berms	0	0
Roads	0	0
Railroads	0	490
Improved Paths	0	660
Development	170	240

1.4 Adjacent Side

	Left	Right
Hillside Slope	Steep	Steep
Continuous w/	Sometimes	Sometimes
W/in 1 Bankfill	Sometimes	Sometimes
Texture	Not Evalua	Not Evalua

1.5 Valley Features

Valley Width (ft) **300**

Confinement Type **Semi-confined**

Rock Gorge? **No**

Human-caused change - valley width? **Yes**

1.6 Grade Controls

Data not displayed due to problem with report.

Step 2. Stream Channel

2.1 Bankfill Width (ft)

2.2 Max Depth (ft)

2.3 Mean Depth (ft)

2.4 Floodprone Width

2.5 Low Bank Height

2.6 Width/Depth

2.7 Entrenchment

2.8 Incision Ratio

2.9 Sinuosity

2.10 Riffles Type

2.11 Riffle/Step Spacing

2.12 Substrate Composition

Silt/Clay Present? **Yes**

Detritus **0.0** %

Large Woody **5**

2.13 Average Largest Particle

Bed

Bar

2.14 Stream Type

E

Is a sub-reach? **Yes**

2.15 Reference Stream Type

(if different from Phase 1)

C 4 c Riffle-Pool

Step 3. Riparian Features

3.1 Stream Banks

Typical Bank **Steep**

Bank Texture	Lower	Upper
Material Type	Sand	Sand
Consistency	Cohesive	Cohesive

Bank Erosion	Left	Right
Erosion Length	0	545
Erosion Height	0.0	3.0
Revetmt. Type	Rip-rap	Rip-rap
Revetmt. Length	350	172

Near Bank Veg.	Left	Right
Dominant	Shrubs/Saplin	Shrubs/Saplin
Sub-dominant	Deciduous	Deciduous

Bank Canopy	Left	Right
Canopy	26-50	26-50
Mid-Channel	Open	

3.2 Riparian Buffer

Buffer Width	Left	Right
Dominant	26-50	>100
Sub-dominant	>100	26-50

Buffer Veg. Type	Left	Right
Dominant	Deciduous	Deciduous
Sub-dominant	Herbaceous	Herbaceous

3.3 Riparian Corridor

Corridor Land	Left	Right
Dominant	Crop	Forest
Sub-dominant	Forest	Pasture
Mass Failures	None	
Mean Failure	0.0	

Brief subreach of C-stream type at upstream end of reach. Cross section / pebble count prevented by high water conditions and fast velocities. Straightening (historic) inferred from linear planform and encroachment of roads / railroad along LB / RB.

Step 4. Flow & Flow Modifiers

4.1 Springs / Seeps **Some**

4.2 Adjacent Wetlands **Some**

4.3 Flow Status **High**

4.4 # of Debris Jams **0**

4.5 Impoundments **None**

Impoundmt. Location

4.6 # of Stormwater **0**

4.7 Upstream Flow **None**

4.9 # of Beaver Dams **0** **0** ft

4.8 Channel Constrictions

Data not displayed due to problem with report.

Step 5. Channel Bed and Planform Changes

5.1 Bar Types

Mid	Point	Side
Multiple	Single	None
Diagonal	Delta	Island
None	None	None

5.2 Other Features

Flood Chute	Neck Cutoff	Chan. Avulsion	Braiding
Multiple	None	None	None

5.3 Steep Riffles and Head Cuts

Steep Riffles	Head Cuts	Trib Rejuv.
None	None	No

5.4 Stream Ford or Animal **No**

5.5 Channel Alterations **Straightenin**

Project:	Upper Otter Creek				March 1, 2006
Stream:	**Upper Otter Creek**	Reach #	**M26**	Segment: **A**	Completion Date: **November 4, 2005**
Organization:	**Rutland NRCD**	Observers:	**KLU, HS**		Rain: **Yes**
Segment Length (ft):	**9,948**	Segment Location:	**From segment break approximately 1500 feet downstream of Wallingford WWTF,**		

Phase 2 Reach Summary

Step 6. Rapid Habitat Assessment Data

Stream Gradient Type **Low**

	Score
6.1 Epifaunal Substrate - Available	**8**
6.2 Pool Substrate	**13**
6.3 Pool Variability	**15**
6.4 Sediment Deposition	**16**
6.5 Channel Flow Status	**18**
6.6 Channel Alteration	**8**
6.7 Channel Sinuosity	**8**
6.8 Bank Stability	**Left: 7 Right: 7**
6.9 Bank Vegetation Protection	**Left: 4 Right: 4**
6.10 Riparian Vegetation Zone Width	**Left: 2 Right: 3**
Total Score	**113**
Habitat Rating	**0.565**
Habitat Stream Condition	**Fair**

Step 7. Rapid Geomorphic Assessment Data

Confinement Type **Unconfined**

	Score	STD	Historic
7.1 Channel Degradation	**16**	**None**	**No**
7.2 Channel Aggradation	**13**	**None**	**No**
7.3 Widening Channel	**16**		**No**
7.4 Change in Planform	**11**		**No**
Total Score	**56**		
Geomorphic Rating	**0.7**		

Channel Evolution Model	
Channel Evolution Stage	**I**
Geomorphic Condition	**Good**
Stream Sensitivity	**High**

Narrative:

PF adjust, wid, & aggrad (localized to undersized crossings, and minimal buffers). If hist straight (inferred from linear PF & rr) resulted in incis, it was v min in extent. Mod. by silts in chann bed or offset by simult. aggrad fr u/s erosion.

March 1, 2006

Phase 2 Reach Summary

Project: Upper Otter Creek
Stream: Upper Otter Creek — Reach # M26 — Segment: A — Completion Date: **November 4, 2005**
Organization: **Rutland NRCD** — Observers: **KLU, HS** — Rain: **Yes**
Segment Length (ft): **9,948** — Segment Location: **From segment break approximately 1500 feet downstream of Wallingford WWTF,**

Step 1. Valley and Floodplain

1.1 Watershed Zone **Response**
1.2 Alluvial Fan **No**

1.3 Corridor Encroachments

Length (ft)	Left	Right
Berms	0	0
Roads	0	3600
Railroads	0	4520
Improved Paths	0	0
Development	190	1230

1.4 Adjacent Side

	Left	Right
Hillside Slope	Steep	Steep
Continuous w/	Sometimes	Sometimes
W/in 1 Bankfill	Sometimes	Sometimes
Texture	Not Evalua	Not Evalua

1.5 Valley Features

Valley Width (ft)	600
Confinement Type	Broad
Rock Gorge?	No
Human-caused change - valley width?	Yes

1.6 Grade Controls

Data not displayed due to problem with report.

Step 2. Stream Channel

2.1 Bankfill Width (ft)	70.8
2.2 Max Depth (ft)	8.5
2.3 Mean Depth (ft)	7.0
2.4 Floodprone Width	350.0
2.5 Low Bank Height	8.5
2.6 Width/Depth	10.1
2.7 Entrenchment	4.9
2.8 Incision Ratio	1.0
2.9 Sinuosity	Low
2.10 Riffles Type	Not
2.11 Riffle/Step Spacing	

2.12 Substrate Composition

Bedrock	0.0 %
Boulder	0.0 %
Cobble	0.0 %
Coarse Gravel	0.0 %
Fine Gravel	100.0 %
Sand	0.0 %
Silt/Clay Present?	Yes
Detritus	0.0 %
# Large Woody	50

2.13 Average Largest Particle

Bed **15** mm
Bar mm

2.14 Stream Type

E 4 Non Plane Bed

Is a sub-reach? **No**

2.15 Reference Stream Type
(if different from Phase 1)

Step 3. Riparian Features

3.1 Stream Banks

Typical Bank	Steep	
Bank Texture	Lower	Upper
Material Type	Silt/Clay	Sand
Consistency	Cohesive	Cohesive
Bank Erosion	Left	Right
Erosion Length	1574	1703
Erosion Height	3.0	3.0
Revetmt. Type	Rip-rap	Rip-rap
Revetmt. Length	104	107
Near Bank Veg.	Left	Right
Dominant	Herbaceous	Herbaceous
Sub-dominant	None	None
Bank Canopy	Left	Right
Canopy	1-25	1-25
Mid-Channel	Open	

3.2 Riparian Buffer

Buffer Width	Left	Right
Dominant	5-25	5-25
Sub-dominant	None	None
Buffer Veg. Type	Left	Right
Dominant	Deciduous	Deciduous
Sub-dominant	Herbaceous	Herbaceous

3.3 Riparian Corridor

Corridor Land	Left	Right
Dominant	Crop	Forest
Sub-dominant	None	Pasture
Mass Failures	None	
Mean Failure	0.0	

Cross section / pebble count limited by high water conditions and fast velocities. Likely some % of sand (not able to be quantified) but fine gravel appears dominant from visual estimate. Straightening (historic) inferred from linear planform and close encroachment of railroad along

Step 4. Flow & Flow Modifiers

4.1 Springs / Seeps	Some
4.2 Adjacent Wetlands	Some
4.3 Flow Status	High
4.4 # of Debris Jams	1
4.5 Impoundments	None
Impoundmt. Location	
4.6 # of Stormwater	0
4.7 Upstream Flow	None
4.9 # of Beaver Dams	0 0 ft

4.8 Channel Constrictions

Data not displayed due to problem with report.

Step 5. Channel Bed and Planform Changes

5.1 Bar Types

Mid	Point	Side
Multiple	None	None
Diagonal	Delta	Island
None	None	None

5.2 Other Features

Flood Chute	Neck Cutoff	Chan. Avulsion	Braiding
Multiple	None	None	None

5.3 Steep Riffles and Head Cuts

Steep Riffles	Head Cuts	Trib Rejuv.
None	None	No

5.4 Stream Ford or Animal **No**
5.5 Channel Alterations **Straightenin**

Project:	Upper Otter Creek		March 1, 2006
Stream:	**Upper Otter Creek**	Reach # **M25**	Segment: **0**
Organization:	**Rutland NRCD**	Observers: **KLU, HS**	

Phase 2 Reach Summary

Stream: **Upper Otter Creek** — Reach # **M25** — Segment: **0** — Completion Date: **November 4, 2005**

Organization: **Rutland NRCD** — Observers: **KLU, HS** — Rain: **Yes**

Segment Length (ft): **10,369** — Segment Location: **From just upstream of the Mill River confluence, downstream to the vicinity of the Creek**

Step 6. Rapid Habitat Assessment Data

Stream Gradient Type **Low**

	Score
6.1 Epifaunal Substrate - Available	**8**
6.2 Pool Substrate	**15**
6.3 Pool Variability	**16**
6.4 Sediment Deposition	**15**
6.5 Channel Flow Status	**18**
6.6 Channel Alteration	**13**
6.7 Channel Sinuosity	**8**
6.8 Bank Stability	**Left: 5 Right: 5**
6.9 Bank Vegetation Protection	**Left: 7 Right: 7**
6.10 Riparian Vegetation Zone Width	**Left: 7 Right: 2**
Total Score	**126**
Habitat Rating	**0.63**

Habitat Stream Condition **Fair**

Step 7. Rapid Geomorphic Assessment Data

Confinement Type **Unconfined**

	Score	STD	Historic
7.1 Channel Degradation	**16**	**None**	**No**
7.2 Channel Aggradation	**15**	**None**	**No**
7.3 Widening Channel	**13**		**No**
7.4 Change in Planform	**11**		**No**
Total Score	**55**		
Geomorphic Rating	**0.6875**		

Channel Evolution Model

Channel Evolution Stage **I**

Geomorphic Condition **Good**

Stream Sensitivity **High**

Narrative:

Widening, PF (localized)

Project: Upper Otter Creek

Phase 2 Reach Summary

March 1, 2006

Stream: **Upper Otter Creek** Reach # **M25** Segment: **0** Completion Date: **November 4, 2005**

Organization: **Rutland NRCD** Observers: **KLU, HS** Rain: **Yes**

Segment Length (ft): **10,369** Segment Location: **From just upstream of the Mill River confluence, downstream to the vicinity of the Creek**

Step 1. Valley and Floodplain

1.1 Watershed Zone **Response**

1.2 Alluvial Fan **No**

1.3 Corridor Encroachments

Length (ft)	Left	Right
Berms	0	0
Roads	6870	0
Railroads	0	0
Improved Paths	0	0
Development	320	0

1.4 Adjacent Side

	Left	Right
Hillside Slope	Very Steep	Hilly
Continuous w/	Sometimes	Sometimes
W/in 1 Bankfill	Sometimes	Sometimes
Texture	Bedrock	Not Evalua

1.5 Valley Features

Valley Width (ft)	500
Confinement Type	Broad
Rock Gorge?	No
Human-caused change - valley width?	Yes

1.6 Grade Controls

Data not displayed due to problem with report.

Step 2. Stream Channel

2.1 Bankfill Width (ft)	83.8
2.2 Max Depth (ft)	13.0
2.3 Mean Depth (ft)	9.3
2.4 Floodprone Width	750.0
2.5 Low Bank Height	13.0
2.6 Width/Depth	9.0
2.7 Entrenchment	8.9
2.8 Incision Ratio	1.0
2.9 Sinuosity	Oxbows
2.10 Riffles Type	Not
2.11 Riffle/Step Spacing	

2.12 Substrate Composition

Bedrock	0.0 %
Boulder	0.0 %
Cobble	0.0 %
Coarse Gravel	0.0 %
Fine Gravel	0.0 %
Sand	100.0 %
Silt/Clay Present?	Yes
Detritus	1.0 %
# Large Woody	13

2.13 Average Largest Particle

Bed

Bar

2.14 Stream Type

E 5 Non Plane Bed

Is a sub-reach? **No**

2.15 Reference Stream Type

(if different from Phase 1)

Step 3. Riparian Features

3.1 Stream Banks

	Lower	Upper
Typical Bank	Steep	
Material Type	Silt/Clay	Sand
Consistency	Cohesive	Cohesive

Bank Erosion	Left	Right
Erosion Length	3730	3200
Erosion Height	3.0	3.0
Revetmt. Type	Rip-rap	None
Revetmt. Length	420	0

Near Bank Veg.	Left	Right
Dominant	Deciduous	Deciduous
Sub-dominant	Herbaceous	Herbaceous

Bank Canopy	Left	Right
Canopy	1-25	1-25
Mid-Channel	Open	

3.2 Riparian Buffer

Buffer Width	Left	Right
Dominant	51-100	5-25
Sub-dominant	5-25	>100

Buffer Veg. Type	Left	Right
Dominant	Coniferous	Coniferous
Sub-dominant	None	None

3.3 Riparian Corridor

Corridor Land	Left	Right
Dominant	Forest	Crop
Sub-dominant	Pasture	Forest
Mass Failures	None	
Mean Failure	0.0	

Poss Str (historic) inferred fr planform. However, channel likely pushed to west valley wall by alluv fan / delta deposits of Mill River. Cross section measurements approx only: 2.2, 2.3, 2.5 are minimum values; 2.6 is max value - channel depth exceeded measuring staff. High water conditions

Step 4. Flow & Flow Modifiers

4.1 Springs / Seeps	Abundant
4.2 Adjacent Wetlands	Some
4.3 Flow Status	High
4.4 # of Debris Jams	1
4.5 Impoundments	None
Impoundmt. Location	
4.6 # of Stormwater	3
4.7 Upstream Flow	None
4.9 # of Beaver Dams	0 0 ft

4.8 Channel Constrictions

Data not displayed due to problem with report.

Step 5. Channel Bed and Planform Changes

5.1 Bar Types

Mid	Point	Side
Single	Single	None
Diagonal	Delta	Island
None	None	None

5.2 Other Features

Flood Chute	Neck Cutoff	Chan. Avulsion	Braiding
None	Multiple	None	None

5.3 Steep Riffles and Head Cuts

Steep Riffles	Head Cuts	Trib Rejuv.
None	None	No

5.4 Stream Ford or Animal **No**

5.5 Channel Alterations **Straightenin**

Phase 2 Reach Summary

March 1, 2006

Project: **Upper Otter Creek**

Stream:	**Upper Otter Creek**	Reach #	**M24**	Segment: **0**	Completion Date: **November 9, 2005**
Organization:	**Rutland NRCD**	Observers:	**KLU, HS**		Rain: **Yes**
Segment Length (ft):	**22,541**	Segment Location:	**From vicinity of intersection between Creek Road and Walker Mountain Road, downstream**		

Step 6. Rapid Habitat Assessment Data

Stream Gradient Type **Low**

	Score
6.1 Epifaunal Substrate - Available	**10**
6.2 Pool Substrate	**15**
6.3 Pool Variability	**15**
6.4 Sediment Deposition	**15**
6.5 Channel Flow Status	**18**
6.6 Channel Alteration	**13**
6.7 Channel Sinuosity	**13**
6.8 Bank Stability	**Left: 5 Right: 4**
6.9 Bank Vegetation Protection	**Left: 4 Right: 4**
6.10 Riparian Vegetation Zone Width	**Left: 4 Right: 5**
Total Score	**125**
Habitat Rating	**0.625**

Habitat Stream Condition **Fair**

Step 7. Rapid Geomorphic Assessment Data

Confinement Type **Unconfined**

	Score	STD	Historic
7.1 Channel Degradation	**16**	**None**	**No**
7.2 Channel Aggradation	**18**	**None**	**No**
7.3 Widening Channel	**16**		**No**
7.4 Change in Planform	**5**		**No**
Total Score	**55**		
Geomorphic Rating	**0.6875**		

Channel Evolution Model

Channel Evolution Stage **I**

Geomorphic Condition **Good**

Stream Sensitivity **High**

Narrative:

PF adjust (meand migr). Local wid at DJs. If hist straight (inferred from linear PF & rr) resulted in incis, it was v min in extent. Mod. by silts in chann bed or offset by simult. aggrad fr u/s erosion. Channel has excell floodplain access.

Project: Upper Otter Creek

Phase 2 Reach Summary

March 1, 2006

Stream: **Upper Otter Creek** | Reach # **M24** | Segment: **0** | Completion Date: **November 9, 2005**

Organization: **Rutland NRCD** | Observers: **KLU, HS** | Rain: **Yes**

Segment Length (ft): **22,541** | Segment Location: **From vicinity of intersection between Creek Road and Walker Mountain Road, downstream**

Step 1. Valley and Floodplain

1.1 Watershed Zone **Response**

1.2 Alluvial Fan **No**

1.3 Corridor Encroachments

Length (ft)	Left	Right
Berms	0	60
Roads	2060	500
Railroads	0	8200
Improved Paths	0	0
Development	180	480

1.4 Adjacent Side	Left	Right
Hillside Slope	Steep	Hilly
Continuous w/	Never	Sometimes
W/in 1 Bankfill	Never	Sometimes
Texture	Bedrock	Not Evalua

1.5 Valley Features

Valley Width (ft)	1900
Confinement Type	Very Broad
Rock Gorge?	No
Human-caused change - valley width?	Yes

1.6 Grade Controls

Data not displayed due to problem with report.

Step 2. Stream Channel

2.1 Bankfill Width (ft)	83.6
2.2 Max Depth (ft)	10.7
2.3 Mean Depth (ft)	8.8
2.4 Floodprone Width	1900.0
2.5 Low Bank Height	10.7
2.6 Width/Depth	9.5
2.7 Entrenchment	22.7
2.8 Incision Ratio	1.0
2.9 Sinuosity	High
2.10 Riffles Type	Not
2.11 Riffle/Step Spacing	

2.12 Substrate Composition

Bedrock	0.0 %
Boulder	0.0 %
Cobble	0.0 %
Coarse Gravel	0.0 %
Fine Gravel	0.0 %
Sand	100.0 %
Silt/Clay Present?	Yes
Detritus	1.0 %
# Large Woody	137

2.13 Average Largest Particle

Bed **20** mm

Bar mm

2.14 Stream Type

E 5 Non Plane Bed

Is a sub-reach? **No**

2.15 Reference Stream Type

(if different from Phase 1)

Step 3. Riparian Features

3.1 Stream Banks

Typical Bank	Steep	
Bank Texture	Lower	Upper
Material Type	Silt/Clay	Sand
Consistency	Cohesive	Cohesive
Bank Erosion	Left	Right
Erosion Length	7050	7620
Erosion Height	5.0	5.0
Revetmt. Type	Rip-rap	Rip-rap
Revetmt. Length	1040	2310
Near Bank Veg.	Left	Right
Dominant	Deciduous	Deciduous
Sub-dominant	Herbaceous	Herbaceous
Bank Canopy	Left	Right
Canopy	1-25	1-25
Mid-Channel	Open	

3.2 Riparian Buffer

Buffer Width	Left	Right
Dominant	26-50	26-50
Sub-dominant	51-100	>100
Buffer Veg. Type	Left	Right
Dominant	Deciduous	Deciduous
Sub-dominant	None	None

3.3 Riparian Corridor

Corridor Land	Left	Right
Dominant	Crop	Crop
Sub-dominant	None	None
Mass Failures	None	
Mean Failure	0.0	

Hist Str inferred from linear planform and encroachment of railroad along RB. Much beaver activity incl LWD recruitment and tree girdling d/s of Walker Mtn Rd

Step 4. Flow & Flow Modifiers

4.1 Springs / Seeps	Abundant	
4.2 Adjacent Wetlands	Some	
4.3 Flow Status	High	
4.4 # of Debris Jams	4	
4.5 Impoundments	None	
Impoundmt. Location		
4.6 # of Stormwater	0	
4.7 Upstream Flow	None	
4.9 # of Beaver Dams	0	0 ft

4.8 Channel Constrictions

Data not displayed due to problem with report.

Step 5. Channel Bed and Planform Changes

5.1 Bar Types

Mid	Point	Side
None	Multiple	None
Diagonal	Delta	Island
None	None	None

5.2 Other Features

Flood Chute	Neck Cutoff	Chan. Avulsion	Braiding
Multiple	Multiple	None	None

5.3 Steep Riffles and Head Cuts

Steep Riffles	Head Cuts	Trib Rejuv.
None	None	No

5.4 Stream Ford or Animal **No**

5.5 Channel Alterations **Straightenin**

Phase 2 Reach Summary

Project: **Upper Otter Creek**
Stream: **Upper Otter Creek** Reach # **M23** Segment: **0** Completion Date: **November 29,**
Organization: **Rutland NRCD** Observers: **KLU, HS** Rain: **Yes**
Segment Length (ft): **14,330** Segment Location: **From vicinity of lumber yard downstream to Cold River confluence, spanning Alfrecia Road.**

Step 6. Rapid Habitat Assessment Data

Stream Gradient Type **Low**

	Score
6.1 Epifaunal Substrate - Available	**11**
6.2 Pool Substrate	**15**
6.3 Pool Variability	**15**
6.4 Sediment Deposition	**18**
6.5 Channel Flow Status	**18**
6.6 Channel Alteration	**13**
6.7 Channel Sinuosity	**8**
6.8 Bank Stability	**Left: 7 Right: 6**
6.9 Bank Vegetation Protection	**Left: 6 Right: 6**
6.10 Riparian Vegetation Zone Width	**Left: 2 Right: 2**
Total Score	**127**
Habitat Rating	**0.635**
Habitat Stream Condition	**Fair**

Step 7. Rapid Geomorphic Assessment Data

Confinement Type **Unconfined**

	Score	STD	Historic
7.1 Channel Degradation	**18**	**None**	**No**
7.2 Channel Aggradation	**16**	**None**	**No**
7.3 Widening Channel	**15**		**No**
7.4 Change in Planform	**15**		**No**
Total Score	**64**		
Geomorphic Rating	**0.8**		
Channel Evolution Model			
Channel Evolution Stage	**I**		
Geomorphic Condition	**Good**		
Stream Sensitivity	**High**		

Narrative:

Minor wid, PF change (local). If hist straight (inferred from linear PF) resulted in incis, it was very minor in extent. Mod. by silts in chann bed or offset by simult. aggrad fr u/s erosion. Channel has excell. floodplain access.

Project: Upper Otter Creek

Phase 2 Reach Summary

March 1, 2006

Stream: **Upper Otter Creek** Reach # **M23** Segment: **0** Completion Date: **November 29,**

Organization: **Rutland NRCD** Observers: **KLU, HS** Rain: **Yes**

Segment Length (ft): **14,330** Segment Location: **From vicinity of lumber yard downstream to Cold River confluence, spanning Alfrecia Road.**

Step 1. Valley and Floodplain

1.1 Watershed Zone **Response**

1.2 Alluvial Fan **No**

1.3 Corridor Encroachments

Length (ft)	Left	Right
Berms	**0**	**0**
Roads	**1440**	**0**
Railroads	**0**	**0**
Improved Paths	**0**	**0**
Development	**445**	**845**

1.4 Adjacent Side

	Left	Right
Hillside Slope	**Steep**	**Flat**
Continuous w/	**Never**	**Never**
W/in 1 Bankfill	**Sometimes**	**Never**
Texture	**Bedrock**	**Not Evalua**

1.5 Valley Features

Valley Width (ft)	**2500**
Confinement Type	**Very Broad**
Rock Gorge?	**No**
Human-caused change - valley width?	**Yes**

1.6 Grade Controls

Data not displayed due to problem with report.

Step 2. Stream Channel

2.1 Bankfill Width (ft)	**91.5**
2.2 Max Depth (ft)	**11.0**
2.3 Mean Depth (ft)	**7.9**
2.4 Floodprone Width	**500.0**
2.5 Low Bank Height	**11.0**
2.6 Width/Depth	**11.6**
2.7 Entrenchment	**5.5**
2.8 Incision Ratio	**1.0**
2.9 Sinuosity	**Oxbows**
2.10 Riffles Type	**Not**
2.11 Riffle/Step Spacing	

2.12 Substrate Composition

Bedrock	**0.0** %
Boulder	**0.0** %
Cobble	**0.0** %
Coarse Gravel	**0.0** %
Fine Gravel	**0.0** %
Sand	**100.0** %
Silt/Clay Present?	**Yes**
Detritus	**0.0** %
# Large Woody	**39**

2.13 Average Largest Particle

Bed

Bar

2.14 Stream Type

E **5** **Non** **Dune-**

Is a sub-reach? **No**

2.15 Reference Stream Type

(if different from Phase 1)

Step 3. Riparian Features

3.1 Stream Banks

	Lower	Upper
Typical Bank	**Moderate**	
Bank Texture	Lower	Upper
Material Type	**Sand**	**Sand**
Consistency	**Cohesive**	**Cohesive**
Bank Erosion	Left	Right
Erosion Length	**2830**	**4200**
Erosion Height	**5.0**	**5.0**
Revetmt. Type	**Rip-rap**	**Rip-rap**
Revetmt. Length	**1500**	**890**
Near Bank Veg.	Left	Right
Dominant	**Deciduous**	**Deciduous**
Sub-dominant	**Pasture**	**Pasture**
Bank Canopy	Left	Right
Canopy	**1-25**	**1-25**
Mid-Channel	**Open**	

3.2 Riparian Buffer

Buffer Width	Left	Right
Dominant	**5-25**	**5-25**
Sub-dominant	**26-50**	**26-50**
Buffer Veg. Type	Left	Right
Dominant	**Deciduous**	**Deciduous**
Sub-dominant	**None**	**None**

3.3 Riparian Corridor

Corridor Land	Left	Right
Dominant	**Pasture**	**Crop**
Sub-dominant	**Crop**	**Pasture**
Mass Failures	**None**	
Mean Failure	**0.0**	

Str (5.5) historic inferred fr planform. Channel likely flowing through alluv fan / delta deposits of Cold River near d/s end. Cross section measurements approx only. High water conditions limited observations.

Step 4. Flow & Flow Modifiers

4.1 Springs / Seeps	**Some**	
4.2 Adjacent Wetlands	**Some**	
4.3 Flow Status	**High**	
4.4 # of Debris Jams	**2**	
4.5 Impoundments	**None**	
Impoundmt. Location		
4.6 # of Stormwater	**0**	
4.7 Upstream Flow	**None**	
4.9 # of Beaver Dams	**0**	**0** ft

4.8 Channel Constrictions

Data not displayed due to problem with report.

Step 5. Channel Bed and Planform Changes

5.1 Bar Types

Mid	Point	Side
None	**Multiple**	**None**
Diagonal	Delta	Island
None	**None**	**None**

5.2 Other Features

Flood Chute	Neck Cutoff	Chan. Avulsion	Braiding
None	**None**	**None**	**None**

5.3 Steep Riffles and Head Cuts

Steep Riffles	Head Cuts	Trib Rejuv.
None	**None**	**No**

5.4 Stream Ford or Animal **No**

5.5 Channel Alterations **Straightenin**

Project:	Upper Otter Creek	**Phase 2 Reach Summary**			March 1, 2006
Stream:	**Upper Otter Creek**	Reach #	**M22**	Segment: **0**	Completion Date: **November 29,**
Organization:	**Rutland NRCD**	Observers:	**KLU, HS**		Rain: **Yes**
Segment Length (ft):	**15,383**	Segment Location:	**From Cold River confluence downstream to East Creek confluence**		

Step 6. Rapid Habitat Assessment Data

Stream Gradient Type **Low**

	Score
6.1 Epifaunal Substrate - Available	**11**
6.2 Pool Substrate	**16**
6.3 Pool Variability	**15**
6.4 Sediment Deposition	**18**
6.5 Channel Flow Status	**18**
6.6 Channel Alteration	**13**
6.7 Channel Sinuosity	**8**
6.8 Bank Stability	**Left: 8 Right: 8**
6.9 Bank Vegetation Protection	**Left: 8 Right: 8**
6.10 Riparian Vegetation Zone Width	**Left: 2 Right: 2**
Total Score	**135**
Habitat Rating	**0.675**
Habitat Stream Condition	**Good**

Step 7. Rapid Geomorphic Assessment Data

Confinement Type **Unconfined**

	Score	STD	Historic
7.1 Channel Degradation	**16**	**None**	**No**
7.2 Channel Aggradation	**18**	**None**	**No**
7.3 Widening Channel	**18**		**No**
7.4 Change in Planform	**16**		**No**
Total Score	**68**		
Geomorphic Rating	**0.85**		
Channel Evolution Model			
Channel Evolution Stage	**I**		
Geomorphic Condition	**Referen**		
Stream Sensitivity	**High**		

Narrative:

If hist straight (inferred from linear PF) resulted in incis, it was very minor in extent. Mod. by silts in chann bed or offset by simult. aggrad fr u/s erosion. Channel has excell. floodplain access, and dimensions expected for E str type.

Project: Upper Otter Creek

Phase 2 Reach Summary

March 1, 2006

Stream: **Upper Otter Creek** Reach # **M22** Segment: **0** Completion Date: **November 29,**

Organization: **Rutland NRCD** Observers: **KLU, HS** Rain: **Yes**

Segment Length (ft): **15,383** Segment Location: **From Cold River confluence downstream to East Creek confluence**

Step 1. Valley and Floodplain

1.1 Watershed Zone **Response**

1.2 Alluvial Fan **No**

1.3 Corridor Encroachments

Length (ft)	Left	Right
Berms	**250**	**0**
Roads	**2810**	**3380**
Railroads	**0**	**0**
Improved Paths	**0**	**0**
Development	**430**	**1820**

1.4 Adjacent Side	Left	Right
Hillside Slope	**Hilly**	**Hilly**
Continuous w/	**Never**	**Never**
W/in 1 Bankfill	**Sometimes**	**Never**
Texture	**Not Evalua**	**Not Evalua**

1.5 Valley Features

Valley Width (ft)	**2000**
Confinement Type	**Very Broad**
Rock Gorge?	**No**
Human-caused change - valley width?	**Yes**

1.6 Grade Controls

Data not displayed due to problem with report.

Step 2. Stream Channel

2.1 Bankfill Width (ft)	**73.5**
2.2 Max Depth (ft)	**13.0**
2.3 Mean Depth (ft)	**9.3**
2.4 Floodprone Width	**1700.0**
2.5 Low Bank Height	**13.0**
2.6 Width/Depth	**7.9**
2.7 Entrenchment	**23.1**
2.8 Incision Ratio	**1.0**
2.9 Sinuosity	**Moderate**
2.10 Riffles Type	**Not**
2.11 Riffle/Step Spacing	

2.12 Substrate Composition

Bedrock	**0.0** %
Boulder	**0.0** %
Cobble	**0.0** %
Coarse Gravel	**0.0** %
Fine Gravel	**0.0** %
Sand	**100.0** %
Silt/Clay Present?	**Yes**
Detritus	**0.0** %
# Large Woody	**37**

2.13 Average Largest Particle

Bed

Bar

2.14 Stream Type

E **5** **Non** **Dune-**

Is a sub-reach? **No**

2.15 Reference Stream Type

(if different from Phase 1)

Step 3. Riparian Features

3.1 Stream Banks

Typical Bank	**Moderate**	
Bank Texture	Lower	Upper
Material Type	**Sand**	**Sand**
Consistency	**Cohesive**	**Cohesive**
Bank Erosion	Left	Right
Erosion Length	**980**	**1730**
Erosion Height	**5.0**	**5.0**
Revetmt. Type	**Rip-rap**	**Rip-rap**
Revetmt. Length	**980**	**1100**
Near Bank Veg.	Left	Right
Dominant	**Deciduous**	**Deciduous**
Sub-dominant	**Herbaceous**	**Herbaceous**
Bank Canopy	Left	Right
Canopy	**26-50**	**26-50**
Mid-Channel	**Open**	

3.2 Riparian Buffer

Buffer Width	Left	Right
Dominant	**5-25**	**5-25**
Sub-dominant	**26-50**	**26-50**
Buffer Veg. Type	Left	Right
Dominant	**Deciduous**	**Deciduous**
Sub-dominant	**None**	**None**

3.3 Riparian Corridor

Corridor Land	Left	Right
Dominant	**Crop**	**Crop**
Sub-dominant	**Pasture**	**Pasture**
Mass Failures	**None**	
Mean Failure	**0.0**	

Str (5.5) historic inferred fr planform. Channel likely flowing through alluv fan / delta deposits of Cold River near u/s end. Cross section measurements approx only: 2.2, 2.3, 2.5 are minimum values; 2.6 is max value - channel depth exceeded measuring staff. High water conditions

Step 4. Flow & Flow Modifiers

4.1 Springs / Seeps	**Some**	
4.2 Adjacent Wetlands	**Some**	
4.3 Flow Status	**High**	
4.4 # of Debris Jams	**0**	
4.5 Impoundments	**None**	
Impoundmt. Location		
4.6 # of Stormwater	**3**	
4.7 Upstream Flow	**None**	
4.9 # of Beaver Dams	**0**	**0** ft

4.8 Channel Constrictions

Data not displayed due to problem with report.

Step 5. Channel Bed and Planform Changes

5.1 Bar Types

Mid	Point	Side
None	**Single**	**None**
Diagonal	Delta	Island
None	**None**	**Single**

5.2 Other Features

Flood Chute	Neck Cutoff	Chan. Avulsion	Braiding
None	**None**	**None**	**None**

5.3 Steep Riffles and Head Cuts

Steep Riffles	Head Cuts	Trib Rejuv.
None	**None**	**No**

5.4 Stream Ford or Animal **No**

5.5 Channel Alterations **Straightenin**

Phase 2 Reach Summary

Project: **Upper Otter Creek**
Stream: **Upper Otter Creek** Reach # **M26** Segment: **B** Completion Date: **November 4, 2005**
Organization: **Rutland NRCD** Observers: **KLU, HS** Rain: **Yes**
Segment Length (ft): **2,330** Segment Location: **Upstream 2330 feet of reach M26 extending from approximately 700 feet upstream to 1500**

Step 6. Rapid Habitat Assessment Data

Stream Gradient Type **High**

	Score
6.1 Epifaunal Substrate - Available	**8**
6.2 Embeddedness	**15**
6.3 Velocity/Depth Patterns	**16**
6.4 Sediment Deposition	**13**
6.5 Channel Flow Status	**18**
6.6 Channel Alteration	**11**
6.7 Frequency of Riffles/Steps	**10**
6.8 Bank Stability	**Left: 9 Right: 6**
6.9 Bank Vegetation Protection	**Left: 7 Right: 7**
6.10 Riparian Vegetation Zone Width	**Left: 4 Right: 8**
Total Score	**132**
Habitat Rating	**0.66**
Habitat Stream Condition	**Good**

Step 7. Rapid Geomorphic Assessment Data

Confinement Type **Unconfined**

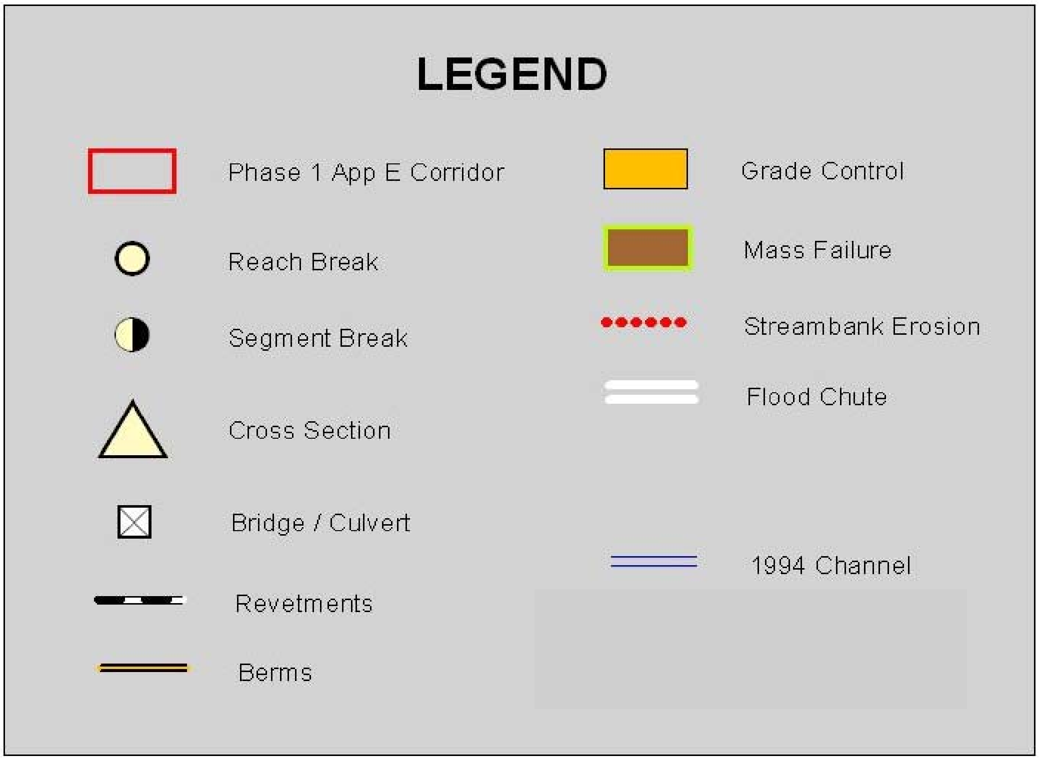
	Score	STD	Historic
7.1 Channel Degradation	**18**	**None**	**No**
7.2 Channel Aggradation	**13**	**None**	**No**
7.3 Widening Channel	**13**		**No**
7.4 Change in Planform	**13**		**No**
Total Score	**57**		
Geomorphic Rating	**0.7125**		
Channel Evolution Model			
Channel Evolution Stage	**I**		
Geomorphic Condition	**Good**		
Stream Sensitivity	**High**		

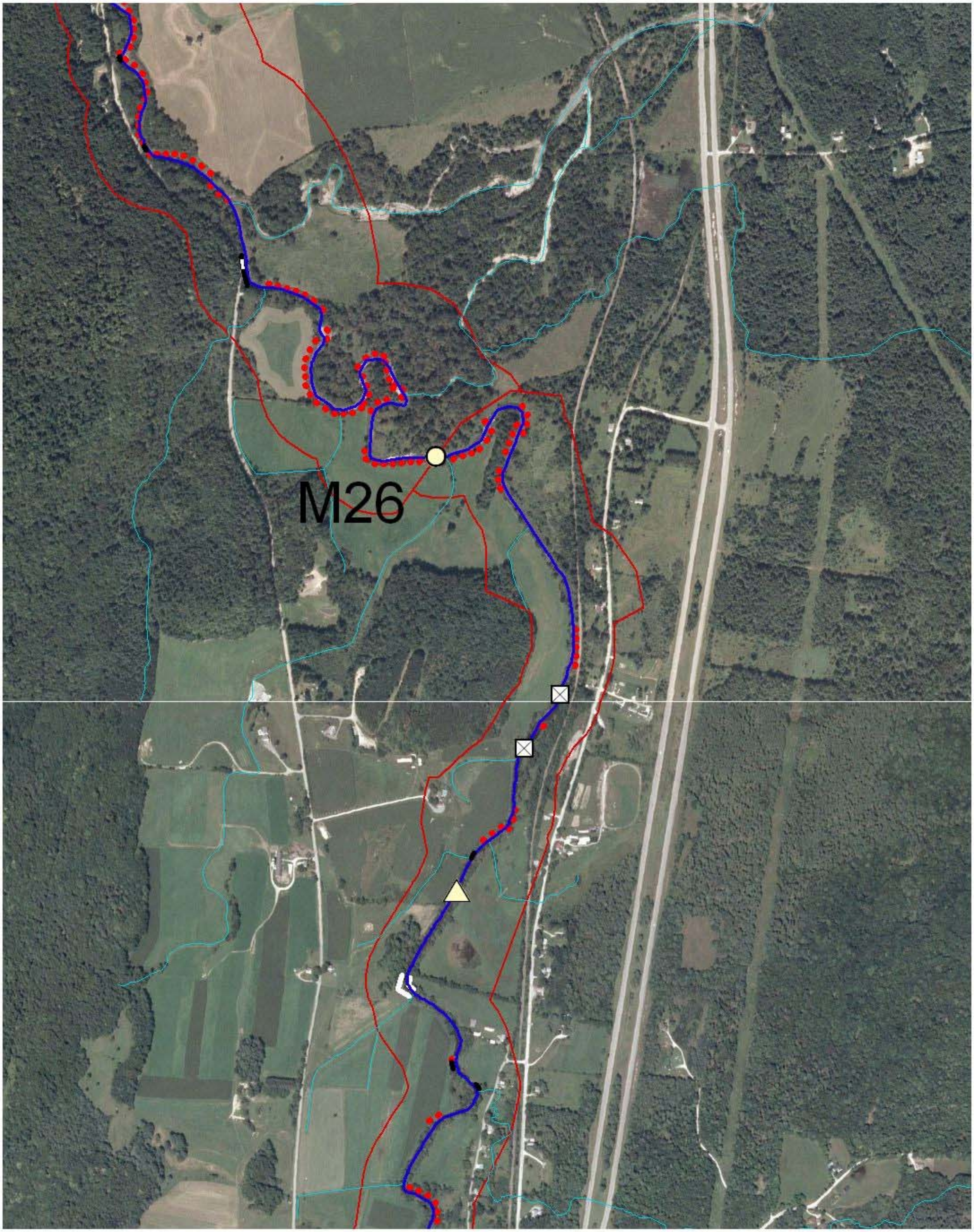
Narrative:
Aggradation, PF adjustment, widening localized to undersized crossing.

APPENDIX B

Annotated Reach-based Orthophotos

The following Legend identifies the various Phase 2 assessment features mapped on the enclosed annotated reach-based orthophotos. Base maps for the enclosed figures are the 1994 1:5000 digital orthophotos available from the Vermont Mapping Program.



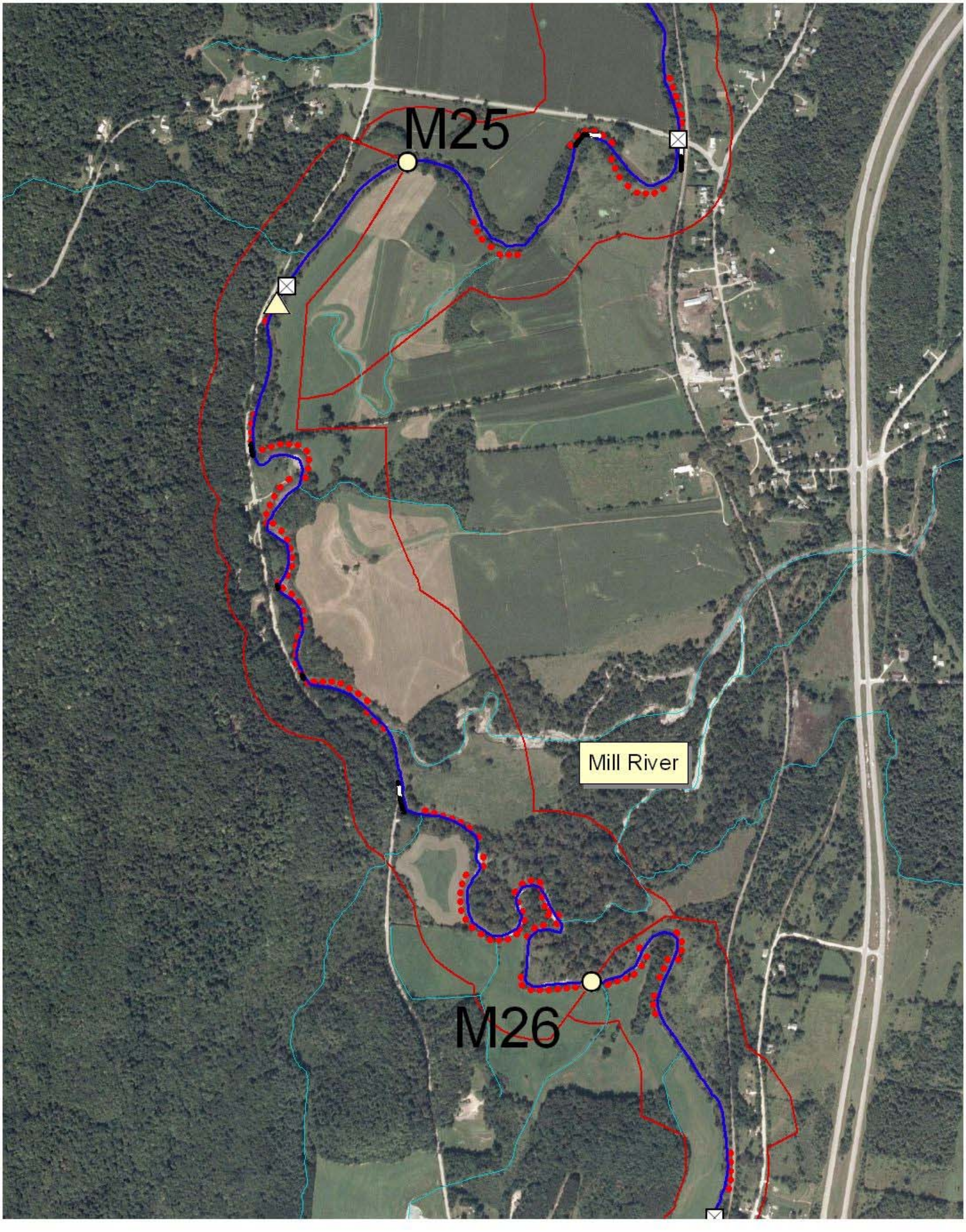


N

1000 0 1000 Feet

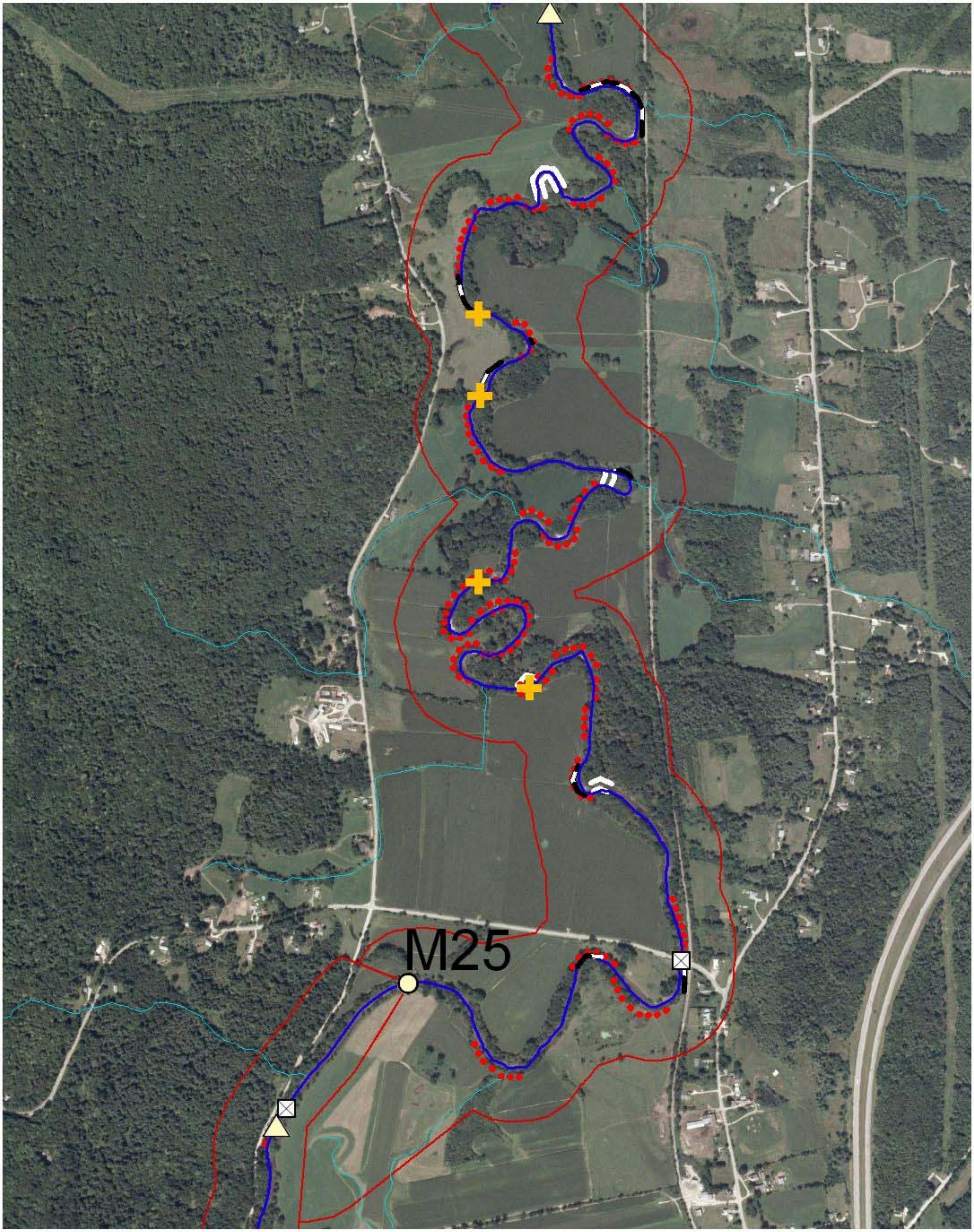
Reach: M26 downstream

Upper Otter Creek
Phase 2 Stream Geomorphic Assessments, 2005



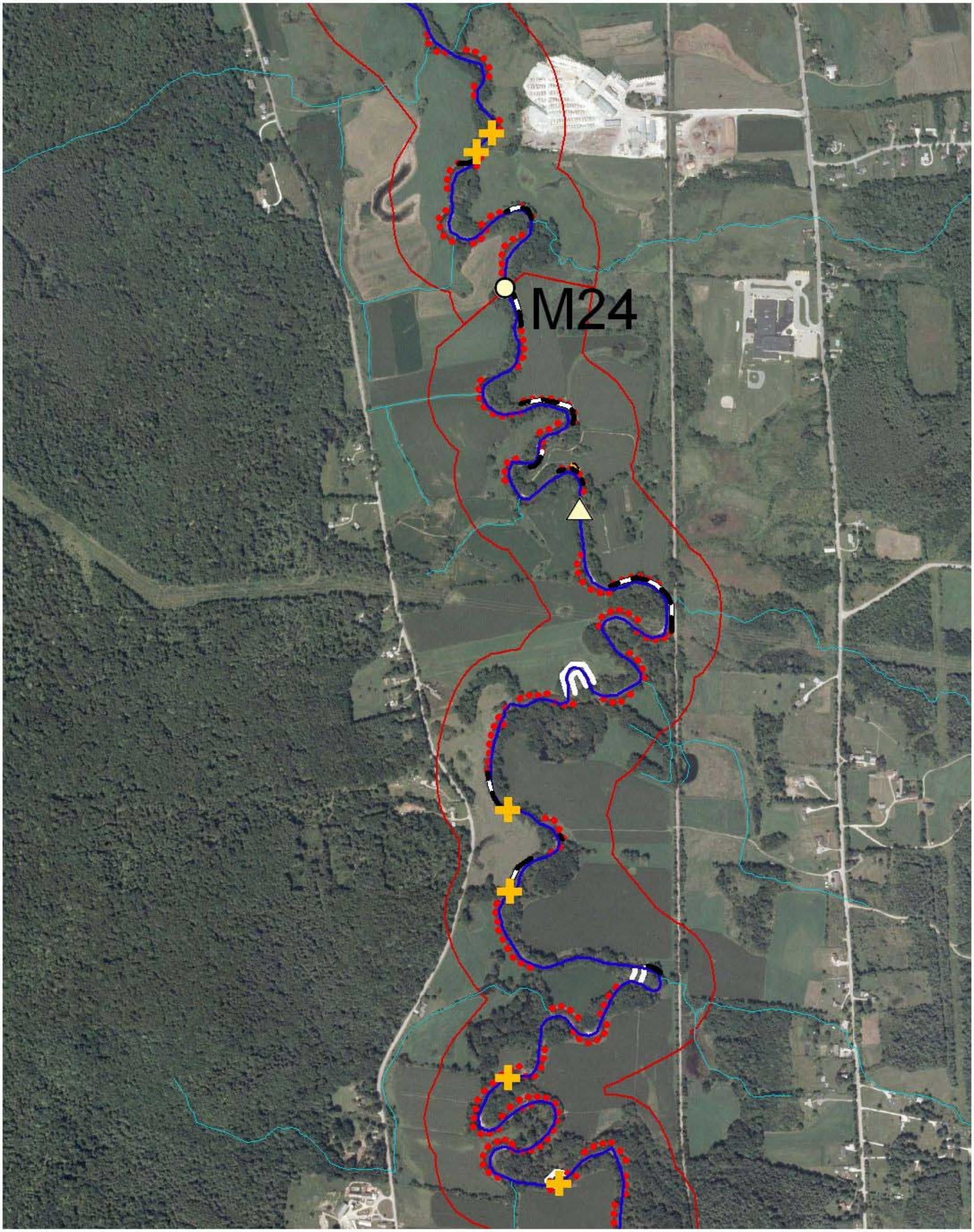
Reach: M25

Upper Otter Creek
Phase 2 Stream Geomorphic Assessments, 2005



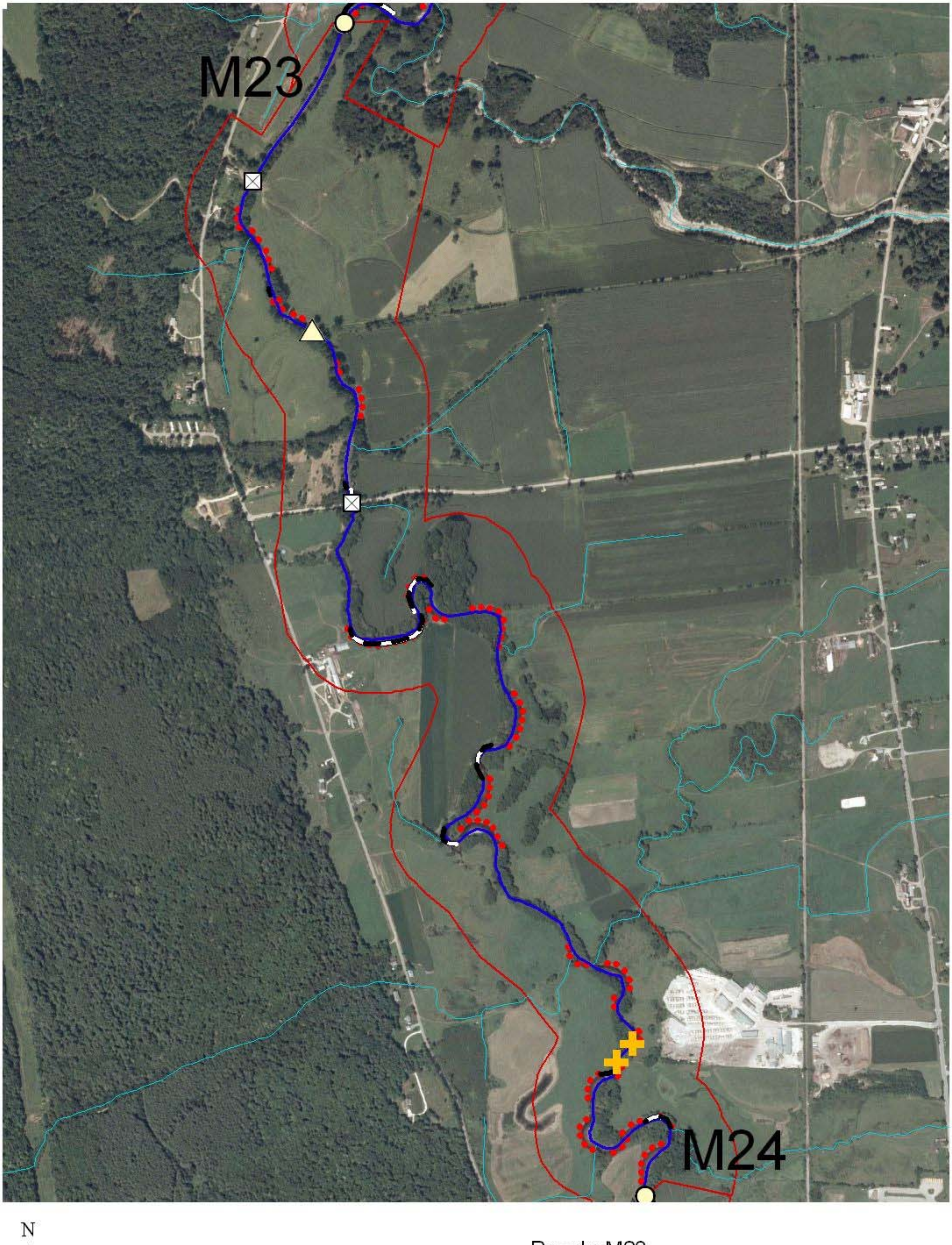
Reach: M24 upstream

Upper Otter Creek
Phase 2 Stream Geomorphic Assessments, 2005



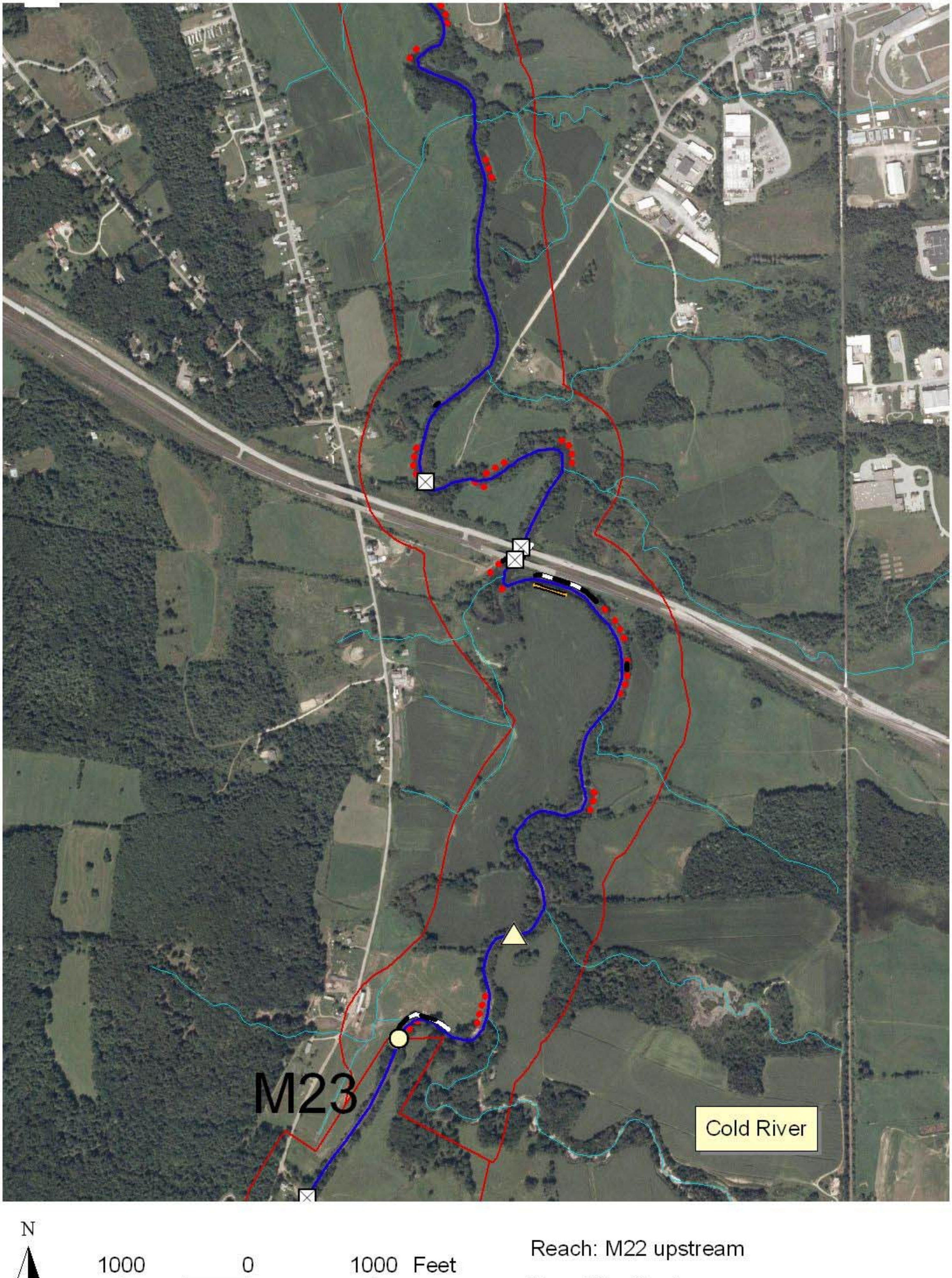
Reach: M24 downstream

Upper Otter Creek
Phase 2 Stream Geomorphic Assessments, 2005



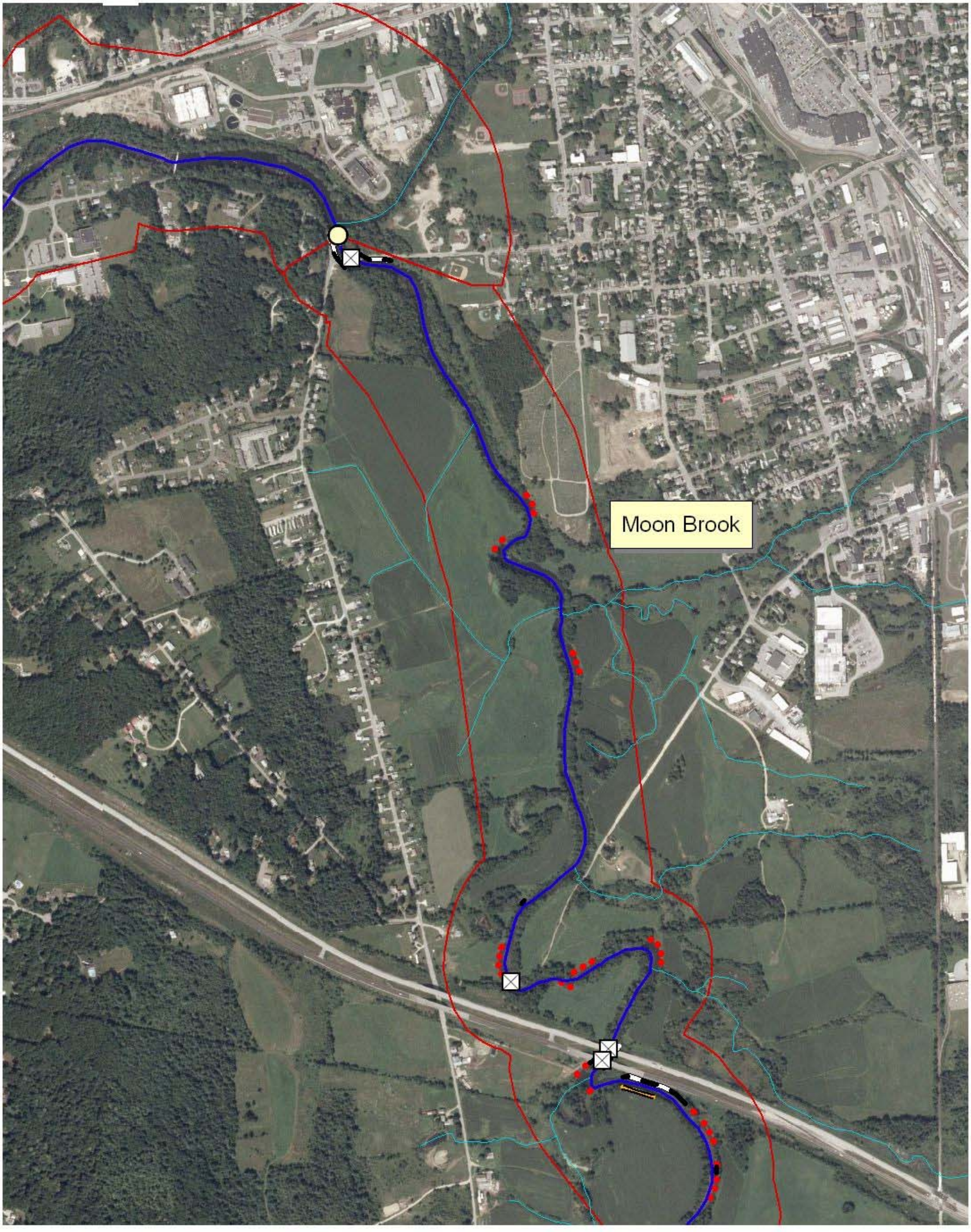
Reach: M23

Upper Otter Creek
Phase 2 Stream Geomorphic Assessments, 2005



Reach: M22 upstream

Upper Otter Creek
Phase 2 Stream Geomorphic Assessments, 2005

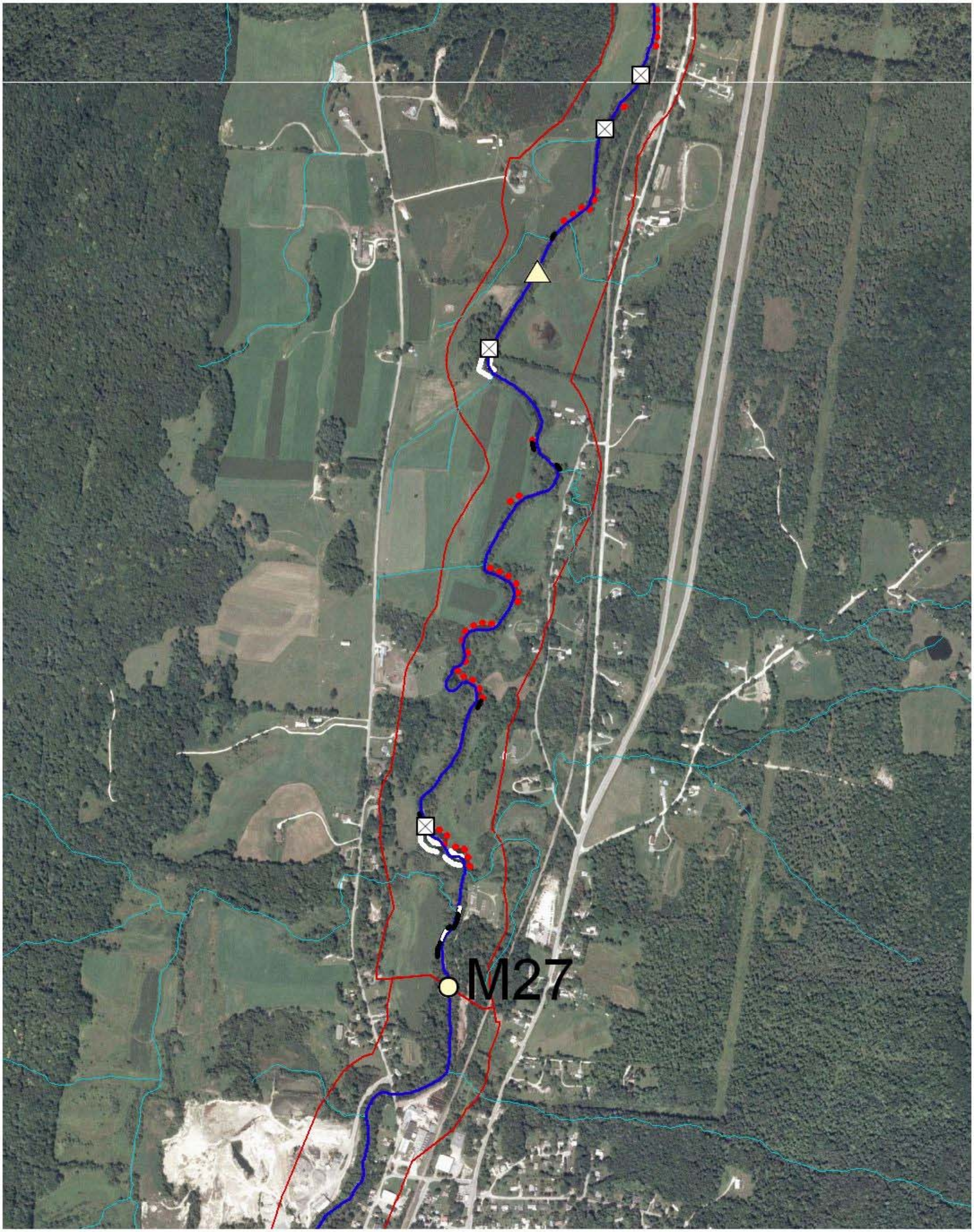


N

1000 0 1000 Feet

Reach: M22 downstream

Upper Otter Creek
Phase 2 Stream Geomorphic Assessments, 2005



N

1000 0 1000 Feet

Reach: M26 upstream

Upper Otter Creek
Phase 2 Stream Geomorphic Assessments, 2005

APPENDIX C

Analysis of Flooding History

Phase 2 Stream Geomorphic Assessment
Upper Otter Creek Watershed

Reaches: M22 – M26
Rutland & Clarendon, Rutland County, Vermont

February 2006

Appendix C:
Analysis of Flooding History

TABLE OF CONTENTS

FIGURES

TABLES

C.1 INTRODUCTION

Otter Creek valley landowners have reported that overbank flooding appears to be more frequent along the 14.2-mile length of Otter Creek main stem between the village of Wallingford and Rutland City.

This appendix presents additional background data relevant to observed flooding trends in the Otter Creek study area and discusses potential contributing factors to flooding. This appendix is not intended to provide a comprehensive flood evaluation or hydrologic analysis of the study area, but rather is intended to provide additional background data for consideration.

C.2 FLOW RECORDS

The United States Geological Survey (USGS) operates a flow gage (Station #04282000) on the Otter Creek located approximately 500 feet upstream of the Business Route 4 crossing (Reach M21). This gage is located 1.2 miles downstream of the five reaches (M22 – M26) assessed during this Phase 2 Stream Geomorphic Assessment (see Figure C.1).

The Center Rutland gaging station measures flow from an approximate drainage area of 308 square miles (or the upper 35% of the Otter Creek watershed). This station has daily flow records dating back to 1928, or approximately 77 years.

C.2.1 Analysis of Peak Flows

A few large floods have occurred on the Otter Creek in the previous 77 years. Figure C.2 graphs the peak flow recorded in any given year over the 77-year record for the Center Rutland gage. The peak annual flow is calculated as the maximum of all the instantaneous flows recorded continuously at the gage throughout the year.

The maximum peak flow recorded during the 77-year period of record was 13,700 cubic feet per second (cfs) on 22 September 1938; the corresponding daily mean flow for this date was 10,100 cfs. This gaging station was not operational during the flood of 1927, the highest flood on record for the state of Vermont (USGS, 1990).

From the existing record for the Center Rutland station, the United States Geological Survey (Olson, 2002) has estimated the approximate return frequency of peak flows. The September 1938 flood was a 100-year event, while the more recent flood events of 1987 and 1973 were estimated as 25-year events. A 100-year event has a 1% chance of recurring in any given year, while a 25-year event has a 4% probability of recurring in any given year.

From review of Figure C.2, the peak flow record for the Center Rutland gage does not appear to indicate an increasing trend of flooding, at least in terms of these larger, more catastrophic events. However, the recent flooding history described by landowners along the Otter Creek valley between Wallingford and Rutland, suggests that moderate flood events are occurring more frequently, with bank overtopping being sustained for longer periods of time. To evaluate this possibility, the mean annual flow records for the Otter Creek at Center Rutland gage were reviewed.

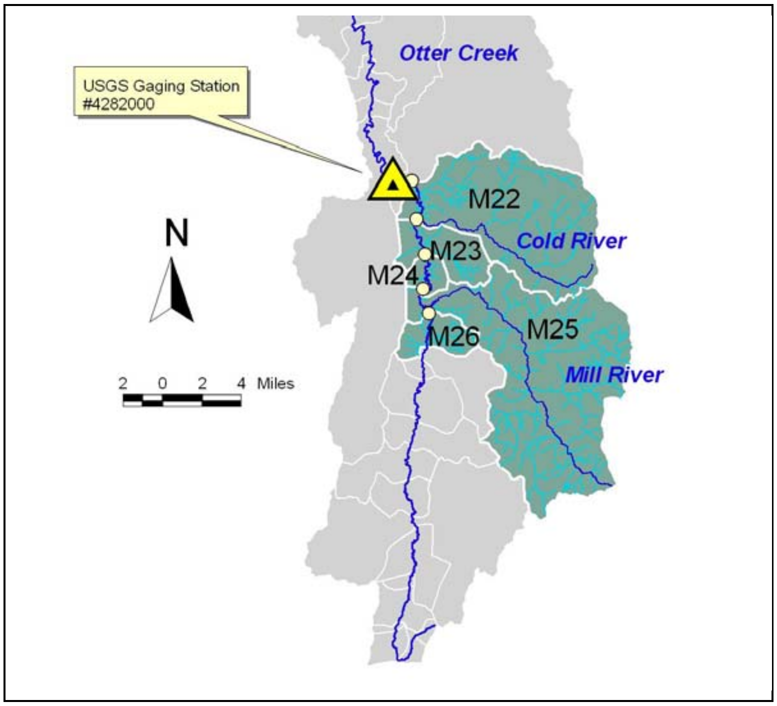


Figure C.1. Location of USGS Gaging Station #4282000 Otter Creek at Center Rutland, VT.

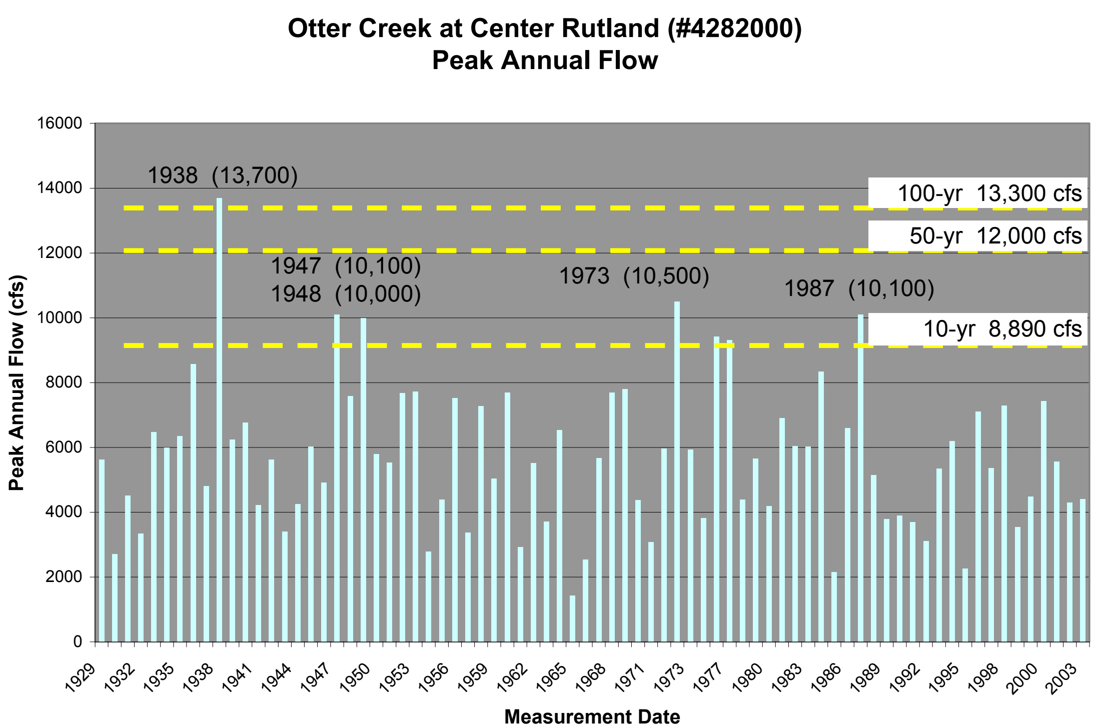


Figure C.2. Recorded Peak Flows for Otter Creek at Center Rutland Gage Station #04282000 (compared to estimated flood peaks after Olson, 2002)

C.2.2 Analysis of Mean Annual Flows

The mean annual flow (MAF) is calculated as the average of all the instantaneous flows recorded continuously at a gage throughout the year. The effects of a singular, large flood event are often dampened by the averaging of all flows within the year, when calculating a MAF. This appears to be the case for years 1938, 1973, and 1987, for example. On the other hand, a "wet" year (like 1954, 1976, or 1996 in Figure C.3 below) might have a high MAF, while not ever recording a remarkably high peak flow.

Mean annual flows for the Center Rutland gage were graphed over the available 75-year period of record from 1929 through 2003 (Figure C.3). (Note that data from 2004 and 2005 are not yet quality assured and available for download from the USGS web site).

The years with highest recorded MAF for the Center Rutland gage are 1976, 1996, and 1954. The white line on Figure C.3 represents a linear trend line. It suggests a slight increasing trend in MAF for the 75-year period of record from 1929 through 2003 (although this was not evaluated to determine if it was statistically significant).

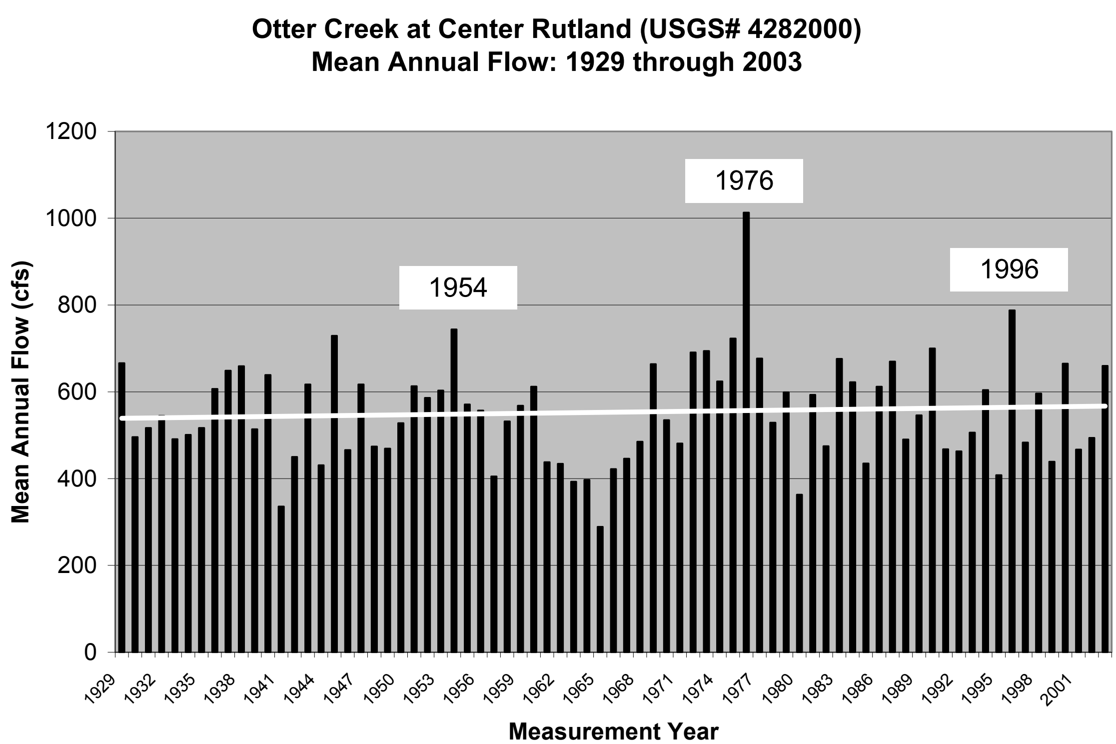


Figure C.3. Recorded Mean Annual Flows from 1929 through 2003
Otter Creek at Center Rutland Gage Station #04282000

C.2.3 Analysis of Daily Mean Flows

From October 2005 through January of 2006, landowners along Otter Creek between Walker Mountain Road and Alfrecia Road experienced flood events similar in nature to the conditions which they have been observing at apparent increased frequency over the last several years. October and November of 2005 were very wet months, and the Otter Creek was observed at bankfull or overtopping stages a few times during the Fall. More recently, during the week of 15 January 2006, flows once again exceeded bankfull.

The daily mean flow is the average of all the instantaneous flows recorded during a 24-hour period. The daily mean flow is lower than the daily peak flow for a given date. For example, the peak flow recorded during the flood of 1938 was 13,700 cfs on 22 September 1938; the corresponding daily mean flow for this date was 10,100 cfs.

Figure C.4 demonstrates the real-time (provisional) daily mean flow data for the Center Rutland gage over the last year and a half. Recent daily mean flows (in blue) are plotted versus the average daily mean flow observed for the previous 76 years of record (in purple). Daily mean flows in October and November 2005, and more recently in mid-January 2006, were well above the average of daily mean flows for this time of year (see far right hand side of graph noted by the arrow).

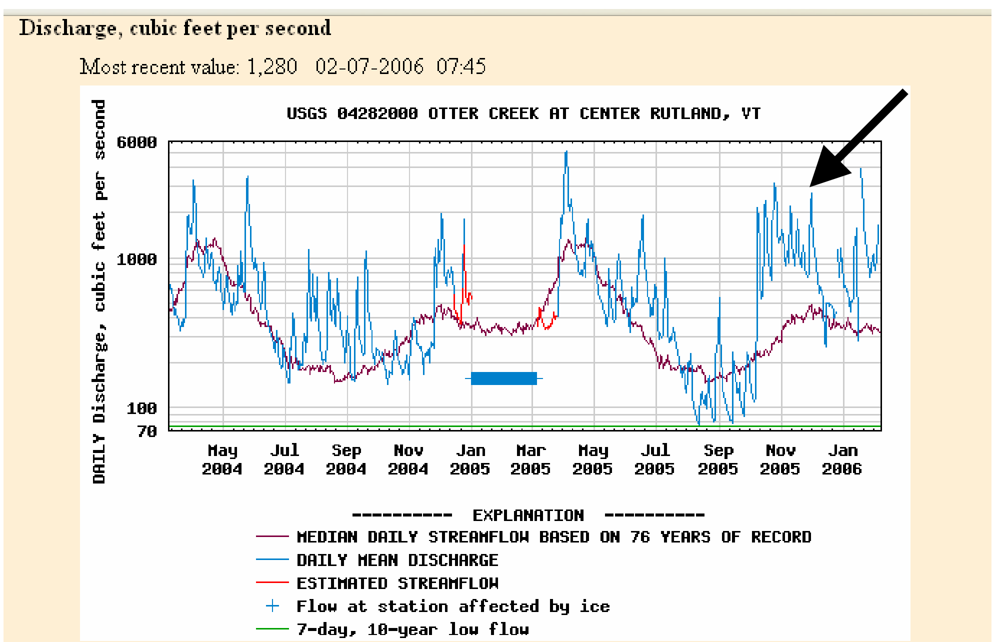


Figure C.4. Recent Daily Mean Flows (provisional) from USGS, Otter Creek at Center Rutland Gage Station #04282000. Note higher than average flows for October and November 2005 and January 2006 (at arrow).

During the time period when the Otter Creek was overtopping its banks between Walker Mountain Road and Alfrecia Road in October and January of 2006, daily mean flows were exceeding 2000 cfs at the Center Rutland gage (up to 10 miles downstream).

Noting this approximate relationship between flooding observed in the upstream valley and daily mean flow records at the Center Rutland gage, the daily mean flow data from 1929 through 2005 were analyzed further. Data were charted to determine how frequently over that 77-year period of record, daily mean flows have exceeded 2000 cfs, and to determine if there has been a trend in those flow exceedences (Figure C.5). From Figure C.5, a slight downward trend is suggested, contrary to the slight upward trend in overall mean annual flows (Figure C.3).

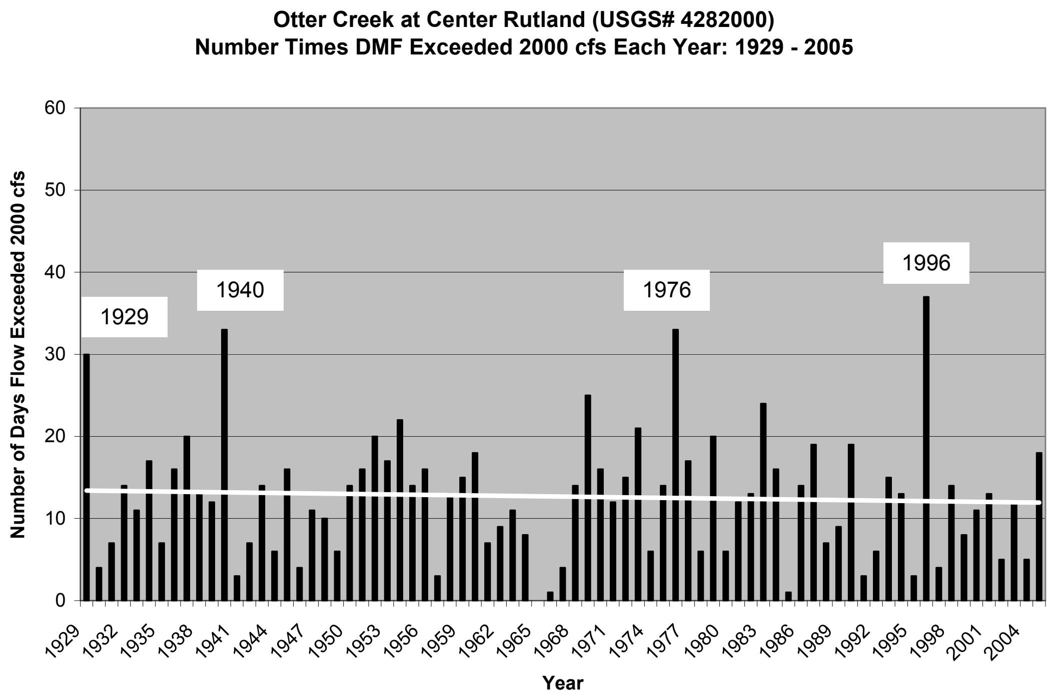


Figure C.5. *Number of Days per Year in which Daily Mean Flow has exceeded 2000 cfs, Otter Creek at Center Rutland Gage Station #04282000. Trendline (in white) indicates slight declining trend*.

Next, daily mean flow values were charted to determine how frequently the recorded flows exceeded values of 1500 cfs and 1000 cfs in each of the years of record (Figure C.6 and Figure C.7). Contrary to the chart for 2000 cfs, these charts indicate slight increasing trends.

If the Otter Creek is, in fact, overtopping its banks in the vicinity of Alfrecia Road and/or Walker Mountain Road during days when the mean flow recorded at the Center Rutland gage is over 1000 cfs or over 1500 cfs, the apparent increasing frequency of flows exceeding these values may support the recent observations of landowners.

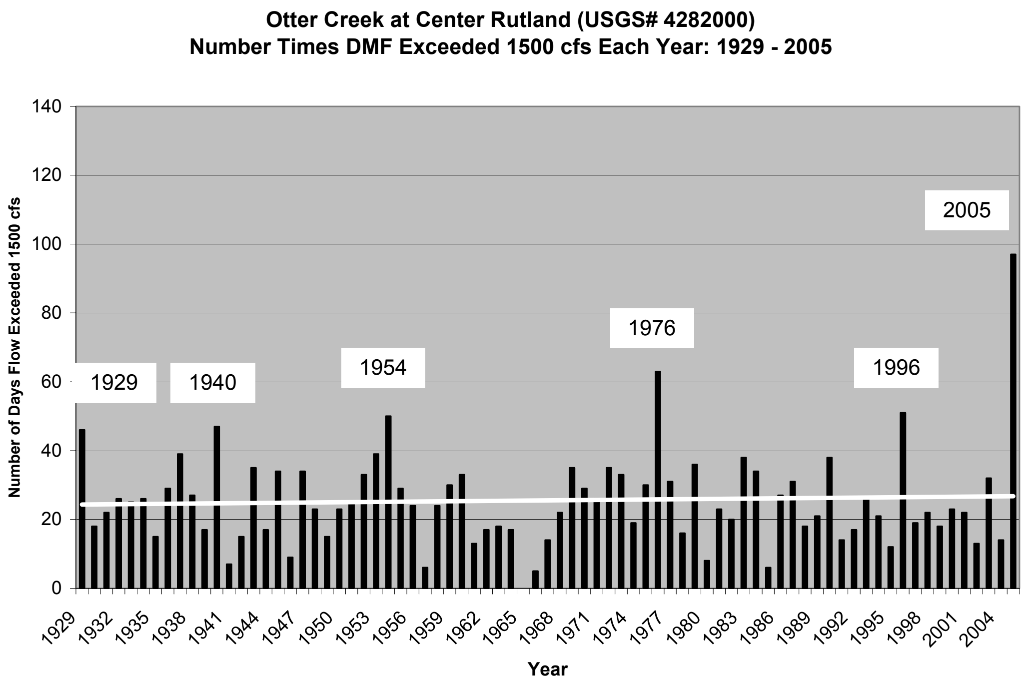


*Figure C.6. Number of Days per Year in which Daily Mean Flow has exceeded **1,500 cfs,** Otter Creek at Center Rutland Gage Station #04282000. Trendline (in white) indicates slight **increasing** trend.*

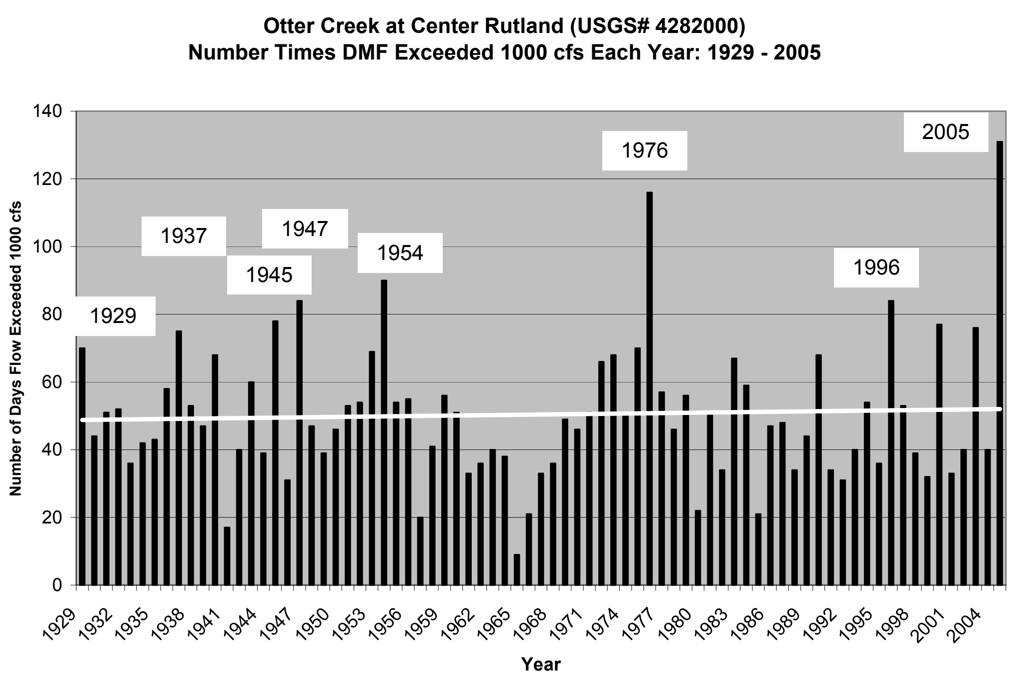


*Figure C.7. Number of Days per Year in which Daily Mean Flow has exceeded **1,000 cfs,** Otter Creek at Center Rutland Gage Station #04282000. Trendline (in white) indicates slight **increasing** trend.*

C.2.4 Summary and Limitations

Overall, analysis of peak flow, mean annual flow, and daily mean flow records for the Center Rutland gaging station indicates that while the frequency of major flood events appears to be declining, the frequency of moderate flood events, which may sustain overbank flood elevations for longer numbers of days, appears to be showing a slight increase over time. These data have not been analyzed to determine if the noted trends are statistically significant.

More detailed analysis would be required to more accurately link overbank flooding conditions in the vicinity of the Walker Mountain Road and Alfrecia Road with a given flow (or range of flows) recorded at the Center Rutland gage. In future, if landowners or the RNRCD can record the specific dates where overbank flooding is observed in the valley, these dates can be linked to flow conditions at the gage for further analysis.

That said, there are considerable limitations to the above analysis of flooding trends along the Otter Creek study area. Flows in river systems are very dynamic; they are the complex result of many overlapping and contributing factors. A detailed discussion of all the governing factors is beyond the scope of this report, but the major governing factors are briefly listed below.

- Flood stages and flows recorded at a gaging station may not directly reflect the conditions in an area of concern located 5 to 10 river miles upstream from the gage. The timing, duration, and frequency of flood stages and flows are affected by the travel times along the valley, and by the contributions of "flood waves" from the contributing tributaries – in this case, the Mill River (in reach M25), the Cold River (in reach M22), and East Creek (in reach M21).

- Patterns of precipitation can vary substantially in the watershed draining to the gage location, and these varying precipitation patterns will affect the flooding patterns in the Otter Creek and its tributaries.

- Flooding also varies as a result of the frequency of precipitation events. The river is more apt to rise when a given size rainfall event (say, 2 inches in 24 hours) occurs within a day or two of several weeks of sustained rainfall (while the ground is still saturated), than when that same size rainfall event occurs after 30 days of no rain (when the ground is dry).

- Flooding conditions can vary considerably from season to season. More rain typically falls in the late Spring through Summer months in the Rutland area (Figure C.8). However, for a given size rainfall event, more runoff (higher flows in the Otter Creek) will typically result during a Fall or Winter month rather than in Summer months. In the Fall months, crops have typically been harvested, and deciduous vegetation is dying back. Less water is intercepted by the leaves and stems of vegetation, or taken up by the root systems, and therefore more water is available to saturate the ground and run-off to the receiving streams and rivers. As the ground freezes through late Fall and Winter months, water is much less able to infiltrate the ground surface. Thus, runoff is often highest for a year during a Winter or Spring thaw event or a late Fall rain storm. Although, a peak annual flow can also occur during the Summer or early Fall during an intense rain event or thunder storm.

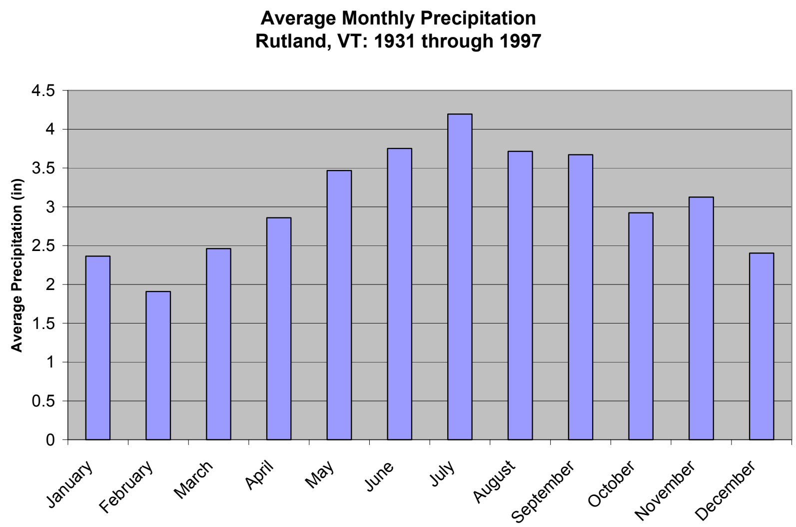


Figure C.8. Average monthly precipitation at Rutland weather station: 1931 through 1997.

- Land use patterns and their distribution across the watershed can also affect the degree to which rainfall infiltrates the ground surface and the speed with which stormwaters are transmitted to the receiving rivers and streams. In this way land use patterns can influence the flooding patterns through the river network.

Factors which may be contributing to the increased frequency of moderate flooding on the Otter Creek are discussed in further detail in the sections below. The topic of land use changes in the watershed draining to the Otter Creek study area has been addressed in more detail in Appendix D.

C.3 POTENTIAL FACTORS CONTRIBUTING TO FLOODING

In past discussions among landowners and at UOCWC meetings, the following environmental conditions or land use changes have been cited as possible contributing factors to apparent increases in flooding along the Otter Creek valley between Wallingford and Rutland. The following sections provide additional data and analysis that can be of use in further discussions.

Potential contributing factors may include:

- Increased frequency and/or magnitude of rainfall;
- Operations of dams that may impound water – there are two dams on the Otter Creek in Rutland City (reach M21);
- Constrictions at bridge or culvert crossings that may impound water during flooding;
- Increased development or agricultural conversions in the watershed draining to this portion of the Otter Creek.

C.3.1 Precipitation Patterns

Precipitation records for the Rutland weather station were obtained for a period of record from 1931 through 1997 from the National Climatic Data Center (www.ncdc.noaa.gov). (More recent data were not readily available). When total annual precipitation is considered over the period of record (Figure C.9), no increasing or decreasing trend is discernable. Figure C.9 illustrates a "dip" in the total annual precipitation through the 1960s when a State-wide drought was recorded – "the longest continuous spell of less than normal precipitation on record" (USGS, 1990).

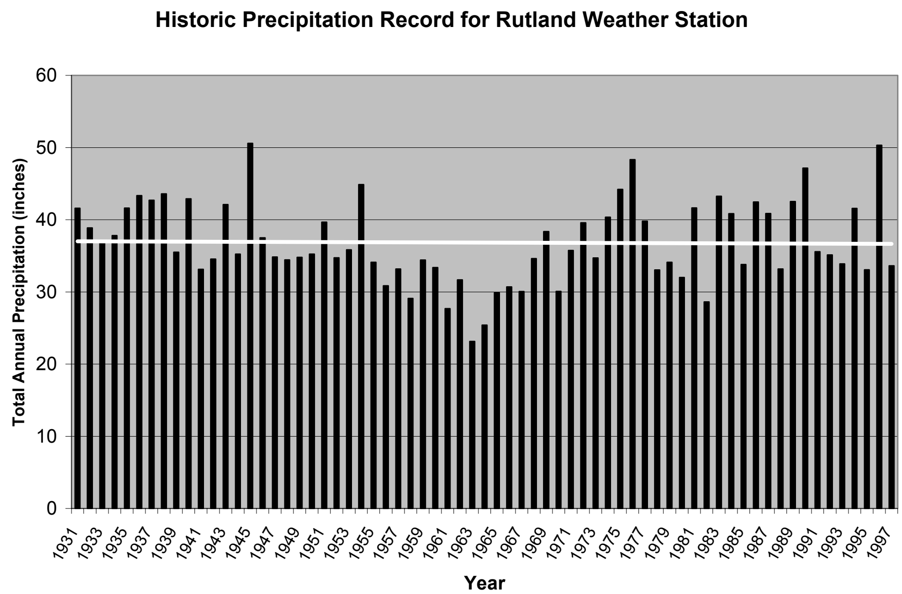


Figure C.9. Historic Annual Precipitation, Rutland Weather Station: 1931 to 1997 Trendline (in white) indicates stable trend.

Total monthly precipitation for each calendar month over the 67-year period was graphed to determine if precipitation trends in any given calendar month were exhibiting trends. Data indicated an increasing trend for some months, decreasing for others, and negligible trend for still other months (Table C.1).

Month	Trend
January	decr (sl)
February	--
March	--
April	--
May	--
June	decr
July	decr
August	incr
September	--
October	incr
November	incr (sl)
December	incr (sl)

Table C.1 Trend in total monthly precipitation from 1931 through 1997, Rutland, VT

Decr = decreasing trend
Incr = Increasing trend
Sl = slight
-- = no discernable trend

The most pronounced increasing trend was indicated by the historic data for the month of August (Figure C.10). More subtle increasing trends were apparent for the Fall months of October, November and December.

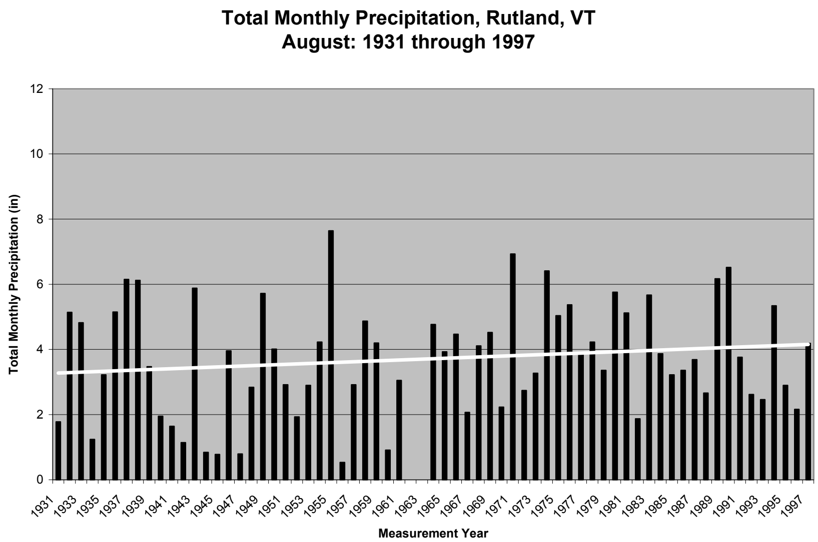


Figure C.10. Historic Precipitation for the Month of August, Rutland Weather Station: 1931 to 1997 Trendline (in white) indicates upward trend.

Thus, while overall annual precipitation trends appear stable (at least through 1997), Summer months (June, July) appear drier and late Summer to Fall months (August, October, November) appear wetter. This apparent change in the distribution of precipitation patterns through the calendar year may have important consequences to the flow patterns in receiving waters. For a given size rainfall event, more runoff will typically result during a Fall or Winter month than will result during Summer months. In the Fall months, crops have typically been harvested, and deciduous vegetation is dying back. Less water is intercepted by the leaves and stems of vegetation, or taken up by the root systems, and therefore more water is available to saturate the ground and run-off to the receiving streams and rivers. As frost conditions arrive in late Fall, water is less able to infiltrate the frozen ground surface. Therefore, an increase in precipitation amounts in Fall months may be contributing to greater than expected flows in receiving streams and rivers in Fall months. More in-depth analysis would be required to validate the above reported trends and determine if they are statistically significant.

C.3.2 Dams on the Otter Creek at Center Rutland

Two dams are located on the Otter Creek in the vicinity of Rutland City, downstream of the East Creek confluence and upstream of the Clarendon River confluence (Table C.2, Figure C.11). Both dams are located in reach M21, a 1.4-mile section of the Otter Creek which is largely a bedrock-controlled channel.

Table C.2 Dams on the Otter Creek at Center Rutland

Dam	Ripley Mills Dam (a)	Center Rutland Dam (a, b)
Status	Unknown	In Service
Purpose	Unknown	Hydroelectric
Year Installed	Unknown	1898
Dam Length (ft)	100	190
Dam Height (ft)	5	30 ft head w/ flashboards in place
Owner	OMYA, Inc.	OMYA, Inc.

Data Sources:
(a) Vermont Center for Geographic Information Systems (www.vcgi.org) Statewide GIS coverage – Vermont Dam Inventory, 2005: EmergencyOther_DAMS
http://www.vcgi.org/metadata/EmergencyOther_DAMS.htm
(b) State of Vermont Water Resources Board, Docket No. WQ-92-12, Water Quality Certificate Application for Center Rutland Hydroelectric Project.

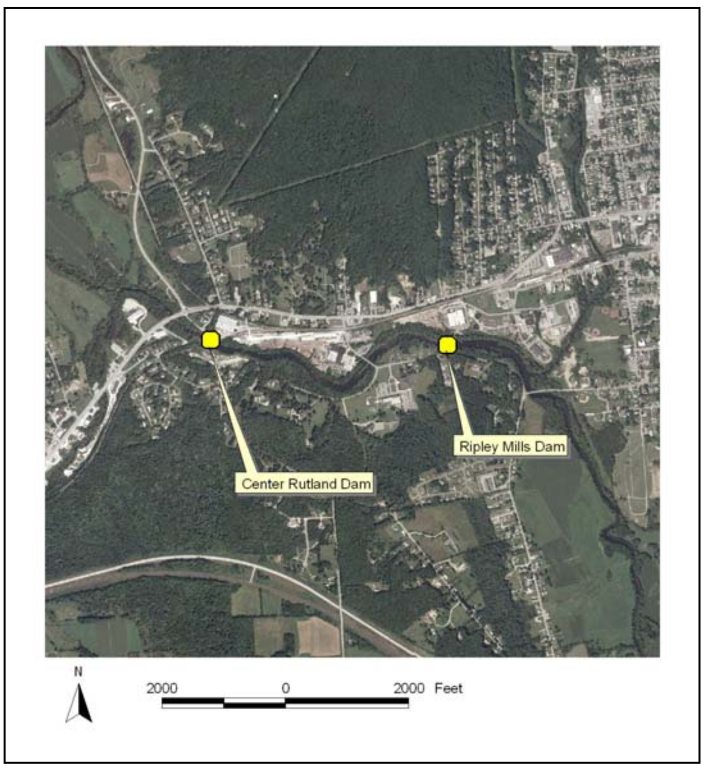


Figure C.11
Location of dams on Otter Creek near Rutland City, Reach M21.

Very little information was available for the Ripley Mills Dam. This dam appears intact on 1995 orthophotos and 2003 NAIP aerial imagery. The Vermont Dam Inventory available from Vermont Center for Geographic Information indicates that this dam is 100 feet long and 5 feet high. Therefore, it could be considered a low-head dam with minimal impounding effects. If so, this dam would have minimal backwater effects upstream in the Otter Creek.

The Center Rutland Dam is approximately 190 feet long positioned at an angle across the Otter Creek channel. There is a 174-foot long spillway. The crest of the spillway is at 504.8 feet elevation, while 2.3 feet of wooden flashboards (top elevation of 507.1) are in place year-round under normal operations (VT Water Resources Board, 1992).

The Center Rutland Dam was constructed about 1898. Since 1992, the dam has operated as a run-of-river dam, meaning that the amount of water leaving the dam area is equal to the amount of water entering the impoundment above the dam. To maintain the run-of-river operations water surface elevation in the impounded area behind the dam is maintained at approximately 0.25 feet above the top of the flashboards, or 507.4 feet elevation (VT Water Resources Board, 1992).

The impounded area above the Center Rutland dam is minor – approximately 13 acres in area, 140 feet in width (perpendicular to the channel), storing approximately 30 acre-feet of water. Maximum backwater effects in the Otter Creek channel are reported to extend approximately 4000 feet upstream, or to a point a few hundred feet downstream of the Ripley Mills dam (VT Water Resources Board, 1992).

Prior to its operation as a run-of-river dam, impounding effects upstream of the dam were noted to fluctuate "up to 1.5 feet during low flows and 1.0 foot during moderate flows" (VTDEC WQD, 1988). Given an overall slope along reach M21 of 3.6 feet per mile (RRPC *et al*, 2005), the maximum historic impounding effect of 1.5 feet seems unlikely to have affected flooding conditions between Alfrecia Road and Walker Mountain Road from 5 to 10 miles upstream of the dam.

C.3.3 Constrictions at Bridge and Culvert Crossings

Within the 14.2-mile study area along Otter Creek (reaches M22 through M26) eight bridge crossings and four old abutment pairs of laid-up stone were encountered during geomorphic assessments in November 2005. Eight of these structures are bankfull constrictors, meaning that they have a narrower span than the width of the bankfull channel measured at the closest upstream or downstream crossing.

Review of the USACE Cold Regions Research and Engineering Laboratory Ice Jam Database, (http://www.crrel.usace.army.mil/ierd/ijdb/) reveals only one incidence of minor ice jam flooding on the Otter Creek in Clarendon along South Creek Road (March 26, 1992). This ice jam was located at a curve in the river and does not appear to have been associated with any specific crossing structure. No other entries were found for locations in Rutland town. One additional ice jam incident was reported for the Mill River in Mount Holly in December of 1973; no entries were reported for the Cold River.

With the exception of the Route 4 highway, all of the above crossings (or abutments at former crossings) have been in place on the Otter Creek for several years, before the current trend of increased flooding frequency has been reported. The Route 4 highway crossing is absent on the USGS topographic map of Rutland, dated 1988, and present on the 1994 orthophotograph of the region; based on these resources, construction of the crossing occurred in the 6-year period between 1988 and 1994.

The Route 4 highway bridges (west-bound and east-bound) are wider than the bankfull width of the Otter Creek at their crossing. There is a substantial clearance above bankfull elevations to the underside of the bridges; the highway is elevated well above the river valley. However, bridge abutments and the base material for the road and bridge approaches fill the Otter Valley at this point, substantially reducing the floodplain area available to the river. There are insufficient data presently to assess whether or not this bridge may be contributing to increased flooding reported by residents in the vicinity of the Alfrecia Road crossing (2 miles upstream of this location) and the Walker Mountain Road crossing (7.5 miles upstream). Updated hydrologic analyses and hydraulic modeling (including resurveyed cross sections) have been prioritized for the Otter Creek between Wallingford and Rutland as part of a FEMA Flood Insurance Rate Map modernization effort (VTDEC WQD, 2004). These analyses may yield insight into the impounding effects of this recent crossing on flood stages.

C.3.4 Changes in Land Use Patterns

Development of the landscape brings impervious surfaces such as rooftops, paved parking areas, additional roads and driveways. These impervious surfaces prevent rainfall from infiltrating through the ground surface into the underlying soils and sediments. To the extent that these impervious surfaces are connected to stormwater ditches and tributaries, increased development of the landscape can lead to increased stormwater runoff to receiving rivers and streams.

Also, some urbanized land surfaces have been disturbed and compacted to the degree that their capacity to absorb rainfall and runoff has been reduced, even if actual impervious surfaces have not been installed. These are often termed, "equivalent" impervious surfaces. Examples include lawn surfaces that have been intensively landscaped, golf courses, parks, and logging clearings. Conversion of forested lands to agricultural lands and improvement of agricultural drainage structures and ditches can also lead to increased magnitudes and velocities of runoff to the receiving rivers and streams.

To determine if land use patterns have changed significantly in that portion of the Otter Creek watershed draining to reaches M22 through M26, available land cover / land use data sets were obtained and evaluated using Geographic Information Systems (GIS). Analysis results were inconclusive. A detailed discussion of the analysis is presented in Appendix D.

C.4 SUMMARY

Overall, analysis of peak flow, mean annual flow, and daily mean flow records for the Center Rutland gaging station indicates that while the frequency of major flood events appears to be declining, the frequency of moderate flood events, which may sustain overbank flood elevations for longer numbers of days, appears to be showing a slight increase over time. Residents along the Otter Creek Valley between Wallingford and Rutland report that overbank flooding has been more frequent since the 1980s.

Potential contributing factors may include:

- a slight increase in precipitation amounts in early to late Fall months of the year, as revealed from analysis of Rutland precipitation records from 1931 through 1997;
- possible impoundment of flood waters behind the new Route 4 highway crossing mid-way along reach M22, that was installed post-1988 and pre-1994; and
- land use changes in the upstream watershed draining to this stretch of Otter Creek that may include:
  - increased conversion of forested lands to developed and agricultural uses, creating more impervious surfaces and equivalent impervious surfaces;
  - increased ditching of agricultural lands and channelization of tributaries that deliver stormwaters much more quickly to the Otter Creek valley; and
  - ongoing channel management (or channel adjustments in response to historic channel management) in major tributaries, the Mill River and the Cold River.

C.5 REFERENCES

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Vermont Center for Geographic Information, www.vcgi.org
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APPENDIX D

Analysis of Land Cover / Land Use Data: 1993 and 2002

Phase 2 Stream Geomorphic Assessment
Upper Otter Creek Watershed

Reaches: M22 – M26
Rutland & Clarendon, Rutland County, Vermont

February 2006

Appendix D:
Analysis of Land Cover / Land Use Data: 1993 and 2002

TABLE OF CONTENTS

D.1 INTRODUCTION

This appendix provides details of the Geographic Information Systems (GIS) land cover /land use data sets reviewed in an attempt to quantify changes in development in the Upper Otter Creek watershed draining to the 14.2-mile stretch of the Otter Creek main stem assessed by geomorphic methods in November of 2005. If an increase in developed land uses was apparent, this may be a contributing cause to reported increases in frequency of flooding along the Otter Creek main stem between Wallingford and Rutland.

Development of the landscape brings impervious surfaces such as rooftops, paved parking areas, additional roads and driveways. These impervious surfaces prevent rainfall from infiltrating through the ground surface into the underlying soils and sediments. To the extent that these impervious surfaces are connected to stormwater ditches and tributaries, increased development of the landscape can lead to increased stormwater runoff to receiving rivers and streams.

Also, some urbanized land surfaces have been disturbed and compacted to the degree that their capacity to absorb rainfall and runoff has been reduced, even if actual impervious surfaces have not been installed. Examples include lawn surfaces that have been intensively landscaped, golf courses, parks, and logging clearings. Conversion of forested lands to agricultural lands and improvement of agricultural drainage structures and ditches can also lead to increased magnitudes and velocities of runoff to the receiving rivers and streams.

D.2 METHODS

The watershed draining directly to reaches M26, M25, M24, M23 and M22 is 141 square miles in size and contains land area located in 10 separate towns (Figure D.1). Land cover / land use data for this watershed area were obtained and analyzed in an attempt to quantify changes in development and conversion to agricultural use.

The following Land cover / Land use (LcLu) data sets available from the Vermont Center for Geographic Information (www.vcgi.org) were utilized in this analysis:

- **1993 –**
  Landcover / Landuse for Vermont and Lake Champlain Basin (LandLandcov_LCLU, edition 2003). Source dates of 1991 to 1993. Further details of this land cover / land use data set are available at: http://www.vcgi.org/metadata/LandLandcov_LCLU.htm.

- **2002** –
  2002 Land Cover/Land Use Dataset for Vermont (LandLandcov_LCLU2002, edition 2002A) Source dates of June and August 2002. Further details of this land cover / land use data set are available at:
  http://www.vcgi.org/metadata/LandLandcov_LCLU2002.htm

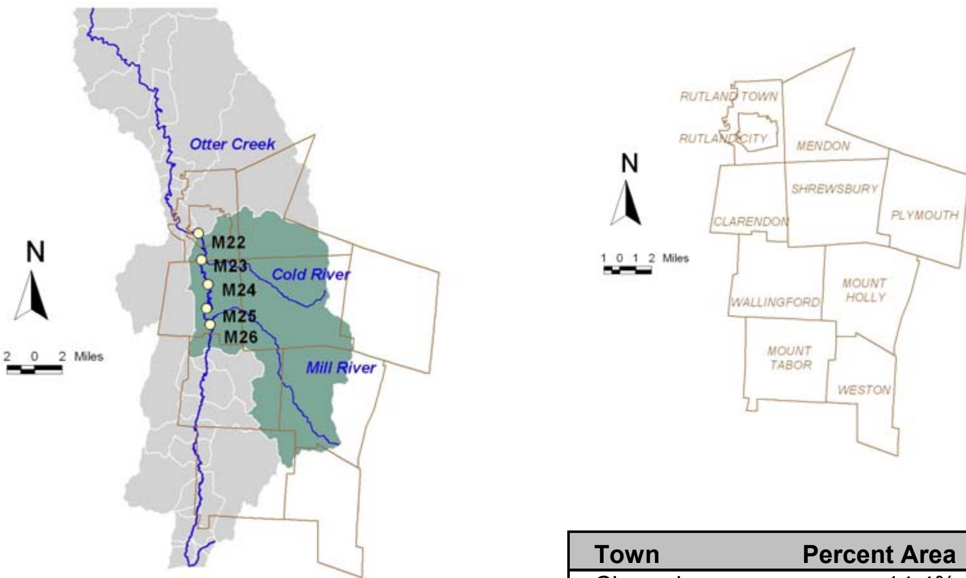


Figure D.1. Watershed draining directly to Reaches M22 – M26 of the Otter Creek main stem.
Area comprised of portions of 10 Rutland and Windsor County towns.

Town	Percent Area
Clarendon	14.4%
Mendon	12.4%
Mount Holly	21.2%
Mount Tabor	2.7%
Plymouth	0.6%
Rutland City	2.5%
Rutland Town	3.8%
Shrewsbury	31.5%
Wallingford	10.4%
Weston	0.6%

Upon reviewing the metadata, the derivation of each data set appeared to be similar enough that LcLu for each year could be directly compared to determine, at a regional scale, if an increase in developed LcLu had occurred between 1993 and 2002.

Classification of the LcLu in each data set follows methods of Anderson, *et al*, 1976. Land surface characteristics are classified into 17 different LcLu categories (Table D.1). For purposes of evaluating land use changes between 1993 and 2002, these 17 categories were consolidated into 7 broader groups: water, wetlands, brush/transitional/barren, forest, agricultural, developed and transportation/utilities. The category of "Developed" contains residential, commercial, industrial, and other urban land uses.

Table D.1 Grouping of Land Cover / Land Use Categories

Land Cover / Land Use		
Category	**Code**	**Group**
Open Water	5	Water
Forested Wetland	61	
Non-forested Wetland	62	Wetland
Brush / Transitional	3	Brush/
Barren Land	7	Transit/Barren
Deciduous Forest	41	
Coniferous Forest	42	Forest
Mixed Forest	43	
Agricultural – Hay/Pasture	212	
Agricultural - Row Crop	211	
Orchard/Tree Farm	22	Agriculture
Other Agricultural Land	24	
Residential	11	
Commercial	12	
Industrial	13	**Developed**
Other Urban	17	
Transportation (Roads) and Utilities (electric transmission)	14	Transportation / Utilities

D.3 RESULTS

A comparison of land cover / land use data from 1993 to 2002 for the study area watershed is presented in Table D.2.

Table D.2 Land Cover / Land Use in Watershed Draining Directly to M22 – M26: 1993 vs. 2002

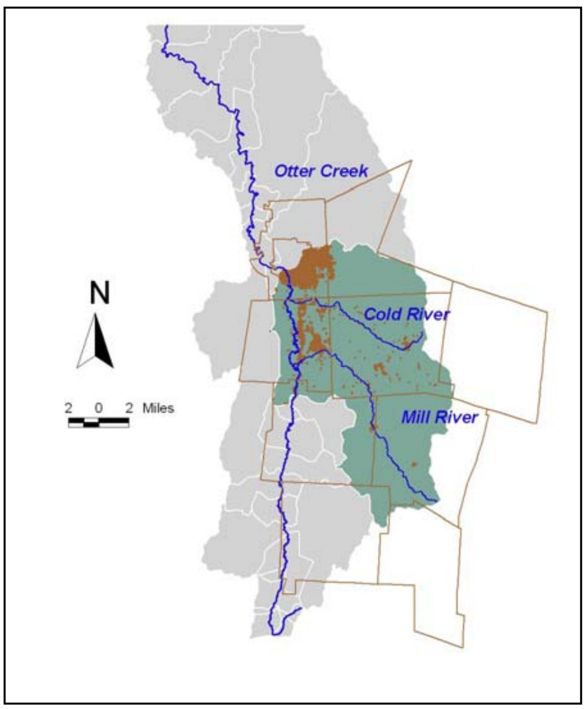
Phase 2 Reach Watersheds	1993		2002	
Land Cover/ Land Use Category	**Watershed Area (sq mi)**	**Watershed Area (%)**	**Watershed Area (sq mi)**	**Watershed Area (%)**
Water	6.4	4.5%	6.3	4.5%
Wetlands	3.3	2.3%	2.8	2.0%
Brush / Transitional / Barren	0.5	0.3%	0.2	0.2%
Forest	109.4	77.4%	100.5	71.1%
Agriculture	**9.1**	**6.5%**	**11.4**	**8.0%**
Developed	**5.9**	**4.2%**	**13.3**	**9.4%**
Transportation / Utilities	6.7	4.8%	6.8	4.8%

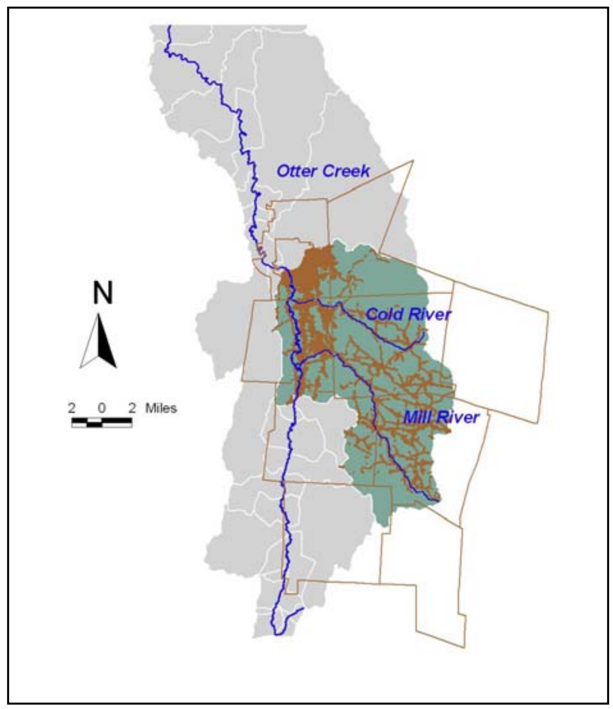
The data suggest a net increase in developed and agricultural LcLu over the 9-year period: agricultural lands increased by just over 2 square miles, while developed lands increased by more than 7 square miles. For the most part, these increases in developed and agricultural lands appear to have been made possible by conversion of previously forested lands.

The apparent increase in developed land is illustrated in Figure D.2, by the brown stippled pattern. From review of this figure, it would appear that the towns of Shrewsbury, Mount Holly, and Clarendon have seen substantial development between 1993 and 2002.

However, upon closer review (Figures D.3 and D.4), it was determined that the two data sets from 1993 and 2002 can not be directly compared. The methods used to delineate "developed" areas under each of the LcLu data sets (1993, 2002) appear to be quite different. As a result, the increase in development suggested in Table D.2 and Figure D.2 is misleading, and the actual change in developed land area in the watershed can not be determined from a comparison of these data sets.

Particularly in the rural settings, the methods used to develop the 2002 LcLu data set, by far, overestimate the actual developed land areas as compared to the methods used to develop the 1993 LcLu data set. Even in areas where there has been no appreciable change in development on the ground between 1993 and 2002, the two methods do not similarly represent the extent of developed land areas (see Figure D.3 and D.4).





(a) (b)

Figure D.2 (a) Developed land area as represented in 1993 LcLu data set;
(b) Developed land area as represented in 2002 LcLu data set.

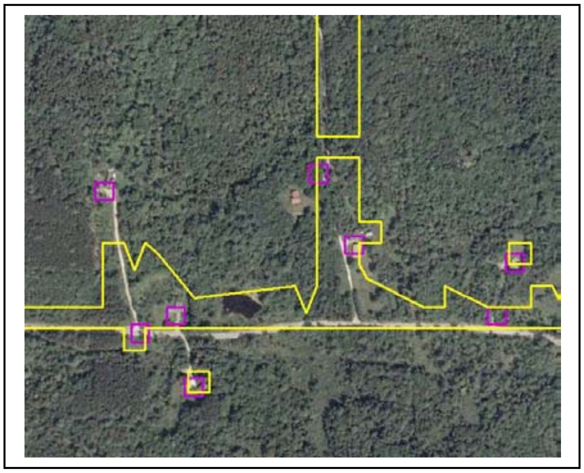


Figure D.3. Delineation of "developed" land cover / land use, near North Shrewsbury, VT.
Yellow line surrounds "developed" lands on 2002 LcLu data set. Purple line surrounds "developed" lands on 1993 LcLu data set.
Base map is 2003 aerial photography.

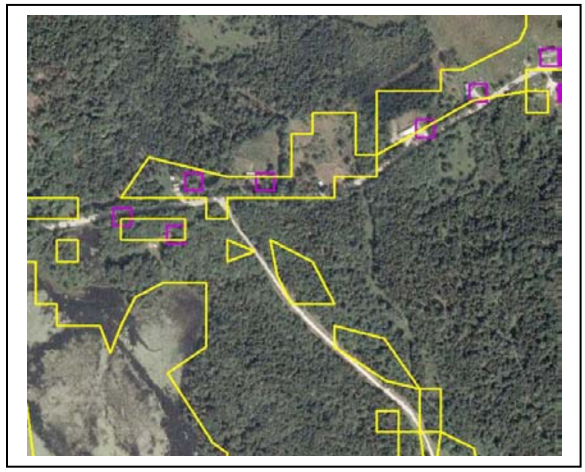


Figure D.4. Another area near North Shrewsbury where 2002 LcLu delineation (yellow) overestimates area of "developed" lands as compared to the 1993 LcLu delineation (purple). 2002 delineation includes areas of forested land along the road at the center of the image, and areas of wetlands at the bottom left of the image. Base map is 2003 aerial photography.

In areas where new structures have been built, comparison of 1995 orthophotos to 2003 aerial imagery reveals that the LcLu delineation methods are of insufficient accuracy and resolution to capture these incremental increases in numbers of structures (see Figure D.5).

(a)

(b)

Figure D.5 "Developed" area from 1993 LcLu data set (outlined in purple) and from 2002 LcLu data set (outlined in yellow); on a 1994 orthophoto base map (a) and 2003 aerial imagery (b). Delineations of "developed" area from each LcLu data set are of insufficient accuracy and resolution to capture the addition of three residential structures (circled in red) between 1994 and 2003 along Middle Road, Clarendon, VT.

D.4 REFERENCES

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer, 1976, *A Land Use and Land Cover Classification System for Use With Remote Sensor Data*. US Geological Survey Professional Paper 964. Washington D.C., Department of the Interior.

Vermont Center for Geographic Information, www.vcgi.org
LandLandcov_LCLU – Landcover/Landuse for VT and Lake Champlain Basin
LandLandcov_LCLU2002 – 2002 Land Cover/Land Use Dataset for Vermont

APPENDIX E

Potential Wetlands Conservation Sites

Preservation of sediment and flow attenuation areas along the river network is an important river corridor management strategy. In the case of the Upper Otter Creek main stem, the focus on developing attenuation areas would be most effective in the upland watershed areas draining to the Otter Creek valley - in particular, along the Cold River and Mill River networks. Several wetland areas and valley settings contiguous to these tributaries have been preliminarily identified through remote sensing for the potential role they could serve in sediment and nutrient attenuation. With the willingness of landowners, these sites may be good candidates for conservation, particularly where existing land uses do not appear to be in conflict with channel adjustment processes. These potential sites are summarized in Table E-1 and identified on the ArcView 3.x shape file included on the Project CD (Appendix F). This list is provisional and requires ground-truthing and landowner outreach to determine if these sites would in fact be effective attenuation areas. Their potential role as attenuation sites should also be confirmed by geomorphic assessments along the Mill and Cold Rivers.

Site	Stream	Road	Town	Description / Justifications	Flow Attenuation	Sediment Attenuation	Nutrient Attenuation	Conservation	Wetland Restoration	Channel Restoration
1	Mill River	Scampsville	Mount Holly	NWI wetlands complex upstream of Scampsville Road crossing. Location of first major reduction in slope along Mill River. Downstream of residential development on RB trib near Route 155 crossing.	√	√	√	√		
2	LB trib to Mill River	Greendale Rd, Route 155	Mount Holly	NWI wetlands along major LB trib to Mill River upstream of Rt 155 crossing. LB trib to Mill River that flows through residential areas, with limited buffers and possible channelization.	√			√	√	
3	RB trib to Mill River	along Tarbellville Rd	Mount Holly	NWI wetlands, hydric soils contiguous to RB trib to Mill River. Downstream of development at Belmont and Star Lake; located at local reduction in slope.	√	√	√		√	√
4	Meadow Brook; LB tr	Route 155	Mount Holly	Freq Flooded soils, alluvial fan setting at confluence with Mill River. Local reduction in slope; evidence of lateral adjustments. Downstream of road and limited residential encroachments along Beaver Meadow Rd. Downstream of glacio-fluvial soils.	√	√		√		√
5	Mill River	Route 155	Mount Holly	NWI wetlands, Freq flooded soils, active lateral adjustments. Local reduction in slope; evidence of lateral adjustments.	√	√		√	√	√

Site	Stream	Road	Town	Description / Justifications	Flow Attenuation	Sediment Attenuation	Nutrient Attenuation	Conservation	Wetland Restoration	Channel Restoration
6	Mill River	Route 155	Wallingford	Active lateral adjustments, coincident with NWI wetlands, Freq flooded soils. Local wider valley setting w/ evidence of active lateral adjustments, downstream of development (East Wallingford) and intensive channel management, where Mill River is flowing through erodible glacio-fluvial sediments.	√	√	√	√	√	√
7	Mill River	Route 103	Wallingford	Area of active lateral adjustments at locally broader valley, and confluence of Freeman Brook. Local wider valley setting w/ evidence of active lateral adjustments, downstream of development (East Wallingford) and intensive channel management, where Mill River is flowing through erodible glacio-fluvial sediments.	√	√	√	√		
8	Mill River	Route 7	Clarendon	Braided channels downstream of Route 7 and upstream of confluence with Otter Creek.	√	√	√	√		
9	trib to Freeman Brook, RB trib to Mill River		Shrewsbury	prior converted wetland downstream of agricultural lands	√	√	√	√	√	
10	Cold River	Middle Rd	Clarendon	area of active lateral adjustments at locally broader valley, and confluence with Otter Creek, downstream of North Clarendon Route 7	√	√	√	√		

APPENDIX F

Project CD