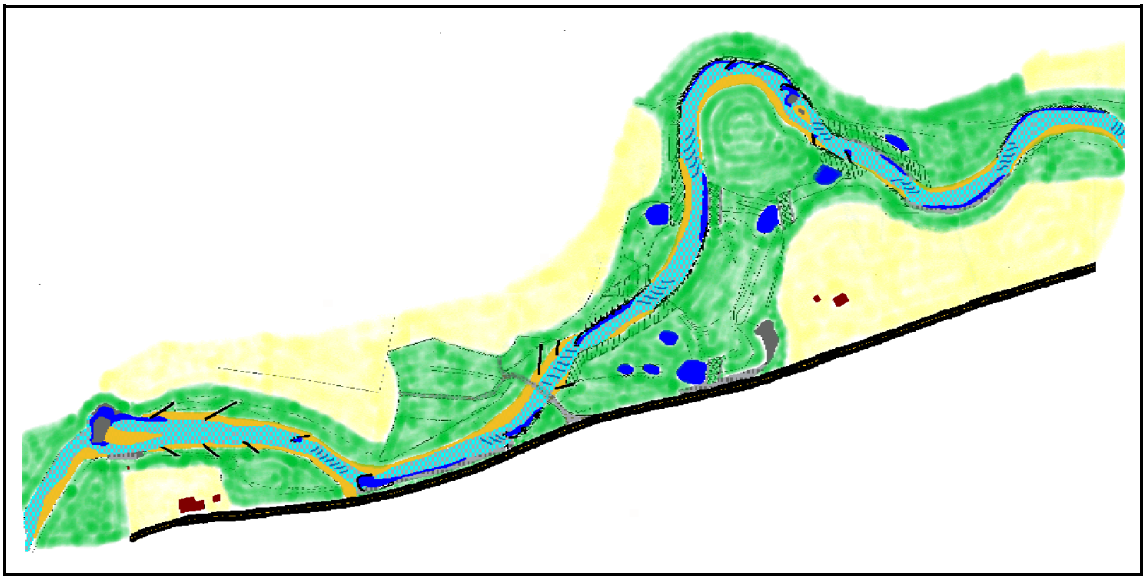
TROUT RIVER PROJECT

A Natural Channel Restoration Project of the Vermont DEC River Management Program



The following document has been prepared by the Vermont River Management Program as a one-year post construction status report for a natural channel restoration project completed on the Trout River in Montgomery, Vermont during 1999-2000. Coordination, design, construction, and monitoring components are described to help current and future river restoration partners understand how natural channel design projects are carried out.

January 5, 2001

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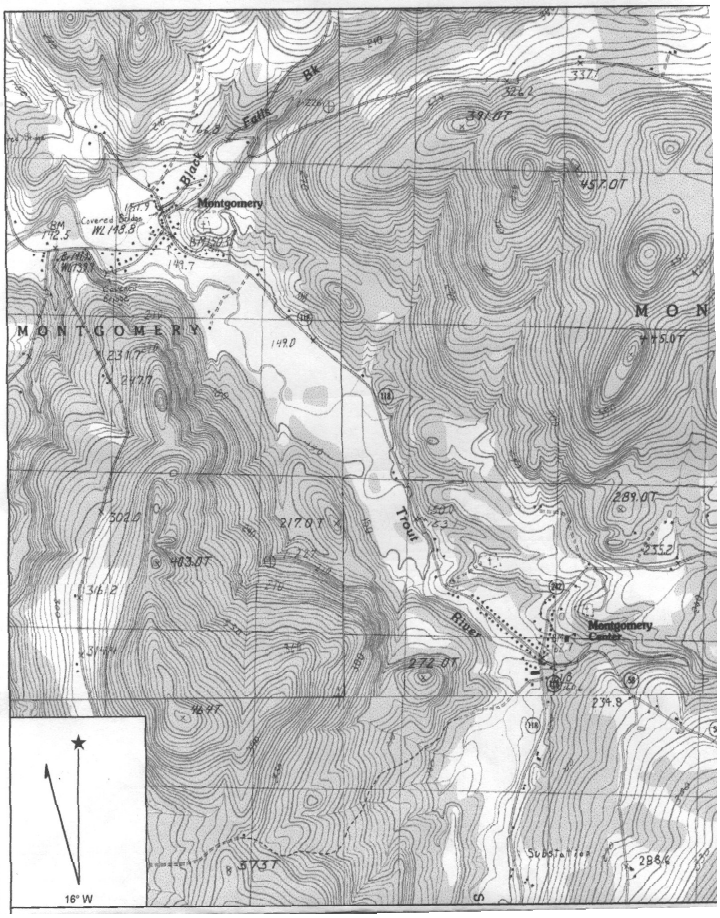
History and Description of the Trout River Restoration Project In Montgomery, Vermont

The Trout River

The flash flood of July 1997 devastated Montgomery and exacerbated an already serious river erosion problem. Historic land use changes, channel management practices, and floods had resulted in an extremely unstable river system. The Trout River, immediately downstream of Montgomery Center, was experiencing very high rates of bank erosion. Little streambank vegetation remained along certain reaches. The river had become so broad and shallow in places that it braided and cut across two meanders. There was a loss of agricultural productivity and property values along the river. Stability of the embankment along VT Route 118 was severely compromised.



Historically, the Trout River has enjoyed the reputation of an excellent brown and brook trout fishery. Loss of a stable morphology, sedimentation, loss of bank vegetation, and elevated water temperatures combined to severely degrade the natural resource and fisheries related values of the river. Loss of a narrow-defined Trout River channel due to changes in morphology has also resulted in the loss of a once popular boating reach.

The beauty of the Trout River valley with its tree lined banks and adjacent farm land historically provided significant aesthetic value to the residents of Montgomery, tourists, and the traveling public. These aesthetic values have been virtually non-existent in recent years.

Landowners downstream from Montgomery Center, where the Trout River was braiding its way through fields, called for extensive state and federal assistance to restore the river. A unique partnership formed to address longstanding river and field erosion problems, and enhance or restore the natural resource values of the Trout River.

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New Solution

For the past 50 years, Vermont landowners with, at times, the support and encouragement of state and federal agencies have used channel dredging and armoring as methods to support intensive riparian land use. There ha**ve** been no good examples for landowners or communities to observe the environmental, social, and economic values of stream stability as maintained primarily by native riparian vegetation. A river restoration project, through which government agencies could demonstrate and landowners could learn the benefits of working at the reach and watershed levels rather than the site-specific level in dealing with erosion and flood damage, was also lacking.

The Trout River Restoration Project was the state's pioneer effort to work with landowners and local community members, and the government agencies and non-profit organizations that represent their diverse interests to begin watershed level restoration. The approach, new for Vermont, used the principles and applied methods of fluvial geomorphology to address the root problems associated with channel stability, rather than traditional channel management techniques that tend to treat only the symptom of erosion.

The project began in Fall 1998 with formalization of landowner co-operation and local project coordination, surveys of the existing reach, and funding proposals.

Watershed and reach-level assessments of the Trout River were critical first steps in identifying the problems of the reach. Hydrology and sediment regime were considered during a watershed assessment. While surveys of channel geometry, riparian condition, and river bed-level processes were conducted during a reach-level assessment. Problem identification was invaluable during the review of remediation alternatives.

During the 1999 and 2000 field seasons, a one mile reach of the Trout River immediately downstream of Montgomery Center was restored using natural channel design techniques. The Trout River design focused on restoring the stable width, depth, meander plan form, slope and riparian vegetation along the project reach. Returning morphologically stable parameters of the river has thus far resulted in effective sediment transport with minimal erosion. At this time, the goals of the project to preserve agricultural lands, stabilize property values, protect a state highway, and restore the river's ecological and recreational values are being met.

Adult Brown Trout (22" long) caught in the Trout River restoration project reach one year after construction

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State Program Objectives

Working with its technical partners, the DEC Rivers Management Program developed the following **program-related objectives** for the Trout River demonstration project.

1. Introduce "Morphological Approach" to river management
   a) Examine what makes a channel stable and why that is important. Use watershed hydrology and sediment regime analyses as part of the problem identification process.
   b) Address problems rather than treat symptoms. Show the relevance of river morphology, channel stability, and channel evolution processes in river management projects.

2. Increase the feasibility of multi-objective projects
   a) Show that it is possible to restore habitat and protect property.
   b) Lower the cost of achieving channel stability.

3. Improve State approach to flood hazard mitigation and flood response
   a) Demonstrate that unstable channels are particularly vulnerable during floods.
   b) Show the value of reference reach data in addressing flood damages
   c) Provide opportunity to develop a new approach to flood recovery

4. Bring together the various technical strengths of state and federal agencies
   a) Collaborate on field research, design work, and construction of a restoration project.
   b) Educate and train agencies, local watershed associations, and general public to recognize the stable forms, its benefits, and practical approaches to watershed management

5. Education opportunities
   a) Provide hands-on public training during data collection phases
   b) Expose various age groups to new river restoration techniques
   c) Conduct workshops about the project

Developing a Work Plan, a Team, and Project Funding

Project Work Plan

A work plan was developed as part of the funding proposal process. Table 1 includes the tasks and projected time-line first envisioned for the project. The actual task completion times are also listed to illustrate the realities of field data collection and the permitting process. It is highly recommended that proponents of restoration projects of this scale develop a work plan with field surveys of reference and existing conditions in one field season and project construction during the following field season. This allows adequate time for regulatory review. All situations, especially those following flood disasters, do not allow for a two year time line. The Vermont DEC is working to develop the technical and regulatory framework necessary to complete natural channel designs and construction on a rapid time line.

Table 1. Project Work Plan and Time Line

Description of Task	Projected Time for Task Completion	Actual Time of Task Completion
Formalize landowner cooperation	September 1998	February 1998
Determine reference reach dimensions	October 1998	November 1998
Hire local project coordinator and secure funding	October 1998	March 1999
Survey existing Trout River segment	December 1998	May 1999
Natural Channel Design	February 1999	June 1999
Review project with regulatory agencies and obtain project permits	April 1999	September 1999
Restore stable channel form	August 1999	November 1999
Conduct post-construction channel surveys to monitor long-term change	October 1999 (and on-going)	November 1999 (and on-going)
Riparian corridor revegetation	October 1999 and April-May 2000	November 1999 Apr.-Oct. 2000

Team Development

The Trout River Project has been a pioneer effort to bring together a diverse group of people, agencies and organizations to begin watershed level restoration. People from the local community, state agencies, and federal agencies were involved.

1. Local community

a) Landowners - offered buffers, soil and plant materials, and in-kind services
b) Town Selectboard - offered in-kind services and project sponsorship
c) Missisquoi River Basin Association (MRBA) - provided funding and volunteers and coordinated the revegetation efforts on the ground.

2. State agencies

a) Department of Environmental Conservation (DEC) - acted as project leader, provided technical assistance, project administration, and had a regulatory role
b) Agency of Transportation - provided funding and technical assistance
c) Vermont Emergency Management - provided funding administration
d) Department of Fish and Wildlife - provided technical assistance and fish surveys
e) Department of Agriculture, Natural Resource Conservation District - funding administration

3. Federal agencies

a) U.S. Fish and Wildlife Service (USFWS) - provided funding, technical assistance, and played a regulatory role
b) Federal Emergency Management Administration (FEMA) - provided funding
c) Natural Resource Conservation Service (NRCS) - provided funding, technical assistance, and funding administration
d) U.S. Forest Service (USFS) - provided technical assistance
e) U.S. Environmental Protection Agency (EPA) - provided funding and played a regulatory role
f) Lake Champlain Basin Program (LCBP) - provided funding

Project Funding Programs

The following agencies and programs contributed funds to support project coordination, design, construction, revegetation, and monitoring. Table 2 includes only those monetary contributions that were used to pay for contracted services on the project.

1. VT Agency of Transportation (VTrans) Research Program
2. VT Agency of Natural Resources (ANR), Performance Partnership and State General Funds
3. Federal Emergency Management Administration (FEMA) Hazard Mitigation Program
4. U.S. Fish and Wildlife Service (USFWS), Partners for Fish & Wildlife Program
5. U.S. Environmental Protection Agency, Sec. 319 Nonpoint Source and 5 Star Grant Programs
6. U.S.D.A. Natural Resource Conservation Service (NRCS), Wildlife Habitat Incentives Program
7. Lake Champlain Basin Program (LCBP)
8. Vermont Conservation License Plate Program

Table 2. Project funding sources used for contracted services

	FEMA	VT License Plate	EPA 319 & 5 Star	USFWS	NRCS	LCBP	ANR	VTrans	Total Cost of Task**
Assessment & Design	X*		X			X	X		20,000
Construction Costs	X	X	X	X	X	X	X	X	132,000
Buffer Revegetation	X	X	X	X	X	X	X		18,000
Public Workshops	X		X			X	X		1,500
Volunteer Coordination		X	X			X	X		4,000

* An "X" has been marked in those tasks that the individual funding source participated in.
** Numbers do not reflect in-kind contributions

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Assessment Results and Project Goals

Watershed Assessment

The Town of Montgomery, located in the eastern portion of Franklin County, is in the northernmost portion of the Green Mountain physiographic region. In the vicinity of Montgomery, the Green Mountains are approximately 20 miles wide. Three mountain peaks within the town rise above 3,100 feet and are generally free of glacial till. Maximum elevation within the town is approximately 3,380 feet. Areas below the 3,100-foot elevation are almost completely covered with till, and lands below 2,000 feet typically contain lake sediments and kamen gravels.

The Trout River, part of the Missisquoi River watershed, is 14 miles long and has a total drainage area of 86 square miles (43 square miles at the project reach). The Trout River runs through a wide "U-shaped" valley between the two population centers of Montgomery Center and the Village of Montgomery. Agriculture is the main land use along this reach, with soil types ranging from silt loam to gravelly loamy sand. The Trout River is formed by the joining of two major tributaries in Montgomery Center, the South Branch and the Jay Br**ook**. Land use along the South Branch is agriculture, while Jay Brook runs through a steep "V" shaped forested valley.

The Town of Montgomery has sustained periodic flooding; resulting in relatively severe flood damage in some areas. Floods of large magnitude occurred in 1888, 1895, 1927, 1973, 1976, and 1997. Approximately 6.5 inches of precipitation fell during the 1927 flood and between 4 and 8 inches of precipitation fell during the 1997 flood. Minor flooding occurs nearly every spring, particularly along the Trout River.

A review of aerial and ortho photographs was completed as part of the watershed assessment. Historical and current land use and land use changes were examined. Channel meander geometry over time was also examined and measured from aerial photographs.

The watershed assessment was completed to determine whether there have been changes to watershed hydrology (the volume and duration of runoff **during and**after storm events) and sediment **regime** (volume and size of bed load materials) that may account for the types of channel instability observed in the restoration reach. For instance the 1941 aerial photo shows a tremendous amount of erosion, lateral channel movement, and aggradation due to watershed deforestation and the consequent changes to watershed hydrology and the hill slope erosion of sediment into the channel. Examination of a 1998 aerial photo and windshield surveys during the spring of 1999 concluded that, at this time, stream bank erosion, land uses, and land management activities in the watershed upstream of the restoration reach were **not** having a significant affect on channel stability below Montgomery Center.

Reach Assessment

A total station mapping survey was completed by ANR, NRCS, and USFWS in the spring of 1999. The survey resulted in twenty-six detailed cross-sections and a longitudinal profile of the river that were used to document the current conditions of the restoration reach.

Meander geometry of the channel was measured from aerial photographs. The most current areal photos that existed for the Trout River were taken before the 1997 flood and did not show the extensive channel braiding that existed in the project reach. In order to more fully understand existing conditions and make accurate decisions about restoration alternatives, current ortho photography was deemed necessary. A contractor was hired to fly and produce aerial photographs from Montgomery Center along the Trout River to East Berkshire. The aerial photos were then orthogonally-corrected.

A review of historic aerial photos and current ortho photos was also completed as part of the reach assessment to better understand the planform or meander geometry adjustments that have taken place within the project reach over time. Local residents, landowners, and resource managers were interviewed to learn about historic channel and land management activities in and adjacent to the project reach. From the data and information collected, the following channel problem synopsis was made:

- ✔ The project area is part of the Trout River alluvial fan, a place of significant change in valley slope where bed load sediments are naturally prone to deposit. Alluvial fans are sensitive to change and may become naturally braided and unstable at times.
- ✔ The removal of riparian woody vegetation decreased the boundary strength of the river banks making it easier for the river to erode its banks than to move its bed and bar material.
- ✔ The river became over-widened exceeding a stable dimension by 75-100% in places (Figure 1), causing a further decrease in the river's power to move sediments. Large mid-channel bars formed in parts of the project reach, further exacerbating bank erosion.

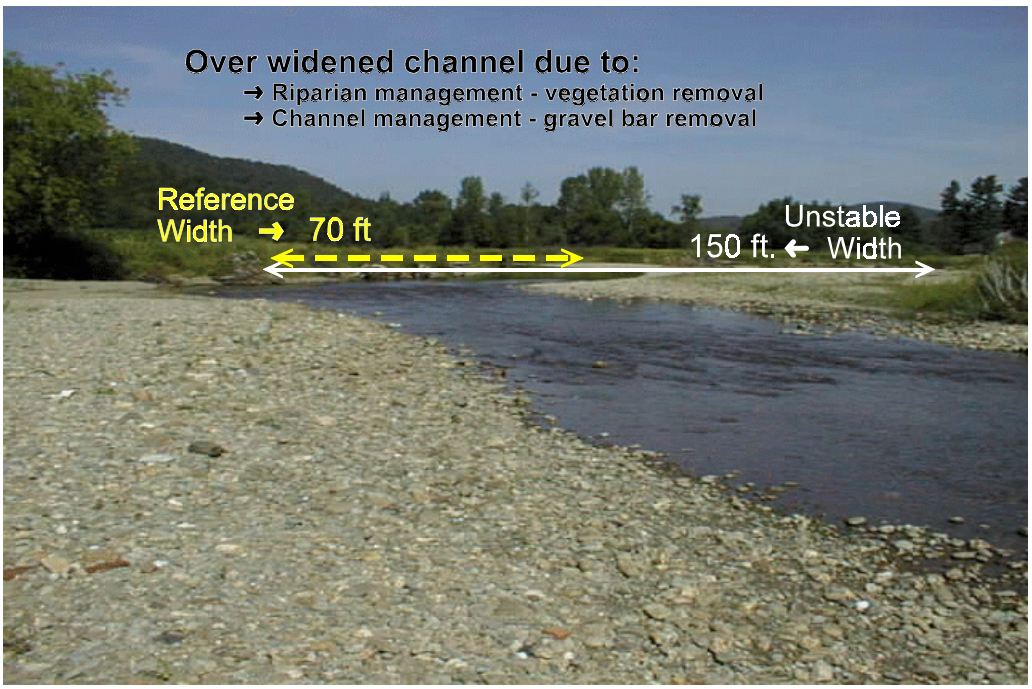

Figure 1. Trout River - unstable width dimension.

- ✔ Extensive gravel mining of the mid-channel and point bars occurred in the 1970s and 80s. The mining had short-term benefits but long-term consequences. Removal of the deposits again over-widened the bankfull channel and reduced sediment transport capacity. Bank erosion and gravel build-up on the bars continued, causing dramatic lateral movement of the channel.

- ✔ Channel armoring started as a way to deal with the bank erosion. These treatments also had short term benefits but long term consequences. For instance, there is high probably that rip-rap used to halt bar growth and bank erosion on the old bendway adjacent to Route 118 only resulted in a higher rate of bar growth, bank erosion, and lateral channel migration of the next downstream bendway. The rip-rap eventually failed.
- ✔ In thirty years, the across-valley distance between bendways grew from 780 ft. to 1110 ft., a 40% increase (Figure 2). An increase in the cross-valley, inter-bendway distance also has a significant impact on the sediment transport capacity of the river. As the meandering of a channel increases the slope of the channel decreases. A channel uses a combination of depth and slope to achieve the power it needs to move its sediment load.

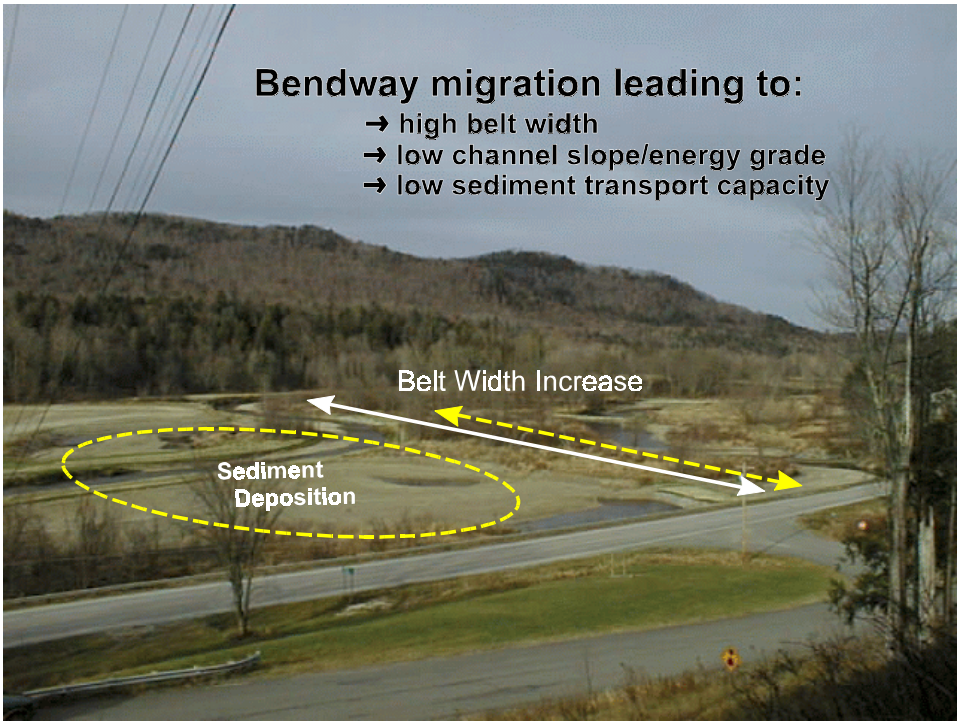

Figure 2. Trout River - unstable pattern and profile.

- ✔ The Trout River had become a wide, shallow, low slope channel with little sediment transport capacity. It was ripe for disaster when the 1997 flood occurred. During and after the flood, the channel became plugged with gravel and major channel avulsion and chute cut-offs occurred.
- ✔ During the initial study phases of this project, the channel was abandoning the old bendways and choosing the straightest steepest course through the new cut-off channels it had created. This new channel was too steep and contained several head-cuts (very steep riffles indicating that the channel was eroding down into its bed).
- ✔ These head-cuts became a major concern for the project team. If they were to continue, the deepened channel would lose access to its floodplain. The containment of larger flood flows within a steepened channel would cause major mass-wasting of the adjacent lands as the channel adjusted its slope (through new meandering) and created new floodplains at a lower elevation.

Project Goals

Given the assessment results, the technical team worked with landowners and other partners to develop a set of specific restoration related goals for the one-mile reach.

1. Create a geomorphically stable channel to avoid:
   a) Severe loss of agricultural soils from the aggradation/degradation process currently underway in the vicinity of the bifurcated channel;
   b) Instability in upstream and downstream reaches of the Trout River resulting from the geomorphic instability of the demonstration reach;
   c) High cost and short life span of a traditional project that would otherwise be implemented and include rip rapping the channel into its previous alignment;
   d) Flood losses that would be severe if the current channel were to experience another major flood; and
   e) Environmental degradation including instream and riparian habitat loss and impacts to Lake Champlain.

2. Create a geomorphically stable channel to restore or enhance:
   a) Sediment transport in a narrower/deeper channel;
   b) Trout habitat with stable riffles and deeper pools;
   c) Riparian and wetland functions, including aquatic and wildlife habitat;
   d) River corridor scenic and aesthetic values;
   e) River recreation including fishing, boating, and swimming.

3. Create a geomorphically stable channel as a public education tool to demonstrate to landowners, towns and state and federal agencies the use of:
   a) Reconstruction techniques to achieve the cross-section, planform, and profile dimensions to effectively transport watershed discharge and sediment loads;
   b) Fluvial geomorphic river design as a cost effective alternative to a traditional erosion control, river restoration, and flood hazard mitigation approach.

New Trout River channel designed with reference dimension, pattern, and profile data.

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Design Criteria & Natural Channel Design

To meet the restoration goals, the technical team sought a project design that resulted in a geomorphically stable channel, using the following definition of stability.

> **<u>STABILITY</u> - The ability of a stream, over time and in the present climate, to transport the flow and sediment of its watershed in such a manner that it maintains its dimension, pattern, and profile without aggrading or degrading**.

River restoration, using natural channel design techniques, is pursued in several ways including a regime theory process using reference reach data and a hydraulic modeling process that includes a sediment continuity analysis. The Trout River restoration design process involved both of these techniques.

Reference Reach Studies

Channels similar in type and valley characteristic to the Trout River with a stable dimension, pattern, and profile were sought in the Missisquoi and Lamoille River valleys. Suitable streams were not located within the time frame of the project so the technical team turned to the Trout River itself to determine reference conditions.

Reference data was collected beginning in 1998. The first set of reference data were collected by the DEC, USFWS, and the MRBA at seven cross-sections along a 2 mile reach below Montgomery Center (Figure 3). Cross-sections and water surface slope measurements were used to provide a "reference" for stable dimensions on the Trout River restoration reach. Pebble counts were also collected at the time of surveying. Pebble count data provided information about what type of material mov**es** (or **does** not mov**e**) through the system and what type of material would need to be transported after construction.

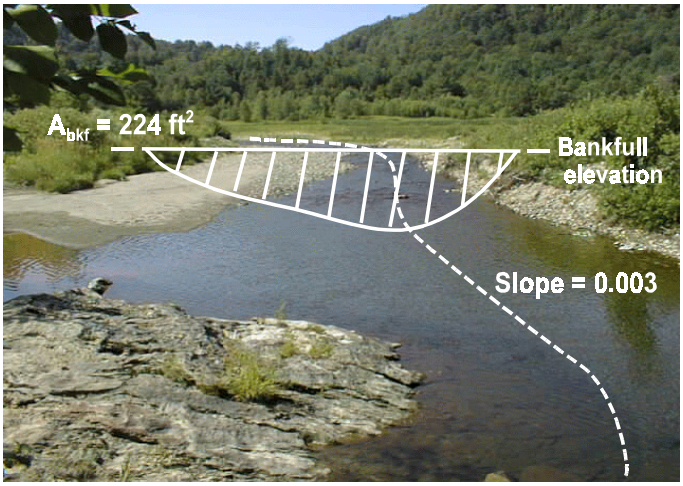


Figure 3. Trout River reference cross-section.

Meander geometry was measured from historic aerial photos and current ortho photos as part of the reference data collection effort. Flows and other hydraulic parameters were estimated using various techniques including an analysis of the nearby North Troy and Berkshire USGS gage data using area to area calculations. The following Tables 3 through 7 include all measured field and map data and the regime equations used to verify these measurements as reference-level data.

Table 3. 1998 Field measurements

Stream Name: Trout River
Location: Two mile reach below Montgomery Center
Organization/Agency: VTANR, USFWS, MRBA

Date: Oct-Nov./1998
Elevation: 492 feet
Drainage Area: 43 SqMi

Downstream ➡ ➡ ➡ ➡ ➡ ➡ Upstream

	TR1	TR2	TR3	TR4	TR4.5	TR5 (pool)*	TR6	E.US Curve
$Width_{bkf}$ (Ft)	95.4	78.4	64.7	93.4	81.9	60.7	74.6	65
$depth_{bkf}$ (Ft)	2.91	3.92	3.75	3.88	3.79	3.56	3.00	4.4
$Area_{bkf}$ (Ft^2)	278	307	242.5	362	310	216	224	285
$depth_{max}$ (Ft)	5.1	5.5	5.5	5.7	4.9	6.4	4.8	
Width/depth	34.41	20.0	17.25	24.07	21.61	17.05	24.87	14.77
$Width_{fpa}$ (Ft)	925.4	428.4	389.7	1200	732	960		
Entrenchment	9.7	5.5	6.0	12.8	8.9	15.8	12.9	
Slope (Ft/Ft)	0.00173					0.003		
Val. Slope (Ft/Ft)	0.00215					0.005		
Sinuosity	1.6		Entire Reach = 1.58			1.108		
Particle D50 (in)	0.69	0.38	0.35				1.83	
Particle D84 (in)	1.43	1.08	1.52				2.57	

Subscripts
bkf- bankfull fpa - flood prone area * TR5 pool transect was not include in the calculations below

Table 4. Flow Calculations

Eastern US Curve

$Q_{bkf} = 61(DA)^{0.82}$
$Q_{bkf} = 61(43)^{0.82} = 1{,}333\ ft^3/sec$

Northern New England Curve (F. Magilligan)

$Q2 = \log^{-1}(1.8837+0.82972(\text{Log } DA))$
$Q2 = \log^{-1}(1.8837+0.82972(\text{Log } 43)) = 1{,}734\ ft^3/sec$

FHWA 3 Parameter Method

$Q2.33 = 0.46921(Q10^{1.00243})$ where Q10 = 3300 cfs from AOT hydraulics at 47.7 sqml, 1973
$Q2.33 = 1580\ ft^3/s$

USGS Area Relationship Method

$Q_x = (A_x / A_y)^{0.67} * Q_y$ where:
A_x = 43 sqml
A_y = 131 sqml (gage on Missisquoi River at North Troy, VT)
Q_y = 4362 cfs from USGS freq analysis for Q2
$Q_x = 2067\ ft^3/s$

Manning's n Method

$Q_{bkf} = 1.486 / [n/(A)(R^{2/3})(S^{1/2})]$ where:
n=0.0292 (see computation below)
A=287 ft^2 (ave. of measured cross-sections)
R=3.24 ft (see computation below)
S=0.003
$Q = 1{,}752\ ft^3/s$

Table 5. Dimension Calculations

Width - W_{bkf}

Field Measured Ave (TR1 - TR6) = 81.4 ft

Regime Theory Equations (Williams, 1986)

	Meander Wavelength	Belt Width	Radius of Curvature	Depth	Depth & Sinuosity
Width	$W = 0.17L_M^{0.89}$ 79.5 ft	$W = 0.27B^{0.89}$ 82.5 ft	$W = 0.71R_C^{0.89}$ 89.8 ft	$W = 21.3D^{1.45}$ 133.2	$W = 96D^{1.23}K^{-2.35}$ 155.1 ft

Mean Depth - d_{bkf}

Field Measured Ave (TR1 - TR6) = 3.54 ft

Regime Theory Equations (Williams, 1986)

	Meander Wavelength	Belt Width	Radius of Curvature	Width	Width & Sinuosity
Mean Depth	$d = 0.027L_M^{0.66}$ 2.58 ft	$d = 0.037B^{0.66}$ 2.58 ft	$d = 0.085R_C^{0.66}$ 3.08 ft	$D = 0.12W^{0.69}$ 2.5 ft	$D = 0.09W^{0.59}K^{1.46}$ 2.35 ft

Cross Sectional Area - A_{bkf}

Field Measured Ave(TR1 - TR6) = 287 ft^2

Regime Theory Equations (Williams, 1986)

	Meander Wavelength	Belt Width	Radius of Curvature
Area	$A = 0.0054L_M^{1.53}$ 210 ft	$A = 0.012B^{1.53}$ 225 ft	$A = 0.067R_C^{1.53}$ 275 ft

Table 6. Planform Calculation

Radius of Curvature - R_c

Measurement of R_c from aerial photos

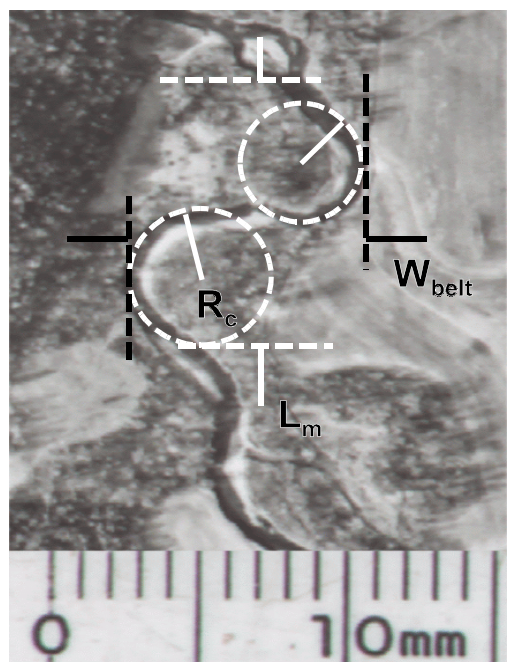
photo yr.	R_c1	R_c2	R_c3	R_c4	R_c5	R_c6	R_c7	R_c8	R_c9	R_c10
1941			256	195					159	
1963	236		236					148	230	177
1974	249	190	249	249		230	151	157	256	92
1998	236			197	229	244	189			

Ave(R_c1 - R_c6, 1941-1998) = **230 ft.**
R_c = 2.5 - 3.2 W_{bkf} 230 ft. / 81.4 ft. = 2.8
R_c = $[L_m K^{1.5}] / [13(K-1)^{0.5}]$ R_c = 201 ft.(Langbein & Leopold, 1966)

Regime Theory Equations. (Williams, 1986)

	Meander Wavelength	Belt Width	Area	Width	Depth
Radius of Curvature	$R_C = 0.22L_M$ 220 ft	$R_C = 0.35B$ 217 ft	$R_C = 5.8A^{0.65}$ 230 ft	$R_C = 1.5W^{1.12}$ 207 ft	$R_C = 42D^{1.52}$ 287 ft

Meander Wavelength - L_m



Measurement of Wavelength L_m from aerial photos

photo yr.	L_m1	L_m2	L_m3	L_m4	L_m5
1941					
1963					750
1974	951		1116	984	
1998	969	941	961	929	575

Ave(L_m1 - L_m4, 1974-1998) = 978 ft.
L_m = 10 -14 W_{bkf} 978 ft / 81.4 ft. = 12

Regime Theory Equations (Williams, 1986)

	Belt Width	Radius of Curvature	Area	Width	Depth
Meander Wavelength	$L_M = 1.63B$ 1,011 ft	$L_M = 4.53R_C$ 1,042 ft	$L_M = 30A^{0.65}$ 1,188 ft	$L_M = 7.5W^{1.12}$ 1,035 ft	$L_M = 240D^{1.52}$ 1,639 ft

Table 6. Planform Calculations (continued)

Measurement of **B** from a**e**ri**a**l photos

photo yr.	B1	B2	B3	B4	B5
1941	781		781	415	
1963					
1974	721			459	
1998	850			638	

Ave(B1/B2 - B4/B5, 1941-1998) = 644 ft.

Regime Theory Equations (Williams, 1986)

	Meander Wavelength	Radius of Curvature	Area	Width	Depth
Belt Width	$B = 0.61L_M$ 610 ft	$B = 2.88R_C$ 662 ft	$B = 18A^{0.65}$ 713 ft	$B = 4.3W^{1.12}$ 593 ft	$B = 148D^{1.52}$ 1,011 ft

Table 7. Dimensionless Ratios and Hydraulic Parameters

Width/Depth Ratio - W/D

K_{entire} = 12,374 ft / 7,815 ft = **1.58**

$W/D = W_{bkf} / d_{bkf}$
Field Measured Ave(TR1 - TR6) = **23**
C4 (mean value) = 20.75 (Rosgen, 1996)

Entrenchment Ratio - ER

$ER = W_{fpa} / W_{bkf}$
Field Measured Ave (TR1 - TR6) = **9.3**
Range (TR1 - TR6) = 5.5 - 13

C4 (mean value) = 5.26 (Rosgen, 1996)

Meander Width Ratio - MWR

$MWR = \text{Belt Width} / W_{bkf}$
MWR = 620 ft / 81.4 ft = **7.6**

Channel Sinuosity - K

K = Channel Length / Valley Length
K_{upper} = 1,885 ft / 1,701 ft = 1.108
K_{lower} = 1,905 ft / 1,188 ft = 1.6

Design Workshop

A design workshop was held in Montgomery Center from May 23-25, 1999 under guidance of Dr. Craig Fischenich, FIScH Engineering of Vicksburg, Mississippi. Dr. Fischenich led the technical team on a field survey of the project reach and confirmed the accuracy of the group's problem identification, reference reach data and regime calculations. As part of the workshop, a hydraulic model of the project was constructed using HEC RAS. The model was used to calculate the variation of sediment transport competency values from cross-section to cross-section throughout the reach. These computations showed the desired decrease in stream power variability through the reach when comparing the existing unstable channel with the design channel. The modeling also confirmed the accuracy of the regime and reference information and the use of a Rosgen C4 analog as a design guide.

One of the primary tasks of the design workshop was to select a stable plan form using the meander geometry reference values. Sediment competency was also a factor in selecting the meander geometry of the river in the area of the channel avulsions. In the riffle areas the river needed competency (power) to transport sediment up to and including the gravel size class but not the small cobble size class. Critical shear stress values were calculated for different channel slopes and depths. Given the sediment competency requirements (i.e., gravels but not cobbles), a desired range of shear stress and hence, slope values were determined. The channel slope values were translated into a range of channel lengths which were in turn used to evaluate the viability of different plan form routes through the channel avulsion area (Figure 4). A plan form that involved the creation of a new 300 foot channel bendway, the use of the existing bendway on the westerly side of the valley and the re-creation of a bendway that existed prior to the flood was chosen to match the reference and regime values and meet the sediment competency requirements.

Threshold Shear			
For 7 ft channel drop Sec. 6 - Sec. 19			
	Slope	Shear	Length
Min for course gravel	0.0025	0.5	2800
Max for small cobble	0.0045	1.0	1555

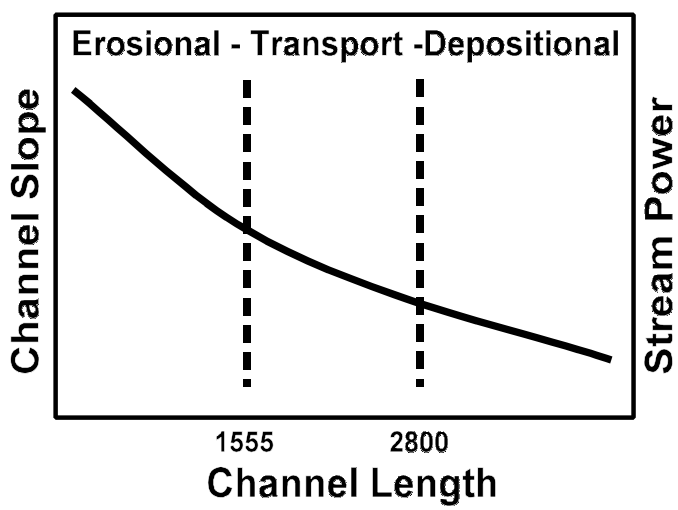


Figure 4. Shear stress analysis to determine channel slope and length through avulsion area.

The preliminary design was then checked against the list of project goals and constraints that were discovered through the assessments and through discussions with landowners and local officials, including: a) maintain river crossings; b) protect State Route 118; c) protect or replace swimming holes; and d) preserve crop land while creating functional woodland buffers.

Natural Channel Design

Table 8 contains a summary of the reference design criteria used during the project design and construction phases of the project.

Table 8. Summary of Channel Design Criteria

Bankfull Discharge - Q_{bkf}	1750 ft^3/sec	Water Surface Slope - S	0.003
Width - W_{bkf}	70 ft	Channel Sinuosity - K	1.58
Mean Depth - d_{bkf}	3.5 ft	Wetted Perimeter - W_p	77 ft
Cross Sectional Area - A_{bkf}	287 ft^2	Hydraulic Radius - R	3.73 ft
Width/Depth Ratio - W/D	20	Roughness Coefficient - n	0.03
Entrenchment Ratio - ER	10.8	Mean Velocity - u	6.1 ft/sec
Meander Width Ratio	8.9	Shear Stress - τ	0.698 lbs./ft.^{2}
Radius of Curvature - R_c	230 ft	Stream Power - ω	0.0608 lbs.ft./s
Wavelength - L_m	1,000 ft	D50 Bed Particle Size	1.83 in / 47.2 mm
Belt Width - B	620 ft	D84 Bed Particle Size	2.57 in / 65.3 mm

The selection of a stable channel dimension, pattern, and profile set the stage for designing the structural components used to stabilize river banks and restore channel and riparian form and function in a manner consistent with the restoration goals. Dr. Fischenich led the technical group through a preliminary selection of structures. The technical group felt that the project goals would be met the best by favoring the use of low tech, low cost, and low maintenance structures. The group wanted to minimize the use of rip rap to the greatest extent possible.

The preliminary design was submitted in an application for state and federal water quality permits (Section 401 and 404 permits). Finer details for the design were worked out as part of the permit process and as amendments subsequent to the permit process. Experience and a longer project design phase will undoubtedly lessen the need for untimely permit amendments which is a frustration for the applicant and the permit review agencies.

Drawings 1 through 5 in Appendix A show detailed plan view features of the project. Descriptions of each structure, method, excavation, and discharge are provided below and are sequentially numbered or labeled from upstream to downstream on the drawings. The proposed planform is marked off in 150 ft intervals from upstream to downstream through the project reach on the plan view drawings. The location or river segment in which the 17 structures or activities are proposed is indicated in the descriptions.

The following list also includes the structures and activities for which permit amendments were received. Amendment 1(a-n) consist of the structural changes intended to address bank erosion which became evident, subsequent to the Town's receipt of the permit, following Hurricane Floyd (September 16-18, 1999), and others intended to further improve fish and wildlife habitat. Amendment 2(a-b) consist of the structural changes made to address bank erosion which followed the Spring 2000 runoff period. Amendment 3(a-c) consist of those structures intended to address a meander cutoff and bank erosion which followed the spring, 2000 runoff period.

Following the description of each structure and its purpose, a brief one-year post construction status report is provided. Typical cross-section drawings and pictures of structures referred to in the following list are located in Appendix B. It should be noted here that the structures placed during the 1999 construction season have experienced five bankfull flow events.

List of Trout River Restoration Structural Components

1) **Vanes on left bank (Drawing 2, Appendix A at 150-300 ft)**. Two rock vanes spaced at 100 ft, angled upstream at 30 degrees. Built to current bankfull elevation (Ordinary High Water - OHW) and sloped down to the channel bed with a profile at one foot above the stable bank form downstream. Shown in vane typical in Appendix B. Purpose - in tandem with vanes located across the channel (#2), these vanes will slow velocities along the bank, collect sediments, and narrow channel from 150 feet to 90 feet. **STATUS:** Structures are intact and meeting intended purposes of slowing velocities and collecting sediments.

2) **Vanes on right bank (Drawing 2 at 300-525 ft)**. Three rock vanes spaced at 100 ft, angled upstream at 30 degrees. Built to current bankfull elevation and sloped down to the channel bed with a profile at one foot above stable bar form. Purpose - in tandem with vanes located across the channel (#1), these vanes will slow velocities along the bank, collect sediments, and narrow channel from 150 feet to 90 feet. **STATUS:** Structures are intact and meeting intended purposes of slowing velocities and collecting sediments.

Amendment 1(a) (Drawing 2 at Station 495 ft.) - Rock Vane to extend the bar building process of the left bank vanes placed at Stations 225 and 300 ft. The purpose of these vanes are to narrow the channel from 120 ft width to approximately 80 ft. **STATUS:** Not constructed yet. Function of upstream vanes to determine future status.

Amendment 1(b) (Drawing 2 at Station 645 ft.) - Rock J Vane to protect against erosion on the left bank and create a pocket pool for adult salmonid fish. Shown in vane typical and picture in Appendix B **STATUS:** Structure is intact and meeting intended purposes of slowing velocities and protecting the bank. The invert of the vane J rocks were set too low and therefore only a very small pool developed off the arm of the vane.

3) **Weir across channel (Drawing 3 at 850-950 ft)**. Vortex rock weir constructed across the channel. Weir will be keyed into rip-rap along Rt. 118 above the bankfull elevation (OHW) on the right bank. Weir will cross bar cut-off chutes on both right and left banks. Shown in weir typical and picture in Appendix B. Purpose - maintain and deepen pool at the ledge just downstream on the right bank to enhance swimming and fish habitat. **STATUS:** Structure is intact and meeting intended purposes of slowing velocities, collecting sediments upstream on the right bank, and maintaining a deep pool along the ledge and against the lunker structures.

4) **Lunkers on right bank (Drawing 3 at 1000-1120 ft)**. Fish lunker boxes placed under a 120 ft. section of traditional rip-rap (#5) along the right bank. Shown in lunker typical and picture in Appendix B. Purpose - provide cover for fish along highway where revegetation options are minimal. **STATUS:** Structures are intact and have remained free of sediments.

5) **Rock revetment along highway (Drawing 3 at 900-1530 ft)**. Bulk toe rock revetment along 510 ft. of the right bank along Rt. 118. The downstream 75 feet of the revetment will be angled out slightly so that the right bank is 10 feet into the existing channel at the downstream-most point of the revetment. The upper-most vane, described in #6 below, will form the downstream-most end of the revetment. Shown in picture in Appendix B. Purpose - repair existing rip-rap along the Rt. 118 highway embankment and begin to slightly redirect and tighten channel in tandem with downstream rock vanes on right bank (#6). **STATUS:** Structure is intact and meeting intended purposes of protecting the highway embankment. Some minor rock launching from the bulk toe and deepening of the thalweg against the rock has been noted.

6) **Vanes on right bank (Drawing 3 at 1500-1800 ft)**. Two rock vanes spaced at 100 ft, angled upstream at 30 degrees. Built to bankfull elevation (OHW), and sloped down to the bed of the channel. Shown in vane typical and picture in Appendix B. Another two vanes, constructed with logs and rock, located 150 feet downstream of the first two and spaced at 100 ft. The downstream vanes are built with a profile set at one foot above the existing downstream bar elevation and do not encroach as far into the channel as the upstream vanes. Purpose - in tandem with the rock revetment located upstream (#5) and vanes on left bank (#7), these vanes will slow velocities along the bank to collect sediments, deepen the thalweg off the end of the upper vanes and narrow channel from 120 feet to 90 feet. **STATUS:** The middle two vanes were not constructed. See Amendment 1(c) below. The upstream vane structure is intact and meeting intended purposes of protecting the right bank and the existing wooded buffer between the river and Rt. 118. The vane placed downstream of the ford on the right bank is also intact and working to protect the new right bank berm.

Amendment 1(c) (Drawing 3 at 1,545 to 1,620 ft.) - Large Rock Wall with Root Wads to replace two of the four vanes planned for the right bank at Stations 1605 and 1845. This change is intended to protect the large deep pool that has developed next the river bank. The vanes planned for this area would have protected the bank by slowing velocities and causing deposition where the pool presently exists. Using the same quantity of large boulders to create a vertical stone wall will protect the river bank while maintaining the scour pool. Two root wads will be placed through the rock to enhance structure in the pool. Using large rock to build vertically will not require any bank shaping and will save the existing overhanging trees. Stacking the large rocks will also create many crevices for fish and macroinvertebrate cover. **STATUS:** Structure is intact and meeting intended purposes of bank protection and pool maintenance.

Amendment 1(d) (Drawing 3) - The rock/wood vanes planned and designed on the right and left banks just below the river crossing at Station 1650 ft. will be constructed with large boulders only. Equipment necessary to cable the tree boles to the boulders will not be available for the project.

7) **Vanes on left bank (Drawing 3 at 1700-1800 ft)**. Two log/rock vanes spaced at 100 ft, angled upstream at 30 degrees. Built to bankfull elevation, and sloped down to channel bed. Purpose - in tandem with vanes located across the channel (#6), these vanes will slow velocities along the bank, collect sediments, and narrow channel from 120 feet to 90 feet. **STATUS:** Structures are intact and meeting intended purposes of encouraging sediment collection and bar development on the left bank.

Amendment 1(e) (Drawing 3 at Station 1,860 ft.) - Rock J Vane to protect the integrity of the root wads by moving the deep fast currents away from the left bank. The structure is also intended to start the pool that will continue downstream along the root wads on the left bank. **STATUS:** Structure is intact and meeting intended purposes of bank protection and pool initiation above the root wads. This J Vane, located at the tail of a steep riffle, has resulted in a large, deep pool. Kayakers have been documented using the vane during high water as a practice run. The structure and pool have resulted in habitat that are holding adult Brown Trout (determined during post-construction electro-fishing). The degree of scour around the J rocks is of concern and will be monitored. In the future, J Vanes placed in this type of bed profile will be designed with bed-level sills that will extend from the J rocks to the opposite bank to prevent excessive scour and failure of footer rocks. Also, it is critical to have the top rock sitting on a sufficient footer to prevent scour of smaller materials on the upstream side of the vane and subsequent back tilting of the top rocks. This vane may be having a negative influence on the development of deep run habitat along the downstream root wad habitat. This will be further evaluated in future cross-section studies.

8) **Root wad revetment on left bank (Drawing 3 at 1800-2085 ft)**. Eight root wad structures to add to and repair existing root wads along the left bank. Shown in root wad typical and picture in Appendix B. Purpose - protect left eroding bank and create scour pockets as fish habitat. **STATUS:** Structures are intact and meeting intended purposes of bank protection and fish habitat.

Amendment 1(f) (Drawing 4 at 1,740 to 2,110 ft.) - Berm Extension at the mouth of abandoned channel A1 upstream to form the right bank of the river. This extension of the berm designed and permitted across the head of abandoned channel A1 (see Structure 9 below) is believed to be critical for maintaining the channel width and depth necessary for transporting sediment through this reach and into New Channel

1. The berm will extend upstream to the vane at Station 1770 ft., will have the same width dimension, but will only be 2.5 ft higher then the pre-existing grade. **STATUS:** Structure is intact and meeting intended purposes of maintaining the cross-section and bed profile of the rood wad reach.

NC1 **New channel (Drawing 4 at 2175-2510 ft)**. Excavate a new 335 ft channel marked NC1. Starting 2025 ft, the thalweg will be shifted to the right, away from the mouth of the old channel marked B1, to enter the new channel (at 2175 ft), just right of center, and moved to a point on the right side of the new channel (at 2510 ft) where it will be located along the rock of the channel block (#11) across the old channel marked B2. Bed features, including riffles, runs, pools, and glides were designed and constructed through the new channel. See picture in Appendix B showing plan form changes. Bed feature water surface and bed slopes were calculated based on dimensionless ratios (e.g., riffle water surface slope/average water surface slope) for C4 stream types. See bed feature design picture in Appendix B. Purpose - Create a stable bendway geometry that has radius of curvature of 337 ft. To construct the new channel, NC1, a temporary channel will be placed in an existing flood chute excavated across a gravel bar to the right side of the channel. The river would enter this temporary channel where new vanes (#6) will be constructed on the right bank (at 1725 ft), cross through the old flood chute, and re-enter the old channel (marked A1) near Rt. 118 where the channel block will eventually be constructed across the old channel (#11). The temporary channel will be 60 ft wide and 4 feet deep as measured from OHW. The old flood chute is already 2 feet deep, requiring only a 2 foot deepening to attain the 4 foot depth. A temporary gravel berm dam (75 cu. yds.) will be placed to divert flows into the temporary channel. The river flowing through this temporary channel will allow the NC1 channel and structures 7, 8, 9, 10, 11 (over B2), 12, and 13 to be constructed in the dry. **STATUS:** The new channel is intact, maintaining its dimension, pattern and profile.

9) **Earth Berms in bifurcated channels (Drawing 4 at 2150-2250 ft)**. Berms at mouths of the old channels labeled A1 and B1 with earthen materials for a length of 100 feet. The fill across old channel B1 will be built to an elevation one foot below bank full (OHW). The earth fill across old channel A1 will be built to bankfull elevation. Shown in berm typical and picture in Appendix B. Purpose - close off old channels and help redirect flow into new channel. **STATUS:** Structure is intact and meeting intended purposes of maintaining the cross-section and bed profile of the reach.

10) **Tree Revetment on right bank (Drawing 4 at 2100-2500 ft)**. Two-tier tree revetment along toe and bank of the new channel. Another 150 feet of tree revetment would be placed on the downstream-most section of left eroding bank of the old channel labeled B1. Shown in tree revetment typical and picture, Appendix B. Purpose - stabilize banks until vegetation takes hold. **STATUS:** The upstream 100 feet of the tree revetment at the cross-over riffle heave collected sediments and are working as intended. Below the cross-over point the tree revetments failed. A number of factors are believed to have contributed to the revetment failure. When the new channel was constructed a 5 to 8 ft. wide, bankfull-elevation bench was constructed with unconsolidated gravel material to create a place for willow brush layers. This bench reduced the desired cross-sectional area of the new channel. The tree revetments, some of which did not adequately cover the bank to the OHW mark, were not sufficient to deflect the flows and protect the loose gravel bench. The bench was eroded out from behind the revetments on the downstream two-thirds of the new bendway.

Amendment 2(a) (Drawing 4 at 2350 to 2500 ft) - 2 Vanes, each 45 feet in length, to protect the right bank of the New Channel #1 upstream of the channel block across abandoned channel B2. The bank was originally protected with tree revetments, which will be replaced with new tree revetments after the vanes are placed. **STATUS:** The vane structures are intact and meeting intended purposes of protecting the right bank and the existing wooded area adjacent to the new channel. Deep six foot pools have formed off the arms of the vanes, where schools of small fish are often observed.

11) **Channel blocks across old channels**. Three earth filled rock covered structures to block flows at bank**full** elevation from entering the old channels labeled A1, A2, and B2. The channel block on B2 would be located across the mouth of the old channel and will form the right bank of the new channel (Drawing 4, Appendix A at 2500-2620 ft). The channel block on A1 would be located 270 feet down the old channel from what will be the active channel. The A1 channel block will be 150 long and tie into the embankment at the toe of Rt. 118 . The A1 channel block will be particularly visible from the road and will be carefully landscaped with vegetation. The channel block on A2 would be located across the mouth of the

old channel. The A2 channel block will be 120 feet long and would serve as a backup for the structures on A1 and B2 (plan view Drawing 4). Purpose - The channel blocks will significantly slow down flowage above the bankfull (OHW) stage through the old channels and flood chutes to allow for sediment deposition. The structure across B2 will also serve to stabilize a critical area of the new bendway. **STATUS:** The upstream channel blocks have remained intact and have met their intended purpose. The downstream most channel block across abandoned channel A2 has suffered significant erosion during **bank-**full flow events. Eventually it was determined after consultation with Dr. Fischenich that the back slope of the Block was too steep. The second time the structure was repaired, a more gentle 8:1 back slope was constructed and revegetated. All of the abandoned channel are collecting fine sediment during high flows, especially B2, and are quickly being colonized by vegetation.

Amendment 1(g) (Drawing 4 from 2,475 to 2,730 ft.) - Earth Berm at the mouth of abandoned channel B1 to further slow the velocities and erosive power of water that will flow over the berm at the head of abandoned channel B1 during flood events. The downstream berm will also maintain surface water in the abandoned channel following high flow events which will enhance wetland habitat adjacent to the Trout River. The tree revetments planned for the downstream-most left bank of the abandoned channel will not be needed. These revetments are needed instead on the left bank of the Trout River from Station 2,100 to 2,250 for additional bank protection below the root wads. The new berm will be vegetated with grasses, willows, and trees. **STATUS:** Structures are intact and meeting intended purposes of maintaining the cross-section and bed profile of the reach. The tree revetments placed below the root wads have worked beautifully to collect sediments, protect the bank, and create salmonid habitat.

Amendment 1(h) (Drawing 4) - Wetland depressions in abandoned channels A1 and B1and adjacent floodplains. Four conical depressions will be created in or near abandoned channel A1, three of which will be 3 ft deep and have a diameter of about 60 ft. A forth depression, just ahead of the channel block on A1, will be 4 ft deep and have a diameter of about 75 ft. A wetland of similar dimension will be created ahead of the channel berm at the mouth of abandoned channel B1. These depressions should hold water following high runoff periods and enhance the wetland values and functions along the Trout River corridor in the vicinity of the project. Shown in wetlands picture in Appendix B. **STATUS:** With each bankfull flow event, the abandoned channels have filled with water as the berms and blocks have been overflowed. Local observers report that these small lakes slowly drain over the course of a week. Afterwards, the wetland depressions hold water for varying lengths of time. Wetland plants, such as sedges, rushes, and cattail have naturally invaded these depressions. Numerous fish and amphibians have been observed in the deeper depressions.

Amendment 2(b) (Drawing 4 at Station 2650) - Rock Vane to protect against further erosion on the right bank downstream of the channel block across abandoned channel B2. **STATUS:** This structure is intact and working very well to divert flows away from a the meander chute cutoff that was widening after construction (see Amendment 3(a)). Sediments are depositing below the vane at the mouth of the cut-off and a large pool has formed below the vane, immediately upstream of the riffle cross-over as the vane turns the river into the downstream bendway.

Amendment 3(a) (Drawing 4 from 2680 to 2730 ft) - Block at the head of the meander chute cutoff that became significantly enlarged through the right bank following spring runoff. The block will work with the vane placed immediately upstream to keep flows in the channel during high flow events. As with other blocks and berms on the project, this block will be designed to allow flows in excess of bankfull to flood over and into the old chute. These flows will slow and pond within the chute due to the block placed at the mouth of the chute (Amendment 2), which will encourage sediment deposition and wetland development. Instead of a rock blanket, as used on the other blocks, a 900 gram coir fiber erosion control blanket will be used to form sand/gravel lifts. Sand and gravel to form the lifts will be taken from the area immediately around from where the block will be formed. The new vane immediately upstream has resulted in a depositional feature at the block location that will provide the needed sand/gravel material. A toe of rock rip-rap will be placed only at the lower 2 feet of the block structure to protect the lower coir fabric lift where the highest scour potential will occur. Willow cuttings will be placed between the lifts during construction. Willow stakes will be placed on top of the blocks during **F**all 2000 and **S**pring 2001. **STATUS:** Structure is intact and thus far meeting its intended purpose.

12) **Tree Revetment on left bank (Drawing 4 at 2800-3120 ft)**. Two-tier tree revetment along the toe and bank. Purpose - stabilize banks until vegetation takes hold. **STATUS:** The tree revetments have worked beautifully to collect sediments, protect the bank, and create salmonid habitat. Local anglers have reported success in fishing for Brown Trout in the deep run that has formed along the revetments.

Amendment 1(i) (Drawing 4 from 2,835 to 2,985 ft) - Three Log Vanes along the left bank to slow water velocities and enhance sediment deposition in the tree revetments, located from Station 2,775 to 3,075 ft. Each log vane will consist of a single 18" diameter, 30' tree bole, sharpened to a point on one end, pushed into the bank, and cabled to the river bed at the appropriate angles to act as a vane. No excavation of the bank will be required. **STATUS:** These structures are intact, but the river run has significantly deepened below the bed elevation to which these log vanes were keyed. The degree to which they are acting as a vane is questionable. They are probably serving more as cover for fish than as extra protection for the bank.

13) **Rock revetment on left bank (Drawing 4 at 3120-3330 ft)** Bulk toe rock revetment starting with a tie back into the left bank and built on the current grade to an elevation greater than mean flow stage and less than bankfull (OHW) stage. The rock revetment would end with a rock vane at the downstream end. The revetment would be backfilled with a live brush layer placed over the rock. Purpose - stabilize bank and create a scour hole to improve habitat around bedrock and boulders. **STATUS:** The bulk rock toe was not constructed (See Amendment 1(j)). The vane is intact and meeting its intended purpose of bank protection and pool development.

Amendment 1(j) (Drawing 4 at 3,150 ft. and 3,225 ft.) - Two Rock Vanes along the left bank to slow water velocities and enhance sediment deposition. These vanes will replace the bulk-toe rip rap planned from Stations 3,105 to 3,340 ft. and work with the vane permitted for at Station 3,340 ft. to protect the left bank around the meander. The first and third vanes of this three vane series will be J Vanes for pool development. **STATUS:** The vanes are intact and meeting their intended purpose of bank protection and pool development. As discussed under the status report for the J Vane under Amendment 1(e), a rock sill and sufficient footers would have improved the design of these structures.

Amendment 3(b) (Drawing 4 from 3300 to 3340 ft) - Block off the right bank across the mouth of the meander chute cutoff described in Amendment 1. This block will slow the velocities of flood water entering the chute and encourage deposition and wetland creation. This block will be constructed in the same manner as the block at the head of the chute without the rock rip-rap at the toe of the coir fabric lifts. The block will not be continuous with the right bank, but rather will be set up into the chute 50 feet to create a backwater fish nursery. **STATUS:** Structure is intact and thus far meeting its intended purpose.

Amendment 1(k) (Drawing 4 at 3,525 ft. and 3,675 ft.) - Two Rock Vanes along the right bank to slow water velocities, enhance sediment deposition, and begin to move the thalweg across the channel to the left into the meander from Station 3,690 ft. to 3,975 ft. **STATUS:** Structures are intact and thus far meeting its intended purpose of bank protection. The upstream vane developed a bar moving the thalweg to the left creating a deep fast run. The downstream vane has formed a deep six foot deep pool.

Amendment 1(l) (Drawing 5 from 3,585 to 3,675 ft.) - Earth Berm at the mouth of abandoned channel A2 to further slow the velocities and erosive power of water that will flow over the channel block at the head of abandoned channel A2 during flood events. The downstream berm will also maintain surface water in the abandoned channel following high flow events which will enhance wetland habitat adjacent to the Trout River. A 90 ft. section of tree revetments will be placed from Station 3,555 to 3,645 ft. on the left bank for additional bank protection between the vanes (described in Amendment 11) . The new berm will be vegetated with grasses, willows, and trees. **STATUS:** Structures are intact and meeting their intended purposes. The combination of vanes and revetments has worked very well on the Trout River to collect sediments along an erodible bank. A small repair was required on the downstream end of the constructed berm where the pre-existing bank was not sufficiently grubbed before the berm was constructed against it. During the fifth bankfull event, waters impounded in the abandoned channel A2 began piping through the base of the berm along old willow branches that were buried during construction.

NC2 **New channel (Drawings 4 and 5 at 3675-3875 ft)**. Excavate a new 200 ft channel marked NC2. The thalweg will start at its present location in the middle of the channel (at 3675 ft) and be moved to a point just right of center at the end of the new channel (at 3875 ft) where it will enter the bendway along the old rock revetment (3900-4260 ft). Purpose - Create a stable bendway geometry that has radius of curvature of 300 ft. **STATUS:** The new channel is intact, maintaining its dimension, pattern and profile.

14) **Earth fill in old channel (Drawing 5 at 3600-3720 ft)**. Fill in mouth of the old channel labeled A3 with woody debris and earthen materials for a length of 120 feet and to an elevation one foot below bank full. Purpose - close off old channel and help redirect flow into new channel. **STATUS:** See amendment 1(m).

Amendment 1(m) (Drawing 5 from 3,615 to 3,900 ft.) - Block at the head and mouth of abandoned channel A3 to form the left bank of the river. A berm had been planned and permitted at the head of abandoned channel A3, but a channel block with rock rip-rap toe protection would be more appropriate for the location due to the likelihood that the river will want to form an outside bendway on the left bank before crossing over to the right bank. The original design anticipated a long glide/run from the pool at the rock outcrop (Station 3,360 ft), through New Channel 2, to the pool along the old rip-rapped bank on the right side of the channel (Station 3,900 to 4,050 ft.). By shifting the thalweg to the left in the New Channel with the vanes described in Amendment 11, a narrower channel with a deeper pool/run will form to enhance habitat through this reach. **STATUS:** The **s**tructure is intact and meeting their intended purpose.

15) **Tree revetment on right bank (Drawings 4 and 5 at 3675-3860 ft)**. Single-tier tree revetment along the toe and bank. Purpose - stabilize banks until vegetation takes hold. Also in this area, we will use 150 ft of bulk toe rock revetment to tie back the existing rock revetment located on the right bank (3900-4260 ft) into the mouth of the drainage ditch (3900 ft), running from Rt. 118 along Scott property, to ensure that flows do not out-flank the rock revetment at the drainage ditch entrance. **STATUS:** The **s**tructures are intact and meeting their intended purposes.

16) **Hard point spurs on right bank (Drawing 5 at 4260-4350 ft)**. Two hard point rock spurs placed at the end of the rock revetment and spaced 50 feet apart. Purpose - divert flows into left channel around mid-channel bar by slowing flows and causing deposition in the right channel. **STATUS:** These structures were not constructed. Simply reshaping the bar seemed to be more appropriate in this reach, see Amendment 1(n).

Amendment 1(n) (Drawing 5 from 4,275 to 4,575 ft) - Point Bar re-establishment to form a 70 ft. wide bankfull channel. The bar will be formed by moving material from the mid-channel bar over to the right bank to complete the point bar that presently exists on the right bank immediately downstream. This dredge and fill operation will involve the movement of approximately 60 CY of gravel material and will allow for the elimination of the two rock spurs that had been planned for and permitted at Stations 4,245 and 4,305 ft. **STATUS:** See Amendment 3(c) below.

Amendment 3(c) (Drawing 5 from 4,300 to 4,550 ft) - Point Bar shaping to form a 70 ft. wide bankfull channel. Activities described in Amendment 1(n) of the Town's 10-15-99 amendment request were effective in eliminating the mid channel bar and erosion on the right bank. However, deepening of runs and pools upstream through the project has produced gravel which is causing the lateral growth of this downstream bar. By lowering the point of the bar and elevating the top of the bar, erosion pressure will be reduced on the left bank and gravel will transport through this reach more effectively to the sediment-starved reaches downstream. The bar will be formed by moving material from the mid-channel point of the bar towards the right bank at the head of the bar. **STATUS:** Bar is intact and maintaining the cross-section and bed features of the reach.

17) **Tree revetment on left bank (Drawing 5 at 4350-4800 ft)**. Single-tier tree revetment along the toe and bank. Purpose - stabilize banks until vegetation takes hold. **STATUS:** Structure is intact and thus far meeting its intended purpose.

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Bank and Buffer Vegetation

Landowners entered into WHIP (Wildlife Habitat Incentives Program) contracts with the Natural Resource Conservation Service (NRCS) to maintain a 35 ft wooded buffers along the Trout River for a period of 15 years. NRCS and the technical team approached the Missisquoi River Basin Association (MRBA) to help the landowners design and establish vegetation on the river banks and within the buffer areas. Several grants were applied for and received to enable MRBA to hire a part-time vegetation coordinator for the project. MRBA's local presence and prior buffer establishment experience made them the ideal organization to formulate and carry out the bank and buffer revegetation program. MRBA was responsible for coordinating the following grants, Youth Corps, and volunteer group efforts to carry out the bioengineering and buffer planting efforts on the Trout.

Name of Donor	Date of Donation	Nature of Donation	Rate/unit Cost of Contribution	Total Cost of Contribution
Ben & Jerry's	February 1999	Cash	$2,000	$2,000
The Tyler Place	March 1999	Cash	250	250
Jos Gravel	May 1999	Cash	20	20
Five Star Grant Program	June 1999	Cash	10,000	10,000
VT Watershed Grant Program	August 1999	Cash	5,000	5,000
Ben & Jerry's	Sept 23-24/99	Labor - 95 hrs	10/hr	950
Cold Hollow Career Center	Oct 13-14/99	Labor - 64.5 hrs	10/hr	645
Missisquoi River Basin Association	Sept-Oct 99	Labor - 30 hrs	10/hr	300
		Mileage - 110 mi	.30/mi	33
Missisquoi River Basin Association	Oct 1999	Tools on loan	various	130
Montgomery Elementary	May 1-5/00	Labor - 135 hrs	10/hr	1,350
Sterling College	April 28/00	Labor - 17.5 hrs	10/hr	175
Ben & Jerry's	April 29/00	Labor - 160 hrs	10/hr	1,600
Cold Hollow Career Center	May 4/00	Labor - 38.5 hrs	10/hr	385
Enosburg High School	May 3/00	Labor - 11.25 hrs	10/hr	112
Fairfield Elementary	June 2/00	Labor - 121.5 hrs	10 hrs	1,215
Franklin County Court Diversion	May 4/00	Labor - 9 hrs	10/hr	90
VT Youth Conservation Corps	May 1-4/00	Labor - 240 hrs	10/hr	2,400
	Aug 21-24/00	Labor - 320 hrs	10/hr	3,200
			Total	**$29,855**

River Bank Bioengineering

During the construction of the Trout River restoration project over 30,000 willow whips were cut from nearby gravel bars and placed along the banks of the Trout River as stickers, fascines, or brush layers. Plugs of live willows (entire plants with soil) were placed by an excavator around the head of vane and weir structures. Figure 5 shows the locations of willow bioengineering treatments along the 4800 ft. restoration project. Willows and top soil, generated during the excavation of the new channels, were significant in-kind contributions on the part of the land owner.

Of the willows cut and placed during the fall, 1999 construction effort, 80-90% of the willows survived and developed new roots and leaves during the spring/summer, 2000. Willows have historically been quick to propagate in the soils and gravels along the Trout River. Long-time residents have rightly surmised that, the River is naturally stable where there are willows. For this reason, continued success of the willow treatments gives the greatest degree of hope for the success of

the overall project. Willows will continue to be cut and placed along the banks where they are lacking as volunteers and school groups become available.

Buffer Establishment

The Trout River project officially began when the four landowners along the project reach agreed, through the U.S.D.A. WHIP program, to create and maintain wooded buffers along the river. The restoration of a channel's natural stability regime is not worth pursuing without a wooded buffer. Likewise, efforts to restore wooded buffers along certain rivers and streams may not be worth pursuing if those channels are profoundly unstable or out of regime. Figure 6. shows the 26.58 total acres of wooded and wetland buffer along the Trout River restoration project consisting of he following four components:

a. The 3.44 acres of revegetated buffer within the 35 ft. corridor as part of WHIP contracts.
b. The 1.9 acres of buffer along the abandoned channels of the project reach (not in WHIP).
c. The 2.69 acres of new enhanced or potential wetland area within the abandoned chnnels.
d. The 18.55 acres of wooded buffer (trees or shrub areas) that existed prior to the project.

The revegetated buffers were planted with 2,210 hardwoods, conifers, and shrubs at a density of approximately 400-450 stems/acre. The following list of native trees and shrubs were purchased and planted as bare root stock:

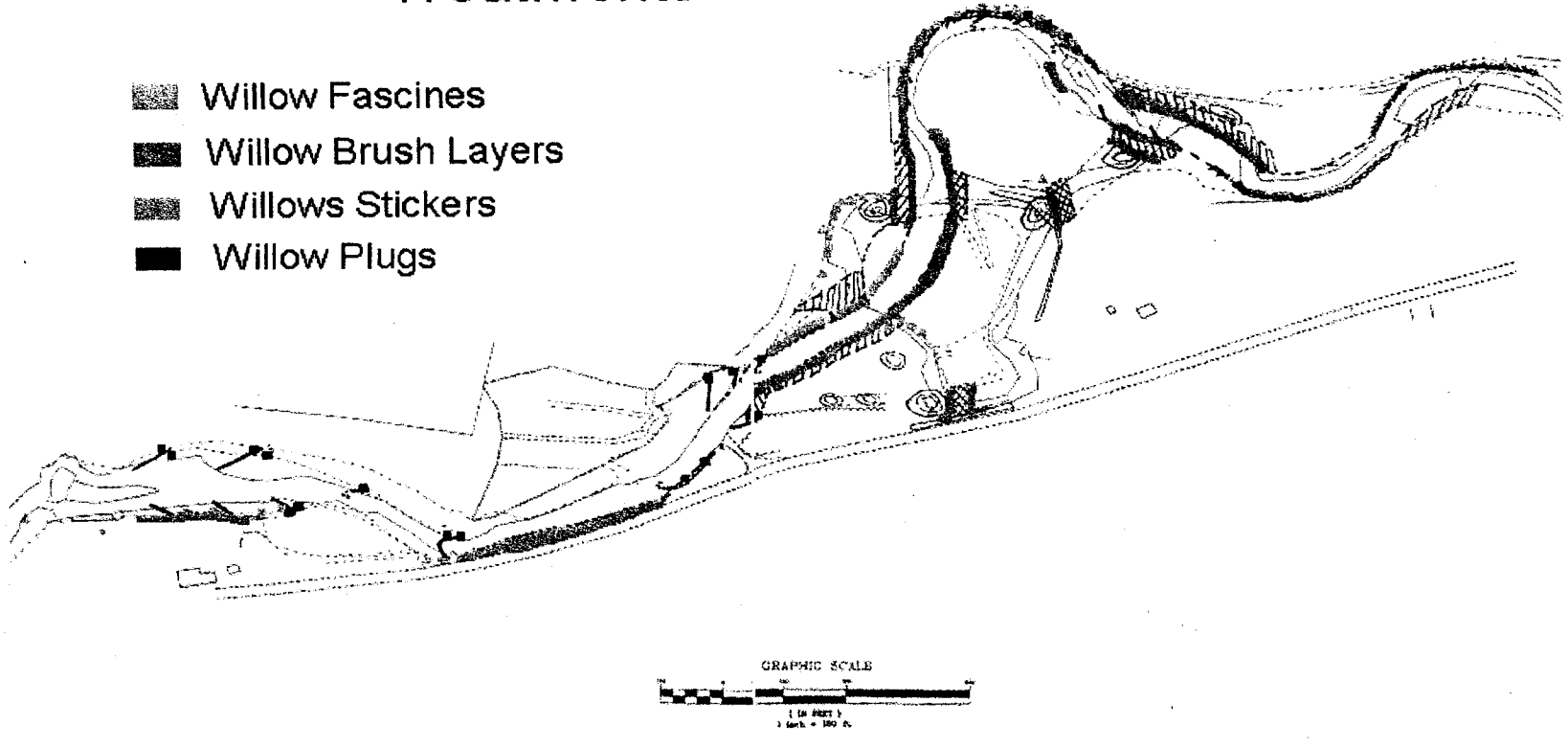
Red Maple	White Ash	Silky Dogwood
Sugar Maple	American Larch	Elderberry
Green Ash	Balsam Fir	Serviceberry
Basswood	Hemlock	Nannyberry
Hornbeam	Redosier Dogwood	Highbush Cranberry
Littleleaf Linden	Crabapple	

The outside perimeter of the revegetated buffer was planted with 8 to 12 ft. hardwoods to enhance the aesthetics of the buffer and serve as a boundary reminder to the agricultural operators working the adjacent corn fields. Photo-degradable brush mats were used at the base of each tree and shrub to block competition from other plants. Watering bags and tree guards were used to protect the larger trees from first year drought and rodents.

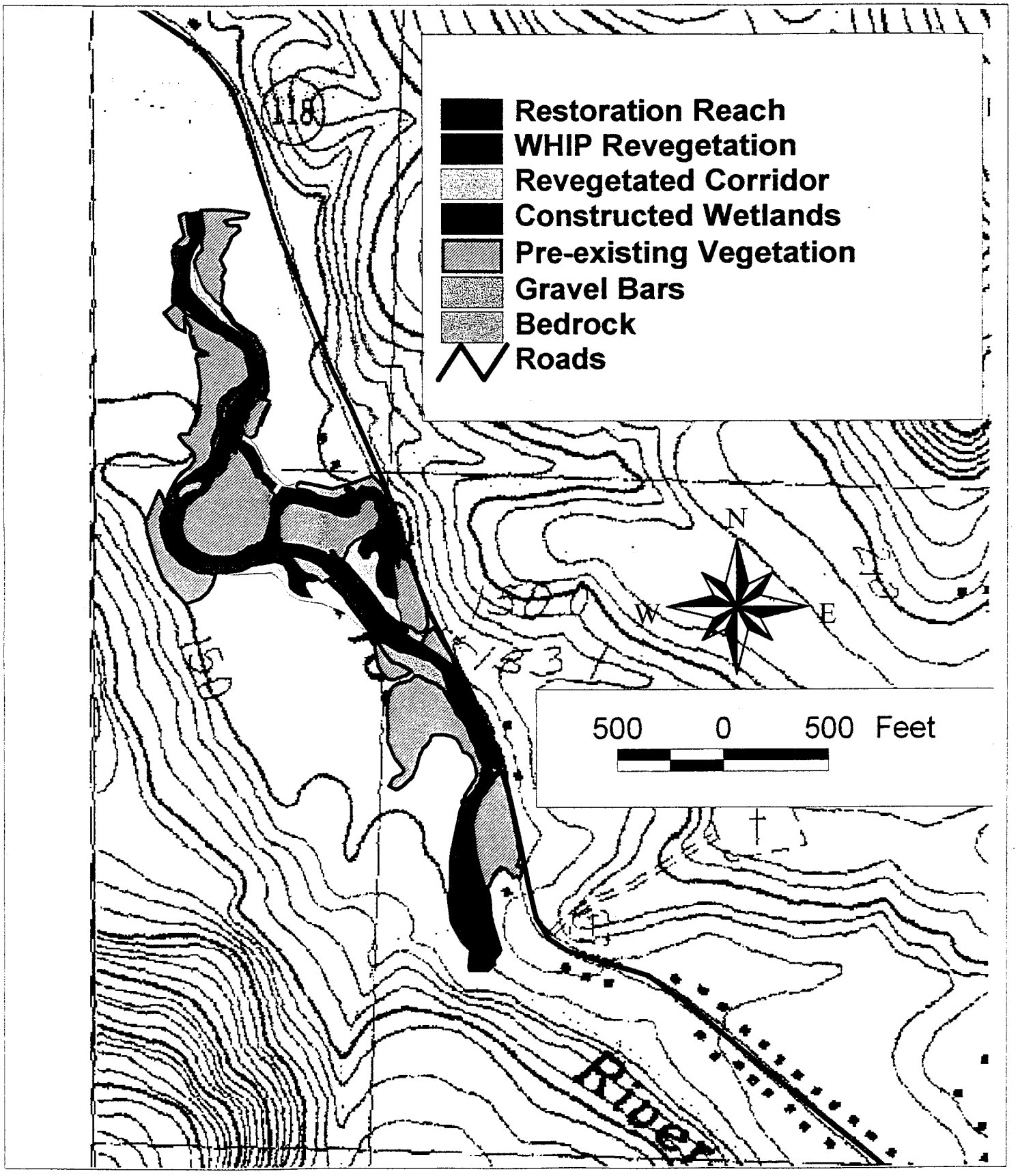
Wetland areas were not replanted. The technical team felt that the top soil spread around the depressions and abandoned channels contain a tremendous bank of native wetland seeds that will propagate in these areas. If wetland and riparian plants fail to colonize these areas, a more aggressive planting option may be pursued. Youth Conservation Corps did remove (dig up) all exotic knotweed growing in the abandoned channels and on the established berms. Knotweed is present in sizeable areas along the project reach and there is considerable doubt that any effective program can be devised to control the exotic from taking over portions of the buffer.

This report will be updated with information on riparian plant survival and recruitment collected during summer, 2001, following the one-year post riparian re-establishment period.

Figure 5. Bioengineering Treatments



Trout River Buffer Vegetation



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Permits and Construction

Working with the Town of Montgomery Selectboard, who agree to serve as project sponsor and the permit applicant for the landowners, the DEC River Management Program developed the project design into permit applications and construction bid packages. Because environmental regulators and construction contractors in New England are largely unfamiliar with fluvial geomorphic concepts and newer channel stabilization techniques, these steps in the project involved a great deal of documentation. As the techniques and benefits of natural channel design become the norm rather than the exception in Vermont it is anticipated that permitting and contracting will require a lot less effort.

Permits

The Town of Montgomery received a Stream Alteration/CWA 401 permit from the Department of Environmental Conservation and a Section 404 permit from the U.S. Army Corps of Engineers to construct the Trout River Project. The State permit largely referenced the more detailed and comprehensive Federal 404 in this case.

Prior to the design workshop, the technical team and the Town Selectboard invited state and federal environmental regulators to visit the restoration site. The site visit was invaluable for gaining consensus for the project goals. Regulators from EPA, USFWS, and the COE traveled to Montgomery from Concord, NH and Boston, MA to join their Vermont-based counterparts in walking the unstable reach. The project was reviewed for both wetland and archeological resource impacts. Acceptance of project was greatly enhanced by the level of landowner and inter-agency cooperation for the project. This project highlights the need for: 1) a greater national consensus for the use of geomorphic-natural channel design concepts; 2) a greater use of general permits to encourage restoration using “natural stability” techniques over “dredge and armor” stability techniques. The Alternatives Analysis in Table 9. was submitted as part of the 404 Permit and includes a cost/benefit comparison of different alternatives.

Table 9. Alternative Analysis

Alternative 1: Do nothing.

The do nothing alternative would result in physical, social and economic damages and losses, including of an additional five acres of land. Expected life: Not applicable. Benefit/Cost ratio (B/C) is less than 0 because the "do nothing" alternative involves continued damage with no benefit.

Alternative 2: Streambank armoring.

Streambank armoring would consist of installing rip-rap along eroding streambanks to prevent further lateral migration. Expected life: 5-20 years. Investment of $211,200 in streambank armoring produces only a %20 alleviation of total damages (0.2 X 60,000 = $20,000. $20,000/$211,200 = 0.09 B/C). The costs do not include the loss of aesthetic, natural, recreational, and educational values.

Alternative 3: Channel dredging.

Channel dredging would be performed to maintain the channel in a desired location ostensibly to prevent flooding and limit channel migration. Expected life: Less than 1 year. No benefits accrued from channel dredging other than limited value of the material which will not offset additional damages caused to stream stability.

Alternative 4: Restoration of stable form of the river.

Restoration of the stable form would consist of reconstruction the stream channel to its stable dimensions, pattern and profile. Includes revegetation of streambanks and placement of in-stream structural treatments to restore natural channel features. Expected life: 25-50 years. Full benefit of $100,000+ + + flood damage repair and protection will be realized for $132,000 investment in restoration of stable form ($100,000/132,000 = 0.76 B/C. Significant additional natural

Contracting and Construction

A construction bid package was developed and a request for bids was advertized during the early summer months of 1999. Bid request notices were sent to a list of heavy equipment contractors that work in northern Vermont, as well as placed in regional newspapers and state contract-related web sites. Contractors were asked to bid the project on a unit price basis and total cost per Bid Item; and by material cost and equipment rental rates. Since most contractors are unfamiliar with this type of construction they tended to over estimate the cost of the project when biding by the unit price; therefore, better estimates were made when done by looking at material cost and equipment rental rates. A pre-bid conference was not held but would have been beneficial to both contractors and the contracting agencies.

The technical team reviewed five bid packages and selected contractors in consultation with the Montgomery Selectboard. G.W. Tatro Construction, Inc. of Jeffersonville, VT was selected to build components of the project requiring heavy equipment. Peter Salinger Bioengineering was selected to install the tree revetment components of the project.

Construction oversight was provided by the DEC, the USFWS, the USFS, and the Missisquoi River Basin Association. Construction activities often required that two technical supervisors be present on the job at the same time at different locations on the project. Many of the structures and new channel alignments required careful surveying during construction with a laser level to ensure their proper installation. The Basin Association played a critical role in efforts to keep community and landowners involved. Another lesson learned: A project of this magnitude would benefit in having a full-time vegetation and erosion control supervisor and crew.

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Goals and Objectives: Status Report

The writing of this report marks one year since a major demonstration project was undertaken to restore stable dimensions, pattern, and profile to the Trout River below Montgomery Center, Vermont. The channel geometry and many of the structures have been tested with several high flow events. Willows along the banks have survived while buffer trees and shrubs have not yet been through a Vermont winter/spring season. This report will end with a status review of the program and project-related goals and objectives that were established at the onset of the project.

Program-Related Objectives

1. Introduce "Morphological Approach" to river management - The project did incorporate methods that identified problems associated with the river's dimension, pattern, profile, and sediment regime before recommending a restoration plan. A benefit/cost analysis examined channel geometry and floodplain issues in the context of channel evolution processes to determine the consequences of different management alternatives. Under the traditional river management approach used in Vermont, these problems and processes would not have been considered and a short-term, expensive treatment of erosion-related symptoms would have been the likely outcome.

2. Increase the feasibility of multi-objective projects - The Trout River Restoration Project cost $27.50/ft compared with $35-40/ft for traditional rip-rap. Project techniques that have promoted the river's natural stability (natural hydraulic and sediment regimes) increase the project's cost/benefit ratio due to their anticipated longer life-spans. In addition, landowners, local residents, and visitors to Montgomery are benefitting from the recreation, aesthetics, fish and wildlife habitat, and opportunities for environmental education that have been documented thus far.

3. Improve State approach to flood hazard mitigation and flood response - The project's problem identification process showed that the damage caused by the 1997 flood in Montgomery may have been avoidable. Many of the lessons learned at the onset of the project were incorporated into "Options for State Flood Control Policies and a Flood Control Program" prepared for the Vermont General Assembly pursuant to Act 137 (1998) by the DEC Rivers Management Program. Identifying and restoring unstable rivers before the flood hits has become a State priority. The River Management Program has received funding and has been working to develop the Reference Reach Data Base that would enable a rapid response to flood damage using the principles and applied methods of fluvial geomorphology.

4. Bring together the various technical strengths of state and federal agencies - the State Agencies of Transportation, Natural Resources, and Emergency Management worked with federal agencies including the NRCS, EPA, USFS, and the USFWS to conduct field research, design the stable channel work, and oversee construction. During this process extensive training and a tremendous transfer of technical information occurred. Table 10. contains a list of the educational and technical presentations that have been conducted to present the Trout River Project and a Geomorphic Approach to River Management. Many of these presentations involved discussions between Agencies on how to involve their programs in this work.

5. Education opportunities - The DEC River Management Program in cooperation with the USFWS Partners for Fish and Wildlife Program, the NRCS, and the Missisquoi River Basin Association have provided interviews to several newspapers and television programs and gave tours of the Trout River Project to school and community organizations from throughout the region and state. The presentations listed in Table 10. reached out to groups throughout New England. The DEC River Management Program with major support from EPA and the USFS has produced an educational video called "Unstable Rivers: Using a Geomorphic

Watershed-Based Approach to River Restoration", which tells the story of the Trout River Project and the science of natural channel stability. Copies of the video are now being distributed to government and non-government organizations and schools throughout the region.

Table 10. Presentations of Trout River Demonstration Project and the Geomorphic-based Approach to River Management and Flood Hazard Mitigation in Vermont

	Audience	In Attendance	Date
1	Missisquoi River Basin Association	15	10/99
2	Town of Montgomery	12	11/99
3	FEMA/Hazard Mitigation Team	8	12/99
4	VT Water Quality Division	50	12/99
5	Water Quality Standards - Stakeholders Committee	35	12/99
6	AOT Planning and Engineering	15	01/00
7	Water Resources Board	8	01/00
8	**Maine DEP/Regional Biologists***	15	01/00
9	VT Fish and Wildlife / Division of Fisheries	60	02/00
10	UVM / School of Natural Resources	25	02/00
11	AOT / District Transportation Administrators	35	02/00
12	Regional Planning Commissions - Emergency Mgt.	35	02/00
13	Lake Champlain Basin Watershed Associations	30	02/00
14	Legislature - House & Senate Nat. Resource Comm.	15	02/00
15	Vermont Grange Legislative Brunch	70	03/00
16	AOT Research Grants Committee	15	03/00
17	**New England Assoc. of Environmental Biologists**	80	03/00
18	**N.E. Environ. Commissioners/EPA Reg. Administrator**	12	03/00
19	**EPA Region I - Boston**	30	03/00
20	AOT Construction Engineers	75	04/00
21	Montgomery Elementary School	15	04/00
22	**N.E. Reg. Natural Channel Design Workshop**	300	04/00
23	Lake Champlain Tech. Advisory Comm. Grand Isle, VT	25	06/00
24	**U.S.F.S. Northeast Reg. Aquatics Workshop**	80	06/00
25	VT Reg. Planning Commission Transportation Planners	30	07/00
26	**New Hampshire DES/USFWS Regulatory Br-Concord**	130	09/00
27	Green Mountain College - River Restoration Class	20	09/00

* Bold type designates a regional or national audience

Project Goals

1. Create a geomorphically stable channel to avoid the further:

a) Severe loss of agricultural soils from the aggradation/degradation process currently underway in the vicinity of the bifurcated channel - Before construction a 1 to 2 inch rain storm would result in 5 to 10 ft of erosion along the bifurcated channel. Some of the eroding land was being used to grow corn and much of it was valuable agricultural soil. Since the project was constructed there has been very minor bank erosion and no further loss of agricultural lands. Through the project reach 17 permanent cross-sections have been surveyed pre, post, and one-year after construction. The analysis of these cross-section and the corresponding longitudinal profiles in Appendix C show that the aggradation/degradation processes occurring in 1998 have not occurred between October, 1999 and September, 2000.

b) Instability in upstream and downstream reaches of the Trout River resulting from the geomorphic instability of the demonstration reach - The head-cuts that were moving upstream in 1998 have been arrested, however, the bedrock control at the head of the project reach made it unlikely that upstream reaches would have been affected by the downstream bed level instability. A study completed by Step-by-Step Consultants following the inception of the project showed that an acre and a half of land was washed away during and after the flood in the avulsion channels. A total of 8,600 cubic yards (1,300 dump trucks) of sediment went downstream. Project cross-section surveys (Appendix C) show that, to date, this process has been arrested. Over-widened reaches further downstream in Montgomery and Berkshire have major sediment sources contributing to their stability problems but the project reach is no longer one of them. The Trout River immediately downstream of the project reach, however, may have been "starved" for gravel because of the aggradation and gravel mining in the Project Reach. Sediment eroding from the downstream bars during normal high water events was not being replaced by gravel that would have moved downstream if the project reach had been more competent in moving gravel. The deepening of runs and pools of the restored project reach and the greater sediment transport achieved through channel geometry adjustments appear to be helping bar development downstream. If a second phase of the project can be realized in the downstream reach to encourage deposition, as a floodplain forming process, then the restored sediment regime of the current project reach will contribute to the overall downstream stability of the Trout River.

c) High cost and short life span of a traditional project that would otherwise be implemented and include rip rapping the channel into its previous alignment - The technical group favored the use of low tech, low cost, and low maintenance structures in the restoration design. While, the group wanted to minimize the use of rip rap to the greatest extent possible, bulk-rock toe and rip-rap blankets were used on some sections of the project reach. The Vermont technical team will continue to evaluate the use of rock toe structures and seek to further reduce the instances of its use in natural channel design projects. The significant advance with respect to this objective is that traditional project designs often have a short life span (and therefore a high cost/benefit ratio) because they do not employ the problem solving techniques used on the Trout River Project to more fully understand and address the root causes of the observed instability.

d) Flood losses that would be severe if the current channel were to experience another major flood - It was projected that if the channel evolution process had played itself out and the river had re-adjusted to a stable form (under the "do-nothing alternative), an additional 5 acres of land would have been eroded away. During and after another major flood this erosion may have occurred in a very short time frame. Since the completion of the restoration project until the writing of this report, the Town of Montgomery has not experienced another major flood.

e) Environmental degradation including instream and riparian habitat loss and impacts to Lake Champlain - Instream and riparian habitat will be addressed below. An estimate of Lake Champlain watershed impacts was made during a consultant study (Step-by-Step, 1999) to evaluate the potential environmental degradation caused by Trout River instability. In addition to the 8,600 cubic yards of sediment erosion (and deposition), the instability-related channel avulsions of the Trout River resulted in the erosion of 6.9 metric tons of total phosphorus. The phosphorus was undoubtedly attached to sediment and not immediately available for biological uptake. This nutrient discharge, however, in light of the overwhelming level of river bank erosion occurring in the Missisquoi River basin, should cause Lake Champlain limnologists to take pause. As nutrients spiral their way into the Lake ecosystem, there are several chemical and biological pathways that could increase the bio-availability of sediment-bound phosphorus. Efforts such as the Trout River restoration project may contribute significantly to the attainment of in-lake nutrient standards.

2. Create a geomorphically stable channel to restore or enhance:

a) Sediment transport in a narrower/deeper channel - HEC-RAS modeling performed by FIScH Engineering showed that the design dimensions, pattern, and profile will consistently generate the stream power and critical shear stress required to move gravels through the restoration reach at bankfull flows. An analysis of post construction and one-year cross-sections and longitudinal profiles (Appendix C) show that aggradation is no longer occurring in the reach. In the section where sediment transport was particularly troublesome (see cross-sections 9 and 14), mid-channel bars are not forming due to the narrower channel widths and significantly greater mean channel depths. The average pre-construction width/depth ratio for the reach was 82.8 as compared with a one-year post construction ratio of 32.7.

b) Trout habitat with stable riffles and deeper pools - Preliminary data indicate that increases of instream cover and depth within the restored reach have resulted in greater numbers of adult Brown Trout holding in the monitored reach. Appendix C contains a series of histograms showing maximum bankfull depths generated from the longitudinal profiles of the pre, post, and one year-post construction channels. Bars to the right of the dotted line represent maximum depths in run, pool, and glide features. Since the Trout River was not limited in Brown Trout young-of-the-year recruitment, it was these deeper habitat areas, required by adult Brown Trout, that were population limiting factors. The histogram analysis shows a significant increase in deeper habitat which is especially important as adult fish refugia during drier, low-flow periods. A similar pre-construction and one year, post-construction histogram analysis of Brown Trout age classes shows a corresponding shift from nearly all young-of-the year Brown Trout to a more varied age class population (Appendix C). The adult Brown Trout were found during the year 2000 electro-fishing study in the tree revetments, root wad structures, and J vane on the left bank immediately below the river ford and within the large rock revetment along the right bank immediately upstream of the river ford. These areas all had a combination of very good depth and cover.

c) Riparian and wetland functions, including aquatic and wildlife habitat - Including the river channel, a riparian corridor consisting of 34.3 acres exists along the 4,800 ft. project reach, an increase of 23 % when compared with the pre-construction corridor. The flood-retention function of wetlands and abandoned channels within the river corridor has increased. Informal surveys show that aquatic and wetland plant colonization and wildlife usage of these areas are also progressing as expected. An EPA wetland specialist is working with Montgomery Elementary School science teachers to design a wetland monitoring and educational program centered around the constructed wetlands.

d) River corridor scenic and aesthetic values - No formal surveys of local residents before and after the project has been performed to answer the question of enhanced river corridor aesthetics. Landowners, Town Selectboard members, local business persons, legislators, teachers, and school children have all provided very positive feedback to the project technical team. As the riparian and river bank vegetation become more established, photographs may help to show the enhancement of scenic and aesthetic values. Before and after construction photographs have been taken a several locations along the project reach and are shown in Appendix D.

e) River recreation including fishing, boating, and swimming - The restoration of deep water along the project reach has enhanced the recreational opportunities of the Trout River. Anecdotal information indicates that there is an increased interest in trout fishing along the project reach, but again no formal surveys have been completed. River morphology survey crews did enjoy taking depth measurements during August, 2000 in the numerous new pools formed below the weir and at the vane structures. As mentioned above, kayakers have been observed using the vanes as cascade practice runs during a high water event in late 1999.

3. Create a geomorphically stable channel to demonstrate the use of:

a) Reconstruction techniques to achieve the cross-section, planform, and profile dimensions to effectively transport watershed discharge and sediment loads - several different stabilization structures or combination of structures and techniques were pioneered in Vermont on the Trout River Restoration Project. These include large rock (3x3x5 ft.) bar building vanes, in-channel vanes, J vanes, and weirs; channel blocks and berms; and the use of bankfull benches on high eroding outside bendways. These structures and activities have resulted in dramatic changes to the channel geometry, appearance, and natural function of some sections of the restoration reach (see before/after photos in Appendix D). High water events on the Trout have already pointed to design and/or installation errors. Attempts were made to correct these problems and the lessons learned will enhance the effective use of these structures on future projects. For instance, the technical team will be especially interested in monitoring the effectiveness of channel cross-sections constructed with bar building vanes v.s. berms. Bar-building vanes are low-cost structures but may involve a much longer time frame in the establishment of the desired bankfull dimensions. Berms are more expensive, more material intensive, and carry a greater risk of failure during the revegetation period, but enable the rapid establishment of a design width and depth.

b) Fluvial geomorphic river design to the public and governmental agencies in Vermont as a cost effective alternative to a traditional erosion control, river restoration, and flood hazard mitigation approach - It is probably safe to say that no other river restoration project in Vermont has been more visited, written about, or televised than the Trout River Project. Hundreds if not thousands of people from many walks of life have learned about the project and its goals. Several state and federal agencies in Vermont are revamping their river programs to incorporate the techniques and lessons learned on the Trout River. Several other multi-partner, multi-objective restoration projects have been completed or are now underway in other parts of Vermont. Maine, New Hampshire, and Massachusetts have invited the technical team to present the Trout River Project to river program managers in their respective state and federal agencies. Best of all, landowners and non-technical members of the public understand geomorphic river restoration and have enthusiastically supported new river stabilization techniques that include protection of both property values and the natural resource values of river corridors.

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