Vermont DEC River Management Program
2009 Annual Report

Dedicated to the restoration and protection of floodplains and river corridors.

River Management

The Problem

Analysis of stream geomorphic assessment data collected during the first five years of the Clean and Clear Program is providing an important result. Of the nearly 1,400 assessed river miles in Vermont, nearly three-quarters (74%) have become confined to deeper, straighter channels and no longer have access to historic floodplains. The increased power of larger floods, contained within the channel, has led to higher rates of bed and bank erosion. Millions of dollars are spent annually in Vermont to protect property. These armaments attempt to keep rivers disconnected from their floodplains and static in the landscape. Erosion hazards and flood losses are increasing. One of the most significant new insights is that river management has become a vicious cycle. Flood recovery and structural constraints (i.e., channel straightening, berming and riprapping) give a sense of security and lead to developments along rivers where they formerly meandered and flooded. Inevitably, and often decades later, a large flood occurs, structures fail, and the cycle repeats itself. Economic, social, and environmental costs are increasing.

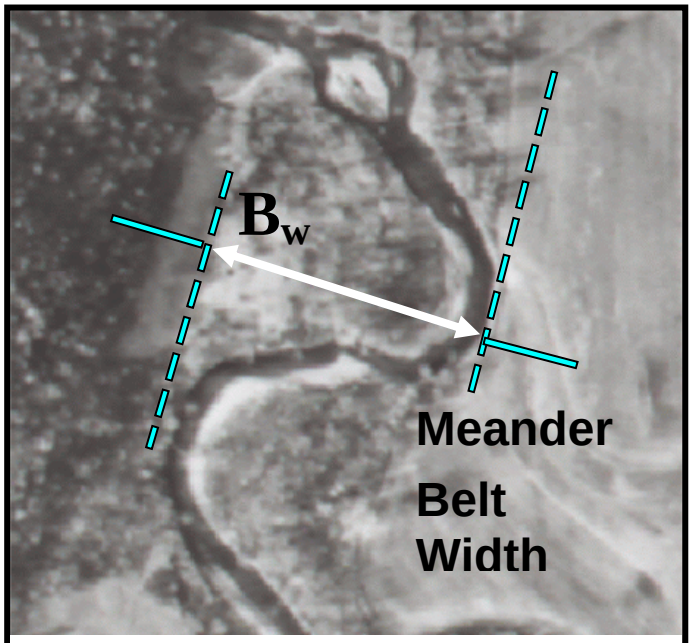
Statewide Stream Geomorphic Assessment Results			
Evolution Stage	**Adjustment Processes**	**Miles**	**Percent**
I	In dynamic equilibrium, only minor vertical and lateral adjustment	342	25
II	Major channel degradation, annual floods not accessing a floodplain	305	22
III	Channel widening, as increased flood energy erodes stream banks	503	37
IV	Major channel aggradation, juvenile floodplains begin forming	203	15
V	New floodplains formed, and dynamic equilibrium restored	18	1

The Vermont River Management Program has evolved with the premise that the cycle must be broken. Otherwise, land-based enterprises will continue to suffer economically because, in addition to erosion hazards, channelization leads to a loss of sediment storage and a net export of life-giving soil and nutrient from a watershed. Rivers that have down-cut and lost access to their floodplains will erode their banks until new floodplains are formed. During the early stages of this channel evolution process, floods remain within deepened channels, and have much more power to erode and carry away anything that enters them. Without floodplains and meanders, it is often the lakes and reservoirs that are the first quiet waters in which rivers deposit the eroded soil and nutrients. Floodplains are essential to stable streams and sustainable water quality management.

The Program

The Vermont Agency of Natural Resources has adopted an avoidance strategy to restore and protect the natural stability of rivers and minimize flood damage. River corridor protection has become the primary tool in the Agency's avoidance tool box. River corridors consist of lands adjacent to and including the present channel of a river. Delineations are based primarily on floodplain function, the lateral extent of stable meanders (i.e., the meander belt width, see Figure), and a wooded riparian buffer to provide streambank stability. The meander belt width is governed by

valley landforms, surficial geology, and the length and slope requirements of the river in its most probable stable form.



Meander belt width ($\mathbf{B_w}$) defined by the lateral extent of meanders when the channel slope is in equilibrium with the sediment transport requirements of the river.

A river is considered stable or in a state of "dynamic equilibrium," if it can adjust its channel geometry (width, depth, and slope) to efficiently discharge, transport, and store water, sediment, and debris without significant aggradation or degradation of its bed (i.e., changes in vertical channel bed position in relation to annually accessed floodplains)[1,2]. A river requires a sufficient corridor to accommodate equilibrium conditions and the channel adjustments that occur when stream geometry is changing vertically and laterally to achieve equilibrium[3]. Failure to provide a sufficient corridor will constrain the river from achieving the equilibrium condition. Thus, managing corridors to accommodate equilibrium and associated channel adjustment processes serves to reduce damages to existing structures and property, avoid new damages, protect public safety, achieve the general health of the river system, and avoid the high cost to install and maintain channelization practices[4]. Precluding the use of channelization practices, in turn, avoids the unintended consequences of transferring bank erosion and other damaging effects from concentrated flow and vertical channel adjustments to other locations along the river[5,6,3].

The River Management Program is providing river corridor delineations as an important spatial context for restoring and maintaining the river processes and dynamic equilibrium associated with floodplain storage of nutrients and high quality aquatic habitats. River corridors are also intended to provide landowners and town, state, and federal agencies with a science-based river and riparian land use planning and management tool to avoid fluvial erosion hazards (FEH). Reducing current and future near-stream investment and achieving natural stream stability promotes a sustainable relationship with rivers over time, minimizing the costs associated with floods and maximizing the benefits of clean water and healthy ecosystems. Vermont ANR river corridor protection, supported by the Clean and Clear Program, consist of technical assistance to a host of

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[1] Leopold, L.B. 1994. A View of the River. Harvard University Press, Cambridge, MA.
[2] Rosgen, D. and L. Silvey, 1996. Applied River Morphology, Wildland Hydrology, Pagosa Springs, CO.
[3] Brierley, G.J., and K.A. Fryirs. 2005. Geomorphology and River Management: Applications of the River Styles Framework. Blackwell Publishing.
[4] Piegay, H. et al. 2005. A Review of Techniques Available for Delimiting the Erodible River Corridor: A Sustainable Approach to Managing Bank Erosion. John Wiley and Sons, River Res. Applic. 21: 773-789.
[5] Brookes, A. 1988. Channelized Rivers; Perspectives for Environmental Management. John Wiley & Sons, Chichester.
[6] Huggett, R.J., 2003. Fundamentals of Geomorphology. Routledge Fundamentals Physical Geography.

municipal, state, and federal river resource and floodplain management programs, Act 250 floodway protections, municipal fluvial erosion hazard zoning, and river corridor easements.

The restoration of floodplain function and stream equilibrium represents long-term insurance against future flood hazards and increased nutrient loading to Lake Champlain. Restoration simply can not occur if river corridors are developed. It is critical that future land use development patterns recognize the dynamic nature of rivers and floodplains. Since most land use decisions occur on the local level, offering incentives is the most effective way of raising public awareness about river corridor and floodplain values and motivating landowners and municipalities to take proactive steps to reduce property loss, protect water quality, and build greater resilience to future flood damages. Protecting natural processes that maintain water quality and aquatic habitat enables the State to avoid the cost of developing and maintaining artificial structures to capture and retain sediments and nutrients. These actions also represent an important step for the State to combat the ill effects of climate change, particularly in light of the hydrologic models that predict a greater frequency of flash flood events.

River Corridor, Buffer, and Floodplain Protection

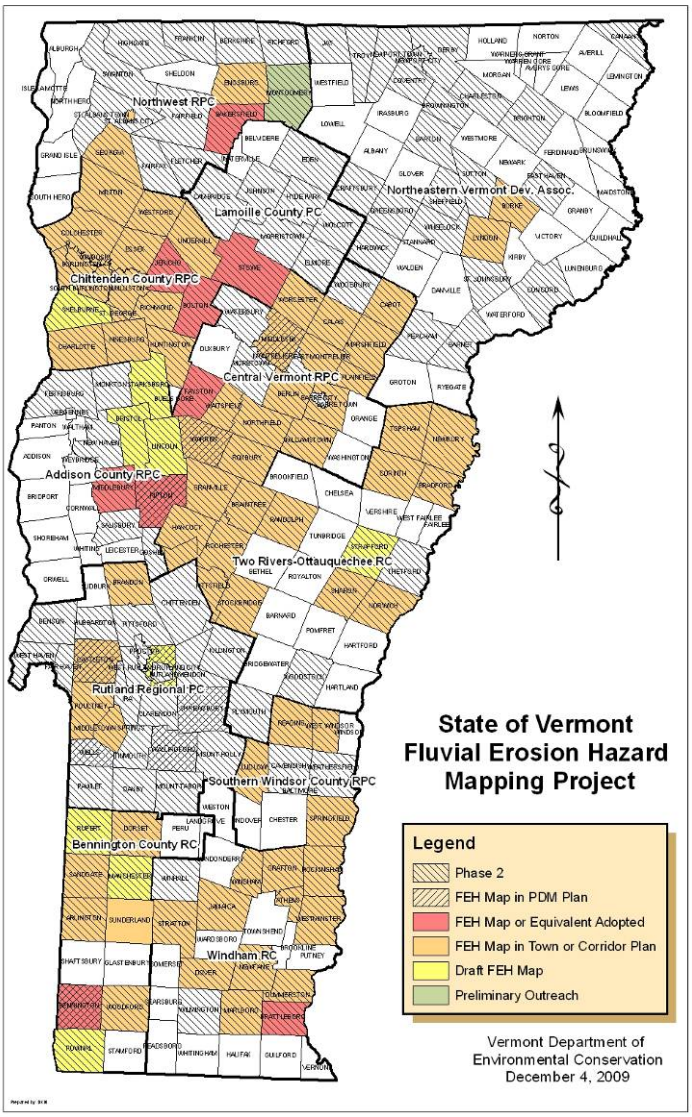
The River Management Program will continue to emphasize the state river corridor and municipal FEH programs, established by Clean and Clear in response to Act 137 (passed by the 1997-98 General Assembly), which required the State to develop appropriate flood hazard mitigation and avoidance measures. A dialogue among state agencies and departments is being pursued to provide meaningful incentives to landowners and communities for more effective buffer protection and flood hazard regulations. State legislation to support this incentive-based approach and ensure involvement at the municipal level may become a part of this dialogue.

Financial incentives for municipalities include qualifying criteria in grants, pass-through funds, technical assistance, and educational support that encourages municipalities to adopt and implement bylaws that conserve and restore river stability, floodplains, wetland and riparian buffer function. Three River Management Program regional scientists and the Fluvial Erosion Hazard Coordinator assist municipalities in developing maps depicting the river corridors, flood attenuation assets, and FEH zones. The ANR, in cooperation with a host of planning organization and the Vermont League of Cities and Towns, conducts outreach and education and annually reports on the status and impact of river corridor easements and zoning, including development of FEH mapping.

The potential phosphorus reduction through river corridor and floodplain protection was revealed through the study of a Clean and Clear funded floodplain restoration project (cost-shared with the USDA) where in just one year, 1.3 metric tons of total phosphorus were captured in sediments deposited on 3 of the 7 restored floodplain sites, available to the Black Creek for first time in 150 years following the removal of a rail levee.

On another project, soils were excavated to create a belt width sized floodplain along 2,000 feet of Wanzer Brook (Fairfield, VT), which had become deeply incised. The quantity of deposited soils that would have, over time, been eroded to the lake contained 5.9 metric tons of total phosphorus.

The River Management Program, in collaboration with the state's regional planning commissions (RPCs), leverages Clean and Clear funding annually to attract Federal Emergency Management Agency (FEMA) Pre-Disaster Mitigation Program planning grants to support corridor protection. The work involves developing Phase 2 stream geomorphic assessment data, generating FEH maps, working with communities to educate them about fluvial erosion hazards, and encouraging and supporting their adoption and implementation of fluvial erosion hazard zoning bylaws including provision of maps and model by-laws. Fluvial erosion hazard data are being incorporated into the Regional Hazard Mitigation Plans. The River Management Program has technically supported the work of the RPCs and their consultants and recently provided the RPCs with a suite of Enhanced Model Flood Hazard Area Regulations including fluvial erosion hazard area protection.



A River Corridor Easement Program has been established in Vermont to conserve river reaches identified as high priority sediment and nutrient attenuation areas. The opportunity to purchase and sell river corridor easements was created to augment the state and municipal fluvial erosion hazard zoning which, if adopted, avoids future encroachment and flood damage, but does not restrict channelization practices. The societally-ingrained notion to stop all erosion, even where few investments are at risk, may limit the channel evolution process and slow the attainment of equilibrium conditions. The key provision of a river corridor easement is the purchase of channel management rights[7].

Total number of communities involved in river corridor planning	168
Phase 1 geomorphic assessment underway or recently completed	33
Phase 2 geomorphic assessment underway or recently completed	42
FEH projects underway or completed as part of town and/or river corridor plans	27
Draft FEH maps completed	69
FEH language, maps, or equivalent adopted as an ordinance	9

[7] Kline, M. 2008. A Guide to River Corridor Easements. Vermont Agency of Natural Resources, Waterbury, VT.

The program works closely with state and federal farm service agencies, the Vermont Housing and Conservation Board, and land trust organizations to combine corridor easements with other land conservation programs. The purpose of the river corridor easement is to allow the river to re-establish a natural slope, meander pattern, and access to floodplains in order to provide flood inundation and fluvial erosion hazard mitigation benefits, improve water quality through hydrologic, sediment and nutrient attenuation, and protect riparian habitats and the natural processes which form them. The easements give the holder, or grantee, the right and opportunity within the corridor to establish a naturally vegetated, floating buffer measured from the river banks as they may move. The landowner may continue to conduct activities such as agriculture and timber harvesting within the river corridor, but is restricted from placing, repairing, or modifying structural elements such as bank armor, levees, or earthen fills. Within the corridor, the easement ensures that watercourses and wetlands are not manipulated so as to alter the natural water level or flow, or intervene in the natural physical adjustment of the water bodies. To date, the program and land trusts have completed, or nearly completed, easements on 12.35 miles of river, which when in equilibrium will have access to over 450 acres of floodplain.

River Name	Stream Length (ft)	Easement acres
White River	1,360	16.3
Little River	1,460	8.4
LaPlatte River	15,100	160.0
North Branch Winooski	900	3.9
Ayers Brook	19,790	50.8
Browns River	2,800	20.3
Hungerford Brook	1,700	7.3
Middlebury River	1,340	11.7
Green River (Arlington)	2,300	11.4
Batten Kill	900	8.9
Mettowee River	3,700	7.5
Wanzer Brook	2,050	4.0
New Haven River	4,318	9.1
Lewis Creek	7,700	147.3
Totals	**65,218**	**450.6**

Flood and Erosion Management and Hazard Mitigation

River Management Program engineers, floodplain managers and scientists provide technical assistance and state funding, and use FEMA flood hazard and pre-disaster mitigation grants to assist non-government entities and municipalities with the planning and implementation of flood and erosion hazard mitigation projects. Mitigation projects and the program's assistance are increasingly used as leverage to get landowners and communities involved in greater river corridor

and floodplain protection. FEMA pre-disaster mitigation planning funds in Vermont should also be used to help communities develop strategic hazard mitigation plans to restore, remove, or retrofit infrastructure likely to become damaged during or after floods.

Regional engineers, through their relationships with private, municipal, and governmental entities, reduce erosion and economic losses associated with flooding through regulation and personal influence (based on trust and respect). The engineers have swayed societal attitudes toward water resource issues, and represent a highly visible and engaged cadre of trained professional with boots on the ground. Maintenance of three regional engineers is critical to this aspect of the program.

Managing human activities to minimize alteration of channel and floodplain hydraulics and to restore the natural hydrology and sediment regimes of rivers is critically important to minimizing erosion and the costs of maintaining property and infrastructure typically lost or damaged during floods. Generally, this work involves using engineering, fluvial geomorphology, and hydrology sciences in the review of proposed projects and minimizing the impacts often inherent in human/river conflicts and conducting the planning and development of pre-disaster mitigation projects. River Management Program regional engineers are in the field constantly, maintaining the face-to-face contact with Vermont residents that is critical in staving off a multitude of flood-related failures. Technical and community assistance develops both trust and acceptance of program management goals and avoids the selection of least-cost structural alternatives that represent expensive long-term costs and public safety threats during floods. These projects typically address impacts associated with channel and floodplain fills and structures used to control river flows and erosion. Mitigation objectives included flood hazard reduction, stream equilibrium, and water quality and aquatic habitat.

State floodplain management staff provide technical assistance and coordination as required in the State's Community Assistance Program and Cooperating Technical Partner grant agreements with FEMA. The Community Assistance Program provides technical support to National Flood Insurance Program (NFIP) enrolled communities. In addition to providing general technical assistance, education, and outreach, staff provides floodplain development reviews in accordance 24 VSA Chap.117, Section 4424. Over the past five years the program has worked diligently to increase the number of NFIP enrolled towns that actively engage and request development reviews by the program as required by law. At present only 30% of the 245 enrolled towns are so engaged. Greater municipal participation is sought as a means to not only achieve NFIP objectives, but achieve the state water resource objective of avoiding flood hazards and protecting beneficial floodplain functions. Under the Cooperating Technical Partner grant, floodplain management staff works with municipalities, Regional Planning Commissions, and FEMA to coordinate and oversee the flood hazard map update process underway in the state. Activities of the floodplain management program, and the need to expand the program (currently a staff of three), will increase as the number of participating municipalities increases.

The quantity of sediment and nutrient loading that occurs during flood events is enormous. It cannot be over-stated that the failure of improperly engineered watershed infrastructure is a huge part of the loading that impairs water quality. Flood recovery is a related program area that deserves special attention in working toward load reduction targets for Lake Champlain. River Management Program engineers save taxpayers significant dollars every year, both in the short and long-term, averting more damage and loss to both infrastructure and the environment. There is also the real threat of loss of life as it relates to people in very vulnerable locations. The pro-

gram works through the State Hazard Mitigation Grant Program and makes recommendations to move individuals out of harm's way.

Floodplain Management Program Activities	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	FY09 Total
Community Assistance Visits	3	2	2	4	11
Community Assistance Contacts	2	1	4	2	9
Floodplain Development Technical Reviews	18	18	33	30	99
Workshops and Outreach events	6	4	7	4	21
Site visits and meetings re: floodplain develop.	4	16	19	9	48
DRB/PC/Selectboard meetings or hearings	3	3	1	1	8
Flood Hazard Bylaw Reviews	7	10	15	14	46
General Tech Assistance - phone calls	296	354	342	279	1,271
General Tech Assistance - emails	426	498	558	421	1,903
Meetings w/State agencies	9	16	4	2	31

Active Restoration

Proactive restoration of water quality and aquatic/riparian habitats differentiates this program activity from the management activities described above. Restoration and remediation activities are critically important in order for Vermont to meet the goals of the Federal Clean Water Act and the State Water Pollution Control Statutes. Fluvial geomorphic and physical habitat assessments are being used to develop river corridor plans for river reaches at the sub-watershed level. Strategic river corridor restoration and protection projects are being identified, developed, and implemented in partnership with local and regional entities. These partnerships, typically supported through grants, create critically important watershed constituencies that raise local awareness, acceptance, and action toward achieving River Management Program goals.

The Lake Champlain Phosphorus TMDL recognized the need for protecting river corridors, and called for a much larger investment in active stream restoration. The River Management Program pursued large-scale river restoration projects using natural channel design techniques in the attempt, using mechanical means, to quickly establish stream equilibrium. It was anticipated that $2 million in capital funds would be spent annually to restore stream stability. Several federal agencies were involved in matching the state's commitment to these projects.

During the construction of active restoration projects in Vermont, however, it became evident that other river corridors and floodplains in the state were being permanently lost due to the continued placement of permanent investments and infrastructure. New encroachments occur at a faster rate than large active restoration projects can be designed, permitted, and implemented. Preventing erosion and damage of new encroachments requires an ongoing commitment to stream channelization, i.e., attempting to make streams static in the landscape.

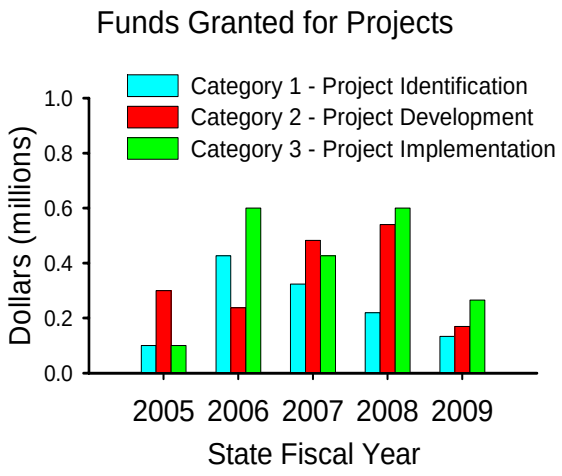
In response, the program now emphasizes an avoidance strategy in order to one day get ahead of the decline in river stability by promoting and investing in river corridor protection.

A change in primary emphasis does not indicate a lesser need for retrofit and restoration practices. Restorative construction techniques, learned during the early years of the program, remain as valuable assets to be employed where permanent conflicts exist between river processes and infrastructure, but the program now approaches each project with the objective of protecting the river corridor from further encroachment if possible. Corridor protection in combination with the active removal of physical constraints (e.g., berms, floodplain fills, and undersized bridges/culverts) are the mainstays of the River Management Program restoration efforts. Geomorphic data, collected as a part of the Clean and Clear Program and in consideration of fluvial processes, have allowed the River Management Program to set restoration objectives more truly at the intersect of hazard mitigation, water quality, and habitat improvement.

The River Management Program works with its sister agencies and partners to offer funding and technical assistance in support of local projects that are part of a larger river corridor protection initiative. For instance, floodplain restoration projects, riverbed and bank stabilization within village centers, bridge and culvert work at frequent road washout areas, and property relocation have all been offered and implemented as incentives to achieve the larger objective of corridor protection. A key aspect of this strategy is the collaboration and consistency with state, federal, municipal, and non-profit programs. The River Management Program is diligent in working with its public and private partners to integrate geomorphic data and corridor planning outputs into agricultural, forestry, transportation, land use, stormwater, and fish and wildlife planning through funding and technical assistance programs. Under the new Vermont river protection and restoration approach, landowners and towns seeking to resolve their river conflicts will increasingly get consistent guidance and support for corridor protection and working towards natural stream stability.

Program Accomplishments

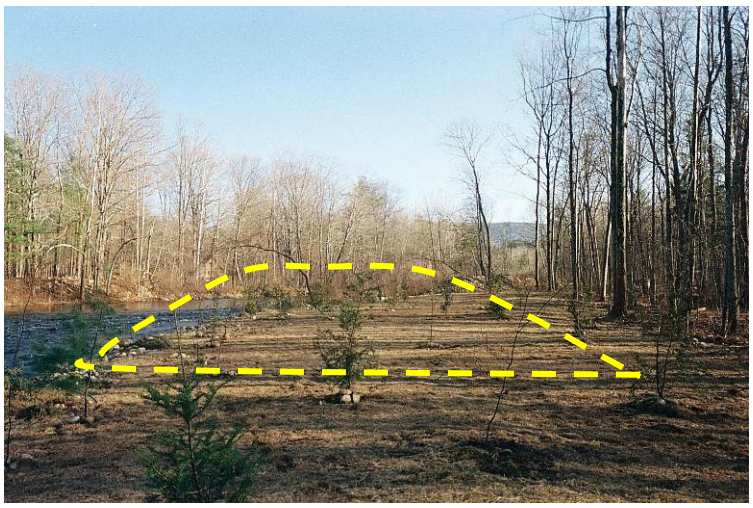
The River Management Program provides technical assistance and grants to a variety of watershed organizations to pursue a sequence of (1) river assessment and project identification, (2) project development, and (3) project implementation (Category 1, 2 and 3 River Corridor Grants, respectively), all based on fluvial geomorphic principles. Category 1 grants support river assessments conducted through a two-phase stream geomorphic assessment process in order to understand observed problems and identify remediation opportunities within a larger watershed context. This is done using nationally recognized and peer-reviewed protocols developed by the River Management Program. Category 2 grants support the creation of river corridor management plans, fluvial erosion hazard maps, and corridor restoration and protection project designs to address channel instability in a holistic, technically sound and socially feasible manner. Category 3 grants fund project implementation. Vermont River Management Program activities during 2009 are summarized for each Vermont river basin below.



Basin 1 – Batten Kill, Walloomsac, and Hoosic Rivers

The Rivers Program continued working with the **Batten Kill** Corridor Planning Steering Committee and has been successful at moving projects toward implementation on the Batten Kill River. Many projects are in the pike including a large easement acquisition on the mainstem of the Batten Kill River where the group is working to partner an ongoing habitat restoration project sponsored by the Vermont Fish and Wildlife Department, the U.S. Forest Service and the Batten Kill Watershed Alliance with an easement acquisition to ensure long-term protection of the river corridor.

A high priority berm removal project is currently underway at the confluence of the Batten Kill and the Roaring Branch in Arlington. Removal of the large berm will allow the stream to flood into the floodplain and deposit sediment upstream of the confluence, and will take the pressure off a large mass failure on the Batten Kill mainstem that is contributing a lot of sediment to the system. Funding for this project was secured through collaboration between state and federal dollars, including the Center for Clean and Clear, U.S. Forest Service, and Battenkill Watershed Alliance.



Looking up the Branch over the area where the berm was.

In addition, a high priority easement on the Green River is about to be acquired and many trees have been planted at strategic sites along the mainstem and tributaries. Years of hard work are starting to pay off as projects get implemented on the ground to restore the river corridor of the Batten Kill.

Work continued on the Walloomsac Berm Relocation Project. The design and funding are in place to relocate a section of the berm located along the Roaring Branch mainstem in Bennington. The project will restore a section of floodplain to the river and reduce sediment loads and property damage downstream of the project. Great strides have been made in Bennington County toward educating towns of the importance to include river corridors in their local planning and zoning ordinances to improve water quality and prevent flood hazards. The towns of Arlington and Sunderland have both agreed to include supportive language in their Town Plans. Bennington has adopted an overlay district to prevent further encroachment on the Roaring Branch and Walloomsac River.

Phase 1 and 2 stream geomorphic assessments were completed on the Hoosic River in Pownal.

Basin 2 – Poultney and Mettowee rivers

River restoration work continues in thy **P**oultney & Mettowee basin. The Nature Conservancy applied for and received Clean and Clear restoration funding to complete a project on their clay plain forest reserve in West Haven. They completed Phase 1 of this project which involved in-

stalling over 20 woody debris jams. Site difficulties were overcome by the use of horses to move large wood logs to the restoration locations. The River Management Program also partnered with the Vermont Land Trust to develop a multitude of river easement projects on the Mettowee River.

Example of a woody debris jam installed on a small tributary to the Hubbardton River. The wood jams help to reduce the velocity of the stream and will improve sediment storage within the river

Horse drawn wood being delivered to lands that are inaccessible to large machines for the river restoration work.

Basin 3 – Otter Creek

Watershed partners worked together to use stream geomorphic assessment data to identify key areas within the watershed, contact landowners, and develop budgets and grant proposals to conserve the important riverside lands. This is proving to be a very productive partnership.

Work continues with corridor planning on the Middlebury River. In Ripton some of the Clean and Clear grant funds were used to leverage federal FEMA dollars to assist with protecting the historic village while simultaneously improving floodplain function and reducing hazards in both the Village of Ripton and downstream in East Middlebury. Many other corridor planning activities are in the planning stages on the Middlebury River including easement acquisition on the South Branch in Ripton and tree plantings on the mainstem. The first river corridor easement was acquired in Southern Vermont using Clean and Clear funds in 2009 in East Middlebury in a highly dynamic section of river. The easement is being held by the Vermont River Conservancy and the easement lands will provide both sediment and flood storage. The two towns along the Middlebury River, Ripton and Middlebury, have both made great strides toward improving water quality and reducing hazards through local planning and zoning. They have both adopted erosion hazard zones to keep further encroachments out of the river corridor.

In the Town of Lincoln the Vermont River Conservancy secured a 1.2 acre easement along the corridor of the New Haven River and is currently working with the town to secure a donated easement on an adjacent 10 acre parcel that is owned by the town.

Lewis Creek Corridor planning and project development continued throughout the year. River Management Program staff worked with the Vermont River Conservancy and the Lewis Creek Association to develop purchase and sale agreements on a critical reach of river on the Lewis Creek mainstem. The group partnered with the Department of Fish and Wildlife Landowner Incentive Program (LIP) to try to leverage federal dollars to match the Clean and Clear money spent on the project.

Basin 4 – South Lake

A Stream Geomorphic Assessment is getting underway on the East Creek direct drainage to Lake Champlain in the South Lake. The assessment will be used to assist the basin planning effort that is just starting up in that region. The River Management Program partnered with the Green Mountain College Geology Department to get students involved in creating and field verifying the reaches that will be assessed in the upcoming field season.

Basin 5 – North Lake

In the LaPlatte watershed, river corridor planning and project development efforts continue, with a current emphasis on the lower reaches of the LaPlatte in Charlotte. Discussions with landowners are underway regarding potential river corridor easements and riparian plantings, as well as an effort to overlay results from the bridge and culvert geomorphic compatibility and aquatic organism passage screening tool with town infrastructure replacement priorities.

Basin 6 – Missisquoi River

In the Town of Fairfield, a 400 foot driveway that separated the Wanzer Brook from its floodplain and included an undersized culvert that exacerbated spring flooding has been relocated to an area that is away from the brook. An appropriately sized culvert was installed that will allow for sediment transport and aquatic organism passage. This work allowed for an expansion of the acreage enrolled in the Conservation Reserve Enhancement Program (CREP). Work continues with the Vermont Land Trust, the Vermont Housing and Conservation Board, the Vermont Agency of Agriculture, Food, and Markets, and the Boomhower family to permanently protect approximately 2,000 feet of the Wanzer Brook through the purchase of a river corridor easement along the brook as it passes through the Boomhower's dairy farm.

In the Town of Highgate a high priority river and wetland restoration project was completed this fall on a tributary to the Rock River. The project was along a 3,600 f. stretch of historically straightened stream and degraded wetlands. To restore the wetlands, a 700 foot berm was removed from the floodplain to allow the reconnection of the stream and floodplain wetlands. Ten wetland depressions were also created in the floodplain to provide wetland habitat as well as the storage of sediment and nutrients. Wood structures and debris jams were placed in the stream

Looking at the removed berm area and the created wetland in the Rock River watershed.

to provide habitat and hydraulic diversity in an otherwise totally straight stretch of stream. A 100 foot buffer was established along the length of stream. In conjunction with a CREP project just upstream of the project site, over a mile of stream is now buffered that previously had corn up to the edge of the stream or was hay that was mowed to the edge of the stream.

Phase 2 field assessments were completed along the Black Creek and Tyler Branch. These assessments continue to build on efforts by the communities to have a better understanding of their rivers and next steps toward holistic management.

Two high priority easements are underway, one on the Tyler Branch and one on the Hungerford. These should be acquired by the end of 2009. These projects are helping to protect key sediment attenuation assets in the watersheds.

In the Trout River, work with the Missisquoi River Basin Association (MRBA) has been moving projects forward that were identified in the Trout River corridor plan. The MRBA has had several "work days" to assist the town of Montgomery and community members to implement projects that reduce sediment and runoff from back roads, and private property.

Basin 7 – Lamoille River

Work continues with the Lamoille Regional Planning Commission to build on data collection efforts within Lamoille County. Phase 2 field assessments were conducted and river corridor plans were developed on the Wild Branch, Elmore Branch, Gihon, Foote Brook, and Rodman Brook.

A "Trees for Streams" project continues with the Caledonia County, Orleans County, Chittenden County and Lamoille County Natural Resource Conservation Districts to accomplish buffer plantings along stretches of the Lamoille mainstem and tributaries. Over 962 hours of volunteer time were coordinated by the Conservation Districts to plant over 3,238 linear feet of stream with 1,845 trees.

An important project was developed with the Lamoille Anglers group, with assistance from the State Lamoille Basin Planner and River Management Program staff. The project will remove old junk cars from the stream bank and establish a planted 50 ft. buffer.

A high priority easement project is underway on the Browns River to protect an important sediment attenuation area in the Town of Jericho. The easement will be acquired by the end of 2009. Continued project development is also happening, including one to remove old abutments that are causing constrictions and erosion in the river.

Basin 8 – Winooski River

In the Winooski watershed, a Phase 2 stream geomorphic assessment was completed on several mainstem reaches to fill in assessment gaps and synthesize the new and existing data into a River Corridor Plan encompassing East Montpelier and Plainfield. Project development is underway in the Kingsbury and North Branch subwatersheds, with one River Corridor Easement on the North Branch ready for execution. An update to the Huntington River Corridor Plan was completed to incorporate upper main stem and tributary reaches assessed in 2008. Opportunities to develop projects with individual landowners in the Huntington watershed have largely been exhausted at this time, and project development focus has shifted towards addressing water quality and geo-

morphic instability issues resulting from road maintenance practices and geomorphically incompatible stream crossing infrastructure.

In the Mad River, work continues to improve Phase 2 data in support of ongoing efforts with the Friends of the Mad River and the towns of Waitsfield and Warren to consider the adoption of Fluvial Erosion Hazard zoning.

River corridor easement in development in Worcester. This reach of the North Branch Winooski River has been historically straightened and is very sensitive to channel adjustment. The easement will encompass approximately 4 acres within which the river will be allowed to redevelop meanders and a state of dynamic equilibrium. This parcel is adjacent to an agricultural parcel that is a very high conservation priority.

Basin 9 – White River

In the White River watershed, project development continues on the Upper White and Tweed Rivers. These efforts have included discussions with landowners about corridor easements and riparian plantings, as well as identifying culverts that are geomorphically unstable and/or barriers to fish passage, and in need of retrofit or replacement. Three culverts in the town of Rochester are currently under consideration for retrofit to address aquatic organism passage barriers. A Phase 2 stream geomorphic assessment was completed on the White River and major tributaries in the Town of Sharon, and a River Corridor Plan is in development for these reaches. This community has expressed interest in addressing fluvial erosion hazards through municipal planning, and discussions to this effect will continue upon completion of the Corridor Plan and Fluvial Erosion Hazard map in the spring of 2010.

Basin 10 – Ottauquechee and Black Rivers

In the Connecticut River drainage, Phase 2 stream geomorphic assessment and corridor planning was initiated on the Black River between Lake Rescue and Echo Lake, as well as some of the major tributaries upstream of Lake Rescue. It is anticipated that results of this assessment will provide some insight into potential sources of sediment causing anecdotally reported changes in aggradational features in Round Pond in the northern end of Lake Rescue.

Basin 11 – West, Williams, and Saxtons Rivers

The Saxtons River stream geomorphic assessment and corridor planning is well underway. Work has already begun to partner with the Vermont Land Trust on an easement acquisition of a high priority site in the Saxtons watershed.

Basin 13 – Southern Connecticut Direct Drainage

Corridor planning activities continue to flourish on the Crosby Brook in Brattleboro. Three of the highest priority projects have been moving toward implementation and are awaiting funds to be completed.

Project implementation continues on the Whetstone Brook. The River Corridor Steering Committee partnered with the Vermont River Conservancy and the West Brattleboro Association to raise funds to conserve one of the few remaining functioning floodplains along the Whetstone. The group has made great strides toward raising the funds needed to buy the land. Once the Vermont River Conservancy owns the land, a permanent river corridor easement will be put on the property to conserve the river function forever.

Basin 14 – Wells, Waits, and Ompompanoosuc rivers

Corridor plans were recently completed on the Wells and Waits Rivers, and it is anticipated that work to develop corridor conservation and restoration projects, as well as working with communities to address fluvial erosion hazards through municipal planning, will continue as it has in other watersheds in central Vermont.

Basin 15 – Passumpsic River

In the Upper Passumpsic watershed Phase 2 assessment work on the Millers Run, West Branch, and East Branch filled in data gaps from past work and supported the writing of corridor plans for those rivers. This represents the completion of a year's worth of work in the Upper Passumpsic and will support future work with the individual towns and landowners to develop protection and restoration projects. Phase 1 and 2 assessment was conducted on the Moose River to fill in data gaps from previous work, which will support protection and restoration activities on the Moose.

Basin 16 – Northern Connecticut Direct Drainage

Phase 1 and Phase 2 assessments were conducted on the Nulhegan River and a report documenting historic and current stressors and the existing geomorphic condition of the watershed has been written. The assessment report will support future conservation activities to be undertaken by the Vermont River Conservancy.

Basin 17 – Black, Barton, and Clyde rivers

In the Lake Memphremagog watershed, Phase 1 and Phase 2 assessments were conducted on the Black River to gather data to serve as a foundation for the writing of a River Corridor Plan.

Outreach

Each year the River Management Program hosts a number of flume workshops. These are hands-on workshops that provide the program and it's partners a way to do education and outreach with a wide range of community members and groups interested in river issues. Workshops are offered to municipal groups, school groups, road crews, watershed groups, and at state and regional conferences.

Participants at a river flume workshop.

The flume is a stream model that allows the River Management Program to set up real-life examples of river related issues. In each workshop, the basics of river dynamics and getting familiar with your watershed are covered. Demonstrations are run to show the potential impacts and long-term effects on our rivers from projects such as bank stabilization, stormwater inputs, development in the floodplain, and infrastructure installations. Topics such as aquatic organism passage and habitat issues are also covered. Discussion focuses on stream processes and how our communities interact with the rivers, potential human impacts on the systems, and how communities can work to reduce their impacts. More knowledge about fluvial erosion hazards and inundation hazards is also gained. By having participants actively participate through discussion and some hands-on demonstration, knowledge and information is shared between participants.

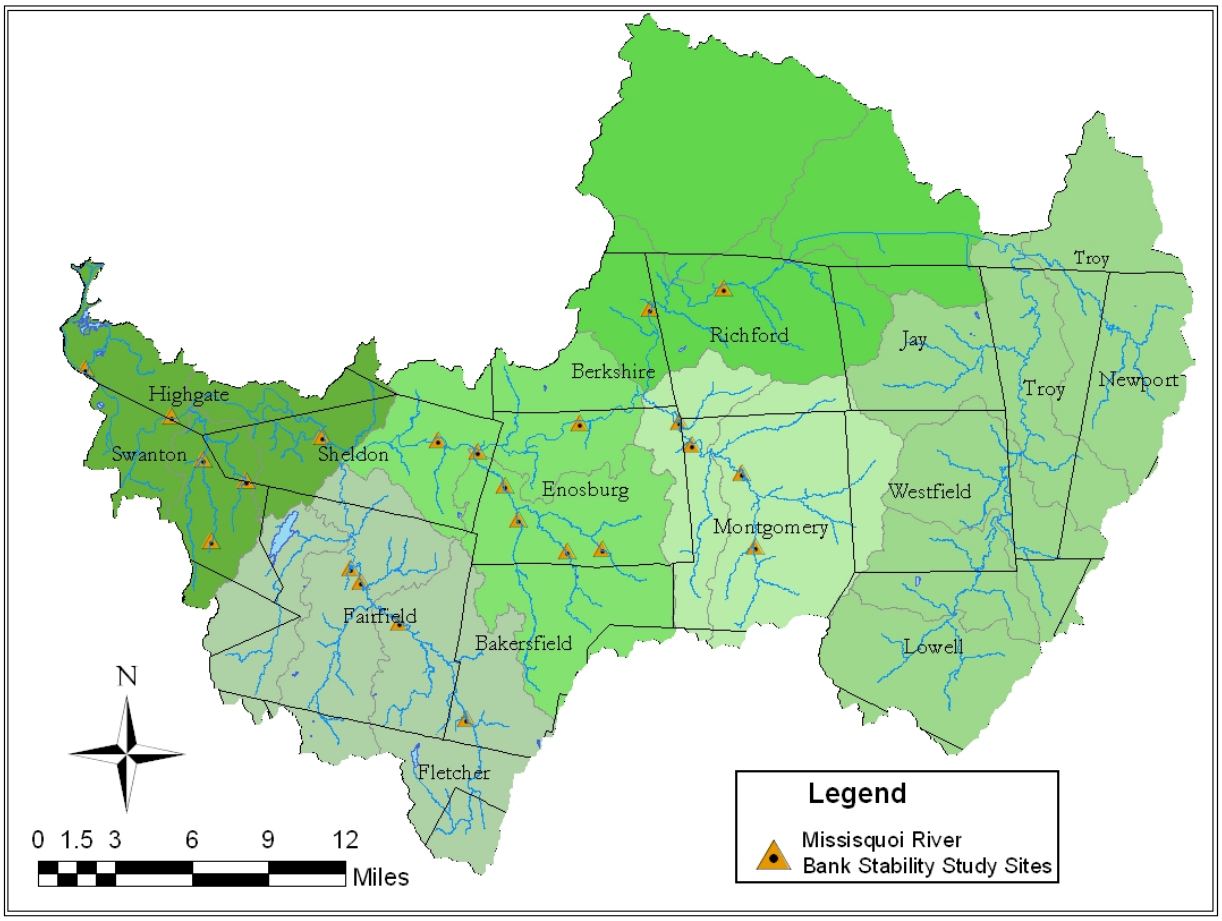
Type of Workshop	Number of workshops	Participants
General Public Education and Outreach	12	Community members, students, watershed groups, and watershed residents
Fish Passage	2	road crews, town officials, and VTrans officials
Municipal Stormwater	2	towns officials, road crews, engineers, and stormwater utility managers
Regional / Basin Planning	2	Regional Planning Commission, town officials, and watershed residents
Lakeshore and River Erosion	2	Regional Planning Commission, community members, and town officials
Total	**20**	

Research

USDA Agricultural Research Station (ARS): Bank Stability and Toe Erosion Model

A fundamental question which has remained unaddressed in the modeling of sediment and nutrient loading to Lake Champlain is, how much of the load is coming from stream instability. To date load allocations have been for wash-off from urban, agricultural, and forest land covers. This past year the River Management Program in partnership with the Center for Clean and Clear and the Lake Champlain Basin Program developed a cooperative agreement with the USDA Agricultural Research Station (ARS), Oxford, Mississippi to carryout research, employing the Bank Stability and Toe Erosion Model (BSTEM), in the Missisquoi Watershed.

Geotechnical tests of bank materials have been conducted at 20 sites in the Missisquoi Basin to determine appropriate input parameters for the modeling effort. Discharge data from USGS gauging stations will be converted to flow depths for each significant storm event for input into the toe-erosion sub-model. Modeling will be conducted iteratively to simulate bank-toe erosion and upper-bank stability for annual hydrographs representing the 99th, 95th, 90th, 75th, 50th, and 25th percentile flow years. Simulation results from the 20 representative reaches along the Missisquoi River main stem and selected tributaries will provide unit loadings data by stream reach and particle-size class. These results will be extrapolated to the non-modeled reaches using field and aerial reconnaissance of the current extent of streambank failures.



Primary USDA BSTEM Research Objectives

1. Estimate of the percentage of the total suspended sediment yield/load entering Lake Champlain from the studied portion of the Missisquoi River watershed that is coming from stream channel erosion processes. These results will be combined with total phosphorus data collected from the eroded soil strata to give insight into P loading into Lake Champlain as a result of stream erosion processes.
2. Increase our understanding of the correlation between stream equilibrium and bank stability in Vermont. Study a range of geomorphic conditions (via careful site selection) to see if geomorphic condition can be used to explain the quantity and rate of bank erosion and planform adjustment. This information will help inform river corridor protection work and the selection of specific floodplain restoration projects.
3. Model the effectiveness of different best management practices in reducing fluvial process derived sediment and nutrient loading. BMPs modeled would include watershed, floodplain, and channel management practices consistent with the State's goal of managing river systems toward equilibrium conditions over time.

Vermont ANR Water Center Partnership with the University of Vermont

The Vermont ANR River Management Program and the University of Vermont Water Resources and Lake Studies Center have pooled resources in recent years in order to jointly support a Watershed and Water Quality Research Program. Clean and Clear funds are used to match federal USGS funds to support grants awarded by the Water Resources and Lake Studies Center through a competitive process. The general objectives of the program are to:

1. Advance scientific understanding of the dynamics, management, and contribution of sediment and nutrients derived from fluvial processes in Vermont's rivers.
2. Establish the socio-economic justifications, costs, and benefits associated with or represented by river corridor protection in Vermont.
3. Contribute to Vermont's river corridor management, restoration, and protection programs.

Projects funded through this joint ANR and University of Vermont program that are currently in progress include the following:

- Improvement of Phosphorus Load Estimates through the use of Enzyme-Hydrolysis Measures of Phosphorus Bioavailability. University of Vermont School of Engineering.

- Quantifying Sediment Loading due to Stream Bank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT Using Advanced GIS and Remote Sensing Technologies. University of Vermont School of Engineering and Rubenstein School of Environment and Natural Resources.

- A Soil-Landscape Modeling Approach to Estimate Riparian Phosphorus Concentrations along Erodible Stream Corridors in Chittenden County, Vermont. University of Vermont Department of Plant and Soil Science.