Reading Vermont's Rivers

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Welcome to VNRC's new publication, *Reading Vermont's Rivers*. We hope you enjoy reading it as much as we've enjoyed creating it.

We have sought to assemble an accessible, informative introduction to how rivers behave and what makes them healthy.

In the pages that follow, you will find articles on rivers written by river scientists, state officials, planners, and road engineers. You will learn how rivers change and what those changes look like. We can have our cake and eat it too: we can manage rivers to reduce the risk of damage to property and even to public safety while at the same time keeping them clean, healthy and full of life.

Perhaps most importantly, this publication is designed to help us understand how we can live in greater balance with our rivers, especially in light of recent, and no doubt future, extreme weather.

A similar paper published a decade ago by the Vermont Agency of Natural Resources that focused on riparian buffers was part of VNRC's inspiration for creating *Reading Vermont's Rivers*. That ANR publication, the *Streamside Sentinel*, is still frequently cited. Our hope is that *Reading Vermont's Rivers* will be as timeless as that piece and that you refer back to it often.

Documents like these don't happen without caring and engaged funders. We extend deep gratitude to the Orchard Foundation, Green Mountain Coffee Roasters, Inc., the Lintilhac Foundation, and the Johnson Family Foundation.

Please, dive in . . . and let us know what you think!

— Jake Brown and Kim Greenwood, VNRC

Inside This Issue

VNRC Vermont Natural Resources Council

The Vermont Natural Resources Council, Inc. is a nonprofit environmental organization founded in 1963 to protect and restore Vermont's natural resources and environment for present and future generations through research, education, collaboration and advocacy.

VNRC is a member-supported organization. Join us in protecting Vermont's waters and environment by visiting www.vnrc.org or telephone us at 802-223-2328.

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It All Starts with Science, but Where Does That Take Us?

By Mike Kline

Where is the science of rivers leading us? This is becoming a common question for river advocates, especially here in Vermont where we value pristine waters and spend our time sampling and measuring our rivers' health. I believe river science is leading us to a new definition of rivers, one that changes our relationship with the lands through which they flow.

First, what do we mean when we say, "the science of rivers?" Is it physics, chemistry, or biology? Or is it river ecology, a science founded upon the principles of all three? As a river ecologist, I am not impartial, but at present, the buzz about river science is about physics. Our growing knowledge and application of fluvial geomorphology, or the science of physical river processes and the landforms created by those processes, is upending many long-held notions about rivers and our ability to manage them.

Science is enlarging the lenses of space and time through which we must see and know a river. The fact that rivers change and move, slowly or quickly, in the landscape over long periods of time seems so fundamental, and yet people still act surprised when they do move. Floods like those caused by Irene show us firsthand that rivers change the land, so much so that we begin to understand that floodplains were formed by the river and perhaps, over time, are very much a part of the river.

Will the science of rivers change our sense of land ownership? Too soon to tell, I think, but if your back field sits atop soils and sediments laid down by the river, then you should probably expect the river to return and reclaim them. Fluvial geomorphology explains that rivers and riverine formations are flowages of water, sediment, and woody debris. When we live and dwell upon fluvial formations, then we must learn what it means to be a part of the river. In the valley bottoms, the idea that, "we are here and the river is over there," is part of a dogma that is literally eroding away.

For centuries, the physical science of rivers was focused on hydrology, or the timing, volume, and duration of flow events throughout the year and over time. Engineers from the time of Leonardo Da Vinci to the present-day U.S. Corps of Engineers working along the great Mississippi have assured us that our coexistence with rivers was a matter of getting the plumbing right. The impounding, diking, diverting, and channeling practices being engineered were then adopted by those with the right equipment and some do-it-yourself attitude. Containing the flow of water to keep it away from our use of the land became a civic responsibility. In nineteenth century Vermont, if your neighbor was negligent in channeling their streams you had the right to go onto their land and do it for them.

During the twentieth century, great minds like Luna Leopold and Hans Albert Einstein (the sons of Aldo and Albert) brought to light that rivers were flowages of water and sediment. To my thinking, "applied" fluvial geomorphology started with this research along with the science of ecology that connects life to the natural physical and chemical processes around us, and the advent of environmental laws that governed the tinkerings of an individual for the collective good of all. For the past decade, Vermont has been honing a practical use of river science and considering river management based on the large-scale hydrologic and sediment-driven processes that define our place within the riverine landscape.

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At first, Vermont jumped onto the bandwagon of re-engineering its channelized rivers into sinuous forms in which water flows and stream power are in equilibrium (or balanced) with resistance and sediment transport functions. The experience was invaluable and is still of great practical use, but this work did nothing to change the expectation that, "we are here and the river is over there." Landowners were eager to sponsor river "restoration" projects if it meant less erosion and damage of their property.

What we as practitioners failed to explain was that, while equilibrium channels may be in a state of "least erosion," distributing the energy and materials of a watershed, they remain dynamic, and that, over time, they will continue to erode and continue to move. Long before the arrival of the stream straighteners from the European continent, the river systems of Vermont were in dynamic equilibrium, where over

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time, their movements covered the entire valley floor. We cannot replace one misperception with another that streams can be made static in the landscape if we can only get them into their natural geometry.

So how do we reconcile that rivers are dynamic flowages of water and sediment, greater than the bank-to-bank channels we have always perceived as "the river," with our existence on the valley floors which includes investments that are fixed and require a permanence of the ground beneath them? How do we balance a desire for rivers to be merely "less" erosive, with the need for them to remain "fixed" whenever and wherever we plunk down a road or building on an adjacent floodplain or valley terrace?

I believe Vermont is a lead agent in following the science to a new paradigm that rivers are a complex set of water and sediment flowages that need far more room to operate within than we have traditionally been willing to give them. We understand that claiming all valley bottom lands and turning every stream into a firehose-like conveyance are not sustainable practices that make us safer or protect the aquatic ecosystems we increasingly value. We are adopting the idea of giving "room for the river," which ironically comes to us from Europe. But I am proud to follow the Dutch people into an era where the stoic construction of human bulwarks against the forces of flowing water and sediments is seen as counterproductive.

The science is leading Vermont to define river corridors as the minimum valley bottom room a river needs to attain and maintain a dynamic equilibrium condition. These corridors accommodate the dimensions, meander pattern, and slope of a channel that can store and transport (i.e., evenly distribute), the water, sediment, and debris produced in the watershed above without unnaturally aggrading (building up) or degrading (eroding downward) the landscape. While many corridors are already occupied with infrastructure and inhabitable structures, Vermont, unlike other jurisdictions, still has thousands of miles of open corridors where the energy, sediments, and debris of floods may be safely dissipated within channels and floodplains in dynamic equilibrium with one another.

In this paradigm, the words "sustainable" and "resilient" are particularly apropos, because, rather than human-engineered structures that cost great sums to build and maintain, we begin to rely on forms and processes maintained by the river itself to mitigate the hazards of flooding, store fine sediments and nutrients that would otherwise pollute places like Lake Champlain or Long Island Sound, and create the complex habitats found in meandering river-floodplain systems.

For those of us following the science of rivers, Tropical Storm Irene and the human actions that took place afterward were a huge wake-up call. Vermont must recognize several realities that have come out of this disaster. First, there are villages, roads, and other critical infrastructure right next to rivers. Perhaps many of these investments were made in places that have turned out not to be such smart building locations. But while they are there, we must recognize that particular river reaches have to be managed more proactively to protect our homes and public infrastructure. In these places, we must use our knowledge of natural river engineering to create naturalized channels (i.e., think rocky gorge) that can remain static by transporting sediment and debris while dissipating flood energy to the greatest extent possible.

Also going forward, we must acknowledge that rivers move, meander, and create a tremendous amount of power, sediment, and debris during floods—floods that will become more frequent because of climate change. Therefore, it is essential that we work with landowners and communities to do buyouts and easements and create incentives for land use regulation that makes room for the river. We must find ways to help communities pull back from and protect critical river corridors and floodplains upstream and downstream of our villages so that the rivers can spill out and release their flood energy and materials in these less-developed areas. Only if we remain at the leading edge of the science, creating a new paradigm for the 21st century where the river is considered in terms of its corridor and floodplains, will we be resilient from flooding, with safe and sustainable communities, cleaner water, and rich and diverse riparian habitats.

Over the past several years, our legislature has put Vermont on the map as the first state to explicitly recognize that managing rivers toward a dynamic equilibrium is in the public interest. They set strong public policy that river corridor and floodplain protection are important state and local endeavors. I am hopeful more and more Vermonters will join this commitment to modern river science. More room for the rivers may be the lowest cost form of flood resiliency we can achieve.

Mike Kline is Vermont Rivers Program Manager at the Vermont Department of Environmental Conservation

River Corridors and River Buffers: The Difference in Plain English

BY KIM GREENWOOD

If you're just learning about river science (and who isn't still learning?), the terms that are used can be a little complicated. Two of the most frequently confused river science terms are "river corridor" and "buffer." The two are very different, but complement each other in river, property, and even public safety protection.

First, "river corridor" is the land area adjacent to a river in which a river moves, or could move, both side to side and up and down, over time. This area is calculated using geometry and river science. Part of the reason the Vermont Agency of Natural Resources defines river corridors is to identify areas near rivers that could be risky for existing and proposed development should rivers suddenly, or even not-so-suddenly, shift channels.

River corridors are invisible lines on the landscape that define the areas that are necessary to accommodate the movement of a stream in its most stable, least erosive, "equilibrium" condition. The width of the corridor is based on physical measurements, comparisons to similar streams, and current characteristics of the stream.

Depending on a lot of different factors, river corridors can be just a few feet wide, a mile wide, or even more.

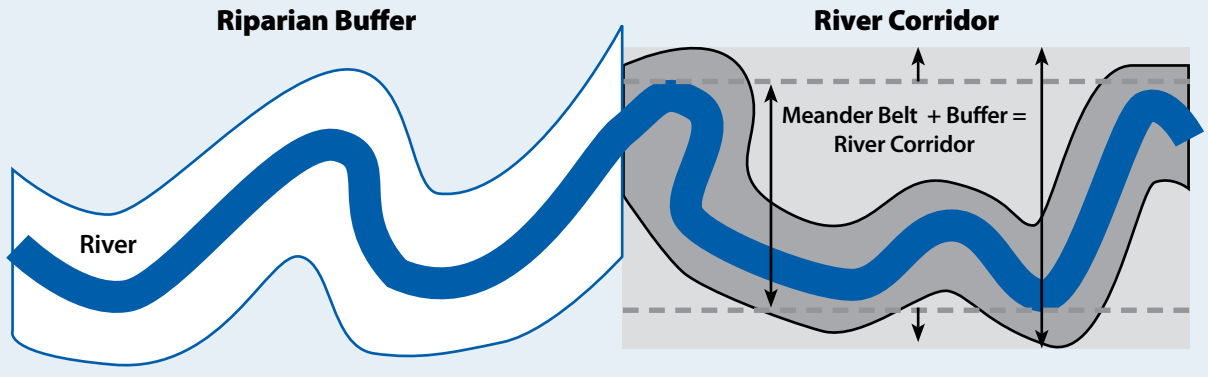
On the other hand, a "buffer" is an undisturbed vegetated strip immediately alongside a river usually containing a mix of trees, shrubs, ground cover plants, dead leaves and other "duff" material on the ground. Generally, a buffer area is much smaller than a corridor and is set within the corridor. Buffers generally exist between rivers and developed areas or other open land. Rivers deep in the undeveloped forest areas, for example, may be surrounded by miles of "buffer".

Buffers can contribute to stream bank stability, depending on size and the amount and type of vegetation. They also filter out sediment and other pollution carried toward rivers by rain or snowmelt. Buffers provide wildlife habitat and shady areas in rivers, assuring cooler water is available for species that live in or near water.

A healthy stream requires the attributes of both river corridors and buffers. It needs a corridor in order to improve stream stability, enhance public safety, reduce flood losses, sustain high quality habitats, and provide long term water quality benefits; it needs a vegetated buffer to provide bank stability, temperature moderation, additional water quality, and habitat function.

Kim Greenwood, C.P.E.S.C., is Water Program Director and Staff Scientist at the Vermont Natural Resources Council. Adapted from various Agency of Natural Resources publications.

Comparing a Buffer Setback to a River Corridor



Adapted from Ohio DNR, Rainwater and Land Development Manual. 2006 Ed., Ch 2. Post Construction Stormwater Management Practices, p. 21.

Born as a Trickle, Delicate Headwaters Feed the System

By Geoffrey M. Goll and Andres Torizzo

Headwaters are often thought about in terms of faraway places at the outer extremes of watersheds, where that one drop of water on a continental divide begins the journey from a trickle to a majestic river, ultimately creating the great deltas of the world. While there are these places where rivers begin, headwaters can be located in nearly every area of a watershed. From simple wetland seeps along a river valley to intermittent and ephemeral streams and wetlands in high elevation areas, they are everywhere.

The US Environmental Protection Agency defines headwater streams as those streams that create the first or second channel in a watershed. These are called "orders" from the first order where water first forms a channel at the top of the branching stream network, to the point where it intersects with another stream. That second stream is considered a second order stream, and so on, to ever growing orders until the water is discharged into a lake and/or the ocean. The further down the river network a given stream is located, the higher the number designation. There are even zero order streams, where there is not yet enough water to form a distinct channel, for the seep or precipitation has too little energy to actually form a stream. Depending on the scale of mapping, stream order designations can have a wide range. For example, a stream that is considered a first order stream (the first definable channel in a network) on a topographic map may actually have many, many smaller defined contributing tributaries when observed in the field. As a result, these designations are somewhat subjective in part because some watershed areas are extremely small, even measured in fractions of an acre. It is at these locations where the source of all of our rivers and lakes start. And it's important to know that the vast majority – 90 percent on average – of a given river system is made up of headwaters. This can be surprising given how invisible headwater areas are compared to big, valley bottom rivers. Headwaters make up almost 50 percent of all the river miles within the United States.

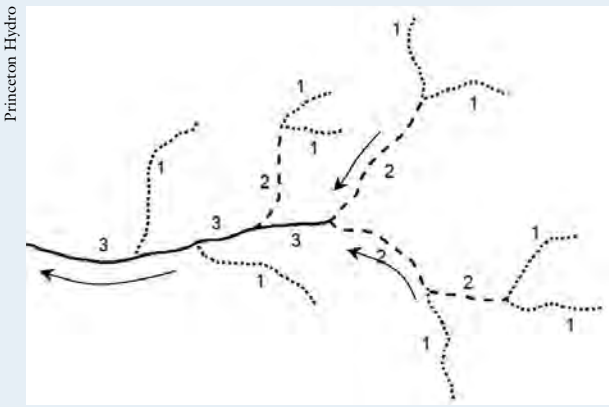
Princeton Hydro

Vermont headwater wetland ("zero order") where there is no definable channel, yet at this 2,400 foot elevation, there is an ample amount of stored water.

Princeton Hydro

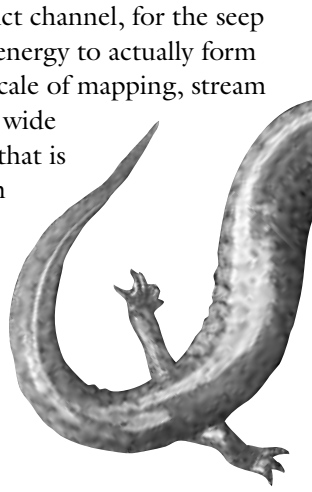
First order headwater stream at elevation 2,200 feet.

Princeton Hydro



Headwater Streams

The chart at left shows how headwater streams are identified by their "order." First order streams are identified with a "1," second order with a "2," and so on. Zero order streams may be even higher up the branched network. They are either too small to form a distinct channel, or are simply a seep emerging out of the soil or rock. Some third order or higher numbered streams can also be considered headwaters, depending on their location and characteristics within the landscape.



Spring salamander (Gyrinophilus porphyriticus), the top predator in the highest of headwater streams. This specimen is about five inches in length.

Headwaters: Not Just in the Woods

In Vermont, impacts to headwaters from land development are obstensibly regulated through Act 250. However, most development in headwater areas doesn't actually trigger Act 250 review. Projects regulated under the Act 250 process are required to provide an evidentiary basis that the development will "meet any applicable health and environmental conservation department regulation regarding reduction of the quality of the ground or surface waters flowing through or upon lands which are not devoted to intensive development." These lands are further classified as "areas characterized by steep slopes and shallow soils; or drainage areas of 20 square miles or less; or above 1,500 feet elevation; or watersheds of public water supplies designated by the State; or areas supplying significant amounts of recharge waters to aquifers." This is not a sufficient definition of a headwater area but rather a regulatory application that can unfortunately lead to confusion and debate. The context could be interpreted to mean that a headwater must be located in a non-urbanized, wild location. Importantly however, headwaters found in a small, highly urbanized watershed can be of equal or even greater value for sustaining downstream water quality than a headwater located in a remote undeveloped area. In a degraded urban stream system, a protected headwater is the thread by which life is sustained downstream. In Vermont, we must recognize that headwaters can exist in our urban areas just as they do in the more remote regions, and that all headwater areas serve important water quality and habitat functions, and deserve protection. These areas also provide the source of food for downstream ecosystems following the processing of organic materials, such as leaves and organic pollutants.

Headwaters: The Lifeblood of Healthy Rivers

Due to their relatively small and manageable areas, yet high percentage of stream systems, headwater streams collectively have a large impact on the control of flood waters and can filter, assimilate, and remove pollutants in rainwater. These small stream segments are reserves of aquatic macroinvertebrates and other organisms that resupply downstream water resources. For example, fish like brook trout cannot colonize the very highest headwater streams, but the absence of these predators provides a refuge for other species such as salamanders.

Collectively, headwater streams are the indicator of a downstream river system's health and vitality. The sensitivity of undeveloped headwater areas is especially pronounced because they are relatively small, typically steep, and have low concentrations of pollutants (i.e. cold, clear water). The resident macroinvertebrates and amphibians have adapted to this environment. As a result, these organisms have a hard

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An Unstable River: The Signs and Symptoms

By Mike Kline and Kim Greenwood

Vermont has many miles of unstable rivers, and they're not hard to identify. Just look for one of the telltale signs: tall eroding banks, often on both sides of the river.

The other physical features that suggest a river is unstable are divided into four categories:

Degradation: The river cuts deeper, down into the earth. The undermining and exposure of bridge footings caused by river action, for example, is often the result of degredation. Degradation is sometimes caused by straightening a channel, which can increase the slope of the river. Water flows faster down this steeper slope and has extra energy to move sediment, causing the river channel to cut deeper or degrade.

Widening: Banks collapse, and the river becomes wider and shallower. Bank collapse and widening follow river degradation, but may also occur when there is increased stormwater runoff. A wider, shallower river does not have the same capacity to move sediment, so soil can build up in the channel.

Aggradation: Sediment loads pile up in the river. This happens when the amount of sediment in the river water increases, and the river lacks the capacity to carry it downstream. In a typical river evolution process, aggradation typically follows channel widening. Piles of sediment in a river can re-direct flow against the banks, causing yet more streambank erosion.

Changes in Planform: These are the changes that often follow excessive aggradation and can be seen from the air when looking down at the river. Planform changes can occur during floods. When there is no streambank vegetation with roots to hold soil in place, rivers cut new channels in the weak part of the bank during high water.

Rivers and their movement become easier to understand once we realize that the shape of the river is the result of a dynamic yet delicate balance between erosion and deposition; between volume and power of water and the size and quantity of sediment resisting the water's power. If one element of the system changes, then others change in response. These factors affect vertical stability, swinging the balance of the stream from aggradation to degradation and back again.

Activities within the watershed can alter the amount of water that infiltrates into the ground. For instance, pavement forces water to run quickly off land and into rivers. Similarly, when woods are clear-cut, water that once trickled through forest soil and leaf litter now runs quickly over land and into a river. Rivers adjust to these changes, usually by getting

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Delicate Headwaters

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time tolerating pollution or soil-laden water. Two of the most important stressors to headwater areas are changes in land cover and hydrologic modification within the watershed. It has been well documented that human activities such as road construction and clear cutting can have dramatic and negative impacts on headwater systems. And once these sensitive but multi-functional systems are disturbed, their cumulative impacts are felt far downstream.

Once these sensitive, but multi-functional systems are disturbed their cumulative impacts is felt far downstream.

On the other hand, when there is precipitation in an undeveloped, healthy headwater area, the water is slowed down by overland flow, allowing pollution to be removed. The water would then flow to a discrete channel or wetland area that is the beginning of a river network. The stream banks and channel bottom materials have equilibrated over the centuries, with the flow regime such that the system is stable and changes imperceptibly, rather than actively and rapidly adjusting to manage runoff.

In Vermont, some of the last untouched or minimally managed headwaters are located on the ridgelines and peaks of the Green Mountains. Through geological processes, glaciation and weathering have formed pockets and deep ridges that support a rich growth of vegetation and organic and residual substrate that store and slowly releases precipitation over time. It is also these high elevation headwaters that are the last to lose their snow cover, extending the cold water base flow extending late into the spring and "mud season." It is the groundwater and interflow in the surficial soils that provide clean and cold water to the lower valleys during the warmer and drier times of the summer. Their protection is paramount to the maintenance of still unimpaired waters, as well as the last best hope for the restoration of those waters that are impaired. It is these waters that can actually help improve the quality of polluted waterways downstream.

Protection of headwaters should be a priority for Vermonters because they will ensure for future generations clean and cold water for fishing, swimming, boating, industry, and drinking. Headwaters are so important to maintaining water quality to Vermonters that it is specifically identified under Criterion 1 of the 10 Act 250 review criteria, which require that any development activity protects water quality, and is given the same weight as other designated water resources including streams, shorelines, and wetlands. We tend to focus on the more visible waterways. However, we should look further up into the watershed and consider better protections for these areas because of their role, one that is critical to healthy river systems.

Geoffrey Goll, P.E., is a Partner at Princeton Hydro, LLC. Andres Torizzo, C.P.E.S.C., C.P.S.W.Q., is Principal Hydrologist at Watershed Consulting Associates, LLC.

Princeton Hydro

Road crossings cause erosion and blockages to aquatic organisms. Such organisms include amphibians and invertebrates, not simply fish.

Princeton Hydro

Second order stream affected by acid rock drainage. When earth is disturbed, it can expose fresh, sulfide-bearing bedrock and iron oxide deposits on stream substrate. The pH level of the stream drops. This can kill life forms in the stream.

With Bumps, Snarls, Snags and Clutter, Healthy Streams Sometimes Ain't Pretty

By Roy Schiff

If you ask someone who fishes in Vermont streams to describe good trout habitat, you'll probably hear phrases like: "cold water" "deep pools" "large boulders" "submerged trees" and "overhanging vegetation." Streams typically contain a distribution of these and other habitat features that are the foundation of a functioning aquatic ecosystem. A functioning aquatic ecosystem provides a continual supply of shelter and food that are critical to trout. Where trout eat and take cover, they can be caught.

Watch, walk, or fish the same stretch of stream channel regularly and you will notice that habitat features naturally change size, shape, and location due to the dynamic nature of flowing waters. Following large floods, the scouring action of the flow can move riffles, pools, and other bed features thousands of feet. A cobble and gravel streambed is cleaned of silts and sands during high flows, leaving small nooks and crannies for clinging insects to recolonize. New supplies of wood and organic materials are delivered to the channel that may exist and decay for many years until the next large flood. The disturbance and changes to a stream channel due to flooding are essential for a healthy functioning aquatic ecosystem.

Healthy habitat is rough and ugly. Tangles of trees and masses of aquatic plants create food factories that form the base of the aquatic food web. It isn't pretty, but it's a successful ecological system. Erosion at the bottom of streambanks creates cavities called "undercut banks" that form important hiding locations for fish and other aquatic organisms. Bank vegetation leaning over and into the water creates shelter for fish and insect reproduction areas. Large boulders protruding from the streambed create turbulent areas that aerate the water, create feeding areas for fish, and provide local pockets in the streambed. Some plants, insects, and fish rely on turbulent flow, while others need deep and slow moving water. A mix of different water depths and speeds, or hydraulic conditions, is important to maintain diversity and longevity in aquatic populations. If you want to watch a fish rise, or try to catch one, head to the most irregular, coarse, and uneven area of the stream and have a look.

Woody debris jam on the Browns River.

Instream habitat is the observable layer of features that result from a naturally varying range of flow, sediment erosion and deposition, the movement of wood, changing river banks, and connectivity (i.e., natural stream processes). Habitat would not exist without these disturbance processes. If the processes change, than habitat will change. Habitat features are formed and maintained over the long term by the natural stream processes that therefore result in the size and diversity of populations of fish and other aquatic organisms. No processes – no fish.

When humans manage rivers, we typically alter stream habitat, unless we explicitly allow for the natural stream processes to remain functioning. While human actions can immediately change the distribution of habitat through direct changes to specific habitat features, human action can also alter the long-term condition of the stream. These changes can be incremental and harder to notice. For example, it's fairly clear that removing woody debris jams following a flood immediately reduces habitat quality because it removes shelter for fish and insects, feeding areas, and refuge locations. However, woody debris removal can also have long-term impacts because it removes wood that, over time, disintegrates and is distributed across miles of stream channel. The removal of wood thus leads to immediate and long-term impacts to aquatic ecosystems.

When people dredge gravel from sediment bars and long stretches of the river channel following floods, they immediately remove the roughness and complexity of the streambed and typically leave a smooth, uniform bed without most habitat elements. While healthy habitat features may return locally over time, large-scale sediment removal can cause an upstream-moving erosion face, or "headcut." Water flowing over this step-like formation within the streambed can disrupt the channel bed over large distances for long periods of time. Digging channels out too deep over large areas also can lead to the down-cutting of the channel known as incision that disrupts both stream-bed and near-bank habitat. Recommendations against widespread gravel dredging following flooding are attempting to avoid the long-term impacts that can harm many miles of river habitat for years while also increasing flood risks – a no-win scenario. The dredging of sediment often leads to immediate and long-term impacts to aquatic ecosystems as well as increased risks during future floods.

Given the possible long-term impacts of all river management alternatives, the first alternative explored during flood recovery should be the "no action" alternative. Perhaps contrary to conventional wisdom, a river will sort itself out, re-stabilize, and form new habitat given ample time and space. If site constraints and the land uses in the river corridor can safely remain, river management by humans should be avoided or minimized to reduce future risks that include long-term damage to habitat. While natural disturbances impact habitat to a certain degree, river management by humans tends to perpetuate and increase the magnitude of the impacts.

For many of us who cherish the wild brook trout streams of the Green Mountains, our local fishing holes, and a walk along a natural stream full of healthy habitat, protection and restoration are important activities moving forward. We should restore and protect the natural stream processes that form and maintain habitat to assure that abundant habitat will exist for the long term. Good habitat is not neat and clean, and it's changing all the time. Let's choose to accept the wood, roughness, erosion, gravel bars, and the dynamic nature of our rivers, for the sake of their long term health.

Roy Schiff, Ph.D., P.E., is a Water Resource Scientist and Engineer at Milone & MacBroom, Inc.

Overhanging vegetation and deep pool on the Batten Kill.

An Unstable River: Signs and Symptoms

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wider or deeper to accommodate the increased flow. These changes are called hydrologic changes.

Vermont rivers are very sensitive to land use changes in their river basins. One recent study by the Vermont Geological Survey concluded that rivers begin to become unstable with as little as two percent of the basin developed. Rivers actively change their shape when change in the land use and land cover exceeds eight percent of the basin. As development increases in Vermont, rivers adjust to these hydrologic changes, generally by getting wider. The Vermont Geological Survey found that rivers under these conditions can widen by as much as two to three times their former width.

Instability in a river can also result from changes to the channel itself. Channelization and dredging for gravel are two examples of physical changes to rivers that stress the system. Straightening or channelizing a river will often have the effect of increasing the slope of the river. As the slope increases, flow velocity and erosive power increase. This extra force causes the river to degrade or erode its bed. Often downstream of a straightened section of river, the water slows and sediment re-deposits. The downstream aggrades and undergoes planform change, often threatening properties.

Underwater or Swept Away?

Flood Impacts Differ

By Kim Greenwood

Vermonters are well acquainted with the damaging effects of flooding. As we look forward, it's important to remember there are two types of flooding impacts: one from water inundation where water rises into low lying land, and the other from river erosion when, for example, a river jumps its bank and rips through an area, taking whatever is in its path with it. Vermont has programs that try to minimize both types of damage.

The difference is important in part because different regulatory programs apply to each. Specifically, the National Flood Insurance Program (NFIP) is promoted by Federal Emergency Management Agency (FEMA) to address inundation hazards, and the River Corridor and Floodplain Management Program was was developed by the Vermont Agency of Natural Resources (ANR) Rivers Program to address fluvial erosion hazards (FEH).

FEMA's Inundation Program

The National Flood Insurance Program (NFIP) is a voluntary program that provides federally-subsidized flood insurance to communities that would like to participate as long as they adopt and administer land use regulations in flood hazard areas designed to reduce the risk of property damage from inundation. Property owners in those communities can purchase NFIP flood insurance to protect their buildings and possessions. Flood insurance rates are based on Flood Insurance Rate Maps (FIRMs), which delineate areas of the floodplain likely to be inundated during a flood. Inundation areas are divided into zones according to flood risk and include the Special Flood Hazard Area and the FEMA regulatory floodway.

The NFIP maps focus on a particular type of flood risk to the low-lying lands next to the river channel. They show the areas that would be covered, or "inundated," by water as floodwaters rise. One way to imagine this is to think of the floodplain as a giant bathtub filling up. As the water first enters the tub, it slowly spreads out until the entire tub bottom is covered in water. Two-thirds of Vermont flood damages to property and infrastructure occur outside of the mapped NFIP floodplain.

Jake Brown/VNRC

Inundation flooding.

Technically speaking, the Special Flood Hazard Area (or floodplain) includes the stream channel plus adjacent land inundated by river discharge during a "base flood". The base flood is sometimes referred to as the "100-year flood", which may give the false impression that a base flood can only occur once every 100 years. A more accurate way of describing the base flood is to say that in any given year, there is a 1% chance that a flood of this size will occur. Some Vermont rivers have experienced more than one "100-year flood" within a decade.

Vermont's Rivers Program

The Vermont ANR Rivers Program has developed a program to supplement the NFIP called the River Corridor and Floodplain Management Program. The rivers program maps a river corridor with an eye toward protecting against fluvial erosion, the predominant form of flood damage in Vermont. The maps, which are based on studies of each stream's physical condition and sensitivity to erosion, provide towns with a powerful flood hazard planning tool.

The river corridor maps are designed with the recognition that rivers are not static. These hazards are most evident when a flooding river dramatically enlarges or makes a catastrophic change in course, resulting in severe erosion of the river bed and banks. A certain amount of erosion is natural when Vermont floods because of the region's relatively steep terrain and flashy, frequent storms. However, due to development and channel engineering over the years (e.g., bank armoring, berming, and channel straightening), many Vermont rivers have become unstable and now have increased FEH risk.

Because the underlying methods of mapping differ significantly, it is not surprising the flood maps created under the federal NFIP program and the state River Corridor maps depicting fluvial erosion hazard areas differ. In some situations, the FEH zone is narrower than the FEMA floodplain, usually as a result of bedrock or elevated landforms that may not have been evaluated in the NFIP studies. In other areas, the FEH zone may extend beyond the FEMA regulatory floodway or even the Special Flood Hazard Area boundaries. These locations are potentially hazardous, and under minimum NFIP guidelines alone, development in these areas may be susceptible to flood damage and/or may contribute to further instability and erosion hazard upstream or downstream. Moreover, on streams where FEMA has mapped "approximate" flood hazards, FEH maps provide communities with essential, more detailed flood risk data.

John Lazenby

Erosion damage from flooding.

Kim Greenwood is Water Program Director and Staff Scientist at the Vermont Natural Resources Council.

Adapted from Agency of Natural Resources publications.

Watershed Communities:
Defined by H_2O, But Really They're a Whole Lot More

BY KATE MCCARTHY

When we think about where we live, we tend to define it in terms of human-made features: for example, we live on our property, defined by parcel lines, or within the boundaries of our towns. These communities are ones we recognize easily. But though we may not think of it on a daily basis, we all live within another type of community as well: a watershed community, formed by the natural features of the landscape, and spanning the political boundaries that often define our worlds.

You may have heard the term watershed before, but what is a watershed, exactly? A watershed is the land area from which all water, both under the land and flowing on top of it, drains to a low point – such as a river, lake, or ocean – much like water emptying from a funnel. All of the rain and snow that falls on the lands within a watershed drains to the same point.

Despite its name, a watershed includes more than just streams and rivers: watersheds also include hills, forests, floodplains, and wetlands. Watersheds can be small or large, but all land is part of some watershed. And because watersheds are defined by topography rather than town lines, we all live in watershed communities that are far broader than what we may realize.

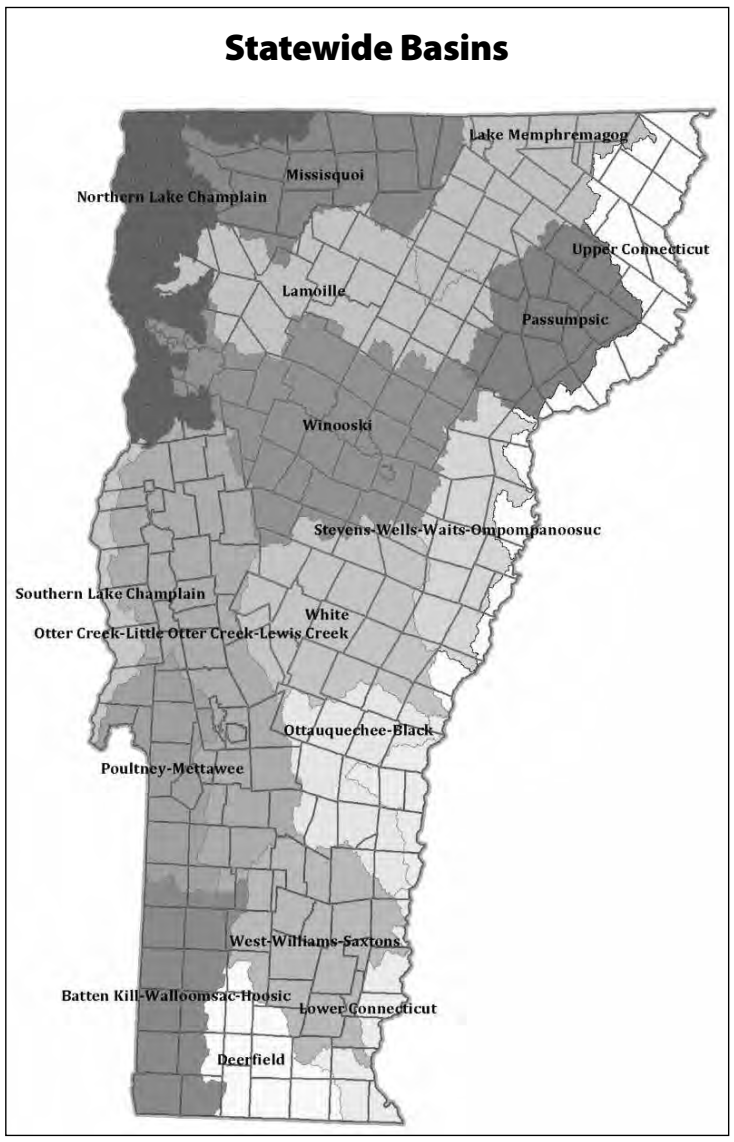
Why does it matter that we're all part of a watershed community? Since all water drains through a watershed, it means that activities in one part of the watershed – development, new roads, forest clearing – affect what happens downstream. In other words, being part of a watershed community means that we're connected through the water we rely on for drinking, irrigation, and manufacturing, as well as through the land use choices made both inside and outside our town's boundaries. In a state where approximately 70% of the population gets its drinking water from groundwater (about 46% from wells and 24% from public systems that use groundwater), the clean water provided by a healthy watershed is essential.

Unfortunately, our watersheds face a number of threats. Impermeable surfaces – things like roofs, parking lots, and roads – keep water from being absorbed into the soils. These surfaces also create stormwater runoff that carries sediment, nutrients, and other pollutants into lakes and streams. A house or dirt road here or there may not seem to have an impact, but every incremental change to the land is a change to its hydrology – the way water moves across the land – so every change matters. Forest fragmentation from development can lead to loss of the tree canopy and the sponge-like forest soils that are so essential to absorbing water that falls from the sky. And rivers that can no longer overflow into their natural floodplains deepen stream channels and erode stream banks, resulting in faster stream flows and (sometimes) the loss of land and other property.

Given that watersheds provide important benefits locally but also across town boundaries, what does this mean for keeping a watershed healthy? What are the best ways to ensure watershed health when our watersheds are affected by a patchwork of different land use patterns and municipal regulations?

It's a complicated question. Unlike municipalities, watersheds don't have their own planning commissions, selectboards, or zoning. In fact, despite the importance of watersheds and they ways they connect communities, there are, surprisingly, no governing bodies that oversee or guide land management on a watershed scale. So, what can be done to help ensure a healthy watershed across town – and sometimes even state – boundaries? There are several approaches.

In Vermont and elsewhere, watershed organizations play an important role. Vermont has dozens of these organizations, and they play an important role in initiating studies and supporting voluntary actions for watershed stewardship. They are typically non-profit organizations that work across municipal boundaries on educational activities, outreach to individual landowners, water quality sampling, river clean ups, and more. Watershed associations will sometimes undertake "stream geomorphic assessments," physical surveys of streams to help understand stream characteristics, including how much space a stream needs to "meander" naturally over time so that it can fulfill its natural functions. Watershed associations rely heavily on volunteer assistance, and are a great way to get involved.



Another approach to caring for the health of the watershed is to develop a watershed plan. This in-depth plan builds on stream geomorphic assessments to identify issues in the watershed, and then develop a prioritized action plan with individual steps for addressing the issues. High quality watershed plans are the result of good science, an outreach process that engages the public, and collaboration between local and state governments, community groups, and non-profit partners. This approach has been used since the late 1980s as the preferred approach to dealing with water quality issues – which makes sense since, as we know, water quality is affected by more than just the conditions of an individual stream.

The Agency of Natural Resources (ANR) undertakes a basin planning process in all of Vermont's major watersheds. Every five years, an official Basin Plan is developed for each major river basin. The Plan summarizes current and past (within five years) assessment, planning, and implementation activities at the state and local level in the basin. It identifies topics or areas of special importance in the basin, identifies available management tools to address those topics, and makes specific recommendations on how to address key topics, including recommendations for continuing community-based planning or implementation action. The process craves citizen involvement and is a great way to get to know your basin and work to make it better.

At the town level, some communities have adopted "watershed districts" or "stormwater management districts" – a type of zoning that may limit development and the amount of impermeable surface in order to protect surface and groundwater quality. These are often found around a community's wellhead protection area. Towns can also discuss watershed issues and management techniques in their municipal plans, which are updated every five years and provide the basis for local action.

These are just a few of the many approaches available for taking care of our watersheds. Watershed management may be a complex issue, but the benefit of clean water and a healthy landscape for Vermonters to enjoy is hard to deny.

Interested and wondering where to start? Your local conservation commission can be a great resource for learning more about how rivers, streams, floodplains, and upland forests are cared for in your watershed. Look also at your town plan to see if there are opportunities to discuss watershed issues. Be curious, ask questions, get involved, and become an active member of your watershed community today!

Kate McCarthy, A.I.C.P., is the Sustainable Communities Program director at the Vermont Natural Resources Council.

The Role of the Watershed Group

Citizens help prepare and recover from floods

By Mary Russ

Vermont's White River is the heart of a picturesque working landscape, rushing down forested hillsides, bubbling along farm fields, winding under covered bridges, and rolling through historic villages before joining the Connecticut River in White River Junction. The river's largely rural watershed contributes to cold, clean water, making the White River a popular recreational destination, and warm weather brings thousands of residents and visitors alike to enjoy tubing, swimming, paddling, fishing, wildlife viewing, and more.

Flooding from Tropical Storm Irene in August 2011 altered this pastoral picture, as 12 of 21 towns in the White River watershed suffered millions of dollars in damage to roads, bridges, businesses, and homes. While local efforts to recover from the flood damage started immediately – and thousands of volunteers chipped in to help in the weeks and months that followed – long-term recovery efforts to restore both man-made and natural watershed assets will take years.

Among many local organizations involved in this long-term effort, the White River Partnership (WRP) has been actively involved in flood recovery activities since Tropical Storm Irene hit Vermont. Like its counterparts in other parts of the state, the WRP is a community-based, non-profit organization working with individuals, communities, local and regional organizations, and state and federal agencies to improve the long-term health of the White River and its watershed with a focus on water quality, fish and wildlife habitat, flood resiliency, and public recreational access.

The WRP – like many of Vermont's watershed groups – found itself in a unique position to help communities recover from Tropical Storm Irene flooding for several reasons. First, the WRP regularly collects extensive scientific assessment and monitoring data about the river and its watershed, which was used to inform flood recovery efforts and can be used to plan for and mitigate future flood damages. Second, the WRP actively cultivates relationships among diverse watershed constituents, and was able to act as a liaison between these individuals and groups to help share information and coordinate effective flood response. Third, the WRP routinely coordinates groups of volunteers and implements complex, on-the-ground restoration projects – skill sets that were particularly useful in both the emergency and also the long-term flood recovery phases.

Examples of how the WRP responded during the emergency, mid-term, and long-term flood recovery phases can illustrate how watershed groups may help prepare for and recover from future flooding events in Vermont.

Emergency flood recovery – Watershed groups can help coordinate technical partner assistance in the immediate aftermath of a major flood event.

The author measures a culvert.

- *US Fish & Wildlife Service liaison project* – Within a week of Tropical Storm Irene, the Northeast Region of the US Fish & Wildlife Service (USFWS) had recruited a team of fisheries biologists and fish passage engineers willing to volunteer their time and technical expertise to address damages to riparian and in-stream habitat as well as stream crossing structures, like culverts and bridges. The WRP acted as a liaison between USFWS personnel and local and state recovery officials to facilitate identification, design, and implementation of flood recovery projects, resulting in the restoration of miles of in-stream habitat as well as the design of almost a dozen replacement stream crossing structures at no cost to the landowners and towns. As a result, the collaboration may be used as a model for future flood-recovery efforts.

Mid-term flood recovery – Watershed groups can help individuals and communities coordinate on-the-ground restoration projects during the mid-term flood recovery phase.

- *Hurricane Flats Farm streambank stabilization project* – Hurricane Flats Farm is a 65-acre organic vegetable and hay farm located on the White River in South Royalton. Flooding from Tropical Storm Irene inundated the farm fields, destroying crops, damaging greenhouses and irrigation systems, depositing thousands of yards of silt, and eroding two 150-square-foot holes in the streambank. The owners requested help addressing 300 feet of eroding streambank, so the WRP worked with the Green Mountain National Forest to design a streambank stabilization project that utilized large woody debris left behind by flood waters. A local contractor harvested dozens of large trees from debris piles in the adjacent fields and buried them at the bottom of the eroding bank – perpendicular to the river – leaving root wads exposed to create a natural log jam. Volunteers helped install coir erosion fabric filled with compacted soil on top of the log jam to stabilize the bank face, and pounded native willow stakes harvested on-site into the fabric to keep it in place. This successful streambank stabilization project is a model for reducing erosion and improving habitat by utilizing natural materials found on-site post-flood, resulting in a stabilization project that costs less than traditional large stone rip-rap installations.

- *Town of Rochester culvert replacement project* – The town of Rochester is located in the upper reaches of the White River watershed and almost all of the town's high-elevation streams overflowed their banks during Tropical Storm Irene. As a result, every culvert and bridge failed in three stream systems that flow into the main stem of the White River, causing massive damage to the town road system, private residences, and a cemetery located along the stream corridors. These damages were a primary focus for USFWS technical experts, who designed replacement structures for seven culverts that failed during the flood. With funds from both the USFWS National Fish Passage Program and the US Forest Service Highway Transportation Aquatic Passage Program, the WRP is working with the town of Rochester, FEMA, and the state of Vermont to replace the seven flood-damaged culverts with stream crossing structures designed to accommodate a 100-year flood event as well as the passage of debris, ice, and aquatic organisms. This project is a model for how federal agencies can bring resources to FEMA projects that improve both the long-term flood resilience of town-owned infrastructure and also natural resource values that were compromised during a flood.

Long-term flood recovery and planning – Watershed groups can help coordinate pre-disaster planning activities as well as adaptive restoration and monitoring activities during the long-term flood recovery and planning phase.

- *Outreach about flood hazard area regulations* – The WRP is working with Two Rivers-Ottauquechee Regional Commission to conduct outreach to five towns in the Upper White River watershed about incorporating river corridor protection measures into municipal ordinances. All five communities were hard-hit by Irene, and their respective planning commissions are very receptive to advice

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Woods Whys

Can Forests Prevent or Mitigate Floods?

BY MICHAEL SNYDER

Healthy forests play an absolutely vital role in moderating water movement over our landscape. Although forests cannot prevent large floods outright, they certainly do minimize the frequency, intensity, and extent of all flooding events, which in turn significantly reduces the damage to life and property that serious flooding causes. It's yet another way in which forests work for us.

Water first enters our landscape in the form of rain, snow, sleet, fog, or hail. Forests may influence the occurrence and distribution of local precipitation, but their most significant contribution is in how forested watersheds receive and deal with all the water that falls on them. Forests absorb and reroute water – thereby diffusing its potentially damaging energy – before slowly releasing the water into seeps, ponds, lakes, rills, brooks, streams, and rivers. The net hydrologic effect of the forest is to delay and reduce the size of the flood peak.

Forested watersheds have complex canopies with varied densities of tree stems and branches, additional layers of non-tree vegetation, extensive root systems, deep, loose soils, and fluffy leaf litter. All of these features allow a large amount of water to infiltrate the soil and be absorbed – like a super-capacity sponge. A rainstorm can drop millions of tons of water on the land. When forest vegetation is present, leaves, stems, and downed woody debris intercept, absorb, and reduce the impact of both falling and running water. This allows the water to evaporate from plant surfaces, soak into the soil and its many pore spaces (animal burrows, decayed-root tunnels, or soil voids), or run off in a gradual manner. Soils in healthy forests are particularly porous and absorbent and can hold staggering volumes of water.

Much of the water absorbed by forest soils is drawn up by plant roots and transpired, moving back to the atmosphere as water vapor. During the growing season this "evapotranspiration" reduces the amount of water in the soil; in some forests it removes as much as 70 percent of the incoming precipitation. This, in turn, renews the soil's ability to absorb even more water.

Consequently – and luckily for us – streamflow responses in forested watersheds tend to be slow and small, and they occur predominantly via subsurface runoff. Indeed, forested watersheds yield lower peak flows and smaller volumes of runoff over a longer time than do nonforested land covers. Accordingly, flood damage in forested areas – and in areas downstream of them – is the smallest among all surface conditions. Forests also minimize soil erosion and landslides, and improve stream channel stability and water quality.

There are limits to the flood-mitigating effects of forests. When soils are fully saturated, any additional rainfall will run off the land, whether it is forested or not. Thus, forests can reduce peak flows from storms of short duration and lower intensity. They can downright prevent flooding that would otherwise occur in lesser storms and smaller watersheds particularly sensitive to rain events. They can minimize the damage from large storms. But they cannot prevent the major floods produced by storms of high intensity and long duration.

Clearly, our needs for abundant clean water and healthy forests are important issues for the 21st century, not only because forests provide critical raw materials for people and industries, but also because they are key factors in the normal functioning of the environment. Water and forests are two of the most profound natural forces on the planet, and they are closely linked. Without water, there are no forests. And without forests we are much more vulnerable to erosion and flooding.

Michael Snyder is Commissioner of the Vermont Department of Forests, Parks, and Recreation. This article is reprinted with the permission of Northern Woodlands *magazine. A not-for-profit organization,* Northern Woodlands *seeks to advance a culture of forest stewardship in the northeast and to increase understanding of and appreciation for the natural wonders, economic productivity and ecological integrity of the region's forests.*

The Role of the Watershed Group

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about how to plan for and protect against future flood damage by incorporating new language in town plans, zoning bylaws, and floodplain bylaws. We hope that the resulting municipal plans and bylaws may be used as models by other watershed communities to improve long-term flood resiliency.

- *Replicating the Hurricane Flats Farm project* – Based on widespread interest from local, state, and federal partners about the streambank stabilization project at Hurricane Flats Farm in South Royalton, the WRP is working with technical partners and the long-term recovery committee for the Upper Valley area to examine the transferability of the alternative approach to erosion control at several sites throughout the Upper Valley. We hope that the resulting projects will test the model for addressing bank erosion in a more flood resilient, habitat-friendly manner.

- *Bethel Phase 2 stream geomorphic assessment* – The town of Bethel was among the hardest hit during flooding from Tropical Storm Irene with an estimated $9 million in public infrastructure damage alone. Several months after Irene, a group of residents started meeting to educate themselves and other interested community members about how rivers work and about opportunities to improve river health in Bethel. One outcome of this grassroots effort is an upcoming Phase 2 stream geomorphic assessment of over 35 miles of the White River and its major tributaries within the town boundaries. To complete the assessment, the WRP will hire a trained consultant to walk the length of each river and stream in Bethel in order to collect data about the current physical condition of the river corridor, which includes the river itself plus the riverbanks and the adjacent floodplain area. Once data collection is complete, the consultant will analyze the data to identify opportunities to implement on-the-ground projects that improve water quality, habitat, and flood resiliency within the river corridor area. Given the level of local interest in the project, the WRP anticipates that project implementation will be both efficient and comprehensive.

In the immediate aftermath of a major flood, Vermont's watershed groups are uniquely situated to play a variety of important roles to help individuals and communities recover quickly and efficiently. By utilizing diverse skills sets and tapping into strong working relationships – and collaborating with other local, state, and regional groups doing the same – our collective efforts can begin the process of healing Vermont's rivers to their picture-perfect legacies.

Mary Russ is Executive Director of the White River Partnership.

Roads, Bridges, Rivers and Streams: Building a Better Relationship

By Scott Rogers and Gina Campoli

Ever since Tropical Storm Irene hit, VTrans' engineers, maintenance technicians and planners have been on a first name basis with Agency of Natural Resources (ANR) river scientists, water quality experts and aquatic biologists. This is a good thing.

In short, VTrans has become more aware of river science and has begun to integrate it into our operations so that our infrastructure and rivers can live in better harmony.

We have learned several things from ANR. We have learned not take the "bull in the china shop" approach when rivers move and shift. We used to believe that rivers, if they threatened infrastructure, needed to be "put back" in place if they changed direction or jumped their banks. We have grown to understand that channeling, berming and other attempts to control river flow must be done carefully with an awareness of the consequences, both upstream and downstream. If we don't, we find ourselves making more frequent and costly repairs to infrastructure. We have adopted some different approaches to assure our infrastructure and our rivers can live in better harmony.

Channeling, berming and other attempts to control river flow must be done carefully with an awareness of the consequences, both upstream and downstream.

We have learned that bigger culverts and bridge openings have significant benefits. VTrans' work is based on the increasing knowledge that culverts and bridges with openings large enough to accommodate hydraulic, geomorphic, and ecological processes – not just water flow itself – are good, long term investments for the state. We have learned that these bigger structures are flood resilient and can withstand disastrous flooding and appear to be less susceptible to erosion and the scouring of bridge piers and abutments, thus lessening maintenance headaches and costs. And these better culverts have the added benefit of improving fish habitat, ANR biologists point out. When water flows through culverts it is constrained. If culverts are perched high above the streambed, fish can be cut off from up and downstream feeding, nesting and other areas critical to their survival. In various parts of the state – in Readsboro, Middlesex, Buels Gore and Jay to name a few locations – VTrans has replaced undersized pipe culverts with natural bottom box arches. Follow-up research by both agencies has shown promising results, with fish numbers increasing at the same time flood damage risks are being minimized.

Because of our increased communications with ANR, we also now know that, at times, raising the bed of the river in one place, and allowing it to regain access to its flood plain in another spot can be a far more cost effective technique to both protect the river and the roadway. Vermonters get a healthier river system and avoid roadway damage, both of which save taxpayer dollars.

And we are learning that there are places on the state roadway system that see repeat damage from flood events. Prior to our inter-agency partnership, maintenance workers would spend time and energy making repairs in a "traditional" fashion, without fully understanding why the river was behaving in the way that it was or that there were alternative methods that would take into account the shifts and changes of a river. For instance, VTrans would put stone where culverts and roadways were eroding, only to see this stone disappear downstream in the next intense rainstorm.

This scientific approach is now being spread throughout VTrans. ANR river engineers are providing training courses for VTrans equipment operators, design engineers and others so that all VTrans staff understand how to best work in and adjacent to the state's waterways. District maintenance workers will now get a hands-on river science learning experience including field work at the water's edge, observing river dynamics and developing options to protect adjacent infrastructure.

There are other examples of a tighter VTrans/ANR partnership. Recently, the legislature asked VTrans, guided by ANR water quality experts, to work more actively with municipalities to address roadway water quality by adding water quality practices to the state's recommended town road and bridge standards. (ANR has identified runoff from the state's thousands of miles of gravel roads as one of the greatest threats to the quality of the state's waterways.) Directing stormwater to U-shaped rock lined ditches on steep roadway slopes, installing erosion control matting when exposing soils, and leveling gravel roads more regularly to spread rather than channel water on the roadway surface are some of the practices included in the standards. Not only do these practices help water quality, they also are smart preventive maintenance techniques to avoid erosion and roadway undermining associated with heavy rainstorms.

Most Vermonters are aware that more intense and frequent storms brought on by climate change have been occurring in our state, including increasing localized wind and rain events toppling trees and washing out roads. VTrans is adapting the state's transportation networks in order to minimize travel disruptions in light of these more frequent and severe events.

The agency is undertaking a comprehensive study to determine vulnerability of the many miles of state's roadway adjacent to rivers and the future risk this vulnerability presents to the system. Once we identify the risk, the state can then begin the long term planning necessary to mitigate these risks. Mitigation measures may include moving roadways away from harm's way, finding alternative routes, and working with land conservation agencies and others to protect floodplains and wetlands that absorb the rivers' flood potential in locations where roadways are threatened.

Climate scientists are telling us the past is no longer an indicator of the conditions of tomorrow. VTrans is committed to resilient transportation infrastructure and strives to be an environmental steward in close collaboration with ANR long into the future. There are big dividends for infrastructure, taxpayers and the environment, and they are already being realized today.

Scott Rogers, P.E., is Director of Operations at VTrans. Gina Campoli is Environmental Policy Manager at VTrans.

Vermont Rivers and Roads Training Program

Both the Vermont Legislature and the state's Agency of Transportation have recognized the need for an increased ability to design, construct and maintain transportation infrastructure alongside Vermont's rivers and streams that is less vulnerable to flood damages. Historically, the Vermont Agency of Natural Resources River Management engineers have provided technical assistance to transportation projects alongside rivers and streams but engineer staffing limitations and pressures to re-open damaged roads following floods can result in the construction of transportation projects without the benefit of technical assistance from a River Management engineer. This can, and has, resulted in instances of increased river instability, heightened risk of future river related damages to transportation infrastructure and the need to reconstruct transportation projects.

To address the need for increased technical ability, the Vermont Agency of Natural Resources, with support from the Vermont Legislature and in cooperation with the Vermont Agency of Transportation (VTrans), has developed The Rivers and Roads Training Program. The program is intended for transportation professionals including: state, municipal and private sector planners, engineers and construction and maintenance workers. The training is organized into three tiers. Tier One provides a general awareness and understanding of river processes and is available online at http://wsmd.vt.gov/rivers/roadstraining/. Tier Two is a classroom and field training that focuses on accommodating river stability and minimizing impacts to aquatic habitat during emergency flood response and recovery operations. Tier Three focuses on the use of the ANR Standards for Stream Alterations to select, design and oversee construction of transportation projects along rivers and streams in both emergency and non-emergency situations.

Irene's Effects:

Waterbury Reflects and Looks Ahead

BY REBECCA ELLIS AND TOM STEVENS

Eighty-four years passed between the flood of 1927 and Tropical Storm Irene in 2011, and while it was impossible to predict the timing and the strength of those storms, we believe we can review their effects in the context of our community's response. This experience highlights the need for education and preparation as we judge our readiness and resilience, especially as it relates to a thickly settled downtown region.

Like many historic Vermont villages, Waterbury is located in the floodplain of the Winooski River. Over time, the downtown has expanded, with development occurring in many cases increasingly closer to the river.

Tropical Storm Irene reminded us of the long dormant dilemma of how to promote compact downtown physical and economic development and maintain historic buildings when those areas are located in a floodplain and subject to risk of inundation of floodwaters. Irene also forced us to consider how we can address the limitations of local governments while at the same time looking to potential strategies that may mitigate damage in the future.

We do not have all the answers, but as Waterbury's state representatives in the legislature, we can provide some insight into how our 250 year-old community responded under real-life circumstances.

Waterbury at a Glance

The Village of Waterbury is located adjacent to a great amount of flood plain. Up until 2011, the existing flood plain successfully captured, with a few exceptions, excess water from the Winooski River. The experience in Waterbury is far different than that of other municipalities. While many communities wrestle with threats from the erosion of rivers, Waterbury's damages have been primarily from inundation of flood waters.

The Village of Waterbury represents the typical downtown settlement pattern in Vermont. It is the economic center of Waterbury as well as smaller neighboring towns and has an evolving mix of residential and commercial businesses, including manufacturers such as Green Mountain Coffee Roasters and Ben & Jerry's. Zoning in the village reflects the many different facets and needs of the every day and economic life.

The Village of Waterbury has evolved over time from a largely residential area to one with a greater commercial mix. Its economy has become reliant on the presence of the large number of workers who commute into the downtown. The flooding due to Tropical Storm Irene served to shine a light on the strengths and weaknesses of past development, and gave us an opportunity to undertake deep discussions and extensive planning for potential events due to extreme weather and climate change.

Discussions, Solutions, Post-Flood

After the flood waters of Tropical Storm Irene subsided, the community began discussing recovery and redevelopment. Waterbury officials, as well as legislators and other government officials, often found themselves arguing with regulators, insurers and others over what, in the end, was the most basic of needs. How will we address the real world needs of a community and municipality — both human and economic — if we are being told our needs do not fit neatly within the box defined by theory, goals and, perhaps, regulation? Where does the need to rebuild and return to "normal" conflict with the need to build smartly and to invest in areas that are not threatened by future events? And finally, how many different points of view can converge on a municipality with few resources and less capacity with an expectation that all views will be integrated smoothly?

Our experience in Waterbury has taught us that the word "resilience" is multi-faceted, and that "response" and "recovery" will require continued education and consultation with experienced individuals and agencies. Resilience may mean looking at a palette of options, from reducing the flood elevation level through flood plain modifications, to rebuilding using the most up-to-date floodproofing techniques. Response means knowing our local inventory of resources and assets, and being prepared to connect immediately with governmental agencies beyond our municipality in order to communicate more clearly our needs in the face of chaos. And recovery means bringing our disparate experiences together in order to contend with the massive bureaucracy – both state and federal – necessary to bring resources to the community.

Local officials can help the community develop a vision that encompasses everything from the mundane — "How can we improve our local zoning and environmental laws to lessen the impact in the future"— to the exciting — "Is it possible to redevelop in a way that will help us achieve resiliency and sustainability?" It is this vision, articulated by the community for the community, that lends a community its lifeline and hope during its darkest hours. Each community must discuss and discover what kind of community it wants to be in the aftermath of a crisis like Tropical Storm Irene. Elected officials, as the conduits through which this conversation can happen, are key to this process.

The authors are members of the Vermont House of Representatives, representing Waterbury.

Planning Tools for Rivers

BY KATE MCCARTHY

River corridors are part of Vermont's distinctive natural landscape of mountains and hills, sparkling ponds, forests, and other natural areas. But the "landscape" in which river corridors exist is made up of more than just nature. Our landscape is the sum of everything we do on the land: the natural features, but also the buildings, roads, utility lines, and other development that, together, create human settlement patterns.

Natural features and human settlement patterns are intertwined, and the location of one can affect the function of the other – sometimes positively, sometimes negatively. In Vermont, nowhere is this more true than in river corridors.

As we saw during the floods of 2011, some of the most dramatic and heartbreaking damage happened when human settlement conflicted with the river corridor, as homes and businesses were lost to both flooding and erosion. As we think about the future health, safety, and financial solvency of our communities, it is clear that we cannot ignore the way that our settlement patterns do – or don't – contribute to flood resilience. This is especially important since, with climate change, we expect storms to be both more frequent and more severe, making it all the more important to avoid these conflicts.

But how do we evaluate and strike that balance? Many existing villages, downtowns, and historic homes are located in river corridor areas, and many people own riverside property that they may want to develop. At the same time, the laws of physics are unforgiving, and mean that a river will be a river, changing, meandering, and rushing as required to do its job: moving sediment and water.

Good Choices Now Equal Less Risk Later

Though we can't control rivers, there is something we do have control over, if we choose: our future land use patterns. The choices we make today about our land use – where we allow new homes, businesses, roads, and other forms of development and redevelopment – will affect river corridor health, which in turn affects public safety, the amount of land and property lost from future floods, and the economic burden on communities from flood events.

Communities can take steps to plan for this.Because rivers have minds of their own, planning for a river is actually probably better thought of as planning with the river – that is, incorporating into the planning process an understanding of river processes. Of course, this task requires considering land use. In Vermont land use planning and regulation take place at the local level. Municipalities can choose (but are not required)

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The True Cost of Floods and How Vermont Can Limit Its Vulnerability

By Barry Cahoon

It's socially and politically tempting to underestimate or downplay the true extent of our physical and economic vulnerability to catastrophic flood damage and loss. After all, if we fully recognized the actual level of flood risk and just how hazardous it is for us individually and collectively, we might have to seriously consider changing our ways. It's human nature to be fearful of and resistant to change.

Vermont, in 2011, experienced three storm events: one each in April, May, and then Tropical Storm Irene in August. Each resulted in state and federal disaster declarations. In strict monetary terms, public expenditures in response to Tropical Storm Irene alone is estimated at $733 million. This estimate includes federal, state, local, insured, and private expenditures.

Many consider the 2011 floods, especially Tropical Storm Irene, to represent an extremely rare event. But upon examination of Vermont's history of flooding, it becomes disturbingly obvious that catastrophic, devastating floods occur frequently in Vermont. Emergency and natural resource agencies know that Tropical Storm Irene was not an anomaly.

Quantifiable monetary costs, however, do not represent the full costs of floods. Many immeasurable losses degrade the social, economic, and ecological values rivers provide Vermont's communities.

In fact, Irene was the sixth large-scale flood, with a statistically derived return frequency of once every 100 years, to devastate the southern 2/3 of Vermont in 84 years. This represents an actual frequency of a storm like Irene once every 14 years. From 1973 through 2011, Vermont experienced 25 catastrophic floods, each having nearly equaled, equaled, or exceeded the intensity of damages associated with Tropical Storm Irene, varying only in geographic location and scale.

Quantifiable monetary costs, however, do not represent the full costs of floods. Many immeasurable losses degrade the social, economic, and ecological values rivers provide Vermont's communities. Studies have attempted to quantify the myriad ecosystem services that natural systems, including rivers, provide for societal well-being. Rather than attempt to translate these to the monetary tally sheet, suffice it to say that individual and community vulnerability to flood loss functionally converts an infinitely valuable, self-sustaining natural resource to a terrifying, uncontrollable monster that can rip apart our homes, our communities, and threaten our very sense of security.

A Flood is Never a Disaster Until We Get in the Way

It's also a tendency of human nature to conclude the cause of conflict, loss, or worse, a disaster, is not our fault but rather the responsibility of some external factor(s). Unrealistic expectations dominate public perspectives of individual and community relationships with fluvial systems. We deny or ignore risk. We believe "the river has always been over there, which is where it belongs." We hold blind faith that flood recovery can restore pre-flood conditions (safety) without re-creating or exacerbating risk. We rationalize that a devastating flood "won't happen again in my lifetime," and we incorrectly

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to create a municipal plan, which requires several chapters, including one on natural resources.

In addition to summarizing a community's current conditions and issues, the plan lays out the community's vision for its future. The "visioning" process – which includes examining community values, needs, and goals – is an important first step for a community that's considering how to manage development in order to live with its rivers.

The planning process provides an important venue for a community conversation that considers property rights as well as considering the upstream effects, downstream effects, and long-term costs of the community's development choices. Using the planning process to tackle river corridor issues can help to build public understanding about the importance of river corridor management, as well as develop approaches that will both keep river corridors healthy and meet community goals. The planning process can also minimize damage, loss, and expenditure from unhealthy corridors/flood events.

In addition to laying out a vision, a municipal plan sets the stage for action (after all, a plan without action is just a doorstop). All implementation actions – whether regulatory, like zoning or subdivision regulations, or non-regulatory, like establishing a conservation commission or conducting a stream geomorphic assessment – flow from the goals, policies, and actions laid out by the community in its town plan.

What kinds of actions might help a community live in harmony with its rivers? There are a wide variety of choices.

Planning for the Corridor

One place to start is with a river corridor plan, which looks at the whole river corridor, rather than just individual parcels, to plan comprehensively for river health. This planning process involves identifying key sections of the corridor that are necessary for river health and flood hazard prevention, and then taking actions such as acquiring or putting easements on them. River corridor management planning is an even more detailed process that can also involve identifying key infrastructure, like culverts, and planning upgrades that will help improve the resilience of the river corridor.

A river corridor plan can then inform other actions (though it's not a prerequisite – check with the Department of Environmental Conservation for other resources.) On the non-regulatory side, there may be parcels of land that, if left undeveloped, can promote flood resilience. In Bennington, for example, the town worked with the Vermont Department of Environmental Conservation to restore a key floodplain near the village in order to minimize damage from future floods. Lands important for flood resilience can also be purchased outright or protected with easements with the help of private landowners and a land trust.

Towns can choose regulatory approaches as well, such as prohibiting development in the floodplain, an approach taken by the town of Waitsfield for example. Another approach is to develop a River Corridor Protection Area, a supplemental zoning district that includes the areas most vulnerable to erosion over time. Within this zone development can be limited or required to be built in a certain way so that the river still has room to meander.

Flood hazard area bylaws or ordinances are another approach. These enable property owners to participate in the National Flood Insurance Program (NFIP). While these bylaws help ensure that development in these areas is built to certain standards and doesn't reduce the function of the floodplain, they can actually serve to encourage development in dangerous places. What's more, the NFIP maps only cover some of areas subject to inundation (flooding), and not necessarily of the areas subject to erosion, which is also a threat in Vermont.

As we work to care for our river corridors and our built environment, planning and implementing solutions now is a strategic way to avoid cost, loss, and destruction later. An ounce of prevention is worth a pound of cure – especially at a time in history when we are running low on local and federal funds to deal with the damage that results from human/river conflicts.

At the end of the day, the best – if not most popular – choice may be to prohibit development in river corridors. These areas only become "hazardous" when development is located in the path of ever-changing stream channels, and we need to acknowledge that where we locate development is our choice. After all, without development, the changes in a stream's bed and banks are simply a natural part of its lifecycle, not a hazard.

Will change be easy? It rarely is, but as communities and individuals, we must challenge ourselves to ask – and answer – the difficult questions about the long-term costs and benefits of our choices about settlement patterns.

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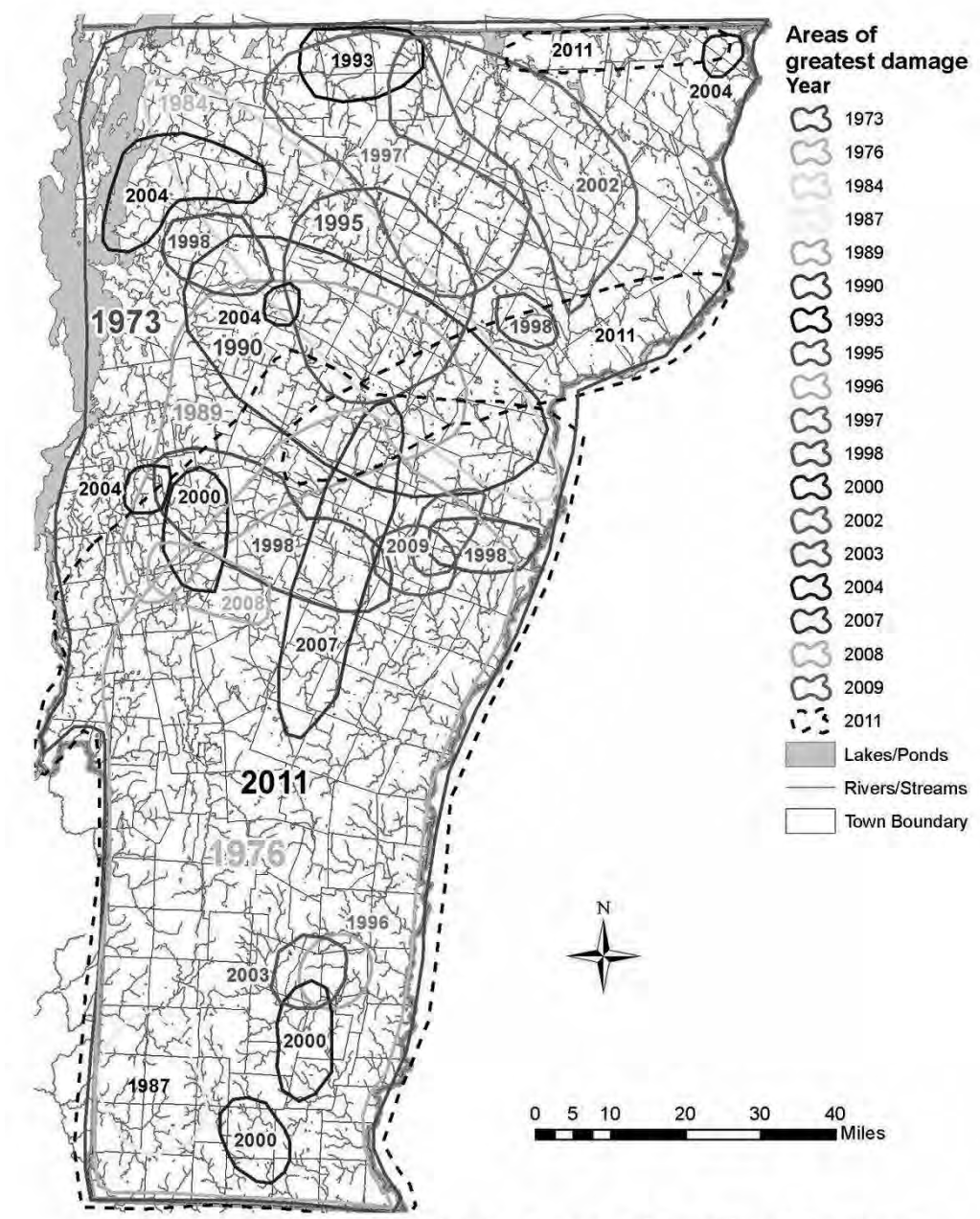
blame some external factor (like not enough river gravel mining) for the loss suffered. But in truth, our vulnerability results directly from our high risk investments in infrastructure and land use that too often tragically conflict with the dynamic nature of rivers. We also sometimes unwittingly increase the risk to ourselves by taking action we think – wrongly – will reduce our exposure.

Many public infrastructure and private property encroachments into historic flow areas of Vermont's rivers depend on maintaining a narrow, channelized, incised and confined stream with little or no flood plain or overbank access. This can result in oftentimes irreconcilable conflict, for which Vermonters may pay the consequences forever. In other words, the choices we made in the past about where to build influence our ability to prevent impacts today. This is the reality of the human condition: we made the best choices we knew then, before we knew better. Now, we have to work around this reality.

This societal relationship with rivers is nothing new. With impunity and without regard for the consequences, we've been usurping all the space in the valley or along the river corridor, building along rivers, and confining rivers with stone. We've done this in deference to our economic and social systems, ever since the time we evolved from hunter-gatherers to an agrarian society. This deeply flawed relationship with rivers, developed through thousands of human generations, seems irrevocably embedded in our collective psyche. But for nearly as long a period of time, rivers, when energized by large storms, have emphatically reclaimed the space we ignorantly took away and, dripping with hubris, figured we need not share.

Unfortunately and distressingly, the most prevalent opportunity to annex even more of the river's space, with intent to confine and constrain rivers to an ever-decreasing proportion of their historic flowage, occurs during flood recovery operations. We dig deeper, incorrectly thinking that will somehow protect us (we know that it doesn't). But, paradoxically, the greatest opportunity to restore a sustainable community relationship with rivers also arises in the post-flood context.



Selected flood disasters - Areas of greatest damage

River Corridor Protection to Limit or Reduce Vermont's Flood Vulnerability

Redefining individual, community and institutional relationships with rivers is possible. A management concept founded on the principle of "dynamic equilibrium" as it relates to the physical nature of fluvial systems makes this achievable.

We are embracing and implementing at all governmental and individual levels a policy of sustaining and restoring dynamic equilibrium in rivers. We are doing this despite the predominance of irreconcilable conflicts, the lack of supportive federal and state policies, and social resistance to acknowledging the extent, magnitude and source of fluvial conflicts. This approach presents tremendous opportunities not only to accept current realities but also to compel better decisions for the future.

Managing rivers for dynamic equilibrium is composed of two basic elements: First, free rivers from human constraints such as encroachments by buildings; and second, avoid creating new encroachments and confinements, almost without exception.

Through collaboration of state agencies and the Vermont Legislature, a number of initiatives have been enacted. Of greatest promise and potential is the community protection of river corridors from further encroachment. Vermont has established financial incentives for local governments to adopt model river corridor protection ordinances that prohibit new development in defined river corridors. A companion program that funds and acquires river corridor land use easements preserves forever the land required for rivers to regain and sustain dynamic equilibrium.

River corridor protection complements the Flood Hazard Area regulations that many municipalities have enacted through participation in the National Flood Insurance Program (NFIP). Community safety from flood hazards is enhanced because the NFIP regulations only address flood inundation and do not recognize the fluvial erosion, avulsion, sedimentation, and debris hazards commonly experienced in Vermont.

Monetarily, just how much potential do these river corridor protection programs represent? How much will flood losses and recovery costs be reduced? How much will rivers benefit intrinsically?

It's reasonable to expect that widespread adoption of model river corridor protection ordinances will level off the continually escalating flood disaster costs driven by continued encroachment. For instance, without protecting corridors from new encroachments, the $15 million spent since 2011 on buy-outs of at-risk structures would be, within a few years, more than offset by new unwise, vulnerable, and unregulated investments.

Local ordinances enacted in conjunction with strategic acquisition of river corridor easements preserve the space for confined, threatening, and unstable rivers to re-establish their dynamic equilibrium. In this scenario, vulnerability on a community scale is significantly reduced, disaster costs trend downward, and rivers are restored to the invaluable, sustainable natural resource that is their nature of being. Everyone wins.

Vermont's rivers will recover and heal from these large storms much sooner than Vermont's communities, because the forces of nature provide an infinite and never-ending supply of energy constantly driving the recovery of fluvial systems toward equilibrium. Vermont's communities, on the other hand, largely remain just as vulnerable, oftentimes even more so, than prior to Tropical Storm Irene. Only limited resources, funding, and options exist to resolve the many immediate and irreconcilable conflicts. River corridor restoration and protection contributes to healing the rivers and protecting our homes.

The extent to which Vermont's rivers can sustain and recover dynamic equilibrium is absolutely dependent upon people and communities choosing to be in equilibrium with rivers. It's up to us to give back to rivers, preserving the space they need and restoring them to the infinitely valuable, sustainable natural systems they should be. People and rivers can, and must, share Vermont.

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To learn more about municipal river corridor protection and river corridor easements, visit: http://www.vtwaterquality.org/rivers/htm/rv_restoration.htm

Conservation and Flood Resiliency

By Liz Thompson

When Rene Boissoneault conserved his land on the Lamoille River in 2010, he was not thinking about flood resiliency. He was thinking about protecting his farmland for future generations, and while he was at it, he protected 15 acres of beautiful, healthy, floodplain forest. Rene is not alone.

Other landowners, further upstream on the Lamoille, have also protected their farmland through conservation easements. These and many other conserved lands, contribute significantly to a resilient landscape in four important ways: by keeping new development out of harm's way; by allowing rivers to access their floodplains; by protecting water quality; and by protecting the natural vegetation of floodplain forests and wetlands, which have a greater ability to absorb and slow floodwaters than open land where water can quickly flow in sheets across the surface of the ground.

On the Third Branch of the White River in Bethel, conserved lands upstream of Bethel Village, in an area where the floodplain is broad, the river meanders widely, and natural floodplain forests line the valley like a string of pearls. These lands fared better in Irene than the more constrained and more developed land downstream, where damage was severe. Protecting floodplain forests through conservation easements also enhances the biological diversity of our landscape. Floodplain forests are a rare natural community type in Vermont, having been largely converted to agricultural use because of the natural fertility and ease of tilling in alluvial soils. Many species of birds and mammals, as well as amphibians, reptiles, and insects, rely on the remaining floodplain forests and associated riparian habitats. Several rare plants are restricted to floodplain forests.

A conservation easement is a powerful tool that a landowner can choose to employ to protect a variety of values for future generations. The Vermont Land Trust and other conservation organizations together hold conservation easements on more than 500,000 acres in Vermont. Most of these conserved parcels have some connection to rivers and streams, whether in the headwaters or in the broad floodplains of the larger rivers. In all cases, development, if allowed at all, is restricted to small, specific areas on the land. In the case of forested lands, clear-cutting or conversion to open land is not permitted. By these basic protections, rivers, streams, and floodplains are protected and contribute to a diverse and resilient landscape.

In a few cases, added protections are offered through a partnership with the Department of Environmental Conservation, adding river corridor protections to the mix. This means that the landowner cedes the right to manage the river to the Department, while retaining the right to farm as long as the land is available to farm.

The Agency of Natural Resources is working to increase flood resiliency in Vermont, and, in partnership with conservation organizations, to develop strategies for using land conservation toward that end.

Land conservation seems to be a no-brainer as a way to create a more resilient landscape. How can we go wrong by protecting the natural, agricultural, and forest values of Vermont's unique and verdant landscape?

Liz Thompson is Director of Conservation Science at the Vermont Land Trust.

Photo courtesy Vermont Land Trust.

Floodplain forests are a rare natural community in Vermont. Inset: Gray's sedge is a rare plant that grows almost exclusively in floodplain forests.

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So, What Now?

We hope you have enjoyed this publication, and learned more about rivers. The next step is to take your knowledge and put it to use! Below is a list of things you can do to help ensure that Vermont's rivers are well managed to increase flood resilience, protect public safety, public and private property, and promote clean water and healthy river habitat.

Join VNRC. VNRC is a membership organization that relies on Vermonters like you for support – not just financial support but grassroots support on the issues that matter to you. If you are inclined to write letters to the editor, call lawmakers, or work in your local community, we can help you get started. Dues are just $35 a year and you can join right now by going to vnrc.org and clicking the red button at the top of the page that says "Donate."

Join a local board or commission in your community. Towns across Vermont are in need of committed and passionate people for their boards and commissions. Consider joining your town's conservation commission or planning commission, or running for selectboard or city council. You can also join the umbrella organization that serves as a central point of contact and support for local conservation commissions, the Association of Vermont Conservation Commissions, or AVCC. To learn more, email Jake Brown, AVCC chair, at jbrown@vnrc.org

Join your local watershed group. Many of Vermont's rivers have watershed groups that focus conservation efforts in particular rivers. Friends of the Winooski River (publishers of an informative guide called *Living in Harmony with Streams*), White River Partnership, Lewis Creek Association and the Friends of the Mad River are a few examples.

Support land conservation in your watershed. Working with landowners to protect riparian lands, conserve river corridors and protect forested headwater areas can increase flood resilience, maintain water quality and achieve other conservation benefits. The Vermont River Conservancy, Vermont Land Trust and local and regional land trusts can assist with conservation efforts.