Human Activities as a Source of Pollutants and Water Quality Problems

1. Land Conversion: loss of forest, wetland, and agricultural lands

The health of the rivers, lakes, and wetlands can be directly related to the type of landcover and associated land use in their watersheds. Pristine waters are associated with mainly undisturbed forested watersheds. The level of impact on water quality becomes higher as land uses intensify through the spectrum of agriculture, timber harvesting, housing, industry, and roads.

Land conversion of Vermont farms and forests from 1982 to 1997 reveals an increase of 74,800 acres of land developed for building sites (Bolduc, et al., 2008). Of these, an estimated 31%, or 23,450 acres, came from agricultural land, whereas an estimated 68%, or nearly 51,000 acres, came from forest land. Estimates from the Natural Resource Conservation Service's Natural Resource Inventory reveal that developed land in Vermont, not including land in rural transportation uses, increased from 158,900 acres in 1982 to about 254,200 acres by 2003, a significant increase of 60% over two decades." (2010 Vermont Forest Resources Plan, Division of Forests).

Conversion of forested lands

Forest is the dominant land cover in Vermont with approximately 76% (4.6 million acres) of the state in forest cover. Most of Vermont's forestland is privately owned (3.8 million acres). Forests protect water quality by slowing runoff, stabilizing soils and filtering pollutants, see Figure 1. Conversion of forest land to other uses interrupts these natural processes and increases the potential for water quality impairment.

1). Intercept rainfall, protect soils, provide shade.

2). Transpiration, nutrient storage, trap air pollutants.

3). Filter sediment and other chemicals.

4). Infiltrate, water and nutrient storage

5). Biological removal of nutrients and pollutants.

Figure 1. Forest Watershed Functions (adapted from DFPR 2009 http://www.vtfpr.org/watershed/waterfunction.cfm.)

Degradation of wetland and riparian function

Wetlands and naturally-vegetated riparian areas protect water quality by efficiently trapping, accumulating, and storing organic, nutrient-rich suspended sediment from land disturbance.

Since the time of European colonization the loss of wetland and riparian function in Vermont has been significant. For example, various estimates place current wetland acreage in Vermont between 220,000 (USFWS National Wetland Inventory) and 600,000 (NRCS National Resource Inventory) acres. The USFWS estimates that 35% of the state’s original wetland acreage has been lost to agricultural development and other uses. This does not include other wetlands that have been degraded due to the loss of some functions such as sediment trapping or nutrient retention. While wetland losses have slowed in recent years, there is still significant incremental loss of wetlands and their functions throughout the state. Riparian areas are also subject to intense development or land use pressure including such activities as agricultural, transportation, and seasonal homes.

Conversion of agricultural to developed lands

A study completed by researchers at the University of Vermont identified developed lands as the predominant contributor of phosphorus loads in the Lake Champlain basin, despite the fact that it is not the predominant land-use in the basin as a whole.[1] On an acre for acre basis, load contributions from developed lands are consistently higher than agricultural lands. Specifically, the study estimated that on average, developed land generally contributes about four times as much phosphorus per acre as agricultural land.

The higher phosphorus export rate from developed land is significant because the same study also found an overall increase in the conversion of agricultural land to developed land in the Lake Champlain basin. A separate analysis of Natural Resource Inventory (NRI) data, by NRCS staff, strongly supports this trend in land use change. NRI data show that, statewide, developed land increased by about 31% from 1982-1997. Developed land increased by about 34% basin-wide in the Lake Champlain basin during that same time period. Based on preliminary analysis using unofficial 2003 data, it appears that developed land in Vermont increased by more than 40% from 1982-2003.[2]

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[1] "Updating the Lake Champlain Basin Land Use Data to Improve Prediction of Phosphorus Loading." Report to Lake Champlain Basin Program. (May 31, 2007). http://www.lcbp.org/publication_detail.aspx?id=211

[2] Personal Communication via email with Ray Godfrey (8/6/2007). Email was accompanied by data tables supporting this statement.

Summary of Agency's Key Strategies that Address Activity

The agency provides assistance to landowners to encourage them to maintain forested land, and protect wetlands and forested buffers including

- Technical assistance through the county foresters and a mix of programs for managing a productive forests for silviculture.
- Incentives to keep working forested lands in production and forested as well as riparian buffers and wetlands intact (Use Value Appraisal Program).
- Encourage restoration of wetlands through the NRCS Wetland Reserve Program
- Encourage landuse planning that reduces amount of land developed per unit of housing/commercial development
- Land acquisition
- Educate the public on the value of forestland, wetlands and buffers.

See also sections on Encroachment within wetland buffers, lake shorelines, and river corridors

For more in-depth information follow the links below:

- Toolbox section for activity
- Stressor factsheets including:




2. Runoff from Developed Lands

Stormwater runoff occurs when precipitation "runs off" impervious surfaces (rooftops, parking lots, drives ways, etc.,) rather than

infiltrating into the soil. As it travels along the land surface, the runoff increases in velocity and volume, picking up a wide variety of pollutants such as sediment, pathogens, and debris. These pollutants are delivered either directly or indirectly to Vermont's rivers, lakes and ponds.

In highly developed areas, such as urban centers, these pollutant loads can be relatively high. Lawn fertilizer, uncollected pet waste, road sand for winter safety, many detergents and lawn litter all contain phosphorus. In an undisturbed setting, much of this phosphorus is broken down by natural processes. In an urban setting, these processes may be disrupted or nonexistent. Instead of nutrient breakdown and uptake by plants or entrainment in soils, many pollutnats are simply carried away to surface waters. To put it simply, a leaf that falls onto a street is more likely to be carried away by swiftly moving stormwater flows in the gutter than a leaf that falls in the forest. Overall, studies have shown that lawns and streets contribute the most to total and dissolved phosphorous loads in residential areas. A USGS study, in cooperation with the City of Madison and the Wisconsin Department of Natural Resources, showed that lawns and streets combined contribute about 80 percent of the total and dissolved phosphorus in runoff from the residential areas studied, with lawns contributing more than streets.(3)

Changes in stream hydrology are also common due to development. Much of urban development involves the construction of buildings, roadways and parking – all of which create impervious surface, that both reduce infiltration and can speed the delivery and amount of stormwater runoff to local receiving waters. These increases in in volume and rate can, in turn, increase rates of erosion and decrease stream stability. As a result, most developed areas employ infrastructure that enhances drainage to protect roads and other structures from flooding, resulting in even higher discharge rates. The increased volume and discharge rates of stormwater runoff from developed land have been linked to channel enlargement processes and severe bank failures. For stream systems that may already be stressed by riparian encroachments and channelization –

the additional energy from stormwater runoff can contribute heavily to in-stream erosion. Studies suggest that Vermont streams channels will begin to erode and enlarge at watershed impervious cover values as low as 3%. Many Vermont streams are highly sensitive to hydrologic modification due to their geologic history and landscape setting.

High percentages of impervious can also reduce ground water levels due to a decrease in infiltration capacity. As a result, streams that depend on ground water to maintain a base flow during dry months can experience periods of extremely low or no flow. This can have devastating effects on aquatic habitat.

Construction sites

Developed lands contribute pollutants during both the construction and post construction phases. The construction phase increases loading via several mechanisms, including:

- The removal of vegetation during the construction phase, which increases the chance for erosion and mobilization of particulate-bound phosphorus during runoff events. Both runoff rates and volume have been shown to increase during the construction phase,(4) while the installation of drainage measures typical of developed areas provide quicker delivery rates. The availability of sediment to the erosive forces of stormwater runoff events and the increase of runoff itself result in the increased potential for loading of sediment-bound phosphorus to nearby surface waters. Because of the efficiency of the delivery system, 50% to 100% of the soil eroded from a construction site can be delivered to a stream. The reclamation phase of most construction projects involve amending the soil with fertilizers (sometimes without soil tests) to achieve grass growth for project closeout.

Industrial sites

Certain industries, by the virtue of their business (e.g., fertilizer manufacturers, paper manufacturers), import nutrients for use in production and therefore run the risk of discharging nutrients in excess of that which might be expected from undeveloped lands. Many industries also require large areas of impervious surface for warehouses, parking lots and access roads that contribute to excess hydrology and thus increased landside and in-channel sediment production.

Certain industries that involve the processing of sand/gravel may be particularly prone to exporting sediment and the associated sediment-bound phosphorus.

Residential sites

Residential areas can generate large amounts of water runoff relative to undisturbed areas. While each site itself may be a small contributor, the cumulative effect is quite large. A typical home with a roof of 1000 square feet can generate 623 gallons of run off in a 1” rainstorm. Multiply that by 100 homes and the result is 62,300 gallons. Add on driveways and outbuildings and the amount grows larger still. This amount of water entering an stream or storm drainage system already dealing with high storm flows can cause localized flooding, erosion, infrastructure damage and combined sewer overflows.

SUMMARY OF AGENCY’S KEY STRATEGIES:

- Implement stormwater BMPs through issuance of individual or general permits for construction and post-construction stormwater discharges, municipal stormwater discharges, and stormwater discharges from industrial facilities. Conducted operational site visits to determine compliance.
- Implement TMDL implementation plans for all twelve of the lowland (non-mountain) TMDLs for stormwater-impaired watersheds.
- Collaborate on illicit discharge and detection elimination studies.
- Promote and support green infrastructure practices that mimic natural hydrology in order to reduce the water volume and water quality impacts of the built environment.
- Implement the Agency of Natural Resources Green Infrastructure Plan collaboratively with other State agencies, local government, federal partners, and NGOs.

For more in-depth information follow the links below:

- Toolbox section for activity
- Stressor factsheets including:





3. Agricultural Activities

Inadequate animal waste, soil and nutrient management results in nutrient loading to surface waters and ground waters and is the major source of agricultural nonpoint source pollution in the State. Pesticide runoff can be another result of improper agricultural activities.

Farmsteads

Farm production areas represent the daily workspace where animals, feed, manure, and fertilizers are stored and therefore is also a location of concentrated nutrients. Over the last 50 years many small dairy operations have gone out of business, and at the same time remaining dairies have grown larger. Although there are fewer milk producers, those that remain produce more milk per animal and the total milk produced state-wide has remained relatively constant over the past 20 years. Much of the increase milk production is the result of genetic selection, as well as aggressive feeding strategies – including an increase in imported feed grains from the Midwest. Current estimates suggest that Vermont farms import over 100,000 tons of phosphorus-rich livestock meal annually. These production driven systems, however, have in many cases exceeded the ability of the farm to properly balance nutrient imports and exports and the excess phosphorus accumulates in farm soils and can be mobilized during wet weather events, as stormwater-related erosion carries both sediment-bound and soluble phosphorus into adjacent receiving waters. This has resulted in increased phosphorus losses from farms and transport to water bodies of concern including Lake Champlain. Although intense production systems were thought to be economically profitable, the external environmental costs associated with the increased phosphorus transported to Lake Champlain and other waters in the state were not considered.

There are a number of potential sources of pollutants, especially phosphorus and pathogens from production areas including barnyards, milk house waste, silage runoff, and improperly stored manure.

- ✓ Most animal production facilities have open outside areas where livestock are concentrated throughout the year. The runoff from these areas is often not collected or treated, and as such can contribute to increased phosphorus losses during periods of heavy rainfall.
- ✓ Dairy operations produce large quantities of wastewater from milk houses, which can include phosphorus from animal wastes and detergents. Most dairy farms either collect their milk house waste in their waste (manure) storage structure or use a septic system to treat the wastewater. In some cases milk house waste is not adequately collected and treated.
- ✓ The majority of Vermont farms have transitioned from tall upright silos to concrete walled bunker silos, which are more cost effective. Most farms cover their silage storages with plastic and tires, concentrated silage leachate and runoff from the bunker silos is typically not collected or stored.
- ✓ Manure is sometimes stacked in areas that are unsuitable and susceptible to runoff.
- ✓ Waste storage structures may be inadequately sized resulting in overflows of manure and/or the need to spread during winter months.

As farms began complying with the winter manure spreading ban that was part of the original Vermont Accepted Agricultural Practices (AAPs), the manure had to be stored for longer periods of time. Liquid manure storage structures or earthen pits were the most common systems employed on Vermont farms. The vast majority of the manure storage structures remain unprotected from precipitation which increases storage capacity requirements and results in the generation of greater volumes of wastes for land application. Due of the cost of hauling the heavier liquid wastes, farmers have been reluctant to haul it to more distant fields. As a result, soil phosphorus levels on many fields, especially those closest to the production area, eventually became elevated beyond optimum crop production levels. Because of soil phosphorus/phosphorus runoff relationships, elevated soil phosphorus levels result in proportionately higher concentrations of phosphorus in runoff, meaning more phosphorus transported to the lake, in areas with elevated soil phosphorus concentrations.

Pastures

In the early 1800's the majority of Vermont was cleared and used as pastureland for sheep, resulting in a great deal of erosion off very steep slopes. Major conservation efforts helped to reforest the hillsides when they were abandoned as the agricultural industry became more mechanized and the market for wool declined. Many farms transitioned from sheep to dairy operations. Early dairy farms were small pasture-based operations, which were eventually replaced by larger confinement operations. The non-milking animals typically still remain on pasture for the summer months, often with poor pasture management because these animals require less daily attention. These areas are often severely overgrazed with uncontrolled access to surface water. These areas are particularly susceptible to higher erosion and increased phosphorus runoff.

There is currently a movement in Vermont back to pasture-based farms. As farms transition to a pasture-based system, however, there is a need for improved pasture management. It is important to balance forage requirements with the land base using a planned grazing strategy to avoid the potential for erosion from over-grazing. Additionally, offsite watering facilities and controlled animal access to streams are necessary to maintain streambank stability and prevent streambank erosion, direct deposition of animal wastes, and loss of riparian buffer capacity. If managed properly, pasture-based agriculture will be good for water quality because it means less soil tilled annually that is subsequently at risk for erosion.

Cropland

Farms in Vermont typically participate in federal government programs which in turn require compliance with 1985 Food Security Act highly erodible land requirements. This means they must follow an approved conservation plan that manages soil erosion on crop land to two times the tolerable soil loss (2T) or less. The "tolerable" soil loss rate is equal to the assumed soil formation rate. Therefore, tolerable soil loss from erosion is not expected to negatively affect soil productivity. The AAPs also require erosion to be controlled to 2T or less. The NRCS nutrient management standard, which is used for voluntary programs and has also been adopted by the State of Vermont under the MFO rule, requires that erosion be controlled to T or less. Sediment bound and soluble phosphorus losses due to erosion can be a major source of phosphorus delivered to surface waters, especially when erosion rates are above T. On many hillside fields there are additional sources of erosion and phosphorus from ephemeral and/or classic gully erosion. Most floodplain fields are depositional areas for the sediment carried downstream thereby keeping it from entering Lake Champlain. Floodplain fields can also be an additional source of sediment and phosphorus. During flood flow events many floodplain fields, because they lack sufficient vegetative cover, experience scour erosion in recurring areas that contribute to phosphorus loads.

Erosion controls deal with sediment losses which help reduce sediment-attached phosphorus losses from fields; however phosphorus can also leave a field in a soluble form during runoff events. With the historic clearing and draining of land in Vermont to create a more suitable agricultural landscape, and the abundance of water in the State, nearly every farm has some stream or water resource within its land boundaries. This makes controlling phosphorus losses especially difficult. Many Vermont farm fields have been tiled and ditched for many decades, leading to the same hydrologic impacts and channel enlargement described above under runoff from developed lands section Plastic drain tile is now used extensively in some parts of the northern lake watershed to lower water tables on crop fields. This can be an effective practice that allows for increased access to fields during wet periods of the year. In some cases the drainage of fields can allow nutrient applications to occur with decreased surface runoff of water and nutrients. However, research in many parts of the country, and in Quebec, has documented increased concentrations of nutrients in tile and ditch discharge.

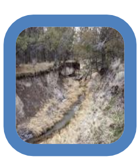
Summary of Agency's Key Strategies that Address Activity:

The agency supports the Agency of Agriculture, Food and Markets work:

- works with farm operators to ensure compliance with Appropriate Agricultural Practices (AAPs)
- regulates medium and large sized farms, requiring nutrient management plans (NMP) and encourage smaller farms to develop NMP
- Encourages agricultural operations to deal with non-point source pollution from production areas and farm fields. Encourage enrollment in federal and State cost share programs and provide additional engineering assistance.
- Help implement controls to deal with soluble losses from ditching and tiling of farm fields through surface and subsurface connections to natural surface waters.

For more in-depth information follow the links below:

- Toolbox section for activity
- Stressor factsheets including:





4. Forestry Management Practices

Timber harvesting has the potential to alter streamflow, sediment, nutrients and water temperature. Sediment is the principal pollutant associated with forest management activities (Pardo 1980; Golden et al. 1984). Sediment originating from the construction and use of logging roads and skid trails generally exceeds that from all other forestry activities (Meghan 1972; Patric 1976). Observations of logging operations in Vermont suggest that gully formation on logging roads and/or skid trails occur on sensitive soils and/or when best management practices (BMPs) are not used. These gullies then become efficient pathways for transporting runoff, sediment and nutrients to receiving waters. Stream crossings are the dominant feature where roads make the major contribution of sediment to water bodies.

Summary of Agency's Key Strategies that Address Activity

- Work with Vermont forest industry to promote use of Acceptable Management Practices (AMPs) in an effort to eliminate discharges resulting from logging operations. AMP Technical Advisory Teams directly assist any logger or landowner when there is a potential discharge, complaint or request for assistance.

- Continue to promote better stream crossing practices on timber harvesting operations through the use of portable skidder bridges.

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheets, including:

5. Hydrologic Modification: changes to river flows or water levels

Dams and hydropower generation

All dams – whether serving useful purposes or not – cause ecological impacts, as illustrated and described in Figure 2. While all of these impacts are important considerations, flow and water level manipulation and sediment regime alteration merit further elaboration.

Instream flow, or the flow of water in a stream or river, is an essential and defining component of a riverine ecosystem. Today it is widely accepted that maintaining the natural flow regime and hydrologic characteristics are important to conserve the physical and biological components of a river. Artificial flow manipulation is usually the major environmental issue at hydroelectric projects regardless of size. Typically, hydroelectric projects alter flows by creating an impoundment above the dam, reducing the amount of flow in the bypass reach between the dam and powerhouse, and modifying g flow downstream of project.

With respect to downstream flow, most hydroelectric projects, especially small projects, are operated as “run-of-river.” That is, the volume of water released below the dam and powerhouse is equal to the volume of water flowing in the stream or river above the dam on a continuous, real-time basis. Put another way, water is not stored in the impoundment to be released at a later time. For these projects, flows in the bypass reach are usually the only flow-related concern, as downstream flow manipulation is not an issue as long as the project is properly maintained and operated.

In addition to run-of-river projects, there are projects that operate in “peaking” mode, where water is stored in the impoundment and released to generate power when the demand for electricity is high. These projects alter downstream flows, potentially resulting in impacts to aquatic organisms and their habitat, by modifying the physical and chemical conditions (i.e. dissolved oxygen and water temperature). In addition, the impoundment elevations at peaking projects tend to fluctuate, resulting in upstream impacts to aquatic habitat and wetlands. The third issue with peaking projects is again the amount of flow that remains in the bypass.

Dams and diversion structures that change the depth and slope of a stream significantly alter the size and quantity of bed sediments and how they are moved, sorted, and distributed along both the cross-section and profile of the channel.[3] In a natural system, a river’s bed sediments (substrate) and eroded riverbank materials are transported downstream during high-flow periods. Due to stream equilibrium process, however, the material that is lost from a reach of river is normally replaced, as flows recede, through deposition of material transported from upstream reaches. When the transport of sediments, e.g., gravels and cobbles, is interrupted in an impoundment, the channel may become vertically unstable. The instability takes two forms. The impoundment becomes a sediment “sink” as the sediments from upstream hit the flattened river reach and are deposited, resulting in *aggradation*, or raising of the natural riverbed. The downstream instability is essentially the opposite effect. The river channel becomes *incised*, or downcuts, as the materials naturally eroded from the streambed during a flood event below a dam are no longer being replaced by an equivalent amount of sediment from upstream. This mode of

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[3]MacBroom, James G. The River Book. Hartford, CT: Connecticut Department of Environmental Protection; 1998.

sediment regime alteration (i.e., sediment discontinuity) has been observed above and below dams, diversions, and undersized culverts throughout Vermont and has a profound effect on stream stability and aquatic habitat.

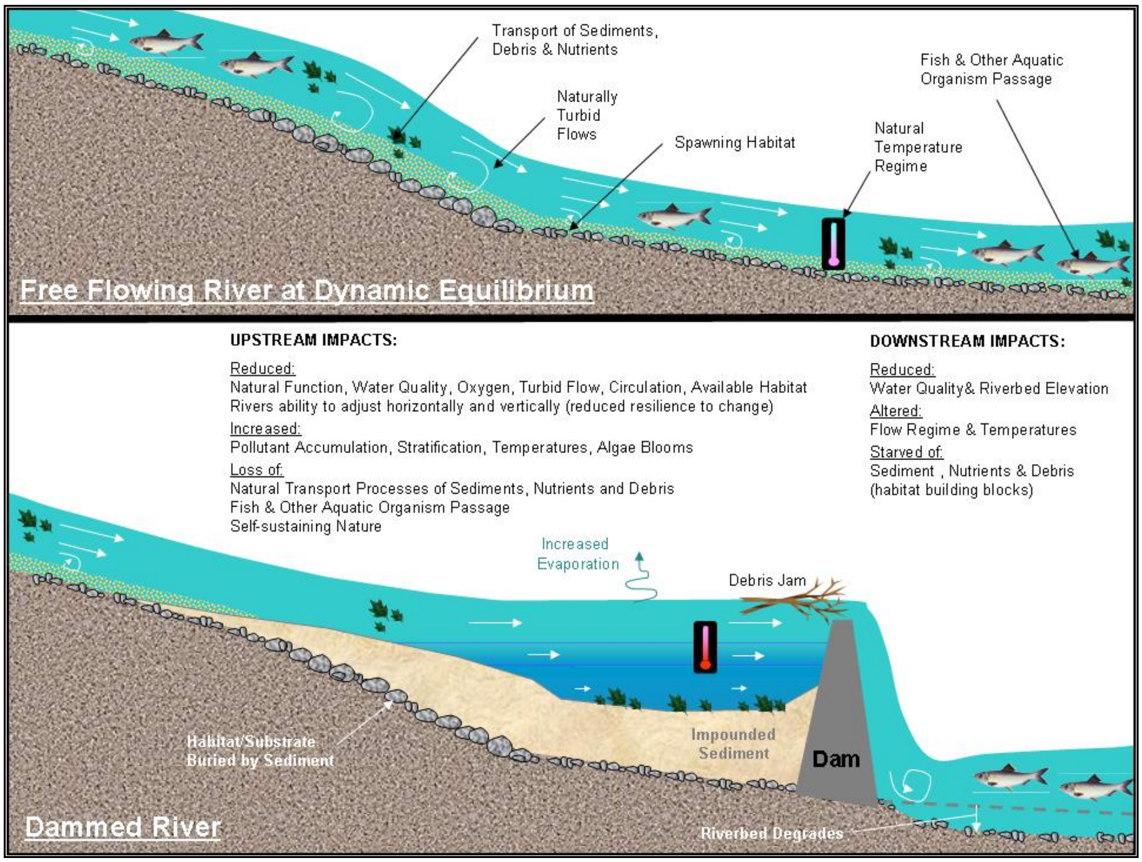

Figure 2 Effects of a dam on a free-flowing river (Graphic courtesy of American Rivers)

Materials aggraded in the slower and deeper water behind the dam alter habitat structure, typically by finer sediments covering or embedding the larger substrates that provide cover for aquatic organisms. In watersheds with high sediment loads, the aggradation process behind a dam during storm events may lead to significant changes in flood stage, bed and bank erosion, and in some cases an avulsion, or change in course of the stream. When channel incision occurs due to sediment starvation downstream of a dam, the streambed may drop in elevation until annual flood flows no longer access the floodplain. The erosion/deposition processes that ensue during channel evolution as new floodplains are created often lead to significant habitat and water quality impacts and fluvial erosion hazards over a period of decades.

During discussions and debates of small hydropower, the terms “small” and “low-impact” are sometimes used interchangeably. They are not the same. Small hydroelectric facilities that are added to existing dams and properly operated can certainly provide societal benefits with limited additional impacts on fish, aquatic habitat, water quality and geomorphic processes. However, this is not true of all facilities, and whether a facility is low-impact must be determined on a case-by-case basis.

Because of their small size, the cumulative impact of developing multiple facilities in a watershed might not be obvious, but the interruption of geomorphic processes within a watershed will have cumulative impacts on aquatic habitat and water quality. Even facilities that would be considered low-impact are not impact free. If they are located at existing dams, the impacts resulting from dams described earlier are present. Bypassed reaches are impacted when water is diverted – the conservation flow does protect habitat, but the quality and quantity of the habitat is degraded relative to natural flow conditions.

There are many dams in Vermont that are not currently serving a useful purpose and, for both economic and ecological reasons, are unlikely to be developed for hydroelectric power. However, these dams will continue to fragment habitat, degrade water quality and cause other impacts on rivers and streams. In terms of developing resiliency to the long-term prediction of an increase in flooding events, droughts and water temperature as a result of climate change, restoring watershed continuity by removing dams and other obstructions will become increasingly important.

Water withdrawals

In addition to dams, Vermont's rivers and streams are affected by water withdrawals that serve a variety of purposes: drinking water supply, irrigation, snowmaking and industrial uses. Many of these withdrawals do not involve dams, but an in-stream intake structure that diverts water to a pump house. Most of these withdrawals are consumptive, that is, the water is used for some purpose and not returned to its source. In some cases, such as when the water is used for heating or cooling, it is returned to the river or lake.

The impacts of water withdrawals on streamflow are similar to those described for hydroelectric projects. Multiple characteristics of the natural flow regime may be affected by water withdrawal activities including, magnitude, frequency, duration, timing and rate of change. However, state regulation of water withdrawals focuses on maintenance of seasonal conservation flows, i.e., the flow downstream of the withdrawal that is necessary to support fish and other aquatic life. In other words, regulated withdrawals are not allowed to operate when the natural streamflow is less than the conservation flow value.

Most of the larger water withdrawals in the state are regulated by the State and operate under permits that require adequate conservation flows. Some are operating under old permits that have lower conservation flow requirements, and there are likely other water withdrawals that are unpermitted.

Water withdrawals from lakes are typically not a problem since streamflow is not an issue. However, large volume withdrawals from lakes in small watersheds can be problematic during dry periods if the flow in the outlet stream is reduced.

Water level manipulation in lakes

Many of Vermont's lakes have dams at their outlets that have varying capabilities to manipulate the water level. The management and regulatory oversight of these is also variable – the Vermont Agency of Natural Resources (ANR) does not have jurisdiction over all situations. Some Vermont lakes are lowered in the fall for the winter period by local residents for the purpose of protection of shoreline structures. Depending on the timing and extent of a winter drawdown, there can be negative impacts on aquatic habitat and biota.

Summary of Agency's Key Strategies that Address Activity

- Issuance of Section 401 Water Quality Certifications for hydroelectric projects and water withdrawals
- Participation in the federal hydroelectric project relicensing process
- Vermont Dam Task Force created to identify opportunities for dam removals where dam owners are willing and funding is available.
- Seek to reduce or eliminate artificial lake level fluctuation and winter drawdowns

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheets, including:




6. Encroachment: wetland buffers, lake shorelands, and river corridors

Fills within rivers and streams, wetlands, and lakes.

While encroachment is not limited to fill, fill activities do represent the most permanent loss for river, stream, wetland and lake habitat. Once an area is filled, it no longer functions as an aquatic resource. In addition to the immediate habitat loss, fills can have ongoing impacts to water quality and floodplain function depending on the quality of the fill material, and the extent and location of the activity. Fill in a river corridor: floodplain, wetland or channel, eliminates sediment and nutrient storage from both channel and land-based sources. In addition, reduction in water and sediment storage also reduces the stability of a river, causing erosion or sediment deposition down stream.

Floodplain fills are common in Vermont. Lands are filled to elevate structures or make land less susceptible to inundation during flood events. These fills eliminate flood flow storage and the attenuation of flood energy, and often cause flood elevations to rise upstream and downstream of the filled area. The loss of flood attenuation tends to concentrate flood energy within the channel causing incision (downcutting). Ironically, fills placed to avoid inundation hazards may ultimately lead to erosion hazards.
Fill that is poorly placed and is not stabilized also represents an ongoing impact as an erosion hazard. In addition to eliminating habitat, fill can provide barriers to wildlife passage. The introduction of fill into an aquatic system has detrimental water quality effects that include iron-fixing bacteria blooms and the introduction of invasive species.

Removal of vegetation.

Part-and-parcel with encroachments to rivers, lakes, and wetlands is the removal of riparian, shoreland, and buffer vegetation. The areas lacking buffer vegetation no longer filter sediment and nutrient pollutants, do not provide for shade cover, coarse woody debris and other organic material, and no longer have the root density and root strength to support the banks, which can contribute to sedimentation problems in the surface water of the lake, river or wetland. On lakes, the removal of shoreland vegetation and replacement with lawn and other development has a substantial impact on the lake, both in terms of an increase in sediment and nutrient pollution, and by resulting in a significant alteration of the shallow water habitat features. (See Lakeshore Development and Alteration of Shallow Water Habitat section below.)

River corridor development

The Vermont Agency of Natural Resources (ANR) uses the river corridor as a primary tool in its avoidance strategy to restore and protect the natural values of rivers and minimize flood damage. River corridor delineations are based primarily on the lateral extent of stable meanders, the meander belt width (Figure 3), and a wooded riparian buffer to provide streambank stability. The meander belt width is governed by the shape of the valley, surficial geology, and the length and slope requirements of the river in its most probable stable form.

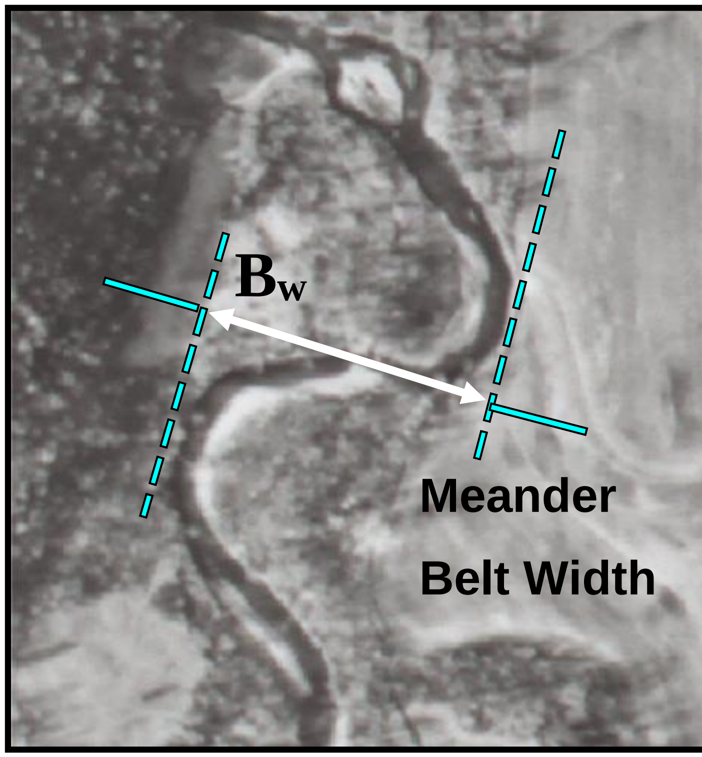

Figure 3. Meander Belt Width (**B_w**) defined by the lateral extent of meanders when the channel slope is in equilibrium with the sediment transport requirements of the river.

River corridors provide an important spatial context for restoring and maintaining the river processes and dynamic equilibrium associated high quality aquatic habitats. River corridors are also intended to provide landowners and town, state, and federal agencies with a science-based river and riparian land use planning and management tool to avoid fluvial erosion hazards (FEH).

Vermont ANR stream geomorphic assessments in have documented extensive, historic channel straightening and subsequent encroachment within the river corridors needed for meander redevelopment and equilibrium conditions to reestablish. These activities have resulted in over-steepened, erosive streams throughout Vermont that have become incised and disconnected from floodplains. Reducing current and future near-stream investment and achieving natural stream stability will promotes a sustainable relationship with rivers over time, minimizing the costs associated with floods and maximizing the benefits of clean water and healthy ecosystems.

Vermont ANR has considered that establishing socially acceptable buffers, as development setback areas, without considering river corridor functions, may make it very difficult if not impossible to establish the corridor setbacks necessary to sustainably achieve the State's water quality and hazard avoidance objectives. Once people build within the corridor, corridor functions are compromised. Buffers as a setback zone, which do not provide for the functions of a corridor, will most likely be eroded away.

A river corridor is designed with a meander belt to accommodate the geometry of the river in its least erosive, equilibrium condition, and extended laterally to include a buffer zone, equal in width to the bankfull channel. Any down valley movement of the channel along the perimeter of the meander belt would, therefore, include sufficient, adjacent open area for the maintenance of perennial, woody vegetation and naturally stable stream

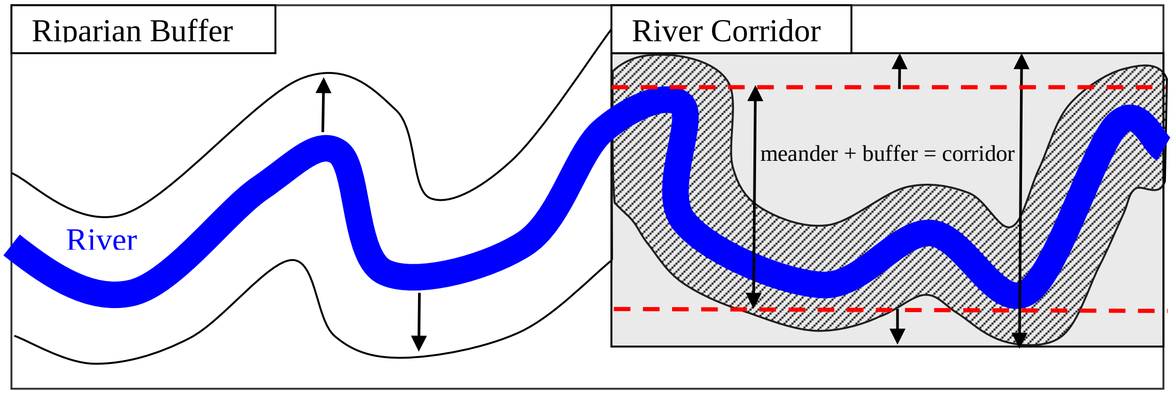

Figure 4. Comparing a buffer setback to a river corridor. Source: Adapted from Ohio DNR, Rainwater and Land Development Manual, 2006 Ed., Ch 2. Post Construction Stormwater Management Practices, p. 21

banks (Figure 4). The vegetated buffer area within the corridor may vary in width depending on the desired functions.

Lakeshore development and alteration of shallow water habitat

The transformation of lakeshores from natural forested and wetland cover to lawns and sandy beaches, accompanied by development (and redevelopment) of residential homes is a major stressor to lakes.

A Wisconsin study found that phosphorus loading to a lake increased by a factor of four and sediment loading increased by a factor of 20 when a shoreland property becomes "suburbanized" through the removal of the natural shoreland vegetation and the replacement with lawns, driveways and buildings.

In a survey of 345 lakes in the Northeast during the early 1990s, the US Environmental Protection Agency and US Fish and Wildlife Service determined that the stress from shoreline alteration was a more widespread problem than even eutrophication and acidification[4]. Since 2005, the VTDEC has documented the effects of shoreline development on nearshore and littoral habitat quality in lakes throughout Vermont, with striking results.

Conversion of treed shorelines to lawn radically changes the chemical, physical, and biological components of lake habitat in the shallow water zone: shading decreases in the littoral zone, the amount of large woody structure is reduced as well as the percent cover of leaf litter while the amount of fine sediments and filling of space between rocks increases. The natural community of aquatic and terrestrial organisms that has evolved to grow, reproduce, and survive in the lake/shore interface will change or disappear as the habitat undergoes physical, chemical, and biological transformation to something with substantially diminished habitat quality.

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[4] (Whiter et al, 2002)

The state lacks a shoreland protection act and only 10% of towns have adequate lakeshore buffer zoning regulations. The Vermont Littoral Habitat Assessment (LHA) project was undertaken on 40 Vermont lakes to quantify the current condition of the nearshore and littoral habitat[5]. It concluded that the lack of a buffer is a significant stressor to Vermont lakes. Overall, findings indicate the changes to shallow water habitat and biota caused by unbuffered development could be mitigated by retaining an intact natural treed buffer along the shore. Preliminary analyses suggest that to protect the shallow water habitat, buildings need to be set back 112 ft or more and at least 51% or more of the immediate shoreline needs to remain in mature trees (>5m tall). A 100-foot plus wide buffer with mature forest, understory, and an uneven spongy duff layer is also optimal for intercepting runoff and dampening the energy of rain.

The Vermont Lake Study also determined the percentage of Vermont lakes that are stressed at the whole lake level due to the extent of unbuffered developed shore using thresholds developed by EPA in the 1990s EMAP survey of Northeastern Lakes. The study estimates that 11% of Vermont lakes are in poor condition, 71% are in fair condition and 18% are in good condition. While the VLS measured the effect and extent of multiple stressors on Vermont lakes, unbuffered lakeshore development was more widespread a stressor than either eutrophication or acidification (Figure 5).

[5] (DEC, 2009)

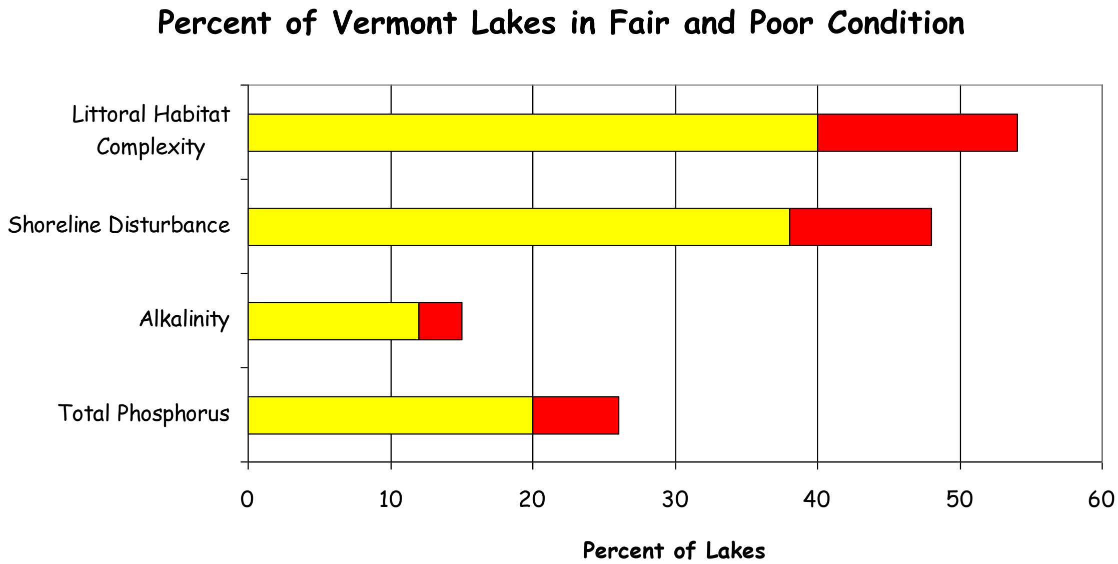

Figure 5. Results of the Vermont Lake Survey, showing the percent of lakes in fair and poor condition due to four different stressors. Yellow and red represent percent of lakes in fair and poor condition respectively.

Summary of Agency's Key Strategies that Address Activity

- Protect significant wetland functions under the Vermont Wetland Rules. Continue to educate community about Rules and assist landowners in complying with rules.

- Provide technical assistance and encourage towns to increase floodplain protection under the auspices of the FEMA's National Flood Insurance Program. Provide maps, technical assistance and incentives to towns in applying land use regulations to protect areas within the river corridor. In addition identify reaches through geomorphic assessments that are particularly valuable sediment and nutrient attenuation assets. Identify as a high priorities those areas in need of permanent protection and conserve irreplaceable functions with the purchase of easements.

- Provide technical assistance and incentives to towns to adopt shoreline protection. Support passage of a statewide buffer bill, similar to those existing in New Hampshire and Maine.

- Provide documentation of floodways, FEH areas, buffers, and lakeshores to Act 250 district commissions.

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheets, including:

   

7. Flood and Erosion Hazard Mitigation

Human investments within river corridors, on floodplains, and adjacent to lake shores has resulted in conflicts between those investments and dynamic movement of streams or lake shorelines. These conflicts lead to great desire and effort to keep streams from moving in the landscape or shorelands from eroding.

Stream channelization to address flood damage

The history of channelization to protect riparian land use investments, and the erosion and flood damage that follow, are among the most significant threats to water quality, aquatic habitat, and public safety in Vermont.

Since the 1950s, an estimated $14 million a year is spent remediating flood damage. A vicious cycle has played out in Vermont where encroachments occur; those encroachments are threatened from flood-related erosion; and then channel works are completed to put the stream back or relocate the stream away from the investments. Years pass, a perception grows that the stream is actually stable, further encroachment occurs, a flood happens, and the cycle repeats itself.

The exact number is not known, but ANR stream geomorphic assessments indicate that somewhere between a third and half the stream miles in Vermont were historically straightened. Most of these same miles were bermed, dredged, windrowed, and/or armored with stone. The physical manipulation of stream depth, width, meander pattern, and slope has resulted in pervasive stream channel incision, widening, and aggradation throughout Vermont. A recently published article in the Journal of American Water Resources Association[6] provided data showing that 75% of the 1,345 miles of stream miles assessed by the ANR were incised and evolving to form new floodplain.

The loss of flow and sediment attenuation due to incision may be contributing to erosion processes and a significant percentage of the nutrient loading to Lake Champlain and other lakes in Vermont. The channelization that occurs after floods also has a large impact on aquatic habitat, primarily due to the loss of instream and riparian cover. Steepened and deepened streams result in higher velocities which scour of the sediments and woody debris that give shelter to aquatic organisms. Straightened channels also lack the riffle-pool sequences and provide shelter and feeding habitats. Habitat in downstream channels and lake littoral zones that receive all the eroded material become smothered and unusable by fish and macroinvertebrates.

For decades state and federal agencies were as convinced as property owners that stabilizing streambanks was always good for water quality. Now, after 10 years of fluvial geomorphic assessment, stream resource managers have the data to understand why the

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[6] Kline, M. and B. Cahoon, 2010. Protecting River Corridors in Vermont. Journal of the American Water Resources Association (JAWRA) 46(2):227-236.

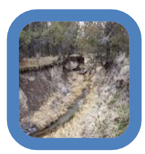
bed and banks of a stream are eroding, and what alternatives people may or may not have to manage stream channel adjustments. In built-up or developed areas, there is often little choice but to keep up with expensive channel works. For this reason, the Vermont River Management Program works with landowners to avoid making large investments next to streams that will rely on channelization to maintain.

Summary of Agency's Key Strategies that Address Activity

- Conduct stream geomorphic assessments and develop river corridor plans to identify and prioritize the actions that will help manage a channel back to equilibrium conditions, and protect the river corridor necessary to accommodate the equilibrium channel.
- Protect technical assistance and regulatory oversight of stream alterations.
- Participate in the Army Corps 404 "dredge and fill" permit process.
- Provide regulatory oversight of shoreland stabilization projects.

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheets, including:




8. Treated and Untreated Wastewater

On-site septic

The list of pollutants in domestic waste water includes nutrients, chlorides and pathogens. A lesser amount of pharmaceuticals and personal care products are also present in waste water but because of a lack of understanding of their fate in soil-based treatment systems, will not be discussed in this section as they are discussed in the section on municipal waste water treatment (see below).

The standard practice for on-site waste water treatment is the separation of solids and liquids followed by the discharge of liquids to soil. When adequate separation from the ground water table is provided, pollutants are filtered out or treated by the soil and its microbial community. As a result, most pathogens expire and nutrients and chlorides are incorporated into the soil. However, on-site treatment does not permanently remove nitrogen and chloride. Eventually both will move readily through soils to reach ground water and often further to surface waters. Nitrogen may under go denitrification, becoming a gas, but chloride remains in the watershed.

Phosphorus is more apt to stay attached to soil particles than nitrogen or chlorides, becoming more available for plant uptake. On-site septic is considered the best treatment for phosphorus removal over wastewater treatment plants. Several studies and analyses of shoreline on-site septic systems conclude that on-site septic are likely not a large contributor to the phosphorus loading problem in Vermont lakes[7]. A non-point source assessment for the Lake Champlain basin as a whole concluded that even under worst-case assumptions, septic systems were not likely to represent more than 5% of the total phosphorus load to Lake Champlain.[8]

Moreover, an evaluation of the benefits of sewering lakeshore camps efforts to reduce phosphorus loads provides evidence that on-site septic ultimately provides more treatment than a wastewater treatment facility. While collection of wastewater for centralized treatment may be necessary in some situations to eliminate discharge of pathogens and protect public health, it is not necessarily a beneficial practice from the standpoint of phosphorus reduction. Phosphorus concentrations discharged from an on-

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[7] a 1991 study done for the Towns of Georgia and St Albans by TWM Northeast, Inc. evaluated the potential for phosphorus loading to the bay from septic systems, based on phosphorus removal rates in soil column tests and on sanitary survey information. Septic systems were estimated to contribute less than 2% of the total phosphorus load to St Albans Bay. This estimate was based on the assumption (not directly verified and likely worst-case) that 20% of the shoreline septic systems provided no phosphorus removal treatment before discharge to the bay.

[8] http://www.lcbp.org/publication_detail.aspx?id=42

site septic system following soil contact would typically be in the range of 0.1 mg/l. Phosphorus concentrations discharged from even the most advanced municipal wastewater facilities are rarely as low as 0.1 mg/l. For example, the discharge permit for the St Albans City Wastewater Treatment Facility limits the phosphorus concentration in this discharge to 0.5 mg/l, which is the strictest phosphorus concentration limit applied to any municipal facility in the state. Treating wastewater on-site though soil contact is nearly always preferable from a phosphorus removal standpoint over collection in sewers, centralized treatment, and discharge back to the lake. In addition, a sewer system will enable more intensive development, which would have the secondary effect of increase runoff to the lake with likely greater impact on the lake than the replaced septic systems.

An adequate separation between point of discharge and ground water level removes the greatest amount of pollutants; however, the majority of on-site septic systems in Vermont were installed without benefit of regulatory oversight. Regulations to separate domestic waste from the ground water table and surface waters when treated on-site were first enacted for subdivisions of single family lots under 10 acres in 1969. It was only in 2002 that all new lots came under state jurisdiction. There are a number of historic villages in the state adjacent to rivers that do not have treatment facilities and where on-site septic systems are likely the source of elevated levels of E. *coli,* an indicator of pathogens, in surface waters.

Municipal wastewater treatment facility

Phosphorus and Nitrogen

Unlike nearly all of the other sources described in this chapter, wastewater discharges represent a regulated and readily measurable source of pollutants, including phosphorus and nitrogen and *E. coli* to waters in the state. There are 91 wastewater treatment facilities (WWTF) that discharge to surface waters in Vermont.

Phosphorus loadings to Lake Champlain from Vermont WWTF have declined by 79% since 1991 and the total discharge of phosphorus from Vermont is now well below the aggregate wasteload allocation contained in the Lake Champlain Phosphorus TMDL. Only a few facilities remain to be upgraded in order to achieve their individual phosphorus wasteload allocations, and all these remaining projects are currently in the design or construction process.

Nitrogen loads from Vermont wastewater treatment plants and other point sources are significantly less than the loads from nonpoint sources. Half of the nonpoint sources are estimated to be atmospherically deprived[9]

Pharmaceuticals and personal care products

During the 2008 reporting period, the US Geological Service (USGS) continued a number of pharmaceuticals and personal care products (PPCP) studies in the Lake Champlain Basin. USGS has analyzed samples of wastewater plant (WWTP) effluent, combined sewer overflow effluent, urban streams, large rivers, an undeveloped (control) stream, and samples in Lake Champlain. An important finding of these studies was that wastewater effluent and CSO effluent were not the only sources of wastewater contaminants**.** Urban streams contributed substantial amounts of wastewater contaminants to Lake Champlain during storms from untreated sewage sources. Two of the streams studied are underlain by old sewer pipes and combined sewer infrastructure; which may leak during storms, releasing sewage to the streams. These findings are the subject of continuing inquiry by USGS.

Industrial wastewater

There are 81 industrial discharges in Vermont, ranging from fish hatcheries to manufacturing facilities. Since industrial discharges are issued NPDES permits (see below) and thus regulated in a manner that will assure that state water quality standards are maintained, water quality problems from industrial discharges are not anticipated. On

[9] http://www.neiwpcc.org/neiwpcc_docs/USGS%20CT%20River%20Monitoring%20Report.pdf

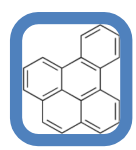
occasion a noncompliance issue may occur, but these are addressed and corrected in a timely manner.

Summary of Agency's Key Strategies that Address Activity

- Regulate or encourage towns to regulate septic system installation
- Implement the Vermont Toxic Discharge Control Strategy (TDCS) to quantify all NPDES discharges in Vermont and to establish water quality criteria and discharge permit limits that can be used to regulate discharges in a manner that will assure that the state water quality standards and receiving water classification criteria are maintained.
- Administer the National Discharge Pollutant Elimination System (NPDES) permit program under federal delegation for discharges from individual, municipal and industrial wastewater treatment facilities to state surface waters.
- Assist towns in obtaining loans to upgrade municipal wastewater systems to reduce pollutant loads.
- Work with industry to reduce waste that would otherwise have to be sent to a wastewater treatment plant.

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheets, including:


9. Transportation Infrastructure

Transportation infrastructure is essential to the Vermont economy and way of life. . Transportation infrastructure includes elements such as roadways, embankments, drainage systems, railroads, driveways, parking lots, recreation paths, sidewalks, airport runways, culverts and bridges.

Vermont has an extensive network of over 15,000 miles of paved and gravel roads (over 90% of which are maintained by local municipalities) 600 miles of operating rail lines (305 state owned), over 70 miles of bicycle/ pedestrian facilities, and many acres of associated private driveways and parking lots.

Transportation infrastructure can be a significant source of nonpoint source (NPS) pollution to rivers and streams if infrastructure is not properly sited, constructed and maintained. Railroads and roadways have historically followed rivers and streams. This close proximity contributes to runoff of pollutants, sediment, and stormwater into waterways.

Undersized bridges and culverts, and floodplain fill for transportation infrastructure constrain the natural movement of waterways, thus exacerbating flooding, erosion, sediment transport and other problems. Road-related fill that causes the river to lose access to its flood plain concentrates more energy within the channel, and will cause erosion and increased flooding in the watershed. Undersized culverts are also an ecological challenge. They can be a barrier to fish and wildlife and prohibit movement through the landscape, thus cutting off and eliminating essential habitat.

Transportation infrastructure leads to NPS pollution in a number of ways, but many of these have to do with the amount and rate of water flowing over the surface of un-stabilized soils. An obvious example is the erosion of the road surface itself when it is not built or maintained with proper drainage.

Other sources of sediment include: erosion from ditches that are not vegetated or lined with stone, bank failures near the road, bridges and culverts that wash out, erosion during road construction and maintenance, and traction sand runoff from winter maintenance of both paved and gravel roads. Correcting these sources of sediment can involve significant under-budgeted costs and transportation disruptions..

The demand for wider, safer roadway facilities is another concern. Bicycle and local pedestrian traffic must be accomodated   Widening existing roads, and adding new sidewalks with curbing often without adequate stormwater infrastructure or treatment, increase and often concentrate stormwater runoff, thus resulting in increased NPS pollution.

Transportation facilities are linked to growth and development patterns. Transportation access is a key factor in the location of development within the watershed. In addition, development patterns spread across the landscape, such as car-oriented commercial strip development on the edges of towns and villages, requires far more impervious surface than compact development patterns. The amount of impervious surface within the watershed and the existence and adequacy of the treatment of storm water discharges from those surfaces greatly affect the quality of the receiving waters

Spreading of salt and sand

Salt and sand are spread during the winter to provide safe driving surfaces. Road salt has been used as a deicing mechanism since the 1940s. Roughly 16 million tons of rock salt were mined in the United States in 2004, and used primarily for road deicing[10]. Use of sodium chloride and calcium chloride, in conjunction with plowing, is recognized as the most efficient way to keep roadways clear in winter[11]. Sodium chloride is also currently the least expensive deicing option available. While road salt is not the only source of chloride in the environment, there is evidence that application at current rates is resulting in increased chloride concentrations and conductivity levels in surface and ground waters in the northern United States.

There is sufficient evidence that chloride and its affect on the aquatic environment warrant closer scrutiny in Vermont:

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[10] (Salt Institute 2006)

[11] (USGS 2006)

- Chloride levels have been steadily increasing in Lake Champlain since 1992. At this time, concentrations in the open waters of the lake (6.8– 25.3 mg/L) are not of biological concern.
- Major lake tributaries are now carrying higher loads of chloride than they have historically.
- Urban streams in the greater Burlington area have the highest chloride concentrations observed to date in Vermont and are experiencing levels considered harmful to biota. Mean chloride concentrations in three of six urban Burlington streams studied in 2005 ranged from 250 – 275 mg/L, exceeding ambient water quality criteria.
- High chloride levels are occurring during summer and winter low flow periods in these small urban streams, strongly suggesting that groundwater contamination may exist. There appear to be no current groundwater data on chloride in these areas.
- Road salt application was linked to increasing chloride concentrations in the West Branch of the Waterbury River in Stowe and Forester Pond in Jamaica[12].

Summary of Agency's Key Strategies that Address Activity

- Support the Better Backroads Program (BBR) financially and with some technical assistance. The program hires technical staff to assist towns in identifying road erosion problems and applying for grant funds. The grant funds are used for inventories, capital budget planning, and erosion correction projects, including the stabilization of ditches, culverts, and roadside banks.
- Support Local Road Programs workshops to promote road BMPs to town road crews, including winter maintenance.
- VTrans provides the Agency with road salt application data on state roads. The agency supports VTrans efforts to identify methods for reducing chloride use.
- Monitor chloride levels in surface waters

[12] DEC

- Continue the outreach and educational efforts of the River Management section and other Agency of Natural Resources programs.
- River management engineers and floodplain managers provide technical assistance and regulate new transportation infrastructure when placed within floodplains and stream channels.
- Continue collaborative research and regulatory efforts with VTrans and other partners.

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheet including:




10. Spreading Aquatic Invasive Species

Acres of beds of nonnative species are now found within our water bodies. These aquatic invasive species (AIS) have reached beyond their historic range and threaten the diversity or abundance of native species or the ecological stability of infested waters. In addition, the spread of AIS threatens commercial, agricultural, aquacultural or recreational activities dependent on such waters.

The potential pathways of introduction for AIS into the state are numerous. The movement of boats and other aquatic equipment is the most visible and readily recognized pathway, but aquarium dumping, improper disposal of live bait, accidental releases from cultivation, and intentional introductions all play a role.

Natural and artificial waterways also serve as conduits for AIS into the Lake Champlain Basin and the state. The Champlain Barge Canal connects the southern end of Lake Champlain to the Hudson-Mohawk watershed, which is, in turn, connected to the Great Lakes drainage basin by the Erie Canal System. The Champlain Barge Canal likely provided access for numerous AIS into the Basin, including zebra mussels, blueback herring, water chestnut, flowering rush, purple loosestrife, white perch, and mud bythnia. The Richelieu River, which flows out of the northern end of Lake Champlain and ultimately into the St. Lawrence River, has a similar potential to move nonindigenous species into and out of the Lake Champlain Basin. For example, tench likely entered Lake Champlain via this waterway. Some preliminary work has been done to identify potential management options for the Champlain Barge Canal, but a great deal more work and funding will be required to eliminate the threat of AIS introductions from the Canal.

Summary of Agency's Key Strategies that Address Activity

- Enforce state legislation that limits spread of AIS to new areas, and regulates the use of mechanical, biological, physical and chemical nuisance control activities in Vermont waters.
- Assist shoreline owners and other community members with the management of AIS by providing technical assistance and financial assistance through the Aquatic Nuisance Control grant-in-aid program.
- Support continued annual state funding for water chestnut to ensure successful control and maintain recently achieved milestones
- Coordinate with Lake Champlain Basin Program on invasive species management in Lake Champlain and its basin
- Maintain readiness to implement Rapid Response protocols when necessary.

For a more in-depth discussion, see the following links:

- Toolbox for activity
- Aquatic Invasive Species stressor factsheet:

11. Air Emissions

Power plants, industrial manufacturing, and motor vehicles are all sources of air emissions that can adversely impact water quality. The compounds in these air emissions fall to the earth in either dry form (such as gas and particles) or wet form (such as rain, snow, and fog). Prevailing winds transport the compounds, sometimes hundreds of miles, across state and national borders.

Pollutants from air emissions result in acid deposition that acidity our lakes and are the predominant source of mercury in our waterbodies. These pollutants become part of the air masses circulating in the upper atmosphere, which flow predominately into the Northeast. With regard to sources that lead to acid deposition, the industrial Midwest is responsible for about half the sulfur dioxide emissions east of the Mississippi. The state of Ohio produces two times more tons of sulfur dioxide than all of New England, New York, and New Jersey put together. It is pollutants from these distant sources that contribute to damages in the Northeast environment.

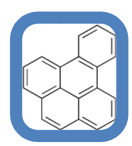
Nitrogen is another component of air emissions. In Vermont, the air emissions provide a significant source of nitrogen.

Summary of Agency's Key Strategies that Address Activity

- The majority of the sources of air emissions are out of state. Continue monitoring and assessing surface waters to develop TMDLs, demonstrate benefits of the federal regulation and the need for further reductions to achieve biological recovery.

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheet, including:



12. Legacy Effects

Legacy sediments

The widespread deforestation of Vermont's landscape through most of the 19th century into the early 20th century resulted in tremendous erosion of upland soils and accumulation of alluvial sediments in the river valleys. Streambank stratigraphy assessments[13] document the aggradation of valley floodplains up to 20 feet in the post-settlement period. Deep deposits of highly organic alluvium are commonly visible in eroding riverbanks throughout the Champlain Valley. In a sample of 245 streambank stratigraphy investigations in the Lake Champlain Basin, Skinas found 150, or 63%, of sites to consist of recently deposited post-settlement alluvial sediments. Depth of alluvium ranged from one foot to 20 feet with an average depth of five feet.

Reforestation during the 20th century dramatically reduced the watershed sediment supply. In the latter half of the century rivers began downcutting through the alluvial sediments. At least 70% of Vermont's rivers have become incised and thereby disconnected from their historic floodplains. These rivers have begun, very efficiently, mobilizing and transporting not only the current-day sediments washing off the land, but more importantly the deforestation-related legacy sediments and nutrients.

Internal Phosphorus Loading

Internal phosphorus loading refers to the process in which phosphorus is supplied to the water of a lake from sources within the lake, usually the lake sediments, as opposed to external loading from streams and land-side sources. Phosphorus entering a lake from watershed sources is taken up by algae and other organisms and then a portion of this phosphorus sinks to the bottom of the lake in the form of dead cells, waste products, and other particulate matter. Depending on the chemical conditions in the sediments and overlying water, this previously deposited phosphorus can be recycled back into the

[13] (Field, Skinas)

water column where it can stimulate algal growth again. A diagram of the phosphorus cycle in St Albans Bay showing the internal loading process is shown in Figure 6.

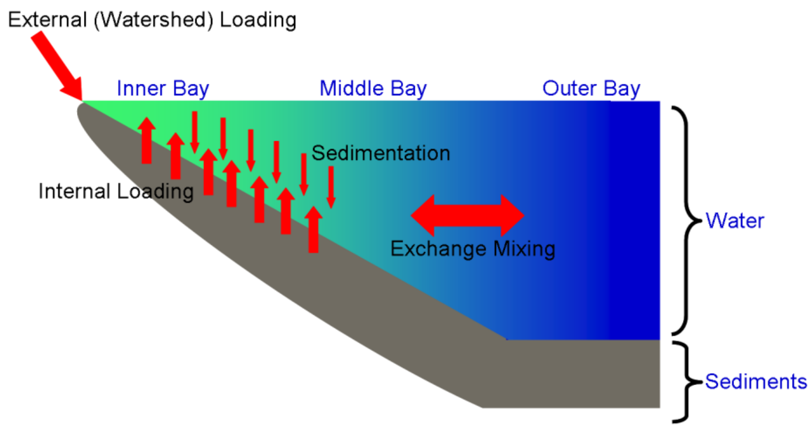


Figure 6 The Phosphorus Cycle in St Albans Bay - showing internal loading.

When external phosphorus loading to a lake has been excessive over a long period of time, large quantities of phosphorus become stored in the sediments. Internal loading from this historic residue of sediment phosphorus can continue long after external loads have been reduced through wastewater treatment improvements and non-point source control. In this situation, internal loading can delay the recovery significantly.

This is the situation that exists in St Albans Bay, as documented by a large body of research on the bay.[14,15] A wastewater treatment plant upgrade and watershed-wide implementation of certain agricultural best management practices (BMPs) in the 1980s did not result in measurable phosphorus reductions in the bay's water. Internal loading is causing phosphorus levels to remain high, especially during the summer months when algae blooms peak. The same situation is likely to exist in Missisquoi Bay, based on research and modeling done for the Lake Champlain Basin Program.[16,17]

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[14] http://www.anr.state.vt.us/dec/waterq/lakes/docs/lp_stalbansphosphorus.pdf

[15] http://www.anr.state.vt.us/cleanandclear/StAlbansBaySedimentPstudy.pdf

[16] http://www.lcbp.org/publication_detail.aspx?id=77

[17] http://www.lcbp.org/publication_detail.aspx?id=78

Landfills and hazardous waste sites

Agency assessments conducted in the early 1990s found that unlined landfills throughout Vermont had caused degradation of ground water and surface water quality. Post-closure maintenance and monitoring is needed to minimize the risks to public health and the environment, and to ensure that necessary corrective actions are taken to protect public health and the environment. Of the 68 municipal solid waste and special waste landfills which have closed and capped since 1989, 16 are not covered by a regulatory document specifying post-closure maintenance and monitoring requirements. About 14 of these landfills do not currently perform post-closure maintenance and monitoring. Additionally, landfills that closed before 1989 were not subject to detailed closure regulations and may require additional attention to ensure that they are not causing environmental degradation.[18] Pollutants generally include iron, manganese and heavy metals. The leaching of iron and manganese from the disturbed nature of the landfill and groundwater interaction impacts habitat more that actual “toxicity” through both precipitation of iron and the smothering effects of iron bacteria. Currently about a dozen stream waterbodies are known to have impacts from these old landfills.

In addition, hazardous waste disposal was not regulated until federal legislation was released in 1980 (The Comprehensive Environmental Response, Compensation, and Liability Act). Sites like the Barge Canal in Burlington and the Elizabeth Mine in Strafford have contaminated both soil and surface water with hazardous waste constituents. Site management by the agency and EPA has begun on these two sites, but many others exist. The number and complexity of sites and variety of potential receptors (surface water, groundwater, soils, and sediments) make reducing the environmental impacts of these sites, especially older sites, challenging. There are 100 active high priority hazardous sites and 500 active medium priority sites in the State. The universe of Vermont hazardous sites (active, inactive, closed) is over 3000. Most monitoring that

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[18] State Of Vermont Revised Solid Waste Management Plan, Agency of Natural Resources DEC, adopted 8/31/2001

occurs is groundwater or soil monitoring so it is difficult to assess river or stream impacts but currently 13 river or stream segments are assessed as having impacts from hazardous waste sites.

Summary of Agency's Key Strategies that Address Activity

Legacy effects

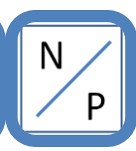
- Support studies that identify appropriate methods for sealing phosphorus into lake bottom sediments. Implement appropriate methods when new loads to the waterbody are sufficiently reduced to maintain appropriate trophic level for waterbody.

Landfills and hazardous waste sites

- Maintain database on hazardous waste sites

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheets, including:

13. Climate Change and Surface Waters

The impacts of climate change on water quality are an emerging issue for Vermont to address. There is general consensus among the scientific community that changing climatic conditions are the result of increased levels of greenhouse gas concentrations in the atmosphere over the last century – much of which are due to anthropogenic sources including industrial processes, combustion of fossil fuels, and landuse changes.

It is also recognized that climate change can affect air and water temperatures and precipitation patterns, which will cause alterations to water quality, hydrology and water availability, resulting in impacts to ecological integrity, and human infrastructure. Higher surface water temperatures reduce levels of dissolved oxygen, creating a condition of hypoxia, disrupting life cycle thermal cues, and directly affecting organism metabolic rates, all of which can be harmful to aquatic life. Additionally, climate models for the northeast predict changes in hydrologic conditions, brought on by a greater frequency of extreme precipitation events, reduced snowpack, and drought conditions. The US Global Change Research Program's *The New England Regional Assessment of the Potential Consequences of Climate Variability and Change*, published in 2006, reports that New England is expected to experience increases in periodic drought and flooding, with an increase in regional precipitation by as much as 30%. The heightened frequency of severe precipitation events could increase pollution and sedimentation from runoff and geomorphic instream channel adjustment. Greater runoff, coupled with expansion of impervious surfaces, could acerbate flood risk and contamination from the overload of stormwater and wastewater systems.

Higher air temperatures and increases in the frequency of periodic drought will lead to greater demand for new and more reliable water supplies, which, in turn, could cause further impacts to surface water quality, ecosystem functions of wetlands, riparian areas, and floodplains, and natural stability of the state's river systems. Climate change is also thought to foster shifts in native natural communities' makeup and range, greater influx of non-native invasive species, a greater frequency of cyanobacterial blooms.

We could also expect significant and costly impacts to infrastructure, including dams, bridges, culverts and road ditches, roads, embankments, and stormwater systems, which could raise serious concerns for public safety. In fact, flooding associated with the failure of dams and undersized stream crossing structures are the most common cause of flood-related fatalities in Vermont.

One of the bigger challenges in confronting climate change impacts to such infrastructure concerns the issue of "non-stationarity" – that is, the understanding that the magnitude, timing, and pattern of rainfall, runoff, and streamflow will be different from what is shown in the historical record. Engineering methods and runoff assumptions rely on historical precipitation and hydrologic data, including design, sizing, and operating parameters for stormwater treatment, floodplain mapping, and bridges and culverts. Stationarity implies that the future is statistically insignificant from the past, and therefore, that the historical record is the best guide to expectations in the future. If the impacts of climate change on hydrologic variables mean that historical data are becoming less representative of future conditions, additional uncertainty will need to be incorporated into the design and operating parameters of stormwater and other infrastructure. In the short term, Vermont will take steps to incorporate more recent hydrological and precipitation data into design calculations and runoff modeling, such as the Northeast Regional Climate Center's update to extreme rainfall intensity duration curves, expected to be made available in 2010.

Figure 7 summarizes the frequency of major flooding and associated damages in Vermont from 1955 through 2008. Note the dramatic increase in the number of damage-causing flood events in more recent years. Certainly, the increase in frequency of flood damage could be attributed to greater development in flood-prone areas, as well as chronic instability from historic and current channelization practices, such as channel straightening, dredging, bank armoring, and berming. A climatic shift in extreme precipitation events may also be having an effect. A closer evaluation of hydrologic and precipitation data will be necessary in order to more effectively isolate the impacts of climate change.

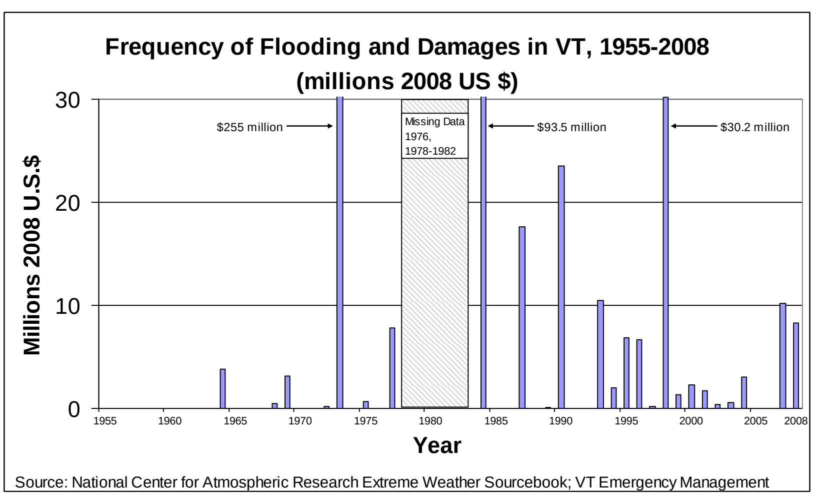


Figure7: Frequency of Flooding and Magnitude of Damages in VT

Summary of Agency's Key Strategies that Address Activity

- Monitor to collect data on water resources: Maintain and expand river gauging network to monitor trends in streamflow
- Develop and implement a statewide climate change plan.

For more in-depth information follow the links below:

- Toolbox for activity
- Stressor factsheets, including: