What is Flow Alteration?

Flow alteration is any change in the natural flow regime of a river or stream or water level of a lake or reservoir induced by human activities.

As illustrated below, five components of the natural flow regime are now recognized as requiring protection to maintain healthy river and lake ecosystems (Figure 1). They are:

- Magnitude – the amount of water flowing in the stream at any given time;
- Frequency – how often a given flow occurs over time;
- Duration – the length of time that a given flow occurs;
- Timing – how predictable or regular a given flow can be expected to occur;
- Rate of change – how quickly flows rise or fall.

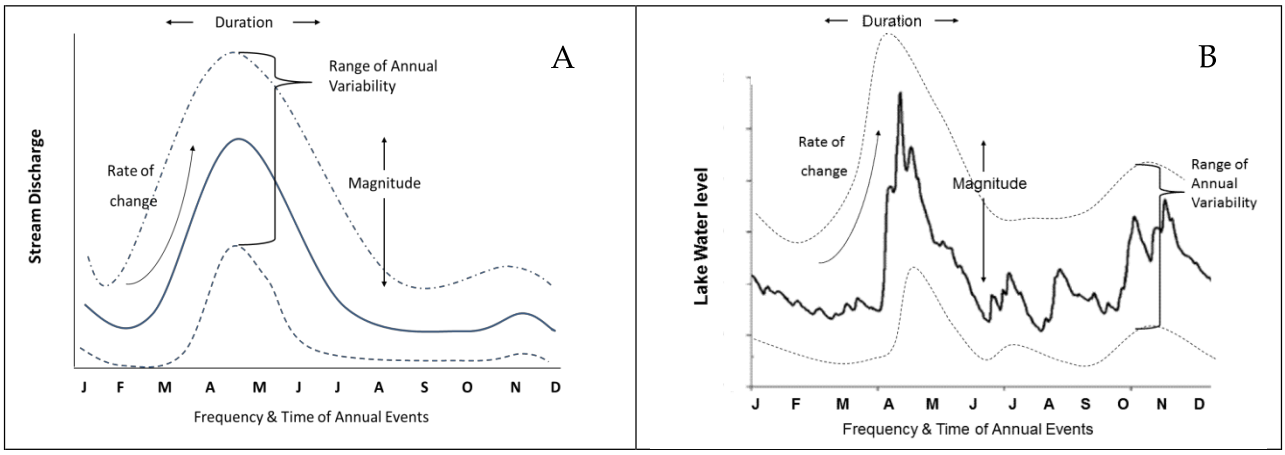

Figure 1: Hydrographs of a river (A) and lake (B) that illustrate the general seasonal pattern and the variability seen in Vermont rivers and lakes, with increased streamflow and water level in the spring followed by receding levels in the summer and an increase in streamflow and water level in the fall.

A natural flow regime refers to a range that each of these five components can be expected to fall within due to the variability of precipitation and other natural hydrologic processes. Significant flow alteration can push these components of flow outside the expected range, leading to environmental degradation. Climate change is another potential driver of shifting flow regimes, and must also be considered in a well-informed approach to addressing flow alteration. These same five components influence lake water level and changes from the natural condition in one or more of these components affect the health of lake ecosystems.

In rivers and streams, the flow regime is considered a 'master variable' that determines the stream form, habitat suitability and ecological function. The flow regime significantly affects the type and amount of habitat and the diversity and abundance of

species that can utilize that habitat. This stressor chapter is focused on the habitat and water quality impacts associated with instream structures and practices that alter the natural flows or water levels (i.e., activities that obstruct, dewater, or artificially flood aquatic and riparian habitats). Altering flows can also have a negative impact on temperature and water chemistry (e.g., pH, dissolved oxygen, and toxicity), which may significantly lower habitat suitability for certain aquatic organisms. Flow regime alterations from increased runoff, such as stormwater, are addressed in the discussion on channel erosion, as are those dams that alter channel morphology and sediment regimes and create an obstruction to aquatic organism passage, but do not alter instream flows or create significant impoundments.

While rivers are much more dynamic than lakes, these systems also have annual cycles to which the plants and animals that inhabit them have adapted. Lake levels naturally fluctuate over the course of the year with higher levels in the spring and often gradually lowering water levels as the summer progresses. In lakes with natural outlets, rapid changes in water level are typically limited to small lakes during severe storms. In these cases, a rapid rise is usually followed by a more gradual decline back to a seasonally normal level. Rapid or frequent lowering of water levels is not normally found in natural systems. Some reservoirs are operated with substantial dewatered zones at various times of the year, depending on uses such as hydroelectric power or flood control.

Many Vermont lakes have a dam on the outlet which has raised the water level of a natural lake between 3 and 10 feet. In some cases, the water level may be drawn down, for varying reasons, in the fall and possibly through the winter. This creates an area of littoral zone exposed to freezing and results in change to the habitat and biota in that area. The consequences of unnatural water level fluctuations in lakes and reservoirs on the ecosystem can be significant. Most immediate is the exposure and stress or death of animals that lack the mobility to move down with the water: mussels, macroinvertebrates, small fish and fish eggs. Any species that have already hibernated may be unable to move. Aquatic plant communities in the dewatered zone can also be degraded, as can wetlands associated with the lake. When native plant communities are killed by drawdowns, often the first species to recolonize those areas are invasive ones. The end result can be a zone bordering the lake that lacks healthy littoral (shallow water), riparian and wetland communities. The extent of this zone depends on the magnitude of the drawdown and the relative slope of the lakeshore and littoral zone. These same dewatered littoral areas have been identified as zones in which atmospherically-deposited mercury may readily be converted to the more toxic methylmercury that is created in dewatered littoral zones and flushed into waters when water levels rebound, subsequently accumulating in fish tissue. This phenomenon has been documented by scientists in numerous research areas and helps explain why fish mercury contamination is more severe in managed reservoirs than in natural lakes. Mercury contamination in fish has consequence for wildlife that rely heavily on fish for their diet (loons, eagles, osprey, otters), and for people who regularly consume fish.

The importance of Flow Alteration as a stressor

Based on the Watershed Management Division's evaluation, flow alteration (including impoundment and dewatering) is a moderately ranked stressor. The effects are usually localized in scale (individual stream reaches, lakes, impoundments, or dewatered wetland areas), but in some cases, they may be evident for miles downstream. Further, flow alteration effects may be numerous on the landscape, so the cumulative impacts can be significant at a watershed level.

Where present, flow alteration is an intensive stressor that moderately to severely degrades aquatic habitat and biota. The most recent statewide water quality assessment indicates that biological condition does not meet water quality standards in over 6,000 acres (~11% of inland lake acres) of lake waters due to flow alteration, while a further 4,400 acres (~8% of inland lake acres) exhibit stress. While the number of lakes that are drawn down is relatively small, the practice tends to occur on larger lakes, increasing the area that is impacted. Further, drawdowns affect a significant amount of the ecologically important littoral zone in the state. This is because many of the largest impounded lakes may also have large stretches of intact riparian vegetation and habitat, but exhibit degraded littoral habitat due to drawdowns. For streams, the biological condition fails to meet water quality standards in over 206 miles (~4% of biologically assessed streams) due to flow alteration, while a further 70 miles exhibit stress.

What objectives are achieved by managing Flow Alteration?

Addressing and preventing flow alteration promotes several surface water goals and objectives, including:

Objective A. ***Minimize Anthropogenic Nutrient and Organic Pollution*** **–** Depending on the nature of the flow alteration, channel and shoreland stability and the integrity of adjacent floodplain function may be affected. Impoundments may become eutrophied from land runoff, accelerated shoreland erosion, and tributary loadings, and fluctuating waters levels can result in repeated re-suspension of bottom sediments. Sediment flows are disrupted in river impoundments; "starving" downstream reaches of sediment and leading to major channel incision and disequilibrium. Addressing channel erosion and curtailing new instream impoundments will help to reduce nutrient and organic loadings.

Objective B. ***Protect and Restore Aquatic, and Riparian Habitat*** – The magnitude, frequency, duration, and timing of flow are dominant factors in riverine ecosystems. The natural fluctuation of water levels in Vermont lake systems are typically small and happen gradually. Alteration of the natural flow and water level patterns may result in direct stress to aquatic organisms and may alter the chemical and physical aspects of aquatic and riparian ecosystems to the point where native species richness, abundance and distribution decline. Dams and water withdrawal structures create habitat discontinuity, restricting the movement of migratory and resident fish and other organisms. Riparian and littoral community integrity is compromised.
Further, in lakes and reservoirs, erosion of the dewatered sediments can occur. Water quality may be affected when intake structures draw water from the surface (elevating temperature) or the bottom of the impoundment (decreasing dissolved oxygen).

Objective C. ***Minimize Flood and Fluvial Erosion Hazards*** - Discontinuity in the sediment regime above and below an impoundment may lead to channel instability and erosion hazards in rivers and streams. The untimely release of water at dams to relieve upstream flooding during high flow events can exacerbate downstream flooding and erosion. Dams may significantly alter the floodway and inundation floodplain by changing the surface water profile during floods. The maintenance of natural water levels in lakes supports the maintenance of healthy aquatic plant beds that dampen the erosive energy of waves and unusual high water events.

Objective D. ***Minimize Toxic and Pathogenic Pollution, and Chemicals of Emerging Concern*** - Research shows that dewatered sediments in reservoirs result in elevated mercury levels in the water and biota. As such, flow alteration can exacerbate mercury contamination in managed waters.

What are the causes and sources of Flow Alteration?

In this stressor chapter, flow alteration, including water level manipulation, has five principal causes:

1. water withdrawals for water supply, snowmaking, industrial uses or agriculture;
2. hydroelectric power;
3. flood control;
4. manipulation of lake and reservoir water levels to support certain recreational uses or manage adjacent infrastructure; and
5. Anthropogenically driven climate change.

These causes stem from construction and operation of dams or other in- stream structures. Further information about the causes and resulting effects of flow alteration may be found in Appendix C.

Monitoring and assessment activities addressing Flow Alteration

Existing monitoring and assessment activities that focus on the causes and effect of flow alteration are listed below. Full descriptions of the programs that carry out these activities may be found in the State Monitoring and Assessment Strategy and in Appendix D. (the toolbox)

- Stream geomorphic assessments
- Vermont Dam Inventory
- River corridor planning
- Floodplain mapping
- Dam safety inspections
- Basin assessment and TMDL planning
- Biological monitoring
- Streamgaging (USGS)
- Fish and wildlife assessments

Key Monitoring and Assessment Strategies to Address Flow Alteration

- Develop a GIS-compatible water withdrawal inventory database that incorporates information on all water withdrawals throughout the state (including those that are *de minimis*) to support analysis of their cumulative impacts on a watershed.

- Develop analytical tools that use the water withdrawal inventory and existing Vermont Dam Inventory, water quality, biomonitoring, wetland, geomorphic and floodplain data in Agency GIS systems to enhance river corridor and basin planning capabilities for use by technical assistance, regulatory and funding programs of ANR and other agencies.

- Maintain and expand a lake level and streamflow gaging network to enable hydrologic monitoring and modeling at in-lake, river reach and watershed scales. The network should include both reference and treatment sites. This strategy is not only important to setting conservation flow and maximum drawdown requirements, but also in assessing the cumulative impacts of lake-level fluctuations and flow alterations within a sub-watershed and in characterizing hydrologic regimes of reference waters identified for monitoring the effects of climate change. Data collection at high elevation sites is essential for an improved understanding of upland hydrology and the Division's ability to protect some of the most at-risk ecosystems in Vermont.

Finally, continued collaboration and support of stream gages maintained by the U.S. Geological Survey is necessary to monitor flows to impaired waters and adequately execute the TMDL process, as federally mandated by the Clean Water Act.

- Provide all relevant data on-line and develop web-based analytical and reporting tools (including maps) to help:
  1. place streams and lakes on the physical/biological condition gradient;
  2. analyze the full suite of flow alteration causes;
  3. analyze the cumulative impact of *de minimis* water withdrawals
  4. identify and prioritize flow protection activities;
  5. conduct alternatives analysis for regulating flow alterations;
  6. evaluate the effectiveness of management actions; and
  7. conduct trend analyses for the development of flow protection BMPs.

Technical assistance programs addressing flow alteration

Existing programs that provide technical assistance in various aspects of managing the causes and sources of flow alteration are listed below. Full descriptions of these programs may be found in Appendix D (the toolbox).

- Streamflow Protection Program
- Vermont Dept. of Fish and Wildlife – Fisheries Division
- Vermont Dam Task Force
- Dam Safety Program
- U.S. Fish &Wildlife Service
- River Corridor and Floodplain Management Program
- Lakes and Ponds Section
- Monitoring, Assessment and Planning Program

Key Technical Assistance Strategies to Address Flow Alteration

- Maintain technical expertise in hydrology to serve multiple programs within the Watershed Management Division.

- Develop and maintain technical expertise to address water level fluctuation and a strategy to stabilize lake water levels to mitigate those impacts.

- Develop and maintain the capacity to technically assist landowners, municipalities, technical consultants, agencies, and organizations in the:

  a. design and execution of data collection and analytical methods necessary to understand flow alteration causes at the appropriate temporal and spatial scales; and,

b. feasibility analysis of hydroelectric power and water withdrawal projects, based on both *a priori* and project-related river assessment and planning.

- Develop and maintain capacity in the private sector to provide hydrology and engineering expertise to proponents of flow alteration activities. This strategy involves training on the State's conservation flow and antidegradation requirements, which may create more efficiency during the regulatory process when proponents select alternatives consistent with the flow and water withdrawal procedures.

- Develop and maintain outreach materials about the impacts that anthropogenic water level fluctuations have on lake ecosystems.

- Develop and maintain the capacity to assist dam owners in the removal of structures that no longer serve a useful purpose.

- Work cooperatively with the Department of Public Service to analyze the potential for hydroelectric power development in Vermont to better inform statewide energy planning.

Regulatory programs addressing flow alteration

Existing programs that regulate flow alteration activities are listed below. Full descriptions of these programs may be found in Appendix D.

- Section 401 Water Quality Certifications
- Section 404 permits
- ANR streamflow procedure
- ANR's Environmental Protection Rules, Chapter 16, Snowmaking
- Act 250/248 permits
- WSMD water level rules for lakes
- 10 V.S.A. Chapter 41 §1003
- 10 V.S.A. Chapter 43
- Stream Alteration Permits
- Flood hazard area regulations

Key Regulatory Strategies to Address Flow Alteration

- Develop and maintain the regulatory and enforcement capacity, using adopted rules and procedures, to exercise the State's jurisdiction over flow alteration activities, including:
  - FERC jurisdictional and non-jurisdictional hydroelectric power projects
  - Water withdrawals including inter-basin transfers
  - Lake level management and the regulation of winter drawdowns

- Run an efficient regulatory program which maximizes the degree to which environmental impact and economic feasibility of flow alteration projects have been vetted before project proponents submit proposals for state technical assistance and regulatory review.

- Develop and maintain an integrated approach to flow management, stream alterations and lake and reservoir water level management. This strategy involves the inclusion of fluvial geomorphic science and objectives with respect to physical integrity and stream equilibrium into the regulation of water withdrawals and hydroelectric power projects. Science from biological and aquatic habitat assessments will also be used.

Funding programs addressing flow alteration

Funding programs that address flow alteration are listed below. Full descriptions of these programs may be found in Appendix D.

- USFWS habitat restoration funds
- Supplemental environmental projects funded through enforcement actions
- State unsafe dam fund
- Ecosystem Restoration Program (ERP)
- Connecticut River Mitigation and Enhancement Fund

Key Funding Strategies to Address Flow Alteration

- Develop and maintain a reliable source of funding to support high priority dam removal projects.

- Develop stable and sustainable sources of funding for the USGS streamgaging program.

Information and education programs addressing flow alteration

Existing programs that inform and educate the general public about the causes and effect of flow alteration are listed below. Full descriptions of these programs may be found in Appendix D.

- Streamflow Protection Program
- Monitoring, Assessment and Planning Program
- Lakes and Ponds Section
- Fish and Wildlife Department
- American Rivers
- Trout Unlimited
- River and lake groups

Key Information and Education Strategies to Address Flow Alteration

- Develop an information and education program that addresses the following topics:
    1. the importance of protecting streamflow and natural lake water levels to healthy river, lake and wetland systems and the provision of ecosystem services and other benefits that result;
    2. the impacts of dams, hydroelectric projects and water withdrawals on lake, river and wetland ecology and ecosystem services; and
    3. the true costs and benefits of hydroelectric power development in the context of a shift toward renewable energy sources, the characteristics of projects that would be considered low-impact.

- Partner with other government agencies (federal, state, local), non-governmental organizations and the private sector to enhance our educational efforts.

- Adopt a marketing approach to our information and education efforts that will engage the public and policy makers, enhancing our ability to deliver the facts in a compelling manner.

- Use social media and other 21st century communication approaches to reach multiple audiences, especially youth and young adults.

- Develop and maintain the State Surface Water Management Strategy as an interactive website where people can get information about how the State is dealing with stressors such as flow alteration, but also provide input on the policies and programs developed to address the stressor.