VERMONT STRONGER

2023 Vermont State Hazard Mitigation Plan

Making Vermont safer and more resilient as we prepare for climate change and natural disasters

VERMONT Emergency Management

Plan Prepared by: Vermont Emergency Management

I: EXECUTIVE SUMMARY

Hazard mitigation is any sustained action that reduces or eliminates long-term risk to people and property from natural hazards and their effects.

The 2023 Vermont State Hazard Mitigation Plan (SHMP) presents the natural hazard impacts most likely to affect Vermont, an assessment of our vulnerabilities, and a mitigation strategy to reduce or eliminate our most significant risks. The 2023 Plan accounts for both observed and projected hazard impacts and accounts for changes in population and development. This Plan places a special focus on how hazards affect people beyond loss of life and property damage to account for quality of life and impacts to our frontline communities.

Mission: to protect life, property, natural resources and quality of life in Vermont by reducing our vulnerability to climate change and natural disasters.

This SHMP is an update to the 2018 Plan, both in the content of the Plan document and its mitigation actions. Vermont Emergency Management, along with key stakeholders, completed a thorough review of the 2018 SHMP at the beginning of the update process to ensure that nothing developed in previous versions would be lost. The most significant changes from the 2018 SHMP are a stronger focus on people and a more thorough review of vulnerabilities, including compounding hazards and their impacts on the natural environment, built environment, economy, and people.

The impact of anticipated yet unpredictable natural events can be reduced through community planning and implementation of cost-effective hazard mitigation efforts.

The State of Vermont understands that it is not only less costly to reduce vulnerabilities to disasters than to repeatedly repair damage, but that we can also take proactive steps to protect our economy, environment, residents, and visitors from inevitable natural hazard events. This Plan recognizes that communities have the opportunity to identify mitigation strategies during all phases of emergency management (preparedness, mitigation, response, and recovery) to more comprehensively address their vulnerability. Though hazards themselves cannot be eliminated, Vermonters can reduce vulnerability to hazards by improving overall understanding of both the natural hazards we face and their potential impacts.

Audience and Use:

The 2023 Vermont SHMP has been developed to help the State of Vermont and local governments identify all natural hazards facing our communities and establish actions that reduce risk. The planning process for this update was much broader than previous mitigation planning efforts in order to better integrate the work of State agencies with those of regional and local governments, as well as nonprofit and private partners. The SHMP will serve as a resource for State agencies and other resilience stakeholders to better understand Vermont's exposure to natural hazards and collectively implement actions that reduce our vulnerability.

While Vermont Emergency Management (VEM) produced this Plan, a large network of stakeholders across Vermont have worked together to develop the capability inventory and actions. Accordingly, few of the actions in the 2023 SHMP fall solely on VEM to implement; most will require ongoing, concerted engagement by multiple stakeholders over the next five years.

This Plan is also intended to be a valuable resource for Local Hazard Mitigation Plan (LHMP) development. The capabilities list and disaster history spreadsheet are examples of resources that can be pulled directly from the SHMP for use in LHMPs. Further, several of the mitigation actions in this Plan aim to simplify the LHMP development process.

THE PROCESS

Vermont Emergency Management (VEM) was the lead agency responsible for updating the 2023 Vermont SHMP. The SHMP update process involved three primary groups: the Planning Team (comprised of VEM and VEM's supporting contractor, **SWCA Environmental Consultants** (SWCA)), the **State Hazard Mitigation Planning and Policy Committee** (SHMPPC), and the **State Hazard Mitigation Plan Steering Committee** (Steering Committee).

Hazard Mitigation staff at VEM (Ben Rose, Recovery and Mitigation Section Chief, Stephanie Smith, State Hazard Mitigation Officer, and Caroline Paske and Brian McWalters, Hazard Mitigation Planners, Matthew Hand and Hanna Pecora, VEM Interns) were responsible for managing the planning process and development of

Photo Credit: Stephanie Smith, VEM

the 2023 SHMP. SWCA was responsible for planning and helping VEM to implement stakeholder engagement related to the Plan, including SHMPPC and Steering Committee meetings, surveys, interview guide, workshops, facilitating Steering Committee review of the draft Plan, and public webinar introducing the updated Plan. For more information on Plan development, see: Planning Process.

Table 1: State Hazard Mitigation Planning & Policy Committee	
Secretary Kristin Clouser	Agency of Administration
Deputy Secretary Douglas Farnham	Agency of Administration (alternate)
Secretary Julie Moore	Agency of Natural Resources
Secretary Lindsay Kurrle	Agency of Commerce and Community Development
Secretary Joe Flynn	Agency of Transportation
Commissioner Jennifer Fitch	Buildings and General Services
Secretary Anson Tebbetts	Agency of Agriculture, Food and Markets
Commissioner June Tierney	Public Service Department
Secretary Jenney Samuelson	Agency of Human Services
Director Erica Bornemann	Vermont Emergency Management
Director Eric Forand	Vermont Emergency Management

The SHMPPC was composed of State agency and departmental leadership that are involved in decision making and implementation related to hazard mitigation. The SHMPPC provided high level guidance and oversight to ensure the SHMP process and plan content aligned with other state-level mandates, policies, and programs. SHMPPC and Steering Committee members noted here were involved during plan development.

Table 2: State Hazard Mitigation Plan Steering Committee	
Alyssa Sabetto	Windham Regional Commission
Andrea Wright	Agency of Transportation
Ben Dejong	Agency of Natural Resources (State Geologist)
Ben Rose	Vermont Emergency Management
Bill Jordan	Public Service Department
Bronwyn Cooke	Agency of Commerce and Community Development
Jared Ulmer	Department of Health (Heat & Climate)
Jason Gosselin	Agency of Human Services
John Broker-Campbell	Agency of Natural Resources (Rivers Program)
Karen Horn	Vermont League of Cities and Towns
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Samara Coble	Vermont Disaster Recovery Fund
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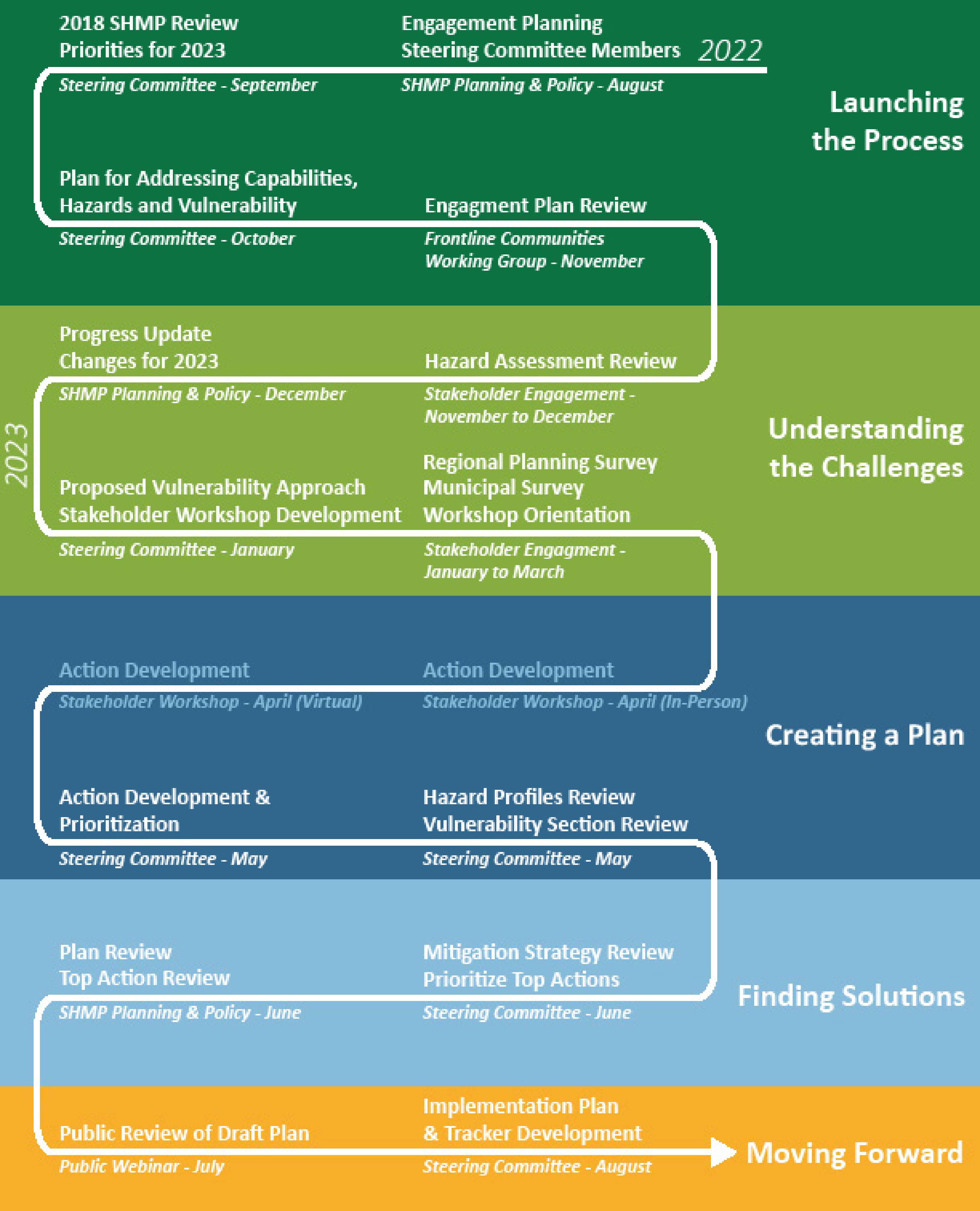

Figure 1: 2023 Vermont SHMP - Stakeholder Engagement Process

KEY CAPABILITY IMPROVEMENTS

This Plan conveys an array of mitigation capabilities that exist within Vermont. The capabilities section and its extensive inventory address the improvements of existing capabilities as well as new capabilities that have been developed since the 2018 SHMP. The most significant improvements or additions to Vermont's mitigation efforts are identified below. For information on all capabilities identified through this process, see: State & Local Capabilities.

Funding Hazard Mitigation:

Funding available in Vermont to complete hazard mitigation activities was unprecedented in 2022 across programs, including FEMA's Hazard Mitigation Assistance (HMA) programs as well as the State's new Flood Resilient Communities Fund (FRCF) at a total of $36.9 million. Funding available exceeded the $34 million available following Tropical Storm Irene.

As a top priority from the 2018 Plan, the **Flood Resilient Communities Fund** (FRCF) has filled gaps in project eligibility under **FEMA's Hazard Mitigation Assistance** (HMA) grants.

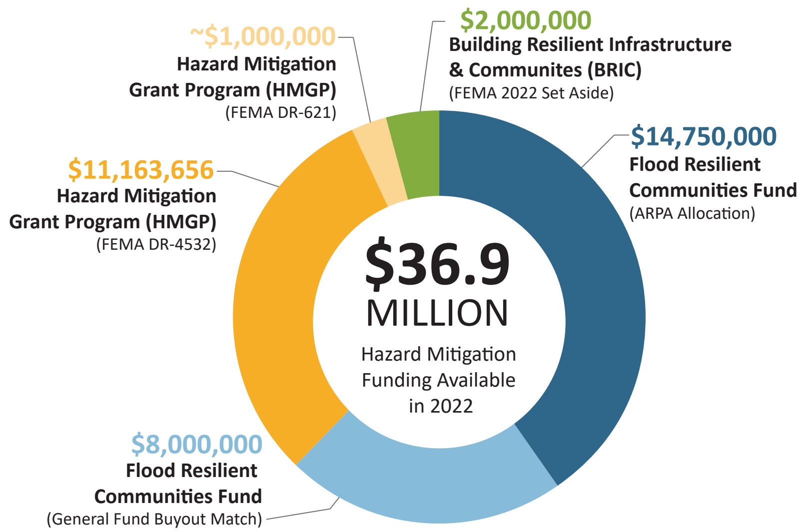

Figure 2: Hazard mitigation funding available in 2022

With a focus on Vermont's erosion risk, the FRCF addresses public safety and water quality concerns posed by climate-related flood hazards through landscape and community resilience measures across Vermont. FRCF prioritizes projects that are not eligible under HMA, to reduce inequity within the HMA programs and to better address flood risk in Vermont. The program aims to leverage other funding sources or filling funding gaps to make projects viable, with a specific focus on buyouts of flood vulnerable properties and floodplain restoration.

As a new funding opportunity that has streamlined the process associated with HMA, FRCF has enabled hazard mitigation funding to reach communities and individual flood-vulnerable households quicker and with a reduced administrative burden. A wider array of applicants are eligible for the program, including non-profits, which has allowed projects to be funded in communities that would not be able to manage a FEMA grant. The seed funding to create this program is from the American Rescue Plan Act (ARPA) and funding is required to be obligated by the end of calendar year 2024 and spent by the end of calendar year 2026. It is a top priority of the 2023 SHMP to establish a permanent state fund to continue hazard mitigation work outside of FEMA eligibility and beyond ARPA.

Vermont Emergency Management

Vermont Department of Environmental Conservation Watershed Management Division

Flood Resilient Communities Fund

Building watershed resilience in the face of climate change

Since Tropical Storm Irene, Vermont has been proactive in addressing vulnerabilities to natural hazards. Through various funding sources, VEM has facilitated the acquisition and demolition of nearly 170 flood-vulnerable properties. Most notably, through coordinated efforts with the State, regional and local project developers, Vermont has been prioritizing larger mitigation initiatives that more comprehensively address vulnerability, like floodplain restoration efforts in Middlebury, Cambridge, and Brattleboro.

In the wake of the COVID-19 pandemic considerable **Hazard Mitigation Grant Program** (HMGP) funding was made available under DR-4532, totaling $11.2 million. The magnitude of COVID-19 disaster declaration substantially increased the capabilities of the HMGP program allowing for numerous projects to receive funding that would not have been available before the disaster declaration. These projects tackled a variety of vulnerabilities including floodplain restorations, property buyouts, dam removals, generators, and infrastructure improvements – increasing resiliency throughout the State.

All HMA programs require a non-federal match, typically 25%, though this match requirement can be lowered for certain communities or funding rounds. The **Building Resilient Infrastructure and Communities** (BRIC) program, for example, allows communities that meet FEMA's definition of Economically Disadvantaged Rural Communities (EDRC) to apply for a 90% federal share. The yearly BRIC program has greatly improved in both flexibility and adaptability over its predecessor, the Pre-Disaster Mitigation program. The State has been provided with more regularity in available funding with consistent increases in the state set-aside in recent years from $600,000 in FY 2020 to $1 million in FY 2021 to $2 million in FY 2022.

Landslide buyout project in Rockingham, VT with funding through the Flood Resilient Communities Fund
Photo Credit: Town of Rockingham

This increase has been valuable for Vermont as it allows for flexibility in the submission of a variety of scoping and planning activities. However, Vermont may have a hard time accessing competitive BRIC funding over this set-aside based on the competitive criteria to-date, which significantly prioritizes funding for states with statewide commercial and residential building codes. While Vermont does have a commercial building code, there has historically not been broad political support for a statewide residential building code, placing Vermont at a significant disadvantage for competitive BRIC funding.

In 2021 and 2022, the Vermont Legislature obligated around $1 billion under the **American Rescue Plan Act** (ARPA). Broadly, funding was invested in broadband infrastructure, clean water, climate action, housing, and economic development. Many of these projects have co-benefits of reducing future risk from natural hazards in Vermont. Additionally, funding was made available to municipalities – the bulk of which functions as State dollars and can be used towards matching of federal funds.

The recent **Infrastructure Investment and Jobs Act** (IIJA) of 2023 has provided additional federal funding to the State through several different programs that aim to tackle resiliency and hazard mitigation in some of Vermont's most vulnerable built assets. The new **Promoting Resilient Operations for Transformative, Efficient, and Cost Saving Transportation** (PROTECT) program will be used to fund upgrades and resiliency projects to transportation infrastructure. The IIJA also allocates dam resilience funding through the Rehabilitation of High Hazard Potential Dams Program aimed at assisting the State in the upkeep and rehabilitation of eligible dams.

Planning & Interagency Coordination:

The **Global Warming Solutions Act** (GWSA, Act 153) was passed by the Vermont State Legislature to create legally binding greenhouse gas emissions reduction requirements. It directed a new **Vermont Climate Council** to consider opportunities for carbon sequestration through conservation and strategies to help Vermont communities prepare for the impacts of climate change. This Council produced a **Climate Action Plan** that outlines actions for the State to meet its greenhouse gas reduction requirements, increase its potential for carbon sequestration, and to prepare for the impacts of climate change. The Agency of Natural Resources' **Climate Action Office** (CAO) is responsible providing coordination, expertise, and capacity on State-led climate initiatives, as well as the monitoring, assessment and tracking of climate adaptation, greenhouse gas mitigation, and resilience activities needed to fulfill the requirements of the GWSA.

Municipal Vulnerability Index:
The Agency of Natural Resources' Climate Action Office has been in the process of developing a tool called the Municipal Vulnerability Index (MVI). This will be a mapping tool with the goal of identifying where Vermont communities are vulnerable to climate change with a focus on pressures that climate change will place on Vermont's transportation, electric grid, housing, emergency services, and communications infrastructure.

Municipal Climate Toolkit:
Additionally, the Agency of Natural Resources' Climate Action Office is currently working to develop a Municipal Climate Toolkit that will connect municipalities with climate action resources. This toolkit will include resources that cover a broad approach, including public health, frontline and impacted communities, how to support a just transition, and how to reach rural communities.

Act 154 was passed in Vermont in 2022, enacting a statewide **Environmental Justice Policy**. This policy codifies Vermont's commitment to providing resources to environmental justice populations for resilience planning and disasters recovery. The Act directs numerous State agencies to embed environmental justice considerations into their operations through the development of an **Environmental Justice Interagency Committee** as well as an **Environmental Justice Advisory Council**. Agencies will be required to develop community engagement plans focused on environmental justice populations and report annually on their alignment with the policy.

Resources & Tools:

Vermont Agency of Transportation (VTrans) has developed the **Transportation Resilience Planning Tool** (TPRPT) to identify bridges, culverts, and road embankments across the State that are vulnerable to damage from floods, estimates risk based on the vulnerability and criticality of roadway segments, and identify potential mitigation measures. This tool was initially developed for pilot watersheds under the FEMA grant to update the 2018 SHMP. As of 2023, all watersheds have now been completed. A statewide training effort is also underway to educate a variety of users, including VTrans District staff, project designers, local municipalities, and regional planners on how to effectively utilize the TRPT.

The **Functioning Floodplain Initiative** (FFI) is a program headed by Vermont's Department of Environmental Conservation (DEC) to identify areas where nature-based projects can have the biggest impact advancing environmental goals. DEC is currently in the process of rolling out the mapping tool for public use and developing next steps for this tool, to include applications such as the development of priority headwater storage conservation and restoration, as well as a benefit-cost assessment tool specific to Vermont.

Greenway Trail Bridge in Cambridge, VT was replaced and the floodplain restored to reduce future flooding in historic downtown Jeffersonville with funding through the Hazard Mitigation Grant Program
Photo Credit: Seth Jensen, LCPC

HAZARD ASSESSMENT

VEM staff used several methods to identify risks in Vermont, including the evaluation of historical data, consideration of our changing climate trends, and feedback from stakeholders during the hazard assessment process.

A task group composed of subject matter experts from the Steering Committee, VEM, and the National Weather Service ranked natural hazard impacts as part of the hazard assessment process, and the Steering Committee confirmed final scores. Ranking was determined by multiplying the probability of occurrence by an average score for potential impact to the built and natural environments, people, and economy. Specific hazard impacts on the built and natural environments, people, and economy are expanded upon within the Hazard Assessment.

The results of the hazard assessment ranking by the Steering Committee are found in Table 3. As with the previous SHMP, fluvial erosion and inundation flooding continue to be the first and second most significant natural hazards in Vermont, respectively. One of the most significant changes from 2018 is the change in ranking for **heat**. In 2018, heat was ranked in the 6th highest row, and in 2023, heat moved ahead of wind, snow, and ice to be the third ranking hazard for Vermont. For more information on all hazards addressed, see: Hazard Assessment.

Table 3: Hazard Assessment

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Fluvial Erosion	4	4	4	4	4	4	16
Inundation Flooding	4	4	4	4	2	3.5	14
Heat	4	2	4	3	2	2.75	11
Wind	4	3	2	2	2	2.25	9
Snow	4	2	3	2	1	2	8
Ice	3	2	3	3	2	2.5	7.5
Drought	3	1	3	3	3	2.5	7.5
Infectious Disease Outbreak	3	1	4	4	1	2.5	7.5
Cold	3	2	3	2	2	2.25	6.75
Invasive Species	3	2	1	3	3	2.25	6.75
Landslides	3	3	2	1	2	2	6
Wildfire	2	3	3	3	3	3	6
Earthquake	2	2	2	2	2	2	4
Hail	3	1	1	2	1	1.25	3.75

*Score = Probability x Average Potential Impact

Table 4: Hazard Assessment Ranking Criteria

	Frequency of Occurrence:	Potential Impact:
	Frequency of Occurrence: Probability of a plausibly significant event impacting the community or regional scale based on previous occurrences and climate change projections.	**Potential Impact:** Severity and extent of damage and disruption to population, property, environment and the economy
1	Unlikely: <1% probability of occurrence per year.	Negligible: isolated occurrences of minor built or natural environmental damage, potential for minor injuries, health, or well-being impacts, or minimal economic disruption.
2	Occasionally: 1–10% probability of occurrence per year, or at least one chance in next 100 years.	Minor: isolated occurrences of moderate to severe built or natural environmental damage, potential for injuries or health or well-being impacts, minor economic disruption.
3	Likely: >10% but <75% probability per year, at least 1 chance in next 10 years.	Moderate: severe built or natural environmental damage on a community scale, injuries, fatalities or impacts to individual and community well-being, short-term economic impact.
4	Highly Likely: >75% probability in a year.	Major: severe built or natural environmental damage on a community or regional scale, multiple injuries or fatalities or severe long-term impacts to individual and community well-being, significant long-term economic impact.

Snowmobile bridge near Waterbury, VT flexes as debris and water rush past following Tropical Storm Irene
Photo Credit: www.mansfieldheliflight.com/flood

Climate Change:

Warming temperatures, shrinking winters and increasing incidence of intense storm events are beginning to have a significant impact on Vermont's economy, people and environment and require immediate attention across all planning efforts. Accordingly, and as a guiding principle of this Plan, we have aimed to recognize and include the impacts of climate change throughout Plan development, most notably reflected in the hazard profiles and mitigation actions. Both direct and indirect impacts of climate change are addressed within pertinent hazard profiles, as well as the potential for compounding impacts.

An example of a concerning compounding impact of climate change is that warming temperatures (Figure 3) will increase the prevalence of invasive species and infectious disease outbreaks. This invasive species is decimating Vermont's ash population, not only shifting the composition of our forests, but also creating additional debris that may exacerbate impacts of other hazards, such as flooding or wildfire. Extreme heat can result in the disruption of many natural environmental processes, increasing the severity of other hazards. As a result, Extreme Heat has risen to the 3rd most important hazard in the Plan, highlighting the threat that rising temperatures poses to Vermont.

Vermont Average Temperature (1895-2023)

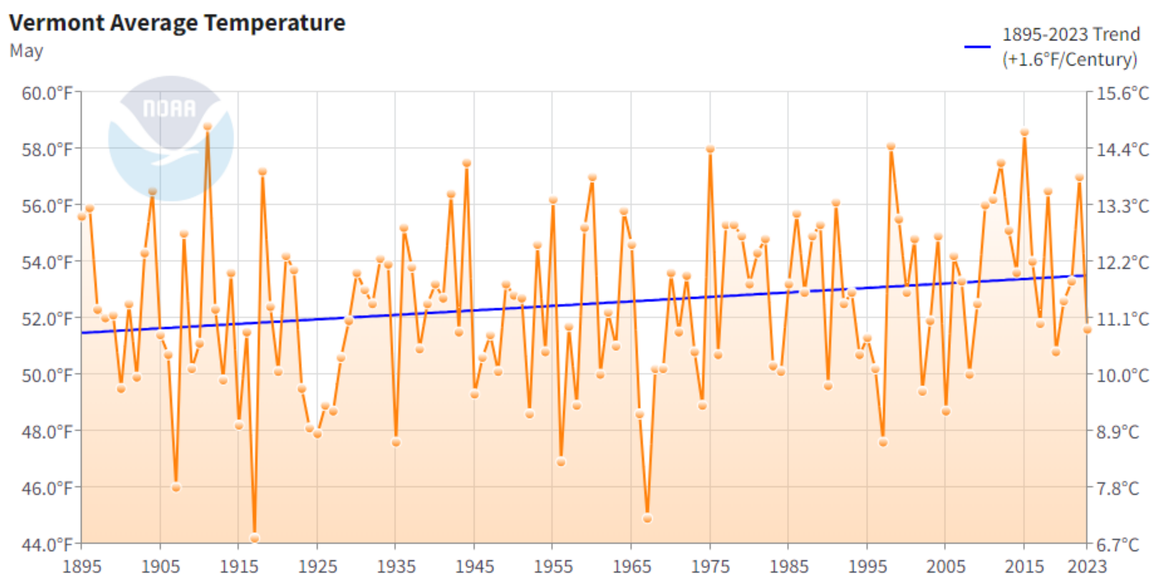

Figure 3: Vermont average temperature (1895-2023)
Data Source: www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/divisional/time-series

Stakeholder engagement session to develop plan actions
Photo Credit: Lisa Kolb, VEM

VULNERABILITY SUMMARY

A significant change from the 2018 Plan to the 2023 Plan was the addition of more in-depth discussions of vulnerability within each hazard profile as well as cross-cutting and compounding hazards. Each hazard profile addresses the impacts of the hazard on people, the built environment, the natural Environment, and the economy. In practice, there is no separating each category as they are each connected with cross-cutting challenges. Many vulnerabilities that are identified within each hazard profile are shared among other profiles, painting a picture of risk and exposure across Vermont. A new Section 5 was added to this 2023 SHMP that summarizes vulnerability across hazards and explores the compounding vulnerabilities observed in the hazard profiles due to the exposure to natural hazards and climate change.

Compounding natural hazards are hazards which may accelerate other hazards. This is not just reserved for hazards that occur simultaneously. A compounding hazard can impact the occurrence of other hazards days, weeks, or months later. Invasive species and extreme heat are two hazards which have been noted to cause major compounding and cross-cutting impacts. Invasive species can accelerate the frequency of landslides, wildfires, and infectious disease outbreaks. Extreme heat has been associated with an increase in drought, wildfire, invasive species, and infectious disease. For more information on vulnerability, see: Vulnerability Summary.

Photo Credit: Town of Huntington

Compounding Social Issues:

Beyond the scope of natural hazards and the potential impacts to the built environment, economy, and the natural environment, Section 5 takes a critical look at the compounding social issues arising from vulnerabilities to people. As the State and municipalities direct planning and funding efforts to adapt to changing climatic conditions concepts of environmental justice are also worked into building a more resilient future. Addressing environmental justice provides the opportunity to connect hazard mitigation, environmental quality, and social equity. As a result, the discussion of vulnerable populations and conditions to natural hazards emphasizes those groups with predetermined risk, such as children, older adults, and the immune-compromised.

Environmental justice acknowledges that the burden of climate change disproportionally falls on low-income, marginalized, and frontline populations. Vermont's Environmental Justice Policy states that environmental justice requires providing a proportional amount of resources for community revitalization, ecological restoration, resilience planning, and a just recovery to communities most affected by environmental burdens and natural disasters. Issues that environmental justice policy seeks to address cover a wide range of topics including housing, food security, economically underprivileged populations, and individual and community well-being.

Additionally, hazards can have far-reaching and complex impacts. As climate change continues to increase the climatological instability of other regions of the United States, Vermont may experience a population influx of "climate refugees." Projected future trends of climate migration illustrate the importance of planning for a possible large-scale increase in population. Affordable housing is an issue that many current Vermont residents are faced with, and as the State welcomes climate migrants, increased demand may push the price of housing higher. The effects of global climate change and local hazards on housing availability, and the related need for safe housing, demonstrates the interconnectedness of hazards with all aspects of our communities.

Local Vulnerability:

Vermont's varied topography and mountainous terrain can result in geographic isolation during storms, in which one town may be severely impacted while a neighboring town remains unscathed. Because of the steep mountain topography, damage from frequently occurring extreme weather events in any specific location may occur often or only once in a lifetime, which makes it difficult to plan for and respond to events. Section 5: Vulnerability Summary identifies the local vulnerabilities that different communities face and works to establish resources for vulnerable communities.

Based on the VEM hazard mitigation planning survey circulated to towns in 2023, upgrading infrastructure and expanded communication before and during disasters are high priorities for better protecting their most vulnerable residents. In order to do this, they not only need funding, but expanded local staff capacity and additional technical assistance. These priorities and needs align with the assessment done through the State hazard mitigation planning process and proposed mitigation strategy.

For more information on vulnerability, see: Vulnerability Summary.

MITIGATION STRATEGY

The Steering Committee, with input from the stakeholder engagement process as noted above, reviewed the 2018 plan actions to develop a mitigation strategy that would be implementable, leverage cross-sector resources and effectively and efficiently reduce Vermont's vulnerability to natural hazards. Below are the actions for this 2023 SHMP, which were retained from the 2018 SHMP:

Protect, restore and enhance Vermont's natural resources to promote healthy, resilient ecosystems.

Enhance the resilience of our built environment – our communities, infrastructure, buildings, and cultural assets.

Develop and implement plans and policies that create resilient natural systems, built environments, and communities.

Create a common understanding of – and coordinated approach to – mitigation planning and action.

In support of these goals, stakeholders developed a significant list of proposed **mitigation actions**. These actions were sorted by goal and then further sorted according to similar themes, called “strategies”. The Steering Committee then prioritized the list of 112 mitigation actions based on each action’s Positive Impact, Negative Impact, and Feasibility. Assessing negative impacts was added during the 2023 SHMP update process to review actual or perceived negative consequences associated with proposed actions. This prioritization process yielded 43 priority actions, which were then further prioritized into the following top ten priorities by the Steering Committee.

Priority Plan Actions:

Utilizing existing FEMA mapping updates and the Functioning Floodplain Initiative, develop an inventory of critical headwater and floodplain storage areas that would result in a measurable abatement of flooding.
Develop a drought plan for Vermont to include analyzing water level/monitoring data to use as predictor of drought and rates of recovery.
Develop a wildfire mitigation plan, to include research on the long-term future risk of wildfire due to climate change, determine existing infrastructure for wildfire suppression, and develop wildfire mitigation options.
Support municipalities in developing a prioritized list of transportation infrastructure improvements that increase resilience using PROTECT and/or other funding sources.
Increase Public Service Department capacity to maximize utilization of available federal dollars (including IIJA, IRA, ARPA, and EDA) towards utility resilience implementation work.
Assess all state/federal funding/technical assistance programs, as well as State permitting programs, to determine areas for better alignment around state hazard mitigation priorities.
Identify sustainable, long-term funding to support hazard mitigation and local match, to include: purchase of hazard-prone properties and easements to conserve river corridors, floodplains, and wetlands identified as key flood attenuation areas.
Complete an assessment of heat risks in urban areas of Vermont and expected impacts on historically disadvantaged populations, identify strategies for mitigating impacts (e.g., urban forestry, green roofs, green infrastructure, and/or other vegetative strategies; increased use of highly reflective and/or high emittance materials for pavement, roofs, and building).
Develop a methodology and protocol for quantifying climate mitigation, resilience, and adaptation impacts (Climate Action Office measuring and assessing progress tool).
Develop an analysis of existing Resilience Hub locations, including identification of new locations, and identification of key components that should be co-located within a Resilience Hub.

The majority of the mitigation actions identified in this Plan require collaboration between multiple organizations. Though this will necessitate significant coordination, we believe it also broadens ownership, and therefore improves the implementation potential of the 2023 SHMP.

For the full list of mitigation actions, including lead entities for implementation, see: Mitigation Strategy.

2: Planning Process

Vermont Emergency Management (VEM) was the lead agency responsible for updating the 2023 Vermont State Hazard Mitigation Plan (SHMP). The SHMP update process involved three primary groups: the Planning Team (comprised of VEM and VEM's supporting contractor, **SWCA Environmental Consultants** (SWCA)), the **State Hazard Mitigation Planning and Policy Committee** (SHMPPC), and the **State Hazard Mitigation Plan Steering Committee** (Steering Committee).

Hazard Mitigation staff at VEM (Ben Rose, Recovery and Mitigation Section Chief, Stephanie Smith, State Hazard Mitigation Officer, and Caroline Paske and Brian McWalters, Hazard Mitigation Planners, Matthew Hand and Hanna Pecora, VEM Interns) were responsible for managing the planning process and development of the 2023 SHMP, to include: convening various groups and providing logistical support; providing subject-matter expertise in hazard mitigation, planning, and FEMA review; researching and writing the Plan document; and making day-to-day decisions on operations throughout the process. SWCA was responsible for planning and helping VEM to implement stakeholder engagement related to the Plan, including SHMPPC and Steering Committee meetings, surveys, interview guide, workshops, facilitating Steering Committee review of the draft Plan, and public webinar introducing the updated Plan.

Figure 4: 2023 Vermont State Hazard Mitigation Plan process timeline

State Hazard Mitigation Planning & Policy Committee

The SHMPPC is composed of State agency and departmental leadership that are involved in decision making and implementation related to hazard mitigation. The SHMPPC provides high level guidance and oversight to ensure the SHMP process and plan content aligned with other state-level mandates, policies, and programs. This committee was responsible for sending delegates to participate on various groups, staying apprised of the SHMP update process, and making recommendations to the Steering Committee on overall coordination with State government. The SHMPPC will be tasked with implementation of Plan actions that are the responsibility of State government. The Planning Team engaged with SHMPPC members three times over the course of the Plan update process. Initial outreach to kick off the process and gather SHMPPC input took place via email in August, and two subsequent virtual meetings in December and June.

State Hazard Mitigation Plan Steering Committee

Under the direction of the SHMPPC, the Steering Committee was responsible for the high-level decision-making and overall guidance of the SHMP update process. Given the interdisciplinary and cross-sector nature of hazard mitigation work, the Steering Committee included a diverse range of cross-sector partners from across Vermont. The Steering Committee members were chosen with the following goals in mind: to ensure that hazard mitigation efforts beyond State government were incorporated into the Plan update; to better coordinate ongoing hazard mitigation work between State agencies and partners; and to build buy-in, relationships and understanding needed to effectively implement the Plan.

Table 5: State Hazard Mitigation Planning & Policy Committee	
Secretary Kristin Clouser	Agency of Administration
Deputy Secretary Douglas Farnham	Agency of Administration (alternate)
Secretary Julie Moore	Agency of Natural Resources
Secretary Lindsay Kurrle	Agency of Commerce and Community Development
Secretary Joe Flynn	Agency of Transportation
Commissioner Jennifer Fitch	Buildings and General Services
Secretary Anson Tebbetts	Agency of Agriculture, Food and Markets
Commissioner June Tierney	Public Service Department
Secretary Jenney Samuelson	Agency of Human Services
Director Erica Bornemann	Vermont Emergency Management
Interim Director Eric Forand	Vermont Emergency Management

The Steering Committee was comprised of staff from State agencies and other entities who are directly involved in implementing the Plan or managing data relevant to the Plan update process. The Planning Team held six Steering Committee meetings over the course of the Plan update process. During and between meetings, Steering Committee members provided detailed review and guidance on Plan content as well as data, information, and other key inputs based on their knowledge of hazards, vulnerabilities, capabilities, and implementation of mitigation actions. SHMPPC and Steering Committee members noted here were involved during plan development.

Table 6: State Hazard Mitigation Plan Steering Committee	
Alyssa Sabetto	Windham Regional Commission
Andrea Wright	Agency of Transportation
Ben Dejong	Agency of Natural Resources (State Geologist)
Ben Rose	Vermont Emergency Management
Bill Jordan	Public Service Department
Bronwyn Cooke	Agency of Commerce and Community Development
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Nicole Dubuque	Agency of Agriculture Food and Markets
Samara Coble	Vermont Disaster Recovery Fund
Sarah Phillips	Agency of Human Services (Office of Economic Opportunity)
Tara Kulkarni	Norwich University

The Steering Committee developed the Plan scope and process, assisted in the development of the stakeholder engagement and outreach plan, identified and prioritized hazards for inclusion, approved and assisted in the development of mitigation actions, set the prioritization process for actions, reviewed and approved the Plan document, and as individuals, provided subject matter expertise throughout Plan development. Steering Committee members were appointed by the VEM Director based on recommendations from the SHMPPC.

Planning Process & Plan Development

August 8, 2022 Initial SHMPPC Outreach — Process Planning:

VEM initially engaged the SHMPPC in August of 2022 to inform them of the update process, solicit initial feedback on the 2018 SHMP, appoint members to the Steering Committee, and review the draft engagement plan.

September 14, 2022 Steering Committee — Process Planning & Kick-Off:

The Steering Committee met for the first time in September 2023 to confirm the update process, including review of the stakeholder engagement plan, process and schedule for the plan update, and the role of the Steering Committee. The Steering Committee discussed strengths and areas for improvement from the 2018 SHMP and planning process. This meeting was held virtually with polling and a shared whiteboard.

October 21, 2022 Steering Committee — Capabilities & Hazard Profiles:

In October, the Steering Committee met to confirm the structure for updates to the State & Local Capabilities and Vermont Profile & Hazard Assessment sections, to confirm the current list of capabilities and identify any new capabilities to highlight within the Plan and to confirm the list of hazards to be addressed. The Steering Committee had an initial conversation to brainstorm topics for the new Vulnerability Summary section of the Plan. This meeting was held in-person and virtually with a shared whiteboard.

November 9, 2022 Stakeholder Group — Frontline Community Engagement:

Following the recommendation of the Steering Committee, a focus group was held in November to discuss the incorporation of frontline community perspectives into the development of the Plan. This small group reviewed and provided recommended edits to the engagement plan and provided recommendations for how the plan calculates risk and impact. Out of this conversation came changes to the risk assessment to focus on how quality of life can be impacted by disaster events instead of the narrower view of only injuries and fatalities, and additional engagement efforts to include a town survey directly addressing local vulnerability and concerns as well as direct individual interviews.

Additionally, there were a number of other State planning efforts identified for coordination with the SHMP update. These included the the Climate Action Office Public Engagement Task Group, Public Service Department's public engagement plan to guide a comprehensive review of Vermont's renewable and clean electricity policies and programs for the Comprehensive Energy Plan, and the Department of Environmental Conservation's work with the Center for Whole Communities, Rights and Democracy Institute, and the Vermont Law School Environmental Justice Clinic to produce a report of recommendations on equitable public participation and community engagement[1]. Meetings were held with project managers of these State efforts to identify opportunities for collaboration and to ensure stakeholders would not be overly burdened with multiple State requests for input into planning processes.

November 2022-March 2023 Direct Stakeholder Outreach — Capabilities & Hazard Profiles:

In November, VEM staff began drafting the State & Local Capabilities section, the Vermont Profile & Hazard Assessment section, and the profiles for each hazard. During plan drafting, VEM staff reached out to Steering Committee members as well as other key stakeholders for one-on-one conversations regarding specific sections of the plan. Draft documents were also shared for review and feedback.

1 https://wholecommunities.org/resources-archive/connecting-people-to-power/

Stakeholder engagement session to develop plan actions
Photo Credit: Lisa Kolb, VEM

December 20, 2022 SHMPPC — Progress Check-In:

The SHMPPC met in December and VEM shared its progress updating the Plan to date, specifically that the 2023 Plan will have the same basic structure and approach as in 2018, with some changes to make the Plan stronger, including a focus on improving how the Plan addresses vulnerabilities in more detail within each hazard profile and within a new Vulnerability Summary and greater focus on impacts to people, specifically frontline communities. SHMPPC members shared input and guidance on areas of focus for the Plan, alignment with the Climate Action Plan, and other engagement efforts with which VEM should coordinate. Following this meeting, VEM set up direct conversations to address better coordination between outreach efforts with the Vermont Agency of Transportation, the Department of Environmental Conservation, the Climate Action Office, and the Public Service Department.

January 27, 2023 Steering Committee — Vulnerabilities & Workshop Planning:

In January, the Steering Committee met to review and discuss a proposed approach to addressing vulnerabilities in the Plan, including a proposed set of approaches for incorporating frontline community perspectives into the planning process and Plan content. Additionally, the committee reviewed a proposed approach and sequence of events for workshopping and prioritizing the list of mitigation actions for the Plan. This meeting was held virtually.

April 7 & April 18, 2023 Stakeholder Workshops — Action Development:

The Planning Team held two stakeholder workshop sessions to support in-depth discussion of the mitigation actions as the draft Plan was being developed. In March, prior to the two stakeholder workshops to develop Plan actions, VEM hosted a virtual workshop orientation webinar as an educational opportunity to explain what hazard mitigation is and how stakeholders can participate in the stakeholder workshops.

In preparation for the stakeholder workshops, VEM staff reviewed the 2018 action list and the actions from the Climate Action Plan. 2018 actions that were completed or noted as no longer relevant during our annual action maintenance process were removed, which is noted in Appendix X: Status of 2018 SHMP Actions.

The two stakeholder workshops took place in April 2023, with both virtual and in-person options offered. Attendees reviewed and discussed all the actions from the 2018 Plan and provided updates and suggested changes. VEM sought input on topics to better address during this update cycle, such as climate migration, slow-developing hazards, and frontline communities. Outcomes of these discussions informed the content of the Plan, particularly the new Vulnerabilities Section and the updated list of mitigation actions in the Mitigation Strategy.

May 4, 2023 Steering Committee — Action Development & Prioritization:

In May, the Steering Committee met to go over the feedback received during the stakeholder workshops and review and update the process for prioritizing plan actions. Following this meeting, VEM staff reviewed all feedback received on plan actions and created the first draft of the 2023 SHMP Mitigation Strategy. VEM met individually with key experts and Plan implementers for the various plan strategies in order to finalize edits to the plan actions.

May 9 & May 12, 2023 Stakeholder Group — Hazard Assessment:

The hazard assessment process to update priority hazard rankings for the 2023 SHMP was completed over two stakeholder meetings in May. Participants were selected based on expertise in hazard probability and impacts on the built environment, people, economy, and natural environment – to include several representatives from the Steering Committee, including the State Climatologist and State Geologist, as well as experts from the National Weather Service.

During the hazard assessment stakeholder group meetings, participants determined changes in probability and impacts due to climate change, changes in development and population demographics, and experience with hazards since the 2018 SHMP. Projected changes in location, range of anticipated intensities, frequency and duration of each hazard were determined in the hazard profile update process. The parameters of a plausibly significant event for each hazard ranked was based on historic occurrences of maximum magnitude events in Vermont, climate change projections, and impacts of events observed in similar climates within the United States. The final ranking of hazards is part of the risk assessment process included within the Vermont Profile & Hazard Assessment.

May 31, 2023 Steering Committee — Hazard Assessment & Vulnerability:

At the end of May, the Steering Committee met to review and finalize the hazard assessment based on feedback from the stakeholder group who completed the hazard assessment. Additionally, the Steering Committee reviewed final drafts of the State & Local Capabilities, Vermont Profile & Hazard Assessment, and Vulnerability Summary sections.

June 16, 2023 Steering Committee — Action Prioritization:

The final Steering Committee meeting during Plan drafting was in June 2023. Prior to this meeting, a survey was sent out to the Steering Committee as well as the stakeholders who participated in the action development workshops to solicit feedback on the draft action list. At this virtual meeting, the Steering Committee finalized plan actions and then voted on top plan priorities within the four goal areas. The four goals of the 2023 SHMP are shown below. This prioritization process resulted in the final action list of 112 actions, 43 priorities, and 10 top Plan priorities.

Protect, restore and enhance Vermont's natural resources to promote healthy, resilient ecosystems.

Enhance the resilience of our built environment – our communities, infrastructure, buildings, and cultural assets.

Develop and implement plans and policies that create resilient natural systems, built environments, and communities.

Create a common understanding of – and coordinated approach to – mitigation planning and action.

June 29, 2023 SHMPPC — Draft Plan & Priority Action Review:

In June, the SHMPPC met virtually to review the final Executive Summary and plan action list as finalized and prioritized by the Steering Committee, including the top Plan priorities. The SHMPPC provided edits to both documents and reviewed the full draft plan when it was submitted to FEMA in July for final comments.

July 12, 2023 Public Review— Draft Plan Review:

The Planning Team scheduled one virtual public meeting in July 2023 to report out on the Plan update process, share a summary of the draft SHMP, and seek input on mitigation actions and priorities from the public; however, the meeting was cancelled due to significant flooding in Vermont in early July. The draft plan was posted publicly on the Vermont Emergency Management website following submission into FEMA review on July 28, 2023 through September 15, 2023. One comment was received and incorporated into the plan draft.

Stakeholder Engagement & Outreach

Table 7 below is a consolidated list of organizations who participated directly throughout the process. Participants were engaged through direct outreach, workshops, existing meetings where the SHMP was discussed, through surveys to towns and RPCs, and participation of the SHMPPC, Steering Committee, or hazard ranking task group.

The involvement of stakeholders was vital to this process. Stakeholders included subject matter experts, implementers, and representatives of frontline communities. The goals of stakeholder engagement included:

- To implement a planning process that includes representation from – and builds relationships between – stakeholders in all sectors and groups.
- To make the planning process and Plan documents transparent and accessible to a full range of stakeholders.

The following approaches were used to engage stakeholders and members of the public in the planning process and integrate their input into the Plan.

Surveys:

Surveys were developed to gather information from a wide range of stakeholders. These included:

- A municipal survey distributed to each Vermont municipality via the VEM newsletter and the Vermont League of Cities and Towns (VLCT). The objective of this survey was to gauge local input regarding emerging challenges, vulnerabilities and frontline community needs. Twenty-two (22) responses were received, representing a diverse group of Vermont communities.
- A Regional Planning Commission (RPC) survey was sent to each RPC asking them to coordinate internally and submit one response per RPC. The objective of this survey was to receive regional insight about emerging challenges and needs within their communities. All RPCs responded to the survey.
- A survey link was posted on the VEM website for the duration of plan development and available for anyone to submit general feedback available.

A summary of feedback received from surveys is included within the Vulnerability Summary.

Interviews:

VEM conducted interviews with two individuals that interacted with the State's buyout program to understand more about the experience and perspective of tenants (for whom buyouts are not voluntary) and homeowners who opted not to pursue a buyout. Results of these interviews are featured in the SHMP as case study examples illustrating the impacts of Hazard Mitigation programs on individual Vermonters, and to help identify opportunities to continue improving these programs.

Coordination on High Hazard Potential Dams:

As part of the SHMP 2023 update, VEM coordinated with State and Federal partners involved in dam safety. Between February and March 2022, VEM and VT Dam Safety worked with USACE Silver Jackets representatives to develop and submit a proposal for technical assistance on the SHMP 2023 High Hazard Potential Dams (HHPD) section through the Silver Jackets Interagency Nonstructural FPMS program.

While dams and dam safety were part of the 2018 SHMP, new policy guidance effective in April 2023 introduced new requirements for HHPD to maintain eligibility for the HHPD grant program. Several meetings were held to identify work that needed to be done to meet the new policy guidance and the steps necessary by partner agencies. FEMA was invited to kick-off the process of addressing SHMP HHPD requirements, with representatives from FEMA Region I mitigation planning and dam safety programs.

A review of requirements and existing data showed that work was needed to clarify the Vermont list of HHPDs. USACE was assigned to perform analysis utilizing DSS-WISE on significant hazard dams that may be HHPD depending on potential population impacted in the case of a dam failure. This work was ongoing at the time of SHMP submittal to FEMA for approval.

Direct Engagement with Individuals and Groups:

VEM staff invited partners and individuals throughout the State to be in touch if they were interested in discussing hazard mitigation. This effort started in earnest early in 2023, with a demonstrated willingness for VEM staff to attend local meetings of agencies and community groups around the State, with a particular focus on groups that include and serve frontline communities. The objective is to meet with people where they are and learn more about what Vermonters are noticing about emerging challenges and needs. Meetings where this Plan was discussed during development included:

- Inter-Agency Advisory Board to the Climate Action Office
- Environmental Justice Advisory Council

Environmental Justice Interagency Committee:

Act 154 was passed in Vermont in 2022, enacting a statewide Environmental Justice Policy. This policy codifies Vermont's commitment to providing resources to environmental justice populations for resilience planning and disasters recovery. The Act directs numerous State agencies to embed environmental justice considerations into their operations through the development of an Environmental Justice Interagency Committee as well as an Environmental Justice Advisory Council. These two groups held their first joint meeting on March 10, 2023.

- Interagency Climate and Energy Workgroup (ICEPAC)
- Interagency Meeting to Discuss VT Equity & Municipality Initiatives
- Vermont Conservation District Managers Meeting
- Climate Action Toolkit Development Meetings
- Municipal Vulnerability Index
- VTrans Partners Meeting on the Resilience Improvement Plan (RIP)

VTrans held a meeting with partner agencies including VEM in March 2023 to discuss coordination of the RIP with related State planning efforts. The RIP was being developed to meet Federal Promoting Resilient Operations for Transformative, Efficient, and Cost Saving Transportation (PROTECT) guidance. The purpose of PROTECT is to help make surface transportation more resilient to natural hazards, including climate change, flooding and other natural disasters through support of planning activities, resilience improvements, community resilience and evacuation routes.

These efforts will continue throughout the updating of the 2023 plan, and beyond, understanding that engagement on the front lines of hazard mitigation is an ongoing, iterative process.

Routine Updates via Newsletters & Partner Meetings:

VEM staff continually provided updates on the planning process and opportunities for involvement on the VEM website and through the VEM newsletter, the RPC list-serve, the Resilient Vermont email list, the Flood Ready list-serve, Vermont League of Cities and Towns (VLCT) newsletter, VEM-RPC monthly meetings, and in one-on-one emails to key stakeholders, organizations or expert reviewers. VEM maintained a full list of all participants who were involved or expressed interest at any point and sent out regular updates to that list. Events and news were also shared periodically on Facebook.

In addition to the outreach and stakeholder involvement opportunities listed above, regular updates were given on the planning process at Vermont Silver Jackets' quarterly meetings. Silver Jackets meetings include coordinating Federal agencies USACE, USGS, NWS, and FEMA. VEMA and ANR's Floodplain Manager staff are also in attendance at Silver Jackets meetings. Regular updates were also given at VEM Chiefs' meetings and VEM full-staff meetings.

Implementation Process Planning & Tool

Following adoption of the 2023 State Hazard Mitigation Plan, VEM will continue to work with the Steering Committee and SWCA over the coming months on the development of an implementation tacking tool to assist with plan monitoring and action tracking.

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Table 7: 2023 State Hazard Mitigation Plan Participants	
Addison County Regional Planning Commission	Town of Worcester
Agency of Natural Resources (FPR Wildfire)	Two Rivers-Ottaquechee Regional Commission
Bennington County Regional Commission	United State Army Corps of Engineers
Central Valley Regional Planning Commission	United States Geological Survey
Champlain Valley Office of Economic Opportunity	United States Geological Survey - New England Water Science Center
Chittenden County Regional Planning Commission	University of Vermont
City of Montpelier	University of Vermont - State Climate Office
Climate Economy Action Center of Addison County	Vermont Agency of Administration
Federal Emergency Management Agency - Region 1	Vermont Agency of Agriculture
Lake Champlain Sea Grant	Vermont Agency of Agriculture, Food & Markets
Lamoille County Planning Commission	Vermont Agency of Commerce and Community Development
Mount Ascutney Regional Commission	Vermont Agency of Human Services
National Weather Service Burlington	Vermont Agency of Natural Resources
National Weather Service Albany	Vermont Agency of Natural Resources - Climate Action Office
Northeastern Vermont Development Association	Vermont Agency of Natural Resources - Rivers Team
Northwest Regional Planning Commission	Vermont Agency of Transportation
Norwich University	Vermont Arts Council
Rutland Regional Planning Commission	Vermont Association of Conservation Districts
SWCA Environmental Consultants	Vermont Association of Planning and Development Agencies
Town of Battleboro	Vermont Buildings & General Services
Town of Bolton	Vermont Department of Environmental Conservation - Dam Safety
Town of Bristol	Vermont Department of Environmental Conservation - Geological Survey
Town of Chittenden	Vermont Department of Health
Town of Cornwall	Vermont Department of Public Safety
Town of Danville	Vermont Disaster Recovery Fund
Town of Dover	Vermont Division for Historic Preservation
Town of Leicester	Vermont Emergency Management
Town of Lunenburg	Vermont Fire Safety
Town of Manchester	Vermont Fish & Wildlife Department
Town of Marshfield	Vermont Housing & Conservation Board
Town of Middlebury	Vermont Housing and Conservation Board - Housing
Town of Norwich	Vermont League of Cities and Towns
Town of Orwell	Vermont Natural Resources Council
Town of Panton	Vermont Office of Economic Opportunity
Town of Putney	Vermont Public Service Department
Town of Royalton	Vermont River Conservancy
Town of Tunbridge	Vermont State Historic Preservation Office
Town of Westminster	White River Partnership
Town of Wilmington	Windham Regional Commission
Town of Windham	

3: State & Local Capabilities

FUNDING HAZARD MITIGATION

This section and the corresponding table identify the funding and incentives, tools and data, technical assistance and training, and regulations that influence hazard mitigation in Vermont. Since inundation flooding and fluvial erosion remain the top priority hazards to which Vermont is vulnerable, the majority of State policies and programs aimed at improving mitigation are centered on inundation flooding and fluvial erosion.

Though this section addresses capability-specific areas for improvement, several of the mitigation strategies identified as top priorities in this Plan will result in both improved existing and new capabilities, which is further addressed in the Mitigation Strategy.

Administration of specific programs, including Hazard Mitigation Assistance, Public Assistance, National Flood Insurance Program and Community Rating System are further detailed throughout this section.

Hazard Mitigation Assistance Program

A long-standing source of funding for hazard mitigation activities is FEMA's Hazard Mitigation Assistance (HMA), which is administered by Vermont Emergency Management (VEM). HMA consists of several distinct programs, including the Hazard Mitigation Grant Program (HMGP), Building Resilient Infrastructure and Communities (BRIC), Flood Mitigation Assistance (FMA), and Legislative Pre-Disaster Mitigation (L-PDM). This funding is intended to support proactive risk reduction across Vermont and is primarily utilized to reduce future flood risk.

HMGP funding is tied to federally declared disasters within the State. The amount of funding available for any HMGP round is typically an amount equal to 15% of the federal aid available for that disaster through Public Assistance and, when applicable, Individual Assistance (see below). While the funding amount is tied to specific disasters, communities seeking HMGP funding do not need to have been impacted by that disaster. The best use of this funding is project implementation – to include developed property buyouts, upsizing culverts and bridges, floodplain restoration, dam removal, and floodproofing or elevation. Eligible projects also include planning activities and generators for critical facilities, as well as Advanced Assistance, which can be used for scoping activities and developing project applications.

BRIC and FMA have annual funding cycles (though the exact dates often change). BRIC funding is divided between State allotments ($2 million per state in the most recent cycle, FY22) and a national competition, where individual projects across the country vie for funding. The BRIC program began in fiscal year 2020 and replaced what was previously the annual Pre-Disaster Mitigation (PDM) program. BRIC funding is available for planning and project scoping activities, as well as project implementation.

FMA is similarly a competitive grant program, which is funded through the National Flood Insurance Program (NFIP) and intended to reduce future risk within NFIP-participating communities and properties. Vermont does not regularly apply for funding under FMA.

L-PDM is a Congressionally Directed Spending program, which began in the fiscal year 2022. Members of Congress request prioritization of specific hazard mitigation projects. Communities with projects identified by their Member of Congress can then apply for up to a pre-determined amount of funding. Following project selection and appropriation, a full application is developed with VEM for submission to FEMA.

Grant Process

While these programs differ in their scope and application process, the HMA programs share the same main features. HMA funding can be used for a range of eligible hazard mitigation activities, including planning, scoping, and implementation. For most implementation activities, a Benefit-Cost Analysis (BCA) is required – except for certain project types where a BCA waiver is available, such as developed property buyouts within the Special Flood Hazard Area (SFHA), with a project cost under $323,000, as well as home elevation projects with a project cost under $205,000. Additionally, a simplified BCA is available for the buyout of developed properties at imminent risk of landslide failure – VEM partners with the State Geologist at the Department of Environmental Conservation (DEC) to make this determination.

Additionally, HMA programs require a non-federal match, typically of 25%, though this match requirement can be lowered for certain communities or funding rounds. The BRIC program, for example, allows communities that meet FEMA's definition of Economically Disadvantaged Rural Communities (EDRC) (called Small and Impoverished Communities in statute) to apply for a 90% federal share. See more discussion below regarding a state definition of EDRC that more accurately reflects Vermont communities. Additionally, VEM received an $8 million General Fund allocation from the Legislature in 2022 to cover match for property buyout projects as well as other FEMA-funded projects as needed.

Under HMA, VEM serves as the applicant and entities seeking funding, to include cities, towns, villages, as well as other segments of government such as Regional Planning Commissions (RPCs) and Conservation Districts (CDs), serve as sub-applicants. The communities submit sub-applications to VEM, which are then evaluated by the interagency Project Review Committee (see below). VEM then submits the State's application to FEMA, with all qualifying sub-applications included.

For each sub-application, FEMA determines whether its eligibility, cost-effectiveness, and programmatic requirements have been met. When sub-applicants are awarded an HMA grant, VEM works with the community to administer the grant to meet FEMA's requirements for reporting, monitoring, and, once the work has been completed, closing out the grant.

VEM has Administration Plans for each round of funding that assist in ensuring that the State manages and administers FEMA funding in accordance with applicable federal statutes and regulations.

Technical Assistance

VEM provides technical assistance to sub-applicant communities throughout the application development and implementation process. During application development, VEM prepares forms and minimizes the demands on local officials' capacity. VEM has, when able, also conducted BCAs for sub-applicants, or hired contract support to develop BCAs. Typically required to satisfy FEMA's cost-effectiveness requirement, BCAs often require technical expertise that is beyond the capacity of local communities.

As it evaluates sub-applications, FEMA will frequently request additional information from the sub-applicant regarding BCAs, environmental and historic preservation review, or other programmatic requirements. VEM coordinates responses to these Requests for Information (RFIs), assisting the local community in answering technical questions and ensuring a timely reply. Even after grants are awarded, technical assistance continues throughout project implementation and the closeout process, which can include requests for cost overruns (available under HMGP as funding allows), as well as the submission of scope of work modifications when needed.

Project Review Committee

Vermont's inter-agency Hazard Mitigation Project Review Committee (PRC) is responsible for evaluating HMA sub-applications and determining which ones are submitted to FEMA. Composed of representatives from VEM, ANR, VTrans, ACCD, and the RPCs, the PRC utilizes the diverse perspectives and expertise of its members in the evaluation process.

The PRC typically meets several weeks before a HMA funding round deadline, depending on the round and when applications are received. Generally, each member of the committee scores each sub-application unless the funding round is non-competitive, in which case they may decide not to score each project but review for eligibility and feasibility. The rubric utilized includes numerous criteria to gauge a proposed project's effectiveness, impact, proactivity, and unique circumstances. For each project, the scores of each committee member are averaged together. Using this average score as a guide, the PRC then makes a final determination on whether to advance a sub-application and submit it to FEMA (scoring sheet included in the Appendix to Section 3).

The PRC uses this same process to evaluate applications for the State's grant program (see Flood Resilient Communities FRCF) below). Applications under FRCF that are advanced by the PRC are then submitted to Vermont's Agency of Administration, which confirms eligibility before making an award.

Table 8: HMGP Financial Summary: DR-1995 (April-May 2011) through DR-4621 (July 2021)

	TOTAL	Buyouts	Infrastructure	Planning	5% Initiative	Advanced Assistance
Lock-In Amount	$41,026,478	--	--	$2,871,854	$2,051,324	--
Application Total (75%)	$42,367,695	$21,235,357	$15,571,796	$2,512,317	$2,571,769	$476,456
Approved	$31,205,778	$17,303,145	$10,041,976	$2,498,607	$1,264,550	$97,500
Pending	$5,298,861	$298,118	$4,849,071	--	$151,673	--
Total Remaining	$8,124,206	--	--	$301,018	-$573,589	--

Table 9: HMGP Project Summary: DR-1995 (April-May 2011) through DR-4232 (June 2016)

Status	Buyout	Infrastructure	Planning	5% Initiative	Advanced Assistance
Approved	73	69	22	7	1
Pending	2	9	0	2	0

- **Buyouts:** 73 approved applications (135 properties); 2 pending applications (2 properties)
- **Infrastructure:** 69 approved - 32 drainage, 9 elevations, 17 generators, 1 road relocation, 1 demolition (4 buildings), 9 floodproof/mitigation; 9 pending - 5 elevation, 1 generator, 3 floodproof/mitigation
- **Planning:** 22 approved applications (142 towns & SHMP)
- **5% Initiative:** 7 approved - 2 projects, 2 plans, 3 buyouts (5 homes), 1 warning siren; 2 pending projects

Financial (top) and project (bottom) summaries for all HMGP disasters in Vermont between April 2011 and June 2016; note that these tables do not include withdrawn or denied projects.

Public Assistance Program

Though primarily a recovery program aimed at repairing damage to public facilities resulting from a disaster, FEMA's Public Assistance (PA) is also a potential funding source for hazard mitigation. When a federally declared disaster occurs in Vermont, funding is made available based on the amount of assessed damages. The State and local governments, as well as certain private entities such as utilities, can apply for PA funding to repair public facilities such as buildings and infrastructure.

PA can also fund hazard mitigation in conjunction with recovery work. PA funding can be used to not only repair a public facility to its pre-disaster condition, but to make improvements to those portions of the facility if they directly reduce the risk of future damage.

VEM, which administers the PA program in Vermont, works with applicants to identify opportunities to incorporate hazard mitigation into their recovery efforts under PA. Applicants are encouraged to expressly request hazard mitigation consideration when applying for PA funding.

The State's use of PA funding for hazard mitigation has had a demonstrable effect. For instance, previous hazard mitigation efforts in the rural Town of Starksboro in Addison County significantly improved the resilience to winter storm events. Following Vermont's most recent federally declared disaster, a severe storm in late December 2022, the relatively low damages in Starksboro resulting from the storm were largely attributed to previous mitigation measures, and Addison County was not included in the declaration request.

FEMA Individual Assistance (IA) is another disaster recovery program that can potentially fund hazard mitigation. IA provides financial and direct services to uninsured or under-insured households affected by a disaster, including funding for the repair or replacement of owner-occupied homes. Beginning in 2021, IA funding can include additional home repair assistance for hazard mitigation, allowing eligible homeowners to rebuild more durable homes.

IA has not been a significant source of funding for Vermont in recent years. IA is only triggered when a state can document a certain amount of damage to individual homes and driveways. In Vermont this high threshold has been met only following very significant storms. Vermont had not had an IA event since 2011 and Tropical Storm Irene until the July flooding in 2023 (by comparison, there have been 17 additional PA events since then, including the most recent two from summer flooding in 2023).

Maps of Public Assistance expenditures by disaster are included in the relevant hazard sections: Inundation Flooding & Fluvial Erosion, Snow Storm & Ice Storm, and Wind.

Emergency Relief and Assistance Fund (ERAF):

The Emergency Relief and Assistance Fund (ERAF) is a State fund that contributes to the non-federal match required under the PA program. This lessens the financial burden on local communities, including those seeking to use PA funding for hazard mitigation. ERAF not only provides funding, but incentivizes local communities to adopt hazard mitigation regulations and plans.

Prior to 2014, the Emergency Relief and Assistance Fund (ERAF) rule provided a default 12.5% State match to municipalities for Public Assistance projects following a federally-declared disaster, with an incentive to increase that State match to 17.5% for municipalities who had taken certain, proactive steps prior to the disaster. In January 2014, after consideration of the ERAF rule's efficacy in encouraging municipalities to be more proactive, the Secretary of Administration sent a letter to all municipal officials in Vermont notifying them of new changes in incentives, which would go into effect in October 2014. These changes are incorporated into the current iteration of the ERAF rule, which is still in effect as of the date of this Plan. Currently, the default for State match following a declared disaster is 7.5%, with 17.5% covered by municipalities receiving Public Assistance funding. In order to achieve 12.5% match status, a municipality must meet the following requirements:

1. Participate in the National Flood Insurance Program (NFIP)
2. Adopt Town Road and Bridge Standards that meet or exceed the 2013 template[1]
3. Adopt a Local Emergency Operations Plan (LEOP) annually after Town Meeting Day and before May 1
4. Submit a Local Hazard Mitigation Plan (LHMP) to Vermont Emergency Management for review

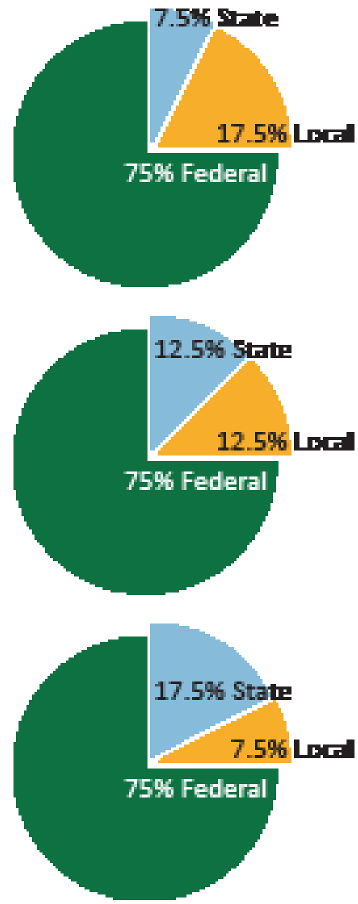

Figure 5: Vermont Emergency Relief & Assistance Fund rates

For municipalities that wish to reduce their required match to 7.5%, increasing the State match to 17.5%, one of the following must be met[2]:

5. Adoption of River Corridor bylaws
6. Enrollment in the National Flood Insurance Program's (NFIP) Community Rating System (CRS), whereby the community must earn credit under Activity 430

The intent of the ERAF rule is to encourage municipalities to take action to improve their community's resilience to future disaster impacts before the next event, which will save taxpayer expenses over time.

Municipalities can access information regarding their current ERAF status through their community reports, located online at http://floodready.vermont.gov (colloquially referred to as "FloodReady"), a website maintained by the Department of Environmental Conservation (DEC). Thirty (30) days after the date of the disaster declaration, Vermont Emergency Management (VEM) Public Assistance staff will take a snapshot of the community reports on FloodReady, which is then used to determine the State match rate for municipalities seeking Public Assistance. It is important to note that this is the process that is currently followed for all federally-declared disasters in Vermont, regardless of disaster type.

1 http://vtrans.vermont.gov/sites/aot/files/operations/TheOrangeBook.pdf

2 http://floodready.vermont.gov/sites/floodready/files/documents/ERAF_Criteria_17%205%25_June2018.pdf

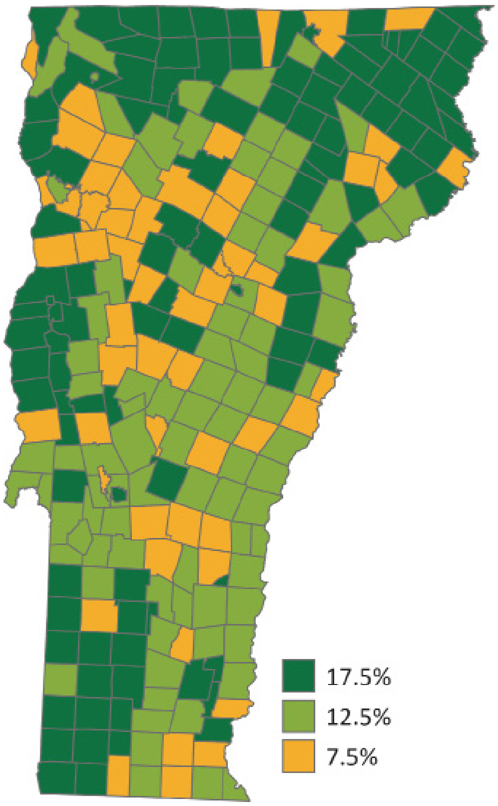

Figure 6: ERAF rate map by municipality (September 2023)
Data Source: http://floodready.vermont.gov

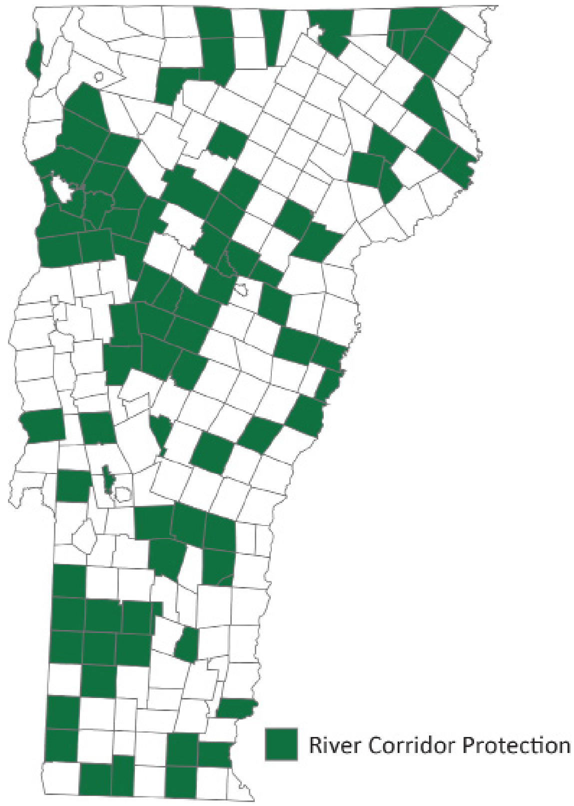

Figure 7: Map of Vermont municipalities with current and interim River Corridor Protections (September 2023)
Data Source: http://floodready.vermont.gov

Vermont Stream Alteration General Permit (SAGP) Revision:

FEMA recognizes Vermont's Stream Alteration General Permit (SAGP) as "codes and standards" for purposes of future Public Assistance repairs (Letter to file "Re: Technical Guidance Concerning the Proposed Revisions to the Vermont Stream Alteration Rule and General Permit" from the FEMA Region I Administrator to the Secretary of the Agency of Natural Resources, dated November 9, 2016). For several disasters following Tropical Storm Irene in 2011, VEM, Agency of Natural Resources (ANR) and Agency of Transportation (VTrans) worked with FEMA Region I on a case-by-case basis to have upsized drainage structures deemed fully eligible for PA funding.

Beginning with DR-4330, which occurred in July 2017 and was declared in August 2017, structure replacements that fall under the jurisdiction of the SAGP and are required to meet the standards of the SAGP are presumed to be PA-eligible. Costs associated with upgrades and improvements to damaged or destroyed structures (i.e., culverts) required by the SAGP will be covered by PA. This significant improvement allows Vermont to more quickly, efficiently, and consistently upgrade vulnerable infrastructure during repairs from natural disasters.

Flood Resilient Communities Fund

The Flood Resilient Communities Fund (FRCF) is a State grant program that was established by the Vermont Legislature in 2021 under Act 74 using appropriations from the federal American Rescue Plan Act (ARPA). FRCF funds efforts to improve landscape and community resilience and reduce the future public safety and water quality impacts of climate-related flood hazards in Vermont, focusing on voluntary buyouts of flood-vulnerable properties.

FRCF was created to fill funding gaps in FEMA eligibility and was a top action identified in the 2018 SHMP. FRCF prioritizes projects that are not eligible under HMA (see above) and aims to leverage other funding sources or fill funding gaps to make projects viable.

Jointly administered by the DEC and VEM, the FRCF grant process shares some similarities to HMA, as well as some key differences. Cities, towns, and villages can apply for FRCF funding, as can other municipal entities and nonprofit organizations. DEC and VEM often work with interested communities to develop effective applications. FRCF's application requirements are less onerous than those of HMA. Applicants fill out a five-page form (some project types require supplemental forms) and submit along with any prepared project designs. There is currently no local match requirement for FRCF.

As with HMA, FRCF applications are evaluated by the interagency PRC for effectiveness, impact, proactivity, and unique circumstances. Applicants advanced by the PRC are then submitted to the DEC Clean Water staff, to ensure ARPA eligibility, then finally to the Vermont's Agency of Administration inter-agency committee which reviews all ARPA funding applications before approval.

Since its inception in 2021, FRCF has awarded nearly $17 million for projects in over 30 Vermont communities (as of October 2023). The program has funded creative projects that would likely have struggled getting to award under HMA, and the streamlined application process has enabled hazard mitigation funding to reach communities more quickly and with a reduced administrative burden.

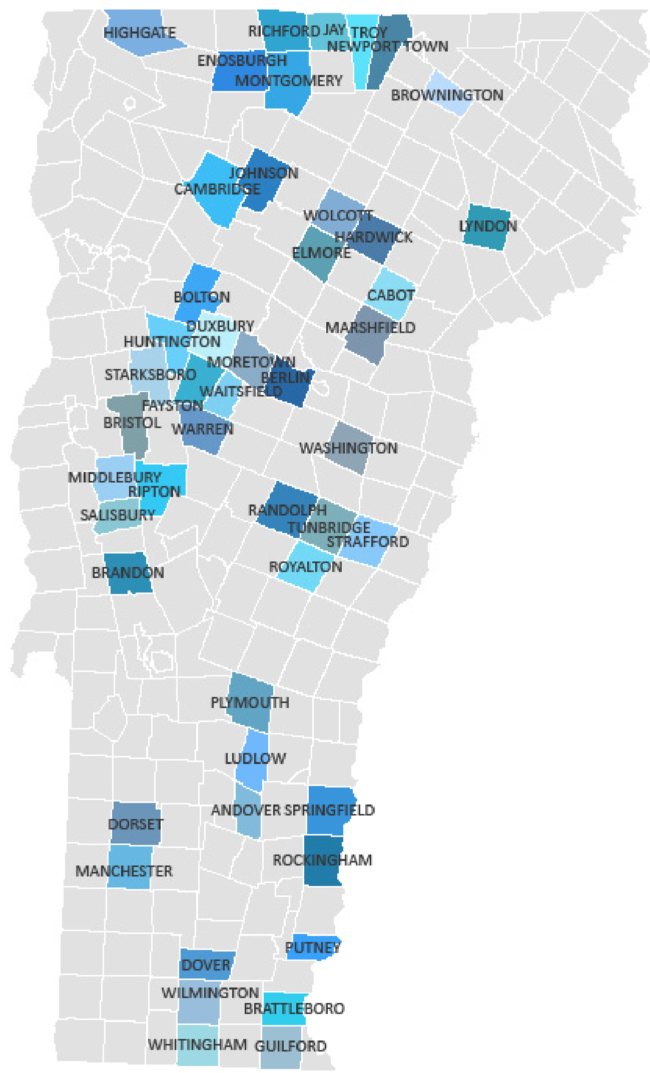

Figure 8: Flood Resilient Communities Fund selected project locations map (October 2023)
Data Source: Vermont Emergency Management

Flood Resilient Communities Fund
Building watershed resilience in the face of climate change

Other Hazard Mitigation Funding

River Corridor Easement Program

The Rivers Program within DEC promotes the protection of river corridors through its River Corridor Easement Program. The program provides a financial incentive to landowners to allow for passive restoration of channel stability by allowing the natural erosive forces of the river to establish its least erosive form over time. Priority is given to those projects, identified in river corridor plans, which protect or restore the flow, sediment, and nutrient attenuation areas within Vermont river basins.

Under a river corridor easement, the landowner sells their river channel management rights within the meander belt width corridor of sensitive and erosive streams. The landowner agrees to restrictions from intervening with erosion and channel adjustments within the corridor, while agriculture and silviculture are permitted outside of the buffer zone within the river corridor. The width and configuration of river corridors are defined by the Rivers Program to accommodate the natural processes, meander pattern and slope of the stream in its equilibrium condition. This reduces conflict with unstable streams and maximizes the public benefits associated with geomorphically stable streams and floodplains.

Vermont Agency of Transportation PROTECT Program

The new Promoting Resilient Operations for Transformative, Efficient, and Cost Saving Transportation (PROTECT) program, established by the federal Infrastructure Investment and Jobs Act, is being administered in Vermont by the Agency of Transportation (VTrans). PROTECT funding will be used to make roads and other transportation infrastructure more resilient to natural hazards. Eligible activities include resilience planning, design, technical capacity building, and transportation resilience improvement projects. The program will provide Vermont with $37 million in formula funds over five years (Fiscal Years 2022-2026). A competitive grant component may create opportunities for State and local governments to access additional funding.

Emergency Watershed Protection Program

The USDA Natural Resources Conservation Service's Emergency Watershed Protection Program (EWP) is potentially available to assist property owners facing exigent risk of property loss due to ongoing erosion after a qualifying storm. Applications for EWP must be submitted by a municipality in which the property is located and submitted to the federal Natural Resources Conservation Service (NRCS) within 30 days of the incident which caused the imminent risk of further damage. The program does not cover infrastructure that has already occurred, and work must be pre-approved by NRCS prior to commencement. NRCS often does not receive funding for a specific incident until months later. Occasionally a project meets all the criteria and can be funded, allowing for stabilization of a stream bank to protect structures and/or private roads.

Vermont Urban and Community Forestry Program

The Vermont Urban & Community Forestry (VT UCF) Program is currently expanding their grants program, with an expected $500,000 being administered in 2024. These funds will be divided among three separate categories of grants, as well as supporting two additional grant programs through other organizations. These include Communities Caring for Canopy, Growing Urban Forests in the Face of Emerald Ash Borer, and Urban & Community Forestry Grants. The additional grant categories are Fruit & Nut Tree Grants through the Vermont Garden Network for the third year and a new Urban Tree Planting Block Grant Program. These funding opportunities can assist municipalities in urban resiliency as the impacts of invasive species and extreme heat negatively impact the health of urban green spaces and increase Urban Heat Island Effect.

American Rescue Plan Act Funding for Housing Development

The federal American Rescue Plan Act (ARPA) has enabled a significant investment in housing development in Vermont. The State has committed around $159 million to various housing initiatives that will aim to bring new housing units to market by 2026.[3] Much of these funds will be administered by the Vermont Housing and Conservation Board (VHCB) and aid in achieving a range of affordable housing aims. VHCB was created to deconflict the dual goals of creating affordable housing and protecting Vermont's natural and cultural resources. As more residents find that their homes are in expanding flood areas or otherwise at risk of hazards, balancing these goals and ensuring an adequate supply of safely located housing will be even more crucial.

Fire Management Assistance Grants

Fire Management Assistance Grant (FMAG) Program grants are available for the mitigation, management, and control of fires on publicly or privately owned forests or grasslands. They are available at 75% cost share. In Vermont, the Department of Forests, Parks and Recreation manages FMAG. FMAG does not cover private property damage.

Dam Resilience Funding

Dam resilience projects and dam safety programs require continual attention and funding due to the risk that is posed by aging dam infrastructure throughout the State. Different funding programs are offered by agencies such as FEMA to successfully fund activities including dam safety training, dam inspections, streamlining submittal and review of EAPs, increased coordination and outreach between the state and federal government as well as with the community.

HMA and FRCF funding (see above) can be used for dam resilience or removal projects. Dam funding applications under HMA and FRCF go through the same process as other hazard mitigation projects under those programs. The Project Review Committee evaluates dam applications based on the project's effectiveness, impact, proactivity, and unique circumstances, then makes a final determination on whether to advance the application to either FEMA or the Agency of Administration.

Programs such as the National Dam Safety Program State Assistant Grant ensure the safety and upkeep of critical pieces of infrastructure that both provide a host of benefits (hydropower, flood control, water supply, etc.) while also posing a risk to downstream populations.[4] The federal government has also allocated funding through the Rehabilitation of High Hazard Potential Dams Program aimed at assisting the technical, planning, design, and construction of eligible dams. Both these programs received a significant amount of funding from the Infrastructure Investment and Jobs Act of 2023.[5]

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3 https://governor.vermont.gov/sites/scott/files/documents/2022%20VT%20ARPA%20SFRF%20Governor%20Report_vF.pdf

4 https://www.fema.gov/press-release/20221013/biden-harris-administration-awards-33-million-national-dam-safety-grants#:~:text=Over%20the%20next%20five%20years%2C%20FEMA%20will%20award,good-paying%20jobs%20and%20help%20address%20the%20climate%20crisis.

5 https://www.fema.gov/emergency-managers/risk-management/dam-safety

Unsafe Dam State Revolving Fund:

DEC administers the Unsafe Dam Revolving Fund, a special fund that provides funding to municipalities, nonprofit entities, and private individuals, for the reconstruction, repair, removal, breaching, draining, or other action necessary to reduce the threat of a dam or portion of a dam determined to be unsafe pursuant to section 1095 of 10 VSA Chapter 43. The dam must first be found to be unsafe via the process laid out in statute for an owner to qualify for funding (see below). Funding is typically provided as a loan, though under some circumstances a portion of the funding is provided as a grant.

High Hazard Potential Dam Grants:

DEC administers rehabilitation of High Hazard Potential Dams Grant (HHPD). HHPD provides technical, planning, design and construction assistance in the form of grants for rehabilitation of eligible high hazard potential dams.

Wrightsville Dam following significant rainfall on July 12, 2023
Photo Credit: Wrightsville Beach Recreation District

Outcomes and Opportunities

In 2022, the VEM Hazard Mitigation Team had unprecedented levels of funding available to assist communities in reducing their risk, at a total of $37 million across programs. Hazard mitigation funding has enabled the implementation of projects across the State that have reduced Vermont's risk to hazards.

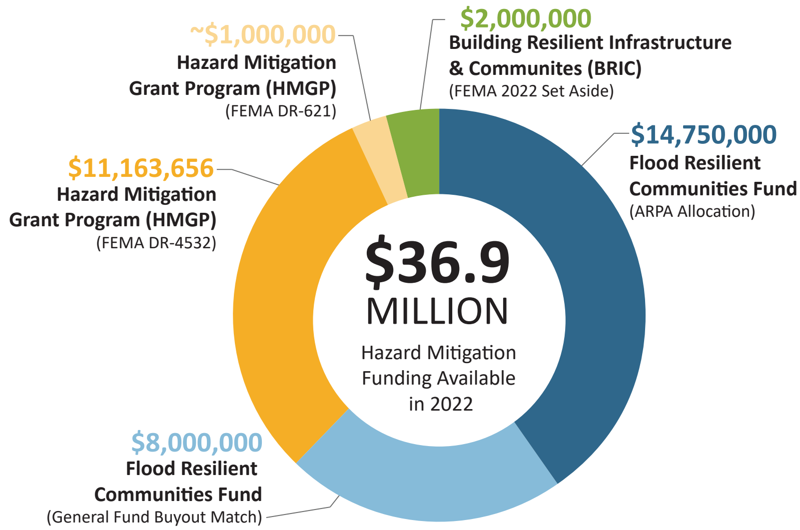

Figure 10: Hazard mitigation funding available in 2022

The effectiveness of these projects has at times been dramatically demonstrated. The Melrose Terrace project in Brattleboro, implemented predominately using funding through FEMA's Pre-Disaster Mitigation (PDM) program, restored the floodplain functionality of five acres that had previously been the site of a public housing development. The project worked as intended during a severe storm event in late December 2022 that dumped as much as two inches of rain across the State, compounded by snowpack melt. By design, the project area flooded, keeping destructive waters away from vulnerable structures and residents. While the storm was significant enough to warrant a federal disaster declaration elsewhere in the State, Brattleboro and Windham County experienced relatively little damage.

The tapestry of funding sources available for hazard mitigation in Vermont creates opportunities and complications. The variety of sources help smooth out volatility in the amount of funding available for any one program.

One of the greatest challenges with accessing HMA funding to reduce flood risk in Vermont is the State's significant erosion-based risk. FEMA's focus on the SFHA, which defines inundation flooding, does not represent Vermont's most significant hazard, which is rivers moving over time and eroding riverbanks (see: Vermont Profile and Hazard Assessment).

Flooding at Melrose Terrace in Barttleboro, VT in December 2022
Photo Credit: Brattleboro Housing Authority

$11.2 million in HMGP funding was recently available under DR-4532, owing to the magnitude of the COVID-19 disaster declaration – however, Vermont encounters significant challenges through the administration of the HMGP program. There are specific project types that fit well under this program, such as upsizing transportation infrastructure and property buyouts within the SFHA, however, it can be challenging to apply for projects that do not perfectly fit the mold of these very limited project types. One specific example is the administration of project scoping applications, or "advanced assistance" – which is intended to allow funding for project development. Based on interpretation at Region I, this funding is only allowed when the resulting application can be applied for under the same round – which would require that a scoping project be applied for immediately following a declared disaster. Another example is applying for planning activities, to include Local Hazard Mitigation Plan (LHMP) development, as well as applications under the 5% Initiative, which allows for education and outreach activities as well as generators. When BRIC funding is available, this program has been used instead for these project types due to VEM's inability to get them funded under HMGP, despite their eligibility within HMA Guidance.

The yearly BRIC program has allowed for significantly more flexibility and adaptability than its predecessor, the Pre-Disaster Mitigation (PDM) program. The state allocation provides more regularity in available funding and the state allocation has been increasing in recent years, going from $600,000 in FY 2020 to $1 million in FY 2021 to $2 million in FY 2022. This increase in the state allocation has been valuable for states like Vermont and has allowed significant flexibility in the submission of a range of scoping and planning activities. While this pot of funding allows for larger competitive applications above the state allocation, Vermont would have a hard time accessing this funding based on the competitive criteria in prior BRIC Notice of Funding Opportunities (NOFOs), which significantly prioritizes funding for states with statewide commercial and residential building codes. While Vermont does have a commercial building code, there is not a statewide residential building code. Given Vermont's significant erosion-based risk (noted above and discussed in more details in Inundation Flooding & Fluvial Erosion), where the State allows development is significantly more important than exactly how residential structures are developed. This distinction is additionally addressed through plan actions within the Mitigation Strategy.

The creation of FRCF, a top plan priority in the 2018 SHMP, not only significantly increased the funding available for flood reduction in the State but created a mechanism for better addressing the gaps we see in FEMA funding availability, to include projects that better address Vermont's erosion-based risk. The priority project type under FRCF is the buyouts of properties that are outside of the SFHA. Additionally, FRCF allows for the buyout of vacant parcels with development pressures and the conservation of headwater storage areas. Through the expansion of eligible project types, the streamlined application process, expansion of the type of eligible applicants, and significant dedicated support from VEM staff, the program has additionally been able to reduce the significant equity concerns that we see within FEMA HMA programs. Due to its flexibility, FRCF can reach communities and individuals that would not have had access to HMA funding.

The most significant example of this is the new process for property buyouts that is under development within manufactured housing communities.

However, even with the variety of resources available, the State must continue exploring potential long-term funding sources. The State expects to receive less HMGP funding in the near-term, and FRCF's seed funding from ARPA resources need to be obligated by the end of calendar 2024. Establishing a State mechanism to fund FRCF is perhaps the most promising approach for funding sustained hazard mitigation activities. Vermont can also pursue additional federal funding. FEMA's recently established Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) program provides participating states with funding to create a revolving loan program. The State could also consider taking action to address the systemic circumstances that hamper its competitive grant applicants to FMA and the BRIC national competition, such as FEMA's emphasis on statewide building codes. Vermont can also explore funding from other sectors. For instance, while the philanthropically funded Vermont Disaster Recovery Fund makes grants to households to aid in post-disaster recovery, there is not currently a corresponding mechanism in that sector for hazard mitigation activities.

Navigating the tapestry of funding opportunities can create administrative burden for local communities with limited capacity to navigate the different scopes and requirements of the various programs. The State makes efforts to ease this challenge. VEM, for example, works with communities to determine which of the grant programs would be the best fit for each project. However, this challenge compounds when different programs are spread across multiple State agencies. Continued efforts at effective interagency coordination can ensure communities can avail themselves of the most apt program for their specific projects.

Cognizant of the capacity constraints facing Vermont's many small communities, the State has placed an emphasis on providing technical support throughout the grant process. For instance, VEM's success in streamlining the application requirements for certain projects like buyouts has reduced the demands on local officials. Yet despite these successes, capacity constraints can continue to challenge the implementation of hazard mitigation activities, especially for certain programs with more onerous and complicated requirements. The State agencies administering these programs continue to develop resources and increase efforts to provide meaningful advising and technical assistance.

Economically Disadvantaged and Rural Communities

The Stafford Act includes language on providing more equitable funding to “small and impoverished communities,” now known as Economically Disadvantaged and Rural Communities (EDRCs), through FEMA’s hazard mitigation assistance programs. An EDRC is eligible for up to 90% federal cost share and 10% non-federal cost share for their mitigation planning and project sub-applications in accordance with the Robert T. Stafford Disaster Relief and Emergency Assistance Act. That is 60% in the required non-federal match funding, lessening local taxpayer burden, which is significant for most small municipalities in Vermont.

VEM officially mapped EDRCs for the first-time during BRIC 2022 application development. EDRCs need to be remapped each year in accordance with the Stafford Act definition:

- Populations are less than 3000; and
- Average per capita annual income of residents does not exceed 80% of the national, per capita income, based on best available data; or
- The local unemployment rate exceeds by one percentage point or more, the most recently reported, average yearly national unemployment.

For the BRIC 2022 application VEM utilized data from the 2020 US Decennial Census for population numbers, 2020 American Community Survey for average per capita income, and 2021 Bureau of Labor Statistics annual aggregate data for unemployment rate. Given the discrepancies within the data available for such small communities, VEM accounted for margin of error in calculations by subtracting half the margin of error for each jurisdiction’s per capita income from the ACS 5-year estimates.

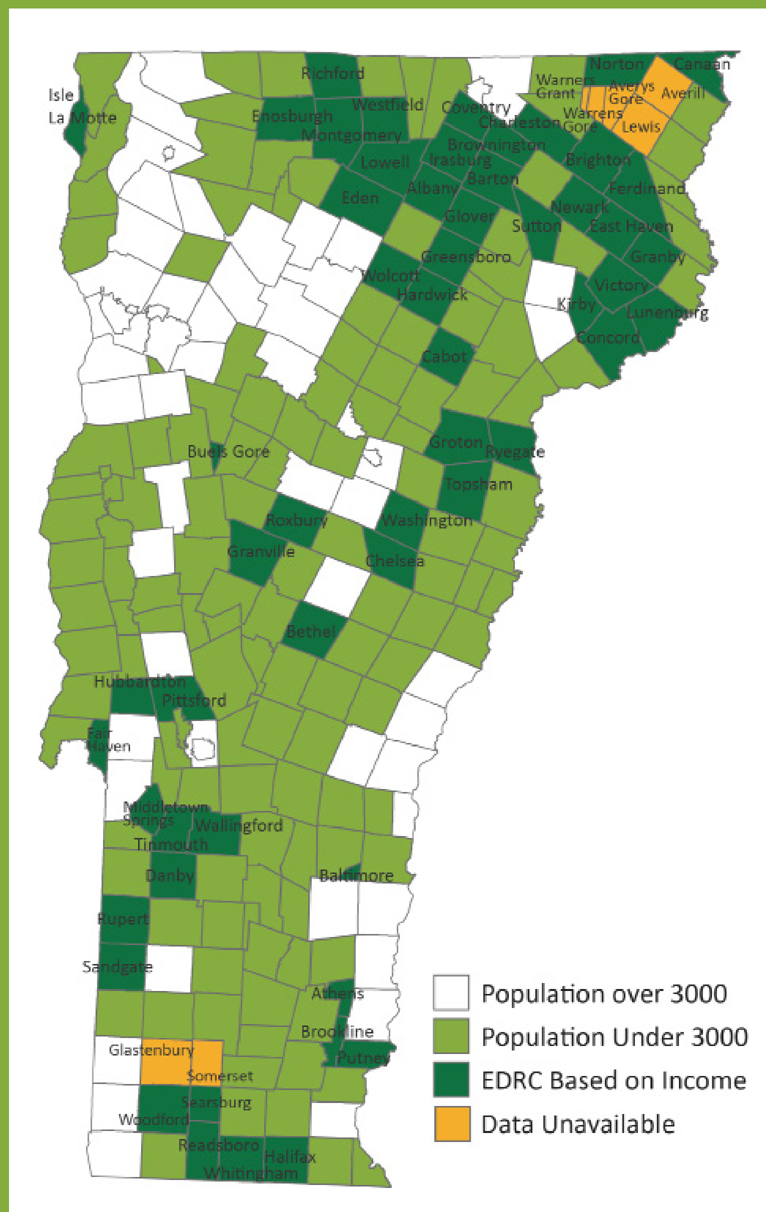

Figure 11: Economically Disadvantaged Rural Communities of Vermont (Income 2020)
Data Source: US Census 2020 ACS 5-year estimates

What was not included in the first EDRC analysis was the last piece of the small and impoverished communities' definition in 44 CFR § 201.2, the Stafford Act. The full definition gives the State the opportunity to identify additional factors that qualify a community as an EDRC. These additional factors must be included in the State Hazard Mitigation Plan.

Two efforts discussed under Planning and Interagency Coordination - the Municipal Vulnerability Index (MVI) as part of Vermont 2020 Global Warming Solutions Act and the mapping of environment justice communities as part of Vermont's 2022 Environmental Justice State Policy – will identify Vermont's EDRC's based on multiple factors that are locally relevant.

VEM plans to revise the 2023 State Hazard Mitigation Plan to include the state-specific additional factors in determining an EDRC upon completion of these initiatives.

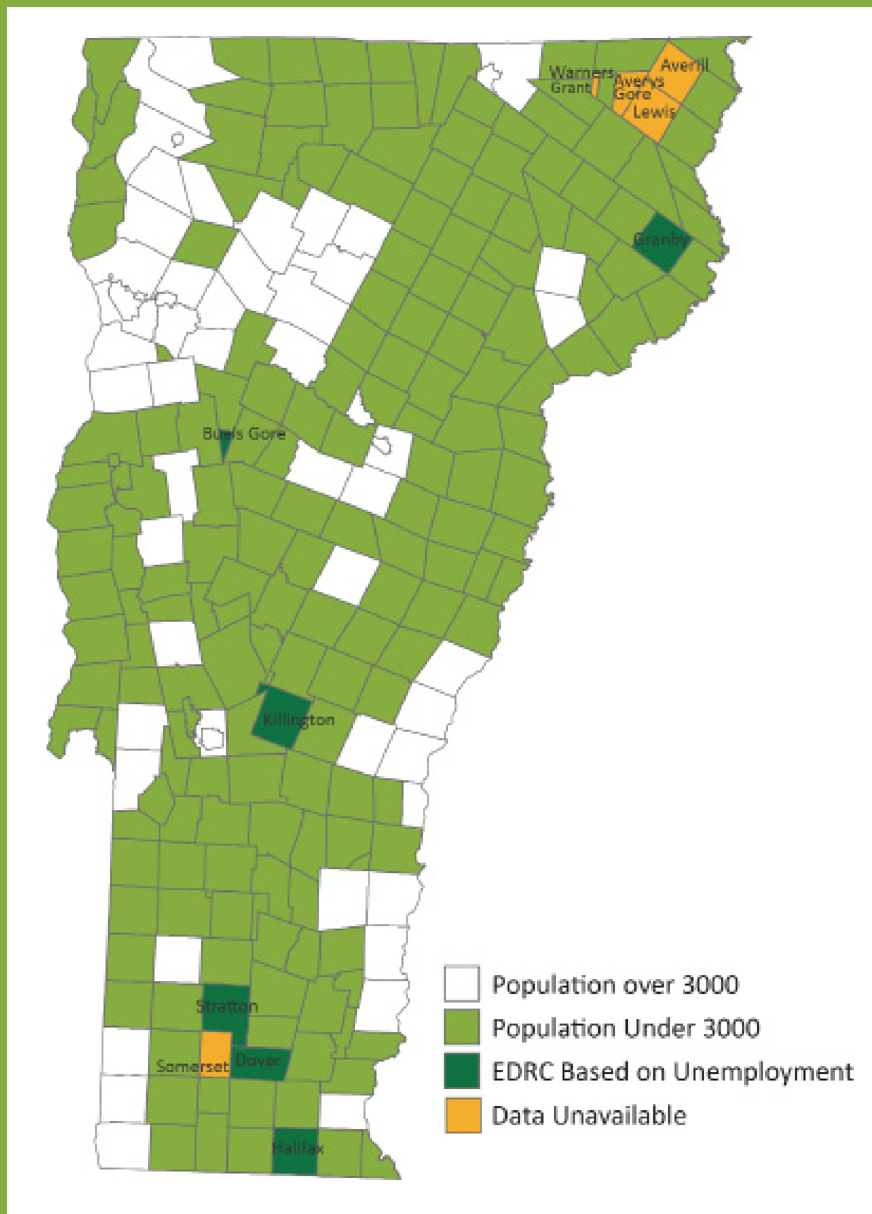

Figure 12: Economically Disadvantaged Rural Communities of Vermont (Unemployment 2021)
Data Source: US Census 2020 Decennial Census

STANDARDS AND PERMITTING

National Flood Insurance Program

The National Flood Insurance Program (NFIP) aims to reduce the impact of flooding on public and private structures by both providing insurance and encouraging proactive adoption and enforcement of floodplain management regulations.[6] Though a federal program, NFIP is largely administered by municipal floodplain managers in participating communities. Program oversight and technical assistance is provided by the State Floodplain Manager & NFIP Coordinator at the Agency of Natural Resources' Department of Environmental Conservation (DEC). Permitting support for locals is provided through their DEC regional floodplain manager, of which there are five across Vermont.[7] Vermont is unique, in that State statute requires communities to submit floodplain development permit applications to DEC for review and comment. DEC regional floodplain managers provide technical review and written comments to assist communities in administration and enforcement of their adopted flood hazard regulations. The Vermont NFIP Coordinator also works with other State agencies including VEM and the Department of Financial Regulation, as well as with the RPCs, participating municipalities, and the FEMA Region 1 Floodplain Management and Insurance Branch.

Acts 138 (2012) and 107 (2014) required the Agency of Natural Resources to adopt a flood hazard area and river corridor rule to regulate activities exempt from municipal regulation and ensure that the State is compliant with NFIP. Activities regulated under the rule include State-owned and operated institutions and facilities, required agricultural and silvicultural practices, and power generating and transmission facilities regulated under the Public Utility Commission. The Flood Hazard Area & River Corridor (FHARC) rule went into in effect in 2015 and exceeds NFIP minimum standards. Specifically, the FHARC rule employs a No Adverse Impact set of standards that includes a 2-foot freeboard requirement, a compensatory flood storage standard, and a river corridor performance standard in consideration of riverine erosion hazards. The standards in the rule served as the framework for the 2018 update to the State model flood hazard regulations discussed below.

6 https://www.fema.gov/national-flood-insurance-program

7 http://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/floodplain-managers

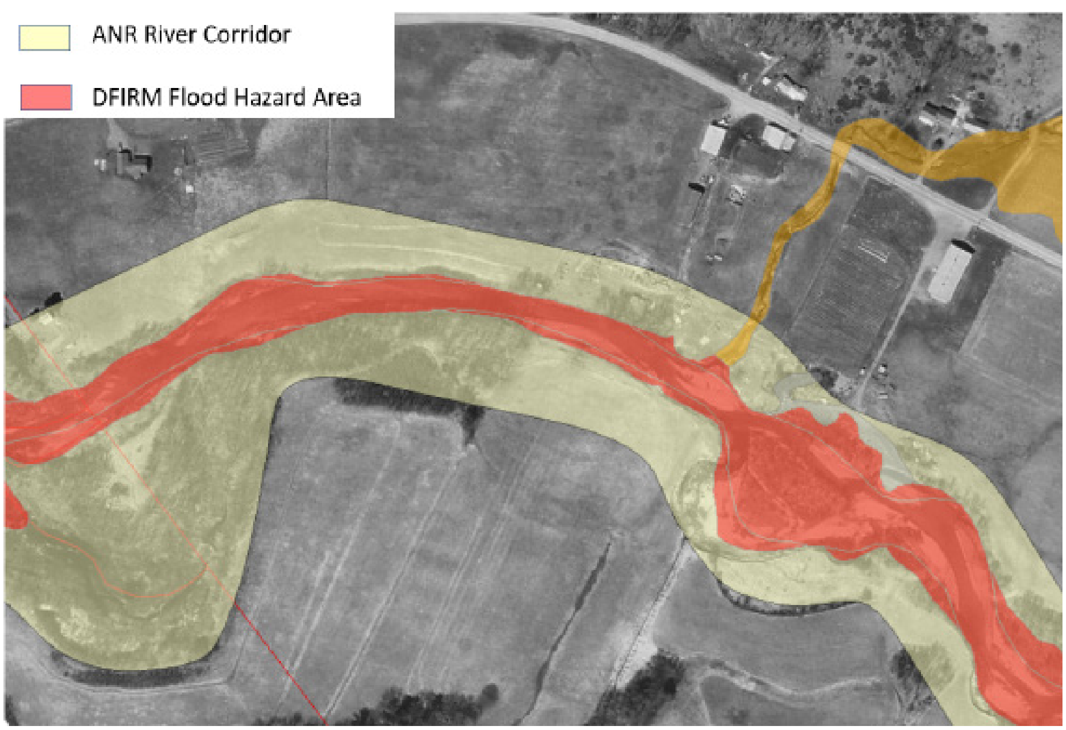

Figure 13: Browns River in Underhill demonstrates the true vulnerability (i.e. River Corridor area) versus the FEMA-mapped vulnerability (DFIRM Flood Hazard Area)

In addition to providing insurance, NFIP is also responsible for developing Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs), which are used as the basis for identifying flood hazard areas where floodplain management and mandatory flood insurance purchase requirements apply. Given their regulatory authority, these FISs and FIRMs are not available in certain areas of the State and are highly variable and often inaccurate in others, making access to NFIP difficult for some, while creating an unnecessary burden for others. For example, a community whose FIRM was last updated in the 1980s may not consider how the river has meandered over the decades, effectively removing some structures from flood hazard areas while including others that were previously not considered vulnerable. Additionally, the FIRMs are static maps depicting inundation hazards at the time of study. FIRMs do not consider the River Corridor – or the minimal land area needed by the river to be least erosive and store floodwater, sediment, and debris. Accordingly, these communities are unable to understand their true vulnerability to flood hazards.

Figure 13 shows a typical situation where the river corridor is much wider than the FIRM-defined flood hazard area due to the river being incised and not having access to its floodplain. This is a particularly dangerous situation whereby the river is highly energized and erosive due to most of the base flood being contained within the channel, yet the FIRM portrays very little risk outside the channel. The river corridor shows the area where the river will continually try to meander and thus, where flood-related erosion is very likely to occur. For more information on River Corridors, see: Inundation Flooding & Fluvial Erosion.

NFIP has historically been the standard for floodplain management in Vermont. Unfortunately, the NFIP minimum standards adopted by most towns allow continued encroachment in floodplains and further degradation of the natural and beneficial floodplain functions, and therefore are insufficient at ensuring community resilience against flooding. In 2008, the NFIP Coordinator's Office within DEC developed a suite of model flood hazard bylaws that went well beyond federal minimum standards. Following nearly a decade of implementation of those bylaws, DEC formed an external stakeholder working group in 2017 to review and provide feedback on new model bylaws that take into account best available data and lessons learned from the previous iteration. These bylaws, released in early 2018, significantly improve upon NFIP minimum standards and more appropriately address Vermont communities' risk to flooding. DEC has developed a comparison of the NFIP minimum standards and the model bylaw higher standards, complete with a rationale for each of the State standards.[8] The overarching goal of the higher standards is for communities to manage for inundation flooding and fluvial erosion hazards via a No Adverse Impact strategy that ensures development is flood resilient, does not increase flood hazards, and protects remaining floodplain resources to store and convey floodwater. As of May 1, 2023, 97 communities have adopted a combination of higher inundation and erosion standards.

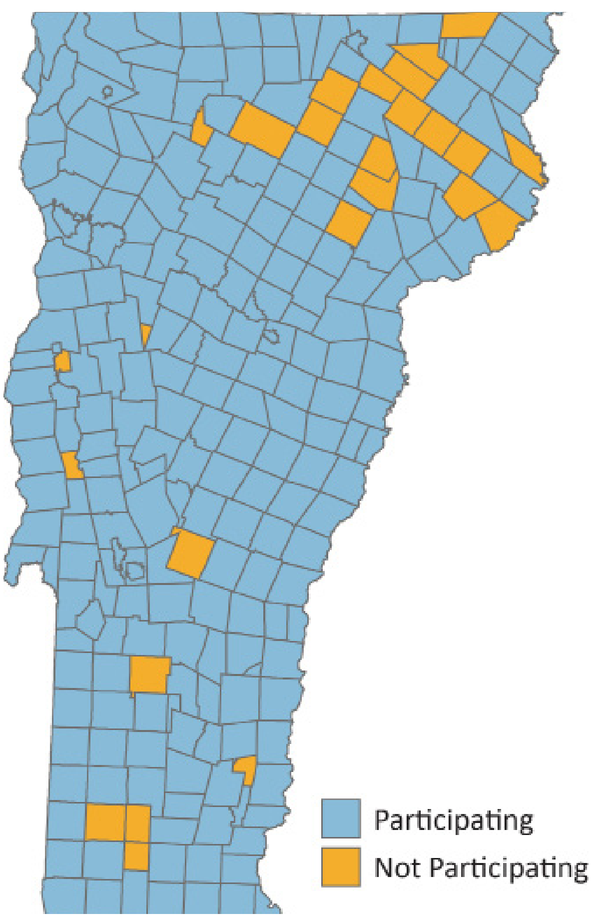

Figure 14: NFIP participation by municipality map (September 2023)
Data Source: http://floodready.vermont.gov

8 http://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_ModelFloodHazardBylaws_HigherStandardsCrosswalk_2018.pdf

As of May 1, 2023, 247 Vermont communities, about 90% in all, participate in NFIP (Figure 14) and most of the non-participating communities are in very low population areas or have limited mapping products available. Since the previous Plan was adopted in 2018, three communities have joined the NFIP, while 27 communities remain non-participatory.

Based on current best available data in Vermont, over 10,000 structures are in a high-risk Special Flood Hazard Area. Of these structures, only around 11% are carrying some flood insurance through the NFIP.

FEMA's National Flood Insurance Program Repetitive Loss (RL) data provide an overview of areas of the State that are vulnerable to repeated flood loss and damages. More information about Repetitive Loss can be found in [Inundation Flooding & Fluvial Erosion](#).

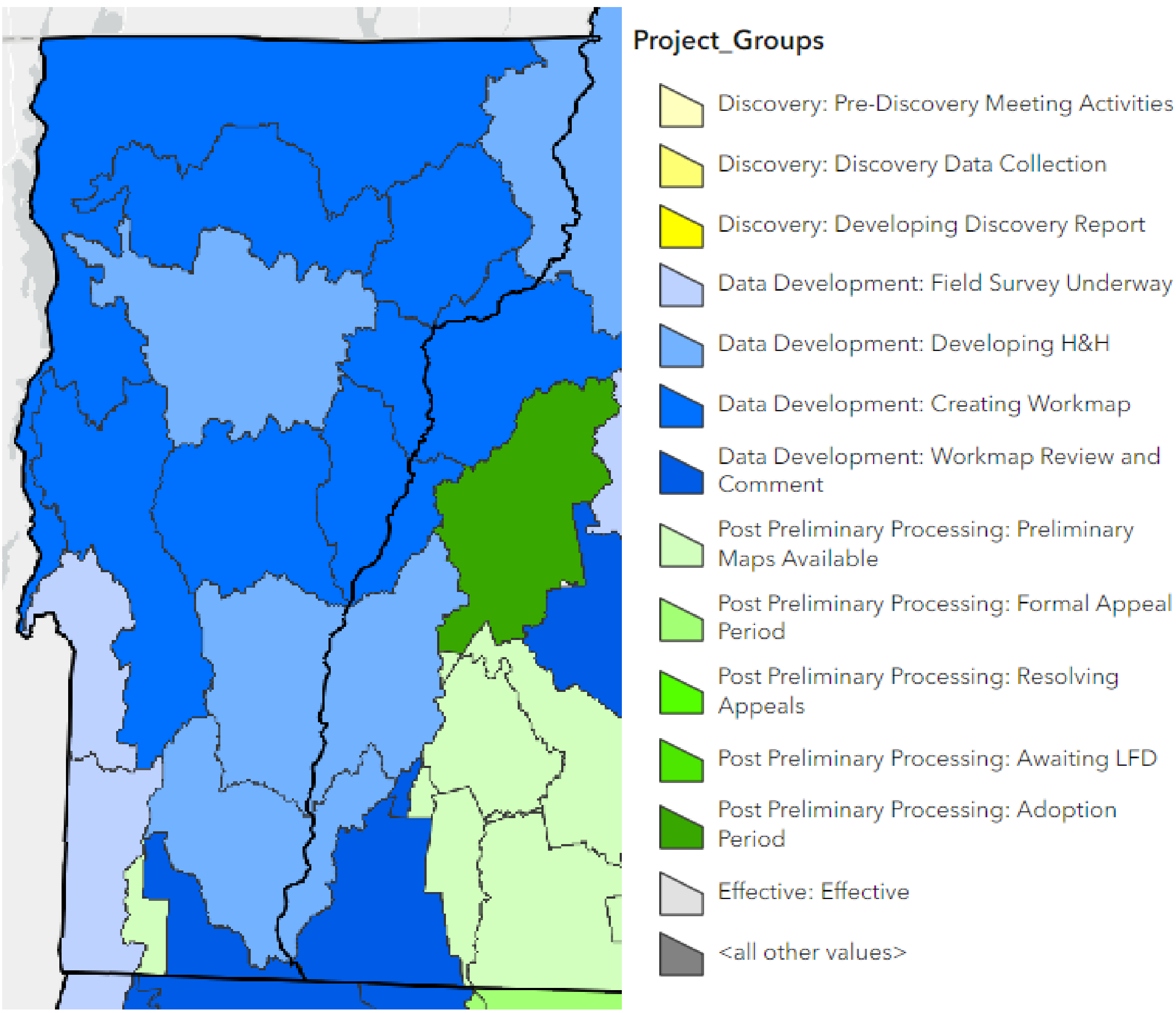

Figure 15: Status of current FEMA mapping studies by watershed (September 2023)
Data Source: Vermont Department of Environmental Conservation

Risk Mapping, Assessment and Planning

An analysis of digital FIRM data in six counties for the 2018 SHMP indicated that 82% of stream miles do not have mapped Special Flood Hazard Areas. There is no mandatory flood insurance requirement as a result, yet flood losses are regularly experienced along these flooding sources. Unfortunately, these losses are not documented by way of a flood insurance claim due to lack of coverage.

Additionally, many towns have antiquated data supporting their mapped flood hazard areas, which do not take into account changes in geomorphology, hydraulics or hydrology, leaving many structures mapped incorrectly or not mapped at all. These mapping deficiencies create additional vulnerabilities to Vermont's built environment, as accurate identification of structures relative to flood hazard areas is difficult to ascertain.

FEMA began updating FISs and providing digital FIRMs (DFIRMS) in 2005 through its Map Modernization and Risk MAP programs. The new flood maps will replace some maps that have been in effect for over fifty years. The new FISs are conducted within a watershed context and the maps themselves will be issued on a county-wide basis. The map updates will be informed by the high-quality topographic data from LiDAR and various modeling techniques.

Partnerships at the federal, State, and local levels have contributed to the work of the flood hazard mapping program. DEC is working to coordinate outreach around the flood hazard map update process in coordination with the regional floodplain managers. The FEMA Risk Map program is not directly funding any work by Vermont at this time. Discretionary funds through FEMA's Community Assistance Program – State Support Services Element have been used to engage Vermont RPCs in a statewide outreach effort to raise awareness of the map updates and to prepare communities for plan and bylaw updates as needed for the adoption of the new FIRMs.

This collaborative work has included ongoing meetings with regional planners, outreach meetings for municipal officials in different regions, online meetings with floodplain managers and engagement with municipal officials in the process of map, plan, and bylaw updates. This collaboration helps the State identify priority areas for flood studies, based on how current and usable existing flood studies are, the extent of changes in local land use, and other on-the-ground considerations. The State relays these priorities to FEMA during the Discovery phase of new studies by watershed.

DFIRM data is already available for six counties (Windham, Windsor, Rutland, Chittenden, Washington and Bennington) and seven communities (Bradford Village, Hardwick, Jay, Montgomery, Newbury, Stowe and Wolcott).[9] An important step for making flood hazard data more accessible and accurate, the statewide update process is tentatively anticipated to be completed over the next five years.

DFIRM data are readily available through the ANR Natural Resources Atlas web mapping application.[10]

9 https://floodtraining.vermont.gov/protection-tools/get-ready-new-fema-flood-insurance-rate-maps#status
10 https://anrmaps.vermont.gov/websites/anra5/

Community Rating System

A voluntary incentive program under NFIP, the Community Rating System (CRS) recognizes and encourages proactive floodplain management activities that exceed the minimum NFIP requirements.[11] Communities that apply for and are admitted into CRS receive discounted NFIP premium rates for property owners in their jurisdiction in 5% increments, with those communities adopting the most stringent floodplain management policies and activities achieving greater discounts. The three goals of CRS are to reduce flood damage to insurable property, strengthen and support the insurance aspects of NFIP, and encourage a comprehensive approach to floodplain management.

Vermont has six CRS-participating communities, two of which meet the Class 9 standards (Bennington and Brattleboro), three that have achieved Class 8 status (Colchester, Montpelier, and Waterbury), and only one that has achieved Class 7 status providing a 15% discount on premium rates within the high-risk flood hazard area (Berlin). DEC Regional Floodplain Managers provide technical assistance to CRS communities and those interested in participating. DEC helps communities understand CRS requirements and achieve or maintain compliance with those requirements.

Recognizing the need to expand proactive floodplain management activities and policies across the State, the Vermont Emergency Relief and Assistance Fund (ERAF) criteria allow for greater allotment of State share following a declared disaster for communities that participate in CRS, among several other standards (see: ERAF). During the mitigation strategy development process of this Plan update, the Working Groups and Steering Committee identified promotion of participation in the CRS as an ongoing action to reduce community vulnerability to flood hazards (see: Mitigation Strategy). Unfortunately, given the rural nature of Vermont, with low town capacity and a lack of statewide adoption of the International Building Code, meeting the CRS requirements for even achieving base-level (Class 9) status presents significant challenges.

Flood Training and Resources

In addition to working directly with municipal floodplain managers, DEC assists local communities administer NFIP and manage their floodplains through a variety of trainings and resources. DEC stages trainings throughout the State and publishes its *Make Room for Rivers* training online. DEC maintains a suite of resources on *Flood Ready Vermont*, including FAQs, guides, and case studies. This includes the Procedure to Determine Substantial Damage or Substantial Improvement to guide local floodplain managers administer the NFIP substantial damage rule following a flood event. Local officials are encouraged to further coordinate with their DEC Regional Floodplain Manager during the substantial damage determination process.

DEC also hosts monthly online drop-in sessions, informal gatherings where municipal officials and other stakeholders can ask questions of DEC and discuss floodplain management topics. Lastly, DEC manages the Flood Resilience Listserv through which new resources and training opportunities are disseminated to stakeholders throughout the State.

NFIP Challenges and Opportunities

Several other NFIP challenges have been identified during regular coordination between the State and FEMA. For instance, there are data accessibility issues for local communities that can hinder effective local floodplain management. NFIP claims and repetitive loss data are maintained in a federal database. Because such data

11 https://www.fema.gov/national-flood-insurance-program-community-rating-system

can include personally identifiable information, access to the database is only provisioned to non-FEMA users following an arduous registration process. In practice, this stymies access for most local officials. Without it, communities are often forced to operate with informational blind spots.

Increasing the number of policy holders and narrowing gaps in coverage among properties at flood risk is another challenge. Participation in NFIP often entails tradeoffs in short-term costs and long-term risk reduction that local communities struggle with. At the national level, there is only piecemeal support for addressing affordability concerns. These issues may sharpen under Risk Rating 2.0, NFIP's new pricing approach that seeks to set more actuarially sound – and, for some property owners, considerably higher – premium rates.

NFIP as currently administered also misses opportunities to promote hazard mitigation among policy holders. NFIP claims do not generally support mitigation. Following a damaging flood event, repair work often presents good opportunities to take mitigation actions such as elevating utilities. However, except in very limited circumstances, NFIP claims will not help cover the costs of these mitigation actions. The new NFIP pricing approach under Risk Rating 2.0 could also do more to encourage hazard mitigation by identifying how mitigation actions can lower risk and thus insurance premiums.

Building Codes

Vermont has adopted building codes for public and commercial building safety and energy standards. The energy code also applies to residential buildings. Vermont's Division of Fire Safety enforces the 2015 National Fire Protection Association (NFPA) 1 Fire Code, 2015 NFPA 101 Life Safety Code, 2015 International Building Code (IBC), 2017 NFPA 70 National Electrical Code, 2021 International Code Council (ICC) International Plumbing Code, and 2015 National Board Inspection Code from the National Board of Boiler and Pressure Vessel Inspectors. The Division of Fire Safety is currently implementing a BRIC grant to update current Building Codes to the 2021 International Building Code (IBC) and the 2021 National Fire Protection Association (NFPA) 1 & 101 and their referenced codes and standards.

Vermont does not have a statewide residential building code, as the adoption and enforcement of residential building code in Vermont is determined at the local level (24 V.S.A. § 3101). The potential hazard mitigation value of a statewide code in Vermont is currently unquantified. While nationwide research has highlighted the value, on average, of residential building codes,[12] Vermont's specific circumstances may limit the applicability of these general findings. While building codes can significantly mitigate a handful of hazard risks, Vermont is not at high risk of many of these hazards, including earthquakes, hurricanes, and tornadoes. While riverine flooding poses a high risk to the State, its most damaging impact in Vermont is fluvial erosion. Building codes may be of limited efficacy against an erosive hazard that can washout the land from underneath a building. This informs the State's emphasis on helping residents build in safe and sustainable locations, rather than stipulating exactly how Vermonters build their homes.

Nonetheless, a statewide residential building code still has the potential to produce cost-effective hazard mitigation benefits, especially for hazards like inundation flooding and high winds. The State intends to study the efficacy of potential residential building codes in Vermont to better inform building code discussion among policymakers (see: Mitigation Strategy).

12 https://www.fema.gov/emergency-managers/risk-management/building-science/building-codes-save-study

Other Standards and Permitting

Wetland Rules

Vermont's Wetland Rules regulate activities in wetlands and their buffer zones (Vt. Code R. 12 004 056). Wetlands are subject to these rules based on the extent to which they provide certain public benefits, including water storage capacity for flood water and storm runoff. Enforced by ANR, the Wetland Rules require that those intending to undertake certain restricted activities acquire a permit. Permit applicants must demonstrate that their intended activities will not lower the quality of the wetland's protected functions and values, including water storage.

Transportation Standards

Since 2003, VTrans has constructed and updated over $1 billion of infrastructure to more resilient and modernized standards for bridges and culverts. These standards consider all of the natural processes that happen in a water way, including sediment and debris transport.

VTrans continues to modernize Vermont's infrastructure every year by these design processes and standards, which considerably increase the resiliency in the upgraded infrastructure. Structures that span bank full width typically allow for more flow to pass at lower velocities and significantly reduce the likelihood of debris or sediment build up. Although Tropical Storm Irene was very destructive, very few structures built to modern standards failed, which validated that the VTrans process established a more resilient transportation system.

Hydraulics Manual Update

The Hydraulics Manual and Hydraulic Standard were updated to incorporate sediment flow data and bank-full width. The updated design standard, specifically for bridges and culverts, better reflect likely sediment flow based on the natural width of each channel and is more resilient to flooding. Establishment of this statewide standard ensures that FEMA's cost share will be based on the cost to re-build a damaged bridge or culvert in a manner that is resilient to future floods.

Dam Safety Program

The Dam Safety Program (DSP) regulates non-power, non-federal dams and acts as the owner and operator at 14 State-owned dams. On the regulatory side, the DSP administers State Statute 10 V.S.A. Chapter 43, managing the Vermont Dam Inventory (see below), a permit program for construction and alteration of dams, an inspection program, an annual registration program, and other related tasks. The DSP also educates dam owners and the public about dam safety issues. On the ownership side, the DSP operates and maintains the three Winooski River Flood Control Dams (Waterbury, Wrightsville, East Barre) as well as eleven other dams throughout the State.

DATABASES AND MAPPING TOOLS

Natural Resources Atlas

The Natural Resources Atlas is a mapping tool managed by ANR that provides geographic and environmental information about sites across the State. Atlas users can navigate to areas of interest by entering an address or using the map display and toggle on or off numerous data layers.

The tool is frequently utilized by hazard mitigation planners. The Atlas includes several data layers particularly relevant to planning, including regulatory flood hazard areas, landslides, and invasive species infestation.

Functioning Floodplain Initiative

Vermont's Department of Environmental Conservation is leading the multistakeholder Functioning Floodplain Initiative (FFI) to identify areas where nature-based projects can have the biggest impact advancing environmental goals. Following a multi-year process of data collection and analysis, DEC is currently in the process of rolling out the mapping tool for public use.

FFI includes a flood resiliency component (along with water quality and ecological integrity components). The FFI analyzes hydrologic data and models fluvial processes to gauge a site's potential for increased floodplain storage capacity, and resulting benefits to public safety and property protection. By comparing these potential benefits against the costs of protecting or restoring floodplain functionality, FFI produces a score that can help guide project prioritization.

Transportation Resilience Planning Tool

VTrans' Transportation Resilience Planning Tool (TRPT) is a web-based application that identifies bridges, culverts, and road embankments across the State that are vulnerable to damage from floods, estimates risk based on the vulnerability and criticality of roadway segments and identifies potential mitigation measures. Development of the tool in pilot watersheds was funded through the DR-4022 subgrant to update the 2018 SHMP and the full State was completed in 2023. The TRPT combines river science, hydraulics and

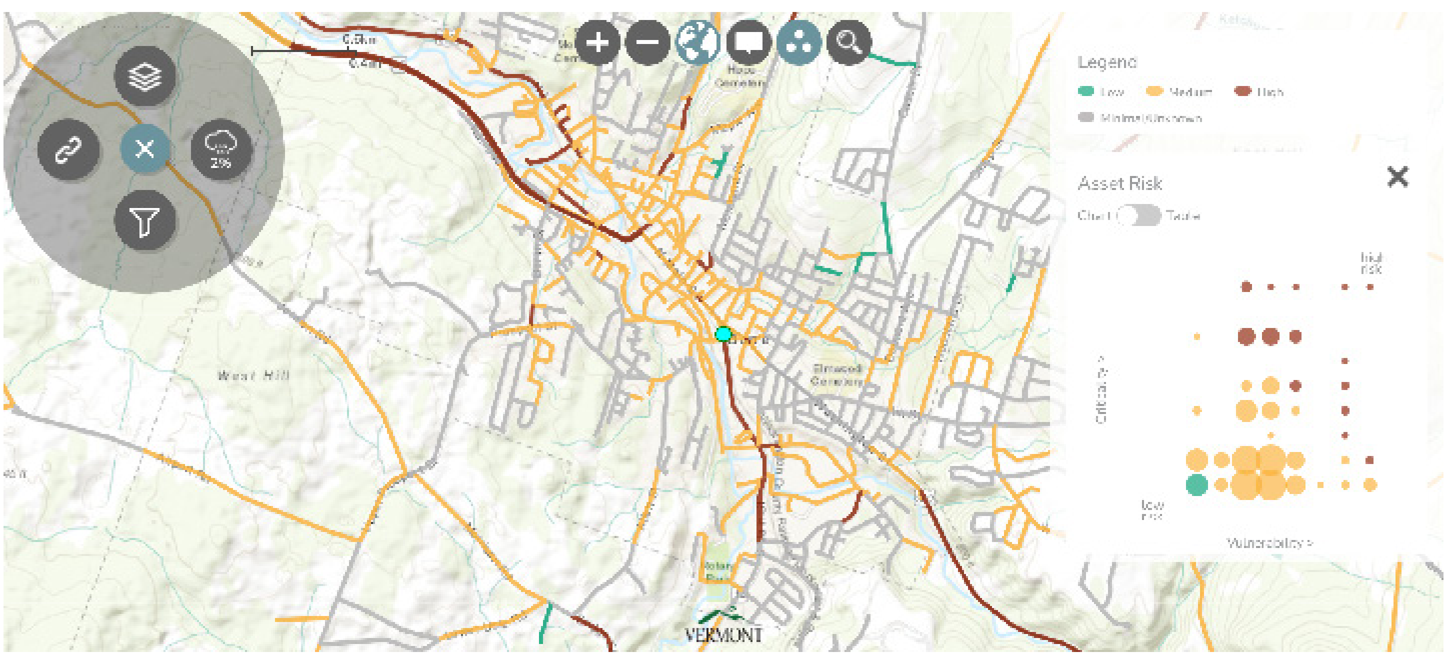

Figure 16: Transportation Resilience Planning Tool highlight of Barre City
Data Source: https://vtrans.vermont.gov/planning/transportation-resilience

transportation planning methods and is applied at a watershed scale. It identifies vulnerabilities in a proactive manner to avoid or mitigate against the impacts of future damages in the most critical, highest risk locations. The TRPT is incorporated in Vermont Project Selection and Project Prioritization, the mechanism VTrans' uses to identify, prioritize, and select state transportation capital improvement projects.

A statewide training effort is underway to provide training on the TRPT to a wide variety of users, including District staff, project designers, local municipalities, and regional planners. The TRPT will be used to inform transportation corridor plans, tactical basin plans, project scoping, capital programming and hazard mitigation planning for state and local highways. Several actions within the Mitigation Strategy relate to the expansion of this tool.

Department of Health Extreme Heat Resources

The Vermont Department of Health has several resources to assist local planners and other stakeholders identify and mitigate the risks of extreme heat to their community. The Heat and Health Data dashboard visualizes the growing risk of extreme heat in the State and the consequences to public health. The dashboard breaks out data on the county-level data for heat indices and thresholds, the number of excessive heat days, and heat-related emergency department visits. The Local Hot Weather Preparedness Guidance includes additional information on extreme heat risks and recommended actions, including adaptation and mitigation measures, for planners to consider. Planners and residents alike can also utilize the interactive map of Vermont's indoor cooling sites, beaches, pools, and other recreational water sites.

Vermont Dam Inventory

The Vermont Dam Inventory (VDI) is a database containing spatial, structural, historic, and regulatory information on most dams in Vermont. Data contained within VDI is managed by the Dam Safety Program within ANR.

Municipal Vulnerability Index

The Climate Action Office at the Agency of Natural Resources is working to develop a tool called the Municipal Vulnerability Index (MVI) which is a requirement of the Global Warming Solutions Act, and a key recommendation in Vermont's Climate Action Plan. The MVI will be a mapping tool with the goal of helping to identify where Vermont communities are most vulnerable to climate change, with a focus on pressures that climate change will place on Vermont's transportation, electric grid, housing, emergency services, and communications infrastructure. The tool is intended for primary use by municipalities to assist in planning for and implementing projects to address climate change. The MVI is expected to be completed in early 2024.

Climate Toolkit

The Vermont Climate Toolkit is being developed through a multi-stakeholder task group comprised of State agency staff, municipal volunteers, and technical assistance providers, with primary support from the Climate Action Office (see below). The Climate Toolkit will connect municipalities with climate action resources. This toolkit will include resources that cover a broad approach, including public health, frontline and impacted communities, how to support a just transition, and how to reach rural communities. The intent is to provide a centralized source for the information relevant for designing and implementing climate action measures or strategies, as well as information on financial resources and technical assistance. The toolkit will also provide opportunities to connect with state agencies and other engaged practitioners for technical advice and expertise.

National Risk Index

The National Risk Index (NRI) is an interactive tool that shows which communities are most at risk to a range of natural hazards. It includes data about the expected annual losses to individual hazards, social vulnerability, and community resilience. Maintained by FEMA, the NRI enables users to view hazard information at Census tract level, and the map display provides a valuable visualization of vulnerability within a jurisdiction.

PLANNING AND INTERAGENCY COORDINATION

Climate Action Plan

In September 2020 the Vermont State Legislature passed the Global Warming Solutions Act (GWSA, Act 153), which created legally binding greenhouse gas emissions reduction requirements; established a Vermont Climate Council; and directed the Council to consider opportunities for carbon sequestration through conservation, and, most relevant to hazard mitigation efforts, strategies for helping Vermont communities prepare for the impacts of climate change. The Vermont Climate Council is made up of 23 members appointed from the Governor's Cabinet, the House of Representatives, and the Senate Committee on Committees. The Council was charged with writing a Climate Action Plan, due by December 1, 2021, that outlines actions for the state to meet its greenhouse gas reduction requirements, increase its potential for carbon sequestration, and prepare for the impacts of climate change. The Council is required to update the Climate Action Plan every four years thereafter.

The process of creating the CAP brought partners together from across State government and non-governmental organizations with technical expertise in climate change or that could represent stakeholders. Climate Council and steering committee meetings were held throughout 2021 to draft the Initial Climate Action Plan, and continue to be held to prepare for the update to the Climate Action Plan due in July 2025.

Rural Resilience and Adaptation Subcommittee

Members of the VEM Hazard Mitigation team provided staff support to this subcommittee of the Climate Council during development of the Initial Climate Action Plan. The Rural Resilience and Adaptation Subcommittee, co-chaired by the VEM Director, championed the inclusion of funding for the Flood Resilient Communities Fund in the State's allocation of American Rescue Plan funding.

The early stages of the 2023 SHMP update were coordinated with the CAP development. VEM staff serving on the Rural Resilience and Adaptation Subcommittee worked to ensure 2018 SHMP actions were included for consideration and eventual adoption into the Initial Climate Action Plan. Where actions were not directly adopted from the SHMP for CAP, actions were reviewed to ensure the plans supported each other.

Climate Action Office

The Vermont Climate Action Office (CAO) is a division within the Agency of Natural Resources. The CAO coordinates and provides expertise and capacity on state-led climate initiatives, as well as the monitoring, assessment and tracking of climate adaptation, greenhouse gas mitigation, and resilience activities necessary to evaluate programs over time in achieving the requirements of the Global Warming Solutions Act (GWSA, Act 153) through implementation of the Climate Action Plan (CAP). The CAO is focused on three core areas:

- Climate Program Coordination
- On-going support of implementation of the Global Warming Solutions Act
- Community and Stakeholder Engagement

Inter-Agency Advisory Board

The Inter-Agency Advisory Board to the Climate Action Office advances coordination across State agencies on climate action. The Board is composed of representatives from the Agency of Agriculture, Food, & Markets, Agency of Commerce and Community Development, Agency of Human Services, ANR, VTrans, Department of Buildings & General Services, Department of Public Service, Vermont State Climatologist, and VEM. The Board meets regularly to coordinate on climate action across State government with a focus on the following objectives:

- Provide a space for proactive coordination on climate action across State government.
- Articulate where policy and financial implications overlap around climate action to ensure resources are maximized.
- Support the monitoring of progress over time in meeting the State's climate goals and requirements.
- Identify and frame up gaps where the CAO might prioritize support.
- Develop state positions on issues related to climate change.

Vermont Silver Jackets

Silver Jackets teams, facilitated by the U.S. Army Corps of Engineers (USACE), exist in all states and several territories of the United States. Silver Jackets Program Goals are to:

- Facilitate strategic life-cycle flood risk reduction.
- Create or supplement a continuous mechanism to collaboratively solve state-prioritized issues and implement or recommend those solutions.
- Improve processes, identifying and resolving gaps and counteractive programs.
- Leverage and optimize resources.
- Improve and increase flood risk communication and present a unified interagency message.
- Establish close relationships to facilitate integrated post-disaster recovery solutions.

The Vermont Silver Jackets team includes representatives from VEM Recovery and Mitigation Section, Vermont Agency of Natural Resources Floodplain Management Section, USACE, FEMA, National Weather Service, U.S. Geological Survey, and the Natural Resources Conservation Service. Other agency partners or local stakeholders are brought in as necessary. Facilitated by USACE, the team meets quarterly to discuss agency updates, how to address flood related challenges through collaboration and resource sharing, and progress in ongoing projects.

Projects are typically completed through the Flood Plain Management Services (FPMS) annual funding for interagency nonstructural work. Funding is applied towards time USACE staff can dedicate to a project, and is not a financial award to the state. Authorized by Section 206 of the Flood Control Act of 1960, as amended (33 U.S. Code § 709a), the FPMS program addresses the need of people who live and work in floodplains to know about flood hazards, and the actions they can take to reduce property damage and prevent the loss of life caused by flooding.

Projects may address any or all portions of the flood risk management life cycle (prepare, respond, recover, and mitigate.) Projects focus on approaches that utilize the USACE's expertise in engineering to provide local communities and states with technical and planning assistance regarding the development and implementation of nonstructural approaches to manage and reduce flood risks. Nonstructural measures promote solutions that reduce flood consequences, as opposed to solely engineered solutions that reduce flood hazards. Natural and nature-based approaches are encouraged when consistent with the state of understanding and uncertainty regarding their flood risk management benefits and may be submitted when they promote nonstructural solutions.

Brandon Flood Loss Avoidance Study

The Brandon, Vermont Flood Loss Avoidance Study set out to demonstrate that mitigation projects are cost-effective and help communities and government agencies decide to continue supporting them. In Brandon, an overflow culvert for the Neshobe River under Route 7 was designed and constructed in 2017 using a FEMA Hazard Mitigation grant of $2.55M. Five properties were acquired, one on Wheeler Road in 2013 and four on Newton Road in 2016 and 2019.

The Flood Loss Avoidance Study for the Neshobe River Overflow Culvert and six property buyouts in Brandon would quantify flood losses avoided due to the implementation of the projects and generate continued support for flood mitigation in Vermont. This project addressed a priority action identified in the 2018 Vermont State Hazard Mitigation Plan, to complete loss-avoidance studies to better understand the positive impact of completed mitigation work, under a strategy to improve local leaders' understanding of hazard mitigation.

High-Water Mark Signs

The 2022 interagency flood risk management proposal was to identify up to five flood-prone communities in Vermont that are interested in installing high-water mark signs and provide support for sign installation to improve local awareness of flood risk and flood risk management. Each community's sign would improve flood risk awareness among residents and visitors. This project addressed the key strategy identified in the 2018 SHMP to increase public knowledge and literacy of hazards and mitigation.

High Hazard Potential Dams

The most recent project completed through the Silver Jackets FPMS interagency nonstructural program was developed to address the recent changes in state hazard mitigation planning guidance and policies effective April 2023. One element of these changes will be to incorporate High Hazard Potential Dam (HHPD) Grant Guidance into State and Local Hazard Mitigation Plan required elements.

The HHPD section will be required if a state or local government plans to apply for HHPD project funding from FEMA. Applicants to the HHPD grant program must have in place a FEMA-approved state hazard mitigation plan that includes all dam risks and complies with the Disaster Mitigation Act of 2000 (Public Law 106–390; 114 Stat. 1552). Additionally, the local government with jurisdiction over the area in which the dam is located must have a FEMA-approved hazard mitigation plan that includes all dam risks. In order to achieve this requirement, VEM and the Vermont Office of Dam Safety will utilize technical assistance through the Silver Jackets program to conduct a risk assessment for HHPDs.

USACE used available tools to analyze data provided by the Office of Dam Safety. The study identified potential hazards to HHPD dams as well as the potential significant economic, environmental, and social consequences of dam incidents.

Environmental Justice Policy

In 2022, Vermont enacted a statewide environmental justice policy through Act 154. The Act codifies Vermont's commitment to providing a proportional number of resources to environmental justice populations for resilience planning and disasters recovery, among a number of other aims. The Act directs numerous State agencies, including ANR, VTrans, and DPS, to embed environmental justice consideration into their operations. Under this policy, these agencies will be required to develop community engagement plans focused on environmental justice populations and report annually on their alignment with the policy. The Act also directs ANR to create an environmental justice mapping tool.

Environmental Justice Advisory Council and Interagency Environmental Justice Committee

The Act established two entities to coordinate and make recommendations regarding implementation of the policy. The Environmental Justice Advisory Council is a multi-stakeholder body that includes representatives from municipal government, social justice organizations, mobile home park residents, environmental justice populations, and Native tribes. Members are chosen based on expertise in environmental justice principles and commitment to achieving environmental justice in Vermont.

The Interagency Environmental Justice Committee is composed of representatives of the covered agencies, to include VEM's State Hazard Mitigation Officer. The committee coordinates the implementation of the policy through tasks such as establishing principles to guide the development of the community engagement plans.

Transportation Planning

Resilience Improvement Plan

As a preliminary step to operationalizing the PROTECT program (see above), VTrans is finalizing the Resilience Improvement Plan (RIP). RIP will identify and analyze Vermont's transportation vulnerabilities to hazard risks. RIP will also develop a framework for project selection and implementation to guide deliberative use of PROTECT funds. Completing RIP will also reduce the non-federal cost share for projects under PROTECT – generally 20% – by as much as ten percentage points.

2040 Vermont Long-Range Transportation Plan

The 2040 Vermont Long-Range Transportation Plan (LRTP) is the State's long-range, transportation plan for all modes of travel. To address the challenges presented by increasingly frequent and severe extreme weather events, LRTP includes a specific directive to "Improve the resilience of the transportation system." The strategies identified as part of meeting this goal include designing infrastructure to withstand severe weather events, advancing VTrans' understanding of transportation system vulnerabilities to severe weather events, incorporating resilience as a factor in project prioritization and design, and providing technical assistance to municipalities to prepare for, withstand, and recover from severe weather events.

Transportation Asset Management Plan

VTrans' 2022 Transportation Asset Management Plan includes a strong theme of resilience throughout to tie together the Transportation Resilience Planning Tool (see above) with asset needs across the state to mitigate risk in the investments we make.

Energy Planning

Integrated Resource Plans

Pursuant to 30 V.S.A. §218c, each regulated electric or gas company in Vermont is required to prepare and implement an integrated resource plan (IRP) for provision of energy services to its customers. IRPs promote hazard mitigation by requiring utilities document their plan for tree trimmings and removals within utility line right of ways. IRPs are also required to evaluate potential investments to improve system reliability, including actions to protect or relocate facilities within floodplains.

Utilities update their IRPs every three years. IRPs are submitted to PSD, which also provides technical assistance during the planning process. Technical assistance often includes guidance on line upgrades and substation relocation to improve resilience to hazards.

Municipal and Regional Energy Planning

The Energy Development Improvement Act (Act 174) established a set of municipal and regional energy planning standards. Use of these standards are voluntary, but municipal and regional energy plans that meet them are entitled to “substantial deference” in the siting process for energy generation. Act 174 promotes hazard mitigation by incentivizing local planners to analyze the suitability of potential energy generation sites. Among the siting constraints planners must consider are regulatory floodways and river corridors. Act 174 plans bolster the resiliency of utilities by noting where such constraints make a location unsuitable for siting.

Nutrition Security Plan

A multi-stakeholder effort led by Vermont Farm to Plate and the Vermont Sustainable Jobs Fund is currently underway to develop a nutrition security plan for the State. The plan will focus on strategies to end food insecurity at the systemic level and strengthen local food supply chains. Prompted by response efforts to supply chain disruptions caused by the COVID-19 pandemic, the plan will likely contain broader insights about strengthening the resilience of Vermont’s food system to hazard risks.

Local Hazard Mitigation Planning

As of June 2023, 177 Vermont cities, towns, and villages have a current local hazard mitigation plan (LHMP), a coverage rate of 63%. Another 31 communities have a LHMP that has expired within the past year. This suggests that around nearly 75% of communities in the State have recently engaged in local hazard mitigation planning.

Local planning is important in multiple respects. The planning process spurs local officials to deliberate on their community's hazard risks and raises awareness amongst other stakeholders. The final plan serves as a valuable resource, with localized risk assessments and an action plan for mitigating those risks. After the plan is finalized, the community continues to monitor and evaluate the effectiveness of the plan, further spurring action on hazard mitigation.

LHMPs are also important because they enable access to funding for mitigation actions. FEMA HMA funding (see above) is generally only available to communities with a current, FEMA-approved LHMP.

Plan Development and Approval Process

LHMPs must satisfy the requirements of FEMA's Local Mitigation Planning Policy Guide ("the Guide") to receive FEMA approval. The Guide includes both procedural and substantive requirements. Communities must undertake a plan development process and engage with various stakeholders. The resulting plan must include components like a hazard risk assessment and a mitigation strategy.

Communities then submit their draft LHMP to VEM. Within 45 days, VEM evaluates whether the draft plan meets the requirements of FEMA's Guide. VEM works with the community on any revisions that are required to meet the Guide, and the community re-submits any subsequent drafts to VEM.

When VEM issues a determination that a draft LHMP satisfies all the requirements, that plan must then be adopted by the community, typically through a resolution of the community's Selectboard or Trustees. Once VEM confirms the plan's adoption, VEM formally approves the LHMP. The plan is then in effect for five years from the date of formal approval.

Program Administration by States

Since 2019, VEM has participated in FEMA's Program Administration by States (PAS) for reviewing local plans. VEM sought and received acceptance into PAS, a mitigation action identified in the 2018 SHMP, by demonstrating its capacity and commitment to hazard mitigation. Vermont's participation in PAS has made the plan approval process significantly more efficient.

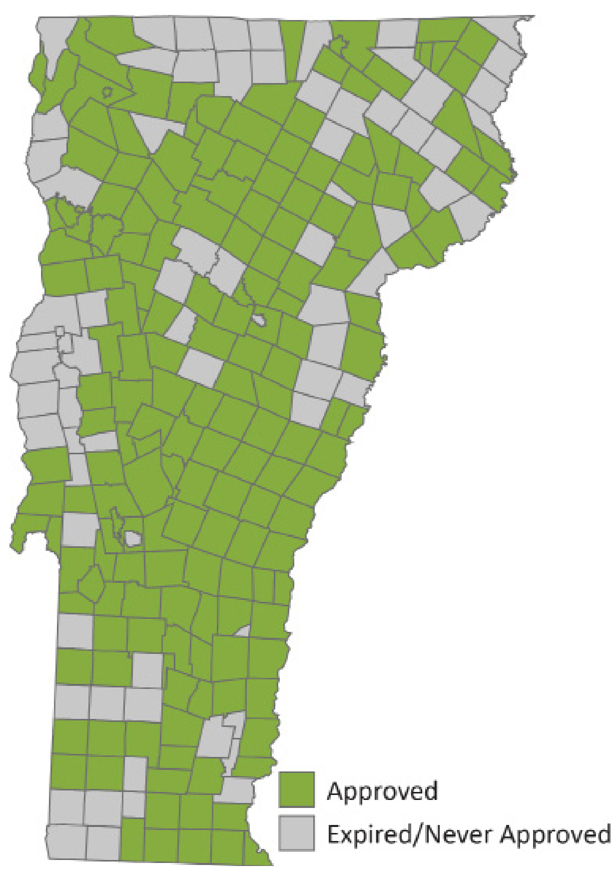

Figure 17: Local Hazard Mitigation Plan status by municipality map (September 2023)
Data Source: http://floodready.vermont.gov

PAS does not alter the requirements for LHMP approval; plans must still satisfy all the requirements of FEMA's Guide. Rather, PAS modifies the approval process. Previously, all draft plans reviewed by VEM were forwarded to FEMA, which would then commence its own review. FEMA made the final determination on a plan's compliance with the Guide. Now, under PAS, VEM has been delegated the authority to evaluate draft plans and issue formal approval when it determines that all requirements have been met. FEMA is notified when a plan is approved and conducts periodic spot-checks of approved plans to ensure continued adherence to the Guide.

Participation in PAS has made the plan approval process much more efficient and is a partnership with planners at FEMA Region I. The multiple layers of review prior to PAS were a source of significant delay at the end of what remains a typically lengthy plan development process. Community frustration with these delays could be compounded by a lack of status updates communicated by FEMA. PAS has enabled VEM to expedite the plan approval process and communicate directly with communities awaiting approval.

Funding and Technical Assistance

VEM helps communities secure funding for local planning mainly through HMA (see above). For instance, in the three most recent BRIC cycles, VEM has applied for and managed funding for the creation or update of 112 local plans. VEM works with Regional Planning Commissions (RPCs; see below) to identify communities without plans or with plans expiring shortly. VEM typically applies directly for HMA funding on behalf of communities seeking to create or update plans, prioritizing among communities expressing interest those whose plans expire earliest. This funding can then be used by the community. Vermont's many small communities often use this funding to contract for the necessary planning expertise. Communities often work with their RPC to develop the plan, though independent consultants are also used in other instances.

VEM provides technical assistance to communities and local planners, answering inquiries throughout the plan development process. VEM also maintains a suite of local planning resources to guide planners through various facets of the process, including community engagement, risk data, and mitigation strategies. VEM also conducts periodic trainings for new local planners and convenes workshops where planner can exchange knowledge, skills, and resources.

The technical demands of the LHMP development process present some inherent challenges for a state like Vermont, where most communities are small and face significant capacity constraints. However, Vermont has taken meaningful action to lower barriers. VEM's process for securing funding for local planning and providing technical assistance has reduced the burdens on small communities and has likely increased local planning participation rates. RPC support for local planning efforts have meaningfully enhanced capacity and bolstered a local planning ecosystem in Vermont that also includes numerous private sector planning consultants. VEM's PAS process has also fostered a more responsive approach to local planning and reduced the amount of time it takes to get a LHMP formally approved.

However, as evidenced by a survey of RPCs (see: Vulnerability Summary), capacity constraints remain and continue to create issues for local communities. Participation remains spotty in some areas of the State where capacity is likely most limited. Around 100 communities have not made or updated a LHMP in the previous five years. Certain required components of local planning, such as gathering hazard data or identifying actions for certain hazards, remain onerous for small communities and discourage participation. Administrative burdens of FEMA planning grants on small communities remains one of the greatest barriers to developing LHMPs despite VEM applying on behalf of communities and managing the FEMA grant.

Even among participating communities, many have struggled to update their LHMPs before previous iterations expire. While communities are typically successful in getting updated LHMPs approved within a year of the previous plan's expiration, the gap does create complications, most visibly regarding HMA and ERAF funding (see above). While these delays are attributable in no small part to the unprecedented disruptions to local governance wrought by the COVID-19 pandemic, they nonetheless warrant attention.

Beyond the planning process, there is variance among communities in the extent to which LHMPs facilitate meaningful hazard mitigation action. Following the plan development and approval process, some communities lack the capacity to effectively monitor implementation of LHMPs and the actions identified in them.

The State must therefore build on efforts to assist local communities and their planners. Additional capacity-building resources, including for RPCs, could enable greater participation by the smallest communities. VEM has continued to expand on its technical assistance, including now urging communities to begin thinking about funding multiple years before their current LHMP expires. And while a plethora of planning resources are available, VEM can focus on disseminating actionable guidance on the more vexing aspects of local planning, including using hazard data, identifying local mitigation actions, and on-going plan monitoring.

Mitigation actions are included in this Plan to address improved resources for local planning. The 2023 SHMP will in itself be a resource for local planning, particularly the evaluation of hazard probability and impacts (See: Vermont Profile & Hazard Assessment). As part of plan implementation (see: Plan Maintenance) the 2023 SHMP, risk assessment data, and mitigation priorities, will be shared with RPCs and local governments at the earliest stages of plan implementation following the SHMP adoption and approval. The SHMP will be available on the VEM website and will be promulgated through meetings and trainings throughout five years of plan implementation. Ongoing technical assistance will be available through VEM as requested.

Local risk assessments and mitigation actions are integrated into the SHMP at the time of the plan update, which officially begins about halfway through the five-year plan cycle. See more in the Vermont Profile & Hazard Assessment and the Vulnerability Assessment on the integration of local risk assessments in the SHMP. The review of local risk assessments and mitigation actions is an ongoing process, as VEM reviews and FEMA-approves LHMPs. While it is important that VEM utilizes local risk assessments for community-verified information on risks and vulnerabilities, it is the responsibility of the State to monitor and find ways to address capacity needs at the local level to develop and implement resilience projects. While mitigation actions in local plans address site-specific vulnerabilities and local needs, the SHMP utilizes local mitigation strategies to identify mitigation actions that better support local mitigation action.

OTHER LOCAL CAPABILITIES

In addition to LHMPs, Vermont cities, towns, and villages typically have several other capabilities that support hazard mitigation.

Municipal Plan

Many communities have municipal plans, which set overall goals and direction for growth and development for that community. Municipal plans typically include a flood resilience section that identifies flood hazard and fluvial erosion hazard areas, and recommends policies and strategies to mitigate risks to public safety, critical infrastructure, and other community assets (24 V.S.A. § 4382(12)). State law empowers communities with qualifying municipal plans to implement a range of other measures, including additional hazard mitigation capabilities.

Capital Budget and Program

Communities with a municipal plan may implement a capital budget and program (24 V.S.A. § 4403(1)). Annual capital budgets lay out the capital projects to be undertaken by that community during the coming fiscal year, while a capital program is a five-year plan (24 V.S.A. § 4430). Communities can use their capital budget and program to plan for and implement a range of hazard mitigation activities, including improvements to infrastructure to increase resilience or acquiring land or easements in hazard-prone areas. The extent to which communities utilize their capital budget and program to advance hazard mitigation can vary greatly.

Zoning Bylaws

Communities with a municipal plan are also authorized to enact a range of zoning and other land use bylaws (24 V.S.A. § 4402, 4410). Communities use these bylaws to regulate the use of land and the placement, spacing, and size of structures for the betterment of public health, safety, or welfare. Communities are expressly authorized to enact bylaws that regulate development in flood areas, river corridors, and other hazard areas (24 V.S.A. § 4424). Flood hazard area bylaws are common in Vermont and mitigate flood risk by limiting development in flood-prone areas. Such bylaws are also necessary for participating communities to comply with NFIP (see above).

River Corridor Bylaws

As of July 3, 2023, ninety-eight (98) communities have opted to enact some form of river corridor (RC) bylaws that are even more protective against flood risk. These regulations are typically based on ANR’s model RC bylaws, and ANR assists communities in mapping their river corridors through a geomorphic assessment. RC bylaws limit development not only in the vicinity of a stream or river’s current path, but also within and nearby its meander belt, the area over which the stream or river’s path may move over time due to channel migration. RC bylaws thus protect homes, infrastructure, and other community assets by mitigating the risk of fluvial erosion over time.

Town Road and Bridge Standards

Vermont cities, towns, and villages also frequently promote hazard mitigation by enacting road and bridge standards. VTrans developed and updates a set of model standards, which communities can adopt. Nearly all Vermont communities have enacted these standards, which regulate the construction, repair, and maintenance of local roads and bridges. The standards aim to, among other objectives, minimize damage to road infrastructure during flood events.

Regional Planning Commissions

Vermont's eleven Regional Planning Commissions (RPCs) were created by statute as nonprofit political subdivisions of the State (Figure 18) with boards of directors appointed by their member communities. In practice, they provide a variety of tasks at the regional level and in assistance to towns, often acting in certain capacities in lieu of county government.

The RPCs and local communities are in the best position to determine their own mitigation needs; therefore, the State relies on these entities to provide information to advance mitigation goals and priorities. Through a collaborative arrangement, VEM, RPCs, and towns identify and prioritize local mitigation needs. These issues are regularly discussed during monthly meetings between RPCs and VEM.

RPCs help towns determine the most appropriate mitigation policy and planning. RPCs work with local town officials to draft flood hazard bylaws, complete paperwork required for NFIP membership, develop mitigation plans, and provide direct grant writing and administrative assistance to local town officials to help implement mitigation projects.

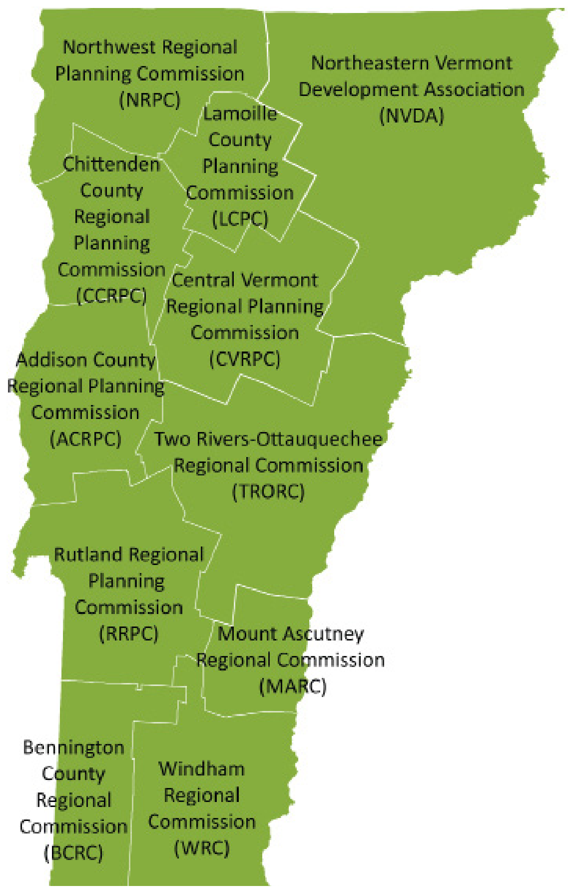

Figure 18: Vermont's 11 Regional Planning Commissions map
For information on the RPCs and their towns, see www.vapda.org

Given the rural nature of Vermont's communities, municipal capacity to develop, manage, and implement appropriate mitigation plans and measures is often insufficient. Accordingly, many towns across the State require assistance from their RPC and/or various State agencies to appropriately address hazard vulnerability.

Community Action Agencies

Vermont has five regional Community Action Agencies (CAAs) that operate through federal, State, and private funding to provide programs and services to low- or moderate-income residents. CAAs work in a variety of mission areas including affordable housing, home weatherization, environmental justice, and, as illustrated most recently by COVID-19, disaster response and recovery. CAAs experience with these areas and focus on low- and moderate-income residents creates opportunities for advancing hazard mitigation, including through outreach to frontline communities.

Outcomes and Opportunities

The local capabilities common to Vermont evince a pragmatic approach to addressing the capacity constraints on the State's many small communities. The municipal planning process guided by State law creates a framework for aligning flood resilience with a community's broader development goals. Model regulations like the RC bylaws and town and bridge standards provide a less burdensome means for communities to enact technical hazard mitigation regulations. And RPCs are a crucial source of expertise to local communities.

However, in a State where many local governments consist of a volunteer staff or a single town manager serving in multiple municipal roles, capacity constraints persist. Some of the smallest communities do not have the capacity to avail themselves of these common capabilities. And even for communities with these capabilities, capacity constraints may limit their effective implementation.

A chief issue is implementing hazard mitigation projects. While communities with LHMPs have identified the priority actions they can take to mitigate hazards, the plan itself is not a mechanism for their implementation. Capital budgets and programs are a potential mechanism for implementation, and LHMPs are supposed to be incorporated into them. However, the extent to which capital budgets and programs are used in practice to implement hazard mitigation projects can vary greatly among communities. Similarly, while numerous State and federal funding sources are potentially available, many communities do not have the capacity to routinely identify, apply for, and manage hazard mitigation grants.

The State can take several approaches to enhancing local capabilities, with a focus on increasing the capacity to effectively implement hazard mitigation projects. Communities could benefit from resources and training specifically geared towards effectively aligning planning efforts and incorporating hazard mitigation projects into municipal plans and capital budgets.

4: Vermont Profile & Hazard Assessment

Vermont Profile

Vermont is located astride the Green Mountains at the center of three ranges of the Appalachians, with the Adirondacks to the west and the White Mountains to the east. Vermont encompasses 9,250 square miles of landmass.

Population Trends:

Geographically, Vermont is the sixth smallest state and the second least populated. The population of Vermont was 625,741 based on the 2010 Census and is estimated to have increased to 643,077 based on the 2020 Census, an increase of approximately 2.77%. As the maps below indicate (Figures 19 & 20), there have been relatively minor changes in population statewide since 2010. Some counties have experienced slight gains (most notably Chittenden, +11,778), and other counties have experienced decreases (most notably Rutland, -1,070).

With a population density of approximately 69.78 persons per square mile, most Vermonters live in small, rural communities with populations of several hundred to several thousand people. The largest city is Burlington, with a population of 44,743 (2020 Census).

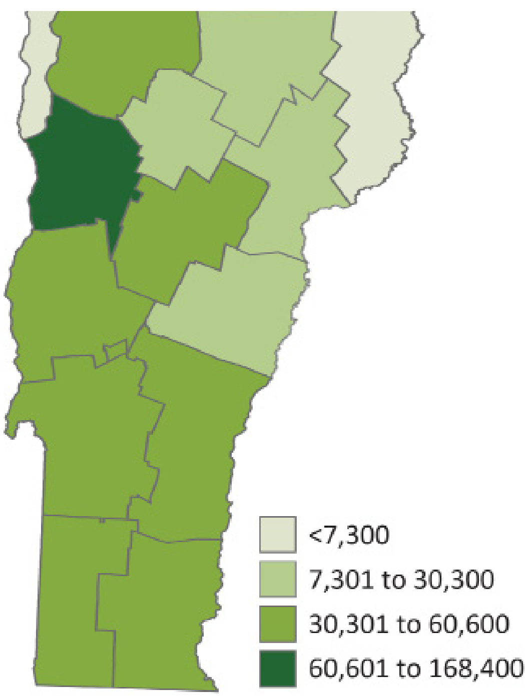

Figure 19: Vermont population by county map (2020)
Source: 2020 Decennial Census

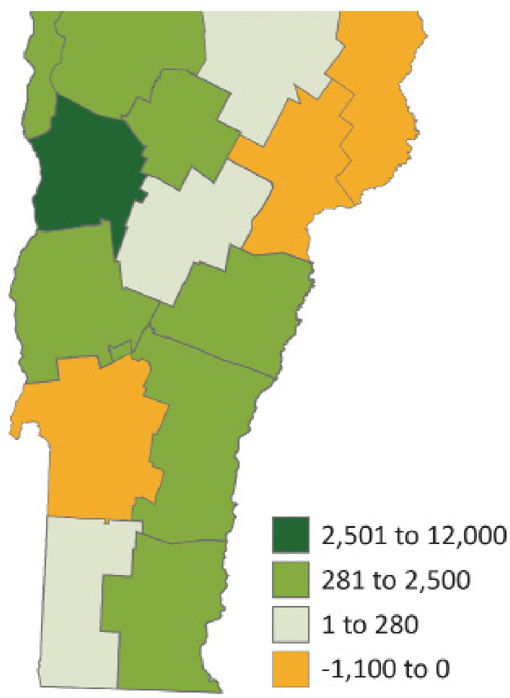

Figure 20: Vermont population change by county map (2010-2020)
Source: 2010 & 2020 Decennial Census

A net increase in population of 4,864 was recorded from July 2020 – July 2021, corresponding with the height of the COVID-19 pandemic.[1] The 2020-21 influx represented a big change from before the pandemic. It followed a net loss in 2019 and totaled more than two and a half times the number of people arriving in 2018. Nearly 95 percent of the migration to Vermont came from within the U.S. The exception was Chittenden County, with a third of the newly settled coming from outside the country. Several counties across Vermont saw growth in population, including Grand Isle, Orange, Windsor, and Franklin counties. Addison, Rutland, and Bennington counties did not have an increase in population according to 2020-2021 census data.

1 http://publicassets.org/wp-content/uploads/2022/07/MJB156.pdf

The EPA has ranked Vermont fourth in a nationwide assessment of resilience to extreme weather events brought on by climate change.[2] The authors of the 2014 State Climate Assessment wrote that Vermont may become a receiving state for regional climate refugees.[3] Climate refugees are settling in Vermont to find more permanent housing with a lower threat of relocation due to natural hazards.[4] With the potential for a high migration rate into the State, Vermont must be able to provide resources such as housing and career opportunities to the new population, which puts pressure on existing and future development.

Development and Housing Trends:

Historically, communities and infrastructure have often been sited in valleys and near water bodies, both globally and in Vermont. This development pattern was based on the assumption that rivers and coastlines would not shift or change course, which in turn relied on an assumption that climate conditions would remain relatively static. Today, New England residents are living in a changing climate with increased precipitation and stronger storms that were predicted to increase in climate change models, and many communities find themselves and their infrastructure increasingly vulnerable to natural disasters like flooding. With the benefit of time, it is now understood that rivers and water bodies naturally adjust and change course, again threatening much of the infrastructure that lies in their path.

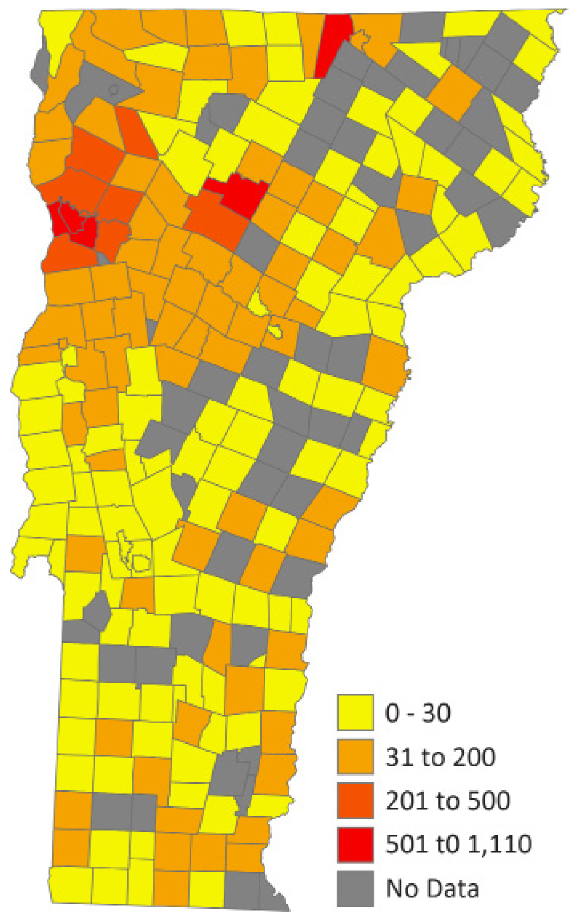

Figure 21: New building permits issued map (2018-2022)
Source: US Census Bureau Building Permits Survey

With current and projected increases in populations due to both the COVID-19 pandemic and climate migration, development planning must account for expected growth while maintaining community values. The VT Climate Action Plan published in December 2021 urges cities and towns to follow a compact settlement pathway, following Vermont's existing village center development patterns. Compact settlement refers to developing within already urbanized centers, as opposed to uninhabited areas. Compact settlement provides health, economic, and environmental benefits. The structure provides a network of resources to community members and protects the environment by preventing forest fragmentation.[5]

At the turn of the century Vermont experienced a development trend that then tapered off as rural population growth stagnated and decreased. This was coupled with a substantial decrease in net development trends between two decades, but the pandemic and climate migration could potentially alter this pattern. Vermont saw the

2 https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100SSN6.txt
3 http://dev.vtclimate.org/wp-content/uploads/2014/04/VCA2014_FullReport.pdf
4 https://www.mynbc5.com/article/climate-migrants-come-to-vermont-and-the-adirondacks/43222337
5 https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/Initial%20Climate%20Action%20Plan%20-%20Final%20-%2012-1-21.pdf

most substantial increase in population in the last decade with almost 5,000 people moving into the State from 2020-2021, which could be attributed to remote work, and an interest in the Vermont lifestyle.[6] With an increase in population comes an increased demand for housing. Figure 21 represents data collected between 2018 and 2022 from the US Census Bureau Building Permits Survey[7] showing the total number of residential building permits issued by each municipality. Municipalities that received the highest number of new building permits over the course of the five-year period since the 2018 SHMP include South Burlington, Burlington, the Town of Newport, Morristown, Williston, Winooski, Colchester, and Essex Junction. These municipalities, in descending order, each added a minimum of 400 housing units between 2018 and 2022. Most of the residential development occurred in and around the more urbanized Chittenden County. The jurisdictions experiencing the most development are not jurisdictions within the top three counties (Windsor, Washington, Windham) rated for the highest risk to all hazards according to the National Risk Index (See: Appendix to Section 4). Areas not highlighted on the map for highest new building permits may still be experiencing changes in population and land use. As a result, analyzing new building permits issued is the best available indicator of development trends across the State.

Unit increases in the past five years could partially represent the population trends associated with COVID-19 and climate change. However, it is important to consider that people may move into existing homes, temporarily living in second homes, or staying with family. Many communities in Vermont have a high percentage of second homes with their owners living elsewhere for most of the year. According to a survey on climate refugees in Vermont conducted through the University of Vermont, 44 out of 232 participants stated they purchased a home in Vermont as their second home.[8]

A review of all Local Hazard Mitigation Plans shows that the vast majority of communities report very little development, if any, since the 2018 State Hazard Mitigation Plan and that vulnerability has remained the same and is not projected to change. To get a better understanding of local development, VEM staff asked Regional Planning Commissions (RPCs) to note significant changes in development trends within their regions over the past five years and their impact on vulnerability, included in Table 9 below. Regions reporting no significant changes in development are not included.

In addition to the feedback from RPCs, several communities were added to Table 9 below based on the review of currently approved LHMPs (for more information on this review process, see: State & Local Capabilities). Predominately, LHMPs report that little, if any, development has taken place since their previous Plan and that vulnerability has remained the same and is not projected to change. This assessment was completed through the lens of the changing climate including anticipated increases in rainfall and hot weather days. See: Climate Change Trends Observed below.

6 https://www.vermontpublic.org/local-news/2022-08-24/long-known-for-its-dwindling-population-vermont-sees-a-recent-uptick-in-new-residents

7 https://www.census.gov/construction/bps/data_visualizations/index.html

8 https://www.uvm.edu/sites/default/files/Center-for-Research-on-Vermont/docs/Survey_Summary_4-pages.pdf

Table 9: Changes in Development by Region

Region	Munipality	Changes in Development & Vulnerability
NVDA	Maidstone	Maidstone observed development around lakes, with an increase in the conversion of seasonal homes. This new development could result in increased flood risk or ice damage.
NVDA	Averill	The population remains relatively small but has experienced conversion of seasonal properties around lakes, resulting in increased shoreland development. These developments increase the risk of flooding to camps and homes.
LCPC	Johnson	The town and village of Johnson both have large populations within the floodplain, which increases as development occurs within the village. Recently there has also been an increase in low-income housing within the floodplain.
LCPC	Stowe	Stowe has seen the greatest population increase in the county. The Stowe Mountain Resort continues to develop land around Mountain Rd and sees an increase in population during the winter months. Due to the increased traffic and development that Mountain Rd sees, if there is an emergency on that road there may be problems regarding access as there are no alternate routes to the top of Mountain Rd.
LCPC	Jeffersonville	Jeffersonville has increased the amount of floodplain restoration projects within the village which has resulted in a decrease in vulnerability as the floodplain is able to mitigate potentially damaging floodwaters.
CVRPC	Barre City	Barre City has seen a 6.2% decrease in population between the 2010 and 2020 census.
CVRPC	Waterbury	Waterbury has observed a 5% increase in population which hasn't impacted the town's overall vulnerability. However, development trends in the Central Vermont region have changed due to an increase in second home purchases which puts increased pressure on the available housing stock.
WRC	Dover	Dover has seen a significant population increase since the COVID-19 pandemic which has resulted in increased demand for emergency services that have yet to increase in capacity.
WRC	Stratton	Stratton observed population increases with new housing construction occurring in more remote locations. Those who live in more remote areas may be more isolated during hazard events and could be cut off.
NRPC	Isle La Motte, Saint Albans Town, Georgia	There has been a small increase in seasonal populations changing to year-round residents, but with negligible impacts due to local zoning along lakeshore. The town's capabilities are limited during summer tourist season and the associated traffic increase. During peak summer season, emergency services could be tied up with motor vehicle or boating accidents, so Isle La Motte relies on mutual aid at times.
NRPC	Richford	There has been an increase in the vulnerable population which the state housed during the pandemic. Richford's social services, limited public transit, healthcare, employment opportunities, and food access are all stated as vulnerabilities to the town.
RPC	Brandon	Brandon has recently completed several significant infrastructure improvements to both transit and utility networks. The town has the long-term goal of encouraging intentional and sustainable growth. Those infrastructure improvements have also included hazard mitigation projects that have made the town less vulnerable to flooding.
RPC	Killington	Killington has observed a population increase and has the potential for significant growth over the next decade. The Town Plan and Zoning Bylaws are designed to provide for orderly community growth, so new development is not expected to increase community vulnerability. The town's TIF District Plan includes plans for a municipal drinking water system and reconstruction of Killington Rd.
CCRPC	Burlington, Winooski, South Burlington, Colchester, Essex, Williston, Shelburne	The suburban and urban towns in Chittenden County have all observed a steady increase in population with no apparent vulnerability concerns.
BCRC	Bennington, Manchester	The most significant development within Bennington County has been limited to the redevelopment of existing buildings with very limited new construction and fewer than 30 units of new housing. Hazard-prone areas in more rural towns have not been impacted by development.

Transportation:

There are 14,171 miles of maintained public roadways, including 3,103 miles of state highways and 378 miles of interstate and 139 miles of Class-1 town highways in Vermont. The remaining mileage is municipally-owned and managed. Of the state-owned highway system, 772 miles are federally designated National Highway System (NHS) (Figure 22). Transportation systems that run north to south within the State are I-89 (northwestward from White River Junction to the Canadian border, serving both Montpelier and Burlington), I-91 (northward from the Massachusetts border to the Canadian border, connecting Brattleboro, White River Junction, St. Johnsbury, and Newport), and I-93 (northern terminus at I-91 in St. Johnsbury, connecting the northern part of Vermont with New Hampshire).

Other significant routes include U.S. Route 5 (running south to north along the eastern border of Vermont, parallel to I-91 for its entire length in the State), U.S. Route 7 (running south to north, along the western border of the State, connecting Burlington, Middlebury, Rutland, and Bennington) and Vermont Route 100 (running south to north almost directly through the center of the State, providing a route along the full length of the Green Mountains).

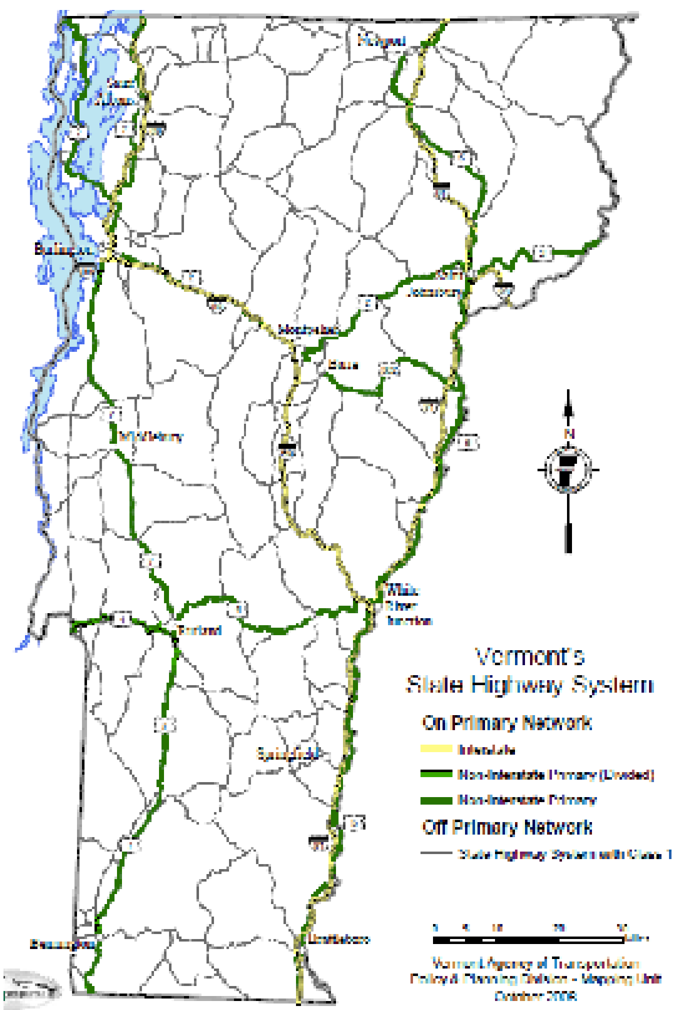

Figure 22: Vermont's state highway system map
Source: Vermont Agency of Transportation

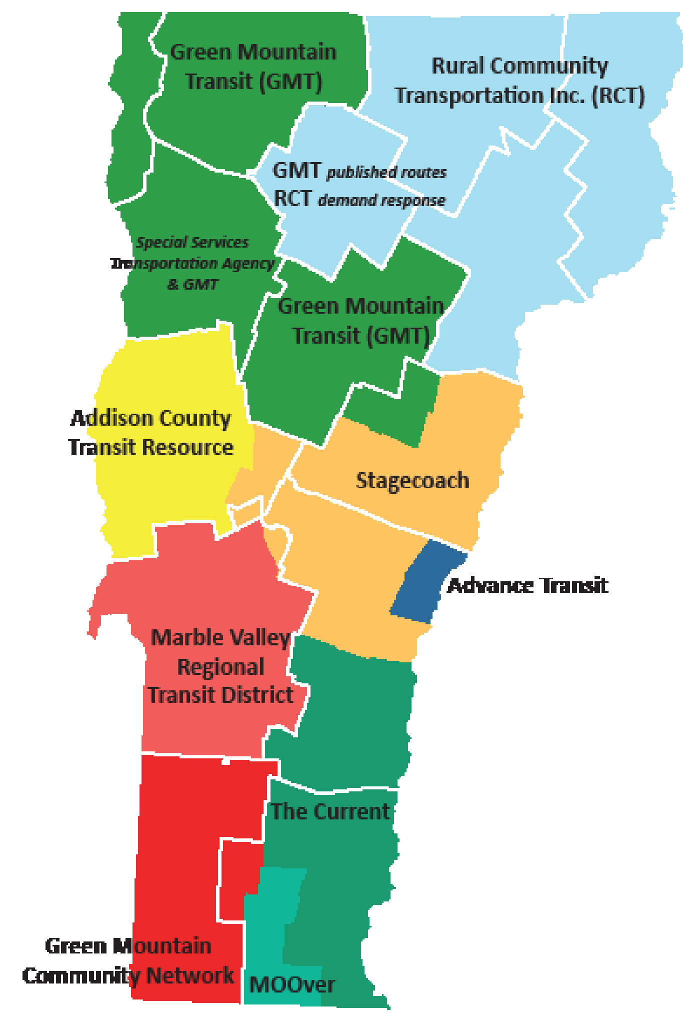

Figure 23: Vermont public transportation service areas map
Data Source: Vermont Public Transportation Association

East-west routes include U.S. Route 2 (crossing northern Vermont from west to east, and connecting the population centers of Burlington, Montpelier, and St. Johnsbury), U.S. Route 4 (crossing south-central Vermont from west to east, from the New York border in the Town of Fair Haven, through the City of Rutland, and across to Killington and White River Junction), U.S. Route 302 (traveling east from Montpelier and Barre, into New Hampshire and Maine), Vermont Route 9 (running across the southern part of the State from Bennington to Brattleboro), and Vermont Route 105 (crossing the northernmost parts of Vermont and connecting the cities of St. Albans and Newport).

Vermont has 520 interstate bridges, 1,835 bridges on state highways, and 1,642 town highway long (over 20') structures. VTrans also maintains 1,265 short structures, which include bridges and culverts with spans from six to twenty feet, as well as over 50,000 smaller culverts. The state operates 30 Park and Ride lots and has assisted in the development of 66 municipal lots.

A VTrans survey conducted in 2016 found that the vast majority of Vermonters (91%) travel in a personal vehicle frequently, with 88% commuting to work in a personal vehicle or carpool. The next largest transportation category was walking, with 45% of respondents walking as a means of transport multiple times per week or month.[9] Fourteen percent reported biking frequently, while 8% noted frequent use of public transportation.

Utilizing the 5-year estimates from the 2021 American Community Survey it was found that the vast majority of Vermont workers over the age of 16 (82%) commute to work in a personal vehicle or by carpooling. The next largest transportation category was walking, with 4% of respondents walking as a primary means of transportation to work. 1% reported using public transit and 2% reported biking as the main method to commute to work. All while 12% reported that they were primarily working from home and not commuting to work.[10]

Vermont is served by Patrick Leahy Burlington International Airport (BTV) as its main commercial airport, with Rutland-Southern Regional Airport (RUT) acting as a non-primary commercial airport. Vermont maintains 16 public airports, 10 of which are owned by the state. Vermont has eleven different bus companies (Figure 23), two ferry companies (Lake Champlain Transportation Co. and Fort Ticonderoga Ferry) and three rail service lines throughout the State. The State of Vermont also has a program called Go Vermont[11], which is a resource for travelers who want to reduce the cost and environmental impact of driving. It provides information on bus routes, biking, or walking and features a free carpool/vanpool matching service and ridesharing tips. The State is served by Amtrak's Vermonter and Ethan Allen Express passenger lines, the New England Central Railroad, the Vermont Railway, and the Green Mountain Railroad. The Ethan Allen Express serves Rutland, Castleton Middlebury, Vergennes, and Burlington, while the Vermonter serves Saint Albans, Essex Junction, Waterbury, Montpelier, Randolph, White River Junction, Windsor, Bellows Falls, and Brattleboro, with a planned extension to Canada terminating at Montreal. Vermont possesses 578 miles of active rail lines 305 miles of which are owned by the State.

9 http://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/Existing%20Conditions%20%20Future%20Trends%206-7-17.pdf
10 https://data.census.gov/table?q=vermont+transportstion&tid=ACSDT5Y2021.B08141
11 https://www.connectingcommuters.org/

High Risk-Factor Populations & Frontline Communities:

Natural hazards can affect everyone in Vermont, but some populations may be more vulnerable to certain types of events, or more significantly impacted during events. It is crucial to consider populations who may have limited access to information and resources due to demographic barriers. The Social Vulnerability Index (SVI)[12] defines overall vulnerability by summarizing four themes: socioeconomic status, household composition and disability, minority status and language, and housing and transportation. Figure 24 depicts this overall score by census block, broken into four relative categories of overall vulnerability. In addition to social vulnerability and the impact on people, vulnerability will also be considered within the realm of the built environment, the natural environment, and the economy, which may vary with each subsequent hazard. These categories are defined below under the "Hazard Impacts" section as they will be considered within each subsequent hazard profile. While many defining factors of vulnerability may overlap between hazards, specific variables significant to each hazard will be discussed in its profile, as well as in Section 5.

Vermonters over the age of 65 is a specific social demographic that is potentially more vulnerable to certain events, such as extreme heat. According to the 2021 ACS, 20.6% of Vermont was over the age of 65, above the national average of 16.8%. Populations over 65 years of age account for a fifth of Vermont's total population, meaning a large portion of the State could be particularly more vulnerable to hazard events. Figure 25 the percent population over 65 by county, with the most significant population in Essex County (23%, 1,408 people).

12 https://svi.cdc.gov/map.aspx

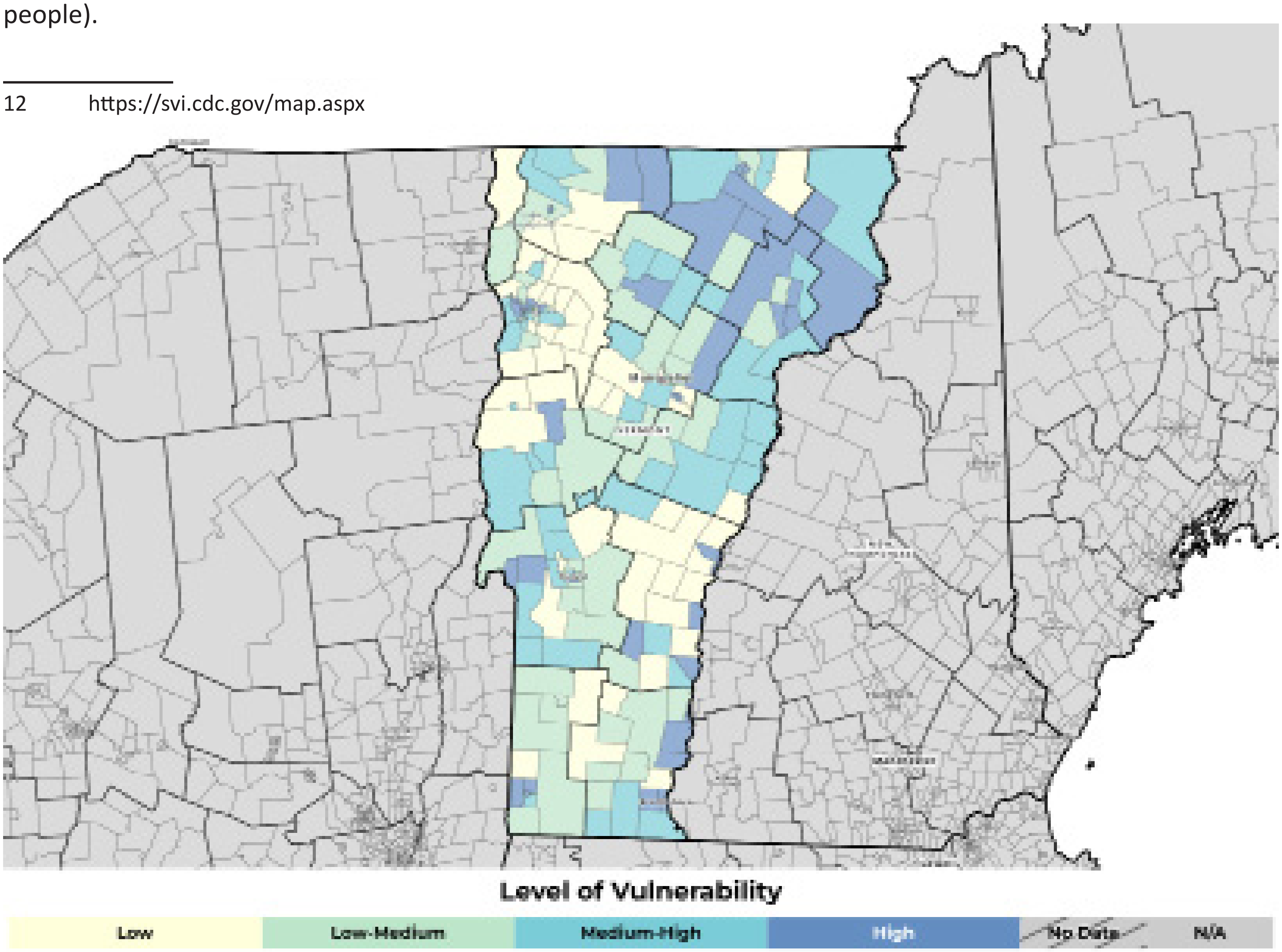

Figure 24: Vermont Social Vulnerability Index (SVI) ranking map
Data Source: Center for Disease Control

Vulnerability can also be economic. Based on estimates from the ACS, Vermont's median household income was estimated at $72,431 in 2021, slightly above the national average of $69,717. To better account for cost of living in Vermont, Vermont's Joint Fiscal Office develops a report biennially that determines a livable hourly wage for Vermonters.[13] This analysis estimates how much an individual would need to make, at a minimum, in order to live in Vermont based on a variety of family configurations and assuming employer-sponsored healthcare. The overall livable wage rate in 2022 was defined as $31,886 in individual income for a full-time worker in a two-person household without children. That equates to a household income of $63,773, which is considerably below the median household income for Vermont, but just below the national average median household income.

The below table includes the various household types considered in the report and their corresponding livable wage figures. These figures were calculated assuming a 40-hour week, 52 weeks a year (Hourly Wage X 40 hours/ week X 52 weeks/year).

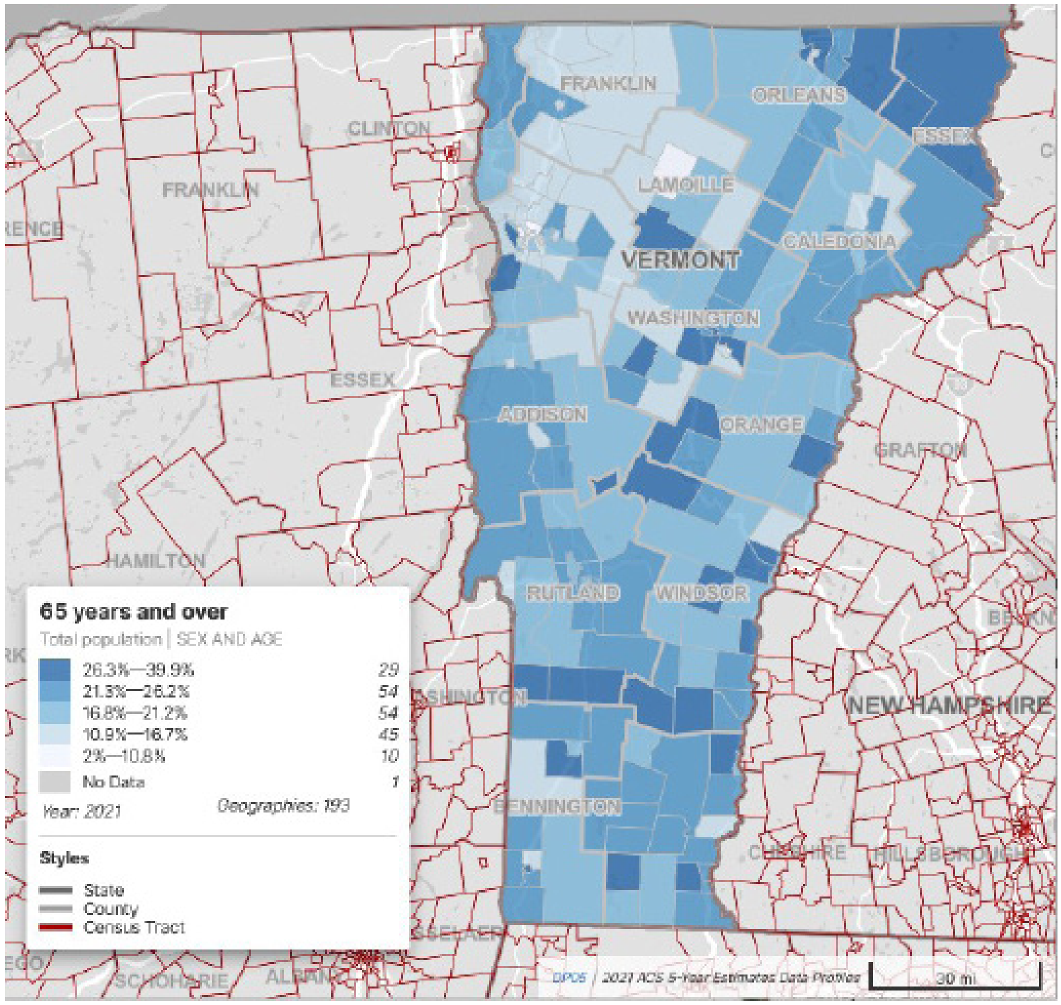

Figure 25: Vermont population over 65-years of age map
Data Source: US Census ACS 5-year estimates

Table 10: 2020 Basic Needs Budget Wages, Per Earner – Vermont's Basic Needs Budget				
Family Type	**Urban Annual Salary**	**Rural Annual Salary**	**Urban Household Salary**	**Rural Household Salary**
Single Person	$41,662.40	$39,104.00	$41,662.40	$39,104.00
Single Parent, One Child	$73,840.00	$64,480.00	$73,840.00	$64,480.00
Single Parent, Two Children	$95,513.60	$82,097.60	$95,513.60	$82,097.60
Two Adults, No Children	$31,428.80	$32,344.00	$62,857.60	$64,688.00
Two Adults, Two Children (one wage earner)	$77,854.40	$76,356.80	$77,854.40	$76,356.80
Two Adults, Two Children (two wage earners)	$54,017.60	$50,585.60	$108,035.20	$101,171.20

Source: Vermont Legislative Joint Fiscal Office

13 http://www.leg.state.vt.us/jfo/reports/2017%20BNB%20Report%20Revision_Feb_1.pdf

Climate Change Trends Observed

Over the past several decades, there has been a marked increase in the frequency and severity of weather-related disasters, both globally and nationally. Most notably, the Earth has experienced a 1.5°F rise in temperature since 1900, with most of that warming occurring since 1970. Over the same time period Vermont has been getting warmer and wetter, with an average air temperature increase of 4°F in winter and 2°F in summer.[14] This has far-reaching impacts on weather patterns and ecosystems. This statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer), is known as climate change.[15]

The Intergovernmental Panel on Climate Change (IPCC) forecasts a temperature rise between 1.5°F and 5°F by 2100, which will affect different regions in various ways over time. Impacts will also directly relate to the ability of different societal and environmental systems to mitigate or adapt to change.[16] Increasing temperatures are forecasted to have significant impacts on weather-related disasters, which will also increase risk to life, economy and quality of life, critical infrastructure and natural ecosystems. The IPCC notes that the range of published evidence indicates that the costs associated with net damages of climate change (including building, transportation, and energy infrastructure) are likely to be significant and will increase over time. It is therefore imperative that recognition of a changing climate be incorporated into all planning processes when preparing for and responding to weather-related emergencies and disasters.

Most of the natural hazards identified below are likely to be exacerbated by changes in climate, either directly or indirectly. This section begins to review changes in our global and regional climate, which are further addressed in the hazard profiles, including:

- **Precipitation:** Inundation Flooding & Fluvial Erosion; Drought; Wildfire; Landslides; Snow Storm & Ice Storm
- **Temperature:** Extreme Cold; Extreme Heat; Drought; Wildfire; Invasive Species; Infectious Disease; Snow Storm & Ice Storm
- **Snow Cover:** Snow Storm & Ice Storm; Drought; Wildfire

The National Aeronautics & Space Administration (NASA) reports that global climate change has already had observable effects on the environment: glaciers are shrinking, sea ice is disappearing, sea level rise is accelerating, heat waves are occurring more frequently and intensely, river and lake ice is breaking up earlier, plant and animal ranges have shifted, and trees are flowering sooner. Though climate change is expected to have global reach, the impacts differ by region. While the southwestern United States is expected to experience increased heat, wildfire, drought and insect outbreaks, the northeastern region is predicted to experience increases in heat waves, downpours and flooding. Accordingly, consideration of climate change was identified as a key guiding principle of the 2023 SHMP, addressed in each of the pertinent hazard profiles and incorporated into all relevant mitigation actions.

Since the beginning of the 20th century, average temperatures in Vermont have increased about 3°F. With the last 11 year period (2010-2020) being the warmest period on record. The intensity of Vermont winters and extreme winter cold has also decreased, with Vermont's freeze free period lengthening by 3 weeks since 1960. On average, lakes and ponds are thawing one to three days earlier per decade. Annual average precipitation has increased around 6" since the 1960s, with the largest increases occurring in the mountainous regions of the state. Winter and spring precipitation is projected to increase throughout this century and warming will increase the proportion of that precipitation that will fall as rain.

14 https://www.healthvermont.gov/health-environment/climate-health/climate-change
15 http://www.ipcc.ch/
16 https://climate.nasa.gov/effects/

Table 11: Observed Climate Trends – Vermont's 2017 Forest Action Plan		
Parameter	**Trend**	**Projections**
Temperature		
Annual Temperature	Increase	By 2050, projected increase in average annual temperature by 3.7-5.8° F; by 2100, increase by 5.0-9.5° F.
Seasonal Temperature	Increase	By 2050, projected increase in average winter temperature (December, January, February) by 4.3-6.1° F; average summer temperature (June, July, August) by 3.8-6.4° F
Hot Days > 90°F	Increase	More frequent and more intense; by the end of the century, northern cities can expect 30-60+ days with maximum daily temperatures >90° F
Cold Days < 0°F	Decrease	Reduction in days with minimum daily temperatures <0° F
Variability	Increase	Greater variability (more ups and downs)
Hydrology		
Annual Precipitation	Increase	By the end of the century, projected total increase of 10% (about 4" per year)
Season Precipitation	Variable	More winter rain, less snow; by 2050, winter precipitation could increase by 11-16% on average; little change expected in summer, but projections are highly variable
Heavy Rainfall Events	Increase	More frequent and intense
Soil Moisture	Decrease	Reduction in soil moisture and increase in evaporation rates in the summer
Snow	Decrease	Fewer days with snow cover (by the end of the century, could lose one-fourth to more than one-half of snow-covered days); increased snow density
Spring Flows	Earlier, Reduced Volume	Earlier snowmelt, earlier high spring flows with reduced volume; could occur ten days to >2 weeks earlier
Summer Low Flows	Increase	Extended summer low-flow periods; could increase by nearly a month under high emissions scenario
Ice Dynamics	Changing	Less ice cover and reduced ice thickness
Extreme Events		
Flood Events	Increase	More likely, particularly in winter and particularly under the high emissions scenario
Number of Short-Term Droughts	Increase	By the end of the century, under high emissions scenario, short-term droughts could occur as much as once per year in some places
Storms	Increase	More frequent and intense (ice, wind, etc.)
Fire	Increase	More likely
Phenology		
Growing Season	Increase	By the end of the century, projected to be 4-6 weeks longer
Onset of Spring	Earlier	By the end of the century, could be 1 to almost 3 weeks earlier
Onset of Fall	Later	By the end of the century, could arrive 2-3 weeks later

Source: fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Vermont_Forests/Library/2017_VT_ForestActionPlan.pdf

According to the 2018 National Climate Assessment, the average annual precipitation in the United States has increased by approximately 4% since 1901.[17] Of particular note, the Assessment also identifies the northern U.S. as being more likely to experience above average precipitation in the winter and spring, with even wetter conditions expected under a high greenhouse gas emissions scenario. In addition to higher annual precipitation in both the observed record and projected models, the northeastern United States is also projected to experience more frequent, heavier rainfall events. Since 1991, the incidence of these heavy precipitation events has been 38% above average for the northeast.[18]

17 https://nca2018.globalchange.gov/chapter/2#key-message-6
18 https://nca2018.globalchange.gov/chapter/2#key-message-6

HAZARD ASSESSMENT

A risk assessment is used to measure the potential loss of life, personal injury, economic impact, and property damage resulting from natural hazards by analyzing the vulnerability of people, the built environment, the economy and the natural environment. VEM staff used several methods to identify risks in Vermont, including the evaluation of historical data, consideration of changing climate trends, and feedback from stakeholders. This examination involved an extensive review of natural disasters in Vermont, both declared and undeclared. Man-made and technological hazards are covered extensively in the 2018 Vermont State Emergency Management Plan (SEMP), which follows a risk assessment methodology similar to that used in this Plan. Accordingly, the following sections of the risk assessment identify the natural hazards that Vermonters can expect to face over the next fifty years and beyond, and the mitigation strategies section reviews the actions underway or planned to address these hazards and risks. As noted in the 2018 SHMP, and confirmed again in the 2023 SHMP, the natural hazards not incorporated are coastal erosion, expansive soils, Karst topography, sinkholes, tsunamis and volcanoes. These hazards are considered non-significant, unlikely hazards in Vermont and therefore do not warrant extensive review and consideration in this Plan.

Hazard Events

Since 2018 Vermont has assessed the impacts of hazard events rather than the events themselves, as it is the impacts, not the events, that can be mitigated. This approach was continued in the 2023 Plan update. For example, inundation flooding, fluvial erosion, and wind can be associated with a hurricane event, but can also impact the State outside of a hurricane event.

A history of Vermont disaster declarations is included in the Appendix to Section 4.

Hazard Impacts

A task group composed of subject matter experts from the Steering Committee, VEM, and the National Weather Service ranked natural hazard impacts as part of the hazard assessment process. Table 12 presents that ranking, determined by multiplying the probability of occurrence by an average score for potential impact to the Built and Natural Environments, People, and Economy. Future probability included an assessment of potentially changing locations of hazard impacts, range of intensities, frequency and duration. This tool can be used for determining hazard mitigation priorities within the State and Local Hazard Mitigation Plans. The column headers are not perfectly siloed. Basic definitions are provided below to better understand the potential impacts under each column header, but each category is cross-cutting and related to the others. Additionally, it is an imperfect process to rank slow-moving hazards, with creeping impacts such as drought or invasive species, using the same criteria as fast-moving hazards such as inundation flooding. Additionally, crossing-cutting issues and other challenges will be further discussed within Section 5 of the Plan. Specific hazard impacts on the built and natural environments, people, and economy are expanded upon in each hazard profile.

Table 13 details the hazard assessment ranking criteria used in Table 12. Hazard ranking is determined by frequency of occurrence (probability) and potential impact. Minor economic disruption is considered isolated and very short-term – characterized by employees unable to make it to work or businesses closed for 1-3 days, and supply chain issues lasting less than a few weeks. Short-term economic impact has further-reaching and longer-lasting impacts, but the state will recover in less than 5 years. Both minor economic disruption and short-term economic impact will be most detrimental to low-income individuals and communities that may not have savings necessary to weather a temporary loss of work. In addition to economic impacts, hazard events can severely impact quality of life for individuals and communities. Certain Individuals and communities may feel the brunt of hazards more so than others depending on several factors. Vermont's Climate Action Plan defines Frontline Communities as those who feel the "worst and first" consequences of climate change. Through the hazard ranking process, the Steering Committee was instructed to think about the impact of each hazard on frontline communities.

The ***Built Environment*** is comprised of the manmade structures and infrastructure in our communities, many of which enable the continuous operation of critical business and government functions that are essential to human health and safety or economic security. Some of these structures and infrastructure, when stabilized, enable all other aspects of society to function. These include: law enforcement facilities, fire stations, town and city halls, and other government buildings and state assets; food, water and shelter facilities; health and medical facilities; energy and fuel facilities; communications systems; transportation systems, including roads and bridges, transit systems, rails, and airports; hazardous materials and storage facilities; and water systems, including wastewater facilities. All of these assets were considered in the development of the hazard assessment. The built environment also includes homes, dams, and other municipal structures such as libraries, and much more. Features of the built environment can be both functionally and culturally valuable to the people living there. After a disaster, the impacts to the built environment are some of the most visible.

Natural Environment encompasses natural resources and ecosystems, but also the natural features integrated with our communities including urban trees and agricultural land. Water, soil, air, forest products, fish and wildlife are all natural resources. Ecosystems include lakes, forests, meadows, and rivers. Ecosystem services are the processes of the natural environment producing benefits to humans such as flood control and water filtration by wetlands. In the absence of human intervention, the natural environment can withstand natural disturbances, and depends on natural hazards to maintain normal ecosystem function. It is due to human dependence on the natural environment for food, water quality, and other natural resources, and human influence on the natural environment, particularly climate change impacts on ecosystem health, that we are concerned with hazard impacts to the environment.

People refers to both life and well-being of those who live in, work in, or visit Vermont. Hazard mitigation planning centers around protecting life and property. Hazards can be deadly, but there are many other impacts of hazards that need to be accounted for. A few examples of potential hazard impacts to people are loss of housing, loss of childcare, displacement, food insecurity, unemployment, illness, psychological trauma, depression, and loss of life.

Economy captures the economic impacts of hazards that can lead to short and long-term financial hardships. Hazards can cause agricultural losses, decline in tourism, damages to storefronts and goods for sale, loss of employers and jobs, and disruption in supply chains. There is also the substantial cost of paying for recovery from hazard events for the state, municipalities, individuals, nongovernmental organizations, and businesses.

The hazards and explanations of their relative probability and impact scores are detailed in the individual hazards assessment sections below. While these hazards are profiled individually, this Plan and the hazard assessment sections recognize that hazards, like their impacts, do not occur in silos; many of the hazards are inter-related and often occur in tandem. To highlight the most significant relationships, the fluvial erosion and inundation flooding assessments were combined. Each individual hazard assessment section also references the other pertinent hazards and their content, when applicable.

Table 12: 2023 Hazard Assessment

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Fluvial Erosion	4	4	4	4	4	4	16
Inundation Flooding	4	4	4	4	2	3.5	14
Heat	4	2	4	3	2	2.75	11
Wind	4	3	2	2	2	2.25	9
Snow	4	2	3	2	1	2	8
Ice	3	2	3	3	2	2.5	7.5
Drought	3	1	3	3	3	2.5	7.5
Infectious Disease Outbreak	3	1	4	4	1	2.5	7.5
Cold	3	2	3	2	2	2.25	6.75
Invasive Species	3	2	1	3	3	2.25	6.75
Landslides	3	3	2	1	2	2	6
Wildfire	2	3	3	3	3	3	6
Earthquake	2	2	2	2	2	2	4
Hail	3	1	1	2	1	1.25	3.75

*Score = Probability x Average Potential Impact

Table 13: Hazard Assessment Ranking Criteria

	Frequency of Occurrence: Probability of a plausibly significant event impacting the community or regional scale based on previous occurrences and climate change projections.	Potential Impact: Severity and extent of damage and disruption to built and natural environments, people, and the economy
1	Unlikely: <1% probability of occurrence per year	Negligible: isolated occurrences of minor built or natural environmental damage, potential for minor injuries, health, or well-being impacts, or minimal economic disruption.
2	Occasionally: 1–10% probability of occurrence per year, or at least one chance in next 100 years	Minor: isolated occurrences of moderate to severe built or natural environmental damage, potential for injuries or health or well-being impacts, minor economic disruption.
3	Likely: >10% but <75% probability per year, at least 1 chance in next 10 years	Moderate: severe built or natural environmental damage on a community scale, injuries, fatalities or impacts to individual and community well-being, short-term economic impact.
4	Highly Likely: >75% probability in a year	Major: severe built or natural environmental damage on a community or regional scale, multiple injuries or fatalities or severe long-term impacts to individual and community well-being, significant long-term economic impact.

Jurisdictional Risk Assessments

In an effort to validate the risk assessment completed by the Steering Committee, and as one of the metrics used to assess local vulnerability, VEM staff asked RPCs to rank the same list of hazards based on the vulnerability in their respective regions. RPC staff are highly qualified to make this assessment based on experience as local liaisons to the State Emergency Operations Center (SEOC) during disaster events, and serving as planning consultants for Local Hazard Mitigation Plans (LHMPS). RPCs ranked vulnerability on a scale from 1-14, with 1 being the most significant and 14 being the least significant. Table 14 represents the responses from each RPC, with an average score based on all responses, ordered from most to least significant. The results of this analysis closely matched the hazard ranking completed by the Steering Committee, further confirming Vermont's most significant hazards (i.e., Fluvial Erosion, Inundation Flooding, Ice and Snow).

Table 14: Hazard Assessment Ranking by Regional Planning Commission

Hazard Impact	2023 Average	Change from 2018	ACRPC	BCRC	CCRPC	CVRPC	LCPC	NRPC	NVDA	RRPC	SWCRPC	TRORC	WRC
Inundation Flooding	1.8	0.4	7	1	2	1	1	1	1	2	1	1	2
Ice	3.6	1.0	2	4	4	2	4	2	5	4	6	3	4
Fluvial Erosion	3.7	-1.4	6	2	1	8	8	5	3	1	2	4	1
Wind	4.1	1.0	1	3	6	3	3	4	2	3	4	13	3
Snow	4.5	0.0	3	5	5	4	2	6	6	6	5	2	5
Cold	5.9	1.5	4	8	8	6	5	3	4	5	8	5	9
Heat	8.0	3.1	5	9	9	9	6	12	7	8	9	6	8
Drought	8.3	1.0	10	10	7	10	7	8	8	9	7	8	7
Infectious Disease	8.5	1.5	8	6	3	5	10	9	10	14	12	7	10
Wildfire	10.0	-1.2	11	11	11	12	12	10	12	7	3	9	12
Invasive Species	10.2	-2.2	12	7	10	13	11	13	9	10	11	10	6
Hail	10.9	-1.4	9	12	12	7	9	11	11	11	13	12	13
Landslides	11.6	-3.2	13	14	13	11	13	7	13	12	10	11	11
Earthquake	13.8	-0.7	14	13	14	14	14	14	14	13	14	14	14

In June of 2023, 177 of the 281 jurisdictions in Vermont had FEMA-approved Local Hazard Mitigation Plans (63%). All currently approved LHMPs were reviewed by VEM staff during the development of the 2023 SHMP in order to inform the risk assessment as well as the determination of the most vulnerable communities, which is further discussed in Section 5: Vulnerability Summary.

In a review of these approved plans, VEM mitigation staff identified natural hazards that were addressed by more than 10 individual jurisdictions (Table 15). The analysis confirms that the most significant concerns at the State level are consistent with reality at the regional and local levels, with Flooding, Fluvial Erosion and Ice Storm and Winter Storms ranking as the most significant hazards. Extreme Heat was included in 10 LHMPs when the last review was done in 2017, and has since been included in 36 plans across Vermont.

The hazard prioritization process in LHMPs is not uniform across municipalities, however it is most common to base the prioritization process on the SHMP hazard ranking table (See Table 12). The local planning teams evaluate hazard impacts, both experienced and projected in the future, on the built and natural environment, people, and the economy. Through this process past and potential losses to vulnerable structures are assessed and integrated into the LHMPs. These assessments are reflected in Section 5: Vulnerability Summary.

The ranking of hazards at the State level versus the regional and local levels does have some discrepancies. Flooding and fluvial erosion are clearly ranked first across the board because many of Vermont's communities have experienced or seen flooding and fluvial erosion and the devastation it causes firsthand. Similarly, snow and ice rank higher in the local assessment over the State hazard assessment. The greatest discrepancy between the State and local assessments is in the ranking of heat as a priority hazard. Historically speaking, heat has not been a major hazard due to a typically cooler climate given the northerly latitude of Vermont. Annual average temperatures and extreme temperatures are on the rise however, and there are observed impacts to people, environment, and infrastructure that have impacts on the economy. We expect extreme heat to become a more common hazard prioritized in Local Hazard Mitigation Plans over the coming years. Drought and wildfires, which become more likely with rising temperatures, are also expected to rise in the hazard rankings across the State. The State will need to be prepared to provide the technical resources and financial support to address these increasing hazards.

Table 15: Hazards Addressed in Local Hazard Mitigation Plans Approved as of June 2023

Hazard	Approved LHMPs	Percent of Approved LHMPs
Flooding	134*	100.0%
Fluvial Erosion	125	93.3%
Winter Storms	115	85.8%
Ice Storm	101	75.4%
High Wind	87	64.9%
Flash Flood	69	51.5%
Extreme Cold	62	46.3%
Hail	48	35.8%
Wildfires	47	35.1%
Drought	46	34.3%
Thunderstorms	42	31.3%
Hurricanes/Tropical Storms	39	29.1%
Landslides	38	28.4%
Earthquakes	38	28.4%
Infectious Disease Outbreak	37	27.6%
Invasive Species	36	26.9%
Extreme Heat	36	26.9%
Extreme Temperatures	33	24.6%
Dam Failure	32	23.9%
Tornadoes	27	20.1%
Ice Jams	26	19.4%
Lightning	26	19.4%

*There were 134 plans approved between 2017 and June 2023. Some plans are multi-jurisdictional.

Note: further discussion on localized vulnerability is addressed in Section 5: Vulnerability Summary.

4-1: Inundation Flooding & Fluvial Erosion

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Fluvial Erosion	4	4	4	4	4	4	16
Inundation Flooding	4	4	4	4	2	3.5	14

*Score = Probability x Average Potential Impact

Flooding is the most common recurring hazard event in Vermont. In recent years, flood intensity and severity appear to be increasing. With a projected increase in more intense precipitation events there is an increased risk of inland flooding particularly in valleys, where people, infrastructure, and agriculture tend to be concentrated.[1] Flood damages are associated with inundation flooding and fluvial erosion. Data indicate that greater than 75% of flood damages in Vermont, measured in dollars, are associated with fluvial erosion,[2] not inundation. These events may result in widespread damage in major rivers' floodplains or localized flash flooding caused by unusually large rainstorms over a small area. The effects of both inundation flooding and fluvial erosion can be exacerbated by ice or debris dams, the failure of infrastructure (often as a result of undersized culverts), the failure of dams, continued encroachments in floodplains and river corridors, and the stream channelization required to protect those encroachments.

Inundation flooding is the rise of riverine or lake water levels, while ***fluvial erosion*** is streambed and streambank erosion associated with physical adjustment of stream channel dimensions (width and depth). Both inundation flooding and fluvial erosion occur naturally in stable, meandering rivers and typically occur as a result of any of the following, alone or in conjunction:

- **Rainfall:** Significant precipitation from rainstorm, thunderstorm, or hurricane/tropical storm. Flash flooding can occur when a large amount of precipitation occurs over a short period of time.
- **Snowmelt:** Melted runoff due to rapidly warming temperatures, often exacerbated by heavy rainfall. The quantity of water in the snowpack is based on snow depth and density.
- **Ice Jams:** A riverine back-up when flow is blocked by ice accumulation. Often due to warming temperatures and heavy rain which causes snow to melt rapidly and frozen rivers to swell.

Inundation and fluvial erosion may both increase in rate and intensity as a result of human alterations to a river, floodplain, or watershed. For instance, when a dam fails there may be significant, rapid inundation which can occur without warning. Public and private structures and infrastructure become vulnerable when they are located on lands susceptible to inundation and fluvial erosion.

An increase in annual precipitation rates due to climate change could potentially exacerbate inundation flooding and fluvial erosion events in the future. Since the 1960s, the state of Vermont has seen a 6" increase in average annual precipitation, likely attributed to the warming of the atmosphere and subsequent increased evaporation rates.[3] According the 2021 Vermont Climate Assessment, the northeastern part of the state has seen the largest annual increase in precipitation, with a 26% increase or 9.1" since the early 1900s.[4] Similarly, heavy precipitation events have been more common in the last century, increasing at a rate of 0.5 days per decade since the 1960s and twice as fast in the summer season.

1 https://nca2018.globalchange.gov/chapter/18/
2 http://floodready.vermont.gov/RCFAQ#4
3 https://climatechange.vermont.gov/vermont-today
4 https://site.uvm.edu/vtclimateassessment/files/2021/11/VCA-Chapter-1-11-4-21-1.pdf

Inundation Flooding

Riverine Inundation Flooding:

The land area where inundation flooding occurs is known as the floodplain. During high water events, water flows out of the riverbank and spreads out across its floodplain. FEMA defines the portion of the floodplain inundated by the 1% annual chance flood as the Special Flood Hazard Area (SFHA); the area where the National Flood Insurance Program (NFIP) floodplain management regulations must be enforced and where the mandatory purchase of flood insurance applies for federally secured loans.

Inundation flooding on larger rivers and streams typically occurs slowly, over an extended period of time but can spread out over a large area of land. Due to the slower onset of inundation flooding on larger rivers, there is time for emergency management planning (e.g., evacuations, electricity shut-off considerations, etc.) to take place. Though the inundation floodwaters are slower to hit, they often take time to recede as well, and exposure to water for an extended period can result in significant property damage. U.S. Geological Survey's (USGS) National Water Information System monitors real-time streamflow gaging stations in Vermont (Table 16).

Table 16: National Weather Service Stream Gauge Status	
(purple)	Major Flooding
(red)	Moderate Flooding
(orange)	Minor Flooding
(yellow)	Near Flood Stage
(green)	No Flooding

Snowmobile bridge near Waterbury, VT flexes as debris and water rush past following Tropical Storm Irene
Photo Credit: www.mansfieldheliflight.com/flood

Lake Inundation Flooding:

Table 17: National Weather Service Lake Champlain Flood Categories	
Major Flood Stage:	101.5’
Moderate Flood Stage:	101’
Flood Stage:	100’
Action Stage:	99.9’

The Lake Champlain Basin has a relatively wet climate, averaging approximately 37.5” of precipitation on an annual basis. As the topography within the basin is comprised of steep mountain slopes and narrow river valleys, floodwaters have access to very little flat area to spread out across and on which to be absorbed, leaving much of the excess water to be funneled directly towards Lake Champlain. The lake is considered to be at flood level once the elevation tops over 100’ above sea level[5] (Table 17). FEMA’s Base Flood Elevation (BFE) of Lake Champlain is 102’. The highest recorded level at the gage in Burlington was 103.27’ on May 6, 2011.

Overall, 2011 was a record-breaking year for Lake Champlain water levels in May and September, as illustrated in Figure 26, which shows the maximum recorded lake level throughout the year with the 2011 lake level. It is worth noting that the published BFE and 2011 flood levels shown below are stillwater elevations and do not consider wave action. In 2011, wave action increased flood levels an additional 3-5’, depending on location, causing significant flood damage for lakeshore property owners.

Because Vermont has no coastal or ocean-front areas, coastal flooding is not an issue; however, increasing development pressures on the lake front in Shelburne, Charlotte and Ferrisburgh may be impacted from erosion, storm water runoff and related pollution. The Lake flooding in spring 2011 impacted a large number of communities, as water levels topped well over the 500-year floodplain and remained above the base flood elevation for over a month.

As the trends outlined above indicate greater precipitation and more frequent severe rainfall events, swollen rivers in the Lake Champlain basin (Figure 27) will continue to cause lake levels to rise, further impacting the nearby built environment vulnerable to inundation, erosion and water quality challenges.

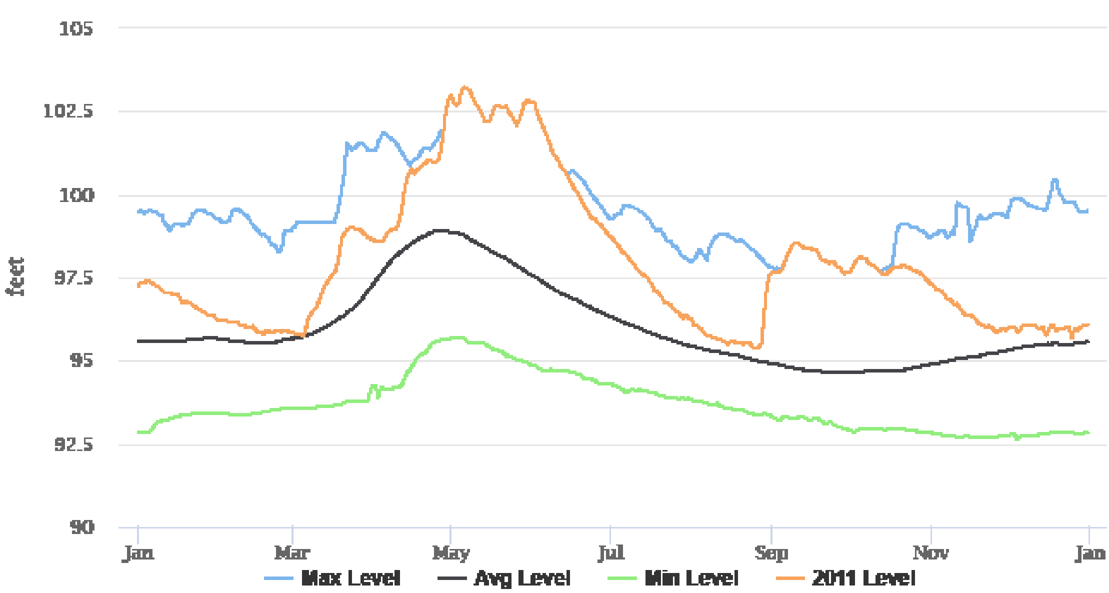

Figure 26: Lake Champlain water level—2011 level and summary level through 2017
Source: https://www.weather.gov/btv/lakeLevel?year=2011

5 http://www.lcbp.org/water-environment/water-quality/flooding/

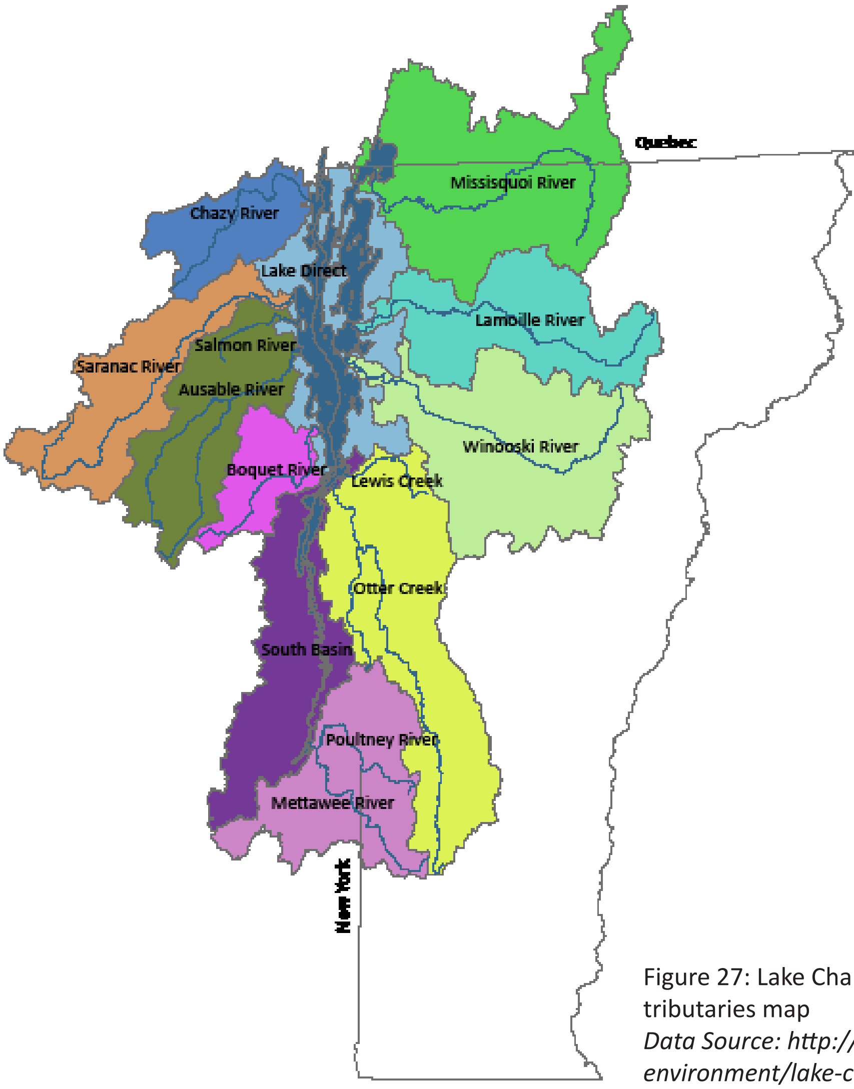

Figure 27: Lake Champlain sub-basins & major tributaries map
Data Source: http://atlas.lcbp.org/nature-environment/lake-champlain/

Inundation Flooding & Fluvial Erosion

In Vermont, most flood-related damage is due to fluvial erosion. Erosion occurs when the power of the flood (i.e., the depth and slope of the flow) exceeds the natural resistance of the river's bed and banks. Rivers that have been overly straightened or deepened may become highly erosive during floods, especially when the banks lack woody vegetation (riparian buffers), or when riverbed sediments have been removed. In areas where rivers are confined due to human activity and development, they have become steeper, straighter, and disconnected from their floodplains. The more a river is bottlenecked, the greater power it will gain, which eventually results in a greater degree of damage to critical public infrastructure such as roads and stream-crossings, as well as homes, businesses, community buildings and other man-made structures built near rivers. Fluvial erosion is also increased downstream when all the eroded materials (i.e., sediment and debris) come to rest in a lower gradient reach, clog the channel, and cause the river to flow outside its banks. When severe enough, fluvial erosion can also be the cause of Landslides (see: Landslides). The land area that a river accesses to meander and overtop its banks to release flood energy without excessive erosion is known as the River Corridor.

A river corridor includes the meander belt of a stream or river and a buffer of 50'. The River Corridor, as defined in Vermont statute 10 V.S.A. § 752, is:

the land area adjacent to a river that is required to accommodate the dimensions, slope, planform, and buffer of the naturally stable channel and that is necessary for the natural maintenance or natural restoration of a dynamic equilibrium condition, as that term is defined in section 1422 of this title, and for minimization of fluvial erosion hazards, as delineated by the Agency of Natural Resources in accordance with river corridor protection procedures.[6]

Vermont's River Corridor maps (Figure 28) delineate river corridors for larger streams and rivers, and standard setbacks for smaller, upland streams. The setbacks were determined by factoring in the same stable stream slope requirements used when delineating a river corridor using a meander centerline setback. These maps are located on the Vermont FloodReady[7] and Vermont Natural Resources Atlas[8] websites.

Severe damage to Vermont Route 4 in Killington, VT due to fluvial erosion during Tropical Storm Irene
Photo Credit: www.mansfieldheliflight.com/flood

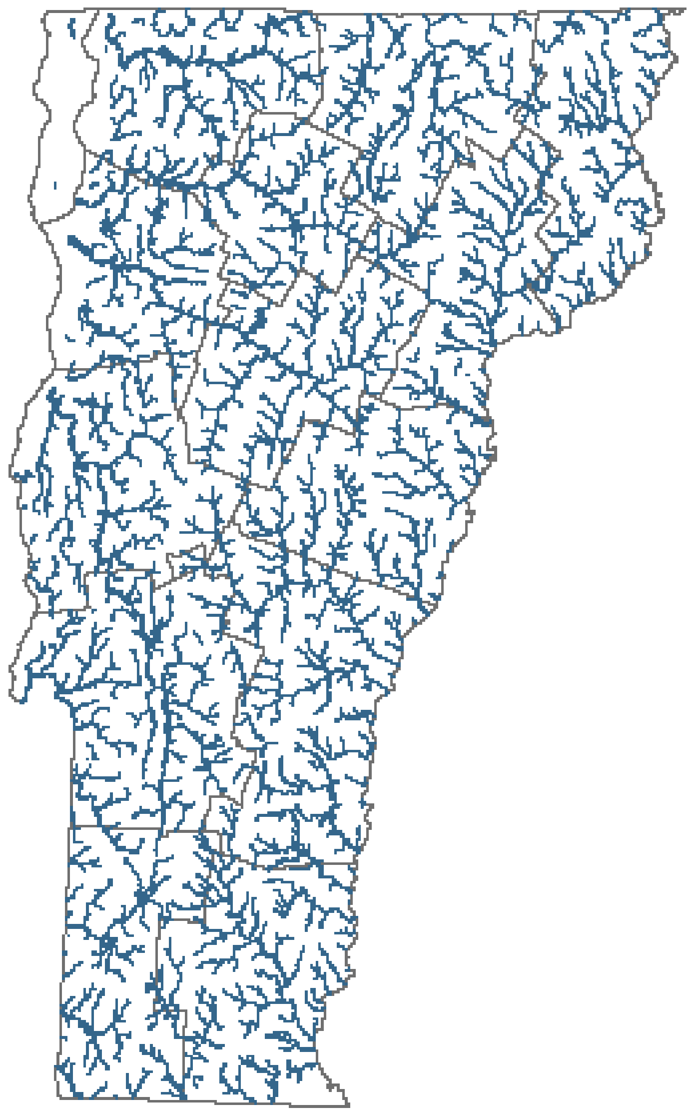

Figure 28: Vermont river corridor map (2015)
Data Source: http://geodata.vermont.gov/

6 https://legislature.vermont.gov/statutes/section/10/032/00752
7 http://floodready.vermont.gov/assessment/vt_floodready_atlas
8 https://anrmaps.vermont.gov/websites/anra5/

Channel adjustments with devastating consequences have frequently been documented wherein such adjustments are linked to historic channel management activities, floodplain encroachments, adjacent land use practices, and/or changes in watershed hydrology associated with conversion of land cover and drainage activities.

Vermont's landscape has historically contributed greatly to the widespread practice of the channelization of rivers and streams to maximize agricultural land uses and facilitate the development of transportation infrastructure. Channelization, in combination with widespread floodplain encroachment, has contributed significantly to the disconnection of as much as 70% of Vermont's rivers from their floodplains. In this unsustainable condition and when energized by flood events, catastrophic adjustments of the channel frequently occur, usually with consequent fluvial erosion damage to adjacent or nearby human investments.

Flash Flooding:

In addition to the inundation flooding and fluvial erosion dangers along rivers and lakes in Vermont, there are significant flash flood dangers near small streams and in alluvial fans. Alluvial fans are areas where streams transition between a steep mountain grade to gentler, flatter valleys below. Flash floods are likely to occur after a severe thunderstorm that produces a large amount of precipitation over a short amount of time. The precipitation falls so quickly that the soil is unable to absorb the water which results in surface runoff that collects in small, upstream tributaries, that then moves quickly downstream at a high velocity. The stream alterations described as increasing fluvial erosion may also exacerbate the effects of flash flooding. Mountainous areas such as Vermont are particularly prone to flash flooding due to the steep terrain. Damage from flooding includes land erosion, property damage, loss of crops, and even human life.

Floods are responsible for more deaths each year than any other hazard except heat in the United States, with the majority being vehicle-related, as the power of moving water is usually underestimated.[9] Flash floods have the power to knock a human off their feet with as little as 6" and move boulders, trees or even houses downstream. This mobile debris can then cause damage to infrastructure, plugging culverts or bridges, further exacerbating damage. Fortunately, in a flash flood, the water will recede quickly, but not before causing damage to properties and structures.

The National Weather Service (NWS) issues a Flash Flood Warning when there is a rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within a short timeframe from the onset of heavy rain, or from a dam or levee failure, or water released from an ice jam.[10]

Ice Jams:

Ice jams occur when warm temperatures and heavy rain cause snow to melt rapidly. Snowmelt combined with heavy rains can cause frozen rivers to swell, which breaks the ice layer on top of the river. The ice layer breaks into large chunks, which float downstream and pile up near narrow passages or other obstructions, such as bridges and dams. The water underneath the ice then looks for another means to pass, often resulting in road overtopping or damage to structures nearby.

Ice jams include those that form in the early winter as ice formation begins (freeze-up jams); those that form as a result of the breakup of ice covers (break-up jams); and those that contain elements of both (combination

9 https://www.weather.gov/media/hazstat/sum21.pdf
10 https://www.weather.gov/btv/wwa_reference

jams). Ice events can include ice jams, the formation of an ice cover that raises water levels upstream or decreases water levels downstream, or any other result of ice formation or break-up.

Vermont's northern latitude means a high likelihood of temperatures dropping sufficiently in the winter to allow freezing of most rivers. It is important to monitor the fluctuations on the State's rivers and potential for these events to occur with the thaws. Human settlement, development, and the associated infrastructure co-exist in proximity to rivers. Residences, buildings, or other infrastructure built within the floodplain will be susceptible to all flood types, including ice jams, especially as they have been identified as an increasingly dangerous hazard in Vermont.

The US. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire, has compiled ice jam information on a regional and national basis.[11] When necessary, VEM and other State mitigation partners contact the nearby USACE office for additional data regarding ice jams. Between 1785 and 2023, there have been 1021 ice jams on 103 rivers at 311 locations. In 2017, Vermont ranked 10th in the country based on the number of ice jam events, but the database has yet to update this information for 2023.[12]

Dam Failure:

While a rare occurrence, dam failure and resulting flooding can be devastating and threaten life and property downstream of dams. Dam failure can occur not only during large storms and high flows, but also during normal, sunny day conditions. While the depths and extents of flooding caused by dam failure are most severe during storms when reservoir elevations and rivers are at their highest, the public is generally conscience of flooding under these conditions. For this reason, it is often the sunny day failure scenario, that occurs with no warning, that is most dangerous.

Dam failure is caused by the overtopping or structural failure of a dam resulting in a significant, rapid release of water, which can lead to flooding. Structural failure can be caused by many factors, such as internal soil erosion in earth embankment dams, sliding or overturning of concrete dams, gate failure, or caused by other means, such as deliberate sabotage.

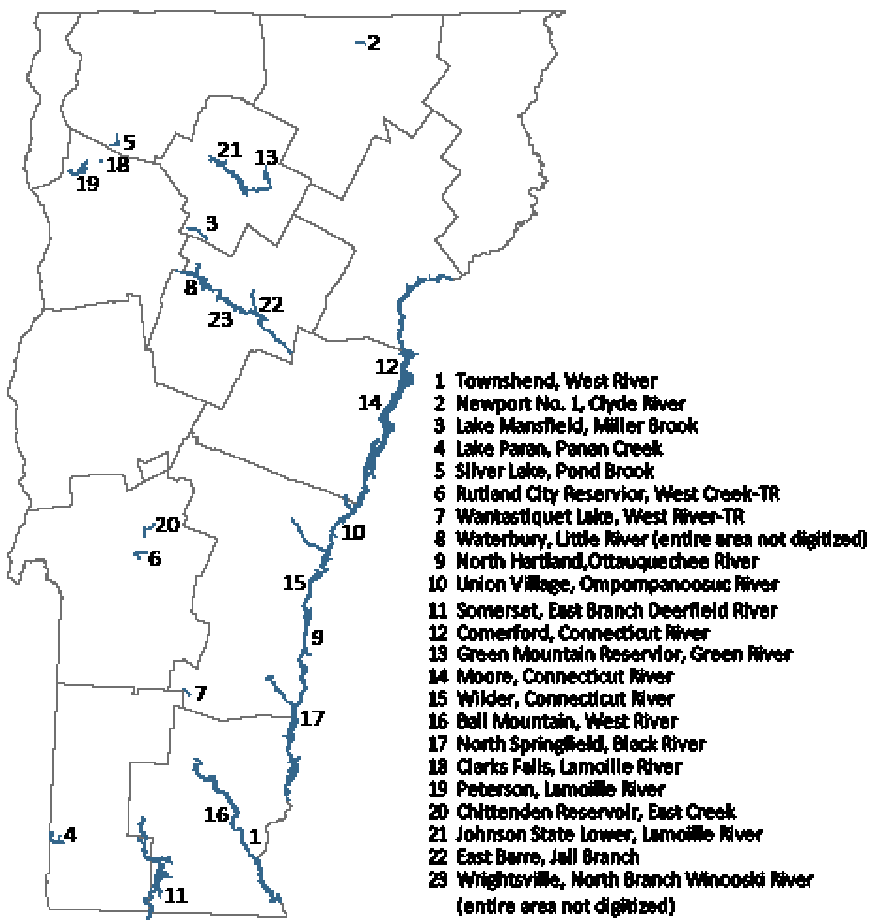

Figure 29: Vermont high-risk dam indundation areas for which there is full or partial* inundation mapping available (*Little River and Wrightsville)

Inundation maps do not account for compounding impacts.
Data Source: http://geodata.vermont.gov/

11 https://icejam.sec.usace.army.mil/ords/f?p=1001:2::::RP:IR_STATE:VT
12 https://www.erdc.usace.army.mil/Locations/CRREL/

Dam failures are most likely to occur for one of five reasons. Overtopping caused by water spilled over the dam is usually a precursor to further dam failure, indicating other deficiencies including inadequate spillway design debris blockage of spillways, or settlement of the dam crest. Foundation defects include impacts to settlement and slope stability. Piping occurs when seepage through the dam causes internal erosion. Cracking caused by natural settlement of the dam and inadequate maintenance and upkeep are also main reasons for dam failure. A majority of the recorded dam failures in the US between 2010 and 2019 were caused by overtopping, while the incident driver has overwhelmingly been driven by flooding.[13]

Dams are classified according to their potential for causing loss of life and property damage in the area downstream of the dam if it were to fail using the general classification system: High Hazard, Significant Hazard, and Low hazard (Table 18). This classification focuses on loss of human life over the impacts on property and the environment, so it's not an effective gauge of those damages. It is important to note that the hazard class is independent of the condition of a dam. Depending on the entity that regulates the dam, these definitions have minor but notable differences. In Vermont, dams are regulated by four distinct entities depending on the purpose and owner of the dam:

- Dams that are part of the production of power (i.e., hydropower) constructed before 1935 (with a few exceptions) are regulated by the State of Vermont Public Utility Commission (PUC). The PUC regulates approximately 25 dams, 6 of which are considered HIGH hazard and 5 of which are considered SIGNIFICANT hazard.
- Hydropower Dams constructed after 1935 (with a few exceptions) are regulated by the Federal Energy Regulatory Commission (FERC). FERC regulates approximately 80 dams, 18 of which are considered HIGH hazard and 7 of which are considered SIGNFICANT hazard.
- Dams owned by the Federal Government (i.e., United States Army Corps of Engineers, USACE) are essentially self-regulated by that agency. Federal entities regulate approximately 5 HIGH hazard dams and 1 SIGNIFICANT Hazard dam.
- Non-federal, non-power dams are regulated by the Department of Environmental Conservation, (DEC). The DEC regulates approximately 41 HIGH Hazard Dams and 110 SIGNIFICANT hazard dams.
- The Dam Safety Program is responsible for management and operation of 14 dams owned by the VT Department of Environmental Conservation. This includes the three Winooski River flood-control dams: Waterbury, Wrightsville, and East-Barre. These three dams are listed as HIGH Hazard dams along with the Silver Lake Dam.[14] DPS also regulates 3 DEC owned SIGNIFICANT Hazard dams.

Table 18: Dam Hazard Classification - PUC and DEC Regulated Dams

Hazard Category	Potential Loss of Life	Potential Economic Loss
High	More than a few	Excessive (Extensive community, industry or agriculture)
Significant	Few	Appreciable (Notable agriculture, industry or structures)
Low	None expected	Minimal (Undeveloped to occasional structures or agriculture)

Table 19: Dam Inspection Schedule - PUC and DEC Regulated Dams

Hazard Category	DEC*	PUC	FERC	Federal
High	Yearly	Every 5 years	Yearly	Yearly
Significant	Every 3 to 5 years	Every 10 years	Yearly	Yearly, Varies
Low	Every 5 to 10 years	None required	Every 3 years	Veries

**The DEC inspection program is currently voluntary and requires permission of the dam owner.*

13 https://damsafety.org/dam-failures
14 https://dec.vermont.gov/water-investment/dam-safety/dec-owned-dams#East%20barre%20dam

A full list of High and Significant hazard dams in Vermont is included in the Appendix to Section 4 or can be viewed in the Vermont Dam Inventory.[15]

The classification systems for FERC and Federally-regulated dams are similar to that above, with the exception of that for the SIGNIFICANT hazard classification, their definition indicates no probable loss of human life, but economic loss, environmental damage, disruption of lifeline facilities, and impact to other concerns is anticipated. The difference in life safety relative to the SIGNIFICANT hazard classification should be noted.

Table 26 provides the general, targeted inspection schedule for formal inspections at dams based on the regulating body in Vermont. In general, the depth and extent of inspections vary based on the timing, condition, and risk associated with the dam being inspected.

Emergency Action Plans (EAPs) are pre-arranged plans developed by dam owners and emergency responders that serve to safeguard life and property in the event of a dam failure. General components of EAPs include: guidance for emergency detection and classification, notification flow charts, responsibilities and preparedness, and flood inundation maps, which are maps that depict the estimated extent, depth, and velocity of floods caused by simulated dam failures. The aforementioned regulatory agencies in Vermont generally require EAPs and are working towards EAP compliance.

The DEC is coordinating efforts to complete EAPs for all significant and high hazard dams within their jurisdiction, generally completing several per year funded through a dam safety grant from FEMA. Nearly all of the high hazard dams in DEC's jurisdiction currently have EAPs, but many are out of date. The Dam Safety Program is also in the process of developing new dam breach analyses, flood mapping, and EAPs for the three Winooski River Flood Control Dams (Waterbury, Wrightsville and East Barre), which are large, high hazard dams owned by the State.

In 2018, the Vermont State Legislature passed a law updating the existing regulation of dams, Statute 10 V.S.A. Chapter 43 which applies to the DEC and PUC. The purpose of the law is to serve to protect public safety and provide for the public good through the inventory, inspection, and evaluation of dams in the State. The law aims to provide a definition for a dam, update and modernize the State's dam inventory and give the DEC rulemaking authority for items such as exemptions, registration, hazard classifications, EAPs, inspections and design standards.

Dam Failure is not a categorized hazard on its own and can be a result of a variety of different natural events that can compromise the integrity of the dam. For example, large storm events that quickly deposit large amounts of water can result in overtopping if enough water isn't released prior to the storm. Seismic events, while rare in Vermont can result in cracking caused by settlement or movement of the dam. Hazards such as these can trigger a dam failure resulting in compounding hazards.

Dam Failure Impacts: People

The impacts of dam failure can be wildly felt by populations in surrounding areas, especially those that live within the inundation area. When dam failure occurs large quantities of water can rush down the abutment resulting in injuries or loss of life for those living in the at-risk area. Damage to residential structures can result in prolonged impacts as people become displaced by the event.[16] Impacts to community lifelines such

15 https://anrweb.vt.gov/DEC/DamsInventory/ListDams.aspx

16 https://damsafety.org/sites/default/files/files/FEMA%20TM%20AssessingtheConsequencesofDamFailure%20March2012.pdf

as transportation, communication, and medical services can result in increased difficulties for recovery and response. Ensuring the safety and security of those impacted should always be a top priority and identifying where those community lifelines may be at risk is critical for dam failure mitigation.[17]

Dam Failure Impacts: Built Environment

Dam failure impacts to the built environment begin with any damage to the dam itself and surrounding structures and equipment that may have been compromised during the failure. This includes power generation facilities, commercial and residential structures, and industrial equipment or supplies nearby. Impacts to residential and commercial structures will extend much further than the immediate area of failure through water damage and fluvial erosion. Flooding can disrupt or damage transportation, water, electrical, and communication infrastructure. The cost of cleanup and repair to services and the dam itself can be exceptionally high at the dam site as well as impacting the surrounding area. Debris and sediment removal is also required before dam repairs can be made.[18]

Dam Failure Impacts: Natural Environment

While different land uses or ecosystems will be impacted by a dam failure event differently, there remain general trends for how an event may impact the natural environment. The event can result in a swift transformation of the natural landscape, potentially stripping vegetation which in turn will be carried with the floodwaters as debris causing further damage. In addition, fast moving waters can result in high rates of erosion, altering the landscape and increasing the sediment load of the water.[19] Water pollution from increased turbidity can be harmful for marine life. The disruption to infrastructure can also result in an increase in point source or non-point source water pollution as infrastructure is compromised.[20] The resilience of ecosystems plays a large role in the magnitude of the impacts experienced after a dam failure.

Dam Failure Impacts: Economy

The disruption to economic activities caused by dam failures can impact a wide variety of industries depending on the use of the dam. Within the State of Vermont, there are 18 hydroelectric dams that work to provide a source or renewable energy to surrounding communities and businesses.[21] If a hydroelectric dam were to fail the loss of power generation capabilities would have widespread indirect impacts on the surrounding communities. Potentially impacting critical power services, such as those to hospitals. Failure of the electrical supply to the grid can impede business operations and other critical infrastructure including traffic lights. An increase in traffic congestion can also be observed while repairs occur in surrounding areas coupled with a potential loss of a main source of power. Other industries may temporarily shut down due to a lack of water or wastewater treatment that may be disrupted by the failure. Dam failures can also result in a decline in tourism for the impacted towns as well as the reservoir that might have been used by recreationalists. Flooding resulting from dam failure can result in a loss of livestock and agricultural crops. The loss of access to the waters kept at bay by dams can also reduce agricultural output due to a loss of irrigation.[22]

17 https://www.fema.gov/emergency-managers/practitioners/lifelines
18 https://damsafety.org/sites/default/files/files/FEMA%20TM%20AssessingtheConsequencesofDamFailure%20March2012.pdf
19 https://damsafety.org/sites/default/files/files/FEMA%20TM%20AssessingtheConsequencesofDamFailure%20March2012.pdf
20 https://www.sciencedirect.com/science/article/abs/pii/S0048969722029503
21 https://dec.vermont.gov/water-investment/dam-safety/dec-owned-dams#East%20barre%20dam
22 https://damsafety.org/sites/default/files/files/FEMA%20TM%20AssessingtheConsequencesofDamFailure%20March2012.pdf

Inundation Flooding & Fluvial Erosion Location

Inundation:

Locations that flood are generally considered to be depicted by Flood Insurance Rate Maps (FIRMs). A FIRM's Special Flood Hazard Area (SFHA) illustrates the floodplain and potential inundation by the 1% annual chance flood. It's important to note that areas that are outside of the SFHA can still be subject to flooding under the right conditions. See State & Local Capabilities for additional details on flood mapping in Vermont.

Fluvial Erosion:

Though all areas of Vermont have the potential to suffer from fluvial erosion impacts, some have an increased chance of impacts due to their location, the patterns of how storms develop and move as well as significant rainfall. Many storm systems move across Vermont from southwest to the Northeast.

Potential fluvial erosion impact areas are mapped using the Agency of Natural Resources' River Corridor, which can be found in the Vermont Natural Resources Atlas[23] and the Vermont Floodready[24] database. Vermont's River Corridor maps delineate river corridors for larger streams and rivers, and standard setbacks for smaller, upland streams. The setbacks were determined by factoring in the same stable stream slope requirements used when delineating a river corridor using a meander centerline setback. A river corridor includes the meander belt of a stream or river and a buffer of 50'.
Stream geomorphic assessments and a fluvial geomorphic database maintained by the Agency of Natural Resources (ANR) have identified main stem rivers often channelized from 60-95% of their lengths. This database is mapped on the ANR website for use by the public for planning and project development.[25]

The Vermont Agency of Transportation (VTrans) maintains a list of "scour-critical" stream crossing structures endangered by streambed scour. The 2015 VTrans Hydraulics Manual[26] addresses channel stability and scouring at bridges as a primary consideration given the consequences of bridge failure, and a 2017 paper detailing a VTrans scour project notes that scour is the leading cause of bridge failure in the United States, with hydraulic/scour-caused damages accounting for 52% of bridge failures.[27] The paper identifies only 815 of the over 4,000 hydraulic bridges have a hydraulic and scour report on file, with approximately 25% of the 2,249 inspected bridges receiving a scour critical rating, using the Federal Highway Administration's (FHWA) National Bridge Inventory coding guide. Should the remaining 1,750+ bridges that have yet to receive an inspection be included in this inventory, it is the assumption of VTrans hydraulic staff that the number of scour critical bridges would increase. As VTrans continues to inspect bridges and identify those that are scour critical, the State will have a better understanding of where its infrastructural vulnerabilities to fluvial erosion are located.

Many other bridges and culverts are endangered by outflanking or debris jams or channel adjustment processes not associated with the structures themselves. Again, there is no specific geographic pattern of distribution; these problems exist uniformly throughout Vermont.

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23 http://anrmaps.vermont.gov/websites/anra5/
24 http://floodready.vermont.gov/assessment/vt_floodready_atlas
25 http://anrmaps.vermont.gov/websites/anra5/?LayerTheme=1
26 http://vtrans.vermont.gov/sites/aot/files/highway/documents/structures/VTrans%20Hydraulics%20Manual.pdf
27 http://vtrans.vermont.gov/sites/aot/files/highway/documents/materialsandresearch/completedprojects/VTrans%20Scour%20Project%20731%20Anderson%20Et%20al%20%28FinalReport%2003-10-17%29.pdf

Where waterways were historically channelized to keep the water away from valued lands and the built environment the hazards have paradoxically been increased. Changes in watershed hydrology significantly influence fluvial stability, preventing streams from meandering, thereby increasing stream flow velocities and worsening erosion. Watershed-scale hydrologic changes have been observed in Vermont as a localized phenomenon, most notably in the Moon Brook in Rutland, Stevens Brook in St. Albans City, Morehouse Brook in Winooski, and Centennial Brook and Bartlett Brook in South Burlington. This channelization trend is also observed in small, rural sub-watersheds where clear-cutting of a large percentage of the watershed land area has occurred. More extensive, regional channelization with which extensive flood damages have been associated include the White River, West Branch of the Little River, Mad River, Huntington River, Great Brook, Williams River, and North Branch of the Deerfield River.

Ice Jams:

Significant ice jams have occurred on the Winooski River in Montpelier, the Deerfield River North Branch in Wilmington and most recently along the Lamoille River in Johnson and the Missisquoi River in Swanton and Highgate. Thus, residents of this region may be particularly vulnerable to ice jam events as compared to the rest of the State.

Significant ice jamming along the Lamoille River in Johnson in early 2018 led to concerns of inundation flooding in the town, including for the mobile home park in the background.

Inundation Flooding & Fluvial Erosion History

- **Rainfall Event, November 3, 1927:** This event was caused by nearly 10" of heavy rain from the remnants of a tropical storm that fell on frozen ground. The flood claimed 84 lives, more than 1,000 bridges, and hundreds of miles railroads and roads. Over 600 farms and businesses were destroyed. Flooding in the White River valley was particularly violent, with the river flowing at an estimated 120,000 cubic feet per second on the morning of the November 4, 1927.
- **Rainfall & Snowmelt Event, March 13–19, 1936:** Historic flood damage in Vermont occurred in the hamlet of Gaysville, which had a large mill, church, stores, and many residences destroyed during the flood. The worst widespread spring flooding occurred when slow-moving storms with warm air combined to drop around 8" of rain on a late winter snow pack that had a water equivalent of 10".
- **Rainfall Event, September 21, 1938:** A very fast-moving hurricane (known as the "Long Island Express") hit Vermont in the early evening causing severe flooding as a result of more than 4" of rain that accompanied the storm. Buildings were lost, power lines downed, and many trees felled.
- **Rainfall Event, June 28-30, 1973:** Widespread flood when up to 6" of rain fell. A Presidential disaster was declared for the entire State and damage was estimated at $64 million (in 1973 dollars).
- **Rainfall Event, August 9-10, 1976 (DR-518):** Remnants of Hurricane Belle caused significant rain and flooding in portions of Vermont, resulting in $100 million in damages (in 1976 dollars) and 10 associated deaths[28].
- **Ice Jam, Montpelier, March 11, 1992 (DR-938):** Approximated a 100-year event, resulting in nearly $5 million (nominal dollars) in damages to local roads, buildings, private businesses, and homes. This disaster effectively shut down many functions of State government and the State legislature for several days, resulting in indirect losses for which no existing data has been generated. The inundation associated with this jam was of very short duration (less than 12 hours); otherwise, disruption of services could have represented a much more serious economic loss.
- **Rainfall Event, June 17–August 17, 1998 (DR-1228):** Intense summer thunderstorm flood when torrential rain deluged the Warren, Randolph, and Bradford areas. A record amount of precipitation fell in Vermont that summer, with Burlington setting a new annual rainfall record of 50.42".
- **Rainfall from Tropical Storm Floyd, September 16, 1999 (DR-1307):** Flooding and wind damage in parts of Vermont.
- **Rainfall Flash Flood Event, July 14-16, 2000 (DR-1336):** 2-4" of widespread rain fell, with locally higher amounts across higher terrain. Specific amounts included 3" in Bennington and 5" in Wardsboro. This rain produced enough runoff to cause the Battenkill to exceed the 6' flood stage by about a foot at Arlington. The Deerfield River rose 6' above unofficial flood stage in Wilmington. Several roads were reported under water. Thunderstorm rainfall, as well as the earlier rainstorm, dumped in excess of 8" in Newfane. In Shaftsbury, County Route 67 was washed out. U.S. Route 7 was closed due to flooding and rockslides. In Windham County, a five-mile stretch of State Route 30 was closed due to flooding and residents were evacuated. Street flooding was reported at Brattleboro.
- **Snowmelt, December 16-18, 2000 (DR-1358):** Despite the fact that DR-1358 (2000) is officially listed as a winter storm, and DR-1101 (1996) occurred in January, damages in both cases were primarily flood-related, particularly for DR-1101, which was flooding associated with rain and a mid-winter thaw that melted a 30" snow pack in two and a half days.
- **Rainfall Flash Flood Event, July 24-August 13, 2003 (DR-1488):** July 24 saw steady rain during the morning hours, with locally heavy rain associated with thunderstorms later in the day. Scattered showers and thunderstorms erupted during the afternoon hours on August 3. A slow moving storm over Windham County produced estimated rainfalls of 3-4" in about four hours, causing flash flooding. Around $1 million in estimated damages.

28 http://www.trorc.org/wp/wp-content/uploads/2013/08/Appendix_I_Flood-Events-in-the-past-100-years.pdf

- **Rainfall Event, August 12, 2004 (DR-1559):** A frontal boundary from northern Vermont southwest across eastern New York resulted in showers and thunderstorms with very heavy rainfall. Flash flooding in Addison County on August 28 resulted in nearly $2 million of estimated damages due to thunderstorms accompanied by torrential rainfall with 2-5" of rainfall falling on already saturated soil. Numerous smaller roads were flooded or washed out, many homes reported flooded basements.
- **Rainfall Flash Flood Event, May 19, 2006:** In May 2006, Burlington received a record amount of rainfall, almost an inch more than the previous record, set in 1983. Rainfall amounts included: the NWS Burlington office in South Burlington with 3.48", Jericho at 3.75" and Mount Mansfield with 4.79".
- **Rainfall Flash Flood Event, June 26, 2006:** Flooding caused extensive damage to the small town of Athens, Vermont. This flooding was caused by persistent rainfall for the entire month of June, exacerbated by excessive rain caused by one storm system passing through. The damage was mostly suffered in roadways because of flash flooding, which turned a normally placid body of water, Bull Creek, into a raging flow. There were reports of a mudslide in Dummerston, which also caused damage to roadways. The State Emergency Operations Center (SEOC) was activated.
- **Ice Jam, March 15, 2007:** Montpelier experienced a significant ice jam event on the Dog River, resulting in extensive planning and preparations for possible flooding. A significant ice jam had been in place on the Winooski in Montpelier since January 20th, causing the Dog River jam. In early 2007, ice jams also caused problems in the towns of Woodstock and Chelsea, including localized road flooding in some locations.
- **Rainfall Flash Flood Event, July 9, 2007 (DR-1715):** Localized heavy rainfall exceeded 3" within two hours with some localized storm totals approaching 6", causing many roads to be flooding or washed out and an estimated $4 million of property damage.
- **Rainfall Flash Flood Event, June 14, 2008 (DR-1778):** Localized heavy rainfall up to 7" occurred in Ripton (Addison County) and 3-5" in Rutland with an estimated $2 million worth of damage in Rutland County, predominately in downtown Rutland.
- **Rainfall Event, July 24, 2008 (DR-1790):** Widespread rainfall of 1-2" occurred during the afternoon and evening of July 24th with localized amounts that exceeded 3", causing flooding in Washington, Lamoille, Orleans and Caledonia counties.
- **Ice Jams, January 25-February 1, 2010:** Ice jams were reported in Montpelier, Ferrisburg, Shelburne, Berkshire and Stratford, accompanied by minor localized flooding in some locations.
- **Ice Jam, March 6, 2011:** An ice jam formed on the Mad River caused damage to roads and threatened flooding to the area near Moretown and several other towns following heavy rainfall on March 5-6.
- **Snowmelt & Rainfall Events, April and May, 2011 (DR-1995, DR-4043):** 2011 was a record year for flooding in the State of Vermont. A total of four disaster declarations were issued, all attributed to flooding and fluvial erosion. The first floods occurred over a two-week period in April and May. These floods impacted the northern half of the State, including the counties of Addison, Chittenden, Essex, Franklin, Grand Isle, Lamoille, Orleans, Washington, and Windham. The damage totaled over $1.8 million in FEMA assistance. Heavy rains in late March/early April on top of a deep late season snowpack resulted in riverine flooding and sent Lake Champlain well over the 500-year flood elevation. Additional spring runoff events resulted in Lake Champlain being above base flood elevation for more than a month. High lake levels coupled with wind driven waves in excess of 3' resulted in major flood damages for shoreline communities. May 6, 2011 was the highest ever recorded level of Lake Champlain in Burlington at 103.27', one of only two recorded levels above major flood stage (101.5ft).
- **Snowmelt & Rainfall Event, May 26, 2011 (DR-4001):** Although not as severe as floods that occurred earlier in the month, multiple counties were included in the declaration, including Caledonia, Essex, Orange, and Washington counties. The river gage on the Winooski in Montpelier crested at 19.05' (major flood stage is 17.5'), the second highest on record (1927 flood: 27.10').

- **Rainfall from Tropical Storm Irene, August 28, 2011 (DR-4022):** Severe damage statewide from record-breaking rainfall associated with Tropical Storm Irene. The storm impacted the entire State, with Public Assistance designations for every county and Individual Assistance designations for 12 of 14 counties. The highest recorded rainfall during this event was on Mendon Mountain, totaling over 11”, making it the greatest single-day rainfall in Vermont’s recorded history. Given the significance of this event on the State, more details are below.
- **Rainfall Flash Flood Event, May 29, 2012 (DR-4066):** Severe storms, tornadoes, and flooding occurred on May 29, 2012, impacting Addison, Lamoille, and Orleans counties. Over $1 million worth of damages estimated. Some of these thunderstorms deposited up to 2” of rainfall in portions of north-central and northeast Vermont. The end result was flash flooding in portions of north-central, northeast Vermont and Addison county with estimated storm totals of 3-5”.
- **Rainfall Flash Flood Event, May 22, 2013 (DR-4120):** Heavy rain event caused flash flooding, predominately in Chittenden County, washing out bridges, culverts, and roads. Over $2 million worth of damages estimated.
- **Rainfall Flash Flood Event, June 25-July 10, 2013 (DR-4140):** Thunderstorms produced a quick 1-3” of heavy rain in a half hour, causing flash flooding across the State, with over $6 million worth of damages estimated. The most significant impacts were in Windsor and Chittenden Counties.
- **Snowmelt & Rainfall Event, April 15, 2014 (DR-4178):** A combination of heavy rain and snowmelt from late-season snowpack caused flooding across northern and central Vermont with nearly $2 million in estimated damages. 4-6” was released from the snowpack.
- **Rainfall Flash Flood Event, June 11, 2015 (DR-4232):** Thunderstorms with 1-2” of heavy rainfall caused flash flooding in Chittenden and Washington Counties with over $1 million in damages.
- **Rainfall Flash Flood Event, June 29-July 1, 2017 (DR-4330):** Heavy rainfall of 3-4” over several days caused pre-saturated soils across much of central Vermont. During the afternoon of July 1, a series of heavy rain showers and thunderstorms moved in delivering very heavy localized rainfall that caused some scattered flash flooding, with an estimated over $8 million in damages.
- **Ice Jam, January 13, 2018:** Swanton and Johnson as well as several smaller jams formed across Vermont.
- **Ice Jam and Heavy Rainfall Event, January 24, 2019:** Following a heavy snowfall event in Bennington and Windham Counties, temperatures surged into the 40s to mid-50s resulting in steady rainfall occurred throughout the day. 1-4 inches of rain was recorded over southern Vermont. The combination of the rainfall along with the mild temperatures melting some of the snow resulted in areal flooding over portions of the region along with minor to moderate river flooding on the Walloomsac River. Some flooding due to ice jams also occurred along the Whetstone Brook and the Bourn Brook resulting in water backing up onto roadways and the Mountain Home Trailer Park, prompting evacuations of over 50 people. Many homes experienced extensive flood damage in the region. Rising waters also resulted in sewer backups in businesses in some areas.
- **Snowmelt and Rainfall Flash Flood Event, April 15, 2019:** Rapid snowmelt and 1-2in/hr rainfall caused rising water levels in Rutland and Windsor Counties, leading to flash flooding and road washouts. Otter Creek in Rutland County specifically caused road washouts, leading to a motorist being trapped and requiring rescue in Killington. The flash flooding resulted in $1.6 million in property damages, most of which occurring in North Pawlet in Rutland County.
- **Rainfall Flash Flood Event, October 31-November 1, 2019:** Steady rain in Chittenden, Washington, Orleans, and Essex Counties developed during the mid to late evening of October 31st and became heavy at times through the early morning hours of November 1st. Rainfall amounts 1.5 to 2 inches were common across much of Vermont with a swath of 2 1/2 to 4 inches across northwest and north central Vermont. Impacts of this event were concentrated around the Winooski, Mad River, Lamoille, and Missisquoi basins. These basins experienced riverine flooding compounded with strong winds (40-50

mph) that resulted in downed trees and structural damaged that escalated power outages to their peak of over 100,000. Estimated public infrastructure damage was in excess of $5 million. Some roadways were washed out or inundated with Burlington experiencing urban street flooding.

- **Heavy Rainfall and Rain on Snow Event, December 25, 2020:** Windham County experienced heavy and steady rain showers between the 24th and 25th. Rainfall totals ranged from 1-3 inches. The region also maintained a snowpack containing 1-3 inches of SWE that was almost all lost during this event. The combination of warm air, rainfall and melting snowpack led to areas flooding across the region. Roads were closed across portions of southern Vermont as a result of flooding with one road being washed out. This event was also accompanied by wind gusts between 40 to 55 MPH.
- **Heavy Rainfall Event, July 29th, 2021:** Bennington and Windham Counties experienced moderate to heavy rainfall during the afternoon of the 29th, where between 2-5 inches of rain fell on top of an already very wet July experiencing 12-18 inches of rain. Nearly two dozen towns in southern Vermont were listed with either minor or major impact due to flooding, according to Vermont Emergency Management, with damage estimates ranging from less than $10,000 to more than $200,000 each. Numerous roads or culverts were closed or washed out. About 350 individuals were reported to be isolated individuals due to main road washouts around their home. President Biden approved a formal request for a Major Disaster declaration for Bennington and Windham counties as a result of the storms. Over $5 million in damages to public infrastructure was identified by Vermont officials, including costs to repair public roads and bridges as well as debris removal. The Saxtons River in the Town of Rockingham observed high floodwater flows, reaching a peak of 10,500 cubic feet, which was the highest flow observed since Irene in 2011.

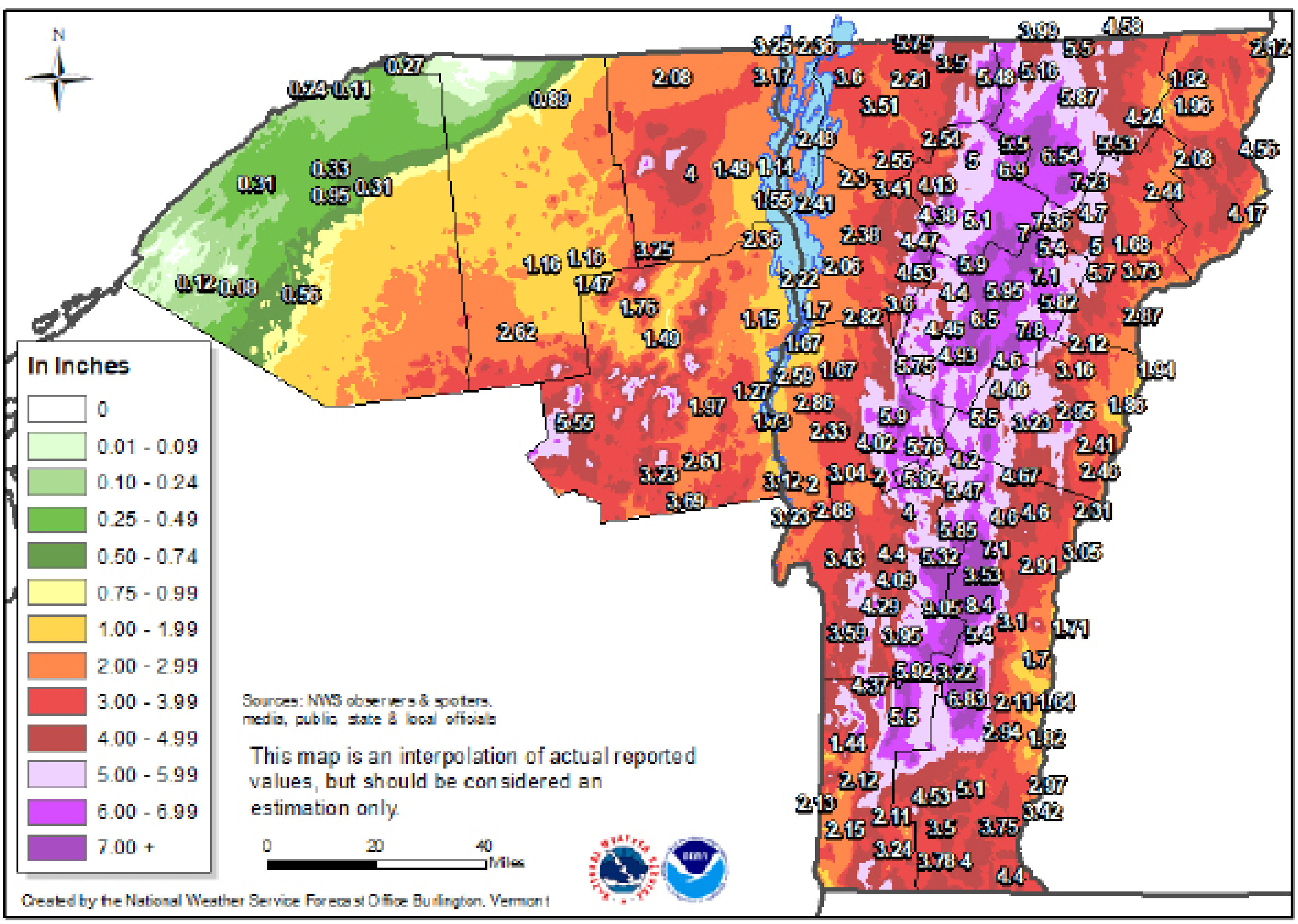


Figure 30: Vermont July 2023 Storm total rainfall map (July 10-11, 2023)
Source: National Weather Service

- **July 2023 Flood Event, July 9, 2023:** At the time of submittal of the SHMP 2023 update, Vermont was actively responding to flooding that began on July 9, 2023. Over 3-days, areas of Vermont saw 9 inches of total rainfall (rain totals for July 10-11, 2023 mapped in Figure 30). The days and weeks following continued to rain, adding to already saturated soils, flooding rivers, and at-capacity dams. The storm caused numerous landslides, road closures, and home damages.

Tropical Storm Irene, August 28, 2011 (DR-4022), Continued:

Inundation flooding and fluvial erosion caused by Tropical Storm Irene was catastrophic, destroying property, infrastructure and taking lives.

After a very wet spring, which lead to multiple disaster declarations and saturated soils, Vermonters watched Hurricane Irene move up the Eastern Seaboard of the United States with great apprehension. The hurricane turned into a tropical storm as it made landfall in New York and Connecticut, shortly before moving northward towards Vermont. As the tropical storm moved into the State, dropping as much as 11” of rain (Figure 31), nearly every river and stream flooded and experienced catastrophic fluvial erosion. Extensive transportation damage was reported, with nearly every State highway affected and many local roads washed away. In Vermont, seven people died and many were injured from the floods.

During Tropical Storm Irene, flooding originated in headwater streams draining the flanks of the Green Mountains, where rainfall totals were highest. As these high-gradient headwater streams filled quickly, the water rushed down the hillsides and inundated the narrow valleys. These high-gradient streams with minimal floodplain attenuation rose and peaked rapidly in a matter of a few hours, and then receded nearly as quickly. By contrast, larger rivers of lower gradient with wide floodplains and contiguous wetlands were able to attenuate the storm flows. Accordingly, these rivers peaked later and receded more slowly.

Below is a brief look at some of the effects of Tropical Storm Irene, according to the Agency of Natural Resources, which explains the impacts from this particular event and highlights how Vermont is vulnerable during a significant precipitation event.

Transportation:

- Roads: >2500 miles of road, ~480 bridges and 960 culverts damaged. Over $350 million in estimated repairs.
- Railroad: >200 miles of rail and 6 bridges in the State-owned rail system damaged, costing the State an estimated $21.5 million.

Emergency Response:

- Main offices for both VEM and ANR were flooded in Waterbury; disaster response headquarters had to be relocated.
- Extensive road damage meant some areas were initially hard to access; 13 communities were without any passable roads leading in or out of town.

Buildings and Infrastructure:

- Power outages for ~158,800 customers.
- 7,215 individuals and families registered for FEMA assistance (by 11/15/11); >$45.9 million in grants and low interest loans for Vermont residents, businesses, and nonprofit organizations were approved by FEMA and the U.S. Small Business Administration; also, nearly $15 million loaned to businesses and farms by Vermont Economic Development Authority.
- FEMA completed nearly 5,000 property inspections to document damage; ~1,500 residences had significant damage (433 of these residences were mobile homes) and at least 1,405 households were temporarily or permanently displaced.
- Municipal infrastructure (including transportation) required an estimated $140 million in FEMA reimbursements, with $2 million in PA dollars obligated for Tropical Storm Irene as of 12/6/11.
- Waterbury State Office Complex, R.A LaRosa Agriculture and Environmental Laboratory, and Vermont State Hospital severely damaged in flooding, displacing ~1,500 employees; costs to rebuild and upgrade the complex were nearly $130 million.

Public Health and Safety:

- American Red Cross set up 13 emergency shelters and distributed ~16,000 meals, plus thousands of water bottles.
- A food safety advisory was released for any food touched by floodwaters.

Water Supply:

- About 30 public water systems issued Boil Water Notices; in many cases, broken pipes lowered a system's water pressure, which increased the likelihood of harmful contaminants mixing with treated drinking water. Drinking water advisory were issued for wells submerged by floodwater.
- An estimated 16,590 people in Vermont were affected by Tropical Storm Irene-related Boil Water Notices

Hazardous Waste and Fuel Spills:

- Potentially hazardous waste mobilized along rivers, contaminating floodwaters and sediment and soil deposits.
- In the first week after Tropical Storm Irene, hazardous spills reported to State officials increased over routine levels by a factor of 14; many spills were related to home fuel tank connections breaking as floodwaters moved tanks.

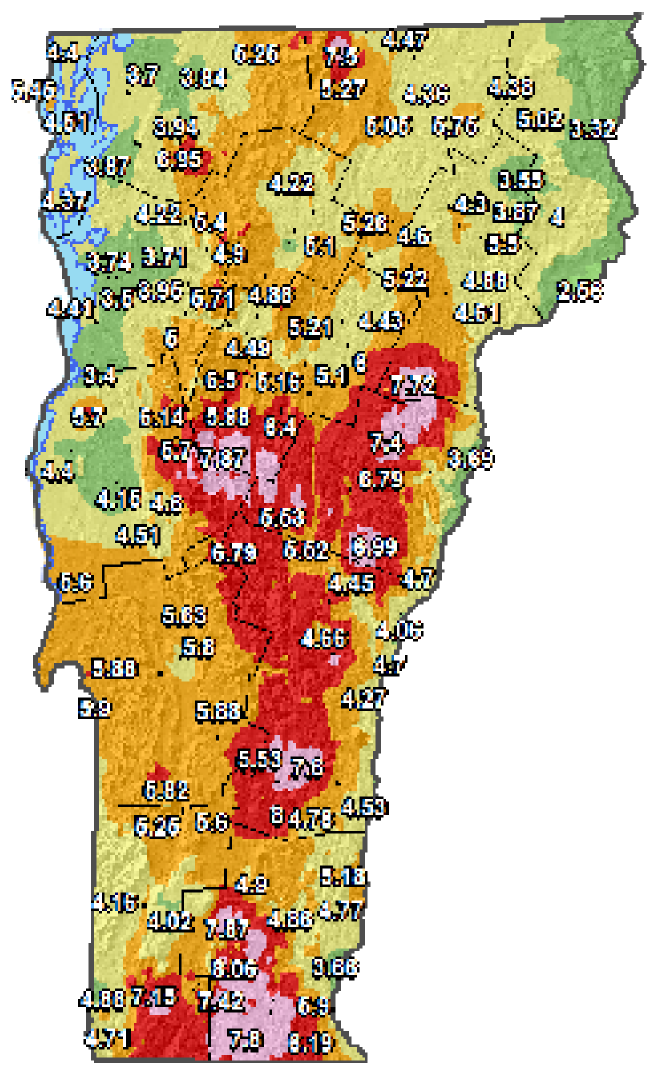


Figure 31: Tropical Storm Irene total rainfall in inches map (August 27-28, 2011)
Source: National Weather Service

- Both U.S. Environmental Protection Agency (EPA) and Vermont Department of Environmental Conservation (DEC) investigated and assessed hundreds of Irene-related spills; oil-water separators were used to process roughly 300,000 gallons of contaminated waters near the Waterbury State Office Complex.
- Over $2 million in total costs have been incurred to the State to clean up aboveground storage tank oil spills.

Wastewater Treatment:

- Seventeen municipal wastewater treatment facilities (WWTFs) reported compromised operations, with issues ranging from pump station overflows to incomplete processing of sewage (no structural damages, but damages relating to mechanical, electrical, and debris accumulation problems). Most problems were resolved within 24 hours and the vast majority within one week; estimated discharge of partially unprocessed or raw sewage is 10 million gallons during this period.
- On-site septic systems around the State were also damaged by high groundwater levels and river or stream erosion. In the two months following Irene, State officials tallied 17 septic system failures.

Solid Waste Disposal:

- Vermont landfills received an estimated 32,000–42,000 tons of storm-related waste during the months that followed Irene.
- Household hazardous waste collections around the State amassed an estimated 4,385 gallons and 8,464 units* of waste, with ~$82,000 cost incurred (*units refer to disposed items and range from small bottles to five-gallon buckets of material).

Forests:

- High flows and saturated ground conditions undermined tree roots, and floating debris injured tree stems. Brief duration of standing water at most locations prevented further near-term tree damage; however, great amounts of accumulated sediment and debris in some streamside forests or establishment of invasive plants may inhibit tree growth over time.
- Aerial surveys found 9,213 acres with trees exhibiting flood damage symptoms from both spring and Tropical Storm Irene-related flooding.
- Green Mountain National Forest reported multiple trail, recreation site, and road closures.

Agriculture:

- Farm fields and barns were washed out or covered with flood sediments and debris; more than 450 farms filed Farm Loss claims with the U.S. Department of Agriculture (USDA), and roughly 20,000 acres of farmland were affected.
- Food advisories forced farmers to throw away food crops that may have been contaminated by floodwaters. Estimated value of crop losses and damage was >$10 million dollars statewide.
- Producers reported more than 1,000 acres of sugar bush damaged by winds.

Water Resources:

- Intense flooding occurred in at least 10 of Vermont's 17 major river basins, demonstrating record or near record flood crest levels along rivers.

- Otter Creek gage in Center Rutland showed the highest flood crest since the gage began operating 83 years ago—9.21’ above flood stage. Mad River gage in Moretown and White River gage in West Hartford both showed second highest flood crests on record – 12.1’ and 10.4’ above flood stage, respectively.
- Nine stream gaging stations in Vermont recorded peak flows estimated to have a 1% or less chance of occurring or being exceeded in any given year.
- Some river locations appeared relatively unscathed, while others underwent catastrophic channel enlargement, deposition, and relocation; pre-Irene geomorphic studies of many Vermont rivers probably flagged some of these damaged areas as being susceptible to channel adjustment.
- In-stream channel work and gravel removal occurred in multiple locations during Tropical Storm Irene recovery period (largely in the 2-3 months after the flood); in some cases, work occurred without official authorization.

Aquatic Life and Habitat:

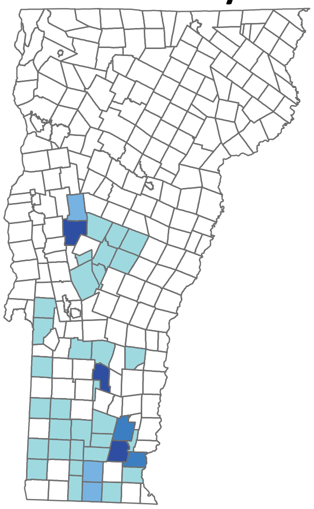
- In many locations, daily turbidity of waters (related to in-stream work) and habitat disruption may stress fish and macroinvertebrates (insects, snails, mussels, crayfish, etc.); extreme scour from powerful floodwaters likely reduced total numbers of fish and macroinvertebrates in some rivers, and species composition of fish and macroinvertebrates may shift to species that more readily withstand these stresses. For example, State fish biologists studied wild trout populations in the Mad and Dog River watersheds both before and after major Tropical Storm Irene-related flooding. After the flood, wild trout populations in studied streams were reduced to 33-58% of pre-flood levels.
- Fish and macroinvertebrate populations have a long history of surviving floods when quality stream habitat is available, and reduced numbers are usually temporary, but an increase in flood return rate due to changing climate may have long-term impacts. In addition, where habitat is compromised (due to historic channelization practices, encroachment, or post-Irene channel remediation efforts such as streambed excavation and fallen tree removal), fish populations may be affected over a longer term, depending on how quickly natural stream processes can re-establish habitat features.
- Increased algae growth with ongoing influx of river silts (elevating available nutrient levels).
- Mussel populations (including some rare, threatened, or endangered species) were harmed as sand and silt deposition and bank collapse buried and suffocated individuals.
- Japanese knotweed, an invasive plant that spreads by sprouting from broken plant rhizomes, has been spread with flood debris, threatening riparian forests, future bank stability, and agricultural fields.

Mobile Home Parks:

- Mobile homes suffered disproportionately in Irene; mobile homes comprise 15% of the total residences damaged while only accounting for 7% of Vermont’s total housing stock.
- 17 mobile home park communities experienced some level of flooding during Irene, with 14 of those parks having at least 1 home destroyed by floodwaters.
- More than 130 mobile homes were completely destroyed.

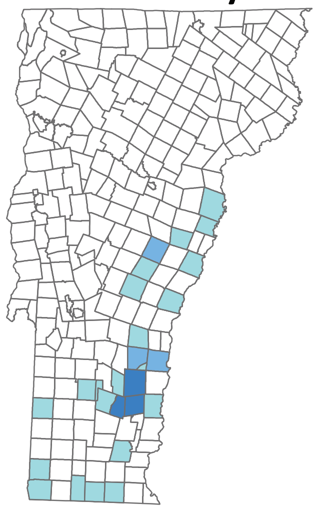
Significant scour along the Riford Brook in Braintree caused severe damage to Riford Brook Road during Tropical Storm Irene.

DR-1336: July 2001



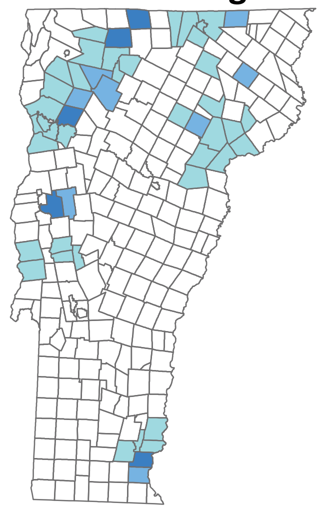
Total: $2,363,000

DR-1488: July 2003



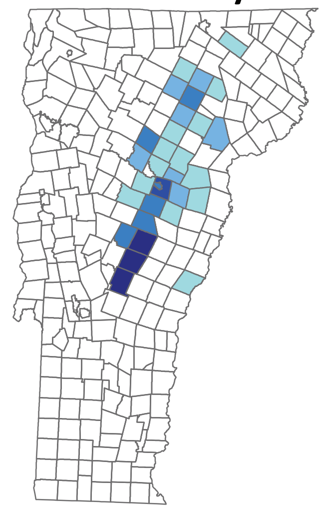
Total: $916,000

DR-1559: August 2004



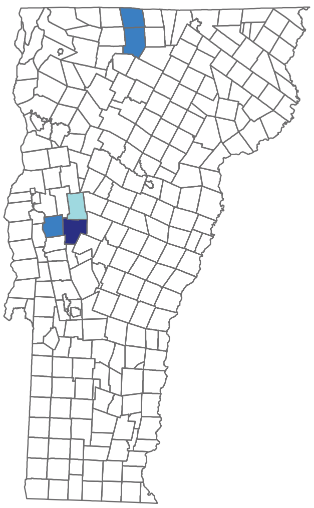
Total: $2,240,000

DR-1715: July 2007



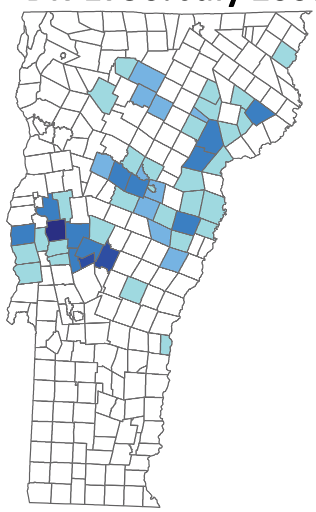
Total: $4,703,000

DR-1778: June 2008



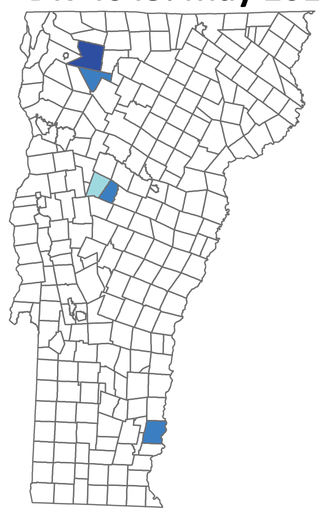
Total: $1,087,000

DR-1790: July 2008



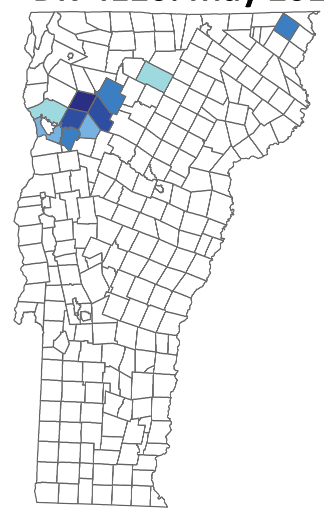
Total: $4,571,000

DR-4043: May 2011



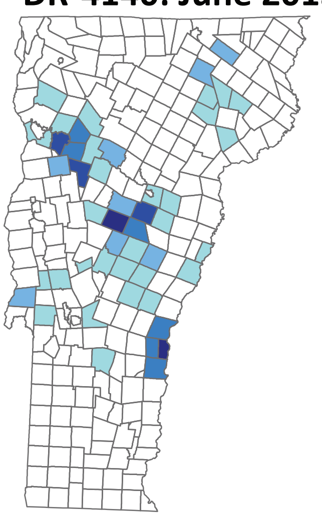
Total: $946,000

DR-4120: May 2013



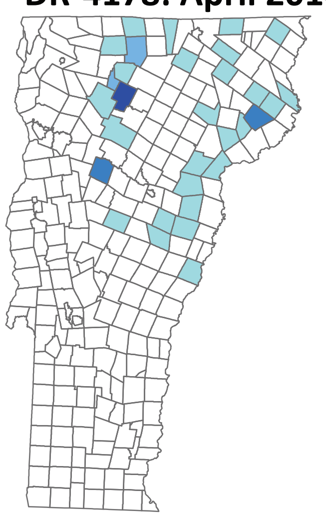
Total: $1,915,000

DR-4140: June 2013



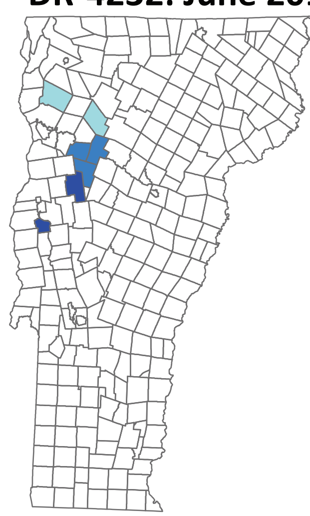
Total: $5,619,000

DR-4178: April 2014



Total: $1,824,000

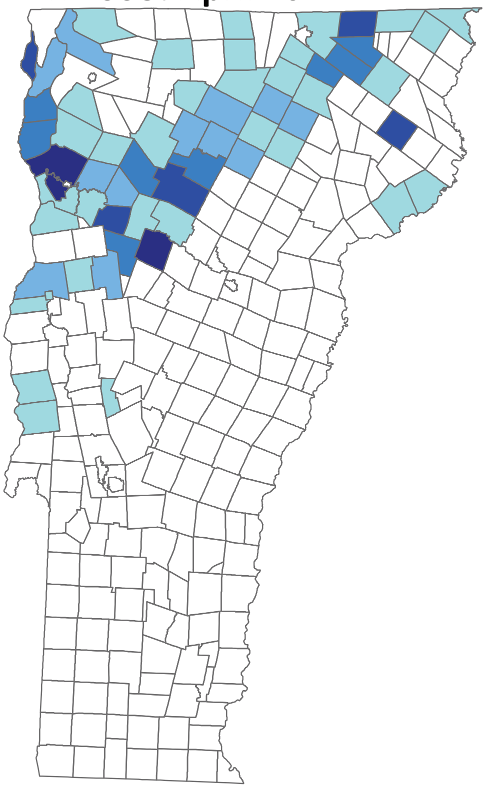
DR-4232: June 2015



Total: $1,227,000

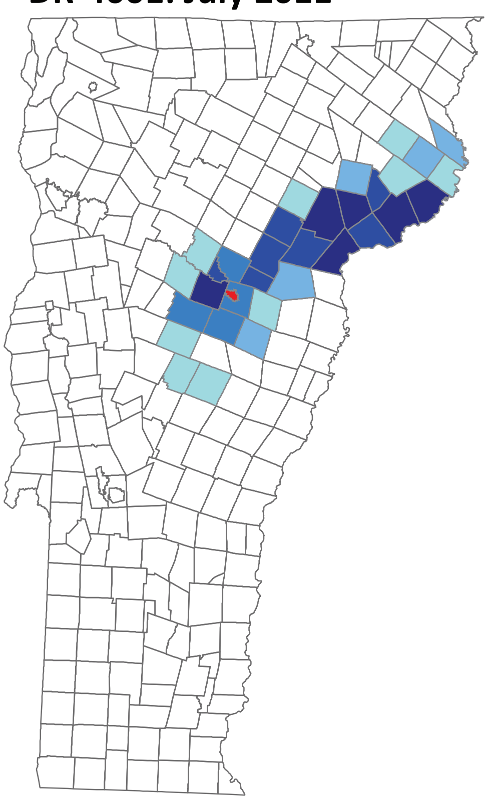
≤ $50,000 | $50,001 - $100,000 | $100,001 - $250,000 | $250,001 - $500,000 | $500,001 - $1,000,000

DR-1995: April 2011



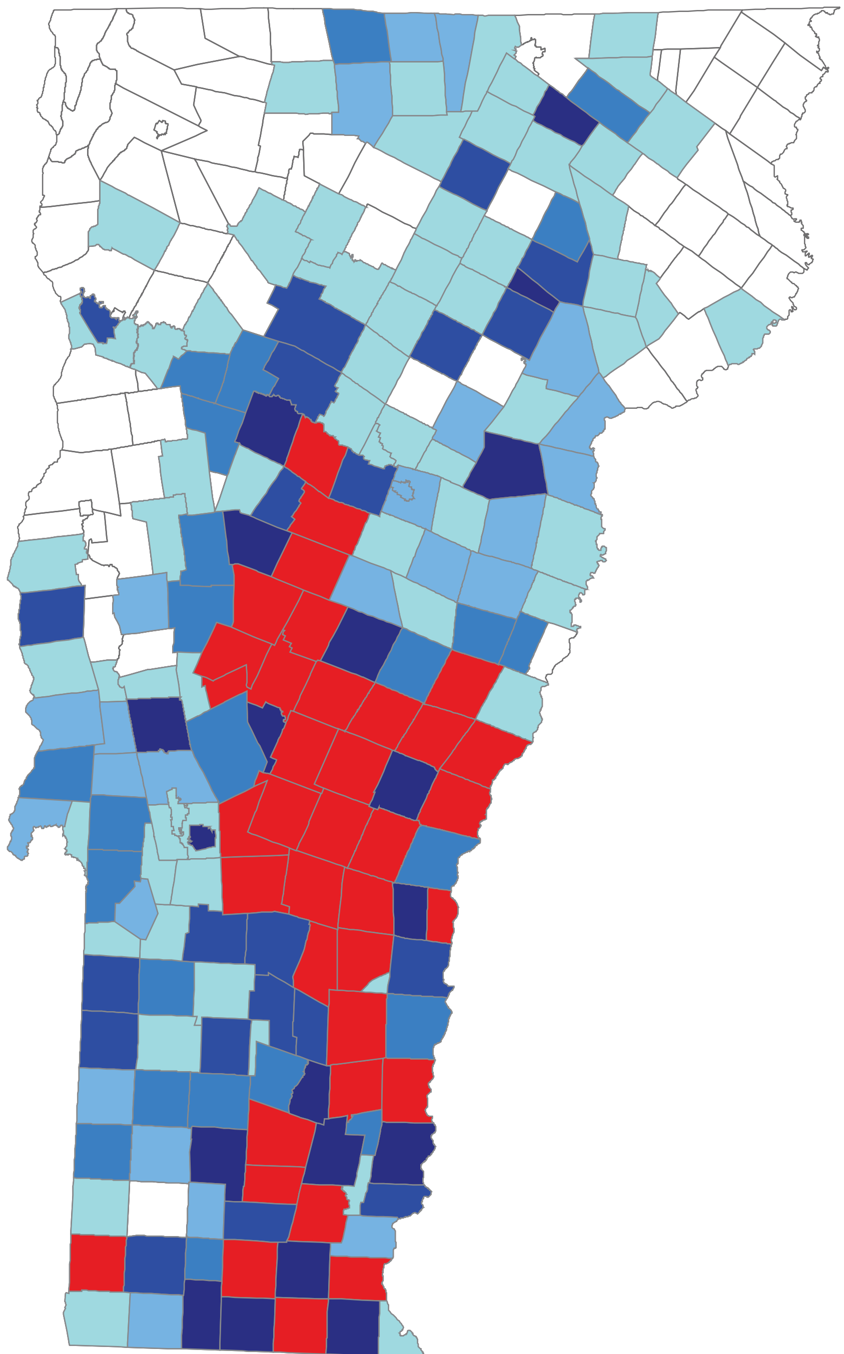
Total: $10,477,000

DR-4001: July 2011



Total: $10,674,000

DR-4022: Tropical Storm Irene, September 2011



Total: $210,461,000

Figure 32: Federally declared flooding disaster public assistance expenditure by municipality (2000-2016)
Data Source: www.fema.gov/openfema

≤ $50,000 | $50,001 - $100,000 | $100,001 - $250,000 | $250,001 - $500,000 | $500,001 - $1,000,000 | ≥ $1,000,001

Inundation Flooding & Fluvial Erosion Trends

According to the 2018 National Climate Assessment, the average annual precipitation in the United States has increased by approximately 4% since 1901 (Figures 34 & 35). More specifically, relative to the period from 1901-1960, precipitation in the northeastern region of the country has increased by 8% since 1991.[29] The Assessment goes on to note that the northern U.S. is projected to experience above average precipitation in the winter and spring, with even wetter conditions expected under a high greenhouse gas emissions scenario. In addition to higher annual precipitation in both the observed record and projected models, the northeastern United States is also projected to experience more frequent, heavier rainfall events. Since 1958, the incidence of these heavy precipitation events has been 55% above average.[30] In Vermont, average annual precipitation has increased by almost 7 inches over the past 50 years[31], suggesting an increasing trend in increased precipitation (Figure 33).

The impacts of both inundation flooding and fluvial erosion are typically far-reaching, disrupting communities by causing damage to the built environment, as well as local and regional economies and the natural environment. Impacts to human life are typically non-fatal, but financial impacts to individuals and families affected by flooding can be significant. Consequently, the State's vulnerabilities to erosion and flooding are numerous.

The anticipated increases in both frequency and magnitude of precipitation in Vermont will lead to alterations of hydrology and water availability. Increased flood inundation, fluvial erosion, and subsequent landslide hazards (see: Landslides) will result in impacts to ecological and geomorphic integrity of river and floodplain systems, and to the built environment. Vermont's historic settlement pattern, in association with the widespread channelization of rivers and loss of functioning floodplains due to encroachments and fill, make Vermont particularly vulnerable to climate change-related increases in flood frequency and magnitude. Moreover, increases in frequency of periodic drought (see: Drought) will not only lead to greater demand for new and more reliable water supplies, but will also reduce the ability of soils to quickly absorb floodwaters, thereby exacerbating flood-related impacts and negatively impacting the natural environment.

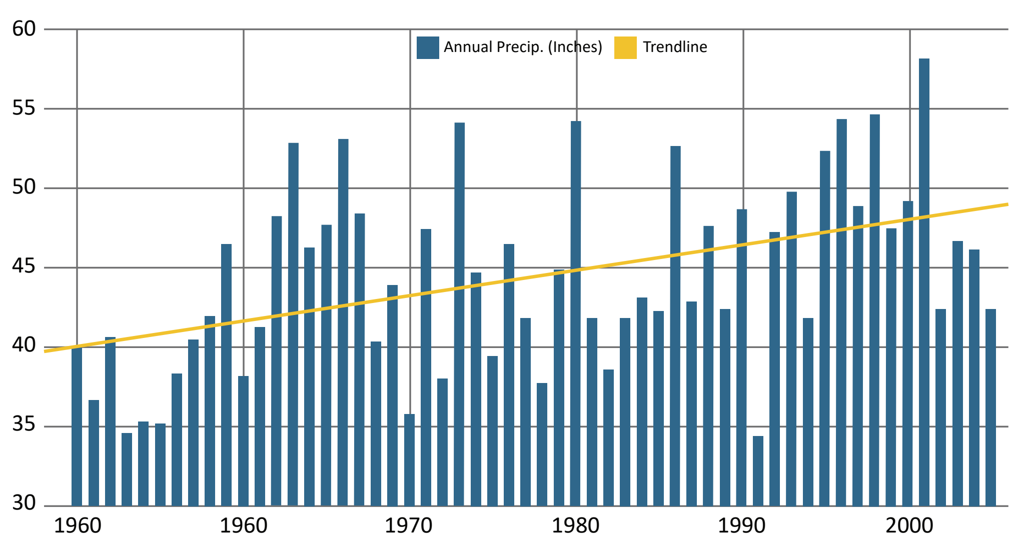


Figure 33: Vermont's annual precipitation (1960-2015)
Source: climatechange.vermont.gov

29 https://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change
30 https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing
31 https://www.healthvermont.gov/environment/climate/climate-change and https://statesummaries.ncics.org/chapter/vt/

Incidence of ice jams in the State are also on the rise, with more significant fluctuations in temperature and decreased snowpack creating an environment prone to greater ice accumulation. As precipitation trends in the northeast indicate that the most significant increases are occurring during winter months, rain events could lead to more frequent ice jam events.

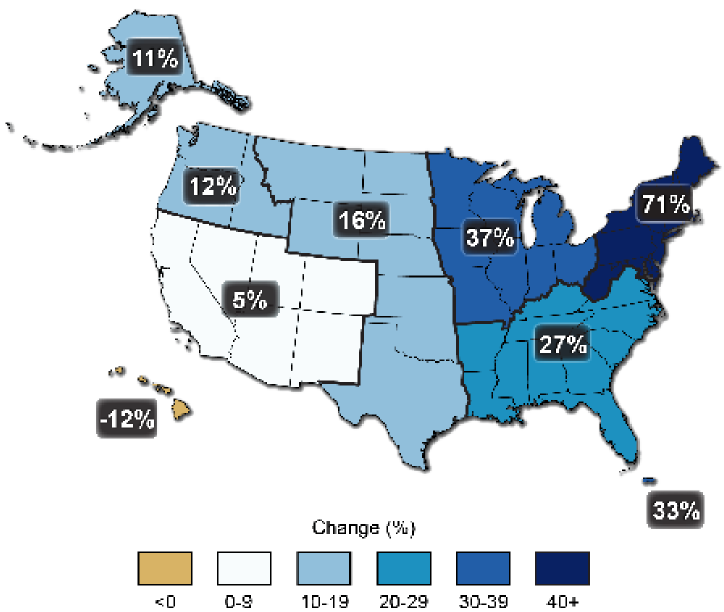


Figure 34: Observed U.S. percent increases in the amount of precipitation falling during very heavy events (defined as the heaviest 1% of all daily events) (1958 to 2012)
Source: https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing

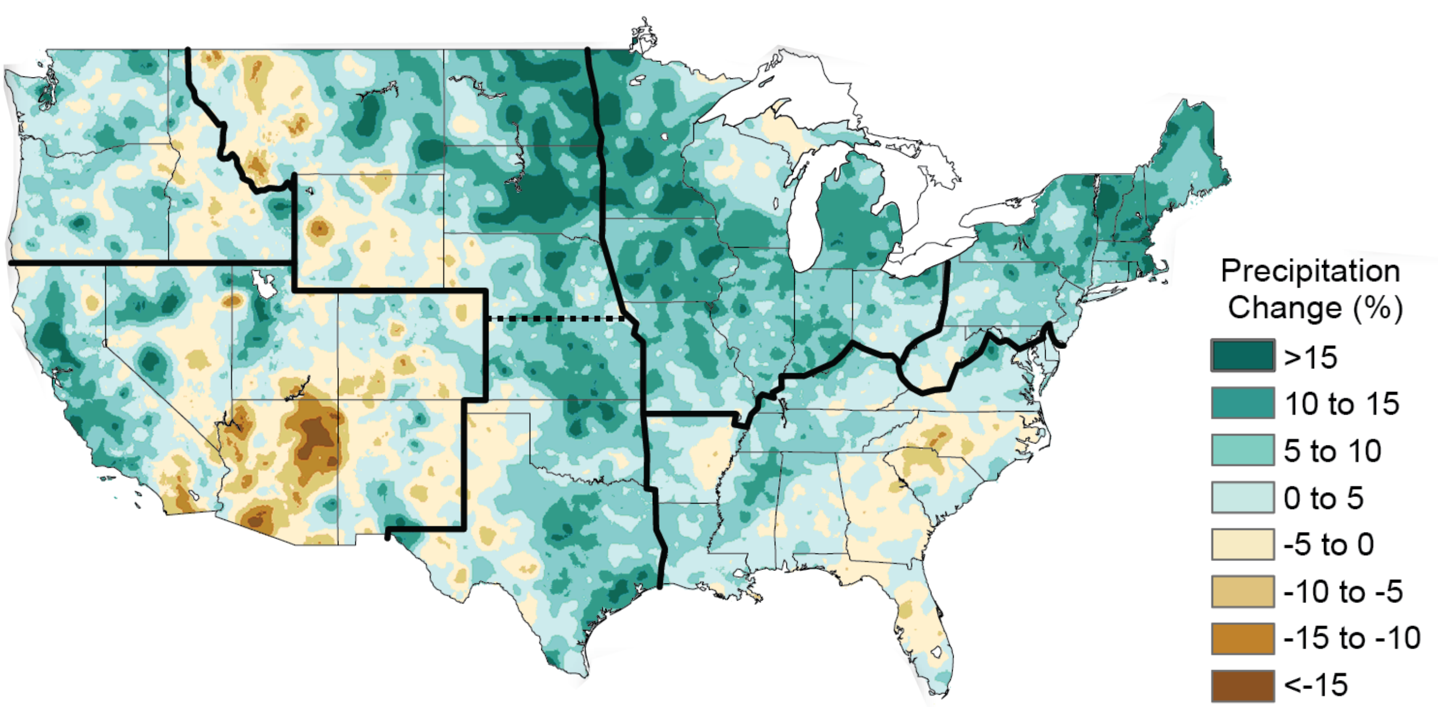


Figure 35: Observed U.S. precipitation change map (1991-2012)
Source: https://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change

Inundation Flooding & Fluvial Erosion Vulnerability

People:

When homes or essential amenities are impacted by flood, the repercussions on people's quality of life are innumerous. Floods and fluvial erosion can also cause loss of life if people do not evacuate in time. Particularly vulnerable individuals are isolated, are not reached by conventional lines of communication, or need mobility assistance. Other people who do not evacuate may have concerns about leaving pets, may be managing young children or dependent family members or may not feel safe leaving their homes. The mountainous nature of interior Vermont can also prevent residents from evacuating or travelling to get supplies. Many settlements and their main connecting roadways are located along valley streams or rivers that may experience flooding or road blockage in large enough events.

Many more people will be affected by the moisture and mold after the flood event than those who will lose their homes all together. Moisture causes mold spores to rapidly reproduce and can cause health effects to the cardiorespiratory systems. Thus, immunocompromised populations and those with preexisting respiratory conditions such as asthma can be particularly vulnerable to the after-effects of flooding.

Flooding is sometimes associated with a loss of electricity, which will impact everything from being able to connect to the internet for work or requesting assistance, to powering life support equipment. We will discuss these compounding impacts more in the Vulnerability Summary.

Built Environment:

Transportation, agricultural, residential, commercial, utility infrastructure and municipal properties are all vulnerable to flood inundation and fluvial erosion hazards. Many of Vermont's historic towns and villages were built along waterways for trade and energy purposes, putting these assets at risk of fluvial erosion within the river corridor. Our best gauge of vulnerability is to look at damages from Tropical Storm Irene. However, the next major flood event will not be identical to Irene, it will take a different track, arrive at a different date, and have different associated hazards accompanying it.

In typical significant flood events seen annually in Vermont the common impacts are road erosion, scour and washouts at culverts and bridges, loss of water pumps, flooding of homes, and sewage or combined sewer overflows.

Extensive erosion damaging a home along Route 11 outside of Chester, VT.
Photo Credit: www.mansfieldheliflight.com/flood/

Manufactured Housing Community Vulnerability

Manufactured housing communities are uniquely vulnerable to flooding. This increased risk is related to siting of communities in flood hazard areas, socioeconomic characteristics of park residents, and limitations of the structures themselves. An assessment completed in 2012 by researchers at the University of Vermont found that one-fifth of Vermont's 247 mobile home parks have at least one lot that is located within a flood hazard area and nearly 12% of all mobile home park lots are located in flood hazards areas.

Two of the major flooding events in 2011 affected 19 mobile home parks across central and southern regions of the State, destroying over 150 mobile homes. Tropical Storm Irene also flooded two parks that are not in mapped flood hazard areas: Barber's Pond Mobile Home Park in Pownal and Tenney's Mobile Home Park in Athens. Both parks were located just outside the limit of the mapped flood hazard area. A flooding event in 2019 also observed inundation flooding in the Mountain Home Trailer Park which resulted in the evacuation of 50 people and extensive property damage. Manufactured homes also made up around 15% of properties damaged in Irene despite only making up 7% of housing stock in the State.

Potential Flood Losses to State Facilities:

In a robust risk assessment completed by Buildings and General Services (BGS) in 2018, all State-owned and leased buildings were analyzed according to their criticality to government operations and their proximity to the river corridor and FEMA-mapped 100-yr and 500-yr floodplains. Building replacement cost, structures' current use, construction type and year, and costs of personal property and computer systems were also considered during this process. Those structures that received the highest overall score were prioritized for a mitigation alternatives analysis that would reduce the structures' respective vulnerabilities.

Updated with 2023 values, it is estimated that there are 785 State-owned assets worth nearly $2 billion in the Special Flood Hazard Area (SFHA), with an additional 173 State-owned assets worth $430 million in the 500-year floodplain. These State-owned assets include park facilities, storage sheds, office buildings, jails, and communication towers. State assets are widely distributed across the State, with slightly higher counts in Windsor and Washington counties.

The State's most vulnerable assets and focus for resource allocation can change based on recent hazards experienced and consequent change in focus and priorities. During Tropical Storm Irene, State buildings in Waterbury were severely impacted, which made them a major priority for mitigation investment, including floodplain restoration and floodproofing. As a result of the significant mitigation investments made, there was minimal damage to State facilities in Waterbury during the July 2023 flooding despite higher flood levels in Waterbury.

During the July 2023 flooding event, the Tax Department at 133 State Street and The Pavilion at 109 State Street in Montpelier were severely impacted. These buildings will be new priorities for mitigation funding over the next few years as their vulnerability was revealed.

In terms of State-owned assets, the office buildings in Montpelier are some of the most vulnerable in Vermont. While not State-owned, the commercial space in Montpelier and Barre, and housing in Barre are all connected to overall resilience and were severely impacted by flooding in July of 2023. State hazard mitigation focus over the next few years will be focused within these communities as well as the others who were most significantly impacted by the July 2023 flood.

The risk assessment methodology, priority structures list and list of potential mitigation actions are located in the Appendix to Section 3.

There are no known State buildings or facilities (other than roadway infrastructure) immediately endangered by ice jams outside the Berlin, Montpelier, and the Waterbury State Office Complex, although no specific inventory or assessment has been performed.

Natural Environment:

In addition to an increase in the frequency and severity of flooding and fluvial erosion, the greater amount of precipitation that climate change is projected to bring to the Northeast may also detrimentally affect water quality. Higher water inflows into lakes and streams increase phosphorus levels, leading to eutrophication, which is the cause of toxic Cyanobacterial blooms (blue-green algae). Cyanobacterial blooms are harmful to the environment, and toxic to animals and people. When considered together, increases in precipitation and temperature exacerbate both the frequency and magnitude of these harmful algal blooms (see: Extreme Heat). Recreationalists accessing Vermont's many lakes need to consider current water quality, and are encouraged to monitor the Vermont Department of Health's Cyanobacteria Tracker Map to check recent lake reports prior to water-based activity.[32]

Fluvial Erosion can also be exacerbated by invasive species. Invasive plants are prevalent along Vermont rivers, which can outcompete native species and increase erosion along stream banks. While the roots of varied native vegetation help to stabilize riverbanks, Japanese Knotweed can contribute to erosion. Japanese Knotweed spreads quickly once established to crowd out and shade other native species and create a monoculture, with very little other growth below the plant. This leaves bare soil and a shallow root system, which do not support the stability of riverbanks[33] (see: Invasive Species).

The natural environment in Vermont has become acclimated to the occurrence of ice jams as a recurring hazard, yet inundation flooding resulting from ice jams can waterlog surrounding landscapes. Flooding can potentially damage vegetation through inundation resulting in drowned plants. Changes resulting in streamflow slowdown can result in soil and bank erosion, stream bed erosion, as well as deposition of pollutants collected from adjacent built infrastructure that can impair water quality, habitats, and flora and fauna.

Flood events commonly cause hazardous materials spills as storage sites and materials are inundated or impacted by fluvial erosion. Based on data from the ANR Vermont Environmental Research Tool[34] the most reported hazardous material spill during a flood event in Vermont is #2 fuel oil, which is used to heat buildings. The spills primarily occur at residential properties across the state, though commonly reported in more urbanized areas with apartment buildings.

32 http://www.healthvermont.gov/tracking/cyanobacteria-tracker
33 https://epscor.w3.uvm.edu/images/copies/t2.pdf
34 https://anrweb.vt.gov/DEC/ERT/Spills.aspx

Economy:

Economic impacts will result from flooding and fluvial erosion both from the disruption of business, as well the cost of recovery. Flood and fluvial erosion can cause loss of inventory either directly from inundation or loss of a structure, and from resulting loss of energy and refrigeration or heating. Facilities without generators or other backup power will be the most impacted.

Fluvial erosion can lead to significant slope failures, resulting in costly repairs and mitigation measures for the built environment. In addition to the acquisition and demolition of several properties across the State following Irene-related erosion, VTrans estimates spending approximately $5.4 million annually on erosion and slope failure projects (see: Landslides).

The Winooski River and Dog River in Montpelier have been identified as particular areas of interest for ice jams, given the history of ice jams and flooding in these locations. More than a dozen serious ice jams events have occurred in Montpelier since 1900. In 1992, an ice jam in Montpelier led to flood inundation in the downtown area, causing more than $5 million in damage to buildings, homes, roads, culverts, and other infrastructure facilities. Ice jams in this location have been identified as far back as the 1700s. It is likely that ice jams will continue to pose a threat to Vermont for the foreseeable future, particularly in the months of January and February.

While other jurisdictions have a history of more frequent ice jam flooding, such as Hardwick, Richford, and Richmond, Montpelier's vulnerability to ice jams may represent the most extreme in the State based on the magnitude of the historic and the potential for future economic loss.

Repetitive Loss:

FEMA, through the National Flood Insurance Program (NFIP), considers any insurable building for which two or more claims of more than $1,000 were paid by NFIP within any rolling ten-year period since 1978 to be a Repetitive Loss (RL) property. With over 122,000 RL properties nationwide, FEMA estimates that these flood-vulnerable structures have resulted in $3.5 billion in claims. In 2004, the National Flood Insurance Reform Act went further to define Severe Repetitive Loss (SRL) properties as those single family properties covered under NFIP that have incurred flood-related damage for which four or more separate claims totaling at least $5,000 each have been paid out, or when there are two or more losses where claim payments exceed the property's value. FEMA estimates that over 6,000 properties in the nation fall under SRL designation.[35]

In Vermont, the following communities have the highest number of Repetitive Loss properties as of September 2023, according to FEMA's NFIP listing: Montpelier (30), Barre City (30), Lyndon (16), and Rutland City (8).

Tropical Storm Irene greatly increased the number of repetitive loss properties in Vermont. According to the 2010 Vermont State Hazard Mitigation Plan (SHMP), there were 65 non-mitigated multiple loss properties in the State of Vermont in 33 towns. In the 2013 Vermont SHMP, there were 139 non-mitigated multiple loss properties in 45 communities. As of early March 2018, there were 176 RL properties in Vermont, 163 non-mitigated multiple loss properties were located within 51 communities. Since 2018 the number of repetitive loss properties has increased to 208 across 72 communities. This data was checked September 2023, however this number is unlikely to include all losses from the Summer of 2023 flooding. 170 unmitigated properties were from 67 communities across the State.

35 https://www.fema.gov/txt/rebuild/repetitive_loss_faqs.txt

There are also areas within Vermont that present significant losses but do not fall under the FEMA definition of a repetitive loss property. For example, Clover Street in Rutland City is repeatedly flooded by Moon Brook after major rainstorms. It is speculated that the major cause of this flooding is an insufficiently sized culvert under the adjacent railroad bed to the west. The culvert does not meet the cost-benefit ratio to qualify for FEMA Hazard Mitigation Assistance (HMA) funding but is a significant threat to the community.

The State of Vermont is committed to ensuring that all repetitive loss properties, whether they meet the FEMA definition or not, are monitored and mitigated to prevent future financial loss and loss of life.

A barrier to potential mitigation of these repetitive loss properties is a discrepancy that exists between the NFIP and HMA branches of FEMA, both of whom keep their own, distinct lists of repetitive loss properties. These lists are not aligned with one another, and the HMA-eligible RL property list is significantly smaller than the NFIP repetitive loss database. For example, as of late 2017, the HMA-eligible RL list was comprised of eight properties, whereas the NFIP list from the same time period listed 176 RL properties, which are considered to be equally vulnerable to flooding.

For a complete list of all communities participating in the NFIP, FEMA keeps an up-to-date Community Status Book Report detailing community information, map effective dates and more.[36] Property owners whose communities do not participate in the NFIP do not have access to flood insurance, making them more vulnerable to the financial difficulties following a flood event that damages their property. Additionally, mitigation projects that take place within the FEMA-mapped Special Flood Hazard Area are not eligible for HMA funding if the community applying for funds is not a participating member of the NFIP, which leaves much of the built environment within that community vulnerable to flood damage.

36 https://www.fema.gov/cis/VT.html

Inundation Flooding & Fluvial Erosion Current Capabilities and Mitigation

As a State with a long history of disasters involving inundation flooding and fluvial erosion, taken together with the increasing trends in both annual precipitation and frequency of significant rainfall events (see: Inundation & Fluvial Erosion: Trends), the Steering Committee considers the probability of a plausibly significant flood inundation or fluvial erosion event to be Highly Likely, with the most significant impacts to the built environment and the economy. Both inundation flooding and fluvial erosion events have a similar, moderate impact to human life. With respect to the natural environment, a significant fluvial erosion event will have major impacts, while inundation flooding will only cause minor damage to the environment. Accordingly, the Steering Committee has ranked fluvial erosion as Vermont's top natural hazard, with inundation flooding ranked second.

Given these rankings, as well as the history of flood-related vulnerabilities in Vermont, the majority of the State's mitigation efforts are focused on inundation flooding and fluvial erosion. Some of the high priority themes and strategies are discussed in detail below; for a complete list of the State's efforts regarding flood mitigation, please visit the Mitigation Strategy and State & Local Capabilities sections.

Buyouts:

Following Tropical Storm Irene, Vermont has been very successful in acquiring and demolishing flood-damaged or flood-vulnerable structures through several funding sources, to include the Flood Resilient Communities Fund, the Hazard Mitigation Grant Program (HMGP), Community Development Block Grant – Disaster Recovery (CDBG-DR), the Vermont Housing & Conservation Board and the Vermont River Conservancy. Over 200 properties have been successfully mitigated in what are colloquially referred to across the State as "buyouts". In recognition of this success, and as the State continues to better understand its structural vulnerability to inundation flooding and fluvial erosion, the Steering and Planning & Policy Committees have identified the long-term funding the Statewide conservation and buyout program, FRCF, as a top priority of this plan. The establishment of this program was prioritized in the 2013 and 2018 Vermont SHMP.

The FRCF aims to not only identify structures vulnerable to flooding and fluvial erosion, but to also take a more proactive approach at purchasing and conserving undeveloped land to prevent future structural vulnerability.

This strategy includes actions on dedicated funding sources and better data acquisition to address vulnerability more comprehensively. Removing repetitive loss structures, flood vulnerable structures, and at-risk mobile home parks can decrease the risk of damage or injury in the event of an impactful flood event.

Headwater and Floodplain Storage and Water Quality Co-Benefits:

During the planning process, a strong theme regarding a holistic approach to flood- and erosion-related mitigation continued to surface. That is, Vermont should consider the mitigative value of flood storage in both headwater forests and down-valley river corridors and floodplains, as well as water quality and invasive species implications that may also affect inundation flooding and fluvial erosion.

In addition to guiding development outside of floodplains and river corridors, several high priority mitigation actions were developed under the strategy aimed at improving land management and headwater storage. These actions, which include developing an inventory of critical headwater storage areas and completing a pilot project to demonstrate the co-benefits of upland conservation and downstream flooding, considering the storage capacity of Vermont's hills and forests. These actions aim to protect small flood prone and headwater storage parcels that are too small for traditional conservation easements. If these areas are conserved and managed appropriately, the risk of downstream flooding due to the amount of water and debris from upland can be reduced. These actions also included an incorporation of best management practices for restoration and expansion of headwater storage, wetlands, and stream corridors through outreach efforts to private lands providing ecosystem services and habitat connectivity. Water storage actions include incentivizing water storage in natural areas, including wetlands, to promote flood resilience and biodiversity through the expansion of wetland easements.

In addition to reducing flood levels due to water and debris runoff from the headwaters and increasing flood storage in valley floodplains, there are water quality co-benefits that can be achieved when riverbanks become more stable (i.e., due to floodplain connectivity) and less runoff – potentially carrying pollutants and invasive species – makes its way to the rivers. As excess nutrients and chemicals are carried from farms and roads into a river, that river's ecosystem is negatively impacted. Eventually, the river will make its way to larger bodies of water like Lake Champlain, where those nutrients can lead to harmful algal blooms (see: Extreme Heat). Invasive species, like Japanese knotweed, readily form along waterways, from road ditches to rivers to lakes, and spread very easily. Their shallow root systems lead to greater bank instability and can further exacerbate not only fluvial erosion, but also water quality issues (see: Invasive Species).

Given the above, the Steering Committee recognized the need for a whole systems approach to flood-related mitigation. The result is a high priority strategy devoted to connecting water quality, flood resilience and native habitat connectivity through recognizing co-benefits of mitigation efforts. There are several grant programs that focus within their own silos, but which could be expanded and leveraged to support these co-benefits. By inventorying the many grant programs and capabilities within the State, new projects supporting both water quality and fluvial erosion mitigation, for example, can be realized.

Education, Outreach & Data:

With all the initiatives, grant programs, data and mapping supporting flood mitigation, especially post-Irene efforts, the State of Vermont's Department of Environmental Conservation (DEC) developed the Flood Ready website[37] as a resource hub for users to access flood-related information. This website, updated daily by multiple State agencies, has received recognition at national conferences and continues to be a primary platform for disbursing useful information, such as grant opportunities, new legislation and community-based reports as pertains to flooding.

In 2018, DEC, with funding from the Lake Champlain Basin Program, created the Flood Training website[38] which provides a suite of case studies, tools and education materials geared at helping municipal officials protect river corridors and floodplains in their communities.

Because twelve years have passed since Tropical Storm Irene brought devastation to the State, flood mitigation outreach is not as impactful as it was in the immediate aftermath of the storm. Many call this phenomenon resilience fatigue. Using language like "100-year" and "500-year" floodplain has led to a lack of understanding of the State's vulnerability to flooding. To continue outreach efforts and expand education regarding flood risks and the importance of mitigation, the Steering Committee prioritized several education-based mitigation actions as part of this plan update process.

37 http://floodready.vermont.gov/
38 http://floodtraining.vermont.gov/

As a primary tool of education and outreach, accurate data and mapping are critical. Accordingly, the Steering Committee has prioritized several actions that fall under the hazard mitigation mapping, data, and research coordination strategy, identifying these actions as critical to expand flood resilience by dovetailing research efforts and sharing hazard data. For example, river corridor mapping is used to identify those areas vulnerable to fluvial erosion, identified above as the top natural hazard impacting Vermont. The data used to develop river corridor maps have been compiled over the years through the tireless efforts of DEC and mapped using funding from a myriad of State and Federal sources. Publishing these maps on the Vermont Natural Resources Atlas allows the State, municipalities, and individuals to better understand fluvial erosion vulnerability and develop steps to address it.

It is important to note, however, that without recognition of this river corridor area by all agencies at the State and Federal levels, Vermont remains vulnerable to fluvial erosion. The Academic Resilience Collaborative (ARC), a high priority action of this plan, will be tasked with addressing fluvial erosion data and research needs and potentially creating an algorithm or model for inclusion of fluvial erosion in the FEMA Benefit-Cost Analysis (BCA) software so that Vermont can access mitigation funds for its primary hazard.

Vermont has also applied for several FEMA HMGP 5% Initiative applications aimed at accomplishing increased awareness of flood vulnerability and mitigation and will continue to request these funds in the future. In addition to these actions and resources the Plan outlines an action to develop a resource for the incorporation of hazard mitigation and water quality projects into local capital planning and budgeting process.

Lake Champlain:

Taking into consideration both the significant lake flooding and erosion along Lake Champlain in 2011 and increased pressures for lake front development, the Vermont Legislature passed into law the Shoreland Protection Act, which regulates activities within 250’ of the mean water level of lakes greater than 10 acres in size. The intent of this Act is to allow reasonable development along the shorelands of lakes and ponds while protecting aquatic habitat, improving water quality, and reducing erosion hazards by maintaining the natural stability of shorelines.[39]

Further considerations of inundation and fluvial erosion vulnerabilities along Lake Champlain are being discussed by the International Joint Commission’s (IJC) Lake Champlain and Richelieu River Study Board.[40]

Though they do not technically meet the definition of coasts, there is currently an effort to analyze and map the shores of the Great Lakes using analyses and procedures standard along the coasts. Performing a coastal analysis of Lake Champlain would add storm surge and wave height considerations to the existing Base Flood Elevation (BFE), which is based strictly on stillwater inundation levels. Though not a current strategy of this plan, future planning and funding efforts should review the results of the Great Lakes study and consider extending the analysis to Lake Champlain.[41]

39 http://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/Shoreland/lp_ShorelandHandbook.pdf
40 http://www.ijc.org/en_/Lake_Champlain_Basin
41 http://www.greatlakescoast.org/great-lakes-coastal-analysis-and-mapping/

Ice Jams:

From February through March 2007, December 2008, January 2010, and again in January through February 2018, the City of Montpelier and State agencies carefully monitored a large fragile ice jam on the Winooski River at Cemetery Bend, which threatened to flood downtown Montpelier. Strategically placed gages along the river allowed authorities to monitor the height of the river and rate of rise, alarm systems are in place to warn citizens of impending flooding, and an ice jam breaker is parked permanently over the winter along this vulnerable bend in Montpelier should the need arise to break up thick ice in anticipation of potential jamming. In addition, the U.S. Army Corps of Engineers (USACE) Cold Region Research and Engineering Laboratory (CRREL) have established a website with monitoring equipment and gages indicating level of rise, depth of water, and river temperature. This can be accessed by emergency management officials so that sufficient warning can be given if flooding appears to be imminent.[42]

In 2011, Montpelier completed a FEMA-funded project to install a pump station at the wastewater treatment facility, which is used to pump treated effluent upstream to three fixed discharge points on the riverbank near where the ice frequently jams. When the ice conditions begin to pose a threat, the City uses the 45°F treated wastewater to weaken the river ice and create open water channels. The weakened ice pack allows the ice to flow down the river and through the natural constriction when the ice releases upstream. So far, this approach has proved to be effective at reducing Montpelier's ice jam threat.

Dam Resilience:

With over 800 dams in the State, approximately 70 of which are classified as HIGH hazard, several mitigation actions were developed that fall under the dam resilience improvement strategy. In addition to those actions, there are several other mitigation efforts underway in the State to address vulnerability to dam-related hazards.

The DEC staffs two full-time Dam Safety Engineers who review permit applications for new dams, rehabilitation of existing dams, and dam removal, conduct dam safety inspections, and work with dam owners to address operation and maintenance issues and larger deficiencies. In addition, the DEC owns and operates the Winooski River Flood Control Dams (Waterbury, Wrightsville, and East Barre), as well as 11 other dams throughout the State and assists other State Agencies including Fish & Wildlife, Forests Parks and Recreation, and Agency of Transportation, who in total, own approximately 90 dams.

The PUC administers 4,500 Safety of Hydroelectric Dams rules developed for dams in their jurisdiction. The PUC consists of a team of environmental technicians and lawyers who have the authority to contract with dam safety consultants for assistance on an as-needed basis.

FERC and Federal Agencies that own dams have robust dam safety staff and guidance backed by nationally accepted standards. The New England District of the USACE owns and operate large flood control dams in the Connecticut River drainage basin.

Following the rules outlined by the FEMA High Hazard Potential Dam (HHPD) program and Hazard Mitigation Assistance (HMA) program, the State aims to support the development of applications under these programs for dam repairs and removals. The State also aims to allocate a funding source to implement rules for improvements and rehabilitation.

42 http://icejams.crrel.usace.army.mil/apex/f?p=524:1

The Vermont Dam Task Force, a group of individuals from both the public and private sector, meet quarterly to discuss dam mitigation, with a primary goal of rehabilitating rivers and improving public safety through dam removal. Finally, The Nature Conservancy of Vermont developed a Dam Removal Screening Tool for the Lake Champlain basin, which categorizes dams by their ecological impact. Recognizing the value of this tool, the Steering Committee prioritized expansion of the tool to other watersheds across the State in this Plan. Building on the value of that tool this plan the development and continued upkeep of digital dam inundation maps for all high hazard dams has been outlined as a mitigation action.

Other Initiatives:

In 2015, the Agency of Commerce and Community Development (ACCD), together with VTrans, the Department of Environmental Conservation (DEC), RPCs and the U.S. Economic Development Administration (U.S. EDA) developed a robust mitigation project identification report for five pilot towns.[43] This report, titled Vermont Economic Resiliency Initiative (VERI), is being used by various agencies to plan for and implement community-identified high priority actions to promote their resilience. Of the five pilot towns, four identified mobile home park vulnerability to flood-related hazards as a priority for project and funding consideration. Since the release of the VERI report, the pilot towns have been working with various State agencies to achieve some of these projects, to include structural elevations and acquisition/demolition of the flood-vulnerable mobile home parks.

The Vermont chapter of the United States Army Corps of Engineers (USACE) Silver Jackets was chartered in August 2016, with representation from various Federal (FEMA, USGS, USACE, and NOAA) and State (DEC, VEM, VTrans and ACCD) agencies. The mission of the Vermont Silver Jackets team is to foster innovative and collaborate partnerships that facilitate and contribute to comprehensive and sustainable management of flood risk throughout the State. Following execution of the charter, the Team began working on its first pilot application for improved flood inundation mapping for the City of Montpelier.
This application was approved by USACE, and work is currently underway.

Other projects that the Team is developing in 2018 include new HEC-RAS modeling for the volatile Whetstone Brook in Brattleboro, a project identified in the Brattleboro chapter of the VERI report, and ice jam modeling along the Lamoille River in Johnson and the Missisquoi in Swanton following the significant ice jam events along those two stretches in early 2018. Additionally, the Silver Jackets are supporting analysis of Significant hazard dams in Vermont to determine if additional dams should be considered High hazards dams eligible for HHPD funding. Together with VEM and ANR, the Vermont Silver Jackets Team is identified as a lead entity for the development of a Benefit/Cost Analysis methodology to facilitate buyouts in areas at risk from flood-related erosion and outside of FEMA-mapped Special Flood Hazard Areas.

A plethora of other mitigation efforts, initiatives and capabilities are underway or being developed in Vermont to address the State's top two natural hazards. For more information on these efforts, please see the Mitigation Strategy and State & Local Capabilities sections.

43 http://accd.vermont.gov/sites/accdnew/files/documents/CD/CPR/CPR-VERI-FinalReport.pdf

4-2: Extreme Heat

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Extreme Heat	4	2	4	3	2	2.75	11

*Score = Probability x Average Potential Impact

This chapter aims to address the history, trends, vulnerability and mitigation efforts associated with extreme heat, prolonged hot weather and rising average annual temperatures. More information on increasing average temperatures can be found in the Climate Change subsection of the Vermont Profile & Hazard Assessment and reflected in the trends and vulnerabilities sections of each hazard profile.

Extreme hot temperatures can have significant effects on human health and commercial and agricultural businesses, as well as primary and secondary effects on infrastructure (e.g. damage to asphalt roadways from softening). What constitutes "extreme heat" can vary across different areas of the world based on what the population is accustomed to in their respective climates. An example of this difference in acclimatization can be understood when comparing analyses of excess mortality due to heat: in New York City, the data show that the heat index threshold needs to reach at least 95°F to measure a significant rise in heat-related mortality, whereas the threshold in Montreal, Canada, only 400 miles north, is 91°F and did not need to factor in heat index. Epidemiological analyses completed by the Vermont Department of Health indicate that heat-related health impacts in Vermont substantially increase when the heat index exceeds the historic 95th percentile threshold, which is about 90°F in hotter areas like Burlington and about 85°F in cooler places like Newport.

Temperature fluctuations are a result of several meteorological processes.[1] Due to the tilt of Earth's axis, regions of the globe receive varying levels of solar radiation. The delta between these levels produces circulation patterns at the global level, which drive air and storm system movement via air masses. Air masses, as defined by NOAA, are thousands of feet thick and extend across large areas of the earth. Air masses that form over tropical ocean regions will become exceptionally hot and humid, while those masses above high latitude continents will become cool and dry. When these air masses meet, a front is created; fronts can either be cold or warm. In addition to these air mass and front-related impacts humans feel at ground level, movement of narrow bands of strong wind high in the atmosphere, known as jet streams, maneuver weather systems below and transfer heat and moisture across the globe. The speed and intensity of the jet stream will affect the duration and temperature associated with a cold or warm front.

Extremely high temperatures can occur when a high-pressure system (under which air is descending toward the Earth's surface) develops and intensifies. Under such conditions, the potential for a heat wave exists. A heat wave is a period of three or more consecutive days during which the maximum temperature meets or exceeds 90°F.

1 http://www.noaa.gov/resource-collections/weather-systems-patterns

In anticipation of extreme heat events, the National Weather Service (NWS) may issue the following advisories in Vermont:

- **Excessive Heat Outlook:** A period of excessive heat is possible within the next 3 to 5 days.
- **Heat Advisory – Take Action:** A period of excessive heat is expected. The combination of hot temperatures and high humidity will create a situation in which heat related illnesses are possible. Heat Advisories are issued when heat indices are expected to reach at least 95°F.
- **Excessive Heat Watch:** A prolonged period of dangerous excessive heat is possible within about 48 hours.
- **Excessive Heat Warning – Take Action:** A prolonged period of dangerous excessive heat is expected within about 24 hours. The combination of hot temperatures and high humidity will create a situation in which heat related illnesses are possible. Excessive Heat Warnings are issued when heat indices are expected to reach at least 105°F.

The Heat Index is a measure of how hot it really feels when relative humidity is factored in with the actual air temperature (Figure 36). For example, if the air temperature is 90°F and the relative humidity is 65%, the heat index – how hot it feels – is 103°F. The red area without numbers indicates extreme danger. The National Weather Service will initiate alert procedures when the Heat Index is expected to exceed 105°F (depending on local climate) for any duration.[2] Full sun can increase the "feels like" temperature by an additional 15 degrees.

Extreme heat and prolonged periods of hot weather, as well as significant, projected increases in average annual temperature, also have direct and indirect effects on other hazards, addressed throughout this Plan: Drought, Wildfire, Invasive Species, Infectious Disease.

Relative Humidity (%)	Temperature (°F)															
	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure and/or Strenuous Acitivity

Caution | Extreme Caution | Danger | Extreme Danger

Figure 36: Heat index
Source: NOAA

2 http://www.nws.noaa.gov/om/heat/heat_index.shtml

Extreme Heat Location

Urbanized areas in Vermont experience higher temperatures than more rural areas of Vermont, particularly during summer months. Data collected by citizen scientists during a 2020 Heat Watch Campaign in urbanized Chittenden County indicated a nearly 10°F difference on a hot August day between the most developed and most natural areas of the study area.[3] The data were then used to estimate that all urban areas in Vermont experience similar temperature variation, and even small urban areas in Vermont experience at least a 3°F difference.[4]

The Urban Heat Island (UHI) Effect describes this phenomenon, as areas covered by pavement, rooftops, or other dark, impervious surfaces absorb and retain more heat than do trees and vegetative surfaces.[5] People, vehicles, and other technology also create waste heat that is released into the surrounding area and increases the UHI effect, especially in densely.[6] Urban heat islands also raise concerns about health equity and climate justice, as residents of the hottest neighborhoods with the least tree cover often experience additional heat-related health risk factors and have fewer resources for adapting to hot weather.

Extreme Heat History

Fortunately, Vermont has historically experienced a climate where extreme heat is less likely than other regions in the country. However, our cool climate contributes to greater risk when it does get hot, as it takes time for a person's body to acclimate to activity during hotter weather, and many buildings in Vermont do not have air conditioning. Heat-related events are beginning to occur in Vermont in much greater frequency and intensity (see: Extreme Heat Trends).

In Burlington, the most recent 5-year average number of days per year with above 90°F temperatures is nearly 12, compared to only 6 days on average between 1991-2020.[7] In 2020, a year when more than half the state experienced moderate-to-severe drought, this figure climbed to 18. Extreme maximum temperatures are often observed during drought years, and in many cases, the records that are broken were long-standing and set during previous droughts (see: Drought).

Between 2000 and 2022, the number of recorded days per year with a daily temperature high greater than or equal to 90°F peaked during 2020 in Burlington at 18 days, closely followed by 2018 with 16 days.[8] It is important to note here, however, that hot weather can have health impacts at even lower temperatures, with health risks increasing considerably when temperatures reach the mid-to-upper 80s.[9]

One summer excessive heat event was recorded by NOAA in Vermont on July 1, 2018 in Bennington and Windham Counties. Temperatures were recorded in the mid-90s with heat indices registering at 105 degrees. While excessive heat was only recorded in Bennington and Windham Counties, all 14 Vermont counties were significantly impacted by this heat event. The July 1, 2018 heat event throughout Vermont, along with other significant events since 2000 are included below.

3 https://osf.io/tezb9/files/osfstorage/60de2d6a31881a027f635f30
4 https://osf.io/yurjw/files/osfstorage/61bf567140147e03269a1da9
5 https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect
6 https://education.nationalgeographic.org/resource/urban-heat-island/
7 http://vt-data-fixture-nescaum-ccsc-dataservices.s3-website-us-east-1.amazonaws.com/data-fixture/?c=Temp/stn/tx90/ANN/USH00431081/
8 http://vt-data-fixture-nescaum-ccsc-dataservices.s3-website-us-east-1.amazonaws.com/data-fixture/?c=Temp/stn/tx90/ANN/USH00431081/
9 http://www.healthvermont.gov/environment/climate

- **August 1-2, 2006:** A heat ridge moved into Vermont during the early morning August 1. Temperatures soared into the 90s but significantly more important were dewpoints that reached the middle to upper 70s to produce excessive heat index values of 100°F to 105°F, some of the highest values in nearly a decade.
- **July 21, 2011:** Temperatures across much of southern Vermont warmed into 90s with dew points in the 70s, combined with the hot temperatures and resulted in heat indices of 100°F to 104°F. This was the 2nd day of a 3 to 4-day heat wave across a large portion of Vermont with heat index values of 100°F to 108°F across the Champlain and Connecticut valleys as well as some interior valleys. One death is attributed to this event in Windsor County.
- **March 17, 2012:** Winter of 2011-12 had temperatures that averaged 4-5°F above normal and snowfall 40-60% of normal. This combination accounted for snow pack across the region to be largely below normal or even non-existent by mid-March. In Vermont, temperatures climbed into the 70s March 18 and low-80s March 19-22. Record heat was recorded across all of Vermont with maximum temperatures 30-40°F above normal and some daily records being broken by 10°F or more. This event caused an estimated reduction of 30% of maple sugar production, resulting in an estimated impact of nearly $10 million. In addition, there was significant loss of ski industry revenue due to a 25-50% reduction in snow loading.
- **July 1, 2018:** High temperatures affected zones in all 14 of Vermont's counties through Independence Day. Temperatures reached the mid-90s, and heat indices were recorded within the range of 95 -110 degrees. The heat wave continued for 6 consecutive days, and Burlington, VT saw the warmest 5 day stretch since 1892. It is important to note that the all-time minimum temperature also broke a previous record of 78 degrees, on July 2nd, 2018 at 80 degrees. Four deaths were attributed to this event, one recorded in Washington County and three in Chittenden County, all related to excessive indoor residential temperatures. Nearly 100 heat-related emergency department visits occurred state-wide during this heat wave, and more than 10 percent of Emergency Medical Service calls on July 1st were heat related.
- **June 18, 2020:** Areas of Vermont and New York experienced the 2nd longest heatwave duration with temperatures in the 90s for six days straight in northwestern Vermont. Burlington recorded the highest temperature in its history on June 22nd and 23rd with a reading of 96 degrees. Zones in 8/14 of Vermont's counties recorded high temperatures during this period of time. One death in Orleans County was associated with this heat wave.

Extreme Heat Trends

From 1895 to 2022, the average annual temperature in Vermont increased by 3.6°F (or 0.2°F per decade).[10] Data from the National Oceanic and Atmospheric Administration (NOAA) further suggest that Vermont's average annual maximum and minimum temperatures increased by approximately 0.4°F and 0.6°F, respectively, per decade since 1960[11], representing an increasing trend in temperature increases within the State. This significant rise in average temperature is even more profound when comparing the differences between seasons: average maximum temperature in the summer (June-August) has risen 0.2°F per decade, while winter (December-February) has experienced an increase of 0.7°F per decade.

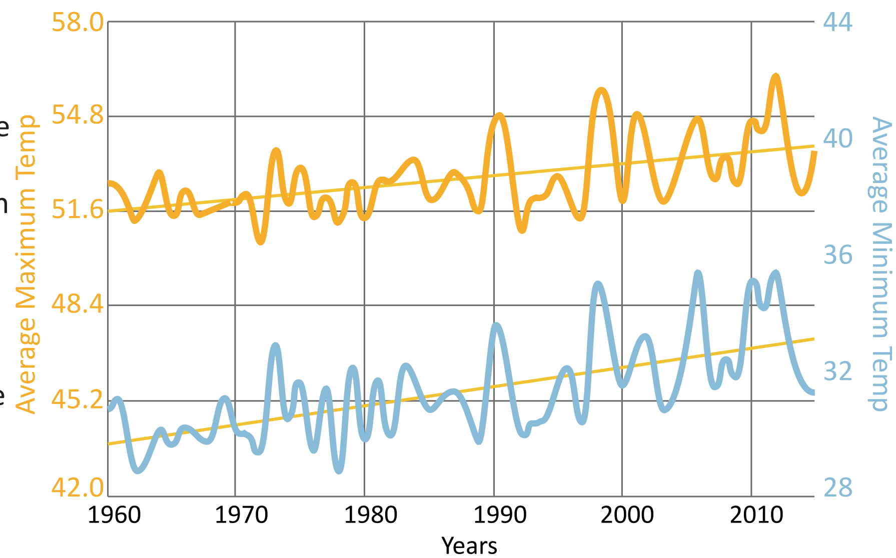


Figure 37: Vermont's average annual maximum & minimum temperatures (1960-2015)
Source: climatechange.vermont.gov

Increases in ground surface temperatures will be further exacerbated by varying levels of greenhouse gases. Climatologists have modeled the projected increases in the number of days over 90°F for both reduced greenhouse gas emissions scenario (B1) and those increases in higher greenhouse gas emissions scenario (A2). This modeling suggests that increases in average temperature of 3°F to 6°F in the lower emissions scenario versus 4.5°F to 10°F under higher emissions conditions can be expected by the 2080s[12] (Figure 38). The most significant warming in this region will occur during the winter months, where average temperatures are projected to increase by 4°F, while the increase in summer months will be less severe, at 2°F, but still considered a significant rise. More information for the compounding impacts of increasing gas emissions on increasing temperatures can be found in the 2018 National Climate Assessment.[13]

Considering the already-observed increase in average annual temperature, the projected rise between 3°F and 10°F by the 2080s, and the impacts of extreme heat or prolonged hot weather, the Steering Committee considered the probability of a plausibly significant extreme heat or prolonged hot weather event to be Highly Likely, with major impacts to people.

10 https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series/43/tavg/ann/2/1895-2023?base_prd=true&begbaseyear=1895&endbaseyear=2022&trend=true&trend_base=10&begtrendyear=1895&endtrendyear=2023

11 https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series/43/tmin/ann/2/1960-2022?base_prd=true&begbaseyear=1960&endbaseyear=2022&trend=true&trend_base=10&begtrendyear=1960&endtrendyear=2022

12 https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-northeast_.html#Reference%201 http://anr.vermont.gov/sites/anr/files/specialtopics/climate/documents/VTCCwhitepapers/VTCCAdaptAgriculture.pdf

13 https://nca2018.globalchange.gov/

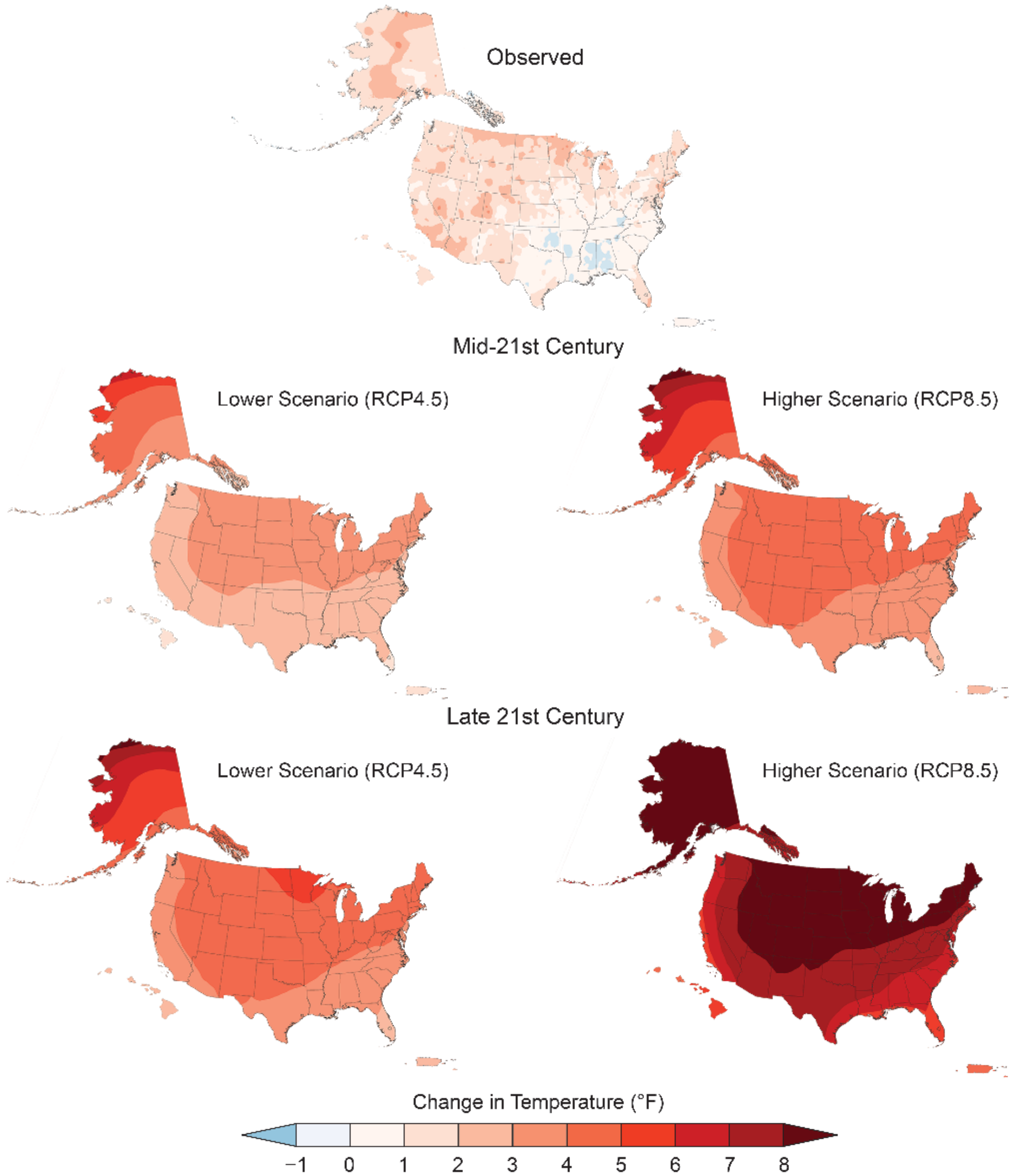


Figure 38: Average mean temperature trends in the U.S. map, February 1895-2020 by decade (95% confidence interval)
Source: Environmental Protection Agency, Climate Impacts in the Northeast

Extreme Heat Vulnerability

People:

The impact of extreme heat or prolonged periods of hot weather to human life is significant. Hot conditions, especially when combined with sun and high humidity, can limit the body's ability to thermoregulate properly. Prolonged exposure to hot conditions can lead to heat cramps, heat exhaustion, heat stroke, or exacerbate other pre-existing medical conditions. Some of these impacts require medical attention and can be fatal.

Epidemiological analyses completed by the Vermont Department of Health indicate that Vermonters are five times as likely to visit the emergency department for heat-related illnesses when the heat index reaches the 80s, 10 times as likely when the heat index reaches the low 90s, and over 20 times as likely when the heat index reaches the upper 90s or hotter.[14] These risks are greatly modified by how acclimated a person is to hot weather – the risk for heat-related health impacts is higher early in the heat season, and lower if it has been consistently hot over the past week or more. Consecutive days of hot weather with warm overnight temperatures further increase the risk of experiencing severe heat-related health impacts. Risk also depends on the "normal" level of heat experienced in an area – places that are relatively cooler will typically experience health impacts at lower heat index values than a place that is relatively warmer.

Older adults, people with chronic health conditions, and people with disabilities are at particularly high risk, especially if they live in housing without air conditioning or are unhoused and cannot access cooling facilities and other support resources. The unhoused may not be or feel welcomed at cooling centers, sleep in hot tents, and carry heavy loads of their possessions in the heat.

Living alone or in an isolated location further increases risks for those who are already susceptible to heat. Other populations at relatively high risk include young children, people that are pregnant, outdoor workers and hobbyists, and people living in more urbanized parts of Vermont. For anyone, taking certain medications, drugs, and alcohol, can increase heat sensitivity.

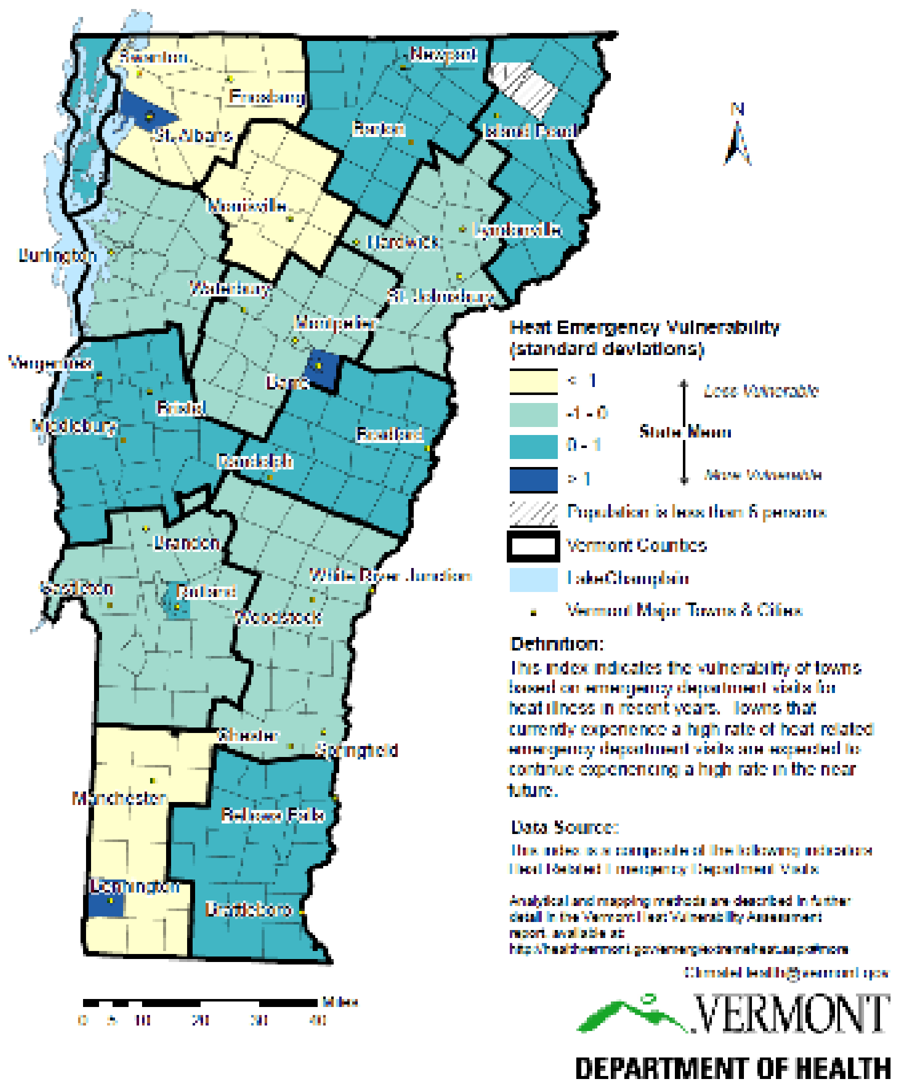


Figure 39: Vermont heat emergencies map by municipality
Source: Vermont Department of Health

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14 https://www.healthvermont.gov/environment/tracking/climate-and-health

The Vermont Department of Health developed a town-level Heat Vulnerability in Vermont report in 2016.[15] The vulnerability index is composed of data representing six heat vulnerability themes (population demographics of a town, socioeconomic status, health status of town residents, environmental characteristics, the ability of town residents to acclimate to hot temperatures and emergency room visits for heat illness) with a thematic vulnerability calculated for each. The hot-weather vulnerability maps by theme, and more information regarding the health impacts of increasing temperatures and prolonged periods of hot weather are available at the Department of Health's Climate & Health website: www.healthvermont.gov/environment/climate. Figure 40 shows the overall vulnerability scores across Vermont.

Though higher temperatures are more likely in the Champlain Valley, southeast region of the State, and in more urban areas, this does not translate to a linear relationship between temperature and vulnerability. Historically, relatively high rates of heat illnesses have been experienced in some of the cooler counties in Vermont, which may be a result of underlying population vulnerabilities (e.g., an older population with more pre-existing health conditions) or a lack of acclimation to hotter conditions. Most urban areas in Vermont do experience relatively higher rates of heat-related illnesses, with the exception of the Burlington area, which is likely related to this area having greater adaptive capacity in terms of material resources and cooling centers.

In addition to the direct health impacts associated with extreme heat, data suggest that other health impacts are also associated with prolonged hot weather and increasing average temperatures. For example, higher concentrations of ground-level ozone are associated with hotter days in the northeast, which can exacerbate heat-related health impacts, particularly for older adults, children, and those with asthma or other respiratory conditions. Wildfire smoke during hot, dry periods is also becoming more common in Vermont, resulting in similar respiratory impacts.

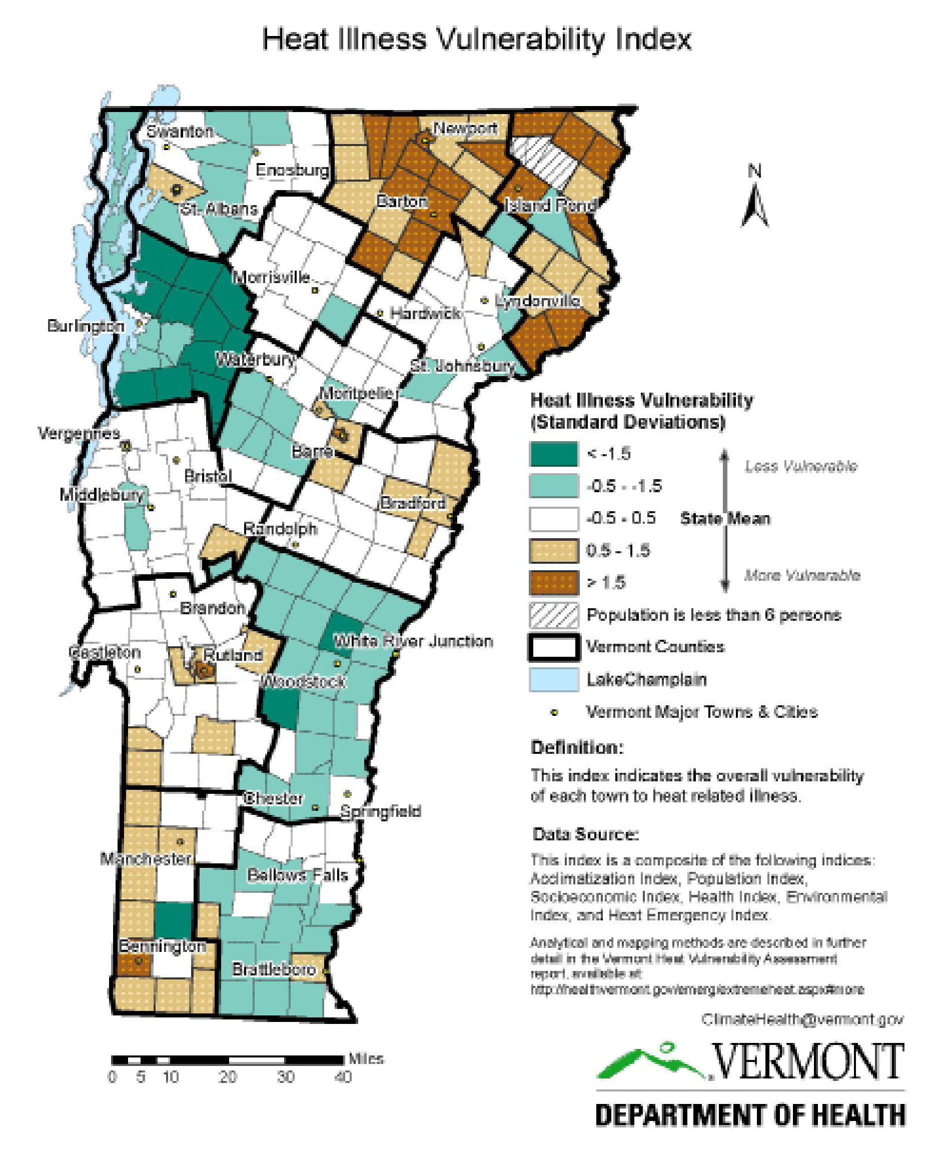

Figure 40: Vermont Heat Illness Vulnerability
Source: Vermont Department of Health

15 http://www.healthvermont.gov/sites/default/files/documents/2016/12/ENV_EPHT_heat_vulnerability_in_VT_0.pdf

Further, increases in the incidence of vector-borne diseases (e.g., Lyme, West Nile and Eastern equine encephalitis) in Vermont and New England at-large have been observed and are partially attributed to warming conditions. The increase in average annual temperatures and shortened winters have allowed mosquitos and ticks to become more active earlier in the spring and remain active later in the fall. Because the incidence of Lyme disease in Vermont is higher than the national average at present, lengthening vector seasons is of great concern to community health in Vermont. Unhoused people or people working outdoors – loggers and farmers, for example – are most vulnerable to vector-borne illness (see: Infectious Disease).

Finally, hot weather can increase thermal stratification in water bodies, where shallow water layers are much warmer and do not readily mix with cooler, deeper water layers. Stratified water layers are most common in late summer and early fall, providing more favorable conditions for development of cyanobacteria blooms in Vermont's lakes and ponds. Some types of cyanobacteria can release natural toxins or poisons (called cyanotoxins) into the water, especially when they die and break down. Swimming or wading in water with cyanobacteria may cause minor skin rashes, sore throats, diarrhea, stomach problems, or occasionally more serious health problems. Children and pets are at higher risk of exposure because they are more likely to play near the shoreline and drink water while swimming.[16]

The rise in average annual temperature and increased occurrence of prolonged hot weather events will also have impacts on infrastructure, the environment and the economy in Vermont. These impacts are also not exclusive to the extreme heat hazard, but rather will affect many other hazards addressed within this Plan.

Those who live in urbanized parts of Vermont will experience higher temperatures on hot sunny days than those who live more rurally. The Urban Heat Island Effect describes the higher temperatures due to the large concentrations of impervious surfaces, whose properties allow higher rates of heat retention than natural surfaces.[17] Thus, during an extreme heat event, urban areas may record higher temperatures, and may require more water and cooling resources than rural areas of Vermont. When considering heat events that have caused fatalities in Vermont history, they are occurring more frequently within residences in urban areas such as Chittenden County and even Waterbury. These incidents illustrate the dangers of the Urban Heat Island Effect, and the dangers behind residences ill-equipped for extreme heat.

Built Environment:

Buildings are much more likely to use cooling systems in homes and buildings during a heat event. Most cooling systems rely on electricity. In the event of power loss resulting from a concurrent storm or from electrical grids overloading, health and safety for a large population could be severely compromised. This is a particular concern for congregate care facilities, shelters, or private residences that house people at especially high risk for experiencing a heat illness. Traditionally Vermont buildings were constructed primarily with winter heating in mind. There is little data on air conditioning in Vermont, but data from similar climate zones in the US suggest that at least half of Vermont homes do not have any form of air conditioning, and most that do have air conditioning only have window units in certain rooms. Improving building weatherization, installing cooling systems, and installing backup power systems are important adaptations to consider in our warming climate, which may be a lengthy, expensive, and cost prohibitive process for many.

Extreme heat can also result in damage to built infrastructure. Materials used in transportation infrastructure have a limited range of tolerance to heat, and the stress is exacerbated by the length of time temperatures are elevated and by stress factors, such as vehicle loadings on roadways and bridges during periods of congestion.

16 http://www.healthvermont.gov/tracking/cyanobacteria-tracker
17 https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect

Extreme heat causes thermal expansion of the concrete and steel and swelling of connections of bridges which can result in collapse. Many places combat this by spraying water on the bridges to cool them down; a potential problem in drought conditions. Paved surfaces, such as roads and runways, are typically made of asphalt or concrete, materials that can be affected, in some cases dramatically and quickly, by heat. Asphalt is a temperature-sensitive material, so when it gets hot, it gets soft, and when it cools it cracks; both factors that can reduce its life span. Concrete pavement can experience buckling if there isn't room for the slabs to expand. It is also common for high temperatures to cause multiple problems for railway infrastructure. These problems include track buckling, sagging of overhead lines, bending of the rails, and expansion and then extreme compression as the rails cool, etc. When the lines become impassable, repairs must wait until the temperature drops and the rails are cool enough.[18] During the Pacific Heat Dome of 2021, damage was reported to roadways, rail and streetcar lines, and power cables. Repairs were delayed because it was too hot to work safely outdoors.

Higher temperatures cause increased rates of evapotranspiration, which can have significant impacts on water resources, especially shallow private wells (see: Drought).

Natural Environment:

Native forests and ecosystems are projected to experience negative impacts of warming trends as well.[19] Higher temperatures will lead to increased evapotranspiration, soil drying rate and the frequency of short-term droughts, limiting water availability for tree growth (see: Drought). With 76% of the Vermont landscape covered by forest, and more than 50 tree species, increases in average annual temperatures will force these species to adapt or face local extinction. Northern hardwood species like maple, yellow birch and American beech are anticipated to be nearly eliminated in the State, replaced by those tree species that thrive in warmer, drier conditions, like oak and pine.

Related to extreme heat, a gradually warming climate interferes with ecosystem balance, leading to cascading effects in the natural environment. Changes are beginning to occur in species and populations as well as timing of reproductive cycles and food availability.[20,21] For some species their ranges will expand further north, other species will adapt to conditions of where they are, while others will go extinct. Some insect species will benefit from greater winter survival and additional reproductive cycles in the longer growing season allowing them to adapt more quickly. Already stressed trees experiencing lower water availability and weakened defense mechanisms will be more vulnerable to pest invasion and disease (see: Invasive Species). Other insect species will face challenges finding food as they emerge to spring vegetation that arrived early and is too mature to consume. This in turn will impact the species higher on the food chain.

With a changing forest composition and greater levels of evapotranspiration, extreme heat and prolonged hot weather could also lead to an increase in the occurrence of wildfires in Vermont (see: Wildfire).

According to a recently published article,[22] the New England has been experiencing a faster warming rate than the rest of the United States. Burlington specifically has had warmer winters in the last 50 years than any other city in the country. Warming winters become concerning for the state's vegetation, as the freeze-thaw

18 https://www.transportation.gov/sites/dot.gov/files/docs/zimmermanrch_Global_CC_Transportation_Infrastructure_NEW_YORK.pdf
19 http://climatechange.vermont.gov/sites/climate/files/documents/Data/VTCCAdaptForestry.pdf
20 https://www.epa.gov/climateimpacts/climate-change-impacts-ecosystems
21 https://toolkit.climate.gov/topics/ecosystems
22 https://www.bostonglobe.com/2022/12/07/science/new-england-winters-are-getting-much-warmer-data-shows/

cycles are threatened. Vegetation with shallow root systems, such as the sugar maple, rely on heavy snowpack to survive through the winter. These trees rely on the snow to protect the soil from freezing, as freezing soil can destroy root systems.[23] Damaged root systems can severely impact tree health and the surrounding environment. If the amount of snow keeps declining, it is predicted that sugar maples would grow 40% slower due to freezing roots, which could kill or severely impact the trees. Diminishing tree health would in turn lead to a decline in the amount of carbon sequestered from the atmosphere. If more carbon remains in the atmosphere, the greenhouse gas effect and thus impacts from climate change are intensified.[24]

Economy:

In addition to the negative impacts towards tree health and the surrounding environment, the economy could suffer from declining maple syrup production. Vermont produces more maple syrup than any other state, generating almost half of the entire country's supply.[25] If there continues to be a decline in snowpack in Vermont, the supply of maple syrup across the state and country could diminish, and many people could be out of jobs.

In Vermont, impacts to agriculture in general due to extreme heat and trends towards warming temperatures is a major economic concern. Crops could drop by nearly 40% in some areas, causing great disruptions on the agricultural sector in Vermont. The Vermont Agency of Natural Resource's Climate Change Adaptation White Paper Series' Agricultural White Paper[26] identifies cold-weather crops, such as field corn, wheat and oats to be the most vulnerable to rising temperatures. The paper continues to note that many fruits grown in Vermont (e.g., blueberries and apples) require approximately 1,000 hours below 45°F to produce profitable yields, and with current climate projections, southern Vermont may not be able to meet these requirements. Maple sugaring, a $200 million industry in Vermont, will need to adapt to changing temperature patterns and adjust tapping schedules, as new estimates suggest that spring is arriving two weeks ahead of the average winter-spring transition.

Vermont's dairy industry is responsible for 70-80% of the State's annual agricultural sales. Dairy farmers across the State will need to pay attention to increasing temperatures, as cows can experience heat stress at as low as 75°F, especially on humid days, which can reduce milk production by up to 20%.

Issues with insect population changes discussed above will also affect crop yields and farm businesses.[27]

23 https://www.npr.org/sections/thesalt/2018/12/07/673713824/not-so-sweet-climate-change-means-slow-growing-sugar-maples-study-finds.
24 https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd545181.pdf
25 https://agriculture.vermont.gov/sites/agriculture/files/documents/AgDevReports/Maple%20Syrup%20Market%20Research%20Report.pdf
26 http://anr.vermont.gov/sites/anr/files/specialtopics/climate/documents/VTCCwhitepapers/VTCCAdaptAgriculture.pdf
27 https://esajournals.onlinelibrary.wiley.com/doi/10.1002/ecm.1553 and https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8150874/

Extreme Heat Current Capabilities & Mitigation

As mentioned throughout the Extreme Heat hazard profile above, increases in annual average temperatures will have wide-reaching impacts to other hazards addressed in this Plan. Accordingly, many of the mitigation strategies and actions addressing the hazard impacts of Drought, Invasive Species, Wildfire and Infectious Disease can be both directly and indirectly tied to Extreme Heat (see: Mitigation Strategy).

The Vermont Urban & Community Forestry Program has partnered with the Arbor Day Foundation since 2017 to offer the Community Canopy (formerly Energy-Saving Trees) Program to residents of urban communities in Vermont.[28] Communities are selected in-part based on their relatively high risk for heat illnesses, according to the Vermont Heat Vulnerability Index, where one of their key risk factors was a lack of tree cover. Guidance is provided to participants to plant trees in locations to maximize summer shade or winter windbreak. Nearly 3,000 trees have been provided to Vermont residents through this program as of 2022. The development of Best Management Practices (BMPs) for tree planting in urban areas and naturalizing vegetation considering heat impacts and invasive species.

The risks posed to Vermont's urban centers is exacerbated by the effects of Urban Heat Island effect. Therefore, this plan proposes actions outlining an assessment of heat risks in urban areas and its impacts on historically disadvantaged populations where, using that assessment to identify proper strategies for mitigating impacts. This plan supports the implementation of UHI mitigation strategies including the active use of urban forestry, green roofs, green infrastructure, and other vegetative strategies. Increasing the usage of highly reflective or high emittance materials for pavement, roofing, and construction can work to increase the albedo of urban spaces.

Other strategies that are being implemented or have been identified to address health risks of hot weather include:

- Updating the Vermont Heat Vulnerability Index to enhance risk factor data and better integrate adaptive capacity;
- Outreach, awareness raising, and capacity building among the public, health and emergency service professionals, and home visiting staff and volunteers;
- Improved systems for providing wellness checks for high-risk individuals at home and providing cooling, hydration, transportation, and medical assistance as needed;
- Assessing cooling capabilities at critical residential care facilities (e.g., long-term care, mental/behavioral health, homeless shelters), municipal and state government buildings, and competing a survey to assess home cooling capabilities;
- Building assessments and retrofits to help weatherize homes and congregate residential facilities housing high-risk individuals, install cooling equipment, improve ventilation, and install backup power;
- Designation of community daytime cooling centers and overnight cooling shelters, which may require building improvements in many communities;
- Enhanced support for unhoused Vermonters, including improved access to indoor cooling, storage, and hygiene facilities, secure outdoor shaded shelter, and material resource support for sun protection, hydration, and personal cooling;
- Adoption of workplace, school, and community policies to cancel or modify activities on hot days; and
- Development of State and local hot weather emergency communications and response plans. The Vermont Department of Health provides extreme heat planning guidance and a planning template for local communities on their website;

28 https://vtcommunityforestry.org/est

- Support expansion of Citizens Assistance Registry for Emergencies (CARE) to better identify households needing extra assistance during hazardous events (including extreme heat) and ensure mechanisms are in place to provide assistance as needed;
- Development of a State Heat Preparedness Plan and supporting the local adoption of heat plans into Local Emergency Management Plans (LEMPs) and mitigation strategies into Local Emergency Management Hazard Mitigation Plans (LHMPs).

The primary entity in Vermont devoted to extreme heat and prolonged hot weather mitigation and preparedness is the Vermont Department of Health Climate & Health Program.[29] The Climate & Health Program maintains a Heat Safety webpage containing heat safety tips in 12 languages, a statewide cooling sites map, outreach support resources, and reports and resources that can be used for understanding heat risks and developing hot weather emergency response and long-term adaptation plans.

29 http://www.healthvermont.gov/environment/climate

4-3: Wind

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Wind	4	3	2	2	2	2.25	9

*Score = Probability x Average Potential Impact

High wind can be the result of any of the following:

- **Wind Storm:** high wind event without precipitation.
- **Hurricanes/Tropical Storms:** the most significant impacts from hurricanes/tropical storms in Vermont are inundation flooding and fluvial erosion (see: Inundation Flooding & Fluvial Erosion). Wind implications of hurricanes/tropical storms are addressed below.
- **Thunderstorm:** high wind event with the potential for compounding impacts due to precipitation (see: Inundation Flooding & Fluvial Erosion), lightning (see: Wildfire), and/or hail (see: Hail).
- **Tornado:** a violently rotating column of air extending from a thunderstorm; not common in Vermont.

Table 20: Beaufort Wind Scale

Force	Wind (mph)	WMO Classification	Appearance of Wind Effects	
			On the Water	On Land
0	< 1	Calm	Sea surface smooth and mirror-like	Calm, smoke rises vertically
1	1-3	Light Air	Scaly ripples, no foam crests	Smoke drift indicates wind direction, still wind vanes
2	4-7	Light Breeze	Small wavelets, crests glassy, no breaking	Wind felt on face, leaves rustle, vanes begin to move
3	8-12	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Leaves and small twigs constantly moving, light flags extended
4	13-18	Moderate Breeze	Small waves 1-4ft becoming longer, numerous whitecaps	Dust, leaves, and loose paper lifted, small tree branches move
5	19-24	Fresh Breeze	Moderate waves 4-8ft taking longer form, many whitecaps, some spray	Small trees in leaf begin to sway
6	25-31	Strong Breeze	Larger waves 8-13ft, whitecaps common, more spray	Larger tree branches moving, whistling in wires
7	32-38	Neal Gale	Sea heaps up, waves 13-19ft, white foam streaks off breakers	Whole trees moving, resistance felt walking against wind
8	39-46	Gale	Moderately high (18-25ft) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	Twigs breaking off trees, generally impedes progress
9	47-54	Strong Gale	High waves (23-32ft), sea begins to roll, dense streaks of foam, spray may reduce visibility	Slight structural damage occurs, slate blows off roofs
10	55-63	Storm	Very high waves (29-41ft) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	Seldom experienced on land, trees broken or uprooted, considerable structural damage
11	64-72	Violent Storm	Exceptionally high (37-52ft) waves, foam patches cover sea, visibility more reduced	Very rarely experienced on land, accompanied by widespread damage
12	73+	Hurricane	Air filled with foam, waves over 45ft, sea completely white with driving spray, visibility greatly reduced	Devastation

Source: http://www.spc.noaa.gov/faq/tornado/beaufort.html

Damages following a significant wind storm that hit western Vermont in 2017. *Photo Credit: Burlington Free Press*

The Beaufort Wind Scale (Table 20) is a tool to measure wind speeds and anticipated effects. Hurricane and tornado strength are categorized with the Saffir-Simpson Hurricane Wind Scale and Fujita Scale respectively.

Wind Storm:

High winds pose a threat to the safety of Vermont's citizens and property. The National Weather Service (NWS) issues a wind advisory when winds are sustained at 31 to 39 mph for at least one hour or any gusts 46 to 57 mph. Sustained winds of 40 to 73 mph or gusts of 58 mph or higher cause the NWS to issue a High Wind Warning.[1]

Hurricane/Tropical Storm:

A hurricane is a tropical cyclone with sustained winds that have reached speeds of 74 mph or higher. A storm reaches hurricane status only after strengthening over a period of days or even weeks. A tropical storm has a maximum sustained one-minute wind speed of 39 to 73 mph. As a hurricane moves toward the coast, it loses wind speed and may be downgraded to a tropical storm. This is the case in many of the tropical storms that have reached Vermont. In general, severe hurricanes are not considered likely, nor do they pose a recurring threat for Vermont.

Hurricanes and tropical storms are hazard events that often result in high winds, inundation flooding, and fluvial erosion impacts. The topography and landscape in Vermont contribute to the risk associated with these three hazard impacts. Many of Vermont's villages, towns and cities are located in or proximate to the floodplain and many roads in Vermont run parallel to rivers (see: Inundation Flooding & Fluvial Erosion).

The Saffir-Simpson Hurricane Wind Scale is a categorical rating system between 1 and 5, which corresponds to the sustained

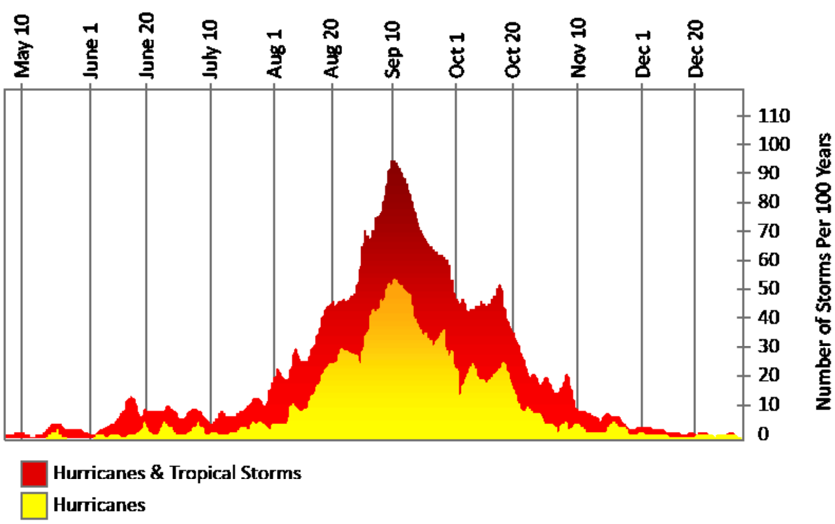

Figure 41: Peak Hurricane Season in the Atlantic Basin
Data Source: https://www.nhc.noaa.gov/climo/

1 https://www.weather.gov/btv/wwa_reference

wind speed of hurricanes (Table 21). This scale serves as an estimate of potential property damage during hurricanes. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and property damage. The Saffir-Simpson Hurricane Wind Scale serves as a good measure for sustained wind speed; however, this scale does not account for the compounding impacts (i.e., inundation and erosion).

Table 21: Saffir-Simpson Hurricane Wind Scale

Tropical Depression	≤38 mph, ≤33 knots, ≤62 km/h	**Tropical Storm**	39–73 mph, 34–63 knots, 63–118 km/h

Category	Wind Speed	Types of Damages Due to Hurricane Winds
1	74-95 mph 64-82 kt 119-153 km/h	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding, and gutters. Large branches of trees will snap, and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph 83-95 kt 154-177 km/h	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (Major)	111-129 mph 96-112 kt 178-208 km/h	Devastating damage will occur: Well-built frame homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (Major)	130-156 mph 113-136 kt 209-251 km/h	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (Major)	≥ 157 mph ≥ 137 kt ≥ 252 km/h	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Source: https://www.nhc.noaa.gov/aboutsshws.php

The Atlantic Ocean hurricane season runs from approximately June 1 through November 30, with the majority of hurricane activity occurring between mid-August through October (Figure 41).

Thunderstorm:

Thunderstorms can produce downburst winds that affect the land immediately beneath a storm. These downburst winds are called microbursts and macrobursts, which move outward from the base of a thunderstorm and can reach speeds in excess of 80 mph. Microbursts (the smaller of the two in terms of area affected) pose an extreme threat to aircraft.

Thunderstorms can range in size and type. An ordinary cell thunderstorm consists of one cell with an updraft and downdraft and produce strong winds, rain, lightning, and even hail. Multicell cluster thunderstorms consist of several ordinary cell thunderstorms in the vicinity of each other. Multicell cluster thunderstorms are extremely prone to causing flash flooding. Squall line thunderstorms move in a line or front that can exceed 100 miles in length, with the strongest rains and winds at the front of the storm. Supercell thunderstorms are the largest, longest lasting, and most devastating thunderstorms. Nearly all tornadoes are formed from supercell thunderstorms. Lightning, hail, flash flooding, and tornadoes are all associated with this type of thunderstorm (see: Hail and Inundation Flooding & Fluvial Erosion).

In Vermont, high winds are most often seen accompanying severe thunderstorms. In fact, straight-line winds are often responsible for most of the wind damage associated with a thunderstorm. These winds are frequently confused with tornadoes because of similar damage and wind speeds; however, they are not rotating like the winds of a tornado.

Thunderstorms and associated hazards can occur anywhere in Vermont at any time of the year; however, spring and summer are the most common times for severe thunderstorms.

Tornado:

A tornado is a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds capable of reaching in excess of 250 mph. Damage paths can be in excess of a mile wide and 50 miles long. The Enhanced Fujita Scale is a categorical rating system between EF0 and EF5 for wind speed during a tornado (Table 22).

Since 1950, Vermont has experienced 49 tornadoes, 14 of which were magnitude F2 (significant) and 19 magnitude F1 (moderate) on the Fujita Scale. F2 tornadoes have maximum wind speeds of 113 to 157 mph, while F1 tornadoes range from 73 to 112 mph. Damage from tornadoes has ranged from a few downed trees to seven injuries during a 1970 tornado in Franklin County. These injuries occurred when a waterspout – a tornado that originates over water instead of land – moved from Lake Champlain to the southern part of Swanton, where it struck a cabin. Property damage has totaled over $5.5 million overall in the State of Vermont due to tornado damage. There have been no deaths as a result of a tornado in Vermont since 1950.

Tornadoes typically occur in Vermont between March and August; however, tornadoes can strike at any time of the year if the essential conditions are present.[2]

Table 22: Enhanced Fujita Scale

Scale	Wind Speed		Types of Damages Due to Hurricane Winds
	mph	km/h	
EF0	65-85	105-137	*Minor or no damage.* Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over. Confirmed tornadoes with no reported damage (i.e., those that remain in open fields) are always rated EF0.
EF1	86-110	138-177	*Moderate damage.* Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	111-135	178-217	*Considerable damage.* Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
EF3	136-165	218-266	*Severe damage.* Entire stories of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations are badly damaged.
EF4	166-200	267-322	*Devastating damage.* Well-constructed and whole frame houses completely leveled; cars and other large objects thrown and small missiles generated.
EF5	>200	>322	*Extreme damage.* Strong-framed, well-built houses leveled off foundations are swept away; steel-reinforced concrete structures are critically damaged; tall buildings collapse or have severe structural deformations; some cars, trucks, and train cars can be thrown approximately 1 mile (1.6 km).

Source: http://www.spc.noaa.gov/efscale/ef-scale.html

2 National Weather Service, http:/www.nws.noaa.gov

Location

Wind, which typically flows from west to east across Vermont, is most significant on mountain peaks, where wind speeds are highest. Downslope windstorms can occur as a result of cold dense air traveling over a mountain peak and accelerating down the slope, reaching high wind speeds at the base of the mountain. Wind flow that is orthogonal to mountains will cause more damaging downslope windstorms than wind flow running parallel . Thus, areas of Vermont that are located at the base of the Green Mountains are especially vulnerable to wind-related hazards.

Wind History

- **Tornado, May 31, 1998:** Bennington County was hit with an EF2 tornado that damaged homes and property in North Bennington. The tornado originated near Round Lake, New York, and moved rapidly eastward into Vermont, producing damage in North Bennington before dissipating in Shaftsbury. Funnel clouds were also reported that day in the Brattleboro area, but no tornadoes were confirmed to have touched down. Strong straight-line winds also damaged areas of Bennington and Windham Counties. Estimated $630,000 in property damages from this event.
- **Tropical Storm Floyd, September 16, 1999 (DR-1307):** Strong winds reaching 51 mph combined with saturated soils from heavy rain resulted in trees and power lines being blown down, causing power outages. A death occurred when a tree fell on a mobile camper in Randolph. $675,000 in estimated damages from the wind.
- **Tornado, June 5, 2002 (DR-1428):** Thunderstorms spawned two tornadoes, one in Woodford Hollow in Bennington County (EF1) and the other one near Wilmington in Windham County (EF2). The first touchdown produced a swath 150 yards wide and a path length of one-half mile. Many trees as large as a foot in diameter were either knocked over or ripped apart. Trees also fell on three automobiles. The second tornado, four miles Northeast of Wilmington, was even stronger despite a narrower swath of 50 yards.
- **Wind Storm, April 15, 2007 (DR-1698):** High winds during this April storm resulted in many trees down and damage to some private homes and public infrastructure, primarily in southern Vermont. $4.8 million in estimated damages from the wind.
- **Tornado, July 18, 2008 (DR-1784):** A tornado was reported in Bakersfield (EF1), causing localized damages. A tornado with winds reaching 100 mph ripped an apartment’s roof off, snapped large trees, and destroyed a barn in the small town of Washington in May 2009. Estimated $150,000 in damages.
- **Wind Storm, December 1, 2010 (DR-1951):** Wind across the higher peaks of the Green Mountains caused strong to damaging down slope winds in excess of hurricane force to the western slope communities and wind gusts approaching 55 mph into the Champlain Valley. Much

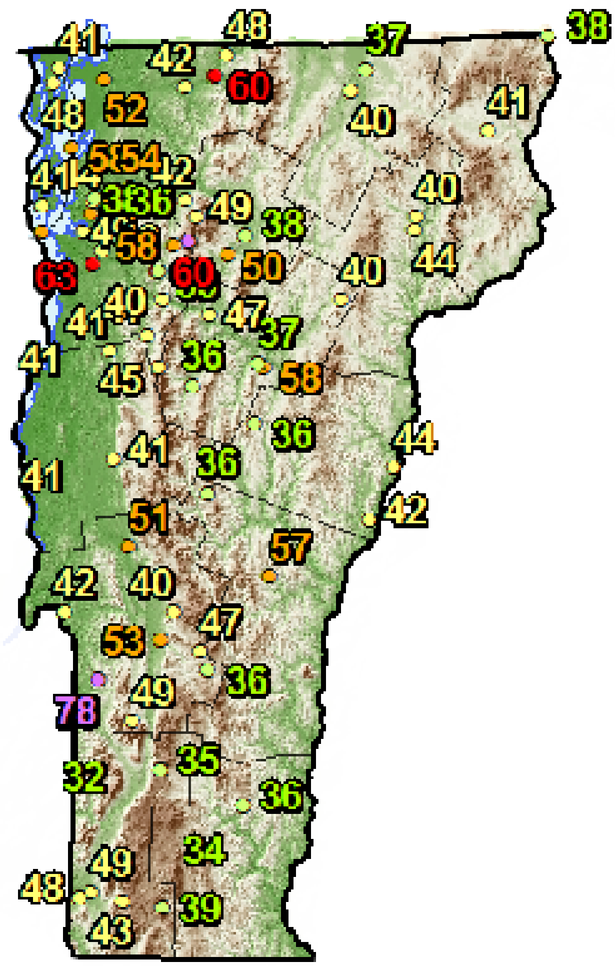

Figure 42: North Country Maximum Wind Gusts, Monday, October 30, 2017 (DR-4356)
Source: NOAA

of this damage was in the form of downed limbs, branches, trees, playground sets and some isolated structural damage in the form of blown off roof shingles. Over 35,000 utility customers lost power with an estimated $3.35 million damages.

- **Tropical Storm Irene, August 28, 2011 (DR-4022):** While the vast majority of the impact from Tropical Storm Irene was due to flooding, damaging north winds of 35 to 45 mph sustained with gusts in excess of 60 mph buffeted Grand Isle county and Lake Champlain. Estimated wave heights of 4-6' and possibly higher damaged boats, moorings and knocked down or uprooted numerous trees with thousands of customers without power. An estimated $1.25 million in property damages is attributed to wind.
- **Tornado, May 29, 2012 (DR-4066):** Severe storms rolled through the Northeast portion of the State. The tornado, rated as an EF0 by NOAA, had wind speeds that peaked at 70 mph, tearing 45 trees out of the ground and pelting area house with marble-sized hail. Estimated $10,000 in property damage.

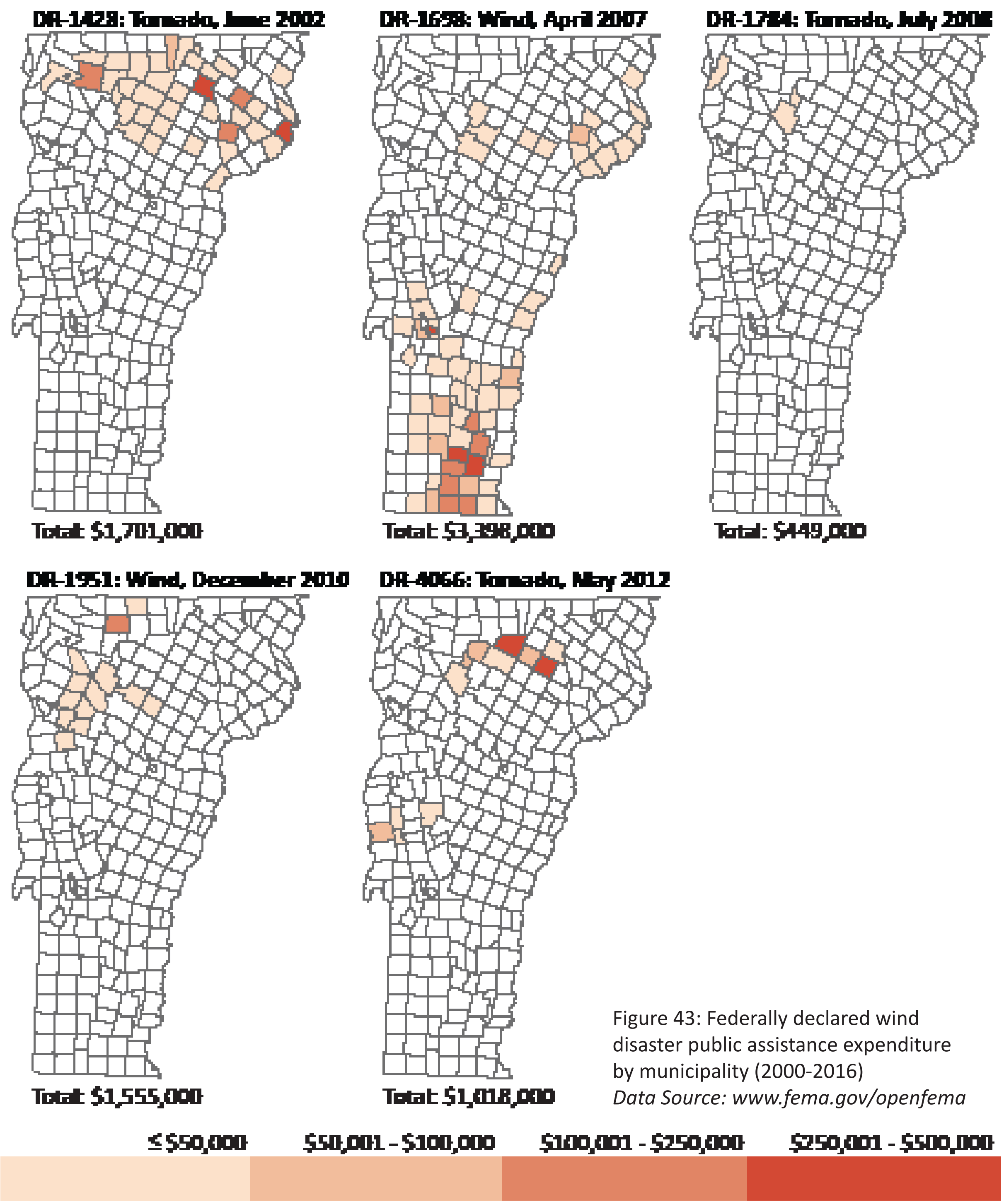

Figure 43: Federally declared wind disaster public assistance expenditure by municipality (2000-2016)
Data Source: www.fema.gov/openfema

- **Hurricane Sandy, October 29, 2012:** Hurricane Sandy came to the Northeast and did not significantly affect Vermont. Nevertheless, Vermont did experience high winds from the storm, especially in the southern part of the State. All of Vermont's 14 counties experienced electric utility impacts, and approximately 64,600 customers lost power. All customers had their power restored in approximately 56 hours. Estimated damages were under $1 million.
- **Wind Storm, October 30, 2017 (DR-4356):** Numerous tree damage and power outages with wind gusts of 40 to 50 mph, reaching 60 mph in some locations. $2.25 million in property damages is estimated from this event. Maximum wind gusts from this event are mapped in Figure 42.
- **Thunderstorm, July 30, 2019:** Severe storms impacted the Northwest portion of Vermont, with winds ranging 57 to 76 mph. Scattered thunderstorms resulted in downed tree limbs, trees, and utility lines. The storms caused an estimated total of $235,000 in property damage. The storms within Champlain Valley in Chittenden County unfortunately caused the loss of 2 lives whilst kayaking near Thayers Beach.
- **Wind Storm, November 1, 2019:** Strong winds affected zones in each of Vermont's 14 counties, resulting in downed tree limbs, power outages, and uprooted trees which affected transportation routes. Wind speeds ranged from 45 to 55 mph and resulted in $903,000 in total property damage. Within Chittenden County, estimated public infrastructure damage totaled close to $5 million, with 100,00 reported power outages.
- **Thunderstorm, August 26, 2022:** Scattered thunderstorms impacted western Vermont counties Chittenden and Rutland, with wind speeds reaching 75 mph. In Rutland County, the storm trapped 5 people and 75 cattle in a barn, resulting in 2 human injuries and the ultimate death of 50 cattle. As a result of the storm, property damage estimated at $506,000 and crop damage at $100,000, significantly affecting the economy of Rutland.
- **Wind Storm, December 23, 2022 (DR-4695):** Strong winds traveling southeast at speeds of 25-35 mph with gusts at 50-60 mph affected majority of the state, along with heavy rain and snow melt leading to flooding. 70,000 utility customers lost access to power at the peak of the storm, with almost 100,000 customers losing power in total as a result of the event. The wind storm resulted in $3.7 million in property damages and one fatality in Rutland County resulting from a falling tree.

Wind Trends

Overall, the occurrence of wind events are considered by the Steering Committee to be Highly Likely in Vermont. Compared to other hazard impacts, the risk due to wind events is moderate for the built environment and minor for natural environment, people, and economy. However, it is likely that as climate change accelerates, we will see exacerbation of wind events such as hurricanes, tropical storms, and thunderstorms.

The strength of hurricanes and tropical storms have a direct relationship with ocean temperatures. As ocean temperatures increase, the rates of evaporation and condensation increase. The water vapor molecules are at a higher temperature due to the warming of the ocean water, and thus as condensation occurs, the atmosphere will consist of a higher concentration of water vapor particles as the high temperatures will allow more water vapor particles to exist in the gas phase. When precipitation eventually occurs, there will be a higher volume of rain releasing heat and subsequently creating stronger winds.[3] As more greenhouse gases are emitted, heat is being trapped in the atmosphere and is more readily absorbed by oceans due to the high heat capacity of water. Thus, as climate change accelerates, we can expect warmer temperatures of the ocean which can in turn lead to stronger hurricanes and tropical storms. Although Vermont is landlocked within New England, hurricanes and tropical storms that travel up the east coast can lead to inundation flooding, fluvial erosion, and high winds. As the severity and frequency of these storms intensify, these impacts may become even more damaging to towns that lie within floodplains.

Similarly, as the temperature of the atmosphere increases, thunderstorms could become more frequent events in Vermont. Warm, moist air can contribute to more severe thunderstorms in a similar way to how it intensifies hurricanes. More water molecules will exist in the gaseous phase due to their temperature, so there will eventually be more precipitation and a greater release of heat. As heat releases to the land, cooler air will take its place due to its higher density, creating wind.[4] Thus, as temperatures continue to rise in Vermont, thunderstorms could become much more frequent which could cause inundation flooding, fluvial erosion, and wind damage to the towns affected. Tornadoes are only the product of 20% of supercell thunderstorms, so it is difficult to predict whether tornadoes will increase in frequency or severity[5], but it is crucial that Vermont is prepared in the case that such events do transpire.

Wind Vulnerability

People:

People who live in rural, isolated communities are particularly vulnerable to windstorms. High winds can take down trees and power lines, and thus block transportation routes, cut off electricity and telecommunication networks, and destroy property. The situation described can be life threatening when emergency and medical services are disrupted, due to either transportation or telecommunication errors. Thus, those who rely on electrical life support systems are particularly vulnerable in the case of a power outage, as well as those who rely on electrical heating and cooling systems. Poorly ventilated generators are also a risk in the case of a windstorm, as blockages caused by wind can potentially lead to carbon monoxide poisoning.[6]

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3 https://news.climate.columbia.edu/2022/10/03/heres-what-we-know-about-how-climate-change-fuels-hurricanes/
4 https://www.eia.gov/energyexplained/wind/#:~:text=Warm%20air%20above%20land%20expands,take%20its%20place%2C%20creating%20wind.
5 https://education.nationalgeographic.org/resource/tornadoes-and-climate-change/
6 https://www.healthvermont.gov/sites/default/files/documents/pdf/English_CO_Safety_Tips.pdf

In the case of telecommunication disruption during a windstorm, isolated populations may have limited access to information and resources that could prevent injury or death. People with limited range of motion might not be able to properly follow safety protocol.

In the event of a tornado, anyone in the direct pathway of the storm is vulnerable to injury or death. Debris could be picked up and cause injury or fatality if a storm shelter is unavailable. Direct deaths are possible from falling powerlines or trees, as well as object missiles that a high wind event might generate. It is important to note that those who reside in manufactured homes and mobile homes are 15 to 20 times more likely to be killed during a tornado, as homes may not be properly anchored to the ground.[7]

Built Environment:

Severe thunderstorms are capable of producing high winds (including downdrafts), large hail, lightning, flooding, rains, and tornadoes. Thunderstorm winds are generally short in duration, involving straight-line winds and/or gusts in excess of 50 mph and tend to affect areas of Vermont with significant tree stands as well as areas with exposed property and infrastructure and aboveground utilities. Winds can cause power outages, transportation and economic disruptions and significant property damage, and pose a high risk of injuries and loss of life.

The most significant concern from a wind event is the impact on infrastructure, predominately utilities. Figure 44 shows the electric utility service territory across the State. High winds pose a serious concern for all electric and telecommunication utilities in Vermont due to the customer outages and damage to infrastructure they may cause. Power outages can have a significant impact on Vermonters, especially if they occur in the winter and summer seasons, impacting access to electrically operated heating and cooling systems.

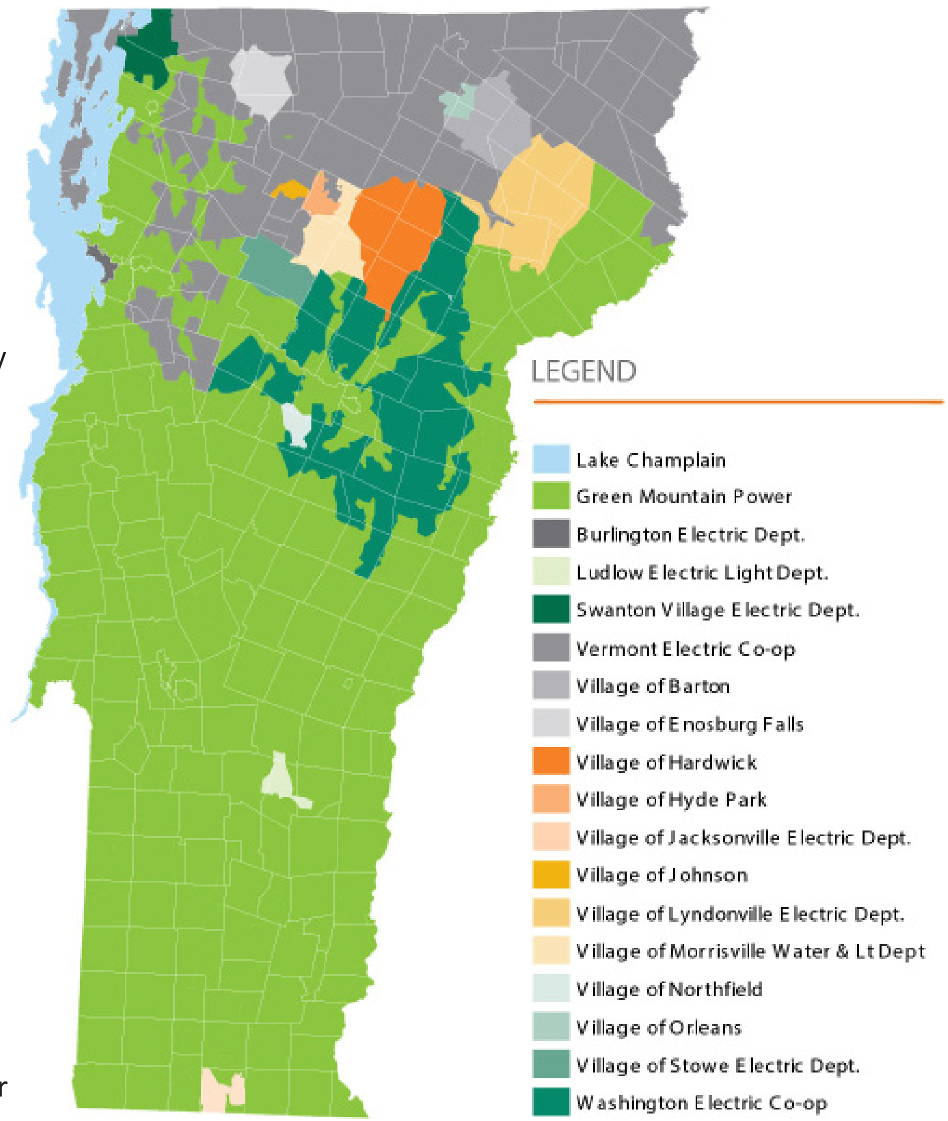


Figure 44: Electric Utility Service territory map from Vermont Public Utility Commission
Source: http://puc.vermont.gov/document/electric-service-territory-map

7 https://www.washingtonpost.com/climate-environment/2023/03/28/mississippi-mobile-home-tornado-damage/

As mentioned above, microbursts of wind can be especially dangerous for aircraft transportation. The downward wind can exceed the lift component of an aircraft, making it impossible to maintain altitude, which for low flying aircraft (especially during takeoff and landing) is extremely dangerous.

High wind events such as tornadoes have the potential to cause significant damage to buildings and building fixtures. Within documented history, Vermont has experienced tornadoes within the range of EF0-EF2. Tornadoes within this range can cause considerable damage to smaller homes and buildings, destroying roofs, foundations, and building fixtures such as solar panels. Mobile homes and manufactured homes are at a higher risk of property damage during a tornado, as both are nonpermanent and can be moved to an alternate location.[8] If manufactured homes are not properly anchored to the ground, they could be easily picked up or destroyed by EF1 and EF2 tornadoes, both of which have occurred within somewhat recent history. Small objects picked up by a tornado can become missiles as they generate speed from the wind, and have potential to cause injury, destruction of property, or death upon being thrown. Although Vermont has only experienced EF0-EF2 tornadoes within documented history, it is not impossible for a stronger storm system to affect the state. In this case, a tornado could destroy everything in its path, and create large-object missiles, intensifying the risk of injury, death, or property damage.

Natural Environment:

High winds pose a danger to the natural environment, as downed trees and uprooted plants can threaten the integrity of the ecosystem. Trees provide habitat and other resources to local organisms. With the destruction of flora comes increased competition among fauna for resources, leading to a higher mortality rate. Along with diminished resources, the destruction of flora will lead to a decrease in carbon sequestration, which negatively affects Earth's atmosphere.

Economy:

Windstorms can also cause major economic loss in terms of forestry and agriculture. Sugar maples are essential to the State's economy, and a severe windstorm could damage or uproot these trees, leading to a decline in the sugaring operation. Similarly, other crops with relatively shallow root systems could be uprooted by high winds, minimizing the economic gain associated with agriculture. Livestock also greatly contributes to Vermont's economy through dairy and meat products. Windstorms can threaten livestock, as seen by the thunderstorm in Rutland County on August 26th, 2022, when the destruction of a barn killed 50 cattle, and caused $100,000 in crop damages alone.[9]

Additionally, wind has the capability to disrupt normal business travel, truck movement, and construction. Downed powerlines, tree limbs, and scattered debris can fall within transportation routes, which can affect commuters and product movement. Businesses may not be able to operate as planned, which can lead to economic decline. Similarly, strong winds can disrupt construction projects as small objects may be removed with wind gusts. A higher demand for reconstruction of buildings and homes may follow a windstorm, which would stimulate revenue for construction workers, but overall increase economic cost associated with the event.

8 https://www.washingtonpost.com/climate-environment/2023/03/28/mississippi-mobile-home-tornado-damage/
9 https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=ALL&beginDate_mm=08&beginDate_dd=26&beginDate_yyyy=2021&endDate_mm=11&endDate_dd=30&endDate_yyyy=2022&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=50%2CVERMONT

Wind Current Capabilities & Mitigation

Several actions within this Plan address wind events (see: Mitigation Strategy), such as the strategy on resilient design and construction standards, including actions around developing sample building standards and educational resources for resilient design and construction. Maximization of Public Assistance (PA) hazard mitigation opportunities and BRIC project scoping funding when available can help put funds towards infrastructure planning and design for increased resilience. Other mitigation actions include increasing the capacity of the Public Service Department to utilize federal funds towards utility resilience implementation work and coordinating a State Energy Security Plan with the SHMP to identify interdependency of other systems on the grid and additional risk analysis requirements. Working to identify and evaluate the feasibility of microgrids for rural energy systems can allow them greater resiliency and independence should other systems fail. These infrastructure improvements, in coordination with utilities and RCP work under Act 174, work to ensure resiliency to a host of hazards beyond wind damage.

This Plan also includes a strategy to identify and protect vulnerable structures and critical infrastructure, with an action to provide technical assistance to utilities in long-range planning for transmission and distribution line upgrades and relocation to improve resilience. Additionally, this strategy includes an action to adapt the VTrans Methods and Tools for Resilience project (2018 SHMP subgrant) for use in mapping utilities and identifying vulnerabilities, which should not be a significant lift, given that the majority of utility lines in Vermont run along roadways.

Though several towns in the State are considering burying power lines for long-term mitigation against both wind and ice events, a statewide approach to power line burying is not being considered at this time due to being cost prohibitive.

4-4: Snow Storm

Strong winter weather can include any of the following, alone or in conjunction:

- **Snow Storms:** a heavy accumulation of snow, which can be accompanied by high wind causing drifting snow, low visibility and hazardous travel.
- **Blizzard:** a storm which contains large amounts of snow and/or blowing snow, with winds in excess of 35mph and visibilities of less than 1/4 mile for an extended period of time (for wind impacts, see: Wind).
- **Ice:** see: Ice Storm.
- **Extreme Cold:** see Extreme Cold.

Severe winter storms bring the threat of heavy accumulations of snow, cold/wind chills, strong winds, and power outages that result in high rates of damage and even higher rates of expenditures.

A heavy accumulation of snow, especially when accompanied by high winds, causes drifting snow and very low visibility. Sidewalks, streets, and highways can become extremely hazardous for pedestrians and motorists. Severe winter storms develop through the combination of multiple meteorological factors. In Vermont and the northeastern United States, these factors include the moisture content of the air, direction of airflow, collision of warm air masses coming up from the Gulf Coast, and cold air moving southward from the Arctic.

Heavy ice accumulation weighing down mature trees and weighing down power lines in northern, VT 2013.
Photo Credit: Vermont Public Radio

NOAA's Weather Predictions Center (WPC) recently unveiled a new prediction tool, the Winter Storm Severity Index (WSSI)[1], to provide an indication of the level of winter event severity and impacts (Table 23). The WSSI does not depict official warnings or exact event timing but provides severity level over a given period. The WSSI currently maintains a 3-day prediction of impacts for the nation, with prototype and experimental systems to display a rolling 24 hr WSSI and a probabilistic WSSI to determine the likelihood of impact, both of which are located on the WPC website.

1 http://www.wpc.ncep.noaa.gov/wwd/wssi/wssi.php

The WSSI is broken down into six components that are individually weighted based on the WSSI categories and then summarized into overall severity:

- **Snow Amount:** to depict severity due to total amount of snow or rate of snowfall accumulation. (Adjustments are made based on climatology and urban areas, e.g. 4" of snow in Atlanta is more severe than 4" in Minneapolis.)
- **Snow Load:** to depict severity due to total weight of snow on structures (ie. Powerlines and roofs) and natural vegetation (i.e., Trees).
- **Blowing Snow:** to depict severity mainly to transportation due to blowing and drifting snow.
- **Ice Accumulation:** to depict severity of transportation and downed trees/powerlines due to the accumulated ice in combination with wind (see: Ice Storm).
- **Ground Blizzard:** to depict severity to mainly transportation of ground blizzards that develop due to a pre-existing snowpack and strong winds.
- **Flash Freeze:** to depict severity primarily to transportation of situations where temperatures rapidly fall below freezing during precipitation, with the presence of liquid water (see: Ice Storm).

Table 23: Winter Storm Severity Index (still under development in 2018)

WSSI Descriptor	General Description of Expected Storm Severity Impacts
None	No snow or ice forecast. No potential for ground blizzard conditions.
Limited	Small accumulations of snow or ice forecast. Minimal impacts, if any, expected. In general, society goes about their normal routine.
Minor	Roughly equates to NWS Advisory Level criteria. Minor disruptions, primarily to those who were not prepared. None to minimal recovery time needed.
Moderate	Roughly equates to NWS Warning Level criteria. Definite impacts to those with little preparation. Perhaps a day or two of recovery time for snow and/or ice accumulation events.
Major	Significant impacts, even with preparation. Typically several days recovery time for snow and/or ice accumulation events.
Extreme	Historic. Widespread severe impacts. Many days to at least a week of recovery needed for snow and/or ice accumulation events.

Location

There is no specific region of Vermont that is more vulnerable to snow storms. Snow accumulation is highest at upper elevations of the Green Mountains, including Mt Mansfield, Killington, Mt Ellen, Camel's Hump, Mt Abraham, Lincoln Peak, Pico Peak, Jay Peak, Bromley, and Stratton Mountain. Orographic lifting caused by the Green Mountains may result in increased snow deposits on the western faces of the Greens. Occasionally the Champlain Valley experiences lake-effect snow as a result of Lake Champlain remaining unfrozen. Only northerly winds are in contact with the North-South oriented lake long enough to generate lake-effect snow, making Addison County most likely to experience lake-effect snow.[2]

2 https://www.lakechamplaincommittee.org/learn/news/item/nature-note-lake-champlains-snow-globe

Snow Storm History

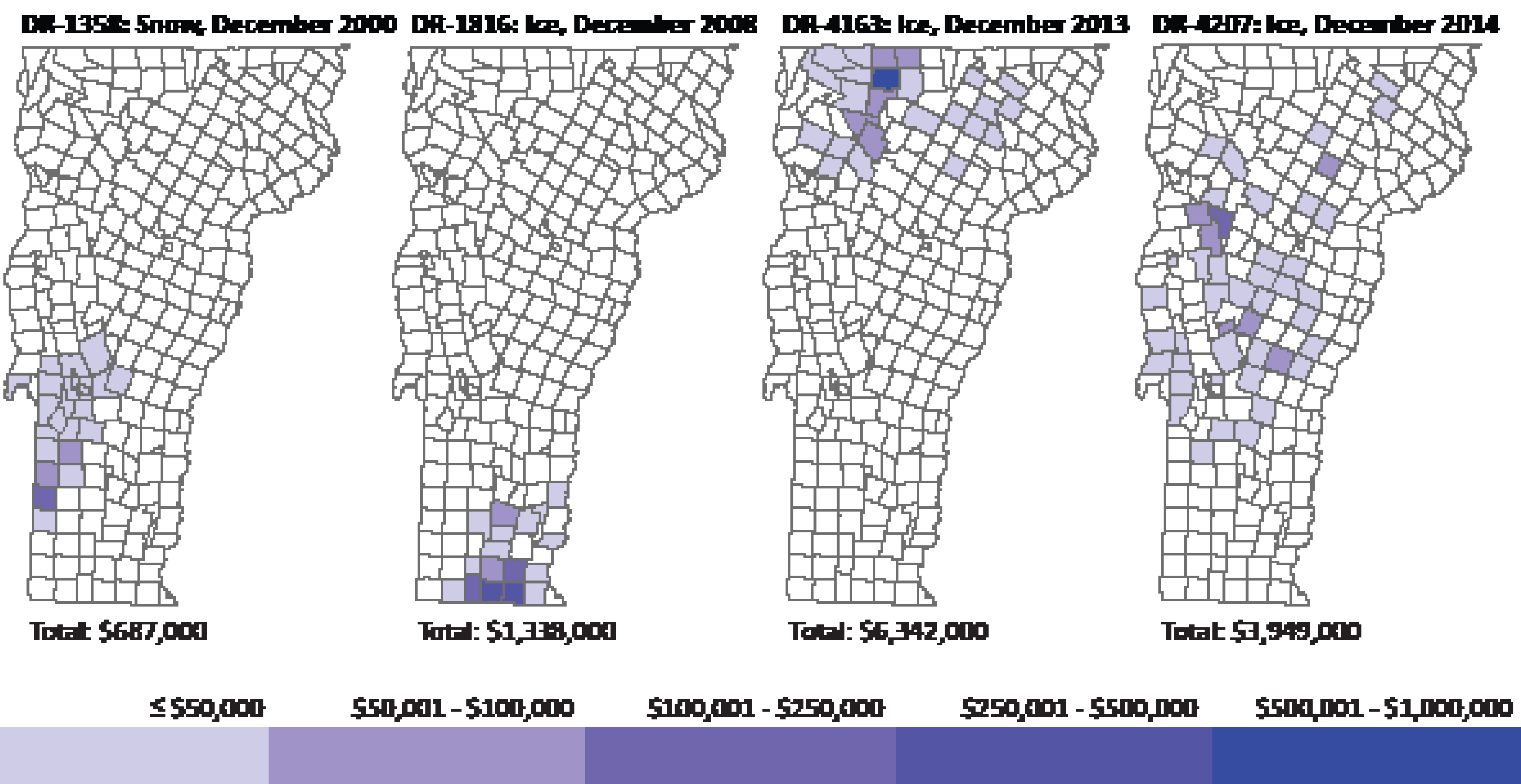
- **Blizzard, February 15-17, 1958:** More than 30” of snow and 26 deaths in New England.
- **Blizzard, December 26-27, 1969:** Snow amounts between 18–36” in northwestern Vermont and 45” in Waitsfield. Governor Dean Davis declared a State disaster. Drifts of snow from the storm piled up to 30’ in places.
- **Snow Storm, December 19, 2000 (DR-1358):** Snow amounts between 7-10”. A few reports included: Berkshire: 9.7”, Eden: 8.2”, Jay Peak 8”, St. Johnsbury: 7.1”, and Worcester: 7”.
- **Snow Storm, March, 2001:** A string of storms hit Vermont in March 2001, beginning with 15-30” of snow on March 5-6, 10-30” on March 22, and 10-20” on March 30.
- **Snow Storm, February 14, 2007:** The second heaviest snowfall ever recorded in the month of February. Some areas of Vermont received from 28-36” of snow in a 24 to 48-hour period. Heavy snow loads on roofs led to the collapse of at least 10 barns, causing the death of some cows and other livestock. Estimated nearly $3 million in property damage.
- **Snow Storm, January 2-3, 2010:** Burlington experienced the most significant snowfall on record from one event with 33.1” of snow.
- **Winter Snow Totals, 2010-2011:** The winter of 2011 was the second snowiest on record for Vermont, with a total of 128.4” of snow. A March blizzard in Burlington brought 25.8” of snow in two days. The storm closed schools for days, and many people were without power. Driving was hazardous due to a 1” layer of ice beneath several inches of snow.
- **Snow Storm, December 28, 2011:** A strong cold front moved across Vermont during the late morning and afternoon hours accounting for a rapid cool down and localized snow squalls with heavy snow. The western slopes of the Green Mountains saw 5-12” of snow along foothill communities. Near white-out conditions in snow squalls and rapidly freezing road ways accounted for numerous vehicle accidents as well as a closure of I-89 between Richmond and Waterbury.
- **Snow Storm, November 26, 2014:** The storm began late morning November 26 and increased in intensity, falling at rates at or greater than 1“ per hour. Snowfall caused slow and difficult travel the day before Thanksgiving. Snow continued through the day and evening with heavy bands at times and tapered off overnight. By the early morning on Thanksgiving, most of southern Vermont saw snowfall of 8-15” with the heaviest amounts across the higher elevations of the southern Green Mountains.
- **Snow Storm, December 9-13, 2014 (DR-4207):** Rain and wet snow moved into Vermont midday December 9 and changed to a heavy, wet snow during the evening. A band of moderate snowfall impacted much of central and northern Vermont during the afternoon and evening hours of December 10, then scattered snow showers ending on December 11-12. Total snowfall totals across Vermont ranged from 3-6” in Essex County to 12-20” across the Green Mountains into the Champlain Valley. The heavy, wet nature of the snowfall with snow to water ratios of 8:1 or less accounted for snow-loaded trees that resulted in more than 175,000 power outages in the region. This was the 2nd most power outages due to weather in Vermont. Over $4 million in property damages estimated.
- **Winter Storm, January 18, 2015:** Initial precipitation across Vermont was in the form of rain with air temperatures in the 30s to around 40 degrees. After more than a week of temperatures frequently near zero, road sub-surface temperatures were in the teens and 20s. Therefore, as rain fell and dusk approached, wet roads quickly became icy roads and led to

Downed tree in Richmond, VT following heavy snowfall in 2014.
Photo Credit: Angela Evancie / Vermont Public Radio

numerous vehicle accidents and closures of state and interstate roads. Rain changed to heavy, wet snow across higher elevations. Snowfall totals were 2 to 6 inches across northern Vermont with some locally higher in higher elevations, which led to scattered power outages.

- **Winter Storm, February 2, 2015:** A storm system originating in the American southwest brought widespread snowfall across the state, ranging from 6-12 inches with temperatures hovering near zero degrees. Impacts were felt across the state, with winter road conditions providing hazards of mobility especially for rural regions.
- **Winter Storm, December 29, 2015:** Snow overspread Vermont around midnight on December 29th and ended by mid to late afternoon, changing to sleet and freezing rain before ending. Snowfall amounts across the area was 3 to 7 inches with limited icing. Motor accidents occurred across the region, including a Semi, SUV crash along Route 4 near Killington, VT during the afternoon that resulted in 3 indirect fatalities.
- **Winter Storm, February 12, 2017:** A northern system over the Great Lakes and a southern system over the Ohio River Valley moved eastward over NY and New England, rapidly intensifying. Depositing wet and dense snow at rates of 1-2 inches per hour that clung to trees, weighing them down. In total, 7 to 12 inches of snowfall occurred through most of the local area, with up to 20 over the higher terrain of the Green Mountains.
- **Blizzard, March 14, 2017:** A major Nor'easter developed off the coast of NC/VA during the morning of the 14th and intensified as it moved north-northeast across southern New England during the night into central Maine by the morning of March 15th. Snow developed across Vermont by mid-morning on the 14th and intensified to at least 1 to 3 inches per hour for several hours during the late afternoon, with some areas witnessing rates of 4 to 5 inches per hour for more than one hour, and overnight hours before gradually diminishing late on the 15th. In addition, blizzard to near blizzard conditions developed around the time of the heaviest snowfall and lasted for 3-4 hours within several miles of Lake Champlain and some higher exposed terrain as well. Total snowfall across Vermont was 12 to 36+

Figure 45: Federally-declared ice and snow disaster public assistance expenditure by municipality (2000-2016)
Data Source: www.fema.gov/openfema



inches with northwest Vermont experiencing the heaviest snowfall. Numerous schools, businesses and local government offices closed for March 14th and 15th with numerous vehicle accidents and stranded vehicles.

- **Snow Storm, December 22, 2017:** A quick moving storm system brought snow to Vermont during the morning commute on December 22nd and ending shortly after the evening commute. A widespread 5 to 10 inches of snow fell across central VT. The timing and intensity of the snowfall lead to hundreds of vehicle accidents and blocked highways for several hours.
- **Winter Storm, January 12, 2018:** A warm moist flow followed by an artic front caused an inch or more of precipitation across Vermont in the form of rain, freezing rain, sleet, and snow. Temperatures 25-20 degrees above normal caused significant snowmelt followed by an inch of rain which caused rivers to approach bankfull with several reports of rivers flooding due to ice jams. Some of these rivers included the Winooski near Montpelier Jct, Lamoille at Johnson, Passumpsic near Lyndonville, Missisquoi near Swanton and the Connecticut river near Windsor. Sharply falling temperatures overnight allowed for a flash freezing of roads making for extremely hazardous travel.
- **Winter Storm, January 19, 2019:** Snow began the afternoon of the 19th and ended by early afternoon on the 20th with accumulations of 8 to 16+ inches. Winds developed and increased to 10 to 20 mph with gusts in excess of 30 mph causing considerable blowing and drifting of the snow. Very cold temperatures were experienced as well, with highs of –5 to 15 degrees and lows of 10 to 20 below zero. Strong winds later in the system created wind chills of 20 to 40 below zero. The combination of all these factors created hazardous travel through the 21st as the very cold temperatures prohibited road chemicals from working effectively. This event occurred throughout the state, blanketing most of the state with snow depths of 10-20 inches varying by location. Greater snow depths occurred at high terrain of Bennington and western Windham counties.
- **Winter Storm, March 22, 2019:** Wet snow conditions and eventual brisk winds of 15 to 25 mph with higher gusts at night combined with the snow weighted trees and power lines to cause thousands of power outages to approximately 10,000-15,000 customers. This event was widespread throughout Vermont, with precipitation rates changing as elevation increased (rain early on in the valleys).
- **Snow Storm, February 7, 2020:** System began with light snowfall which later became steadier snowfall mixed with freezing rain and sleet. Later, snow became heavier with rates of 1-2+ inches per hour. This combination made for extremely hazardous travel and led to numerous schools closing, early closings of businesses and state government offices. Approximately 10-20,000 people lost power, especially in the central and eastern parts of the state. Two-day snowfall across the area was generally 10 to 20 inches with icing under 1/4 inch across the southern Champlain Valley.

Table 24: Top 20 Greatest Snowstorms in Burlington (NOAA)

Rank	Snowfall	Month/Year	Rank	Snowfall	Month/Year
1	33.1”	January 2-3, 2010	11	19.1”	March 16,-17, 1937
2	30.4”	March 14-15, 2017	12	18.8”	December 14-15, 2003
3	29.8”	December 25-26, 1969	13	18.7”	March 12-13, 2014
4	25.8”	March 6-7, 2011	14	18.3”	December 6-7, 2003
5	25.7”	February 14-15, 2007	15	17.8”	January 3-4, 2003
6	24.7”	January 13-14, 1934	16	17.8”	February 4-5, 1995
7	22.9”	March 5-6, 2001	17	17.7”	March 3-4, 1994
8	22.4”	March 13-14, 1993	18	17.2”	February 6-8, 2008
9	20.0”	November 25, 2000	19	17.1”	February 25-26, 1966
10	19.7”	January 25-28, 1986	20	16.9”	December 25, 1978

Data Source: www.weather.gov/media/btv/climo/extremes/top20snow.pdf

- **Snow Storm, November 26, 2021:** Rain transitioned into a wet snow beginning at higher elevations around noon and eventually into the Champlain Valley by early evening. Snowfall amounts ranged from a wet few inches in the Champlain Valley with 4 to 8 inches in the some of the higher elevations in the Green Mountains. The wet nature of the snow led to scattered power outages in the foothills.
- **Winter Storm, March 14, 2023:** A winter storm with snow accumulations of up to 11 inches and wind gusts up to 45 mph impacted the entire State of Vermont on the 14th to 15th of March. Temperatures hung around freezing throughout the event period. The heavy wet snow caused trees to fall and lose limbs, blocking multiple roadways and pulling down powerlines causing blackouts across the state. Roadway closures were primarily seen in Windham, Windsor, and Bennington counties. This event was reported to be the worst in five years and activated the State Emergency Operations Center.

Snow Storm Trends

The Steering Committee considered the probability of a plausibly significant snow event has a probability of Highly Likely, with minor impacts to the built environment and the economy, moderate impacts to people, and negligible impacts to the natural environment.

Table 25: Snowfall Extremes by Vermont County — 1-Day, 2-Day and 3-Day Storms

County	1-Day	Amount	2-Day	Amount	3-Day	Amount
Addison	3/14/1933	25.6”	2/25/2010	28.8”	3/14/1993	28.2”
Bennington	3/14/1984	37.0”	3/14/1984	38.0”	3/5/1947	42.0”
Caledonia	2/25/1969	33.0”	2/26/1969	34.5”	2/26/1969	35.5”
Chittenden	2/14/2007	25.3”	1/3/2010	35.3”	1/3/2010	37.6”
Essex	12/7/2003	24.0”	12/8/2003	43.0”	12/9/2003	43.0”
Franklin	3/14/1993	24.0”	12/27/1969	30.0”	3/18/1937	33.0”
Grand Isle	3/7/2011	19.0”	3/7/2011	23.3”	3/7/2011	23.3”
Lamoille	4/10/2000	25.0”	2/15/2007	36.0”	2/16/2007	36.0”
Orange	3/13/2014	24.5”	12/8/2003	26.0”	12/22/2008	29.2”
Orleans	2/5/1995	42.0”	2/6/1995	48.0”	2/6/1995	48.0”
Rutland	12/7/2003	25.0”	12/7/2003	27.0”	12/8/2003	28.5”
Washington	3/14/1993	31.0”	12/28/1969	36.0”	12/29/1969	44.0”
Windham	12/19/1986	34.0”	12/19/1986	34.5”	3/5/1947	41.0”
Windsor	2/14/2014	30.0”	11/23/1943	39.0”	12/4/1942	41.0”

Source: https://www.ncdc.noaa.gov/snow-and-ice/snowfall-extremes/VT

According to the 2018 National Climate Assessment, there is an observable increase in the frequency of the most severe winter storms in the Northeast since observations began in 1950.[3] While the frequency of heavy snowstorms has increased over the past century, there has been an observed decline since 2000 and an overall decline in total seasonal snowfall.

The National Centers for Environmental Information within NOAA manage data pertaining to snow coverage across the country.[4] Due to rising minimum temperatures and a shortening winter season, snow cover on the ground has also seen significant decreases. Seven weather stations, located in Bethel, Burlington International Airport, Cavendish, Newport, Rochester, Rutland and St. Johnsbury have consistently recorded the number of days with greater than 1” of snow cover since 1963. The results (Figure 46) indicate that this number is trending downward, with the most significant decreases occurring in the past decade.

3 https://nca2018.globalchange.gov/chapter/2#key-message-8
4 https://www.ncdc.noaa.gov/cdo-web/datatools

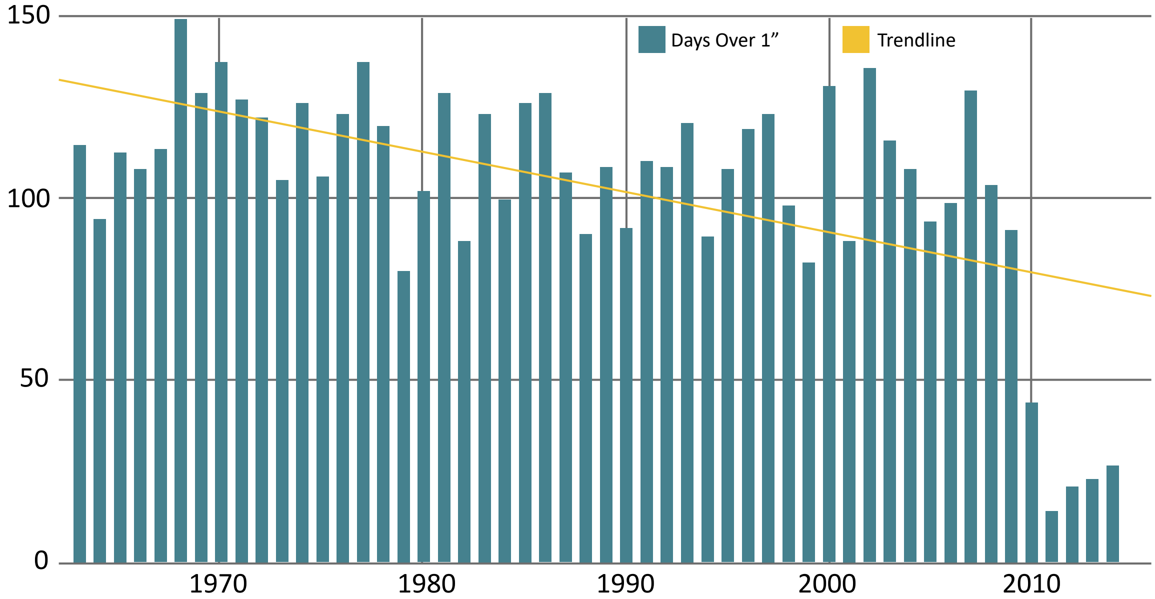


Figure 46: Number of days in Vermont with greater than 1-Inch snow cover (1960-2015)
Data Source: http://climatechange.vermont.gov

Snow Storm Vulnerability

People:

There are no standard loss estimation models or methodologies for the winter storm hazards. Potential losses from winter storms are, in most cases, indirect and therefore difficult to quantify. The impacts of snow and ice storms are typically felt by rural residents and those with low access or mobility first. Snow can cause extensive disruptions to transportation and connection between people and services, including a disruption in communication infrastructure. People in rural areas are particularly at risk of being cut off. Transportation becomes extremely difficult, with a decline in visibility combined with road surface conditions that can put motorists in danger. Heavy snow can immobilize a region and paralyze a city, stranding commuters, closing airports, halting the flow of critical supplies, and disrupting emergency and medical services. The weight of snow can bring down trees and power lines, cutting off power to homes and businesses needed for electric heating system, lights, and life support equipment. Homes with generators or propane-based heating systems can lead to carbon monoxide poisoning if not properly ventilated.[5] Snow accumulation can trap carbon monoxide in ventilation systems and redirect it into a home. Homes may be isolated for days, sometimes requiring emergency personnel to navigate hazardous conditions for wellness checks on vulnerable populations. In the mountains, heavy snow can lead to avalanches.[6]

Built Environment:

The structural impacts of snow can vary in severity, with even minimal snow accumulation causing disruption. One of the greatest impacts on infrastructure from snow is the downing of powerlines, causing widespread blackouts. Industries that rely on power to function can be severely impacted by loss of power, such as dairy farmers who need power in order to milk the cows. Under certain circumstances large quantities of snow on the roofs of buildings can cause them to cave in, potentially trapping people inside or damaging property. Homes with flat or low-pitched roofs, including many manufactured housing units, are at greatest risk of snow load caused collapses. Dangerous conditions due to snow on roadways and other transportation infrastructure can disrupt key supply lines throughout the State.

5 https://www.healthvermont.gov/sites/default/files/documents/pdf/English_CO_Safety_Tips.pdf
6 https://disasterphilanthropy.org/resources/extreme-cold/

Natural Environment:

The impacts of snow and ice storms to the natural environment can be extensive for both flora and fauna. Accumulated heavy snow can weigh down trees, causing limbs to break off and fall. Our natural environment is more adapted to these changes, whereas urban landscaping often faces unique challenges of soil compaction, shallow root systems, and impervious surfaces that interact with winter weather differently than less disturbed environments. Soil compaction and underlying infrastructure can prevent urban tree roots from moving lower towards sources of groundwater and places that don't freeze during the winter.

As a result, prolonged exposure to frost can impact the hydraulic conductivity for street trees by breaking these columns resulting in air filled conduits. Expanding air bubbles during temperature fluctuations can further impact tree health.[7] Species selected for planting along town and city streets are encouraged to be native species that are suited for the local climate as well as being adapted to conditions often found along roads.[8] In the Green Mountains, rapid accumulations of snow after a snowfall can cause avalanches to occur.[9] While uncommon in the Northeast, avalanches are not impossible with one occurring March 14th, 2018, at Smugglers Notch in Cambridge.[10] Avalanches can pose a risk to the natural environment by destroying vegetation within their paths.

Economy:

The cost of snow removal, repairing damages, and the loss of business can have severe economic impacts on cities and towns. For Class I highways in Vermont, winter maintenance (which includes salt application rates, cost per centerline mile of plowing, and hourly cost of plowing) was totaled to around $6,400 per mile.[11] This study accounted for only the Class I highways, leaving significant costs for local roadways for towns to pay for. In 2010, the town of Jericho spent $14,969 on winter maintenance and grading for 7/10ths of a mile for a gravel road.[12] With roughly 55% of Vermont roads being dirt or gravel, this can become a significant expenditure for the State and towns.[13] With automotive transit being a major aspect of society, snow accumulation blocking or hindering travel can increase commuting and travel times or preventing it entirely, impacting business success. Vermont has prominent agricultural and forestry industries that focus mainly on dairy products/other livestock products[14] and maple sugaring respectively.[15] Winter storms and cold snaps can increase stress on livestock, potentially leading to a loss of livestock if extreme. Heavy snow on the limbs of trees, both sugaring and orchard, can damage stock and hurt associated businesses.

7 https://www.frontiersin.org/articles/10.3389/fpls.2016.00867/full
8 https://vtrans.vermont.gov/sites/aot/files/highway/documents/environmental/VTrans%20Landscape%20Guide.pdf
9 https://www.weather.gov/safety/winter-snow
10 https://www.burlingtonfreepress.com/story/news/local/2018/03/15/according-alert-areas-where-avalanches-may-greater-risk-orleans-lamoille-washington-eastern-fran/427399002/
11 https://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/Class%20I%20Town%20Highways%20White%20Paper.pdf
12 https://www.ccrpcvt.org/wp-content/uploads/2016/02/SkunkHollowRoad_RevisedReport_20110602.pdf
13 https://www.burlingtonfreepress.com/story/news/local/2015/03/15/march-vermont-mud-eye/24783751/
14 https://ustr.gov/map/state-benefits/vt
15 https://extension.psu.edu/maple-syrup-production

Climate Change

Climate change continues to alter the natural processes of our environment, including the hazards we face. The frost-free season in Vermont is projected to decrease, with observed declines of three weeks since 1960.[16] Winter in Vermont has been reported to be warming 2.5 times faster than the global average annual temperatures since 1960.[17] Warming is having a direct impact on typical winter weather conditions including pond and lake ice reduction, freeze thaw cycle changes, ice dams, decreasing snowpacks impact on soil and roots, and shifting agricultural production times.

Changes in snow accumulation patterns due to climate change can also impact the soil profile. As snowpack thickness declines over the years, the insulating layer of heat that snow provides against winter air is removed, leaving the ground at a higher risk of freezing. Additionally, the layer of snow often acts as habitat for burrowing species such as mice that may not be able to dig through the frozen ground, and a decline in snowpack can put those populations at risk.

Expected reductions in snow cover leave the exposed ground more vulnerable to freezing during extreme cold events, which can cause significant impacts to building infrastructure (see: Extreme Cold), and also lead to decreased tourism revenues across the State (see: Extreme Heat).

Warmer winters are also impacting vital Vermont industries such as maple sugaring. The process of maple sugaring requires a narrow window of temperatures for sap to flow, typically when temperatures swing below freezing (at or below 0°C / 32°F) at night and above freezing during the day. This has historically taken place between Town Meeting Day and April of each year. However, sugar maple trees now begin releasing their sap approximately 8.2 days earlier and stop producing usable sap 11.4 days earlier than they did 40 years ago - a trend coinciding with regional climate changes recorded over the same time period.[18] This can be a problem for producers who use historic sap flow initiation dates to determine when they should tap their trees, meaning shifting start times can cause producers to miss out on key sap runs. Sugar maples are also faced with shifting habitat ranges that are distinguished by decreased snowpack which creates a deeper frost layer, dramatically reducing the ability of the sugar maple to take up water and nutrients through frost damaged roots.[19]

Changes in snow accumulation and the decreasing length of the frost-free season can significantly impact Vermont's ski and snowboarding industry. Alpine ski resorts throughout the State typically rely on winter snow deposits to sustain operations, but with the proportion of precipitation falling snow decreasing resorts must either adapt or face losses. The industry can offset some of the decrease in snowfall by creating artificial snow on their trails, however this is both expensive and is still reliant upon cold conditions. As winter temperatures continue to warm at rates faster than the rest of the year, the ability to maintain successful and profitable ski resorts gets increasingly more difficult. Ensuring that resorts are operable during the end of year holiday season has been getting worse as the first snow has continued to come later into the season. The end of year holiday can generate as much as one third of a ski resort's annual revenue, so losing it can severely impact business models.[20]

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16 https://climatechange.vermont.gov/vermont-today
17 https://www.uvm.edu/news/gund/vermont-getting-warmer-and-wetter-climate-change-study
18 https://vt.audubon.org/news/end-maple-maple-sugaring-amid-changing-climate
19 https://www.themaplenews.com/story/study-shows-declining-winter-snowpack-is-hurting-the-sugar-maple/231/
20 https://anr.vermont.gov/sites/anr/files/specialtopics/climate/documents/VTCCwhitepapers/VTCCAdaptRecreation.pdf

Snow Storm Current Capabilities & Mitigation

State facilities and individual towns are generally well prepared to deal with winter storms. VTrans winter maintenance road crews are experienced and well-equipped to keep highways open and municipal road crews are also generally well-prepared to maintain local roads.

This Plan has identified a mitigation strategy to develop resilient design and construction standards (see: Mitigation Strategy) in the form of auditing existing building codes, which would include standards for snow loading and ice accumulation. Additionally, several strategies aimed at increasing public knowledge about hazards and mitigation, supporting frontline communities and coordinating hazard mitigation mapping must consider snow and ice storm events during implementation.

This Plan also includes a strategy to identify and protect vulnerable structures and critical infrastructure, with an action to provide technical assistance to utilities in long-range planning for transmission and distribution line upgrades and relocation to improve resilience, which would include impacts due to ice events and snow loading. Additionally, this strategy includes an action to adapt the VTrans Methods and Tools for Resilience project (2018 SHMP subgrant) for use in mapping utilities and identifying vulnerabilities. This strategy also proposes the identification and evaluation of the feasibility of rural energy systems in coordination with utilities and RPC work under Act 174. This strategy also works towards increasing the capacity of the Public Service Department to maximize the utilization of federal funds towards utility resilience implementation work. In addition to other actions that broadly apply to many other hazards, the plan is coordinating a State Energy Security Plan identifying the interdependency of other systems on the grid and additional risk analysis requirements.

4-5: Ice Storm

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Ice Storm	3	2	3	3	2	2.5	7.5

*Score = Probability x Average Potential Impact

Ice storms are characterized by ice accretion from freezing rain, which can weigh down trees and power lines, causing outages and potentially occurring in conjunction with flooding (see: Inundation Flooding & Fluvial Erosion). Ice storms can occur alone or in conjunction with snow storms (see: Snow Storm), blizzards (see: Snow Storm, for wind impacts, see: Wind), and extreme cold (see: Extreme Cold).

Significant accumulations of ice can cause hazardous conditions for travel, weigh down trees and power lines, and cause power outages. Freezing rain can also be combined with mixed precipitation and snowfall, hiding ice accumulation and further hindering travel. Ice accumulation on waterways is associated with the potential for ice jams and flooding (see: Inundation Flooding & Fluvial Erosion).

NOAA's WPC WSSI (see: Snow Storm), includes ice accumulation as a weighted factor to depict severity of transportation and downed trees/powerlines due to the accumulated ice in combination with wind. Flash freeze is also a weighted factor used to depict severity primarily to transportation of situations where temperatures rapidly fall below freezing during precipitation with the presence of liquid water.

Location

There is no specific region of Vermont that is more vulnerable to ice storms. Ice tends to accumulate earlier and remain longer during the winter season in mountainous regions of the State.

Ice Storm History

- **Ice Storm, January 6, 1998 (DR-1201):** Known as The Great Ice Storm, an unusual combination of precipitation and temperature led to the accumulation of more than 3" of ice in many locations, causing closed roads, downed power lines, and damage to thousands of trees. This storm was estimated as a 200-500 year event. Power was out up to 10 days in some areas and 700,000 acres of forest were damaged in Vermont. Vermont suffered no fatalities, unlike Quebec where 3 million people lost power and 28 were killed. Temperatures rose after the storm, causing the ice to melt and permitting crews to reopen roads, which kept many residents from freezing in their unheated homes. Over $6 million worth of estimated property damage.
- **Ice Storm, December 11, 2008 (DR-1816):** Winter storms and high winds resulted in extensive power outages, primarily in southern Vermont counties. Upward of 40,000 homes were without power for several days during this period.
- **Snow Storm, December 28, 2011:** A strong cold front moved across Vermont during the late morning and afternoon hours accounting for a rapid cool down and localized snow squalls with heavy snow. The western slopes of the Green Mountains saw 5-12" of snow along foothill communities. Near white-out conditions in snow squalls and rapidly freezing road ways accounted for numerous vehicle accidents as well as a closure of I-89 between Richmond and Waterbury.

- **Ice Storm, December 20-21, 2013 (DR-4163):** Approximately 1/4-1/3" of ice accumulation from freezing rain on December 20 with an additional 1/2-3/4" of ice accumulation as well as 1- 2" of sleet December 21 in portions of northern Vermont. Very cold temperatures (-10°F to teens) followed the event with no melting, thus ice stayed on trees and utility lines through December, prolonging recovering. The greatest impact was in northwest Vermont, with widespread tree and utility line damage as well as numerous vehicle accidents. More than 75,000 customers were without power from hours to days. Over $4 million in property damage estimated.
- **Winter Storm, December 29, 2015:** Snow overspread Vermont around midnight on December 29th and ended by mid to late afternoon, changing to sleet and freezing rain before ending. Snowfall amounts across the area was 3 to 7 inches with limited icing. Motor accidents occurred across the region, including a Semi, SUV crash along Route 4 near Killington, VT during the afternoon that resulted in 3 indirect fatalities.
- **Winter Storm, January 12, 2018:** A warm moist flow followed by an artic front caused an inch or more of precipitation across Vermont in the form of rain, freezing rain, sleet, and snow. Temperatures 25-20 degrees above normal caused significant snowmelt followed by an inch of rain which caused rivers to approach bankfull with several reports of rivers flooding due to ice jams. Some of these rivers included the Winooski near Montpelier Jct, Lamoille at Johnson, Passumpsic near Lyndonville, Missisquoi near Swanton and the Connecticut river near Windsor. Sharply falling temperatures in the overnight allowed for a flash freezing of roads making for extremely hazardous travel.
- **Ice Storm, January 12, 2020:** A moisture laden storm tracking along an old cold front positioned itself on the international border near western Vermont on the 11th of January with temperatures across Vermont ranging in the 50s to 60s. As the front progressed south into Vermont, moderate to heavy rain fell across the region. During the early morning of the 12th the cold front slipped south and ¼ to ½ inches of ice accretion was widespread, resulting in hazardous travel and scattered power outages.

Ice Storm Trends

The Steering Committee considered the probability of a plausibly significant extreme ice event to be Likely, with minor impacts on built environment and natural environment, and moderate impacts on people and economy.

According to the 2018 National Climate Assessment, there is an observable increase in the frequency of the most severe winter storms in the Northeast since observations began in 1950.[1]

Ice Storm Vulnerability

People:

Ice storms can cause extensive disruptions to transportation and connection between people and services, including disruptions in communication infrastructure. People in rural areas are temporarily cut off from emergency services. Transportation becomes extremely difficult. Bridges and overpasses become particularly dangerous as they tend to freeze before other surfaces. Ice accumulation can immobilize a region, stranding commuters, closing airports, halting the flow of critical supplies, and disrupting emergency and medical services. The weight of ice can bring down trees and power lines, cutting off power to homes and businesses needed for electric heating system, lights, communications and life support equipment. Homes with generators

1 https://nca2018.globalchange.gov/chapter/2#key-message-8

or propane-based heating systems can lead to carbon monoxide poisoning if not properly ventilated.[2] Homes may be isolated for days, sometimes requiring emergency personnel to navigate hazardous conditions for wellness checks.

Built Environment:

The greatest impact on infrastructure from ice storms is typically the downing of powerlines, causing widespread blackouts. Industries that rely on power to function can be severely impacted by loss of power, such as dairy farmers who rely on electric milking machines to milk the cows. Dangerous conditions due to ice on roadways and other transportation infrastructure can disrupt key supply chains.

Natural Environment:

The impacts of ice storms on the natural environment can be extensive for both flora and fauna. Accumulated ice can weigh down trees, causing limbs to break off and fall. Our natural environment is more adapted to these changes, whereas urban landscaping often faces unique challenges of soil compaction, shallow root systems, and impervious surfaces that interact with winter weather differently than less disturbed environments. Soil compaction and underlying infrastructure can prevent urban tree roots from moving lower towards sources of groundwater and places that don't freeze during the winter. As a result, prolonged exposure to frost can impact the hydraulic conductivity for street trees by breaking these columns resulting in air filled conduits. Expanding air bubbles during temperature fluctuations can further impact tree health.[3]

Native species that are well suited to local climate conditions are ideally selected for planting along town and city streets.[4] The use of salt on roads during the winter can increase water stress, affect soil quality, mineral nutrition, and accumulation to toxic levels within salt sensitive plants. Exposure to high levels of salt in salt sensitive plants can result in poor growth, stunted leaves, heavy seed loads, twig and branch die-back, leaf scorch, and premature leaf drop. Plants stressed by excessive salt are also more susceptible to biotic diseases and insect pests.[5] A reduction in the use of chloride-based de-icers is encouraged for the general health of soils and plants. Street trees can often be seen with a coat of white paint on the lower 2-3 ft of the trunk. This maintenance is done to prevent sunscald, a condition where the bark will crack due to large temperature fluctuations during the winter. Since white paint has a higher albedo than the bark, it is used to reflect solar energy that would typically warm up the trunk only to freeze and crack when the sun disappears behind a cloud/sets.[6]

Economy:

The costs of ice prevention, repairing damage from ice storms and loss of business during ice events can have severe economic impacts on cities and towns. For Class I highways in Vermont, winter maintenance (which includes salt application rates, cost per centerline mile of plowing, and hourly cost of plowing) was totaled to around $6,400 per mile.[7] This study accounted for only the Class I highways, leaving significant costs for local roadways for towns to pay for. In 2010, the town of Jericho spent $14,969 on winter maintenance and

2 https://www.healthvermont.gov/sites/default/files/documents/pdf/English_CO_Safety_Tips.pdf
3 https://www.frontiersin.org/articles/10.3389/fpls.2016.00867/full
4 https://vtrans.vermont.gov/sites/aot/files/highway/documents/environmental/VTrans%20Landscape%20Guide.pdf
5 https://plant-pest-advisory.rutgers.edu/impact-of-road-salt-on-adjacent-vegetation/
6 http://pubs.cahnrs.wsu.edu/publications/wp-content/uploads/sites/2/publications/fs197e.pdf
7 https://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/Class%20I%20Town%20Highways%20White%20Paper.pdf

grading for 7/10ths of a mile for a gravel road.[8] With roughly 55% of Vermont roads being dirt or gravel, this can become a significant expenditure for the state and towns.[9] With automotive transit being a major aspect of society, icy road conditions hindering travel can limit commuting and travel, forcing businesses to temporarily close. Vermont has prominent agricultural and forestry industries that focus mainly on dairy products/other livestock products[10] and maple sugaring respectively.[11] Winter storms and cold snaps can increase stress on livestock, potentially leading to a loss of livestock if extreme. Freezing rain on the limbs of trees, both sugaring and orchard, can damage stock and hurt associated businesses.

Ice Storm Current Capabilities & Mitigation

State facilities and individual towns are generally well prepared to deal with ice storms. VTrans winter maintenance road crews are experienced and well-equipped to keep highways open and municipal road crews are also generally well-prepared. Most critical State facilities have emergency backup generators in case of loss of power due to icing.

This Plan has identified a priority mitigation strategy (see: Mitigation Strategy) to increase Public Service Department capacity to maximize utilization of available federal dollars (including IIJA, IRA, ARPA, and EDA) towards utility resilience implementation work. A mitigation strategy to identify and evaluate microgrid feasibility for rural energy systems/hubs - including assessing locations for resilience hubs in coordination with utilities and RPC work under Act 174 will also address ice storm vulnerability. The next step action will be to identify scales of resilience and opportunities across distribution utilities and appropriate opportunities to support equitable access to resilience - assessing disparity between utility providers.

Though several towns in the State are considering burying power lines for long-term mitigation against both wind and ice events, a statewide approach to power line burying is not being considered at this time due to being cost prohibitive.

8 https://www.ccrpcvt.org/wp-content/uploads/2016/02/SkunkHollowRoad_RevisedReport_20110602.pdf
9 https://www.burlingtonfreepress.com/story/news/local/2015/03/15/march-vermont-mud-eye/24783751/
10 https://ustr.gov/map/state-benefits/vt
11 https://extension.psu.edu/maple-syrup-production

4-6: Drought

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Drought	3	1	3	3	3	2.5	7.5

*Score = Probability x Average Potential Impact

Drought is a deficiency of moisture that results in adverse impacts on people, animals, or vegetation over a sizeable area (NOAA National Weather Service) or a period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance (American Meteorological Society). It is a complex phenomenon that is difficult to monitor and assess because it develops slowly and covers extensive areas, as opposed to other disasters that have rapid onsets and obvious destruction. The effects of drought can linger long after the drought has ended. The northeast United States can also experience "flash" or rapid-onset droughts with intense dry periods of about 2 to 6 months followed by a period of above-normal precipitation.

Drought is an inherent, cyclical component of natural climatic variability and can occur at any place at any time. High winds, low humidity, and extreme temperatures can all amplify the severity of the drought. It is difficult to determine the onset, duration, intensity, and severity of a drought, all of which affect the consequences and corresponding mitigation techniques. The different types of drought have different corresponding impacts on people and our environment.

Types of Drought[1]:

- **Meteorological:** a reduction in rainfall from a normal precipitation pattern in regard to the amount, intensity, or timing of the event as well as changes in the temperature, humidity, and wind patterns. The strict threshold differs for every nation; the United States defines meteorological drought as receiving less than 2.5mm of rainfall in 48 hours. Meteorological drought is the first drought stage detected.
- **Agricultural:** deficient moisture conditions that cause a lasting effect on crops and non-natural vegetation. It is dependent on rainfall, temperature, topography, evapotranspiration, permeability, and porosity of soils, precipitation effectiveness, and vegetative demand. Agricultural drought begins when the available soil moisture supports the actual evapotranspiration rate at only a fraction of the potential evapotranspiration rate.
- **Hydrological:** related to the effects of decreased precipitation on surface or subsurface water supply. It is the last stage of drought and is lagged behind meteorological and agricultural drought because water infiltrates down to the groundwater during the latter portion of the hydrological cycle. Subsurface water supply is the last drought component to return to normal when meteorological conditions and aquifer recharge return.
- **Socioeconomic:** what happens when the consequences of the drought start to affect the socioeconomic sector. It occurs when the demand for an economic good is greater than the available supply due to weather-related drought. Examples of such goods include water, hydroelectric power, food grains, meat, dairy, and much more. Socioeconomic drought affects the associated population both individually and collectively.
- **Ecological:** defined as "a prolonged and widespread deficit in naturally available water supplies — including changes in natural and managed hydrology — that create multiple stresses across ecosystems." More info on Ecological drought: https://snappartnership.net/teams/ecological-drought/.

1 http://drought.unl.edu/DroughtBasics/TypesofDrought.aspx

The severity of a drought depends on the duration, intensity, and geographic extent of the water shortage, as well as the demands on the area's water supply. Droughts are rated in classifications from D0–D4, depending on the severity of the drought, the amount of time it will take for vegetation to return to normal levels, and the possible effects of the drought on vegetation and water supply (Table 26).

Drought differs from other natural hazards in multiple ways. First, drought is not as obvious as other hazards; it does not have the property destruction of a tornado or hurricane nor the apparent ecological destruction of a wildfire. Second, there is a lack of an exact and universally accepted definition of drought. Finally, the beginning and end of a drought is difficult to determine: though the surface water content may have recovered from a period of drought, the replenishment of groundwater levels is a longer process. In addition, droughts are often spread over a larger geographic area than other natural hazards. These things considered, the economic effects of a drought can be just as devastating as any other natural hazards.

Table 26: Drought Severity Classification

Category	Description	Possible Impacts
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures Coming out of drought: some lingering water deficits pastures or crops not fully recovered
D1	Moderate Drought	Some damage to crops, pastures Streams, reservoirs, or wells low, some water shortages developing or imminent Voluntary water-use restrictions requested
D2	Severe Drought	Crop or pasture losses likely Water shortages common Water restrictions imposed
D3	Extreme Drought	Major crop/pasture losses Widespread water shortages or restrictions
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses Shortages of water in reservoirs, streams, and wells creating water emergencies

Source: http://droughtmonitor.unl.edu/AboutUSDM/DroughtClassification.aspx

Location

Though Vermont encompasses a small geographic area, the State has distinct regions that can experience significantly different weather patterns and react differently to the amount of precipitation they receive. According to the U.S. Drought Monitor's archived data, the southeastern portion of the State is more vulnerable to prolonged periods of more significant drought, likely due to its lower elevation and landlocked location.[2]

Drought History

Vermont has a highly variable, unpredictable climate. Droughts, while low frequency hazards, are of serious concern to the population of Vermont. It is often difficult to recognize the onset of a drought during its preliminary stages, and together with Vermont's variable climate can lead to the disregard for the seriousness of an oncoming drought. Even though the State usually has adequate rainfall, droughts occasionally occur.

2 https://statesummaries.ncics.org/vt

Several severe droughts have been recorded during the last century, while moderate and mild droughts are much more common. The droughts in the mid-1960s were the most severe in Vermont. Every county in the State experienced Exceptional Drought (D4) conditions in May of 1965 (Figure 47). Since the 1960s Vermont has experienced several less severe periods of drought (Figure 48).

There were two declared statewide droughts in June and July 1995. These droughts were due to a lack of rainfall, which required officials to put restrictions on water usage. Lack of rain combined with some of the highest temperatures led crop loss in some areas. The drought persisted through the summer of 1995, and a third, more severe drought affected Southern Vermont in August of that year. From 1998 to 1999 parts of the state in Chittenden and Franklin Counties experienced Exceptional Drought (D4), and much of the state experienced Moderate Drought (D1) or Abnormally Dry conditions (D0).[3]

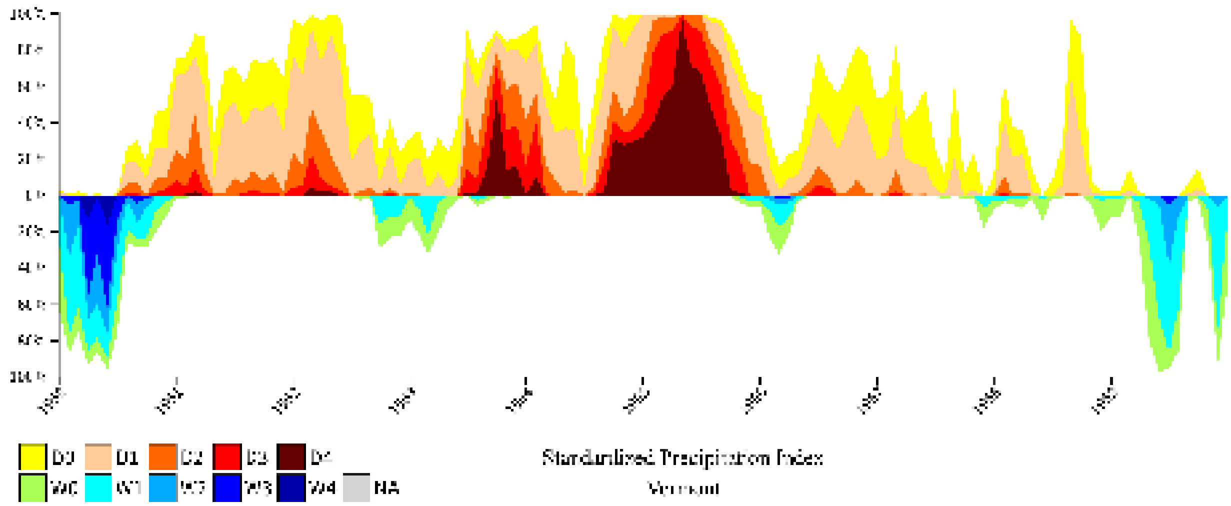

Figure 47: Standardized precipitation index historical data for Vermont (1960-1970)
Data Source: National Integrated Drought Information System

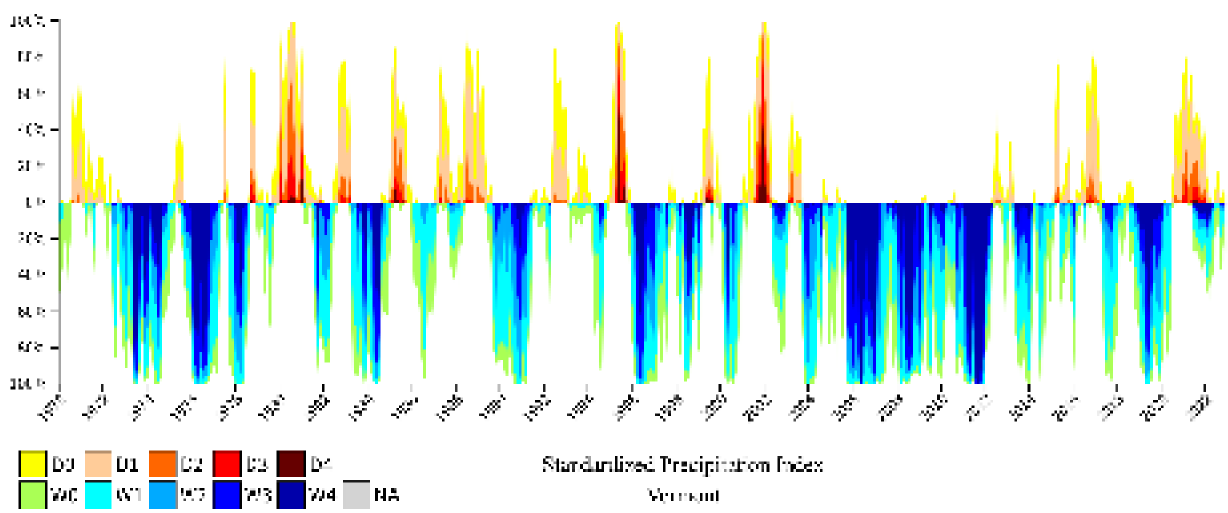

Figure 48: Standardized precipitation index historical data for Vermont (1970-2023)
Data Source: National Integrated Drought Information System

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3 https://www.drought.gov/historical-information?state=vermont&dataset=1&selectedDateUSDM=20110719&selectedDateSpi=19990701&dateRangeSpi=1998-1999

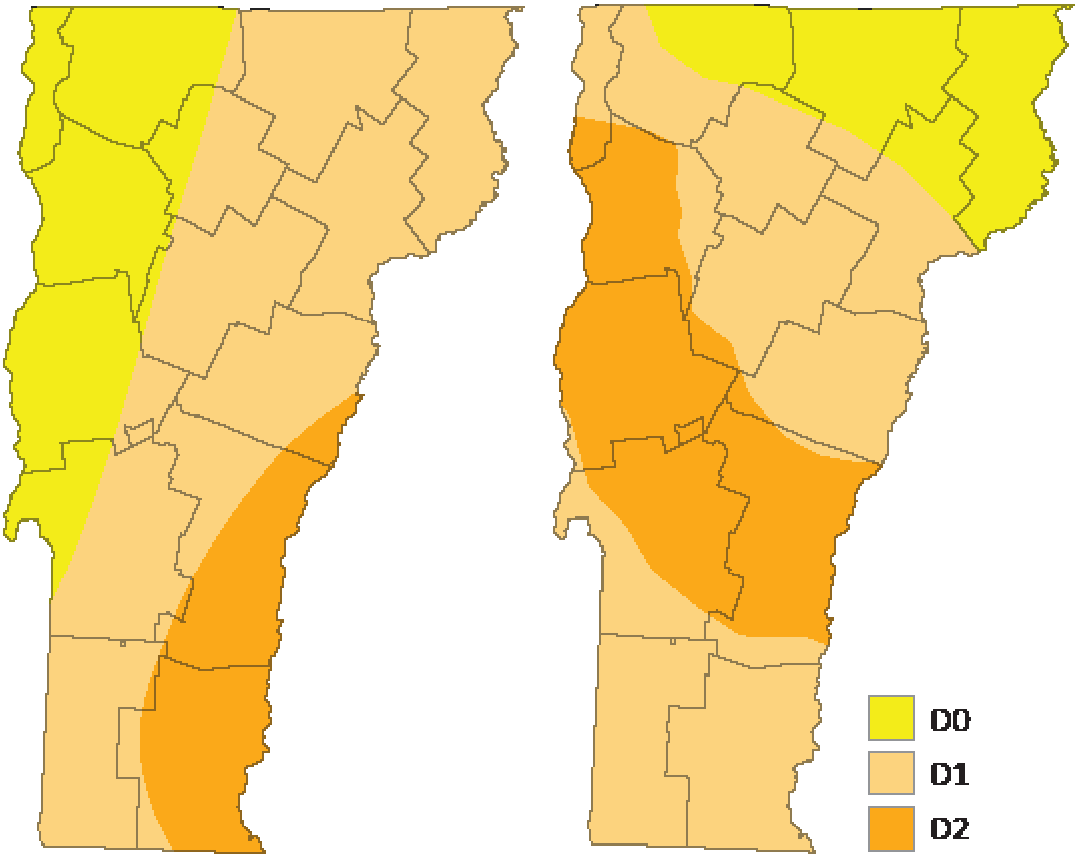

Figure 49: Map of abnormally dry (D0) to severe drought (D2) during significant drought periods in Vermont in late 2001 (left) and late 2016 (right)
Data Source: https://www.drought.gov/drought/states/vermont

Image of Lake Champlain's widening shoreline. *Photo Credit: Charlotte Scott*

In 2001-2002, Vermont was affected by a Severe Drought (D2), which peaked at over 14% of the State at the D2 level between November and December of 2001 and nearly 100% of the State in at least Moderate Drought (D1) (Figure 49). In response to the 2001-2002 drought, the Vermont Agency of Natural Resources Drought Plan[4] was developed in consultation with VEM to guide its activities in response to droughts and extended periods of dry weather. The plan is a set of operating procedures that outline the responsibilities of various programs, lines of communication to be used, and the general sequence of actions to be followed based on the severity of the situation. Additionally, the plan provides a set of qualitative and quantitative Vermont-specific drought severity indices and recommended actions based on drought level. This drought section has been part of the State Emergency Operations Plan since 2013.

In late summer/early autumn of 2007, ground water shortages were evident in several areas of Vermont. This was particularly apparent near shallow wells.

Portions of Vermont were in Severe Drought (D2) from October 2016 through April 2017, peaking at 29.15% of Vermont in October and November 2016 and 80% of the State was in at least Moderate Drought (D1) (Figure 50). Moderate Drought conditions returned in October of 2017 and again in June 2018. From September to November of 2018 the State experienced another Severe Drought. Then from June 2020 to October 2021 much of the State was under Moderate Drought to Abnormally Dry conditions. From September to October of 2020 29.4% of the State was under Severe Drought conditions.

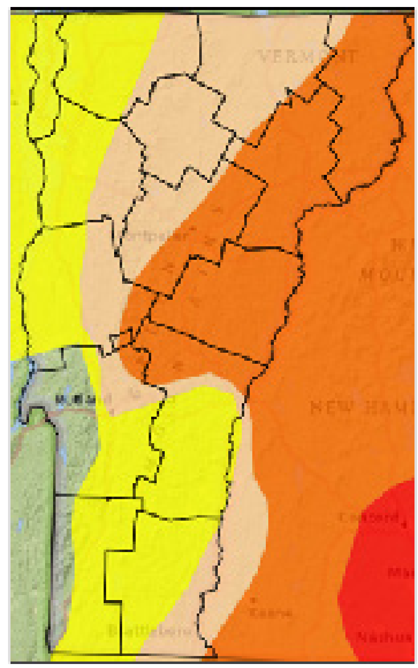

Figure 50: Map of abnormally dry to severe drought in the 2001 drought
Data Source: National Integrated Drought Information System

Drought Trends

Relative to other regions of the country, severe droughts are not frequent occurrences in Vermont. However, floods and droughts are respectively two of Vermont's highly likely and likely natural disasters. Vermont's precipitation trend is an on upward trajectory, having seen increases in average annual precipitation of 7.5 inches since 1900.[5] At the same time Vermont is seeing an increase in average annual maximum and minimum temperature (see: Extreme Heat, Extreme Cold), which is contributing to an increased likelihood of drought. Higher temperatures lead to increased rates of evaporation, combined with dry periods between intense precipitation events will lead to increased dry conditions. The wet and dry extremes are expected to increase over time in Vermont.

The U.S. Drought Monitor (USDM) started in 2000, and with it came updated methods of drought reporting so that a separate dataset is available for drought conditions since 2000. The USDM relies on drought experts to synthesize the best available data and work with local observers to interpret the information. Prior to 2000 droughts were characterized by Standardized Precipitation Index (SPI). Figure 51 displays the USDM drought dataset available since 2000. From 2001 to 2002, 2016 to 2017, 2018 to 2019, and 2020 to 2023, New England experienced historic drought conditions not seen since the 1960s.[6] From 2000 to 2018, there had been two Severe Droughts (D2) droughts in Vermont. Since 2018 there have been three Severe Droughts.

The occurrence of several D2 (Severe Drought) events in the 21st century, with increased occurrences in the latter half of the 2010s, led the Steering Committee to consider the probability of a plausibly significant

4 http://drought.unl.edu/archive/plans/drought/state/VT_2005.pdf
5 https://site.uvm.edu/vtclimateassessment/files/2022/08/VCA-entire-8-3-22-web.pdf
6 https://www.drought.gov/dews/northeast

drought event to be “Likely”, therefore receiving a Probability score of 3. The Steering Committee’s projected potential impacts were considered to be “Minor” or “Moderate,” receiving a score of 2.5.

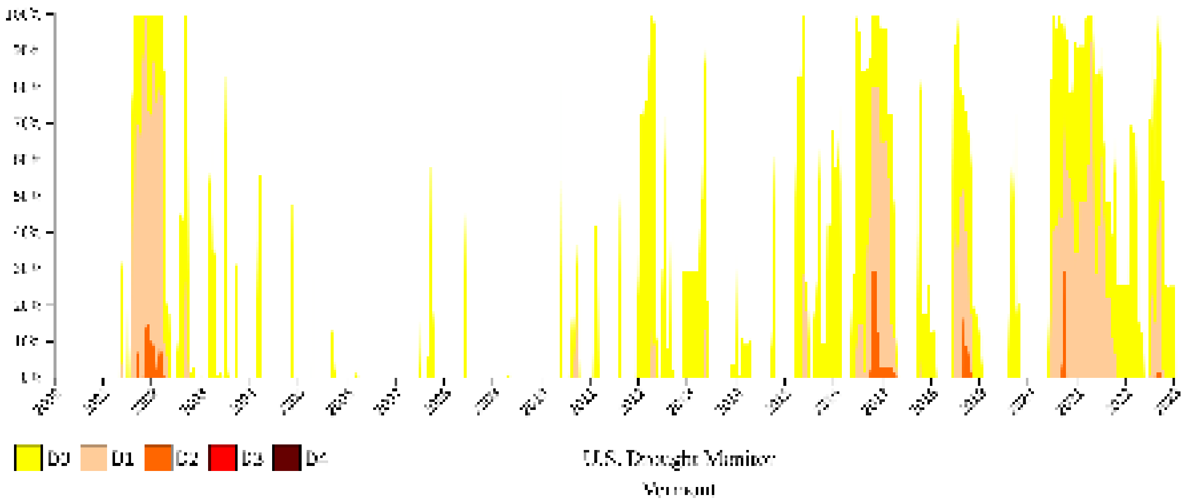

Figure 51: US Drought Monitor historical drought intensity for Vermont (2000 - Present)
Data Source: National Integrated Drought Information System

Drought Vulnerability

People:

The impacts of drought are typically felt by rural residents first. Drought can cause extensive damage to gardens, agricultural crops and livestock. Drought can also lead to dry or low water levels in wells needed for drinking water. Low water levels often do not just mean that an individual, family, or shared home has a threatened water supply, but can also concentrate water contaminate levels and lead to resulting in potential health concerns. The USGS estimates that 97% of the rural population of the United States receives their drinking water through groundwater pumping, where access to municipal/village water is unavailable.[7]

The Vermont State Climatologist and Vermont State Geologist have been working together to secure funding to map the State’s groundwater resources to better understand statewide vulnerability to the hazard. The need for these data are expressed both in this Plan (see: Mitigation Strategy) and the 2018 Vermont Groundwater Management Plan. From the Drinking Water and Groundwater Protection Division in the DEC. Drought impacts on people are further discussed under Built Environment, Natural Environment, and Economy.

Built Environment:

Structural impacts of drought are very uncommon, making the risk to State buildings, facilities, infrastructure, or governmental functions low. Trends of increased periods of drought may require the construction of new community water supplies with better storage capability and drilling new deeper wells on properties where wells have run dry. As water levels in underground aquifers fall, the ground runs the risk of subsidence. Subsidence is the sinking of the ground which can impact roads, buildings, and water pipes, and can lead to the formation of sinkholes.[8]

7 https://water.usgs.gov/edu/droughtandgw.html
8 https://www.drought.gov/sectors/navigation-and-transportation

Natural Environment:

The impacts of drought to the natural environment can be extensive. Soil moisture, streams, and groundwater are all depleted due to drought. Drought depletes water availability for both cultivated and wild plants and animals. As a result of the 1998 to 1999 drought, tens of millions of dollars' worth of hay, corn, and other crops were lost.[9] During past droughts in Vermont, deciduous trees have experienced leaf scorch, leaf yellowing, and early leaf color, which is not just a symptom of poor tree health, but also subdues fall foliage color that "leaf peeping" tourists travel from out of state to see. The effects on trees are visible both in forested and urban or suburban areas.[10]

Impacts of drought are projected be more severe for urban trees because of the effects of the built environment on temperature and water cycling.[11] Drier forests are also more prone to wildfire (see: Wildfire). Less visible effects of drought on ecosystem imbalance can lead to species decline and extinction. For example, vernal pools may dry before reproductive cycles of pool-breeding amphibians have completed.[12]

Economy:

The economic impact of a significant drought event is greater than the risk to life or property. Though dollar losses from droughts are not estimated to date, certain losses could be investigated. Drought has effects on the economy in all seasons. In warm weather we can expect decreased agriculture and forestry production, impacts to surface water supplies and fisheries, costs associated with the construction of new community water supplies with greater storage capacity and individual or community wells that have been deepened to capture additional yields. In the forestry industry drought can negatively impact forest stock by increasing mortality and reducing growth. A reduced vegetative cover can also increase the impacts of wind and water erosion[13] (see: Wind and Inundation Flooding & Fluvial Erosion). In the fall drought effects may cause declines in "leaf peeping" tourism due to subdued color. In the winter drought can impact precipitation in the form of snow, leading to stresses on winter recreation businesses. In the spring, loss of snowpack can leave trees vulnerable to the cold impacting maple product production as well as reducing early season water availability vegetation would have received from a melting snowpack.

Drought Current Capabilities & Mitigation

The Drinking Water and Groundwater Protection Division in the DEC published a Groundwater Management Strategy in 2018 to help ensure adequate quantity and quality of groundwater, including during periods of drought.[14] The Office of the State Geologist develops groundwater resource maps for towns and conducts ongoing statewide assessments to help towns plan for adequate supply. The resources this program provides are intended for community planning purposes, so that future water supplies can be sited. Communities with groundwater wells that have adequate yields in times of drought have a degree of protection, where low yield areas may be more vulnerable.

9 https://vermonthistory.org/journal/70/vt701_204.pdf
10 Sandra Wilmot, November 1999 as cited in Dupigny-Giroux, L.-A. (2002).
11 https://site.uvm.edu/vtclimateassessment/files/2022/08/VCA-entire-8-3-22-web.pdf
12 https://www.fs.usda.gov/ne/newtown_square/publications/other_publishers/OCR/ne_2004brooks01.pdf
13 https://www.fs.usda.gov/ccrc/topics/effects-drought-forests-and-rangelands
14 http://dec.vermont.gov/sites/dec/files/dwgwp/DW/2018%20Groundwater%20Management%20Plan.pdf

The 2018 Vermont Groundwater Management Plan[15] identifies groundwater protection as a necessary precaution to minimize vulnerability to future fluctuations in groundwater levels due to both anticipated increased precipitation and prolonged drought periods. The plan goes further to note that while groundwater protection is an issue understood at the local, regional, State and Federal levels, careful consideration of it only takes place during times when problems with groundwater levels may arise.

The Best Management Practices Program (6 V.S.A. § 4821) offers the potential to create opportunities for drought protection practices such as irrigation and on farm water storage. Water monitoring is also vital for other sectors beyond residential and agricultural use, as the recreational and tourism sectors can be negatively impacted by the occurrence of a drought.

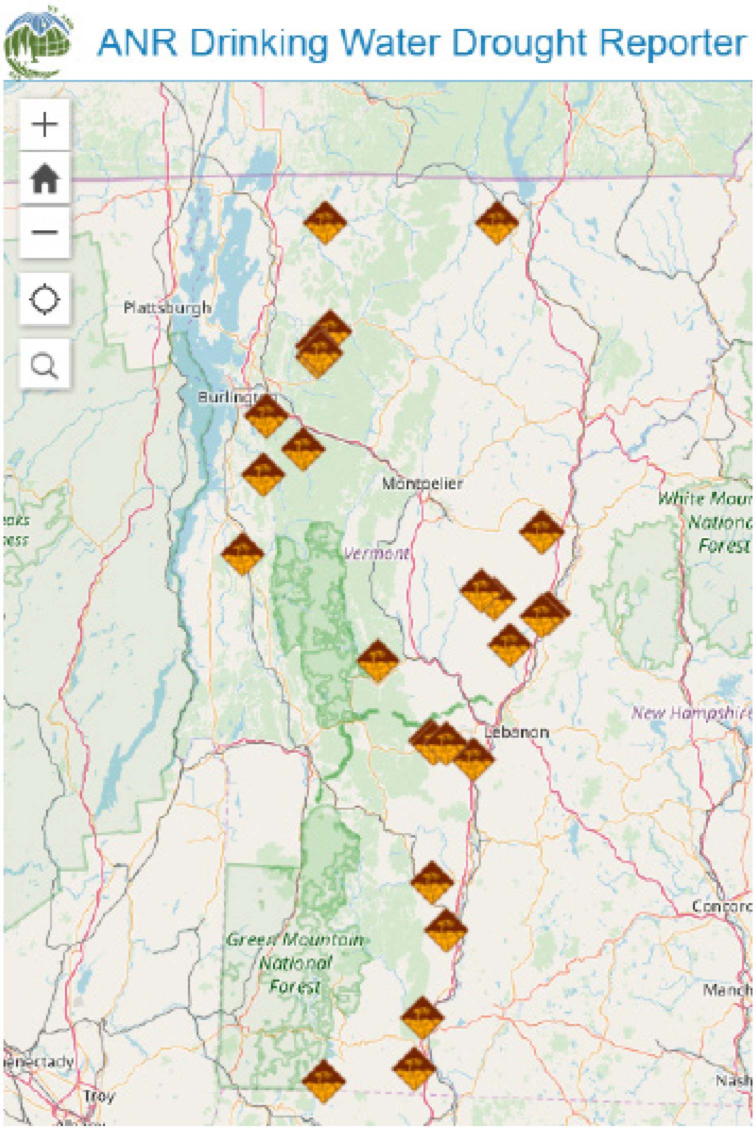

Figure 52: ANR's Drinking Water Drought Reporter Map
Source: https://anrmaps.vermont.gov/websites/droughtreporter/

As noted above in Drought Trends & Vulnerability, the Vermont State Climatologist and State Geologist have been pursuing grants to secure funding for groundwater resource mapping. Knowing where the State's groundwater resources are located is considered critical information, necessary to understand the State's vulnerability and then to develop mitigation actions and strategies aimed at reducing drought vulnerability. A drought plan for Vermont, groundwater resource mapping, expansion of the number of monitoring wells across the State and a thorough analysis of water level monitoring data have been identified as mitigation actions under the 2023 SHMP's "Promote Drought Resilience" strategy (see: Mitigation Strategy). This strategy also supports increasing the capacity for monitoring surface water supply and quality, assisting local communities in water systems and lines to determine alternative water sources to wells, and increased coordination between State and Federal resources and funding around monitoring and mitigation against drought. Further, the 2018 Vermont Groundwater Management Plan identifies "exploring partnerships with FEMA to fund water data acquisition related to drought" as part of its long-term approach to increasing the State's understanding of and resilience to the hazard.

The Vermont Drought Task Force, made up of representatives from several State and federal agencies, is convened quarterly to discuss current drought conditions, share drought-related information, identify data gaps and needs and develop conservation guidance to all citizens, when applicable. The Task Force developed the Drinking Water Drought Reporter[16] online tool, which allows the Agency of Natural Resources to compile drought data and identify areas vulnerable to drought impacts.

15 http://dec.vermont.gov/sites/dec/files/dwgwp/DW/2018%20Groundwater%20Management%20Plan.pdf
16 https://anrmaps.vermont.gov/websites/droughtreporter/

4-7: Infectious Disease

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Infectious Disease	3	1	4	4	1	2.5	7.5

*Score = Probability x Average Potential Impact

The Vermont Department of Health defines an infectious disease as one that is caused by micro-organisms, such as bacteria, viruses or parasites. A vector-borne disease is an infectious disease that is transmitted to humans by blood-feeding arthropods, including ticks, mosquitoes and fleas, or in some cases by mammals (e.g. rabies).

According to the Vermont Department of Health, infectious disease dynamics depend on a range of factors, including: land use, human behavior, climate, efficacy of healthcare services, population dynamics of vectors, population dynamics of intermediate hosts and the evolution of the pathogens themselves.

Table 27: Threat Categories of Vector-Borne and Other Infectious Disease

Threat Classification	Disease
Diseases already present in Vermont that may be exacerbated by climate change	West Nile Virus
	Eastern Equine Encephalitis
	Lyme Disease
	Anaplasmosis
	Babesiosis
	Tularemia
	Powassan
Diseases that may spread to Vermont even without contribution of climate change, whose spread to and transmission of Vermont could be exacerbated by climate change	St. Louis Encephalitis
	Western Equine Encephalitis
	La Crosse Encephalitis
	Ehrilichiosis
	Rocky Mountain Spotted Fever
Diseases with vectors that may spread to Vermont by the end of the century under a higher emission scenario	Dengue
	Chikungunya
Disease that have competent vectors or may in the future have competent vectors in Vermont, but are unlikely to become established in Vermont despite a vector presence	Yellow Fever
	Malaria
	Chagas Disease
	Rift Valley Fever
Diseases that may be present in Vermont or may spraed to Vermont in the future but whose link with climate changes expected in Vermont is tenuous	Batonellosis
	Rabies
	Hanta Virus
	Leptospiriosis
	Plague
	Valley Fever
	Anthrax
	Q Fever

Source: Vermont Department of Health

Many of these diseases require continuous monitoring, as they present seasonal threats to the general population. An epidemic emerges when an infectious disease occurs suddenly in numbers that are in excess of normal expectancy. Infectious disease outbreaks put a strain on the healthcare system, can cause continuity of operations challenges for local businesses, impact the economy, and interrupt daily life for everyone within a community. These outbreak incidents are a danger to emergency responders, healthcare providers, schools, and the public. Examples include Coronavirus 19 (Covid-19), influenza (e.g. H1N1), pertussis, West Nile virus, and many other diseases.

Upon consideration of five climate and health reviews, The Vermont Department of Health has separated vector-borne and other infectious diseases into five threat categories (Table 27). More details on this classification system and the diseases can be found in the 2016 Vermont Climate Health Report.[1]

Infectious Disease History

Pandemic influenza, considered to be a global outbreak, spread quickly around the world and was observed in 1918, 1957, 1968 and in 2009 with the novel H1N1 strain. The 2009 H1N1 outbreak, though not considered a serious threat to Vermont, still affected some Vermonters. The great influenza epidemic of 1918 killed millions worldwide and would likely cause hundreds to thousands of deaths in Vermont should a similar outbreak occur today. It is anticipated that a more serious strain of the usual flu will occur some year and that vaccines might not be ready in time to combat rapid spread.

Lyme disease continues to pose a significant and growing threat to Vermonters. Cases have been tracked by the Vermont Department of health for several decades (Figure 53). Habitat shifts and changes in climate continue to create favorable conditions for pathogen-carrying ticks to proliferate.

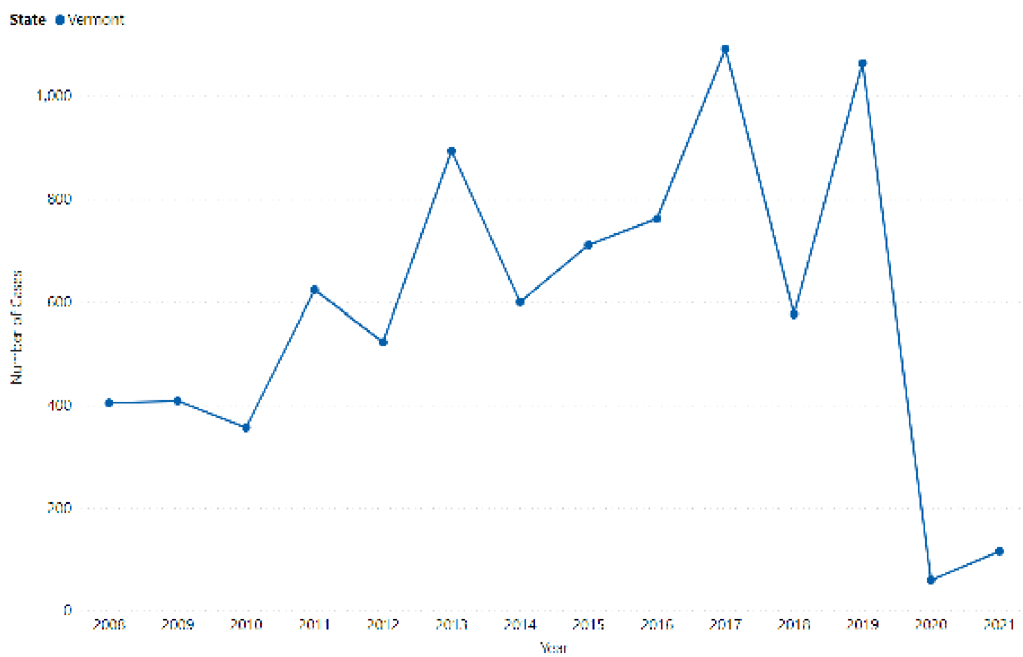

Figure 53: Vermont yearly cases of lyme disease reported
Source:

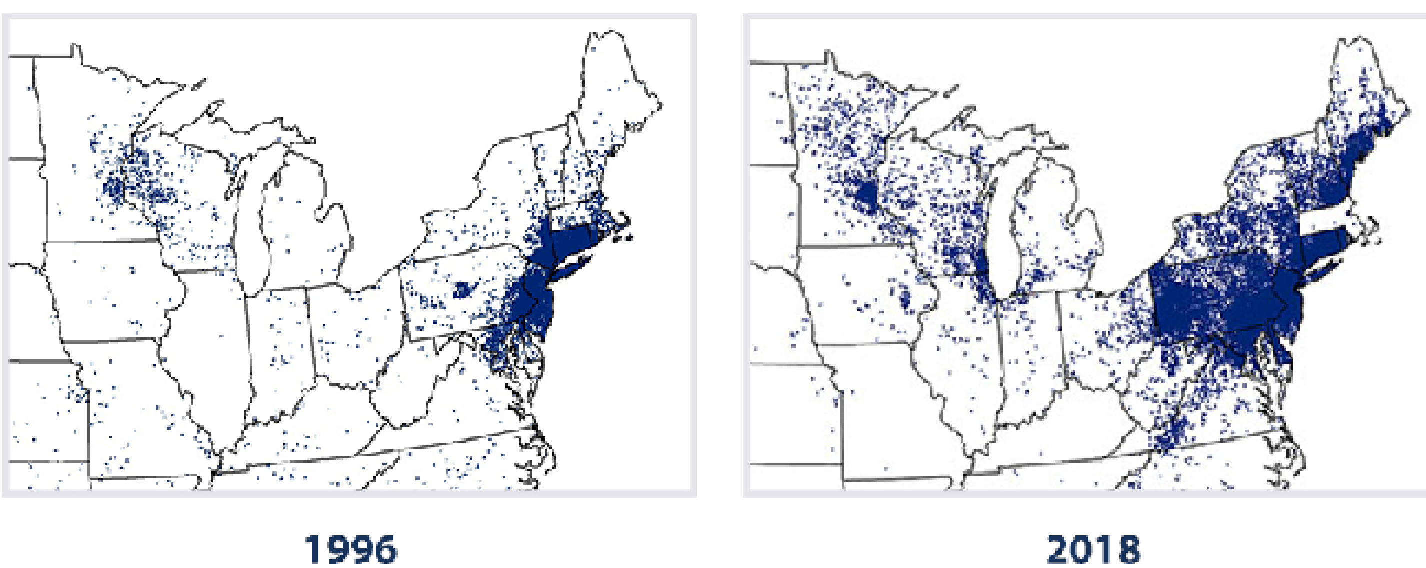

Figure 54: Reported lyme disease cases map 1996 (left) and 2018 (right)
Source: https://www.epa.gov/climate-indicators/climate-change-indicators-lyme-disease

1 https://www.healthvermont.gov/sites/default/files/documents/pdf/ENV_CH_ProfileReport.pdf

The Covid-19 pandemic beginning in 2020 led to a complete disruption of daily life within Vermont. A state of emergency was issued on March 13, 2020 by Governor Phil Scott to help ensure Vermont had the resources necessary to respond to the Covid-19 public health emergency. In the following weeks, a series of executive orders were issued restricting activities likely to result in transmission or use up valuable medical resources. Some of these included restricting visitor access to long term care facilities, suspending in person PreK-12 education, closure of bars and restaurants, suspension of elective and non-essential medical surgeries, interstate travel restrictions, and limits on non-essential gatherings.

Covid-19 restrictions stayed in effect until June 14, 2021 when 80% of Vermont's eligible population (those 12 and older) received at least one dose of Covid-19 vaccine, in accordance with the State's Vermont Forward Plan.[2] As of October 2023, there were a total of 152,618 cases and 929 deaths due to Covid-19 in Vermont.[3] Lessons learned include systems vulnerability to novel pandemics, and the need for planning for future disease threats. The State of Vermont will continue to develop infectious disease mitigation strategies to better prepare for future outbreaks.

Infectious Disease Trends

According to the Centers for Disease Control (CDC), the number of reported cases of vector-borne infectious disease more than tripled between 2004 and 2016.[4]

Infectious diseases that fall into the first threat classification category, such as West Nile Virus (WNV) and Eastern Equine Encephalitis (EEE), maintain a presence in New England. Access to long periods of heat (see: Extreme Heat) and abundant precipitation (see: Inundation Flooding & Fluvial Erosion) provide the perfect habitat for these mosquito-borne diseases. Perhaps the most significant trend in infectious disease vulnerability in Vermont is that of tickborne diseases, including Lyme disease, anaplasmosis, and babesiosis. For example, Vermont ranked highest in the United States for Lyme disease incidence in 2019, though this ranking changes annually. Additionally, Vermont's increase in forest cover could provide a more suitable habitat for ticks and their hosts, which may lead to further spread of Lyme disease in the State. Outdoor workers and recreationalists are especially vulnerable to tickborne diseases, as exposure to ticks is greater. Tickborne diseases are more prevalent in the southern and western halves of the State, as the warmer climate contributes to longer periods of tick activity.

An incident that contaminates water supplies or results in people eating spoiled food could have significant health implications. Animals infected with the rabies virus present localized threats. The potential for infection of Vermont's commercial animal population with foreign animal diseases such as, foot and mouth disease, brucellosis, or highly pathogenic avian influenza viruses could cause widespread economic problems. A health threat could also potentially result from an act of bio- or agro-terrorism.

Given increasing trends for global travel, several diseases not typically observed in Vermont may be introduced by infected travelers. For example, the Zika virus, transmitted from infected mosquitoes to humans, received international attention during an outbreak in 2015 and persists today. The CDC and Vermont Department of Health recommend pregnant women, or women attempting to become pregnant, not travel to areas of the world where Zika is present,[5] as the virus can pass from mother to fetus, causing potentially significant birth defects.

2 https://governor.vermont.gov/Covid19response
3 https://coronavirus.jhu.edu/region/us/vermont
4 https://www.cdc.gov/vitalsigns/pdf/vs-0518-vector-borne-H.pdf
5 https://wwwnc.cdc.gov/travel/page/zika-information

The Steering Committee considered the probability of a plausibly significant infectious disease outbreak event to be Likely, with the major impacts felt by people, followed then by major direct and indirect impacts to the economy.

Infectious Disease Vulnerability

People:

People who are most vulnerable to infectious disease include immunocompromised individuals, elderly and young populations, and healthcare workers. Due to weakened immune systems or compounding factors of other illnesses or stressors these populations are at heightened risk of infection and death.

Pandemic can also impact people in ways other than infection; increased transmission rates through certain vectors can cause disruption to daily life and mental health consequences due to disruptions and fear of infection. Infections can quickly overburden available beds within healthcare facilities. During the COVID-19 pandemic the U.S. faced rapidly escalating demand due to staff availability and burnout, limited space and supplies, and shortages of personal protective equipment (PPE) for health care providers. Insufficient intensive care unit (ICU) bed availability and increasing community case burden have also been implicated as risk factors for poor COVID-19 patient outcomes.[6] Densely populated areas were often centers of outbreaks, where even the largest hospitals can be overwhelmed. Even with fewer infections, rural areas may be less equipped for pandemic response due to lack of bed space, staffing and other resources.

Built Environment:

The daily operations of society can be upended by pandemics. This can include shifts in demand of certain resources such as fuel, with less people commuting to work due to stay at home orders. Lockdowns resulted in an increase in the demand for delivery services, bolstering those sectors while brick and mortar stores experienced a reduction in revenue as people opted for E-commerce.[7] Utility services also needed to adapt to changing demand patterns in a remote world. Increases in waste generation from homes due to lockdown and social distancing measures coupled with panic retail buying at the beginning of the pandemic were observed. An increase in the use of single use products to contain the spread of COVID-19 saw an additional load placed on waste management services.[8]

With office work shifting more towards remote options during the pandemic, utilities and telecom providers saw increased demand for high-speed internet in order to maintain usual business operations. On the other hand, as a higher percentage of the workforce tele-commuted the demand for office space declined significantly, resulting in businesses revisiting their leases and rentals of office space. A decline in the demand for physical office space can impact the market for new commercial construction. The long-term implications of changing demand are still unfolding, as businesses expand post-COVID and cautiously step into a new workplace norms.[9]

6 https://www.forbes.com/sites/williamhaseltine/2021/07/26/overwhelmed-us-hospital-systems-a-look-into-the-future/?sh=83b675b7c62a

7 https://www.census.gov/library/stories/2022/04/ecommerce-sales-surged-during-pandemic.html#:~:text=According%20to%20the%20most%20recent,to%20%24815.4%20billion%20in%202020

8 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7447614/

9 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9670738/

Natural Environment:

The natural environment provides habitat for many vectors of disease that impact human, livestock, and pet populations. Species such as mosquitoes, ticks, and fleas can host infectious diseases harmful to humans such as malaria, Lyme disease, and plague,[10] so environments that favor these vectors also increase the potential for disease outbreaks. Coronaviruses that cause MERS and SARS originated in animals and made the jump to humanity. However, the origin of the recent COVID-19 pandemic has not been conclusively identified at this time.[11] Diseases that are able to jump from wildlife to humans can also jump from humans to wildlife. This was seen with the infection of whitetail deer and other species of animals with COVID-19, though no deer in Vermont tested positive for the virus.[12]

Climate Change

Some infectious diseases that fall into the first threat classification category identified in Table 27 (i.e., currently present in Vermont and which may be exacerbated by climate change) are increasing in incidence in New England. For example, with both temperature (see: Extreme Heat) and precipitation (see: Inundation Flooding & Fluvial Erosion) expected to increase in Vermont, mosquito vector activity will likely increase, as well as the vector's period of activity, lengthening seasonal risk of mosquito-borne diseases. For example, between 1964 and 2010, Eastern Equine Encephalitis (EEE) cases have become more common in New England, though they remain constant in the southeastern states.

Perhaps the most significant trend in infectious disease vulnerability in Vermont is that of Lyme disease, which ranked the highest incidence in the nation in 2019. The Vermont Department of Health reports that the number of reported cases of Lyme disease have increased dramatically over the last decade, and with shortening winters, the potential for infection through tick bites continues to grow. Additionally, Vermont's increase in forest cover could provide a more suitable habitat for ticks and their hosts, which may lead to further spread of Lyme disease in the State. Outdoor laborers and recreationalists are especially vulnerable to tick bites that may cause Lyme disease. Lyme disease is reported more commonly in the southern and western halves of the State, where warmer climate may contribute to longer periods of vector activity.

Climate change can increase the range of diseases and their vectors and increase rates of infection. Warmer temperatures allow more diseases and their vectors to venture further north where harsh winters temperatures previously inhibited expansion.

Economy:

Infectious disease and large-scale pandemics can cause disruptions to daily life and economic activities that can negatively impact the local and statewide economy. Following COVID-19 and Governor Scott's emergency order on March 13th, 2020, the service sector in Vermont experienced 77% of all unemployment claims. High unemployment increased the incidence of households falling behind on rent or mortgage payments. Vermont

10 https://www.cdc.gov/ncezid/dvbd/index.html#:~:text=Vectors%20are%20mosquitoes%2C%20ticks%2C%20and,around%20for%20thousands%20of%20years

11 https://www.niaid.nih.gov/diseases-conditions/origins-coronaviruses

12 https://www.biorxiv.org/content/10.1101/2023.04.25.538264v1

saw statewide revenue shortfalls with the tourism industry taking a particularly hard hit.[13] The economic impact of the pandemic was felt most keenly by those without financial safety nets. Low-income Vermonters were less likely to have remote work options. A UVM study reported that 16% of Vermonter's were concerned about their ability to pay for necessities like food and rent, 19% used savings to cover monthly spending and 10% said they had reduced ability to buy fresh fruit and vegetables.[14] Pandemic response actions such as lockdowns and social distancing orders worked well to slow the spread of disease, but economic impacts on the livelihoods of thousands of Vermonters were of significant magnitude and duration.

Infectious Disease Current Capabilities & Mitigation

The Vermont Department of Health regularly updates its website with news, events and reports that users can utilize in consideration of infectious disease mitigation.[15] VDH has ongoing preparedness activities to respond to infectious disease outbreaks.

Given the Steering Committee's "Likely" ranking of infectious disease outbreak in the hazard assessment, largely in part due to the recent COVID-19 pandemic which greatly impacted Vermont and highlight areas in health and public safety policy and infrastructure that could be improved on. There are no actions in this plan that specifically address infectious disease mitigation. However, several strategies and actions are included under the goal of creating a common understanding of – and coordinated approach to – mitigation planning and action. These focus on data acquisition and dissemination of all hazards, as well as increasing public awareness of the hazards that Vermont faces. Increasing community resiliency through awareness and provided support in the form of funding and technical assistance.

We recognize the possibility that FEMA guidelines will change during the five years when this plan will be in effect, allowing for broader use of Public Assistance and/or Hazard Mitigation Assistance funding with respect to mitigating public health system vulnerabilities and resiliency in responding to infectious disease outbreaks and similar public health emergencies. In the event of such increased flexibilities, Vermont will endeavor to take advantage of the opportunities provided.

13 https://ljfo.vermont.gov/assets/Subjects/Economic-Impacts-on-Vermont/52498f2da7/Economic-Fallout-of-the-COVID-19-Pandemic-in-New-England.pdf
14 https://www.uvm.edu/news/story/uvm-survey-pandemics-impact-falling-disproportionately-lower-income-groups
15 http://www.healthvermont.gov/disease-control

4-8: Extreme Cold

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Infectious Disease	3	2	3	2	2	2.25	6.75

*Score = Probability x Average Potential Impact

What constitutes "extreme cold" can vary across different areas of the country based on what the population is accustomed to in their respective climates. Vermont is adapted to cold conditions; however very cold temperatures remain a threat despite their commonality during Vermont winters.

Temperature fluctuations are a result of several meteorological processes.[1] Due to the tilt of Earth's axis, regions of the globe receive varying levels of solar radiation. The delta between these levels produces circulation patterns at the global level, which drive air and storm system movement via air masses. Air masses, as defined by NOAA, are thousands of feet thick and extend across large areas of the earth. Air masses that form over tropical ocean regions will become exceptionally hot and humid, while those masses above high latitude continents will become cool and dry. When these air masses meet, a front is created; fronts can either be cold or warm. In addition to these air mass and front-related impacts humans feel at ground level, movement of narrow bands of strong wind high in the atmosphere, known as jet streams, maneuver weather systems below and transfer heat and moisture across the globe. The speed and intensity of the jet stream will affect the duration and temperature associated with a cold or warm front.

A large area of low pressure and cold air surrounding the poles, known as a polar vortex, is strengthened in the winter (Figure 55). When these polar vortex winds are distorted, due to cyclical strengthening and weakening or interaction with high-amplitude jet stream patterns, they have the potential to split into two or more patterns, allowing artic air to flow southward along a jet stream.[2] As this arctic air is able to access more southerly regions, extreme cold conditions can be observed in Vermont, which also have the potential to remain over the region for extended periods.

The NOAA Wind Chill Chart identifies those temperatures and associated wind speeds that may cause frostbite if skin is exposed to the air over a certain period of time (Figure 56).

In anticipation of extreme cold temperatures, the National Weather Service may issue the following watches, warnings or advisories,[3] which are aimed at informing the general public as well as the agricultural industry:

- **Wind Chill Warning:** Dangerously cold wind chill values are expected or occurring.
- **Wind Chill Watch:** Dangerously cold wind chill values are possible.
- **Wind Chill Advisory:** Seasonably cold wind chill values but not extremely cold values are expected or occurring.
- **Hard Freeze Warning:** Temperatures are expected to drop below 28°F for an extended period of time, killing most types of commercial crops and residential plants.
- **Freeze Warning:** Temperatures are forecasted to go below 32°F for a long period of time, killing some types of commercial crops and residential plants.

1 http://www.noaa.gov/resource-collections/weather-systems-patterns
2 http://climatechange.cornell.edu/what-is-a-polar-vortex/
3 https://www.weather.gov/safety/cold-wind-chill-warning

- **Freeze Watch:** Potential for significant, widespread freezing temperatures within the next 24-36 hours.
- **Frost Advisory:** Areas of frost are expected or occurring, posing a threat to sensitive vegetation.

In the fall, both abrupt cold snaps and record warmth can be observed, where the latter tends to be associated with southerly flow. Similarly, in winter, both extreme cold and record warm conditions occur, which can affect river flow (i.e. ice jam), snow cover, ground insulation and the agricultural industry.

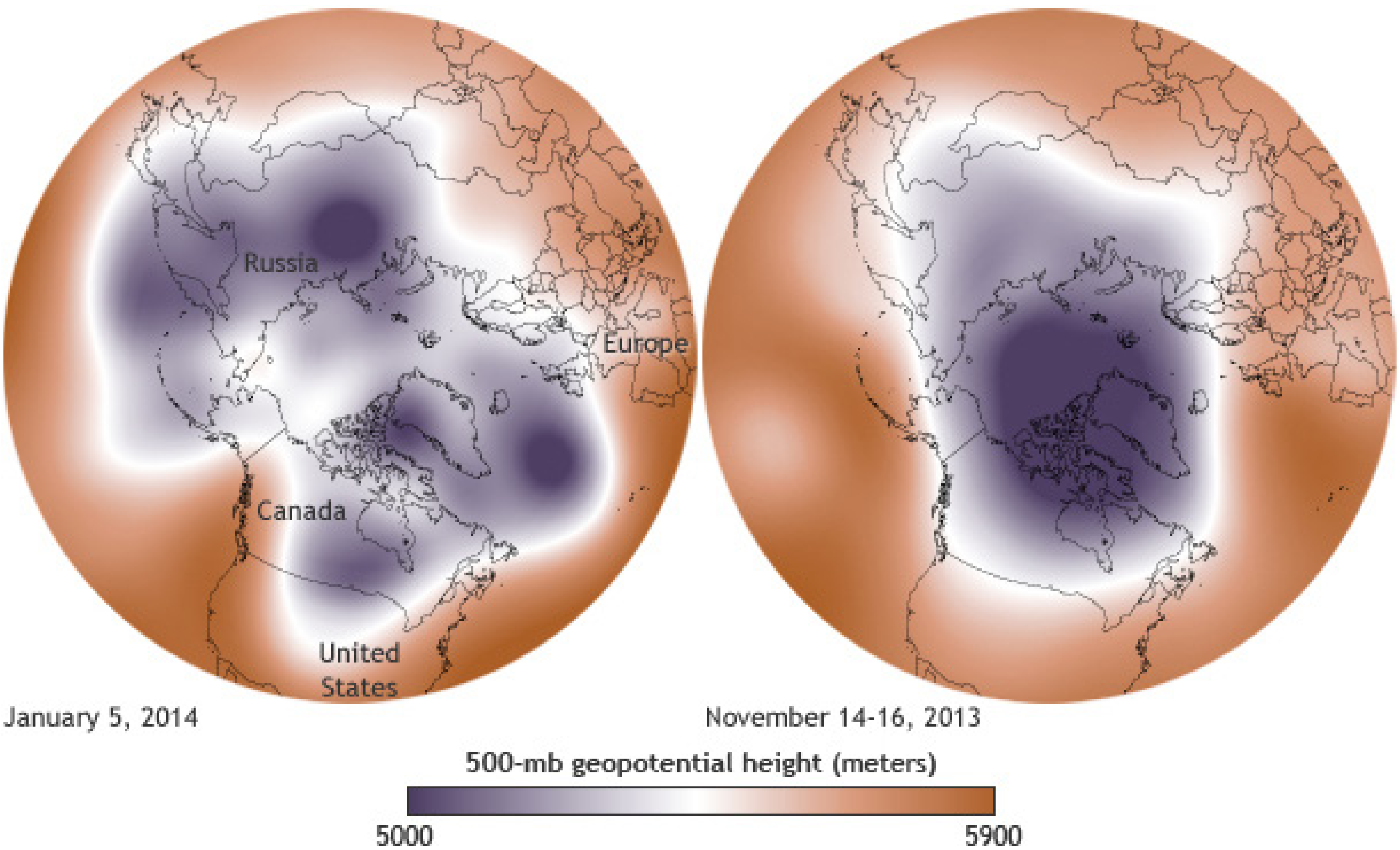

Figure 55: Wavy polar vortex configuration (left) versus more typical, compact configuration (right)
Source: https://www.climate.gov/news-features/event-tracker/wobbly-polar-vortex-triggers-extreme-cold-air-outbreak

Wind Speed (mph)	Temperature (°F)																	
Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes | 10 minutes | 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T = Air Temperature (°F) and V = Wind Speed (mph)

Figure 56: Wind chill temperature index
Source: NOAA

Extreme Cold Location

Vermont is situated in the northern reaches of the continental United States, bordering Quebec, Canada. This northerly location as well as the presence of the Green Mountains can create extreme cold conditions throughout Vermont. However, extreme cold is generally located within the northern counties, namely those in the Northeast Kingdom. Conditions at the high elevations of the Green Mountains are also susceptible to extreme cold. According to the NOAA Storm Events Database, extreme cold events that impacted Vermont throughout the winter of 2022 were heavily concentrated in Northeast and Central Vermont, reinforcing the cold prone areas described.[4]

Extreme Cold History

The winter of 1933–1934 was particularly cold, and the lowest temperature ever recorded for the State (-50°F) occurred at Bloomfield on December 30, 1933. Prior to this, extreme cold temperatures were widespread on January 4 and December 18, 1835, with -40°F at Montpelier and White River, -38°F at Bradford, -30°F at Rutland and -26°F at Burlington. Following the winter of 1933–1934, more than 20% of the apple trees in Vermont were eliminated, although this figure was less than 2% for the Macintosh variety. Temperature is a very important variable in promoting apple growth. The dwarf trees introduced in the 1860s lacked the winter hardiness needed to be truly viable in Vermont. The severe winter of 1917–1918 destroyed almost all of the Baldwin and other strains. Only the Macintosh variety survived, and it remains the dominant strain grown today. In 2001, temperature fluctuations in the spring produced a different loss. Daily maximum temperatures of at least 90°F followed by minimum temperatures near 20°F accelerated the flowering of the apple blossoms, which were then killed by the low nighttime temperatures.

One of the most prolonged cold episodes lasted from January 18 to February 3, 1969. Maximum temperatures were below 0°F. Water mains and other connections froze and burst in record numbers across the State. Since then, extreme cold has been recorded in February 1993 and again on January 19, 1997. In both cases, cold dense air moving out from an Arctic high-pressure system caused temperatures to plummet. Daytime highs in 1993 were 10°F, while the minimums were -5°F. The winter of 1997 holds the record for longest streak of consecutive days below freezing, without a thaw, at 51 days.

More recently, the winter of 2015 maintained below freezing temperatures for 27 days, while the period between December 24, 2017 and January 8, 2018 (or 16 consecutive days) did not exceed 32°F.

Between the winters of 2000 and 2018, the number of recorded days per year with a daily temperature low of less than or equal to 0°F peaked during the 2015 winter at 31 days in Burlington, 44 days in Montpelier, 55 days in Island Pond and 32 days in Bennington.

NOAA storm event history for Vermont includes several extreme cold/wind chill events since 2000, none of which included any deaths, injuries, or recorded damages:

- **January 17, 2000:** A northwest wind averaging between 15-30 mph across southern Vermont, impacting Bennington and Windham Counties, with the addition of temperatures between 0°F to -10°F, produced dangerously low wind chill values of -50°F to -60°F.
- **January 25, 2007:** An arctic cold front moved across Vermont on January 24, delivering very cold

4 https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Extreme+Cold%2FWind+Chill&beginDate_mm=12&beginDate_dd=01&beginDate_yyyy=2021&endDate_mm=12&endDate_dd=31&endDate_yyyy=2022&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=50%2CVERMONT

temperatures of 0°F to -25°F by the following morning. A secondary cold front accounted for the combination of brisk northwest winds of 10-15 mph and temperatures -5°F to -20°F with wind chill readings of -25°F to -40°F across the State. Another arctic front pushed across the area on January 29 and brought early morning low temperatures of -10°F to -30°F.

- **March 6-9, 2007:** An arctic cold front swept across the State March 5 causing temperatures to plummet to -5°F to -20°F by dawn March 6. These frigid temperatures, accompanied by winds of 15-30 mph created dangerously cold wind chills of -20°F to -40°F. Brisk winds with temperatures around 0°F continued through the day. The winds subsided after sunset but it remained extremely cold through the morning of March 7. Arctic high pressure settled across New England March 9 with morning lows of -10°F to -34°F across Vermont.
- **January 14, 2009:** An arctic cold front moved across Vermont which delivered some of the coldest temperatures across the region in several years as temperatures dropped over 20°F within several hours, averaging 20°F to 25°F below normal values, which were already at climatological winter minimums. Nighttime minimums were -10°F to -30°F across Vermont with isolated readings colder than -40°F. These extremely cold temperatures led to numerous cold weather related problems including numerous dead vehicle batteries and broken home/business water pipes.
- **January 23, 2011:** Bitterly cold air settled into the region and temperatures plummeted to -10°F to -25°F below zero across southern Vermont in Bennington and Windham Counties. Brisk westerly winds diminished during the evening, becoming light and variable to calm after midnight, resulting in wind chill readings of -25°F to -35°F.
- **January 8, 2015:** Wind chills colder than -25°F to -40°F were observed overnight January 7, with morning lows of -15°F to -35°F across Vermont, with the coldest temperatures within the southern Green Mountains and observed wind chills in the mountains from -40°F to -70°F. These dangerously cold wind chills lead to delayed school openings of 2 hours or cancelled classes on the morning of January 8.
- **February 15, 2015:** An extremely frigid Arctic air mass pour into the region from the north, beginning during the late morning hours and a strong pressure gradient allowed for very strong winds. Northwest winds frequently gusted over 30 mph, with some gusts as high as 39 mph through the evening. Temperatures fell quickly through the day and dropped below zero for Sunday night into the morning of February 16. Some temperatures were as cold as -20°F with chill values of -20°F to -45°F, predominately in Bennington and Windham Counties. Many towns had warming shelters open and there were reports of bursts water mains and pipes due to the frigid temperatures.
- **February 13, 2016:** Behind an Arctic cold front, very cold temperatures poured into the region upon brisk northwesterly winds, reaching lows of -12°F to -28°F along with winds gusting 20 to 40 mph, wind chill values reached -25°F to -45°F in Bennington and Windham Counties.
- **December 27, 2017-January 1, 2018:** A frigid Arctic air mass poured into the region December 27 with gusty northwesterly winds. Low temperatures fell to as low as -5°F to -14°F with wind chill values as low as -37°F in Bennington and Windham Counties. Temperatures plummeted from -10°F in Windham County to -18°F Bennington County with wind chills ranging from -11°F to -31°F during the early morning hours of New Year's day and dropping to -15°F to -35°F throughout the morning.
- **January 5-7, 2018:** A brutally cold Arctic air rushed southward into Vermont, resulting in an extended period of extremely cold conditions. The coldest wind chills occurred during the mornings of January 6 and 7, when frigid air combined with westerly winds gusting to 30 to 40 mph resulted in widespread wind chills as low as -20°F to -40°F. High temperatures on January 6 were mainly in the single digits above and below zero. Many warming shelters were opened across the Vermont as a result of the cold weather.
- **January 30-31, 2019:** An arctic cold front tracked through southern Vermont during the afternoon of the 30th, accompanied by a heavy snow squall. Frigid air poured in behind this front along with strong

westerly winds. Wind chills the morning of the 31st fell to 15 to 35 degrees below zero.

- **January 28-29, 2021:** A combination of an arctic airmass and gusty winds resulted in dangerously cold wind chills across southern Vermont the night of January 28th into January 29th, 2021. Low temperatures ranged from 11 degrees below zero up to 5 degrees above zero. Wind chill values ranged from 31 degrees below zero up to 3 degrees below zero.
- **January 11-15, 2022:** An Arctic high-pressure system brought dangerously cold temperatures across Vermont, with actual air temperatures of 10 to 15 below over the course of the event. Gusts of 10 to 20 mph delivered wind chills that fell to -15 to -35 degrees over most areas.

Extreme Cold Trends

The Steering Committee considered the probability of a plausibly significant extreme cold event to be Likely, with moderate impacts to people, followed then by minor impacts to the economy, built and natural environment.

According to NOAA Climate Center,[5] annual average temperatures for the contiguous United States from 1895-2020 are increasing at a rate of 0.16°F per decade (Figure 45), an increase from 0.15°F in 2016.[6] Indicating that the probability of extreme cold temperatures in Vermont is decreasing. However, while there is an overall warming trend, there may be an increase in severity of individual winter weather events in some locations. Some climate models show a weakening of the polar vortex, which can cause the artic jet stream to become "wavier" bringing cold temperatures further south than normal. While the science is still emerging, it contributes to the narrative or more weather extremes due to climate change as global climate systems are thrown out of balance.[7]

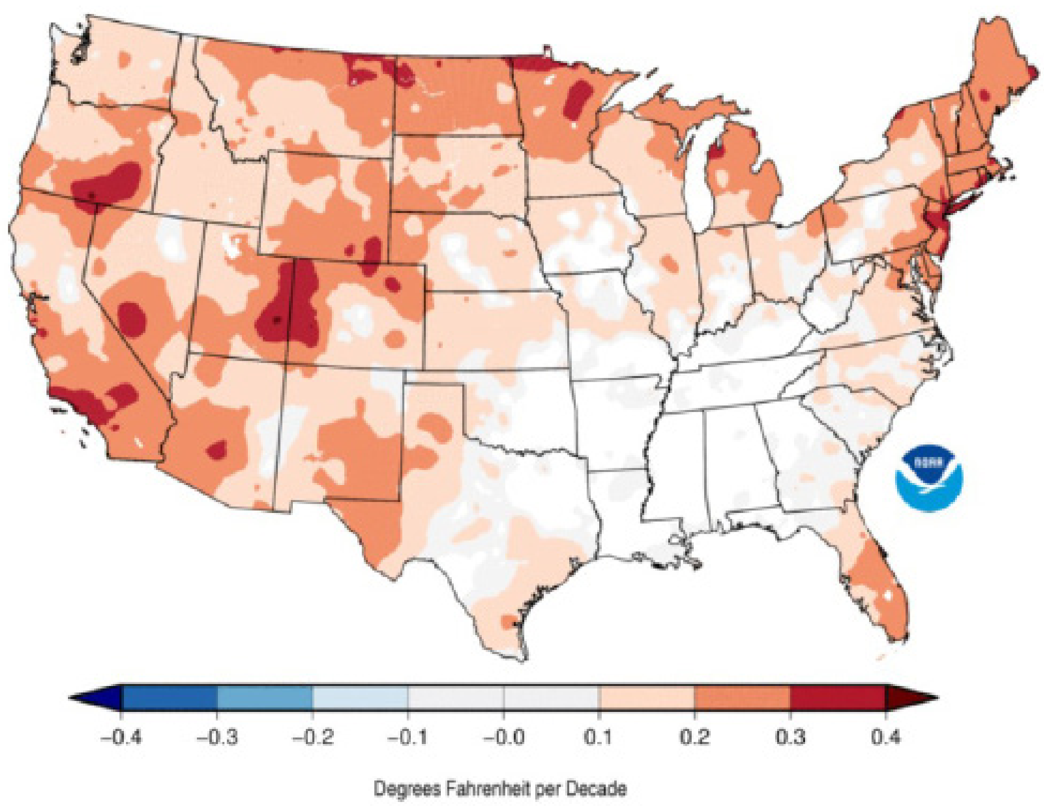

Figure 57: Average mean temperature trends in the U.S. map, February 1895-2020 Per Decade (95% confidence interval)
Source: National Centers for Environmental Information, 5km Gridded Dataset (cGlimGrid)

5 https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/national/time-series/110/tavg/ytd/12/1895-2023?base_prd=true&begbaseyear=1901&endbaseyear=2000&trend=true&trend_base=100&begtrendyear=1895&endtrendyear=2023
6 https://www.epa.gov/climate-indicators/climate-change-indicators-high-and-low-temperatures
7 https://www.noaa.gov/multimedia/infographic/science-behind-polar-vortex-you-might-want-to-put-on-sweater

However, Vermont remains vulnerable to extreme cold temperatures and periods of prolonged cold temperatures, especially in the northeastern portion of the State. This region, colloquially referred to as the Northeast Kingdom, can see temperatures as low as -35°F. Because this area also receives the most snowfall, is the most rural region in the State, and has the oldest average resident age, it is considered to be the most vulnerable to impacts related to extreme cold temperature.

According to the Vermont Department of Health, between 2009 and 2018 there were 4 cold-related deaths (i.e. deaths caused by exposure to cold air or water temperatures), 110 inpatient hospitalizations, and 56 EMS responses.[8] The cold-related deaths figure does not take into consideration deaths by drowning following falls through ice or those deaths related to trauma experienced from slipping on ice. This number also does not consider those deaths resulting from ice-related traffic events.

Climate data confirms that since 1901, the average surface temperature across the contiguous 48 states has risen at an average rate of 0.17°F per decade. Average temperatures have risen more quickly since the late 1970s (0.32 to 0.55°F per decade since 1979). Nine of the top 10 warmest years on record for the contiguous 48 states have occurred since 1998, and 2012 and 2016 were the two warmest years on record.[9] The most significant warming observed in New England was during the winter months.

Extreme Cold Vulnerability

People:

The effects of extreme cold weather events can have severe impacts on Vermont's most marginalized and vulnerable communities. Those most at risk include houseless people, those living alone (especially the elderly), elderly and young populations, as well as individuals who may not be able to afford heating utilities. Each vulnerable population experience unique risks that need to be accounted for. Houseless people being exposed to the frigid conditions directly.[10] Exposure to cold temperatures can cause frostbite or hypothermia and even lead to heart attacks during physically demanding outdoor activities such as snow shoveling or winter hiking. Prolonged exposure to cold temperatures can lead to severe physical and mental damage and potentially death. Elderly and young populations can be at higher risk for cold related illnesses, both children and elderly people lose body heat faster than it can be generated, leaving them vulnerable to hypothermia. For elderly people, a body temperature of 95°F can cause many health problems, such as a heart attack, kidney problems, liver damage, or worse.[11]

Since hypothermia can begin without the person knowing, due to an onset of numbness, it can pose a threat to those who live alone potentially unaware that it is too cold in their house. This goes even further for people who can't afford to properly heat their living space, preventing the home from being properly heated due to economic reasons. Extreme cold weather is often paired with power outages in the region, as a result of stressed-out generators being overloaded or a winter storm knocking out power lines. With buildings closed up tight to prevent heat loss, the risk for carbon monoxide (CO) poisoning is increased. CO is generated by burning fuel including generators, grills, camp stoves, kerosene heaters, or other fuel-burning equipment.[12]

8 https://www.healthvermont.gov/sites/default/files/documents/pdf/ENV_CH_illness-death-due-to-hot-cold-weather.pdf
9 https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-temperature
10 https://www.healthvermont.gov/environment/climate/winter-weather
11 https://www.nia.nih.gov/health/cold-weather-safety-older-adults
12 https://www.healthvermont.gov/environment/climate/winter-weather

It is highly advised that none of the above are operated indoors as well installing an operational CO detector within the house. When temperatures dip below freezing, incidents of icy conditions increase, which can lead to dangerous driving conditions and pedestrian-related slipping hazards. It is recommended that people stay indoors during extreme cold events unless absolutely necessary, and even then, to exercise caution while driving or walking on surfaces that have not been properly salted.

Built Environment:

As stated before, extreme cold weather can put a lot of stress on the electrical infrastructure of a region due to increased usage and weaknesses in aging wires and facilities. The power outages that result can have a widespread impact on the health of human and economic assets that may be at risk without sufficient power or heating. While the national electric grid is often resilient enough to avoid massive outages due to plant failures, it is not impossible. For example, in February of 2021 Texas' ERCOT electric grid failed due to extreme cold knocking gas and coal power plants offline as well as many of the few wind turbines freezing. The cut in supply could not match the increased demand due to heating, generating rolling blackouts across the State.[13] While ERCOT is separate from the National Grid, which Vermont is a part of, it demonstrates that efforts to improve the resiliency of electrical infrastructure is still important for security. Other public utilities are also exposed and at risk due to extreme cold, mainly wastewater and water infrastructure. With temperatures well below freezing, water within pipes can begin to freeze and ice expands potentially causing pipes to burst. This can occur in municipally run water systems, but it is far more common within homes with smaller pipes and stagnant water. It is advised that faucets are left dripping with cabinet and bathroom doors left open to allow warmer air to circulate.[14]

Extreme cold spells can result in the freezing of moisture within the ground and in infrastructure, which can negatively impact road infrastructure (i.e. frost heaves), water lines (i.e. burst pipes from water-ice expansion) and perennial crops that rely on the snow for protection from cold temperatures and winds. Frost heaves and potholes can result in shorter lifespans for many Vermont roadways with frost heaving having the potential to impact the foundations of buildings (typically unheated buildings such as detached garages and sheds).

Natural Environment:

The impacts of extreme cold on the natural environment can be extensive, even if plants and animals in Vermont are more acclimated to cold weather. Deep freezes, especially for extended periods of time, can cause fauna and livestock to freeze to death or seek shelter in warmer areas (mainly human residencies in the instance of mice who may lack snow-cover). An increase human-wildlife interactions can pose a threat to both communities. Plant life is often dormant or cold hardy enough to weather cold temperatures, sustained extreme cold and freezes that happen before trees can prepare can cause the life-sustaining sap within a tree to freeze. Resulting in damaged or trees that have exploded from a rupture.[15] This can become an increasing problem in the future with winters that tend to fluctuate in temperature increasing the chance of a hazardous freeze-thaw cycle. Agricultural businesses can also take a toll from extreme cold, as deep freezes can injury crops with frost damage, decreasing the productivity depending on when in the growing season an event occurs.

Economy:

13 https://www.dallasfed.org/research/economics/2023/0117
14 https://firesafety.vermont.gov/sites/firesafety/files/documents/HOT%20TOPICS%20winter%20storm%20%20.pdf
15 https://www.nationalforests.org/blog/how-do-trees-survive-the-winter

The economic impacts of extreme cold can come from a wide variety of sources, many of which were mentioned in the previous vulnerabilities' sections. Extreme cold can prevent people from going into work for safety reasons, cause damage to the electrical grid, and impact the agricultural operations within the state. With dairy production, maple sugaring, and orcharding being main sources of Vermont food products, extreme cold can negatively impact these industries. In dairy production, cattle are generally cold tolerant and are comfortable down to 20°F. Most cows are managed outside even under extreme conditions and can benefit from extra care when effective temperature (ambient temperature and wind chill) drops below 0°F.[16] Below 0°F cattle can begin to freeze and are at risk of injury or even death. Both maple sugaring and orchards rely on trees to support their industries and as stated before in the Natural Environment section, bitterly cold temperatures can damage trees. Orchards in particular can be prone to damage due to the popular usage of Dwarfing, which have been tested to be less cold hardy than other rootstocks.[17]

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16 https://www.extension.iastate.edu/smallfarms/caring-cows-cold#:~:text=In%20general%20cows%20are%20cold,drops%20below%200%C2%B0F

17 https://waldenheightsnursery.com/soils-plants/dwarf-rootstock-mortality-in-cold-climates/

Climate Change

Vermont is also experiencing a decline in the level of snow cover (Figure 58). During these more frequent, warmer winters, snow, which acts as a protective, insulating layer between the cold air and the ground, is less likely to accumulate and more likely to melt. A loss of snowpack can reduce the albedo, inducing a positive feedback loop of warming. As more solar radiation is absorbed by the environment rather than being reflected.

Vermont's rivers and lakes are impacted from fluctuating periods of warmth and extreme cold. The continued freeze-melt-freeze cycle on rivers leads to increased ice accumulation, which can then be broken into large sheets of mobile ice during the next period of warming. This phenomenon is called ice jamming, which often results in flooding (see: Inundation Flooding & Fluvial Erosion).

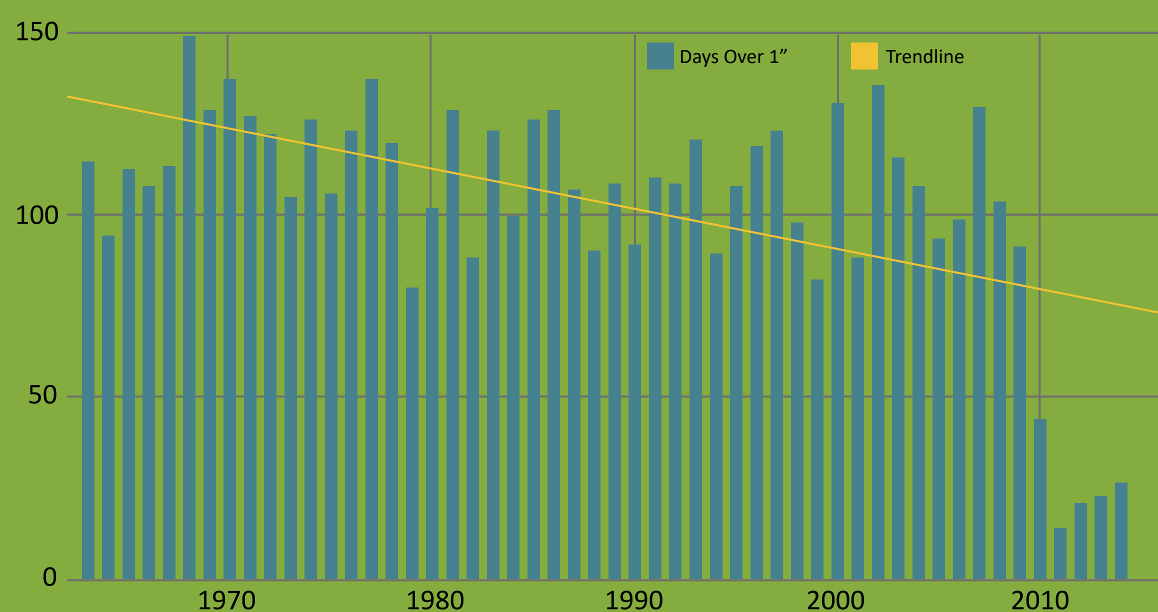


Figure 58: Number of days in Vermont with greater than 1-Inch snow cover (1960-2015)
Data Source: http://climatechange.vermont.gov

Ice fishing is a popular winter sport in Vermont, with Lake Champlain and smaller lakes throughout the state providing ample opportunities to fish. However, warming winter temperatures have reduced the thickness of the ice as well as the time spent frozen. For example, Lake Champlain hasn't frozen over in January since 2004 and March of 2019 was the last time the lake had completely frozen over20. These conditions threaten ice-based winter recreation such as ice fishing. In February of 2023, three fishermen fell through the on Lake Champlain and died, leading to cancelation of the ice fishing derby due to safety concerns.

As winter conditions warm, there is a greater chance of temperatures rising and falling around the freezing point, leading to more freeze thaw events. Events like this can have major transportation impacts including more potholes and frost heaving that leads to broken and fractured roads. Frost heaves can also impact the structural integrity of bridges and building foundations as the ground shifts, forcing parts of the foundation to move upwards while others do not. Ice dams can also form more frequently on rooftops since daily temperature fluctuations allow snow to melt during the day and refreeze at night. After several days of this freeze-thaw cycle the melted water can work its way up through the shingles and into the attic, causing water damage and occasionally roof collapse.

The occurrence of deep cold spells is not necessarily a negative for every species. Extreme cold is an often necessary process to prevent certain insect pest species from overwintering and developing a resistance to pesticides through increased overwintering survival, increased number of generations, increased risk of invasive insect species and insect-transmitted plant diseases, as well as changes in their interaction with host plants and natural enemies. This can have disastrous effects on agricultural operations and forest ecosystems that rely on winter as a part of their natural pest management strategy.[18] An increase in the number of insect generations afforded by overwintering can increase the potential for pesticide resistance. A decline in extreme cold spells can also increase the prevalence of insect species such as ticks that can make human interactions with nature more hazardous. Ticks with Lyme disease are typically not found in those same areas that are most prone to extreme cold, high elevation areas and northeast Vermont. As the climate warms, these areas become less exposed to extreme cold. Meaning that these areas will increasingly become suitable habitat for ticks, increasing their prevalence in the region and increasing their populations in areas that already have them.[19] Mice often act as hosts for ticks, and if conditions get warmer and the mouse population is not kept at bay. There can be an increase in the tick presence in those areas as well. However, this is also a double-edged sword as increasing temperatures decrease the available snowpack, which can put mice at risk of freezing should an extreme cold event occur.

18 https://doi.org/10.3390/insects12050440

19 https://www.healthvermont.gov/sites/default/files/documents/pdf/ENV_CH_TickborneDiseasesReport.pdf

Extreme Cold Current Capabilities & Mitigation

Because extreme cold temperatures often occur in tandem with winter storms (see: Snow Storms & Ice Storms) or lead to ice jam flooding (see: Inundation & Fluvial Erosion), residents who lose power during Vermont's coldest months need warm shelters where they can be protected from harsh conditions and reduce the potential for health-related impacts of exposure to cold temperatures, such as hypothermia or frostbite.

Several strategies in this Plan (see: Mitigation Strategy) aimed at increasing public knowledge about hazards and mitigation, supporting vulnerable populations and coordinating hazard mitigation mapping must consider extreme cold and exposure to prolonged cold weather events during implementation. In order to address the dangers of at-risk populations freezing in their homes, an action was developed to complete a review of nationwide building codes (to include residential and energy codes) to determine what codes could be best suited to Vermont, including standards for new construction and best practices for existing buildings for weatherization and retrofits and integration into existing Vermont codes. This study is to include impacts to frontline communities. Additionally, an action to evaluate methods for resilient construction standards of manufactured housing that maintain affordability for low- and moderate-income residents was prioritized in the Mitigation Strategy.

4-9: Invasive Species

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	**Average:**	
Invasive Species	3	2	1	3	3	2.25	6.75

*Score = Probability x Average Potential Impact

The National Invasive Species Council defines an invasive species as one that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Invasive species can overwhelm native species and their habitats, forcing the native species out. They are considered to pose the second greatest threat to biodiversity globally. Invasive plants in Vermont, such as Japanese knotweed, common reed (Phragmites), and purple loosestrife, and garlic mustard can change soil composition, change water tables, and disrupt insect cycles. They often lack food value upon which wildlife depends. Some invasive animals prey heavily upon native species while others, such as the alewife and zebra mussel, out-compete native species for food and nutrients with significant impacts reverberating up and down food chains.

The spread of invasive species is primarily caused by human activity. Common examples include[1]:

- **Ships:** Can carry aquatic organisms in their ballast water or on the hull.
- **Wood Products:** Insects can get into wood, shipping palettes, and crates that are shipped around the world as well as travel in firewood.
- **Ornamental Plants:** Some ornamental plants can escape into the wild and become invasive.
- **Pet Trade:** Some invasive species start as pets that are intentionally or accidentally released.

The Nature Conservancy reports that invasive species have contributed directly to the decline of 42% of the threatened and endangered species in the United States. Further, the annual cost to the U.S. economy is estimated at $120 billion per year, with more than 100 million acres suffering from invasive plant infestation.[2] Freshwater ecosystems and estuaries are especially vulnerable to invasion, as these areas are very difficult to contain and reverse.[3] In Vermont specifically, examples of economic impacts of invasive species can be observed in the costs of managing invasive water chestnut in Lake Champlain[4] and payments to private landowners to improve tree regeneration and wildlife habitat by controlling buckthorn and honeysuckle in forests.[5] Additionally, water pipes in Lake Champlain must now be cleaned out regularly to rid them of invasive zebra mussels.

Water chestnuts reproduce rapidly in nutrient-rich and slow-moving waters, making Lake Champlain a hotspot for these invasives.[6] They can cause severe damage to the surrounding aquatic ecosystem it inhabits by limiting nutrients, crowding out native species, and lowering the dissolved oxygen concentration. Early detection of these plants is crucial due to their prolific nature, and they should be removed from the area quickly before

1 https://www.vtinvasives.org/intro-to-invasives/what-are-invasive-species
2 https://www.nature.org/en-us/about-us/where-we-work/united-states/ohio/stories-in-ohio/invasive-species-protecting-native-plants-and-animals/
3 https://www.nature.org/ourinitiatives/urgentissues/land-conservation/forests/invasives-101.xml
4 http://dec.vermont.gov/sites/dec/files/wsm/lakes/ans/docs/2016VTWCFinalReport.pdf
5 https://efotg.sc.egov.usda.gov/api/CPSFile/29237/314_VT_OTH_Brush_Management_Landowner_Acknowledgement_2020
6 https://vtfishandwildlife.com/learn-more/landowner-resources/liep-invasive-species-program/aquatic-invasive-plants/water-chestnut

they germinate.[7] Total removal can take anywhere from five to twelve years by hand or mechanically, which comes at high cost to Vermont's economy. Early detection might lower removal time and thus lower total costs, so taxpayer dollars could be put towards other state agencies.

Buckthorn and honeysuckle crowd out native Vermont species, increasing competition for nutrients and sunlight. Honeysuckle was introduced in the area to tackle erosion and wildfire, by decreasing the wildland-urban interface, but began to reproduce rapidly and take over parts of Vermont.[8] Buckthorn operates similarly, growing leaves at a faster rate than other native plants and effectively dominating the amount of available sunlight. Aside from depleting sunlight and nutrients in the area, buckthorn can act as a host for crown rust fungus and Asian soybean aphid, which can damage soybean and oat production.[9] Hand-pulling and chemical treatment are options to remove populations of buckthorn and honeysuckle, but sometimes the responsibility lies with private landowners. If populations aren't detected early by private landowners, both plants could reproduce quickly and spread to areas across the state of Vermont affecting forest health.

Another species that has negatively impacted aquatic ecosystems in Vermont is the zebra mussel. Zebra mussels, much like many other invasives, reproduce quickly and can cover the entirety of lake bottoms. Such a process limits the amount of sunlight and nutrients that can be received by organisms residing at lake bottoms, leading to an increase in mortality. They are also known to filter out key nutrients from the lakes they reside in, which limits resources that native species rely on. Due to how microscopic the larvae are, the species is very difficult to remove entirely, so it is crucial that steps are taken to prevent further spread and overpopulation.[10] In order to prevent further spread, as mentioned above, water pipes must be monitored and cleaned out regularly, which is a costly but necessary precaution to protect native species.

Invasive pests such as Emerald Ash Borer (EAB), first found in Vermont in 2018, have serious financial implications for forest landowners and municipalities alike. EAB feeds on ash trees in Vermont, deeply damaging each tree and hindering its ability to move carbohydrates and water resources as necessary.[11] Infected trees will die between three and five years after the introduction of EAB. Productive timber is destroyed by EAB and trees along roads become hazards as they die and pulldown powerlines. Preventative measures are crucial to prevent the further spread of these insects and protect native ash populations, such as traps, which will be further discussed below under Invasive Species Mitigation.

Additionally, invasive species can directly or indirectly cause harm to human health. Giant hogweed, wild parsnip and wild chervil are three invasive plant species in Vermont that have phytophototoxic properties, meaning direct contact of their sap with human skin can cause a chemical reaction that makes skin hypersensitive to ultraviolet light. Vermonters have received serious skin burns from the toxicity of the sap of these plants combined with exposure to sunlight. Another example is that of Japanese barberry, which has been proven to increase the incidence of Lyme disease by providing sheltered habitat that increases the abundance of small rodents, which act as hosts to the ticks that carry Lyme disease pathogens.[12]

7 https://vtfishandwildlife.com/learn-more/landowner-resources/liep-invasive-species-program/aquatic-invasive-plants/water-chestnut
8 https://www.vtinvasives.org/invasive/honeysuckles-shrub
9 https://vtfishandwildlife.com/learn-more/landowner-resources/liep-invasive-species-program/terrestrial-invasive-plants/common-buckthorn
10 https://vtfishandwildlife.com/learn-more/landowner-resources/liep-invasive-species-program/aquatic-invasive-animals/zebra-mussels
11 https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Forest_Health/Library/EAB%20Landowner%20FAQs.pdf
12 https://mnfi.anr.msu.edu/invasive-species/JapaneseBarberryBCP.pdf

Invasive Terrestrial Plants & Forest Pests:

Vermont's Agency of Agricultural, Food and Markets (VAAFM) maintains a list of invasive plants and regulates their importation, movement, sale, possession, cultivation and distribution[13] based on the following categories:

- **Noxious Weed:** any plant in any stage of development, including all current and subsequent subspecies, varieties, and cultivars, and parasitic plants whose presence, whether direct or indirect, is detrimental to the environment, crops or other desirable plants, livestock, land, or other property, or is injurious to the public health or the economy generally.
- **Class A Noxious Weed:** any noxious weed that is not native to the State, not currently known to occur in the State on the date of listing, and poses a serious threat to the State.
- **Class B Noxious Weed:** any noxious weed that is not native to the State, is of limited distribution statewide, and poses a serious threat to the State, or any other designated noxious weed being managed to reduce its occurrence and impact in the State, including those on the Federal Noxious Weed List[14].

The State also maintains a watch list,[15] updated regularly, of non-native plants that have the potential to become invasive in Vermont based on their behavior in northeastern states. One-third of the plant species found in Vermont are not native to the State, but only about 8% have the potential to create environmental and economic harm due to their ability to grow rapidly, profusely, and widely. These are the plant species monitored on the watch list, which acts as a resource for public information and to enlist volunteers to monitor potentially harmful plants in Vermont, although it has no regulatory force.

Vermont's Department of Forests, Parks and Recreation (FPR) is responsible for survey, detection, and management of forest pests in Vermont.[16] Additionally, the Vermont Invasives Gallery of Land Invasives is a resource for identification of invasive plants and forest pests.[17]

Aquatic Invasive Species (AIS):

13 https://agriculture.vermont.gov/public-health-agricultural-resource-management-division/plant-health-and-pest-management/plant-2
14 https://www.law.cornell.edu/cfr/text/7/360.200
15 https://fpr.vermont.gov/forest/forest-health/invasive-plants
16 https://fpr.vermont.gov/forest/forest-health/pests-and-other-causes-damage
17 https://www.vtinvasives.org/gallery-of-land-invasives

Adult Emerald Ash Borer and the results of larvae burrowing through the bark of an Ash tree.
Source: https://www.nature.org/ourinitiatives/urgentissues/land-conservation/forests/interactive-media-emerald-ash-borer-slideshow.xml

The Department of Environmental Conservation (DEC) has a Vermont Aquatic Invasive Species Program that coordinates management activities associated with both aquatic invasive and nuisance species. The AIS webpage has information about the types of AIS, monitoring, spread prevention, grant opportunities and laws and regulations relating to AIS.[18] The Vermont AIS Program has identified twelve high-priority invasive and nuisance species affecting the State and issues informational pamphlets in an attempt to prevent their proliferation.

Invasive Species Location

Invasive species are commonly introduced via travel routes, accidentally brought into Vermont with the transportation of people and goods, such as ship ballast water, firewood, shipping palettes, and crates.[19] The presence of cold Vermont winters has historically been key in keeping more southern plant and insect species from colonizing Vermont. However, as winters in Vermont become increasingly milder the ability for invasive species to overwinter and reproduce in Vermont increases. This can already be seen in the changes in distribution of Hemlock Woolly Adelgid, which has overwintered in southern Vermont counties allowing the spread of the invasive pest to continue.[20] Distribution of invasive species throughout Vermont is generally dependent on the species in question, but due to the human connection to their introduction they are often first found in close proximity to human development.

Invasive Species History

Because invasive species often spread over a long period of time, identification of a hazard event concerning invasive species is rather difficult. Vermont, like much of the eastern United States, has long been susceptible to invasive species brought from overseas – whether they were plants intentionally transported or organisms clinging to vessels.[21] The State has a long history of invasive species infestation at the aquatic (e.g. water chestnut), terrestrial (e.g. Japanese knotweed) and forest pest (e.g. Emerald ash borer) levels.

- Most notably, the emerald ash borer, first discovered in Michigan in 2002, has spread to 30 states and three Canadian provinces and was reported and confirmed to be in Vermont in 2017.
- The hemlock wolly adelgid was first discovered on native trees in Vermont for the first time in 2007. It was first introduced to the United States in the 1920s, making its way into Vermont territory 87 years later.[22]
- The zebra mussel was discovered in Lake Champlain in the summer of 1993. This discovery came shortly after the first zebra mussel was discovered in North America in the state of Michigan in the summer of 1988.[23]
- Common buckthorn was likely introduced to the state of Vermont sometime during the mid 20th century. It was brought to North America from Europe, likely for ornamental uses.[24]
- The water chestnut, which spreads rapidly across lakes and ponds, preventing recreation and choking out sunlight from native aquatic species, has been actively managed since 1982.
- Honeysuckle was introduced to North America sometime in the 1800s and has spread to many states

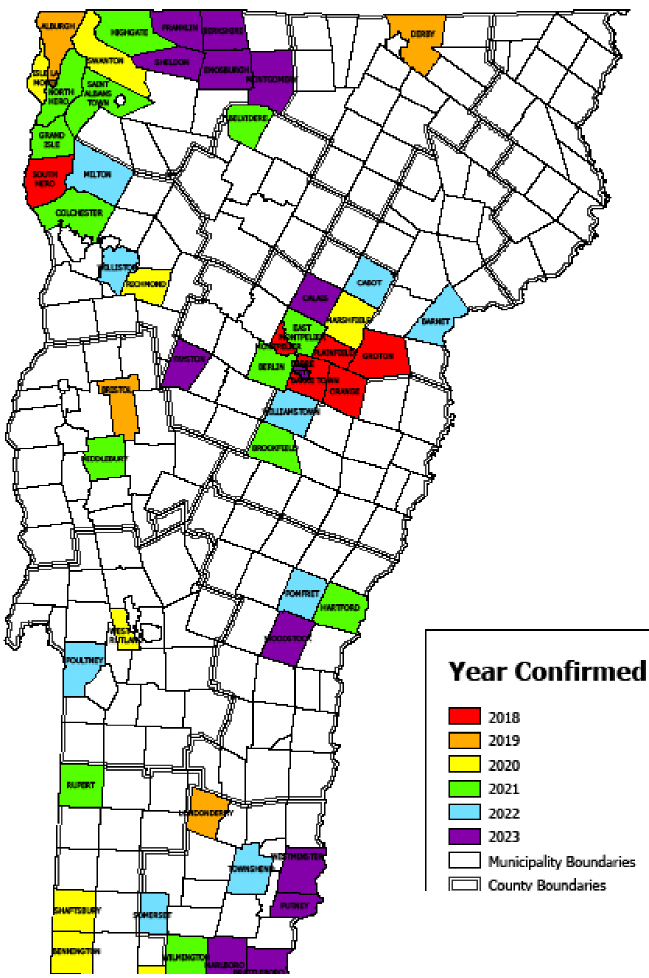
18 http://dec.vermont.gov/watershed/lakes-ponds/aquatic-invasives
19 https://www.invasivespeciesinfo.gov/what-are-invasive-species
20 https://vtinvasives.org/news-events/news/summer-2017-vermont-hemlock-woolly-adelgid-update
21 https://docs.google.com/spreadsheets/d/123tCXdNH8yhZ_A7obICfLzAtBos6kBy2qZCmrFDtO_o/edit#gid=0
22 https://vtinvasives.org/invasive/hemlock-woolly-adelgid
23 https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/bb-17.pdf
24 https://www.vtinvasives.org/news-events/news/spotlight-common-buckthorn

including Vermont since then.[25] It was introduced for erosion and wildfire control but has since increased competition among native vegetation for sunlight and other natural resources.

- Japanese knotweed, an invasive plant that spreads by sprouting from broken plant rhizomes, was introduced into the United States in the 1800s and has been established in New England ever since.

Invasive Species Trends

Native forests and ecosystems are projected to experience negative impacts of these warming trends, as well.[26] With 76% of the Vermont landscape covered by forest, and more than 50 tree species, increases in average annual temperatures will force these species to adapt. Potential impacts on forests include increased stress on native tree species, shifts in forest composition due to a climate more suitable for southern species, and the potential for isolated species having a reduced ability to migrate and respond to climate change.[27] Of particular concern are the Asian longhorned beetle (not yet found in Vermont), emerald ash borer and hemlock wolly adelgid, which have killed millions of trees across the U.S. and Canada.



In 2017, the first reported cases of the emerald ash borer (EAB) occurred in Vermont in Orange, Washington and Caledonia Counties.[28] Emerald ash borer larvae burrow through the inner layer of the ash tree's bark, impeding the tree's ability to conduct water and nutrients throughout the tree.[29] Lacking sufficient water and nutrients, healthy ash trees can die within 1-4 years of exhibiting first signs or symptoms of ash borer invasion and, because 5% of Vermont's trees are ash, the State's forest composition is extremely vulnerable to this invasive species. It is estimated that the majority of ash trees infested with the emerald ash borer will die, causing public hazards from standing dead trees that may impact structures and infrastructure, as well as add to riverine debris during high precipitation events (see: Inundation Flooding & Fluvial Erosion). Since 2017, the extent of EAB invasion in Vermont as spread to 46 municipalities (Figure 59) and every county with the exception of Essex.[30] General trends show that EAB is spreading throughout the state and can endanger Vermont's entire ash tree population.

Figure 59: Confirmed locations of Emerald Ash Borer in Vermont map
Source: Center for Geographic Information

25 https://www.fs.usda.gov/database/feis/plants/vine/lonjap/all.html
26 http://climatechange.vermont.gov/sites/climate/files/documents/Data/VTCCAdaptForestry.pdf
27 https://fpr.vermont.gov/forest/climate-change
28 https://www.vtinvasives.org/land/emerald-ash-borer-vermont
29 https://www.arborday.org/trees/health/pests/emerald-ash-borer.cfm
30 https://www.vtinvasives.org/sites/default/files/images/CL01252023.pdf

Hemlock woolly adelgid is an invasive pest that feeds on hemlock trees, first discovered in Vermont in 2007 and primarily located in the southern counties including Bennington, Windham, and Windsor.[31] Due to our harsh winters in Vermont, hemlock woolly adelgid has not caused significant mortality among hemlocks; however, south of Vermont where winters are milder the species' impacts are a significant concern. Based on Vermont's trend of increasing temperature (see: Extreme Heat), this invasive is expected to be a much more significant concern in the future. In the winter of 2016-2017, a significant portion of the hemlock woolly adelgids were able to survive the winter, which was not the case in the previous three winters.[32]

In addition to concerns over Vermont's ash population, northern hardwood species like maple, yellow birch and American beech are anticipated to be nearly eliminated in the State, replaced by those tree species that thrive in warmer, drier conditions, like oak and pine. Additionally, the changing climate will allow for greater survival and reproduction of forest pest species, as trees that are stressed due to lower water availability reduce their ability to maintain sufficient defense mechanisms, making them more vulnerable to pest invasion and disease. As trees die at an increasing rate, concerns regarding wildfire susceptibility also rise (see: Wildfire).

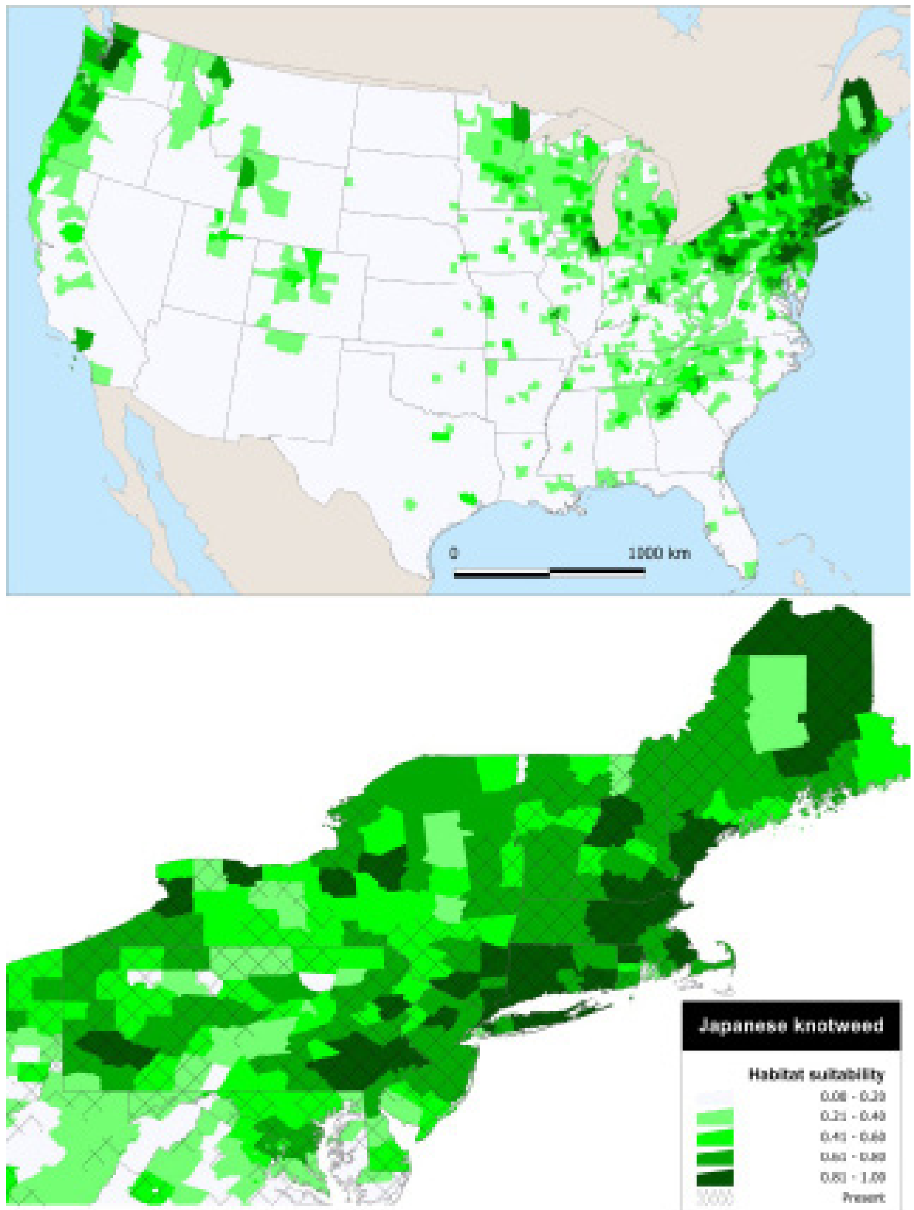


Figure 60: Model Predictions of Habitat Suitability - Japanese Knotweed
Source: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0001635

Along the State's riverbanks, Japanese knotweed continues to spread uncontrollably, negatively affecting native insect populations, and therefore birds, fish and mammals, that rely on those insects as a food source. With shallow root systems, the spread of Japanese knotweed significantly reduces streambank stability, thereby exacerbating fluvial erosion (see: Inundation Flooding & Fluvial Erosion). Road maintenance efforts near ditches infested by Japanese knotweed allow for quick spread of the knotweed's rhizomes and stems. While Japanese knotweed is already prevalent in Vermont, figure 60 illustrates the area of potential spread based on habitat suitability.

31 http://hiro.ento.vt.edu/hwa/wp-content/uploads/2023/02/HWAdistribution2022.pdf
32 https://vtinvasives.org/news-events/news/summer-2017-vermont-hemlock-woolly-adelgid-update

The Steering Committee considered the probability of a plausibly significant extreme invasive species event to be Likely, with major impacts to the economy and natural environment, followed then by minor impacts to the built environment and negligible impacts to people.

Climate Change

As Vermont's climate continues to change throughout the 21st century invasive plants continue to expand their range as conditions become more suitable for them while native species become stressed as they are pushed towards the edges of their habitat range. This stress is not limited to natural ecosystems as increasing global temperatures will put added stress on agricultural systems leading to a decline in yield coupled with a decline in resilience to disturbances or invasive pests that can decimate populations. Changing climate can create greater pest resistance to herbicide and pesticides with a greater chance of species adaptation. Increasing global temperatures will also stress out native species, leaving them more susceptible to out-competition by better adapted invasives.

Warming temperatures and an increase in mild winters (see: Extreme Cold) can allow insect borne diseases greater access to Vermont with increased chances of overwintering. These introductions may not be invasive, but it is a shift in species distribution and range that could threaten human health in the state. As the global climate continues to shift at a rapid rate, species better adapted for warmer climates will continue to proliferate, with changes in ecosystem composition threatening to destabilize basic ecosystem functions. Costs associated with the disturbances invasives cause will continue to mount, with mitigation costs also rising as it becomes increasingly difficult to manage for abundant pests with no major predator.

Invasive Species Trends Vulnerability

People:

Invasive species can pose a risk to people by acting as vectors for disease as well as introducing new diseases to unprepared populations. Invasive plant life can also increase the incidence of insect borne disease by providing appropriate habitat for carriers, such as ticks (see: Infectious Disease). For those species that have been investigated, several invasive plant species such as Japanese honeysuckle and barberry have been shown to harbor and enhance tick, host, and pathogen populations by enhancing microhabitat and survival. Additionally, non-native tick species such as Asian longhorn tick have been introduced and potentially new invasive tick-borne pathogens or hosts can, and likely will, be introduced in the future.[33]

Invasive species such as the Asian Lady Beetle (Harmonia axyridis), which present similarly to native ladybug species, has been documented to enter structures and homes in search of overwintering sites. Typically, they will fly to buildings during autumn and congregate in large numbers in these structures. While many insects that attempt to overwinter within homes pose little harm to humans, they can act as a nuisance the beetles emit an acrid odor and can stain surfaces with their yellowish secretions when disturbed.[34] Many other invasive insects have managed to find their way into homes and other heated structures to survive the winter.

33 https://www.doi.gov/sites/doi.gov/files/uploads/tick-borne_disease_white_paper.pdf
34 http://entomology.ca.uky.edu/ef416

As invasive species impact the biodiversity and productivity of landscapes across Vermont, food security can become an issue. If invasives consume or out-compete native or crop species, that can lead to a decline in yield for farms across the State. Species such as the Emerald Ash Borer (EAB) can impact the health of forest stands such as ash, which can result in forests comprising of standing dead trees that have the potential to fall or drop branches that can harm workers of recreationalists below. The vast distribution of ash populations around the state can increase the chance that individual properties have ash that may eventually be impacted, increasing the vulnerability of homeowners and their properties from dead snags of ash. Many invasive species trace their origins as ornamental species that were introduced to America for gardens and other decorative purposes but made their way.[35]

Built Environment:

With exponentially increasing connectivity ever since the age of exploration to globalization, human made vectors have been a primary source of invasive species transportation from continent to continent. Since the human built environment is often the first thing impacted by an invasive species during transportation, invasives have had a long history of impacts to the built environment. The United States currently lacks the comprehensive authority necessary to effectively prevent, eradicate, and control invasive species that impact the human-built environment. This prevents rapid response to some of the most damaging invasive species. Invasive species can impact different sectors of the built environment including power systems, water systems, transportation systems, and building systems.[36]

Power systems, such as hydroelectric dams, power plants, and transmission lines, can become compromised through the introduction of invasives. Invasives can work their way into critical portions of infrastructure where systems can become blocked or weakened by the invasive. Invasives can have an indirect impact on these systems.

For example, EAB targets all species of North American ash including green ash (Fraxinus pennslyvanica) and white ash (Fraxinus americana) and as a result EAB can girdle a tree within 2 years through the feeding patterns of its larvae which is planted inside the trunk. This can lead to ash stand mortality within 5 years.[37] Such a drastic decline in a species can cause snags (dead trees still standing) to fall and interfere with transmission lines or on homes and other buildings, posing a threat to homeowners with ash trees on their property. Water systems such as dams, irrigation networks, levees, and hatcheries are also under threat through the introduction of species that weaken structures as well invasives that can introduce disease or harm aquaculture operations. Transportation systems such as roads, navigation channels, airfields, and lock chambers can be subject to increased maintenance and repairs to ensure proper functionality as invasives work their way into the infrastructure. The structural integrity of buildings is also a cause for concern.[38] Invasives can be a threat to the operational capacity of many critical built systems if not managed properly.

One species of important note is Japanese knotweed,[39] originally an ornamental plant introduced into the US from Europe in the 1800s. It can establish new colonies from a small piece of root or stem and can spread when contaminated soil is transported. It grows extremely fast, is incredibly persistent, and hard to eradicate. The species is commonly found along waterways and thrives well in wet environments. And as

35 https://www.cambridge.org/core/journals/invasive-plant-science-and-management/article/abs/identifying-highimpact-invasive-plants-likely-to-shift-into-northern-new-england-with-climate-change/3283EBFF2D0857A40C172F05786A8FD6
36 https://www.doi.gov/sites/doi.gov/files/uploads/invasive_species_impacts_on_federal_infrastructure.pdf
37 https://doi.org/10.1007/s10530-012-0341-7
38 https://www.doi.gov/sites/doi.gov/files/uploads/invasive_species_impacts_on_federal_infrastructure.pdf
39 https://vtinvasives.org/sites/default/files/fact-sheets/KnotweedFactSheet_2019.pdf

result of the impacts of Tropical Storm Irene in Vermont, Japanese knotweed became incredibly prevalent, traveling downstream during flooding creating new colonies throughout the state. This species increases the susceptibility of erosion where present by creating dense thickets that outcompete native species, leaving the soil beneath bare, threatening riverbanks. Japanese
Knotweed stands reduce species diversity, alter natural ecosystems, and negatively impact wildlife habitat. In addition to these ecological impacts, it can have economic impacts by its ability to grow through pavement and damage infrastructure.

Natural Environment:

Invasive species are considered invasive due to their ability to outcompete native species in their natural environments without the threat of a predator that can keep their populations in check. This allows invasive populations to run rampant and devastate local ecosystems. Impacts to the natural environment include habitat loss, where invasive species displace native species resulting in local extinction of species and a decline in biodiversity.[40] A decline in biodiversity often leads to a decline in the resilience of an ecosystem in the event of major disturbances. New species often lack a predator which gives them an advantage over native species while competing for limited resources.

Alteration to the local ecosystems and habitats can have ripple effects that impact many other facets of life. Indirect impacts of an invading species are an important component of its overall environmental impacts. Changes in species composition was equally important as a driver of indirect effects. Successful management of invasive species is likely to require not only control of the invader but also restoration of diverse native species, as they are important for many ecosystem functions. This highlights the importance of biodiversity as a driver of ecosystem functioning also in real-world systems, this will reduce costs in the long-run.[41]

Economy:

The economic and social impacts of invasive species include both direct effects of a species on property values, agricultural productivity, public utility operations, native fisheries, tourism, and outdoor recreation, as well as costs associated with invasive species control efforts. A 2021 study estimated that invasive species have cost North America $2 billion per year in the early 1960s to over $26 billion per year since 2010.[42] Invasive species cumulatively (from 1960–2017) cost the agriculture and forestry sectors US$ 527.07 billion and US$ 34.93 billion, respectively. Impacting the productivity of these economic sectors and adding costs that some businesses cannot absorb.

Certain invasives such as the zebra mussel, that originated from shipping businesses with uncleaned hulls, can cut of energy to economic activities within cities by clogging intake pipes for power generation and water treatment facilities. Sea lampreys can reduce the populations of commercially significant fish species through predation without a natural predator to keep them in check.[43] Asian lady beetles are also becoming a concern of the wine industry. Due to their noxious odor, even small numbers of beetles inadvertently processed along with grapes can taint the flavor of wine.[44]

40 https://oceanservice.noaa.gov/facts/invasive.html
41 https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2745.13268
42 https://neobiota.pensoft.net/article/58038/
43 https://www.andersoneconomicgroup.com/Portals/0/upload/AEG%20-%20AIS%20Impact_%209-20-2016%20Public%20new.pdf
44 http://entomology.ca.uky.edu/ef416

Invasive Species Current Capabilities & Mitigation

The Vermont Invasives website maintains a crowd-sourced invasive species map that allows users to upload locations and photos of invasive species, which acts as an aid in determining spread rate and control measures across the State.[45] This comprehensive website also includes information on all of the significant invasive species affecting Vermont, including identification, treatment and prevention measures. The Lake Champlain Basin Program also has information regarding the aquatic invasive species threatening the Lake Champlain Basin and how to prevent their spread.[46]

Additionally, Vermont joined the United States Department of Agriculture (USDA)'s 31-state quarantine boundary, aimed at reducing the movement of emerald ash borer-infested ash wood to un-infested regions outside of Vermont's borders.[47] The February 2018 State of Vermont Action Plan for the Emerald Ash Borer identifies the Agency of Agriculture, Foods and Markets and the Department of Forests, Parks and Recreation as the lead agencies responsible for developing a means by which the emerald ash borer can be quickly detected/identified and managed. The intent of the Action Plan is to establish effective lines of communication between pertinent State agencies and to clearly identify the roles and responsibilities of each agency in preventing the spread of the emerald ash borer across Vermont.[48]

A new mitigation strategy against EAB was implemented in the spring and fall of 2021, in the category of biocontrol. 2,600 pupae and adult wasps belonging to the species Tetrastichus plannipenisi, Oobius agrili, and Spathius galinae were introduced into Vermont ecosystems in an attempt to control the population of the Emerald Ash Borer. These wasps are parasitic, and lay eggs within the bodies of EAB, which kills the beetles and thus protects native ash trees in Vermont. Oobius agrili and Spathius galinae lay their eggs within EAB eggs and can withstand the cold temperatures known to the Vermont area, making them more efficient biocontrol species than the Tetrastichus plannipenisi.[49] Throughout 2023, foresters plan to monitor the wasp species' survival rates in order to properly identify the effectiveness of this mitigation strategy.

Given the compounding impacts invasive species have on other hazard impacts addressed in this Plan (see: Inundation Flooding & Fluvial Erosion and Wildfire), several of the high priority actions regarding hazard mapping and data sharing are pertinent to invasive species mitigation. Also, as the climate models project increases in both temperature and precipitation, it is anticipated that invasive species infestation in Vermont will continue to grow and, as such, the State's efforts concerning education and outreach of the hazards associated with invasive species need to be bolstered in the years to come. Accordingly, an action to support the education of the general public around invasive species and their role in altering the beneficial functions of natural ecosystems was developed (see: Mitigation Strategy).

45 http://www.inaturalist.org/projects/mapping-for-healthy-forests-vermont
46 http://www.lcbp.org/water-environment/aquatic-invasive-species/
47 https://www.vtinvasives.org/sites/default/files/images/NE_EAB_Quarentine%205.7.18.pdf
48 http://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Forest_Health/Library/State%20of%20Vermont%20Action%20Plan_Emerald%20Ash%20Borer.pdf
49 https://www.vlct.org/article/release-wasps-biocontrol-emerald-ash-borers-vermonts-forests

4-10: Landslides

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	**Average:**	
Landslide	3	3	2	1	2	2	6

*Score = Probability x Average Potential Impact

Landslides can be the result of the following:

- Slope saturation from intense Rainfall/Snowmelt, see: Inundation Flooding & Fluvial Erosion.
- Oversteeping of slopes due to stream erosion or undercutting, see: Inundation Flooding & Fluvial Erosion.
- Invasive Species, see: Inundation Flooding & Fluvial Erosion; Invasive Species.
- Reduction of material strength due to weathering.
- Addition of excess load onto slopes, often due to human activity.
- Earthquake or artificial vibration, see: Earthquake.

The term "landslide" describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, organic matter, or artificial fill. The materials may move by falling, toppling, sliding, spreading, or flowing and generally move in either a planar fashion, classified as translational, or curved, classified as rotational or slump. They can be as large as several cubic miles or as small as a few cubic meters and are able to move as quickly as a free fall or as slowly as a multi-century creep.[1] Landslides that move a significant amount of material quickly and over a large area have the capacity to cause substantial damage to infrastructure, buildings and the natural environment, as well as cause injuries and fatalities.

This Plan will use the term "landslide" in place of the term 'Mass Wasting,' which is defined as any down-slope movement of soil and rock under the direct influence of gravity. Landslides are a specific type of mass wasting,[2] however "landslide" is more commonly used and understood than "mass wasting."

Factors that can trigger a landslide or a slope failure include fluvial erosion, soil saturation (especially in areas of increased precipitation), the freeze-thaw cycle in soils and bedrock, human modification of a slope due to excavation and development, surface drainage patterns, loss of vegetation, and earthquakes. Landslides are commonly initiated in the same areas more than once, and if a landslide occurs the best practice is to exercise caution in the area as it may still be unstable.[3]

Fluvial erosion is an important contributing factor to landslides. In the past, unless an area is identified as hazardous through a fluvial geomorphic assessment and a river corridor plan, these landslide-vulnerable areas have been mis-identified as non-hazardous because they are located well above the elevation that would be designated as hazardous under FEMA flood hazard area maps. A landside mapping protocol developed by the Vermont Geological Survey and their partners is intended to address this shortcoming. However, without

1 https://pubs.usgs.gov/circ/1325/pdf/C1325_508.pdf
2 https://www.usgs.gov/faqs/what-landslide-and-what-causes-one
3 https://www.uvm.edu/news/cas/landslides-take-team-solve-geology-professor-says

recognition of fluvial erosion as a significant hazard worthy of inclusion in flood hazard mapping at the federal level, states like Vermont with a high incidence of landslides and fluvial erosion are unable to address mitigate vulnerability to these hazards.

According to the United States Geological Survey (USGS), "Although landslides are primarily associated with mountainous regions, they can also occur in areas of generally low relief. In low relief areas, landslides occur as cut-and-fill failures (roadway and building excavations), river bluff failures, lateral spreading landslides, collapse of mine-waste piles (especially coal), and a wide variety of slope failures associated with quarries and open-pit mines." This is true of Vermont, where landslides are commonly observed well away from the slopes of the Green Mountains.

Landslides Location

Landslides in Vermont often involve unconsolidated materials and are most common along rivers where erosion occurs. Vermont's mountainous areas lie above fractured bedrock with thin soil cover, which led to increased rock-slope instability. Avalanches of debris, defined as material containing a relatively high percentage of coarse fragments, occur most commonly in the western and central portions of the State, typically on south-facing slopes.[4] With updated LiDAR data, and information received via the Vermont Landslides Inventory Reporting Tool, the Vermont Geological Survey and their academic partners have been developing high-resolution landslide hazard maps, county-by-county, as funding is available, which allows the State to better understand locations that are more vulnerable to landslides. This reporting tool has also created an inventory for past occurrences and helped researchers better understand the spatial distribution of landslides.[5] Vermont's rugged topography makes many regions susceptible to landslide, with heightened risk around areas with steep slopes or moving water which can erode steep banks.

Route 131 in Cavendish devastated by slope failure.
Photo Credit: www.mansfieldheliflight.com/flood/

4 https://pubs.usgs.gov/bul/2043/report.pdf
5 https://anrgeodata.vermont.gov/datasets/landslides/explore?

Landslides History

Outside of buildings bought out through FEMA programming, minimal data exists on damages associated with landslides. Often, active landslides occur in tandem with periods of significant rainfall and erosion, so disaster declarations and damage estimates specific to landslide damages are not well defined.

A landslide in Jeffersonville that failed along the Brewster River in April 1999 cost nearly $300,000 for channel and floodplain restoration as well as the purchase of a vulnerable residence.

In April of 2004, a soil slope failure occurred in Hardwick, resulting in significant engineering and construction activities, the buyout of a single residence, and ongoing maintenance totaling $1.4 million in costs. Additionally, in December of 2005, a significant rockslide occurred in Montpelier, affecting Elm and Cliff Streets. The Governor issued an emergency declaration, and the Federal Highway Administration (FHWA) approved a $2 million project to stabilize the remaining slope and to make repairs to damaged utilities and roadways under the FHWA Emergency Relief (ER) program.

Significant landslides were observed in Smugglers Notch in the summer of 2006 and in subsequent years. In 2009, a detailed assessment of slope stability issues in Smugglers Notch was completed.[6] This report highlighted that rock falls, rockslides, and debris flows have occurred in Smugglers Notch for thousands of years, and can be expected to continue into the future. Road damage information from VTrans included in this report shows that landslides are nearly annual events. Rock falls in this area can involve large individual blocks, the largest block to fall on record was the 11,500-ton piece that fell off the west face north of Easy Gully in July 1983. Debris flows are the other main type of landslide that occur in the Notch and can be expected to range from a few cubic meters of mud, pebbles, and boulders, up to many thousands of cubic meters. The largest recorded debris flow occurred on the east side in May 1986 and was about 299,008 cubic meters of material. This blocked VT Route 108 and the West Branch near the Cambridge-Stowe line. Future debris flows can also be expected to sweep down to and across Route 108. Even though the largest debris flow occurred on the east side of the Notch, activity appears to be more frequent on the west side. According to recorded landslide history in the Notch, slides tend to occur between May and December. The Vermont Geological Survey has been working with VTrans to monitor and better understand rockslide activity using drone-based photogrammetry.

Extensive landslide activity occurred as a result of the heavy rains of 2011. In central Vermont, high water conditions resulting from the melting of thick snowpack and heavy spring rains, as well as from a flash flood event in late May, led to an increase in reported landslides. Widespread slope failures also occurred throughout much of central and southern Vermont as a result of Tropical Storm Irene later that year. Many of these landslides appear to have occurred on the sites of earlier slides that were reactivated by the heavy rains and powerful floodwaters (for more information on impacts from Tropical Storm Irene, see: Inundation Flooding & Fluvial Erosion).

As a result of the landslides associated with Tropical Storm Irene, the May 2011 period of heavy precipitation, and previous landslide occurrences, the following properties were subject to continued risk warranting purchase through the Hazard Mitigation Grant Program (HMGP). While fluvial erosion and stream toe erosion of steep slopes are major contributing factors to landslides in Vermont, the Protocol for Identification of Areas Sensitive to Landslide Hazards in Vermont (discussed below) includes larger scale landslides which are not or may not be captured by floodplain mapping. Since low eroding banks are adequately captured by floodplain mapping, a somewhat arbitrary bank height of 3-4 meters is used to differentiate the larger scale landslides.

6 https://anrweb.vt.gov/PubDocs/DEC/GEO/HazDocs/SMuggs2009Rpt2Pls.pdf

The landslide properties listed in Table 28 have been selected based on the following criteria:

- They were awarded an HMGP grant using FEMA's Landslide BCA Methodology and/or
- The damaged structure sat atop a bank higher than 3 meters.

Table 28: Landslide-Vulnerable Properties Purchased With HMGP, CDBG and/or Vermont Housing & Conservation Board (VHCB) Funds

Name/Time	Town	County	Date of Occurrence	Cost of Buyout
40 School Street	Readsboro	Bennington	8/28/2011	$142,212
42 School Street	Readsboro	Bennington	8/28/2011	$155,668
62 School Street	Readsboro	Bennington	8/28/2011	$191,998
3013 Danby-Pawlet Road	Danby	Rutland	8/28/2011	$76,859
15 Hilltop Avenue	Barre City	Washington	5/29/2011	$227,976
21 Hilltop Avenue	Barre City	Washington	5/29/2011	$152,732
86 Waterman Hill Road	Hartford	Windsor	8/28/2011	$238,219
104 Waterman Hill Road	Hartford	Windsor	8/28/2011	$235,778
36 Town Garage Road	Westminster	Windham	8/28/2011	$58,090
280 Cameron Road	Plainfield	Washington	8/28/2011	$251,700
266 and 268 Texas Hill Road	Huntington	Chittenden	7/4/2013	$262,500
64 Bolder Wood Lane	Bolton	Chittenden	2019	$165,000
2272 Machia Road	Highgate	Franklin	8/2020	$62,000
2128 Brockways Mills Road	Rockingham	Windham	7/29/2021	$187,000

In 2009, a PDM grant award allowed the Vermont Geological Survey (VGS) to further study landslide-prone areas and develop a useful protocol to assess future risks.[7] The report notes that accurate LiDAR data provides the best starting point for landslide analysis in Vermont; therefore, VGS selected seven sites to attempt to represent conditions in various parts of the State. Since LiDAR coverage was limited in the State at the time, six of these study sites were conducted in Chittenden County and one in Lamoille County. The protocol was found to work best for translational landslides. The report states that, "the most important parameters for identifying translational landslides are slope angle and roughness, although soil type and topographic wetness index are also important at some site areas." The State has since been successful in generating statewide LiDAR data and is currently updating our LiDAR dataset with Quality-Level 1 (8 points per square meter) statewide coverage (see: State Capabilities List).

A house sits atop an active landslide in Plainfield, VT. This house was acquired and demolished by the Town using Vermont Housing & Conservation Board funding.

7 http://dec.vermont.gov/sites/dec/files/geo/TechReports/VGTR2012-1LandslideProtocol.pdf

Table 29: Significant Landslides in Vermont				
Property Damage (Adjusted for inflation)	**Begin Date**	**End Date**	**Location**	**Fatalities**
$11,304.35	5/2/1983	5/2/1983	Rutland	0
$104,000.00	5/23/1986	5/23/1986	Lamoille	0
$91,228.07	5/11/1989	5/11/1989	Bennington	0
$300,000.00	4/4/1999	7/4/1999	Jeffersonville	0
$360,000.00	Spring 2002	Spring, 2002	Lake Willoughby	0
$1,433,424.88	04/18/2004	4/18/2004	Hardwick	0
$2,000,000.00	12/26/2005	12/26/2005	Montpelier	0
n/a	5/30/2019	5/31/2019	Waterbury	0
$48,413.97	5/31/2020	5/31/2020	Cambridge	0

Table 29 lists significant landslides that have impacted the State of Vermont, excluding those associated with Tropical Storm Irene.

On May 30th and 31st of 2020, two significant landslide events occurred at Smugglers Notch, Cambridge and Cotton Brook, Waterbury. The Smugglers Notch event occurred the morning of the 31st, a portion of the cliff face high up on the west side just north of Cass's Gully broke off and fell onto the talus slope below. As they fell, large blocks of schist bounced, rolled, or slid down the talus slope. Many trees were damaged, snapped, or swept along by the falling pieces of rock. At least two large blocks reached Vermont Route 108 in the floor of the Notch, damaging at least one vehicle. There were no injuries reported. This event has been one of the largest rock fall events in the Notch in the last 30 years. Of 23 landslide events at Smugglers Notch and Mount Mansfield for which the month of occurrence can be determined, all occurred between April and December, with 20 of them occurring between May and October. The peak occurrence is in July.[8]

Two types of slope failures or landslides occur in the Smugglers Notch area. The first broad class of landslides is rock falls and rockslides, which involve one or many large pieces of rock detaching from a cliff and falling, bouncing, or sliding down a slope. Most of the boulders on the floor of the Notch appear to be the result of such rock falls. The rock fall in May of 2020 was in this first class. The second class of landslides is debris flows, which are slurries of water, mud, pebbles, cobbles, and boulders that flow within shifting channels on the talus slopes below the cliffs. In the Notch, they are caused by heavy rainstorms. Both rock falls and debris flows appear to be triggered by intense rainfall events and/or rapid snowmelt. Landslides have occurred in Smugglers Notch for thousands of years and we can expect large rock falls and slides and damaging debris flows to continue long into the future.[9]

The landslide that occurred on the slopes along the Cotton Brook sometime between the 30th and 31st of May in 2020 resulted in a landslide area with a primary scarp of approximately 12 acres and with additional failure blocks near the head scarp (additional 2.2 acres). The landslide area increased by more than 10% in the days following the initial landslide, and the site remained unstable with a high risk for future failures; one heavily used hiking trail in the area was permanently closed. The landslide resulted in massive sedimentation in Cotton Brook, from the landslide location to the mouth of the brook at the west shore of the Waterbury Reservoir.[10] Additional failures can bring down large blocks of trees and soil, potentially causing additional blockage of Cotton Brook, and the Vermont Geological Survey and partners continue to monitor its development.

8 https://dec.vermont.gov/geological-survey/hazards/landslides/smugglers-notch-rockfall
9 https://dec.vermont.gov/geological-survey/hazards/landslides/smugglers-notch-rockfall
10 https://dec.vermont.gov/geological-survey/hazards/landslides/cotton-brook

Landslide Trends

In the years since the 2018 SHMP was published, the State has developed and published a landslide inventory containing landslide locations from the Vermont Geological Survey's preliminary landslide inventory, verified landslides from the public Geoform, and other technical reports. These data can be accessed from Vermont ANR's GIS Open Data and are updated regularly. The Vermont Geological Survey responds to and monitors landslide and rockfall events, maps areas prone to erosion and landslides, and is working with partners from Norwich University to implement landslide hazard mapping protocols throughout the State. In 2015 the Division began a program to provide planning-level landslide hazard maps for all Vermont counties, contingent upon funding and availability of LiDAR. Landslide hazard susceptibility maps were prepared for Addison County, the Town of Highgate, and Washington County in 2016 - 2017; Chittenden County was completed in 2018 and added to the statewide GIS data inventory. Caledonia and Orange County were prepared in 2021 and 2019 respectively. Reports for the Mad River Valley, Smugglers Notch, and the Middlebury River Watershed have also been prepared.[11] The State continues to produce landslide hazard mapping throughout the State. These maps help Vermont prepare for safer growth and development, develop mitigation and hazard avoidance strategies (FEMA), avoid economic loss, and be prepared (USGS preparedness list) to respond to events.

11 https://dec.vermont.gov/geological-survey/hazards/landslides

Major slope failure along the Cold River in Shrewsbury, VT. *Photo Credit: Alan Shelvey*

Vermont has not previously developed an adequate tracking system to establish frequency of this hazard. In general, landslides tend to fail during wetter periods including springtime, with the combined effects of snowmelt, early spring rains, and low evapotranspiration, and in fall when high-intensity storms commonly originating as Nor'easters bring heavy rains to the State. Vermont continues to experience increasing precipitation with an additional 1.4" per decade (since the 1960s; rates which fluctuate depending on which season is being observed),[12] which reduces slope stability. Based on increasing precipitation trends and on reported landslides in the Vermont Landslides Inventory Reporting Tool.[13] The Steering Committee graded the probability of a landslide occurring to be "Likely" which would be a significant event at least once in the next ten years. The impacts of landslide events were rated Moderate for the built environment, Minor for people and the natural environment, and Negligible for the Economy.

The population trends within Vermont indicate that there will be a population increase throughout the 21st century.[14] While Vermont is in no way immune to the impacts of climate change, the state is expected to see fewer extreme impacts compared to other states.[15] As a result, more people may move to Vermont from hazard-prone areas for safety reasons. In the event of rapid migration, Vermont needs to be prepared both socially and structurally to handle newcomers. Regional Planning Commissions (RPCs) around the state have made assessments that many communities are not prepared for increased migration.[16] One of Vermont's main planning goals is to develop in a way that maintains historic development patterns of compact centers surrounded by rural landscape.[17] This is done to prevent suburbanization and the fragmentation of Vermont's natural landscape. As neighborhoods expand to include areas adjacent or away from these centers, alterations to the landscape can be harmful in the long run.

Development pressures can put more structures at risk of landslide events. For example, multiple businesses and housing units exist along a slope on Riverside Ave in Burlington. This slope has a long history of filling, development, and mitigation that has left 80ft of unconsolidated materials overlaying bedrock, which can be unstable. Damaging washouts and slides along this slope have occurred due to over-steepened slopes, unstable fill, poorly maintained storm drains, and surface runoff. Major failures occurred in 1955 and in 2019 and several smaller events were triggered between that moved large amounts of fill material. Three structures were under review to determine if they posed an imminent risk of failure (within the next 5 years); two businesses and one residential structure. Structures were assessed for their integrity, pointing out cracks in the foundations and landscape indicators of weakened earth. While the State has gone ahead with recommending the buyout of one of the three properties in question (the residential building), there is still a risk of slope failure which can endanger remaining occupied properties, nearby road infrastructure, and the Winooski River at the base of the slope.[18] As our population increases and puts pressure on further development, careful consideration of existing unstable slopes and lessons learned from previous failures are important to minimize the future risk of landslide hazards.

12 https://site.uvm.edu/vtclimateassessment/files/2021/11/VCA-Chapter-1-11-4-21-1.pdf
13 https://vtanr.maps.arcgis.com/apps/GeoForm/index.html?appid=505af0d19dd44faaa912ef3d5c80a3b6
14 https://publicassets.org/library/publications/vermont-is-growing-and-so-is-its-labor-force/
15 https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100SSN6.txt
16 https://vtdigger.org/2019/09/17/climate-change-will-vermonts-population-increase-from-climigration/
17 https://accd.vermont.gov/community-development/designation-programs/neighborhood-development-areas
18 Memo: June 9th, 2022 - Landslide Hazard Evaluation at Riverside Avenue, Burlington, Vermont – From State Geologist to VEM

Landslide Vulnerability

People:

The effects of landslides on people and communities in Vermont is most pronounced in identified at-risk regions. In remote and mountainous regions, landslides can impact hikers and other people engaging in outdoor recreation, sweeping them away or crushing them under the weight of the failed materials. Due to the changing landscape and unstable ground, search and rescue operations can prove difficult. Throughout the US, landslides result in an average of 25-50 deaths annually. Human health hazards that can result from landslides include physical bodily harm from debris, illness resulting from disrupted systems (i.e., sewage), and the loss of road access restricting access to other regions including medical care.[19] The impact on access and communication will be discussed further in the Built Environment section.

Built Environment:

Slope instability, which can result from increased ground saturation due to heavy rainfall or significant snowmelt, is further exacerbated by human activity, often in the form of infrastructure construction that either mishandles surface runoff, overloads the tops of slopes, or undercuts the bases of slopes. Roads that sit along steep slopes near rivers are especially vulnerable to damage or complete failure from a landslide event. Bridges and culverts placed near waterways similarly can be damaged or swept away by the debris of a landslide. Buildings and other structures can be damaged as well, especially if they are in historical landslide sites, steep slopes, slopes altered by construction, channels along streams or rivers, and areas where humans have directed surface runoff.[20] Recreational spaces like trails can be drastically altered by slope failures, as was the case for the Monroe Trail that was destroyed by the Cotton Brook landslide. The destruction of roadways can limit the transportation corridors between regions, making it difficult to respond to emergencies caused by landslides as well as other emergencies in the near future.

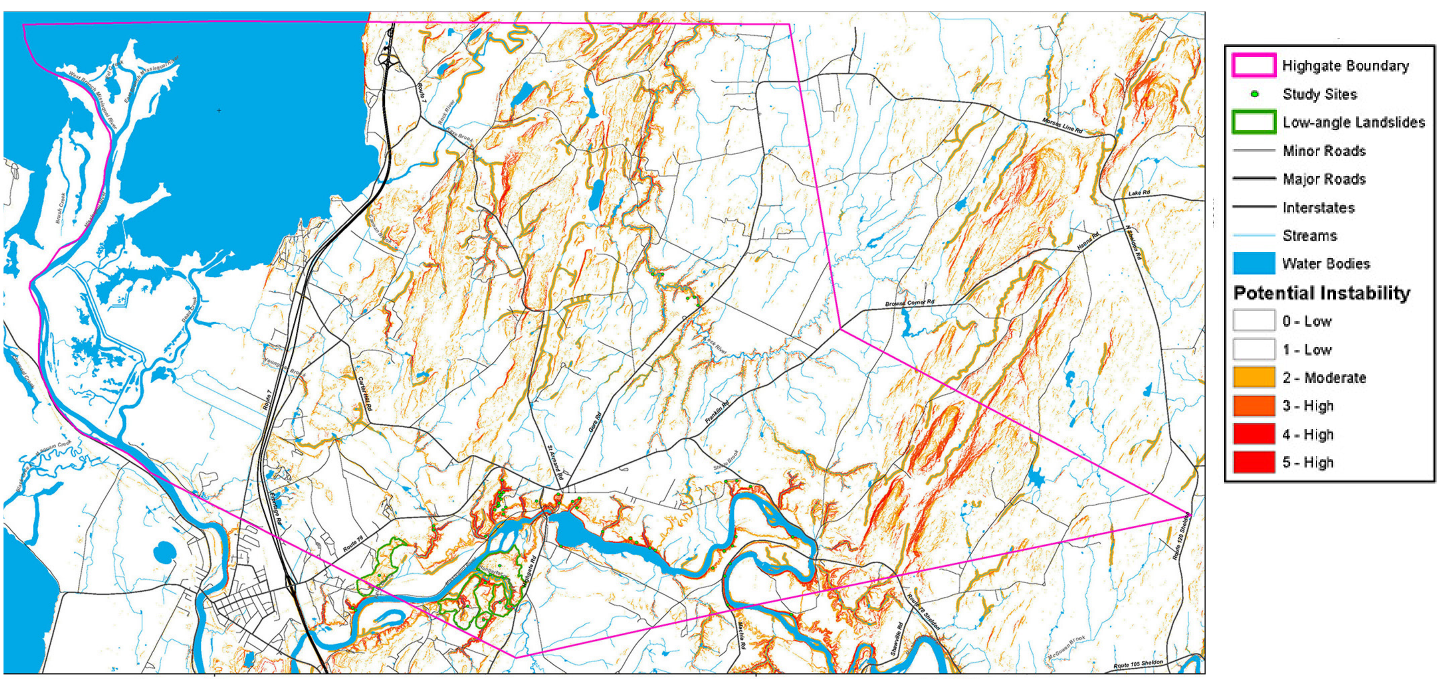


Figure 61: Town of Highgate landslide map
Source: http://dec.vermont.gov/sites/dec/files/geo/TechReports/VGTR2016-1AddisonCtyLS.pdf

19 https://www.cdc.gov/disasters/landslides.html
20 https://www.cdc.gov/disasters/landslides.html

Natural Environment:

The impacts that landslides can have on the natural environment is more concentrated yet often leads to greater changes than some of the other listed hazards. Landslide events can quickly and significantly alter the topography of the earth's surface with massive amounts of debris moving downslope. In turn, that debris can impact the character and quality of rivers and groundwater flow when large amounts of earth and organic materials enter streams as sediment resulting from landslides and erosion activity, thus reducing the potability of the water and quality of habitat for fish and wildlife.[21] Sedimentation can lead to many waterway issues by clogging fish gills, reducing resistance to disease, lowering growth rates, and affecting fish egg and larvae development.[22] Increased turbidity of the water can prevent the growth of vegetation disrupting the Biochemical Oxygen Demand (BOD) of the water, making it more difficult for marine species to breathe.[23] The habitat destruction and disruption caused by landslides is not confined to waterways, as forested ecosystems in the path the landslide can be swept away, stripping forest cover away, impacting wildlife habitat.[24] The changes in the natural environment experienced by this hazard are fast acting and severe, requiring plenty of time for ecosystems to recover.

Economy:

The economic impacts that landslides cause is dependent on where the event took place. Vermont has recorded over 3,000 landslides, with many occurring in the northern and central parts of the State along the spine of the Green Mountains.[25] These regions are often sparsely populated and home to numerous ski resorts and hiking trails. The Green Mountains act as the heart of Vermont, not only physically, but also culturally as the rural idyll used to generate tourism brings many people to Vermont to ski and explore the outdoors, especially during the fall. Outdoor recreation accounts for 4.1% of Vermont's GDP as of 2021, the third highest in the nation behind Hawai'i and Montana.[26] Damage to this sector can have an impact on the State's economy. Other economic impacts come in the form of lost stock if a landslide occurs on a plot of land being used for timber, sugaring, or other kind of production.

Landslides Current Capabilities & Mitigation

To reduce Vermont's vulnerability to landslides, the Vermont Geological Survey, a division under the Department of Environmental Conservation (ANR-DEC), has developed a web-based reporting tool[27] for the general public to submit information to the State Geologist regarding potential landslides in real-time. As outreach efforts are made to increase awareness about the tool, the visibility to both known and unknown landslide-prone areas is expanded. This will allow the Vermont Geological Survey team to have access to more data, thereby increasing the ability to predict future slope failures. Further increasing public knowledge and engagement in landslide hazard mitigation can help improve local resiliency. An action outlined under the strategy to: increase public knowledge and literacy of hazards and mitigation aims to develop a resource for the incorporation of hazard mitigation and water quality projects into local capital planning and budgeting processes.

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21 https://link.springer.com/chapter/10.1007/978-3-540-69970-5_31
22 https://cfpub.epa.gov/npstbx/files/ksmo_sediment.pdf
23 https://dnr.wisconsin.gov/topic/labCert/BODanalysis
24 https://link.springer.com/chapter/10.1007/978-3-540-69970-5_31
25 https://www.uvm.edu/news/cas/landslides-take-team-solve-geology-professor-says
26 https://accd.vermont.gov/tourism/research
27 https://vtanr.maps.arcgis.com/apps/GeoForm/index.html?appid=505af0d19dd44faaa912ef3d5c80a3b6

The strategy to access seismic vulnerability outlines three actions conduct seismic analyses and install monitoring stations at critical facilities, select bridges, and cultural sites in conjunction with educational institutions across the State. Analyses conducted are to use the 2016 NESEC study, HAZUS, ROVER, and the UVM Seismic Vulnerability Ranking System.

The Vermont Geological Survey then use these data to prioritize towns and counties that are in need of high-resolution landslide hazard maps, which are being developed currently, as funds are available.

When these landslide data are then overlaid with development in a town or region, vulnerability can be better understood, and mitigation strategies defined. Though landslides are identified throughout this Plan's mitigation actions, reducing structural vulnerability to landslide hazards was identified as its own, standalone mitigation strategy with six separate actions created to accomplish the strategy (see: Mitigation Strategy). Those actions identified under the hazard mitigation mapping, data and research strategy have direct implications to landslide mitigation, as the State continues to seek out funding sources to better locate and understand Vermont's vulnerability to the hazard.

Accordingly, structural and infrastructural landslide mitigation projects are also taking place across Vermont. As mentioned in the History of Landslides section above, ten landslide-vulnerable houses were purchased and removed as a result of the landslides associated with Tropical Storm Irene (Table 29). Two of these structures were located in the Town of Highgate, whose landslide hazards have been mapped by the Vermont Geological Survey (Figure 55). Using this map to identify vulnerable infrastructure and structures, the Town applied for a landslide slope stabilization project under the HMGP for their transfer station, which was built near a failing slope and requires significant mitigation work. The first phase of this project, funded by FEMA, was completed in early 2018 at a cost of approximately $230,000; second phase of work is expected to begin in summer 2023 at a cost of approximately $2M.

The Town of Shrewsbury had to have substantial work done after Tropical Storm Irene due to significant slope failures along the Cold River, including approximately $887,000 in Public Assistance funds for road repair and slope stabilization. The Town, recognizing there were several hazardous areas along this landslide-prone stretch that required immediate attention, then submitted a PDM application to relocate a portion of the Upper Cold River Road identified as being an imminent threat of catastrophic failure. This project, funded by FEMA, was completed in January of 2020 at a cost of $516,677.19.

Landslide buyout project in Rockingham, VT with funding through the Flood Resilient Communities Fund
Photo Credit: Town of Rockingham

4-11: Wildfire

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Wildfire	2	3	3	3	3	3	6

*Score = Probability x Average Potential Impact

A wildfire is the uncontrolled burning of woodlands, brush, or grasslands. According to FEMA, there are four categories of wildfires that can occur throughout the United States:

- **Wildfires:** Fueled by natural vegetation; typically occur in national forests and parks, where federal agencies are responsible for fire management and suppression.
- **Interface or Intermix Fires:** Urban wildfires in which vegetation and the built environment provide fuel.
- **Firestorms:** Events of such an extreme intensity that effective suppression is virtually impossible; occur during extreme weather and generally burn until conditions change or the available fuel is exhausted.
- **Prescribed Fires and Prescribed Natural Fires:** Fires that are intentionally set or selected natural fires that are allowed to burn for beneficial purposes.

Wildfires can be a result of naturally occurring influences such as lightning, drought and extreme heat (see: Drought, Extreme Heat), and human influences such as a discarded cigarette, improperly extinguished campfire, or a stray spark from nearby railroad tracks. The potential for threat of wildfires is dependent upon topography and slope, surface fuel characteristics, recent climate conditions, current meteorological conditions, and fire behavior. Once a wildfire threatens a community, it is often too late to protect nearby structures, and populations must be evacuated for their own safety. These fires could have the potential to damage structures and utilities as well as hundreds of acres of woodlands.

The 2017 Vermont Forest Action Plan,[1] developed by the Department of Forests, Parks and Recreation, defines "wildland fire" as any non-structure fire that occurs in vegetation or natural fuels, including prescribed fire and wildfire. Most wildland fires in Vermont are quickly reported and contained, though fires burning deep in ground fuels or in remote locations require more time and effort to fully suppress. Town Forest Fire Wardens and local fire departments primarily handle wildland fire control with assistance from other towns and the State, when necessary.

Vermont has a reliable system of local fire suppression infrastructure coordinated at the State-level. Vermont's climate, vegetation type, and landscape discourage major wildfire. The majority of fires in Vermont are caused by burning debris.[2]

1 http://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Vermont_Forests/Library/2017_VT_ForestActionPlan.pdf
2 http://fpr.vermont.gov/sites/fpr/files/2017%20Vermont%20Wildland%20Fire%20Program%20Annual%20Report.pdf

The National Weather Service (NWS) issues a Red Flag Warning when there is the potential for extreme fire danger within 24 hours based on the following criteria:

- Winds sustained or with frequent gusts > 25 mph
- Relative Humidity at or below 30% anytime during the day
- Rainfall amounts for the previous 5 days less than 0.25” (except 3 days in pre-greenup)
- Lightning after an extended dry period
- Significant dry frontal passage
- Dry thunderstorms
- Keetch-Byram Drought Index values of 300 or greater (summer only)

Lightning:

In addition to being hazardous to human life, lightning can damage infrastructure, plants, and property, and can spark forest fires. According to the NWS, lightning is the first thunderstorm hazard to arrive and the last to leave. Lightning can strike up to 50 miles away from a thunderstorm, carry up to 100 million volts of electricity, and reach temperatures upward of 50,000°F.

Since 1950, there have been 93 documented events of lightning strikes in Vermont, resulting in 4 deaths and 17 injuries.[3] Lightning is an unpredictable and disbursed weather-related event, making it challenging to mitigate.

Wildfire Location

76% of Vermont is forested[4] – 79% and 21% privately- and publicly-owned, respectively.[5] Wildland-urban interfaces (WUI) are particularly vulnerable to wildfire events and could potentially experience higher rates of damage, as the potential for rapid spread among a large geographical area is present. A map of state assets within the WUI is included under Built Environment in the vulnerabilities section.

Wildfire History

The wildfire threat in Vermont is relatively low based on historical occurrences. Wildfire conditions in Vermont are typically at their worst either in spring when dead grass and fallen leaves from the previous year are dry and new leaves and grass have not come out yet, or in late summer and early fall when that year’s growth is dry. In drought conditions, this risk is obviously higher. The risk of wildfire due to drought was severe enough to warrant a statewide ban on open burning in 1966. That was the last such statewide ban until one was issued in 1999 due to drought. However, due to a very dry April 2000, the State once again had to declare a temporary burning ban, and at the end of 2001, the State remained in a drought. There was a statewide ban on open burning in October 2005, which was rescinded in April 2006. There was a threat of explosive fire growth potential in March 2012. This was due to low humidity, warm temperatures, and strong winds. In addition, dry grass was a wildfire threat during the spring of 2012 due to a mild winter leaving grass exposed through the drier winter months. Most recently, May 2015 saw a statewide burning ban which lasted for two weeks to combat the D1 drought conditions.

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3 https://www.ncdc.noaa.gov/stormevents/

4 Morin, R.S.; Domke, G.M.; Walters, B.F.; Wilmot, S. 2017. Forests of Vermont, 2016. (http://fpr.vermont.gov/forest/forest_business/forest_statistics/fia)

5 https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Vermont_Forests/Library/rb_nrs120.pdf

Despite the drought in 2016-2017, Vermont's 2017 Wildland Fire Program Annual Report notes that the 2017 fire season was well below normal at 49 acres burned from 51 fires. The average between 2012 and 2016 was 109 fires and 317 acres per year.[6] There has not been a major wildfire in Vermont in the last 50 years. NOAA's Storm Events Database only include one documented wildfire event since 1950. This event was in July of 2002 in Windham and Bennington Counties, with no deaths, injuries, or noted damages:

> "Smoke, from many forest fires across the Nemiscau region of northern Quebec, became trapped under a subsidence inversion, and was transported south across southern Vermont from the evening hours of July 5, to the late evening of July 7. The forest fires were sparked by exceptionally hot and dry weather over that part of Canada followed by an unusual amount of thunderstorm activity, resulting in many lightning strikes. The circulation between high pressure over Hudson's Bay and a low pressure off the Canadian Maritimes transported the smoke southward. The smoke obscured the sky, and even reduced surface visibilities to as low as one mile, especially on the early morning of July 7. Advisories were issued warning people with respiratory problems to remain indoors and all individuals to curb outside activity. No major problems were reported to the National Weather Service as a result of this smoke. By late Sunday, July 7, the low pressure weakened and moved further east, allowing the wind to back into more of a westerly direction, finally dissipating the smoke[7]."

Vermont also experienced substantial impacts from Canadian wildfire smoke from June 5 to 8, 2023. The entire state experienced poor air quality, especially in the southwestern corner of the state. In Bennington Vermont, the record highest ever 24-hour average concentration of fine particulate matter (PM2.5) at Morse Airport was broken on June 6 (56µg/m3), then again on June 7 (64µg/m3), far exceeding the previous record of 42µg/m3 set in 2005. The air quality index was above 150 on June 6 and 7, which is considered by the EPA to be "unhealthy" for all populations. Air quality was even worse to the south and west of Vermont, with the Air Quality Index exceeding 400 in some locations, considered "hazardous" for all populations, resulting in cancellations of outdoor activities and widespread distribution on N95 masks to the public.

Wildfire Trends

Although wildfires are currently uncommon in Vermont, the Steering Committee acknowledged that extended periods of warming due to climate change have the potential to increase the occurrence of wildfire events, thus ranking Wildfire with a probability score of Occasional. Vermont is seeing an increase in average annual maximum and minimum temperature (see: Extreme Heat), which is also contributing to an increased likelihood of drought (see: Drought) and wildfire risk, though an increase in precipitation events (see: Inundation Flooding & Fluvial Erosion) may limit that risk during certain times of the year. Furthermore, due to a lack of wildfires in recent history, there may be more

A forest fire in Bolton, VT in 2016 due to dry conditions and warm temperatures.
Photo Credit: Lars Lund

6 http://fpr.vermont.gov/sites/fpr/files/2017%20Vermont%20Wildland%20Fire%20Program%20Annual%20Report.pdf

7 https://www.ncdc.noaa.gov/stormevents/

fuel available for a large-scale wildfire. Unhealthy wildfire smoke from out-of-state wildfires is also expected to affect Vermont more frequently and severely in the future, as climate change is already increasing wildfire risks in the western United States and Canada.

Wildfire trends are constantly changing. Predictive models for fire potential are often generated each month or season. These models incorporate the state of fuels across various areas based on the latest precipitation and soil moisture anomalies, drought, and snow depth data. While giving an overall prediction for each season, models cannot incorporate the daily weather changes that affect fire risks. The Wildland Fire Assessment System is available online from the U.S. Forest Service.[8] This system provides national fire danger ratings that are updated daily. The maps take into account current and antecedent weather, fuel types, and both live and dead fuel moisture.

The potential impact from a plausibly significant wildfire event is expected to be Moderate on the built environment, natural environment, people and the economy. Given the Occasional probability of wildfire in Vermont, the risk is considered to be relatively low.

Wildfire Vulnerability

People:

Populations that are more vulnerable to wildfire include firefighters, isolated residents, and immunocompromised individuals. Firefighters are directly involved with the process of extinguishing wildfires, and thus are at higher risk for severe burns, cardiovascular and respiratory issues, and injury from fallen timber. Wildfires that are not extinguished can trap isolated residents in their homes if evacuation routes are blocked. Emergency vehicles may not be able to reach isolated populations due to damage blocking the transportation routes. Emergency transportation routes must also be considered additionally for immunocompromised populations. Those with preexisting cardiovascular and respiratory conditions may experience life-threatening symptoms due to smoke exposure. Unhoused individuals are at particularly high risk from wildfire smoke, and emergency shelter or N95 masks may be needed to help mitigate health impacts. Emergency resources must be considered to prevent an increase in the mortality rate associated with a wildfire event.

In addition to affecting immunocompromised populations, wildfires will affect the health of the general public. The air quality of the surrounding area is diminished after a wildfire due to the emissions of toxic pollutants. Emissions of volatile and semi-volatile organic materials and nitric oxides can remain in the air after a wildfire occurs and can cause cardio-respiratory illness when exposed to high concentrations.[9] In addition to wildfire events that occur within the state, air quality in Vermont could be compromised as smoke travels into Vermont from other locations in the United States and Canada, especially as these events increase in frequency and severity.

8 http://www.wfas.net
9 https://csl.noaa.gov/factsheets/csdWildfiresFIREX.pdf

Built Environment:

In general, wildfire risk is considered statewide, though a specific location where infrastructure and life are potentially more vulnerable to structural fire is the wildland-urban interface (WUI). The WUI represents the area where infrastructure interacts with undeveloped land, creating the potential for fire to move from a forested environment to a grassed neighborhood.

An analysis of State assets that are within the WUI showed that there are state assets valued at approximately $582 million within the WUI (Figure 62), with a nearly $800 million replacement cost. Vulnerbale state assets are distributed across Vermont, with a slightly higher number in St. Johnsbury and Springfield, Vermont. A list of those state assets is included in the Appendix to Section 4. Assets that are leased or near, but not within the WUI are not included in the value and replacement costs.

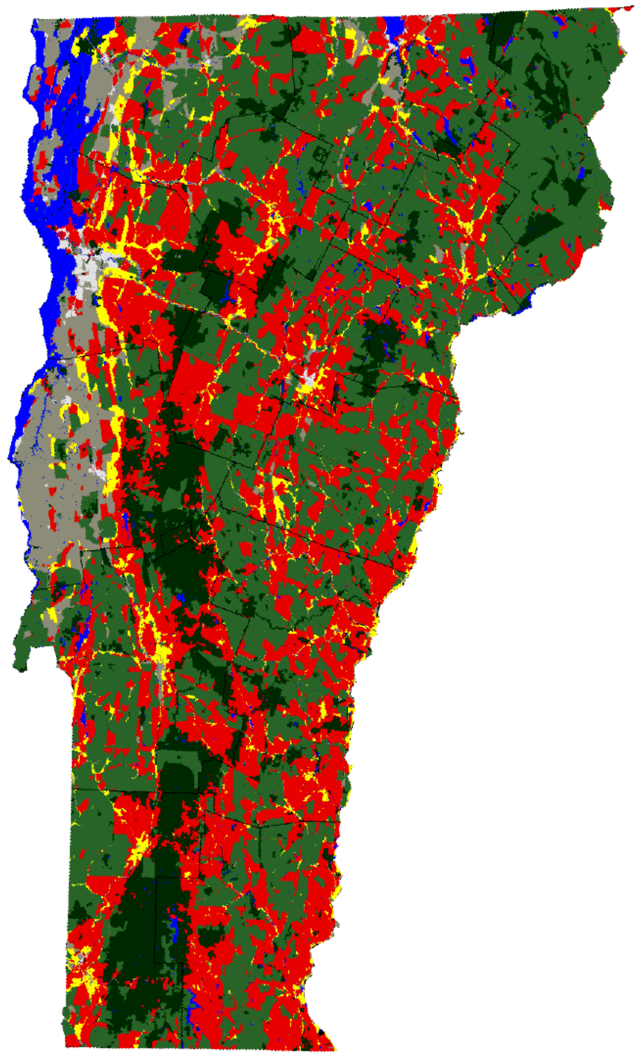

Figure 62: 2010 Wildland Urban Interface (WUI) map for Vermont
Source: http://silvis.forest.wisc.edu/maps/wui/2010/download

Natural Environment:

The 2017 Vermont Forest Action Plan defines the WUI as a priority landscape, noting that:
"Although the WUI term originates in wildland fire management, the WUI is also a useful indicator of human influence on natural ecosystems. The WUI is an area where people and their homes affect the natural environment, contributing to the loss of habitat for native species, forest fragmentation, the introduction of exotic species, domestic pets that can disturb or prey on birds and other wild animals, and poorer water quality due to runoff from pavement and lawns. These trends will threaten biodiversity and ecosystem health if WUI residents and communities are not attentive to the potential harms and actively caring for the environment around their homes." (pg. 45)[10]

Wildfire events have potential to cause significant loss to flora and fauna in areas impacted. Wildfire will burn both flora and fauna, damaging habitat and causing injury or loss of life. Trees and other vegetation are particularly prone to burning during drought and extreme heat events when conditions are dry. Wildfires can also affect the cardiovascular and respiratory health of fauna and could cause injury from fallen timber. Ash from wildfires can travel to nearby water sources through runoff, containing contaminants and toxic metals.[11] This is especially dangerous for aquatic organisms, as their ecosystem is damaged. Higher mortality rates in aquatic life are associated with higher concentrations of contaminants and toxins. These compounding impacts from wildfire may increase in probability as drought events increase in frequency and severity.

10 http://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Vermont_Forests/Library/2017_VT_ForestActionPlan.pdf
11 https://www.usgs.gov/centers/california-water-science-center/science/water-quality-after-wildfire

Wildfire is a natural hazard that some species depend on for suitable habitat. For example, prescribed burning may benefit oak forests by reducing competition, litter depth and seed predation, and an increase in light and nutrient availability. Although these are controlled burns as opposed to unmanaged wildfire, it is possible that some wildfire events may burn in patterns beneficial to surrounding oak species. Some understory vegetation such as blueberries and huckleberries are considered fire-adapted, and their presence in Vermont's Green Mountains may indicate a history of fires shaping the environment.[12]

Economy:

Wildfires can be especially disruptive to the economy if they spread to farms and forests designated for timbering. Wildfires can spread quickly in hot and arid climates, so Vermont is particularly at risk for wildfires during droughts or extreme heat events. Crops such as apples, food-grade grains, hemp, maple, and other produce are essential to Vermont's economy within both the food and beverage industries.[13] Wildfire could destroy the fields allocated to these crops, and thus destroy potential GDP. Similarly, forestry operations could experience a loss in timber if a high quantity of trees are victim to wildfire.

As dairy products are also responsible for a large proportion of economic gain in Vermont, it is important to consider the threat to livestock that wildfire can pose. Just as humans may suffer cardiovascular and respiratory conditions from wildfire smoke, livestock could suffer injury or potential death depending on the concentration of smoke around them. Damage to farm buildings could also put livestock at risk of injury or death, which would affect the output of dairy products.

The economy of Vermont is also largely dependent on tourism, accounting for $3 billion in revenue yearly.[14] As mentioned above, wildfire can impact water quality through the introduction of contaminants from ash. A decline in water quality could impact Vermont's economy, as water sources may not be safe for recreational activities. Fishing may be limited if the water quality is affecting the mortality rate of the fish. It also may be unsafe to swim or participate in water sports as water quality declines. Wildfire also has the potential to damage recreational areas including trail systems. Such damage could impact tourists' decision to visit Vermont, and thus decrease the total revenue obtained by the State.

12 https://vtecostudies.org/blog/fire-management-in-the-green-mountains/

13 https://agriculture.vermont.gov/sites/agriculture/files/doc_library/Vermont%20Agriculture%20and%20Food%20System%20Plan%202020.pdf

14 https://accd.vermont.gov/tourism

Wildfire Current Capabilities & Mitigation

Several actions within this Plan address wildfire (see: Mitigation Strategy), such as the strategy on reducing risk from wildfire, including actions around developing a wildfire mitigation plan, supporting the development of Community Wildfire Protection Plans (CWPPs) at the local level, and assessing the risk maps hosted by the State Foresters Alliance and the National Association of State Foresters to accurately reflect Vermont's fire risk.

Within Vermont, much of the focus around wildfire is on the preparedness and response phases. On the prevention side, per Vermont statute, open burning of natural and untreated wood, brush, weeds, or grass requires a 'Permit to Kindle Fire' from the Town Forest Fire Warden. When there is significant fire danger, open burns can be banned entirely. The drought mitigation strategy (see: Mitigation Strategy) includes actions that will assist in preparedness planning for wildfire, including actions to expand monitoring wells and develop groundwater resource maps.

Large-scale mitigation for wildfire is predominately not feasible in Vermont. The 2017 Vermont Forest Action Plan has a much stronger focus on preventing forest fragmentation, which runs counter to mitigation actions, such as defensible space. The Action Plan including strategies to:

- Strengthen collaborative land use planning and policy efforts with partners to conserve forests, developing strategies to reduce or mitigate the rate of forest conversion and reduce forest fragmentation and parcelization at local, statewide, and regional levels (Strategy 3).
- Prepare for, mitigate, and respond to emergency events such as wildland fires and significant weather events (Strategy 16).
- Provide training and technical support, and maintain partnerships for wildland fire prevention and response (Strategy 53).

On a local level, a number of Regional Planning Commissions (RPCs) have assisted local communities with preparing Community Wildfire Protection Plans (CWPPs), which are aimed at lessening the impacts of interface wildfire. These CWPPs are authorized and defined in Title I of the Healthy Forests Restoration Act (HFRA, PL 108-148, 2003), which does not prescribe the exact form of a CWPP, but states that they should address local forest and range conditions, values-at-risk, and priorities for action. CWPPs are another tool to assist communities in understanding their vulnerability and can inform Local Hazard Mitigation Plans (LHMPs).

4-12: Earthquake

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Earthquake	2	2	2	2	2	2	4

*Score = Probability x Average Potential Impact

According to the USGS, an earthquake occurs when two blocks of the Earth suddenly slip past one another along what is called a fault or fault plane. As the two blocks slide, stored energy is released producing radiating seismic waves that result in an earthquake. The location below the Earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the Earth is called the epicenter.[1]

Earthquakes in the northeastern United States generally have deep foci (>10 km) and are considered to be intraplate; that is, they occur within plates rather than along current tectonic plate boundaries. Earthquakes that occur within an intraplate seismic zone are not typically expressed on the ground surface and are, therefore, more difficult to model.[2] Although there are numerous faults exposed at the ground surface in the northeastern United States, most are ancient and there is no evidence for significant ongoing motion along these faults.

A computer earthquake damage simulation (HAZUS program) conducted by the Vermont State Geologist's Office in 2012[3] suggests that there is little earthquake risk in Vermont at 100-year and 250-year recurrence intervals; however, there is a potential risk at the 500-year recurrence level. A Report on the Seismic Vulnerability of the State of Vermont[4] postulated six 500-year "strong" earthquake epicenters in the Northeast that could be expected to cause damage in Vermont are located at Middlebury (5.7 magnitude), Swanton (5.7 magnitude), Montreal, Quebec (6.8 magnitude), Goodnow, New York (6.6 magnitude), Tamsworth, New Hampshire (6.2 magnitude), and Charlevoix, Quebec, Canada (6.6 magnitude).

Using these epicenters and magnitudes, further HAZUS runs confirmed that these earthquakes (absent Charlevoix) have moment magnitudes and epicenters close enough to Vermont to result in significant damage. These five earthquakes have predicted peak ground accelerations (PGAs), used to measure the amplitude of the largest acceleration at a given site during an earthquake, greater than 0.1g and would cause widespread damage resulting in tens to hundreds of millions of dollars in structural and economic losses and undetermined casualties. The Swanton and Middlebury earthquakes were estimated to have PGAs of 0.4g and total losses exceeding $300 million dollars each (HAZUS-MH projections). In addition to the five postulated 500-year earthquakes that would affect Vermont, the 2002 occurrence of a 5.3 magnitude earthquake near Plattsburgh, New York, indicates that this epicenter should also be considered.

1 https://www.usgs.gov/programs/earthquake-hazards/science-earthquakes
2 Hubenthal M, Stein S, & Taber J. 2011. A Big Squeeze: Examining and Modeling Causes of Intraplate Earthquakes in the Earth Science Classroom. The Earth Scientist, 27 (1), 33-39.
3 https://anrweb.vt.gov/PubDocs/DEC/GEO/HazDocs/Wong_2012sm.pdf
4 http://dec.vermont.gov/sites/dec/files/geo/HazDocs/Ebell_1995.pdf

Middlebury Scenario:

- Building Damage: HAZUS-MH estimates that over 3,600 buildings will receive at least moderate damage. Of these, 38 buildings will be completely destroyed. This is over 2% of the total number of buildings in the State. For essential facilities, HAZUS-MH also estimates that on the day of the earthquake, 98% of hospital beds will be available and by 30 days, 100% will be operational. One school will receive moderate damage. It is predicted that over 262 families will be displaced from their homes and 62 will need temporary shelter.
- Transportation and Utility Systems: HAZUS-MH estimates minimal disruption of the transportation and utility systems. However, over 2,000 households are expected to be without electrical power for up to 3 days.
- Casualties: The model predicts 69 casualties requiring medical attention, 12 needing hospitalization, and 2 killed by the earthquake.
- Economic Loss: Direct building losses are estimated at greater than $308 million; 10% of these losses are due to business interruption. HAZUS-MH estimates that damage to transportation systems will be $34 million. Approximately $0.21 million would be needed to repair damaged communication systems.
- Government Buildings: 14 structures are predicted to receive slight damage, 6 will receive moderate damage, and 1 will be extensive.

Montreal Scenario:

- Building Damage: HAZUS-MH estimates that over 3,400 buildings will receive at least moderate damage. This is over 2% of the total buildings in the State. Of these, 23 buildings will be completely destroyed. For essential facilities, HAZUS-MH also estimates that on the day of the earthquake, 95% of hospital beds will be available and by 30 days, 100% will be operational. It is predicted that over 229 families will be displaced from their homes and 56 will need temporary shelter.
- Transportation and Utility Systems: HAZUS-MH estimates no disruption of the transportation and utility systems and no households are expected to be without electrical power.
- Casualties: The model predicts up to 70 casualties requiring medical attention, 12 needing hospitalization, and 2 killed by the earthquake.
- Economic Loss: Direct building losses are estimated at greater than $198 million; 17% of these losses are due to business interruption. HAZUS-MH estimates that damage to transportation systems will be $18 million. Approximately $0.03 million would be needed to repair damaged communication systems.
- Government Buildings: 15 structures are predicted to receive slight damage, 7 moderate damage, and 1 extensive.
- Developed in the early 1900s, the Modified Mercalli Intensity (MMI) scale assesses an earthquake's intensity qualitatively, based on the effects that are experienced on the ground. The lower the MMI score, the more likely the earthquake was only felt by people near the epicenter. As the intensity score increases, damage to structures are observed.

Earthquake Location

Earthquakes can occur anywhere in the State of Vermont. Please see earthquake history and trends for more details on location.

Table 30: Modified Mercalli Intensity (MMI) Scale			
Intensity	**Shaking**	**Description/Damage**	**Richter**
I	**Not felt**	Not felt except by a very few under especially favorable conditions.	1.0-3.0
II	**Weak**	Not felt except by a very few under especially favorable conditions.	3.0-3.9
III	**Weak**	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.	
IV	**Light**	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.	4.0-4.9
V	**Moderate**	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.	
VI	**Strong**	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.	5.0-5.9
VII	**Very Strong**	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.	
VIII	**Severe**	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.	6.0 and higher
IX	**Violent**	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.	
X	**Extreme**	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.	
XI	**Extreme+**	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.	
XII	**Extreme++**	Damage total. Lines of sight and level are distorted. Objects thrown into the air.	

Source: https://earthquake.usgs.gov/learn/topics/mag_vs_int.php

Earthquake History

Vermont is classified as an area with low to moderate seismic activity. Since 1900, Vermont has only experienced three earthquakes registering 2.5 or greater on the Richter Scale. The two strongest recorded earthquakes measured in Vermont were of a magnitude 4.1 on the Richter Scale. One was centered in Swanton and occurred on July 6, 1943, and the second occurred in 1962 in Middlebury. The 1962 earthquake was felt throughout New England and resulted in broken windows and cracked plaster, while the Swanton earthquake caused little damage. It is likely that small earthquakes will continue to occur in the coming years.

In addition, earthquakes centered outside the State have been felt in Vermont. Twin earthquakes of 5.5 occurred in New Hampshire in 1940. In 1988, an earthquake with a magnitude 6.2 on the Richter Scale took place in Saguenay, Quebec and caused shaking in the northern two-thirds of Vermont (Ebel, et. al. 1995).

On April 20, 2002, a 5.1 magnitude event in Plattsburgh caused shaking in Vermont with damage near the epicenter in New York. In the last five years, there have been only five earthquakes in the New England/ Northern New York and Southeast Ontario/Southwest Quebec region that recorded 3.0 magnitude or higher on the Richter Scale: 7/4/14 Saint-Andre-Avellin, Quebec, magnitude 3.0; 1/12/15 Wauregan, Connecticut, magnitude 3.3; 7/15/15, Hawkesbury, Canada, magnitude 3.3; 11/18/15, Cornwall, Canada, magnitude 3.2; 10/19/17, Mont-Tremblant, Canada, magnitude 3.1.

Earthquake Trends

Unlike some natural hazards, it is not currently possible to predict when or where an earthquake may occur in New England. Due to Vermont's intraplate location, earthquakes in this region are not as well understood as those locations that lie along a plate boundary. Given this inability to predict the location and extent of the next earthquake, coupled with our history of relatively minor and very infrequent events, the Steering Committee considered the probability of a plausibly significant event to occur once in every one hundred years with negligible impacts to the State's built environment, people, economy, and natural environment.

Though New England sits intraplate, there are areas of the region that record higher rates of peak ground accelerations. The Adirondack region of New York and the geographical region of Canada between Ottawa and Montreal have higher PGAs, which have had recorded earthquakes that caused ground movement in Vermont. Because of this PGA distribution, the northwest region is more vulnerable to earthquake than the rest of the State (Figure 63). Further, as the Vermont Geological Survey continues to better understand the distribution of the State's landslides (see: Landslides), it is currently understood that the northwest region is also relatively prone to landslide hazards. As earthquakes often cause landslides, these two hazards can have a compounding effect and exacerbate impacts.

Many earthquake events have been recorded outside of the Vermont boundary, but residents can occasionally feel ground movement and have experienced minor non-structural impacts from these events. The USGS has a "Did You Feel It?" (DYFI) reporting tool that allows users to submit reports of ground movement, which then helps seismologists better understand the extent and impacts of ground movement (Figure 64).[5] This tool can then be used to research past events and increase awareness of a region's vulnerability to earthquake effects, allowing people to then develop mitigation actions accordingly.

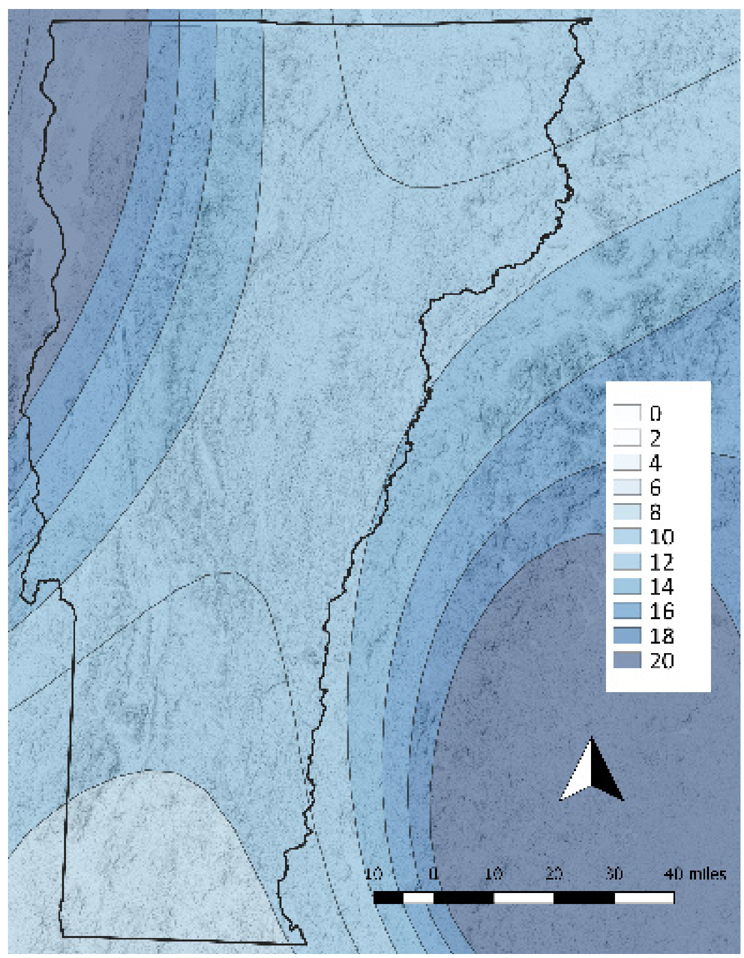

Figure 63: Peak acceleration expressed as a percent of gravity (%g)
Source: https://earthquake.usgs.gov/hazards/hazmaps/conterminous/

Earthquake Vulnerability

People:

The impacts that earthquakes can have in Vermont tend to be minimal, relative to other regions of the country that rest on tectonic plate boundaries. With few earthquakes occurring with a magnitude of 2.5 or greater over the past century. Population density in Vermont is higher now than ever before, potentially increasing the risk for human lives near to impacted areas. People who live in both urban and rural areas can be at risk due to structural damage in buildings that can trap or harm residents. Earthquake-triggered events such as landslides can cut

5 https://earthquake.usgs.gov/data/dyfi/

off access to aid in rural areas, preventing emergency services from reaching remote areas. People with low mobility or that are hospitalized can experience additional risk during a seismic event. A significant earthquake may cause many simultaneous emergency situations and thus may severely strain the ability of emergency service providers to respond adequately to all the accident sites.[6] Should an event be strong enough to damage dams or cause dam failure, thousands of people could be put at risk downstream. For example, failure of the Waterbury Dam could put 10,000 people in harm's way, and up to 800 people may perish (largely in Waterbury), and 1,200 buildings would be impacted.[7]

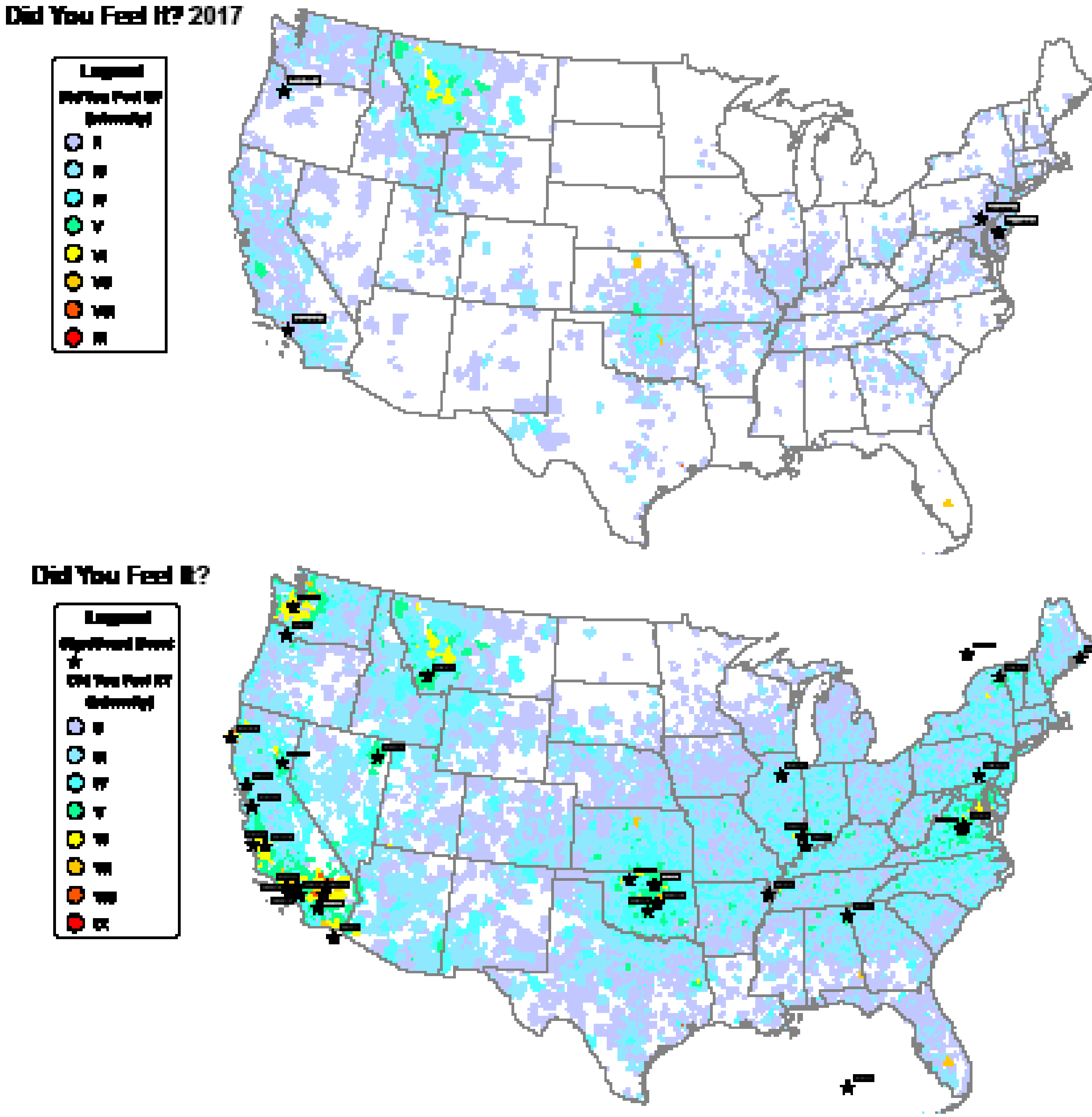

Figure 64: U.S. Earthquake Responses in 2017 (top) and Cumulative (1991-2017)
Source: https://earthquake.usgs.gov/data/dyfi/summary-maps.php

6 https://dec.vermont.gov/sites/dec/files/geo/StatewidePubs/eduleaf1EQ.pdf
7 https://dec.vermont.gov/sites/dec/files/WID/Dam_Safety/Waterbury%20Dam%20Fact%20Sheet%20-201215.pdf

Built Environment:

Seismic impacts on the built environment are likely going to be the most pronounced out of the vulnerability categories. Earthquakes can cause structural damage to buildings that are not properly built or rated to withstand seismic events. Enough movement can cause cracking and glass shattering in ill-prepared structures. Ground movement can cause the cracking and breaking of roadways, resulting in obstacles to travel. Utilities such as electricity, water, sewage, and gas can all be impacted through ground shaking, especially if these are subsurface utilities. The Vermont Gas pipeline (aka the TransCanada Pipeline), which runs for more than 750 miles from Canada through Highgate, VT to Middlebury with underground transmission and distribution lines,[8] represents critical infrastructure potentially vulnerable to ground shaking, especially when considering its location along the northwestern and west-central region of the State. Cracks in this pipeline can cause gas leaks that lead to untold environmental damage in conjunction with the structural damage to the pipeline.

According to the National Earthquake Hazard Reduction Program of the U.S. Geological Survey, there is approximately a 10% chance that parts of Vermont will experience shaking of at least 8 to 10% of gravity in any given 50-year period. This level of shaking is sufficient to cause property damage. There is roughly a 2% chance that parts of Vermont will experience shaking of at least 18-20% of gravity in any given 50-year period. Such shaking is sufficient to cause considerable damage to property. These estimates are for sites directly underlain by solid rock. Sites with thick soils may experience greater shaking due to amplification of seismic waves. Also, the height and method of construction of a building have a great influence on how it will behave in a quake.[9]

Natural Environment:

The impacts of earthquakes on the natural landscape are largely dependent on the magnitude of the event and the local geology of the region. Given that Vermont is situated on an intraplate zone, there are no major fault lines nearby that pose significant hazards. Most impacts earthquakes can have on the natural environment are caused by ground movement. Ground resonance, surface faulting, and ground failure can all occur as a result of a seismic event. The thickness and strength of soils has a great influence on how strongly an earthquake is felt. Thick deposits of weak sediments can amplify seismic waves and make the quake feel stronger than on sites directly underlain by solid rock. Also, some types of saturated soils may liquefy and deform under the shaking of an earthquake.

Vermont's varied topography can trigger collateral mass wasting hazards where unconsolidated materials rest on unstable slopes. Under enough stress, earthquakes can cause failures in dams that can threaten thousands who live downstream of Vermont's hydroelectric and flood control dams. For example, should the Waterbury Dam fail flooding will occur and impact the landscape from Middlesex to Burlington.[10] Flooding could damage crops and important forested sites within the path of the floodwaters. Many agricultural operations take place on the fertile soils of Vermont floodplains, which can put those fields at risk. Typically, farmers are adapted to seasonal flooding that replenishes soil nutrients, but unexpected flooding can cause a loss of agricultural goods.

8 https://puc.vermont.gov/natural-gas
9 https://dec.vermont.gov/sites/dec/files/geo/StatewidePubs/eduleaf1EQ.pdf
10 https://dec.vermont.gov/sites/dec/files/WID/Dam_Safety/Waterbury%20Dam%20Fact%20Sheet%20-201215.pdf

Economy:

Earthquakes can have significant economic impacts throughout the state. Impacting critical infrastructure including roadways, dams, utilities, pipelines, and buildings. Road access can be hampered by cracking caused by ground shifting limiting mobility and requiring maintenance to repair. Dams, aside from causing widespread destruction in the event of their failure, are important sources of recreational and economic activity. Should a dam be damaged, its ability to generate electricity for surrounding homes and businesses can be infringed.[11]

Urban centers often have their utility lines and water pipes buried to decrease obstruction and to regulate temperatures in the winter to prevent freezing. Ground movement can damage or sever these connections, stopping the flow of critical utilities while also requiring urgent repairs. Strategic gas and oil pipelines could also be at risk of damage that causes leaks, causing health impacts for nearby populations and the surrounding environment. As a provider of economic activity and a source of energy in the region, damage can severely impact the local economy. Lastly, structural damage to buildings can temporarily or permanently close businesses who might need to rebuild or reinforce damaged properties. A breakdown in the transfer of goods throughout the State will cause a decline in economic activity for many export or service-based industries.

Earthquake Mitigation

Given the low probability of a significant event, earthquake mitigation is often not a high priority at the State, regional or local level; however, as it is well understood by the Steering Committee that a significant earthquake event could have substantial impacts to infrastructure and human life, several mitigation actions have been developed as part of the Plan update process. The three actions included in the plan for seismic activity are: conduct thorough seismic analyses of select bridge sites, based on UVM's seismic vulnerability ranking system, and prioritize projects, conduct detailed seismic analyses for critical facilities identified in the 2016 NESEC study as well as cultural facilities using HAZUS and ROVER, and partner with educational institutions to install monitoring stations across Vermont to better understand current seismic activity (see: Mitigation Strategy). These analyses will better inform subject matter experts of the State's vulnerability to earthquakes and provide data necessary for mitigation project development.

11 https://dec.vermont.gov/sites/dec/files/WID/Dam_Safety/Waterbury%20Dam%20Fact%20Sheet%20-201215.pdf

4-13: Hail

Hazard Impacts	Probability	Potential Impact					Score*:
		Built Environment	People	Economy	Natural Environment	Average:	
Hail	3	1	1	2	1	1.25	3.75

*Score = Probability x Average Potential Impact

Hail is a form of precipitation composed of spherical lumps of ice. Known as hailstones, these ice balls typically range from 5-50 mm in diameter on average, with much larger hailstones forming in severe thunderstorms (see: Wind). The size of hailstones is a direct function of the severity and size of the thunderstorm by which it is produced. No matter the size, hail can damage property, young and tender plants, and cause bodily harm to those unfortunate enough to be caught outside.

Table 31: TORRO Hailstorm Intensity Scale

	Intensity Category	Typical Hail Diameter (mm)	Probable Kinetic Energy (J/m2)	Typical Damage Impacts
H0	Hard Hail	5	0-20	No damage
H1	Potentially Damaging	5-15	>20	Slight general damage to plants, crops
H2	Significant	10-20	>100	Significant damage to fruit, crops, vegetation
H3	Severe	20-30	>300	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored
H4	Destructive	25-40	>500	Widespread glass damage, vehicle bodywork damage
H5	Destructive	30-50	>800	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries
H6	Destructive	40-60		Bodywork of grounded aircraft dented, brick walls pitted
H7	Destructive	50-75		Severe roof damage, risk of serious injuries
H8	Destructive	60-90		Severe damage to aircraft bodywork
H9	Super Hailstorm	75-100		Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
H10	Super Hailstorm	>100		Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open

Source: http://www.torro.org.uk/hscale.php

Hailstorms usually occur in Vermont during the summer months and generally accompany passing thunderstorms. While local in nature, these storms can be significant to area farmers, who can lose entire fields of crops in a single hailstorm. Large hail is also capable of property damage, including both structures and vehicles. Hailstone size can range from the size of a pea to the size of a melon (Table 32).

Table 32: Hail Size and Diameter in Relation to TORRO Scale

Size Code	Maximum Diameter (mm)	Description
0	5-9	Pea
1	10-15	Mothball
2	16-20	Marble, grape
3	21-30	Walnut
4	31-40	Pigeon's egg > squash ball
5	41-50	Golf ball > Pullet's egg
6	51-60	Hen's egg
7	61-75	Tennis ball > cricket ball
8	76-90	Large orange > Soft ball
9	91-100	Grapefruit
10	>100	Melon

Source: http://www.torro.org.uk/hscale.php

Location

Hail can occur anywhere in Vermont. See hail history below for details on locations of previous occurrences.

Hail History

There have been 626 hail events in Vermont since 2000, causing over $585,000 in property damage and $261,000 in documented crop damage.[1] The largest recorded hail was 3.3" in Westford in July 2009, with an estimated $100,000 in damages. The second largest hail event was in June 2011, with recorded hail of 3.25" in Shaftsbury.

Table 33: Hail Events Summary: 2000-2022

Hail Size	Days with an Event	Impacted Jurisdictions	Property Damage	Crop Damage
3-3.5"	2	Shaftsbury, Westford	$50,000	$50,000
2.5-2.99"	3	Duxbury, Moretown, Westford	$40,000	$20,000
2.0-2.49"	7	Bellows Falls, East Brookfield, Fairfax Falls, (MPV)-Montpelier ARPT, New Haven Mills, Swanton	$45,000	$20,000
1.75-1.99"	26	Alburg, Bellows Falls, Bethel, Brandon, Brookfield, Castleton, Center Rutland, Danville, East Barnard, East Burke, East Dover, Enosburg Center, Fayston, Franklin, Irasburg, Irasville, Jonesville, Lower Waterford, Lunenburg, Mill VLG, Morgan Center, New Haven, Newfane, North Hero, Orleans, Passumpsic, Peru, Pittsfield, Proctor, Richford, Shaftsbury, South Wallingford, St. Johnsbury, St. Johnsbury Center, Waitsfield, Warren, West Barnet, West Waterford, Westford, Westminster	$286,000	$1,000
1.5-1.74"	21	Bowman Corners, Bradford, Burlington, Charlotte, Chittenden, East Montpelier Center, Egypt, Essex JCT, Fair Haven, Greensboro, Ira, Johnson, Lyndonville, Milton, Moretown, New Haven Mills, Newark Hollow, Northfield, Peacham, Richford, Rutland, Shaftsbury, Shelburne, South Starksboro, Underhill, Underhill Center, West Addison, West Fairlee Center, Weybridge	$105,000	$0
1.25-1.49"	22	Albany, Benson, Bethel, Bridport, Bristol, Burlington, East Arlington, East Burke, Fayston, Halifax, Highgate Spgs, Lowell, Middlebury ARPT, Milton, Newport, Passumpsic, Pittsfield, Richford, Richmond, Riverside, Sheldon, Shoreham, South Richford, South Starksboro, St. Johnsbury, St. Johnsbury Center, Sunderland, Taftsville, West Lincoln, West Waterford, Westford	$0	$20,000
1.0-1.24"	96	Addison County, Bennington County, Caledonia County, Chittenden County, Essex County, Franklin County, Grand Isle County, Lamoille County, Orange County, Orleans County, Rutland County, Washington County, Windham County, Windsor County	$46,000	$150,000
0.87-0.99"	62	Addison County, Bennington County, Caledonia County, Chittenden County, Essex County, Franklin County, Grand Isle County, Lamoille County, Orange County, Orleans County, Rutland County, Washington County, Windham County, Windsor County	$6,000	$0
0.75-0.86"	63	Addison County, Bennington County, Caledonia County, Chittenden County, Essex County, Franklin County, Grand Isle County, Lamoille County, Orange County, Orleans County, Rutland County, Washington County, Windham County, Windsor County	$2,000	$0

Source: https://www.ncdc.noaa.gov/stormevents/

1 v https://www.ncdc.noaa.gov/stormevents/

Hail is considered a relatively infrequent occurrence in Vermont. Those hail events that do occur tend to be highly localized and limited to a relatively small area. Table 33 is a summary of all hail events between 2000 and 2022.

Hail Trends

The Steering Committee considers the probability of hail to be Likely, given the frequency with which Vermont has some form of hail event. Relative to Vermont's other hazards, the impact from hail is considered to be negligible to infrastructure, life, the economy and the environment. Overall hail ranked lowest compared to all other natural hazards that can impact Vermont in the 2023 hazard assessment.

According to the 2018 National Climate Assessment, though there is an observable increase in severity of winter storms, changes in the frequency or severity of hail events are still uncertain but are being extensively studied.[2]

Hail Vulnerability

People:

With an average hail size of 5-50 mm in Vermont, there is a chance that residents could be injured on impact. The largest recorded hail size in Vermont history was about 84 mm, and although no one was injured or killed, it is possible that another future event could produce similarly damaging hail. People without access to shelter during hailstorms are particularly vulnerable to potential injury or death, which includes unhoused populations. Farmers may also be more vulnerable to hailstorms than other groups of people. Loss of crops or livestock during such events can significantly impact farmers' financially and overall well-being.

Built Environment:

Since 2000, hailstorms in Vermont have caused about $585,000 in property damage. Buildings, homes, and cars can be significantly damaged by hailstorms as hail size increases, depending on the material with which they were built. For instance, vinyl siding on homes is popular due to its ability to withstand wind, but it can be damaged easily by large hailstones.[3] Cars are subject to body damage such as scratches and dents, as well as shattered glass if hailstones are large enough.

Natural Environment:

Hail has the potential to damage tender vegetation. Hail can tear through leaves, destroy seedlings, impact stems and bark, and cause damage to fruits.[4] Hail damage to vegetation affects their ability to create energy necessary to maintain life and can increase chances of infection.[5]

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2 https://nca2018.globalchange.gov/chapter/2/
3 https://www.hanover.com/resources/tips-individuals-and-businesses/prepare-now-learn-how/understanding-effects-hailstorms
4 https://www.fdacs.gov/content/download/11354/file/pp347.pdf
5 https://myswingle.com/hail-damage-tree-shrubs/

Economy:

Although significant hailstorms occur relatively infrequently, they are still important to consider, given Vermont's primarily agrarian economy. As mentioned above, significant hail events can lead to extensive crop damage, which can negatively impact Vermont's many farms. Since 2000, hailstorms have caused $261,000 in crop damage, a majority of which is attributed to hail size between 1.0-1.24" and 3-3.5" respectively. Larger hailstones have a greater chance of destroying crop fields, but it is evident with the hailstones sized 1.0-1.24" causing $150,000 in damage since 2000 that it depends on the severity of the storm.

While hail can directly damage these crops, other aspects of Vermont's economy may be indirectly affected. There have been reports of hailstorms destroying entire hay fields and cornfields. These crops are usually used to feed animals, thus dairy farms and other farms that breed livestock can also be affected. This can cause a domino effect increasing prices of feed for livestock, which in turn increases the price of milk and other dairy products, further impacting the economy.

Hail Mitigation

Due to the unpredictability of hailstorms and the negligible impacts to infrastructure, life, the economy and the environment, there is little in the way of hail mitigation in Vermont. Most efforts related to hail are in the response and recovery sectors, not mitigation.

However, implementation of certain actions within the Plan will address hail (see: Mitigation Strategy), such as the strategy an assessment to better understand the impacts from hazard events on the unhoused and a review of nationwide building codes (to include residential and energy codes) to determine what codes could be best suited to Vermont, including standards for new construction and best practices for existing buildings (e.g., weatherization, retrofit - tied into manufactured housing) - integration into existing Vermont codes, including impacts to frontline communties.

5: Vulnerability Summary

Each hazard profile in this plan included discussion on vulnerability in categories of People, Built Environment, Natural Environment, and Economy. In practice there is no separating these categories of vulnerability, they are all connected with cross-cutting challenges. This section explores compounding vulnerabilities due to exposure to natural hazards and climate change.

COMMON ISSUES ACROSS HAZARDS

As the vulnerability sections of hazard profiles were developed there were potential hazard impacts on people, the built environment, the natural environment, the economy that came up repeatedly. These reoccurring vulnerabilities begin to paint a picture of risk and exposure across Vermont's landscape. The following is a summary of who and what may be most impacted by multiple hazards that can occur in Vermont.

People:

People who were identified as having risk factors that increase susceptibility and exposure in multiple hazards profiles were:

- those on electricity-dependent in-home life support equipment;
- isolated residents;
- rural residents;
- people with access or mobility differences;
- older adults;
- people who are pregnant;
- those who are immunocompromised or living with chronic health conditions;
- unhoused individuals;
- manufactured/mobile home residents;
- outdoor workers;
- children;
- people lacking the economic resources to adequately prepare, adapt, and recover.

There is a great deal of crossover amongst the demographics identified above. There are also compounding issues that make certain individuals more vulnerable to hazard events.

When asked who their frontline communities were in a Vermont-wide survey of municipal staff and volunteers, towns across Vermont overwhelmingly responded that their aging populations were the most vulnerable to hazards and would have the most difficult time recovering. The demographic of older adults was followed by low or "modest" income persons and those who live alone. Other frontline communities were those on in-home medical equipment, businesses, and residents in the floodplain, those with mobility challenges, mobile home residents, those with mental health conditions, rural and isolated persons, those without backup heat or water, people living near railroads lines, farm/agricultural business owners and workers, and maple sugar makers.

Other common themes included that multiple hazards could lead to carbon monoxide poisoning from generators improperly installed or with failed ventilation systems, and communication is essential for people's wellbeing before, during, and after a hazard event.

Built Environment:

The built environment assets that are vulnerable to multiple hazards in Vermont are electrical, water, transportation, and communication infrastructure. Loss of these systems would have direct impacts on people's ability to heat and cool their homes, power in-home life support equipment, travel and receive emergency assistance, access safe drinking water, and maintain a functioning home or business.

Multiple hazards can disrupt these major infrastructure systems with cascading effects. For example, a loss of electricity will impact well pumps, heating systems, and the internet.

Emerging vulnerabilities include dependence on electricity for internet, cell coverage, and charging vehicles. Many people in Vermont depend on electricity to maintain wireless internet for cell coverage, often their only phone. Additionally, many people working from home depend on electricity and wireless internet to work from home and send or receive information.

Natural Environment:

Common impacts to the natural environment due to multiple hazards are to tree and forest health, water quantity and quality, soil, and overall ecosystem balance. These impacts to the natural environment affect people as well. For example, water quality issues can impact drinking wells, recreational fish habitat, swimming areas, and other natural assets Vermont depends on. Water, soil and tree health also have impacts on the economy further discussed below.

Natural disasters are part of the normal cycles of our landscapes and ecosystems. Negative consequences of natural hazards are primarily seen where the natural environment interacts with built environment, people, and economy. The resilience of the natural environment to disasters is changing with climate change, as typical weather patterns are altered and plant and animal life are not given time to adapt to new conditions. The health of the natural environment is often a first indicator of slow-moving hazards such as drought, invasive species and other hazard impacts accelerated by climate change.

Economy:

In assessing the economic vulnerabilities across hazards, the major economic impacts of hazard events and climate change in Vermont are seen in tourism, agriculture, and forestry products.

Multiple concerns exist for the dairy industry due to electricity loss, extreme temperatures and water stress. Dairy cows maintain a range of temperatures where they are comfortable and conditions outside those parameters can often lead to stress which can reduce the yield produced. Most dairy farms in Vermont are open to the outdoors and do not use air conditioning systems beyond fans. Electricity is needed for the cooling, refrigeration, and pasteurization of milk products, and a loss of electricity will require dumping of milk produced. Hazards that impact industries linked to dairy farming, such as feed crops, can also result in ripple effects that impact industry after industry.

Across hazards, vulnerabilities were also observed in maple syrup production. Sugaring as an industry falls between agriculture, forestry, and tourism and because of these overlapping relationships impacts to this industry can have pronounced impacts. Maple sugaring is a key industry within the State, as Vermont produces roughly 42% of maple products in the nation.[1] Changes in climate have resulted in shifts to the native range of

1 https://www.uvm.edu/news/story/study-vermont-maple-industry-contributes-more-300-million-sales-states-economy

sugar producing trees. This includes shifts northward towards areas that receive colder winters, with weather that creates freeze thaw events allowing sap to flow.[2] This would typically take place over several weeks, however, as spring temperatures begin earlier the sugaring season decreases in length.

Under historic conditions, the insulating layer of a thick snowpack regulates ground temperatures and protects tree roots. Snowpack has been declining in Vermont over the past few decades, exposing the root systems of sugar maples to colder temperatures. A deeper frost layer dramatically reduces the ability of the sugar maple to take up water and nutrients through frost damaged roots. A reduction in the snowpack has been shown to decrease the growth rate of sugar maples by 40%.[3] Growth is also hindered by invasive pests such as the spotted lanternfly and the Asian long-horned beetle which could target maples as they expand northward.[4] These declines in the productivity and success of sugar maples impact both the sugaring and forestry industries.

Impacts to the forestry industry are also noticeable through a variety of hazards including drought, invasive species, and wildfire. These hazards can compound to increase impacts. Droughts can negatively impact forest inventories by increasing mortality and reducing growth due to a reduction in water availability.[5] Wildfire conditions can also be created during prolonged droughts due to how dry vegetation is, increasing its flammability. The loss of stock as a result of a fire event can be an economic loss not easily recovered. One of the largest threats to forestry industries across the country is the presence of invasive species that either target species (e.g., emerald ash borer)[6] or strangle native plant species (e.g., asiatic bittersweet).[7]

The out-competition of native species critical to Vermont forestry threatens the success of the industry, resulting in large investments into invasive species removal. The increasing abundance of invasive species within forests can lead to a change in the fuel dynamics present in the event of a fire. Observations indicate that changes in fuel characteristics brought about by nonnative species invasions can lead to changes in fire behavior and alter fire regime characteristics such as frequency, intensity, extent, type, and seasonality of fire impacting native plant and animal communities. Invaded forest communities in the Northeast often had a substantially higher cover of shrubs than uninvaded communities, resulting in increased height and density of surface fuels and suggesting an increased potential for fire to carry into the tree canopy.

Impacts to the agricultural sector can result in significant losses in crop production. These losses can take a major toll on the economic success of farmers. Crop insurance is a tool that can be used by farmers to protect the value of their goods in the event of their destruction. There are many different crop insurance programs offered throughout the state which can be found on the University of Vermont Extension website.[8] In 2022, Vermont farmers paid $1.5 million in crop insurance, protecting 86,301 acres providing $42.3 million in liability protection. Of the amount protected, $2.1 million was paid from insurers to farmers to cover losses in 2022,[9] providing some economic safety net for farmers dealing with natural hazards. Not all farms are covered by insurance, however, having determined that payments are too great a burden to maintain.

Hazards cause business disruptions including supply chain issues, loss of inventory and cost of recovery, and

2 https://www.fs.usda.gov/ccrc/topics/maple-syrup
3 https://www.themaplenews.com/story/study-shows-declining-winter-snowpack-is-hurting-the-sugar-maple/231/
4 https://www.vtinvasives.org/news-events/news/two-new-invasive-species-could-invade-north-country-landscape-officials-trying-to-protect-sugar
5 https://www.fs.usda.gov/ccrc/topics/effects-drought-forests-and-rangelands
6 https://vtinvasives.org/land/emerald-ash-borer-vermont
7 https://vtinvasives.org/invasive/bittersweet-asiatic
8 https://www.uvm.edu/extension/agriculture/ag-risk-management
9 https://cropinsuranceinamerica.org/vermont/

an inability for employees and customers to travel. Other notable impacts seen across hazards were to water quality and fish habitat, another essential tourism draw and cultural asset.

Vermont prides itself on maintaining a connection to the rural countryside, curating an image of the rural idyll that helps drive much of Vermont's tourism. Seasonal drivers of tourism include autumnal foliation, winter sports, and fishing. Changes in water availability and climate stress can limit how vibrant the colors of leaves appear, impacting how many people choose to visit Vermont. The same goes for winter recreation, as a decline in snow will negatively impact ski resorts. Hazards like wildfire can impact access to many of Vermont's famous hiking trails such as the Long Trail, if such a hazard presents a danger to recreationalists. Water quality impacts across hazards can impact fish habitat and related tourism.

CROSS-CUTTING VULNERABILITIES AND COMPOUNDING ISSUES

Beyond the potential of simultaneous occurrence, several of the hazards also have the potential to cause other hazards. Causal relationships are identified in Table 34 (with causal hazards identified in green and resulting hazards identified in blue) and further addressed in pertinent hazard assessment sections. Combined with the projected increases in both precipitation and temperature, this assessment highlights the more significant compounding impacts that Vermont can anticipate in the future due to climate change.

Table 34: Causal Relationships Between Hazard Impacts

Secondary Hazard Impact (Result) / Primary Hazard (Causal)	Fluvial Erosion	Inundation Flooding	Ice	Snow	Wind	Heat	Cold	Drought	Landslides	Wildfire	Earthquake	Invasive Species	Infectious Disease	Hail
Fluvial Erosion														
Inundation Flooding														
Ice														
Snow														
Wind														
Heat														
Cold														
Drought														
Landslides														
Wildfire														
Earthquake														
Invasive Species														
Infectious Disease														
Hail														

Compounding Natural Hazards

Extreme heat and the presence of invasive species are examples of compounding natural hazards that affect Vermont. Compounding natural hazards are hazards and events which may accelerate another hazard in the process, increasing the vulnerability of the affected area. It is important that compounding natural hazards are closely monitored, as an increase in frequency can have a creeping effect on correlated natural hazards.

Heat:

Extreme heat events in Vermont have increased in frequency in the past decade, causing large-scale impacts on people who live in affected areas. In a ranking determined by the product of probability and the average potential impact of each hazard, extreme heat was the third most significant hazard experienced in Vermont for 2023. The high ranking was due to the factors listed above, and the cross-cutting impacts associated with drought, wildfire, invasive species, and infectious disease.

As higher temperatures lead to higher evapotranspiration rates, the probabilities of drought and wildfire events increase. Evapotranspiration can leach moisture from vegetation and soil, which can cause short-term drought in an extreme heat event. However, with the average annual temperature in Vermont increasing by 3.6°F,[10] the State is experiencing much warmer climates in shorter periods of time. Native species that are accustomed to colder climates may not easily adjust to warmer, and potentially drier climates. Such an increase in average annual temperature is likely to lead to a higher frequency of drought, as more moisture is lost to the surrounding atmosphere. Similarly, as this process unfolds, wildfire events may increase in frequency. Vegetation with lowered moisture levels have a higher probability of burning in the event of a wildfire. An ecosystem with much lower moisture levels might experience a rapid-moving and more devastating wildfire due to increased flammability.

A warmer climate may lead to an increase in invasive species and infectious disease outbreaks in Vermont. As the United States experiences warming due to climate change, animals and plants will undergo climate migration to the Northeast region due to its comparative resilience. Within this migration, it is likely that Vermont will see the introduction of more invasive species who can now withstand Vermont's warmer climate. Just as the quantity of invasive species may increase with heat in Vermont, infectious diseases outbreaks increase in probability. As noted in the Invasive Species profile, vector-borne diseases (e.g., Lyme, West Nile, and Eastern equine encephalitis) are more frequent in warmer climates. Heat can also cause water stratification, leading to increased levels of cyanobacteria, which can cause minor skin rashes, sore throats, diarrhea, stomach problems, or occasionally more serious health problems.

Compounding hazards can have detrimental impacts on adaptation behaviors and emergency response strategies. Cyanobacteria blooms are common during periods of extreme heat, which may make some water bodies unavailable as a cooling resource. Similarly, the COVID-19 pandemic created a barrier to providing safe congregate emergency shelters. Using air conditioning is one of the most effective ways to prevent heat-related health impacts – power loss concurrent with periods of extreme heat have had fatal impacts in some parts of the country in recent years, particularly when medical or long-term care facilities have experienced extended power loss during extreme heat.

Invasive Species:

Just as heat can precipitate multiple other hazards, the presence of invasive species can accelerate the frequency of landslides, riverine erosion, wildfires, and infectious disease outbreaks. Invasive species are an example of a creeping hazard, in which large-scale change occurs over time, instead of through one major event. Over time, invasive species crowd out native species and take over entire ecosystems. As invasive species crowd out native trees and shrubs on steep slopes, landslides may increase in frequency as less of a barrier exists to prevent such mass wasting events. Similarly, the defoliation and crowding out of native species may lead to increased probability of wildfire. Buildup on the forest floor may allow wildfire to spread more easily and affect a wider geography. Invasive plants also have the potential to harbor disease-carrying insects such as ticks and mosquitos. As invasive plants crowd-out native species and increase in quantity, more of these disease-carrying insects can exist in a given ecosystem and thus the probability of an outbreak will increase.

10 https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series/43/tavg/ann/2/1895-2023?base_prd=true&begbaseyear=1895&endbaseyear=2022&trend=true&trend_base=10&begtrendyear=1895&endtrendyear=2023

Compounding Social Issues

Environmental Justice:

In Vermont, significant planning and funding is currently being directed to adapt to climate change conditions at the same time as we try and find room in our existing cities, towns, and villages for more affordable housing. A range of existing and compounding social, environmental, built, and economic issues have been discussed in this plan. Historical planning, private development, and government investment have contributed to the environmental and social issues within hazard prone areas.

Addressing environmental justice (EJ) provides the opportunity to connect hazard mitigation, environmental quality, and social equity. The U.S. Environmental Protection Agency (EPA) defines EJ as:

The fair treatment and meaningful involvement of all people regardless of race, color, national origin, culture, education, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair Treatment means that no group of people, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal environmental programs and policies.

EJ scholars have broadened the EPA definition to include vulnerable groups such as children, older adults, the immune-compromised, and future populations. A more recent body of research shows vulnerability to climate change as an environmental burden on those who have limited resources to move, mitigate, or adapt to climate change effects. Vermont's environmental justice policy defines an environmental justice focus community as having annual median household income not more than 80 percent of the State median household income; Persons of Color and Indigenous Peoples (BIPOC) comprise at least six percent or more of the population; or at least one percent or more of households have limited English proficiency.

The disproportionate burden of climate change and natural hazards on low-income, marginalized, and vulnerable populations is an environmental justice issue. Vermont's new environmental justice policy states that environmental justice requires providing a proportional number of resources for community revitalization, ecological restoration, resilience planning, and a just recovery to communities most affected by environmental burdens and natural disasters.

Vulnerability can also fluctuate with life cycles; the very young and very old are in vulnerable categories, particularly in lower income communities. Pre-existing illnesses and physical disabilities of elderly populations limit their mobility and their capacity to cope with climate change impacts, including slow moving and extreme weather events. Depending on multiple factors people may not be able to evacuate during an emergency due to mobility, financial limitations, or a lack of family or friends to relocate to.

An analysis by University of Vermont researchers found that mobile homes are more likely than permanent structures to be located in a flood hazard area. During Tropical Storm Irene, mobile parks and over 561 mobile homes in Vermont were damaged or destroyed. Mobile homes make up 7.2 percent of all housing units in Vermont and were approximately 40 percent of sites affected by Tropical Storm Irene.

Another University of Vermont study reports that BIPOC individuals were seven times more likely to have gone without heat in the past year, and over two times more likely to have trouble affording electricity.[11]

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11 https://legislature.vermont.gov/Documents/2022/Docs/ACTS/ACT154/ACT154%20As%20Enacted.pdf

Historically underprivileged populations have greater vulnerabilities to climate change around the world. Marginalized populations lack political power, financial resources, and mobility. This is in part due to discriminatory practices that segregate those with less socioeconomic power into the highest-risk neighborhoods, usually without access to insurance and loans as security against climate change impacts. In a post-disaster scenario, disparities become more visible as some households can afford to rebuild, while others either live in unhealthy conditions or lose their homes completely due to the cost of rebuilding and insurance. Wealthy homeowners and municipalities are also better able to participate in home buyout programs and relocate within their communities.

How Vermont mitigates risk of exposed assets can either reduce or perpetuate vulnerabilities. People living in hazard prone areas have felt and will feel the brunt of hazard and climate change impacts. In investing resources in hazard prone and marginalized communities, Vermont must ensure that these communities can benefit from improvements, rather than be pushed out by competition for housing and loss of affordability.

Meaningful consideration of environmental justice issues is vital in the planning process for Vermont, and identification of environmental justice issues or unintended consequences of a mitigation action on frontline communities should trigger not only minor revisions to the project, but major changes to the plans and projects for the floodplain and other hazard prone areas.

Food Security:

Food security can be impacted in multiple ways due to hazard events and climate change. Each hazard profile in this Plan discusses impacts to agriculture, which has downstream impacts on food availability. For example, an early frost in May can mean that there is limited local fruit and vegetables available that year, driving up the costs of groceries for consumers.

Additionally, disaster events can cause closures of grocery stores for extended periods of time. Given the rural nature of Vermont, a region covering multiple towns may only have one grocery store available, and closure of that grocery store will impact the entire region and its communities.

Housing:

Vermont is currently experiencing a historic housing shortage. There is a shortage of all affordable housing options in both rural and more urban parts of the State including availability of starter homes and smaller, affordable housing units. The lack of housing prices out young families and older adults that need to downsize their homes while remaining within their communities and social networks. This has impacts on the tax base as well as local school populations. Many local elementary schools are under pressure to close due to waning student numbers. Given Vermont's topography and population density, these local elementary schools are necessary to allow for the safe and efficient transportation of students to and from school. A loss of local schools also removes potential shelters and localized resilience hubs in isolated communities.

During the Covid-19 pandemic, historically low interest rates for mortgages and fear of urban locations led to a house-buying rush in Vermont. The competition for homes and low housing stock has made homeownership unattainable for many people. The cost of rent has also increased with demand. According to a 2022 study from Hazard University's Joint Center for Housing Studies, the median home price along the central border with New Hampshire was $325,172, requiring a household income of $89,415. In northwest Vermont the median home price was $420,917, requiring an income of $115,742.[12] The median household income in Vermont was $67,674.[13] Those home prices have continued to rise with historic low inventories as people hold onto existing homes and low mortgage interest rates that have since risen in response to inflation.

The in-migration of people to Vermont during the Covid-19 pandemic, and accelerated housing crisis, serves as a warning of issues we will face in housing as people move away from exposed coastal areas and hotter climates to Vermont to escape climate change impacts. As discussed within the environmental justice section, many of the people moving to Vermont will be wealthier, having the assets to move away from the worst climate change impacts, further exacerbating affordability of housing in Vermont if supply cannot keep up with demand. Climate migration is further discussed under Future Trends and Concerns.

The housing crisis means that people are not able to afford safe homes. Individuals and families may be forced to buy or rent homes that are susceptible to flooding or erosion. For those who do buy homes, affording to weatherize or resiliently retrofit a home may be unattainable. Renters are typically not able to weatherize or retrofit a home.

With current and projected increases in populations due to both the Covid-19 pandemic and climate migration, development planning must account for expected growth while aligning with community character and vision. The VT Climate Action Plan published in December 2021 urges cities and towns to follow a compact settlement pathway, following Vermont's existing village center development patterns. Compact settlement refers to developing within already established residential and commercial centers, as opposed to uninhabited areas. Compact settlement provides health, economic, and environmental benefits. The structure provides a network of resources to community members and protects the environment by preventing forest fragmentation.[14] However, given Vermont's history of development along waterways and in the floodplain, there is a balance to strike between compact development within already urbanized centers, and ensuring that we are not putting people and businesses in harm's way.

Many people were experiencing homelessness prior to the Covid-19 pandemic, many more lost their homes during the Covid-19 pandemic. Vermont determines the number of people living outside, or houseless, on a single day each year with the point-in-time count. Prior to the onset of Covid, Vermont's count hovered around 1,000 and 1,500 people in contrast to 2021 with a count of 2,591 and 2022 when the count rose to 2,780.[15] During the emergency declaration phase of Covid-19, housing programs were available for many people experiencing homelessness. With the end of federal funding for these programs through the emergency declaration in May 2023, the question of where these Vermonters will go is under discussion.

People without homes are significantly more vulnerable to hazards events. They are potentially exposed to extreme heat and cold, wildfire smoke, ticks, and mosquitoes, and are exposed to elements of all natural hazards in Vermont. Many people experiencing homelessness are older adults or have chronic health conditions that can be exacerbated by extreme heat. Both heat and cold can lead to deaths.

12 https://www.jchs.harvard.edu/son-2022-affordability

13 https://www.census.gov/quickfacts/VT

14 https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/Initial%20Climate%20Action%20Plan%20-%20Final%20-%2012-1-21.pdf

15 https://s3.documentcloud.org/documents/22122817/homelessness-report.pdf

Individual and Community Well-Being:

One change in the 2023 plan from the 2018 plan is how we assess hazard impacts on people. Conventional methods assess the impact of hazards by the number of people injured or killed by a hazard event. This method misses most of the picture of how hazards impact lives. For example, a small flood may cause mold to grow in a home, and while this did not cause death, it can have significant long term health impacts on those living there. Another example could be invasive species, or the many hazards that impact the health and longevity of trees. Numerous studies show the benefits of trees in urban and suburban neighborhoods. Loss of trees can influence mental health, a sense of place, heat, wind, and flood mitigation, and well-being at a community scale.

Futures Trends and Concerns

Since the 2018 State Hazard Mitigation Plan, Vermont has experienced the acceleration of climate change, as well as the effects of a global pandemic. Large-scale disasters will continue in the future and Vermont may experience a large population increase. Keeping these possibilities in mind, future trends and concerns are addressed below.

Climate Migration:

Climate migration was discussed generally during 2018 plan development. Ultimately, the Steering Committee decided that this was a topic to consider in more detail in the next version of the SHMP. Climate refugees will not be from one place or demographic. As portions of the U.S. become more arid and as sea levels continue to rise, Vermont may begin to see significant increases in population.

The increasing occurrence of compounding natural disasters in more vulnerable regions of the country may result in a changing demographic profile migrants coming to Vermont. Vermont will continue to see an increase in population due to migrants who decide to change residency as they face climate vulnerability at their primary residencies. These communities can result in a population spike that increases the stressors on housing, education, healthcare, social services, water supplies, sewage treatment, transportation, public health services, law enforcement services, and other aspects of society that would not have the capacity to handle such a change. Many factors play into the decision making of where to migrate if forced to including age, race, gender, and severity that can make it hard to determine how far people are willing to travel.[16] A sudden uncontrolled climate migration event will be difficult to prepare for unless action is taken now to expand the capacity of Vermont to anticipate significant population increases. Affordable housing is an issue that many current Vermont residents are faced with, and as the State welcomes climate migrants, demand may skyrocket the price of housing even further.

Climate migrants may be a future vulnerable population to consider within each hazard profile. The lack of affordable housing will not only impact the population of Vermonters already seeking homeownership or affordable rents, but also climate migrants and refugees.

The Unexpected Effects of Hazard Events:

FEMA's identification of "community lifelines" (safety and security, food-water-shelter, health and medical, energy (power and fuel), communications, transportation, and hazardous materials) reflects broad recognition

16 https://communityresilience-center.org/wp-content/uploads/2020/12/Climate_Migration_Report.pdf

that hazard events can have complex, far-reaching, compounding, and cascading consequences. For example, a long-term outage of electrical power across a wide region, regardless of whether precipitated by ice storm, wind event, cyber-attack, or other cause, will disrupt individual lives and social order in profound and potentially life-threatening ways. The immediate response concerns for events which rise to the level of creating "social chaos" is cross-cutting and ties back to Vermont's State Emergency Operations Plan including the Prevention and Protection Mission Area Plan, which covers "Long-Term Utility Outage" among "Technological and Human-Caused Hazards".

Local Vulnerability

In conjunction with the risk assessment, VEM staff conducted a vulnerability assessment, which predicts the extent of damage that may result from a hazard event of a given intensity in a given area and considers damage to the existing and future built environment, the natural environment, and populations within Vermont. Vulnerability was determined by identifying the threats posed to people, property, the environment, and the economy. Hazard-specific vulnerability is detailed further in the individual hazard profiles.

Though a small state, Vermont's topography and mountainous setting can result in geographic isolation during severe storms, which can have significant localized impacts. A localized storm can drop a significant amount of water into a small watershed, devastating one town or cutting it off from the rest of the State, while causing no damage to an adjacent town on the other side of a mountain. The mountainous areas in Vermont vulnerable to these phenomena are numerous. Because of the steep mountain topography, damage from frequently occurring extreme weather events in any specific location may occur often or only once in a lifetime, which makes it difficult to plan for and respond to events.

Coupled with this topographic isolation, the rural nature of the State can also result in isolation from necessary emergency response efforts. Most communities in Vermont have an identified local Emergency Operations Center (EOC) and/or shelter for its residents, should an event warrant their opening and often require a back-up energy source, typically in the form of generators. To keep these critical facilities functioning in times of need, VEM is regularly contacted for equipment and training requests and financial assistance. Other critical facilities that have applied for funding through the State are wastewater treatment plants and fire departments, which require back-up energy sources during events that may result in community-wide power loss (e.g., flooding, windstorm, ice/snow storm), or which require flood-proofing to reduce vulnerability to flood damage.

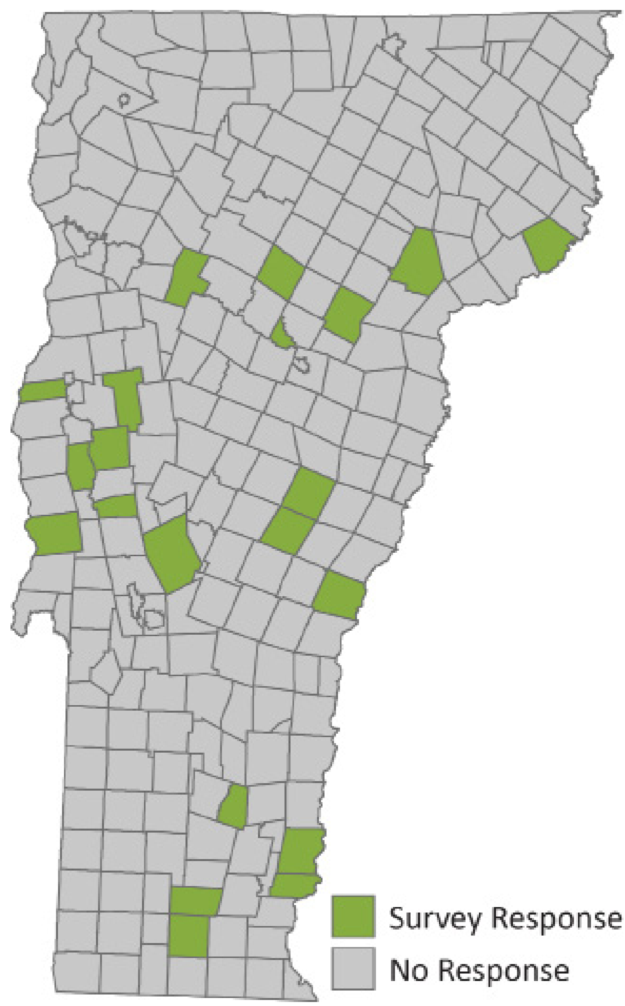

Figure 65: Town survey responses map by town
Source: Vermont Emergency Management

Town Survey:

Based on the VEM hazard mitigation planning survey circulated to towns in 2023, improving land use regulations, upgrading infrastructure, and expanded communication before and during disasters are high priorities for better protecting their most vulnerable residents. In order to do this, communities not only need funding, but expanded local staff capacity and additional technical assistance. These priorities and needs align with the assessment done through the State hazard mitigation planning process and proposed Mitigation Strategy.

Additionally, the town survey illustrated that towns want to adopt river corridor bylaws and enforce floodplain development regulations, but continue to face barriers both technical, capacity related, and politically.

Specifics in infrastructure improvements included right sizing culverts and bridges to withstand precipitation and snowmelt events that meet or exceed bankfull width of a waterway, strengthening distribution lines, upgrading village water lines, establishing microgrids, and addressing transportation vulnerabilities due to landslides and fluvial erosion. Multiple towns identified the importance of protecting community gathering spaces, such as general stores and municipal buildings, as critical for overall resilience.

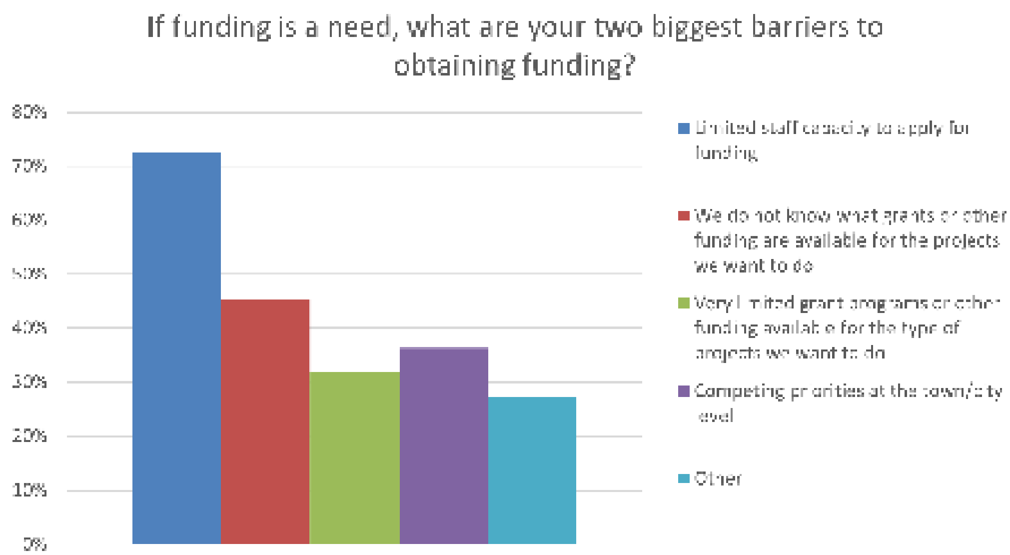

Figure 66: Barrier to obtaining funding from town survey
Source: Vermont Emergency Management

After Covid-19 and the multiple funding sources that became available for recovery efforts, the problem was no longer entirely a municipal funding need, but that communities needed help in managing the funding that was now available. In the survey of towns conducted for the SHMP, over 70% said that limited staff capacity to apply for funding was a barrier to obtaining funding. Small towns also found the funding programs to be complex and confusing to understand what grants could be used for different projects. The second most common response to the survey was that towns do not know which grants are available for the projects they want to do. Staff capacity and clarity of funding programs were existing challenges that were exacerbated after the global pandemic and remain challenges for Vermont's municipalities.

In addition to ranking hazard significance, in a survey to RPCs, subject matter experts also listed the communities within their regions that are most vulnerable to natural hazards and explained what makes them vulnerable. The responses are represented in Figure 66 and Table 35. VEM staff used this local vulnerability information to inform the assessment of each hazard and the mitigation strategy (see: Mitigation Strategy).

Table 35: Local Vulnerability by Regional Planning Commission

RPC	Municipality	Vulnerability
ACRPC	Goshen	Populations are clustered along rivers within narrow valleys in high elevations. Small community, limited resources.
ACRPC	Lincoln, Ripton	Populations are clustered along rivers within narrow valleys in high elevations.
ACRPC	Starksboro	Populations are clustered along rivers within narrow valleys in mid-high elevations. Small community, limited resources.
ACRPC	Whiting	Small community with very limited resources.
BCRC	Bennington	The downtown area is within a flood zone.
BCRC	Pownal	Many mobile home parks exist within floodplains and are subject to frequent flooding.
CCRPC	Bolton, Huntington, Jericho, Richmond, Underhill	Steep roads vulnerable to fluvial erosion and flooding.
CVRPC	Barre City, Montpelier	Downtowns in floodplain prone to flooding and ice jams, vulnerable populations at risk due to cold, critical facilities potentially at risk, ice and wind capable of causing power/internet outages
CVRPC	Northfield	Much of the town exists within a floodplain, and the river has a sharp bend adjacent to the downtown area which makes the town vulnerable to ice jams and associated debris.
CVRPC	Plainfield	Vulnerable to flooding due to topography and soils, debris jam potential, and public infrastructure in need of upgrade. Limited transportation routes and potential for isolation. Proximity to the Marshfield Dam.
CVRPC	Waterbury Town/Village	Downtown location and critical facilities prone to flooding and near Waterbury Dam, age and condition of infrastructure, vulnerable populations, potential for long-term power outages.
LCPC	Johnson/Cambridge	Vulnerable to flood inundation and ice jams due to low lying downtown, as well as snowfall, wind, and extreme cold due to winter storms affecting Lamoille County.
MARC	Chester	The village is located at the confluence of 5 different rivers/streams, vulnerable to flooding and erosion and still seeing effects from Irene, Route 11 and Route 35 are at risk of blockage.
MARC	Ludlow/Ludlow Vlg	Critical infrastructure located within floodplain, including the village center.
NRPC	Bakersfield	Transportation routes parallel rivers and streams and are vulnerable to flooding, as well as events that cause treefall and block roads. Undersized culverts are not built to handle intense precipitation. Much of the population relies on medical equipment and specialized healthcare.
NRPC	Enosburgh	Fluvial erosion and inundation risk, power lines vulnerable to ice, forested land cover, winds from the west gain strength over lake.
NRPC	Highgate	Much of town at risk of inundation and fluvial erosion in the spring, ice jam-related flooding in East Highgate, power lines vulnerable to ice, soil composition is primarily sand on top of clay which makes the town vulnerable to landslides.
NRPC	Montgomery	Soils and topography create risk of flooding and erosion, power lines vulnerable to ice, remoteness and forested land cover, winds from the west gain strength over lake.
NRPC	Isle La Motte	Island landform vulnerable to flood inundation, one road connects island to neighboring town, remote, transportation and communication network interrupted due to winter storms, power lines vulnerable to ice, winds from the west gain strength over lake.

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RPC	Municipality	Vulnerability
NRPC	Swanton Town/Village	Pre-flood regulations development at risk of flood inundation, power lines vulnerable to ice, winds from the west gain strength over lake.
NVDA	Coventry	Vulnerable to ice jams
NVDA	Hardwick	Majority of development around bodies of water, at risk of flooding and ice jams.
NVDA	Lyndon	Multiple towns drain into the area.
NVDA	Newport, St. Johnsbury	Vulnerable to flooding due to proximity to rivers.
RRPC	Mendon, Brandon, Pawlet, Rutland City	Infrastructure in the river corridor vulnerable to flooding and fluvial erosion. Towns are extremely vulnerable to flash flooding and road washouts which may block transportation. High percentage of gravel roads on steep slopes.
TRORC	Hancock, Pittsfield, Rochester, Stockbridge	Steep slopes that were damaged by Irene at risk of fluvial erosion, road infrastructure located near water bodies vulnerable to inundation risk, easily isolated during storm events as transportation routes may be blocked.
TRORC	Strafford	Majority of homes and infrastructure located along West Branch of Ompompanoosuc River, putting the town at risk of flooding.
WRC	Jamaica	Historic development pattern cause vulnerability to fluvial erosion and inundation, affecting the surrounding town and transportation routes. Subject to fast-moving floodwaters and erosion due to topography
WRC	Londonderry	Villages within the floodplain with development pressures in vulnerable areas, Dam in disrepair in North Village, EAB present
WRC	Marlboro	Topography and development patterns create a risk of fluvial erosion, Rt 9 vulnerable to erosion due to steep banks and slides in river corridors
WRC	Newfane	Transportation infrastructure and development are low-lying and downstream within a floodplain which accelerates vulnerability to flooding, especially vulnerable to landslides along their roads.
WRC	Wilmington	Location of downtown and historic development pattern cause a risk of flooding and fluvial erosion, history of ice jams in North Branch and downtown, EAB present.

Source: Regional Planning Commission Survey

Overview of Most Vulnerable Jurisdictions Based on State and Local Government Risk Assessments:

Local knowledge of the communities most threatened by the identified hazards is by far the most valuable data available. However, FEMA has developed tools for national assessments of risk that provide broader scale information on local and regional vulnerability than are valuable for planning purposes.

The National Risk Index (NRI)[17] includes data about the expected annual losses to individual natural hazards, multiplied by social vulnerability, and divided by a calculation of community resilience. This data is available at county and census tract levels. A single census tract can include multiple jurisdictions in Vermont due to low population density.

Expected annual loss is determined based on exposure, annualized frequency (probability of a specific hazard occurrence any given year), and historic loss ratio risk factors for 18 natural hazards. The hazards assessed are avalanche, coastal flooding, cold wave, drought, earthquake, hail, heat wave, hurricane, ice storm, landslide, lightning, riverine flooding, strong wind, tornado, tsunami, volcanic activity, wildfire, and winter weather. Not all the hazards listed effect Vermont.

17 https://www.fema.gov/flood-maps/products-tools/national-risk-index

Social vulnerability is determined through the Centers for Disease Control (CDC) Social Vulnerability Index (SVI). Community resilience score is determined by University of South Carolina's Hazards and Vulnerability Research Institute (HVRI)'s Baseline Resilience Indicators for Communities (HVRI BRIC), which uses ACS data from 2020. Building exposure value includes residential, commercial, industrial, government, and education buildings.

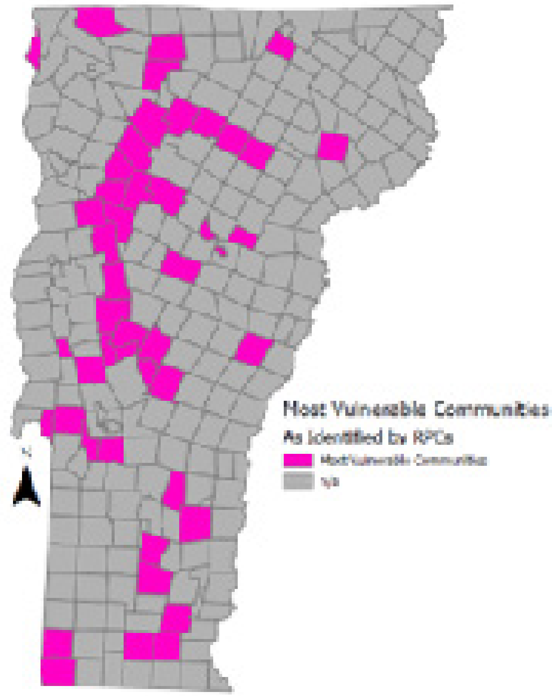

Figure 66: Most vulnerable Vermont communities
Source: Vermont Emergency Management

The NRI helps to identify jurisdictions most threatened by the hazards that have potential to impact the state to help hazard mitigation and emergency planners prioritize allocation of resources. The NRI does not account for climate change, therefore it is important to refer to Vermont Profile & Hazard Assessment and the hazard profiles in this plan to understand impacts of climate change on individual hazard probability and intensities.

The NRI allows the user to compare risk index values for counties and census tracts for relative risk scores. For Vermont, a comparison of risk to all natural hazards by county shows the highest-ranking counties are Windsor, Washington, Windham, and Rutland in that order (See: Appendix to Section 5).

Washington County was determined to be the most vulnerable location in the State with respect to damage and loss from hazard events, and potential impacts to populations, structures, and infrastructure. Washington ranks highest in expected annual losses for landslides and riverine flooding. The NRI does not include an assessment for fluvial erosion, our top-ranking hazard in Vermont, but fluvial erosion is associated with landslides and riverine flooding.

Washington County is considered most vulnerable because of the concentration of public services, and community lifelines based there. The overall resilience of Vermont could be impacted if public services based in Washington County were disrupted. Lifelines are the most fundamental services in the community that, when stabilized, enable all other aspects of society. Washington is a densely settled area along the I- 89 corridor that contains the State Capitol and State office buildings, including the State Emergency Operations Center (SEOC) and offices for the Agency of Human Services, VEM, Fire Safety, and the State Police in Waterbury. I-89 is susceptible to flooding along many sections of the highway and connecting roads along the Winooski River.

Within Washington County, the NRI analysis at the census tract level indicates that Barre, Waterbury, and Montpelier are highest ranking in risk exposure (See: Appendix to Section 5). This NRI assessment aligns with the local assessment provided by RPC survey results. The NRI and local assessments further align with FEMA's designation of Barre City as a Community Disaster Resilience Zone (CDRZ).

The Community Disaster Resilience Zones Act, signed into law by President Joe Biden on December 20, 2022, amends the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The act directed FEMA to identify census tracts that are most at risk of the effects of natural hazards and climate change. Utilizing the NRI, FEMA identified the areas that have high natural hazard risk based on the intersection of annualized estimated losses to buildings, people, agriculture from natural hazards; social vulnerability; and community resilience.

Referring to the Vermont Social Vulnerability Index (SVI), the same census tract that qualifies Barre City as a CDRZ, has 5 SVI flags, which is relatively high compared to the state. The Barre City census tract indicates 28% are living in poverty, 30% are disabled, 23% are children between 0 and 17 years of age, 76% are single parents, and 23% have no car available to them. Relating these factors back to risk factors for people as they are impacted by hazards - recovery will be more financially challenging for this area, many people will have barriers to evacuation and will be dependent on a high functioning public transportation system, and people will have very limited capacity to prepare for, shelter, and recover from hazard events. After a disaster, families with young children are especially tied to their community, needing social support, access to their school and daycares, access to healthy affordable meals, and other factors of routine and stability. These needs are compounded for single parent households.

Outside of Washington county, six additional communities (in Windham and Windsor counties) have "relatively moderate" NRI scores, the highest rating in Vermont, they are Rutland City, Ludlow, Windsor, and Brattleboro (See: Appendix to Section 5). Every community in Vermont is a priority for building resilience to natural hazards and climate change, and each community has its own strengths and vulnerabilities. It is impossible to name the most vulnerable or the most resilient community in Vermont, as it depends on many factors, including place in time. The NRI is a useful starting place for a conversation on prioritization of hazard mitigation investment, however, it is not a comprehensive assessment of community needs.

One tool available for assessing communities that are most vulnerable to climate change is the Justice40 Initiative Climate and Economic Justice Screening Tool[18] from the White House Council on Environmental Quality (CEQ). The screening tool looks at flood and wildfire impacts accounting for climate change as well as community demographic data. The interactive map uses datasets that are indicators of burdens in eight categories: climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. Identified communities experiencing burdens in the above listed categories are the communities that are disadvantaged because they are overburdened and underserved.

Based on an analysis of data from the Climate and Economic Justice Screening Tool, Vermont has 47 jurisdictions that qualify as "disadvantaged" communities. They are in Table 36.

Only a few Justice40 disadvantaged communities align with NRI identified most vulnerable communties. The communities that were ranked as relatively moderate in Vermont are Waterbury, Barre City, Rutland City, Ludlow, Windsor, and Brattleboro. More details on the NRI report for these communities can be found in the Appendix to Section 5 Relatively Moderate Census Tracts Comparison Report - National Risk Index.

Table 36: Justice40 Initiative Disadvantaged Communities in Vermont 2023

Jurisdiction	County	Regional Planning Commission
Canaan	ESSEX	Northeastern Vermont Development Association
Richford	FRANKLIN	Northwest Regional Planning Commission
Norton	ESSEX	Northeastern Vermont Development Association
Averill	ESSEX	Northeastern Vermont Development Association
Holland	ORLEANS	Northeastern Vermont Development Association

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18 https://screeningtool.geoplatform.gov/en/about#8.56/44.7918/-71.6971

Jurisdiction	County	Regional Planning Commission
Jay	ORLEANS	Northeastern Vermont Development Association
Troy	ORLEANS	Northeastern Vermont Development Association
Lemington	ESSEX	Northeastern Vermont Development Association
Avery's Gore	ESSEX	Northeastern Vermont Development Association
Warren's Gore	ESSEX	Northeastern Vermont Development Association
Warner's Grant	ESSEX	Northeastern Vermont Development Association
Morgan	ORLEANS	Northeastern Vermont Development Association
Lewis	ESSEX	Northeastern Vermont Development Association
Westfield	ORLEANS	Northeastern Vermont Development Association
Charleston	ORLEANS	Northeastern Vermont Development Association
Bloomfield	ESSEX	Northeastern Vermont Development Association
Saint Albans City	FRANKLIN	Northwest Regional Planning Commission
Ferdinand	ESSEX	Northeastern Vermont Development Association
Brunswick	ESSEX	Northeastern Vermont Development Association
Barton	ORLEANS	Northeastern Vermont Development Association
Glover	ORLEANS	Northeastern Vermont Development Association
East Haven	ESSEX	Northeastern Vermont Development Association
Granby	ESSEX	Northeastern Vermont Development Association
Greensboro	ORLEANS	Northeastern Vermont Development Association
Guildhall	ESSEX	Northeastern Vermont Development Association
Victory	ESSEX	Northeastern Vermont Development Association
Lunenburg	ESSEX	Northeastern Vermont Development Association
Saint Johnsbury	CALEDONIA	Northeastern Vermont Development Association
Concord	ESSEX	Northeastern Vermont Development Association
Barre City	WASHINGTON	Central Vermont Regional Planning Commission
Rochester	WINDSOR	Two Rivers-Ottauquechee Regional Commission
Bethel	WINDSOR	Two Rivers-Ottauquechee Regional Commission
Fair Haven	RUTLAND	Rutland Regional Planning Commission
Bennington	BENNINGTON	Bennington County Regional Commission
Brattleboro	WINDHAM	Windham Regional Commission
Pownal	BENNINGTON	Bennington County Regional Commission
Montgomery	FRANKLIN	Northwest Regional Planning Commission
Maidstone	ESSEX	Northeastern Vermont Development Association
Winooski	CHITTENDEN	Chittenden County Regional Planning Commission
Rutland City	RUTLAND	Rutland Regional Planning Commission
Burlington	CHITTENDEN	Chittenden County Regional Planning Commission
Newbury	ORANGE	Two Rivers-Ottauquechee Regional Commission
Bradford	ORANGE	Two Rivers-Ottauquechee Regional Commission
Newport Town	ORLEANS	Northeastern Vermont Development Association
Newport City	ORLEANS	Northeastern Vermont Development Association
Rockingham	WINDHAM	Windham Regional Commission
Ludlow	WINDSOR	Mount Ascutney Regional Commission

Source: Justice40 Initiative Climate and Economic Justice Screening Tool

Those communities that contained census tracts that were identified as both disadvantaged in the Justice40 Climate and Economic Justice Screening Tool and as at relatively moderate risk in the NRI are Brattleboro, Ludlow, Rutland City, and Barre City. Utilizing the Justice 40 and NRI mapping tools, this Plan identified Brattleboro, Ludlow, Rutland City, and Barre City as the most vulnerable jurisdictions to climate change.

The communities that were also identified as most vulnerable by the local risk assessment by RPCs are Ludlow and Barre City. While we already discussed Barre City in context of its CDRZ designation by the federal government, Ludlow can also be assessed with the Vermont SVI. Ludlow has a population of 1,769, 17% live in poverty while only 4.4% are unemployed. About 18% are children between 0-17 years of age, and 28% are over the age of 65, 15% of residents are disabled, and nearly 50% are single parents. Despite the rural nature of Ludlow, 7% have no car available to them.

This Plan will also look at the data on hazard impacts and expected annual losses (EAL) available through the NRI for Barre City and Ludlow. The NRI includes the data from the CDC Social Vulnerability Map, as discussed in this section, and mapped in Section 4 of this Plan.

EAL for Barre City is estimated at $1,214,801 for all hazards. Barre City is most vulnerable to riverine flooding and landslide for EAL, rated at Very High. Social Vulnerability is considered relatively high for the Barre City census tract for all hazards assessed.

For Ludlow the EAL is $727,672. No hazards rank Very High for EAL in Ludlow. Riverine flooding and hurricane have the highest EAL values at Relatively High and Relatively Low respectively. Social vulnerability in Ludlow is also considered relatively high for all hazards assessed.

Windsor ranked second between Barre City and Ludlow on the NRI for over risk rating and therefore will be included in this summary discussion. Windsor's EAL was determined to be $910,917. EAL for landslide was Very High, while the total values for riverine and flooding and hurricane were higher than landslide, the ratings were relatively High and Relatively Low respectively.

Looking at development trends as indicated by residential building permits in Section 4 of this Plan, there is very little crossover with areas that are most vulnerable to hazard impacts and climate change and are experiencing development. The exception being Newport Town, which has a Relatively Low NRI risk rating, but is a Justice40 disadvantaged community, and had relatively high building permit applications from 2018 to 2022.

In summary, Barre City, Windsor, and Ludlow rank highest for risk in the NRI. Barre City and Ludlow rank as at Relatively Moderate risk in the NRI, are identified as disadvantaged and vulnerable to climate change by the Justice40 screening tool, and were also identified as most vulnerable in the local risk assessment by RPCs. Riverine flooding, hurricane, and landslide were all top hazards posing risk to these communities, which is consistent with the hazard assessment from Section 4 of this Plan.

A broader analysis of high-risk factor populations across the State can be found in Vermont Profile & Hazard Assessment.

The Resilience Analysis and Planning Tool (RAPT) is another FEMA planning tool that incorporates real-time data including stream gauges and hurricane tracks, and accounts for climate change. However, it falls short of accounting for climate change in Vermont, as it only includes sea level rise. It is still a useful tool for examining potentially vulnerable community lifelines that can be impacted by hazards in Vermont.

FEMA requires that vulnerability is assessed in terms of community lifelines – safety and security, food water, and shelter, health and medical, energy (power & fuel), communications, transportation, and hazardous materials. To assess hazard vulnerability of community lifelines based in Washington County, RAPT designated community lifeline structures, infrastructure, and public services were counted and analyzed. The data collected is summarized in Table 37. Maps in Appendix to Section 5 (community lifeline maps) show that there is a concentration of the above community lifeline assets in flood prone areas, specifically in Barre, Montpelier, and Waterbury. This assessment does not account for transportation, communications, power, water, wastewater, and other infrastructure assets that are part of connected systems such as powerlines and sewer systems. It also does not account for difficult-to-quantify assets. Please see the vulnerability sections in each hazard profile for more discussion. FEMA emphasizes the importance of community lifeline identification because lifelines provide an outcome-based, survivor- centric frame of reference that assists responders with: Root Cause Analysis; Interdependencies; Prioritization; and Ease of Communication.

Table 37: Washington County Community Lifeline Vulnerability Assessment

Community Lifeline	Type	Count
Safety & Security	SEOC; Fire Stations; Law Enforcement Location	1; 24; 9
Food, Water & Shelter	Shelters and Cooling Centers; Food & Water Retail Stores	39; 47
Health & Medical	Urgent Care; Dialysis; Hospitals; Nursing Homes, Pharmacies; Public Health Departments	1; 1; 3; 16; 13; 19
Energy	Power Plants	8
Communications	Cell Towers/ Telecommunication Nodes	5
Transportation	Airports; Amtrak Stations	5; 2
Hazardous Materials	Hazardous Materials Generators*	334

**From Vermont Agency of Natural Resources Atlas*

Vulnerability of State-Owned or Operated Assets:

Buildings and General Services (BGS), through a 2018 SHMP subgrant, is the lead agency for a statewide assessment of State-owned buildings located either in the FEMA-mapped floodplain and/or the river corridor. This assessment, which included all State-owned and leased properties, considered both criticality of the buildings' functions and the vulnerability of the structures based on location. The State asset inventory list includes State owned or operated critical facilities, buildings, infrastructure, and community lifelines.

As the two most significant hazards identified in this Plan, the BGS risk assessment project focused primarily on fluvial erosion and flood inundation vulnerability. Further, assessing risk based on these hazards was straightforward, as BGS could access both State and FEMA mapping data specific to fluvial erosion and inundation flooding. Using these data, BGS assessed vulnerability of an individual structure according to its proximity to the FEMA-mapped 100- and 500-yr floodplains, as well as the river corridor. An overall vulnerability score was assigned to each structure using a point system outlined in the Appendix to Section 3. Structures were then assessed according to their criticality to the following State functions:

- Emergency Operations
- Government Operations
- Public Safety
- Public Health
- Public Service
- Economic Activity
- Cultural Resources

BGS then used the scores for criticality and vulnerability to determine building prioritization for developing mitigation measures. The risk assessment also includes information on each building's current function, construction type and year, number of floors, building replacement cost, cost of personal property and cost of computer equipment. A detailed description of this risk assessment, prioritization process and alternatives analysis for the top priority State-owned structures can be found in the Appendix to Section 3.

Though the BGS project focused primarily on fluvial erosion and inundation flooding (See: Inundation Flooding & Fluvial Erosion), the data acquired are pertinent to all natural hazards profiled in this Plan that could impact State-owned or leased structures. That is, a building's replacement cost will be the same regardless of what hazard was responsible for its destruction. Similarly, a building's criticality score does not differ hazard-to-hazard. Further, without high fidelity hazard mapping data for all natural hazards, determining true vulnerability of a structure based on proximity to a clearly delineated hazard area is very difficult. Type, age, and intended use of a structure can impact vulnerability. This information can be viewed in the Appendix to Section 5, State asset inventory and replacement value.

To address the need for high-fidelity hazard mapping data, improved landslide susceptibility mapping, for example, is an identified need for Vermont. Similarly, wildfire can impact anywhere in the State, but data layers depicting the WUI (See: Wildfire) provide some idea of areas with high potential impacts. While other hazards, such as wind, extreme temperatures, invasive species, snow, ice, earthquake, and hail impact the entire State more unpredictably or uniformly. Updated with 2023 values, the replacement cost for all State-owned assets is over $1.65 billion. Any number of the State's assets could be impacted by natural hazards requiring substantial repair or replacement. Please refer to the built environment vulnerability sections within each hazard profile - impacts to the built environment can equally impact State, local, or personal assets. The full list of all State-owned buildings and their replacement costs as defined above in is the Appendix to Section 4.

The Vermont Agency of Transportation, VTrans, has developed a Resilience Improvement Plan (RIP) to prioritize transportation infrastructure improvements. The prioritization is based on risk scores, repeat damages,[19] Social Vulnerability Index[20] Score, public transportation routes, emergency distribution access, and interagency coordination or aligned project priorities from other agencies. The RIP is available as a story map, including prioritized road and structure projects.[21] A clear priority for climate change resilience improvements in 2023 is VT 125 between Middlebury and Ripton. This segment of road runs along the Middlebury River as it winds down the Green Mountains and is subject to fluvial erosion and landslides. In addition to residents and visitors of Ripton and Hancock, Middlebury College has a campus extension with residents dependent on VT 125 for access to critical amenities.

The VTrans 2022 Transportation Asset Management Plan (TAMP)[22] estimates the value of Vermont's national highway system roads at $7,512 million and $3,504 million for structures. During Tropical Storm Irene, over 2500 miles of road, 480 bridges and 960 culverts were damaged equaling over $350 million in estimated repairs. Additionally, over 200 miles of rail and 6 bridges in the State-owned rail system were damaged, costing the State an estimated $21.5 million.

Changes in State Asset Vulnerability:

Since the 2018 SHMP, Vermont's overall resilience continues to improve while the hazards that we face become more extreme. The State continues to adapt to the changing climate conditions and respond to the emerging needs of the people living and working in Vermont. Climate change has potentially made State assets more vulnerable to hazards; however, the State has significantly reduced vulnerability in the continuation of public services, and all community lifelines, because the State government has made strides including remote work, enabling essential services to continue even when State office buildings are impacted by hazards.

As illustrated in the State of Vermont-Owned Assets and Replacement Values appendix, there has not been significant new development of State-owned structures. No new development of State assets has occurred within the SFHA since the 2018 SHMP.

The most significant development of note was the Roxbury fish hatchery, which was mitigated with Public Assistance funding following Tropical Storm Irene. One additional new development was the Agency of Agriculture Food and Markets Laboratory and Department of Environmental Conservation's Environmental Laboratory located in Randolph, Vermont. These State functions were previously housed at the State Office Complex in Waterbury; however, they were in temporary facilities following Tropical Storm Irene and have now been re-built in a safer joint location.

19 https://experience.arcgis.com/experience/85cedee1a4f84144b00b1b3231cef8d9/page/Home/?views=Vulnerability%2CDDIR-Detail
20 https://ahs-vt.maps.arcgis.com/apps/MapSeries/index.html?appid=9478be15d6d4410f8eef8d420711310b
21 https://storymaps.arcgis.com/stories/f67e4a5fa5404f008682b8da3f401be2
22 https://vtrans.vermont.gov/sites/aot/files/planning/documents/2022%20TAMP%20Update%20-%20FINAL.pdf

Key Issues

The following overview highlights key issues that were identified based on our analysis of existing capabilities and gaps at the State and local level. Capabilities and gaps enable or hinder our ability to address our vulnerabilities identified through the risk assessments. These key issues directly informed the development of our highest priority mitigation actions. Each key issue below has the connected mitigation action identified.

- The historic downtowns in Vermont are vulnerable to flooding due to their location along waterways. Flooding is projected to worsen with extreme precipitation events. Development is needed in existing developed areas for long term sustainability. To lessen flood threats, headwater storage and floodplain storage areas need to be protected. First, an analysis to prioritize conservation is required (Addressed in Action 3).
- Drought risk and vulnerability is projected to increase in Vermont. There is limited data available to assess and plan for the impacts of drought in Vermont. Further study is needed to provide water availability data for drought predictions and rates of recovery (Addressed in Action 13).
- The threat of wildfire in Vermont has increased due to climate change. A comprehensive statewide wildfire mitigation plan is needed to determine existing infrastructure for wildfire suppression and identify gaps in resources and capabilities to be better prepared for future wildfire events (Addressed in Action 17).
- Transportation assets across Vermont, including roads, bridges, and culverts, are vulnerable to natural hazards and climate change. Planning and implementing the replacement and upsizing of infrastructure to withstand hazard events often exceeds technical and financial resources at the local level (Addressed in Action 32).
- Vermont's energy, telecommunications, water, and wastewater utilities are vulnerable to the impacts of natural hazards and climate change. The Public Service Department needs additional capacity to utilize unprecedented federal funding currently available for improving infrastructure resilience to the greatest benefits for Vermont (Addressed in Action 38).
- The many State and federal technical assistance, funding, and permitting programs have the potential to be more effective if better coordinated. Potential recipients find the number of programs confusing, face challenges in coordinating grant timelines, and struggle to meet different program objectives that could be better aligned (Addressed in Action 66)
- Barriers to hazard mitigation include coming up with local match for FEMA grants, buyouts for flood and erosion prone properties outside the SFHA and vacant parcels, and sufficient funding for floodplain and wetland restoration projects. The FRCF filled this need with ARPA funding, however ARPA funding is temporary and sustainable long-term funding is needed to continue this work (Addressed in Action 69).
- Heat has become a greater threat in Vermont due to climate change. The Urban Heat Island Effect multiplies the threat of heat, particularly impacting high risk factor residents. Vermont needs better information on what works best to address the needs of our frontline communities as we face climate change impacts (Addressed in Action 90).
- As Vermont plans and implements projects to improve resilience to natural hazards and climate change, the State needs better tools to monitor and evaluate effectiveness of methods and project types to determine needed improvements. Additionally, progress needs to be tracked to ensure accountability and continued public and financial support (Addressed in Action 97).
- Vermont is composed of decentralized rural communities and thus many communities depend on more developed neighboring communities for needed amenities. It is not currently feasible for each individual small town to provide every good and service necessary for their residents and visitors. The places where people currently go to meet essential needs (e.g., education, groceries, daycare, employment) can be assessed to determine places that can be bolstered as resilience hubs for larger regions.

6: Mitigation Strategy

The State of Vermont intends to create an efficient, effective, and consistent Hazard Mitigation Strategy that will focus efforts and priorities, enhance mitigation capabilities, and integrate State, regional, and local planning and risk assessment efforts in the short-term and long-term. The goals, objectives and actions stated herein are meant to serve as guidance for State of Vermont decision-makers in allocating resources for the Building Resilient Infrastructure and Communities (BRIC) program, Hazard Mitigation Grant Program (HMGP), Flood Mitigation Assistance (FMA) program, and the Flood Resilient Communities Fund (FRCF), among many others.

Additionally, this action list is intended to be a resource to VEM and partner agencies, as they continue to collaborate with non-governmental stakeholders throughout Vermont during implementation. As the actions contained within this Plan reach significantly beyond what any one entity would be able to implement or fund, continued collaboration is considered necessary for more effectively leveraging resources, thereby improving likelihood of implementation.

The State mitigation strategy is also linked to local government mitigation strategies. As one product of mitigation actions implemented by State agencies, the State mitigation strategy aims to create the environment in which local governments can implement effective mitigation actions that meet the needs of local communities. Given the resources needed, many mitigation actions will need to be identified and implemented at the local level to meaningfully involve residents and stakeholders in aligning community resilience building with community vision and needs.

For an overview of the robust stakeholder engagement process undertaken to develop the vision, mission, goals, guiding principles, and actions that follow, see: Planning Process. To better understand how the actions relate to the identified hazards and the specific vulnerabilities created by those hazards, see: Hazard Assessment.

VISION: Vermont will be safe and resilient in the face of climate change and natural disasters.

MISSION: To protect life, property, natural resources and quality of life in Vermont by reducing our vulnerability to climate change and natural disasters.

GOALS

Protect, restore and enhance Vermont's natural resources to promote healthy, resilient ecosystems.

Enhance the resilience of our built environment – our communities, infrastructure, buildings, and cultural assets.

Develop and implement plans and policies that create resilient natural systems, built environments, and communities.

Create a common understanding of – and coordinated approach to – mitigation planning and action.

Guiding Principles for Mitigation Planning and Action:

- We will ensure that hazard mitigation work strengthens and protects Vermont's economy and affordability.
- We will reduce the risks and impact of hazards on frontline communities.
- We will ensure that hazard mitigation action accounts for – and helps us adapt to – climate change.
- We will work to build relationships and partnerships for action across sectors and disciplines.

Action Development & Prioritization Process

The 2023 SHMP continued to follow the Plan goals from the 2018 SHMP to help guide the mitigation strategy planning process. Actions identified by stakeholders through the mitigation action workshops were sorted by goal and then further sorted according to similar themes, called "strategies".

The mitigation actions were ranked based on the below criteria (Table 38), developed by the Steering Committee. Using the High, Medium, and Low rankings for Positive Impact, Potential Negative Impact, and Feasibility within the action list, VEM began the process of defining priority actions under each goal, which were reviewed and modified by the Steering Committee. Overall Impact score was determined by weighing positive impacts against potential negative impacts.

It was important to the Steering Committee that both the positive and negative unintended consequences of an action were identified during the action development stage. Furthermore, potential negative impacts to people were the focus of the action impact analysis. Potential negative impacts move Vermont away from goals of greater equity, and increase environmental, social, and/or financial disparities between people and communities. For example, an action that is intended to protect one group of households from flooding cannot redirect the flood waters to another group of households that may have lower socio-economic standing due to current or historic disenfranchisement. The Steering Committee and other stakeholders recognize that unintended consequences of an action are not always immediately apparent, therefore all projects will have systems of monitoring and evaluation tied to them to identify negative impacts to environment, people, economy, or built environment. Actions with known negative impacts that cannot be feasibly reduced or minimized, are not included in the mitigation strategy.

Any action that received a High Positive Impact, Low Negative Impact, and High Feasibility score, were automatically considered to be a priority action. The Steering Committee decided to also consider inclusion of certain High Impact actions with lower Feasibility scores in the priority action list based on Feasibility being potentially flexible or subject to future change. Additional actions were added to the priority list based on the discretion of the Steering Committee. The prioritization of actions for all mitigation actions followed the same process, including High Hazard Potential Dam actions which were developed alongside the other mitigation actions in this plan, and were evaluated and prioritized through the same process.

For more information on the process for development of the 2023 SHMP actions, the criteria and action prioritization, see: Planning Process.

Table 38: Action Prioritization Criteria	
Positive Impacts	
High	Tangible, and measurable outcomes that directly: • Benefit the environment, OR • Benefit people/disproportionately impacted populations, OR • Reduce risk in our built environment, OR • Benefit the economy, OR • Create the opportunity to do one of the above (e.g. filling a data gap), AND • Reduce vulnerability to a high priority hazard (erosion, inundation, heat, wind)
Medium	Outcomes that may be more difficult to measure, that directly or indirectly: • Benefit the environment, OR • Benefit people/disproportionately impacted populations, OR • Reduce risk in our built environment, OR • Benefit the economy, OR • Create the opportunity to do one of the above (e.g. filling a data gap), AND • **Reduce vulnerability to a profiled hazard**
Low	Outcomes that may be difficult to measure, but have the potential to directly or indirectly: • Benefit the environment, OR • Benefit people/disproportionately impacted populations, OR • Reduce risk in our built environment, OR • Benefit the economy, OR • Create the opportunity to do one of the above (e.g. filling a data gap), AND • **Reduce vulnerability to a profiled hazard**

Potential Negative Impacts/Consequences	
High	Potential negative impacts were identified, **and/or** further study is needed to identify unintended consequences and methods to reduce the impacts. Additional resources need to be secured and/or substantial effort and/or time is needed to monitor projects for unintended consequences and to reduce or eliminate negative consequences.
Medium	Potential negative impacts were identified, **and** further study is needed to identify unintended consequences and methods to reduce the impacts. Potential negative impacts include perceived impacts. Additional resources and time that **are readily available** are necessary to monitor projects for unintended consequences and to reduce or eliminate negative consequences.
Low	**No or minimal** negative impacts identified. Minimal negative impacts are easily addressed or eliminated. Resources for monitoring the project for unintended consequences are available.

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Feasibility	
High	• Have political and community support, AND • Are consistent with current state laws/policies, AND • Have funding/ other required resources available or identified, AND • Are technically/ logistically feasible
Medium	• Have political and community support, OR • Are consistent with current state laws/ policies, OR • Have funding/ other required resources available or identified, AND • Are technically/ logistically feasible
Low	• Have political and community support, OR • Are consistent with current state laws/ policies, OR • Have funding/ other required resources available or identified, OR • Are technically/ logistically feasible

In addition to the priorities that were High Positive Impact, Low Negative Impact, and High Feasibility, the Steering Committee also voted individually on their top three actions from the priority list, resulting in the following top priority actions:

Table 39: Top Priority Actions

Natural Resources	Utilizing existing FEMA mapping updates and the Functioning Floodplain Initiative, develop an inventory of critical headwater and floodplain storage areas that would result in a measurable abatement of flooding. (DEC Rivers)
Natural Resources	Develop a drought plan for Vermont to include analyzing water level/monitoring data to use as predictor of drought and rates of recovery. (UVM VSCO)
Natural Resources	Develop a wildfire mitigation plan, to include research on the long-term future risk of wildfire due to climate change, determine existing infrastructure for wildfire suppression, and develop wildfire mitigation options. (FPR)
Built Environment	Support municipalities in developing a prioritized list of transportation infrastructure improvements that increase resilience using PROTECT and/or other funding sources. (VTrans)
Built Environment	Increase Public Service Department capacity to maximize utilization of available federal dollars (including IIJA, IRA, ARPA, and EDA) towards utility resilience implementation work. (PSD)
Plans & Policies	Assess all State/federal funding/technical assistance programs, as well as State permitting programs, to determine areas for better alignment around state hazard mitigation priorities.
Plans & Policies	Identify sustainable, long-term funding to support hazard mitigation and local match, to include: purchase of hazard-prone properties and easements to conserve river corridors, floodplains, and wetlands identified as key flood attenuation areas. (VEM)
Plans & Policies	Complete an assessment of heat risks in urban areas of Vermont and expected impacts on historically disadvantaged populations, identify strategies for mitigating impacts (e.g., urban forestry, green roofs, green infrastructure, and/or other vegetative strategies; increased use of highly reflective and/or high emittance materials for pavement, roofs, and building). (VDH)
Education & Outreach	Develop a methodology and protocol for quantifying climate mitigation, resilience, and adaptation impacts (Climate Action Office measuring and assessing progress tool). (CAO)
Education & Outreach	Develop an analysis of existing Resilience Hub locations, including identification of new locations, and identification of key components that should be co-located within a Resilience Hub.

The complete mitigation action list includes all 112 actions, categorized by similar themes into 22 strategies that then fall under the appropriate overarching goal, of which there are four. The list also identifies the:

- source of the action,
- pertinent category (e.g., technical assistance, data gap),
- hazard(s) that the action addresses,
- entity(ies) responsible for implementing the action,
- potential resources to fund action implementation,
- timeline for completing the action, and
- the overall Impact and Feasibility ratings.

For those actions that use the term “hazard-prone areas”, the Steering Committee aimed to address all hazards
For those actions that use the term “hazard-prone areas”, the Steering Committee aimed to address all hazards
to which that specific action may reduce vulnerability. To that end, “hazard-prone areas” can mean a FEMA-mapped Special Flood Hazard Area, an area identified as vulnerable to landslides, or those regions of the State that are more vulnerable to drought or extreme cold, for example.

Though the mitigation action list identifies the hazard(s) addressed, some hazard-specific actions and capabilities can also be found and further explained in the mitigation subsection within each of the hazard profiles (see: Hazard Assessment).

Table 40: 2023 State Hazard Mitigation Plan Actions Acronym List:

AAFM	Vermont Agency of Agriculture, Food & Markets	NRCD	Vermont Natural Resources Conservation Districts
ACCD	Vermont Agency of Commerce & Community Development	NRCS	USDA Natural Resources Conservation Service
ADS	Vermont Agency of Digital Services	PSD	Vermont Public Services Department
AHS	Vermont Agency of Human Services	RM	Readiness Matrix
ANR	Vermont Agency of Natural Resources	RPC	Regional Planning Commission
AOA	Vermont Agency of Administration	SHPO	Vermont State Historic Preservation Officer
ARC	Academic Resilience Collaborative	SC	Steering Committee
BGS	Vermont Buildings & General Services	TNC	The Nature Conservancy
CDBG	Community Development Block Grant	USDA	United States Department of Agriculture
CLF	Conservation Law Foundation	USDA-RD	USDA - Rural Development
COAD	Community Organizations Active in Disaster	USGS	United States Geological Survey
CRO	Community Resilience Organizations	UVM	University of Vermont
CVOEO	Champlain Valley Office of Economic Opportunity	VAAHM	Vermont Association of Hospitals and Health Systems
DPS	Vermont Department of Public Safety	VCGI	Vermont Center for Geographic Information
EMPG	Emergency Management Performance Grant	VEM	Vermont Emergency Management
EPC	Emergency Preparedness Conference	VHCB	Vermont Housing & Conservation Board
ERAF	Emergency Relief & Assistance Fund	VHS	Vermont Historical Society
EWP	Emergency Watershed Protection Program	VLCT	Vermont League of Cities & Towns
FEMA	Federal Emergency Management Agency	VLT	Vermont Land Trust
FHWA	Federal Highway Administration	VNRC	Vermont Natural Resources Council
GMP	Green Mountain Power	VOAD	Voluntary Organizations Active in Disaster
HWA	FEMA Hazard Mitigation Assistance	VRC	Vermont River Conservancy
HMGP	FEMA Hazard Mitigation Grant Program	VTrans	Vermont Agency of Transportation
HMTAP	FEMA Hazard Mitigation Technical Assistance Programs	WG	Working Group
NESEC	Northeast States Emergency Consortium	WUV	Watersheds United Vermont
NFIP	FEMA National Flood Insurance Program		

7: Maintenance & Implementation

The State of Vermont's various agencies have always been invested in mitigation activities, as identified in previous State Hazard Mitigation Plans (SHMPs). The events following Tropical Storm Irene, however, magnified the need for coordination and a comprehensive approach to mitigation and resilience planning statewide. As evidenced throughout this Plan, the results of this have been a multi-stakeholder coordination effort to build a stronger, more resilient Vermont. For information on the stakeholder engagement process and involvement of the State Hazard Mitigation Planning and Policy Committee (SHMPPC), see: Planning Process.

2018 Vermont State Hazard Mitigation Plan Implementation

The 2018 SHMP provided a foundation upon which Vermont could implement identified mitigation projects as well as continue to carry out implementation through Hazard Mitigation Assistance (HMA) and other funding sources. Progress made on previously identified mitigation actions is summarized in the Appendix to Section 6. Capabilities that were developed based on 2018 SHMP actions are noted in the State Capabilities List with additional details and significant improvements since 2018 explained in State & Local Capabilities.

Additional mitigation needs identified through the significant stakeholder engagement process are included in the Mitigation Strategy. The State Capabilities List also notes specific needs that have been identified and whether they are addressed by actions in the 2023 SHMP.

Following the approval of the 2018 SHMP, mitigation priorities continue to be a priority at the policy level within the State Hazard Mitigation Project Review Committee (SHMPRC) and the State Hazard Mitigation Planning & Policy Committee (SHMPPC). The former is tasked with the technical review of all Hazard Mitigation Assistance (HMA) grant applications submitted to the State for consideration as well as applications under the Flood Resilient Communities Fund (FRCF), while the latter committee is responsible for discussing mitigation goals and policies to ensure cohesion across State agencies (see: State & Local Capabilities).

Following its creation, the SHMPPC met as needed to review mitigation progress, changes in policies and to reconsider prioritization of the 2018 SHMP actions based on new data. In 2022, the focus of the SHMPPC shifted from implementation of the 2018 SHMP to development of the 2023 SHMP (see: Planning Process).

2023 State Hazard Mitigation Plan Implementation:

The previous SHMP provided the guidance and foundation upon which to build the Steering Committee, update this Plan, and give insight into Vermont's continually-evolving approach to mitigation. The 2023 planning process continued the expanded stakeholder engagement process developed with the 2018 SHMP with the intent of developing an action plan to be implemented by a broad range of stakeholders throughout Vermont, which led to increased ownership of the Plan and, consequently, improves the likelihood of implementation success.

Based on their day-to-day functions, the State entities identified in Table 40 are responsible for contributing to mitigation of Vermont's hazards (in addition to Vermont Emergency Management).

Table 40: State Entities with Primary Responsibility by Hazard	
Fluvial Erosion	Department of Environmental Conservation; Vermont Agency of Transportation; Buildings & General Services
Inundation Flooding	Department of Environmental Conservation; Vermont Agency of Transportation; Buildings & General Services
Ice	Vermont Agency of Transportation; Public Service Department
Snow	Vermont Agency of Transportation; Public Service Department
Wind	Public Service Department
Heat	Department of Health
Cold	Department of Health
Drought	Department of Environmental Conservation – State Geologist
Landslides	Department of Environmental Conservation – State Geologist; Vermont Agency of Transportation
Wildfire	Department of Forests, Parks & Recreation
Earthquake	Department of Environmental Conservation – State Geologist
Invasive Species	Agency of Agricultural, Food & Markets; Agency of Natural Resources
Infectious Disease	Department of Health
Hail	Public Service Department

Monitoring and Evaluating the 2018 State Hazard Mitigation Plan:

Vermont's 2023 SHMP is a dynamic document. To ensure that the SHMP remains current and relevant to Vermont's mitigation needs, it is important for the Plan to be periodically monitored and evaluated. It is the policy of Vermont Emergency Management (VEM) that the SHMP will be monitored and evaluated at least once a year and following a declared disaster. The responsibility for the maintenance and updating of the Plan lies with VEM's State Hazard Mitigation Officer and Hazard Mitigation Planners, in coordination with the SHMPPC.

VEM mitigation staff and the SHMPPC will annually undertake a review of progress and efficacy of the SHMP actions in reaching the stated goals and strategies. Additionally, the SHMP will be reviewed following a declared disaster for any potential changes in vulnerability and to identify priority projects that can be implemented through available funding programs.

To review progress on achieving mitigation goals annually with the SHMPPC, a report will be compiled by VEM mitigation staff defining progress on mitigation actions and SHMP implementation. These detailed reports will include:

- The status of mitigation actions on the full mitigation action list (see: Mitigation Strategy);
- How well each action (completed or in progress) has contributed to the mitigation goals and strategies and reduced vulnerability; and
- A review of the defined mitigation priorities and an assessment of priorities moving forward.

The SHMPPC will carefully review the mitigation action report and make recommendations for amendments or changes to priorities for the following year.

To improve monitoring and track progress of mitigation activities, these annual meetings will be combined with more regular informal exchanges of information among stakeholders, in conjunction with the RVT. The 2023 SHMP will rely on both the SHMPPC and the RVT, as well as the Steering Committee and stakeholders, to improve the likelihood of implementation of Plan actions by expanding stakeholder involvement and leveraging resources across Vermont. The RVT will be managed by staff in the Global Center for Resilience and Security at Norwich University and will play an active role in SHMP implementation.

The RVT will host biannual meetings of the full network to check-in on progress of resilience goals as defined in the Resilient Vermont Crosswalk , which was originally developed in 2013. This biannual meeting will be held in conjunction with SHMP stakeholders at a check-in on SHMP implementation and began in 2019. In the opposite years, beginning with a SHMP Implementation Kick-Off meeting directly following plan approval (see: Planning Process), members of the implementation working groups will be convened to review progress and effectiveness of the 2023 SHMP implementation.

Between these annual meetings, the implementation working groups will continue to meet and make progress on their respective mitigation actions. VEM mitigation staff and Norwich University staff will coordinate these working group meetings and SHMP implementation.

2028 State Hazard Mitigation Plan Update Process

The SHMP update process, completed every 5 years, will incorporate changes in local, State and Federal statutes, changes in development and vulnerability, and changes in mitigation priorities in Vermont. VEM mitigation staff will be responsible for managing the update in close coordination with the SHMPPC. The update process will begin 18 months prior to the expiration of the 2023 SHMP.

A comprehensive update of the SHMP will examine:

- The overall efficacy of the SHMP in addressing real mitigation needs.
- Actual savings realized by implementing cost effective projects.
- How mitigation efforts support environmental protection regulations.
- Areas for organizational and programmatic improvement.
- How to more efficiently combine Federal, State, and local resources to implement the most cost effective hazard mitigation projects and planning.
- How to better coordinate and implement State, regional and local mitigation efforts.

Plan Update Procedures:

1. The State Hazard Mitigation Planning & Policy Committee (SHMPPC) will appoint a Steering Committee to work with VEM mitigation staff to manage the Plan update and the stakeholder engagement process.
2. The Steering Committee will determine if the hazard evaluation criteria are still appropriate or if modifications or additions are needed based on changing conditions since the last update. Data needs will be reviewed and data sources will be identified and collected.
3. VEM mitigation staff and partners will review each section of the SHMP to determine progress achieved in reaching mitigation goals and strategies. The following will be determined:
   i. The status report concerning how well VEM and partners are achieving goals and strategies
   i. Whether goals and strategies still address current conditions
   i. Any obstacles in achieving mitigation goals and strategies
   i. Whether or not revisions to strategies, goals, and actions are warranted
4. A draft report will be prepared by VEM mitigation staff based on these evaluation criteria:
   v. Changes in community and governmental processes, which are hazard-related and have occurred since the last review
   vi. Progress in implementation of Plan initiatives and projects
   vii. Effectiveness of previously-implemented initiatives and projects
   viii. Evaluation of unanticipated challenges or opportunities that have occurred since the previous SHMP was adopted
   ix. Evaluation of hazard-related public policies, initiatives and projects
   x. Review and discussion of the effectiveness of public and private sector coordination and cooperation
5. The SHMPPC and the appointed Steering Committee will review the draft Plan. Consensus will be reached on changes to the draft.
6. VEM mitigation staff will incorporate changes and schedule public hearings in accordance with Vermont Title 3, Chapter 67, Paragraph 4020b.
7. VEM mitigation staff will provide a 30-day advance notice of the public hearings with specific notice to:
   i. Executive director of each Regional Planning Commission (RPC),
   i. Agency of Commerce and Community Development (ACCD),
   i. Agency of Natural Resources (ANR),
   i. Agency of Transportation (VTrans),
   i. The council of Regional Commissions, and
   i. Business, conservation, environmental, low-income advisory and other community groups or organizations that have requested notice prior to the date the hearing is announced.
8. VEM mitigation staff will accommodate input received at the public hearings and will provide proposed revisions to members of the Steering Committee for consideration.
9. VEM mitigation staff will schedule a second round of public hearings per #6 and #7 above, if necessary.
10. VEM mitigation staff will finalize the Plan and provide it to the SHMPPC and Steering Committee for final concurrence.
11. Upon full SHMPPC concurrence, VEM mitigation staff will forward the updated SHMP to the Governor's Authorized Representative (GAR) for approval and submission to FEMA Region I.
12. Following FEMA Region I review and the State updating the plan based on any Required Revisions, FEMA will give the notice of Approval Pending Adoption (APA), following which the GAR will sign off and the plan will be returned to FEMA for final approval.

Post-Disaster Review Procedures:

In the aftermath of a declared disaster, if deemed necessary, a special review may occur in accordance with the following procedures:

1. Within six months of a declared emergency event or when feasible, VEM may initiate a post-disaster review and assessment. Members of the SHMPPC will be notified that the assessment process has commenced.
2. This post-disaster review and assessment will document the facts of the event and assess whether the existing SHMP effectively addresses the hazards and its vulnerabilities.
3. A draft after action report of the review and assessment will be distributed to the SHMPPC.
4. A meeting of the SHMPPC will be convened by VEM mitigation staff to make a determination on whether the Plan needs to be amended. If the SHMPPC determines that no modification is needed, then the report will be distributed to stakeholders.
5. If the SHMPPC should determine that modification of the Plan is needed, VEM mitigation staff will draft an amended Plan that will reflect their recommendations.