TOWN OF ROYALSTON MULTI-HAZARD MITIGATION PLAN

5-YEAR UPDATE 2020 - DRAFT FOR MEMA REVIEW 8.24.20

Prepared for the Town of Royalston by Tighe & Bond

FEMA

Volume 1

TABLE OF CONTENTS

Contents

Appendices

TABLE OF CONTENTS

List of Figures

TABLE OF CONTENTS

List of Photos

List of Maps

TABLE OF CONTENTS

List of Tables

TABLE OF CONTENTS

ACKNOWLEDGEMENTS AND CREDITS

Acknowledgements and Credits

This Hazard Mitigation Plan (HMP) 5-year update was prepared for the Town of Royalston under the direction of the Massachusetts Emergency Management Agency (MEMA) and the Massachusetts Department of Conservation and Recreation (DCR). The HMP update was funded by the Executive Office of Energy and the Environment Municipal Vulnerability Preparedness (MVP) Grant Program.

Massachusetts Emergency Management Agency – Samantha Phillips, Director

Massachusetts Executive Office of Energy and the Environment – Kathleen A. Theoharides, Secretary

Department of Conservation and Recreation – Jim Montgomery, Interim Commissioner

Municipal Vulnerability Preparedness and Hazard Mitigation Advisory Group

Name	Department
Jim Barclay, Director	Royalston Emergency Management Agency
Kate Collins, Chair	Royalston Planning Board
Deborah D'Amico, Chair	Royalston Select Board
Curt Deveneau, Chief/Roland Hamel, Sargent	Royalston Police Department
Jon Hardie, Administrator	Royalston IT System
Tom Kellner, Member	Millers River Watershed
Rebecca Krause-Hardie	Royalston Finance Director
Christine Long, Clerk	Royalston Select Board
Keith Newton, Superintendent	Royalston Department of Public Works
Keith Newton, Chief	Royalston Fire Department
George Northrop, Chair	Royalston Conservation Commission
Maureen Blasco, Secretary	Royalston Conservation Commission
Phil Rabinowitz, Chair	Royalston Capital Planning Committee

EXECUTIVE SUMMARY

Executive Summary

Hazard Mitigation planning is a proactive effort to identify actions that can be taken to reduce the dangers to life and property from natural hazard events. In the communities of the Montachusett region of Massachusetts, hazard mitigation planning tends to focus most on flooding, the most likely natural hazard to impact these communities. The Federal Disaster Mitigation Act of 2000 requires all municipalities that wish to be eligible to receive FEMA funding for hazard mitigation grants, to adopt a local multi-hazard mitigation plan and update this plan in five-year intervals.

The 5-year update for the Royalston Hazard Mitigation Plan (HMP) was prepared with funding from the Commonwealth of Massachusetts Executive Office of Energy and the Environment under the Municipal Vulnerability Preparedness Grant (MVP) Program. The planning process included updating the plan to reflect the 2018 Massachusetts State Hazard Mitigation and Climate Action Plan (SHMCAP) and incorporating natural hazard risk and vulnerability assessments into the plan including future impacts due to climate change. The Town of Royalston recognized climate change as a factor that will affect weather patterns, flooding extent, habitat and species distribution, an ultimately impact the ability to recover from disaster and risk to the citizens of Royalston.

Several notable changes to the 5-year update include:

- Revised goals and objectives for Royalston Hazard Mitigation Planning
- Expansion of natural hazard risk to include climate change
- Expanded public participation through involvement of the MVP Core Team, Stakeholders and Community Resilience Building Workshops
- Clearly defined and systematically prioritized mitigation strategies

A resiliency vision for Royalston includes empowering the residents, neighboring communities and Town Leaders to make near, mid and long-term changes that will reduce future climate change impacts, protect its vital community assets, and adapt to changes already occurring. The mitigation actions included in the 2020 Hazard Mitigation Plan complement and support this resiliency vision.

INTRODUCTION

Section 1 Introduction

Planning Requirements under the Federal Disaster Mitigation Act

The Federal Disaster Mitigation Act, adopted in 2000, requires that after November 1, 2004, all municipalities that wish to continue to be eligible to receive Federal Emergency Management Agency (FEMA) funding for hazard mitigation grants must adopt a local Hazard Mitigation Plan (HMP) and update the plan every 5-years. This planning requirement does not affect federally authorized disaster assistance funding and is exempt from this requirement.

The Town of Royalston has received grant funding from the Executive Office of Energy and the Environment (EEA) Municipal Vulnerability Preparedness (MVP) Grant Program to complete the 5-year update of the HMP in conjunction with completing the MVP Community Designation process. The federal hazard mitigation planning is administered in Massachusetts by the Massachusetts Emergency Management Agency (MEMA) in partnership with the Department of Conservation and Recreation (DCR).

The single jurisdiction local HMP for Royalston produced under this grant is designed to meet the requirements of the Disaster Mitigation Act, following guidance provided in FEMA's Local Mitigation Planning Handbook (March 2013)[1] and FEMA's Local Mitigation Plan Review Guide (October 1, 2011)[2]. Where text in the Hazard Mitigation Plan meets an element identified in the Review Guide, it is called out in a blue box in the margins.

What is Hazard Mitigation?

The purpose of hazard mitigation is to reduce loss from current and future natural hazards. Storms and other natural disasters such as floods, earthquakes, and hurricanes can cause loss of life, damage to buildings and infrastructure, and negatively affect a community's economic, social, and environmental well-being. The Town of Royalston has developed the HMP as a means to permanently reduce or alleviate the losses of life, injuries, and damage to property resulting from natural hazards through adopting long-term strategies. These long-term strategies address not only municipal infrastructure but also societal, economic, and environmental assets of Royalston through planning, policy changes, programs, projects, educational outreach, and other activities. The desired outcome of implementing the HMP will be creating a more resilient community that is better prepared prior to a natural disaster and can recover more quickly after one occurs.

How does the Municipal Vulnerability Planning Process augment the HMP?

The MVP grant program allows municipalities in the Commonwealth to begin the process of preparing for climate change resiliency. The MVP planning process engages the local community–as they participate in identifying community strengths and vulnerabilities and prioritize actions to improve resiliency to natural

[1] FEMA (2013), "Local Mitigation Planning Handbook", https://www.fema.gov/media-library/assets/documents/31598.
[2] FEMA (2011), "Local Mitigation Plan Review Guide", https://www.fema.gov/media-library/assets/documents/23194.

hazard risk including impacts of climate change. Communities who complete the MVP program become certified as an MVP community and are eligible for MVP Action grant funding and other opportunities.

The MVP effort supplements the HMP process by providing a statewide and major basin specific climate change data to use in the natural hazard risk assessment and a consistent methodology for public engagement through the Community Resilience Building (CRB) workshops. **Figure 1.1** below demonstrates the overlap between the MVP and HMP development. The MVP has additional emphasis on future climate driven hazards and targeted outreach to environmental justice (EJ) and vulnerable populations.

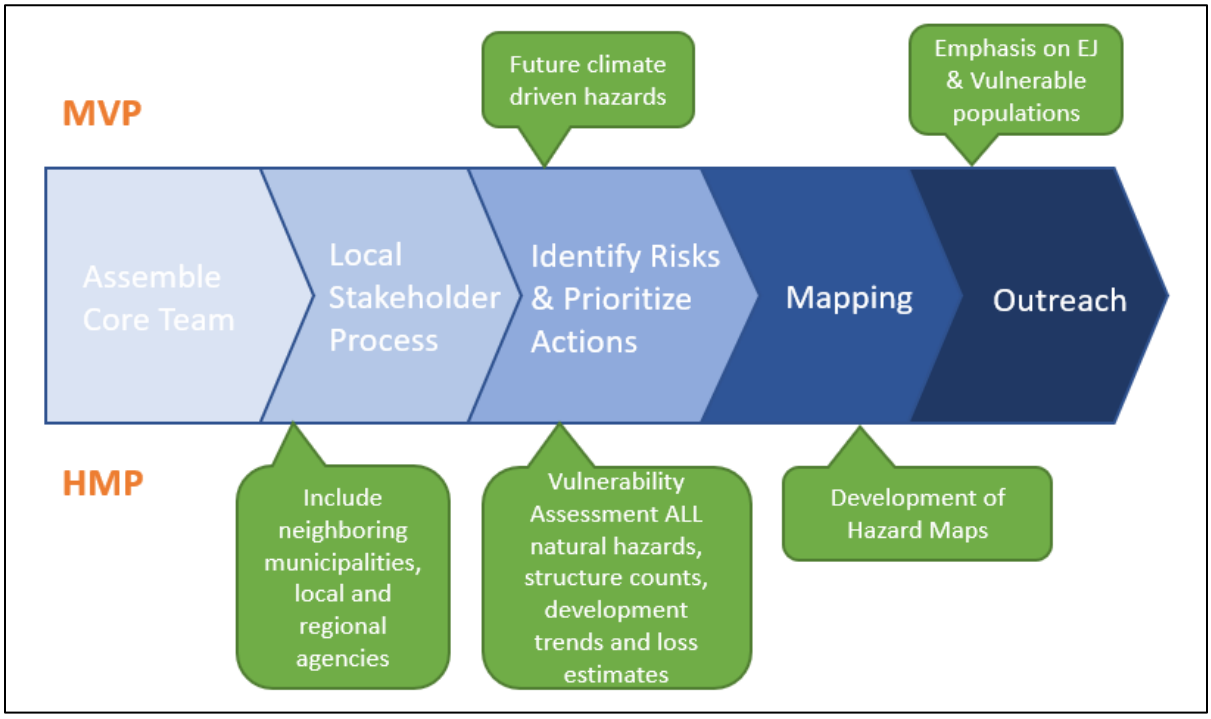


Figure 1.1: Overlap between the MVP and HMP development processes.

INTRODUCTION

1.1 COMMUNITY PROFILE

The Town of Royalston is located in the northwestern corner of Worcester County, in the northwestern part of central Massachusetts (**Figure 1.2**). Royal- shire (which was the original name) was purchased from the General Court of Massachusetts by nine proprietors in 1753, and settlement began in 1762. In 1765 it was incorporated as the Town of Royalston. [3] Royalston borders Athol and Phillipston to the south, Templeton to the southeast, Winchendon to the east, Richmond and Fitzwilliam in Cheshire County New Hampshire to the North, Warwick in Franklin County to the west, and Orange in Franklin County to the southwest.

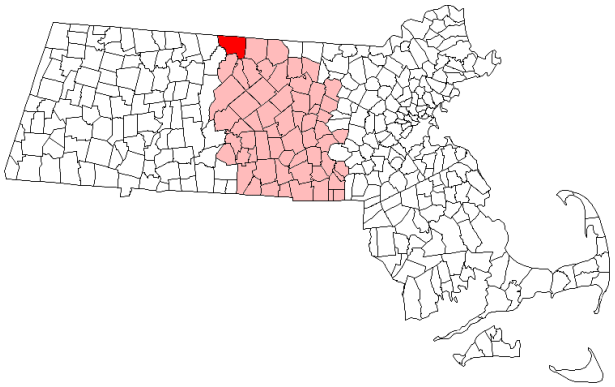


Figure 1.2: Map of Massachusetts towns with Worcester County highlighted in light red and Royalston highlighted in dark red (source: Justin H. Petrosek).

Royalston is located 28 miles west of Fitchburg, 43 miles northwest of Worcester, 74 miles northwest of Boston, and 193 miles from New York City. State Route 68 runs through the Town from West Royalston to Phillipston and State Route 32 runs through the Town from Richmond, New Hampshire to Athol, Massachusetts. Encompassing 42.55 square miles, the Town of Royalston is one of the largest towns in Massachusetts, and is known for its natural resources and outdoor recreation opportunities.

Photo 1.1: Royalston Town Hall.

There are three small villages within Royalston: Central Village, South Royalston, and West Royalston. South Royalston has the highest population density of the three villages and contains the Town's commercial businesses.

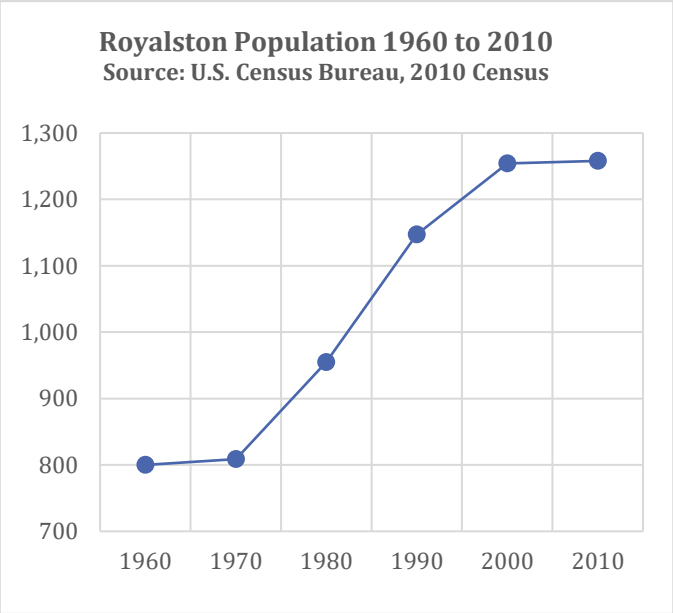
The Central Village of Royalston, which is located near Frye Hill, also has a local historic district known as the Royalston Common Historic District, which contains the Town Common, the Town Hall, the Phinehas S. Newton Library and the Post Office. The Historic District consists of 45 buildings, the majority being private homes, and was listed in the National Register of Historic Places in 1976.[4]

[3] Town of Royalston (2020), "About Royalston", https://www.royalston-ma.gov/about-royalston.

[4] Massachusetts Cultural Resource Information System (MACRIS) (1975), "NRHP nomination for Royalston Common Historic District" , http://mhc-macris.net/Details.aspx?MhcId=ROY.A.

1.2 ROYALSTON DEMOGRAPHICS

The population in Royalston peaked in 1840 with 1,667 residents. Population loss has occurred since then due to westward migration, disease, and the loss of banks and businesses. Since 1960, the population has slowly increased from 800 to 1,258 residents as of the 2010 U.S. Census[5] and 1,160 per the 2018 American Community Survey[6]. Due to the large land area of the Town, the population density, 29 people per square mile, is very low by state standards.[7]



As of the 2018 American Community Survey, the total number of households is 487, with 2.4 persons per household. The median age of residents in Royalston is 52.1, which is about 1.3 times the median age in Worcester County and in the Commonwealth of Massachusetts.

The Town of Royalston has very little ethnic or racial diversity, with 97 percent of the population self-identifying as white on the 2010 Census and 99 percent identifying as white on the 2018 American Community Survey.[8]

1.3 ROYALSTON'S ECONOMY

Royalston had considerable economic growth from 1776 to 1800 as local tanneries, grist and sawmills were established, with the majority of residents employed in agriculture. In the early 1800's Royalston had two centers of population: Royalston Center, also called Royalston Commons, which was the geographic center of the town, and the village of South Royalston, which had its own mills and small businesses. By the late 1800s Royalston's regional importance as an industrial center began to decline.[9]

Currently, Royalston is a residential and agricultural community, with the largest employer being the Royalston Community School. Additional important economic resources in Town include the Royalston General Store and the Village School.

---

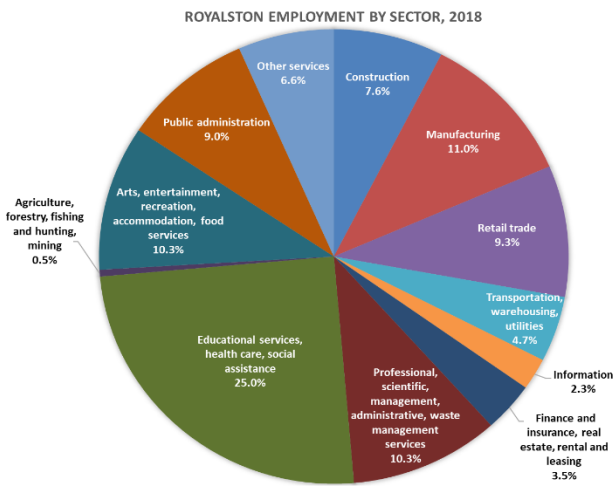
[5] U.S. Census Bureau, "Tables, Minor Civil Divisions: 2010-2019", https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-cities-and-towns.html#tables

[6] U.S. Census Bureau, (2018) "American Community Survey": https://www.census.gov/programs-surveys/acs

[7] Town of Royalston (2010), "Town of Royalston Open Space and Recreation Plan"

[8] Census Reporter, "Royalston town, Worcester County, MA", https://censusreporter.org/profiles/06000US2502758580-royalston-town-worcester-county-ma/

[9] Massachusetts Historical Commission (MHC) (1984), "MHC Reconnaissance Survey Town Report: Royalston"



Based on the U.S. Census 2018 American Community Survey, of the 1,010 persons in Royalston aged 16 years and over, 621 are considered to be civilian employed.

The majority of the employed population in Royalston work in Educational Services, Health Care, or Social Assistance (25%), followed by manufacturing (11%), arts, entertainment, recreation, accommodation, and food services(10%), and professional, scientific, management, administrative, and waste management services (10%).

1.4 ROYALSTON'S NATURAL ENVIRONMENT

Royalston today has within its boundaries three waterfalls, state forests and thousands of areas of conservation land that all present a diversity of recreational opportunities.

Major waterbodies include the Millers River, Tully River, Tully Lake, Lawrence Brook, and Stockwell Brook. Royalston is also home to Tully Trail and the New England trail. Outdoor recreation areas such as Doane's Falls, Royalston Falls, Spirit Falls, Jacobs Hill, Tully Lake and Recreation area, and the many cemeteries, forests and wildlife management areas give the town its unique characteristics.

Photo 1.2: View from Tully Mountain loop trail (source: Town of Royalston Open Space and Recreation Plan, 2010-2016).

Topography

The terrain of Royalston is rugged, and comprised of glacially-derived landscape features such as glacial till deposit and scoured rock outcrops. Elevations in Town peak at 1,361 feet at White Hill near the Warwick Town line, with a ridge of rocky hills running north to south from the middle of Town to the Town of Athol. Other peaks in Town include Gale Hill (1,053 feet) in the southwest, Tory Hill (1,167 feet) in the north-center, Harrington Hill (1,212 feet) and Bliss Hill (1,255 feet) in the east, and Prospect Hill (1,333 feet) in the north-center. Overall, the Town is rocky, steep, and sloping, with three waterfalls (Doane's Falls, Spirit Falls, and Royalston Falls).

Vegetation

Approximately 87% of Royalston is forested.[10] There are three official state forests located in Royalston, the Royalston State Forest, Otter River State Forest, and Warwick State Forest, as well as the Ehrich Memorial Forest and Chase Memorial Forest, which are conserved through the New England Forestry Foundation. Royalston is located in the Northern Hardwoods-Hemlock-White Pine forest zone of Massachusetts[11], with commonly observed tree species that include hardwoods beech, black birch, grey birch, paper birch, sugar maple, red maple, and red oak.

Water Resources

Royalston is located within the Millers River Watershed, which encompasses an area 392 square miles in size over 23 towns in north central Massachusetts and New Hampshire along its 51 mile course to the Connecticut River.[12] In Royalston, the Millers River cuts east-west across the southeastern part of town (**Figure 1.3**).

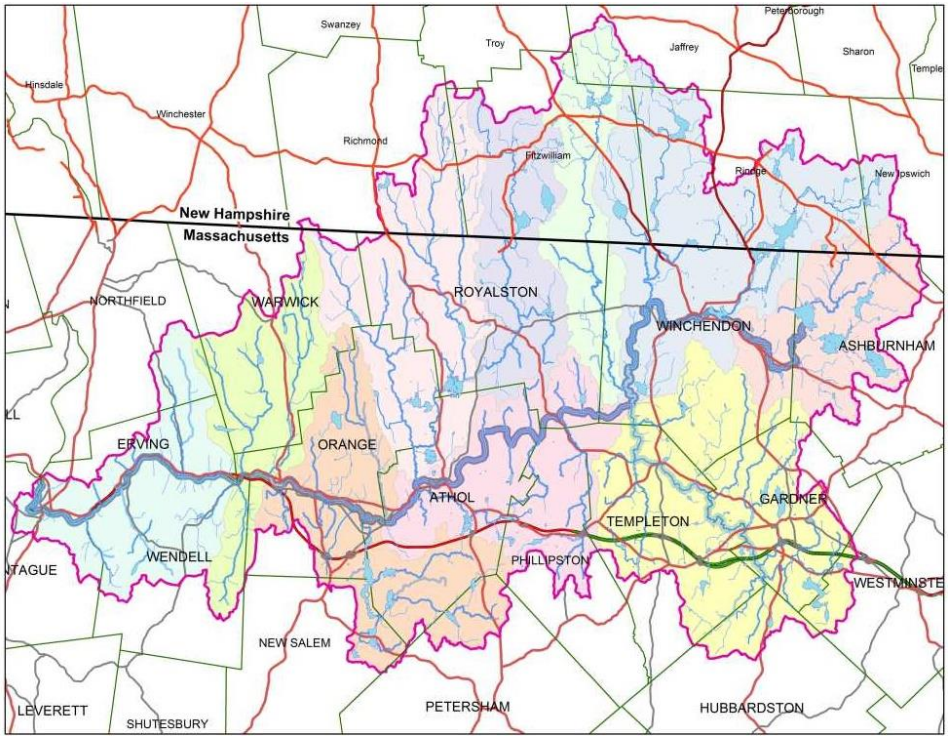


Figure 1.3: Major streams and sub-watersheds in the Millers River basin. The main stem of the Millers River is in dark blue (source: Millers River Watershed Council, https://millerswatershed.org/maps/).

[10] Town of Royalston (2010), "Town of Royalston Open Space and Recreation Plan"

[11] Massachusetts Natural Heritage & Endangered Species Program (NHESP) (2016), "Northern Hardwoods – Hemlock – White Pine Forest": https://www.mass.gov/files/documents/2016/08/no/northern-hardwoods-hemlock-white-pine-forest-fs.pdf

[12] Millers River Watershed Council: https://millerswatershed.org/about-the-watershed/

Notable scenic environments in Royalston include three waterfalls, Doane's Falls, Royalston Falls, and Spirit Falls. Smaller water resources in Royalston include Lawrence Brook and its tributaries, which drain central Royalston and are the source of Doane's Falls; Scott Brook, which flows from New Hampshire through the northeast corner of Royalston and joins with Towne Brook to form Priest Brook, a major tributary of the Millers River; Little Pond, a 12-acre pond west of the Town Common that is the source of Spirit Falls; and Tully Lake, the impoundment created by Tully Dam.

Per the 2010 Royalston OSRP, approximately 6% of the land area of Royalston is considered to be water and wetlands. Wetland resource areas are primarily found along Tully Lake, Long Pond, Falls Brook, Lawrence Brook, Millers River, Beaver Pond, Boyce Brook, and Towne Brook, but forested wetlands and vernal pools occur throughout the Town.

There are no known major aquifers identified within Royalston; however, based on the existence of potential aquifer materials (floodplain alluvium and sand and gravel deposits) near the East Branch of the Tully River, Lawrence Brook, Millers River, and Priest Brook, these areas have been identified as potential aquifer areas.[13]

1.5 ROYALSTON INFRASTRUCTURE

Transportation Systems

No major roads run through the Town of Royalston; the nearest major road, Route 2, runs through Phillipston and Templeton to the south. The Town has approximately 71.6 miles of roadways, 24.7 of which are collector roads (low to moderate capacity roads that provide access from local roads to arterials). Major roads and evacuation routes in Town include Route 32 (Athol-Richmond Road), Route 68 (Warwick Road/Main Street), Athol Road, North Fitzwilliam Road, and Winchendon Road. [14]

There are two bridges in Town identified as structurally deficient in the 2015 HMP. The North Fitzwilliam Road bridge over Lawrence Brook has been replaced, and the Stockwell Road bridge over Lawrence Brook was repaired in 2020. Additional bridges in Town include the Doane's Falls Bridge, the South Village Bridge, and the Lawrence Brook Bridge on South Royalston Road.

There are three designated Helicopter Landing Zones (LZ) in Town, which are not formal helicopter landing pads but represent areas where a helicopter could feasibly land in the event of an emergency. Helicopter LZ 1 is located near Tully Lake, Helicopter LZ 2 is located near Birch Hill Dam with a designated alternate location near the Royalston Fish and Game Club, and Helicopter LZ 3 is located near the Royalston Community School.

There is no public transportation available in Town, as the region's transportation authority (Montachusett Regional Transportation Authority, MART) does not serve the general population in Royalston.

[13] Town of Royalston (2010), "Open Space & Recreation Plan 2010-2016"
[14] Town of Royalston (2013), "Housing Production Plan"

Similarly, the Springfield terminal rail line passes through South Royalston along the Millers River, but there is no public transportation access on the rail line.

Water and Wastewater

The Town of Royalston currently does not have a public water supply company and is served by a mix of public and private wells. The South Royalston Improvement Corporation, a private utility, provides water to the South Royalston Village area from a bedrock well. Approximately 100 residential properties in South Royalston Village are also served by public sewer. The Town has a wastewater treatment plant located in South Royalston and three pumping stations to convey wastewater to the treatment facility.

Photo 1.3: Royalston Wastewater Treatment Facility.

Flood Control Structures

There are two High Hazard dams within the Town of Royalston, both part of a network of flood control dams on the Connecticut River and its tributaries, and both owned and operated by the Army Corps of Engineers. Tully Dam, located on the eastern branch of the Tully River in the southwest corner of Town, forms the 1,262-acre reservoir known as Tully Lake. Birch Hill Dam, located on the Millers River in the southeast corner of Town, forms a 4,384-acre reservoir area, 4,221 acres of which are leased to the Massachusetts Department of Conservation and Recreation (DCR) for recreation and fish and wildlife purposes.

1.6 FEDERAL/STATE DISASTER DECLARATIONS

Royalston has experienced 18 natural hazard incidents that triggered federal or state disaster declarations since 1954, listed in **Table 1-1**. Most events involved winter storms.

Table 1-1
Federal and State Disaster Declarations 1954-2018

Disaster #	Dates	Unofficial Storm Name	Impact
DR-4379	March 13, 2018	"Winter Storm Riley"	Severe winter storm, snowstorm, flooding- Nor'easter
DR-4214	January 26-29,2015	"Winter Storm Juno"	Severe winter storm, snowstorm, flooding- Nor'easter
DR-4110	February 8-10, 2013	"Winter Storm Nemo"	Severe winter storm, snowstorm and flooding
DR-4051	October 29-30, 2011	"Snowtober"	Severe Storm
DR-1994	June 01, 2011		Severe Storm and Tornadoes
DR-1813	December 11, 2008	December Ice Storm	Severe Winter and Ice Storm
DR-1614	October 7-16, 2005	Nor'easter	Severe Storms and Flooding

Disaster #	Dates	Unofficial Storm Name	Impact
DR-1512	April 2004		Heavy Rain and Flooding
DR-1364	March 2001	March Blizzard	Severe winter storm, snowstorm
DR-1224	June-July 1998		Heavy Rain and Flooding
DR-1090	January, 1996	January Blizzard	Severe winter storm, snowstorm
DR-975	December 11-13, 1992		Winter coastal storm
DR-914	8/19/1991	Hurricane Bob	Category 2
DR-790	March-April 1987		Severe Storms and Flooding
DR-751	9/27/1985	Hurricane Gloria	Category 3
DR-546	February 6-8, 1978		Coastal storms, flood, ice, snow
DR-43	August 1955	Hurricane Connie/ Diane	Category 2
DR-22	October 1954	Hurricane Carol	Category 2

1.7 Available Documents

A4a b

See **Appendix A** for a list of all reports, plans, studies, and technical information that was used in the development of the MVP/HMP 5-year Update. Information that was used to develop key findings is cited directly in the document.

Section 2 The Planning Process

A1 a e

To develop this combination MVP/HMP report, the Town of Royalston followed the planning process framework consistent with FEMA's hazard mitigation planning guidance and EEA's Community Resilience Building framework, while focusing on local needs and priorities, and maintaining a regional perspective on natural hazard events. The combined process included the following main steps:

1. **Identifying and Mapping the Hazards** – The Town used data from federal, state, and locally developed data to identify hazards that impact Royalston. A profile of each hazard was developed including previous occurrences, magnitude and severity of the hazard, and probability for future occurrences. Maps were created to show areas affected by the identified natural hazards and were used as the basis for developing the risk assessment. The **Natural Hazards Risk Assessment** is included in **Section 3**.
2. **Assessing the Critical Community Assets and Potential Damages** – Critical community assets including municipal facilities, infrastructure, vulnerable populations, economic, and natural resources were located and compared with hazard data to identify those that may be vulnerable to hazards. Royalston developed estimates of the potential impacts of certain hazard events on the community including flooding, earthquakes, and hurricane winds. Further discussion is included in the **Asset Inventory** in Section 4 **and the Vulnerability Assessment** in Section 5.
3. **Reviewing Existing Mitigation** – Royalston has implemented many mitigation strategies including floodplain zoning, wetland protection, and other measures as well as enforcing the State Building Code. All current municipal mitigation measures were documented and discussed as part of the **Capabilities Assessment** in Section 6.
4. **Developing Mitigation Strategies** – The Town worked with a designated planning group, local stakeholders, and their consultants to identify new mitigation measures, utilizing information gathered from the hazard identification, vulnerability assessment, and exiting mitigation measures to determine where additional work is needed to reduce potential future damages from hazard events. The **Mitigation Strategy** discussed in Section 7 includes goals and objectives, mitigation actions, and an implementation strategy.
5. **Implementing and Updating the Plan** – Implementation is the final and most important part of any planning process. Hazard Mitigation Plans must also be updated on a 5-year basis making preparation for the next Plan update an important on-going activity. A schedule for implementation, **Plan Evaluation and Maintenance** is included in Section 8.
6. **Plan Approval and Adoption** – Once a final draft of the HMP update is complete it is sent to MEMA for the state level review and pending the completion of any revisions, it is sent to FEMA for approval. Once FEMA approves the Plan, FEMA issues a conditional approval pending adoption of the Plan by the Town of Royalston. The **Plan Approval Process** is included in Section 9.

The steps included public participation as an important component of the process, providing critical information about the local occurrence of hazards, a discussion on regional issues, and to build support for hazard mitigation activities.

Public participation was accomplished through the Community Resilience Building Process. Royalston held six public meetings open to the general public to present and discuss aspects of the Hazard Mitigation Plan 5-year Update .

THE PLANNING PROCESS

2.1 THE PLANNING TEAM

A2 a b

The **MVP/HMP Core Team**, listed in Table 2-1, was assembled at the start of the MVP/HMP 5-year update project to solicit input from multiple staff in the Town of Royalston ,including the Royalston Planning Board. The advisory group met to kick-off the HMP planning process. The meeting was led by Jim Barclay, Emergency Management Director, and the Town's consultant, Tighe & Bond. Presentations served to outline the MVP/HMP project, to discuss MVP/HMP goals, and to provide guidance for town staff on project responsibilities.

Table 2-1
Royalston MVP/HMP Core Team

Name	Department
Jim Barclay, Director	Royalston Emergency Management Agency
Kate Collins, Chair	Royalston Planning Board
Deborah D'Amico, Chair	Royalston Select Board
Curt Deveneau, Chief	Royalston Police Department
Jon Hardie, Administrator	Royalston IT System
Tom Kellner, Member	Millers River Watershed
Rebecca Krause-Hardie, Director	Royalston Finance Director
Christine Long, Clerk	Royalston Select Board
Keith Newton, Superintendent	Royalston Department of Public Works
Keith Newton, Chief	Royalston Fire Department
George Northrop, Chair	Royalston Conservation Commission
Maureen Blasco, Secretary	Royalston Conservation Commission
Phil Rabinowitz, Chair	Royalston Capital Planning Committee

2.2 OUTREACH STRATEGY

A2 a c

The Town of Royalston completed the required public outreach for the HMP through the MVP Community Resilience Building Workshop, and other public meetings. Outreach efforts included Core Team meetings, a public meeting held during the development of the HMP, the CRB public workshops, MVP listening session, presentation to the Select Board, and multi-media outreach including public notices on the Town's website.

A3 a b

Table 2-2 summarizes the meetings and public forums conducted throughout the MVP/HMP update.

Table 2-2
Meetings and Public Forums

Meeting Date	Topic	Audience / Purpose
Kickoff Meeting- 1/23/2020	Kickoff meeting	Core Team Members

Meeting Date	Topic	Audience / Purpose
Public Meeting – 2/27/2020	Presentation of Natural Hazards Index, Community Assets and Vulnerability Risk Assessment	Core Team Members, Royalston Residents and neighboring communities
Public Workshop#1- 5/18/2020	Community Resilience Building Workshop- Vulnerable Populations and Cultural Facilities	Invited Stakeholders
Public Workshop#2- 6/1/2020	Community Resilience Building Workshop- Critical Facilities and Built Environment	Invited Stakeholders
Public Workshop#3- 6/8/2020	Community Resilience Building Workshop- Natural Resources and Open Space	Invited Stakeholders
Core Team Working Meeting 6/10/20	Review Survey Results Mitigation Strategies	Core Team Members
Public Listening Session 6/15/2020	Draft MVP Report- Presented at Planning Board Meeting	Core Team Members, Royalston Residents and neighboring communities
Core Team Working Meeting 6/22/20	Rank Mitigation Strategies	Core Team Members
Select Board Meeting 8/7/ 2020	Draft HMP Report	Select Board, Core Team Members, Royalston Residents and neighboring communities

Community Resilience Building Workshops

Community stakeholders were invited to participate in three CRB workshops on May 18th, June 1st, and June 8th. Due to the COVID 19 pandemic, the workshops were held online. A summary of findings from the workshop and the list of community stakeholders invited to the workshops is included in **Appendix B**.

MVP/HMP Listening Session

A listening session to present the draft report and review the high priority actions identified through the CRB workshops was held on June 15 at a Planning Board Meeting. Due to the COVID 19 pandemic, the listening session was held online. The Royalston Emergency Management Director led the workshop with support from Tighe & Bond. Ten municipal staff and residents were in attendance. The listening session included a presentation that briefly overviewed the MVP process, including findings followed by a discussion period. A copy of this presentation is included in **Appendix B**. The February public meeting materials are included in **Appendix C**.

Select Board Meeting to approve the Draft HMP

On August 7, 2020, the Select Board voted to approve sending the draft HMP to MEMA for review.

Section 3 Natural Hazards (Risk Assessments)

3.1 HAZARDS IDENTIFICATION

State Hazards

The 2018 Massachusetts State Hazard Mitigation and Climate Action Plan (SHMCAP)[15] provides an in-depth overview of natural hazards in Massachusetts. The SHMCAP identifies 15 natural hazards that have an impact or have a history of impacting communities in the Commonwealth of Massachusetts. These hazards are as follows:

Hydrologic & Geologic Flood Related Hazards-

- Inland Flooding- including Riverine Flooding, , Urban Drainage Flooding, Ground Failure, Ice Jams, and Dam Overtopping
- Drought
- Landslides
- Coastal Flooding
- Coastal Erosion
- Tsunami

Atmospheric Hazards

- Extreme Temperatures
- Wildfires
- Invasive Species

Extreme Weather

- Hurricane and Tropical Storms
- Nor'easters
- Severe Winter Weather (includes snow, blizzards and ice storms)
- Tornadoes
- Other Severe Weather (includes high winds, thunderstorms,)

Non-Climate Related Hazards

- Earthquake

Selection of Hazards that affect the Town of Royalston

B1 a

As suggested under FEMA planning guidance, the Planning Team reviewed the full range of natural hazards identified in the SHMCAP and identified natural hazards that have impacted Royalston in the past or could

[15] MEMA (2018), "Massachusetts State Hazard Mitigation and Climate Adaptation Plan": https://www.mass.gov/files/documents/2018/10/26/SHMCAP-September2018-Full-Plan-web.pdf.

impact Royalston in the future. The hazards selection for Royalston was made using local expertise from the Core Team, information from the 2015 Montachusett Region Hazard Mitigation Plan,[16] the 2018 SHMCAP, and other sources.

Royalston has elected to include all 15 hazards from the SHMCAP as the basis for evaluating hazards for the Royalston HMP 5-year update, with the addition natural hazard risk of cyanobacteria. Coastal natural hazards including coastal flooding, coastal erosion and tsunamis are not applicable for this inland community. Climate change impacts are integrated into the natural hazard elements where appropriate, consistent with the strategy used in the 2018 SHMCAP.

Table 3-1 includes list of all hazards selected by Royalston for inclusion in the HMP update. The Planning Team reviewed each natural hazard and developed **Table 3-1** below indicating the history and possibility for future occurrence of each hazard, current frequency and geographical extent, severity of hazard impact, and results of a hazard index rating based on a scale of 1 (highest risk) through 5 (lowest risk).

The definitions of geographical extent, probability of occurrence, frequency, geographical extent, and impact severity are provided in **Table 3-2**.

Table 3-1
Relevant Natural Hazards for Royalston

Type of Natural Hazard	History of Occurrence in Royalston	Hazard Probability	Hazard Frequency	Geographic Extent	Severity of Impact	Hazard Risk Ranking
Hydrological Hazards						
Flood Related						
• Heavy Rain	Yes	4	3	2	3	1
• Ice Jams	Yes	3	3	1	4	2
• Beavers	Yes	4	3	1	2	2
• Snow Melt	Yes	3	2	2	2	3
• Dam Failure	Yes	1	1	1	4	4
Coastal Flooding	No	0	0	0	0	NA
Drought	Yes	2	3	3	2	2
Atmospheric Hazards						
High Winds	Yes	4	3	3	3	1
Hurricanes/Tropical Storms	Yes	3	3	3	3	1
Severe Winter-Storm/Nor'easter	Yes	3	3	3	3	1

[16] MRPC (2015), "Montachusett Region Natural Hazard Mitigation Plan 2015 Update": https://www.mrpc.org/sites/g/files/vyhlif3491/f/uploads/montachusett_region_natural_hazard_mitigation_plan_2015_update_adopted_by_communities.pdf

NATURAL HAZARDS (RISK ASSESSMENTS)

Type of Natural Hazard	History of Occurrence in Royalston	Hazard Probability	Hazard Frequency	Geographic Extent	Severity of Impact	Hazard Risk Ranking
Heavy Snow	Yes	4	3	3	2	1
Ice Storms	Yes	4	3	3	3	1
Severe Weather-Thunderstorms	Yes	4	3	2	2	2
Blizzards	Yes	3	2	3	2	2
Extreme Temperature	Yes	4	3	3	1	2
Tornadoes	Yes	3	1	1	3	3
Geological Hazards						
Coastal Erosion	No	0	0	0	0	NA
Earthquake	Yes	2	2	2	1	4
Landslide	No	1	0	1	2	5
Tsunami	No	NA	NA	NA	NA	NA
Other Hazards						
Wildfires	Yes	3	3	1	1	3
Invasive Species	Yes	4	3	1	1	3
Cyanobacteria	Yes	3	3	1	1	3

The hazard risk rankings were calculated by assigning points to each hazard (see **Table 3.2**) and totaling the scores. A score of 12-13 ranked as #1,10-11 as #2, 8-9 as #3, 6-7 as #4, and 4-5 as #5. #1 is ranked as the highest hazard risk and # 5 the lowest hazard risk for Royalston.

Table 3-2

Hazard Profile Definitions [17]

Points		Description
Hazard Probability (Possible occurrence in the future)		
1	Unlikely	Less than a 1% probability over the next 100 years
2	Possible	1-10% probability in the next year or at least one chance in the next 100 years
3	Likely	10-100% probability in the next year or at least one chance in the next 10 years
4	Highly Likely	Near 100% probability in the next year

[17] MEMA (2018), "SHMCAP"

Points		Description
Hazard Frequency		
0	Very Low	Events that occur less frequently than once in 1,000 years (less than 0.1% per year).
1	Low	Events that occur from once in 100 years to once in 1,000 years (0.1% - 1% per year).
2	Medium	Events that occur from once in 10 years to once in 100 years (1% - 10% per year).
3	High	Events that occur more frequently than once in 10 years (greater than 10% per year).
Geographical Extent (Area Impacted by a Given Natural Hazard)		
1	Small	Less than 10% of the Town affected
2	Medium	10-50% of the Town affected
3	Large	More than 50% of the Town affected
Severity of Impact from Hazard		
1	Minor	Limited and scattered property damage; no damage to public infrastructure (roads, bridges, trains, airports, public parks, etc.); contained geographic area (i.e. one or two communities); essential services (utilities, hospitals, schools, etc.) not interrupted; no injuries or fatalities.
2	Serious	Scattered major property damage (more than 10% destroyed); some minor infrastructure damage; wider geographic area (several communities); essential services briefly interrupted up to 1 day; some minor injuries.
3	Extensive	Consistent major property damage (more than 25%); major damage public infrastructure damage (up to several days for repairs); essential services are interrupted from several hours to several days; many injuries and possible fatalities.
4	Catastrophic	Property and public infrastructure destroyed (more than 50%); essential services stopped for 30 days or more, multiple injuries and fatalities.

Royalston Climate Change Projections

Climate change projections for Royalston were reviewed using data from the Northeast Climate Adaptation Science Center (NE CASC)[18] at the University of Massachusetts Amherst developed for inclusion in the 2018 SHMCAP.

Researchers from the NE CASC at the University of Massachusetts Amherst developed downscaled projections for changes in temperature, precipitation, and sea level rise for the Commonwealth of Massachusetts. EEA has provided support for these projections to enable municipalities, industry, organizations, state government and others to utilize a standard, peer-reviewed set of climate change projections that show how the climate is likely to change in Massachusetts through the end of this century. These projections are incorporated into the 2018

[18] Resilient MA Climate Change Clearinghouse for the Commonwealth: http://resilientma.org/datagrapher/

SHMCAP. To ensure consistency with the SHMCAP, Royalston has adopted data developed for the Millers River Watershed region from the State-wide climate change projections (2018, NE CASC and EEA[19]). Climate change for each natural hazard risk is discussed within the hazards profiles below.

3.2 HAZARD PROFILES

B2 a b c.

Hazard profiles are provided in Sections 3.3-3.6 for each of the 16 natural hazards that could impact Royalston in the future or have impacted the Town in the past. Each hazard profile includes a definition and description of the hazard, previous occurrence and extent, local areas of impact, and probability for future occurrence. A discussion of previous occurrences includes historic data. Evaluation of the extent or severity of the hazard includes the measuring scale for a specific hazard. Locally identified areas of impact include maps showing the areas identified by the hazard whenever possible. The probability of future occurrences is based on best available science and historic events using the hazard probability scale provided in **Table 3.2**.

For each natural hazard, the major vulnerability issues for four key sectors are summarized. The key sectors or categories of community assets include:

- Special populations and places (vulnerable populations and cultural assets)
- Built environment (municipal buildings and critical infrastructure)
- Natural environment
- Economy

Resources used to develop the natural hazard profiles are referenced as footnotes throughout the chapter.

[19] EEA (2017). "Statewide and Major Basins Climate Projections Final, 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan Natural Hazards Risk Assessment"

3.3 Hydrologic Hazards

3.3 HYDROLOGIC HAZARDS

Floods are the most common type of hydrologic hazard in Royalston. Flood hazard includes inland flooding as the direct result of heavy rains, Nor'easters, ice jams, beavers, snow melt, and dam failure. Coastal flooding does not impact this inland community. At the other end of the spectrum, drought impacts are included as a hydrologic hazard for Royalston, primarily based on the negative impacts to water supplies and agriculture.

Inland Flooding

Flooding typically occurs where the rate of precipitation from a severe storm like a Nor'easter or tropical storm causes a large amount of rain in a short period of time, overwhelming the capacity of natural or constructed drainage systems causing overflows. Inland flooding along rivers and streams is known as **riverine flooding.**

Flooding due to **poor drainage** occurs in flat areas where runoff or rain collects and cannot drain. Poor drainage after flood events is usually associated with poorly infiltrating soils and undersized stormwater conveyance, including channelized streambeds and culverts that do not have adequate capacity to handle runoff from larger storm events. Most of the systems in Royalston were not designed to handle specific storm event volumes. Larger storm events and other sources of water including snow melt or ice jams and high groundwater can overload the system and result in backups, flooding streets and properties.

FEMA Flood Hazard Areas

Areas at risk of flooding are mapped by FEMA as part of the National Flood Insurance Program (NFIP) established in 1968 to reduce the nation's flood losses via local floodplain management practices. A floodplain is defined by the NFIP as any land area susceptible to being inundated by floodwaters from any source[20]. FEMA's flood maps, the Flood Insurance Rate Maps (FIRM) delineate flood zones that are defined according to varying risk of, or potential for, flooding due to the land area's characteristics (proximity to a waterbody, topography/slope) and current waterbody conditions (water levels, historic storm experience).

The frequency and severity of flooding are measured based on the probability that a certain river discharge (flow) will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different flooding levels. For example, the 100-year flood has a 1-percent chance of being equaled or exceeded in any given year. The 100-year flood, or 1% chance annual flood is **not** inherently a flood that will occur once every 100 years.

The 100-year flood is used by the NFIP to guide floodplain management and determine the need for flood insurance. The term "500-year flood" or 0.2% annual chance flood, is the flood that has a 0.2-percent chance of being equaled or exceeded each year.

[20] https://www.fema.gov/national-flood-insurance-program/definitions

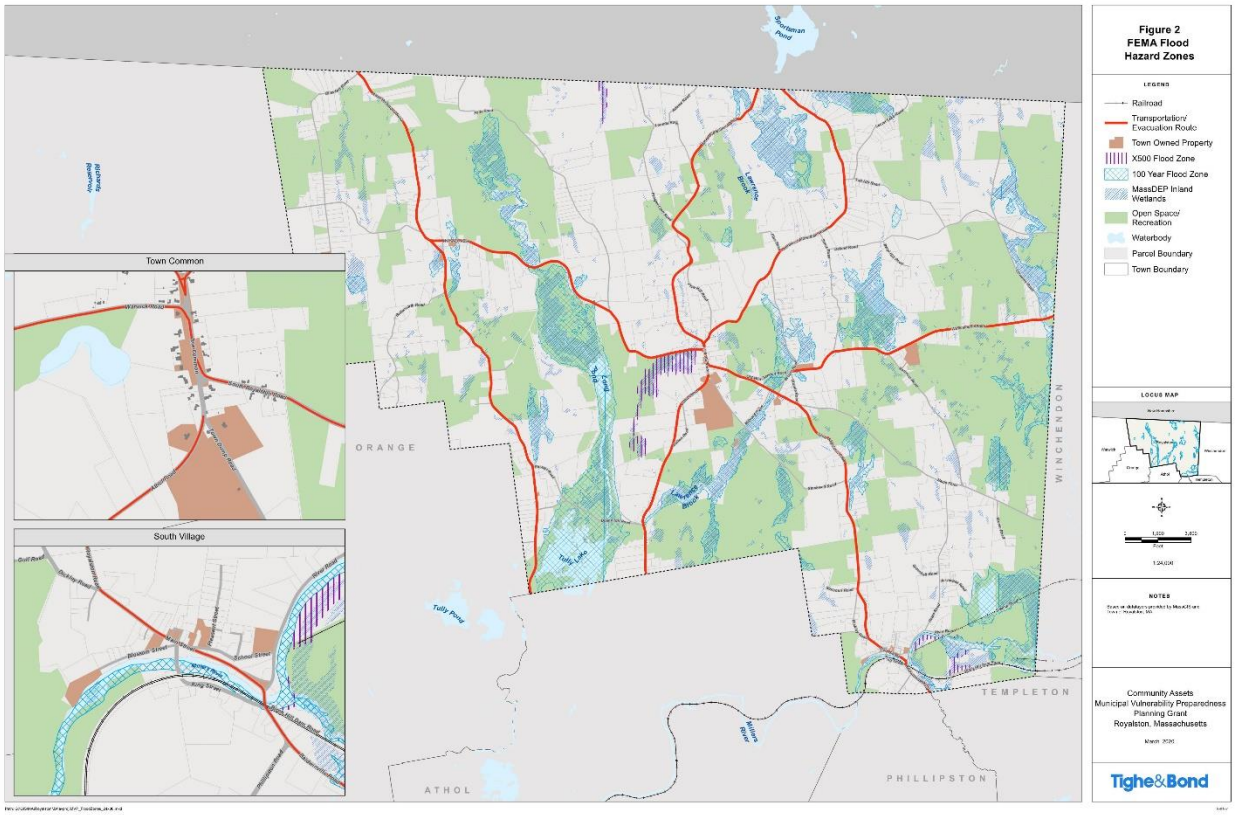


Figure 3.1: Royalston's FEMA Flood Hazard Zones

The 100- and 500- year floodplains and areas subject flooding within Royalston, shown above in **Figure 3.1** were defined by the National Flood Insurance Program with an effective date of June 15, 1983. **Table 3-3** describes the risk associated with each zone.

Table 3-3
Definitions of FEMA Flood Zones

Risk Type	Zone	Description
Low Risk	C (unshaded)	Area of minimal flood hazard
Moderate Risk	B (medium shade	0.2 % Annual Chance Flood
High Risk	A	1% Annual Chance Flood *Inland floodplains that do not have a base flood elevation (BFE)*

Previous Occurrence and Extent of Town-Wide Flooding (Inland)

Flooding was the most prevalent serious natural hazard identified by local officials in Royalston's annex of the 2015 Montachusett Region Hazard Mitigation Plan and continues to be the biggest natural disaster that impacts the area today. In the past 10 years alone, Worcester County has experienced 56 flooding events[21]. Notable flood events include the Great Flood of 1936, the Hurricane of September 1938 (a Category 3 hurricane), the Blizzard of 1978 (the most devastating Nor'easter in Massachusetts history)[22], and flooding due to ice dams on the Miller's River in 2005. **Table 3-4** summarizes these historic and other notable flooding events.

Table 3-4
Historic Flooding Events and Local Impacts for Royalston

Date	Type of Event	Local Impacts
March 1936	The Great Flood of 1936	Damage from flood and ice jams. Prompted the Flood Control Act of 1936
September 21, 1938	The Great New England Hurricane - Cat 3	10-17 inches of rainfall was recorded. The highest recorded elevation at Birch Hill Dam was 829.9 feet
August 31, 1954	Hurricane Carol- Cat 2	
August 12, 1955	Hurricane Connie - Cat 2, followed by Diane	2 hurricanes struck within 12 days with 7 inches of rain causes stream flooding and streets washed out.
September 12, 1960	Hurricane Donna - Cat 2	10-20 inches of rain. Wettest tropical cyclone to impact New England.
February 1978	The Blizzard of '78	Most devastating Nor'easter in Massachusetts history. 30 inches snowfall, with 20-foot drifts recorded.
January 24, 2005	Ice Dam	Flooding from ice. Ice Dam on Millers River in Athol caused flooding and forced evacuation of nearby homes
October 15, 2005	Flooding	Extreme rainfall and flooding from slow moving system.
June 11, 2006	Flood	Wet microbursts and extreme rainfall.
March 12-16, 2010	Nor'easter	Heavy rainfall and riverine flooding over several days total rainfall from 3-6 inched with widespread flooding.
August 28, 2011	Hurricane Irene	Heavy rainfall and record flooding
December 17, 2016	Winter Storm Flooding	Heavy snow, strong winds and riverine flooding
January 4, 2018	Heavy Snow	10-17 " snowfall
January 13, 2018	Ice Dam Flooding	Ice broke free at a location on the Millers River in South Royalston. Damage was sustained to the Exchange Street Bridge in Athol forcing the closure of the bridge. The Exchange Street bridge was replaced in 2020.
March-14-15, 2018	Winter Storm Riley- Heavy Snow	7-22" " snowfall. FEMA Disaster DR-4372.
October 17, 2019	Bomb Cyclone	Heavy Rainfall and High Winds

[21] NOAA Storm Event Data base (https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=25%2CMASSACHUSETTS)
[22] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan

Locally Identified Areas of Impact

Currently, flooding in low lying areas occur during heavy rains. The excessive stormwater runoff floods low-lying areas and surcharges the existing inadequate or malfunctioning drainage systems. Town officials reviewed areas of flooding concern in the 2015 HMP. A list of areas of local flooding concern is provided in **Table 3-5**. The FEMA Flood Zones and areas of flooding concern are shown on **Figure 3.1.**

Table 3-5
Locally Identified Areas of Flooding (2015)

	Location	Flooding Concern
1	River Rd and Neal Rd	Inadequately sized culvert at Millers River floods especially with snow melt
2	Millers River @ Main Street Bridge (Rt 68)	Slow moving section above the Bridge has high potential for ice dam
3	Stuart Rd and Doane Hill Road	Road shuts down to allow controlled flooding. Could impact traffic and emergency response.
4	Brook north of Little Pond and Warwick Rd (Rt 68)	Frequent flooding. Improvements made but potential for flooding remains
5	Collar Brook @ Butterworth Rd-	The roadway floods in this low spot. Road cannot be widened
6	Lawrence Brook @ North Fitzwilliam Rd.	Culvert floods where bridge was replaced
7	Old Turnpike Road	Snow melt and heavy rain impact access on this gravel road
8	Lawrence Brook @ Northeast Fitzwilliam Rd	Large rainfall event washed out bridge and road. A new bridge and elevated road were installed. Runoff is still an issue from upgradient road locations.
9	Brown Road and Stone Road	Flooding occurs due to presence of beaver dams. Alternative access required when roads flood
10	Winchendon Rd	Major Road Access. New paving, drainage and guard rails installed.
Drainage Related Flooding		
11	Delano Rd south of Taft Hill Road	Flood related erosion
12	Royalston Rd (Rt 68) , east of Stockwell Rd and west of Woods Rd	Large embankment abuts roadway, vulnerable to erosion
13	Rt 32 at Stuart Road	Flooding and frost heave causes traffic to depart from travel lane creating a road hazard.
Dam Hazards		
14	Tully Dam	High Hazard Dam. Potential breach would create widespread flooding, damages and potential loss of life
15	Birch Hill Dam	High Hazard Dam. Potential breach would create widespread flooding, damages and potential loss of life

	Location	Flooding Concern
Beaver Related Flood Hazards		
16	Collar Brook south of Athol/Richmond Rd (Rt 68)	Beaver dam reach has washed out Rt 68 many times
17	Falls Rd and Warwick Rd	Domino effect of multiple breaches impacting roadway
18	Collar Brook north of Athol/Richmond Rd	Steep terrain, beaver dam breach will flood Athol/ Richmond Rd
19	Boyce Brook, north and south of Falls Rd	15 beaver dams in this area
20	Lawrence Brook	Beaver activity an 3-4-foot-high dam
21	Brook southeast of North Fitzwilliam Rd	Beaver dam holds significant volume with potential to impact North Fitzwilliam Rd
21	Scott Brook at Old Turnpike Rd	Beaver activity
23	Town Brook, north of Laurel Lake Rd	Beaver dam holds significant volume with potential to impact Laurel Lake Rd
24	Brook between Prospect Hill Rd * North Fitzwilliam Rd	Beaver activity scoured sides of brook; potential breach of dam will impact culvert crossing on North Fitzwilliam Rd
25	Beaver Brook from Birch Hill WMA to Lawrence Brook	Multiple beaver dams, if breached domino effect will wash out Winchendon Road, then Stone and Brown Rd
26	Stockwell Brook at New Boston Rd	Beaver dam breached in the past; dam is maintained annually
27	Lawrence Brook, northeast of Stone Bridge	Beaver dams present
28	Lawrence Brook at Stone Bridge	Potential beaver dam breach will impact Stone Bridge
29	Millers River, south of Royalston Rd	Beaver activity

Repetitive Loss Structures

B4 a

The frequency and locations of flood hazard events in Royalston can be estimated based on the reported loss occurrences for repetitive loss properties and from local knowledge of flood hazard areas.

As defined by the Community Rating System (CRS) of the NFIP, a repetitive loss property[23] is any property which the NFIP has paid two or more flood claims of $1,000 or more in any given 10-year period since 1978. A severe repetitive loss property is any NFIP-insured property that has met at least one of the following paid flood loss criteria since 1978, regardless of ownership:

- Four or more separate claim payments of more than $5,000 each (including building and contents payments); or
- Two or more separate claim payments (building payments only) where the total of the payments exceeds the current value of the property.

[23] For more information on repetitive losses see http://www.fema.gov/business/nfip/replps.shtm

There are no repetitive loss structures in Royalston according to claims data dating from January 1978 to September 30, 2019[24].

Probability of Future Occurrence

The potential effects of climate change significantly impact inland flooding due to the increased frequency of severe storm events including nor'easters and hurricanes. Global climate change models suggest that Worcester County may experience by 2100[25]. The Planning Team has determined that it is **HIGHLY LIKELY** that flooding will impact the Town of Royalston in the future. The Town has implemented both structural and non-structural measures to withstand floods from heavy rain, ice jams, beaver dams, snow melt and dam/culvert failure. The Town is enforcing the State Code in flood prone areas (100-year floodplain as shown on the FIRM)

In spite of these best efforts, a storm with sufficient magnitude could result in damages far greater than any the community has known, impacting the economy, natural resources, cultural and historic assets, and buildings and structures. Therefore, it is in the best interest of the Town and residents to understand how climate change may influence flooding and begin proactive planning to adapt or mitigate these impacts.

Inland Flooding with Climate Change

Precipitation and temperature changes due to climate change are key factors that will impact inland flooding in the future. These changes have the potential to modify the current floodplain, impacting areas of Royalston that have not flooded in the past. .According to the Northeast Climate Impacts Assessment report of 2007, annual precipitation levels are expected to increase across New England by as much as fourteen percent (14%) by the end of this century, with an estimated thirty percent (30%) increase in precipitation during winter months.

Future annual precipitation statistics for the Millers River Watershed from NE CASC show an increase from the current 45.58 inches to as much as 50.13 inches per year by the 2030s, and as much as 52.99 inches per year by 2100[26].

The climate projections suggest that the frequency of high-intensity or extreme rainfall events will trend upward. As shown in **Figure 3.2**, the amount of precipitation released by storms in the northeast has increased by 71% from the baseline level (recorded 1901-1960) and present-day levels (measured 2001-2012)[27], [28].

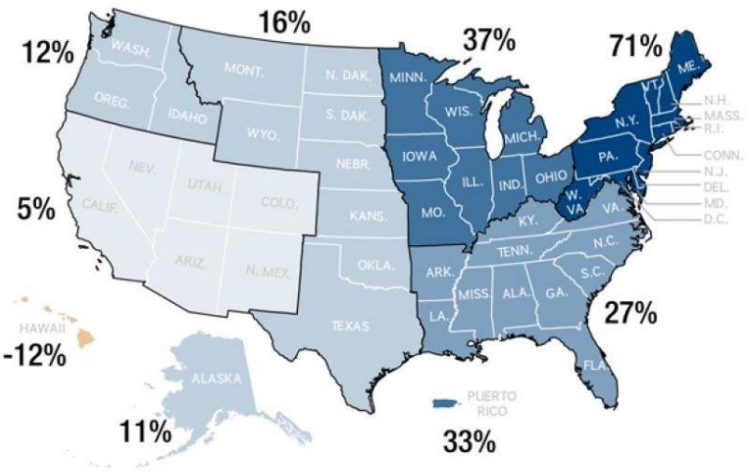


Figure 3.2: Nationwide comparison of increase in extreme precipitation

[24] FEMA Region 1 and Massachusetts State Floodplain Coordinator correspondence
[25] MEMA (2018), "SHMCAP"
[26] NE CASC (2018), "Massachusetts Climate Change Projections - Statewide and for Major River Basins": resilientMA.org
[27] MEMA (2018), "SHMCAP"
[28] National Climate Assessment (NCA) (2014), https://nca2014.globalchange.gov/

Overall, it is anticipated that the severity of flood-inducing weather events and storms will increase, with events that produce sufficient precipitation to present a risk of flooding likely increasing. A single intense downpour can cause flooding and widespread damage to property and critical infrastructure.

The number of days each year with extreme precipitation over one inch are variable for the Millers River Basin, fluctuating between loss and gain of days (**Table 3-6**). Seasonally winter season is expected to see the highest projected increase of 0-1 days by mid-century and 0-1 days by the end of century.

Table 3-6
Projected Annual Frequency of Future Extreme Precipitation Events in the Millers River Basin

	2030s	2050	2070	2100
Number of Days >1" precipitation	-0.03 – 1.69	0.37 – 2.49	0.89 – 2.58	0.69 – 3.39
Number of Days >2" precipitation	-0.05 – 0.30	-0.01 –0.34	-0.02 – 0.38	0.03– 0.42
Number of Days >4" precipitation	-0.01 – 0.03	-0.01 – 0.04	-0.01 – 0.03	-0.02 – 0.05

Source: NE CASC, 2017

Extreme Precipitation Impact on Engineering Design

Estimating changes in the expected intensity of future rainfall events is constantly evolving, with technological advancements, increases in available precipitation records, and climate change models. Utilizing rainfall values that reflect the changing climate are important in engineering design. Accounting for extreme precipitation is necessary to design adequate capacity in drainage system and provide sufficient structural elevation to avoid flooding.

There are a variety of opinions on the definition of "extreme precipitation", and which precipitation metric to compare over time. Rainfall can be compared using statistical thresholds (e.g. 95th percentile), absolute thresholds (e.g. greater than 1 inch) and return intervals (e.g. 100-year storm), all of which can be applied over a range of time scales from minutes to years.[29]

The "design storm" approach is a practical way to compare extreme precipitation amounts that is consistent with values used for engineering design. Rainfall amounts are compared over time periods based on storms of a similar size and duration called recurrence intervals or "return period", typically ranging from a 2-year to 100-year storm event. For example, a 2-year storm event has a 1 in 2 chance of occurring in a given year or a 50% probability. A 100-year storm event has a 1 in 100 chance of occurrence in a given year, or a 1% probability. A "design storm" is based on the historical precipitation records for a particular return interval and duration of the storm event such as a 2-year, 24-hour storm.

[29] MEMA (2018), "SHMCAP"

To assist the Town in planning for climate change, methods to calculate future design storm events for a variety of recurrence intervals were reviewed. Available data included a review of data from the National Oceanic and Atmosphere Administration (NOAA) Atlas 14[30], Northeast Regional Climate Center (NRCC) data[31] and the 2017 NE CASC state-wide precipitation climate change data[32]. The NOAA Atlas 14 dataset has been used for a number of years as an improved source of extreme precipitation. The Atlas was completed in 2016 and is the most current rainfall intensity dataset in Massachusetts. The NRCC or Cornell data is a second commonly used source for extreme precipitation. **Table 3.7** shows the 24-hour rainfall depths for Royalston Massachusetts using both NOAA Atlas 14 and NRCC data choosing the higher value for each recurrence interval shown. .

Table 3.7
Royalston Massachusetts 24-hour Rainfall Depth Estimates -NOAA Atlas 14 and NRCC Extreme Precipitation Tables

Recurrence Interval Storm Event	NOAA 24 hour Rainfall Depth for Royalston Massachusetts (inch)
2-year	2.90
10-year	4.37
25-year	5.31
50-year	6.22
100-year	7.42

Implications for Inland Flooding with Climate Change

Rainfall is expected to increase in spring and winter months particularly in Massachusetts, with increasing consecutive dry days in summer and fall. More total rainfall can have an impact on the frequency of minor but disruptive flooding events, especially in areas where storm water infrastructure has not been adequately sized to accommodate higher levels.

More intense downpours often lead to inland flooding as soils become saturated and stop absorbing more water, river flows rise, and the capacity of storm water systems is exceeded. Flooding may occur as a result of heavy rainfall, snowmelt, ice or dam failure, but precipitation is the strongest driver of flooding in Massachusetts. Winter flooding is also common in the state, particularly when the ground is frozen. Royalston experienced 18 flood-related disaster declarations from 1954 to 2018 with many of these falling in winter, or early spring, or during recent hurricanes.

Royalston's current FEMA Flood Insurance Maps provide an important baseline for gaging the extent of future flood condition, however it is important to note that FEMA defined floodplain areas are based on historic and existing conditions; but do not include future or projected climate conditions. This floodplain will expand in the future as extreme precipitation impacts inland flood levels.

[30] NOAA Precipitation Frequency Data Server (PFDS), "NOAA Atlas 14 Point Precipitation Frequency Estimates: MA": https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ma

[31] NRCC, "Extreme Precipitation Tables for Royalston, MA" : http://precip.eas.cornell.edu/data.php?1594238635726

[32] NE CASC, "Massachusetts Climate Change Projections": https://necsc.umass.edu/projects/massachusetts-climate-change-projections

Flooding Impacts on Royalston's Key Sectors

Inland Flood Exposure And Vulnerability By Key Sector[33]	
Built Environment	Flooding can also wash out sections of roadways and bridges, as well as cause extensive damage to public utilities and disruptions to the delivery of services.
Natural Resources And Environment	Severe floods cause a wide range of environmental impacts. Animals can lose their habitats if habitat elements are swept away or destroyed. Riverbank and soil erosion transform existing habitats and deposit sediment in downstream areas. If high levels of nutrients are present in the soil, this can also lead to eutrophication in downstream ecosystems.
Economy	Economic losses due to a flood include, but are not limited to damages to buildings (and their contents) and infrastructure, agricultural losses, business interruption (including loss of wages), impacts on tourism, and tax base.
Vulnerable Populations	Populations that are particularly vulnerable to this hazard include the economically disadvantaged, who may face greater difficulty in evacuating, and individuals with medical needs who may have not be able to receive required medical care either during evacuation or if isolated by flooded infrastructure.

Ice Jams

Ice jams occur in the winter or early spring when normally flowing water begins to freeze. There are two types of ice jams; a freeze up and a breakup jam. A freeze up jam forms in the early winter as ice formation begins. This type of jam can act as a dam and begin to back up the flowing water behind it. The second type, a break up jam forms as a result of the breakup of ice cover, causing large pieces of ice to move downstream potentially acting as a dam, impacting culverts and bridge abutments

Previous Occurrence and Extent

Twenty-two ice jams have occurred on the Millers River between 1913 and 2018. Fourteen ice jams occurred within South Royalston , six in Athol , and two in Winchendon). The most recent ice jam and break out in February 2018 caused extensive damage to the Exchange Street Bridge, that has now been replaced.

Locally Identified Areas of Impact

Heavy snow fall and frigid temperatures throughout the Northeast increase the chance of flooding from snowmelt and ice jams. When river ice piles up at shallow areas, bends and islands it blocks the flow of water and may cause flooding of nearby homes and businesses. Ice jams that become lodged within the abutment of bridges can threaten the integrity of the structures. Heavy equipment, such as cranes with wrecking balls and explosives may have to be used to break up ice jams to reduce potential property and structural damages and losses. Areas that are impacted by ice jams are listed in Table 3.5.

Probability of Future Occurrence

The Planning Team has determined that it is **LIKELY** that ice jams will impact the Town of Royalston in the future. Based on climatic conditions in the area, ice jams will continue into the future causing damage to bridges and roads and buildings within the floodplain. To minimize ice jams, special consideration should be made during reconstruction of any bridges or dams which tend to be where ice jams are more likely to occur.

[33] MEMA (2018), "SHMCAP"

Beavers

Beavers build their dams in areas where there is increased residential development, roads and agricultural use of the land, the flooding that results can cause serious public and private property damage, often threatening homes, septic systems, low-lying roadways, and other public infrastructure. These hazards of course relate directly to other hazards such as rainstorms, hurricanes, floods, and winter related storms.

Previous Occurrence and Extent

The beaver is a valuable component of Massachusetts' fauna. Beavers have played an active role in New England's ecology for thousands of years. Beavers are natural "engineers" of the land, they are agents of change, creating wetlands out of uplands and streams, and providing habitat for a variety of plants and animals. However, not long ago the beaver was absent from the Montachusett Region. In fact, it was absent from the late 1700s to the early 1900s. Intensive unregulated hunting and trapping, combined with deforestation to clear land for agriculture, led to the disappearance of beaver habitat and the beaver. In the early 1900's, forested habitat started to recover when many farmers abandoned their farms in order to take jobs in cities or to start new farms in the more fertile Midwestern United States. With the forests able to retake the landscape, the beaver was able to return and an important component of the Montachusett Region's native ecosystems was restored. However, beavers returned to a landscape that had been substantially altered by people.

Locally Identified Areas of Impact

When beavers in the Montachusett Region build their dams in areas where there is increased residential development, roads and agricultural use of the land, the flooding that results can cause serious public and private property damage, often threatening homes, septic systems, low-lying roadways, and other public infrastructure. It was stated at all of the Montachusett Region individual Hazard and Vulnerability Sessions that beavers continue to pose a significant problem. The state and local governments have responded to this crisis with a complex regulatory process. The process places its highest priority on protecting in-ground septic systems and road networks. Most of the regulatory process has been developed to respond to threats to the public health and safety. On September 18, 2004 a series of beaver dams along Lawrence Brook broke in sequence and created serious downstream flooding and erosion. A large chunk of Route 68 was washed out, cutting the Town in half until the State was able to repair the roadway. Areas that are impacted by beavers are listed in **Table 3.5**.

Probability of Future Occurrence

Beaver activity will most certainly continue to persist throughout the Montachusett Region, as the factors that have allowed them to expand their range (increase in suitable habitat, wetland protection, and a decrease in hunting and trapping) are expected to remain constant over the next decade. The Planning Team has determined that it is **HIGHLY LIKELY** that beaver activity will impact the Town of Royalston in the future.

Snow Melt

Snow melt has the potential to cause significant flooding throughout Royalston. This can be a serious problem for areas that have received large amounts of snow throughout the winter season. When temperatures rapidly increase, so does the rate at which snow melts; frozen soil also increases the risk of flood as water from melting snow is not able to seep into the ground.

Snowmelt flooding occurs when the major source of water involved in a flood is caused by melting snow. Unlike rainfall that can reach the soil almost immediately, the snowpack can store the water for an extended amount of time until temperatures rise above freezing and the snow melts. This frozen storage delays the arrival of water to the soil for days, weeks, or even months. Once it begins to melt and does reach the soil, water from snowmelt behaves much as it would if it had come from rain instead of snow by either infiltrating into the soil, running off, or both. Flooding can occur when there is more water than the soil can absorb or can be contained in storage capacities in the soil, rivers, lakes and reservoirs.

Previous Occurrence and Extent

Royalston averages about seven severe winter storms per winter (See Table 19**:** Winter Storms in Montachusett Region by Month), which can cause flooding during times when temperatures can increase quickly/substantially particularly in the spring which has resulted in numerous previous occurrences. The winter of 1935-1936 was one of the worst cases of snow melt/ flooding. As of early March that winter it was estimated that the snowpack in New England averaged about 7.5 inches of water. In Southern New England, snow water equivalents of 3.5 inches were normal. On March 9, a warm, moisture-laden front moved into, and stalled over New England resulting in increased temperatures as well as heavy rainfall. The combination of heavy rain and melting snow resulted in severe flooding.

Locally Identified Areas of Impact

Royalston is vulnerable to snow melt; heavy snow fall, frigid temperatures followed by a sudden transition to warmer temperatures throughout the Northeast increase the chance of flooding from snowmelt potentially causing flood related damage to homes and businesses, roads and buildings particularly within the floodplain.

Probability of Future Occurrence

With the climatic conditions that occur in Royalston each year including an average of seven severe winter storms per year, snow melt will certainly continue into the future which can cause flooding during times when temperatures can increase quickly/substantially particularly in the spring. The Planning Team has determined that it is **LIKELY** that snowmelt will impact the Town of Royalston in the future

Man-made Dams and Culvert Failure

A dam is an artificial barrier that has the ability to impound water for the purpose of storage or control of water. Dam failure is a catastrophic type of failure characterized by a sudden, rapid, and uncontrolled release of impounded water. Dam failure can occur as a result of structural failure, independent of a hazard event, or as the result of the impacts of a hazard event such as flooding associated with storms or an earthquake. In the event of a dam failure, the energy of the water stored behind even a small dam can cause loss of life and property damage if there are people or buildings downstream. The number of fatalities from a dam failure depends on the amount of warning provided to the population and the number of people in the area in the path of the dam's floodwaters. Dam failure in general is infrequent but has the potential for severe impacts. An issue for dams in Massachusetts is that many were built in the 19th century without the benefits of modern engineering or construction oversight.

The Massachusetts DCR has three hazard classifications for dams:

High Hazard:	Dams located where failure or mis-operation will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).
Significant Hazard:	Dams located where failure or mis-operation may cause loss of life and damage home(s), industrial or commercial facilities, secondary highway(s) or railroad(s) or cause interruption of use or service of relatively important facilities.
Low Hazard:	Dams located where failure or mis-operation may cause minimal property damage to others. Loss of life is not expected.

In general, DCR requires that dams that are rated as low hazard be inspected every ten years while dams that are rated as significant hazards must be inspected every five years. High hazard dams must be inspected every two years. Owners of dams are responsible for having their dam inspected. MGL Chapter 253 and 302 CMR 10.00 requires that dam owners prepare, maintain and update Emergency Action Plans for all High Hazard Potential dams and certain Significant Hazard Potential dams.

Non-jurisdictional dams are not regulated by the Office of Dam Safety or under their jurisdiction. Typically these dams are under 6 feet in height and/or under 15 acre-feet in storage and do not have an assigned 'Hazard Code'. Dams owned and regulated by the Federal Government are also typically non- jurisdictional but DO have an assigned Hazard Code.

Culverts

A culvert is defined as a structural opening under a roadway that allows water to pass from one side of a roadway to the other. A culvert can impound water similar to a dam under certain flood conditions, and if conditions are extreme, culverts can fail, causing road and property damage. A culvert can fail under the following conditions:

- Clogged with debris and sediment, invasive species and other vegetation
- Buildup of flood water or on the upstream side of the culvert exceeding the capacity of the culvert
- Loss of structural integrity
- Culvert and road are washed out during a heavy rain or from snowmelt
- Soil around the culvert erodes, and without support, the culvert will buckle or sag and the culvert will collapse

Previous Occurrence and Extent

Historically, dam failure has had a low occurrence in the Montachusett Region. However, many of the dams within the Region are more than 100 years old, and some are even older, meaning the possibility of dam failure is not inconceivable. Inadequately sized culverts are a major problem across Royalston. Few older culverts were designed based to meet minimum storm events. There have been several culverts that have been washed out due to flooding in the past.

Locally Identified Areas of Impact

The Department of Conservation and Recreation (DCR) Office of Dam Safety lists 2 high hazard dams in Royalston. The Town also has two (2) dams non-jurisdictional dams (Fish Pool Dam and Putney Mill Dam).

Birch Hill Dam- Completed by the US Army Corps of Engineers in 1941 in response to traumatic floods of the Millers River in 1936 and 1938, Birch Hill Dam proved its worth in 1987, when it prevented an estimated $9 million in damages from another flood. The project consists of an earthfill dam with stone slope protection 1,400 feet long and 56 feet high; four gated rectangular conduits, each six feet wide, 12 feet high, and 34 feet long; and three concrete chute spillways, each with a concrete weir. The three weirs have a total length of 1,190 feet and have crest elevations that are 12 feet lower than the top of the dam.

There is no lake at Birch Hill Dam. Lake Denison, a natural lake situated within the project grounds, is located two miles upstream of the dam. The flood storage area of Birch Hill Dam, which is normally empty and is only utilized to store floodwaters, covers 3,200 acres and extends upstream through the towns of Royalston, Winchendon, and Templeton. The project and associated lands total 4,637 acres. When combined with the adjoining Otter River State Forest that is operated by the state, over 8,500 acres are available to the public. Birch Hill Dam can store up to 16.26 billion gallons of water for flood control purposes. This is equivalent to 5.3 inches of water covering its drainage area of 175 square miles.

Tully Lake Dam- The dam at Tully Lake in Royalston lies across the East Branch of the Tully River. The project consists of an earthfill dam with stone slope protection 1,570-feet long and 62-feet high; a gated concrete circular tunnel 274-feet long with a diameter of six feet; and a concrete chute spillway cut in rock with a 255-foot concrete weir. The weir's crest elevation is 16 feet lower than the top of the dam. In April 1987, two storms dropped about 6 inches of rain, raising the water level to over 35 feet at the dam, utilizing 62% of the storage capacity. It is estimated that Tully Lake prevented over $3 million in damages to downstream property from this one storm.

The project has prevented $28.1 million in flood damages since it was built (as of September 2011).

Tully Lake contains a recreation pool that fluctuates seasonally. From the spring until the fall, the lake has a maximum depth of 16 feet and covers 300 acres. From fall to spring, the pool is drawn down to a depth of 11 feet. The flood storage area of the project totals 1,130 acres and stretches into Athol. This area is empty most of the time and is utilized only to store floodwaters. The lake and all associated project lands cover 1,263 acres. Tully Lake can store up to 7.17 billion gallons of water for flood control purposes. This is equivalent to 8.3 inches of water covering its drainage area of 50 square miles.

Undersized or structurally deficient culverts are listed in **Table 3.5.**

Probability of Future Occurrence

The Planning Team has determined that it is **UNLIKELY** that dam failure will impact the Town of Royalston in the future. Climate change is likely to increase the severity of extreme precipitation events, increasing the probability that culverts may exceed their capacity The Planning Team did not rate the probability for future occurrence of culvert failure, but are including culverts in the community assets for vulnerability analysis.

Dam Failure Impacts on Royalston's Key Sectors

Dam and Culvert Failure Exposure and Vulnerability By Key Sector[34]	
Built Environment	Flood waters from dam and culvert failure may potentially cut off evacuation routes, limit emergency access, and create isolation issues. Utilities such as overhead power lines, cable and phone lines in the inundation zone are also vulnerable.
Natural Resources And Environment	Following a dam failure, the impounded reservoir would experience a reduction water levels, displacing aquatic organisms and exposing the benthic community to air. Downstream, habitat impacts would likely include direct mortality of flora and fauna, toppling of trees and removal of soil and inhibition of plant respiration in areas that remain flooded for long periods of time.
Economy	In addition to buildings and infrastructure in the inundation area, any habitat or agricultural operations in the area would also be exposed to this hazard, which could cause extensive economic damage if crops were ruined.
Vulnerable Populations	Given the relatively short warning time associated with dam failure, culvert or tide gate failure, any population that is exposed inundation and cannot rapidly evacuate would be considered vulnerable. This population includes households without vehicles, the elderly and young children who may be unable to get themselves out of the inundation area.

Drought

Drought is a period characterized by long durations of below normal precipitation.[35] Drought conditions typically last a season or more and result in water shortages, causing adverse impacts on vegetation, animals, and people. A drought may also increase the probability of a wildfire occurring. Drought characteristics vary significantly from one region to another, since it is relative to the normal precipitation in that area. Drought is a temporary aberration, and is different from aridity, which is a permanent feature of climate in areas where low precipitation is normal, such as in a desert.

Previous Occurrence and Extent

The entire planning area can be affected by drought, impacting local water resources often requiring voluntary or required water-use restrictions. In Massachusetts, drought is defined by a combined look at six indices, as defined by the Massachusetts Drought Management Plan (the Plan) (EEA and MEMA, 2019[36]) as follows:

- Precipitation
- Streamflow
- Groundwater
- Lakes and impoundments
- Fire danger (Keetch-Byram Drought Index, KBDI)
- Evapotranspiration (Crop Moisture Index, CMI)

[34] MEMA (2018), "SHMCAP"
[35] NOAA (2008), "Drought Public Fact Sheet": http://www.nws.noaa.gov/om/brochures/climate/DroughtPublic2.pdf
[36] EEA and MEMA (2019), "Massachusetts Drought Management Plan," https://www.mass.gov/doc/massachusetts-drought-management-plan/download

These indices are analyzed on a monthly basis to generate a hydrological conditions report and used to determine the onset, severity and end of droughts. Five levels of increasing drought severity are defined in the Plan – Normal, Mild Drought, Significant Drought, Critical Drought and Emergency. The drought levels are associated with state actions as outlined in the Plan. Recommendations of drought levels are made by the Drought Management Task Force (DMTF) to the Secretary of EEA who declares the drought level from each region of the state. Current drought status and indices data can be viewed through the Northeast Drought Early Warning System dashboard.[37]

While drought does involve multiple indices, historic multi-year droughts were identified by the USGS by analyzing annual and cumulative departures from long-term average streamflow at gauging stations across Massachusetts. Streamflow deficits were analyzed and recurrence intervals computed for selected droughts. The droughts of 1929-32, 1939-44, 1961-69, and 1980-83 stand out as particularly significant because of their severity and areal extent. The severest drought on record in the Northeastern United States was during 1961 through 1969. Water supplies and agriculture were affected because of the severity and long duration of the drought.[38]

More recently drought periods include 10 months of drought in 2002 and 10 months of drought from June 2016 through March 2017[39]. An overview of drought-prone regions in the Commonwealth is provided in **Figures 3.3** and **3.4**[40][41].

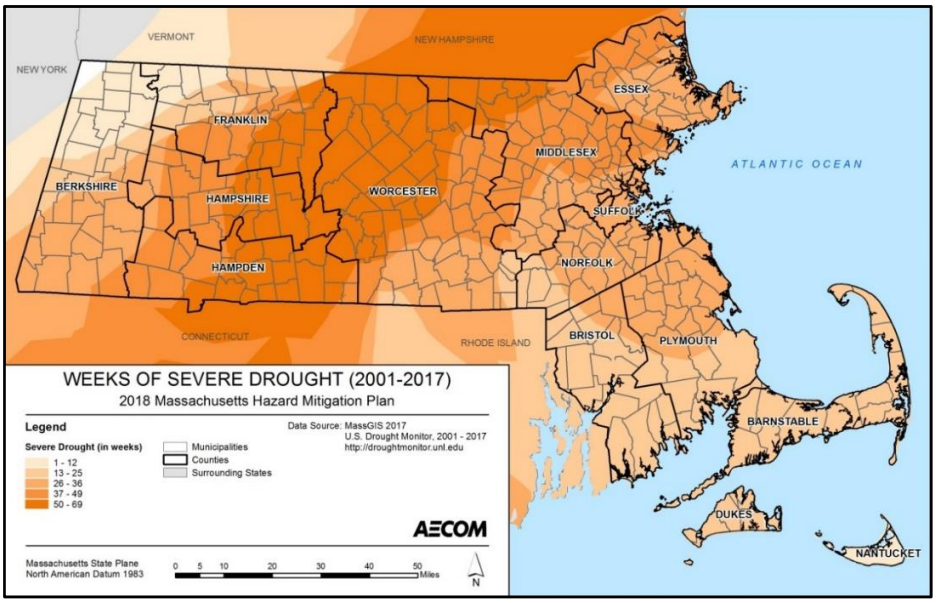


Figure 3.3: Weeks of Severe Drought (2001-2017)

[37] http://nedews.nrcc.cornell.edu
[38] U.S. Geological Survey (USGS) (1989), "Water-Supply Paper 2375 National Water Summary 1988-89--Floods and Droughts: Massachusetts Floods and Droughts"
[39] http://www.mass.gov/eea/wrc/droughtplan.pdf
[40] MEMA (2018), "SHMCAP"
[41] NOAA (2017), "U.S. Drought Monitor": https://droughtmonitor.unl.edu/

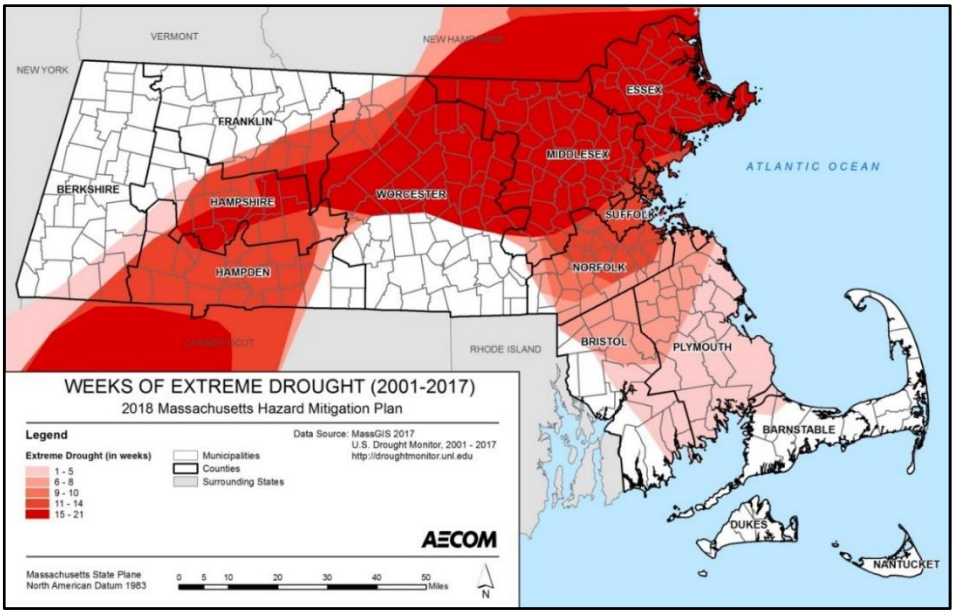


Figure 3.4: Weeks of Extreme Drought (2001-2017)

Droughts will create challenges for local water supply by reducing surface water storage and the recharge of groundwater supplies, including private wells. Droughts also negatively impact drinking water quality. More frequent droughts could also exacerbate the impacts of flood events by damaging vegetation that could otherwise help mitigate flooding impacts. Droughts may also weaken tree root systems, making them more susceptible to toppling during high wind events.

Locally Identified Areas of Impact

The entire planning area can be affected by drought, impacting local water resources often requiring voluntary or required restrictions on water use. Royalston obtains 100% of their water supply from groundwater including private and public water supply wells. The Massachusetts Office of the USGS provides local data to monitor streamflow and drought conditions across Massachusetts. The USGS maintains the statistics and streamflow information on their Water Watch website,[42] and the DCR Water Resource Commission issues monthly reports of hydrologic conditions[43] Data obtained from Orange Municipal Airport a USGS Stream gage on the Millers River and a USGS groundwater well in Templeton[44] provides information on local conditions for Royalston that are interpreted by the USGS and DCR to establish the local water conditions.

[42] http://newengland.water.usgs.gov/drought/index.html
[43] https://www.mass.gov/drought-management
[44] https://groundwaterwatch.usgs.gov/AWLSites.asp?mt=g&S=423717072043101&ncd=awl

Probability of Future Occurrence

The 2013 Massachusetts Drought Management Plan[45] conducted an extensive review of precipitation indices since the beginning of data collection in 1850. The probability of each drought level, as identified in the 2013 Massachusetts Drought Management Plan, is shown in **Table 3-8.**

Table 3-8
Frequency of Drought Events

Drought Level	Frequency Since 1850	Probability of Occurrence in a Given Month
Emergency Drought	5 occurrences	2% chance
Critical Drought (formerly Warning)	5 occurrences	2% chance
Significant Drought (formerly Watch)	46 occurrences	8% chance

Drought with Climate Change

Although research suggests that the overall amount of precipitation is likely to increase under climate change, the length of time between rain events is also expected to increase. Prolonged dry periods increase the probability of drought conditions occurring.

Table 3-9 indicates how much these durations are likely to increase according to the "high" and "low" limits of the NE CASC data for the Miller River basin. This data suggests that the average time between rain events is likely to remain fairly constant; however, individual drought events could still increase in frequency and severity. The western portion of the Commonwealth experiences fewer dry periods than the eastern portion, and this trend is likely to continue in the future.

Table 3-9
Continuous Dry Days by Planning Year

Planning Year	2030	2050	2070	2100*
Projected Range of Consecutive Dry Days	16.32 – 17.92	15.71 – 18.04	15.56 – 18.45	15.9 – 18.52

*Because the study generated 5-year averages for future conditions, "2100" values from this study are derived from the period centered around 2095, the further year available. This practice is generally considered to provide a useful approximation for conditions this far in the future.

The Planning Team determined that based on past history of drought events and climate change data provided by the NE CASC, it is **POSSIBLE** that drought will impact the planning area in the future.

[45] EEA and MEMA (2013), "Massachusetts Drought Management Plan": https://drought.unl.edu/archive/plans/drought/state/MA_2013.pdf

Drought Impacts on Royalston's Key Sectors

Drought Exposure and Vulnerability By Key Sector[46]	
Built Environment	Drought impacts on elements of the built environment are limited, except to the extent that drought conditions increase the risk of wildfires.
Natural Resources and Environment	Prolonged droughts can have severe impacts on ecosystems and natural resources, as most organisms require water throughout their life cycle. Forests managed for timber or other economic uses could experience reduced growth rates or mortality during periods of drought.
Economy	The economic impacts of drought can be significant in the agriculture, recreation, forestry, and energy sectors. Crop failure can also result in an increase in food prices, placing economic stress on a broader portion of the economy.
Vulnerable Populations	Citizens with a private water supply, such as a well, are more vulnerable to drought than those who receive water through a public provider. Drought can also increase the concentration of airborne pollutants, presenting a health hazard for those with respiratory health conditions like asthma.

[46] MEMA (2018), "SHMCAP"

3.4 Atmospheric Hazards

3.4 ATMOSPHERIC HAZARDS

Extreme Temperatures

Extreme temperatures are defined as temperatures that are far outside the normal ranges for the season in a specific area. Extreme cold events are characterized in a temperate zone by the air temperature dropping to approximately 0 ºF or below. Extreme heat is identified as the number of days with a maximum temperature greater than or equal to 90ºF and greater than or equal to 100ºF.

Extreme Cold

The extent (severity or magnitude) of extreme cold temperatures can be measured through the Wind Chill Temperature Index (**Figure 3.5**). Wind Chill Temperature is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body loses heat at a faster rate, causing the skin's temperature to drop.

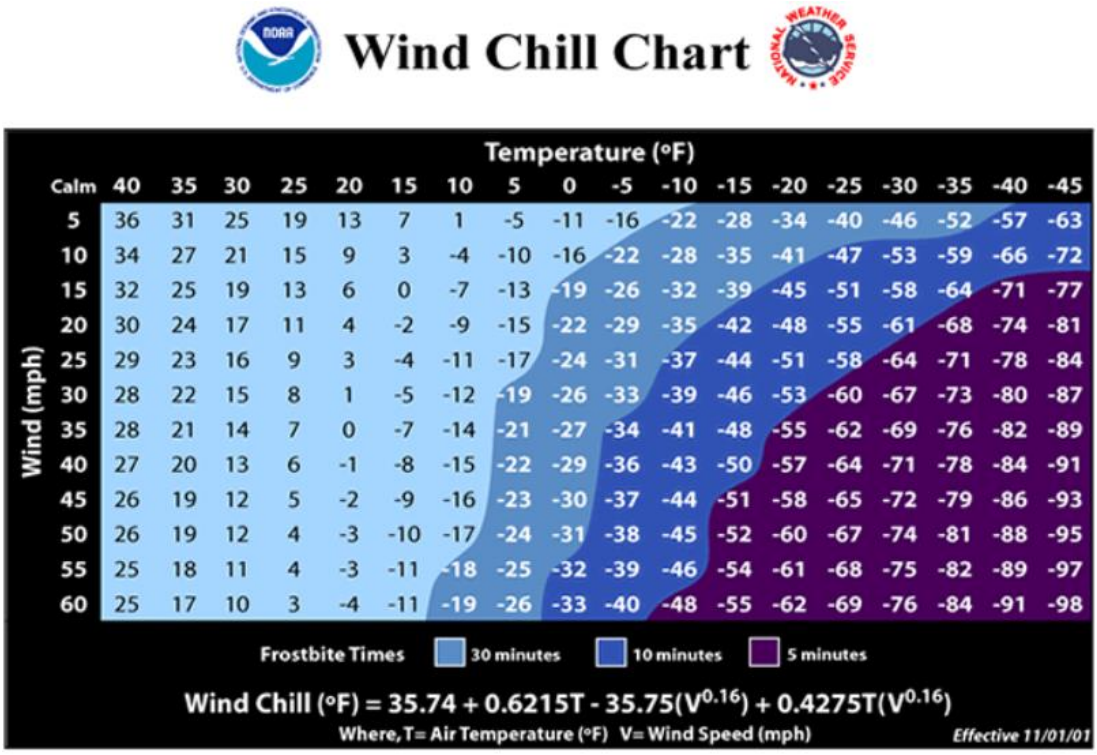


Figure 3.5: NOAA Wind Chill Index[47]

When winter temperatures drop significantly below normal, staying warm and safe can become a challenge. Extremely cold temperatures often accompany a winter storm, which may also cause power failures, icy roads and freezing ice in rivers, streams and lakes.

[47] NOAA Wind Chill Index: http://www.nws.noaa.gov/om/cold/wind_chill.shtml

Cold weather also can present hazards indoors. Many homes will be too cold, either due to a power failure or because the heating system is not adequate for the weather. Exposure to cold temperatures, whether indoors or outside, can cause other serious or life-threatening health problems. The use of space heaters and fireplaces to stay warm, and/or the use of generators and candles in power outages, increases the risks of residential fires and carbon monoxide poisoning.

Extreme Heat

The extent of extreme heat is documented by the National Weather Service (NWS) Heat Index. The NWS issues a Heat Advisory when the Heat Index is forecast to reach 100-104°F for 2 or more hours. The NWS issues an Excessive Heat Warning if the Heat Index is forecast to reach 105+ °F for 2 or more hours. The Heat Index describes a temperature that the body feels, and is based both on temperature and relative humidity (**Figure 3.6**). A heat wave is defined as 3 or more days of temperatures 90°F or above.

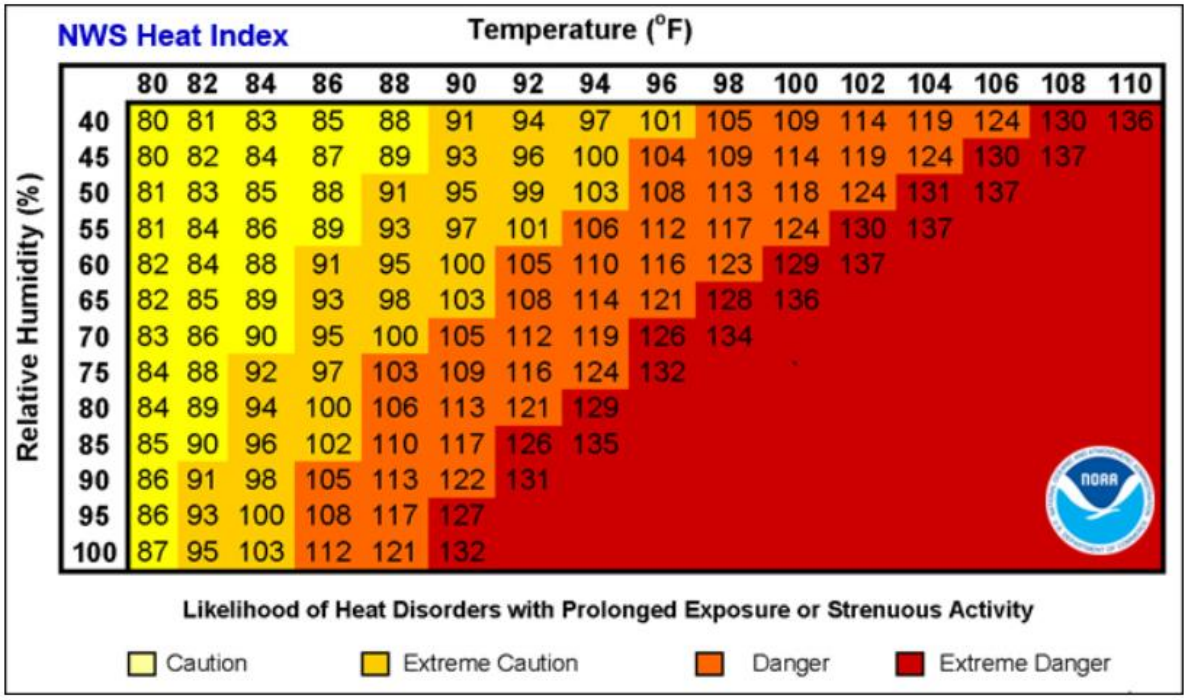


Figure 3.6: NOAA Heat Index[48]

Extreme heat is currently the leading weather-related cause of death in the United States.[49] Prolonged exposure to high temperatures can cause heat-related illnesses, such as heat cramps, heat syncope, heat exhaustion, heat stroke, and death. Heat exhaustion is the most common heat-related illness and if untreated, it may progress to heat stroke. Additionally, heat is expected to contribute to the exacerbation of chronic health conditions.[50] In

[48] NOAA Heat Index: http://www.nws.noaa.gov/om/heat/heat_index.shtml
[49] Luber, G., & McGeehin, M. (2008b), "Climate change and extreme heat events." American Journal of Preventive Medicine, 35(5), 429–435. http://doi.org/10.1016/j.amepre.2008.08.021
[50] Kravchenko, J., Abernethy, A. P., Fawzy, M., & Lyerly, H. K. (2013). "Minimization of heat wave morbidity and mortality." American Journal of Preventive Medicine, 44(3), 274–282. http://doi.org/10.1016/j.amepre.2012.11.015

particular, hyperthermia—elevated body temperature due to failed thermoregulation can be caused by heat stroke — is a contributing factor to cardiovascular, metabolic, and other causes of death.[51]

Those at particularly high risk of adverse health effects from extreme heat exposure are older adults, children, those living alone and/or with chronic illnesses, urban residents, minorities, lower income families, people with less education, and people without access to air conditioning. In addition, people with chronic mental disorders or pre-existing medical conditions (e.g., cardiovascular disease, obesity, diabetes, neurologic or psychiatric disease), and those participating in outdoor manual labor or sports in hot weather also are at increased risk for heat-related illness.[52] Extreme heat adversely impacts utility companies that may struggle meet the extra demand created by operation of air conditioners. Brown outs may result in secondary impacts to vulnerable populations.

Previous Occurrence and Extent

According to NOAA NCDC data, the entire area is vulnerable to extreme temperatures. For the past decade, Massachusetts has been reporting 2 to 4ºF warmer than the 20th Century Average.[53] **Figure 3.7** depicts the trend of maximum high summer temperatures and minimum low winter temperatures from 1895 to 2015.

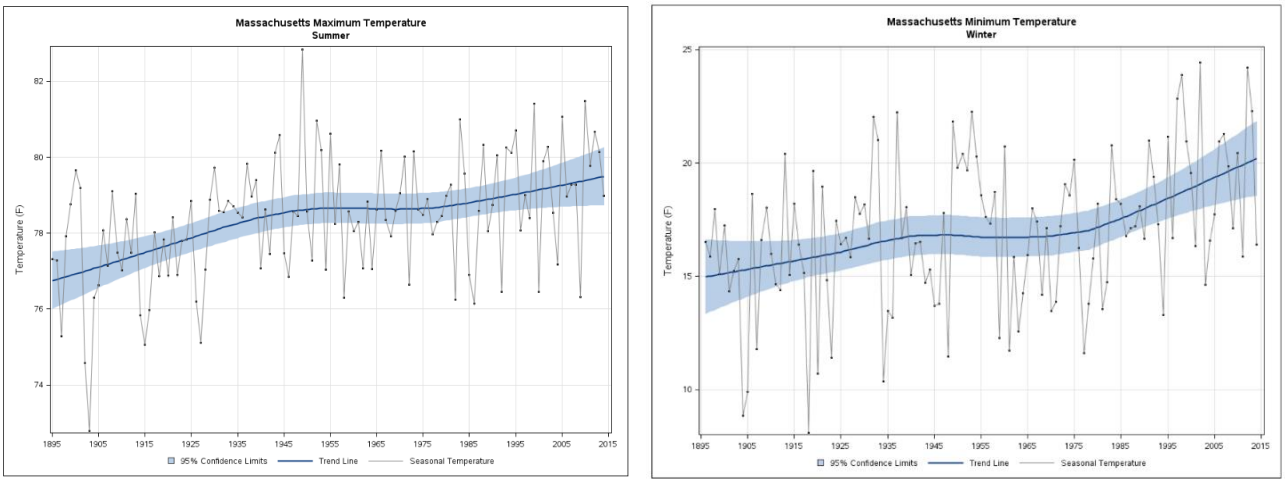


Figure 3.7: Maximum Summer (left) and Minimum Winter (right) Monthly Temperatures in Massachusetts (1895-2015)

According to the Northeast Regional Climate Center at Cornell University, 2012 was the warmest year in the US to date, and the third hottest summer. Extreme heat for Royalston is most common in July with the record high of 100ºF set in July 2018. Extreme cold temperatures are most common in January-February with the lowest recorded temperatures being –29ºF in January 1957. On February 2016 cold weather broke m any state records with windchill in Worcester measured at -44º.

[51] O'Neill, M. S., & Ebi, K. L. (2009). "Temperature Extremes and Health: Impacts of Climate Variability and Change in the United States." Journal of Occupational and Environmental Medicine, 51(1), 13–25. http://doi.org/10.1097/JOM.0b013e318173et22
[52] Holstein, J., Canouï-Poitrine, F., Neumann, A., Lepage, E., & Spira, A. (2005), "Were less disabled patients the most affected by 2003 heat wave in nursing homes in Paris, France?" Journal of Public Health (Oxford, England), 27(4), 359–365.
[53] https://www.ncdc.noaa.gov/temp-and-precip/state-temps/

Table 3-10 shows the recent history of extreme temperatures for Royalston (past 12 years), using data for Orange Airport, downloaded from the NOAA National Centers for Environmental Information.[54] A total of 134 days were reported with temperatures above or equal to 90ºF with 2 days above or equal to 100ºF. A total of 227days were reported with temperatures less than or equal to 5ºF with 134 days less than or equal to 0ºF.

Table 3-10
Extreme Temperatures for Royalston 2007-2020

Year	Number of days ≥90 degrees	Number of days≥ 100 degrees	Number of days ≤5 degrees	Number of days ≤0 degrees
2008	5	0	18	8
2009	5	0	33	19
2010	16	0	11	5
2011	8	1	24	18
2012	16	0	7	2
2013	17	0	16	7
2014	*	*	31	21
2015	7	0	39	34
2016	16	0	14	6
2017	8	0	10	4
2018	24	1	6	2
2019	12	0	18	8
TOTAL	134	2	227	134

*data missing 5/16/2014-7/24/2014

Locally Identified Areas of Impact

Extreme heat has occurred in Royalston. The entire planning area is at risk for impacts due to extreme temperatures.

Probability of Future Occurrence

The IPCC forecasts temperatures continuing to increase worldwide during the 21st century due to the GHG emission trajectory we are on. The latest scenarios from the 2015 United Nations Paris Climate Summit for average temperature changes across all RCP greenhouse gas emissions scenarios show a continuation of increased global temperatures. The average temperature in Massachusetts between 1961 and 1990 has been approximately 46.4 degrees Fahrenheit (°F). By mid-century this is anticipated to increase by approximately four to five degrees (3.6 to 5.4°F). By the latter part of the 21st century (2100) average temperatures are expected to increase by five to nine degrees (5.4 to 9°F).

[54] https://www.ncdc.noaa.gov/cdo-web/

More recent Massachusetts Statewide Climate Projections shown in **Table 3-11** are consistent with the findings that Royalston (Millers River Basin) is expected to experience increased average temperatures throughout the 21st century.[55] Maximum and minimum temperatures are also expected to increase throughout the end of the century. These increased temperature trends are expected for annual and seasonal projections.

Table 3-11
Seasonal and Annual Temperature Projections for Millers River Basin Region

Millers River Basin		Observed Baseline 1971-2000 (°F)	Projected Change in 2030s (°F)	Mid-Century Projected Change in 2050s (°F)	Projected Change in 2070s (°F)	End of Century Projected Change in 2090s (°F)
Average Temperature	Annual	44.72	+2.16 to +4.45	+2.95 to +6.27	+3.48 to +8.87	+3.86 to +10.82
	Winter	22.38	+2.35 to +5.23	+2.94 to +7.62	+3.81 to +9.09	+4.18 to +10.45
	Spring	43.18	+1.50 to +3.39	+2.29 to +5.16	+2.56 to +7.32	+3.00 to +8.92
	Summer	65.96	+2.21 to +4.53	+3.06 to +7.12	+3.38 to +10.47	+3.79 to +12.90
	Fall	46.97	+2.09 to +5.17	+3.62 to +6.54	+3.50 to +9.38	+3.95 to +11.74
Maximum Temperature	Annual	56.56	+1.98 to +4.20	+2.60 to +6.41	+3.06 to +9.06	+3.45 to +11.03
	Winter	33.12	+1.91 to +4.48	+2.46 to +6.73	+3.02 to +7.97	+3.41 to +9.04
	Spring	55.22	+1.31 to +3.23	+2.09 to +5.25	+2.57 to +7.62	+3.05 to +9.18
	Summer	78.66	+1.89 to +4.65	+2.75 to +7.42	+3.19 to +11.00	+3.63 to +13.57
	Fall	58.78	+2.33 to +4.98	+3.54 to +7.00	+3.28 to +9.86	+3.94 to +12.23
Minimum Temperature	Annual	32.89	+2.31 to +4.88	+3.29 to +6.43	+3.79 to +8.75	+4.20 to +10.86
	Winter	11.64	+2.74 to +6.12	+3.52 to +8.41	+4.42 to +10.21	+4.79 to +11.66
	Spring	31.14	+1.59 to +3.76	+2.36 to +5.62	+2.74 to +7.11	+3.07 to +8.76
	Summer	53.27	+2.38 to +4.60	+3.22 to +7.29	+3.57 to +9.93	+3.97 to +12.34
	Fall	35.15	+1.81 to +5.27	+3.38 to +6.56	+3.61 to +9.01	+3.97 to +11.41

Seasonally, maximum summer and fall temperatures are expected to see the highest projected increase throughout the 21st century.

- Summer mid-century increase of 2.8 °F to 7.4 °F (3-9% increase); end of century increase of 3.6 °F to 13.6 °F (5-17% increase).
- Fall mid-century increase of 3.5 °F to 7.0°F (6-12% increase); end of century increase by and 3.9 °F to 12.2 °F (7-21% increase).

[55] NE CASC (2017), "Massachusetts Climate Change Projections": https://necsc.umass.edu/projects/massachusetts-climate-change-projections

Seasonally, minimum winter and fall temperatures are expected to see increases throughout the 21st century.

- Winter mid-century increase of 3.5 °F to 8.4 °F (30-72% increase); end of century increase by 4.8 °F to 11.7 °F (41-100% increase).
- Fall mid-century of 3.4 °F to 6.6 °F (10-19% increase); end of century increase of 4°F to 11.4 °F (11-32% increase).

Based on historic data and local projections, the Planning Team determined that it is **HIGHLY LIKELY** that extreme temperatures will impact the planning area.

Extreme Temperature Impacts on Royalston's Key Sectors

Average and Extreme Temperature Exposure and Vulnerability By Key Sector[56]	
Built Environment	Extreme heat events can sometimes cause short periods of utility failure due to increased usage from air conditioners and other appliances. Heavy snowfall and ice storms, associated with extreme cold temperature events, can also cause power interruption. Backup power is recommended for critical facilities and infrastructure.
Natural Resources and Environment	Because the species that exist in a given area are designed to survive within a specific temperature range, extreme temperatures events can place significant stress both on individual species and ecosystems. Warming temperatures across the globe force species poleward, or upward in elevation, while species that cannot relocate fast enough face local extinction.
Economy	Extreme temperature events can have significant economic impacts, including loss of business function and damage/loss of inventory. The agricultural industry is the industry most at risk in terms of economic impact and damage due to extreme temperature and drought events.
Vulnerable Populations	Populations that are most at risk to extreme cold and heat events include individuals aged over 65, infants and young children, individuals who are physically ill, low-income individuals who cannot afford proper heating and cooling, and those whose jobs involve exposure to extreme temperature events.

[56] MEMA (2018), "SHMCAP"

Severe Weather-Wind Related Hazards

Severe weather wind related hazards include hurricanes, tropical storms, and tornadoes as well as high winds during severe rainstorms and thunderstorms. The typical wind speed in Royalston range from 3-10 miles per hours over the course of the year, with peak gusts over 50 mph.[57]

The prevailing wind direction is west, and the highest wind speeds occur January through March. **Figure 3.8** shows the average monthly wind speed for the contiguous US for March based on wind conditions in the lower troposphere.[58] The Northeast United States, including Worcester County, have some of the highest average wind speeds in the contiguous US.

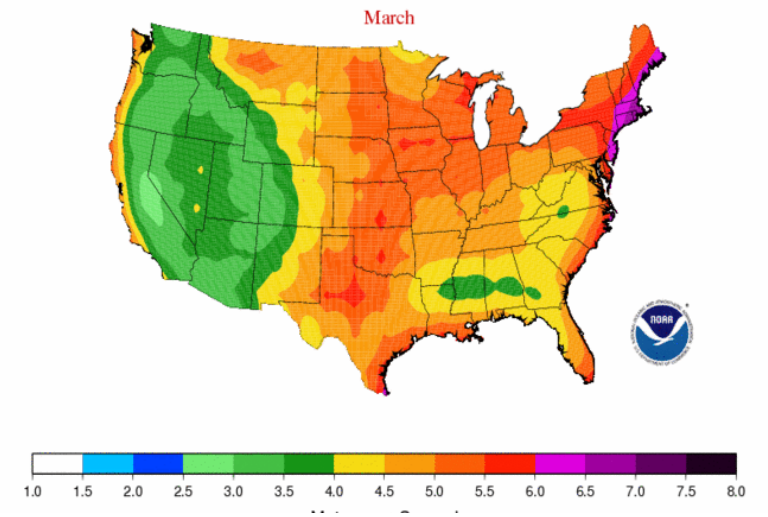


Figure 3.8: March Average Wind Speeds in the Lower Troposphere (1971-2000)

High winds can occur as an isolated event or accompany other weather events such as:

- Before and after frontal systems
- Hurricanes and tropical storms
- Severe thunder and lightning storms
- Tornadoes
- Nor'easters

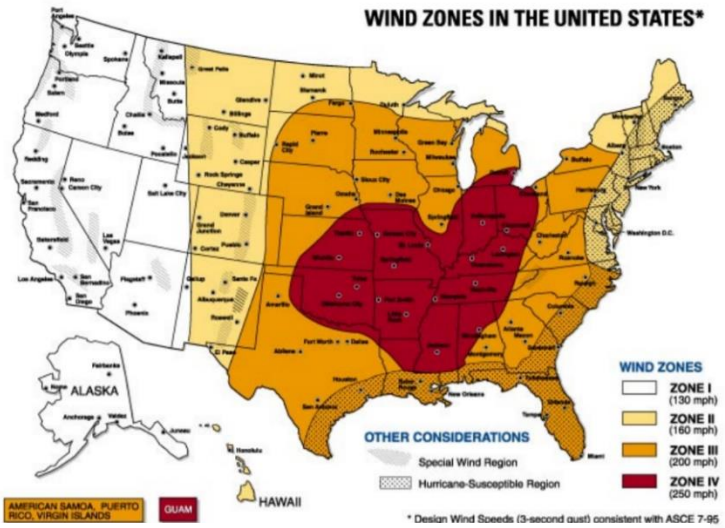


Figure 3.9: Wind Zones in the United States

National wind zone designations were developed by FEMA based on 40 years of tornado history and 100 years of hurricane history. As shown in **Figure 3.9**, Worcester County lies within Zone II with maximum winds of 160 mph. Royalston is also within the Hurricane-Susceptible Region along with the entire East Coast and Gulf of Mexico.[59]

[57] NOAA Climatic Wind Data for the United States 1930-1996- Data for Boston
[58] https://www.ncdc.noaa.gov/societal-impacts/wind/w-mean/201603
59 FEMA Taking Shelter from the Storm: Building a Safe Room Inside Your House. https://www.fema.gov/pdf/library/ism2_s1.pdf

Table 3-12 includes the high wind warning categories issued by the NWS for both non-tropical and tropical events. Winds measuring under 30 mph are not considered to be hazardous under most conditions.[60]

Table 3-12
NWS High Wind Warning Categories

Type of Warning	Wind Speeds
Non-tropical event over land	
Wind Advisory	Sustained winds of 31-39 mph for at least 1 hour, or any gust 46 to 57 mph
High Wind Warning	Sustained winds 40+ mph or any gust 58+ mph
Non-tropical event over water	
Small Craft Advisory	Sustained winds 25-33 knots
Gale Warning	Sustained winds 24-47 knots
Storm Warning	Sustained winds 48 to 63 knots
Hurricane Force Winds	Sustained winds 64+ knots
Tropical storm events (inland or coastal)	
Tropical Storm Warning	Sustained winds 39 to 73 mph
Hurricane warning	Sustained winds of 74+ mph

Effects from high winds can include downed trees and/or power lines, damage to structures, etc. This is especially true after periods of heavy snow, rain or prolonged drought due to the weakening of tree branches and roots. High winds can cause scattered power outages and are a hazard for the boating, shipping, and aviation industry sectors. More specific discussion on severe weather high wind events impacting Royalston follows.

Hurricanes/ Tropical Storms

A tropical cyclone is a rotating, organized system of clouds and thunderstorms that originate over tropical or subtropical water. The 4 types of tropical cyclones are classified as follows:

- **Tropical Depression:** A tropical cyclone with maximum sustained winds of 38 mph (33 knots) or less.
- **Tropical Storm:** A tropical cyclone with maximum sustained winds of 39 to 73 mph (34 to 63 knots).
- **Hurricane:** A tropical cyclone with maximum sustained winds of 74 mph (64 knots) or higher.
- **Major Hurricane:** A tropical cyclone with maximum sustained winds of 111 mph (96 knots) or higher, corresponding to a Category 3, 4 or 5 on the Saffir-Simpson Hurricane Wind Scale.

Hurricanes are characterized by high winds and extratropical moisture resulting in torrential rainfall, especially if the storm is slow moving. The rotational nature of hurricanes often results in winds changing direction as the storm passes, altering wave generation and surge setup.

[60] MEMA (2018), "SHMCAP"

A hurricane is strongest as it travels over the ocean and is particularly destructive to coastal property as storms hit the land. In the Atlantic Basin, the hurricane season runs from June 1 to November 30 with peak activity occurring in early to mid-September.[61]

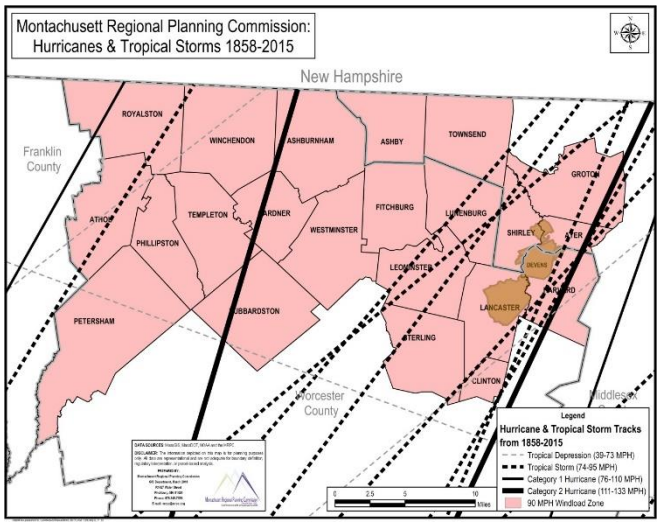
Hurricanes are classified by the Saffir-Simson Scale, which categorizes intensity linearly based upon maximum sustained winds, barometric pressure, and storm surge potential. **Table 3-13** shows the wind speeds, surges, and range of damage caused by different hurricane categories:

Table 3-13
Saffir/Simson Scale to Measure Hurricane Intensity

Scale No. (Category)	Winds (mph)	Surge (ft.)	Potential Damage
1	74-95	4-5	Minimal
2	96-110	6-8	Moderate
3	111-130	9-12	Extensive
4	131-155	13-18	Extreme
5	>155	>18	Catastrophic

Previous Occurrence and Extent

The National Oceanic and Atmospheric Administration (NOAA) has been keeping records of hurricanes since 1858 . From 1858 to 2015, the Montachusett Region has had one Tropical Depression, seven Tropical Storms, one Category 1 Hurricane, and two Category 2 Hurricanes pass directly through the Region. **Figure 3.10** displays the historic tracks of hurricanes across the Region.



Within the last 25 years, hurricanes and tropical storms that have impacted Massachusetts include Hurricane Gloria (1985), Irene (Category 2, 2011), Earl (Category 4, 2010), and Bob (Category 2, 1991); and Tropical Storms Sandy (2012), Bill (2009), Hanna (2008), and Beryl (2006).[62] Historically the 1938 Hurricane known as the Great New England Hurricane, a Category 3 hurricane, was the most severe to have impacted Royalston, with high winds and record rainfall.

While historic records include 28 tropical storms and hurricanes for New England, only 3 events have resulted in FEMA hurricane-related disasters for Worcester County as listed in **Table 3-14**.

Figure 3.10: Hurricanes & Tropical Storms in Montachusett Region (1858-2015)

[61] National Hurricane Center Educational Resources http://www.nhc.noaa.gov/climo/
[62] MEMA (2018), "SHMCAP"

Table 3-14
FEMA Hurricane-Related Declared Disasters Impacting Worcester County

FEMA Disaster #	Name	Date	Category
DR-751	Hurricane Gloria	9/27/1985	Cat 3
DR-914	Hurricane Bob	8/19/1991	Cat 2
EM-3315	Hurricanes Earl	9/1/-9/4/2010	Cat 4

Locally Identified Areas of Impact

Based on past history, the Planning Team determined the entire planning area is at risk for impacts due to hurricanes and tropical storms.

Probability of Future Occurrence

According to the 2018 SHMCAP and NOAA Hurricane Research Division, the Commonwealth has a 6 to 30 percent chance of a tropical storm or hurricane affecting the area each year. The probability increases moving from the northwest corner of the state to the southeast, with the highest probability along the coast, specifically Cape Cod and the Islands. New England averages about one hurricane per decade, but there is some evidence that more and stronger hurricanes occur when Atlantic Sea-Surface-Temperatures are warm. While the science of global warming and hurricanes is evolving, present research calls for slightly stronger and wetter storms, but changes in frequency are unknown. Based on the past regional and local history of tropical cyclones, the Planning Team determined that it is **LIKELY** that a hurricane or tropical storm will impact the area in the future**.**

Hurricane Impacts on Royalston's Key Sectors

Hurricane Exposure and Vulnerability By Key Sector[63]	
Built Environment	Hurricane flooding can also wash out sections of roadways and bridges, as well as cause extensive damage to public utilities and disruptions to the delivery of services. Hurricane wind can down trees and powerlines and damage buildings.
Natural Resources and Environment	As the storm is occurring, flooding, or wind – or water-borne detritus can cause mortality to animals if it strikes them or transports them to a non-suitable habitat. In the longer term, environmental impacts can occur as a result of riverbed scour, fallen trees, or contamination of ecosystems by transported pollutants.
Economy	Hurricanes and severe winter storms, can greatly impact the economy, including loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss, road repair, and rental loss due to the repair/replacement of buildings.
Vulnerable Populations	Of the population exposed, the most vulnerable include the economically disadvantaged and population over the age of 65. Economically disadvantaged populations are more likely to evaluate the economic impact of evacuating, and individuals over 65 are more likely to face physical challenges in evacuating or to require medical care while evacuated.

[63] MEMA (2018), "SHMCAP"

Winter Storms

Hazards associated with Heavy Snow, Nor'easters, Blizzards, and Ice Storms can be similar in many ways and therefore have been categorized under Winter Storms although each of these hazard events is separately distinguished under Probability of Future of Events.

Photo 3.1: Damage from the 2008 winter storm in Royalston

Nor'easters

Nor'easters are a ferocious type of northeastern coastal storm that typically occur in the winter months. The storm's name refers to the continuous strong northeasterly winds blowing in a large counter-clockwise circulation pattern around a low-pressure center, resulting in heavy snow and rain, gale force winds, rough seas, and coastal flooding that often cause shoreline erosion. The radius of these storms can extend up to 1,000 miles.[64] Impacts along the coast are typically worse than inland locations due to the additional moisture picked up from the ocean. Nor'easters may be especially damaging because they can sit stationary for several days, affecting multiple tidal cycles and producing extended periods of heavy precipitation, resulting in increased flooding, shoreline erosion, and damage to coastal infrastructure.

There is no widely used scale to classify Nor'easters, but a combination of scales including the Beaufort Scale for wind speed, Regional Snowfall Index for snowfall, and precipitation associated with a historic recurrence interval (i.e. 100-year rainfall) can be combined to evaluate the magnitude of the storm.

For Royalston, precipitation amounts of 8.7 inches are associated with a 100-year storm event (1% chance of occurring in any one year). Winter and spring flooding from Nor'easters may be exacerbated due to snow melt and frozen ground conditions. The severity of a nor'easter also depends on the time of occurrence relative to the lunar tide cycles (spring or neap tides) and during what tide stage the maximum storm surge occurs at (high tide or low tide). Depending on the metric used to measure the storm, assigned severity may also take into account the storm's societal and economic impacts.

The level of damage in a hurricane is often more severe than a Nor'easter, but historically Massachusetts has suffered more damage from Nor'easters because of the greater frequency of these coastal storms (1 to 2 per year). As another comparison, the duration of high surge and winds in a hurricane is 6 to 12 hours while a Nor'easter can last from 12 hours to 3 days.

Nor'easters are not typically named the way that hurricanes are by the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS), though locally coined names have been used. For example, Winter Storm Juno and Winter Storm Nemo were named by the Weather Channel in 2014 and

[64] MEMA (2018), "SHMCAP"

2015.[65] The unofficial storm naming is controversial with meteorologists because winter storms can reform more than once, making naming redundant, but naming a storm may bring more attention to the event and help people comply with advance emergency preparations.

Previous Occurrence and Extent

There have been 14 winter storm related federally declared disasters during the time frame of 1996 through 2018 (**Table 3-15**) which include nor'easters.

Table 3-15
FEMA Nor'easter and Winter Storm Related Disaster Declarations (1996-2018) Impacting Royalston

Disaster #	Dates	Unofficial Storm Name	Impact
DR-4379	March 13, 2018	"Winter Storm Riley"	Severe winter storm, snowstorm, flooding-Nor'easter
DR-4214	January 26-29,2015	"Winter Storm Juno"	Severe winter storm, snowstorm, flooding-Nor'easter
DR-4110	February 8-10, 2013	"Winter Storm Nemo"	Severe winter storm, snowstorm and flooding
DR-4051 / EM-3343	October 29-30, 2011	"Snowtober"	Severe Storm
DR-1813 / EM-3296	December 11, 2008	December Ice Storm	Severe Winter and Ice Storm
DR-1614	October 7-16, 2005	Nor'easter	Severe Storms and Flooding
EM-3201	December 3, 2003	December Blizzard	Severe winter storm, snowstorm
EM-3191	December 6-5, 2003		Severe Snowstorm
EM-3175	February 17, 2003	February Blizzard	Severe winter storm, snowstorm
DR-1364 / EM-3165	March 2001	March Blizzard	Severe winter storm, snowstorm
DR-1090	January, 1996	January Blizzard	Severe winter storm, snowstorm
EM-3103	March 16, 1993		Blizzard, high winds and record snowfall
DR-975	December 11-13, 1992		Winter coastal storm
DR-546	February 6-8, 1978		Coastal storms, flood, ice, snow

Locally Identified Areas of Impact

The entire planning area is at risk for impacts due to Nor'easters. Royalston's overall vulnerability for Nor'easters is similar to severe winter weather and flooding.

[65] https://en.wikipedia.org/wiki/Winter_storm_naming_in_the_United_States

Probability of Future Occurrence

Nor'easters may occur at any time of the year; however, they are most common from September to April. Based on the historical record of the top winter storm events from 1953 to 2018,

Nor'easters have an average frequency of 1 or 2 per year. Nor'easters are likely to become more intense in the future due to potential effects of climate change including increased snowfall, sea level rise, storm surge and a concentration of storm events in the coldest winter months.

Increased sea surface temperature in the Atlantic Ocean will cause air moving north over this ocean to hold more moisture. As a result, when these fronts meet cold air systems moving from the north, an even greater amount of rain and snow than normal can be anticipated to fall on Massachusetts. Although no one storm can be linked directly to climate change, the severity of rain and snow events has increased dramatically in recent years.

Based on the historic record of Nor'easters impacting Royalston and the future predictions for increased severity and intensity of Nor'easters, the Planning Team determined that is **HIGHLY LIKELY** that a Nor'easter will impact the planning area in the future.

Nor'easter Impacts on Royalston's Key Sectors

Nor'easter Exposure and Vulnerability By Key Sector[66]	
Built Environment	Flooding can also wash out sections of roadways and bridges, as well as cause extensive damage to public utilities and disruptions to the delivery of services. Wind can take down power lines, disrupting power service and damage buildings.
Natural Resources and Environment	The environmental impacts of nor'easters are similar to those of hurricanes and severe winter storms. They often involve flood and wind damage, can cause direct mortality to individuals, and transform habitats.
Economy	Nor'easter events, similar to hurricanes and severe winter storms, can greatly impact the economy, including loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss, road repair, and rental loss due to the repair/replacement of buildings.
Vulnerable Populations	Of the population exposed, the most vulnerable include the economically disadvantaged and population over the age of 65. Economically disadvantaged populations are more likely to evaluate the economic impact of evacuating, and individuals over 65 are more likely to face physical challenges in evacuating or to require medical care while evacuated.

Severe Winter Storms: Snow and Blizzard

Severe Winter Weather includes snowstorms, blizzards, and ice storms. A winter storm occurs when there is significant precipitation during periods of low temperatures. Winter storms are a combination of hazards because they often involve wind, ice, and heavy snow fall.

[66] MEMA (2018), "SHMCAP"

Winter storms can occur from early autumn to late spring and include any of the following events:[67]

- Blizzards
- Blowing snow
- Snow squalls
- Ice pellets and sleet
- Icing
- Coastal flooding
- Snow showers and flurries
- Snow melt
- Ice jams and flow

Impacts from winter weather – in addition to non-passable streets and sidewalks – include downed power lines causing loss of electric power service, catch basins being buried and sometimes clogged, water service pipes bursting and shut-off valves being buried (more common when cold and windy), fire hydrants being buried by snow, older water mains bursting, and dangerous icicles forming on buildings. Snow can also block building ventilation, increasing the risk of indoor carbon monoxide poisoning and place a heavy load on roofs.

Previous Occurrence and Extent

Snow and other forms of winter precipitation occur frequently in Royalston, with a normal 30-year average between 50-70 inches per year as shown in **Figure 3.11**.[68] The one day records snowfall of 31.9 inches was recorded at Worcester Regional Airport on January 27, 2015.

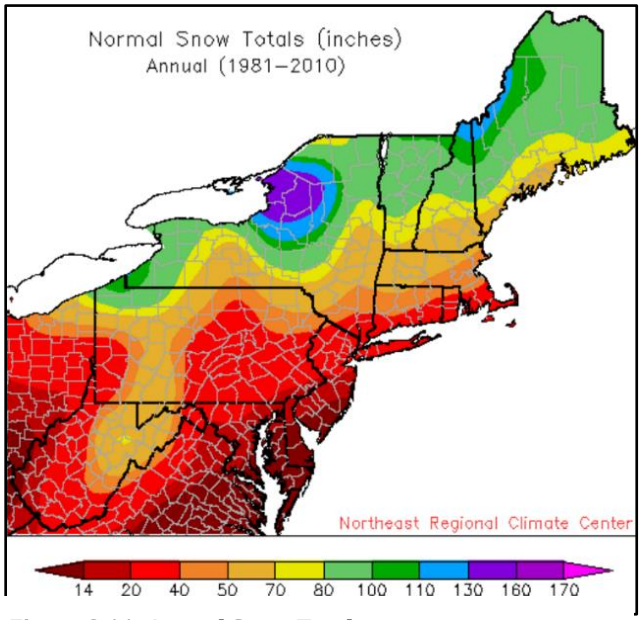


Figure 3.11: Annual Snow Totals

One of the most significant for the Montachusett Region occurred on December 11, 2008 when the Region's dependence upon electricity was exposed when a winter storm brought significant sleet and a heavy layer of ice resulting in downed trees and power lines, blocked roads, and large scale power outages causing the Governor to declare a State of Emergency. Within the Region, there were over 43,264 households and businesses without power. The storm raised heavy controversy over the slow return of power; it wasn't until approximately December 24th when power was essentially restored to all of the Montachusett Region with utility workers from more than several states called in to provide essential repair services. A rare October snowstorm in the year 2011 also had a significant impact on the Montachusett Region with many households and businesses losing power for several days as tree limbs with leaves that were still green downed power lines and blocked roads.

Federally-declared disasters from winter storm events in Worcester County are provided in **Table 3-20**. According to NESIS data, 59 winter storms rated as "notable" or higher have occurred since 1953. Therefore, although there is significant interannual variability in the frequency and severity of winter storms, this hazard should be expected to occur every winter.[69]

[67] http://www.nws.noaa.gov/om/winter/index.shtml
[68] http://www.nrcc.cornell.edu/regional/climatenorms/climatenorms.html
[69] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan

Photos 3.2 and 3.3: Damage from the 2008 winter storm in Royalston

Locally Identified Areas of Impact

The entire planning area is at risk for severe winter weather. During these events, the areas along the higher elevation may experience higher snow accumulations and higher winds than other areas of.

Royalston's overall vulnerability to winter weather is primarily related to restrictions to travel on roadways, inaccessible or icy sidewalks, temporary road closures, school closures, and potential restrictions on emergency vehicle access. Other vulnerabilities include power outages due to fallen trees and utility lines, and damage to structures due to heavy snow loads.

Probability of Future Occurrence

Based on the record of previous occurrences, winter storm events in Royalston are high frequency events as defined by the 2018 SHMCAP. This hazard may occur more frequently than once in five years (greater than 20% per year). Climate change impacts are predicted to increase the severity of winter storms because changing circulation patterns and warming ocean water allowing additional moisture to fuel the storm to greater intensity. Based on the past record, the Planning Team concludes that it is **HIGHLY LIKELY** that severe winter weather will impact Royalston in the future.

Severe Winter Storm Impacts on Royalston's Key Sectors

Severe Winter Storm Exposure and Vulnerability By Key Sector[70]	
Built Environment	All elements of the built environment in Royalston are exposed to the severe winter weather hazard.
Natural Resources and Environment	Winter storms are a natural part of the Massachusetts climate, and native ecosystems and species are well-adapted to these events. However, more extreme winter storms can result in direct mortality, habitat modification, and flooding when snow and ice melt, especially in areas with high road salt applications.

[70] MEMA (2018), "SHMCAP"

Severe Winter Storm Exposure and Vulnerability By Key Sector[70]	
Economy	Potential impacts from winter storms include loss of utilities, interruption of transportation corridors, loss of business function and loss of income during business closures. The cost of snow and ice removal and repair of roads from the freeze/thaw process can also strain local financial resources.
Vulnerable Populations	Populations over 65 are considered most susceptible due to their increased risk of injury and death from falls and overexertion and/or hypothermia from attempts to clear snow and ice, or related to power failures. Residents with low incomes may not have access to housing or their housing may be less able to withstand cold temperatures (e.g., homes with poor insulation and heating supply).

Tornadoes, High Winds and Thunderstorms

Tornadoes

A tornado is a violently rotating column of air extending from a cumuliform cloud, such as a thunderstorm, to the ground. Tornadoes are not always visible as funnel clouds because they may appear nearly transparent until they pick up dust and debris. The average tornado moves from southwest to northeast, but they can move in any direction and can suddenly change direction. The average speed of a tornado is 30 mph, but they can be stationary or move as fast as 70 mph. The strongest tornadoes have rotating winds of more than 200 mph.[71] **Table 3-16** shows the Enhanced Fujita Tornado Damage Scale developed by T. Theodore Fujita.[72]

Table 3-16
Enhanced Fujita Scale Levels and Description of Damage

EF-Scale Number	Intensity Phrase	3-Second Gust (MPH)	Type of Damage Done
EF0	Gale	65-85	Some damage to chimneys; breaks branches off trees; shallow rooted trees pushed over; sign boards damaged
EF1	Moderate	86-110	Peels surfaces off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
EF2	Significant	111-135	Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	Severe	136-165	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
EF4	Devastating	166-200	Well-constructed houses leveled; structures with weak foundations blown off some distances; cars thrown and large missiles generated.

Previous Occurrence and Extent

Worcester County has been impacted by more tornados than any other county in Massachusetts. Since 1950, there have been 15 tornados in the region, most recently in 2015. Two (2) were rated as F0 on the Fujita Tornado

[71] Thunderstorms, Tornadoes, Lightning: Nature's Past Violent Storms, A Preparedness Guide, US Department of Commerce, NOAA, and the National Weather Service
[72] http://www.spc.noaa.gov/efscale/

scale, seven (7) were F1, four (4) were F2, one (1) was F3 and one (1) was F4. The most devastating tornado ever to occur in New England was an F4 that occurred on July 9, 1953. It first touched down in Petersham, and then traveled on a 46-mile southeast path through Barre, Rutland and Holden, across Worcester into Shrewsbury, Westborough and Southborough. Within a matter of minutes, more than 90 people were dead, and over 1,300 injured and fifteen thousand were left homeless.

Locally Identified Areas of Impact

Figure 3.12 shown below shows the areas historically impacted by Tornadoes since the 1950's.

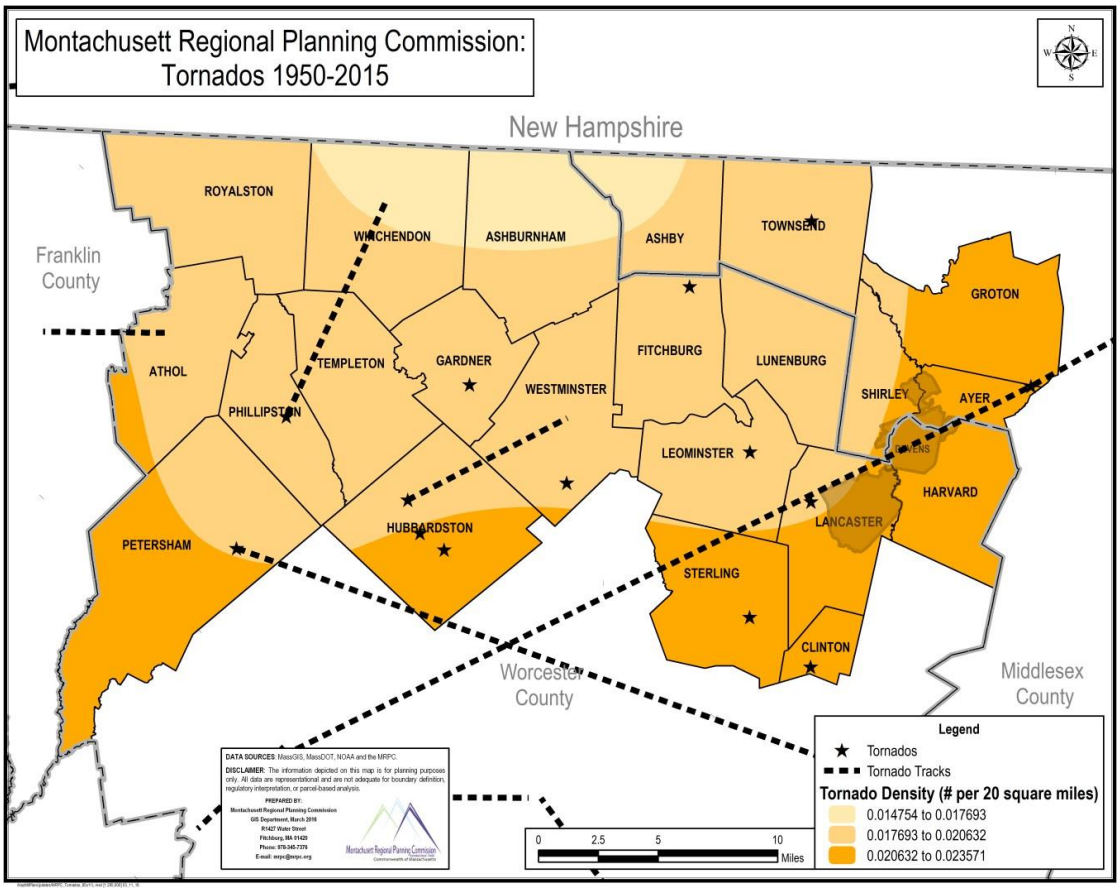


Figure 3.12: Tornadoes in the Montachusett Region (1950-2015)

Probability of Future Occurrence

From 1950 to 2015 there has been, on average, one tornado every 4.3 years. With 9 of the 15 tornados being classified as a relatively weak F0 or F1 tornado, the remaining 6 tornados are classified as major F2 or higher tornados and can be expected approximately every 11 years. Based on the past record, the Planning Team concludes that it is **LIKELY** that tornadoes will impact Royalston in the future.

Thunderstorms

A thunderstorm is a storm with lightning and thunder produced by a cumulonimbus cloud, usually producing gusty winds, heavy rain, and sometimes hail. The NWS classifies a thunderstorm as 'severe' when it produces

damaging wind gusts in excess of 58 mph (50 knots), hail that is 1 inch in diameter or larger (quarter size), or a tornado.[73]

Three basic ingredients are required for a thunderstorm to form: moisture to form clouds and rain, rising unstable air warm air that can rise rapidly, and lift- caused by cold or warm fronts, sea breezes, mountains, or the sun's heat. While less severe than other types of storms, a thunderstorm can lead to localized damage and represents a hazard risk for all communities in Massachusetts. An average thunderstorm is 15 miles across and lasts 30 minutes; severe thunderstorms can be much larger and longer. Southern New England typically experiences 18 to 27 days per year with severe thunderstorms (**Figure 3.13**).[74]

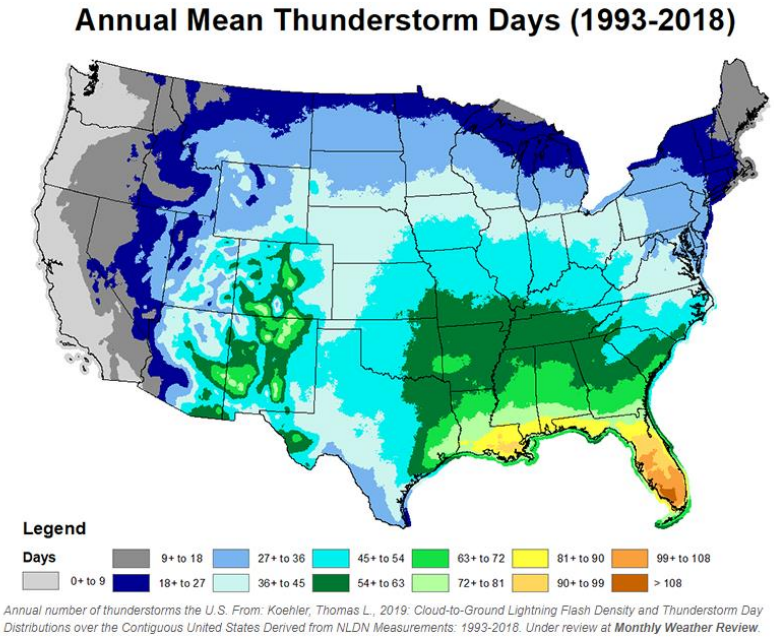


Figure 3.13: Annual Average Number of Thunderstorm Days in the U.S.

Thunderstorms have masses of air, an updraft (rising air), and a downdraft (sinking air). A strong downdraft, also known as a downburst, can cause tremendous wind damage similar to a tornado. Damage from hail and lightning are secondary impacts to thunderstorms. Hail can cause damage to vehicles and crops especially when the hail stones are large in diameter.

Previous Occurrence and Extent

Research on the NOAA Storm Event Database[75] from 1950 to 2019 indicates there were 471 severe wind related storms in Worcester County that include thunderstorms, tornadoes, lightening, hail and strong winds which averages about 6 wind related storms per year. 216 thunderstorms events occurred in the Montachusett Region over the 69-year period, or 3.13 per year and 121 hail events over the same period, or 1.75 events per year.

[73] NWS, Severe Weather Definitions: https://www.weather.gov/bgm/severedefinitions
[74] NWS, Introduction to Thunderstorms: https://www.weather.gov/jetstream/tstorms_intro
[75] https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=25%2CMASSACHUSETTS

According to the NOAA National Climatic Data Center (NCDC), Worcester County experienced the following events between January 1, 1950 and December 31, 2019:

- 33 days with reported Tornado (EF0-F4 magnitude, 92 deaths and 1254 injuries, $264.243 M property damage)
- 53 days with reported Lightning (29 injuries, $2.054 M property damage)
- 121 days with reported Hail (0.75-2-inch diameter, 125.000 K property damage)
- 48 days of reported High/Strong Wind (up to 65 knots, 1 death, 4 injuries, $1.227 M property damage)
- 216 days of reported Thunderstorm Wind (up to 110 knots, 4 deaths, 8 injuries,$14.319M property damage

Locally Identified Areas of Impact

Based on local experience and NOAA weather records, the entire planning area has experienced severe weather events due to wind, including lightning, hail, strong winds, thunderstorms and tornadoes.

Probability of Future Occurrence

Based on the past regional and local history of severe weather wind events, the Planning Team determined that it is **HIGHLY LIKELY** that a weather event due to wind, including lightning, hail, strong winds, and thunderstorms will impact the area in the future**.** The planning team thinks that it is **LIKELY** that a weather event due to tornadoes will impact the area in the future

Tornado Impacts on Royalston's Key Sectors

Tornado Exposure and Vulnerability By Key Sector[76]	
Natural Resources and Environment	Direct impacts may occur to flora and fauna small enough to be transported by the tornado. Even if the winds are not sufficient to transport trees and other large plants, they may still uproot them. Material transported by tornados can also cause environmental havoc in surrounding areas, particularly of contaminating materials are introduced into the atmosphere or local water supplies.
Economy	Tornado events are typically localized; however, in those areas, economic impacts can be significant. Types of impacts may include loss of business function, water supply system damage, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Recovery and clean-up can also be costly.
Vulnerable Populations	Vulnerable populations include all those who may have difficulty evacuating, including car-free households, individuals over 65, and households with young children. Individuals with limited internet or phone access may not be aware of impending tornado warnings. The potential insufficiency of older or less stable housing to offer adequate shelter from tornados is also a concern.

[76] MEMA (2018), "SHMCAP"

3.5 Geologic Hazards

3.5 GEOLOGIC HAZARDS

Earthquake

An earthquake is the movement or trembling of the ground produced by a sudden displacement of rock in the Earth's crust. The theory of plate tectonics is commonly used to explain much of the earthquake activity in the world. The plates over the Earth are in constant slow motion and this movement can cause earthquakes, most frequently at the boundary of the plates.[77]

In general, magnitude measures the size of an earthquake, while intensity measures the effects, which vary according to how far you are from the earthquake and the soils you are on.[4] Two scales are frequently used to measure earthquakes: Richter Scale measures the amount of energy released by an earthquake, or its magnitude. The Richter Scale ranges from 3.5 to 8.0, where 3.4 may be felt but doesn't cause damage, to an 8 which includes Great Earthquakes, and serious damage over extremely large areas. The Modified Mercalli Intensity Scale measures the intensity or impact of an earthquake on people and the built environment, and the Scale ranges from a Level 1, where the earthquake is not felt except by very few under especially favorable circumstances to a X11, with total damage: where all works of construction are damaged or destroyed, lines of sight and level are distorted, and objects are thrown into the air.[4]

Earthquake hazards have multiple impacts beyond the obvious building collapse. Buildings may suffer structural damage that may or may not be readily apparent. Earthquakes can cause major damage to roadways, making emergency response difficult. Water lines and gas lines can break, causing flooding and fires. Another potential vulnerability is equipment within structures. For example, a hospital may be structurally engineered to withstand an earthquake, but if the equipment inside the building is not properly secured, the operations at the hospital could be severely impacted during an earthquake. Earthquakes can also trigger landslides.

Previous Occurrence and Extent

According to the 2018 SHMCAP, New England experiences an average of 5 earthquakes per year. Between 1627 and 2008, 366 earthquakes were recorded in Massachusetts. Most earthquakes in the northeast region tend to be small in magnitude and cause little damage; however, between 1924 and 2012 there have been 104 earthquakes measured at a magnitude of 4.5 or greater on the Richter Scale. Due to the geologic composition and rock structure in the Northeast, seismic shaking for many of these larger earthquakes were felt throughout all of New England. Most of the earthquakes originated from the La Malbaie fault in Quebec or from the Cape Ann fault located off the coast of Rockport. The list below includes earthquakes that affected Massachusetts:

- August 8, 1847: No data available on the extent of hazard.
- November 27, 1852: No data available on the extent of hazard.
- December 10, 1854: No data available on the extent of hazard.
- September 21, 1876: No data available on the extent of hazard.

[77] Earthquake Causes and Characteristics, FEMA Emergency Management Institute Training Guide, https://training.fema.gov/emiweb/is/is8a/is8a-unit3.pdf

- May 21, 1880: No data available on the extent of hazard.
- January 21, 1903: No data available on the extent of hazard.
- April 24, 1903: No data available on the extent of hazard.
- October 15, 1907: No data available on the extent of hazard.
- January 7, 1952: Earthquake occurred off of Cape Ann and the reported felt area extended from Providence, RI to Kennebunk, ME.
- April 24, 1925: No data available on the extent of hazard.
- January 28, 1940: No data available on the extent of hazard.
- October 16, 1963: Intensity VI, caused plaster to fall in a house, crack walls, dishes and windows.
- October 30, 1963: No data available on the extent of hazard.
- October 24, 1965: Slight damage to homes on Nantucket, house timbers creaked, doors, windows and dishes rattled.
- December 30, 2012: Magnitude 1.2 earthquake about 7 miles south of Gardner, MA. No extent data available.
- April 2012: A swarm of 12 or more earthquakes occurred off of the New England coast about 250 miles east of Boston. The largest of these earthquakes measured a magnitude of 4.4 on the Richter Scale. This swarm of earthquakes was of particular concern because of the major earthquake on the continental shelf further north in 1929 that produced a deadly and damaging tsunami in Nova Scotia.

There have been no earthquake declared disasters for Massachusetts. There have been no recorded earthquake epicenters within Royalston and there have been no historical recorded effects on the Town associated with earthquake impacts originating from outside of Royalston. FEMA has published maps with seismic design categories (SDCs) for building design and construction professionals. Most of New England is classified as SDC "B," as areas that could experience shaking of moderate intensity.[78]

Locally Identified Areas of Impact

Based on mapping by FEMA, the entire planning area is at risk from impacts due to earthquakes.

Probability of Future Occurrence

Earthquakes cannot be predicted and may occur at any time of the day and any time of the year. However, for the purpose of this Plan, the USGS 2014 Seismic Hazard Map was used to review the probability of future occurrence as shown in **Figure 3.14**.[79]

[78] https://www.fema.gov/earthquake-hazard-maps
[79] https://earthquake.usgs.gov/hazards/hazmaps/conterminous/index.php#2016

The data is derived from seismic hazard curves and depict probabilistic ground motions with a 2% probability of exceedance in 50 years. For Royalston, moderate peak gravity acceleration from 8-10% is predicted.

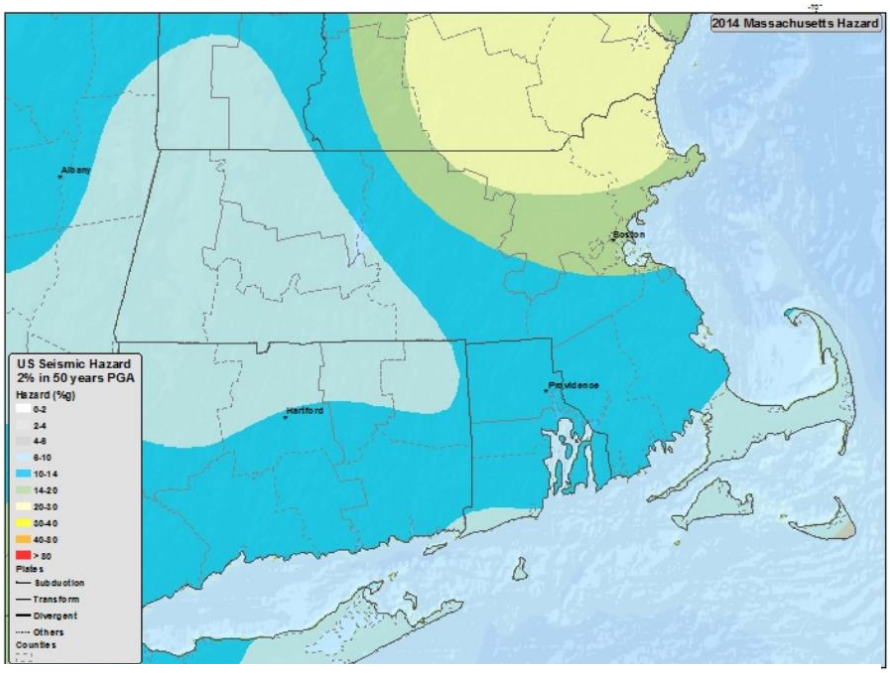


Figure 3.14: 2014 Seismic Hazard Map of New England

Royalston is similar to many communities in Massachusetts and may not be prepared for earthquakes. Although new construction under the most recent building codes will be built to seismic standards, much of the development in the Town predates the most recent building code.

The Planning Team determined that it is **POSSIBLE** that an earthquake will impact Royalston in the future and therefore are including it in the Multi-Hazard Mitigation Plan.

Earthquake Impacts on Royalston's Key Sectors

Earthquake Exposure and Vulnerability By Key Sector[80]	
Built Environment	In addition to direct impacts, earthquakes also present a risk associated with hazardous materials releases, which have the potential to impact a production or storage facility during transportation, or a result of pipeline damage. These events could cause widespread interruption of services, as well as air and water contamination.
Natural Resources and Environment	If strong shaking occurs in a forest, trees may fall – resulting not only in environmental impacts but also potential impact to any industries relying on that forest. If shaking occurs in a mountainous environment, cliffs may crumble and caves may collapse. Disrupting the physical foundation of the ecosystem can cause species displacement and modify the species balance in that ecosystem and leave the area more vulnerable to the spread of invasive species.

[80] MEMA (2018), "SHMCAP"

Earthquake Exposure and Vulnerability By Key Sector[80]	
Economy	Earthquake losses can include structural and non-structural damage to buildings (which could include damage to architectural components like ceilings and lights, or power systems), loss of business function, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings.
Vulnerable Populations	Socially vulnerable populations are the most likely groups to be affected by this hazard based on a number of factors, including their physical and financial ability to react or respond during a hazard, the location and construction quality of their housing, and the ability to be self-sustaining after an incident due to limited ability to stockpile supplies.

Landslide

Landslides encompass a wide variety of ground movements under the effect of gravity including rock falls, slope failures, and shallow debris flows. In the Commonwealth of Massachusetts, landslides are primarily caused by slope saturation by water, which increases the weight on the slope, as well as the pore pressure.[81] Increasing the pore pressure will decrease the cohesiveness of the soil, making the land more vulnerable to outside pressures (i.e. gravity). In Massachusetts, landslides are often caused by construction-related failures, undercut slopes, and water saturation.

- Construction-related failures are caused by construction activities that weaken the slope by increasing the steepness of the bank and decreasing supporting material along the bank.
- Undercut slopes occur when streams, tides, or other water movement cut into the toe of the slope, eventually undermining.
- Slope saturation on a slope occurs after high precipitation events and drastic water level changes that augments the weight on the slope and diminishes the slope's cohesiveness.

Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15 percent of a given area has been involved in landsliding, medium incidence means 1.5 to 15 percent of an area has been involved, and low-incidence means that less than 1.5 percent of an area has been involved. Royalston has a low incidence of landslides.

Previous Occurrence and Extent

Landslides tend to coincide with other natural disasters such as earthquakes and floods that exacerbate relief and reconstruction efforts. As a result, landslide frequency is related to the frequency of other hazards. There have been zero federally declared landslide disasters from 1954 to 2012.[82] According to the 2018 SHMCAP, there are roughly 1 to 3 landslides events each year. There is no specific data on events in Royalston. Town officials did not identify any problems with areas of geologic instability such as sinkholes or subsidence, or any past occurrences with landslides, sinkholes or subsidence.

[81] MEMA (2018), "SHMCAP"
[82] MEMA (2018), "SHMCAP"

Locally Identified Areas of Impact

The entire planning area is identified as low risk for landslides.

Probability of Future Occurrence

Due to the low incidences of historic landslides, the Planning Team determined that it is **UNLIKELY** that landslides will impact Royalston in the future. Potential effects of climate change could increase the likelihood of landslides due to slope saturation with more frequent and intense storms, and reduced vegetation cover due to the increased frequency of drought events or increased urbanization.

Landslide Impacts on Royalston's Key Sectors

Landslide Exposure and Vulnerability By Key Sector[83]	
Built Environment	Landslides can cause damage to elements of the built environment and can interfere with travel if large enough to block or damage roads.
Natural Resources and Environment	Landslides can affect many facets of the environment, including the landscape itself, water quality, and habitat health. Transported soil may harm aquatic habitats, and mass movement of sediment may result in stripping of forests and other vegetated systems.
Economy	Direct costs include the actual damage sustained by buildings, property, and infrastructure. Indirect costs from a large landslide event could include clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity.
Vulnerable Populations	Populations who rely on potentially impacted roads for vital transportation needs are considered to be particularly vulnerable to this hazard.

[83] MEMA (2018), "SHMCAP"

3.6 Other Hazards

3.6 OTHER HAZARDS

Wildfire

Fire needs the right combination of heat source, fuel, and oxygen in order to ignite and thrive. Availability of fuel, weather conditions, and terrain all dictate how a fire will behave. Fires are classified as disasters when they affect people or developed areas. Fires can start from a variety of natural or anthropogenic causes. Urban fires occur in developed landscapes, where a fire has the potential to spread from one structure to another.

A wildfire is any non-structural fire that occurs in the vegetative wildlands. The 3 major classes of wildfires are surface, ground, and crown fires. A surface fire creeps slowly on the forest floor, while killing or damaging trees. Often occurring during droughts, ground fires burn organic ground cover below the forest floor. Rapidly spreading due to wind, crown fires quickly jump along the treetops.

Major urban and wildfires often result from other hazards, such as storms, earthquakes, gas leaks, transportation accidents, hazardous material spills, criminal activity, or terrorism. In contrast, small structural fires occur frequently from mundane events.

Previous Occurrence and Extent

The wildfire season in Massachusetts typically begins in late March and usually culminates in early June, following the driest live fuel moisture periods of the year. Historically, April has the highest wildfire danger.[84]

Locally Identified Areas of Impact

The Royalston Fire Department responds to approximately 25 - 30 wildfires annually. Royalston's forested areas are primarily composed of pitch pine, mixed conifer, oak, and oak mixed, which are considered by the State fire officials to be the forest types at highest risk for wildfires. Within the past year there were no wildfires that resulted in significant property damage, and several brush and grass fires. The most common cause of fires in Royalston is the careless disposal of smoking materials.

The Northeast Wildfire Risk Assessment Geospatial Work Group under the U.S. Forest Service determined the wildfire risk based off of fuels, wildland-urban interface and topography.[85] As shown in **Figure 3.15,** Royalston is mapped as having very low risk.

[84] MEMA (2018), "SHMCAP"

[85] U.S. Forest Service Fire Modeling Institute, USA Wildland Fire Potential: https://www.arcgis.com/home/item.html?id=fc0ccb504be142b59eb16a7ef44669a3

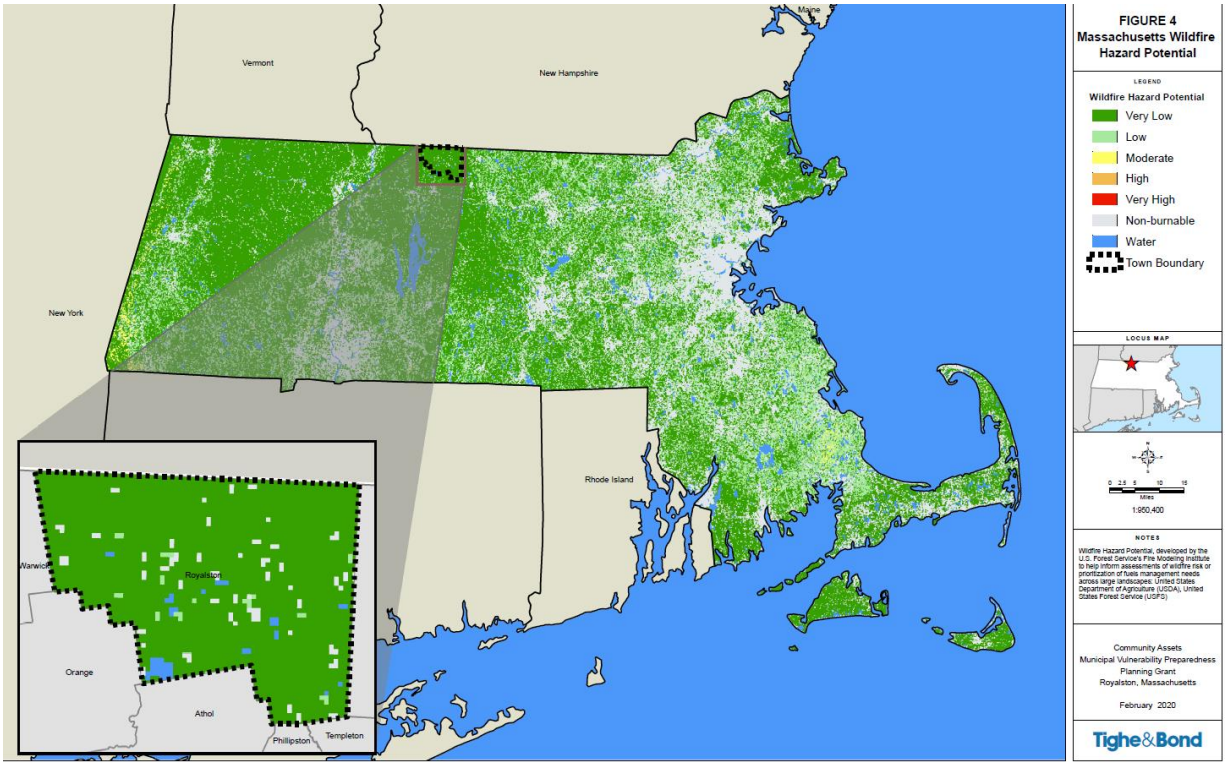


Figure 3.15: Wildfire Risk in Royalston

Probability of Future Occurrence

It is difficult to predict the likelihood of wildfires given the complexity of predicting the factors leading to fires. Fires will continue to present a risk, and that risk is likely to increase with potential drought impacts of climate change. Periods of hot, dry weather and more frequent lighting strikes may increase wildfires. Research has found that the frequency of lightning strikes could increase by approximately 12 percent for every degree Celsius of warming. The Planning Team determined that it is **LIKELY** that a wildfire will impact the planning area based on the large amount of forested land in Royalston and past history of fires.

Wildfire Impacts on Royalston's Key Sectors

Wildfire Exposure and Vulnerability By Key Sector[86]	
Built Environment	Fires can create conditions that block or prevent access and can isolate residents and emergency service providers. They can also damage infrastructure elements such as power and communication lines.
Natural Resources and Environment	Fire serves important ecological purposes; however, it can also cause environmental impacts. In addition to direct mortality, wildfires and the ash they generate can distort the flow of nutrients through an ecosystem, reducing the biodiversity that can be supported.

[86] MEMA (2018), "SHMCAP"

Wildfire Exposure and Vulnerability By Key Sector[86]	
Economy	Wildfire events can have major economic impacts on a community, both from the initial loss of structures and the subsequent loss of revenue from destroyed business and decrease in tourism. Additionally, wildfires can require thousands of taxpayer dollars in fire response efforts.
Vulnerable Populations	All residents whose homes are located in wildfire hazard areas are vulnerable to this hazard. Smoke and air pollution from the wildfires can also be a severe health hazard, especially for sensitive populations, including children, the elderly, and those with respiratory and cardiovascular diseases.

Invasive Species

The Massachusetts Invasive Plant Advisory Group (MIPAG) defines invasive plants as "non-native species that have spread into native or minimally managed plant systems in Massachusetts, causing economic or environmental harm by developing self-sustaining populations and becoming dominant and/or disruptive to those systems." [87] These species have biological traits that provide them with competitive advantages over native species, particularly because in a new habitat they are not restricted by the biological controls of their native habitat. As a result, these invasive species can monopolize natural communities, displacing many native species and causing widespread economic and environmental damage.

The Massachusetts Invasive Plant Advisory Group (MIPAG) recognized 69 species as "Invasive," "Likely Invasive," or "Potentially Invasive." In order to be considered “invasive,” a plant species must meet the following criteria[88]:

- Be nonindigenous to Massachusetts.
- Have the biologic potential for rapid and widespread dispersion and establishment in minimally managed habitats.
- Have the biologic potential for dispersing over spatial gaps away from site of introduction.
- Have the biologic potential for existing in high numbers away from intensively managed artificial habitats.
- Be naturalized in Massachusetts (persists without cultivation in Massachusetts).
- Be widespread in Massachusetts, or at least common in a region or habitat type(s) in the state.
- Have many occurrences of numerous individuals in Massachusetts that have high numbers of individuals forming dense stands in minimally managed habitats.
- Be able to out-compete other species in the same natural plant community.
- Have the potential for rapid growth, high seed or propagule production and dissemination, and establishment in natural plant communities.

[87] https://www.massnrc.org/mipag/
[88] https://massnrc.org/mipag/docs/MIPAG_FINDINGS_FINAL_042005.pdf#page=6

The damage rendered by invasive species is significant. The 2018 SHMCAP sites an estimate that about 3 million acres within the United States (an area twice the size of Delaware) are lost each year to invasive plants. The massive scope of this hazard means that the entire Commonwealth experiences impacts from these species. Furthermore, the ability of invasive species to travel far distances (either via natural mechanisms or accidental human interference) allows these species to propagate rapidly over a large geographic area.[89]

Regulations on Invasive Species

Massachusetts has a variety of laws and regulations in place that attempt to mitigate the impacts of these species. The Department of Agricultural Resources (DAR) has added the plant species described to a list of noxious weeds regulated with prohibitions on importation, propagation, purchase and sale in the Commonwealth. Additionally, the Massachusetts Wetlands Protection Act (310 CMR 10.00) includes language requiring all activities covered by the Act to account for, and take steps to prevent, the introduction or propagation of invasive species.

In 2000, Massachusetts passed an Aquatic Invasive Species Management Plan, making the Commonwealth eligible for federal funds to support and implement the plan through the federal Aquatic Nuisance Prevention and Control Act. The Commonwealth also has several resources pertaining to terrestrial invasive species, such as the Massachusetts Introduced Pest Outreach Project, although a strategic management plan has not yet been prepared for these species. More specific regulations are discussed below.

330 CMR 6.0(d) requires any seed mix containing restricted noxious weeds to specify the name and number per pound on the seed label. 339 CMR 9.0 restricts the transport of currant or gooseberry species in an attempt to prevent the spread of white pine blister rust.

There are also a number of state laws pertaining to invasive species. Chapters 128, 130, and 132 of Part I of the General Laws of the state include language addressing water chestnuts, green crabs, the Asian longhorn beetle and a number of other species. These laws also include language allowing orchards and gardens to be surveyed for invasive species, and for quarantines to be put into effect, at any time.

Locally Identified Areas of Impact- Flora

The 35 plant species listed on the MIPAG website(last updated April 2016) as "Invasive"[90] are listed in **Table 3-17**.

Table 3-17
Invasive Species (Flora) in Massachusetts

Species	Common name
Acer platanoides	Norway maple
Acer pseudoplatanus	Sycamore maple
Aegopodium podagraria	Bishop's goutweed, bishop's weed; goutweed
Ailanthus altissima	Tree of heaven

[89] MEMA (2018), "SHMCAP"
[90] MIPAG, (2016) "Annotated Species Lists: Invasive": https://www.massnrc.org/mipag/invasive.htm

Species	Common name
Alliaria petiolata	Garlic mustard
Berberis thunbergii	Japanese barberry
Cabomba caroliniana	Carolina fanwort; fanwort
Celastrus orbiculatus	Oriental bittersweet; Asian or Asiatic bittersweet
Cynanchum louiseae	Black swallow-wort; Louise's swallow-wort
Elaeagnus umbellata	Autumn olive
Euonymus alatus	Winged euonymus, burning bush
Euphorbia esula	Leafy spurge; wolf's milk
Frangula alnus	European buckthorn, glossy buckthorn
Glaucium flavum	Sea or horned poppy, yellow hornpoppy
Hesperis matronalis	Dame's rocket
Iris pseudacorus	Yellow iris
Lepidium latifolium	Broad-leaved pepperweed, tall pepperweed
Lonicera japonica	Japanese honeysuckle
Lonicera morrowii	Morrow's honeysuckle
Lonicera x bella [morrowii x tatarica]	Bell's honeysuckle
Lysimachia nummularia	Creeping jenny, moneywort
Lythrum salicaria	Purple loosestrife
Myriophyllum heterophyllum	Variable water-milfoil; two-leaved water-milfoil
Myriophyllum spicatum	Eurasian or European water-milfoil; spike water- milfoil
Phalaris arundinacea	Reed canary-grass
Phragmites australis	Common reed
Polygonum cuspidatum / Fallopia japonica	Japanese knotweed; Japanese or Mexican bamboo
Polygonum perfoliatum	Mile-a-minute vine or weed; Asiatic tearthumb
Potamogeton crispus	Crisped pondweed, curly pondweed
Ranunculus ficaria	Lesser celandine; fig buttercup
Rhamnus cathartica	Common buckthorn
Robinia pseudoacacia	Black locust
Rosa multiflora	Multiflora rose
Salix atrocinerea/Salix cinerea	Rusty Willow/Large Gray Willow complex
Trapa natans	Water chestnut

Source: Massachusetts DNR

Massachusetts has also implemented biological control programs aimed at controlling the invasive species purple loosestrife (*Lythrum salicaria*), mile-a-minute vine (*Persicaria perfoliata*), hemlock woolly adelgid (*Adelges tsugae*), and winter moth (*Operophtera brumata*). Glossy Buckthorne, (*Frangula alnus*) is present throughout Royalston's forest understories and wetlands. Japanese barberry (*Berberis Thumbergii*), non-native honeysuckeles (Lonicera spp.), Oriental bittersweet (Celastris obiculatus), and Japanese knotweed (polygonum cuspidatum) are found around the Royalston Common an South Royalston[91].

Locally Identified Areas of Impact- Fauna

According to the 2018 SHMCAP, there are a number of animals that have disrupted natural systems and inflicted economic damage on the Commonwealth, as described in **Table 3-18**. Because of the rapidly evolving nature of the invasive species hazard, this list is subject to modification.

Table 3-18
Invasive Species (Fauna) in Massachusetts

Species	Common name
Lymantria dispar	Gypsy moth (insect)
Ophiostoma ulmi, Ophiostoma himal-ulmi, Ophiostoma novo-ulmi	Dutch elm disease (fungus)
Adelges tsugae	Hemlock woolly adelgid (insect)
Cryphonectria parasitica	Chestnut blight (fungus)
Anoplophora glabripennis	Asian long-horned beetle
Cronartium ribicola	White pine blister rust (fungus)
Carcinus maenus	European green crab (crab)
Hemigrapsis sanguineus	Asian shore crab
Membranipora mambranacea	Lace Bryozoan
Codium fragile ssp. fragile	Codium
Didemnum vexillum	Tunicate
Palaemon elegans	European Shrimp
Dreissena polymorpha	Zebra mussel

Over the years, a number of non-native species have been found in Royalston including Hemlock wooly adelgid (*Adelges tsugae*), and winter moth (*Operophtera brumata*), Asian long horned beetle, and White pine blister rust.

Probability of Future Occurrence

Because the presence of invasive species is ongoing, rather than a series of discrete events, it is difficult to quantify the frequency of these occurrences. However, increased rates of global trade and travel have created many new pathways for the dispersion of exotic species. A warming climate may place stress on colder-weather species, while allowing non-native species accustomed to warmer climates to spread northwards. Elevated

[91] 2017, "Town of Royalston Open Space & Recreation Plan, 2010-2016"

atmospheric CO2 concentrations could reduce the ability of ecosystems to recover after a major disturbance, such as flood or fire. As a result, invasive species, which are often able to establish more rapidly following a disturbance, could have an increased probability of successful establishment or expansion.

The Planning Team determined that it is **HIGHLY LIKELY** that invasive species will continue to impact the planning area in the future.

Invasive Species Impacts on Royalston's Key Sectors

Invasive Species Exposure and Vulnerability By Key Sector[92]	
Built Environment	As described above, water bodies such as reservoirs could be exposed to the zebra mussel if it is introduced.
Natural Resources and Environment	Invasive species present a significant threat to the environment and natural resources present in Royalston. Research has found that competition or predation by alien species is the second most significant threat to biodiversity, only surpassed by direct habitat destruction or degradation.
Economy	Invasive species are widely considered to be one of the most expensive natural hazards in the United States, as invasive control efforts can be quite extensive and these species can damage crops, recreational amenities, and public goods such as water quality.
Vulnerable Populations	Individuals who are particularly vulnerable to the economic impacts of this hazard would include all groups who depend on existing ecosystems for their economic success.

[92] MEMA (2018), "SHMCAP"

Section 4 Asset Inventory

Section 4 provides an inventory of the community assets that are important to the Town of Royalston. This Section is broken up into three parts: a discussion of current and future land use trends, a description of the community asset categories used, and the results of the Royalston Community Assets Inventory. Identifying community assets allows the Town to investigate how they will be impacted by the different natural hazards.

4.1 LAND USE TRENDS-FUTURE DEVELOPMENT

Growth and development in Royalston has historically been limited to agricultural and forestry operations, and residential development clustered around the village centers or along existing roads. Approximately 41% of the land area in Royalston is designated as permanently protected open space, with another 26% managed under Massachusetts Chapter 61 for forestry, agriculture, or wildlife conservation. However, due to the large size of the Town and relatively low level of current development, a build-out analysis conducted by the Montachusett Regional Planning Commission in 2002 determined that, based on zoning and land use regulations, approximately 17,299 acres in Town are developable. If the developable lots were to be developed to maximum build-out levels, the 17,299 acres could be converted to 4,784 new house lots with a total of approximately 14,250 new residents. However, this level of build-out is unlikely, and the Town expects to see continued slow development consistent with historical levels of approximately 50 new units per decade. [93]

Based on Fiscal Year 2019 Assessors Data, 625 parcels are undeveloped. Of those, 269 parcels are classified as Use Code 130, Vacant Land in a Residential Zone or Accessory to a Residential Parcel, Developable Land, while 113 parcels are classified as Use Code 132, Undevelopable Land. The remaining undeveloped parcels are classified as accessory parcels, sand and gravel mining, electric transmission right-of-way, forest land designated under Chapter 61, productive land (field crops, woodlots, and pasture), recreational land, public service properties, and land owned by DCR or DFW.

Potential Future Development

Based on 2019 Assessors data, there are 5,735 parcels in Royalston classified as developable land (land use codes 130, 390, or 440). Of those, there are 89 parcels greater than 10 acres in size and potential future use as subdivisions.

The Buildout Analysis completed in 2001 by the Massachusetts EEA as part of the Community Preservation Initiative[94], which projected the development that could occur in an area under current law, estimated that buildout conditions would consist of 15,512 residents, 5,749 residential units, 17,299 acres of additional developable land area, 155 miles of additional roadway, and no additional commercial/industrial buildable floor area.

[93] Town of Royalston (2010), "Open Space & Recreation Plan, 2010-2016"
[94] Town of Royalston (2004), "Open Space & Recreation Plan, 2004-2009"

ASSET INVENTORY

4.2 COMMUNITY ASSET INVENTORY

Photo 4.1: Whitney Hall (Town offices)

FEMA defines a community asset as anything that is important to the character and function of a community. Community assets can be split up into four different categories: People, Economy, Built Environment, and Natural Environment.

The People category includes populations that are more vulnerable to disaster (e.g., elderly, children, visiting populations), densely populated areas, and societal assets such as cultural and historical resources. Economy is included because economic drivers are a major part of disaster recovery. Community assets in the Economy category can include major employers, commercial centers, and locations providing food, medical supplies and building materials. The Built Environment is the largest category and includes existing structures, infrastructure (transportation and utilities) and critical facilities important for disaster response and evacuation (e.g., police, fire stations and medical facilities). The Natural Environment category is meant to capture any natural resources important to the community's character, economy (tourism, recreation, and the protection of clean air and water), and ecosystem services (e.g., wetlands providing flood storage).

Table 4.1 summarizes the community asset categories included in FEMA guidelines, relevant critical sectors within each category, and the general characteristics that describe why these assets are important to include in a hazard mitigation plan.

Table 4.1
Community Asset Categories and Characteristics

FEMA Community Asset Categories	Critical Sectors	Characteristics of Community Assets
People- Societal Assets	Schools, Vulnerable Populations, Cultural and Historical Facilities	Areas of greater population density, or population with unique vulnerabilities or less able to respond and recover during a disaster.
Built Environment-Infrastructural Assets	Critical Municipal Facilities, Water, Wastewater, Energy, Stormwater, Transportation	Critical facilities necessary for a community's response to and recovery from emergencies, infrastructure critical for public health and safety, economic viability, or for critical facilities to operate.
Economic Assets	Seaport, Business District, Food and Medical Supplies, Building Supplies	Major employers, primary economic sectors and commercial centers where loss or inoperability would have severe impact on the community and ability to recover from a disaster.
Environmental Assets	Natural Resources	Areas that provide protective function to reduce magnitude of hazard impact and increase resiliency. Areas of sensitive habitat that are vulnerable to hazard events, protection of areas that are important to community objectives, such as the protection of sensitive habitat, provide socio-economic benefits, etc.

ASSET INVENTORY

Each Community Asset Category was further subdivided into subtypes (e.g., schools, bridges, cemeteries, municipal offices) to provide a more comprehensive picture of resources. In total, 79 site-specific community assets were identified within the four FEMA categories.

Map 1 (1a-1h), provided at the end of **Section 4**, shows the locations of all identified community assets relative to FEMA flood zones, and a detailed list of assets is provided in **Tables 4.4**, **4.5**, **4.6, and 4.7** below. **Section 5 Vulnerability Risk Assessment** provides a discussion on **natural hazards that may impact** the community assets, and their vulnerability.

People – Societal Assets

Societal assets in Royalston include historic and cultural resources, buildings that support community needs, vulnerable populations, and gathering places (**Table 4.2**). . Strengths include the central information and support resources at the Phinehas S. Newton Library and Post Office, and the strong community social network and neighbor-helping-neighbor arrangement in Town. Vulnerabilities include the need for repairs to many of the historical buildings, the fact that many buildings in Town are historical resources and are vulnerable to storm damage, and that the Royalston Community School and other Town-owned facilities do not have generators or other emergency back-up power.

Photo 4.2: Phinehas S. Newton Public Library

Table 4.2
Societal Assets in Royalston

Name	Subtype
Gale and Gates Cemetery	Cemetery
Jonas Alliene Cemetery	Cemetery

ASSET INVENTORY

Name	Subtype
Lawrence Brook Cemetery	Cemetery
Maple Cemetery	Cemetery
Newton Cemetery	Cemetery
Riverside Cemetery	Cemetery
Olde Centre Cemetery	Cemetery
Under the Hill Cemetery	Cemetery
Hillside Cemetery	Cemetery
First Congregational Church	Church
Second Congregational Church	Church
Vale do Amanhecer	Church
Royalston Historical Society	Historic
Royalston Historical District	Historic District
Royalston Town Hall	Municipal / Historic /Culture
Whitney Hall	Municipal / Historic
Phinehas S Newton Library	Municipal / Cultural
Town Common	Municipal / Historic / Recreation
South Village Common	Municipal / Recreation
Tully Lake Campground	Open Space / Recreation
Royalston Rod & Gun Club	Open Space / Recreation
Winchendon Rod & Gun Club	Open Space / Recreation
South Village	People / Dense Development
Royalston Post Office	Post Office
The Village School	School / Private
Royalston Community School	School / Public

Built Environment – Infrastructural Assets

Infrastructural sectors with vulnerabilities or strengths in Royalston consist of flood control infrastructure, transportation corridors, critical facilities, and communications and energy (**Table 4.3**). Infrastructural asset strengths include the relatively new wastewater treatment plant, which has back-up power, National Grid's Hazard Tree Program that identifies and removes trees that endanger power lines, flood control provided by the Tully and Birch Hill Dams, evacuation routes used by both Town residents and adjacent communities, and emergency services provided by the Fire and Police Departments. Vulnerabilities are that the evacuation routes are subject to flooding, culverts in Town are undersized and overtop even under minor rainfall

conditions, the railroad transports hazardous materials adjacent to waterways, and back-up power is not widely available.

Photo 4.3: Birch Hill Dam.

Table 4.3
Infrastructural Assets in Royalston

Name	Subtype
Baldwinville Wastewater Pumping Station 96-4555-AM	Alarmed Pumping Station
King St. Wastewater Pumping Station 96-4556-AM	Alarmed Pumping Station
Main St. Wastewater Pumping Station 96-4557-AM	Alarmed Pumping Station
Doane's Falls Bridge	Bridge
Northeast Fitzwilliam Road Bridge	Bridge
South Village Bridge	Bridge
Stockwell Road Bridge	Bridge
Lawrence Brook Bridge on South Royalston Road	Bridge
Birch Hill Dam	Dam
Tully Dam	Dam
Royalston Fire Station	Municipal / Public Safety
Royalston Fire Station #2	Municipal / Public Safety
Royalston Police Station	Municipal / Public Safety

ASSET INVENTORY

Name	Subtype
Whitney Hall	Municipal Offices
Royalston Town Hall	Municipal Offices / Meetings
Raymond Building	Municipal Offices (future)
Royalston Transfer Station	Municipal / Transfer Station
Royalston Substation #701	Power Utilities
Royalston Water Tank	PWS Tank
Blossom Street Rock Well	PWS Well
The Village School	PWS Well
Tully Lake Campground	PWS Well
Helicopter LZ 1 - Tully Lake	Transportation
Helicopter LZ 2 - Birch Hill Dam (alternate: Royalston Fish & Game)	Transportation
Helicopter LZ 3 - The Village School	Transportation
Railroad Tracks	Transportation
Route 32	Transportation/Evacuation Route
Route 68	Transportation/Evacuation Route
Athol Road	Transportation/Evacuation Route
North Fitzwilliam Road	Transportation/Evacuation Route
Northeast Fitzwilliam Road	Transportation/Evacuation Route
Winchendon Road	Transportation/Evacuation Route
South Royalston Wastewater Treatment Plant	Wastewater Treatment Plant
Public Safety Communication Tower	Communication Tower
Center SLCCs	Telephone Connection
South SLCC	Telephone Connection
West SLCC	Telephone Connection

Environmental Assets

Environmental assets identified in Royalston as having vulnerabilities or strengths are hydrologic resources, open space and conservation lands, parks and recreational areas, and lands used for forestry and agriculture. (**Table 4.4**). Strengths include the space provided for community functions on parks and recreation land, the recreation, tourism, and environmental education opportunities provided by conservation lands, and water and air purification provided by forested lands. Vulnerabilities of environmental assets are flooding due to high groundwater and erosion and other impacts to resource areas and public safety concerns related to the high number of visitors to conservation areas.

Photo 4.4: Doane's Falls (Scenic Adventures Photography, 2014)

Table 4.4
Environmental Assets in Royalston

Name	Subtype
Bullock Park	Open Space / Recreation
Doane's Falls/Coddings Meadow	Open Space / Recreation
Jacob's Hill/The Ledges/Spirit Falls	Open Space / Recreation
Royalston Falls	Open Space / Recreation
Chase Memorial Forest	Open Space / Recreation
Ehrich Memorial Forest	Open Space / Recreation
Royalston Academy Conservation Area	Open Space / Recreation
Royalston State Forest	State Forest
Warwick State Forest	State Forest
Otter River State Forest	State Forest
East Branch Tully River and Long Pond	Waterbody / Recreation / Wetland
Millers River	Waterbody / Recreation / Wetland
Eagle Reserve	Waterbody / Recreation / Wetland
Tully Lake and Tully Lake Recreation Area	Waterbody / Recreation
Collar Brook	Waterbody/Wetland
Kinney Brook	Waterbody/Wetland
Birch Hill Wildlife Management Area	Wildlife Management Area

Name	Subtype
Lawrence Brook Wildlife Conservation Area	Wildlife Management Area
Fish Brook Wildlife Management Area	Wildlife Management Area
Millers River Wildlife Management Area	Wildlife Management Area

Economic Assets

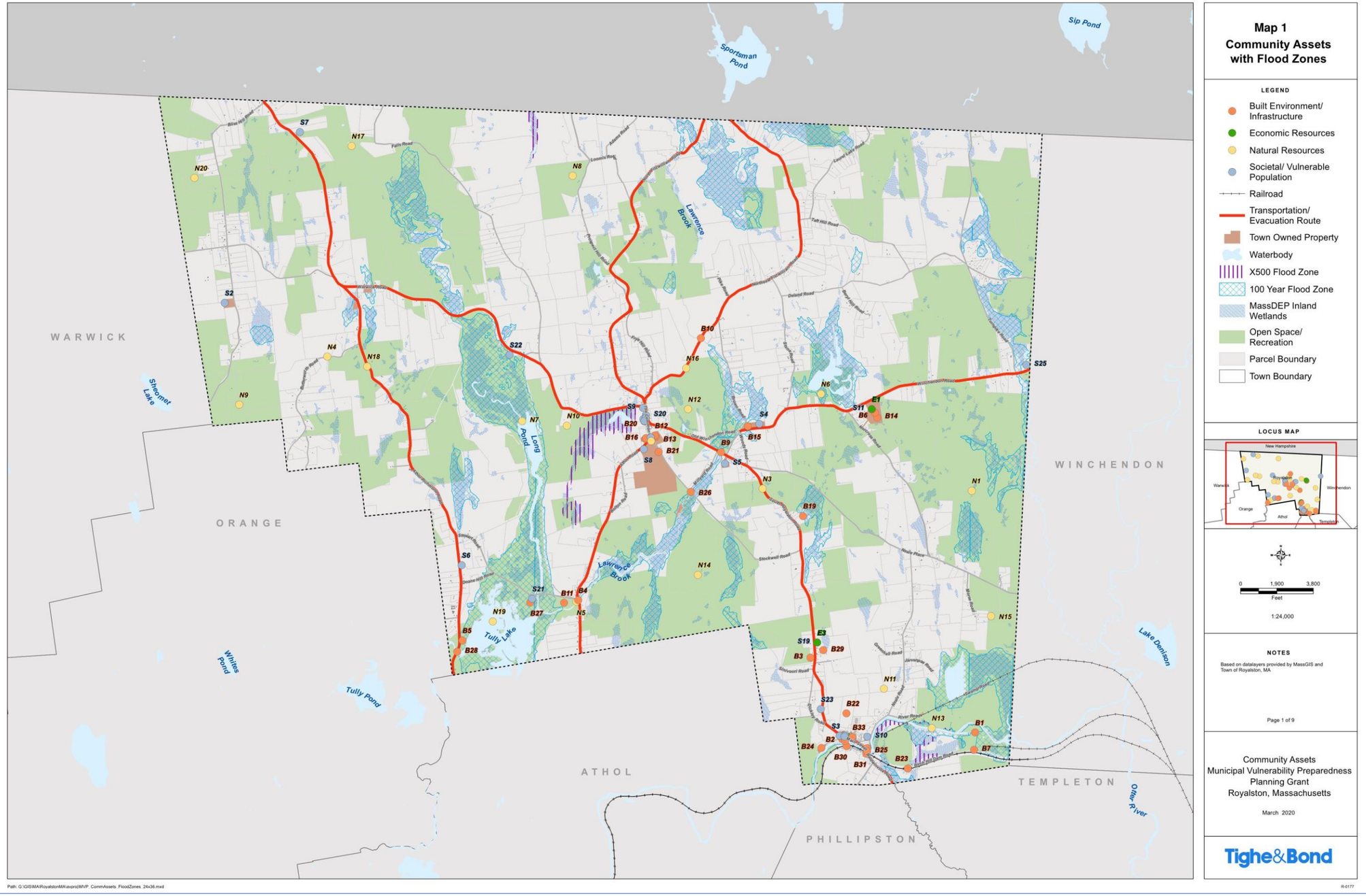
Economic assets in Royalston are limited to the major employers (schools) and the general store (**Table 4.5**).

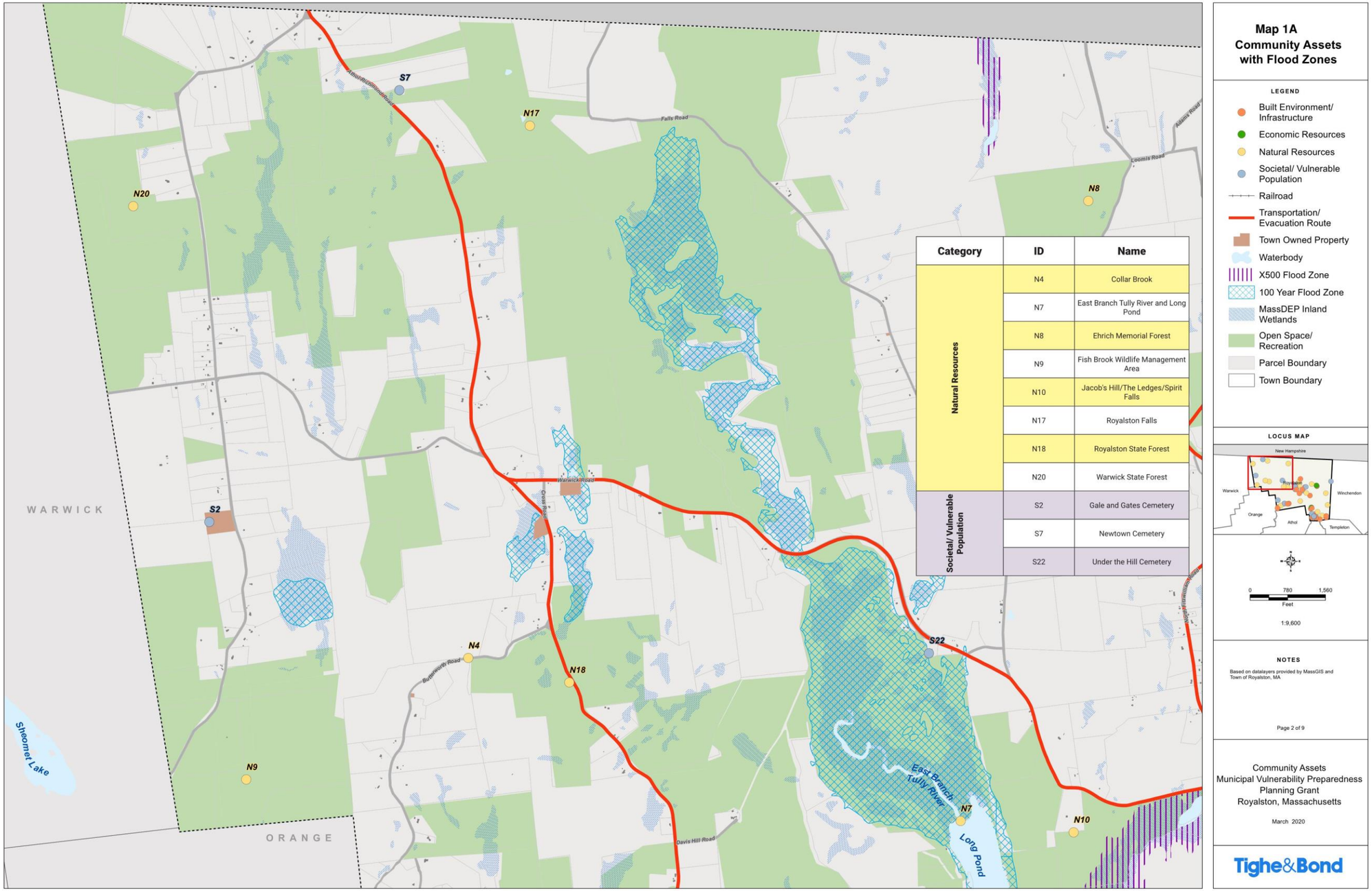
Photo 4.5: Royalston General Store

Table 4.5
Economic Assets in Royalston

Name	Subtype
Royalston General Store	Food/Grocery
Royalston Community School	Major Employer
The Village School	Major Employer

ASSET INVENTORY





Category	ID	Name
Natural Resources	N4	Collar Brook
	N7	East Branch Tully River and Long Pond
	N8	Ehrich Memorial Forest
	N9	Fish Brook Wildlife Management Area
	N10	Jacob's Hill/The Ledges/Spirit Falls
	N17	Royalston Falls
	N18	Royalston State Forest
	N20	Warwick State Forest
Societal/ Vulnerable Population	S2	Gale and Gates Cemetery
	S7	Newtown Cemetery
	S22	Under the Hill Cemetery

Map 1A
Community Assets with Flood Zones

LEGEND

- Built Environment/ Infrastructure
- Economic Resources
- Natural Resources
- Societal/ Vulnerable Population
- Railroad
- Transportation/ Evacuation Route
- Town Owned Property
- Waterbody
- X500 Flood Zone
- 100 Year Flood Zone
- MassDEP Inland Wetlands
- Open Space/ Recreation
- Parcel Boundary
- Town Boundary

LOCUS MAP

0 780 1,560
Feet

1:9,600

NOTES

Based on datalayers provided by MassGIS and Town of Royalston, MA

Page 2 of 9

Community Assets
Municipal Vulnerability Preparedness
Planning Grant
Royalston, Massachusetts

March 2020

Tighe&Bond

Path: G:\GIS\MA\RoyalstonMA\arvproj\MVP_CommAssets_FloodZones_24x36.mxd

R-0177

Category	ID	Name
Built Environment/ Infrastructure	B9	Lawrence Brook Bridge
	B10	Northeast Fitzwilliam Road Bridge
	B15	Royalston DPW Building
	B26	Stockwell Road Bridge
Natural Resources	N3	Chase Memorial Forest
	N16	Royalston Academy Conservation Area
Societal/ Vulnerable Population	S4	Jonas Alliene Cemetery
	S5	Lawrence Brook Cemetery

Map 1B
Community Assets with Flood Zones

LEGEND

- Built Environment/ Infrastructure
- Economic Resources
- Natural Resources
- Societal/ Vulnerable Population
- Railroad
- Transportation/ Evacuation Route
- Town Owned Property
- Waterbody
- X500 Flood Zone
- 100 Year Flood Zone
- MassDEP Inland Wetlands
- Open Space/ Recreation
- Parcel Boundary
- Town Boundary

LOCUS MAP

0 400 800
Feet

1:4,800

NOTES

Based on datalayers provided by MassGIS and Town of Royalston, MA

Page 3 of 9

Community Assets
Municipal Vulnerability Preparedness Planning Grant
Royalston, Massachusetts

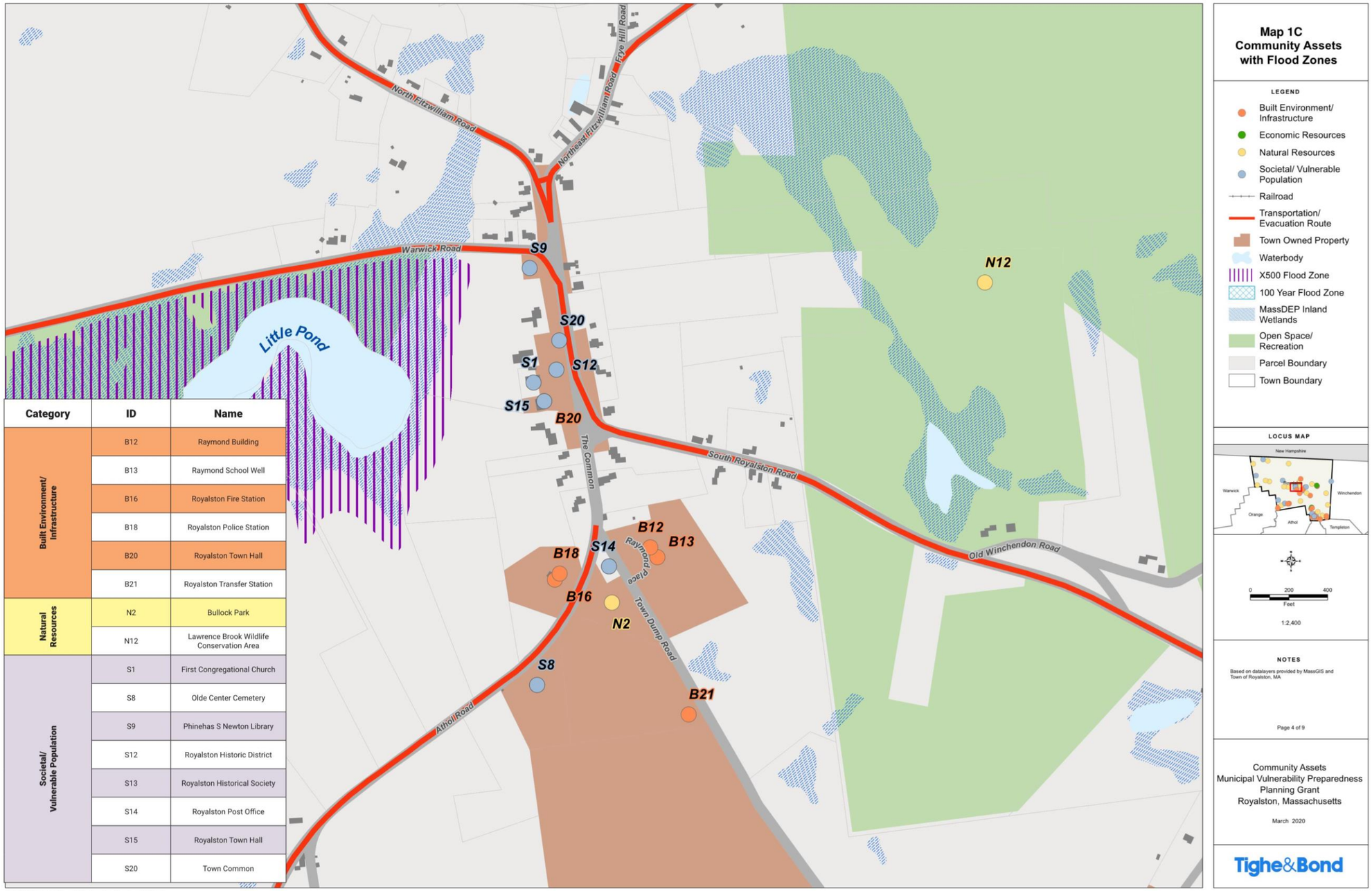
March 2020

Tighe&Bond

Path: G:\GIS\MA\RoyalstonMA\layproj\MVP_CommAssets_FloodZones_24x36.mxd

R-0177

ASSET INVENTORY



Category	ID	Name
Built Environment/ Infrastructure	B12	Raymond Building
	B13	Raymond School Well
	B16	Royalston Fire Station
	B18	Royalston Police Station
	B20	Royalston Town Hall
	B21	Royalston Transfer Station
Natural Resources	N2	Bullock Park
	N12	Lawrence Brook Wildlife Conservation Area
Societal/ Vulnerable Population	S1	First Congregational Church
	S8	Olde Center Cemetery
	S9	Phinehas S Newton Library
	S12	Royalston Historic District
	S13	Royalston Historical Society
	S14	Royalston Post Office
	S15	Royalston Town Hall
	S20	Town Common

Path: G:\GIS\MA\Royalston\MA\arcpro\MVP_CommAssets_FloodZones_24x36.mxd

Map 1C
Community Assets with Flood Zones

LEGEND

- Built Environment/ Infrastructure
- Economic Resources
- Natural Resources
- Societal/ Vulnerable Population
- Railroad
- Transportation/ Evacuation Route
- Town Owned Property
- Waterbody
- X500 Flood Zone
- 100 Year Flood Zone
- MassDEP Inland Wetlands
- Open Space/ Recreation
- Parcel Boundary
- Town Boundary

LOCUS MAP

0 200 400
Feet

1:2,400

NOTES

Based on datalayers provided by MassGIS and Town of Royalston, MA

Page 4 of 9

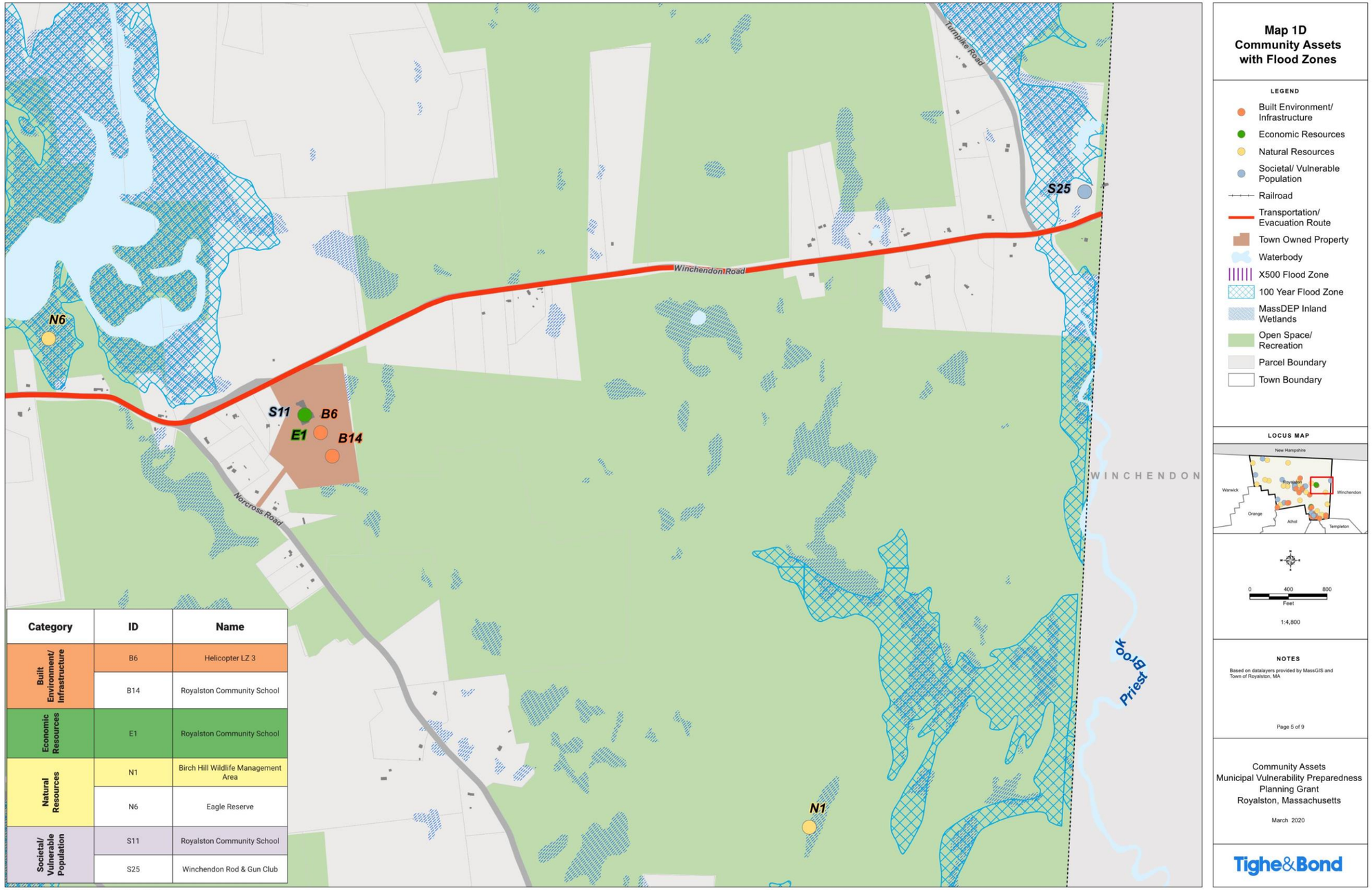
Community Assets
Municipal Vulnerability Preparedness
Planning Grant
Royalston, Massachusetts

March 2020

Tighe&Bond

R-0177

ASSET INVENTORY



Category	ID	Name
Built Environment/ Infrastructure	B6	Helicopter LZ 3
	B14	Royalston Community School
Economic Resources	E1	Royalston Community School
Natural Resources	N1	Birch Hill Wildlife Management Area
	N6	Eagle Reserve
Societal/ Vulnerable Population	S11	Royalston Community School
	S25	Winchendon Rod & Gun Club

Path: G:\GIS\MA\Royalston\MA\arcproj\MVP_CommAssets_FloodZones_24x36.mxd

Map 1D
Community Assets with Flood Zones

LEGEND

- Built Environment/ Infrastructure
- Economic Resources
- Natural Resources
- Societal/ Vulnerable Population
- Railroad
- Transportation/ Evacuation Route
- Town Owned Property
- Waterbody
- X500 Flood Zone
- 100 Year Flood Zone
- MassDEP Inland Wetlands
- Open Space/ Recreation
- Parcel Boundary
- Town Boundary

LOCUS MAP

0 400 800
Feet

1:4,800

NOTES

Based on datalayers provided by MassGIS and Town of Royalston, MA

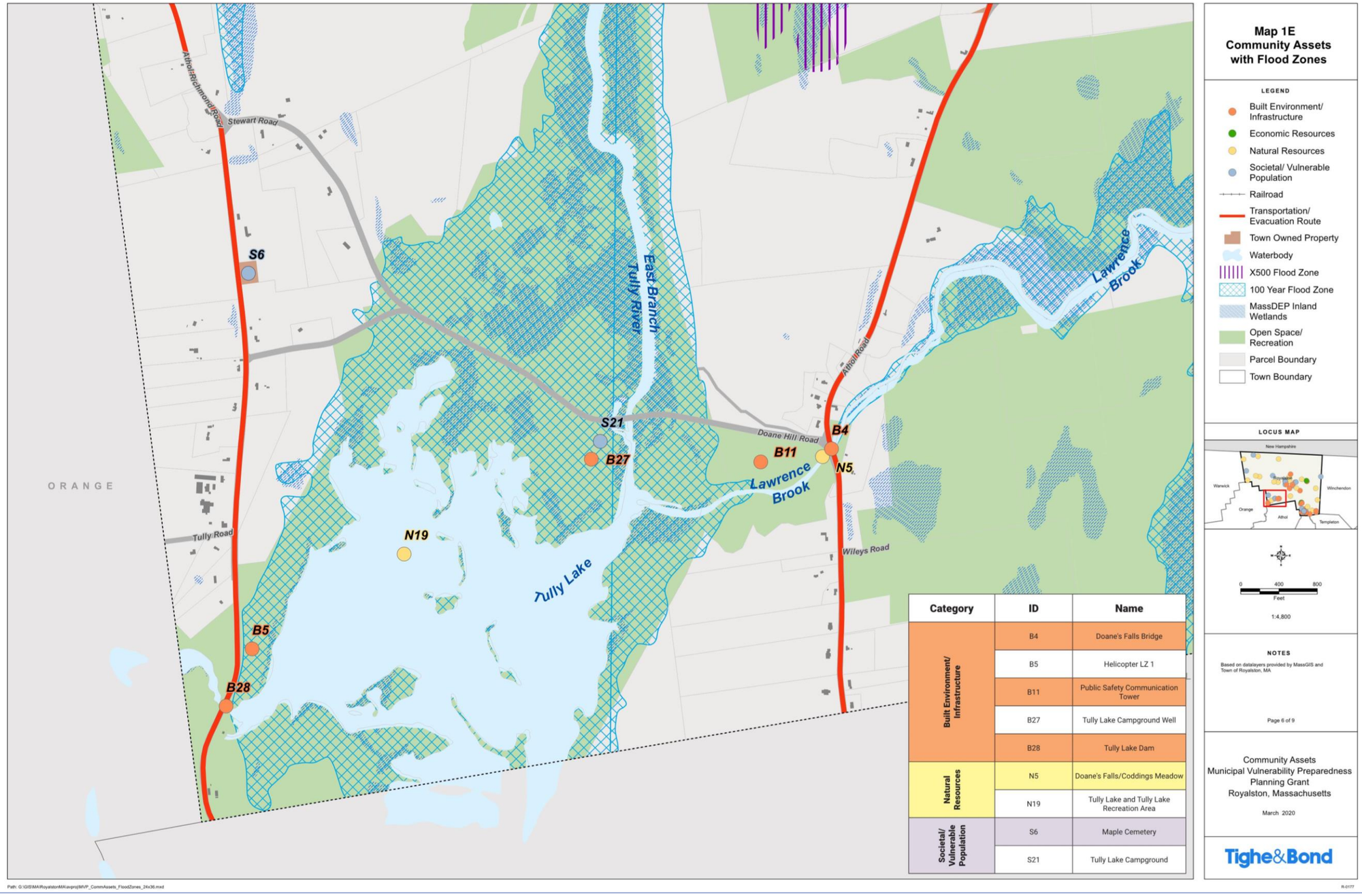
Page 5 of 9

Community Assets
Municipal Vulnerability Preparedness
Planning Grant
Royalston, Massachusetts

March 2020

Tighe&Bond

R-0177



Category	ID	Name
Built Environment/ Infrastructure	B4	Doane's Falls Bridge
	B5	Helicopter LZ 1
	B11	Public Safety Communication Tower
	B27	Tully Lake Campground Well
	B28	Tully Lake Dam
Natural Resources	N5	Doane's Falls/Coddings Meadow
	N19	Tully Lake and Tully Lake Recreation Area
Societal/ Vulnerable Population	S6	Maple Cemetery
	S21	Tully Lake Campground

Map 1E
Community Assets with Flood Zones

LEGEND

- Built Environment/ Infrastructure
- Economic Resources
- Natural Resources
- Societal/ Vulnerable Population
- Railroad
- Transportation/ Evacuation Route
- Town Owned Property
- Waterbody
- X500 Flood Zone
- 100 Year Flood Zone
- MassDEP Inland Wetlands
- Open Space/ Recreation
- Parcel Boundary
- Town Boundary

LOCUS MAP

0 400 800
Feet

1:4,800

NOTES

Based on datalayers provided by MassGIS and Town of Royalston, MA

Page 6 of 9

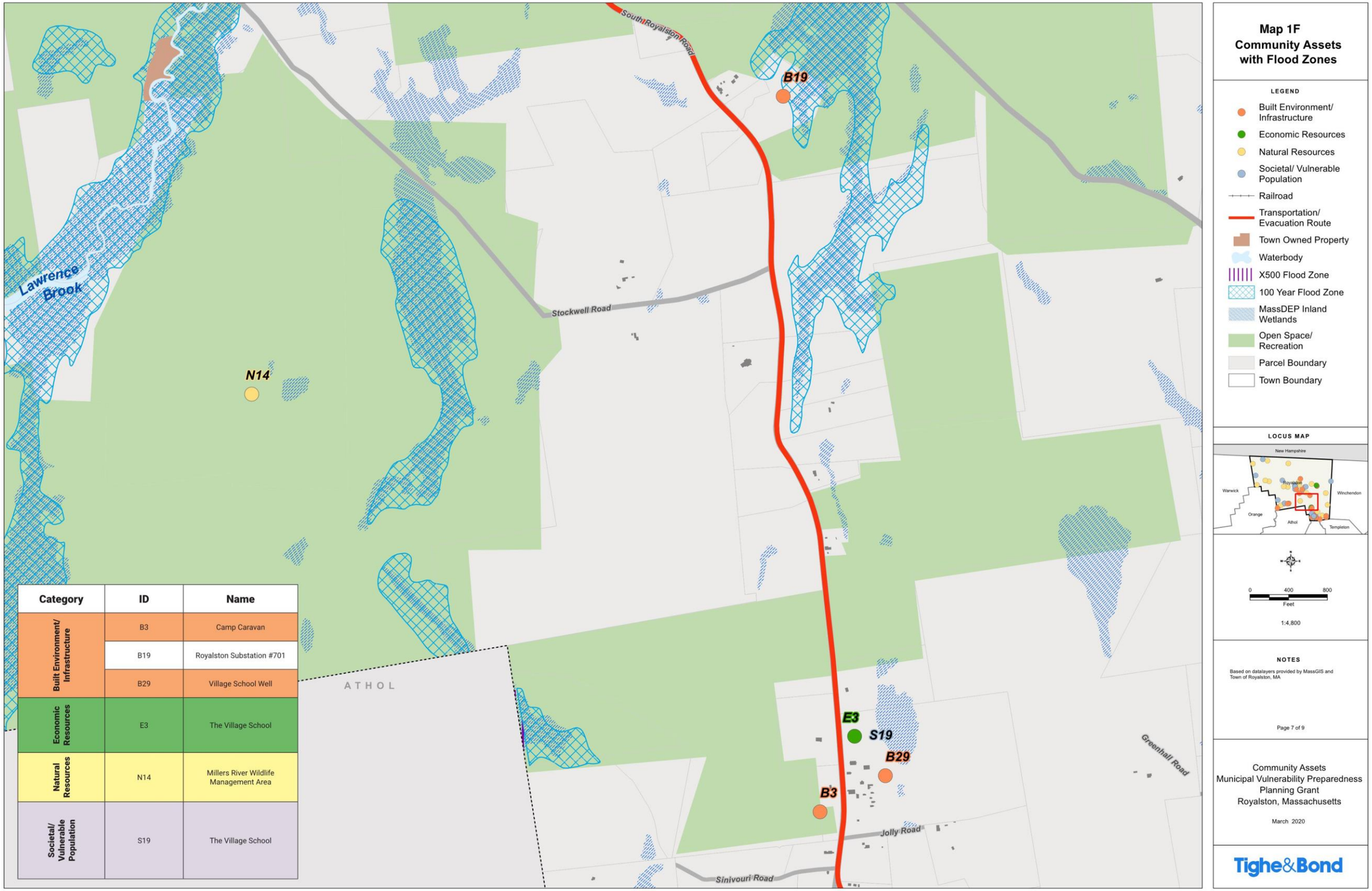
Community Assets
Municipal Vulnerability Preparedness Planning Grant
Royalston, Massachusetts

March 2020

Tighe&Bond

Path: G:\GIS\MA\RoyalstonMA\lavproj\MVP_CommAssets_FloodZones_24x36.mxd

R-01777



Category	ID	Name
Built Environment/ Infrastructure	B3	Camp Caravan
	B19	Royalston Substation #701
	B29	Village School Well
Economic Resources	E3	The Village School
Natural Resources	N14	Millers River Wildlife Management Area
Societal/ Vulnerable Population	S19	The Village School

Map 1F
Community Assets with Flood Zones

LEGEND

- Built Environment/ Infrastructure
- Economic Resources
- Natural Resources
- Societal/ Vulnerable Population
- Railroad
- Transportation/ Evacuation Route
- Town Owned Property
- Waterbody
- X500 Flood Zone
- 100 Year Flood Zone
- MassDEP Inland Wetlands
- Open Space/ Recreation
- Parcel Boundary
- Town Boundary

LOCUS MAP

0 400 800
Feet

1:4,800

NOTES

Based on datalayers provided by MassGIS and Town of Royalston, MA

Page 7 of 9

Community Assets
Municipal Vulnerability Preparedness Planning Grant
Royalston, Massachusetts

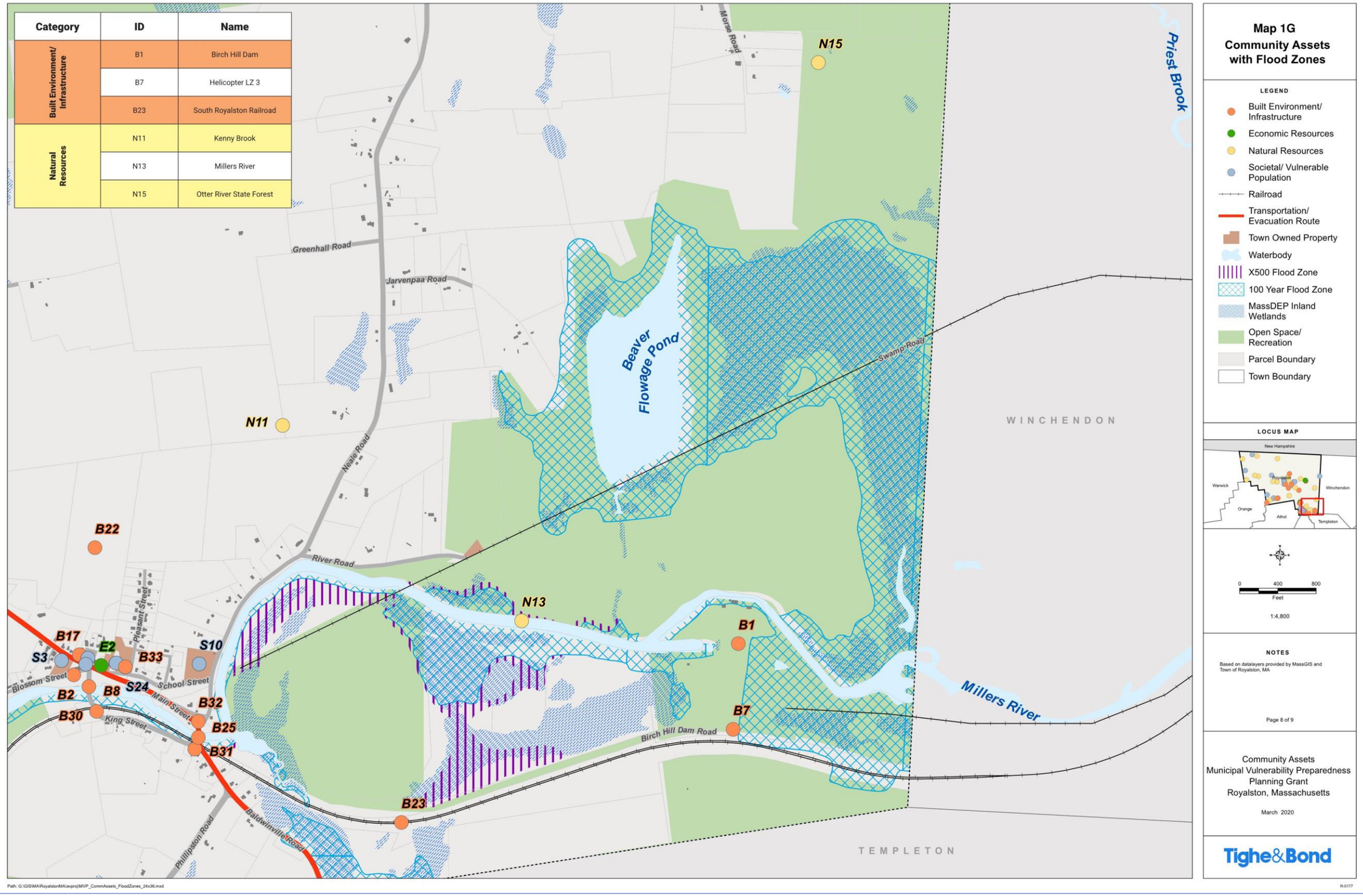
March 2020

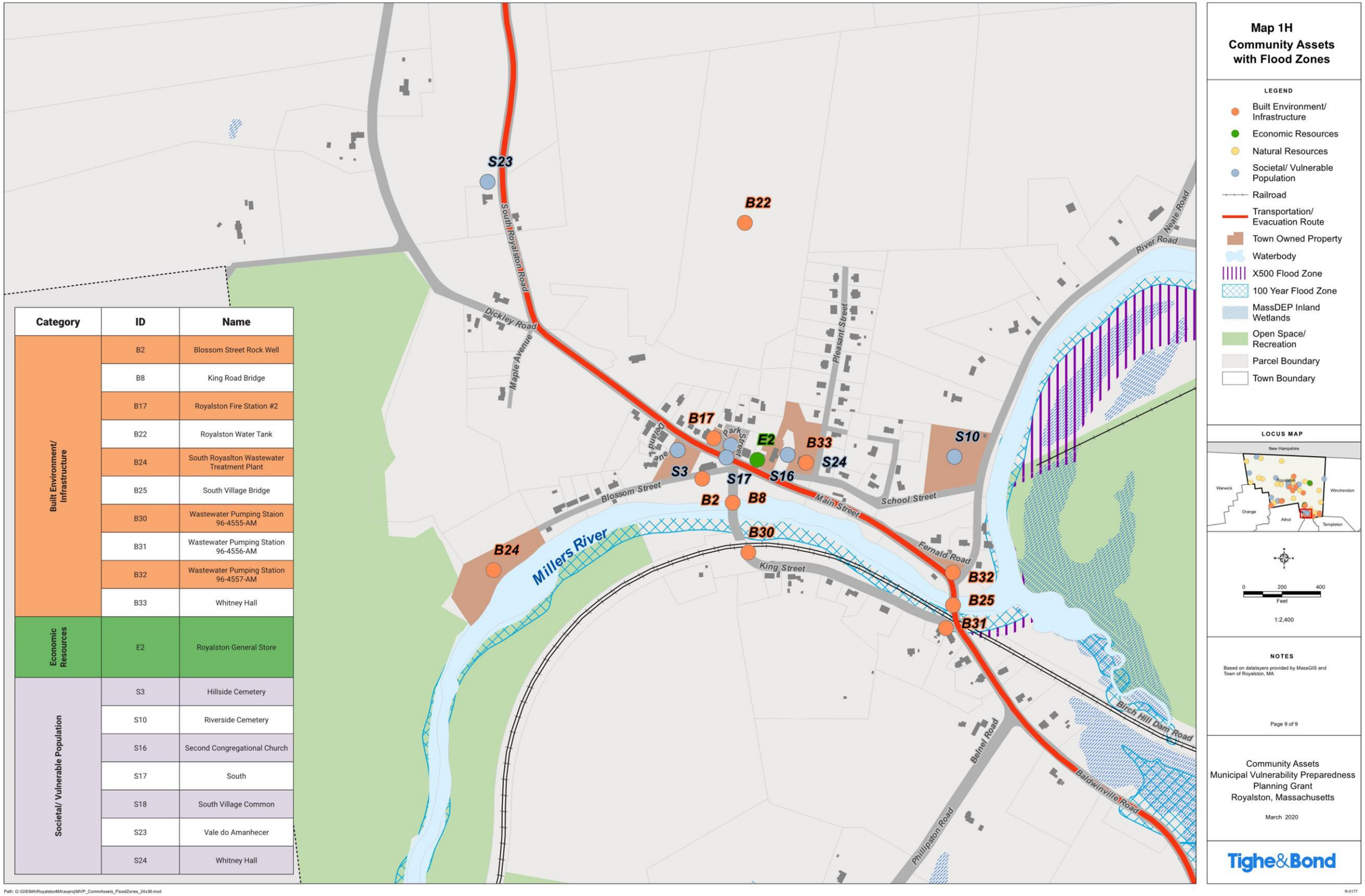
Tighe&Bond

Path: G:\GIS\MA\RoyalstonMA\lavproj\MVP_CommAssets_Flood2zones_24x36.mxd

R-0177

ASSET INVENTORY





Category	ID	Name
Built Environment/ Infrastructure	B2	Blossom Street Rock Well
	B8	King Road Bridge
	B17	Royalston Fire Station #2
	B22	Royalston Water Tank
	B24	South Royaslton Wastewater Treatment Plant
	B25	South Village Bridge
	B30	Wastewater Pumping Staion 96-4555-AM
	B31	Wastewater Pumping Station 96-4556-AM
	B32	Wastewater Pumping Station 96-4557-AM
	B33	Whitney Hall
Economic Resources	E2	Royalston General Store
Societal/ Vulnerable Population	S3	Hillside Cemetery
	S10	Riverside Cemetery
	S16	Second Congregational Church
	S17	South
	S18	South Village Common
	S23	Vale do Amanhecer
	S24	Whitney Hall

Map 1H
Community Assets with Flood Zones

LEGEND

- Built Environment/ Infrastructure
- Economic Resources
- Natural Resources
- Societal/ Vulnerable Population
- Railroad
- Transportation/ Evacuation Route
- Town Owned Property
- Waterbody
- X500 Flood Zone
- 100 Year Flood Zone
- MassDEP Inland Wetlands
- Open Space/ Recreation
- Parcel Boundary
- Town Boundary

LOCUS MAP

0 200 400
Feet

1:2,400

NOTES

Based on data/layers provided by MassGIS and Town of Royalston, MA

Page 9 of 9

Community Assets
Municipal Vulnerability Preparedness
Planning Grant
Royalston, Massachusetts

March 2020

Tighe&Bond

Path: G:\GIS\MA\RoyalstonMA\arcproj\MVP_CommAssets_Flood2zones_24x36.mxd

R-0177

Section 5 Vulnerability Assessment

5.1 VULNERABILITY ASSESSMENT OVERVIEW

B3 b

The purpose of the vulnerability assessment is to estimate the extent or magnitude of potential damages from natural hazards of varying types and intensities. Section 5 ties together the hazards identified in Section 3 and the community assets identified in Section 4 to estimate the potential losses that Royalston could experience during a natural hazard event. There are three assessments included in **Section 5** of the 2020 Royalston Hazard Mitigation Plan:

1. **HAZUS-Multi Hazards (MH) Assessment:** Hazus is a standardized hazard assessment methodology created by FEMA. This vulnerability assessment includes estimation of damages for hurricanes and earthquakes using HAZUS-MH software and is described in **Section 5.2**.

2. **Exposure Assessment of Parcels and Building Flood Risk**: This assessment was completed using GIS analysis for existing flooding and future flooding due to climate change for the entire Town, assessor's data, and the most recent FEMA Flood Zones. This assessment is described in **Section 5.3.1**.

3. **Vulnerability Assessment for Future Development:** This assessment was completed for areas slated for future development, identifying natural hazard risk from hurricanes, earthquakes, and flooding, and is further described in **Section 5.3.2.**

5.2 HAZUS-MH FOR HURRICANES AND EARTHQUAKES

Methodology

Hazus-MH (multiple-hazards) is a computer program developed by FEMA to estimate losses due to a variety of natural hazards. For the purposes of this Plan, Hazus-MH was used to estimate losses due to hurricane winds and earthquakes. The following overview of Hazus-MH is taken from the FEMA website:[95]

"Hazus is a nationally applicable standardized methodology that estimates potential losses from earthquakes, hurricane winds, and floods. FEMA developed Hazus under contract with the National Institute of Building Sciences (NIBS).

Hazus uses state-of-the-art GIS software to map and display hazard data and the results of damage and economic loss estimates for buildings and infrastructure. It also allows users to estimate the impacts of earthquakes, hurricane winds, and floods on populations.

Estimating losses is essential to decision-making at all levels of government, providing a basis for developing mitigation plans and policies, emergency preparedness and response, and recovery planning."

There are three modules included with the Hazus-MH Version 4.2 software: hurricane wind, flooding, and earthquakes, that reflects 2010 Census Data. There are also three levels at which Hazus-MH can be run. Level 1 uses national baseline data and is the quickest way to begin the risk assessment process. The analysis in this Plan was completed using Level 1 data.

[95] For more information on the Hazus-MH software, go to https://www.fema.gov/hazus

Level 1 relies upon default data on building types, utilities, transportation, etc. from national databases as well as census data. While the databases include a wealth of information on the community, it does not capture all relevant information. In fact, the HAZUS training manual notes that the default data is "subject to a great deal of uncertainty."

However, for the purposes of this Plan, the analysis is useful. This Plan is attempting to only generally indicate the possible extent of damages due to certain types of natural disasters and to allow for a comparison between different types of disasters. Therefore, this analysis should be considered a starting point for understanding potential damages from the hazards.

Results - Hurricanes

For the purposes of this Plan, a Category 2 and a Category 4 storm were chosen to illustrate damages. The reason is to present more of a "worst case scenario" that would help planners and emergency personnel evaluate the impacts of storms that might be more likely in the future, as we enter into a period of more intense and frequent storms. **Table 5.1** below presents estimated damages from hurricanes.

Table 5.1
Estimated Damages from Hurricanes

Damage Categories	Category 2 Storm (Carol peak gust 100)	Category 4 Storm (Donna peak gust 152mph)
Building Characteristics		
Estimated total number of buildings	1,269	1,269
Estimated total building replacement value (Year 2010 $) (Millions of Dollars)	$351.3	$351.3
Building Damages		
# of buildings sustaining minor damage	0	0
# of buildings sustaining moderate damage	0	0
# of buildings sustaining severe damage	0	0
# of buildings destroyed	0	0
Population Needs		
# of households displaced	0	0
# of people seeking short-term public shelter	0	0
Debris		
Building debris generated (tons)	0	0
Tree debris generated (tons)	37	1,740
Value of Damages (Thousands of dollars)		
Total economic losses from property damage	$77.0	$160.0
*No Category 4 or 5 hurricanes have been recorded in New England. However, a Category 4 hurricane was included to help the community understand the impacts of a hurricane beyond what has historically occurred in New England.		

Results - Earthquakes

The Hazus earthquake module allows users to define a number of different types of earthquakes and to input a number of different parameters. The module is more useful where there is a great deal of data available on earthquakes. In New England, defining the parameters of a potential earthquake is much more difficult because there is little historical data.

The earthquake module does offer the user the opportunity to select a number of historical earthquakes that occurred in Massachusetts. For the purposes of this Plan, two earthquakes were selected: an earthquake with a 5.1 magnitude and 10 fault depth and a 5.8 with 10 fault depth. **Table 5.2** below presents estimated damages from earthquakes.

Table 5.2
Estimated Damages from Earthquakes

Damage Categories	Magnitude 5.1	Magnitude 5.8
Building Characteristics		
Estimated total number of buildings	1,269	1,269
Estimated total building replacement value (Year 2010 $)(Millions of dollars)	$351.3	$351.3
Building Damages		
# of buildings with no damage	579	221
# of buildings sustaining slight damage	383	386
# of buildings sustaining moderate damage	219	376
# of buildings sustaining extensive damage	69	153
# of buildings completely damaged	19	133
Population Needs		
# of households displaced	40	151
# of people seeking short-term public shelter	22	82
Debris		
Debris generated (tons)	8	28
Value of Damages (Millions of dollars)		
Total property economic loss	$43.5	$120.8
(42.677579° N, -72.187872° W) epicenter location.		

5.3 EXPOSURE ASSESSMENT OF PARCEL AND BUILDING FLOOD RISK

An exposure assessment was used to estimate losses due to flooding. An exposure assessment is a geospatial evaluation where geographic areas and hazards are mapped together to show the physical relationship to one another. The geospatial relationship can also be used to quantify the number and value of parcels and structures within the hazard area to estimate losses. For flooding, a GIS-based exposure analysis was used to identify potential losses of developed properties that fall within Royalston's 100-year and 500-year flood zones, as defined in **Section 3.2.1**.

The analysis for current conditions was based on Royalston's 2019 Assessor's data and the most recent FEMA approved flood zones (6/15/1983). Future flooding with climate change was evaluated using the extent of the 500-year flood zone.

Existing Flood Vulnerability Assessment Methodology

The vulnerability assessment will identify locations that are at risk from flooding inundation based on current and historic flooding extent as defined by the FEMA 100-year flood plain and predicted future flooding extent using the 500-year flood. The following assumptions were used in the methodology.

Risk of Current Flooding- FEMA Analysis for Developed Parcels, and Community Assets

Current risk of flooding is evaluated based on the most recent approved FEMA flood zones (dated 6/15/1983).

- Developed properties and Community Assets currently within the FEMA mapped A, and AE zones were identified, including areas with defined base flood elevations or inundation depth.
- Determination of risk was based on whether a mapped building is within the zone, not based on whether the parcel boundary alone is within the zone.
- The total building value for A zone parcels is included in Table 5.3. Individual properties and land use classifications were not identified for privacy.
- Community Asset located within FEMA flood zones were also identified

Risk of Future Flooding- FEMA Analysis for Developed Parcels

- Developed properties currently within the FEMA mapped X500 zones will be identified following the same selection criteria as described above for A zone analysis.

Results

Out of a total of 617 developed parcels in Royalston about 12% (78) are located in the FEMA 100-year flood plain. .Based on the building value of the developed property, estimated potential losses for inland areas are tabulated in **Table 5.3**.

Table 5.3
Flooding Vulnerability in Royalston Current Development- Building Values

FEMA 100-year Flood Zone	Number of Developed Parcels within the Zone	Building Value
A	73	$10,044,700
AE	5	$423,400
Total	78	$10,468,100,

A total of 8 of Royalston's developed parcels are located within inland or riverine 500-year flood hazard areas. Out of a total of 617 developed parcels in Royalston about 1% (8) are located in the FEMA 500-year flood plain. . Based on the building value of the developed property, estimated potential losses for inland areas are tabulated in **Table 5.4**.

Table 5.4
Future Flooding Vulnerability in Royalston Current Development- Building Values

FEMA 500-year Flood Zone	Number of Developed Parcels within the Zone	Building Value
X500	8	$1,541,500

The total value of properties located within flood zones is $12,009,600 .

Community Assets within Flooding Zones

A total of eight community assets were located within the 100-year flood zone:

- Department of Public Works Building -B15

- Jonas Alliene Cemetery- S4
- Helicopter LZ1 -B5
- Tully Lake Campground Well- B27
- Tully Lake Campground S21
- Winchendon Rod & Gun Club -S25
- South Royalston Wastewater Treatment Plant B24
- Wastewater Pumping Station- B31

5.4 FUTURE DEVELOPMENT IN HAZARD AREAS

The Town of Royalston has identified parcels where development has been proposed, is underway or is expected to occur in the future. Of the 5,735 parcels identified as developable land, 89 parcels are greater than 10 acres in size and have the potential to be subdivided. Future development proposals will need to meet all floodplain zoning and that careful attention is paid to drainage issues.

Section 6 Capability Assessment

6.1 EXISTING PLANNING MECHANISM

C6 b.

C1 a

The Planning Team updated information regarding existing planning mechanisms to mitigate natural hazards in the Town of Royalston **Table 6.1** summarizes the local plans that include hazard mitigation elements. The complete FEMA Capabilities Worksheets are included in **Appendix D**.

Table 6.1
Summary of Current Planning Efforts related to Hazard Mitigation

C6 d

Date of Plan	Status	Plan Name	Department Responsible For Update
2010	To be updated in 2020	Open Space and Recreation Plan- describes landscape character, flood control, dams, invasive species	Royalston Open Space and Recreation Committee (Select Board)
2019	Update in Progress	Comprehensive Emergency Management Plan - identifies assets at risk	Royalston Emergency Management Agency
2019	In Progress	Capital Improvement Plan- includes capital assets used in mitigation	Select Board
2019	Completed	Regional Comprehensive Economic Development Strategy	Montachusett Regional Planning Agency
2020	Completed	Regional Transportation Plan, "Working Towards the Future" 2020 goals include improving access along evacuation routes in the region and reduction of greenhouse gases	Montachusett Regional Planning Agency

Royalston Open Space and Recreation Plan(OSRP) - The Town of Royalston OSRP and plan updates are approved by EEA. The purpose of the plan is to guide future management and development of the Town's Recreation and Open Space assets. Guided by the plan, the Town has identified and supported the acquisition of parcels protected by the Wetlands Protections Act and Rivers Act and advanced other water quality improvement measures. The plan will be reviewed and updated in 2020-2021. The next Open Space & Recreation Plan update will occur after the adoption of this HMP update. The Town will make efforts to align related goals and objectives of the two plans.

Royalston Comprehensive Emergency Management Plan (CEMP) – The CEMP addresses mitigation, preparedness, response and recovery from a variety of natural and man-made emergencies. The plans contain important information regarding flooding, hurricanes, tornadoes, dam failures, earthquakes, and winter storms. Therefore, the CEMP is a mitigation measure that is relevant to all of the hazards discussed in this plan. Royalston's Emergency Management Agency (REMA) maintains the plan on an ongoing basis.

Capital Improvement Plan sets the community's investment goals for major public infrastructure projects and other improvements for a ten-year period.

6.2 EXISTING ADMINISTRATIVE CAPACITY

The Town has multiple staff members and volunteer boards that assist with planning, development, and implementation of hazard mitigation. The roles are further described below.

A2 a b

The **Planning Board** and **Building Inspector** enforce local bylaws and State Building Code to ensure that development in Royalston conforms to all applicable codes, regulations and Town bylaws, which ensures that buildings are safe for people to inhabit and minimizes the risk of natural hazards from development. In addition, the Planning Board and Building Inspector have the authority to regulate development through project approval (Planning Board) and enforcement (Building Inspector.) Their actions are guided by the Town's bylaws. The Town's Flood Plain Overlay District regulations are enforced through the Zoning Bylaw.

The **Select Board** assists with dissemination of information in the event of an emergency through social media, the development of a new Town website (online as of July 2020), and through the **Broadband Committee**, Town-wide broadband internet access.

The **Department of Public Works (DPW)** is responsible for maintenance programs to reduce risk, including tree trimming, maintenance of the municipal stormwater drainage system, cleaning of public waterways as needed, brush clearing, and clearing snow from major arterial routes to ensure access for emergency vehicles. The DPW works with the **Police Department** to enforce residential parking bans during snow removal.

The **Fire Department** issues a limited number of burn permits based on fire hazard levels, air quality, and wind conditions, and participates in multiple mutual aid agreements with regional agencies, southwest New Hampshire, and MEMA to provide and receive assistance during emergency events.

The **Royalston Emergency Management Agency (REMA)** supports all aspects of the Hazard Mitigation Plan, with an emphasis on community preparedness and emergency response. REMA implements the CEMP and provides education on community preparedness, disseminates information to the public in the event of a possible natural disaster through CodeRED and reverse 911, and is leading the Town's HMP update and resiliency planning efforts. The Emergency Management Director coordinates with both the Royalston Fire and Police Departments and DPW to align Hazard Mitigation strategies with the Departments ongoing programs and policies.

The Tree Warden addresses problem trees.

The **Montachusett Regional Planning Commission (MRPC)** develops regional plans and goals for the Town of Royalston and the greater Montachusett region.

The **utility companies** perform regular inspections and coordinate with the **Tree Warden** to perform tree maintenance to cut branches threatening power lines and overhead utilities.

The **Army Corps of Engineers** performs periodic inspections of the high-hazard Birch Hill Dam and Tully Dam in accordance with the requirements of the **Massachusetts Office of Dam Safety.**

6.3 EXISTING FUNDING MECHANISMS

The Town has multiple funding mechanisms in place or planned to help fund mitigation projects.

- Capital Improvement Funding has been used for flood control projects, Town equipment and facility improvements. REMA has specific line items in the 10-year Capital plan to be funded in a future FY.
- The Town charges user fees for water and sewer, including new hookups to maintain these utilities and expand services.
- The Town has utilized funding from a variety of State and Federal sources to fund hazard mitigation projects including FEMA Pre-Disaster Mitigation, Flood Mitigation Assistance, Hazard Mitigation Assistance, and Emergency Management Performance Grants. The Town recently received state funding to participate in the MVP planning project to provide additional opportunities for public involvement.
- Community Development Block Grant Funds have been used to maintain town infrastructure and maintain compliance with the American with Disabilities Act. .
- The Town imposed limited impact feet for new development on a case-by-case basis.
- Other state funding programs include grants from EEA, MEMA, and Green Communities.

6.4 EDUCATION AND OUTREACH METHODS

Due to the abundant natural resources in Royalston, there are a number of environmental non-profits that meet regularly and provide public education regarding environmental resources and potential concerns in Town. Numerous Town committees provide the public with information on climate change, conservation efforts, and natural resources protection. The Emergency Management Director has taken advantage of Red Cross and FEMA-led workshops to train neighborhood volunteers to assist first responders during emergencies such as providing support for shelter operations.

Other Agencies involved in education and outreach include:

- Energy Committee - information on responsible energy use
- Conservation Commission - information on wetlands protection. –
- Select Board- Annual Town clean-up event
- Fire Department - annual Fire Prevention week at all school
- Medical programs and Fire Prevention Presentations are held with community groups upon request.
- Public meetings are held when bacteria is found in water.

The Public is informed about publicly funded mitigation projects/programs by the following methods:

- Community meetings and group presentations including lectures and workshops
- News items and feature stories on fire safety, environmental education and responsible water use in Royalston Community newspaper,

- Placement of the required information on the Town's website, Post Office, Public Libraries and Town Hall, and
- Public information/coordination meetings sponsored by the Select Board.

Local citizen groups or non-profits help with outreach focused on environmental protection, emergency preparedness access, stream flow alterations and invasive species including the Millers River Watershed Council, and the Trustees of Reservations.

6.5 EXISTING MITIGATION MEASURES

Flood Hazard Mitigation Measures

C2 a

Participation in the National Flood Insurance Program (NFIP)

The Town of Royalston complies with the NFIP by enforcing floodplain regulations, maintaining up-to-date floodplain maps, and providing information to property owners and builders regarding floodplains and building requirements. FEMA maintains a database on flood insurance policies and claims. This database can be found on the FEMA website at https://www.fema.gov/policy-claim-statistics-flood-insurance. Out of a total of 1316 properties in Royalston, 2 flood insurance policies in force for sites located within the 500-year flood zone. The total insured value is $630,000 and there have been no reported claims.

Land Acquisition for Open Space- Community Preservation Committee makes recommendations to Town meeting for acquisition, creation and preservation of open space.

Public Works Operations/Maintenance Activities – The DPW maintains and cleans all drainage structures including catch basins and culverts on a regular schedule. The DPW periodically maintains the Town's waterways including trash and debris removal. The following specific activities serve to maintain the capability of the drainage system through the reduction of sediment and litter build up and proper maintenance and repair.

Street sweeping –Street sweepings are conducted once a year.

Roadway treatments – Sand and salt are used to treat roadways.

Snow disposal –The Town conducts snow removal operations with its own equipment in some areas. However, most of the operations are conducted by snow-removal contractors.

Tree Maintenance Activities – The DPW conducts its own tree maintenance and uses its own equipment to trim and remove trees as needed or hires professionals for tree work.

Communications Equipment –REMA utilizes multiple methods to broadcast information about emergency conditions including state emergency broadcasting methods, CodeRED, Reverse 911, community list serve email, social media, and posting to the Town website.

Emergency Power Generators – Royalston Fire Department stations, Royalston Police Department, and DPW currently have back-up generators, and REMA has 6 portable generators that can be used to run pumps, lighting and supply limited emergency power for small scale activities. The Fire Department, DPW, and REMA share maintenance responsibilities of generators.

Royalston Regulations and Ordinances

A summary of the Town bylaws and State and Federal regulations that provide flood mitigation benefits is provided in **Table 6.2**.

Table 6.2
Regulations, Bylaws and Policies That Provide Flood Mitigation

Regulatory Category	Applicable Section	Flood Mitigation Benefit
Zoning Bylaw Special Districts	Flood Plain District-	Overlay district for most vulnerable sections of Town, includes FEMA flood zones. Development must meet State Building Codes, Title V, and Wetlands Protection Regulations. The ordinance defines its Flood Plain District as special flood hazard areas as the 100-year floodplain as shown on Flood Insurance Rate Map (FIRM) dated June 15, 1983. The FIRM needs to be updated.
Zoning Bylaw Procedures	Section V- Development Review Requirements, Section B- Site Plan Review and Approval Section VI. C. Low Impact Development Standard	Site plans are required to include information on surface and ground water drainage and erosion control
Community Preservation Committee	General Bylaws, Article XIX, part B (2)	Community Preservation Committee duties include making recommendations to Town meeting for acquisition, creation and preservation of open space
State Regulations	DCR Dam Safety Regulations	The state has enacted dam safety regulations mandating inspections and emergency action plans. All new dams are subject to state permitting.
100-Year Flood Zone	Federal Regulations	FEMA regulations require elevation about 100-year flood level for new and substantially improved residential structures located in the floodplain.

Wind Hazard Mitigation Measures

Massachusetts State Building Code – The Town enforces the Massachusetts State Building Code whose provisions are generally adequate to protect against most wind damage. The code's provisions are the most cost-effective mitigation measure against high wind given the extremely low probability of occurrence. If a tornado were to occur, the potential for severe damages would be extremely high.

Tree-trimming program – The utility companies that operate in Royalston perform inspections and coordinate with the Tree Warden to trim and remove hazardous branches and trees as needed to protect overhead utilities. The Town needs assistance in dealing with trees that are protected by the Shade Tree Act but threaten the safety of roadways during storms with heavy precipitation, wind, and /or ice.

Winter Storm

Residential Parking Bans- Parking bans are put in place to enable effective snow removal from residential streets. The Police Department is responsible for enforcement.

Snow Removal- DPW is responsible for clearing snow from major arterial routes and to ensure access for Emergency Access Vehicles. Additional equipment and personnel are needed for effective and timely snow clearing during storm events.

Wildfire Hazard Mitigation Measures

Permits Required for Outdoor Burning – The Fire Department Chief limits burn permits based on fire hazard levels, air quality, and wind speed and direction. Improvements included development of a Fire Department policy on burn permit limitations and formal tracking system of when burn permits implemented. Currently, notification on the day of burning is communicated to the Fire Department only through voicemail.

Mutual Aid Agreements – The Fire Department has mutual aid agreements with regional agencies FRCOG, Midstate (FD 8), southwest New Hampshire, DPW MA Ch 40, and MEMA to provide and receive assistance during emergency events.

Limited Brush Clearing – The DPW frequently provides brush clearing to provide access to Emergency Service vehicles.

Public Education - Increase awareness by educating property owners on actions that they can take to reduce risk to property by developing and distributing an educational pamphlet on Fire Safety and Prevention (SAFE PROGRAM) and (SENIOR SAFE) and wildfire prevention.

Geologic Hazard Mitigation Measures

Massachusetts State Building Code – The State Building Code contains a section on designing for earthquake loads (780 CMR 1613.0). Section 1613 states that the purpose of these provisions is "to minimize the hazard to life to occupants of all buildings and non-building structures, to increase the expected performance of higher occupancy structures as compared to ordinary structures, and to improve the capability of essential facilities to function during and after an earthquake." This section goes on to state that due to the complexity of seismic design, the criteria presented are the minimum considered to be "prudent and economically justified" for the protection of life safety.

The code also states that absolute safety and prevention of damage, even in an earthquake event with a reasonable probability of occurrence, cannot be achieved economically for most buildings.

Section 1604.5 sets up seismic hazard exposure groups and assigns all buildings to one of these groups. Group III includes buildings that have a substantial public hazard due to occupancy or use and Group IV are those buildings having essential facilities that are required for post-earthquake recovery, including fire, rescue and police stations, emergency rooms, power-generating facilities, and communications facilities.

Multi-Hazard Mitigation Measures

There are several mitigation measures that impact more than one hazard. These include the Comprehensive Emergency Management Plan, the Massachusetts State Building Code, Public Alerts and Emergency Warning Systems.

Comprehensive Emergency Management Plan (CEMP) – Every community in Massachusetts is required to have a CEMP. These plans address mitigation, preparedness, response and recovery from a variety of natural and man-made emergencies. These plans contain important information regarding flooding, dam

failures, and winter storms. Therefore, the CEMP is a mitigation measure that is relevant to many of the hazards discussed in this Plan. Royalston is currently in the process of updating the CEMP.

Massachusetts State Building Code- The Massachusetts State Building Code is enforced by the Building Inspector, including many detailed regulations regarding wind loads, earthquake resistant design, flood-proofing, and snow loads.

CodeRED and Reverse 911 - The Town utilizes CodeRED and reverse 911 to provide residents with natural disaster warning information. The Town is currently integrating CodeRED with the improved federal Integrated Public Alert & Warning System (IPAWS).

Local Emergency Planning – Royalston has its own local Emergency Management Agency (REMA). REMA works to minimize negative effects of local, regional, or national emergencies and disasters of natural or man-made origins on the citizens of Royalston, by assessing and mitigating against known hazards, preparing thoroughly for, responding appropriately to, and pro-actively assisting with recovery from such events. The Royalston Emergency Management Director coordinates with adjacent Towns and regional planning agencies, attends MEMA, FEMA, and Homeland Security meetings, coordinates Community Emergency Response Teams (CERTs), and .is working with the Town's public safety departments and Select Board to equip the Royalston Community School to serve as an emergency shelter during major disasters.

Section 7 Mitigation Strategy

7.1 MITIGATION GOALS AND OBJECTIVES

C3 a b

D3 a

The Planning Team reviewed and updated the 2015 Hazard Mitigation Plan Goals. The 2020 Hazard Mitigation Plan includes specific plan goals, objectives and addresses additional community assets including the environment, economy and cultural facilities.

2020 Royalton Hazard Mitigation Goals

1. **Public Health and Safety**

Recommended Goal: Protect the health and safety of the public.

Objectives:

- Promote cost-effective hazard mitigation actions that protect and promote public health and safety from all hazards.
- Encourage people to be prepared before, during and after a hazard event by providing neighborhood training events and neighbor-helping-neighbor based on the MEMA model.
- Ensure that services related to public health (e.g., sanitation, water, debris removal, hospital access, and emergency services) can function during and after a hazard.
- Ensure that evacuation can happen in an organized and efficient manner.
- Minimize secondary impacts from hazards, such as the release of pollutants. (e.g., fuel spills into waterbodies).
- Promote public communications including materials and voice communications.

2. **Protection of Existing Infrastructure**

Recommended Goal: Protect existing properties and structures

Objectives:

- Provide resources for residents and businesses to make their buildings and properties more disaster resistant.
- Educate the public on measures they can take to protect their property from natural hazards.
- Maintain existing drainage to protect residential and municipal areas from flooding.
- Ensure that critical facilities and infrastructure are protected from hazards.
- Ensure that future development / redevelopment does not make existing properties more vulnerable to hazards.

3. **Protection of Natural Resources**

Recommended Goal: Increase resilience by protecting and enhancing natural resources.

Objectives:

- Protect natural areas (including open space, wetlands, green spaces) to ensure that they buffer impacts to developed areas during a natural disaster.
- Protect and increase tree canopy.
- Manage stormwater with Low Impact Development techniques (provide capital resources to encourage investment in LID upgrades).
- Optimize techniques to provide safe lakes and river access to avoid erosion.

4. **Emergency Response to Hazards**

Recommended Goal: Ensure that essential services can function during and after a hazard event.

Objectives:

- Ensure that critical infrastructure is protected from natural hazards.
- Ensure that key service emergency personnel and employees can get into and around to provide services.
- Promote effective and consistent interdepartmental communication.
- Maintain the Comprehensive Emergency Management Plan (CEMP).

5. **Planning for Future Development**

Recommended Goal: Minimize hazard risks for future development

Objectives:

- Encourage future development in areas that are not prone to natural hazards.
- Enforce existing zoning and building regulations and make updates to address known hazards and risks.
- Ensure that future development meets federal, state, and local standards for preventing and reducing the impacts of natural hazards including impacts due to climate change on natural and historic resources.

6. **Regional Cooperation**

Recommended Goal: Work regionally to mitigate impacts from natural hazards and to respond and recover from hazard events.

Objectives:

- Continue to participate in regional efforts.
- Cooperate with other agencies, communities, and private entities.
- Understand priorities and capabilities of other entities to allow for resource-sharing, mutual aid, and entering into memoranda of understanding (MOU).

7. **Hazard Awareness**

Recommended Goal: Maintain Hazard Awareness

Objectives:

- Track and compile hazard related data.
- Understand the potential implications of climate change on the frequency and extent of natural hazard events and incorporate that knowledge into hazard mitigation efforts.
- Maintain publicly available information on natural hazard risks in the Town
- Integrate hazard mitigation into other Town initiatives and plans.
- Encourage local agencies representing vulnerable populations to work with the Town to participate in development of the hazard mitigation plan.
- Plan outreach events educating the broader community on hazard risks and community vulnerability, and the benefits of hazard mitigation.

8. **Hazard Mitigation Resources**

Recommended Goal: Determine priorities for directing resources for hazard mitigation and response.

Objectives:

- Maintain adequate staff resources and facilities.
- Prioritize mitigation projects.
- Continue to include mitigation projects in the Capital Improvement Plan.
- Pursue various funding sources.
- Encourage private property owners to implement measures to protect their own properties.

7.2 MITIGATION ACTIONS

C4 abc

What is Hazard Mitigation?

Hazard mitigation means to permanently reduce or alleviate the losses of life, injuries, and property resulting from natural hazards through long-term strategies. These long-term strategies include planning, policy changes, education programs, infrastructure projects, and other activities.

Hazard mitigation measures can generally be sorted into six categories, according to FEMA's Local Multi-Hazard Mitigation Planning Guidance:

1. **Prevention:** Government administrative or regulatory actions or processes that influence the way land and buildings are developed and built, and direct public activities to reduce hazard losses. Examples include planning and zoning, building codes, capital improvement programs, open space preservation, and stormwater management regulations.

2. **Property Protection:** Modification or removal of existing buildings or infrastructure to protect them from a hazard. Examples include acquisition, elevation, relocation, structural retrofits, flood proofing, storm shutters, and shatter resistant glass.
3. **Public Education and Awareness:** Actions to inform and educate citizens, elected officials, and property owners about the potential risks from hazards and ways to mitigate them. Such actions include outreach projects, real estate disclosure requirements, hazard information centers, and school-age and adult education programs.
4. **Natural Resource Protection and Green Infrastructure:** Actions that, in addition to minimizing hazard losses, preserve or restore the functions of natural systems. These actions include low impact development, sediment and erosion control, stream corridor restoration, watershed management, urban forest and vegetation management, and wetland restoration and preservation.
5. **Structural Projects:** Actions that involve the construction of structures to reduce the impact of a hazard. Such structures include storm water controls (e.g., culverts), floodwalls, seawalls, retaining walls, and safe rooms.
6. **Emergency Services Protection:** Actions that will protect emergency services before, during, and immediately after an occurrence. Examples of these actions include protection of warning system capability, protection of critical facilities, and protection of emergency response infrastructure.

Funding to implement hazard mitigation projects may come from a variety of federal, state, and local sources. FEMA currently has three mitigation grant programs: the Hazards Mitigation Grant Program (HGMP), the Pre-Disaster Mitigation program (PDM), and the Flood Mitigation Assistance (FMA) program. The PDM program is being replace by Building Resilient Infrastructure and Communities (BRIC) in the Fall of 2020. The links below provide additional information on these programs.

HMGP: http://www.fema.gov/government/grant/hmgp/index.shtm

PDM: http://www.fema.gov/government/grant/pdm/index.shtm

BRIC: https://www.fema.gov/bric

FMA: http://www.fema.gov/government/grant/fma/index.shtm

Other potential funding sources include EEA MVP Action Grants, EEA Environmental Dam and Seawall Removal and Repair Fund, Massachusetts State Revolving Funds, U.S. Army Corps of Engineers, and the Small Business Administration.

Progress on Prior Actions

D2a

The Planning Team reviewed the 2015 Mitigation Actions to determine what progress had been made towards implementation. **Table 7.1** provides an update on all previous mitigation actions including the description, responsible department, implementation status, and comments to describe the status.

C6 **d**

Progress has been realized on several proposed actions. For example, the two projects on the 2015 HMP that address the need for shelter during disasters have been combined (see **Table 7.1**). At the time of the 2015 HMP, the Royalston Community School had been identified as a possible shelter and several attempts were made to collaborate with the Athol-Royalston Regional School District (ARRSD) to share in the cost of

backup power to that location. However, due to lack of sufficient funding, the town has identified an alternate location as a possible shelter and is working to secure state and local funding for renovations and backup power.

Another example of progress is in communication with the public. In April of 2020 a new town website went online. Our Emergency Management Director regularly updates main page "alerts" as well as information on the Public Safety portal. In addition, Royalston's Facebook page, launched in January of 2020, reaches residents with updated information and alerts.

One project was determined to be an ongoing capability and was transferred to Section 6.5. One project was completed and removed from the mitigation strategy list. The remaining 6 projects are ongoing or in progress and were added to the future mitigation actions list.

Table 7.1
Review of 2015 Mitigation Actions-

D2a

Hazard(S) To Mitigate	Action Item # and Description	Responsible Department	Status: Completed/ Existing Capability/ In Progress/ Deferred/ Deleted	Explanation Of Status as of 2018
All Natural Hazards	1) Work with neighboring communities to establish a Community Emergency Response Team (CERT) to more effectively respond to all natural hazards thus mitigating any damage.	Select Board, Police & Fire Departments, Emergency Management Director	In Progress	Carried forward. Royalston CERT Members are managed by Templeton EMD and members attend monthly meetings in Templeton. Training is done by both Royalston and Templeton
All Natural Hazards	2) Inventory supplies at existing shelters and develop a needs list, back-up power and storage requirements. Supplies must be adequate to eliminate or reduce risk to human life.*	Emergency Management Planning Committee, School Facilities Manager	In Progress, modified to include 3 below	Carried forward. Royalston community school is marginally useful as shelter. Working to change this. Royalston has inventories of all supplies.
All Natural Hazards	3) Ensure that identified shelter has sufficient back- up utility service in the event of a primary power failure to reduce or eliminate risk to human life	Building Inspector, Emergency Management Director	Modified- included in 2) above	Carried forward - Royalston Community School has none
All Natural Hazards	4) Explore a viable way to improve communication to the public in addition to public radio in case of a natural hazard to reduce or eliminate risk to property and human life.*	Emergency Management Director	In Progress	Town utilizes CodeRED and reverse 911, social media, and website New website went online in July 2020
All Natural Hazards	5) Develop Regional Sheltering Plan w/ Templeton to provide shelter resources in case of a natural hazard to reduce or eliminate risks to human life.	Emergency Management Director	Deleted	Plan discontinued.

MITIGATION STRATEGY

Hazard(S) To Mitigate	Action Item # and Description	Responsible Department	Status: Completed/ Existing Capability/ In Progress/ Deferred/ Deleted	Explanation Of Status as of 2018
Flooding	6) Develop a priority list and possibly seek funding through the Hazard Mitigation Grant Program (HMGP) for the replacement of undersized culverts throughout Town to reduce or eliminate flooding risk.	Board of Selectmen, Highway Department	In Progress, modified	Carried forward. Undersized culverts have been identified. Lack of 25% match funding.
Atmospheric and Winter Related Hazards	7) Develop a Mitigation Plan to provide access to water, information, shelter and food stores to people in remote locations of the Town and incorporate into community's comprehensive plans.	Emergency Management Director	In Progress (CEMP)	Carried forward. Initiated. Additional time needed due to lack of funding.
Atmospheric and Wildfire Hazards	8) Increase awareness by educating property owners on actions that they can take to reduce risk to property by developing and distributing an educational pamphlet on Fire Safety and Prevention (SAFE PROGRAM) and (SENIOR SAFE) and wildfire prevention.	Fire Department	Existing Capability	Project is undertaken on a periodic basis
Atmospheric and Wildfire Hazards	9) Participate in the creation of a Regional Debris Management Plan to mitigate identified hazards in order to reduce the risk of wildland fire and atmospheric related hazards.	Board of Selectmen, Planning Board, Emergency Management Director	In Progress (stalled)	Carried forward due to lack of funding.

Projects with **Existing Capabilities** are now included in the Capabilities Assessment in **Section 6**

Projects Ongoing or **In Progress** have been included in Future Actions Table

Projects that have been **Completed or Deleted** are removed from the Future Action Table

Mitigation Action and Adaptation Strategy for 2019

C4abc C6a

The Planning Team developed a revised Mitigation Action Plan for the 2020 Plan. The revised plan includes 6 projects listed as in progress from the 2015 Plan-and 34 new projects identified by Town and Planning Team members. The completed list of 40 projects were reviewed and refined by members of the Planning Team who would lead in implementing the action.

The goal of the Plan is to reduce Royalston's vulnerability to hazards, and by selecting and implementing the most costs effective mitigation actions the Town will be on the road toward implementing that goal. The Planning Team completed a Risk and Benefit Assessment to prioritize the most cost-effective mitigation actions, as described below.

Benefit Cost Review Methodology

C5ab

The cost benefit review is the first step in completing a prioritization of mitigation projects. FEMA does not dictate how the cost benefit review is completed; however, it is a required element for the plan. For the Royalston HMP, the prioritization of projects was based on a benefit cost review using the FEMA STAPLEE method. STAPLEE is a cost/benefit analysis tool that includes considerations for **S**ocial, **T**echnical, **A**dministrative, **P**olitical, **L**egal, **E**nvironmental and **E**conomic issues.

In its simplest application, the STAPLEE method consists of a table where actions (and mitigation options) are shown along the vertical axis and the STAPLEE categories along the horizontal axis (see inset below). Each action is analyzed per the categories in STAPLEE and a mark is placed in each category that the action affects in a positive way. The action with the most marks achieves a higher priority.

STAPLEE Criteria	S (Social)		T (Technical)			A (Administrative)			P (Political)			L (Legal)			E (Economic)				E (Environmental)				
Considerations → for Alternative Actions ↓	Community Acceptance	Effect on Segment of Population	Technical Feasibility	Long-term Solution	Secondary Impacts	Staffing	Funding Allocated	Maintenance/ Operations	Political Support	Local Champion	Public Support	State Authority	Existing Local Authority	Potential Legal Challenge	Benefit of Action	Cost of Action	Contributes to Economic Goals	Outside Funding Required	Effect on Land/ Water	Effect on Endangered Species	Effect on HAZMAT/ Waste Sites	Consistent with Community Environmental Goals	Consistent with Federal Laws

For Royalston's HMP, the basic STAPLEE basic method was modified to allow for a more detailed evaluation accounting for both **benefits** and **costs** and reflects the types of mitigation actions being considered for the Town. For many of the criterion values, a range of scores were assigned. **Table 7.2**, includes the values that were considered for each STAPLEE criteria and potential scores. A final score for each mitigation action was tabulated as the sum of the cost score and the benefit score.

Table 7.2
STAPLEE Benefit Cost Review: Criteria, Considered Values and Rating Scores

CRITERIA	COSTS		BENEFITS	
	Cost Values	**Cost Rating Scores**	**Benefit Values**	**Benefit Rating Scores**
Social	Adversely Affects Segment of the Population or Community Values	-3=yes -2=maybe -1=no	Benefits a Large Segment of the Population	3=large 2=med 1=small
Technical	Years to Implement Project	-1=1 year -2= 2-3 years -3= 4 or more	Easy to Implement with Local Resources	3= yes
Administrative	Operations and Maintenance $$ Required	-3=high -2=med -1=low or none	Sufficient Staffing Available	3=yes 2=maybe 1=no
Political	Public Opposition	-3=high -2=med -1=low	Local Champion-Politically Acceptable	3= yes
Legal	Action Potentially Subject to Legal Challenge	-3 Subject to legal challenge	Existing Local Authority to Implement	3= state or local authority
Economic	Approximate Cost	$=$0-$50,000 $$= $50,001-$100,000 $$$ = $100,001-$1,000,000 $$$$= >$1,000,001	Funding Available	3= yes
Environmental	Adverse Environmental Impacts	-3=high -2=med -1=low	Other Community Goals Achieved	3=yes

Once a total cost benefit rating score was calculated for each mitigation action, all of the mitigation actions were ranked as high, medium and low priority for implementation by hazard category based on the range of scores for each hazard.

Table 7.3 includes the list of 41 future mitigation actions sorted by type of hazard including the total benefit cost rating score and final overall ranking. The Approximate Costs utilize the same notation as Table 7.2 Economic Cost Rating. The timeframe for implementation of each action is divided into near term (1-2 years), mid term (3-4 years) and long term (5 years or more).

Table 7.3
2020 Mitigation Action Plan

Hazard	Mitigation Action	Project Type	Lead Department	Additional Funding Sources	Approximate Cost	Timeframe	Consistency with Mitigation Goals	Consistency with other Town Plans	Rating	Priority Ranking
All Hazards	1. Inventory emergency supplies and develop a needs list. Provide back-up power and storage facilities. Supplies must be adequate to eliminate or reduce risk to human life. (ongoing-	Emergency Service Protection	Emergency Management	MEMA	$	Near	Public Health & Safety	Comprehensive Emergency Management Plan	14	High
All Hazards	2. Work with neighboring communities to establish a Community Emergency Response Team (CERT) to more effectively respond to all-natural hazards thus mitigating any damage (ongoing).	Emergency Service Protection	Emergency Management	MEMA/FEMA	$	Near	Hazard Mitigation Resources	Comprehensive Emergency Management Plan	14	High
All Hazards	3. Conduct a communication needs survey for elderly populations	Public Education and Awareness	Select Board	MEMA/FEMA	$	Near	Public Health & Safety	Municipal Vulnerability Preparedness Plan	13	High
All Hazards	4. Designate a space for Emergency Management Department	Emergency Service Protection	Select Board		$$$$	Mid	Hazard Mitigation Resources	Municipal Vulnerability Preparedness Plan	11	High
All Hazards	5. Survey to determine who has access to backup or off-grid power, computer, internet	Emergency Service Protection	Select Board		$$	Mid	Public Health & Safety	Municipal Vulnerability Preparedness Plan	10	High
All Hazards	6. Enable access to communication networks for vulnerable populations (ongoing modified)	Property Protection	Select Board	EOEA/ FEMA	$	Near	Public Health & Safety	Municipal Vulnerability Preparedness Plan	8	Medium
All Hazards	7. Support development of Town-wide broadband	Public Education and Awareness	Select Board	FEMA	$$$$	Near	Public Health & Safety	Municipal Vulnerability Preparedness Plan	8	Medium
All Hazards	8. Conduct Raymond Building Shelter Assessment and implement recommendations	Structural	Select Board	SFR	$	Mid	Protection of Existing Infrastructure	Municipal Vulnerability Preparedness Plan	7	Medium
All Hazards	9. Provide access to gasoline during emergency events	Emergency Service Protection	Emergency Management	FEMA	$$	Long	Emergency Response to Hazards	Municipal Vulnerability Preparedness Plan	6	Medium
All Hazards	10. Preserve and protect historical records	Property Protection	Select Board	MVP Action	$	Mid	Protection of Existing Infrastructure	Municipal Vulnerability Preparedness Plan	5	Low
All Hazards	11. Install generators or other back-up power supply at Library, Town Hall, and Raymond Building	Emergency Service Protection	Emergency Management	FEMA	$	Mid	Emergency Response to Hazards	Municipal Vulnerability Preparedness Plan	4	Low

Hazard	Mitigation Action	Project Type	Lead Department	Additional Funding Sources	Approximate Cost	Timeframe	Consistency with Mitigation Goals	Consistency with other Town Plans	Rating	Priority Ranking
High Wind/ Hurricanes/ Tropical Storms	12. Develop a *Comprehensive Emergency Management Plan* to provide access to water, information, shelter and food stores to people in remote locations of the Town and incorporate into community's comprehensive plans (ongoing-modified)	Emergency Service Protection	Emergency Management	FEMA	$	Near	Emergency Response to Hazards	Municipal Vulnerability Preparedness Plan	14	High
High Wind/ Hurricanes/ Tropical Storms	13. Improve coordination with Tree Warden to remove hazardous trees/branches that cause icing on key routes that may also be Scenic Roads	Natural Resource Protection and Green Infrastructure	DPW		$	Mid	Emergency Response to Hazards	Municipal Vulnerability Preparedness Plan	9	High
High Wind/ Hurricanes/ Tropical Storms	14. Conduct Town-wide Tree Inventory and canopy assessment resulting in a GIS layer	Natural Resource Protection and Green Infrastructure	DPW	MVP Action	$	Near	Protection of Natural Resources	Municipal Vulnerability Preparedness Plan	7	Medium
High Wind/ Hurricanes/ Tropical Storms	15. Develop Tree Planting Plan that considers climate change impact to species, invasives and resilience planning for forest and street trees, develop meaningful strategies for tree health and planting where canopy is lean	Natural Resource Protection and Green Infrastructure	DPW	MVP Action	$	Near	Protection of Natural Resources	Municipal Vulnerability Preparedness Plan	7	Medium
High Wind/ Hurricanes/ Tropical Storms	16. Develop Tree Management Plan to maintain trees to prevent power losses due to wind through removal of dead and/or dangerous trees and tree branches and balance safe removal of hazard trees with Scenic Rds./Public Shade Tree considerations	Natural Resource Protection and Green Infrastructure	DPW	MVP Action	$	Mid	Protection of Natural Resources	Municipal Vulnerability Preparedness Plan	2	Low
Brush Fire	17. Develop plan to mitigate wildfire risk in times of drought	Prevention	Fire/ Emergency Management	FEMA	$	Long	Hazard Awareness	Municipal Vulnerability Preparedness Plan	11	High
Brush Fire	18. Improve signage about hiking safety and environmental stewardship	Public Education and Awareness	Select Board	DCR	$	Mid	Hazard Awareness	Municipal Vulnerability Preparedness Plan	6	Medium
Brush Fire	19. Increase penalties and enforcement to prevent dumping in forests and wetland areas	Prevention	Conservation Commission		$	Near	Protection of Natural Resources	Municipal Vulnerability Preparedness Plan	5	Low

Hazard	Mitigation Action	Project Type	Lead Department	Additional Funding Sources	Approximate Cost	Timeframe	Consistency with Mitigation Goals	Consistency with other Town Plans	Rating	Priority Ranking
Brush Fire	20. Participate in the creation of a Regional Debris Management Plan to mitigate identified hazards in order to reduce the risk of wildland fire and atmospheric related hazards (ongoing)	Emergency Service Protection	Emergency Management		$	Mid	Regional Cooperation	Capital Improvement Plan	3	Low
Brush Fire	21. Identify, preserve, and increase wildlife corridors	Natural Resource Protection and Green Infrastructure	Conservation Commission	DCR	$	Mid	Protection of Natural Resources	Open Space Plan	1	Low
Earthquakes	22. Reduce structural stress on first floor of Town Hall	Structural	Select Board	SRF	$$	Long	Protection of Existing Infrastructure	Capital Improvement Plan	4	High
Flood	23. Coordinate with U.S. Army Corps of Engineers on Emergency Response Plans for Corps properties in Royalston	Prevention	Emergency Management		$$	Near	Regional Cooperation	Comprehensive Emergency Management Plan	14	High
Flood	24. Coordinate with the Trustees on Emergency Response Plans for Trustees' properties in Royalston	Prevention	Emergency Management		$	Near	Regional Cooperation	Comprehensive Emergency Management Plan	13	High
Flood	25. Share results of Town Center drainage study with private landowners	Structural	Select Board			Mid	Protection of Existing Infrastructure	Municipal Vulnerability Preparedness Plan	12	High
Flood	26. Prioritize bridges and culverts that have been identified as having historic flooding or failure (in-progress modified)	Structural	DPW	MVP/ EEA	$	Mid	Protection of Existing Infrastructure	Capital Improvement Plan	9	Medium
Flood	27. Update Town by-laws to require that culvert replacements address road crossing for wildlife and meet MA River and Stream Crossing Standards	Prevention	Planning Board	MVP/ EEA	$$	Near	Planning for Future Development	Municipal Vulnerability Preparedness Plan	8	Medium
Flood	28. Conduct drainage study of all Town-owned assets in Town Center and Bullock Park	Structural	DPW	MVP	$$	Mid	Protection of Existing Infrastructure	Municipal Vulnerability Preparedness Plan	8	Medium
Flood	29. Inspect and complete inventory of stream restrictions, including culverts, bridges, and beaver dams	Prevention	DPW	MVP/ DCR	$	Mid	Protection of Existing Infrastructure	Municipal Vulnerability Preparedness Plan	6	Medium

Hazard	Mitigation Action	Project Type	Lead Department	Additional Funding Sources	Approximate Cost	Timeframe	Consistency with Mitigation Goals	Consistency with other Town Plans	Rating	Priority Ranking
Flood	30. Improve roadside drainage on Rt 32, Warwick Road, North Fitzwilliam, Winchendon Road, and Athol Road	Structural	DPW	FEMA	$$	Mid	Protection of Existing Infrastructure	Capital Improvement Plan	6	Medium
Flood	31. Complete hydrogeologic model of the watershed to assess vulnerability from 100-yr and 500-yr flood under climate change conditions and update flood maps to reflect current and future conditions	Prevention	DPW	FEMA	$	Mid	Protection of Existing Infrastructure	Municipal Vulnerability Preparedness Plan	6	Medium
Flood	32. Assess the feasibility of green infrastructure to solve existing environmental issues	Natural Resource Protection and Green Infrastructure	Planning Board	M VP	$	Mid	Planning for Future Development	Municipal Vulnerability Preparedness Plan	6	Medium
Flood	33. Improve culvert capacity at priority locations- Brown Road (DPW), Butterworth Road @ Collar Brook, Neale Road @ Kenny Brook	Structural	DPW	EOEA/ FEMA	$	Mid	Protection of Existing Infrastructure	Capital Improvement Plan	2	Low
Flood	34. Analyze and address erosion and flooding while protecting adjacent wetland resource areas	Natural Resource Protection and Green Infrastructure	Conservation Commission	MVP Action	$	Mid	Protection of Natural Resources	Municipal Vulnerability Preparedness Plan	1	Low
Sever Winter Storms/ Nor'easters/ Snow/Ice	35. Evaluate reduced use of chemicals on roads	Natural Resource Protection and Green Infrastructure	DPW		$$	Near	Emergency Response to Hazards	Municipal Vulnerability Preparedness Plan	11	High
Sever Winter Storms/ Nor'easters/ Snow/Ice	36. Formalize neighbor-helping-neighbor program	Property Protection	Emergency Management	EOEA/ FEMA	$	Near	Public Health & Safety	Comprehensive Emergency Management Plan	12	High
Sever Winter Storms/ Nor'easters/ Snow/Ice	37. Address conditions of municipal buildings	Structural	Select Board	SRF	$	Mid	Protection of Existing Infrastructure	Capital Improvement Plan	5	Low
Invasive Species	38. Conduct public outreach to increase awareness of dangers of invasive species	Public Education and Awareness	Conservation Commission	DER/ MVP	$	Near	Hazard Awareness	Open Space Plan	12	High
Invasive Species	39. Evaluate current methods for vegetation management and reduced use of pesticides on Town land	Natural Resource Protection and Green Infrastructure	Conservation Commission	DER/ MVP	$	Mid	Hazard Awareness	Open Space Plan	12	High
Invasive Species	40. Survey invasive species infestations on Town land and investigate methods of control	Natural Resource Protection and Green Infrastructure	Conservation Commission	DER/ MVP	$	Long	Hazard Awareness	Open Space Plan	9	Low

7.3 PROJECT TIMELINE FOR 2020 MITIGATION ACTIONS

C6 de

Table 7.3 includes 17 projects ranked with a high priority, 14 with a medium priority and 10 with a lower priority over all hazard categories. Although all projects are important to the Town, a number of priority projects are summarized below relative to recommended timing of the individual mitigation actions. The Town has identified its Capital Improvement Plan, Open Space Plan, Comprehensive Emergency Management Plan and targeted grants as mechanisms to integrate mitigation actions over the next five years.

Several high priority projects are in progress but will take several years to complete, these projects include:

- Work with neighboring communities to establish a Community Emergency Response Team (CERT)
- Update the Town's Comprehensive Emergency Management Plan
- Complete Raymond Building Shelter Assessment

Ten priority projects are identified to begin in year one requiring one-two years to complete:

- Conduct a communication needs survey for elderly population
- Formalize a neighbor-helping neighbor program
- Conduct public outreach to increase awareness of danger of invasive species
- Enable access to communication networks for vulnerable populations
- Support the development of the Town-wide broadband network
- Designate a space for the Emergency Management Director
- Survey to determine who has access to backup or off-grid power
- Improve coordination with the Tree Warden to remove hazardous trees from key routes
- Evaluate reduced use of chemicals
- Conduct Town-wide Tree Inventory and canopy assessment resulting in a GIS layer

Priority projects identified to begin in year two or three include:

- Evaluate current methods for vegetation management and reduced use of pesticides on Town land
- Develop Tree Planting Plan that considers climate change impact to species, invasives and resilience planning for forest and street trees, develop meaningful strategies for tree health and planting where canopy is lean
- Conduct a drainage Study of all Town-owned assets in Town Center and Bullock Park
- Update Town by-laws to require that when replacing culverts, include road crossing for wildlife and meet MA River and Stream Crossing Standards
- Inspect and prioritize bridges and culverts that have been identified as having historic flooding

- Inspect and complete inventory of stream restrictions, including culverts, bridges, and beaver dams

Priority projects identified to begin in three to five years include:

- Complete hydrogeologic model of the watershed to assess vulnerability from 100-yr and 500-yr flood under climate change conditions and update flood maps to reflect current and future conditions
- Improve roadside drainage on Rt 32, Warwick Road, North Fitzwilliam, Winchendon Road, and Athol Road
- Improve culvert capacity at priority locations- Brown Road (DPW), Butterworth Road @ Collar Brook, Neale Road @ Kenny Brook

7.4 CONTINUED COMPLIANCE WITH NFIP

C2a

The Town continues to enforce required elements of the National Flood Insurance Program so that they may continue to participate in the program including:

- Issuing or denying floodplain development/ building permits
- Inspecting all development to assure compliance with the local floodplain zoning by-law
- Maintaining records of floodplain development
- Assisting in the preparation and revision of floodplain maps
- Helping residents obtain information on flood hazards, floodplain map data, flood insurance and proper construction measures.

The Town periodically reviews the zoning by-law for consistency and uses the most recent FIRM data to determine base flood elevation or the best available scientific data for determinations of base flood elevation if no FIRM data is available to achieve a reasonable measure of flood protection.

7.5 CHANGES IN PRIORITY FROM 2015 TO 2020

While flooding continues to be the number one priority for Royalston, the 2020 risk and vulnerably analysis have shifted priorities to include addressing the full range of identified natural hazards. Mitigation projects were included for the following natural hazards that were not part of the 2015 Plan:

- Invasive Species
- Earthquakes

Section 8 Plan Evaluation and Maintenance

8.1 WHO IS INVOLVED?

Each department identified in the Royalston Hazard Mitigation Plan is responsible for implementing specific mitigation actions detailed in the Mitigation Actions section of the plan (**Section 7**). Every proposed action listed in the Future Mitigation Action section is assigned to a specific "lead" department as a way to assign responsibility and accountability and increase the likelihood of subsequent implementation. Annual review will enable specific actions to be modified, if needed, rather than wait until the 5-year update, allowing mitigation projects to evolve in a timely manner as circumstances dictate.

A6 d

Royalston Emergency Management Director and the Select Board will jointly be responsible for ensuring that the Plan is monitored, evaluated, and updated throughout the next five years.

8.2 HOW WILL THE PLAN BE MAINTAINED?

The following activities describe how the plan will be maintained and updated over the next five years:

A6 ad

Plan Monitoring

Members of the Planning Team will communicate annually to report on the implementation status of each Mitigation Action identified in **Section 7**, noting accomplishments, challenges, and recommended modifications to identified actions. The Planning Team will also describe and document any new hazard data that can be incorporated in the Hazard Profile section of the Plan, noting any new hazard location, extent, and impact.

At least once per year, the Planning Team will update the implementation status of Mitigation Actions and an evaluation of the appropriateness of the actions, noting any changes warranted.

Plan Evaluation

A6 bd

The Planning Team will communicate annually to evaluate the purpose and goals of the Hazard Mitigation Plan to ensure the Plan continues to serve its purpose. The annual review will include the following activities:

- Submit survey to all members of the implementation group and other interested local stakeholders. The survey will poll the members on any changes or revisions to the plan that may be needed, progress and accomplishments for implementation, and any new hazards or problem areas that have been identified.
- Review survey results and make recommendations if any changes to the plan are needed
- Review the Mitigation Goals in the 2020 Royalston Hazard Mitigation Plan
- Discuss recent activities to reduce loss of life and property such as grants received/applied for and any completed Mitigation Actions

- Discuss ongoing or recent planning efforts that are consistent with the Mitigation Goals and Actions of the 2020 Royalston Hazard Mitigation Plan

Plan Update

A6 cd

The 2020 Royalston Hazard Mitigation Plan will be reviewed and updated every five years to ensure there is no lapse in Plan coverage. The Plan update process will be scheduled one to one and a half years before the Plan is set to expire.

8.3 WHEN WILL THE PLAN BE MAINTAINED?

A start date and time periods were assigned to each Mitigation Action in Section 7 to assess whether actions are being implemented in a timely fashion. Also, the Planning Team will communicate annually to discuss progress on Mitigation Actions.

Following a disaster declaration, the 2020 Royalston Hazard Mitigation Plan will be revised as necessary to reflect lessons learned or to address specific issues and circumstances arising from the event. It will be the responsibility of the Royalston Emergency Management Director to coordinate with the Planning Team and ensure that appropriate stakeholders are invited to participate in the plan revision and update process following a declared disaster event.

8.4 INCORPORATION WITH OTHER PLANS

A5 a

Upon approval of the Royalston Hazard Mitigation Plan by FEMA, the Planning Team will provide all interested parties and implementing departments with access to a copy of the Plan and will initiate a discussion regarding how the Plan can be integrated into that department's ongoing work. At a minimum, the Plan will be shared with the following departments, commissions, and boards:

C6 e

- Fire Department
- Police Department
- Planning Board
- Conservation Commission
- Building Inspector
- Broadband Committee
- Emergency Management
- Public Works
- Tree Warden
- Health Department
- Historical Commission
- Select Board

The Plan will also be posted on the Town's website. The posting of the Plan on the website will include a mechanism for citizen feedback such as an e-mail address to send comments.

Section 9 Plan Adoption

Once the draft of the Royalston Hazard Plan is reviewed by the Planning Team, stakeholders, and the general public, the Plan is reviewed by MEMA and FEMA. If approved by MEMA and FEMA, the Royalston Select Board can officially adopt the Plan. If and when the Plan is approved, it enters into the five year "maintenance" phase. This Section describes the timeline for plan adoption and includes documentation of the Plan adoption by the Select Board.

9.1 TIMELINE FOR PLAN ADOPTION

The timeline for Plan Adoption is as follows:

August, 2020: After initial approval by the Royalston Select Board at its August 7, 2020 meeting, the Planning Team submitted the Royalston Hazard Mitigation Plan to MEMA on August 10, 2020. MEMA reviewed the Plan and returned it to the Town with required edits. The Royalston Hazard Mitigation Plan was then submitted to FEMA for final review.

_____: FEMA issued an Approved Pending Adoption status on _____.

_____: The Royalston Select Board officially adopted the Hazard Mitigation Plan on _____. during a regularly scheduled meeting.

E1 a

9.2 PLAN ADOPTION

The Certificate of Adoptions is provided in this section.

PLAN ADOPTION

PUT ON SELECTBOARD
LETTERHEAD
DATE

TOWN OF ROYALSTON
CERTIFICATE OF ADOPTION

A RESOLUTION ADOPTING THE TOWN OF ROYALSTON
HAZARD MITIGATION PLAN

WHEREAS the Town of Royalston established a Committee to prepare the *Hazard Mitigation Plan*; and

WHEREAS the *Hazard Mitigation Plan* contains several potential future projects to mitigate potential impacts from natural hazards in the Town of Royalston, and

WHEREAS a duly-noticed public meeting was held by the Select Board on _____

WHEREAS the Town of Royalston authorizes responsible departments and/or agencies to execute their responsibilities demonstrated in the plan, and

NOW, THEREFORE BE IT RESOLVED that the Town of Royalston formally approves and adopts the *Hazard Mitigation Plan* in accordance with M.G.L. 40 §4 or the charter or the bylaws of the Town of Royalston.

ADOPTED AND SIGNED ON [Month___Day___, 20__]

[INCLUDE SIGNATURE BLOCKS HERE]

J:\R\R0177 Royalston Sewer\007 - MVP Planning Grant\Task 10 Draft HMP update\Draft Royalston Multi-Hazard Mitigation Plan.docx

APPENDIX A

Appendix A Bibliography

References

American Planning Association (4/17/2000) Policy Guide on Planning for Sustainability, Report.

American Planning Association (3/15/2017) Regional Green Infrastructure at the Landscape Scale, Report.

Commonwealth of Massachusetts (9/1/2013) State Hazard Mitigation Plan, MEMA and DCR, Plan.

Community Opportunities Group, Inc. (12/23/2013) Town of Royalston Housing Production Plan, Report.

EPA (7/2014) Flood Resilience Checklist, Checklist.

EPA (12/2015) Tools Strategies and Lessons Learned From EPA Green Infrastructure Technical Assistance Projects, Office of Wastewater Management, Report.

FEMA (10/1/2011) Local Mitigation Plan Review Guide, Plan Review Guide - Final 9/30/2011, Report.

Massachusetts Department of Conservation and Recreation (5/1/2008) Massachusetts Heritage Landscape Inventory Report- Royalston Reconnaissance Report, Upper Quaboag Watershed & North Quabbin Region Landscape Inventory, Report.

Massachusetts Executive Office of Energy and Environmental Affairs (3/1/2018) Massachusetts Statewide and Major Basins Climate Projections Guidebook Supplement Projections.

Massachusetts Executive Office of Energy and Environmental Affairs (9/1/2018) Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Report.

Massachusetts Executive Office of Energy and Environmental Affairs (9/1/2019) Massachusetts Drought Management Plan, Report.

Massachusetts Historical Commission (6/1/1984) MHC Reconnaissance Survey Town Report, Royalston, Associated Regional Report: Central Massachusetts.

Montachusetts Regional Planning Commission (12/1/2014) Montachusetts Regional Natural Hazard Mitigation Plan 2015 Update, Report.

Schleck, Brent (7/8/2014) Climate Funding Opportunities, NOAA, Report.

Town of Royalston (10/1/2010) Town of Royalston Open Space & Recreation Plan 2010-2016, Report.

Town of Royalston (unknown) Royalston Cemeteries, List.