RURAL DIRT ROAD ASSESSMENT & RECOMMENDATIONS REPORT

SANDISFIELD MASSACHUSETTS

SHEFFIELD MASSACHUSETTS

Town of New Marlborough MASSACHUSETTS

MVP Municipal Vulnerability Preparedness

BSC GROUP

RURAL DIRT ROAD ASSESSMENT AND RECOMMENDATIONS REPORT

Contents

Acknowledgements

This plan would not be possible without the knowledge and assistance of community leaders and municipal staff in the Towns of New Marlborough, Sandisfield, and Sheffield. The project was conducted by BSC Group, Inc., with funding from the Massachusetts Executive Office of Energy and Environmental Affairs Municipal Vulnerability Preparedness Action Grant.

Executive Summary

Climate change is already having measurable effects on infrastructural, societal, and environmental systems in western Massachusetts. Changing climatic conditions such as increased average temperatures, total annual precipitation, and storm intensity, exacerbates the risk associated with weather related hazards such as inland flooding, snow and ice events, drought, and wind/microbursts. These conditions are rapidly changing the way municipalities consider the distribution of risk and how to appropriately manage resources in response to these changes.

The expansive rural transportation network of unpaved roads in western Massachusetts is uniquely vulnerable to changing climate conditions. The effects of a changing climate have already been observed, and it is anticipated that adverse financial, social, and economic impacts related to rural dirt roadway infrastructure will be exacerbated as climate exposure becomes more frequent and extreme. Rural dirt roads are relied on to provide both local and regional connection through and around mountains, rivers, streams, and valleys. This network presents a significant challenge, and the continual maintenance of rural dirt roadways in western Massachusetts represents a significant cost for municipalities. Additionally, the social costs related to public health and safety, public services, and school bus routes are strained by the effects of a changing climate.

While it is generally acknowledged that dirt roads are becoming increasingly challenging to maintain in response to the effects of climate change, there has yet to be a formal localized assessment of these challenges. Therefore, this multi-community project seeks to assess the vulnerability of rural dirt roads within the context of climate change resilience through a better understanding of these challenges, development of a prioritization methodology, and identification of recommended solutions. To support this effort, BSC Group and the Towns of Sheffield, New Marlborough, and Sandisfield undertook a Vulnerable Dirt Road Scoring and Prioritization process to generate a prioritized list of dirt roadways in each community based on sensitivity to the impacts of climate change and criticality. The development and refinement of the data collection tool and recommendations outlined in this report occurred through a series of meetings with representatives from each municipality, online data collection (survey and mapping), and field testing. The resulting process is designed to be flexible and transferable to other communities that face the challenge of maintaining dirt roads.

Introduction

Over 1.6 million miles of unpaved (dirt and gravel) roads exist within the United States, providing a vital part of the nation's transportation system.[1] These dirt roads, as they are often referred to throughout this report, traverse mountains, valleys, foothills and floodplains, intercepting streams, brooks, and wetlands along the way. Dirt roads connect adjacent rural communities and provide residents and visitors access to important local cultural, recreational, and economic resources. This assessment and recommendations report has therefore been developed to account for the important role dirt roads have in rural western Massachusetts.

Rural dirt roads within mountainous regions of western Massachusetts are uniquely vulnerable to the effects of changing climate conditions – effects that have already been observed. It is anticipated that adverse financial, social, and economic impacts related to climate effects on rural dirt roadway infrastructure will be exacerbated as climate exposure becomes more frequent and extreme. In addition to their role in connecting communities and economic centers, dirt roads are also an important cultural aspect of western Massachusetts communities. The effects of extreme storm events are placing additional burden on rural infrastructure, public services, and the environment. While it is generally acknowledged that dirt roads are becoming more challenging and costly to maintain in response to the effects of climate change, there has yet to be a formal assessment of these challenges. As such, this regional (multi-community) project seeks to assess the vulnerability of rural dirt roads within the context of climate change resilience through a better understanding of these challenges, development of a prioritization methodology, and identification of recommended solutions.

The expansive network of rural dirt roads throughout western Massachusetts are particularly vulnerable to the effects of changing precipitation patterns, flooding, and freeze-thaw cycles. In addition, many rural unpaved roadways within western Massachusetts are located directly adjacent to steep slopes making them subject to conditions where intense runoff and/or landslides are increased. Under extreme precipitation and flooding events, roadways often become "washed out" and impassable leading to public health and safety concerns as well as recurring costly repairs for the municipality. Similarly, roadway washouts present unique environmental hazards when sediment is washed into waterways, private property and sensitive ecosystems. Evidence of damaged transportation infrastructure such as bridges or culverts has also been observed. Damaged roadways characterized by ruts, potholes, mud, washboards, and dust make unpaved

---

[1] *Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads*, prepared by USDA Forest Service in collaboration with Penn State Center for Dirt and Gravel Road Studies, 2012.

rural roads difficult to navigate, dangerous for motorists, and costly for personal vehicle maintenance.

To better understanding the vulnerability of dirt roads within the context of climate change, the project team first identified key conditions underlying the need for this assessment. The criteria described in the remainder of this section recognize ongoing and anticipated issues within the three case study municipalities and the region more broadly.

Public Safety/Emergency Evacuation/School Bus Routes

Many of the main roads within Sheffield, New Marlborough and Sandisfield are used as regional evacuation, emergency, or school bus routes. During severe storm events, main roads may become impassable and secondary roadways, which are often unpaved, are needed to provide emergency support or public services. The deteriorating condition of rural dirt roadway infrastructure under changing climate conditions presents a significant vulnerability for communities. Similarly, public and private residential properties located on dirt roadways present safety risks when emergency support services cannot reach these properties. These examples of climate risk are further exacerbated for socially vulnerable populations, such as residents over the age of 64 that are prevalent throughout the region (70-100th percentile compared to state percentiles).

Photo: Jesse Costa/WBUR

Municipal Expenditures

Dirt roads make up a significant portion of the lane miles of road that municipalities in western Massachusetts are responsible for maintaining. The following table outlines the percentage of dirt roads in Sheffield, Sandisfield, and New Marlborough.

Municipality	Lane Miles of Road*	% of Dirt Roads Within Municipality (Approx.)	% of Municipal Highway Budget Allocated to Dirt Roadway Maintenance (Approx.)
New Marlborough	83.6	46%	32%
Sandisfield	81.0	58%	40%
Sheffield	81.2	21%	13%

**Lane mile = total distance of roadway multiplied by the number of lanes (usually 1 or 2 lanes in rural communities)*

Maintenance costs of these roadways represent a large percentage of municipal expenditures because of the continual maintenance related to unpaved roadway infrastructure. Unlike paved roads, gravel and dirt roads can sometimes deteriorate from excellent to failed conditions in less than a year.[2] Moreover, repeated damage to specific areas of dirt roadways results in a cycle of repairs that drain municipal coffers. In the face of increasing storm events, municipalities find their budgets and road crews challenged by the need to repair and ensure safety on damaged roads. The percentage of municipal budgets allocated to dirt roadway maintenance is anticipated to increase as the effects of climate change related hazards become increasingly prevalent.

[2] Promothes Saha, Khaled Ksaibati, "Developing an Optimization Model to Manage Unpaved Roads", *Journal of Advanced Transportation*, vol. 2017, https://doi.org/10.1155/2017/9474838

Maintaining Rural Character of Western Massachusetts

> Unpaved roads are common across the Massachusetts landscape. A familiar sight in rural communities, unpaved roads offer a sense of timelessness, helping residents connect with the days of cart paths and carriage roads. Often narrow and bordered by stone walls and mature shade trees, and often following an alignment parallel to streams and brooks, unpaved roads offer a scenic escape from the realities of concrete and pavement. The preservation of unpaved roads is important to the character of the Massachusetts landscape.[3]

In western Massachusetts, dirt roads are central to maintaining the rural character of western Massachusetts municipalities. During the Municipal Vulnerability Preparedness (MVP) planning process for all three towns[4] of Sheffield, New Marlborough, and Sandisfield, participants understood the economic, social, and environmental challenges related to rural dirt road vulnerability within the context of climate change, leading them to rank this issue as among the most important MVP Actions for the region. In addition to their value as a scenic resource, dirt roads "have the advantage of lower construction costs than paved roads, require less equipment and skilled operators, and generate lower speeds than their paved counterparts."[5]

Ecological Sensitivity

Dirt roads are prone to erosion, and therefore act as channels through which sediments and nutrients can reach sensitive waterbodies, causing significant adverse effects on water quality. Road runoff generally takes the path of least resistance, and if drainageways are unstable and not well vegetated, the runoff from dirt roads impacts adjacent natural resources such as rare species habitat areas, rivers, wetlands, floodplains, and drinking water wells. In addition, sedimentation from dirt roads can also raise streambeds, thereby exacerbating flooding and the impacts of a changing climate. The extensive network of unpaved roads in western Massachusetts is part of the overall environment, and there is a vital connection between the two. Consequently, this connection is an important consideration for maintaining and constructing dirt roads.

---

[3] *The Massachusetts Unpaved Roads BMP Manual*, prepared by Berkshire Regional Planning Commission for the MA Department of Environmental Protection, 2001.

[4] MVP Municipal Planning ("Findings") Reports are available on the MVP Program website at: https://resilientma.org/mvp/index.html

[5] *The Massachusetts Unpaved Roads BMP Manual*, prepared by Berkshire Regional Planning Commission for the MA Department of Environmental Protection, 2001.

Increased Vehicular Traffic Related to Development Pressure

There has been a notable increase in vehicular traffic on rural dirt roads, and two key factors have been connected to this increase. First, the concept of climate migration, which refers to the voluntary or forced relocation (permanent or temporary) of people or communities in response to the effects of climate impacts. Examples of this are increasingly prominent as people seek to avoid the adverse effects of climate change that may include hazards such as forest fires, drought, sea level rise, and poor air or water quality. In western Massachusetts, for example, people from regional metropolitan areas such as Boston and New York City have permanently left cities in favor of the more rural environments. A growing number of second homeowners, representing temporary residents and vacationers, has also been observed over the past decade. Second, similar permanent or temporary migration behavior has been observed in response to the 2020 COVID-19 public health crisis. These development pressures, which include additional vehicle miles traveled on dirt roads and an increased prevalence of large delivery trucks traveling throughout the region, have added stress to already vulnerable dirt roadways, which are not designed to accommodate current vehicular stressors.

Weatogue Road Case Study

A case study focused on Weatogue Road in Sheffield was conducted to inform this Assessment and Recommendations report. Weatogue Road is a rural dirt road in Sheffield Massachusetts running north-south along the Housatonic River, connecting Sheffield to Connecticut and to an east-west running roadway system. This roadway is subject to the climate hazards discussed above, notably extreme precipitation (both intensity and total) and freeze-thaw conditions. Weatogue Road has been an important area of interest for Sheffield for the past few years with ongoing washouts and incremental attempts to repair the roadway with expensive and insufficient results. Washouts in this area present a significant safety hazard for roadway travelers, as this road provides regional connectivity, and runoff from the road affects a unique environmental ecosystem: The Trustees of Reservations' (TTOR) Bartholomew's Cobble, which supports rare species habitat associated with the Housatonic River.

In 2015 preliminary mitigation schemes were proposed that did not meet TTOR's expectations for protection of down gradient rare species habitat. In 2019, a study of past mitigation efforts and a meeting between the Town of Sheffield, BSC Group and TTOR occurred to discuss next steps. The study investigated mitigation options to manage and direct the increased stormwater flow across Weatogue Road from concentrated stormwater flows associated with expanding upgradient gullies. This study determined that, due to many factors (that may include increased groundwater breakout upgradient of the road with associated erosion and gullying of the steep slope adjacent to the roadway), inadequate stormwater management along the adjacent private property and roadway right-of-way contributes to erosion on and along the roadway and adjacent steep slopes, leading to sedimentation within rare species habitat and the Housatonic

River. While private property ownership considerations remain an ongoing aspect of the planning efforts related to addressing drainage issues at this location, the need for Sheffield to move forward with planning, hydrologic and engineering assessments, and design of best management practices that may include nature-based solutions, was a necessary step to establishing a climate resilient drainage path across this dirt roadway. The details of this case study are provided at the end of this report.

WEATOGUE ROAD (FACING SOUTH)

Background

Climate Change and Dirt Road Infrastructure

The impacts of climate change are already being experienced in western Massachusetts and across the Commonwealth, with stronger, more frequent storms, a reduction in the number of days below freezing, delays in winter freezing, and earlier spring thaws, that enhance flooding and erosion – and our communities are struggling under these conditions. Trends show that these climate change hazards are expected to increase in severity over the coming decades, causing even more strain on our society, environment, and infrastructure. This strain includes public health risks associated with heat, polluted water, poor air quality, and safety risks from unprecedented flooding impacts. A climate data infographic has been attached to this report for reference. Downscaled climate data tables have also been provided as an attachment to this report.[6]

The Intergovernmental Panel on Climate Change (IPCC) explicitly identifies unpaved roads as uniquely vulnerable to "a number of climate-based factors, especially to increasingly intense precipitation leading to washout and disruption of service."[7] While large storms and flood events may catastrophically wash out sections of dirt roads, seasonal rain events and snowmelt also contribute to persistent road degradation. Heavy rainfall events have increased measurably across the Northeast in recent decades, including western Massachusetts, and the frequency and severity of such events is expected to rise further, likely resulting in more frequent flooding. Winter precipitation is projected to increase with a shift toward increased rain and substantially decreased snow. Exposure to flooding and extreme snow events shortens the life expectancy of roads. The stress of water and snow may cause damage, requiring more frequent maintenance, repairs, and rebuilding. The projected increase in winter precipitation falling as rain instead of snow means that winter flooding could occur more frequently if the frozen ground cannot absorb precipitation. Landslides and washouts could also occur more frequently, as saturated soils are exposed to more rainwater.

The effects of a changing climate have already been observed on rural dirt roadways in western Massachusetts. Changing temperature and precipitation patterns, along with associated flood related hazards are a major concern for municipalities such as Sheffield, New Marlborough, and Sandisfield. Precipitation events characterized by increasingly intense rainfall is well documented within these communities. Sheffield and Sandisfield, for example, list inland

---

[6] Source data for this climate data infographic is provided on the Massachusetts Municipal Vulnerability Preparedness Program website at: https://www.mass.gov/municipal-vulnerability-preparedness-mvp-program.

[7] https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap10_FINAL.pdf

flooding as the top climate related hazard within their 2018-2019 Massachusetts Municipal Vulnerability Preparedness (MVP) Planning efforts. Similarly, New Marlborough identified inland flooding as part of its MVP Planning efforts that occurred in 2020.[8]

According to climate change projections provided by resilientMA.org, as the climate continues to change, increased precipitation will occur during winter months falling as either rain, snow, or ice. The risk of flooding within rivers such as the Housatonic and its tributaries will become increasingly prevalent under these conditions. Climate projections also predict warmer annual average temperatures with changes to temperature patterns that will likely affect freeze-thaw cycles. It is anticipated that adverse financial, social, and economic impacts related to climate effects on rural dirt roadway infrastructure will be exacerbated as climate exposure becomes more frequent and extreme. The effects of extreme storm events are placing additional burden on rural infrastructure, public services, and the environment.

Based on a review of relevant literature and drawing upon local institutional knowledge, certain consequences of climate change were identified as significant climate vulnerabilities for unpaved road infrastructure in western Massachusetts. Some of the key consequences relate to reductions in the number of cold days (days below freezing), delays in winter freezing, and earlier spring thaws, all of which contribute to increased rates of dirt road deterioration.[9] These changes have impacted "mud season" in western Massachusetts.

Mud season occurs in places where the ground freezes in winter and thaws in spring, typically in late winter and early spring when dirt roads become muddy from melting snow and rain. In the spring, as the snow recedes, the surface of the road gets muddy and soft. This is caused by the upper layer of the road bed thawing. The water that thaws is trapped between the ice below and the surface, and as a result it is unable to drain easily. This leads to potholes, rutting, and muddiness that make driving difficult, and sometimes nearly impossible. While in the past there has typically been one annual mud season in the spring, towns in western Massachusetts are now experiencing multiple freeze-thaw cycles over the winter months, causing persistent and severe mud seasons that span multiple seasons.

[8] For more information about the MVP Program, visit https://www.mass.gov/municipal-vulnerability-preparedness-mvp-program

[9] Daniel, J. S., Jacobs, J. M., Miller, H., Stoner, A., Crowley, J., Khalkhali, M., & Thomas, A. (2018). Climate change: potential impacts on frost–thaw conditions and seasonal load restriction timing for low-volume roadways. *Road Materials and Pavement Design*, *19*(5), 1126-1146.

Mud season was a particularly salient issue in the late winter-early spring of 2021 when this report was being prepared. Municipal employees and residents suggested the area experienced among the worst episode of freeze-thaw in memory, where over two feet of frozen ground surface melted following two 70-degree F days in early March. Examples of residents stranded at their homes due to impassible roadways and large trucks buried in mud were common throughout the region.

PHOTO: TOWN OF SANDISFIELD, MA

Key Factors for Dirt Road Sensitivity

Sensitivity in the context of this assessment is defined as how a roadway's functionality is affected when exposed to a source of natural or constructed disturbance such as a rainfall event or the presence of design features of a dirt roadway. Drawing upon stakeholder engagement and a review of publications and resources available for use as references on dirt road construction and maintenance (see *Attachment 1: Data Collection Memo*), the following standardized list of eleven key factors for sensitivity was identified for dirt roads. This table is followed by more detailed descriptions of these sources of vulnerability.

Key Sensitivity Factor	Relationship to Dirt Roads	Indicator(s)
Grade/Slope of Road	Unpaved roads with steeper grades (i.e., hills) are vulnerable to faster water flows and more erosion than flatter roads.	Slope (steepness of the road)
Adjacency to Steep Slopes	Roads that lie at an angle to the slope of the landscape may redirect emerging water from upslope into the road. Runoff volume generally increases with steepness of slope.	Presence of slopes along the roadway
Floodplain	Extreme flood events can cause extensive damage to best management practices used on dirt roads	Road is located in special flood hazard area (floodplain)

Entrenched Road	Roads that are entrenched, or lower than the surrounding terrain on either side, collect drainage from the surrounding area and trap it in the road corridor.	Road is lower than the surrounding terrain on either side
Wetlands	Perpetually wet conditions can expedite road degradation, which requires more frequent maintenance and often creates hazardous driving conditions	Roadway intercepts wetlands
Intersections w/ paved roads or driveways	Road issues occur at the interface of paved and unpaved roads.	Presence of intersections with paved roads or driveways
Constructed Drainage	Poorly constructed or maintained drainage including surface ditches and country drainage – or the lack thereof – exacerbates water issues that degrade unpaved roads	Lack of constructed drainage; flowing or ponding water in ditches; and erosion, scouring, or downcutting of ditches
Culverts	Culverts remove water from under a road that would otherwise contribute greatly to road degradation	Condition of culverts (intact, damaged, collapsed, or filled/plugged culverts)
Road Surface Shape	Unpaved roads require more side slope than asphalt roads because the road surface is permeable and the roughness slows runoff. Steeper roads require a more pronounced crown to ensure that water flows off to the side instead of down the road surface.	The shape of the roadway (flat or crowned)
Slope Stability	Unpaved Slope stability refers to areas where slope movements (the geomorphic process by which soil, sand, and rock move downslope) have occurred or are likely to occur in the future under the right conditions of prolonged antecedent moisture and high intensity rainfall.	Slope Stability Score[10]

[10] *Slope Stability Map of Massachusetts*, Massachusetts Geological Survey, 2013. Accessed 11/10/20, http://mgs.geo.umass.edu/biblio/slope-stability-map-massachusetts

Susceptible Tree Canopy	Trees are vulnerable to wind, and more susceptible trees may be knocked down and block passage along the traveled way.	Presence of trees susceptible to being downed by wind along roadway

Placement of the Road on the Landscape

The placement of a road on the landscape affects the direction and velocity of both surface water flow and seeps (groundwater discharges) that intersect the road. Roads that lie parallel to the slope of the landscape – that is, roads with steeper grades – easily channel water down their length unless the road is effectively managed and maintained. Roads that lie at an angle to the slope of the landscape – that is, roads that are adjacent to steep slopes – may redirect emerging water from upslope into the road. These two factors emerged as the most impactful sources of sensitivity for dirt roads across the three towns. In general, unpaved roads that are steep and/or flanked by steep slopes are more adversely impacted by extreme weather events and experience more significant erosion than dirt roads that are flatter and/or surrounded by flat land.

Locations In/Adjacent to Floodplains and Wetlands

One of the most important goals for constructing and maintaining dirt roads is to remove surface and subsurface water from roadways. This is not possible in every situation, particularly for sections of roads that pass through floodplains and wetlands, which naturally occur and cannot be drained. Flooding poses an obvious risk to dirt roads, but wet areas often have weak subgrades and are therefore more vulnerable to rutting and potholes due to very poor soil support. The location of a roadway in a floodplain and/or the presence of wetlands and riparian vegetation are thus indicators of current and/or potential problem areas that if not addressed properly, may create hazardous conditions for motorists.

Wetland Along Roberts Road, Sandisfield

Entrenched Roads

Many unpaved roads have become entrenched, or lower than the surrounding terrain on either side, over time due to traffic, maintenance, and erosion. Entrenched roads collect drainage from the surrounding area and trap it in the road corridor. As this drainage flows downhill, it generally increases in both volume and velocity. This results in erosion of road material away and causes more frequent road maintenance. This can lead to and exacerbate drainage problems on the road.[11]

Entrenched roads trap drainage on the roadway. As this drainage flows downhill, it generally increases in both volume and velocity, resulting in the erosion of road material.

Intersections with Paved Roads and Driveways

Through stakeholder engagement, areas where dirt roadways interface with pavement emerged as a key challenge for maintaining dirt roads. The intersections of dirt roads and paved roads are challenging because deicing salts placed on paved roads during the wintertime migrate onto dirt roads, where it leads to muddiness, rutting, and potholes.

[11] *Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads*, prepared by USDA Forest Service in collaboration with Penn State Center for Dirt and Gravel Road Studies, 2012.

Intersections between dirt roadways and driveways pose another unique set of challenges. Paved driveways are often direct conduits for stormwater runoff to drain quickly from properties into the street, collecting oil, deicing salts, fertilizers, and gasoline residue along the way. Driveways also capture runoff from nearby rooftops, generating an even larger volume of stormwater than what falls on the driveway. These issues are compounded a general lack of stormwater drainage in and along the roadways.

Unpaved driveways are also an issue, as runoff from sloped gravel or dirt driveways typically carries a significant amount of sediment. A large portion of this material washes onto the roadway or clogs up stormwater infrastructure. Extreme rain events are especially challenging, as sheet flow runoff from both paved and unpaved driveways exacerbates erosion along dirt roads. This issue has become increasingly prevalent given the growing number of residences and other development along dirt roads. This construction is creating new paths for runoff onto the road, and there is little to no regulation of private driveways once the curb cut permit is issued. As a result, there is a general lack of maintenance at the interface between driveways and dirt roads.

Constructed Drainage and Culverts

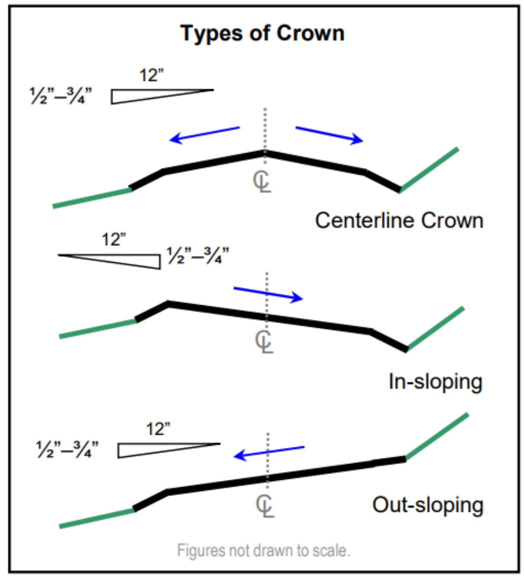
Often the right-of-way for a dirt road is too narrow or the road is entrenched (cut too deep into the parent soil) to allow for the construction of an ideal road cross section that includes proper side ditches for drainage. These roads must rely on the edge of the road to convey water. In extreme weather events, this road edge "ditch" may become washed out. If the ditch has remained clear of debris that can redirect water out into the road, the traveled way may remain intact and the washed-out edge can be repaired. Poorly constructed or maintained drainage including surface ditches and country drainage – or the lack thereof – exacerbates water issues by impeding the:

- Drainage of subsurface water from the road base and subgrade
- Collection of surface runoff and channeling of it away or to a proper crossing point in the road
- Service of constructed drainage as a storage area for large amounts of rainfall
- Collection and retainment of soil particles that normally would be washed into a channel way.

Culverts are degraded where deposited sediment blocks the outlet or where erosion at the inlet alters stream flow away from the culvert and onto the bank or road.

Road Surface Shape (Crown or Cross-Section)

The shape of the road surface is also known as the crown or cross-section, which refers to the pitch given to one side or to both sides of the surface of a road to shed water and reduce potholes. Some road surfaces are crowned (centerline crown) out-sloped (tilted downhill) or in-sloped (tilted uphill). These types of crown are illustrated in the accompanying figure. The crown of a road enables quick water movement from the road surface into ditches and, when sloped correctly, prevents water from running lengthwise down the road. Consequently, this template is the first line of defense against erosion. The shape of the road surface varies with changes in topography, hillslope position, road gradient, and surface and subsurface drainage features. Additional criteria include environmental and resource considerations, safety, traffic requirements, and traffic service levels.[12] Ultimately, when sloped incorrectly – or not at all – erosion, rutting, and other surface deformations are likely to appear on dirt roads.



Types of Crown (Source: Penn State University Center for Dirt and Gravel Road Studies)

Slope Stability

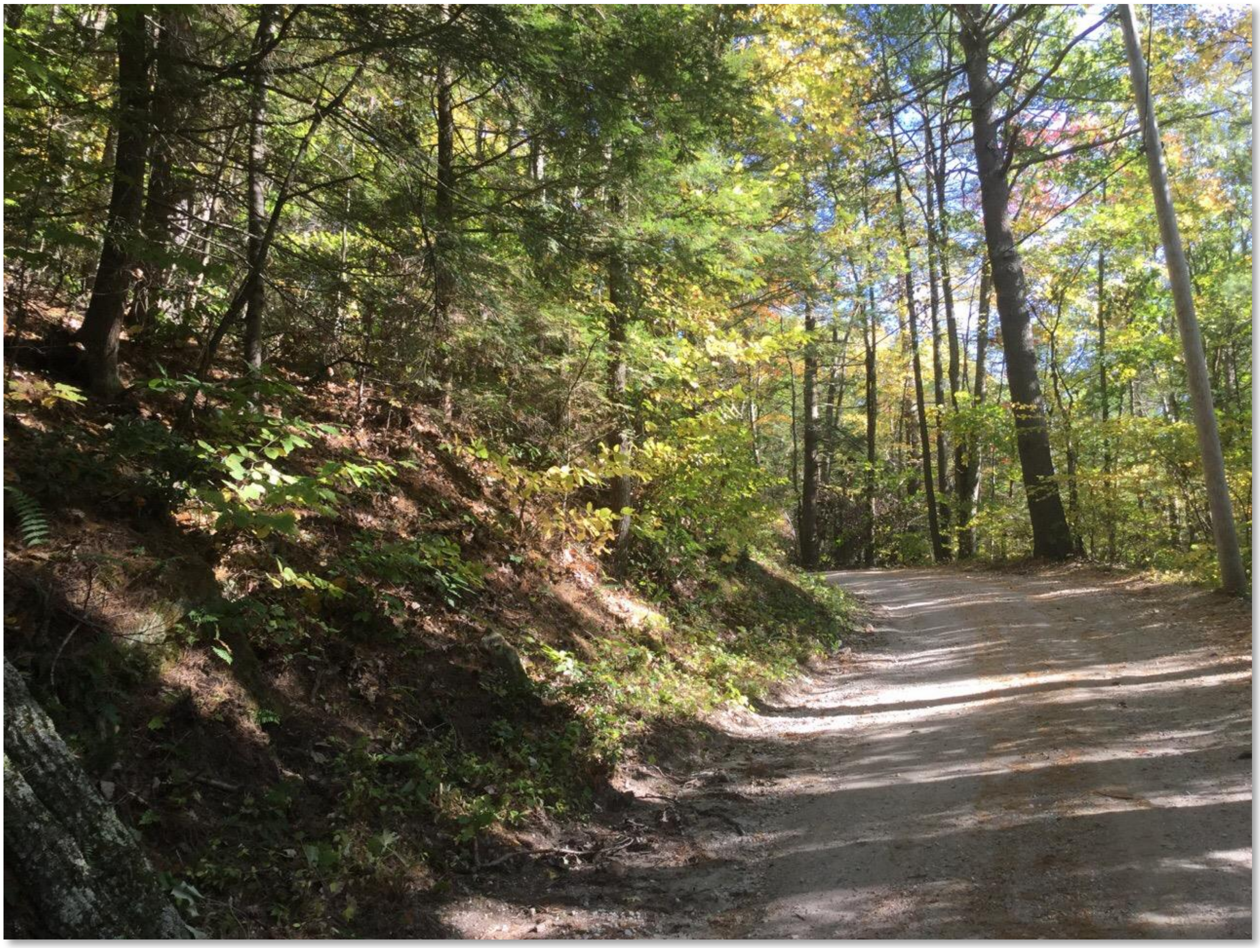
Slope stability refers to areas where slope movements (the geomorphic process by which soil, sand, and rock move downslope) have occurred or are likely to occur. Slope stability information was obtained from the Slope Stability Map of Massachusetts produced by the Massachusetts Geological Survey at the University of Massachusetts, Amherst. The stated intent of this map is "to provide the public, local government and local and state emergency management agencies with a map showing the location of areas where slope movements have occurred or may possibly occur in the future under the right conditions of prolonged antecedent moisture and high intensity rainfall. It is also anticipated that the Massachusetts Department of Transportation (MassDOT) working with municipalities will find this information useful in planning upgrades and improvements to culverts and drainage along roadways in the future."[13]

---

[12] *Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads*, prepared by USDA Forest Service in collaboration with Penn State Center for Dirt and Gravel Road Studies, 2012.

[13] http://mgs.geo.umass.edu/biblio/slope-stability-map-massachusetts

The use of the Slope Stability Scores produced by the Massachusetts Geological Survey requires access to and proficiency with using GIS. As such, rural municipalities may not have the capacity to factor these scores into their dirt road assessments.



Example of steep adjacent slopes and an in-sloping roadway crown on Campbell Falls Road, New Marlborough, MA

Susceptible Tree Canopy

Trees are frequently knocked down by weather-related events. Major damage to parts of trees or even entire trees can result from high winds, snow and ice. These fallen trees and tree limbs pose significant risks for roadways by blocking access and downing powerlines. Additionally, fallen trees are a significant hazard to human health and life during severe weather events when a vehicle is either struck by a tree or crashes into a downed tree on the road.[14] The presence of trees susceptible to being downed is not unique to dirt roads; however, dirt roads are often narrow and located in rural areas with significant tree canopy immediately adjacent to and overhanging

[14] Schmidlin, T. W. (2009). Human fatalities from wind-related tree failures in the United States, 1995–2007. *Natural Hazards*, *50*(1), 13-25.

roadways. Additionally, sick and damaged trees, as well as certain tree species, are more susceptible to being knocked down. Consequently, the prevalence of trees susceptible to being downed along a dirt road factors into the roadway's climate sensitivity.

Other Factors

The preceding list of key factors for the sensitivity of dirt roads is not exhaustive; rather, it focuses on factors that lend themselves to being most reliably and consistently assessed in the field. The condition of the road surface is not included because of the myriad factors impacting roadway surface conditions. For example, corrugation, also known as washboarding, is caused by four primary factors: 1) the driving habits of people (hard acceleration and aggressive breaking); 2) lack of moisture; 3) poor quality of gravel, and 4) a lack of crown on the surface (i.e., flat road surface).[15] Typical roadway maintenance, particularly the manner in which the roadway is graded, can also lead to corrugations and other surface deformations. As a result, the roadway surface condition is not a reliable indicator for dirt road sensitivity.

[15] *Gravel Roads Construction and Maintenance Guide*, prepared by the Federal Highway Administration, August 2015, https://www.fhwa.dot.gov/construction/pubs/ots15002.pdf

Project Methodology

BSC Group and the Towns of Sheffield, New Marlborough, and Sandisfield undertook a Vulnerable Dirt Road Scoring and Prioritization process to generate a prioritized list of dirt roadways based on sensitivity to the impacts of climate change and criticality. This process, described below, is flexible and designed to be transferable to other communities that face the challenge of maintaining dirt roads. A municipality can tailor the evaluation criteria based on unique variables in the community.

Data Collection

Vulnerability in the context of dirt roads is a function of a road's exposure to extreme weather and climate effects, sensitivity to climate effects, and adaptive capacity. Exposure refers to whether the road is located in an area experiencing direct effects of climate change; sensitivity refers to how the roadway fares when exposed to a climate variable; and adaptive capacity refers to the transportation system's ability to cope with existing climate variability and future climate change. In assessing the vulnerability of dirt roads, this project assumes that all dirt roads are exposed to the identified climate and extreme weather variables. Therefore, the sensitivity and criticality of dirt roads was evaluated to generate of a priority rankings matrix for each municipality.

The development and refinement of the data collection tool and recommendations outlined in this report occurred through a series of meetings with representatives from each municipality, online data collection (survey and mapping), and field testing.

Core Planning Team Meetings and Survey

The Rural Dirt Roads Core Planning Team kicked off the project with a meeting in June 2020. This Core Team was comprised of municipal staff from the three communities of Sheffield, New Marlborough, and Sandisfield. Members include town administrators, municipal board members (e.g. Board of Selectmen), highway superintendents and staff, and representatives from the police and fire departments. This group of municipal staff members worked with BSC Group to draw upon local institutional knowledge to help identify the predominant sources of climate exposure for dirt roads (increased precipitation, seasonal temperature variability, extreme weather events), common challenges/sources of vulnerability for dirt roads, and known locations where significant rural dirt roadway vulnerabilities exist.

A survey was completed by Core Team members to capture information related to the following topics:

1. Type of extreme weather event that has the biggest impact to dirt roads in the community (extreme precipitation events, flood events, extreme heat, extreme cold, fluctuating temperatures/seasonal temperature variability, other).
2. Which types of use are most adversely effected by dirt roads damaged following a storm event (residential vehicular travel, school bus routes, emergency access/evacuation routes, tourism / access to recreational areas, ecological resources, other).
3. Observations related to the adverse impacts of damaged dirt roads in the community.
    a. Geographic areas presenting the biggest source of vulnerability for dirt roads (areas low in the landscape typically characterized by floodplains, areas high in the landscape adjacent to mountainous areas with steep slopes, areas where this a confluence with paved and dirt road, other)
4. Limitations for the maintenance of dirt roads (drainage, property boundaries, limited right-of-way, limited vegetative cover, heavy truck traffic, other).
5. Effective repair or management measures used on dirt roads.
6. Most damaged/repeatedly damaged dirt roads in the municipality.
7. Regulatory constraints to maintaining dirt roads.

Development of Online Data Collection Tool

A web-based Geographic Information Systems (GIS) tool with pertinent geospatial information related to this assessment was created to solicit input from municipal stakeholders. Infrastructural, societal, and environmental data such as dirt roadways, floodplains, steep topography, sensitive soils, sensitive receiving waterbodies, and critical infrastructure/assets were used to facilitate decision-making processes during Core Team planning efforts. This online mapper allowed Core Team members to add data points to specific locations along dirt roads where issues exist, such as areas where the road has repeatedly washed out or experiences frequent rutting and washboarding. This data, as well as the input collected through the institutional knowledge meetings and survey, was subsequently integrated into a mobile GIS application for tablet-based field data collection efforts.

If an online mapper is not available for a municipality, alternative methods can be used to solicit input from stakeholders. Printed maps depicting dirt roadways, floodplains, and waterbodies may be distributed, which will allow stakeholders to provide valuable input regarding specific locations.

Development and Implementation of Field Data Collection Tool

To understand the sensitivity of dirt roads to climate change, this study assessed 18 to 24 dirt roadways in each of the three communities, accounting for nearly 85% of the municipal owned dirt roadways across the three case municipalities. Roadways were chosen based on identification by Highway Department staff from each town as well as data collected through the online mapper. The field data collection effort involved BSC staff members traveling the dirt roads in each community to collect data on a tablet related to the sensitivity of dirt roadways, including the status of environmental conditions such as adjacency to wetlands, floodplains, steep slopes, paved roads, and other conditions detailed above. Highway Department staff from each municipality brought BSC staff to several representative problem areas in the community, and BSC staff subsequently completed field data collection on their own.

Vulnerable Dirt Road Scoring and Prioritization

Step 1 – Develop a Sensitivity Score for Dirt Roads

Sensitivity scores provide a quantitative measure of the conditions that increase the vulnerability of dirt roads to the effects of climate change. The variables used to score for dirt road vulnerability were derived from the following three sources: 1) the literature review of dirt road resources (please refer to *Attachment 1: Data Collection Memo*); 2) Institutional knowledge gathered from Core Team meetings, interviews, and an online survey; and 3) data collected from the online data viewer. These variables and their ranking scores correspond with the key factors for dirt road sensitivity described above.

Scoring explanations for each sensitivity ranking category are provided below and on the following page.

Sensitivity Ranking Matrix					
Ranking	**1. Floodplain**	**2. Intersections w/ paved roads or driveways**	**3. Grade/Slope of Road**	**4. Constructed Drainage**	**5. Entrenched Road**
4	100-year	≥ 21	Steep		Yes
3	500-year	11-20	Slightly Steep	Poor or None	
2		1-10			
1	None	0	Flat	Adequate	No

Ranking	6. Adjacency to Steep Slopes	7. Slope Stability Score	8. Crown	9. Wetlands	10. Susceptible Tree Canopy	11. Culverts
4	Yes - Unprotected or Grass	.01 - .99		Present	Significant	
3	Yes - Trees and Shrubs	2	Flat	Significant Seep	Moderate	Failed
2	Yes - Structural Stabilization	3 - 4		Minimal Seep	Slight	Compromised
1	No	0 or -9999	Crowned	None	None	Intact/None

To score for sensitivity, each dirt road was assigned a score from 1 – 4. Scoring categories were reviewed and discussed among the Core Team and refined during field implementation. The field data collection tool template is included in the Appendix. BSC Group staff traveled each dirt road and assigned a score for each individual sensitivity category. An overall sensitivity score was calculated for each dirt road by summing all of the rankings. The minimum sensitivity score for a dirt road is a 10 and the maximum sensitivity score is 41.

The key factors for sensitivity that can be assessed in the field are somewhat limited. Factors that are not easily assessed during field data collection include subsurface water and hydrologic connectivity. While visual indicators such as ruts and potholes in the road surface are useful for identifying subsurface water problems, the extent to which the visual indicator relates to vulnerability is obscured by the municipality's road maintenance schedule.

Example Sensitivity Scores shown on the following page are based on the key variables assessed in the field.

Example Sensitivity Score Calculations						
Roadway	1. Floodplain	2. Intersections w/ paved roads or driveways	3. Grade / Slope of Road	4. Constructed Drainage	5. Entrenched Road	6. Adjacency to Steep Slopes
Dodd Rd (Sandisfield)	1	3	3	3	4	4
Hammertown Rd (Sandisfield)	1	3	4	3	4	3
Barnum St (Sheffield)	1	2	4	3	4	3
Weatogue Rd (Sheffield)	3	2	4	3	4	3
Brewer Hill Rd (New Marlborough)	1	3	4	3	1	1
Campbell Falls Rd (New Marlborough)	4	2	4	3	4	3

Roadway	7. Slope Stability Score	8. Crown	9. Wetlands	10. Susceptible Tree Canopy	11. Culverts	Sensitivity Score
Dodd Rd (Sandisfield)	1	3	1	3	1	**24**
Hammertown Rd (Sandisfield)	2	3	4	4	2	**30**
Barnum St (Sheffield)	3	1	1	4	2	**28**
Weatogue Rd (Sheffield)	3	3	4	4	2	**35**
Brewer Hill Rd (New Marlborough)	1	3	1	2	1	**21**
Campbell Falls Rd (New Marlborough)	2	3	4	3	2	**34**

Step 2 – Prepare Criticality Matrix & Calculate Criticality Scores

The next step in this vulnerability assessment involved determining the criticality of each roadway, based on as the following factors: cost to repair and maintain, community access, impact on public health and safety, and economic impact. To conduct the criticality assessment, each municipality scored each dirt road based on the criticality ranking matrix on the following page developed by the project team. The scoring categories were reviewed and discussed among the Core Team members to reflect information and local knowledge that is readily available. The categories are therefore flexible, and other municipalities can adapt the matrix to reflect local factors and available data.

Criticality Scoring Matrix		
Category	**Definition**	**Scoring (1-3)**
Maintenance/Cost	Roadway is a source of recurring repair / maintenance due to weather related impacts	1 = Rarely/Never 2 = Sometimes 3 = Frequent
Community Access	• Educational access (bus route or school on dirt road) • Recreational area access (recreational area on dirt road) • Municipal resource access (Town Hall, Fire Department, DPW, etc.)	1 = None of these 2 = One (1) of these 3 = Two (2) or more of these
Impact on Public Health and Safety	• Emergency evacuation route (aka main connection) • Vulnerable population and emergency access (known vulnerable population living on road) • Number of residences on road	1 = None of these 2 = One (1) of these 3 = Two (2) or more of these
Impact on Local Economy	• Local business(es) / employer(s) / farm(s) located on dirt road	1 = None 2 = Moderate 3 = Significant

The minimum criticality score for each dirt road is a 4. The maximum value for a roadway is 12. An example of the Criticality Score calculation, using the same dirt roads in the previous step, is shown below.

Example Criticality Score Calculations					
Roadway	**Maintenance**	**Access**	**Public Health**	**Economy**	**Raw Criticality Score**
Dodd Rd (Sandisfield)	2	3	3	3	11
Hammertown Rd (Sandisfield)	2	2	3	2	9
Barnum St (Sheffield)	3	3	3	2	11
Weatogue Rd (Sheffield)	3	3	1	1	8
Brewer Hill Rd (New Marlborough)	3	2	2	1	8
Campbell Falls Rd (New Marlborough)	3	2	2	2	9

Step 3 – Calculate Prioritization Index Scores

The final step of this assessment scoring methodology combines sensitivity scores and criticality scores for each roadway to determine a Prioritization Index Score using the following formula:

Sensitivity Score + Criticality Score = Prioritization Index Score

The Prioritization Index Score, is intended to provide additional decision support for the municipalities when determining how to prioritize their resilience efforts. Example Prioritization Index Scores shown below.

Roadway	Raw Criticality Score	Sensitivity Score	Prioritization Index Score
Dodd Rd (Sandisfield)	11	24	46
Hammertown Rd (Sandisfield)	9	30	48
Barnum St (Sheffield)	11	28	39
Weatogue Rd (Sheffield)	8	35	43
Brewer Hill Rd (New Marlborough)	8	21	37
Campbell Falls Rd (New Marlborough)	9	34	52

Methodological Limitations and Assumptions

This methodology is predicated on a number of assumptions. First and foremost, it is assumed that all dirt roads are already vulnerable to changing climate conditions that are distributed across the community. That is, a dirt road in one part of the municipality is equally vulnerable to sources of climate exposure as a dirt road in another location – the critical differences between dirt roads instead relate to the key sensitivity factors outlined above (e.g., adjacency to steep slopes). Likewise, this project assumed that roadway conditions will continue to deteriorate as climate change hazards are expected to increase in severity over the coming decades. For example, more precipitation will exacerbate erosion issues that are already occurring on dirt roads.

A second, and related, methodological assumption is an important feature of this assessment. This methodology recognizes limited data that would normally be used to conduct a robust quantitative analysis given asset or community feature. Given the large geographic region evaluated for this assessment and limited data to quantify the extent of future climate impacts, the chosen approach to address data limitations is deemed effective for this data collection effort.

Finally, a third methodological consideration was applied to this data collection effort. Early in this endeavor, the project team recognized that any dirt road may have multiple sources of sensitivity to climate change. For example, a long dirt roadway that passes through steep mountainous areas and flat foothill areas adjacent to wetlands or floodplains may have numerous sources of vulnerability. This condition supports scoring any given road in segments based on source of sensitivity. Due to resource limitations, this project evaluated each roadway as a single unit with a combined sensitivity, criticality, and overall prioritization index score.

Each of the three methodological considerations listed above are important factors to consider for future iterations of this methodology or future data collection efforts.

Dirt Road Resiliency Recommendations

Maintaining unpaved roads in western Massachusetts presents a greater challenge today than ever before. The combination of more frequent severe weather and increased traffic negatively impacts dirt roadway conditions and strains municipal maintenance budgets. However, this assessment of rural dirt road vulnerabilities in the towns of Sheffield, New Marlborough, and Sandisfield has highlighted key resiliency themes and solutions.

Resiliency Recommendations

Dirt Road Characteristics and Climate Exposure - Detailed geospatial information related to climate exposure and dirt roads is limited. Three significant assumptions were used to develop this methodology: 1) all dirt roads are already vulnerable to changing climate conditions that are distributed across the community; 2) climate data that may be used to conduct a quantitative scoring system for dirt roads subject to varying types of climate exposure is limited; and 3) dirt roads commonly exhibit numerous sources of sensitivity on a given road. This condition would suggest evaluating dirt roads in a segmented manner and providing a different vulnerability score based on a given location. Addressing these three methodological limitations requires significantly greater resources than this project allowed for. Future iterations of this assessment methodology or the development of more site-specific, location-based dirt road vulnerability assessments should consider these limitations and address as needed.

Climate Data Projections – More recent and nuanced climate projections could be applied to future dirt road assessments. Downscaled climate data provided by the MVP program is a useful starting point to consider changing climatic conditions within the Housatonic River Basin through the end of century (See Appendix). For this level of assessment these climate projections reveal important general climatic changes that will occur, for example increased precipitation in winter months and a greater frequency of temperature extremes. These general seasonal characteristics provide an important measure for baseline climate resilience planning, but is limited relative to the design and implementation of climate resilience measures. Future climate adaptation planning on dirt roads should consider more robust climate data. Hydraulic assessments to measure sub-watershed precipitation, runoff, and flood conditions is important. Climate modeling of future wind conditions is also an important measure for evaluating tree canopy health and risk.

Dirt Road Vulnerability – This assessment evaluated entire lengths of dirt roads as a single unit and made broad assumptions regarding the characteristics of these roadways. These assumptions included physical characteristics of a roadway such as naturally occurring features, construction infrastructure, or their role in public services. A refined analysis that accounts for dirt road condition (e.g. characteristics of surface materials relative to the surrounding environment) would allow for more robust quantification of roadway vulnerability. Additionally, information that includes transportation specific information such as traffic counts, vehicle speed characteristics, or types of vehicles that utilize the roadway would also allow for a more robust analysis. Understanding that other communities may have different dirt roadway characteristics than those used to develop the scoring methodology used in this report, this prioritization scoring tool has been developed to allow for modifications based on conditions that may be unique to a particular community.

Dirt Road Sensitivity and Criticality Analysis – Understanding that other communities may have different dirt roadway characteristics than those used to develop the scoring methodology used in this report, this prioritization scoring tool has been developed to allow for simple modifications based on evaluations of sensitivity and criticality that may be unique to a particular community.

Engineering Resilience – Many factors contribute to the vulnerability of dirt roads relative to a changing climate. The engineering and construction/maintenance of dirt roads remains a constant struggle for municipalities tasked with managing dirt roads. The most significant factor to consider when conducting dirt road management is moving water off the dirt road and improving drainage along roadside shoulders.

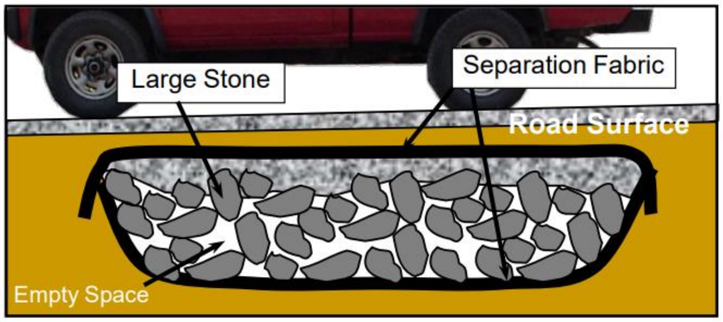
Water management, including the use of constructed stormwater management features, on dirt roads often exacerbate the problem rather than addressing the underlying symptoms of road degradation and erosion.[16] While traditional methods of stormwater management are typically considered standard practices, these approaches may be worsening the problem. It is important to recognize these conditions and address appropriately. Well-built roads, for example, use a variety of materials of different size aggregates and permeability for different parts of their structure. This design criterion is increasingly resilient to the effects of increased precipitation or flooding.[17] Stormwater management culverts or small bridges also frequently get clogged due to erosive forces along roadside shoulders and small mountainous streams.

Considerations of the surrounding environment are also important. The *Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads* field guide prepared by the USDA Forest Service in collaboration with Penn State Center for Dirt and Gravel Road Studies identifies installation of French mattresses as a best practice for addressing subsurface water. The benefits

---

16 *Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads*, prepared by USDA Forest Service in collaboration with Penn State Center for Dirt and Gravel Road Studies, 2012.

[17] Russ Lanoi. *A Ditch in Time: An Owner's Manual for Those Who Live and Travel on Dirt & Gravel Roads* (2012). Accessed January 28, 2021, https://ruralhometech.com/wp-content/uploads/2019/03/Road-Book-by-RL-8-17.pdf.



SIDE VIEW SCHEMATIC OF A FRENCH MATTRESS (SOURCE: PENN STATE CENTER FOR DIRT AND GRAVEL ROAD STUDIES)

of French Mattress include: stabilizing the road base in areas where the road is weakened by water saturation; allowing for bidirectional free flow of water through road base; maintaining dispersed flows and preventing gully erosion above or below the structure; suitability in wetland situations where a traditional pipe may unintentionally lower the wetland water level; a long service life with little to no need for maintenance; difficult for beavers to plug; and maintaining natural vegetative communities and habitat.

Smaller and Larger French Mattresses During Construction (Source: Penn State Center for Dirt and Gravel Road Studies)[18]

While a number of established dirt road best management guides and practices exist, the key is to focus on addressing the symptoms of dirt road degradation rather than immediate fixes to the problem.[19] This of course can be challenging in emergency or reactionary circumstances where life and safety may be at risk due to a damaged dirt roadway. A change in philosophy away from

[18] Penn State Center for Dirt and Gravel Road Studies Technical Bulletin for French Mattress - https://www.dirtandgravel.psu.edu/sites/default/files/General%20Resources/Technical%20Bulletins/TB_French_Mattress.pdf

[19] The MVP program Nature-Based Solutions toolkit calls for addressing the root cause of an issue and exploring options that could reverse or mitigate the cause rather than temporarily treating symptoms. See https://resilientma.org/mvp/content.html?toolkit=nature_based

collecting water and towards *dispersing* water is needed to reduce environmental impacts and simplify road maintenance[20] – and collectively, over time, will support the resilience of dirt roads.

> Many local owned paved and dirt roadways are subject to frequent flooding and washouts, especially those adjacent to steep slopes. Many of these roadways provide important emergency access and bus routes…With the many dirt roads, Sheffield needs to address water on the roads and crossing them. This may entail hardening some roadways, and using green design and nature based solutions to support the roads in other locations.
> *– Sheffield MVP Findings Report and Survey Response*

Nature-Based Solutions – An emerging approach to climate adaptation is a focus on nature-based solutions that emphasize the protection, restoration, and/or management of ecological systems to safeguard public health, provide clean air and water, increase natural hazard resilience, and sequester carbon.

Nature-based solutions offer numerous co-benefits [21] that address challenges faced by communities:

Climate Resilience by reducing risks from flooding, erosion, and fallen trees

Cost-Effective Alternatives to providing unanticipated repair work and safety improvements resulting from climate change hazards

Supporting Ecosystem Services through preservation and enhancement of biodiverse systems

Supporting Economic Activity by maintaining the unpaved roadways that provide access to important economic activities such as recreation, farming, and logging

---

[20] *Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads*, prepared by USDA Forest Service in collaboration with Penn State Center for Dirt and Gravel Road Studies, 2012, p. 47

[21] This list adapted from the MVP Nature-Based Solutions Toolkit, https://resilientma.org/mvp/content.html?toolkit=nature_based

The application of nature-based solutions to dirt road management provides a cost-effective, climate resilient, environmentally sustainable approach that supports economic activity, human health, and well-being. While the use of nature-based solutions may not always be an obvious solution for dirt roads, this broad-encompassing approach to climate adaptation and resilience is important tool for consideration. The following subsections that outline municipal dirt road policies and opportunities for community engagement provide examples of nature-based solutions for consideration.

Municipal Dirt Road Policies provide non-structural approaches that involve municipal bylaws/ordinances and/or policies that support conservation, natural resource protection, or flood overlay districts. These approaches often establish a basis for future implementation of nature-based solutions. The following bulleted items derived from this study should be considered for integration into existing municipal regulations, or as part of new regulations and policies organized around dirt road management:

- Develop and implement bylaws to address impacts stemming from the influx of new residents and pronounced uptick in the number of delivery trucks and other larger vehicles (passenger trucks and SUVs) traversing dirt roads.
- Develop climate resiliency design guidelines for private properties along dirt roads, particularly for driveways and stormwater management features and approaches.
- Design and implement speed management policies and practices to address larger vehicles (passenger and delivery) traveling on dirt roads.
- Implement traffic volume management to understand and provide for the safe, orderly and efficient movement of persons and goods along dirt roads, and to protect and enhance the quality of the local environment on and adjacent to dirt roads.
- Traffic studies are an important decision-making tool for municipalities that want to better understand how people travel through rural communities. As impacts from climate change increasingly and adversely effect dirt roads, it can be anticipated that rural transportation systems will look different in the coming decades than it does today. A better understanding of what future transportation patterns look like will help guide ongoing roadway management policy relative to the effects of climate change. Pairing the findings from this report with municipal/regional scale transportation studies is recommended. Future analysis of rural roadway transportation systems should consider the following: 1) cost-benefit analysis of ongoing maintenance costs and the upfront costs to build more climate resilient roadway infrastructure, 2) identification of alternate transportation routes within a community should certain roadways become temporarily or permanently closed, and 3) identification of dirt roadways where risks to public health and safety make these roadways candidates for paving.
- Establish robust regional partnerships and mutual aid agreements with nearby communities, which are important sources of support.

- Standardize pavement/dirt interface management. Paved aprons (approximately 10 – 20 feet) into the dirt road help alleviate the transition challenges, including mud and potholes.
- Acquire land adjacent to dirt roadways to alleviate limitations posed by narrow rights-of-way to implementing best management practices and nature-based solutions.
- Implement and enforce seasonal load restrictions (SLRs) and winter weight premiums (WWPs). During certain times of year – particularly during the spring when there is typically a daily freeze-thaw cycle – it is necessary to limit the weight of traffic and encourage drivers to not get too far off the edge of the road. Property owners should schedule heating fuel deliveries to minimize large truck traffic at this time of year as well. Alternatively, deliveries made in the early morning before the road has had a chance to thaw may be arranged if conditions are suitable.[22] Relatedly, coordination with the local farming and logging industry to limit the weight of traffic during certain times of year will also help lessen dirt road degradation. Agriculture and timber are important to the rural economies in western Massachusetts; however, large tractors and logging trucks traversing the dirt roads are contributing to their increased rates of deterioration.

Community Engagement and Education – Limiting non-climate stressors through community education and engagement is an important strategy for ensuring the resilience of dirt roads. For example, educational campaigns that address sources of vulnerability such as travel speed, private property water management, and public right-of-way maintenance would help address some of the non-climate stressors. The local service industry (e.g. contractors) are potential conduits for disseminating information. Local jeep and four-wheeler owners that utilize dirt roads to access off-road areas should also be engaged so that they understand and can mitigate ongoing damage due to their inappropriate use of dirt roads. Lastly, municipalities may seek to formalize stewardship programs in which designated community stewards watch over road, ditch, and culvert conditions to report any conditions that could cause further damage to the road if not taken care of soon.

[22] John "Tiny" Thompson. "Road Agent Explains Mechanics of Mud Season." The Andover Beacon. Accessed January 28, 2021. https://andoverbeacon.com/index.php/10741/road-agent-explains-mechanics-of-mud-season/

Case Study: Weatogue Road, Sheffield, MA

FORTHCOMING

Appendices

A. Climate Data Infographic

B. MVP Downscaled Climate Data Tables (Housatonic Basin)

C. Data Collection Memo (June 2020)

D. Sensitivity and Criticality Scoring Results (New Marlborough, Sandisfield, and Sheffield)

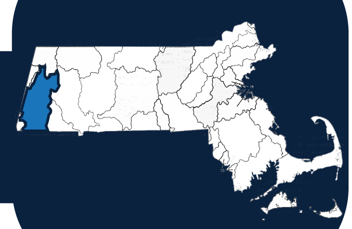
E. Field Data Collection Tool

A. Climate Data Infographic

CLIMATE CHANGE

New Marlborough, Sandisfield, Sheffield, Massachusetts Housatonic Watershed Basin

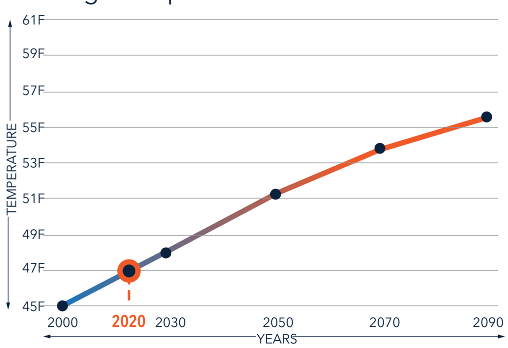
Alford, Becket, Cheshire, Dalton, Egremont, Great Barrington, Hancock, Hinsdale, Lanesborough, Lee, Lenox, Monterey, Mount Washington, New Ashford, New Marlborough, Otis, Peru, Pittsfield, Richmond, Sandisfield, Sheffield, Stockbridge, Tyringham, Washington, West Stockbridge, and Windsor



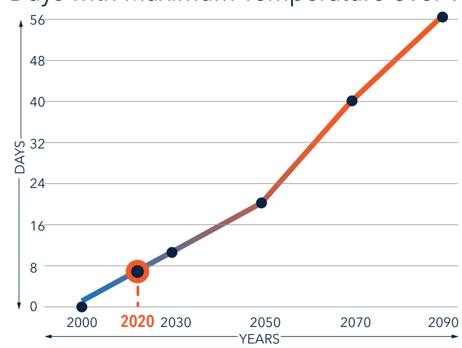
Global warming is caused by the accumulation of greenhouse gases within the atmosphere. Gases that contribute to the greenhouse effect include water vapor, carbon dioxide, methane, and nitrous oxide. On earth, human activities such as burning fossil fuels and land deforestation have altered the delicate balance of atmospheric conditions that regulate our climate. The effect of these changes cause global climate change that are likely to be significant and to increase over time.

EXTREME TEMPERATURES

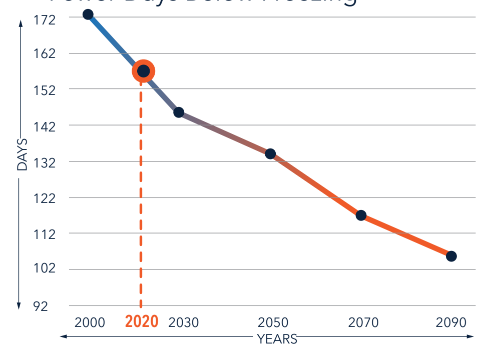
Average Temperatures



Days with Maximum Temperature over 90˚F



Fewer Days Below Freezing

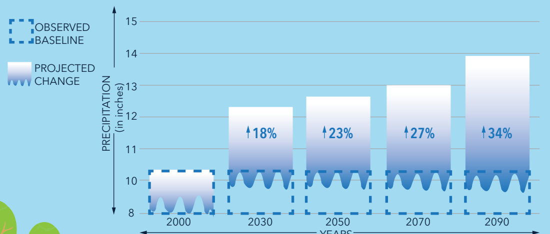


What can NEW MARLBOUROUGH expect as CLIMATE CHANGES?

Climate change has already had observable effects on the environment. Rising temperatures, changes in precipitation patterns, droughts and heat waves, sea-level rise, and extreme storm events have **altered the distribution of risk and how resources are managed.**

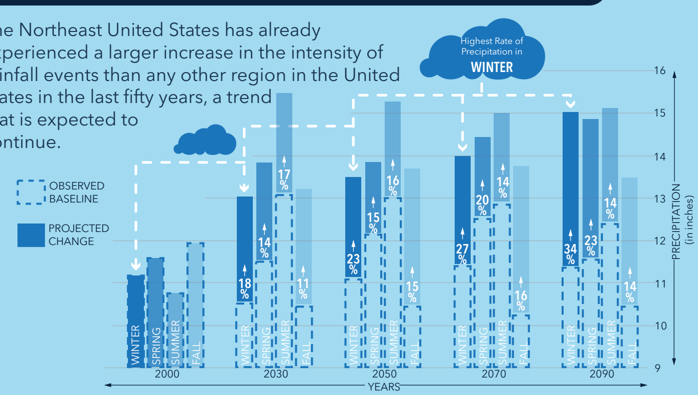
Extreme Snow And Ice Events

Total Annual Precipitation is expected to increase within the Housatonic Basin over the remainder of the century. Most of this increase is expected to occur during winter months where precipitation will fall as either rainfall or extreme snow or ice events.



More Annual Precipitation and Inland Flooding

The Northeast United States has already experienced a larger increase in the intensity of rainfall events than any other region in the United States in the last fifty years, a trend that is expected to continue.



Blizzards, Nor'Easters and Hurricanes

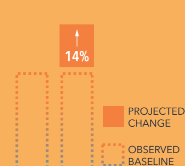
Storm events fueled by higher temperatures, increased evaporation, and atmospheric moisture leads to stormy weather of increased duration and intensity.

Wind / Microbursts

Hazardous wind conditions most commonly accompany extreme storm events. High winds and microburst conditions present unique hazards to infrastructure, public safety and important natural resources.

Drought Conditions

Due to the combined effects of higher temperatures, reduced groundwater recharge from extreme precipitation events, earlier snowmelt, summer and fall droughts may become more frequent.



Heatwaves

Extreme heat events are expected to become more frequent and intense. Socially vulnerable populations are particularly vulnerable to the dangers related to extreme temperature conditions.

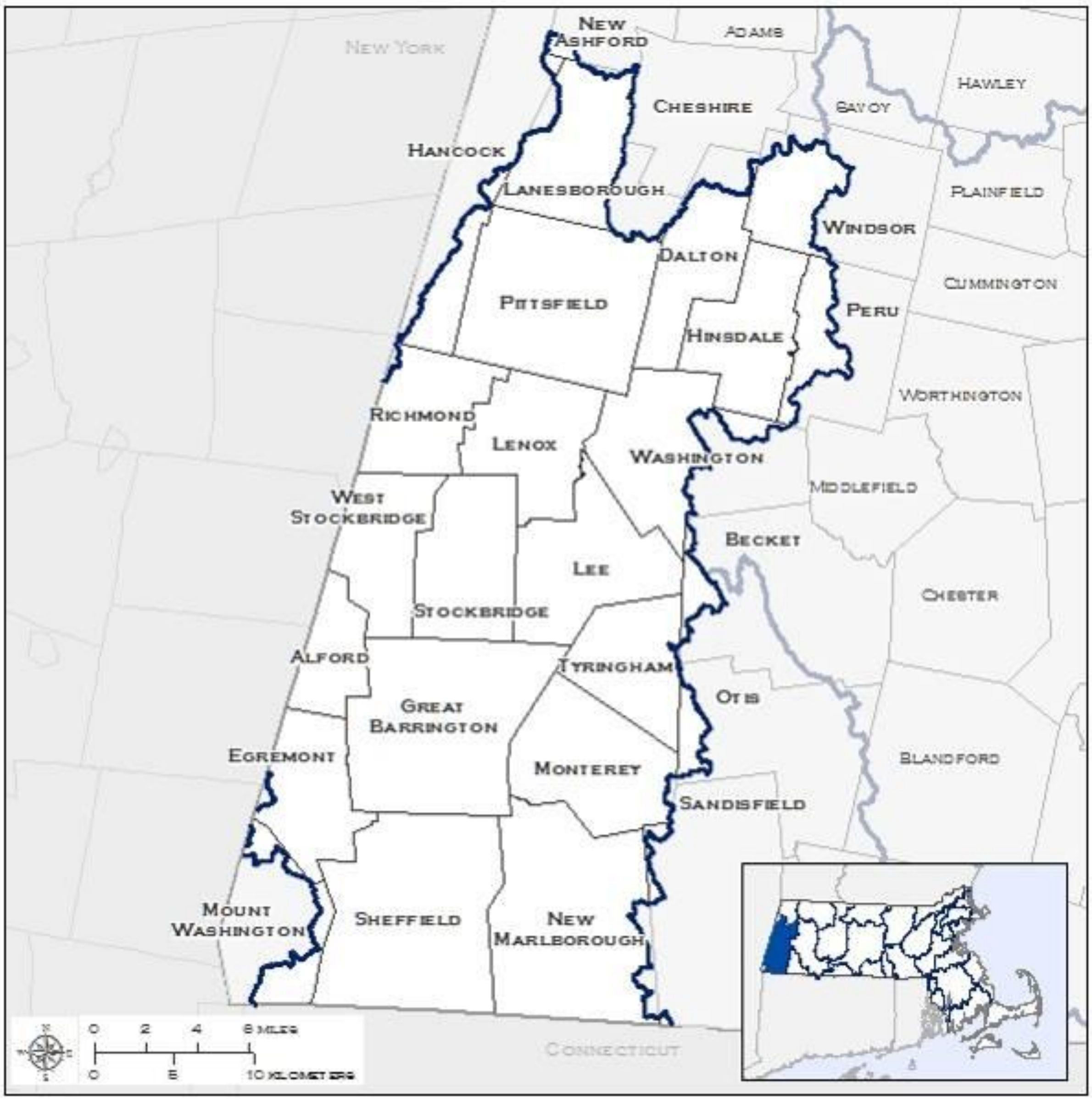
Sources: Massachusetts Executive Office of Energy and Environmental Affairs; ResilientMA.org

BSC GROUP

B. MVP Downscaled Climate Data Tables

HOUSATONIC BASIN

MUNICIPALITIES WITHIN HOUSATONIC BASIN:
Alford, Becket, Cheshire, Dalton, Egremont, Great Barrington, Hancock, Hinsdale, Lanesborough, Lee, Lenox, Monterey, Mount Washington, New Ashford, New Marlborough, Otis, Peru, Pittsfield, Richmond, Sandisfield, Sheffield, Stockbridge, Tyringham, Washington, West Stockbridge, and Windsor



Many municipalities fall within more than one basin, so it is advised to use the climate projections for the basin that contains the majority of the land area of the municipality.

HOUSATONIC BASIN

Housatonic 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	44.3	+2.2 to +4.6	+3.1 to +6.7	+3.7 to +9.3	+4.3 to +11.3
	Winter	22.5	+2.6 to +5.9	+3.3 to +8.8	+4.4 to +10.5	+4.7 to +12.0
	Spring	42.7	+1.8 to +3.4	+2.4 to +5.6	+3.0 to +7.7	+3.5 to +9.5
	Summer	65.1	+2.3 to +4.4	+3.0 to +6.9	+3.5 to +10.0	+4.1 to +12.3
	Fall	46.6	+2.4 to +5.3	+3.8 to +6.9	+3.8 to +9.8	+4.1 to +12.0
Maximum Temperature	Annual	55.4	+2.0 to +4.4	+2.7 to +6.9	+3.3 to +9.5	+3.9 to +11.4
	Winter	32.3	+2.1 to +5.1	+2.8 to +7.9	+3.6 to +9.4	+3.9 to +10.9
	Spring	54.2	+1.5 to +3.4	+2.3 to +5.6	+2.8 to +8.0	+3.5 to +9.6
	Summer	77.0	+2.1 to +4.6	+2.7 to +7.3	+3.4 to +10.5	+4.0 to +12.8
	Fall	57.7	+2.5 to +5.2	+3.5 to +7.4	+3.6 to +10.1	+4.2 to +12.4
Minimum Temperature	Annual	33.2	+2.4 to +4.9	+3.5 to +6.9	+4.2 to +9.1	+4.5 to +11.3
	Winter	12.6	+2.8 to +6.6	+3.9 to +9.6	+5.2 to +11.5	+5.5 to +13.1
	Spring	31.2	+1.9 to +3.7	+2.5 to +6.0	+3.3 to +7.5	+3.7 to +9.2
	Summer	53.1	+2.5 to +4.6	+3.3 to +7.1	+3.8 to +9.7	+4.2 to +11.8
	Fall	35.6	+2.1 to +5.3	+3.6 to +6.8	+3.9 to +9.4	+4.0 to +11.6

- The Housatonic basin is expected to experience increased average temperatures throughout the 21st century. 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.
- Seasonally, maximum summer and fall temperatures are expected to see the highest projected increase throughout the 21st century.
  - Summer mid-century increase of 2.7 °F to 7.3 °F (3-9% increase); end of century increase of 4 °F to 12.8 °F (5-17% increase).
  - Fall mid-century increase of 3.5 °F to 7.4°F (6-13% increase); end of century increase by and 4.2 °F to 12.4 °F (7-21% increase).
- Seasonally, minimum winter and fall temperatures are expected to see increases throughout the 21st century.
  - Winter mid-century increase of 3.9 °F to 9.6 °F (31-76% increase); end of century increase by 5.5 °F to 13.1 °F (43-104% increase).
  - Fall mid-century of 3.6 °F to 6.8 °F (10-19% increase); end of century increase of 4.0°F to 11.6 °F (11-33% increase).

HOUSATONIC BASIN

Housatonic Basin		Observed Baseline 1971-2000 (Days)	Projected Change in 2030s (Days)	Mid-Century Projected Change in 2050s (Days)	Projected Change in 2070s (Days)	End of Century Projected Change in 2090s (Days)
Days with Maximum Temperature Over 90°F	Annual	1	+3 to +10	+4 to +20	+6 to +39	+7 to +57
	Winter	0	+0 to +0	+0 to +0	+0 to +0	+0 to +0
	Spring	<1[54]	+<1[54] to +<1[54]	+<1[54] to +1	+<1[54] to +2	+<1[54] to +3
	Summer	1	+3 to +9	+4 to +18	+5 to +33	+7 to +47
	Fall	<1[54]	+<1[54] to +1	+<1[54] to +2	+<1[54] to +5	+<1[54] to +7
Days with Maximum Temperature Over 95°F	Annual	<1[54]	+<1[54] to +3	+<1[54] to +6	+1 to +15	+1 to +27
	Winter	0	+0 to +0	+0 to +0	+0 to +0	+0 to +0
	Spring	0	+0 to +<1[54]	+0 to +<1[54]	+0 to +<1[54]	+0 to +1
	Summer	<1[54]	+<1[54] to +3	+<1[54] to +6	+1 to +14	+1 to +25
	Fall	0	+0 to +<1[54]	+<1[54] to +<1[54]	+<1[54] to +1	+0 to +2
Days with Maximum Temperature Over 100°F	Annual	0	+0 to +<1[54]	+<1[54] to +1	+<1[54] to +3	+<1[54] to +7
	Winter	0	+0 to +0	+0 to +0	+0 to +0	+0 to +0
	Spring	0	+0 to +0	+0 to +0	+0 to +<1[54]	+0 to +<1[54]
	Summer	0	+0 to +<1[54]	+<1[54] to +1	+<1[54] to +3	+<1[54] to +7
	Fall	0	+0 to +<1[54]	+0 to +<1[54]	+0 to +<1[54]	+0 to +<1[54]

- Due to projected increases in average and maximum temperatures throughout the end of the century, the Housatonic basin is also expected to experience an increase in days with daily maximum temperatures over 90 °F, 95 °F, and 100 °F.
  - Annually, the Housatonic basin is expected to see days with daily maximum temperatures over 90 °F increase by 4 to 20 more days by mid-century, and 7 to 57 more days by the end of the century.
  - Seasonally, summer is expected to see an increase of 4 to 18 more days with daily maximums over 90 °F by mid-century.
  - By end of century, the Housatonic basin is expected to have 7 to 47 more days.

[54] Over the observed period, there were some years with at least 1 day with seasonal Tmax over a certain threshold while in all the other years that threshold wasn't crossed seasonally at all.

HOUSATONIC BASIN

Housatonic Basin		Observed Baseline 1971-2000 (Days)	Projected Change in 2030s (Days)	Mid-Century Projected Change in 2050s (Days)	Projected Change in 2070s (Days)	End of Century Projected Change in 2090s (Days)
Days with Minimum Temperature Below 0°F	Annual	16	-5 to -10	-7 to -12	-8 to -13	-9 to -14
	Winter	15	-5 to -10	-7 to -11	-8 to -12	-8 to -13
	Spring	1	-0 to -1	-0 to -1	-0 to -1	-0 to -1
	Summer	0	-0 to -0	-0 to -0	-0 to -0	-0 to -0
	Fall	0	-0 to -0	-0 to -0	-0 to -0	-0 to -0
Days with Minimum Temperature Below 32°F	Annual	173	-11 to -28	-19 to -39	-22 to -54	-24 to -63
	Winter	87	-1 to -6	-12 to -9	-3 to -16	-4 to -20
	Spring	49	-4 to -10	-6 to -15	-7 to -19	-9 to -21
	Summer	<1[55]	-0 to -0	-0 to -0	-0 to -0	-0 to -0
	Fall	37	-5 to -13	-9 to -16	-9 to -21	-9 to -25

- Due to projected increases in average and minimum temperatures throughout the end of the century, the Housatonic basin is expected to experience a decrease in days with daily minimum temperatures below 32 °F and 0 °F.
- Seasonally, winter, spring and fall are expected to see the largest decreases in days with daily minimum temperatures below 32 °F.
    - Winter is expected to have 2 to 9 fewer days by mid-century, and 4 to 20 fewer days by end of century.
    - Spring is expected to have 6 to 15 fewer days by mid-century, and 9 to 21 fewer days by end of century.
    - Fall is expected to have 9 to 16 fewer days by mid-century, and 9 to 25 fewer days by end of century.

[55] Over the observed period, there were some years with at least 1 day with seasonal Tmin under a certain threshold while in all the other years that threshold wasn't crossed seasonally at all.

HOUSATONIC BASIN

Housatonic Basin		Observed Baseline 1971-2000 (Degree-Days)	Projected Change in 2030s (Degree-Days)			Mid-Century Projected Change in 2050s (Degree-Days)			Projected Change in 2070s (Degree-Days)			End of Century Projected Change in 2090s (Degree-Days)		
Heating Degree-Days (Base 65°F)	Annual	7822	-670	to	-1372	-901	to	-1924	-1058	to	-2516	-1214	to	-2905
	Winter	3850	-215	to	-543	-291	to	-807	-389	to	-952	-437	to	-1099
	Spring	2059	-149	to	-298	-209	to	-481	-257	to	-639	-310	to	-765
	Summer	224	-75	to	-127	-100	to	-164	-120	to	-193	-130	to	-202
	Fall	1690	-193	to	-432	-311	to	-538	-309	to	-744	-325	to	-863
Cooling Degree-Days (Base 65°F)	Annual	261	+160	to	+348	+223	to	+603	+263	to	+940	+310	to	+1262
	Winter	0	+0	to	+0	+1	to	+4	+2	to	+2	+2	to	+11
	Spring	12	+6	to	+19	+11	to	+37	+14	to	+63	+12	to	+97
	Summer	231	+127	to	+281	+169	to	+473	+200	to	+730	+239	to	+931
	Fall	18	+18	to	+60	+28	to	+99	+35	to	+177	+42	to	+235
Growing Degree-Days (Base 50°F)	Annual	1900	+387	to	+744	+528	to	+1187	+627	to	+1776	+714	to	+2238
	Winter	3	+0	to	+8	+1	to	+8	+0	to	+14	+2	to	+20
	Spring	207	+52	to	+118	+83	to	+203	+104	to	+308	+109	to	+407
	Summer	1389	+213	to	+406	+276	to	+636	+322	to	+920	+376	to	+1127
	Fall	293	+101	to	+259	+154	to	+363	+158	to	+550	+201	to	+688

- Due to projected increases in average, maximum, and minimum temperatures throughout the end of the century, the Housatonic basin is expected to experience a decrease in heating degree-days, and increases in both cooling degree-days and growing degree-days.
- Seasonally, winter historically exhibits the highest number of heating degree-days and is expected to see the largest decrease of any season, but spring and fall are also expected to see significant change.
  - The winter season is expected to see a decrease of 8-21% (291-807 degree-days) by mid-century, and a decrease of 11-29% (437 -1099 degree-days) by the end of century.
  - The spring season is expected to decrease in heating degree-days by 10-23% (209-481 degree-days) by mid-century, and by 15-37% (310 -765 degree-days) by the end of century.
  - The fall season is expected to decreases in heating degree-days by 18-32% (311 -538 degree-days) by mid-century, and by 19-51% (325 -863 degree-days) by the end of century.
- Conversely, due to projected increasing temperatures, summer cooling degree-days are expected to increase by 73-205% (169 -473 degree-days) by mid-century, and by 104-403% (239-931 degree-days) by end of century.

- Seasonally, summer historically exhibits the highest number of growing degree-days and is expected to see the largest decrease of any season, but the shoulder seasons of spring and fall are also expected to see an increase in growing degree-days.
  - The summer season is projected to increase by 20-46% (276 -636 degree-days) by mid-century, and by 27-81% (376 -1127 degree-days) by end of century.
  - Spring is expected to see an increase by 40-98% (83-203 degree-days) by mid-century and 53-197% (109-407 degree-days) by end of century.
  - Fall is expected to see an increase by 53-124% (154-362 degree-days) by mid-century and 69-235% (201-688 degree-days) by end of century.

HOUSATONIC BASIN

Housatonic Basin		Observed Baseline 1971-2000 (Days)	Projected Change in 2030s (Days)	Mid-Century Projected Change in 2050s (Days)	Projected Change in 2070s (Days)	End of Century Projected Change in 2090s (Days)
Days with Precipitation Over 1”	Annual	6	+0 to +2	+<1[56] to +3	+1 to +3	<1[56] to +4
	Winter	1	+0 to +1	+<1[56] to +1	+<1[56] to +1	<1[56] to +1
	Spring	1	+0 to +<1[56]	+0 to +1	+0 to +1	<1[56] to +1
	Summer	2	+0 to +1	+0 to +1	+0 to +1	+0 to +1
	Fall	2	+0 to +1	+0 to +1	+0 to +1	+0 to +1
Days with Precipitation Over 2”	Annual	1	+0 to +<1[56]	+0 to +<1[56]	+<1[56] to +1	<1[56] to +1
	Winter	<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]
	Spring	<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]
	Summer	<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]
	Fall	<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]
Days with Precipitation Over 4”	Annual	<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]
	Winter	0	+0 to +0	+0 to +0	+0 to +0	+0 to +0
	Spring	0	+0 to +0	+0 to +0	+0 to +0	+0 to +<1[56]
	Summer	0	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]
	Fall	0	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]	+0 to +<1[56]

- The projections for expected number of days receiving precipitation over one inch are variable for the Housatonic basin, fluctuating between loss and gain of days.
  - Seasonally, the winter season is generally expected to see the highest projected increase.
  - The winter season is expected to see an increase in days with precipitation over one inch of 0-1 days by mid-century, and of 0-1 days by the end of century.
  - The spring season is expected to see an increase in days with precipitation over one inch of 0-1 days by mid-century, and an increase of 0-1 days by the end of century.

[56] Over the observed period, there were some years with at least 1 day with seasonal precipitation over a certain threshold while in all the other years that threshold wasn't crossed seasonally at all.

HOUSATONIC BASIN

Housatonic Basin		Observed Baseline 1971-2000 (Inches)	Projected Change in 2030s (Inches)	Mid-Century Projected Change in 2050s (Inches)	Projected Change in 2070s (Inches)	End of Century Projected Change in 2090s (Inches)
Total Precipitation	Annual	47.4	+0.2 to +4.4	+1.1 to +6.4	+1.6 to +6.9	+1.6 to +7.7
	Winter	10.2	-0.5 to +1.8	+0.1 to +2.4	+0.2 to +2.8	+0.8 to +3.5
	Spring	12.1	-0.1 to +1.7	+0.2 to +1.8	+0.4 to +2.4	+0.5 to +2.8
	Summer	13.2	-0.2 to +2.2	-0.1 to +2.2	-0.4 to +1.9	-0.8 to +1.9
	Fall	11.9	-1.4 to +1.4	-1.3 to +1.8	-1.4 to +1.8	-1.7 to +1.7

- Similar to projections for number of days receiving precipitation over a specified threshold, seasonal projections for total precipitation are also variable for the Housatonic basin.
  - The winter season is expected to experience the greatest change with an increase of 1-23% by mid-century, and of 8-34% by end of century.
  - Projections for the summer and fall seasons are more variable, and could see either a drop or increase in total precipitation throughout the 21st century.
    - The summer season projections for the Housatonic or basin could see a decrease of 0.1 to an increase of 2.2 inches by mid-century (decrease of 1% to increase of 16%), and a decrease of 0.8 to an increase of 1.9 inches by the end of the century (decrease of 6% to increase of 14%).
    - The fall season projections for the Housatonic basin could see a decrease of 1.3 to an increase of 1.8 inches by mid-century (decrease of 11% to increase of 15% and a decrease of 1.7 to an increase of 1.7 inches by the end of the century (decrease of 14% to increase of 14%).

Housatonic Basin		Observed Baseline 1971-2000 (Days)	Projected Change in 2030s (Days)	Mid-Century Projected Change in 2050s (Days)	Projected Change in 2070s (Days)	End of Century Projected Change in 2090s (Days)
Consecutive Dry Days	Annual	16	-0 to +1	-0 to +2	-0 to +2	-0 to +2
	Winter	11	-13 to +1	-1 to +1	-1 to +1	-1 to +1
	Spring	11	-1 to +1	-1 to +1	-1 to +1	-1 to +1
	Summer	11	-1 to +1	-0 to +1	-1 to +2	-1 to +2
	Fall	11	-0 to +2	-0 to +3	-0 to +3	-0 to +3

- Annual and seasonal projections for consecutive dry days, or for a given period, the largest number of consecutive days with precipitation less than 1 mm (~0.04 inches), are variable throughout the 21st century.
  - For all the temporal parameters, the Housatonic basin is expected to see a slight decrease to an increase in consecutive dry days throughout this century.
  - Seasonally, the fall and summer seasons are expected to continue to experience the highest number of consecutive dry days.
    - The fall season is expected to experience an increase of 0-3 days in consecutive dry days by the end of the century.

C. Data Collection Memo (June 2020)

BSC GROUP

33 WALDO STREET, WORCESTER, MA 01608 - www.bscgroup.com
TEL 508-792-4500 - 800-288-8123

MEMORANDUM

To: Project Planning Team
Date: June 19, 2020
From: BSC Group, Inc.
Proj. No.
Re: Data Collection - Memorandum

This data collection memorandum provides a list of online publications and resources available for use as references on dirt road construction, maintenance and best management practices. The purpose of this data review is to identify useful information or gaps in data relative to dirt road vulnerability in the context of climate change. A web-link has been provided to each resource along with a publication summary and statement of applicability to the MVP Dirt Road Project. Text in bold is provided to highlight concepts identified during core team planning efforts relative to this project. This memorandum is organized in a manner that can be updated or amended as new information is collected.

Publication/Website	Summary	Project Applicability
	Best Management Practice Manuals	
Massachusetts Unpaved Road Manual (2001, MassDOT)	Guidance document on unpaved road management. Provides BMPs that can **improve water quality while enhancing the quality of unpaved roads**.	• Applicable to low use dirt roads that have not been significantly entrenched and have sufficient ROW width and easement to allow for the installation of water diverting devices. This document lacks guidance on BMP approaches to roadways with narrow ROW.
US Federal Highway Administration, Vulnerability Assessment and Adaptation Framework, 3rd Edition (2018)	A collection of case studies and examples of climate adaptation assessment frameworks.	• This resource does not explicitly address dirt road vulnerability, but provides many examples of assessment frameworks for use in the application of a dirt road vulnerability assessment.
US DOT, Federal Highway Administration, Gravel Road Construction and Maintenance Guide (2015)	Manual organized by the following topics: **routine maintenance and rehabilitation, drainage, surface gravel, dust control/stabilization, and innovative maintenance techniques**. This resource provides maintenance considerations for many dirt road conditions.	• Provides ten questions to better assess whether a road should be paved. • Doesn't provide specific solutions to specific problems but overall maintenance BMPs. • Includes information on road upgrades for increase in vehicular volume and vehicle size. • Manual set up in a very visual way. Could be used as a model to lay out the project's resulting BMP's.
USDA Forest Service in collaboration with Penn State Center for Dirt and Gravel Roads- Field Guide; Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads	Field guide provides examples of **environmentally sensitive maintenance practices.** Implementation of this field guide is intended to: reduce erosion and sediment, maintain subsurface hydrologic	• Chapter 1 is dedicated to "keys to diagnosing road problems" with an **emphasis on addressing the causes of the symptoms of the problem instead of simply addressing symptoms**. • The remaining chapters provide best

	connectivity, restore drainage density to natural conditions, and eliminate diversion potential. Implementation of these measures is intended to **reduce long term maintenance costs and lengthen maintenance cycles**.	management practices for common dirt road problems, including entrenched roads.
PASER Gravel Road Manual (2002, Wisconsin DOT)	Guidance for planning maintenance and management of gravel roads. Manual discusses common problems and typical repairs and provides a **numerically based ranking system** for evaluating conditions and rating exiting conditions on a given roadway.	• Aspects of this evaluation criteria can be incorporated into a field assessment process.
Penn State Center for Dirt and Gravel Roads (2020) https://www.dirtandgravel.psu.edu/	Comprehensive website resource providing a variety of **best management practices including Environmentally Sensitive Maintenance principles on low volume roads**. Policy guidance also provided for State Conservation Commission funding program.	• What would be required to have a similar program in MA? Money is allotted to conservation commissions through the transportation bill for projects improving water quality.
University of New Hampshire, Center for Infrastructure Resilience to Climate (UCIRC) (2020) https://ceps.unh.edu/research/unh-center-infrastructure-resilience-climate	The UNH Center for Infrastructure Resilience to Climate (UCIRC) is dedicated to **accelerating and advancing the development of new methods and approaches to planning, design, and operation and maintenance of climate and weather resilient transportation and building infrastructure systems**. UCIRC works hand-in-hand with New Hampshire's private sector, providing engineering companies with the resources to be more competitive and to bring innovative ideas to market.	• Current research focus on topics including: State agency decision-making policy on the **opening and closing of roadways during freeze-thaw conditions**, the development of a statistical approach to enhance downscaling of climate and weather parameters for New England, **and changing freeze-thaw impacts on low volume roads in seasonal frost areas**.
Rural Roads Active Management Program, Lake Champlain Watershed, New York (2014)	Developed with funding from the Watershed Improvement Coalition to reduce phosphorus inputs into waters associated with Lake Champlain. Establishes a "Rural Roads	• Ideas for potential future partnerships and pooling of funds; • Ideas for potential funding sources; • Ideas for public outreach/BMP material presentation • **BMPs and recommendations are**

	Active Management Program (RRAMP) to provide county and municipal highway departments **techniques to improve travel corridor risk assessment, project prioritization strategies, best management practices selection and funding assistance for critical sites**. Introduction to road erosion issues and **cost-effective techniques that can be used to enhance and maintain rural roads**. This resource provides **checklists** for assessments of dirt roads.	**general and cursory- good introduction to the issue and possible solutions but not specifically targeted to the issues our communities may be facing**.
Gravel Road Maintenance Manual (Maine, 2016) / Implementing Powerpoint	Manual for landowners and municipal agencies to assist with the maintenance of dirt roads. Maintenance recommendations are focused on protection of water resources within a watershed. Manual incorporates the classic privately held camp road as well as the more recently established two lane dirt roads. Manual is organized as a **troubleshoot guide** with specific road problems and fixes. **Manual incorporates a general introduction to erosion principles and the role of the vegetative buffer common to many other resources of this type**.	• Opportunities for BMPs and improvements of existing conditions on roads that are not travelled by heavy equipment or receive high volume of use. • Provides BMP and maintenance recommendations for narrow and wide based dirt road corridors. • Power point examples provide before and after photos of issues and implemented solutions.
Dirt and Gravel Road BMP Guide, Private Landowners , Virginia (2019)	This resource provides similar assessment approaches as the other resources. **This resource also provides color design standards within associated description limitations and other considerations**.	
Monitoring the Success of BMPs- Research		
Evaluating the Effectiveness of Best Management Practices on Rural Back Roads of Vermont: A Retrospective Assessment (2014)	Study assessed 45 BMPs installed as part of the Vermont Better Backroads Program across VT. Applications varied from stone to culverts, revetments and NBS. Assessment highlighted	• Opportunity to analyze and predict the effectiveness of BMPs including NBS based on similar road conditions and locations. • Useful information to develop public outreach/education.

	BMPs implemented in different road settings that persisted through several climate events. Report findings found that road grade was the strongest predictor of project condition, with BMP's on steeper slopes likely to fail, followed by road orientation with BMP's on slope-parallel roads more vulnerable than cross-slope roads. Expose to extreme floods was a slo a significant predictor of MP efficacy as was the presence of vegetated borders on road sites.	• GIS evaluation metrics include: grade, orientation, profile, vegetated border, exposure to flood, roadway age.
Off-Road Discovery, Gravel and Country Roads Driver Training Techniques		• Useful information to develop public outreach/education
Alternative Solutions		
To Pave or Not To Pave: Making informed decisions of when to update a gravel road (MN DOT, 2006) and http://www.mnltap.umn.edu/	The decision to pave vs. remain unpaved is highly dependent on vehicle trips per day relative to maintenance costs. Variability exists across studies with cost/maintenance savings at around 150-200 vehicle trips per day.	• Paving certain roadways may be a preferred option and should be considered as an evaluation criteria.
USDA, USFS, Soil Bioengineering: an alternative for roadside management (2000)	Publication discusses viable alternatives to stabilizing areas of soil instability with emphasis on areas adjacent to public roadways.	• Solutions are specific to areas that receive 30" or more of annual precipitation. • Provides evaluation criteria to determine if bioengineering can be an effective tool as a roadside BMP. • NBS that requires a wider roadway layout or easement or cooperation with landowner.

cc:

D. Prioritization Index Scoring Results

New Marlborough

Sandisfield

Sheffield

New Marlborough Sensitivity Score

Roadway	Floodplain	Intersections w/ paved roads or driveways	Grade/Slope of Road	Constructed Drainage	Entrenched Road	Adjacency to Steep Slopes	Slope Stability Score	Side Pitch	Wetlands	Susceptible Tree Canopy	Culverts	Sensitivity Score
Brewer Branch Rd	1	3	4	3	4	3	2	3	1	4	3	**31**
Brewer Hill Rd	1	3	4	3	1	1	1	3	1	2	1	**21**
Campbell Falls Rd	4	2	4	3	4	3	2	3	4	3	2	**34**
Canaan Valley Rd	4	3	4	3	4	3	2	3	4	4	3	**37**
Knight Road (West)	1	2	3	3	4	3	1	3	1	3	1	**25**
Cross To Canaan Valley Rd	3	4	4	3	4	3	2	3	4	4	2	**36**
East Hill Rd	4	3	4	3	4	4	2	3	4	3	3	**37**
Foley Hill Rd	1	2	4	3	4	3	2	1	1	4	3	**28**
Hartsville Mill River Rd	4	2	3	3	4	3	3	3	1	4	2	**32**
Hotchkiss Rd	4	3	4	3	4	3	2	3	4	4	2	**36**
Keyes Hill Rd	4	2	4	3	4	3	3	3	1	2	1	**30**
Knight Rd (East)	1	2	3	3	4	2	1	3	1	3	1	**24**
Leffingwell Rd	1	3	4	3	4	3	1	3	1	3	2	**28**
North Road	3	3	4	3	4	3	2	3	4	4	1	**34**
New Marlborough Branch Rd	1	2	3	3	4	3	2	3	1	4	1	**27**
New Marlborough Hill Rd	1	3	4	3	4	3	2	3	4	4	1	**32**
Rhodes and Bailey Rd	4	4	4	3	4	3	2	3	4	4	2	**37**
Sisson Hill Rd	1	2	3	1	4	1	1	3	1	3	2	**22**
Umpachene Falls Rd	4	2	4	3	4	3	2	3	1	3	1	**30**

New Marlborough Criticality and Prioritization Index Scores

Roadway	Maintenance	Access	Public Health	Economy	Raw Criticality Score	Sensitivity Score	Prioritization Index Score
Brewer Branch Rd	3	3	2	2	10	31	51
Brewer Hill Rd	3	2	2	1	8	21	37
Campbell Falls Rd	3	2	2	2	9	34	52
Canaan Valley Rd	3	3	2	1	9	37	55
Knight Road (West)	3	2	1	1	7	25	39
Cross To Canaan Valley Rd	3	2	2	1	8	36	52
East Hill Rd	3	1	2	2	8	37	53
Foley Hill Rd	3	2	3	2	10	28	48
Hartsville Mill River Rd	2	2	2	1	7	32	46
Hotchkiss Rd	3	2	2	1	8	36	52
Keyes Hill Rd	3	1	1	1	6	30	42
Knight Rd (East)	3	2	3	1	9	24	42
Leffingwell Rd	3	2	2	1	8	28	44
North Rd	3	2	2	1	8	34	50
New Marlborough Branch Rd	2	2	1	1	6	27	39
New Marlborough Hill Rd	2	2	2	1	7	32	46
Rhodes and Bailey Rd	3	1	2	1	7	37	51
Sisson Hill Rd	2	2	1	2	7	22	36
Umpachene Falls Rd	3	2	1	1	7	30	44

Sandisfield Sensitivity Score

Roadway	Floodplain	Intersections w/ paved roads or driveways	Grade/Slope of Road	Constructed Drainage	Entrenched Road	Adjacency to Steep Slopes	Slope Stability Score	Side Pitch	Wetlands	Susceptible Tree Canopy	Culverts	Sensitivity Score
Bosworth Rd	1	2	4	3	4	3	1	Flat	4	4	2	**28**
Clark Rd	1	2	4	3	4	3	2	Flat	1	4	1	**25**
Cronk Rd	1	3	4	3	4	3	1	Flat	1	4	3	**27**
Dodd Rd	1	3	3	3	4	4	1	Flat	1	3	1	**24**
E Hubbard Rd	1	2	4	3	4	3	3	Flat	4	4	2	**30**
Elk Rd	1	2	4	3	4	3	2	Flat	1	4	2	**26**
Fox Rd	1	2	4	3	4	3	2	Flat	1	4	1	**25**
Gremler Rd	1	2	3	3	4	3	1	Flat	1	4	1	**23**
Hammertown Rd	1	3	4	3	4	3	2	Flat	4	4	2	**30**
Lower West St	1	3	4	3	4	3	2	Flat	4	3	2	**29**
N Beech Plain Rd	1	4	3	3	4	3	1	Flat	4	4	2	**29**
Norfolk Rd	4	3	4	3	4	3	1	Flat	1	4	1	**28**
Prock Hill Rd	1	2	4	1	1	1	1	Flat	1	3	1	**16**
Roberts Rd	1	2	3	3	4	3	1	Flat	4	3	2	**26**
Rood Hill Rd	4	3	4	3	4	3	2	Crowned	4	4	2	**33**
S Beech Plain Rd	1	3	4	3	4	3	2	Flat	4	4	3	**31**
Sears Rd	1	2	4	3	4	3	2	Flat	4	4	2	**29**
Shade Rd	4	2	3	3	4	3	1	Flat	4	4	3	**31**
Silverbrook Rd	1	3	4	3	4	3	2	Flat	1	4	3	**28**
Stump Rd	1	3	3	1	4	3	1	Flat	1	3	2	**22**
Sullivan Rd	4	2	3	3	1	3	1	Flat	4	3	2	**26**
Viets Rd	1	2	4	3	4	3	1	Flat	4	4	3	**29**
Webster Rd	1	2	3	3	4	1	1	Flat	1	4	1	**21**
West St	1	2	3	3	4	3	1	Flat	4	4	2	**27**

Sandisfield Criticality and Prioritization Index Scores

Roadway	Maintenance	Access	Public Health	Economy	Raw Criticality Score	Sensitivity Score	Prioritization Index Score
Bosworth Rd	2	3	2	2	9	28	46
Clark Rd	3	1	2	2	8	25	41
Cronk Rd	3	2	2	1	8	27	43
Dodd Rd	2	3	3	3	11	24	46
E Hubbard Rd	2	2	2	2	8	30	46
Elk Rd	2	1	2	1	6	26	38
Fox Rd	3	2	2	2	9	25	43
Gremler Rd	1	1	2	1	5	23	33
Hammertown Rd	2	2	3	2	9	30	48
Lower West St	2	3	3	2	10	29	49
N Beech Plain Rd	3	3	3	2	11	29	51
Norfolk Rd	2	2	3	2	9	28	46
Prock Hill Rd	1	2	3	2	8	16	32
Roberts Rd	2	2	2	2	8	26	42
Rood Hill Rd	2	2	2	2	8	33	49
S Beech Plain Rd	3	3	3	3	12	31	55
Sears Rd	2	2	2	3	9	29	47
Shade Rd	2	2	2	2	8	31	47
Silverbrook Rd	3	2	3	2	10	28	48
Stump Rd	2	1	2	3	8	22	38
Sullivan Rd	2	2	1	2	7	26	40
Viets Rd	3	2	3	2	10	29	49
Webster Rd	2	1	1	1	5	21	31
West St	2	3	2	2	9	27	45

Sheffield Sensitivity Score

Roadway	Floodplain	Intersections w/ paved roads or driveways	Grade/Slope of Road	Constructed Drainage	Entrenched Road	Adjacency to Steep Slopes	Slope Stability Score	Side Pitch	Wetlands	Susceptible Tree Canopy	Culverts	Sensitivity Score
Barnum St	1	2	4	3	4	3	3	1	1	4	2	**28**
Bow Wow Rd	1	2	3	1	1	3	1	3	4	3	1	**23**
Brush Hill Rd	1	2	4	3	4	3	2	3	1	4	1	**28**
Bull Hill Rd	4	2	4	3	4	3	3	3	1	4	1	**32**
Covered Bridge Ln	4	1	3	3	4	1	1	3	1	1	1	**23**
Curtiss Rd	1	2	3	1	1	3	1	3	4	4	1	**24**
East Rd	1	2	3	3	1	4	2	3	1	3	1	**24**
Foley Rd	4	4	4	3	1	3	2	3	4	3	2	**33**
Ford Hill Rd	1	2	4	3	1	3	2	3	1	4	2	**26**
Giberson Rd	4	2	3	3	4	2	1	3	4	3	1	**30**
Kelsey Rd	4	3	4	3	1	3	1	3	4	4	2	**32**
Legeyt Rd	1	2	3	3	1	3	1	3	1	3	1	**22**
Lime Kiln Rd	4	2	1	1	1	4	1	3	4	2	1	**24**
Salisbury Rd	4	3	1	1	1	1	1	1	4	2	1	**20**
Upper Barnnum St	1	2	4	3	4	3	1	1	1	4	1	**25**
Veeley Rd	1	2	3	3	4	3	2	3	1	4	1	**27**
Water Farm Rd	4	2	4	3	4	3	2	3	1	4	2	**32**
Weatogue Rd	3	2	4	3	4	3	3	3	4	4	2	**35**

Sheffield Criticality and Prioritization Index Scores

Roadway	Maintenance	Access	Public Health	Economy	Raw Criticality Score	Sensitivity Score	Prioritization Index Score
Barnum St	3	3	3	2	11	28	39
Bow Wow Rd	2	2	3	1	8	23	31
Brush Hill Rd	2	2	1	1	6	28	34
Bull Hill Rd	2	1	2	1	6	32	38
Covered Bridge Ln	1	3	1	1	6	23	29
Curtiss Rd	1	2	1	1	5	24	29
East Rd	2	2	2	2	8	24	32
Foley Rd	2	2	3	2	9	33	42
Ford Hill Rd	2	2	1	1	6	26	32
Giberson Rd	2	3	3	1	9	30	39
Kelsey Rd	1	2	3	1	7	32	39
Legeyt Rd	2	3	3	2	10	22	32
Lime Kiln Rd	1	3	3	2	9	24	33
Salisbury Rd	1	2	3	1	7	20	27
Upper Barnum St	1	2	1	1	5	25	30
Veeley Rd	2	2	3	1	8	27	35
Water Farm Rd	1	2	3	1	7	32	39
Weatogue Rd	3	3	1	1	8	35	43

E. Field Data Collection Tool

Field Data Collection Tool

Vulnerable Dirt Road Sensitivity Scoring

This template is intended for evaluating sources of vulnerability for dirt roads in the field without the aid of a tablet or smartphone. Please refer to the "Key Factors for Dirt Road Sensitivity" section for details regarding each source of vulnerability to be evaluated.

Road Name	# of Inter-sections w/ Paved Roads or Driveways	Grade / Slope of Road	Constructed Drainage	Entrenched Road	Adjacency to Steep Slopes	Side Pitch	Wetlands	Susceptible Tree Canopy	Culverts	Floodplain
Example: Smith Road	*7*	*Steep*	*Adequate*	*Yes*	*Yes - Trees and Shrubs*	*Flat*	*No*	*Significant*	*Comprom-ised*	*500-Year*

Sensitivity Scoring Categories

Ranking	Intersections w/ paved roads or driveways	Grade/Slope of Road	Constructed Drainage	Entrenched Road	Adjacency to Steep Slopes	Crown	Wetlands	Susceptible Tree Canopy	Culverts	Floodplain
4	≥ 21	Steep		Yes	Yes - Unprotected or Grass		Present	Significant		100-year
3	11-20	Slightly Steep	Poor or None		Yes - Trees and Shrubs	Flat	Significant Seep	Moderate	Failed	500-year
2	1-10				Yes - Structural Stabilization		Minimal Seep	Slight	Compromised	
1	0	Flat	Adequate	No	No	Crowned	None	None	Intact/None	None