August
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Resilient Ways Forward:

Transportation Resilience Improvement Plan

DUTCHESS COUNTY
TRANSPORTATION COUNCIL
Better ways from here to there

Disclaimer

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Executive Summary

Our changing climate affects how we live, travel, and play in Dutchess County. Some of us already feel these impacts in how we heat and cool our homes, how much we pay for food, or even how we think about the future. Our transportation system is no different. Events like superstorms, hurricanes, heat waves, extreme winds, and snowstorms damage our infrastructure and disrupt transportation services. How and where we have built infrastructure and provided services may no longer be adequate. And while the impacts of a changing climate may not be all negative, they still require us to adjust the way we build, maintain, and think about our transportation system. These changes present us with challenges, as well as opportunities, to create a more resilient transportation system that minimizes disruptions to our lives and better prepares us to meet the uncertainties of a changing climate.

Figure 1. Poughkeepsie Waterfront flooding after Superstorm Sandy in 2012 (Source: DCTC)

Overview

The Dutchess County Transportation Council (DCTC) is committed to creating a more resilient transportation system to better handle future climate uncertainties. The DCTC launched Resilient Ways Forward (RWF) to better understand and address climate vulnerability across the county. Figure 2 summarizes the key objectives and the climate hazards, assets, and recommendations of this effort.

Three key questions guided RWF and the development of several resources:

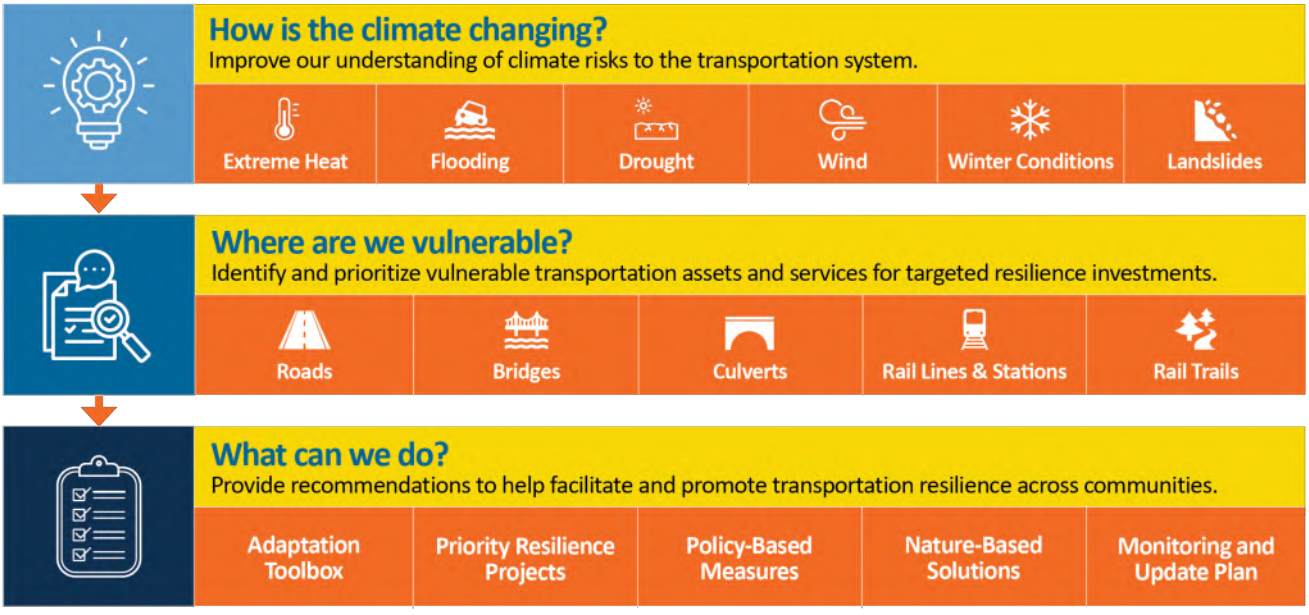

Figure 2. Summary of the priority objectives of RWF (Source: DCTC)

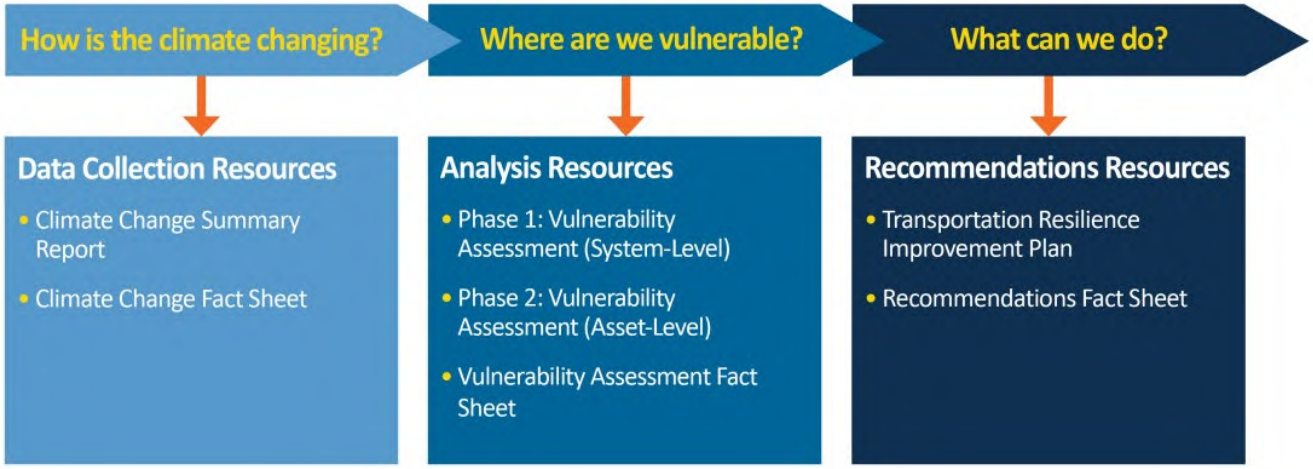

Figure 3. Key questions that guided RWF and the resources developed (Source: DCTC)

This report, the Resilient Ways Forward Transportation Resilience Improvement Plan (RWF TRIP), summarizes the study's findings and outlines a path forward with strategies, project ideas, and recommendations for making our transportation system more resilient to the changing climate. This report also satisfies the requirements outlined in FHWA's Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) guidance, unlocking a reduction in the non-federal cost share for transportation resilience projects awarded a PROTECT discretionary grant in the future.[1, 2]

Vulnerability Assessment

The RWF TRIP relies on a two-phased Climate Vulnerability Assessment to inform the direction and scope of its recommendations. Phase 1 of this assessment provided a system-level, sensitivity analysis of our transportation system to six climate hazards: extreme heat, flooding, drought, wind, winter conditions, and landslides; this helped identify which climate hazard/transportation asset pairs to analyze further in Phase 2. Phase 2 provided a more detailed, asset-level assessment of exposure and criticality for those highly sensitive hazard/asset pairs (e.g., flooding risks for roads); this culminated in calculating a vulnerability score for each hazard/asset pair to help with prioritization. Our methodology used many of the best practices outlined in the Federal Highway Administration's (FHWA) Vulnerability Assessment and Adaptation Framework, along with lessons learned from other transportation agencies.

We integrated the results from Phase 2 into an interactive online mapping tool. The map viewer allows infrastructure owners and managers to identify vulnerable assets and helps to inform potential resilience projects to address these vulnerabilities.

[1] FHWA. 2022, July 29. Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Formula Program Implementation Guidance. https://www.fhwa.dot.gov/environment/sustainability/resilience/policy_and_guidance/protect_formula.pdf

[2] FHWA. 2022. Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Discretionary Grant Program. https://www.fhwa.dot.gov/environment/protect/discretionary/

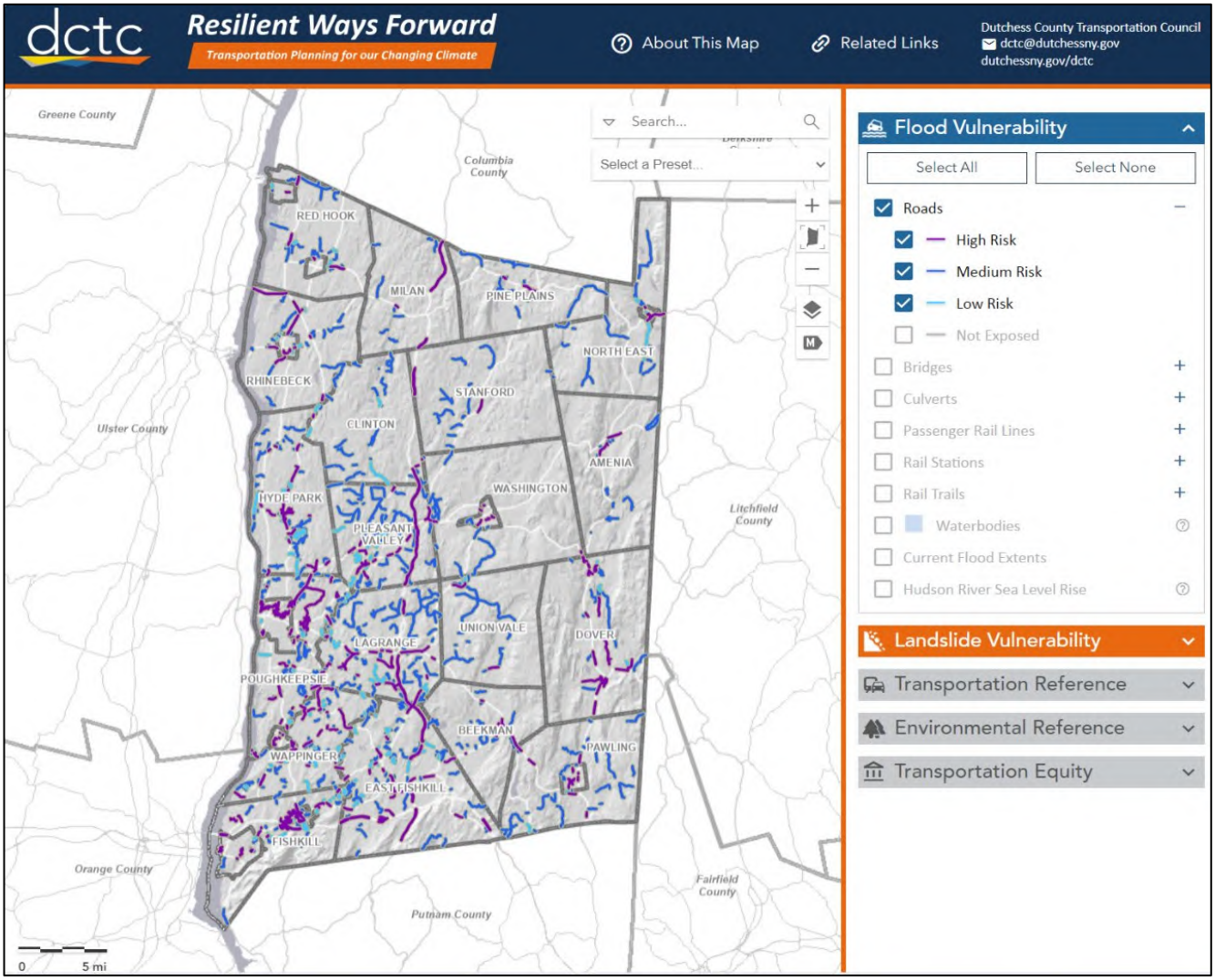

Figure 4. Snapshot of the RWF Map Viewer (Source: DCTC)

Resilience Recommendations

To support our long-range vision of creating a safer, more reliable, resilient, and equitable transportation system, we developed a suite of resilience recommendations based on our priority climate vulnerabilities. These recommendations are designed for decision-makers and partner agencies to evaluate and implement, aiming to reduce the vulnerability of infrastructure and services to climate change impacts. Enhancing systemwide resilience across our county will require both asset-level infrastructure improvements and local- and county-level policies and initiatives to encourage the implementation of resilience activities. As such, we developed a holistic set of resilience recommendations that includes:

- **Adaptation measures** for infrastructure owners and service providers to consider applying at vulnerable locations (Figure 5). The adaptation measures are also available online: Adaptation Toolbox.
- **Policy-based measures** that jurisdictions and agencies can consider implementing to improve resilience (Figure 5)
- **Priority resilience project ideas** that partner agencies are considering pursuing (Table 1)

Figure 5. Overview of resilience measures (Source: DCTC)

Table 1. List of priority resilience project ideas (all address flooding risk)

Agency	Number of Project Ideas	Asset Types Covered	Types of Projects
New York State Department of Transportation (NYSDOT)	9	Roads, Bridges, Culverts	• Elevating roads • Rehabilitating drainage systems • Replacing culverts & scour-critical bridges
County Public Works (DPW)	19	Bridges	• Replacing scour-critical bridges

Next Steps

We look forward to working alongside our partner agencies to build a more resilient transportation system. The DCTC will play a key role in facilitating collaboration and engagement with partners and stakeholders, integrating resilience and future climate data into current and future planning reports, programming federal funds for eligible projects, and encouraging training, education, and professional development among partners.

Introduction

For the two cities, twenty towns, and eight villages that comprise Dutchess County, climate change is not just a future problem. Superstorms and hurricanes have washed out roads and bridges and inundated railroad lines. Extreme winds have downed trees and power lines, causing outages for thousands of customers, and snowstorms have created dangerous conditions leading to vehicle crashes and transit suspensions.

Severe weather events like these underscore the importance of planning now to prepare Dutchess County residents and businesses for our changing climate. The Dutchess County Transportation Council (DCTC) seeks to create a more resilient transportation system that minimizes disruptions and better prepares us to meet the uncertainties of a changing climate.

AT A GLANCE: CLIMATE CHANGE IMPACTS IN DUTCHESS COUNTY

Not Just a Future Problem

- Average annual temperatures have increased nearly 3°F since 1960 and high temperatures are occurring with greater frequency and intensity.
- In the last decade, Dutchess County has experienced several winter storms with 1-2 feet of snow, including in 2017, 2018, 2020, and 2023. These resulted in road closures, travel bans, and transit disruptions.
- Dutchess County typically receives about 44 inches of rain each year and has seen many extreme precipitation and flooding events. Sea level rise has caused the Hudson River water level to rise more than one foot since 1900.

A severe storm in 2018 recorded intense winds up to 105 mph, downing trees and utility wires. Amtrak and Metro-North also suspended service in the county.

During Hurricane Ida in 2021, 4-6 inches of rain fell overnight, washing out a large culvert. A State of Emergency was issued for the entire county.

Creating Climate Readiness Together

Flooding related to weather events will likely be one of the greatest impacts of climate change on our county. Data about increased rainfall may not be news to the Poughkeepsie residents who used canoes to navigate flooded streets when the Fall Kill Creek overflowed after Hurricane Irene or the Metro-North train passengers who were stuck for hours after a July 2023 rain event. But they would probably agree that now is the best time to plan and adapt for climate impacts. **Creating a Transportation Resilience Improvement Plan (TRIP) is one of the single best investments Dutchess County can make to adapt to our changing climate.**

Many components of our county's transportation system were not designed to withstand extreme weather events. As a result, how and where we have built infrastructure and provided services may no longer be adequate. While the impacts of a changing climate may not all be negative, they require us to adjust the way we build, maintain, and think about our transportation system. Although there are significant challenges associated with climate impacts, we have a unique opportunity to create a more resilient transportation system that minimizes disruptions and prepares for the uncertainties of a changing climate.

The DCTC developed this Resilient Ways Forward (RWF) TRIP to better understand and address climate vulnerability across the county and across agencies. The RWF TRIP outlines a path forward for making today's transportation system more resilient to our changing climate.

"*Resilient Ways Forward* provides decision-makers and agencies with the information needed to help prioritize how and where we can build resilience– especially at the local and county level."
DCTC Transportation Program Administrator, Mark Debald

TRIP Development Process

As the designated Metropolitan Planning Organization (MPO) for Dutchess County, the DCTC can help facilitate and promote transportation resilience across communities and agencies. We developed the RWF TRIP in coordination with key stakeholders to help prepare the county for future climate change and ultimately create a more resilient transportation system. The RWF TRIP summarizes where the transportation system is most vulnerable to the impacts of climate change and provides adaptation recommendations that infrastructure owners and managers can implement to reduce climate impacts.

What is resilience?

The RWF TRIP uses the FHWA definition of resilience as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."

We followed national best practices, such as the Federal Highway Administration's (FHWA) Vulnerability Assessment and Adaptation Framework, to develop the RWF TRIP, which kicked off in late 2022 and involved three main steps (see Figure 6):

1. **Data Collection:** We collected and analyzed climate and transportation data to better understand how the climate is changing in Dutchess County and how the transportation system is currently affected. We published our findings from this analysis in a Climate Change Summary Report.
2. **Analysis:** We then conducted a two-phase risk-based vulnerability assessment that provided a countywide evaluation of how the transportation system is vulnerable to climate change. We published two reports summarizing the methodology and results from the assessment: Phase

1 - System-Level Analysis; and Phase 2 - Asset-Level Analysis (see the Climate Vulnerability Assessment section for more details).

3. **Recommendations:** Based on the information and findings from Steps 1 and 2, we compiled a range of resources and recommendations that decision-makers and agencies can use to improve the resilience of their transportation assets and operations (see the Resilience Recommendations section for more details).

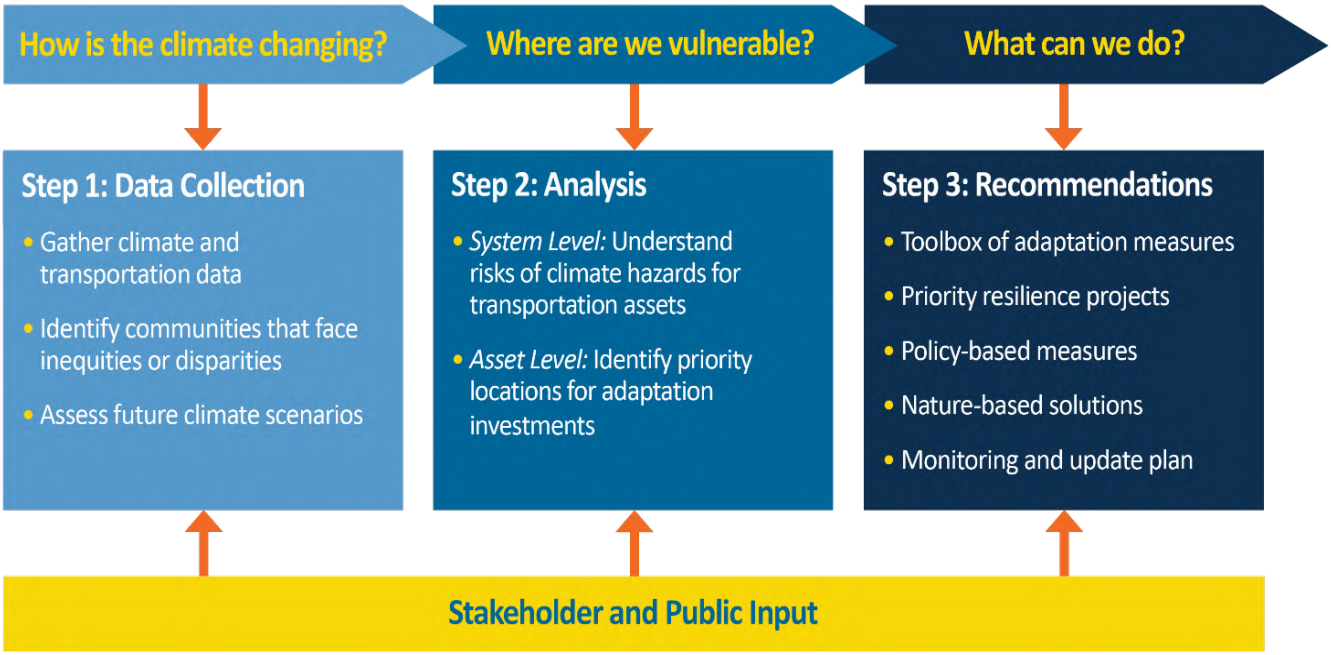

Figure 6. Summary of the RWF TRIP development process (Source: DCTC)

While the RWF TRIP summarizes each of these steps, it focuses in detail on Step 3 - the resilience recommendations for decision-makers and transportation agencies. Readers are encouraged to review the reports linked above for more information on climate change and the vulnerability assessment. Since many of the recommendations discussed here pertain to transportation agencies, the primary audience of the RWF TRIP is transportation infrastructure owners and managers across the county, including but not limited to municipal highway and public works departments, County Public Works (DPW) and County Public Transit, the Metropolitan Transportation Authority (MTA), and the New York State Department of Transportation (NYSDOT).

Goals and Objectives

The RWF TRIP aims to prepare the county to meet the uncertainties of a changing climate. By assessing current and future climate risks and providing recommendations and resources to facilitate adaptation efforts, the RWF TRIP will help improve the resilience of the transportation system in Dutchess County and help maintain essential functions and services during extreme weather events. Figure 7 summarizes the key objectives of the RWF TRIP.

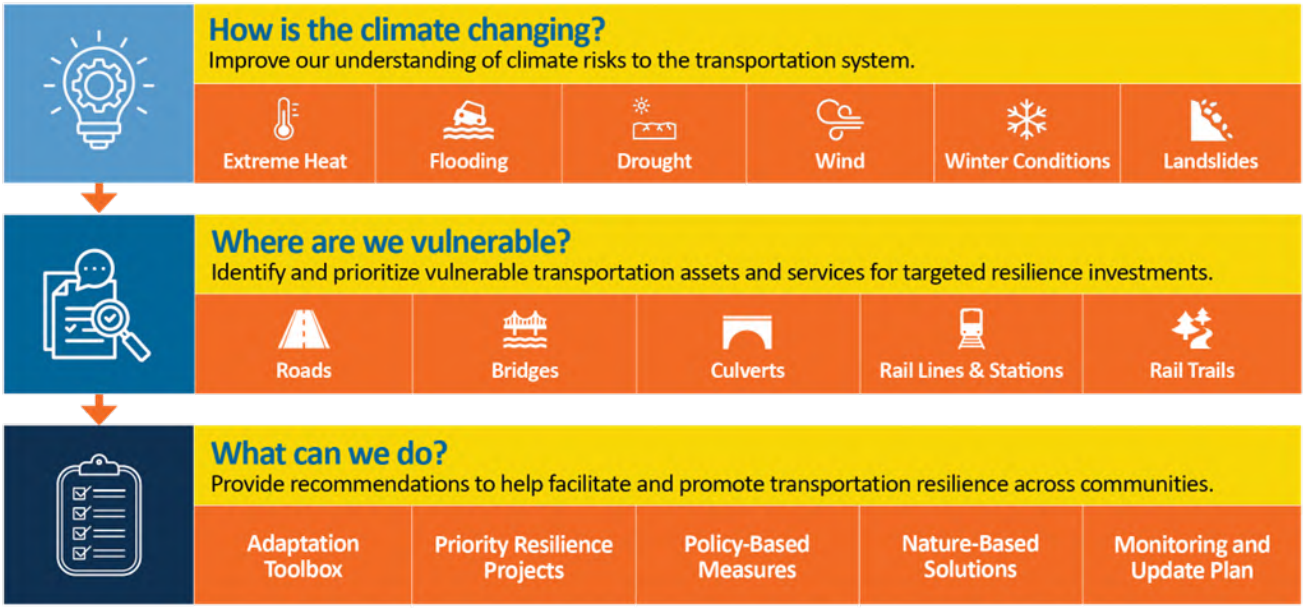

Figure 7. Summary of the priority objectives of the RWF TRIP (Source: DCTC)

We developed the RWF TRIP to meet the requirements outlined in FHWA's Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) guidance.[3] MPOs who develop resilience improvement plans (RIPs) that meet PROTECT requirements, can reduce the non-federal cost share for transportation resilience projects in the RIP by 7% (see Appendix F: Potential Funding Sources for a summary of eligible project types under PROTECT). An additional 3% reduction is available if the RIP is incorporated into the MPO's long-range transportation plan. If the projects listed in DCTC's RIP (see Priority Resilience Project Ideas), are submitted for a resilience improvement grant through the PROTECT Discretionary Grant Program, the DCTC will receive preference in the award selection process in addition to the non-federal cost share benefits. Additionally, projects that are included in the RIP do not require a Benefit Cost Analysis as part of the competitive grant application.[4] Appendix A: PROTECT Requirements Checklist summarizes the required elements of a RIP and which sections of the RWF TRIP address each of the PROTECT requirements.

[3] FHWA. 2022. Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Discretionary Grant Program. https://www.fhwa.dot.gov/environment/protect/discretionary/

[4] FHWA. Notice of Funding Opportunity for Fiscal Years 2022 and 2023 Promoting Resilient Operations for Transformative, Efficient, and Cost Saving Transportation (PROTECT) Program. 2023. https://www.transportation.gov/rural/grant-toolkit/promoting-resilient-operations-transformative-efficient-and-cost-saving

Systemic Approach to Transportation Resilience in Dutchess County

Improving resilience across the county's transportation infrastructure and services requires a holistic approach that covers all components of the transportation system and reflects the on-the-ground experiences of residents and practitioners alike. Throughout the RWF TRIP development process, we implemented a systemic approach to resilience. This included:

- Identifying and addressing climate vulnerabilities across 12 transportation asset categories and six climate hazards for the entire county
- Consistently engaging key stakeholders and the public to gather feedback, ground-truth findings from the vulnerability assessment, and solicit project ideas to include as priority resilience investments
- Aligning the RWF TRIP with existing plans and initiatives across the state, region, and county
- Considering equity, especially when evaluating vulnerability and developing specific resilience recommendations.

How the RWF TRIP Will Increase Resilience

As the designated MPO for Dutchess County, we can help facilitate and promote transportation resilience across communities. The RWF TRIP will increase the resilience of our county's transportation system providing a suite of resources and recommendations to facilitate the implementation of adaptation measures and policy-based measures by practitioners. The RWF TRIP also provides a detailed understanding of which transportation assets and locations are most vulnerable to climate hazards in the county, allowing us and our partners to prioritize locations for resilience projects.

We intentionally aligned the RWF TRIP with long-range planning and related climate initiatives in the county, including our long-range plan, Moving Dutchess Forward. Our long-range plan serves as a strategic guide for the next 20 years, with the stated vision of making Dutchess County's transportation system safer, more reliable, resilient, and equitable by 2045. The plan provides a high-level overview of potential climate change impacts on the transportation system but recommends a more detailed Climate Vulnerability Assessment to assess conditions and prioritize resilience improvements. The RWF TRIP fulfills that recommendation, identifying ways to address climate hazards that are most likely to affect transportation assets and services in Dutchess County. The RWF TRIP will serve as a major component in the next update to the long-range plan in 2025-2026. The RWF TRIP is also aligned with other plans from the region, including the county's Hazard Mitigation and Climate Adaptation plans, the Mid-Hudson Regional Sustainability Plan, and Local Utility Climate Change Resilience Plans. See Appendix B: Policies and Plans in the Region for more details.

Scope of the RWF TRIP

Timeframe and Geographic Scale

Located in the Mid-Hudson Valley, Dutchess County includes a mix of urban/village centers, suburban communities, and rural/agricultural areas (see Figure 8). In addition to serving local transportation needs, the county's transportation system also provides essential road and rail connections to large population and employment centers in the greater New York City metropolitan area, road connections across the Hudson River to Orange and Ulster Counties, and interstate freight connections for the Northeast.

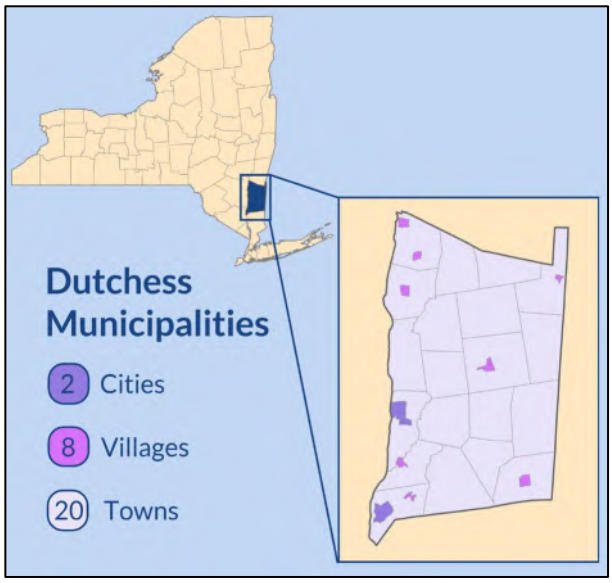

Figure 8. Map of Dutchess County (Source: DCTC)

The RWF TRIP outlines both immediate and long-range resilience planning activities and investments across the entire county. The RWF TRIP evaluates both historical trends and climate change projections through 2050, the timeframe of Moving Dutchess Forward, and 2080, which captures the useful life of current transportation infrastructure in the county.

Transportation Assets and Climate Hazards

We completed a Climate Vulnerability Assessment of the county's transportation system as part of the development of the RWF TRIP to identify the transportation assets and locations that are most vulnerable to climate hazards (see the Climate Vulnerability Assessment section). Table 2 summarizes the transportation asset types and climate hazards considered in the assessment. The results of the vulnerability assessment helped identify potential resilience projects for the RWF TRIP (see the Priority Resilience Project Ideas section).

Table 2. Transportation assets and climate hazards included in the vulnerability assessment

Transportation Assets:					
Roads		Rail trails		Rail lines/stations	
Bridges		Sidewalks		Bus system/facilities	
Culverts		Regional airport		Park and rides	
Highway garages		Beacon ferry dock		Transit hub	
Climate Hazards:					
Extreme heat		Wind		Drought	
Flooding		Winter conditions		Landslides	

Implementing Resilience: DCTC and Key Partners

As the designated MPO for the county, the DCTC ensures that federal transportation funds are programmed through a comprehensive, locally driven planning process, which provides a forum for state and local officials to discuss transportation issues.

DCTC's Key Responsibilities:

- Developing core transportation products, including a long-range transportation plan, a 5-year capital program, which designates federal funding to highway, bridge, walking, bicycling, and transit projects, and an annual planning program that outlines upcoming planning studies and tasks.
- Contributing to regional transportation planning efforts with Orange and Ulster counties as part of the Mid-Hudson Valley Transportation Management Area (TMA).
- Conducting countywide studies to understand key issues, including climate vulnerability, traffic trends, safety issues, and human services transportation.
- Collaborating with communities on local planning efforts, such as parking and corridor studies, pedestrian plans, safety assessments, and data collection and analysis.

Although we have limited direct influence over emergency management and transportation infrastructure and services, we serve a key role in supporting decision-makers and agencies by facilitating collaboration and coordination, promoting resources and recommendations, and programming federal funds for eligible projects. See the Next Steps for Implementation section for more information on our role moving forward.

Stakeholder Engagement

We understand that effective transportation planning is possible when the public is empowered to participate in the process and influence decisions that affect their lives. We also rely on our partners to implement resilience projects. As such, we conducted extensive stakeholder engagement throughout the RWF TRIP development process. This included both public outreach efforts focused on general education about the RWF TRIP, with targeted opportunities for input (see Figure 9), and more detailed and frequent outreach efforts for key stakeholders who are ultimately responsible for carrying out the resilience recommendations described in the RWF TRIP. Stakeholders also helped ground-truth the findings from the risk-based vulnerability assessment and ensure that the RWF TRIP is a useful resource for decision-makers and agencies across the county.

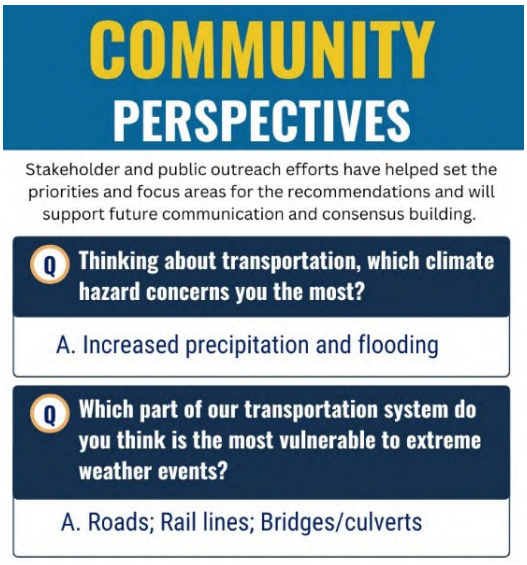

Figure 9. Community input on priorities for the RWF TRIP (Source: DCTC)

We created a steering committee of key partners to provide input at each stage of the RWF TRIP development process:

- Dutchess County Planning & Development
- Dutchess County Office of Central and Information Services (OCIS)
- DPW
- Dutchess Soil & Water Conservation District
- Dutchess County Emergency Management
- NYSDOT
- Pleasant Valley Highway Department
- Cornell Cooperative Extension Dutchess County

In addition, we worked with other key stakeholders, including MTA/Metro-North Railroad and several local highway departments. We also held two virtual public meetings, which were recorded and posted on the project website, and hosted an online map-based survey to gather information about how extreme weather events have affected people's ability to travel.

Table 3 summarizes the series of stakeholder engagement activities conducted throughout the development of the RWF TRIP.

Table 3. Steering committee and stakeholder engagement

Engagement Activity	Timeline	Focus
Steering Committee Meeting #1	December 2022	Discuss and finalize the project scope and workplan
Stakeholder Interviews (NYSDOT, County DPW, Metro-North Railroad)	Spring 2023; Winter 2024	Discuss major climate impacts to the transportation system and confirm priority asset/hazard combinations; Vet and inform adaptation strategies and policies
Steering Committee Meeting #2	April 2023	Discuss the climate change summary report
Virtual Public Meeting #1	June 2023	Summarize climate change trends and transportation impacts; Collect past extreme weather incidents through a map-based survey
Stakeholder Workshop #1	July 2023	Vet findings of Phase 1 of the vulnerability assessment to ensure agreement on the asset/hazard combinations that move forward to Phase 2
Steering Committee Meeting #3	October 2023	Discuss the draft completed vulnerability assessment
Stakeholder Workshop #2	March 2024	Discuss the Adaptation Toolbox to address key vulnerabilities
Virtual Public Meeting #2	April 2024	Present the results of the vulnerability assessment; Discuss adaptation measures
Steering Committee Meeting #4	June 2024	Discuss the RWF TRIP recommendations, projects, and next steps

In addition to steering committee meetings and interviews, the DCTC also hosted two working sessions for stakeholders (see Figure 10). These events provided an opportunity to reach a broader audience than the steering committee members. In addition to steering committee members,

participants included representatives from highway departments for the Towns of Fishkill, Poughkeepsie, and Red Hook and Village of Wappingers Falls, Dutchess County Public Transit, Metro-North Railroad, and the Cary Institute, a local environmental organization. We held our first workshop in July 2023 to present the methodology and preliminary results from Phase 1 of the vulnerability assessment, and to vet our findings with infrastructure owners and managers. We held a second workshop in March 2024 to present the draft Adaptation Toolbox and get feedback from stakeholders on both the content and format of the Toolbox – all done to make the material as useful as possible.

Increasing the resilience of Dutchess County's transportation system will require continued collaboration and coordination between the DCTC and the many agencies responsible for identifying and implementing resilience projects across the county.

Figure 10. Photos from the two stakeholder working sessions held in July 2023 (left) and March 2024 (right) to gather feedback on the vulnerability assessment results and the adaptation toolbox, respectively (Source: DCTC)

Climate Vulnerability Assessment

In support of the RWF TRIP, we conducted a risk-based vulnerability assessment to identify which assets and locations are most vulnerable to climate hazards and prioritize potential solutions. This section provides an overview of the methodology and key findings.

How Is the Climate Changing?

To inform the vulnerability assessment, we first reviewed how climate and extreme weather events have and will continue to change in Dutchess County (see the Climate Change Summary Report for more details). Climate projections were reviewed for 2050 (2036-2065) and 2080 (2066-2095) relative to a baseline period of 1950-2013. We selected the focus hazards for the vulnerability assessment based on the county's Hazard Mitigation Plan and past impacts to the transportation system from these types of events. Figure 11 summarizes how the climate is changing in the county and how the transportation system can be impacted by each climate hazard.

Hazard	Current	Future	Transportation Concerns
Extreme Heat	• Average annual increases of nearly 3°F since 1960 • High temperatures occur with greater frequency and intensity	• Average temperatures continue to rise • Extreme temperatures will occur	• Pavement can soften or crack • Train rails can buckle • Travelers experience discomfort
Flooding	• About 44 inches of rain/year • Many extreme precipitation events • Hudson River water level has risen more than one foot since 1900	• Precipitation will become increasingly variable • More frequent and intense heavy rain events • Sea level rise and storm surge along the Hudson River more frequently	• Damage to roads, bridges, and rail lines • Closures, delays, and safety risks
Drought	• Notable flash droughts in 2002, 2017, and 2022.	• Longer periods without precipitation	• None identified
Wind	• Multiple high wind events	• Greater potential for high winds as intensity of hurricanes, tropical storms, and tropical depressions increases	• Speed or travel restrictions • Road closures • Damage to traffic signals, road signs
Winter Conditions	• Winters have warmed 3x faster than summers • Later snowfall and earlier snowmelt	• Fewer days below freezing (32°F) • Greater snowfall during major winter storm events	• Dangerous driving conditions • Road closures, travel restrictions • Increased maintenance costs • Roads can crack and buckle
Landslides	• Southern and western parts of Dutchess County at risk due to steep slopes	• Precipitation-driven landslides could occur more frequently	• Major damage to infrastructure • Safety risks for travelers

Figure 11. Summary of findings from the Climate Change Summary Report (Source: DCTC)

Where Are We Vulnerable?

We used a two-phase approach for the vulnerability assessment (see Figure 12). Phase 1 analyzed the sensitivity of various components of the transportation system to specific climate hazards. Phase 2 built on the findings from Phase 1 and identified specific assets and locations where Dutchess County's transportation system is most vulnerable to the impacts of climate change. For additional details on the vulnerability assessment, see the Phase 1: System-Level Analysis Report and the Phase 2: Asset-Level Analysis Report.

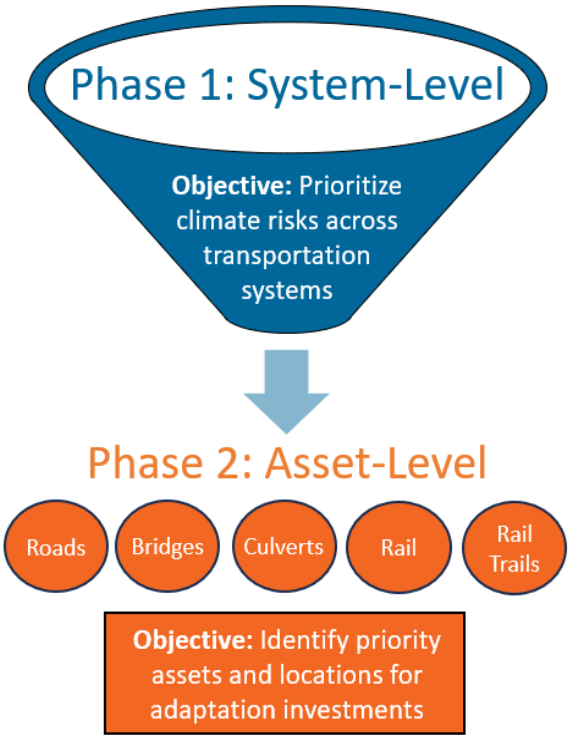

Figure 12. Overview of the Climate Vulnerability Assessment phases (Source: DCTC)

Methodology Overview

The methodology for this assessment built on current best practices as outlined in the Federal Highway Administration's (FHWA) Vulnerability Assessment and Adaptation Framework and lessons learned from other transportation agencies to create a defensible and useful vulnerability prioritization process.

Phase 1: System-Level Analysis Methodology

Phase 1 provided a system-level analysis of the sensitivity of major components of the transportation system to each of the six climate hazards. This assessment screened for priority climate vulnerabilities across the transportation system to be analyzed further in Phase 2. See the Transportation Assets and Climate Hazards section for the complete list of transportation asset types and climate hazards included in Phase 1.

We rated the sensitivity of each asset/hazard pair on a scale of low, medium, and high across two transportation components:

- **Physical infrastructure** – to what degree the asset suffers damage or loses functionality
- **Service operations and user experience** – to what degree users are affected by service disruptions

What is sensitivity?

The degree to which an asset is affected by exposure to a climate hazard. Assets with high sensitivity experience more significant impacts from the climate hazard than assets with low sensitivity.

We used the findings from the Climate Change Summary Report, other literature, professional judgement, and input from stakeholders to rate these two dimensions of sensitivity for each asset/hazard pair. Asset/hazard pairs that received a high sensitivity rating for physical infrastructure advanced to Phase 2.

Phase 2: Asset-Level Analysis Methodology

Phase 2 further analyzed the highly sensitive pairs from Phase 1 to determine which specific assets (such as individual road segments) are most vulnerable to climate hazards. We used a geospatial analysis to evaluate the vulnerability of roads, bridges, culverts, rail lines/stations, and rail trails to flooding and landslides, and then scored the vulnerability of each asset using the equation below[5]:

$$(Exposure\ Score)(70\%) + (Criticality\ Score)(30\%) = Vulnerability\ Score$$

We defined vulnerability as the weighted combination of an asset's exposure and criticality. Assets with high exposure and criticality are considered highly vulnerable to climate hazards. See the Key Terms box below for more detailed definitions of exposure, criticality, and vulnerability.

Key Terms

Exposure indicates whether an asset is in an area that is affected by climate hazards. Assets that have high exposure, such as those located in floodplains, are more likely to be affected by climate hazards than those that are not.

Criticality is the level of importance of an asset to the transportation system. For example, roads with higher traffic volumes are more critical than roads with lower traffic volumes because if they are damaged or closed, more people are affected. The consequence to the transportation system is significant for highly critical assets.

Vulnerability is the susceptibility of an asset to adverse impacts from climate hazards. Exposure and criticality can be used to determine how vulnerable an asset is to climate hazards; high exposure and criticality indicate high vulnerability.

For each asset/hazard pair, we evaluated criticality using three indicators, as appropriate:

- DCTC's Transportation Equity Index score for the location
- Proximity of the asset to key public safety services (i.e., police stations, fire stations, emergency services, and hospitals)
- Average daily traffic volume for roads, bridges, and culverts

These indicators helped determine the relative importance of the asset to the transportation system and the potential impact to the transportation system if the asset were affected by the climate hazard. We also included equity considerations as part of the criticality evaluation criteria to prioritize assets in underserved communities. See Appendix E: Equity Dataset Comparison, for more details on available equity datasets, including the DCTC Transportation Equity Index and the Justice40 Climate and Economic Justice Screening Tool (CEJST).

[5] Exposure is the primary driver of climate vulnerability and thus this component is weighted more heavily in the vulnerability score calculation.

Equity & Transportation Resilience

Transportation is essential for accessing healthcare, education, employment, and basic services. Underserved populations tend to have limited transportation options, and when climate related events occur, their ability to access these services can be further compromised. Investing in transportation resilience ensures that these communities, and their access to basic needs, are prioritized.

Vulnerability Assessment Results

Phase 1 Results

Table 4 summarizes the sensitivity ratings for each asset/hazard pair from Phase 1. Table 5 and Table 6 show the rating scales used in Phase 1. Physical transportation infrastructure tends to be most sensitive to flooding and landslides, while transportation service operations and users tend to be most sensitive to flooding, winter conditions, and landslides.

Table 4. Summary system-level analysis results for Dutchess County

	Climate Hazard											
	Extreme Heat		Flooding		Drought		Wind		Winter Conditions		Landslides	
Transportation Asset	I	S	I	S	I	S	I	S	I	S	I	S
Roads	Medium	Low	High	High	Low	Low	Low	High	Medium	High	High	High
Bridges	Medium	Low	High	High	-	-	Low	High	Medium	High	High	High
Culverts	-	-	High	High	Low	-	Low	-	Low	-	Medium	-
Rail lines/stations	Medium	Medium	High	High	-	-	Low	High	Medium	Medium	High	High
Bus system/ facilities	Low	Medium	Low	Medium	-	Low	Low	Medium	Low	High	Low	Low
Sidewalks	Low	High	Low	Medium	-	Low	Low	Low	Low	Medium	Medium	Medium
Rail trails	Low	High	High	High	-	Low	Low	Low	Low	Low	Medium	Medium
Regional airport	Medium	Low	NE	NE	Low	-	Low	Medium	Low	Low	NE	NE
Highway garages	Low	-	Medium	-	-	-	Low	-	Low	-	Medium	-
Park and rides	Low	Low	Medium	Medium	-	-	Low	Low	Low	Medium	NE	NE
Transit hub	Low	Medium	NE	NE	-	-	Low	Low	Low	Medium	NE	NE
Beacon ferry dock	Low	Low	Low	Medium	Low	-	Low	Medium	Medium	Medium	NE	NE

I = **Infrastructure Rating:** the degree to which asset (physical infrastructure) undergoes damage or loses functionality
S = **Service Operations and User Experience Rating:** the degree to which users are affected by service disruptions
NE = **Not Exposed:** asset was pre-screened and is not exposed to hazard
(-) = **Unaffected:** asset is unaffected by the hazard

Table 5. Physical infrastructure sensitivity rating scale

Low	When exposed to the hazard, the asset suffers minor to no damage and maintains functionality.
Medium	When exposed to the hazard, the asset suffers damage requiring repairs to resume full functionality.
High	When exposed to the hazard, the asset is damaged beyond repair or destroyed, and cannot resume normal function until replaced.

Table 6. Service operations and user experience sensitivity rating scale

Low	When exposed to the hazard, there is minimal to no impact to service or discomfort to users.
Medium	When exposed to the hazard, service is disrupted or suspended for up to a day. Or, hazard exposure causes discomfort for users.
High	When exposed to the hazard, service is suspended for more than 24 hours and disruptions may continue for days to weeks after the event as infrastructure repairs are made. Or, hazard poses risk of injury or death to users.

Phase 2 Results

Phase 2 took a closer look at flooding and landslide vulnerability for specific assets and locations to prioritize for adaptation investments. Table 7 summarizes the breakdown of asset vulnerability scores, categorized as high, medium, low, or not exposed. For each asset/hazard pair, the exposure and criticality of each asset were scored on a scale of 0 to 3. These scores were then weighted and added together to determine the vulnerability score, with 3 being the highest possible score. The full results from Phase 2 can be viewed in the Phase 2: Asset-Level Analysis Report and accompanying Map Viewer.

For flooding, rail lines had the largest percentage of assets (in miles) with high (11%) and medium (62%) vulnerability scores, indicating that flooding is a widespread risk for our rail lines. For landslides, 1% or fewer of assets received a high vulnerability score, so while this risk is not widespread, it can be very costly and disruptive when/where it does occur.

Table 7. High, medium, low vulnerability score count by asset for flooding and landslides

	Flooding				Landslide			
Asset Type	**High**	**Medium**	**Low**	**Not Exposed**	**High**	**Medium**	**Low**	**Not Exposed**
Roads (miles)	180 (6%)	337 (11%)	47 (2%)	2,490 (82%)	37 (1%)	77 (3%)	263 (9%)	2,678 (88%)
Bridges	9 (3%)	20 (6%)	78 (21%)	259 (71%)	4 (1%)	7 (2%)	21 (6%)	234 (91%)
Culverts	4 (1%)	19 (4%)	264 (57%)	177 (38%)	Not assessed			
Rail Lines (miles)	14 (11%)	78 (62%)	6 (5%)	28 (22%)	1 (1%)	11 (9%)	2 (2%)	122 (89%)
Rail Stations	0 (0%)	3 (27%)	1 (9%)	7 (64%)	0 (0%)	3 (27%)	0 (0%)	8 (73%)
Rail Trails (miles)	3 (7%)	23 (47%)	2 (3%)	20 (42%)	Not assessed			

We identified 12 road segments as having high vulnerability to both flooding and landslides (Table 8), and where possible, included them in our list of prioritized adaptation investments.

Table 8. Assets with high vulnerability scores for both flooding and landslides

Name	Mileage (mi)	From (South or West)	To (North or East)	Owner	Municipality
Pump House Road	0.5	Heath Road	End	Local	Town of Fishkill
Van Steuben Road	0.26	Kip Drive	Kip Drive	Local	Town of Fishkill
Market Street	0.16	Creek Road	McKinley Street	Local	Village of Wappingers Falls
McKinley Street	0.21	Market Street	Market Industrial Park	Local	Village of Wappingers Falls
Alexander Lane	0.18	Market Street	End	Local	Village of Wappingers Falls
Dog Tail Corners Road	0.63	Berkshire Road	5th Lane	County	Dover
Old State Route 22	0.62	Reagans Mill Road	Overlook Road	County	Dover
Creek Road	0.38	Connor Road	Market Street	County	Wappinger
Route 22	0.55	Kitchen Corners Road	Furlong Road	State	Dover
Route 55	0.96	Velie Road	Route 82	State	LaGrange
Route 82	0.47	Route 55	Burdick Road	State	LaGrange
Interstate 84 East & West	0.88	Main Street ramps	West of Route 9 ramps	State	Town of Fishkill

Interactive Map Viewer

We integrated the results from Phase 2 of the vulnerability assessment into an interactive online mapping tool. The map viewer allows infrastructure owners and managers to identify vulnerable assets and helps to inform potential resilience projects to address these vulnerabilities.

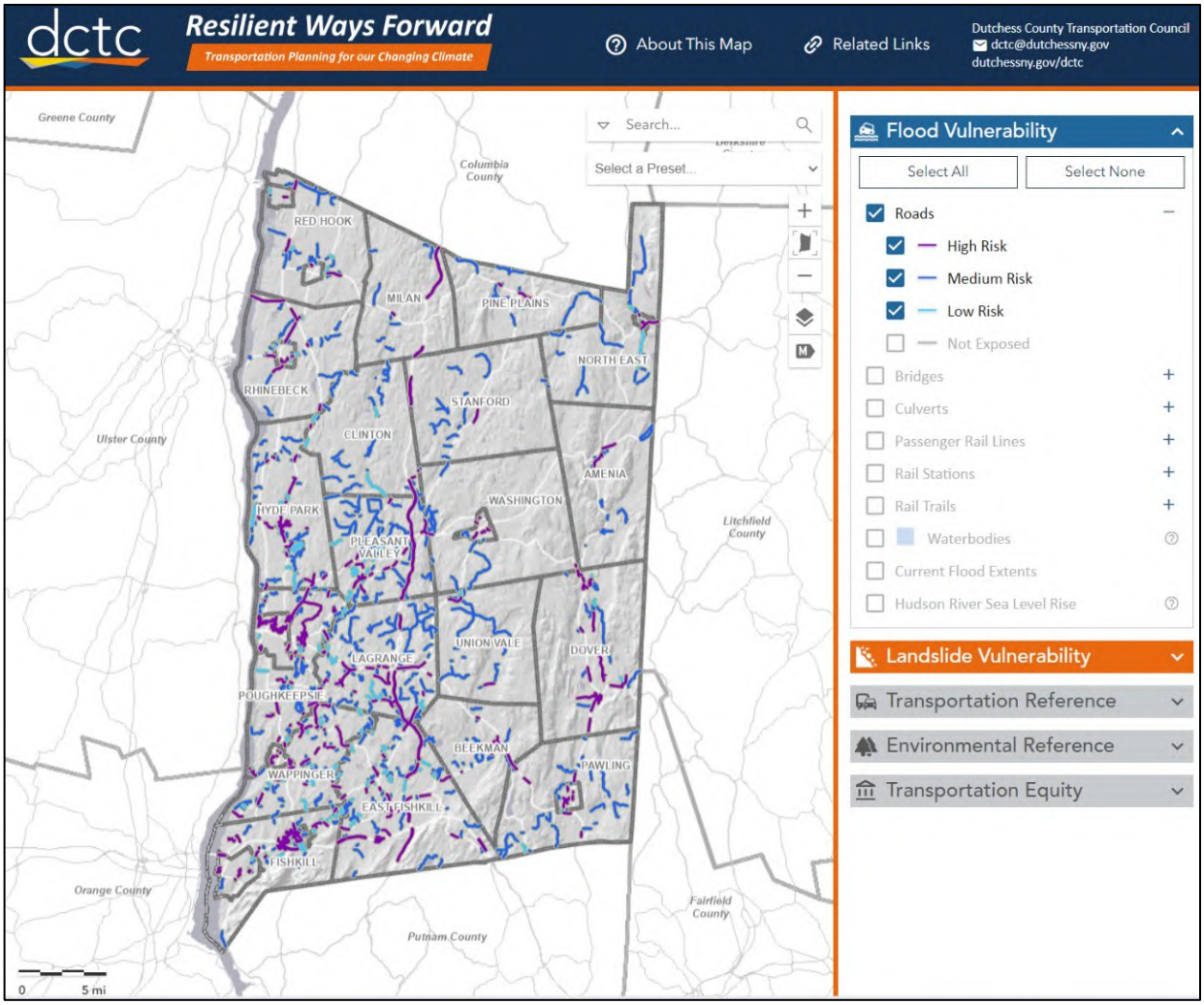

Figure 13. Snapshot of the RWF Map Viewer (Source: DCTC)

Vulnerability Assessment Update Plan

To ensure that asset vulnerability is monitored and minimized over time, and to incorporate updated climate and asset data as it becomes available, we developed an update plan for the vulnerability assessment that describes potential incremental and substantial updates that we can make in the future. The vulnerability assessment update plan focuses on the key inputs to the vulnerability assessment (e.g., climate exposure and criticality data), and as new or updated data becomes available, we can make corresponding updates to the vulnerability assessment and companion mapping tool.

Table 9 summarizes the criteria for future updates to the vulnerability assessment. The criteria column describes the specific trigger that would encourage an update to be made, such as when new

climate change data is integrated into national or state reports. Table 9 also includes potential approaches for tracking each update criterion.

Table 9. Vulnerability assessment update criteria

Criteria	Recommended Update	Level of Effort	Timeframe	Tracking Approach
Updated climate change data integrated into national (e.g., Intergovernmental Panel on Climate Change Assessment or National Climate Assessment) **or state reports** (e.g., the NYS Climate Impacts Assessment)	Full update of the vulnerability assessment	Significant	Every 4 years	Maintain a database of all data sources used in the vulnerability assessment and complete an annual check for updates.
Updated exposure or criticality datasets (e.g., Federal Emergency Management Agency [FEMA] flood maps, DCTC Transportation Equity Index)	Update asset-level vulnerability scores (Phase 2)	Moderate	Bi-annually	Same approach as above.
New or updated asset data (e.g., elevation data, culvert information)	Update asset-level vulnerability scores (Phase 2)	Moderate	Bi-annually	Same approach as above. Coordinate with key partners to monitor the release of new datasets for the county and state.
Investments in infrastructure resilience	Manual modification of vulnerability scores for assets that have received resilience upgrades	Minor	Annually	Develop a database or survey where local agencies can alert the DCTC of new investments. Consider incorporating resilience investments in DCTC's outreach to communities about funding opportunities.

What Can We Do?

Addressing the county's vulnerabilities to climate impacts and ultimately creating a more resilient transportation system will require a systemic approach to implementing resilience improvements across the county. The DCTC and its partners can use the results of the vulnerability assessment to implement both asset-based adaptation measures and policy-based measures to increase resilience and prioritize resilience investments for future projects. The Resilience Recommendations section describes the suite of resources and recommendations we developed to support our partners and reduce the vulnerability of the county's transportation system to climate impacts. The following summarizes the resilience recommendations included in the RWF TRIP:

- Adaptation Measures
- Priority Resilience Projects
- Policy-Based Measures
- Natured-Based Solutions
- Monitoring and Update Plan

Critical Interdependencies

It is important to recognize that the transportation system is part of a larger and interconnected system, relying on various other sectors for functionality and efficiency. For example, disruptions in the energy sector, such as power outages, can directly impact transportation service by disabling traffic signals and rail service. Similarly, other sectors depend on the transportation system to maintain their services and operations. For example, a damaged road can prohibit utility crews from safely accessing a damaged substation. A strong understanding of interdependencies and cascading impacts across sectors is critical for achieving climate resilience.

Figure 14. Central Hudson repairing a damaged utility pole blocking the road following a winter storm (Source: Central Hudson)

While this vulnerability assessment focuses on the impacts of climate hazards on transportation assets, we acknowledge that cumulative and ongoing impacts of climate hazards across various sectors must be considered for system-level planning. This assessment took a preliminary look at certain interdependencies by evaluating the proximity of transportation assets to public safety services (police stations, fire stations, emergency services, and hospitals) within the vulnerability assessment scoring. While this is a start, the implications of a transportation asset being damaged or a service being disrupted should be further assessed to understand the critical interdependencies between the transportation system and key community assets. This understanding of systemwide impacts of climate change on community assets will begin to be further explored as a part of the County's Climate Adaptation Plan, which is set to be completed in early 2025.

Resilience Recommendations

Understanding the county's vulnerability to climate impacts is just one component of creating a more resilient transportation system. To achieve our long-range vision of creating a safer, more reliable, resilient, and equitable transportation system, we developed a suite of resilience recommendations that decision-makers and partner agencies can review and implement to reduce the vulnerability of their infrastructure and services to climate change impacts. Enhancing systemwide resilience across the county will require both asset-level infrastructure improvements and local- and county-level policies and initiatives to encourage the implementation of resilience activities. As such, we developed a holistic set of resilience recommendations that includes:

- **Adaptation Toolbox (measures)** for infrastructure owners and service providers to consider applying at vulnerable locations
- **Priority resilience projects** that partner agencies are considering pursuing
- **Policy-based measures** that jurisdictions and agencies can consider implementing to improve resilience across the county

Adaptation Toolbox

We developed an Adaptation Toolbox to offer infrastructure owners and service providers a range of potential adaptation measures, including nature-based solutions, to consider for future investments. The adaptation measures are targeted at reducing impacts to the high priority asset/hazard pairs identified in the Climate Vulnerability Assessment (see the Vulnerability Assessment Results section for more details).

Nature-Based Solutions (NBS)

The use of living and nonliving plant materials in combination with natural and synthetic support materials for multiple purposes including streambank stabilization, erosion reduction, and vegetative establishment.[6]

See Appendix D: Nature-Based Solutions Profiles for more information.

The Toolbox was vetted with stakeholders during an in-person workshop to ensure its applicability, practicality, and usefulness in the context of Dutchess County. While the Toolbox includes a discussion of important factors for consideration for each measure (see Table 10), the feasibility of carrying out each measure remains at the discretion of infrastructure owners and service operators, and is dependent on available resources, site-specific context, and operating environments. There is no one-size-fits-all solution when it comes to infrastructure resilience.

[6] FHWA. 2009. Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance. https://pubs.usgs.gov/of/2019/1008/ofr20191008.pdf

Table 10. Adaptation Toolbox factors for consideration

Factors for Consideration					
Capital Costs	**Operations & Maintenance**	**Effectiveness**	**Flexibility**	**Barriers to Implementation**	**Equity**
What are the initial costs to implement the measure?	*What is required to maintain the measure over its useful lifespan?*	*How effective is the measure at mitigating vulnerability?*	*Does the measure allow for modifications to scale up or down, as needed?*	*What potential obstacles prevent the measure from being effectively implemented?*	*What factors should be considered to ensure that the measure is equitably implemented?*

The adaptation measures in the Toolbox are summarized below by climate hazard. Each adaptation measure helps to reduce vulnerability and increase the resilience of the transportation system to these climate hazards. For more details on each measure, see Appendix C: Adaptation Toolbox and the web-based Adaptation Toolbox.

Flooding:

1. Identify evacuation routes for highly vulnerable assets and critical transportation routes
2. Prohibit overweight/oversized vehicles on weakened pavement
3. Clear vegetation and debris from culverts more frequently[7]
4. Implement sensor technologies and monitoring programs and increase awareness of monitoring systems[8]
5. Elevate low-lying bridges
6. Enhance the road sub-grade
7. Improve road shoulders to increase lateral support
8. Raise the road profile in flood-prone areas
9. Install geotextiles, such as green mats, on embankments
10. Install medians to strategically hold and/or convey stormwater
11. Upsize culverts and other stormwater management infrastructure[9]
12. Reconfigure stream channels
13. Construct rocks strategically in streams to dissipate water energy and reduce flooding
14. Use natural materials to restore stream banks
15. Place logs or branches in streams to reduce water flow
16. Plant vegetation buffers along roads
17. Revegetate areas along streams
18. Restore wetlands
19. Install swales, ditches, and rain gardens[10]

[7] This measure also reduces risks associated with landslides.
[8] This measure can reduce risks associated with all climate hazards.
[9] This measure also reduces risks associated with landslides.
[10] This measure also reduces risks associated with landslides.

20. Use permeable pavements[11]
21. Install retention/detention ponds and bioswales
22. Relocate infrastructure away from the floodplain

Landslide:

23. Establish setback requirements for roads near slopes
24. Plan and communicate detour routes
25. Use technology to monitor conditions
26. Build retaining walls
27. Install reinforcing elements in soil, such as soil nails
28. Install geotextile filtering fabrics
29. Grade or terrace slopes
30. Plant native vegetation to stabilize slopes
31. Stabilize slopes using bioengineering techniques

Extreme Heat:

32. Conduct heat awareness campaigns
33. Establish cooling spaces near high-traffic sidewalks, rail trails, and bus stops
34. Provide shade trees and shade structures along rail trails and sidewalks
35. Use cool trail materials (i.e. reflective and permeable pavements)
36. Install and/or operate hydration and misting stations along rail trails and sidewalks

Wind:

37. Remove unhealthy, dead, or dangerous trees
38. Clear vegetation more frequently
39. Implement reporting systems that monitor/detect/track roadway obstructions
40. Encourage utilities to bury overhead transmission and distribution lines in high-risk areas

Winter Conditions:

41. Strategically apply salt (or salt alternative) prior to and during hazardous winter driving conditions
42. Install snow fences along critical routes or high hazard areas
43. Install insulated and/or heated bus shelters[12]
44. Increase frequency of bus service during extreme cold periods

[11] This measure also reduces risks associated with winter conditions.
[12] This measure also reduces risks associated with extreme heat.

Priority Resilience Project Ideas

The risk-based vulnerability assessment and the Adaptation Toolbox are intended to serve as resources to help agencies identify and develop priority resilience projects. To develop a set of priority project ideas, we distributed an online form for infrastructure owners and managers to submit resilience project ideas.

A total of 28 project ideas were submitted to reduce flooding risk for roads, bridges, and culverts across the county (Table 11). NYSDOT submitted nine project ideas to reduce flood risk, including elevating roads, rehabilitating drainage systems, and replacing scour-critical bridges. County DPW submitted 19 project ideas to replace scour-critical bridges.

Table 11. List of priority resilience project ideas

Agency	Asset Type(s)	Location	Description	Est. Cost
NYSDOT	Roads, Culverts	NY Route 987G (Taconic State Parkway)/Todd Hill Wetland Town of LaGrange RMs: 987G 8203 1115-1120	This project proposes to raise the roadway on this segment of the Taconic State Parkway (TSP) near Todd Hill Road, located in the Town of LaGrange in Dutchess County. The work will include the replacement of several small culverts along this section of the corridor. During extreme rainfall events the roadway experiences significant flooding and roadway overtopping due to a low roadway profile and inadequate small culverts.	$14.0M
NYSDOT	Roads, Bridges, Culverts	NY Route 987G (Taconic State Parkway)1* Town of East Fishkill RMs: 987G 8203 1097-1099	This section of the TSP located in the Town of East Fishkill, Dutchess County is within the 100 year "overflow" flood elevation of the Whortlekill Creek. This project proposes to reconstruct the interchange and enlarge the waterway openings of various structures in the vicinity. The work would include replacement of the bridge that carries the TSP over NY Route 82 (BIN 1032319), three culverts that carry the TSP over the Whortlekill Creek (CINs C830132, C830122, C830123), and one abandoned private culvert immediately downstream. This project has independent utility, but due to proximity and related scope/need, this work could be combined with the work on Route 82. (2*,3*)	$45.0M
NYSDOT	Culverts, Roads	NY Route 82(2*) Towns of LaGrange & East Fishkill RMs: 82 8201 1078-1086	This segment of NY Route 82 located in the Towns of East Fishkill and LaGrange in Dutchess County is below the 100 year flood elevation of the Whortlekill Creek. This project proposes to replace the culvert that carries NY Route 82 over the Whortlekill Hill Creek (CIN C821090). The roadway and approaches will be elevated as needed. This project has independent utility, but due to proximity and related scope/need, this work could be combined with the larger TSP interchange project (1*) and the work further south on Route 82. (3*)	$13.0M

Agency	Asset Type(s)	Location	Description	Est. Cost
NYSDOT	Roads	NY Route 82 (3*) Town of East Fishkill RMs: 82 8201 1074-1077	This project proposes to rehabilitate or install a proper drainage system in the vicinity of this segment of NY Route 82 in the Town of East Fishkill, Dutchess County to prevent flooding and roadway overtopping. This project has independent utility, but due to proximity and related scope/need, this work could be combined with the larger TSP interchange project (1*) and the work further north on Route 82. (2*)	$4.0M
NYSDOT	Roads, Bridges, Culverts	I-84 Town of East Fishkill RMs: 84I 8202 1080-1090	This project proposes to raise the roadway of this segment of Interstate 84 located in the Town of East Fishkill, Dutchess County to prevent flooding and roadway overtopping during extreme rain fall events. The work will include the rehab/replacement of several aged and undersized bridges and culverts along the corridor including: CINs CA00064, CA00065, CA00066, and CA00067 which carry Interstate 84 over Unknown Streams and BINs 1032541 and 1032542 which carry Interstate 84 over Wiccopee Creek and BIN 1032530 which carries Fishkill Hook Road over Interstate 84.	$60.0M
NYSDOT	Bridges, Roads	NY Route 52 (Gayhead Pond Inlet) Town of East Fishkill RMs: 52 8204 2109-2110	This project proposes to replace the scour-critical bridge carrying NY Route 52 over Gayhead Pond Inlet (BIN 1026860) located in the Town of East Fishkill, Dutchess County. The bridge will be replaced with a wider structure to allow for increased capacity of the passage of water during extreme rain fall events. The roadway and approaches will be elevated as needed.	$10.0M
NYSDOT	Roads	Route 22 Town of Dover RMs: 22 8204 1070-1074	This project proposes to address the low roadway profile and inadequate drainage along Route 22 just north and south of Furlong Road, located in the Town of Dover in Dutchess County.	$5.0M
NYSDOT	Culverts	Route 55 Town of LaGrange RMs: 55 8203 2071-2078	This segment of NY Route 55 located in the Town of LaGrange in Dutchess County is within the floodplain. This project proposes to replace the culvert that carries NY Route 55 over an Unknown Stream (CIN C821048).	$5.0M
NYSDOT	Culverts	Route 82 Town of LaGrange RMs: 82 8201 1116-1118	This segment of NY Route 82 located in the Town of LaGrange in Dutchess County is within the floodplain. This project proposes to replace the culvert that carries NY Route 82 over an Unknown Stream (CIN C821052).	$5.0M
DPW	Bridges	Bridge B-15, BIN 3342720; CR 7 over Whaley Lake Stream. Town of Beekman	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M

Agency	Asset Type(s)	Location	Description	Est. Cost
DPW	Bridges	Bridge B-17, BIN 3342730; CR 7 over Whaley Lake Stream. Town of Beekman	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge C-30, BIN 3342870; CR 13 over Wappinger Creek. Town of Clinton	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge C-9, BIN 3342790; Maple Lane over Locust Creek. Town of Clinton	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge D-27, BIN 3342930; Dover Furnace Road over Mill River. Town of Dover	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge L-15, BIN 3343240; Stringham Road over Sprout Creek. Town of Lagrange	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge L-2, BIN 3343200; Gidley Road over Sprout Creek. Town of Lagrange	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge L-33, BIN 3370340; East Noxon Road over Jackson Creek. Town of Lagrange	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge PP-6, BIN 3343520; Carpenter Hill Road over Shekomeko Creek. Town of Pine Plains	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge R-4, BIN 3343760; Miller Road over Landsman Kill. Town of Rhinebeck	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M

Agency	Asset Type(s)	Location	Description	Est. Cost
DPW	Bridges	Bridge RH-19, BIN 3343740; Echo Valley Road over Saw Kill. Town of Red Hook	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge U-29, BIN 3343940; CR 21 over Fishkill Creek. Town of Union Vale	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge W-27, BIN 3344090; Fowler Road over East Branch Wappinger Creek. Town of Washington	This project would replace the existing bridge, identified as scour-critical, to address flooding. This is a near-term priority, with design planned for 2027 and construction by 2029-2030.	$3.5M
DPW	Bridges	Bridge W-5X, BIN 3344030; County Road 86 over Deer Hill Creek. Town of Washington	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge S-12, BIN 3343810; Homan Road over Cold Spring Creek. Town of Stanford	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge S-13, BIN 3365140; Cold Spring Road over Wappinger Creek. Town of Stanford	This project would replace the existing bridge, identified as scour-critical, to address flooding. This is a near-term priority, with design underway and construction planned for 2026.	$3.5M
DPW	Bridges	Bridge S-36, BIN 3343840; Depot Lane over Wappinger Creek. Town of Stanford	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge W-25, BIN 3344080; Canoe Hill Road over East Branch Wappinger Creek. Town of Washington	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M
DPW	Bridges	Bridge B-4, BIN 3342690; Dorn Road over Fishkill Creek. Town of Beekman	This project would replace the existing bridge, identified as scour-critical, to address flooding.	$3.5M

Policy-based Measures

The adaptation measures listed in the Adaptation Toolbox section can increase the resilience of specific transportation assets and services in the county. However, local- and county-level policies and initiatives are needed to facilitate and encourage broader implementation of resilience activities. We developed the policy-based measures below to improve systemwide resilience. These measures are presented as options for member jurisdictions and partner agencies to consider and implement as appropriate.

Policy-based measures are broadly grouped into four categories: emergency planning, community outreach, local planning, and capacity-building and collaboration. Each policy-based measure is accompanied by resources (where available) to support implementation.

Emergency Planning

Implement reliable and consistent emergency alert systems for extreme weather events

Planning Leads: County and Local Agencies; First Responders

Implement or improve existing emergency communication systems to alert the public in advance of extreme weather events, paired with guidance on how to respond and stay safe. Many municipalities have existing systems to share emergency alerts, either through email, text, or social media. However, using social media to reach a more broad and diverse audience could be explored, as well as considering how to equip staff to develop the platforms. In addition, it may be helpful to align municipal alert systems with county-level and/or school-district alerts.

Resources:

- The Arsht-Rockefeller Foundation describes implementing an alert system for extreme heat and provides a case study on Philadelphia.
- The U.S. Department of Homeland Security (DHS) provides several warning alerts that can be implemented at the local level on its Emergency Alerts page.

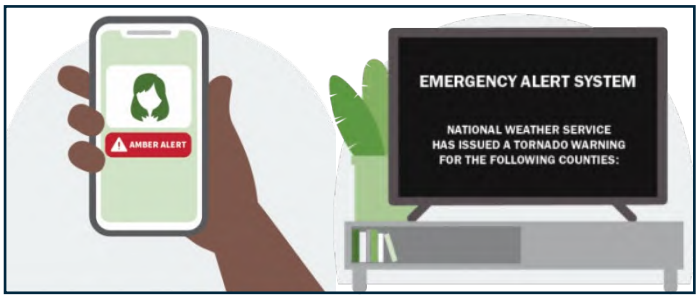

Figure 15. Different warning alert options from the DHS (Source: DHS)

Prepare emergency response teams in advance of storm events to clear debris

Planning Leads: County and Local Agencies; First Responders; Utility Providers

Ensure that emergency response teams are identified and adequately prepared and equipped to be deployed in advance of a storm event. Emergency response teams can clear obstructions caused by downed trees and power lines to make roadways accessible for emergency response and transport.

Figure 16. Central Hudson replacing a damaged utility pole following a severe storm (Source: Poughkeepsie Journal)

Some municipalities in the county have emergency response teams with a few people on-call in advance of extreme weather events; municipalities should ensure that teams are prepared in advance.

Update local emergency plans to include recovery steps for extreme weather events

Planning Leads: County and Local Agencies

Update existing emergency plans to outline recovery steps for extreme events such as floods, landslides, and winter storms. This can include identifying specific clean-up and recovery tasks and which agencies or departments are responsible.

Resources:

- FEMA's Response and Recovery Climate Change Planning Guidance provides background on climate change and its impact on emergency management operations, and steps on how to incorporate climate change into existing planning processes and products.
- FEMA's Pre-Disaster Recovery Planning Guide for Local Governments helps local governments prepare for recovery by developing pre-disaster recovery plans through engaging with community members and partners.

Community Outreach

Conduct public education campaigns to increase awareness of climate hazards and their potential impacts

Planning Leads: Local Environmental Organizations; County Planning; County Health

Conduct public education campaigns to raise awareness about climate hazards, the dangers they pose, and how communities and individuals can increase their resilience to the associated impacts.

Resources:

- The National Oceanic and Atmospheric Administration's (NOAA) Climate Education Program provides resources to help advance public climate literacy, including the Toolbox for Teaching Climate and Energy.
- The Adrienne Arsht-Rockefeller Foundation Resilience Center has a Heat Action Platform that provides information and case study materials on heat awareness campaigns.

Figure 17. Process diagram from NOAA's Climate Education Program for teaching climate and energy (Source: NOAA)

Develop trainings and resources for communities to increase resilience to climate impacts

Planning Leads: Local Environmental Organizations; County Planning

Develop trainings and resources for communities to enhance their transportation systems' resilience to climate impacts. Environmental organizations, in collaboration with local governments, could develop resources on establishing resilience hubs,[13] especially in disadvantaged communities, or guides that summarize available federal and state funding for resilience efforts.

Resources:

- The National League of Cities discusses how several communities, including Raleigh, New Orleans, and Boston, have partnered with environmental organizations within their communities to increase their resilience to climate change.
- The District of Columbia developed Community Resilience Hubs that provide information and services to build resilient communities, before, during, and after emergency events.

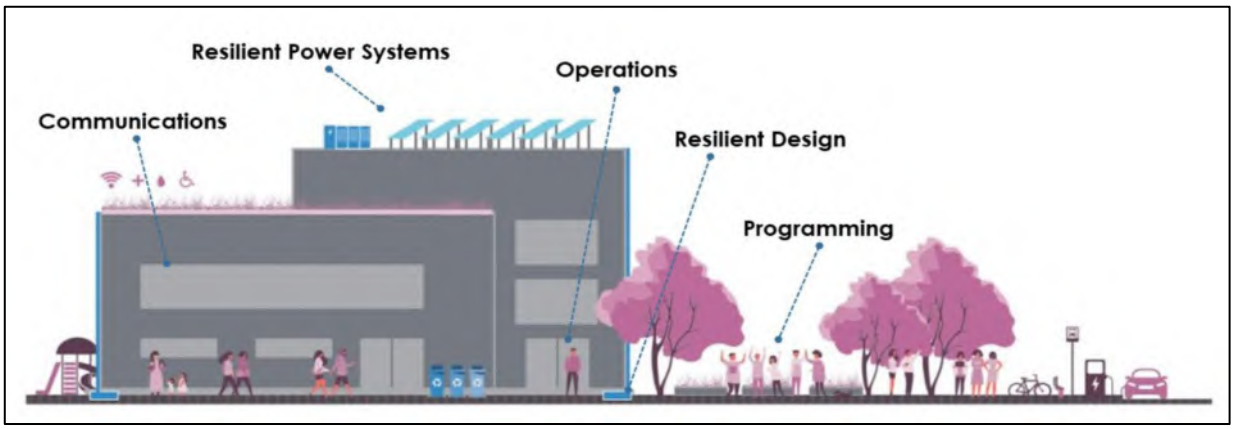

Figure 18. Example District of Columbia Resilience Hub diagram (Source: DOEE)

Conduct community outreach and engagement to better understand transportation resilience requirements and needs

Planning Lead: DCTC; County Planning

Engage directly with communities to understand what projects would be most helpful to increase their transportation resilience.

Resources:

- U.S. Climate Resilience Toolkit's Tools for Equitable Climate Resilience: Fostering Community-Led Research and Knowledge provides step-by-step guidance and lessons learned on how to effectively engage with community members to understand climate impacts and to develop more equitable climate resilience measures.

[13] Resilience hubs are community-serving facilities augmented to support residents, coordinate communication, and distribute resources to build resilience before, during, and after climate related emergency events. See an example of a resilience hub being implemented in Washington, D.C.: https://doee.dc.gov/service/community-resilience-hubs

Local Planning

Update land use regulations to restrict development in high-risk areas

Planning Leads: Municipal Boards

Update land use regulations, including zoning and building codes, to restrict development in areas with high flood or landslide risk.

Resources:

- New York State Department of State provides Basic Land Use Tools for Resiliency, including details on zoning.
- Boston, Massachusetts developed a set of design guidelines and a zoning overlay district to promote flooding resilience in vulnerable areas of the city through its Coastal Flood Resilience Guidelines & Zoning Overlay District.
- Dutchess County's Zoning and Environmental Mappers could be helpful resources for municipalities interested in updating their land use regulations.

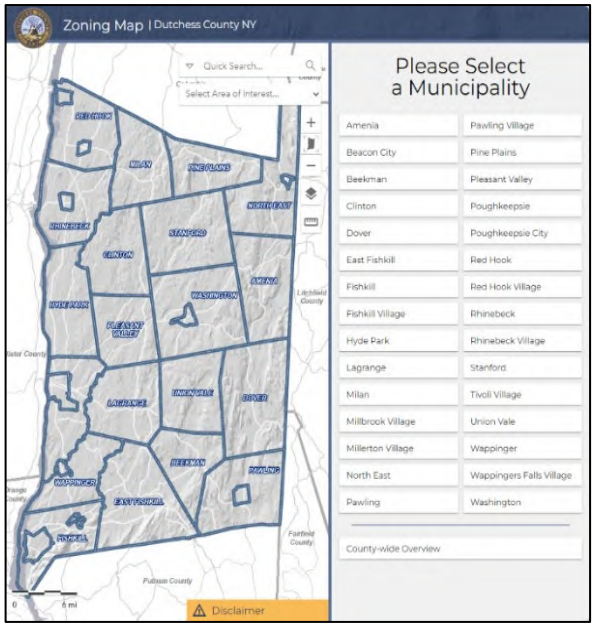

Figure 19. Dutchess County zoning app (Source: DCTC)

Update stormwater management plans to accommodate more severe storm events

Planning Leads: County and Local Highway/Public Works Departments

Update stormwater[14] management plans to reflect current and forward-looking climate information and protect moderate- to highly critical infrastructure. For example, the stormwater management plan could include new design standards and green infrastructure practices[15] that account for changing precipitation patterns and larger storms to reduce flood risk to infrastructure and minimize waterway contamination.

Resources:

- Cornell University developed an online tool to help localities understand future rainfall intensities.
- The U.S. Environmental Protection Agency (EPA) has a Climate Adaptation and Stormwater Runoff guide.

[14] Stormwater is rainwater or melted snow that runs off into streets, lawns, and other sites, and is eventually absorbed into the soil or flows into a river or stream. Increased precipitation from more frequent and severe storm events due to climate change can overwhelm the design capacity of stormwater management systems and lead to backups and contamination of local waterways. This impact can be exacerbated by development that converts vegetated areas to impervious surfaces like paved surfaces and buildings.

[15] Within the Infrastructure Investment and Jobs Act (IIJA), the Healthy Streets Program provides grants to eligible entities to reduce the extent of stormwater runoff and flood risks (as well as heat impacts).

- New York City created a NYC Stormwater Resilience Plan to understand and plan for changes in flooding.

Provide guidance to municipalities on developing a community transportation resilience plan

Planning Lead: DCTC; County Planning

Develop a guidance document or provide recommendations to help municipalities develop transportation resilience plans to reduce their risk to climate hazards. The resilience plans could bring residents, community organizations, and agencies together to improve transportation and ensure that the perspectives of community members are considered.

Figure 20. Example of community engagement conducted by DCTC as part of a local planning initiative (Source: DCTC)

Resources:

- New York State's Climate Smart Communities program includes several actions that could help guide municipalities in developing community transportation resilience plans. These actions are within the PE7 category and include Climate Vulnerability Assessment, Evaluate Policies for Climate Resilience, and Climate Action Plans.
- The San Francisco Bay Area's Metropolitan Transportation Commission brought local residents, community organizations and transportation agencies together to improve transportation for low-income communities. Together, they developed more than 30 Community-Based Transportation plans for communities as well as guidelines and program evaluation documents.

Establish a local designation program or encourage municipalities to participate in the Climate Smart Communities Program to incentivize resilience efforts

Planning Lead: DCTC; County Planning

Establish a program to incentivize resilience work at the local level by designating municipalities as a 'Resilient Ways Forward Community'. An alternative could be to encourage municipalities to seek certification as a Climate Smart Community. This could encourage municipal boards, elected officials, and even homeowners' associations to pursue resilience-related projects and policies. The DCTC or County Planning could also put municipalities in touch with the county's Climate Smart Communities Task Force to provide support and resources on becoming a Climate Smart Community.

Resources:

- Municipalities can pursue Climate Smart Communities (CSC) certification through New York State. Benefits of certification include increased access to funding, free technical assistance, and opportunities to network with other communities.

Monitor and evaluate progress towards increasing resilience

Planning Leads: All agencies implementing resilience projects

Develop and track metrics to determine whether adaptation measures are successful. For example, agencies could track the number of resilience projects implemented, the decrease in flood-related impacts, and changes in tree canopy or impervious surface coverage.

Resources:

- The U.S. Climate Resilience Toolkit provides an approach on using indicators and metrics in resilience planning: How Will We Know We're Adapting?
- FHWA recently published draft resilience metrics for evaluating the effectiveness and impacts of resilience projects under the PROTECT program.

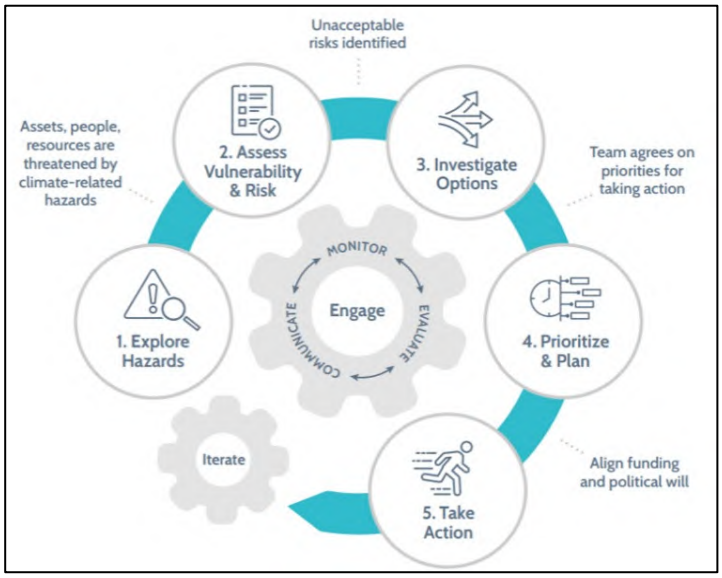

Figure 21. Diagram of NOAA's Steps to Resilience, which includes a consistent process of monitoring and evaluating progress (Source: NOAA)

Capacity-Building & Collaboration

Leverage existing groups and standing meetings to host resilience working sessions with key local and state partners

Planning Lead: DCTC or County Planning

Leverage existing work groups and standing meetings, such as monthly Highway Superintendent meetings, to promote resilience tools, practices, and funding opportunities with local and state partners 1-2 times per year. These sessions could increase collaboration, facilitate the sharing of best practices for climate adaptation, and better align available resources. Resilience working sessions also provide an opportunity for local and state partners to share updates and lessons learned from their own resilience projects or initiatives. The DCTC could also consider combining resilience working sessions with other topics that would encourage more attendance, such as announcing funding opportunities.

Resources:

- The U.S. Climate Resilience Toolkit provides a range of training courses to help practitioners acquire tools, skills, and knowledge related to climate resilience. These trainings could help inform the development of resilience working sessions. For example, the Community Resilience Building Workshop training provides free downloadable guides on how to lead community resilience workshops.

- Examples of regional climate resilience workgroups or climate-focused task forces could help guide the development of resilience working sessions in Dutchess County. Examples include:
    - The Chesapeake Bay Climate Resiliency Workgroup
    - Maine Community Resilience Working Group
    - City of Philadelphia Flood Risk Management Task Force
- The County's Climate Smart Communities Task Force (CSCTF) and Environmental Management Council (EMC) could be helpful for identifying appropriate partners.
- The NY Silver Jackets Group is made up of representatives from New York State and Federal agencies who work to better manage ongoing and future flood risks in the state. Local governments could consider participating in the Silver Jackets.

Increase coordination and collaboration between municipal boards, planning boards, highway departments, and other relevant departments

Planning Leads: Municipal Boards and Departments

Increase collaboration and coordination between municipal boards, planning boards, highway departments, and other relevant departments, especially when updating comprehensive plans and reviewing development proposals. This can help ensure that the highway department and other relevant departments have an opportunity to share any concerns related to new projects, especially those with the potential to worsen climate risks.

Next Steps for Implementation

To successfully enhance the resilience of Dutchess County's transportation system, collaboration and coordination across local agencies and partners is necessary. We have played a key role in developing a suite of potential adaptation measures for the county and bringing together partners and stakeholders to get their buy in and support. We have also made great strides in understanding the potential impacts of climate change on the region's transportation system. We can continue to take steps to advance the county's transportation resilience though continued collaboration and engagement, integrating resilience within our long-range plan and other county plans, and encouraging technical trainings to enhance the county's expertise on climate resilience.

We also look forward to seeing how our partners in the region advance their own resilience work by pursuing funding for and implementing specific transportation resilience improvement projects.

Collaboration and Engagement

We can continue to facilitate collaboration across partners and stakeholders to promote the potential adaptation measures and determine where multiple partners can pool resources and efforts to implement resilience measures. For example, we can attend scheduled Highway Supervisors' meetings to share information and encourage members to use the vulnerability assessment results in their work, identify specific adaptation projects, and pursue funding for implementation.

In addition to collaborating with our partners, we can continue to collaborate and engage with the community. The policy-based measures in the Community Outreach section focus on community outreach, raising awareness of climate change hazards and building resilience to climate impacts. These efforts can continue to expand and help promote awareness and buy in on the proposed adaptation measures.

Integrating Resilience

We can evaluate opportunities to integrate resilience and climate data into ongoing and new planning processes. Our current long-range plan, Moving Dutchess Forward, includes resilience as part of its vision. Using the results of this RWF TRIP, we can strengthen that resilience vision, integrate future climate data into our decision-making and planning processes (e.g., calls for projects and project evaluation), and ultimately include some resilience projects in our capital program. In addition, incorporating the RWF TRIP into our next long-range plan will provide a further reduction in the local match requirement for projects funded through the PROTECT program.

Training and Professional Development

We can encourage County transportation engineers and partner agencies to complete training and participate in professional development opportunities. For example, we can encourage engineers to review FHWA resilience design resources and take FHWA trainings on climate change. The National Highway Institute is the training arm of the FHWA and has developed training for transportation practitioners to understand climate change concepts, interpret projects, and apply this information to

transportation decision-making, including project development and preliminary design.[16] See the full list of Training and Technical Assistance opportunities. This will enhance the county's expertise on climate resilience and project development and design.

[16] U.S. Department of Transportation, 2024. Training and Technical Assistance. https://www.transportation.gov/priorities/climate-and-sustainability/training-and-technical-assistance

Future Improvements

The RWF TRIP is a significant milestone in our work to increase the resilience of the transportation system in Dutchess County. We are dedicated to continuing and expanding upon the work completed under this effort to ensure that the county remains prepared to address the impacts of climate change. In addition to encouraging and facilitating the implementation of the adaptation measures and policy-based measures included in the Resilience Recommendations section, we will update the vulnerability assessment results as needed in the future (see the Vulnerability Assessment Update Plan). Climate science is constantly evolving, and as new or improved climate data or information becomes available, we can update the vulnerability assessment methodology as appropriate to further refine its understanding of where and what is most vulnerable in the county.

Potential future improvements to the RWF TRIP could include:

- **Collecting local information on impacts:** Another way we can improve the vulnerability assessment results in the future is by incorporating more information from residents and infrastructure owners and managers regarding current hazard concerns. For example, we distributed a survey as part of the vulnerability assessment to collect information on climate-related impacts to the transportation system. We could develop a consistent data-gathering process across the county for similar information. Local information on climate impacts could help ground-truth the results from the vulnerability assessment and ensure that all vulnerable locations are accurately scored.
- **Incorporating forward-looking changes in precipitation due to climate change:** The vulnerability assessment primarily used the FEMA floodplain maps to assess flood exposure. However, these maps are based on historical data and do not consider future climate change. We could consider purchasing data sets that include future inland flood risk, including pluvial flooding, which occurs when an extreme rainfall event creates a flood separate from a body of water. Incorporating future climate data will enhance our and the region's understanding of future flood risk.
- **Continue to work with partners to identify resilience projects:** We worked with key partners throughout the development of the RWF TRIP to help facilitate the identification of potential resilience projects to include in the resilience investment plan (see the Priority Resilience Project Ideas section for more details). We can update this list on a routine basis (e.g., annually) and continue to help partners identify resilience projects for high-vulnerability locations/assets.
- **Assess critical interdependencies:** We could further assess critical interdependencies between the transportation system and other key sectors to better understand how the transportation system could be affected by damage or disruptions to other key sectors and vice versa.

Monitoring and Measuring Progress

In addition to updating the vulnerability assessment as needed (see the Vulnerability Assessment Update Plan for more details), we can track and evaluate extreme weather events and their impacts to understand how they are changing. We can also establish measures to understand the

effectiveness of implemented resilience projects. Iteratively evaluating climate impacts is essential for understanding how the climate is changing and determining whether resilience projects have been effective at reducing vulnerability.

The DCTC can most reliably track federally funded resilience projects, including those that receive PROTECT funding. Our partners at local municipalities, County DPW, NYSDOT, County Transit, Metro-North and other agencies could assist by tracking items such as road and bridge closures due to extreme weather events and the number and/or duration of transit service disruptions due to extreme weather events. We can also support any performance measures developed for NYSDOT's Resilience Improvement Plan. We can explore different approaches for tracking indicators, such as through a database where indicators are recorded and organized, while also monitoring best practices across the MPO community as more resilience plans are completed.

Appendix A: PROTECT Requirements Checklist

Table 12 lists the required and optional elements of a Resilience Improvement Plan per the PROTECT program guidelines and where each element is addressed in this document.

Table 12. PROTECT requirements for a Resilience Improvement Plan

The Resilience Improvement Plan…	Corresponding RWF TRIP Section
Shall…	
Be for the **immediate and long-range planning activities** and investments of the State or MPO with respect to resilience of the surface transportation system within the boundaries of the State or MPO as applicable	• Systemic Approach to Resilience in Dutchess County
Demonstrate a **systemic approach** to transportation system resilience and be **consistent with and complementary of the State and local mitigation plans** required under section 322 of the Stafford Act (42 U.S.C. 5165)	• Systemic Approach to Resilience in Dutchess County • Appendix B: Policies and Plans in the Region
Include a **risk-based assessment** of vulnerabilities of transportation **assets** and **systems** to **current and future weather events** and natural disasters, such as severe storms, flooding, drought, levee and dam failures, wildfire, rockslides, mudslides, sea level rise, extreme weather, including extreme temperatures, and earthquakes (23 U.S.C. 176(e)(2)(A-C))	• Climate Vulnerability Assessment
Document the geographic scale considered and the logic supporting it	• Systemic Approach to Resilience in Dutchess County
Shall, as appropriate…	
Include a description of how the plan will improve the ability of the State or MPO to respond promptly to the **impacts of weather events and natural disasters** and to be prepared for changing conditions, such as sea level rise and increased flood risk.	• Resilience Recommendations: Policy-based Measures • Resilience Recommendations: Adaptation Toolbox • Appendix C: Adaptation Toolbox
Describe the **codes, standards, and regulatory framework**, if any, adopted and enforced to ensure resilience improvements within the impacted area of proposed projects included in the Resilience Improvement Plan;	• Resilience Recommendations: Policy-based Measures • Next Steps for Implementation
Consider the benefits of combining hard surface transportation assets, and **natural infrastructure**, through coordinated efforts by the Federal Government and the States;	• Resilience Recommendations: Adaptation Toolbox • Appendix C: Adaptation Toolbox • Appendix D: Nature-Based Solutions Profiles
Assess the resilience of other **community assets**, including buildings and housing, emergency management assets, and energy, water, and communication infrastructure;	• Climate Vulnerability Assessment • Future Improvements

The Resilience Improvement Plan…	Corresponding RWF TRIP Section
Use a long-term planning period; and	• Systemic Approach to Resilience in Dutchess County
Include such other information as the State or MPO considers appropriate. (23 U.S.C. 176(e)(2)(E)(i)-(vi)).	• Appendix E: Equity Dataset Comparison • Appendix F: Potential Funding Sources
Cover a period at least as long as the relevant SLRTP, MTP, or asset management plan. A longer period that considers the service lives of relevant assets is recommended.	• Systemic Approach to Resilience in Dutchess County • Climate Vulnerability Assessment
May also…	
Designate **evacuation routes and strategies**, including multimodal facilities, designated with consideration for individuals without access to personal vehicles;	• Resilience Recommendations: Adaptation Toolbox • Appendix C: Adaptation Toolbox
Plan for **response to anticipated emergencies**, including plans for the mobility of emergency response personnel and equipment and access to emergency services including for vulnerable or disadvantaged populations;	• Resilience Recommendations: Policy-based Measures
Describe **resilience improvement policies, including strategies**, land-use and zoning changes, investments in natural infrastructure, or performance measures that will inform the transportation investment decisions of the State or MPO with the goal of including resilience;	• Resilience Recommendations: Adaptation Toolbox • Resilience Recommendations: Policy-based Measures • Appendix C: Adaptation Toolbox
Include an **investment plan** that: (i) includes a list of priority projects; and (ii) describes how PROTECT Formula Program funds apportioned to the State would be invested and matched, which shall not be subject to fiscal restraint requirements; and	• Resilience Recommendations: Priority Resilience Projects
Use **science and data** and indicate the source of data and methodologies. (23 U.S.C. 176(e)(2)(D)(i)-(v)).	• Climate Vulnerability Assessment
Include time frames for project implementation.	• Next Steps for Implementation
Include measurable outcomes and goals in their plans.	• Next Steps for Implementation • Future Improvements

Appendix B: Policies and Plans in the Region

To ensure a systemic approach to transportation resilience across the county, the RWF TRIP is aligned with existing policies and plans from the region. This appendix provides details on state, local, and county-level resilience plans that helped inform the development of the RWF TRIP. For example, the County Public Works Department regularly references the New York State Risk Management Guidance, which includes design guidance for future climate risks, to incorporate as appropriate in County infrastructure projects.

Table 13. Summary of resilience plans that helped inform the development of the RWF TRIP

Resilience Plans	Descriptions
State and Local	
New York Climate Impacts Assessment[17]	The New York Climate Impacts Assessment investigates how climate change impacts New York State's communities, ecosystems, and economy, using up-to-date future climate projections. In addition, the assessment presents information about strategies for adaptation and resilience and how New York can prepare for the impacts of climate change.
New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act[18]	In 2014, the Community Risk and Resiliency Act (CCRA) was signed to bolster New York's defense against rising sea levels and extreme flooding. The State Flood Risk Management Guidance ensures projects involving new structures or the repair of damaged structures consider future climate risks, including sea level rise, storm surge, and flooding, to enhance resiliency and preparedness efforts in the state. The guidance includes guideline elevations to determine vertical flood elevation and horizontal floodplains to be considered during siting and design phases of project. In addition, the document helps communities and the public understand the risk to both public and private development from flooding under current and anticipated future conditions.
Mid-Hudson Regional Sustainability Plan[19]	The plan was developed as part of the New York State Energy Research and Development Authority's Cleaner Greener Communities program and provides a series of objectives that reflect the region's diverse landscapes, demographics, economy, culture, and history and provides a common vision for the region's sustainable development. The Mid-Hudson Sustainability Plan is categorized by the following focus areas: Transportation, Waste Management, Climate Change Adaptation, Land Use, Water Management, Energy, and Agriculture.

[17] Stevens, A., & Lamie, C., 2024. New York Climate Impacts Assessment: Understanding and preparing for our changing climate. https://nysclimateimpacts.org

[18] New York State Department of Environmental Conservation, 2020. New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act. https://extapps.dec.ny.gov/docs/administration_pdf/crrafloodriskmgmtgdnc.pdf

[19] Mid-Hudson Regional Sustainability Plan, 2013. https://www.orangecountygov.com/documentcenter/view/1469

Resilience Plans	Descriptions
Local Utility Climate Change Resilience Plans	Two local utilities that serve portions of Dutchess County, including Central Hudson[20] and New York State Electric & Gas Corporation[21] (NYSEG), both filed a Climate Change Resilience Plan (CCRP) in 2023 that identifies infrastructure-strengthening investments and process changes to combat the impacts of extreme weather and climate change on the utility's distribution, transmission, and substation systems. The Plans focus on the priority vulnerabilities identified in the Climate Change Vulnerability Study. The CCRPs enhance the utilities' resilience to climate driven impacts and help mitigate service interruptions for customers.
MTA Climate Resilience Roadmap[22]	The MTA Climate Resilience Roadmap is a comprehensive framework that aims to fortify the transit system against the impacts of climate change. The Roadmap is comprised of a Climate Vulnerability Assessment and ten core climate resilience goals targeted to address climate threats facing MTA infrastructure, including strategies to reduce flooding and erosion risk to both the Harlem and Hudson Line. Specifically, Goal 7 focuses on reducing flooding to the Metro-North Railroad system, which runs along the Hudson River in Dutchess County.
Dutchess County	
Moving Dutchess Forward	Moving Dutchess Forward is the long-range transportation plan for Dutchess County. A key part of the vision outlined in the plan is to make the county's transportation system more resilient. The plan includes a section on Climate Change Trends that discusses rising temperatures, greater precipitation, and increased flooding. This section also outlines key steps for the DCTC to take to address these challenges, including sharing the results and recommendations of RWF. The plan also includes an online flood vulnerability map that shows roads, bridges, bus routes, and rail lines in flood zones, and reported flood events.
Hazard Mitigation Plan	Dutchess County's Department of Emergency Response is leading an update of the Dutchess County Hazard Mitigation Plan for the County and its jurisdictions. This plan is an opportunity to detail a variety of potential hazards, including those posed by climate change. The goal of this plan is to identify projects that can reduce damages from future

[20] Central Hudson, 2023. Climate Change Resilience Plan. https://www.cenhud.com/globalassets/pdf/my-energy/climate-change-resilience-plan/case-number-22-e-0222-climate-change-resilience-plan.pdf
[21] New York State Electric & Gas Corporation, 2023. Climate Change Resilience Plan. https://www.nyseg.com/documents/40132/5898083/NYSEG+Nov+2023+Climate+Change+Resilience+Plan_12.06.23.pdf
[22] Metropolitan Transportation Authority, 2024. Climate Resilience Roadmap. https://new.mta.info/document/136871

Resilience Plans	Descriptions
	natural and non-natural hazards. The plan will include a risk assessment and a hazard mitigation strategy, and the study will focus on existing buildings and potential future development, infrastructure, and critical facilities that might be impacted.
Natural Resources Inventory	The County's Natural Resources Inventory (NRI) is a website that catalogs the physical and biological characteristics present within the county, collects the data in a usable format, and interprets the findings. The NRI, including its accompanying Environmental Mapper, serves as a planning and project review tool for municipalities at the local level and as a tool for county or regional planning and project assessment. The NRI website also serves as a valuable resource for landowners and educators looking to learn and teach about their local landscapes. The County's NRI website covers many topics pertaining to the local environment, including an in-depth analysis of the county's climate and anticipated impacts of climate change.
Dutchess County Climate Action Plan	The Dutchess County Government Operations Climate Action Plan (CAP) will be a strategy document that sets goals and outlines a set of initiatives that reduce greenhouse gas (GHG) emissions associated with government operations. Using a GHG emissions inventory as the foundation, the CAP will define GHG reduction targets and provide a framework for achieving those targets. By developing such a plan for its own operations, the County can provide local communities with examples that help to inspire communitywide action. This plan is currently in development and is set to be completed mid-2024.
Dutchess County Climate Adaptation Plan	The Dutchess County Climate Adaptation Plan will aim to identify communitywide vulnerabilities and identify foundational actions for adapting to climate change and building resilience in the county. The County's Climate Adaptation Plan will outline a vision and set of strategies to improve the county's resilience to climate change based on its local physical, economic, and social vulnerabilities. This plan is currently in development and is set to be completed in early 2025.

Appendix C: Adaptation Toolbox

This appendix provides an overview of each adaptation measure in the Adaptation Toolbox. We developed the Toolbox to offer infrastructure owners and service providers a range of potential adaptation measures to consider. The adaptation measures are targeted at reducing climate impacts to the high priority asset/hazard pairs identified through the Climate Vulnerability Assessment. Table 14 provides an icon key for the transportation assets and climate hazards referenced in the Toolbox. The feasibility of implementing any given measure is at the discretion of the infrastructure owner and dependent on the site-specific context.

Table 14. Asset and hazard icons

Asset Icons		Hazard Icons	
Roads		**Flooding**	
Bridges		**Landslide**	
Culverts		**Extreme Heat**	
Bus Systems and Facilities		**Wind**	
Rail Lines and Stations		**Winter Conditions**	
Sidewalks			
Rail Trails			

Adaptation measures are organized into the following categories based on the primary objective of each measure:

- **Plan & Prepare:** Develop climate risk management and/or emergency management plans and procedures.
- **Maintain & Manage:** Use maintenance and operations measures to enhance resilience. For instance, monitor and upgrade equipment more frequently, implement technologies that monitor climate stressors, etc.
- **Strengthen & Protect:** Fortify infrastructure to withstand future climate conditions. Strengthen existing infrastructure through retrofits and strengthen planned infrastructure through designs that account for future conditions. For example, design structures with greater drainage capacity, use materials suited to high temperatures, or build protective structures.
- **Enhance Redundancy:** Identify and develop alternatives to system components. For example, increase bus service during rail interruptions.
- **Recover:** Develop post-event recovery and restoration procedures.
- **Retreat:** Abandon facilities located in extremely vulnerable or indefensible areas and relocate, if needed, to less vulnerable locations.

Flooding

There are 22 potential measures to reduce flood risk to roads, bridges, culverts, rail lines/stations, and rail trails. These measures can help reduce flood risks to both physical infrastructure and services/operations. Certain measures in this section also help reduce risks associated with landslides, winter conditions or all hazards (these are indicated with a *).

Plan & Prepare

Source: iStock

1. Identify evacuation routes for highly vulnerable assets and critical transportation routes

Identify transportation routes that can remain reliably traversable during severe flood events.

Source: Stock photo

2. Prohibit overweight/oversized vehicles on weakened pavements

Prohibit heavy loads on weakened pavements in the immediate aftermath of a flooding event to prevent sudden failure or severe damage. Identify appropriate detour plans.

Maintain & Manage

Source: Cloud9Service

3. Clear vegetation and debris from culverts more frequently

Clear vegetation and debris from drainage systems and clear drains more frequently to prevent clogging and flooding, especially before major storms. Determine appropriate maintenance schedule based on site-specific considerations.

This measure can also help reduce **landslide risk by reducing surface runoff.*


Source: Blickfeld

4. Implement sensor technologies and monitoring programs and increase awareness monitoring systems

Employ cameras and sensors to help monitor and prepare for storm events (i.e., sensors to monitor rainfall, runoff, water levels, and stormwater systems), and increase awareness of existing monitoring systems to enhance usage and data.

This measure can also help reduce risk **to all hazards.*

Strengthen & Protect


Source: Shutterstock

5. Elevate low-lying bridges

Based on flood projections and flood history, elevate bridges to prevent inundation and reduce service disruptions.


Source: Prodyogi

6. Enhance the road sub-grade

Enhance and harden the road sub-grade (the material underneath the constructed road) to prevent damage or failure to pavement structures caused by inundation.


Source: Flickr

7. Improve road shoulders to increase lateral support

Road shoulders typically do not have the subsurface structure built out to the extent that roads do, so improving road shoulders can help provide additional lateral support to prevent road damage during inundation. For gravel shoulders, this can include paving them. For shoulders that are already paved, this could include increasing the size, width, or depth of the shoulders.

Source: Allentown PA

8. Raise the road profile in flood-prone areas

Raise the road profile to allow the road to remain passable during flooding and extend its service life.

Source: Geosynthetics Magazine

9. Install geotextiles, such as green mats, on embankments

Install geotextiles on embankments to enhance drainage and strengthen the base of pavement structure. This can include using native dogwood stakes to facilitate natural vegetation development.

Source: Connection News

10. Install medians to strategically hold and/or convey stormwater

Implement depressed medians (a ditch/swale between divided roadways) to hold stormwater and raised medians (a curbed section that typically occupies the center of the roadway) to convey stormwater away from roadway.

Source: Daily Civil

11. Upsize culverts and other stormwater management infrastructure

Upsize culverts and other stormwater management infrastructure (e.g., pipes, drains, etc.) where necessary.

This measure can also help reduce **landslide risk by reducing surface runoff.*

Source: Trout Headwaters

12. Reconfigure stream channels

Modify channels to improve stream conditions and reduce flooding. Work with relevant agencies and landowners to determine feasibility to implement measure.

Source: Riparian Engineering

13. Construct rocks strategically in streams to dissipate water energy and reduce flooding

Rocky in-stream techniques (e.g., riffles, spurs) involve constructing rocks strategically in streams to help dissipate water energy and reduce flooding. Work with relevant agencies and landowners to determine feasibility.

Source: Geosynthetics Magazine

14. Use natural materials to restore stream banks

Natural materials are used to restore eroding areas along rivers or streams. For example, vegetation can be planted along banks with rock or log revetments. Work with relevant agencies and landowners to determine feasibility.

Source: Shropshire Council

15. Place logs or branches in streams to reduce water flow

Large woody debris (fallen trees, logs, and branches) can be placed in streams to reduce the flow of water and help connect the stream channel to its floodplain, reducing flooding. Work with relevant agencies and landowners to determine feasibility to implement measure.

Source: Pinterest

16. Plant vegetation buffers along roads

Vegetation buffers can be added along roadways to reduce the severity and duration of inundation events.

Source: Tinker's Creek

17. Revegetate areas along streams

Re-establish native vegetation at degraded riparian sites to help stabilize streams. Work with relevant agencies and landowners to determine feasibility to implement measure.

Source: New York Nature

18. Restore wetlands

Re-establish former wetlands or rehabilitate degraded ones to reduce flooding. Work with relevant agencies and landowners to determine feasibility to implement measure.

Source: Drainage and Erosion

19. Install swales, ditches, and rain gardens

Install swales and ditches to help improve stormwater drainage. This can also include implementing contouring or rain gardens to reduce surface runoff which can help increase slope stability.

This measure can also help reduce **landslide risk by reducing surface runoff and thereby increasing slope stability.*

20. Use permeable pavements

Source: Stormwater

Use permeable pavements in low traffic areas, including parking lots, to slow, filter, and clean stormwater runoff. These types of pavements can also be used around bridges and bus stations that experience frequent freeze-thaw periods. They should not be implemented on high-traffic roads where clogging of pavements could cause significant issues.

This measure can also help with **winter conditions by allowing standing water to filter and thereby avoiding freeze-thaw cycles and preventing ice formation on roads and bridges.*

Source: Cornell

21. Install retention/detention ponds and bioswales

Install retention/detention ponds and bioswales (or biofiltration swales) to collect, redirect, and filter stormwater.

Retreat

Source: King County

22. Relocate infrastructure away from the floodplain

Remove at-risk structures from the floodplain. This can also include restoring the stream channel to its natural configuration to create additional flood storage.

Landslide

There are nine potential measures to reduce landslide risk to roads, bridges, and rail lines/stations. These measures can help reduce landslide risk to both transportation physical infrastructure and services/operations.

Plan & Prepare

Source: Stock photo

23. Establish setback requirements for roads near slopes

Reduce landslide risk by establishing setback requirements and building roads away from unstable slopes.

Source: Stock photo

24. Plan and communicate detour routes

Identify locations where detours are needed due to a landslide. Design detours and alert the community.

Maintain and Manage

Source: Quarry

25. Use technology to monitor conditions

Use technology-based monitoring techniques to help monitor landslide risk, such as geotechnical monitoring, remote sensing, and satellite imagery.

Source: Cincinnati

26. Build retaining walls

Build retaining walls to fortify slopes using concrete, steel, and other hard materials.

Source: Constructionor

27. Install reinforcing elements in soil, such as soil nails

Install reinforcing elements such as soil nails into the soil in a grid pattern to increase overall slope stability. Soil nails are typically threaded steel bars that help create a composite mass in the soil and improve the overall stability of the slope.

Source: BTL Liners

28. Install geosynthetics filtering fabrics

Install geosynthetic filtering fabrics (i.e., geotextiles, geogrids, geocells) to reinforce soil.

Source: AftonVilla

29. Grade or terrace slopes

Modify the slope gradient by redistributing soil or rock mass or creating flat or gently sloping areas on steep slopes to minimize landslide potential.

Source: CGIAR

30. Plant native vegetation to stabilize slopes

Plant native vegetation such as trees, shrubs, and grasses along slopes to prevent erosion.

Source: Virginia Department of Transportation

31. Stabilize slopes using bioengineering techniques

Apply bioengineering techniques to stabilize slopes. Bioengineering involves the use of live plants and natural elements. Examples of techniques include brush layering, soil bioengineering, and live crib walls.

Extreme Heat

There are five potential measures to reduce extreme heat risk to rail trails and sidewalks. These measures can help reduce extreme heat risks to transportation services/operations.

Plan & Prepare

Source: New York Times

32. Conduct heat awareness campaigns

Implement local heat awareness campaigns on the dangers of extreme heat events. Encourage people to stay inside during extreme heat events, and if outside, to be prepared with extra water, protective clothing, sunglasses, etc. Post information materials/QR codes at trail heads with heat safety best practices.

Source: OregonLive

33. Establish cooling spaces near high-traffic sidewalks and rail trails

Create a network of cooling spaces (e.g., businesses, churches, community organizations, etc.) to provide heat relief.

Strengthen & Protect

Source: CreativeRec

34. Provide shade trees, shade structures, and shelters along rail trails, sidewalks and at bus stops

Design and install shade structures, shade trees, and shelters along rail trails, sidewalks and at bus stops to reduce heat stress and provide relief. Include benches or other seating areas.

Source: Independent

35. Use cool trail materials (i.e. reflective and permeable pavements)

Cool trail materials, including reflective and permeable pavements, can lower ambient temperatures for people walking or biking.

Source: WaterNewsNetwork

36. Install and/or operate hydration stations and misting stations along rail trails and sidewalks

Permanent or temporary hydration and misting stations at key junctures along rail trails can provide relief from heat.

Wind

There are four potential measures to reduce wind risk to roads, bridges, rail lines/stations. These measures can help reduce wind risks to transportation services/operations.

Maintain & Manage

Source: Mass Producing Trees

37. Remove unhealthy, dead, or dangerous trees

Remove unhealthy/dead/dangerous trees near moderate to highly critical roads, bridges and rail lines and around utility poles and wires.

Source: Colin White Tree Surgery

38. Clear vegetation more frequently

Increase the frequency of vegetation clearance cycles to ensure overgrowth and broken and dead vegetation is cleared before storms.

Source: FRA

39. Implement reporting systems that monitor/detect/track roadway obstructions

Develop a system that allows community members to voluntarily report obstructions (e.g., through an app).

Source: Stock Photo

40. Encourage utilities to bury overhead transmission and distribution lines in high-risk areas

Encourage utilities to bury overhead transmission and distribution lines to reduce downed wires and limit health and safety concerns associated with live wires, particularly in areas of new development where it is more cost-effective to implement (compared to retrofits).

Winter

There are four potential measures to reduce winter risk to roads, bridges, rail lines/stations, and bus systems/facilities. These measures can help reduce winter risks to transportation services/operations.

Plan & Prepare

Source: Stock photo

41. Strategically apply salt (or salt alternative) prior to and during hazardous winter driving conditions

Salt application on roads should be applied strategically to minimize environmental impacts. Include consideration of salt alternatives (such as brine) and alternative application methods to minimize environmental impacts (i.e., closed loop systems).

Source: County Transit

42. Install bus stop shelters

Provide bus stop shelters to protect riders from the elements. Consider insulated or heated shelters, especially at high-use stops.

This measure can also help reduce **extreme heat risk by providing shade.*

Strengthen & Protect

Source: News Archive

43. Install snow fences along critical routes or high hazard areas

Install snow fences near critical road segments and bus routes to reduce snow blow across the roads. This can include 'living snow fences' made of trees/bushes. Traditional snow fences can be a temporary measure implemented during the winter season.

Enhance Redundancy

Source: Poughkeepsie Journal

44. Increase frequency of bus service during extreme cold periods

Increase bus frequency, particularly along high-ridership routes, to reduce waiting time. Determine appropriate temperature thresholds to increase frequency, while accounting for staff and vehicle availability and roadway conditions.

Appendix D: Nature-Based Solutions Profiles

Case Study #1: Vegetation for Erosion Control/Stabilization

Problem and Solution

Heavy precipitation events are expected to become more frequent and intense, leading to severe and longer flooding.[23] Flooding can significantly damage roads, especially roads that run along streams or rivers, where erosion can cause pavement and embankment failure. In addition to physical infrastructure damage, flooding can lead to severe and long-lasting road closures, delays, detours, and safety hazards.

Figure 22. Riparian buffer planted on a road-stream crossing in Shenandoah National Park in Virigina (Source: Ecosystem Services)

For roads and rail trails that cross or are adjacent to streams, planting native vegetation also known as riparian vegetation (Figure 22) [24] alongside the road, rail trail, and/or stream can help with erosion control and bank stabilization. This measure has the potential to reduce damage to road infrastructure and reduce the severity and duration of inundation during heavy rain events.

Effectiveness

Figure 23 illustrates how planting native vegetation can help decrease erosion and flood risk. To help stabilize the soil and bank materials, vegetative roots bind soil layers together. In addition, native vegetation helps absorb water, reducing the velocity of surface runoff, and decreasing the overall risk of severe flooding. As vegetation matures within a project area, it becomes increasingly more effective as the roots become more established and can absorb higher rates of water. The effectiveness of this

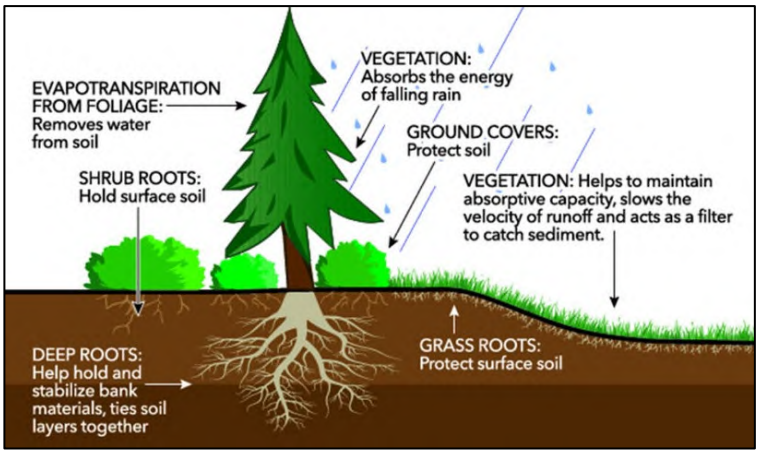

Figure 23. Illustration of vegetation and its various functions (Source: R. Roshana, 2018)

[23] U.S. Federal Government. NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Days with more than one inch of precipitation in Dutchess County, NY. https://crt-climate-explorer.nemac.org/ Accessed February 2023.
[24] Riparian vegetation refers to vegetated zones adjacent to streams or wetlands.

measure is also dependent on the vegetation type, the width of the total area planted, soil conditions, and geographic locations.

Ecological Benefits

A well vegetated area can provide a wide variety of ecological benefits. Not only does vegetation provide erosion control, but it also acts as a buffer against litter and filters pollutants before they reach a stream or river. Planted native vegetation supports pollinators and generates food for other species. In addition, plantings composed of native vegetation can buffer against invasive species and provide a breeding and nesting habitat that can support biodiversity.

Siting and Design Considerations

Siting considerations should include the following:

- Soil conditions[25], particularly avoiding poor quality compacted soil that may not be optimal for plant growth
- Right-of-way or property access may be restricted or limited
- Elevation, steep slopes, and terrain width. Too steep or narrow terrains may not be suitable to plant vegetation due to inadequate soil stability, lack of water retention, nutrient runoff and access.

Design considerations should include the following:

- Appropriate buffer width to meet specific site objectives; 50 to 200 feet is recommended for flood mitigation, while only 25-50 feet is recommended for bank stabilization.[26]
- Tolerance levels of specific native vegetation[27] and its suitability to the project site conditions (e.g., inundation frequency, velocity of runoff, soil condition, lighting, etc.). See Dutchess County Soil & Water Conservation District for a list of deciduous trees[28] and shrubs[29] that help with erosion control ("E").
- Mixing a diverse set of native vegetation, including grasses, shrubs, and trees within the project area. Figure 24 demonstrates a comprehensive example of planting zones based on the plant species and characteristics. Note that a proper planting zone may not be possible if the project area has a limited right-of-way.

[25] For information on soil conditions in Dutchess County, see the Natural Resources Inventory https://nri.dutchessenvironment.com/physical-resources/#toggle4

[26] Palone, R. S. and Todd, A. H. 1998. Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers. USDA Forest Service, N. E. Area NA-TP-02-97. Radnor, PA, Published May 1997, revised June 1998. https://chesapeakeforestbuffers.net/wp-content/uploads/2016/01/cbp_13019_edited.pdf

[27] To determine native vegetation for Dutchess County, see New York Flora Atlas https://newyork.plantatlas.usf.edu/Results.aspx or Dutchess County Soil and Water Conservation District https://dutchessswcd.org/wp-content/uploads/rain_gardens.pdf

[28] List of deciduous trees from Dutchess County Soil & Water Conservation District https://dutchessswcd.org/seedling-sale/deciduous-trees/

[29] List of deciduous shrubs from Dutchess County Soil & Water Conservation District https://dutchessswcd.org/seedling-sale/deciduous-shrubs/

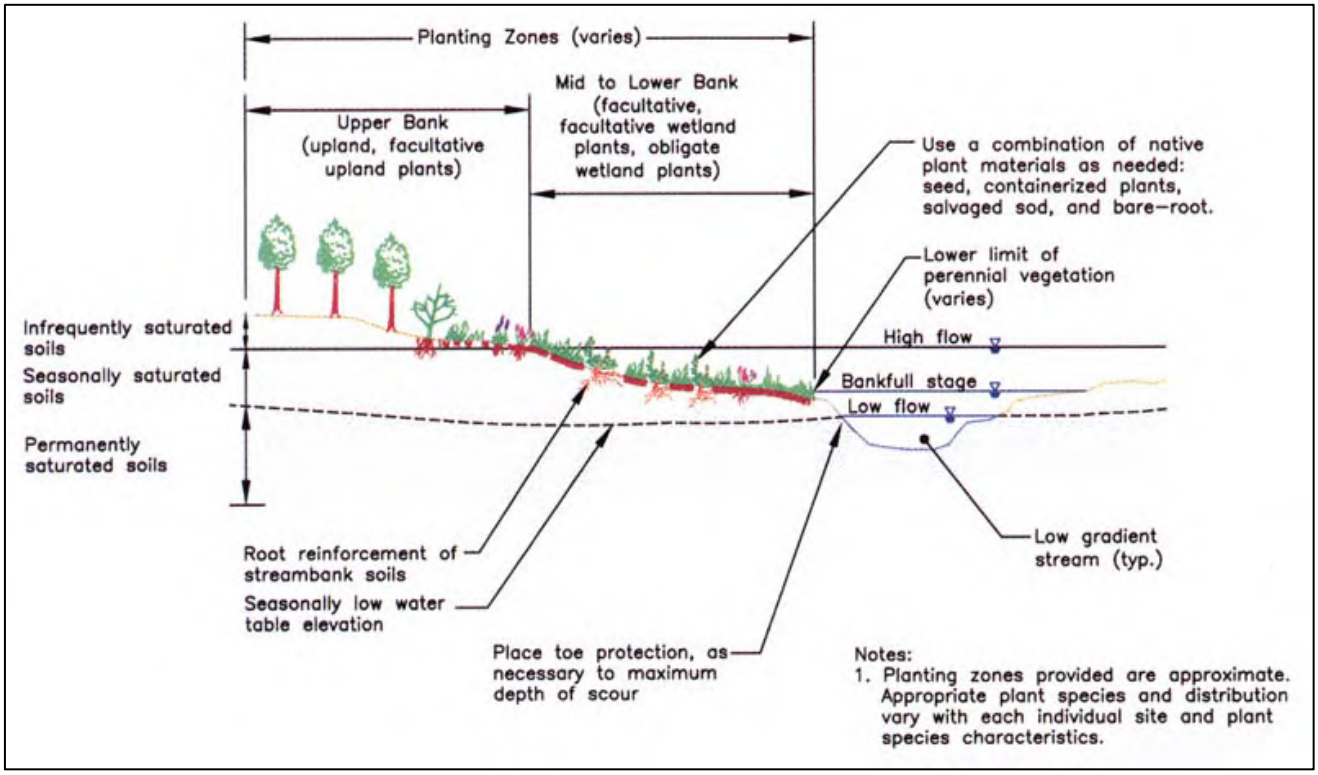

Figure 24. Vegetation cover conceptual design (Source: The National Cooperative Highway Research Program)

Cost

The upfront capital costs include the initial purchase of the native plants, the necessary supplies and equipment to prepare the project area, and the labor associated with implementing the measure (including technical expertise and physical labor). The average installation cost per acre is estimated to be $4,000.[30] Maintenance costs are higher during the first growing season while the plants become established, while the longer-term costs generally decrease over time as mature plants require less maintenance (i.e., mulching, irrigation, fertilizing). Capital costs and maintenance costs are dependent on the price of native plants, the soil quality of the project area, project area size, and labor and equipment costs.

Maintenance

For the first growing season, monthly maintenance and inspections are essential to ensure healthy vegetation growth and establishment. During this period, some plants may require irrigation to ensure survivability, and possible replanting if a severe drought or flooding event were to damage the young plants. After the first growing season, routine maintenance and inspections can occur annually. Maintenance activities could include weed and pest control, mowing, fertilizing, pruning, mulching,

[30] Noting that this value was originally derived from Oregon in 2008 ($2,800) and was adjusted to 2024 to account for inflation. State of Oregon Department of Environmental Quality, 2010. Cost Estimate to Restore Riparian Forest Buffers and Improve Stream Habitat in the Willamette Basin, Oregon. https://www.oregon.gov/deq/wq/Documents/willRipCostRev2.pdf

etc. Signage or other notice should be implemented to ensure maintenance crews do not accidentally mow or remove native plants in the riparian zone.

Challenges

Establishing a healthy riparian vegetation site (as shown in Figure 25) poses several challenges. Technical expertise (including ecologists or botanists) is required in selecting suitable native vegetation species for the given project area and determining optimal planting conditions. In addition, site and jurisdiction limitations, including other physical infrastructure and right-of-way, may impact the project site selection. Permitting may also present challenges, as some regulatory agencies may require a monitoring period to evaluate project success. An extreme weather event, including a nor'easter, flooding, etc., may disrupt the implementation or success of the riparian vegetation, especially if it occurs within the first growing season.

Figure 25. A mature vegetation buffer in Bedford County, PA (Source: Alliance for the Chesapeake Bay)

Potential Partners

The following groups operate within Dutchess County and could serve as potential partners capable of advising on nature-based solution planning and implementation:

- **Dutchess County Soil & Water Conservation District (DCSWCD)**: The DCSWCD focuses on natural resource problems and solutions. The District provides technical assistance as well as education on soil, water, and related natural resources.
- **Cornell Cooperative Extension Dutchess County (CCEDC)**: CCEDC puts knowledge to work in pursuit of economic vitality, ecological sustainability, and social well-being by bringing local experience and research-based solutions together. Extension staff and trained volunteers deliver education programs, conduct applied research, and encourage community collaborations.
- **Cary Institute of Ecosystem Studies**: The Cary Institute of Ecosystem Studies is dedicated to understanding how ecosystems work and has scientists that are global experts in the ecology of freshwater, forests, disease, and cities.
- **Hudsonia, Ltd.**: Hudsonia is a local non-profit organization dedicated to protecting the natural heritage of the region. Hudsonia works to advance effective conservation science strategies, including the use of gentle, non-toxic vegetation management methods.
- **NYS DEC Hudson River Estuary Program**: The Hudson River Estuary Program helps people enjoy, protect, and revitalize the Hudson River and its valley. The program helps manage and restore key species and via estuary grants, supports local communities in the Hudson River

Valley to take ownership of their resources while contributing to the overall health and beauty of the region.

- **Dutchess County Environmental Management Council (EMC)**: The Dutchess County EMC is the county's official citizen advisory board on matters that affect the local natural environment. The EMC was created to advise and educate the county, local governments, and the public on local environmental issues.
- **Local Conservation Advisory Councils (CACs) and Conservation Boards (CBs)**: In municipalities throughout New York, CACs and CBs serve as important advisory bodies to local communities by providing an environmental perspective on land use proposals, comprehensive plans, stewardship of natural areas, and other issues. Cornell Cooperative Extension maintains a list of CAC and related boards in Dutchess County.

Additional Resources

- Using Natural Measures to Reduce the Risk of Flooding and Erosion, New York City Department of Environmental Conservation
- Shoreline Stabilization Techniques, NYS Department of Environmental Conservation
- Plant Materials for Riparian Revegetation, Hoag, J. C. and Landis, T.D.

Project Implementation Example: Pike Branch at Wilton Road Stream Stabilization

Problem: Between Telegraph Road and Wilton Road in Alexandria, Virigina, a 1,350 linear foot stream section had a history of channel instability. Despite several retaining walls being built, the stream was still experiencing severe erosion. The instability threatened surrounding properties, sanitary sewers, stormwater infrastructure, and the stability of trees.

Project Solution: Virginia DOT and Fairfax County focused on stabilizing the stream channel to protect public infrastructure and property. The design included bank grading, reconnection of the channel to the floodplain, and planting a large vegetated riparian buffer. To date, the new corridor has held up during heavy precipitation events and has prevented erosion along the bank. Vegetation has successfully established, including sycamore and willow trees, creating habitats for wildlife and pollinators. Any trees removed during clearing were integrated into the floodplain or used to create mulch.

Co-benefits: The vegetated buffer improves wildlife habitats and enhances native vegetation. Residents also support the aesthetic improvements of the corridor. In addition, the vegetation and stream now removes nearly 4,000 pounds of phosphorous, improving water quality in the area.

Challenges: The project encountered some challenges during implementation. Road collapse due to a geotechnical slope failure during the design phase required emergency repairs and an accelerated schedule. The timeline of the project moved too quickly to allow for proper outreach and public feedback opportunities. This project also required careful communication with Fairfax County when coordinating existing and future stormwater infrastructure. Additionally, several utility pipes, poles, and overhead utility assets were relocated.

Figure 26. Condition of the stream before stream stabilization techniques (Source: Fairfax County)

Source: *Fairfax County, Virginia, 2023. Pike Branch at Wilton Road Stream Stabilization. https://www.fairfaxcounty.gov/publicworks/stormwater/pike-branch-wilton-road-stream-stabilization*

Additional Vegetation Strategies for Erosion Control and Stabilization

Vegetated Riprap

This includes adding live vegetation to rocky materials (stone, boulders, etc.) near the banks of rivers and streams to stabilize streambanks. Natural live vegetation includes plant cuttings and live stakes.

Design Guidelines:

- McCullah, J. 2001. Techniques for Vegetating Riprap Revetments. Juneau Watershed Partnership, Vol III Techniques for Vegetating Riprap Revetments.
- NCHRP. 2006. Riprap Design Criteria, Recommended Specifications, and Quality Control. Transportation Research Board of the National Academies. NCHRP Report 544 – Environmentally Sensitive Channel- and Bank-Protection Measures.
- NCHRP. 2018. Vegetated Riprap. Dirt Time.
- NCHRP. 2016. Evaluation and Assessment of Environmentally Sensitive Stream Bank Protection Measures. Report 822.
- NHWA. 2009. Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance. HEC No. 23
- ODOT. 2014. Bank Protection. Chapter 15. Hydraulics Design Manual.
- FHWA. 2009. Bridge Scour and Stream Instability Countermeasures: Experience, Selection and Design Guidance – Third Edition. Hydraulic Engineering Circular No. 23 (HEC-23). FHWA-NHI-09-111. September 2009.

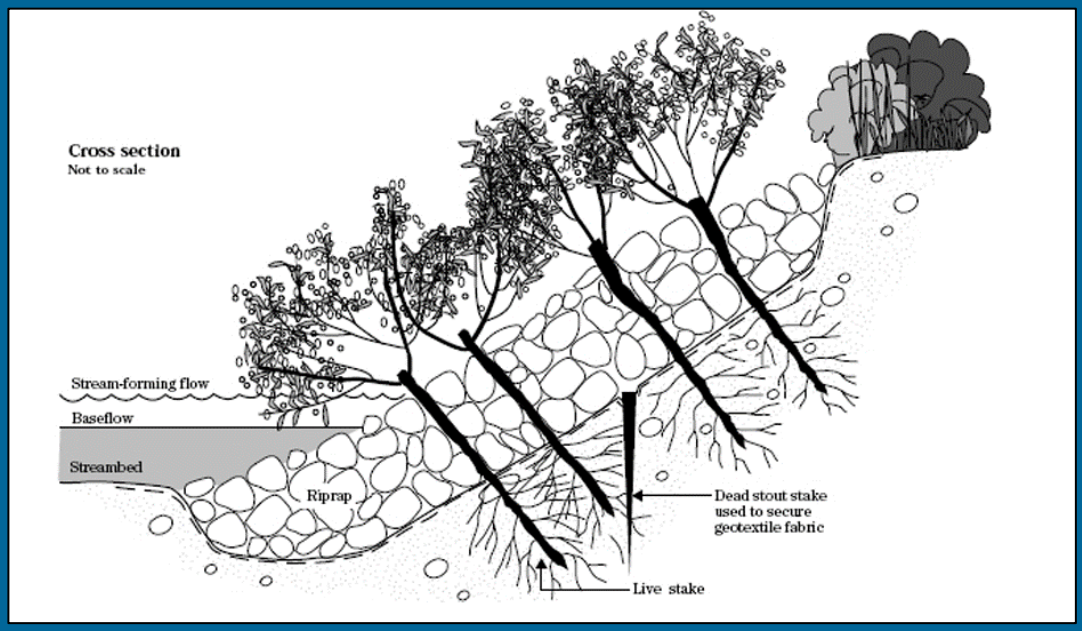

Figure 27. Example of vegetated riprap (Source: NY DEC)

Additional Vegetation Strategies for Erosion Control and Stabilization

Natural Material Revetments

Includes adding natural impact-resistant materials to a stream bank to dissipate energy, prevent slope failure and erosion, and create habitat diversity. Natural impact-resistant materials include boulders, root wads, logs, and live brush mattresses.

Design Guidelines:

- Baird, D.C., et al. 2015. Bank Stabilization Design Guidelines. Report No. SRH-2015-25. Bureau of Reclamation.
- Bentrup, G., and Hoag, J.C. 1998. The Practical Streambank Bioengineering Guide. USDA Natural Resources Conservation Service.
- FHWA. 2021. Applying Engineered Logjams and Dolosse for Streambank Stabilization.
- HPD Construction. 2021. 21 Key Revetments Advantages and Disadvantages.
- Renz, K. 2014. The Skagit River Permanent Restoration Project. North Cascades Institute.
- NCHRP. 2004. Environmentally Sensitive Channel- and Bank-Protection Measures. Technique Guidelines, Rootwad Revetments. NCHRP Report 544. Transportation Research Board.
- USDA. 2007. The Use of Large Woody Material for Habitat and Bank Protection. Technical Supplement 14J. August 2007.

Figure 28. Rootwad revetment in Clear Creek, Redding, CA (Source: VDOT)

Case Study #2: Rain Gardens/Swales to Treat Stormwater Runoff

Problem and Solution

Rainfall and extreme storm events, including nor'easters and tropical storms, are projected to increase in intensity, leading to more severe and longer flood duration.[31] More severe flooding can overwhelm the design capacity of stormwater management systems and lead to backups, causing localized flooding and damage to physical infrastructure like roads. In addition, stormwater backups can cause greater runoff of contaminants and pollutants, adversely impacting the quality of local waterways.[32]

Figure 29. Rain Garden alongside Broadway in Kingston, NY (Source: Duchess County)

Swales and rain gardens, which are depressed areas planted with native vegetation, also known as bioretention, can collect stormwater runoff, reduce runoff peak flow rates and volumes, and mitigate flooding. In addition, swales and rain gardens can treat and filter stormwater runoff pollutants, mitigating water quality risks and debris accumulation in the area. Figure 29 shows an example of a rain garden on Broadway in Kingston, NY., and Figure 30 shows an example of a rain garden in New York City.

Figure 30. Rain garden alongside a road in Queens, NY (Source: NYC Water)

Rain gardens and swales are most applicable and beneficial in locations where they can effectively capture and manage stormwater runoff. Some of these locations include parking lots, near driveways, landscape buffers next to sidewalks, public parks, playgrounds, and roadside medians.

[31] U.S. Federal Government. NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Days with more than one inch of precipitation in Dutchess County, NY. https://crt-climate-explorer.nemac.org/.
[32] EPA, 2024. Climate Adaptation and Stormwater Runoff. https://www.epa.gov/arc-x/climate-adaptation-and-stormwater-runoff

Effectiveness

Bioretention practices are most effective when designed upfront to reduce and treat storm water at pre-determined volumes. For example, Maryland has designed bioretention methods to reduce stormwater produced from a 1-inch storm event.[33] Generally, bioretention practices are most effective at reducing stormwater flow and treating pollutants from runoff associated with small to medium storms. Stormwater runoff is collected by the rain garden or swale and pools at the surface, allowing filtering and settling of suspended solids and sediments at the mulch layer before it enters the plant and soil media for infiltration and pollutant removal (see Figure 31).[34] Large storms can overwhelm the plant based drainage system and reduce the ability of the swale or rain garden to filter out pollutants, as surface soil layers can clog over time due to excessive sediment loading.[35]

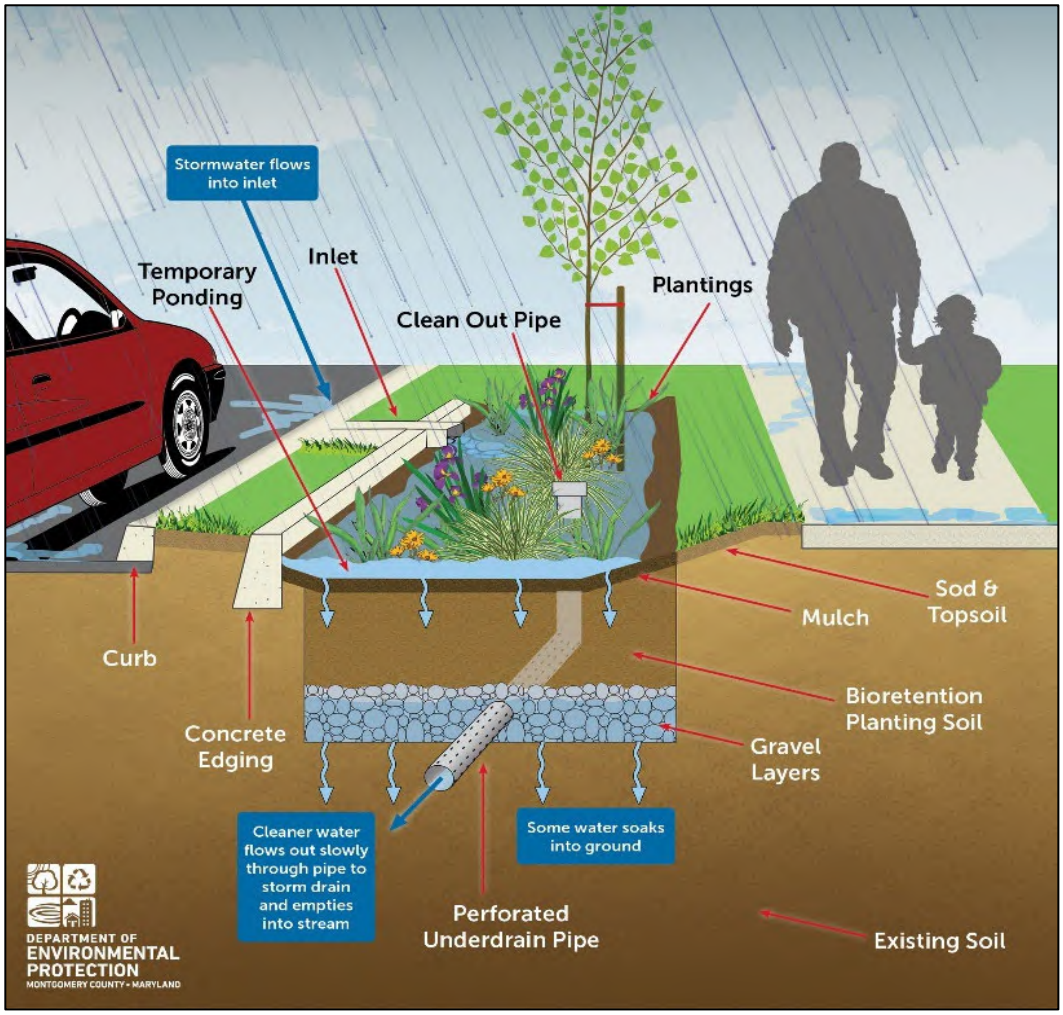

Figure 31. Illustration of the components and processes of bioretention (Source: Montgomery County of Department of Environmental Protection)

[33] EPA, 2021. Stormwater Best Management Practice-Bioretention (Rain Garden). https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf

[34] Stormwater PA, 2006. Pennsylvania Stormwater Best Management Practices Manual Chapter 6. https://www.stormwaterpa.org/assets/media/BMP_manual/07_Chapter_6.pdf

[35] EPA, 2024. Climate Adaptation and Stormwater Runoff. https://www.epa.gov/arc-x/climate-adaptation-and-stormwater-runoff

Ecological Benefits

Bioretention practices have several ecological benefits, especially when built with native vegetation. Rain gardens can effectively treat stormwater, minimizing pollution and ensuring the local groundwater is recharged. The plants absorb pollutants, the soil filters out pollutants, and then filtered water infiltrates into the groundwater. The planted native vegetation also supports pollinators, helps minimize soil erosion, encourages biodiversity, and provides a habitat for many species.

Siting and Design Considerations

Siting considerations should include the following:[36,37]

- The project area should have a small slope of about 5% to ensure sufficient elevation difference between the inflow and outflow. This ensures that stormwater runoff can flow through the filter media[38] in a specified amount of time (usually less than 24-48 hours).
- The bottom layer of the rain garden and the seasonal high groundwater table are separated by a minimum of two feet. This maintains infiltration rate and prevents possible groundwater contamination from contaminated stormwater.
- The project area should collect runoff from an area of no more than 1-2 acres.

Design considerations should include the following:[39]

- Select appropriate native vegetation[40] based on the project area's hydrologic regime. For example, native vegetation that can tolerate both wet and dry conditions should be planted towards the bottom of the rain garden, while the edges should be planted with species that can thrive in dry conditions.
- The design should allow a small amount of water, about 6-12 inches, to temporarily pond above the filter bed.

Cost

The cost of implementing bioretention practices can range from $50,000 to $200,000 per acre of impervious surface, which includes pre-construction costs (site discovery, surveying, design, planning, etc.), construction costs (capital, labor, material and overhead costs, etc.) and land costs.[41,42] Some

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[36] EPA, 2021. Stormwater Best Management Practice-Bioretention (Rain Garden). https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf

[37] Texas A&M AgriLife, 2021. Stormwater Management: Rain Gardens. https://watersmart.tamu.edu/files/2013/05/Stormwater_rain-gardens_AgriLife.pdf

[38] Filter media is a layer of soil or soil-like material (typically a mixture of sand, gravel, compost, or organic matter) that removes contaminants and pollutants from water as it passes through.

[39] EPA, 2021. Stormwater Best Management Practice-Bioretention (Rain Garden). https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf

[40] To determine native vegetation for Dutchess County, see New York Flora Atlas https://newyork.plantatlas.usf.edu/Results.aspx or Dutchess County Soil and Water Conservation District https://dutchessswcd.org/wp-content/uploads/rain_gardens.pdf

[41] EPA, 2021. Stormwater Best Management Practice-Bioretention (Rain Garden). https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf

[42] King, H., and Hagan, P., 2011. Costs of Stormwater Management Practices in Maryland Counties. https://mde.maryland.gov/programs/Water/TMDL/TMDLImplementation/Documents/King_Hagan_Stormwater%20Cost%20Report%20to%20MDE_Final%20Draft_12Oct2011.pdf

other initial costs could include excavation and hauling of existing soil, adding new soil, filter fabric, mulch, native vegetation, and perforated pipes.[43] However, bioretention ponds can be strategically placed in areas that already require landscape maintenance, such as parking lots or right of ways. The cost to maintain a rain garden compared to traditional landscaping, such as turfgrass or ornamental vegetation, may be lower, since a rain garden requires less watering and less frequent mowing.[44]

Maintenance

Rain gardens and swales require regular landscaping maintenance to ensure proper functionality, especially when they are first developed. Some maintenance activities include pruning vegetation, watering during dry periods, dead plant removal and replacement, inlet and outlet inspection for sediment accumulation, and replacement of filter media. Table 15 provides additional maintenance activities and the recommended frequency of each.

Table 15. Typical maintenance activities for bioretention practices (consult local stormwater manuals for specific considerations) (Source: EPA)

Activity	Frequency	Maintenance Notes
Prune	1-2 times per year	Vegetation often grows vigorously during rainy seasons. Prune vegetation to maintain capacity and flow rates.
Mow	2-12 times per year	Frequency depends on the location and desired aesthetic appeal which will inform whether maintenance staff should include these areas as part of more regular mowing procedures.
Water	Once every 2-3 days for first 1-2 months; sporadically after establishment	If drought conditions exist, plants may need watering after the initial year. Native and established vegetation may flourish without watering.
Fertilize	Once initially	One-time spot fertilization for first year vegetation.
Remove/replace dead plants	Once per year	Within the first year, 10% of plants can die. Survival rates improve with time. Removing dead plants also removes excess nutrients that would otherwise enter the system.
Inspect inlet	Once after first rain of the season, then monthly during rainy season	Check for sediment accumulation to ensure flow rates meet design criteria. Remove any accumulated sediment.
Inspect outlet	Once after first rain of the season, then monthly during rainy season	Check for erosion of the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	Once per month	Tasks include collecting trash, checking plant health, spot weeding, and removing invasive species.
Replace top few inches of filter media	If ponding occurs for more than 48 hours	Replace the top few inches of filter media. Sediment accumulation reduces the bioretention practice's performance and drainage ability.

[43] Texas A&M AgriLife, 2021. Stormwater Management: Rain Gardens. https://watersmart.tamu.edu/files/2013/05/Stormwater_rain-gardens_AgriLife.pdf

[44] EPA, 2021. Stormwater Best Management Practice-Bioretention (Rain Garden). https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf

Rain Garden Stewardship Program

Source: NYC DEP

To help maintain New York City's rain gardens, NYC has developed a Rain Garden Stewardship Program. The Program provides opportunities for community members to volunteer and help the Department of Conservation (DEP) manage stormwater. Rain Garden Stewards carry out necessary maintenance tasks to help keep the City's rain gardens clean and functioning properly.

The City developed a Maintenance Manual that includes equipment checklists, step-by-step guidance for carrying out specific tasks, photos of weeds, and many other resources. Similar programs can be implemented in Dutchess County to help maintain rain gardens and create opportunities for community members.

Challenges

Implementing successful bioretention practices poses several challenges. One of the main challenges is that rain gardens are not suitable for capturing and treating water from large storm events and will be limited in mitigating flood impacts. Additionally, built infrastructure and right of ways may limit the area available for bioretention practices. Technical expertise is also required to select appropriate native vegetation, and to determine the optimal planting and maintenance requirements.

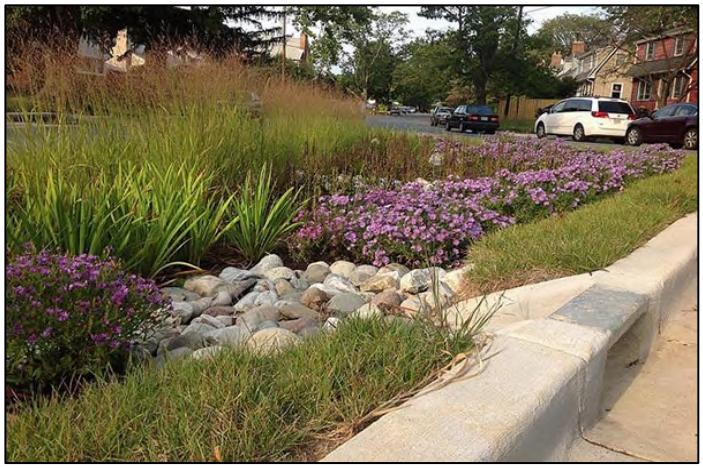

Figure 32. Bioretention example alongside a road in Maryland (Source: Montgomery County of Department of Environmental Protection)

Potential Partners

The following groups operate within Dutchess County and could serve as potential partners capable of advising on nature-based solution planning and implementation:

- **Dutchess County Soil & Water Conservation District**: The DCSWCD focuses on natural resource problems and solutions. The District provides technical assistance as well as education on soil, water, and related natural resources.
- **Cornell Cooperative Extension Dutchess County**: CCEDC puts knowledge to work in pursuit of economic vitality, ecological sustainability, and social well-being by bringing local experience and research-based solutions together. Extension staff and trained volunteers deliver education programs, conduct applied research, and encourage community collaborations.
- **Cary Institute of Ecosystem Studies**: The Cary Institute of Ecosystem Studies is dedicated to understanding how ecosystems work and has scientists that are global experts in the ecology of freshwater, forests, disease, and cities.

- **Hudsonia, Ltd.**: Hudsonia is a local non-profit organization dedicated to protecting the natural heritage of the region. Hudsonia works to advance effective conservation science strategies, including the use of gentle, non-toxic vegetation management methods.
- **NYS DEC Hudson River Estuary Program**: The Hudson River Estuary Program helps people enjoy, protect, and revitalize the Hudson River and its valley. The program helps manage and restore key species and via estuary grants, supports local communities in the Hudson River Valley to take ownership of their resources while contributing to the health and beauty of the region.
- **Dutchess County Environmental Management Council (EMC)**: The Dutchess County EMC is the county's official citizen advisory board on matters that affect the local natural environment. The EMC was created to advise and educate the county, local governments, and the public on local environmental issues.
- **Local CACs and CBs**: In municipalities throughout New York, CACs and CBs serve as important advisory bodies to local communities by providing an environmental perspective on land use proposals, comprehensive plans, stewardship of natural areas, and other issues. Cornell Cooperative Extension maintains a list of CAC and related boards in Dutchess County.

Additional Resources

- Local documents on rain gardens
    - Rain Gardens: Gardening with Water Quality in Mind, Dutchess County Soil and Water Conservation District
    - Rain Garden, Town of LaGrange
    - Rain Gardens & Rain Barrels, East Fishkill
    - Rain Gardens, Lower Hudson Coalition of Conservation Districts Rain Gardens
    - From Flooding to Drought and Back Again, Dutchess County
    - Stormwater Management Design Manual, New York State Department of Environmental Conservation:
- Chesapeake Stormwater Network
- Woody Shrubs for Stormwater Retention Practices, Cornell University
- A Community Guide Growing Greener, Massachusetts Watershed Coalition
- Ghirardi Family WaterSmart Park Maintenance Guide, Texas Commission on Environmental Quality and the U.S. EPA

Project Implementation Example: Broadway Streetscape Project in Kingston, NY.

Project Goal: Incorporate green infrastructure including bioswales and trees in the sidewalks to redirect stormwater away from the drainage system.

Project Details: To help achieve Kingston's goal, 49 bioswales were installed from East St. James Street to Grand Street that help divert stormwater from flooding into the Rondout Creek and reduce the volume of stormwater that goes to the city's water treatment plant, improving the city's water quality. The trees, shrubs, and grasses that occupy the bioswales not only allow stormwater to slowly infiltrate the ground rather than enter the stormwater system but also add greenery to the community and provide ecological benefits to pollinators and other native species. In addition, the City installed two interpretive panels that explain the function of the bioswale.

Lessons Learned: Incorporating green infrastructure into the streetscape project enabled the City to leverage funds from NYSDEC's Climate Smart Communities Program, NYSERDA's Cleaner, Greener Communities Program, and NYSEFC's Green Infrastructure Grant. However, the bioswales added significant upfront and ongoing costs to the project. Maintenance has been a particular challenge. The curb openings tend to clog with debris and trash, so additional staff were needed to remove trash, pull weeds, and maintain mulch. Multiple small bioswales are more challenging to maintain than one central pond, but that is typically not an option along an urban street. The City also found that the pre-cast concrete curbs moved over time; they had to place drilled anchors to keep them in place. Cast in place curbs would have worked better. However, City staff have received numerous compliments about the greenery along the street.

Before **After**

Figure 33. Bioswale construction in Kingston, NY (Source: Kingston, NY and DCTC)

Source: *The City of Kingston, NY., 2020. Broadway Streetscape Project. https://kingston-ny.gov/broadwaystreetscapeproject*

Project Implementation Example: New York City Green Infrastructure Program

Problem: New York City has faced significant challenges related to stormwater management, especially during heavy rain events. With over 70% of NYC's land mass covered by impervious surfaces such as roads and buildings, stormwater runoff overwhelms the sewer system and leads to flooding and pollution of local waterways. These issues have been exacerbated by climate change, which brings more frequent and intense rainfall events.

Project Solution: To address these challenges, the Department of Environmental Protection (DEP), along with community groups and local agencies, launched a major expansion of the city's Green Infrastructure Program, including the construction of 9,000 curbside rain gardens across Brooklyn, the Bronx, and Queens (Figure 34). Each rain garden can absorb 2,500 gallons of stormwater during a single storm event, reducing flooding that can impact roadways, and reducing the volume of stormwater that enters the city's sewer system. Stormwater runoff is designed to be attenuated in less than 48 hours and rain gardens are inspected weekly by the city.

Co-benefits: The curbside rain gardens provide numerous benefits to New Yorkers and the environment. The increased vegetation, including tree canopy, help improve air quality, provide shade during hot summer months, and add natural beauty to the neighborhoods. This particularly benefits communities with historically few natural amenities.

Figure 34. Rain garden in New York City (Source: The Bond Buyer)

Source: *City of New York, 2019. City Doubles Size of Largest Green Infrastructure Program in Nation, Making NYC More Resilient to Global Warming. https://www.nyc.gov/office-of-the-mayor/news/406-19/city-doubles-size-largest-green-infrastructure-program-nation-making-nyc-more-resilient-to*

Case Study #3: Shade Trees for Heat

Problem and Solution

Extreme heat events are projected to increase in frequency, duration, and severity across New York State.[45] Extreme heat exposure can increase the risk of heat stress and heat related illnesses. This is especially concerning for people walking and bicycling and for transit riders waiting outdoors in the heat.

Heat islands are urbanized areas that experience higher temperatures than surrounding rural areas due to the concentration of buildings, roads, and other infrastructure that absorb and retain heat from the sun.[46] As shown in Figure 35, higher-density areas like the City of Poughkeepsie, City of Beacon, and the Fishkill area generally see higher summer land surface temperatures than forested and rural areas. These places often lack sufficient greenery or natural cooling spaces, resulting in urban heat islands that can exacerbate the effects of extreme heat and heat waves.

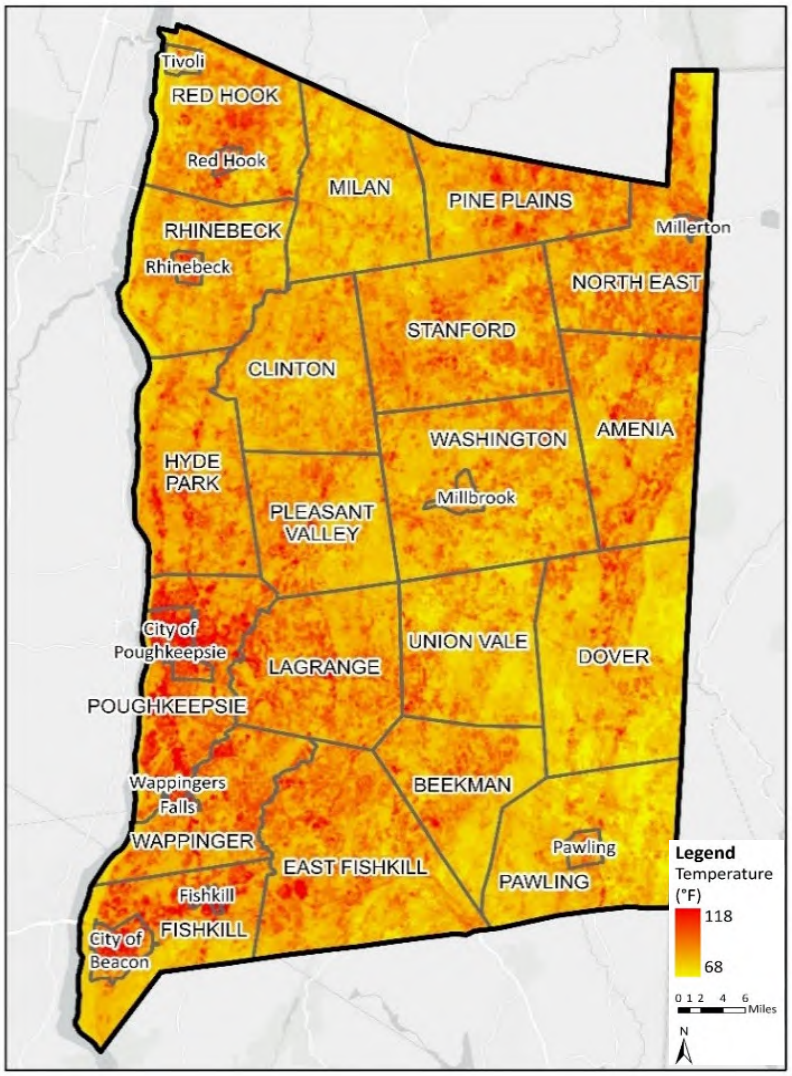

Figure 35. Median summer land surface temperatures in Dutchess County from 2018 to 2022 (Source: DCTC)

To mitigate heat impacts, tress can be planted in strategic locations along sidewalks, bus stops, train stations, rail trails, parking lots, and near buildings to increase shade (Figure 36).[47] Research shows that air temperatures are 1.4°F cooler under trees and 2.9°F cooler in urban forests than in areas lacking tree cover.[48]

[45] New York State. Adapting to Extreme Heat in New York State. https://dec.ny.gov/environmental-protection/climate-change/effects-impacts/extreme-heat

[46] EPA, 2024. Heat Island Effect. https://www.epa.gov/heatislands

[47] EPA, 2023. Using Trees and Vegetation to Reduce Heat Islands. https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands#Anch2

[48] Knight, T., et al., 2021. How effective is 'greening' of urban areas in reducing human exposure ground-level ozone concentrations, UV exposure and the 'urban heat island effect'? https://environmentalevidencejournal.biomedcentral.com/articles/10.1186/s13750-021-00226-y#citeas

Effectiveness

Trees can help lower the air temperature by providing shade and evapotranspiration. Tree leaves and branches reduce the amount of solar radiation that reaches the ground. For example, in the summertime, only about 10-30% of the sun's energy is transmitted through the canopy and reaches the area under a tree. The remainder of the sun's energy is absorbed by the leaves, and some is reflected back into the atmosphere.[49]

Figure 36. Cooling parking lots (Source: Local Ecologist)

In addition, trees absorb water through their roots and emit vapor through their leaves, cooling the surrounding air (Figure 37). Various studies have found that suburban areas with mature trees are 4-6°F cooler than new suburbs without trees.[50]

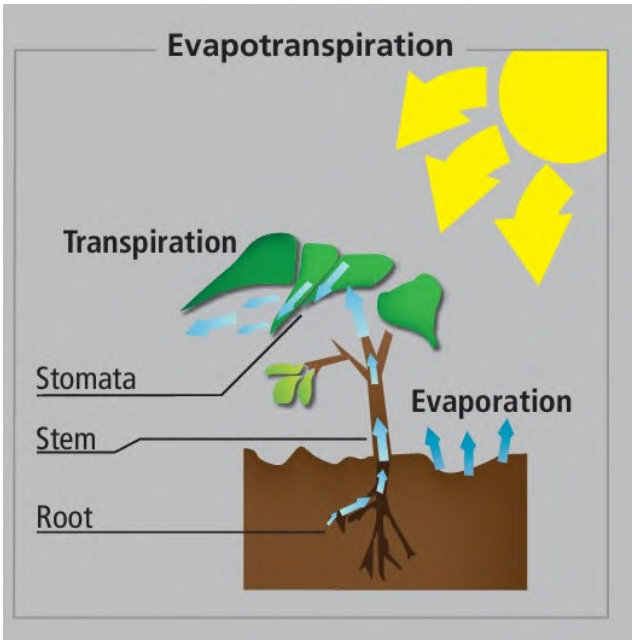

Figure 37. Evapotranspiration process (Source: EPA)

Ecological Benefits

Shade trees provide multiple ecological benefits, including removing air pollutants, storing and sequestering carbon, enhancing water quality, and increasing habitat and biodiversity. Trees are also able to absorb storm water during precipitation events and help reduce subsequent runoff and flooding.[51] Trees also improve streetscape aesthetics and can help calm traffic speeds. Figure 38 summarizes some of the many benefits trees provide to communities and the environment.

[49] Ibid.
[50] EPA, 2023. Using Trees and Vegetation to Reduce Heat Islands. https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands#Anch2
[51] Ibid.

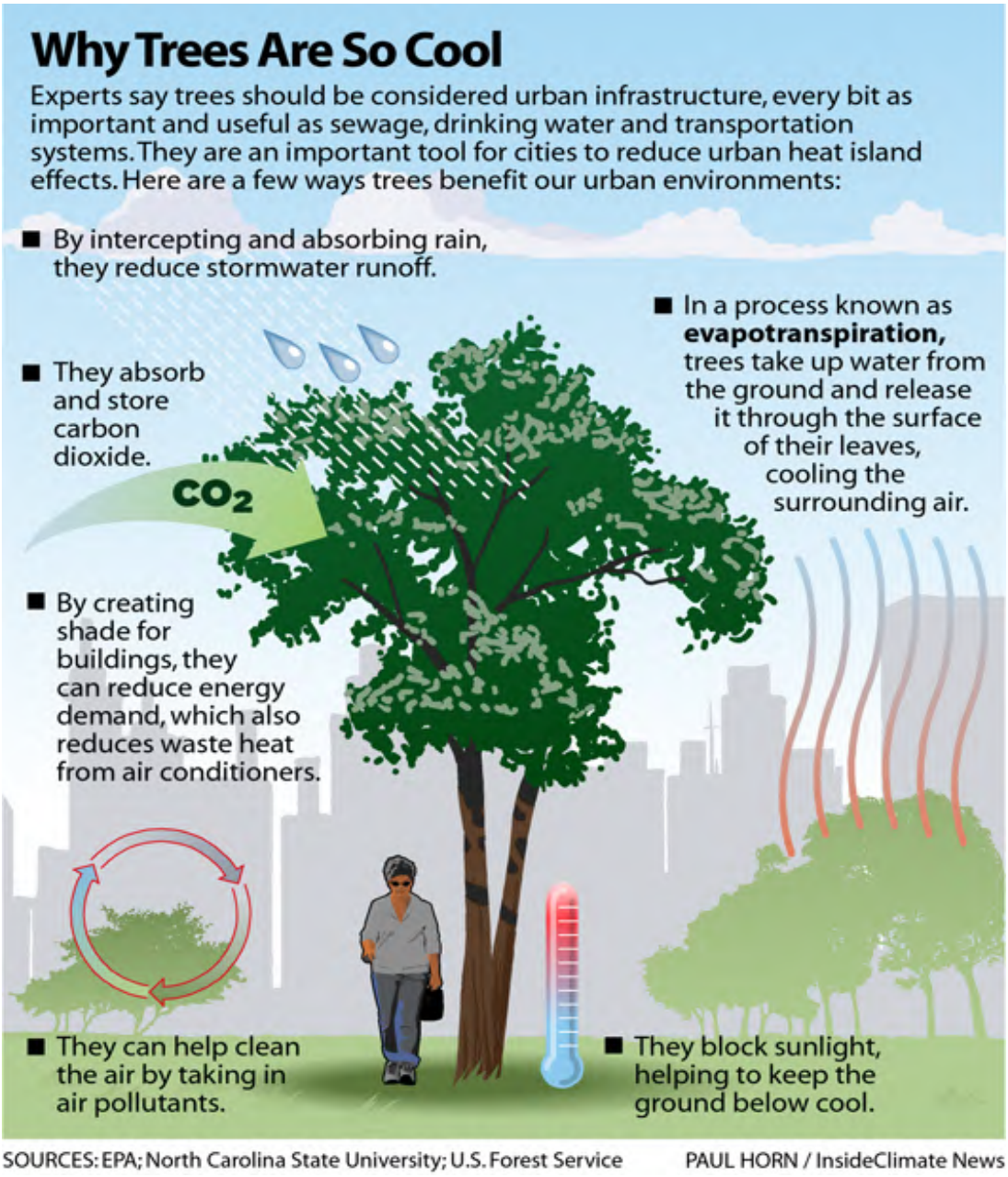

Figure 38. Summary of ecological benefits of trees (Source: Inside Climate News)

Siting and Design Considerations

Siting considerations should include the following:

- Ensure the tree will not block or interfere with any signs, streetlights, or overhead utility wires (at planting or maturity). In addition, mark out any underground utilities to avoid planting over them.[52]

[52] Dozier, 2015. Getting to the Root of the Issue: Ensuring Sidewalks and Steet Tress Can Successfully Coexist. https://www.dutchessny.gov/Departments/Planning/Docs/MarchApril2015-FINAL-printerfriendly.pdf

- Ensure there is adequate space for roots to grow adjacent to the street or sidewalk. Generally, trees that grow up to 30 feet should be planted at least 3-4 feet from sidewalks. Trees that grow 30-50 feet tall should be planted 5-6 feet from sidewalks, and trees that grow more than 50 feet should be planted at least 8 feet from sidewalks.[53]
- Plant street trees near bus stops, train stations, sidewalks, and trails to provide shade for travelers. Coordinate with benches or other seating where feasible. Consider planting street trees between the curb and sidewalk to maximize shade potential to both the sidewalk and road areas, as pictured in Figure 39.[54]
- Understand the characteristics of the soil and underground environment to ensure it is suitable for the selected tree species. Characteristics to consider are soil pH, soil texture, drainage, and if the soil is densely compacted.[55]

Figure 39. Trees planted between the sidewalk and curb (Source: Treehugger)

Design considerations should include the following:

- Select appropriate tree species that are likely to survive with minimal maintenance given the area's climate (future climate projections for the area can also be considered to inform appropriate tree species[56]). Key factors to consider include the tree's projected height and canopy spread (to reduce contact with overhead power lines), the size and growth of its roots, the tree's sun, soil, and water requirements, and if the tree produces any berries or flowers.[57] Refer to the following documents to select a tree species suitable for Dutchess County:
  - Page 15 of NYSDOT's Landscape Improvements specifications
  - Common tree plantings from the Village of Rhinebeck Tree Commission
  - Tree Selection Booklet from the Village of Rhinebeck Tree Commission
  - Cornell University's Woody Plants Database – Recommended Urban Trees
- If planting along a sidewalk, consider the following measures to protect the tree and root system and limit sidewalk damage:[58]

[53] Larum, 2023. Planting Space Along Sidewalks: Tips for Growing Trees Around Sidewalks. https://www.gardeningknowhow.com/ornamental/trees/tgen/planting-trees-along-sidewalks.htm

[54] Dozier, 2015. Getting to the Root of the Issue: Ensuring Sidewalks and Steet Tress Can Successfully Coexist. https://www.dutchessny.gov/Departments/Planning/Docs/MarchApril2015-FINAL-printerfriendly.pdf

[55] Polomski, R., et al., 2020. Site Considerations When Selecting Plants. https://hgic.clemson.edu/factsheet/choosing-a-planting-location/

[56] The Climate Change Atlas helps determine the current distribution of tree habitats in the eastern United states and how these habitat distributions might change in response to different climate scenarios.

[57] EPA, 2008. Trees and Vegetation in Reducing Urban Heat Islands: Compendium of Strategies. https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_2.pdf

[58] Dozier, 2015. Getting to the Root of the Issue: Ensuring Sidewalks and Steet Tress Can Successfully Coexist. https://www.dutchessny.gov/Departments/Planning/Docs/MarchApril2015-FINAL-printerfriendly.pdf

    - Structural soil - a mix of crushed gravel and soil that provides space for tree roots and sufficient support for overlying pavement.
    - Gravel sub-base - a layer of washed gravel under the sidewalk to prevent roots from growing up and lifting the sidewalk.
    - Root barriers - plastic panels installed in the soil along the sidewalk or around the tree to guide roots downward and away from sidewalks.
- Ensure water can infiltrate to the roots by planting a landscaped buffer, groundcover, or using permeable pavers (Figure 40).[59]
- In areas with heavy pedestrian traffic, install tree gates or guards to protect trees from physical damage and soil compaction caused by people walking on tree pits.[60]
- Where possible, plant trees at regular intervals of 20-40 feet along sidewalks or streets.[61]

Figure 40. Example of groundcover planted around a tree to allow water infiltration (Source: DCTC)

Cost

The main costs for shade trees include the tree and materials, initial planting activities, and watering and other ongoing maintenance activities, such as pruning and pest and disease control. A research study conducted in 2005 assessed tree planting costs in five U.S. cities.[62] The study found the annual cost of planting and maintaining trees totaled $13-$65 per tree ($21-$105 in 2024 dollars). Pruning was often the most expensive cost, accounting for about 25-40% of total annual costs. The study also determined that the cities accrued a benefit ranging from $1.40-$3.00 ($2.25-$4.80 in 2024 dollars) for every dollar invested in tree planting and maintenance.

Maintenance

Regular maintenance ensures good tree health and maximizes shade benefits. The main maintenance activities include watering, pruning, and mulching. It is recommended to develop a maintenance agreement that specifies which parties are responsible for regular inspections, watering, pruning, etc. to ensure that trees are properly cared for.[63]

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[59] Dozier, 2015. Getting to the Root of the Issue: Ensuring Sidewalks and Steet Tress Can Successfully Coexist. https://www.dutchessny.gov/Departments/Planning/Docs/MarchApril2015-FINAL-printerfriendly.pdf

[60] Martineau, K., 2018. So Much Depends on a Tree Guard. https://news.climate.columbia.edu/2018/01/23/tree-guard-stormwater-runoff/

[61] EPA, 2008. Trees and Vegetation in Reducing Urban Heat Islands: Compendium of Strategies. https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_2.pdf

[62] McPherson, E.G., et al., 2005. Municipal forest benefits and costs in five US cities. https://www.fs.usda.gov/psw/publications/mcpherson/psw_2005_mcpherson003.pdf

[63] Dozier, 2015. Getting to the Root of the Issue: Ensuring Sidewalks and Steet Tress Can Successfully Coexist. https://www.dutchessny.gov/Departments/Planning/Docs/MarchApril2015-FINAL-printerfriendly.pdf

Watering is key to survival, especially in the first three years of a tree being planted.[64] NYSDOT waters once a week between April 1st and November 15th in the absence of 1 inch of rainfall within five consecutive days, and twice a week during July and August.[65]

Challenges

There are a couple of challenges in planting and maintaining successful shade trees. Selecting the appropriate site and tree species is important to maximize the benefits of shade trees, including understanding growth patterns of certain trees and local climate and soil conditions. Choosing trees and sites that are well suited for each other ensures that trees can thrive and provide effective shade in the long term.

Figure 41. Sidewalk being lifted due to tree root interference (Source: DCTC)

In addition, tree-sidewalk conflicts can pose significant challenges. Tree-sidewalk conflicts occur when trees are planted along a sidewalk and the roots encounter dense soil or pavement.[66] When this happens, the roots either change direction, stop growing, or adapt by remaining close to the surface, causing them to lift the sidewalk (Figure 41). See the Design Considerations above for methods to mitigate tree-sidewalk conflicts.

Potential Partners

The following groups operate within Dutchess County and could serve as potential partners to advise on shade tree planning and implementation:

- **Dutchess County Soil & Water Conservation District (DCSWCD)**: The DCSWCD focuses on natural resource problems and solutions. They provide technical assistance, including tree risk assessments, as well as education on soil, water, and related natural resources. They also hold an annual seedling sale, and have a bare root planting guide on their website.
- **Cornell Cooperative Extension Dutchess County (CCEDC)**: CCEDC puts knowledge to work in pursuit of economic vitality, ecological sustainability, and social well-being by bringing local experience and research-based solutions together. They have a Master Gardener training program and provide technical assistance on tree planting, horticulture, soils, and other related topics.
- **Local Conservation Advisory Committees (CACs) and Conservation Advisory Boards (CABs)**: CACs and CABs serve as important advisory bodies to municipalities by providing an environmental perspective on land use proposals, comprehensive plans, stewardship of

[64] Southern Group of State Foresters, 2024. Urban Tree Care. https://southernforests.org/urban-tree-care/
[65] NYSDOT, 2022. Landscape Improvements Contract. https://www.dot.ny.gov/portal/pls/portal/MEXIS_APP.BC_CONST_NOTICE_ADMIN.VIEWFILE?p_file_id=39723&p_is_digital=Y
[66] Dozier, 2015. Getting to the Root of the Issue: Ensuring Sidewalks and Steet Tress Can Successfully Coexist. https://www.dutchessny.gov/Departments/Planning/Docs/MarchApril2015-FINAL-printerfriendly.pdf

natural areas, and other issues. Cornell Cooperative Extension maintains a list of these Boards in Dutchess County.

- **Local Tree Commissions**: Several municipalities in the county have a Tree Commission (or Shade Tree Commission), which works to promote and protect trees on public and private land.

Additional Resources

- Rhinebeck Village Tree Commission, Village of Rhinebeck, NY.
- The Cornell Guide for Planting and Maintaining Trees and Shrubs, Cornell University
- Landscape Improvements Contract, New York State Department of Transportation
- TreeKeeper street tree map, Village of Rhinebeck, NY.

Project Implementation Example: Street Tree Planting in Rhinebeck, NY.

Project Goal: To remove dead and damaged trees and replace them with a variety of trees that are better suited to increasing temperatures and that will enhance the village by providing shade, improving species diversity, and slowing traffic.

Project Details: The tree planting project was funded by the Frost Memorial Fund and organized by the Village of Rhinebeck Tree Commission in 2022. A total of 15 hazardous trees were removed, mostly Norway Maples that had suffered from extreme heat. The Tree Commission planted a variety of 29 sustainable trees, including Sugar Tyme, Red Oak, Metasequoia, Bloodgood London Plane, Gleditsia 'Shademaster' Honeylocust, and others. When determining appropriate tree species, the project team considered overhead electric lines and ensured shorter tree species were planted in areas of lower clearance. In addition, the project team considered the total available space for growth and homeowner preferences. Volunteers routinely watered the trees for the first year and pruned the trees from the ground. The planted trees will be more resilient to warming temperatures, while increasing shade, providing habitat for birds and pollinators, sequestering stormwater and carbon, increasing beauty, and helping slow traffic.

In addition, twice a year, the Tree Commission offers to plant trees in the right-of-way at no cost to the property owner. Pruning is provided by trained volunteers for the first five years.

Figure 42. Tree planting in the Village of Rhinebeck (Source: Village of Rhinebeck Tree Commission)

Source: *Village of Rhinebeck Tree Planting Commission*

Appendix E: Equity Dataset Comparison

The DCTC is dedicated to advancing equitable resilience projects and initiatives in the county. To do so, the DCTC incorporated equity considerations in the vulnerability assessment scoring approach to ensure that assets in underserved communities are prioritized for resilience investments (see the Climate Vulnerability Assessment section for details). Additionally, the DCTC included equity as one of the key considerations for the Adaptation Toolbox to ensure that projects consider equity implications in their development and design (see the Adaptation Toolbox section for details).

There are many available equity datasets at the federal, state, and local levels that can be used to understand which communities may be disproportionately affected by climate change impacts. The DCTC chose to use its own Transportation Equity Index as this dataset was developed specifically for the county and has been locally vetted. It is the preferred local dataset for understanding how to address transportation inequalities and was therefore the most appropriate dataset to use to prioritize climate change vulnerabilities.

However, if applying for PROTECT discretionary grants, the DCTC will also need to consider federal equity datasets. The merit criteria for PROTECT discretionary grants include Justice40: a federal initiative to provide disadvantaged communities with 40% of the overall benefits from certain federal investments, including the PROTECT discretionary grants.[67] PROTECT discretionary grant applicants are required to demonstrate, to the extent possible, that the specific project outcomes result in 40% of the benefits going towards Justice40 communities (disadvantaged communities).[68] These communities are identified using the federal Climate and Economic Justice Screening Tool (CEJST). Projects that do not meet these criteria are still eligible projects with a meaningful chance of being funded; however, they will not receive merit points in the evaluation process for benefiting disadvantaged communities. It is important to note that the specific project does not necessarily need to be located within a disadvantaged community to provide benefits to that community. For example, a project to reduce flooding and improve water quality through stormwater system improvements and stream restoration could be located upstream of the communities it would benefit.

To support infrastructure owners and managers in the county who are interested in applying for PROTECT discretionary grants, this appendix compares CEJST to DCTC's Transportation Equity Index and identifies which priority resilience project ideas are located within disadvantaged communities based on each dataset. Project sponsors are encouraged to explore how their projects can benefit neighboring disadvantaged communities when applying for PROTECT discretionary grants.

Dataset Comparison

Table 16 compares the DCTC Transportation Equity Index to CEJST, with a focus on the data inputs and the outputs of each tool. Whereas the DCTC Transportation Equity Index is focused primarily on transportation equity issues, CEJST takes a broader look at equity by including other considerations, such as agricultural risks, housing disparity, and pollution. Another key difference between the two

[67] The White House. 2022. Justice40. https://www.whitehouse.gov/environmentaljustice/justice40/

[68] FHWA. 2022. Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Discretionary Grant Program. https://www.fhwa.dot.gov/environment/protect/discretionary/

tools is that DCTC's tool assesses disparity within the county by comparing each census tract to the county average, while CEJST compares census tracts across the U.S. A census tract may not be considered disadvantaged from a national perspective but could still be disproportionately at-risk within Dutchess County.

Table 16. Equity dataset comparison

	DCTC Transportation Equity Index[69]	CEJST[70]
Geographic Scope	Dutchess County	All 50 states, the District of Columbia, and the U.S. territories
Data Indicators Used	Percentage of census tract population belonging to the following focus populations: • Black • Asian • Hispanic • Youth (under 18) • Older adults (65 and over) • Disabled • Low-income • Foreign-born • Limited English Proficiency These groups were chosen based on their inclusion in Civil Rights Law, federal Environmental Justice guidance, and best practices from other MPOs. They are meant to represent those that have historically been marginalized by land use and transportation decision-making.	34 datasets are used as indicators of burden. The burdens are organized into the following categories: • Climate change (expected agricultural, building, and population loss rates; projected flood and wildfire risk) • Energy (energy cost, $PM_{2.5}$ in the air) • Health (asthma, diabetes, heart disease, low life expectancy) • Housing (historic underinvestment, housing cost, lack of green space, lack of indoor plumbing, lead paint) • Legacy pollution (abandoned mine land, proximity to hazardous waste facilities) • Transportation (diesel particulate matter exposure, transportation barriers, traffic proximity and volume) • Water and wastewater (underground storage tanks and releases, wastewater discharge) • Workforce development (linguistic isolation, poverty, unemployment, high school diploma) Low-income data is also used with each category of burden to identify disadvantaged communities.
Output	**Equity Index (score of 0-16):** Represents the census tract's percentage compared to the county average. Communities with high	**Disadvantaged community designation:** A community is highlighted as disadvantaged if it is:

[69] DCTC. 2023. Equity Index: Methodology. https://movingdutchessforward.com/wp-content/uploads/2023/05/Goal_2_Equity_Analysis_Methodology_2023_Updated_5.23.pdf.
[70] Council on Environmental Quality. CEJEST Methodology. https://screeningtool.geoplatform.gov/en/methodology.

	DCTC Transportation Equity Index[69]	CEJST[70]
	equity scores tend to be more significantly impacted by the loss of a transportation option because they often have limited or no access to alternative modes of transportation.	1. On land within the boundaries of Federally Recognized Tribes; 2. In a census tract that is (a) at or above the threshold for one or more environmental, climate, or other burdens (see above), and (2) at or above the threshold for an associated socioeconomic burden; or 3. In a census tract that is completely surrounded by disadvantaged communities and is at or above the 50th percentile for low-income.

Priority Resilience Project Ideas

Table 17 lists the priority resilience project ideas (see Priority Resilience Project Ideas for more information) and the DCTC Transportation Equity Index score and the CEJST disadvantaged community designation for the project location. For the reasons explained above, more of the county is considered within a transportation equity area under DCTC's Transportation Equity Index than under the national CEJST scoring approach.

Table 17. Comparison of DCTC Transportation Equity Index and CEJST for the priority resilience project ideas

Priority Resilience Project Ideas			DCTC Transportation Equity Index Score	CEJST Disadvantaged Community
Agency	Asset(s)	Location		
NYSDOT	Roads, Culverts	NY Route 987G (Taconic State Parkway)/Todd Hill Wetland Town of LaGrange RMs: 987G 8203 1115-1120	1	No
NYSDOT	Roads, Bridges, Culverts	NY Route 987G (Taconic State Parkway) Town of East Fishkill RMs: 987G 8203 1097-1099	2	No
NYSDOT	Culverts, Roads	NY Route 82 Towns of LaGrange & East Fishkill RMs: 82 8201 1078-1086	3	No
NYSDOT	Roads	NY Route 82 Town of East Fishkill RMs: 82 8201 1074-1077	3	No
NYSDOT	Roads, Bridges, Culverts	I-84 Town of East Fishkill RMs: 84I 8202 1080-1090	2	No
NYSDOT	Bridges, Roads	NY Route 52 (Gayhead Pond Inlet) Town of East Fishkill RMs: 52 8204 2109-2110	1	No

Priority Resilience Project Ideas			DCTC Transportation	CEJST Disadvantaged
Agency	Asset(s)	Location	Equity Index Score	Community
NYSDOT	Roads	Route 22 Town of Dover RMs: 22 8204 1070-1074	6	No
NYSDOT	Culverts	Route 55 Town of LaGrange RMs: 55 8203 2071-2078	1	No
NYSDOT	Culverts	Route 82 Town of LaGrange RMs: 82 8201 1116-1118	1	No
DPW	Bridges	Bridge B-15, BIN 3342720; CR 7 over Whaley Lake Stream. Town of Beekman	2	No
DPW	Bridges	Bridge B-17, BIN 3342730; CR 7 over Whaley Lake Stream. Town of Beekman	2	No
DPW	Bridges	Bridge C-30, BIN 3342870; CR 13 over Wappinger Creek. Town of Clinton	2	No
DPW	Bridges	Bridge C-9, BIN 3342790; Maple Lane over Locust Creek. Town of Clinton	2	No
DPW	Bridges	Bridge D-27, BIN 3342930; Dover Furnace Road over Mill River. Town of Dover	8	No
DPW	Bridges	Bridge L-15, BIN 3343240; Stringham Road over Sprout Creek. Town of Lagrange	2	No
DPW	Bridges	Bridge L-2, BIN 3343200; Gidley Road over Sprout Creek. Town of Lagrange	1	No
DPW	Bridges	Bridge L-33, BIN 3370340; East Noxon Road over Jackson Creek. Town of Lagrange	1	No
DPW	Bridges	Bridge PP-6, BIN 3343520; Carpenter Hill Road over Shekomeko Creek. Town of Pine Plains	5	No
DPW	Bridges	Bridge R-4, BIN 3343760; Miller Road over Landsman Kill. Town of Rhinebeck	3	No
DPW	Bridges	Bridge RH-19, BIN 3343740; Echo Valley Road over Saw Kill. Town of Red Hook	3	No
DPW	Bridges	Bridge U-29, BIN 3343940; CR 21 over Fishkill Creek. Town of Union Vale	3	No
DPW	Bridges	Bridge W-27, BIN 3344090; Fowler Road over East Branch Wappinger Creek. Town of Washington	1	No
DPW	Bridges	Bridge W-5X, BIN 3344030; CR 86 over Deer Hill Creek. Town of Amenia/Washington	4	Yes
DPW	Bridges	Bridge S-12, BIN 3343810; Homan Road over Cold Spring Creek. Town of Stanford	2	No

Priority Resilience Project Ideas			DCTC Transportation Equity Index Score	CEJST Disadvantaged Community
Agency	Asset(s)	Location		
DPW	Bridges	Bridge S-13, BIN 3365140; Cold Spring Road over Wappinger Creek. Town of Stanford	2	No
DPW	Bridges	Bridge S-36, BIN 3343840; Depot Lane over Wappinger Creek. Town of Stanford	2	No
DPW	Bridges	Bridge W-25, BIN 3344080; Canoe Hill Road over East Branch Wappinger Creek. Town of Washington	1	No
DPW	Bridges	Bridge B-4, BIN 3342690; Dorn Road over Fishkill Creek. Town of Beekman	1	No

The priority project ideas listed above may change as additional ideas are identified or proposed by agencies during the implementation of Resilient Ways Forward. As more resilience project ideas are added, DCTC will reassess the benefits and impacts of possible PROTECT projects on vulnerable populations, whether they are identified through the DCTC Transportation Equity Index assessment or the Justice40 CEJST.

Appendix F: Potential Funding Sources

This appendix provides a compilation of funding opportunities from federal and state sources that could be pursued for implementation of transportation projects focused on climate adaptation and resilience. Though this summary does not include sources like the federal Surface Transportation Block Grant Program or Off System Bridge Program, resilience improvements can and should be addressed when using such funding.

Federal Funding Sources

PROTECT Discretionary Grant Program

Description: The Bipartisan Infrastructure Law established the PROTECT Discretionary Grant Program to help make surface transportation more resilient to natural hazards, including climate change, sea level rise, flooding, extreme weather events, and other natural disasters through support of planning activities, resilience improvements, community resilience and evacuation routes, and at-risk costal infrastructure. Units of local government, special purpose districts or public authorities with a transportation function, among several other entities, are eligible to apply.

Project Eligibility: The PROTECT Discretionary Grant Program provides funding for:

1. **Planning Grants** to include resilience planning, predesign, design, or the development of data tools to simulate transportation disruption scenarios, including vulnerability assessments.
2. **Resilience Improvement Grants** to improve the ability of an existing surface transportation asset to withstand one or more elements of a weather event or natural disaster, or to increase the resilience from the impacts of changing conditions.
3. **Community Resilience and Evacuation Route Grants** to strengthen and protect evacuation routes that are essential for providing and supporting evacuations caused by emergency events, including resilience improvements if they will improve evacuation routes.
4. **At-Risk Coastal Infrastructure Grants** to strengthen, stabilize, harden, elevate, relocate, or otherwise enhance the resilience of highway and non-rail infrastructure (i.e., bridges, roads, pedestrian walkways, and bicycle lanes, culverts, and tide gates) to protect highways that are subject to or at future risks of coastal flooding, coastal erosion, wave action, storm surge, or sea level rise.

Source: https://www.fhwa.dot.gov/environment/protect/

PROTECT Formula Program

Description: The U.S. Department of Transportation's (U.S. DOT) Federal Highway Administration (FHWA) has announced new guidance and formula funding to help states and communities prepare for extreme weather events related to climate change. New York State DOT has been designated $293,145,000 over 5 years to support state-wide efforts to increase the resilience of communities, transportation assets, and evacuation routes, and to address high-risk highway infrastructure.

Project Eligibility: A state may use its PROTECT Formula Program funds for:

1. **Planning Activities** limited to developing a Resilience Improvement Plan
2. **Resilience Improvements** to improve the ability of an existing surface transportation asset to withstand one or more elements of weather event/natural disaster, or to increase the resilience from the impacts of changing conditions
3. **Community Resilience and Evacuation Route** activities that strengthen and protect evacuation routes that are essential for providing and supporting evacuations caused by emergency events, including resilience improvements if they will improve evacuation routes
4. **At-Risk Coastal Infrastructure** activities to strengthen, stabilize, harden, elevate, relocate or otherwise enhance the resilience of highway and non-rail infrastructure, including bridges, roads, pedestrian walkways, and bicycle lanes, and associated infrastructure, such as culverts and tide gates

Source: https://www.fhwa.dot.gov/environment/protect/

Fiscal Year 2023 Disaster Supplemental Grant Program

Description: The FY 2023 Economic Development Administration (EDA) Disaster Supplemental will award investments in regions experiencing severe economic distress or other economic harm resulting from Hurricanes Ian and Fiona, and of wildfires, flooding, and other natural disasters occurring in calendar years 2021 and 2022. The EDA solicits applications under the authority of its Economic Adjustment Assistance (EAA) program. EAA funds can be awarded to assist a wide variety of activities related to disaster recovery, including economic recovery strategic planning grants, and public works construction assistance.

Project Eligibility: The entire Mid-Hudson region meets the area eligibility requirement from the remnants of Hurricane Ida in 2021. Under this competitive grant, projects must incorporate principles related to EDA's Investment Priority #2, Recovery & Resilience, which builds economic resilience to and long-term recovery from various future disruptions to the greatest extent possible, including extreme weather events and the impacts of climate change.

Technical Assistance: Applicants can reach out Hudson Valley Regional Council Executive Director Carla Castillo at ccastillo@hudsonvalleyrc.org if they are interested in receiving technical assistance.

Source: https://www.eda.gov/strategic-initiatives/disaster-recovery/supplemental

Public Transportation Emergency Relief Program

Description: The Federal Transit Administration's (FTA) Emergency Relief Program enables FTA to assist public transit operators in the aftermath of an emergency or major disaster. The program helps states and public transportation systems pay for protecting, repairing, and/or replacing equipment and facilities that may suffer or have suffered serious damage as a result of an emergency, including natural disasters such as floods, hurricanes, and tornadoes.

Project Eligibility: The program can fund capital projects to protect, repair, or replace facilities or equipment that are in danger of suffering serious damage, or have suffered serious damage as a result of an emergency. The program can also fund the operating costs of evacuation, rescue operations, temporary public transportation service, or reestablishing, expanding, or relocating service before, during or after an emergency.

Source: https://www.transit.dot.gov/funding/grant-programs/emergency-relief-program

Infrastructure for Rebuilding America (INFRA) Grant Program

Description: INFRA (the Nationally Significant Multimodal Freight & Highway Projects program) awards competitive grants for multimodal freight and highway projects of national or regional significance to improve the safety, efficiency, and reliability of the movement of freight and people in and across rural and urban areas. The INFRA grant program funding is available under the Multimodal Project Discretionary Grant combined Notice of Funding Opportunity. The following applicants can apply: a state or group of states, a MPO that serves an urbanized area, a unit of local government, a political subdivision of a local government, a special purpose district or public authority with a transportation function, and several others.

Project Eligibility: Eligible projects include:

1. A highway freight project on the National Highway Freight Network
2. A highway or bridge project on the National Highway System
3. A freight intermodal, freight rail, or freight project within the boundaries of a public or private freight rail, water (including ports), or intermodal facility and that is a surface transportation infrastructure project necessary to facilitate direct intermodal interchange, transfer, or access into or out of the facility
4. A highway-railway grade crossing or grade separation project
5. A wildlife crossing project
6. A surface transportation project within the boundaries or functionally connected to an international border crossing that improves a facility owned by federal, state, or local government and increases throughput efficiency
7. A project for a marine highway corridor that is functionally connected to the National Highway Freight Network and is likely to reduce road mobile source emissions
8. A highway, bridge, or freight project on the National Multimodal Freight Network

Source: https://www.transportation.gov/grants/infra-grant-program

Greening America's Communities

Description: Greening America's Communities (formerly known as Greening America's Capitals) is an EPA program to help cities and towns develop an implementable vision of environmentally friendly neighborhoods that incorporate innovative green infrastructure and other sustainable design strategies. EPA provides design assistance to help support sustainable communities that protect the environment, economy, and public health.

Source: https://www.epa.gov/smartgrowth/greening-americas-communities

Rebuilding American Infrastructure with Sustainability and Equity (RAISE)

Description: RAISE is a discretionary grant program for investments in surface transportation, including road, rail, transit, and port infrastructure that will have a significant local or regional impact. RAISE can provide funding directly to any public entity, including municipalities, counties, port authorities, tribal governments, MPOs, or others. This flexibility allows partners at the state and local levels to work directly entities that own, operate, and maintain much of our transportation infrastructure, but otherwise cannot turn to the Federal Government for support.

Project Eligibility: Eligible projects include:

1. Capital projects including but not limited to:
    a. highway, bridge, or other road projects
    b. public transportation projects
    c. passenger and freight rail transportation projects
    d. port infrastructure investments (including inland port infrastructure)
    e. the surface transportation components of an airport
    f. intermodal projects
    g. projects to replace or rehabilitate a culvert or prevent stormwater runoff to improve habitat for aquatic species while advancing the goals of the RAISE program
    h. projects investing in surface transportation facilities that are located on Tribal land and for which title or maintenance responsibility is vested in the Federal Government
    i. any other surface transportation infrastructure project that the Secretary considers to be necessary to advance the goals of the program.
2. Planning projects, including planning, preparation, or design (for example - environmental analysis, equity analysis, community engagement, feasibility studies, benefit cost analysis, and other pre-construction activities) of eligible surface transportation capital projects that will not result in construction with RAISE FY 2024 funding.

Source: https://www.transportation.gov/RAISEgrants/about

Community Change Grants

Description: EPA's Environmental and Climate Justice Program includes Community Change Grants with approximately $2 billion dollars in Inflation Reduction Act funds to benefit disadvantaged communities through projects that reduce pollution, increase community climate resilience, and build community capacity to address environmental and climate justice challenges. These place-based investments are focused on community-driven initiatives to be responsive to community and stakeholder input. They are designed to assist communities most adversely and disproportionately impacted by climate change, legacy pollution, and historical disinvestments.

Project Eligibility: The activities to be performed under the grants generally fall under the following categories:

- Climate resiliency and adaptation
- Mitigating climate and health risks from urban heat islands, extreme heat, wood heater emissions, and wildfire events
- Community-led air and other (including water and waste) pollution monitoring, prevention, and remediation
- Investments in low- and zero-emission and resilient technologies and related infrastructure
- Workforce development that supports the reduction of GHG emissions and other air pollutants
- Reducing indoor toxics and indoor air pollution
- Facilitating the engagement of disadvantaged communities in State and Federal advisory groups, workshops, rulemakings, and other public processes

Technical Assistance: Applicants can receive free Community Change Equitable Resilience Technical Assistance to help them develop applications for the Community Change Grant. The EPA will accept requests for this technical assistance until 50 recipients have been identified.

Source: https://www.epa.gov/inflation-reduction-act/inflation-reduction-act-community-change-grants-program

Water Infrastructure Finance and Innovation Act (WIFIA)

Description: EPA's WIFIA program provides funding to support water infrastructure projects. The WIFIA program is a federal loan and guarantee program at EPA that aims to accelerate investment in the nation's water infrastructure by providing long-term, low-cost supplemental loans for regionally and nationally significant projects.

Project Eligibility: WIFIA credit assistance can be used for a wide range of projects, including:

- Drinking water treatment and distribution projects
- Wastewater conveyance and treatment projects
- Nonpoint source pollution management program
- Management, reduction, treatment, or recapture of stormwater
- National estuary program projects
- Enhanced energy efficiency projects at drinking water and wastewater facilities
- Desalination, aquifer recharge, alternative water supply, and water recycling projects
- Drought prevention, reduction, or mitigation projects

Source: https://www.epa.gov/wifia

State Funding Sources

Green Innovation Grants Program (Green Stormwater Infrastructure)

Description: The Green Innovation Grants Program includes a Green Stormwater Infrastructure component that supports projects across New York State that utilize unique EPA-designated green stormwater infrastructure design and cutting-edge green technologies. Green stormwater infrastructure projects improve water quality by reducing and treating stormwater at its source through infiltration and/or evapotranspiration. Green stormwater infrastructure projects selected for funding are intended to:

- Maximize opportunities to leverage the multiple benefits of green stormwater infrastructure
- Spur innovation in the field of stormwater management
- Build capacity to construct and maintain green stormwater infrastructure
- Facilitate the transfer of new technologies and practices to other areas of the State

Project Eligibility and Funding: Grants can fund up to 90% of eligible project costs for a green stormwater infrastructure project in a municipality that meets the Median Household Income criteria, or that serves, protects, or benefits an environmental justice area. All other green infrastructure projects are eligible to receive up to 75% of total eligible project costs. Eligible projects for funding include:

1. Bioretention
2. Downspout Disconnection
3. Establishment or Restoration of Floodplains, Riparian Buffers, Streams or Wetlands
4. Green Roofs or Green walls
5. Permeable Pavement
6. Stormwater Harvesting and Reuse
7. Stormwater Street Trees/Urban Forestry Programs

Source: https://efc.ny.gov/gigp

Water Quality Improvement Project (WQIP) Program

Description: The WQIP program is a competitive reimbursement grant program that funds projects that directly improve water quality or aquatic habitat, promote flood risk reduction, restoration, and enhanced flood and climate resiliency, or protect a drinking water source.

Project Eligibility and Funding: Projects must directly improve water quality or aquatic habitat or protect a drinking water source. Eight project types and their maximum award amounts are listed below. All project types have a required match of 25%.

1. Wastewater Treatment Improvements ($1M-$15M)
2. Non-agricultural Nonpoint Source Abatement and Control ($100K-$10M)
3. Vacuum Trucks in Municipal Separate Storm Sewer System (MS4) Areas ($345K)
4. Land Acquisition for Source Water Protection Program ($5M)
5. Salt Storage ($600K)
6. Dam Safety Repair/Rehabilitation ($5M)
7. Aquatic Connectivity Restoration ($250K)
8. Marine District Habitat Restoration ($750K)

Source: https://dec.ny.gov/get-involved/grant-applications/wqip-program

Climate Smart Communities (CSC) Grant Program

Description: The CSC Grant program provides 50/50 matching grants to cities, towns, villages, and counties in New York for eligible climate change mitigation, adaptation, and planning and assessment projects.

Project Eligibility and Funding: Funds are available for two broad project categories - implementation and certification. The first category supports implementation projects related to the reduction of GHG emissions (mainly outside the power sector) and climate change adaptation. The second supports planning and assessment projects aligned with CSC certification actions. Eligible implementation projects include:

1. Increase natural resiliency to future flood risks, e.g., through living shorelines and nature-based landscape features
2. Relocate or retrofit critical infrastructure to reduce future flood risks.
3. Replace or right-size flow barriers to facilitate emergency response or protect people, infrastructure, and natural resources
4. Address anticipated future extreme heat conditions through the creation of community cooling centers
5. Improve emergency preparedness and response systems (excluding radio communication systems) for anticipated future extreme climate conditions

Source: https://dec.ny.gov/environmental-protection/climate-change/resources-for-local-governments/grants-for-climate-action

Non-Agricultural Nonpoint Source Planning and MS4 Mapping Grant

Description: The Non-Agricultural Nonpoint Source Planning and MS4 Mapping Grant (NPG) is a competitive, reimbursement grant program that funds planning reports for nonpoint source water quality improvement projects and mapping of Municipal Separate Storm Sewer Systems (MS4s). The program aims to prepare nonpoint source projects for construction and application for implementation funding, and to encourage and support cooperation among regulated MS4s to complete mapping of their stormwater system.

Project Eligibility and Funding: Eligible projects under Nonpoint Source Planning Reports include:

1. Decentralized Wastewater Treatment Facilities for Failing On-Site Treatment Systems
2. Green Infrastructure
3. Stormwater Retrofits
4. Streambank/Shoreline Stabilization
5. Comprehensive Stream Corridor Assessment
6. Stream Sediment and Debris Management Plan
7. In-Waterbody Controls for Nutrients
8. Bathing Beach Restoration
9. Stream Culvert Repair and Replacement
10. Berm Removal
11. Floodplain Creation/Restoration/Reconnection
12. Wetland Creation/Restoration
13. Coastal Storm Erosion Risk Management
14. Dam Safety

Source: https://dec.ny.gov/get-involved/grant-applications/non-agricultural-nonpoint-source-planning-ms4-mapping-grant

Tributary Restoration for Culverts and Road Stream Crossings

Description: The New England Interstate Water Pollution Control Commission and the New York State Department of Environmental Conservation's (NYSDEC) Hudson River Estuary Program invite proposals for projects that will help communities restore aquatic organism passage (AOP) and habitat connectivity, reduce localized flood risks, and improve water quality in and along Hudson River estuary tributaries.

Project Eligibility and Funding: Specifically, this program seeks proposals to design and/or construct AOP improvements and road stream crossing (RSX) replacements and retrofits in the Hudson
River estuary watershed. RSX include bridges, culverts, arches, and other similar structures that allow water to pass under infrastructure that would otherwise block the natural flow of rivers and streams. This RFP includes the following project types:

- Type 1: Design Plan to Replace or Retrofit a RSX - Deliver final plans, spec sheets, bid documents and prepare materials for a complete environmental permit application to replace or retrofit a RSX (e.g., grade controls, baffles, weirs, and other support structures) at a site that is the location of herring or eel habitat, or an aquatic barrier.
- Type 2: RSX Replacement and Retrofit Projects - Replace or retrofit a RSX (e.g., grade controls, baffles, weirs, and other support structures) at a site that is the location of herring or eel habitat, or an aquatic barrier.

Source: https://neiwpcc.org/wp-content/uploads/2024/04/RSX_NEI_RFP-2024-Extension.pdf

Environmental Justice Community Impact Grants

Description: The NYSDEC is pleased to announce funding for projects that will implement state assistance funding through the Environmental Justice Community Impact Grant program to not-for-profit corporation (NFP) community-based organizations for projects that address exposure of communities to multiple environmental harms and risks ("projects").

Project Eligibility and Funding: Eligible projects for grant funding must be located within or serve an Environmental Justice Community, as defined in DEC Commissioner Policy 29, Environmental Justice and Permitting.

Source: https://dec.ny.gov/sites/default/files/2024-05/RFA_CIG_R11_Final.pdf

Green Resiliency Grants

Description: The New York State Environmental Facilities Corporation is pleased to announce the availability of $60 million in grant funding through the Green Resiliency Grant (GRG) program under the Clean Water, Clean Air and Green Jobs Environmental Bond Act of 2022 (Bond Act). GRG grants are awarded on a competitive basis to projects that implement green infrastructure practices across New York State, including green roofs, green streets, and permeable pavement.

Project Eligibility and Funding: Eligible projects include:

- Restoration of non-instream features recommended through the Resilient NY Program;
- The creation and enhancement of nature-based landscape features such as flood plains, riparian buffers, streams, and wetlands;
- Installation of:
    - Bioretention and bioswales;
    - Cisterns;
    - Downspout disconnection;
    - Green roofs and green walls;
    - Permeable pavements or other permeable surfaces;
    - Stormwater street trees;
    - Urban forestry programs; and
    - Stormwater retention, retrofits, and slow-release designs.

Source: https://efc.ny.gov/grg

Appendix G: Fact Sheets

This appendix provides a compilation of the three fact sheets developed to summarize the main activities of the RWF effort:

- The Climate Change Fact Sheet
- The Vulnerability Assessment Fact Sheet
- The Resilience Recommendations Fact Sheet

Resilient Ways Forward

Transportation planning for our changing climate

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How is the climate changing?

Step 1: Data Collection

To become more resilient to climate change, we need to better understand regional climate trends and the likely impacts on our transportation system.

Climate Hazard Summary for Dutchess County

Hazard	Current	Future	Transportation Concerns
Temperature	• Average annual temperature has increased by nearly 3°F since 1960 • High temperatures occur with greater frequency and intensity	• Average temperatures continue to rise • More extreme temperatures will occur	• Pavement can soften, crack, or buckle • Rail lines can buckle • Travelers experience discomfort
Flooding	• About 44 inches of rain/year • Many extreme precipitation events • Hudson River water level has risen more than one foot since 1900	• Precipitation will become increasingly variable • More frequent and intense heavy rain events • Sea level rise and storm surge along the Hudson River more frequently	• Damage to roads, bridges, and rail lines • Closures, delays, and safety risks
Drought	• Notable flash droughts in 2002, 2017, and 2022.	• Longer periods without precipitation	• No direct impacts
Wind	• Multiple high wind events	• Greater potential for high winds as intensity of hurricanes, tropical storms, and tropical depressions increases	• Speed or travel restrictions • Road closures • Damage to traffic signals, road signs
Winter Conditions	• Winters have warmed 3x faster than summers • Later snowfall and earlier snowmelt	• Fewer days below freezing (32°F) • Greater snowfall during major winter storm events	• Dangerous driving conditions • Speed or travel restrictions • Road closures • Increased maintenance costs • Roads can crack and buckle
Landslides	• Southern and eastern parts of Dutchess County at risk due to steep slopes	• Precipitation-driven landslides could occur more frequently	• Major damage to infrastructure • Safety risks for travelers

Resilient Ways Forward

The Dutchess County Transportation Council is preparing a Climate Vulnerability Assessment of our transportation system. The Climate Vulnerability Assessment, titled ***Resilient Ways Forward***, will identify locations where our transportation system is most vulnerable to the impacts of climate change. It will also find ways to adapt to or reduce the adverse impacts of climate change on our transportation system.

We are here!

How is the climate changing?

Step 1: Data Collection

- Gather climate and transportation data
- Identify communities that face inequities or disparities
- Assess future climate scenarios

Where are we vulnerable?

Step 2: Analysis

- *System Level:* Understand risks of climate hazards for transportation assets
- *Asset Level:* Identify priority locations for adaptation investments

What can we do?

Step 3: Recommendations

- Toolbox of adaptation options
- Design guidelines
- Policy-based actions
- Implementation plan
- Monitoring and update plan

Stakeholder and Public Input

Interactive Map Survey

Virtual Public Meeting #1

Virtual Public Meeting #2

Stay Informed

- This fact sheet provides an overview of the **Climate Change Summary Report**. Read the full report
- Visit **ResilientWaysForward.com** to learn more and to sign up for email updates.
- Have extreme weather events affected your ability to get around? We want to hear from you! Add comments to our interactive Map Survey

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Resilient Ways Forward

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Where are we vulnerable?

Step 2: Analysis
Phase 1: System-Level

The Dutchess County Transportation Council (DCTC) is preparing a Climate Vulnerability Assessment, titled ***Resilient Ways Forward***, that identifies where our transportation system is most vulnerable to the impacts of climate change. This will help us find ways to reduce and adapt to the adverse impacts on our transportation system. The Phase 1 System-Level Report analyzes the sensitivity of various components of the transportation system to specific climate hazards. The Phase 2 Asset-Level Report identifies specific assets and locations where the transportation system is most vulnerable to the impacts of climate change.

Measuring Sensitivity

The Phase 1 System-Level analysis evaluates how sensitive our transportation system is to six climate hazards: extreme heat, flooding, drought, wind, winter conditions, and landslides. For each type of transportation asset, sensitivity is measured on a scale of low, medium, or high, focusing on the sensitivity of physical infrastructure and services/user experience. Physical transportation infrastructure is most sensitive to flooding and landslides, while transportation services and users are most sensitive to flooding, wind, winter conditions, and landslides.

	Climate Hazard											
	Extreme Heat		Flooding		Drought		Wind		Winter Conditions		Landslides	
Transportation Asset	I	S	I	S	I	S	I	S	I	S	I	S
Roads	Medium	Low	High	High	Low	Low	Low	High	Medium	High	High	High
Bridges	Medium	Low	High	High	-	-	Low	High	Medium	High	High	High
Culverts	-	-	High	High	Low	-	Low	-	Low	-	Medium	-
Rail lines/stations	Medium	Medium	High	High	-	-	Low	High	Medium	Medium	High	High
Bus system/ facilities	Low	Medium	Low	Medium	-	Low	Low	Medium	Low	High	Low	Low
Sidewalks	Low	High	Low	Medium	-	Low	Low	Low	Low	Medium	Medium	Medium
Rail trails	Low	High	High	High	-	Low	Low	Low	Low	Low	Medium	Medium
Regional airport	Medium	Low	NE	NE	Low	-	Low	Medium	Low	Low	NE	NE
Highway garages	Low	-	Medium	-	-	-	Low	-	Low	-	Medium	-
Park and rides	Low	Low	Medium	Medium	-	-	Low	Low	Low	Medium	NE	NE
Transit hub	Low	Medium	NE	NE	-	-	Low	Low	Low	Medium	NE	NE
Beacon ferry dock	Low	Low	Low	Medium	Low	-	Low	Medium	Medium	Medium	NE	NE

Key

I = Infrastructure Rating: the degree to which the asset (physical infrastructure) undergoes damage or loses functionality
S = Service Operations and User Experience Rating: the degree to which users are affected by service disruptions

NE = Not Exposed: asset was pre-screened and is not exposed to hazard
(-) = Unaffected: asset is unaffected by the hazard

Resilient Ways Forward **Vulnerability Assessment Phase 1 Report:** Read the full report.
www.ResilientWaysForward.com

Resilient Ways Forward

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Where are we vulnerable?

Step 2: Analysis
Phase 2: Asset-Level

Identifying Priorities

Phase 2 provides an asset-level (e.g., individual road segment) vulnerability assessment of the priority asset/hazard pairs to identify specific assets for improvements. Vulnerability is calculated based on whether an asset is in an area affected by a climate hazard (such as a floodplain) and whether the asset is critical to the transportation system (based on traffic volume, proximity to key destinations, and location in an equity area).

A summary of the vulnerability results for our transportation assets are shown below. The numbers indicate how many assets of each type are categorized as high, medium, low, or no vulnerability to flooding and landslides.

Priority Transportation Asset/Climate Hazard Pairs Analyzed in Phase 2

Climate Hazard	Transportation Asset
Flooding	• Roads • Bridges • Culverts • Rail lines & stations • Rail trails
Landslides	• Roads • Bridges • Rail lines & stations

Example:

- **180 = miles of roads with high vulnerability to flooding**
- **6% = percentage of roads analyzed with high vulnerability to flooding**

	Climate Hazard							
	Flooding				Landslides			
Transportation Asset	High	Medium	Low	Not Vulnerable	High	Medium	Low	Not Vulnerable
Roads (miles)	180 (6%)	337 (11%)	47 (2%)	2,490 (82%)	37 (1%)	77 (3%)	263 (9%)	2,678 (88%)
Bridges	9 (3%)	20 (6%)	78 (21%)	259 (71%)	4 (1%)	7 (2%)	21 (6%)	234 (91%)
Culverts	4 (1%)	19 (4%)	264 (57%)	177 (38%)	Not assessed			
Rail Lines (miles)	14 (11%)	78 (62%)	6 (5%)	28 (22%)	1 (1%)	11 (9%)	2 (2%)	122 (89%)
Rail Stations	0 (0%)	3 (27%)	1 (9%)	7 (64%)	0 (0%)	3 (27%)	0 (0%)	8 (73%)
Rail Trails (miles)	3 (7%)	23 (47%)	2 (3%)	20 (42%)	Not assessed			

Assets with high vulnerability scores will be prioritized for future adaptation investments. Medium and low scoring assets also have vulnerabilities that should be addressed over time. This analysis, coupled with input from stakeholders and the public, will inform Step 3: Recommendations.

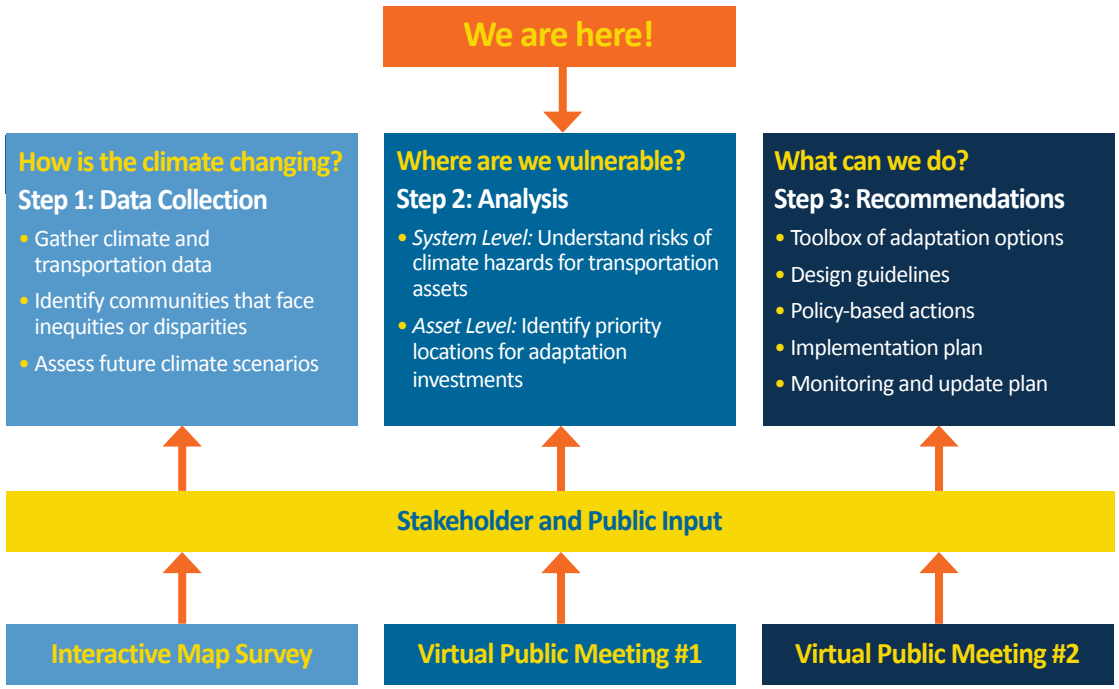
Resilient Ways Forward

Transportation planning for our changing climate

The Climate Vulnerability Assessment Phase 1 and Phase 2 Reports inform state, county, and local governments and transportation agencies about where their infrastructure and services are most vulnerable to our changing climate. This information will help them prioritize future resilience investments. The final report for ***Resilient Ways Forward*** will summarize the findings from Phase 1 and Phase 2 and provide strategies and recommendations to address vulnerabilities and prioritize resilience investments.

Reports

- **Climate Change Summary:** Read the full report
- **Climate Vulnerability Assessment Phase 1:** Read the full report
- **Climate Vulnerability Assessment Phase 2:** Read the full report



Stay Informed

- Visit **ResilientWaysForward.com** for more information.
- Learn about the public meetings and sign up for email updates at **ResilientWaysForward.com/get-involved**

www.ResilientWaysForward.com
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Resilient Ways Forward

Transportation planning for our changing climate

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What can we do?

Step 3: Recommendations

The Dutchess County Transportation Council (DCTC) prepared a Climate Vulnerability Assessment, titled ***Resilient Ways Forward***, that identifies where our transportation system is most vulnerable to the impacts of climate change.

To further our long-range vision of creating a safer, more reliable, resilient, and equitable transportation system, we developed a **suite of resilience recommendations** based on our priority climate vulnerabilities. These recommendations are designed for decision-makers and partner agencies to evaluate and implement, with the goal of making our transportation infrastructure and services more resilient to our changing climate.

Key Questions and Objectives

How is the climate changing?

Improve our understanding of climate risks to the transportation system.

- Extreme Heat
- Flooding
- Drought
- Wind
- Winter Conditions
- Landslides

Where are we vulnerable?

Identify and prioritize vulnerable transportation assets and services for targeted resilience investments.

- Roads
- Bridges
- Culverts
- Rail Lines & Stations
- Rail Trails

What can we do?

Provide recommendations to help facilitate and promote transportation resilience across communities.

- Adaptation Toolbox
- Priority Resilience Projects
- Policy-Based Measures
- Nature-Based Solutions
- Monitoring and Update Plan

Resilience Recommendations

ADAPTATION TOOLBOX

A suite of adaptation measures for infrastructure owners and service providers (e.g., highway departments and public transit agencies) to consider applying at vulnerable asset locations.

RESILIENCE PROJECTS

Resilience projects that partner agencies may pursue to improve vulnerable assets. These include New York State Department of Transportation projects to reduce flood risk, and Dutchess County Department of Public Works projects to replace scour-critical bridges.

POLICY-BASED MEASURES

A set of measures for local jurisdictions and partner agencies to consider and implement to improve system-wide resilience.

Transportation Resilience Improvement Plan: Read the full plan.

www.ResilientWaysForward.com

Resilient Ways Forward

Transportation planning for our changing climate

Resilience Recommendations

The **Adaptation Toolbox** includes more than 40 measures to increase the resilience of our transportation system to climate hazards (flooding, landslide, extreme heat, wind, and winter conditions). Local- and county-level **policies and initiatives** are essential to facilitate and encourage the broader implementation of these resilience measures, so we also developed a series of **policy-based measures** to improve system-wide resilience.

See Our Online Adaptation Toolbox for details about each resilience measure. Launch the Toolbox

Climate Hazard	Resilience Measures
Flooding	• Infrastructure enhancements • Nature-based solutions • Stream and waterway management • Technological solutions and strategic planning
Extreme Heat	• Public awareness and education • Cooling infrastructure
Winter Conditions	• Roadway maintenance • Public transportation and services
Landslide	• Infrastructure protection • Slope management • Technological and monitoring solutions
Wind	• Vegetation management • Monitoring and reporting

Policy-based Measures	Resilience Measures
✔	• Emergency planning • Community outreach • Local planning • Capacity-building and collaboration
Transportation Asset	**Resilience Project Ideas**
Roads Bridges Culverts	• New York State Department of Transportation road, bridge, and culvert projects • Dutchess County Department of Public Works bridge projects

Future Project Ideas: To support agencies applying for federal PROTECT (Promoting Resilience Operations for Transformative, Efficient, and Cost-Saving Transportation) grants, we will update our priority project list as we continue to identify ways to address resilience. We encourage our partners to submit project ideas using our online form.

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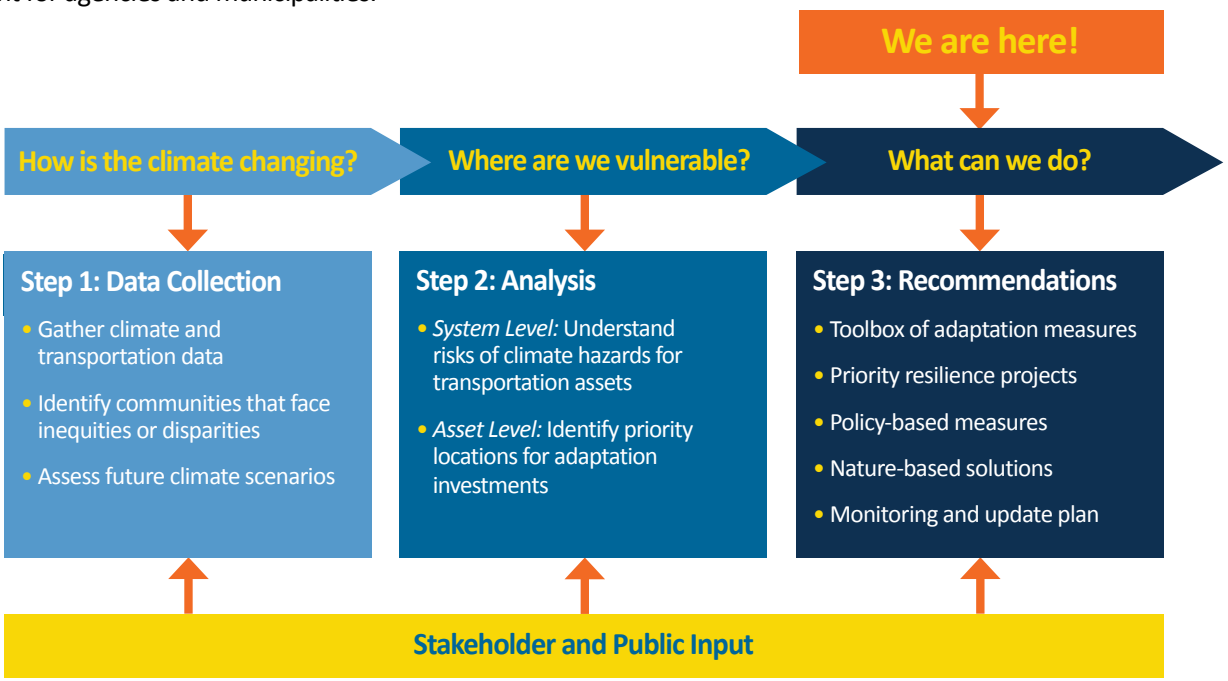
Transportation Resilience Improvement Plan

The ***Resilient Ways Forward*** **Transportation Resilience Improvement Plan (TRIP)** summarizes our study findings and outlines a path forward with strategies, project concepts, and recommendations for making today's transportation system more resilient to our changing climate.

Next Steps

We look forward to working with partner agencies and the community to build a more resilient transportation system. We will play a key role in facilitating collaboration between partners and stakeholders; integrating resilience and future climate data into current and future planning; programming federal funds for eligible projects; and encouraging training, education, and professional development for agencies and municipalities.



Resources

- **Climate Change Summary: Read the report**
- **Climate Change Fact Sheet: Read the fact sheet**
- **Climate Vulnerability Assessment Phase 1: Read the report**
- **Climate Vulnerability Assessment Phase 2: Read the report**
- **Climate Vulnerability Assessment Fact Sheet: Read the fact sheet**
- **Transportation Resilience Improvement Plan: Read the plan**

Stay Informed

Visit **ResilientWaysForward.com** for more information.

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