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Resilient Ways Forward:

Vulnerability Assessment Phase 2

DUTCHESS COUNTY
TRANSPORTATION COUNCIL
Better ways from here to there

Disclaimer

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Table of Contents

Definitions

- **Exposure:** Whether an asset is located in an area that is affected by climate hazards. Assets that have high exposure, such as assets located in floodplains, are more likely to be affected by climate hazards than those that are not.
- **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.
- **Criticality:** The level of importance of an asset to the transportation system. For example, roads with higher volumes are more critical than roads with lower volumes. If high volume roads are damaged or closed, more people are affected. The consequence to the transportation system is significant for highly critical assets.
- **Vulnerability:** The susceptibility of an asset to adverse impacts from climate hazards. Exposure, sensitivity, and criticality can be used to determine how vulnerable an asset is to climate hazards; high exposure, sensitivity, and criticality indicate high vulnerability.

Introduction

Resilient Ways Forward seeks to understand how and where our transportation system is most vulnerable to climate change. As part of this process, the Dutchess County Transportation Council (DCTC) completed a two-phase climate vulnerability assessment (see Figure 1). Phase 1, completed in August 2023, analyzed the sensitivity of various components of the transportation system to specific climate hazards, based on a low, medium, and high scale across physical infrastructure and service operations. Phase 2 builds on this work and identifies specific assets[1] and locations where our transportation system is most vulnerable to the impacts of climate change.

The vulnerability assessment focused on six hazards: extreme heat, flooding, drought, wind, winter conditions, and landslides. Table 1 summarizes how these hazards are projected to change in the future. See the DCTC Climate Change Summary Report for more detailed information on each of these hazards.

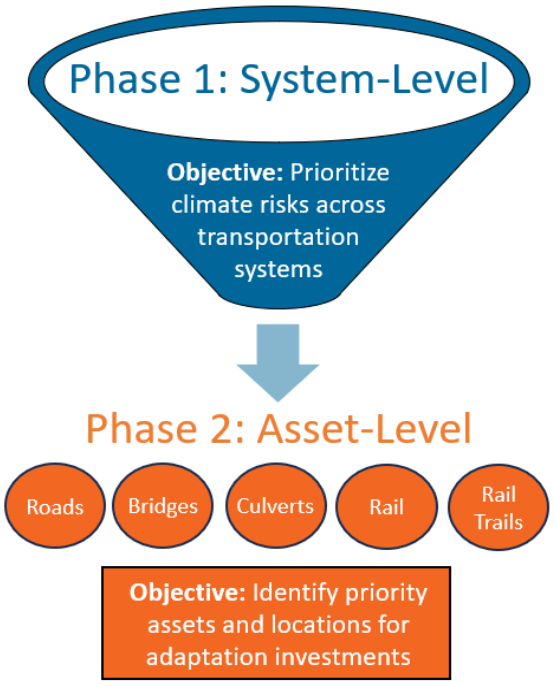


FIGURE 1. OVERVIEW OF THE CLIMATE VULNERABILITY ASSESSMENT PHASE 1 AND PHASE 2

TABLE 1. SUMMARY OF CLIMATE HAZARD PROJECTIONS

Hazard	Projected Changes
Extreme Heat	Extreme high temperatures will occur with greater frequency. From 1981-2010, Dutchess County saw an average of eight days each year where the high temperature reached 90°F or above. This could increase to 27-35 days per year by 2050 and 34-61 days by 2080.[2]
Flooding	Precipitation is expected to become more variable each year, with some years receiving much more precipitation than other years. Heavy rain events are also expected to become more frequent and intense, leading to flooding.[3] Along the Hudson River, areas could experience greater storm surge depth and extent during a coastal storm due to sea level rise.[4]

[1] Throughout this report, 'assets' refers to individual pieces of infrastructure under each category. For roads, rail lines, and rail trails, the assets are segments of the roadway, rail line, and rail trail, respectively. For bridges, culverts, and rail stations, the assets are the bridges, culverts, and rail stations themselves.
[2] U.S. Federal Government. NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Days with maximum temperature over 90 degrees Fahrenheit in Dutchess County, NY. https://crt-climate-explorer.nemac.org/
[3] 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/
[4] Hudson River Flood Impact Decision Support System. 2018. www.ciesin.columbia.edu/huson-river-flood-map/

Hazard	Projected Changes
Drought	Dutchess County is expected to experience longer periods without precipitation, increasing the risk of drought. However, the specific timing or duration of future droughts remains difficult to predict.[5]
Wind	Dutchess County could experience higher winds as the intensity of hurricanes, tropical storms, tropical depressions, and other extreme weather events (e.g., thunderstorms) increases.[6, 7]
Winter Conditions	Dutchess County will experience fewer days each year below freezing (32°F) which will cause precipitation to fall more often in the form of rain rather than snow. However, when winter storms do occur, they are projected to be more severe and include greater snowfall.[8, 9] Additionally, winter is expected to be shorter in Dutchess County, with the first fall freeze occurring later and the last spring freeze occurring earlier in the year. During the winter, Dutchess County is expected to see temperatures fluctuating around freezing more often, which is likely to result in increased icing (instead of snow, which is caused by very cold temperatures).
Landslides	The southwest and eastern parts of Dutchess County have steep slopes where landslides or rockfalls are more likely to occur.[10]

Phase 1 provided a system-level analysis of the sensitivity of major components of the transportation system to each of the six climate hazards. The purpose of this assessment was to screen for priority climate vulnerabilities across the transportation system that should be analyzed further in Phase 2. Phase 2 drills down to an asset-level (e.g., individual road segment), indicator-based assessment of the exposure and criticality of highly sensitive asset/hazard pairs identified in Phase 1.[11]

Table 2 shows the asset/hazard pairs identified for further analysis in Phase 2. These pairs were selected based on the Phase 1 findings as well as the availability of spatial data necessary to complete an asset-level analysis.

[5] Krakauer, Nir, et al. 2019. Trends in Drought over the Northeast United States. MDPI. https://www.mdpi.com/2073-4441/11/9/1834

[6] Chung, Maya, et al. 2021. Climate change is probably increasing the intensity of tropical cyclones. Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-probably-increasing-intensity-tropical-cyclones

[7] Seneviratne, S.I., et al. 2021. Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766, doi:10.1017/9781009157896.013

[8] U.S. Federal Government. NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Days each year with minimum daily temperatures below 32 degrees Fahrenheit in Dutchess County, NY. https://crt-climate-explorer.nemac.org/.

[9] Dupigny-Giroux, L.A., et al. 2018. Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18

[10] NASA. 2022. Landslide Susceptibility Map. https://gpm.nasa.gov/landslides/projects.html.

[11] 'Indicator-based' means that attributes or measures associated with each asset were used to perform a quantitative analysis. In this assessment, specific indicators of exposure and criticality were used.

TABLE 2. PRIORITY ASSET/HAZARD PAIRS ANALYZED IN PHASE 2

Hazard		Assets	
	Flooding	Roads	Rail lines/stations
		Bridges	Rail trails
		Culverts	
	Landslides	Roads	Rail lines/stations
		Bridges	

Phase 1 Findings

Table 3 summarizes the Phase 1 sensitivity ratings for each asset/hazard pair across two dimensions:

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

Physical transportation infrastructure is most sensitive to flooding and landslides, while transportation service operations and users are most sensitive to flooding, winter conditions, and landslides. This means that flooding and landslides are most likely to cause significant physical damage to transportation infrastructure. For example, flooding can scour bridges and washout rail lines, and landslides can bury or block culverts. Flooding, winter conditions, wind, and landslides are most likely to cause significant disruptions to transportation service operations. All four hazards can present safety risks to users (i.e., if there's standing water on roadways or icy conditions on train platforms) and may result in lengthy service disruptions or suspensions.

Although some assets received high service and user experience sensitivity ratings for **extreme heat** (sidewalks and rail trails), **wind** (roads, bridges, and rail lines/stations) and **winter conditions** (roads, bridges, and bus system/facilities), these pairs were not able to be analyzed in Phase 2. An asset-level analysis requires spatial data for both the asset and hazard, to identify specific assets that are more prone than others to the impacts of a hazard(s). Although not analyzed further in Phase 2, adaptation options for these highly sensitive asset/hazard pairs will be emphasized in the follow-on adaptation plan and recommendations.

For additional details on the Phase 1 methodology and results, see Resilient Ways Forward: Vulnerability Assessment Phase 1.

TABLE 3. SUMMARY PHASE 1 RESULTS FOR DUTCHESS COUNTY

	Extreme Heat		Flooding		Drought		Wind		Winter Conditions		Landslides	
	I	S	I	S	I	S	I	S	I	S	I	S
Roads	M	L	H	H	L	L	L	H	M	H	H	H
Bridges	M	L	H	H	-	-	L	H	M	H	H	H
Culverts[12]	-	-	H	H	L	-	L	-	L	-	M	-
Rail lines/ stations	M	M	H	H	-	-	L	H	M	M	H	H
Bus system/ facilities[13]	L	M	L	M	-	L	L	M	L	H	L	L
Sidewalks	L	H	L	M	-	L	L	L	L	M	M	M
Rail trails	L	H	H	H	-	L	L	L	L	L	M	M
Regional airport	M	L	NE	NE	L	-	L	M	L	L	NE	NE
Highway garages	L	-	M	-	-	-	L	-	L	-	M	-
Park and rides	L	L	M	M	-	-	L	L	L	M	NE	NE
Transit hub	L	M	NE	NE	-	-	L	L	L	M	NE	NE
Beacon ferry dock[14]	L	L	L	M	L	-	L	M	M	M	NE	NE

I = Physical infrastructure sensitivity rating
S = Service operations and user experience sensitivity rating
NE = Asset was pre-screened and is not exposed to the hazard
(-) = Asset is unaffected by the hazard

[12] Large culverts are treated as bridges in this assessment, similar to the National Bridge Inventory (NBI). The culvert ratings are for smaller culverts. Dutchess County defines minor culverts as those with a diameter of less than 5 feet. Culverts with diameters of 5 feet or more are considered major culverts. Once the diameter reaches 20 feet it is considered a bridge.

[13] Bus system/facilities focuses on impacts to bus stops, shelters, the bus fleet, and the bus garage. Impacts to bus routes that are a result of damage or disruption to the roadway are considered under roads.

[14] The Beacon ferry dock includes consideration of the alternative bus service offered when ferry service is shut down. The bus picks up and drops off customers at the same locations as the ferry service, which reduces service disruptions and discomfort for passengers. This asset category does not include consideration of the Newburgh ferry dock as it is out-of-county infrastructure.

Summary of Phase 2 Results

This section summarizes the key findings from the Phase 2 analysis (see the methodology and results sections below for more details). Phase 2 identified priority assets and locations to target adaptation investments. Table 4 summarizes the breakdown of asset vulnerability scores, categorized as high, medium, low, or not exposed. For flooding, rail lines have the largest percentage of assets (in miles) with high (11%) and medium (62%) vulnerability scores. For landslides, 1% or less of assets received a high vulnerability score. Rail stations have the highest percentage of assets with medium (27%) landslide vulnerability.

TABLE 4. 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			

Twelve road segments were identified as having high vulnerability to both flooding and landslides and should be prioritized for adaptation investments (Table 5 and Figure 2).

TABLE 5. ASSETS WITH HIGH VULNERABILITY SCORES FOR BOTH FLOODING AND LANDSLIDES

Road Name	Mileage (mi)	From (South or West)	To (North or East)	Road Owner	Municipality	GIS ID
Pump House Road	0.5	Heath Road	End	Local	Town of Fishkill	14168
Van Steuben Road	0.26	Kip Drive	Kip Drive	Local	Town of Fishkill	12458
Market Street	0.16	Creek Road	McKinley Street	Local	Village of Wappingers Falls	6675; 14260
McKinley Street	0.21	Market Street	Market Industrial Park	Local	Village of Wappingers Falls	11038
Alexander Lane	0.18	Market Street	End	Local	Village of Wappingers Falls	15656
Dog Tail Corners Road	0.63	Berkshire Road	5th Lane	County	Dover	4588

Road Name	Mileage (mi)	From (South or West)	To (North or East)	Road Owner	Municipality	GIS ID
Old State Route 22	0.62	Reagans Mill Road	Overlook Road	County	Dover	7991
Creek Road	0.38	Hamilton Road	Market Street	County	Wappinger	207
Route 22	0.55	Kitchen Corners Road	Furlong Road	State	Dover	7699
Route 55	0.96	Velie Road	Route 82	State	LaGrange	5483
Route 82	0.47	Route 55	Burdick Road	State	LaGrange	4843
Interstate 84 East & West	0.88	Main Street ramp	West of Route 9 ramps	State	Town of Fishkill	1116 4821

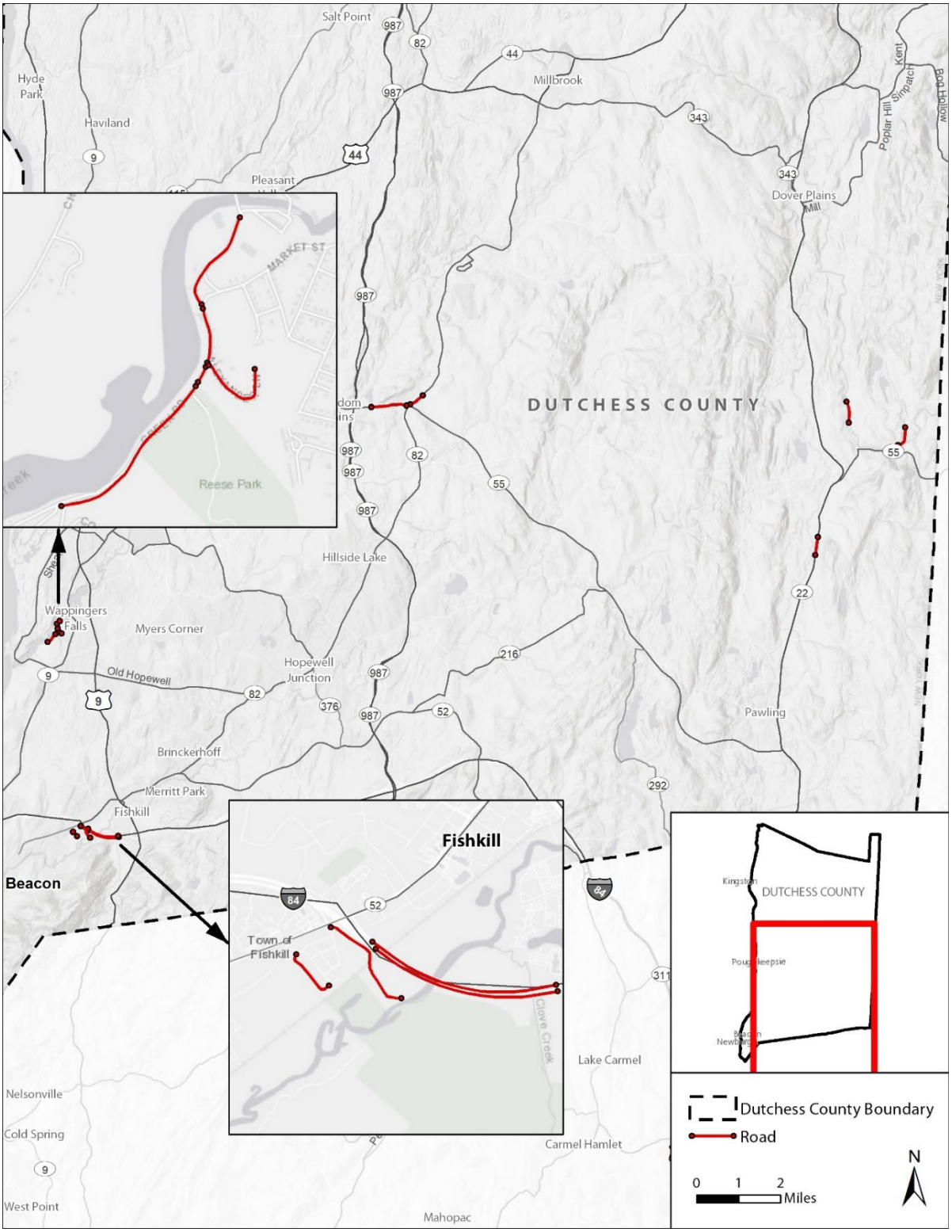


FIGURE 2. ASSETS WITH HIGH VULNERABILITY SCORES FOR BOTH FLOODING AND LANDSLIDES[15]

[15] Roads were segmented based on their underlying GIS properties. Some road segments are exceptionally long, especially on major highways, which can result in an entire segment being flagged as high vulnerability because a portion of the segment is in a floodplain or susceptible to landslides. Additionally, some road segments include elevated roadways, but appear as high vulnerability to flooding because other parts of the segment are not elevated.

Phase 2 Asset-Level Analysis: Methodology

The methodology used in this assessment builds 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.

Whereas Phase 1 assessed the general sensitivity of assets and services to various climate hazards, Phase 2 assesses the vulnerability of individual assets to flooding and landslides. The total vulnerability score for each asset was calculated using the equation below.

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

In this assessment, vulnerability is defined as the weighted combination of asset 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 located in an area that is affected by climate hazards. Assets that have high exposure, such as assets 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 volumes are more critical than roads with lower 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, the exposure and criticality of each asset were scored on a scale of 0 to 3.[16] These scores were then weighted and added together to determine the vulnerability score, with 3 being the highest possible score.

Table 6 shows the vulnerability score thresholds that correspond to high, medium, and low vulnerability ratings for each asset/hazard pair.

[16] An exposure score of 0 indicates that the asset is not exposed to the climate hazard. Assets that scored a 0 for exposure therefore also received a vulnerability score of 0, even though they may have a high criticality score.

TABLE 6. FINAL VULNERABILITY SCORE THRESHOLDS

Final Vulnerability Rating	Vulnerability Score Value
High	2.5 – 3.0
Medium	2.0 – 2.49
Low	0.01 – 1.99
Not exposed	0

Table 7 lists the data sources used in this assessment and indicates whether they were used to determine flood or landslide exposure or criticality. DCTC also collected feedback on the preliminary results from the study advisory committee and other stakeholders and adjusted exposure scores as needed to reflect local context and known issues from past events.[17]

TABLE 7. DATA SOURCES

Data Source	Flooding Exposure	Landslide Exposure	Criticality
FEMA 100-year and 500-year flood maps	✓		
Hudson River Flood Impact Decision Support System Version 2	✓		
Moving Dutchess Forward: Flood Zone Events[18]	✓		
Resilient Ways Forward: Share Your Story[19]	✓		
NYSDOT Frequent Flood Locations	✓		
NYSDOT Flood Risk National Bridge Inventory (NBI)	✓		
NYSDOT Flood Risk Large Culverts	✓		
Dutchess County Culverts	✓		
NASA Landslide Susceptibility		✓	
Dutchess County Steep Slopes		✓	
Fallen Rock signage on County roads		✓	
DCTC Transportation Equity Index			✓
Proximity to Public Safety Services (police, fire, EMS, hospital)			✓
Traffic Volume (Average Annual Daily Traffic)			✓

[17] For scores that did not resonate with partners due to local context (e.g., asset is elevated) or past experience (e.g., asset has flooded in the past), DCTC overrode the calculated exposure score to reflect no exposure (0), or high exposure (3) based on agency feedback. The final vulnerability score was then recalculated using the modified exposure score.
[18] The Flood Zone Events included in the Moving Dutchess Forward map are locations where flooding has affected transportation facilities. Photos and locations were submitted by municipal and county staff and are not comprehensive.
[19] DCTC conducted an online mapping survey, Resilient Ways Forward: Share Your Story, to gather information from the public and other local agencies on specific locations that have been affected by extreme weather events.

Criticality Datasets

For each asset/hazard pair, criticality was evaluated using three indicators, as appropriate: DCTC's Transportation Equity Index score for the location, the proximity of the asset to key public safety services, and (for roads, bridges, and culverts) the roadway's average daily traffic volume. These indicators are helpful for determining 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. The datasets used for these indicators are described below:

- DCTC's Transportation Equity Index
  - DCTC developed a Transportation Equity Index using Census tract data to measure the cumulative vulnerability of a community to transportation decisions. Data from the 2020 Census and 2017-2021 American Community Survey (ACS) was used to identify focus populations that have been historically marginalized by land use and transportation decision making. The Index was used as one of the criticality datasets to highlight the need for resilience investments in these communities. Communities with high equity scores tend to be more significantly impacted by loss of a transportation option because they often have limited or no access to alternative modes of transportation.
  - Communities with an indicator value of 10+ received a transportation equity score of 3, an indicator value of 6-9 scored a 2, and an indicator value of 0-5 scored a 1.
- Proximity to Public Safety Services
  - Public safety service locations include police stations, fire stations, emergency services, and hospitals. Transportation assets near these service locations are crucial for providing access to public safety services during extreme weather events and natural disasters and should therefore be prioritized for resilience investments.
  - Assets within 0.5 miles of 3+ destinations received a public safety service score of 3, 2 destinations scored a 2, 1 destination scored a 1, and 0 destinations scored 0.
- Traffic Volume
  - Roads with higher traffic volumes are prioritized for investment since they are more critical to a functioning transportation system. Though lower-volume roads are important for local access, the loss of a higher-volume road has a greater impact across the county.
  - Roads with an average daily traffic volume of 5,000+ received a score of 3, 1,500-5,000 scored a 2, and 0-1,500 or no data scored a 1.

Equity and 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.

Flooding

Roads

Flooding exposure for roads[20] was scored using FEMA 100- and 500-year floodplain maps, coupled with public input and future sea level rise scenarios. Before scoring flood exposure, elevated road segments were removed from the analysis as they are above the floodplain. The 100-year floodplain indicates a historical 1% annual chance of flooding. The 500-year floodplain indicates a historical 0.2% annual chance of flooding and includes areas in the 100-year floodplain. Although FEMA flood maps are a useful tool to understand flood exposure at a specific location, these maps are based on historical data and do not consider future climate change. The frequency and intensity of heavy precipitation events are expected to increase with climate change. As such, the current 500-year floodplain can be used as a proxy for the future 100-year floodplain to estimate future flood vulnerability. [21]

Self-reported input on where flood events have occurred in the county was used to supplement the FEMA flood maps. Public input was received through DCTC's Moving Dutchess Forward plan and the *Resilient Ways Forward* mapping survey. DCTC also incorporated input from other agencies on where past flood events have occurred, including NYSDOT's frequent flood locations. If a flood event was reported, the asset received an exposure score of 3 regardless of its floodplain or sea level rise rating.

Sea level rise and the 100-year and 500-year coastal storm events (i.e., storm surge) were also incorporated in the flood exposure scoring. Under an intermediate high scenario, Dutchess County is expected to see 18 inches of sea level rise by 2060 and could expect additional flooding from storm surge during coastal storm events.[22]

Table 8 and Table 9 show the scoring scales used for exposure and criticality respectively.

TABLE 8. EXPOSURE SCORING SCALE FOR FLOODING AND ROADS

Indicator	Weight	Indicator Value	Score
Flood Data	70%	Within FEMA 100-year floodplain OR 18" sea level rise + 100-year coastal event OR Past flood experience; Not elevated	3
		Within FEMA 500-year floodplain OR 18" sea level rise + 500-year coastal event; Not elevated	2
		Not in any floodplain OR Elevated	0

[20] Roads were segmented based on their underlying GIS properties. Some road segments are exceptionally long, especially on major highways, which can result in an entire segment being flagged as high vulnerability because a portion of the segment is in a floodplain. Additionally, some road segments include elevated roadways, but appear as high vulnerability to flooding because other parts of the segment are not elevated.

[21] FEMA. Federal Flood Risk Management Standard. https://www.fema.gov/floodplain-management/intergovernmental/federal-flood-risk-management-standard.

[22] Center for International Earth Science Information Network (CIESIN). 2018. Hudson River Flood Impact Decision Support System Version 2. https://www.ciesin.columbia.edu/hudson-river-flood-map/.

TABLE 9. CRITICALITY SCORING SCALE FOR FLOODING AND ROADS

Indicator	Weight	Indicator Value	Score
Transportation Equity Score	10%	10+	3
		6-9	2
		0-5	1
Proximity to Public Safety Services	10%	Within ½ mile of 3+ destinations	3
		Within ½ mile of 2 destinations	2
		Within ½ mile of 1 destination	1
		Within ½ mile of 0 destinations	0
Average Daily Traffic Volume	10%	5,000+	3
		1,500-5,000	2
		No data, or 0-1,500	1

Rail Lines, Stations, & Rail Trails

Flood vulnerability scoring for rail lines, stations, and rail trails uses the same methodology as roads, except that volume/ridership is not included in the criticality scores because neither rail nor rail trails have redundant routes like roadways. Volume and ridership are therefore less informative, as all routes are relatively critical.

Before scoring flood exposure, elevated rail trail segments were removed from the analysis as they are already above the floodplain. No rail lines are elevated. Self-reported input on where flood events have occurred in the county was used to supplement the FEMA flood maps. DCTC also incorporated input from other agencies on where past flood events had occurred. If a flood event was reported, the asset received an exposure score of 3 regardless of its floodplain or sea level rise rating.

For rail lines, if two parallel adjacent tracks' vulnerability scores differed, the pair received the higher of the two scores, recognizing that any repairs or improvements would likely be made to both tracks.

Table 10 and Table 11 show the scoring scales used for rail/rail trail flooding exposure and criticality respectively.

TABLE 10. EXPOSURE SCORING SCALE FOR FLOODING AND RAIL LINES, RAIL STATIONS, & RAIL TRAILS

Indicator	Weight	Indicator Value	Score
Flood Data	70%	FEMA 100-year floodplain OR 18" sea level rise + 100-year coastal event OR Past Experience of Flooding; Not elevated (Rail trails only)	3
		FEMA 500-year Floodplain OR 18" sea level rise + 500-year coastal event; Not elevated (Rail trails only)	2
		Not in any floodplain OR Elevated (Rail trails only)	0

TABLE 11. CRITICALITY SCORING SCALE FOR FLOODING AND RAIL LINES, RAIL STATIONS, & RAIL TRAILS

Indicator	Weight	Indicator Value	Score
Transportation Equity Score	15%	10+	3
		6-9	2
		0-5	1
Proximity to Public Safety Services	15%	Within ½ mile of 3+ destinations	3
		Within ½ mile of 2 destinations	2
		Within ½ mile of 1 destination	1
		Within ½ mile of 0 destinations	0

Bridges

Flooding exposure for bridges was scored using NYSDOT National Bridge Inventory (NBI) data. Bridges that do not cross water were considered to not be exposed to flooding, and received a final score of 0. For all other bridges, the following criteria was used to determine exposure scores:

- **Scour Vulnerable**[23]: Bridge has had a non-designed retrofit or rehab to correct a previous scour condition. Bridge is safe for one storm event but would then need to be protected again.
- **Scour Critical**: Bridge could be potentially damaged or collapse in a large storm event and is not protected by riprap or other similar methods.
- **Flood Routine**: The roadway is likely to overtop at/near the bridge at a storm event equal to, or more frequent than, a 10-year storm.
- **Flood Extreme**: The roadway is likely to overtop at/near the bridge at a storm event above a 10-year storm, but below a 100-year storm.

Table 12 and Table 13 show the scoring scales used for exposure and criticality respectively.

TABLE 12. EXPOSURE SCORING SCALE FOR FLOODING AND BRIDGES

Indicator	Weight	Indicator Value	Score
Flood Data	70%	Flood routine OR (flood extreme AND scour critical/vulnerable)	3
		Flood extreme (but not scour critical/vulnerable)	2
		Scour critical/vulnerable (but not flood extreme or flood routine)	1
		Not flagged as flood routine/extreme or scour critical/vulnerable, or does not cross water	0

[23] Scour refers to the erosion of soil surrounding a bridge foundation.

TABLE 13. CRITICALITY SCORING SCALE FOR FLOODING AND BRIDGES

Indicator	Weight	Indicator Value	Score
Transportation Equity Score	10%	10+	3
		6-9	2
		0-5	1
Proximity to Public Safety Services	10%	Within ½ mile of 3+ destinations	3
		Within ½ mile of 2 destinations	2
		Within ½ mile of 1 destination	1
		Within ½ mile of 0 destinations	0
Average Daily Traffic Volume	10%	5,000+	3
		1,500-5,000	2
		No data, or 0-1,500	1

Culverts

Culverts are inherently designed to pass water and therefore located in areas that are relatively likely to experience heavy water flows. Currently, there is no broadly reliable data on whether culverts are sufficiently sized to handle flood events in Dutchess County. DCTC relied on culvert condition data for the analysis. Culverts in poor condition are more likely to be damaged or fail during a flood event.

Flooding exposure for large culverts was scored using NYSDOT NBI Large Culvert condition data and Dutchess County Culvert condition data (see Table 14). Large culverts have an opening greater than or equal to 5 feet and a length less than or equal to 20 feet. The ratings are an overall condition evaluation, and include the culvert's alignment, settlement, joints, structural condition, and scour.

TABLE 14. CULVERT CONDITION RATINGS[24]

NBI Rating	Description
0 - 3	Severe damage. Includes any condition described in 4 but is excessive in slope to closed bridge that requires replacement. Severe movement or differential settlement of segments, or loss of fill. Metal culverts have extreme distortion and deflection in one section and extensive corrosion.
4	Considerable damage. Large spalls, heavy scaling, wide cracks, loss of backfill. Considerable settlement or misalignment, and considerable scouring or erosion at curtain walls, wingwall or pipes. Metal culverts have significant distortion and deflection throughout.
5	Moderate damage. Extensive cracking and leaching, or spalls on concrete. Minor settlement or misalignment, noticeable scouring, or erosion at curtain walls, wingwalls, or pipes. Metal culverts have significant distortion and deflection in one section.
6 and greater	No deficiencies and insignificant scrape marks to initial disintegration, minor chloride contamination, local scouring. Metal culverts have a smooth symmetrical curvature with superficial corrosion.

[24] New York Department of Transportation, 2020. Bridge and Large Culvert Inventory Manual. https://www.dot.ny.gov/divisions/engineering/structures/manuals/bridge-inventory-manual

Table 15 and Table 16 show the scoring scales used for exposure and criticality respectively.

TABLE 15. EXPOSURE SCORING SCALE FOR FLOODING AND CULVERTS

Indicator	Weight	Indicator Value	Score
Culvert Condition Rating	70%	Condition Rating >0 and <4	3
		Condition Rating >=4 and <5	2
		Condition Rating >=5 and <6	1
		Condition Rating >=6	0

TABLE 16. CRITICALITY SCORING SCALE FOR FLOODING AND CULVERTS

Indicator	Weight	Indicator Value	Score
Transportation Equity Score	10%	10+	3
		6-9	2
		0-5	1
Proximity to Public Safety Services	10%	Within ½ mile of 3+ destinations	3
		Within ½ mile of 2 destinations	2
		Within ½ mile of 1 destination	1
		Within ½ mile of 0 destinations	0
Average Daily Traffic Volume	10%	5,000+	3
		1,500-5,000	2
		No data, or 0-1,500	1

Landslides

Roads & Bridges

Landslide exposure for roads[25] and bridges was scored using NASA landslide susceptibility scores. These scores indicate how susceptible the terrain is to landslides, which is based on factors such as slope, rock and soil type, forest cover change, distance to road networks, and distance to fault zones. High susceptibility corresponds to high landslide risk if the terrain is exposed to intense rainfall.[26]

Recognizing that the gridded NASA landslide data is a coarse resolution for the county, the level of risk may be overestimated. To supplement this data, steep slopes greater than or equal to 100%[27] and within 25 feet of the road or bridge and the locations of "Fallen Rock" signs on county roads were factored into the exposure score. These localized datasets are useful in tandem with the NASA landslide susceptibility data to capture potentially vulnerable areas in the County.

Table 17 and Table 18 show the scoring scales used for exposure and criticality respectively.

[25] Roads were segmented based on their underlying GIS properties. Some road segments are exceptionally long, especially on major highways, which can result in an entire segment being flagged as high vulnerability because a portion of the segment has high exposure to landslides.

[26] NASA. 2022. Landslide Susceptibility Map. https://gpm.nasa.gov/landslides/projects.html.

[27] The percent of slope is not equivalent to the degree of slope. Percent of slope is defined as rise divided by run, multiplied by 100. For example, a 45-degree slope has a 100% percent slope.

TABLE 17. EXPOSURE SCORING SCALE FOR LANDSLIDES AND ROADS & BRIDGES

Indicator	Weight	Indicator Value	Score
Landslide Data	70%	Landslide susceptibility score of 5 (very high) OR segment has a record of rockfalls	3
		Landslide susceptibility score of 4 (high) AND steep slope greater than or equal to 100% within 25ft	2
		Landslide susceptibility score of 4 (high)	1
		Landslide susceptibility score of 1, 2, or 3 (very low, low, or moderate)	0

TABLE 18. CRITICALITY SCORING SCALE FOR LANDSLIDES AND ROADS & BRIDGES

Indicator	Weight	Indicator Value	Score
Transportation Equity Score	10%	10+	3
		6-9	2
		0-5	1
Proximity to Public Safety Services	10%	Within ½ mile of 3+ destinations	3
		Within ½ mile of 2 destinations	2
		Within ½ mile of 1 destination	1
		Within ½ mile of 0 destinations	0
Average Daily Traffic Volume	10%	5,000+	3
		1,500-5,000	2
		No data, or 0-1,500	1

Rail Lines & Stations

Landslide exposure scoring for rail uses the same methodology as roads and bridges. For rail criticality, traffic volume/ridership was not included because there are not redundant routes like roadways. Rail ridership is therefore less informative as all routes are relatively critical.

If two parallel adjacent rail tracks' vulnerability scores differed, the pair received the higher of the two scores, recognizing that any repairs or improvements would likely be made to both tracks.

Table 19 and Table 20 show the scoring scales used for exposure and criticality respectively.

TABLE 19. EXPOSURE SCORING SCALE FOR LANDSLIDES AND RAIL LINES & STATIONS

Indicator	Weight	Indicator Value	Score
Landslide Data	70%	Landslide susceptibility score of 5 (very high)	3
		Landslide susceptibility score of 4 (high) AND steep slope greater than or equal to 100% within 25ft	2
		Landslide susceptibility score of 4 (high)	1
		Landslide susceptibility score of 1, 2, 3 (very low, low, or moderate)	0

TABLE 20. CRITICALITY SCORING SCALE FOR LANDSLIDES AND RAIL LINES & STATIONS

Indicator	Weight	Indicator Value	Score
Transportation Equity Score	15%	10+	3
		6-9	2
		0-5	1
Proximity to Public Safety Services	15%	Within ½ mile of 3+ destinations	3
		Within ½ mile of 2 destinations	2
		Within ½ mile of 1 destination	1
		Within ½ mile of 0 destinations	0

Phase 2 Asset-level Analysis: Results

Using the methodology described above, flood and landslide vulnerability was calculated for all applicable assets on a low, medium, and high scale. This section breaks down the results for each asset/hazard pair analyzed in Phase 2. The results discussion focuses on high scoring assets, which emerge as clear priorities for further analysis and future investments. It is important to note that medium scoring assets still have notable levels of vulnerability that should be minimized over time.

For a summary of the Phase 2 results and highlights of the analysis, refer to Summary of Phase 2 Results (page 9). For a list of the highest-scoring assets, see the Appendix: High Vulnerability Assets.

Flooding

Flood vulnerability was assessed for roads, bridges, culverts, rail lines, rail stations, and rail trails. Figure 3 summarizes the number of assets (in miles or count as appropriate) that received a high flood vulnerability score. These assets emerge as priorities for further analysis and future investments to reduce flood vulnerability.

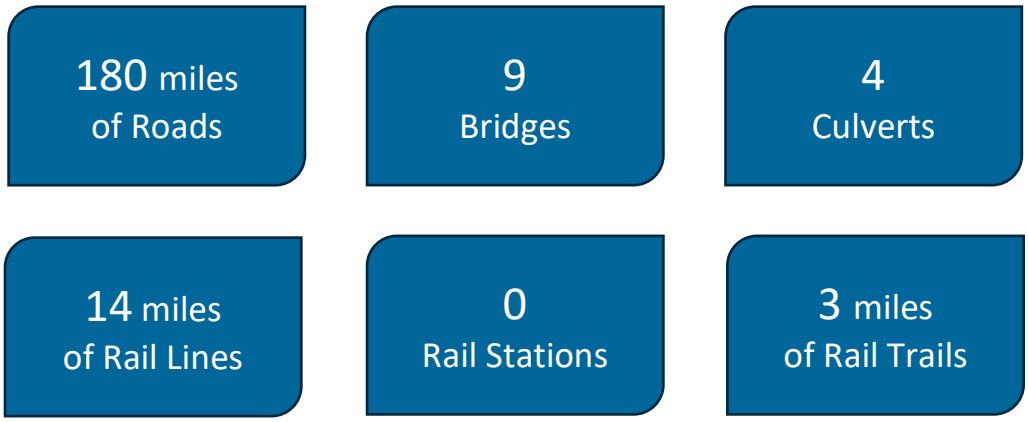


FIGURE 3. SUMMARY OF ASSETS WITH HIGH FLOOD VULNERABILITY

Roads

Roads have a high sensitivity to flooding. If exposed, roads can experience erosion of paved surfaces, structural integrity degradation, embankment failure, and severe and long-lasting closures and delays. Just over 3,000 miles of roads were assessed for flooding vulnerability. The assessment identified 180 miles (6%) with high vulnerability to flooding, and 337 miles (11%) with medium vulnerability to flooding.

Of the 180 miles of roads with high flood vulnerability, 6% are located in an area with a high transportation equity score as defined by DCTC, and 64% are high-volume roads, demonstrating how critical many of the roads with high vulnerability are.

Figure 4 shows a map with the final vulnerability scores for roads and flooding. Interactive versions of the Phase 2 result maps are available on the *Resilient Ways Forward* Map Viewer.

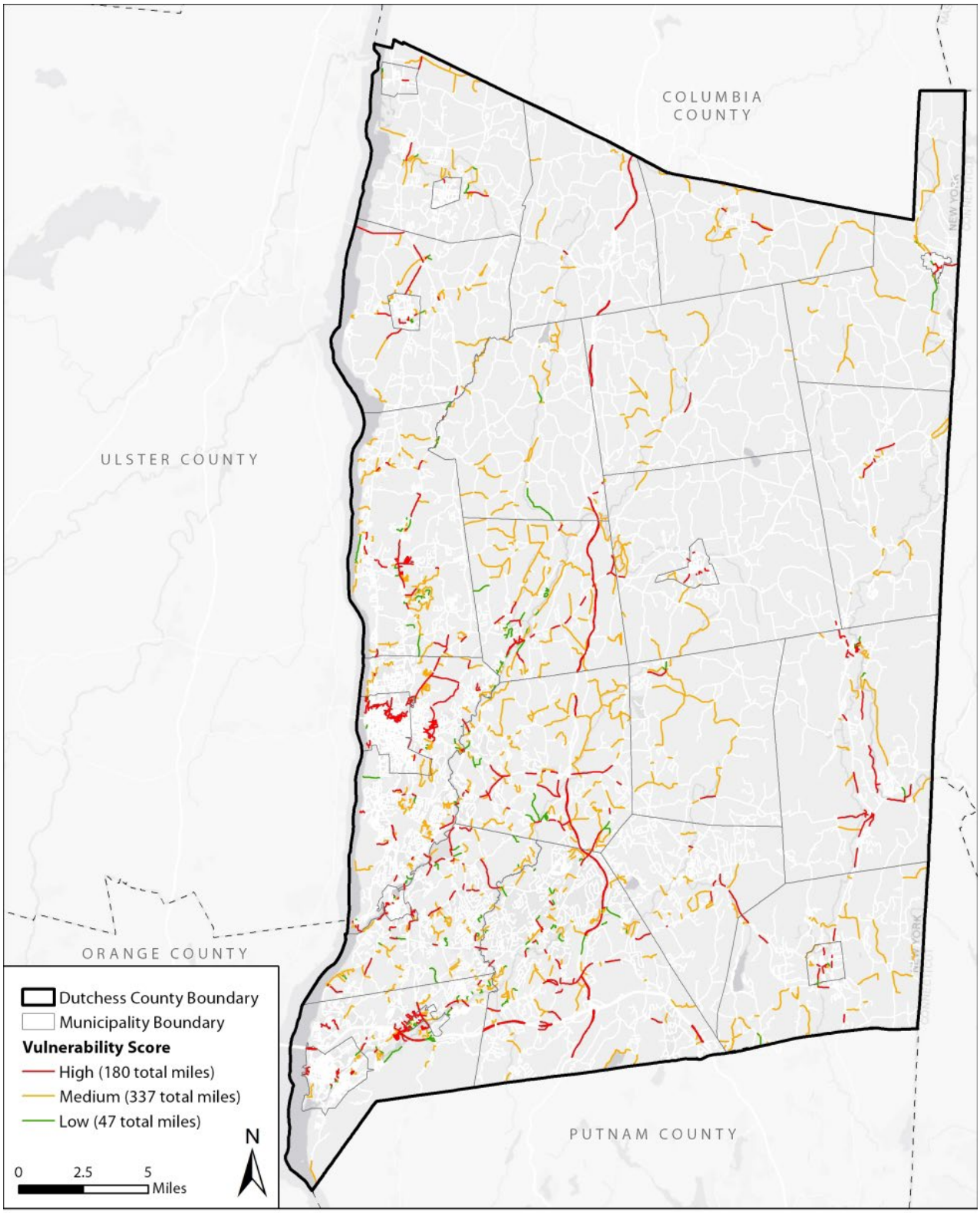


FIGURE 4. FINAL VULNERABILITY SCORES FOR ROADS AND FLOODING

Bridges

Bridges are generally designed to handle flood events. Out of the 366 bridges assessed, nine (3%) received a high flood vulnerability score and 20 (6%) received a medium flood vulnerability score. Most bridges (71%) are currently not exposed to flooding as they are designed to be at a higher elevation than the water they cross. Of the nine bridges with high vulnerability shown in Table 21, six are on high volume roads. None of the nine bridges with high flood vulnerability are in an area with a high transportation equity score.

TABLE 21. BRIDGES WITH HIGH VULNERABILITY SCORES FOR FLOODING

Bridge Owner	Municipality	Bridge BIN	Road Carried	Feature Crossed	High Volume
Local	Dover	2342910	Nellie Hill Road	Wells Brook	No
Local	Pawling	2223040	West Main Street	Pawling Creek	No
County	Fishkill	3343130*	Washington Avenue	Fishkill Creek	Yes
County	LaGrange	3358430*	Degarmo Road	Wappinger Creek	Yes
County	LaGrange	3343280	County Road 21	Jackson Creek	Yes
County	LaGrange	3358440*	Degarmo Road	Wappinger Creek	Yes
County	LaGrange	3343240	Stringham Road	Sprout Creek	No
NYSDOT	East Fishkill	1026860	Route 52	Gayhead Pond Inlet	Yes
NYSDOT	Town of Red Hook	1005370	Route 9	Sawkill Creek	Yes

*Bridge BIN 3343130 was replaced in 2023, and BINs 3358430 and 3358440 in 2016.

Figure 5 shows a map with the final vulnerability scores for bridges and flooding.

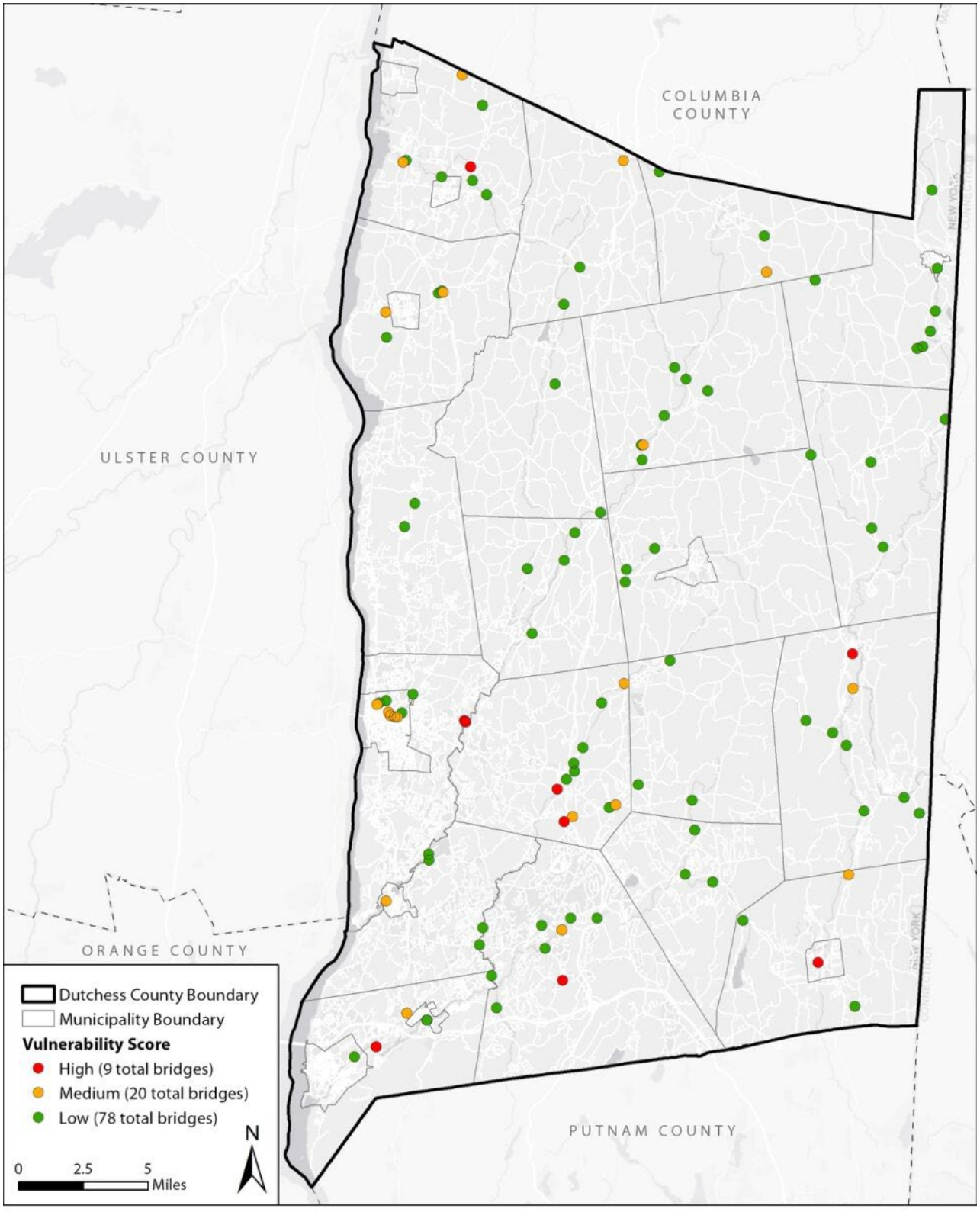


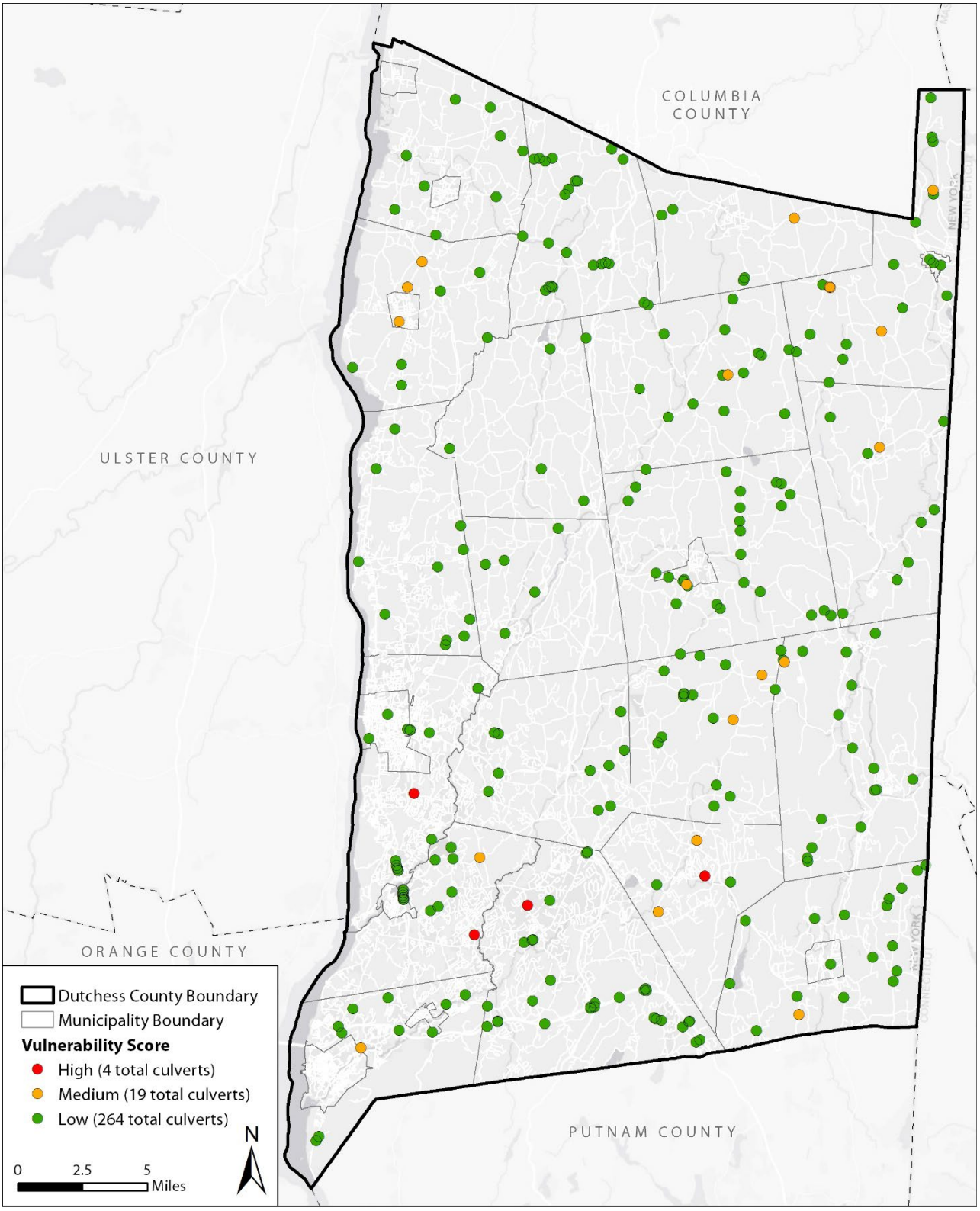
FIGURE 5. FINAL VULNERABILITY SCORES FOR BRIDGES AND FLOODING

Culverts

Culverts can get clogged or backed up if exposed to flooding and have the potential to wash out or collapse if flooding is severe. Of the 464 culverts assessed, four (1%) received a high flood vulnerability score and 19 (4%) received a medium flood vulnerability score. The remainder of culverts have either a low vulnerability score for flooding (57%) or are not exposed (38%). The four highly vulnerable culverts are in the towns of East Fishkill, Poughkeepsie, Beekman, and Wappinger.

Of the four culverts with high flood vulnerability, three are below high-volume roads. No culverts are in an area with a high transportation equity score.

Figure 6 shows a map with the final vulnerability scores for culverts and flooding.



Flood Vulnerability for Culverts

FIGURE 6. FINAL VULNERABILITY SCORES FOR CULVERTS AND FLOODING

Rail Lines & Stations

Rail lines are not designed to run on flooded tracks and can experience damage and service disruptions if flooded. There are two active rail lines in Dutchess County, the Hudson Line and Harlem Line. The Hudson Line runs along the Hudson River and is low lying. The Harlem Line runs north-south in the eastern part of the county. Both lines have a large portion of miles in the 100-year floodplain and are susceptible to flooding.

The two active rail lines total 126 miles. Of these, 14 miles (11%) received a high vulnerability score for flooding; 78 miles (62%) received a medium vulnerability score; six miles (5%) received a low vulnerability score; and 22% of miles are not exposed to flooding.

Figure 7 shows the breakdown of flood vulnerability scores for each of the rail lines. Rail line miles categorized as not exposed (with a flood vulnerability score of zero) are not included in this figure. Of the exposed rail lines, on the Hudson Line, 13% of miles have high vulnerability to flooding, while on the Harlem Line, 20% of miles have high vulnerability to flooding.

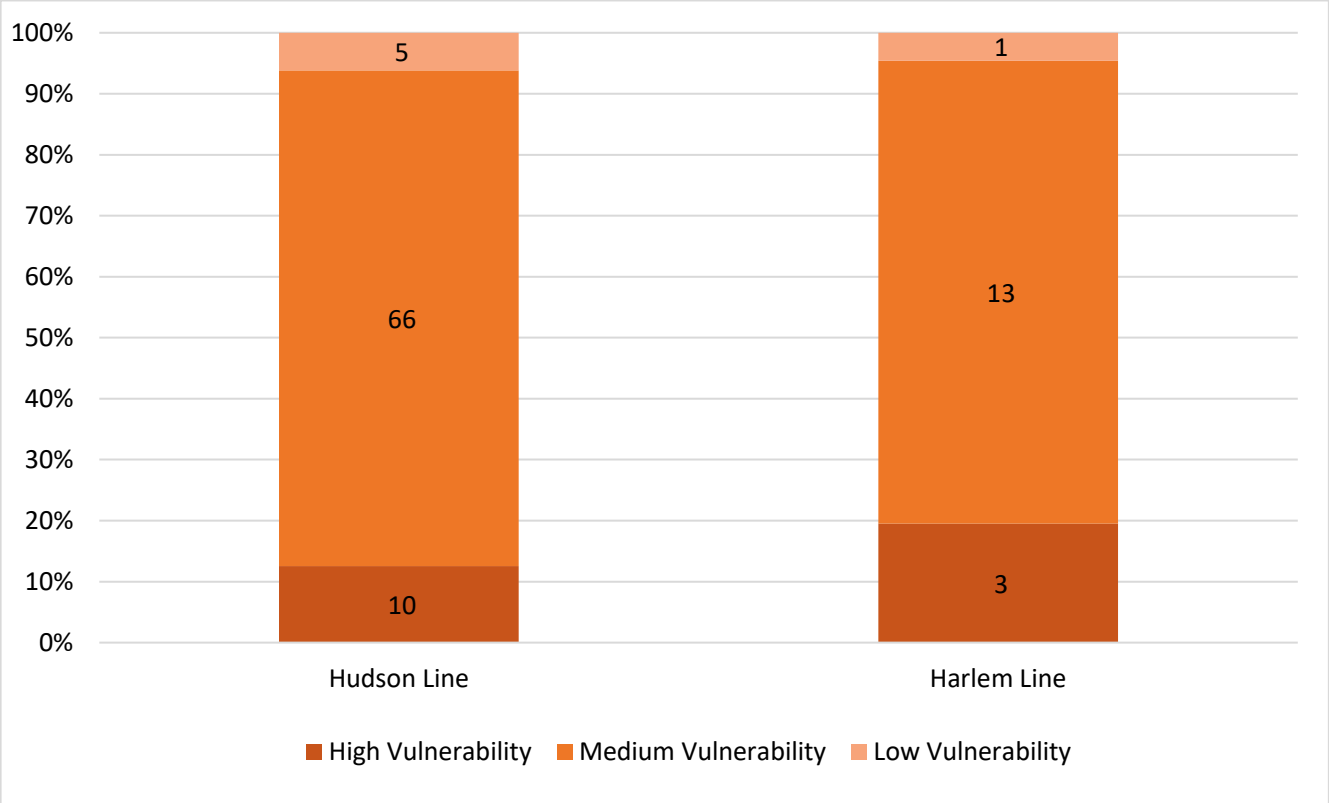


FIGURE 7. PERCENTAGE AND COUNT OF RAIL LINE MILES WITH HIGH, MEDIUM, AND LOW FLOOD VULNERABILITY

Floodwater and moving debris can damage rail stations and reduce accessibility for passengers if flooded. None of the 11 rail stations have high vulnerability to flooding, though three stations received a medium score (Harlem Valley-Wingdale, Ten Mile River, and Beacon), and one received a low score (New Hamburg). None of the four stations have high equity scores.

Figure 8 shows a map with the final vulnerability scores for rail lines and stations and flooding.

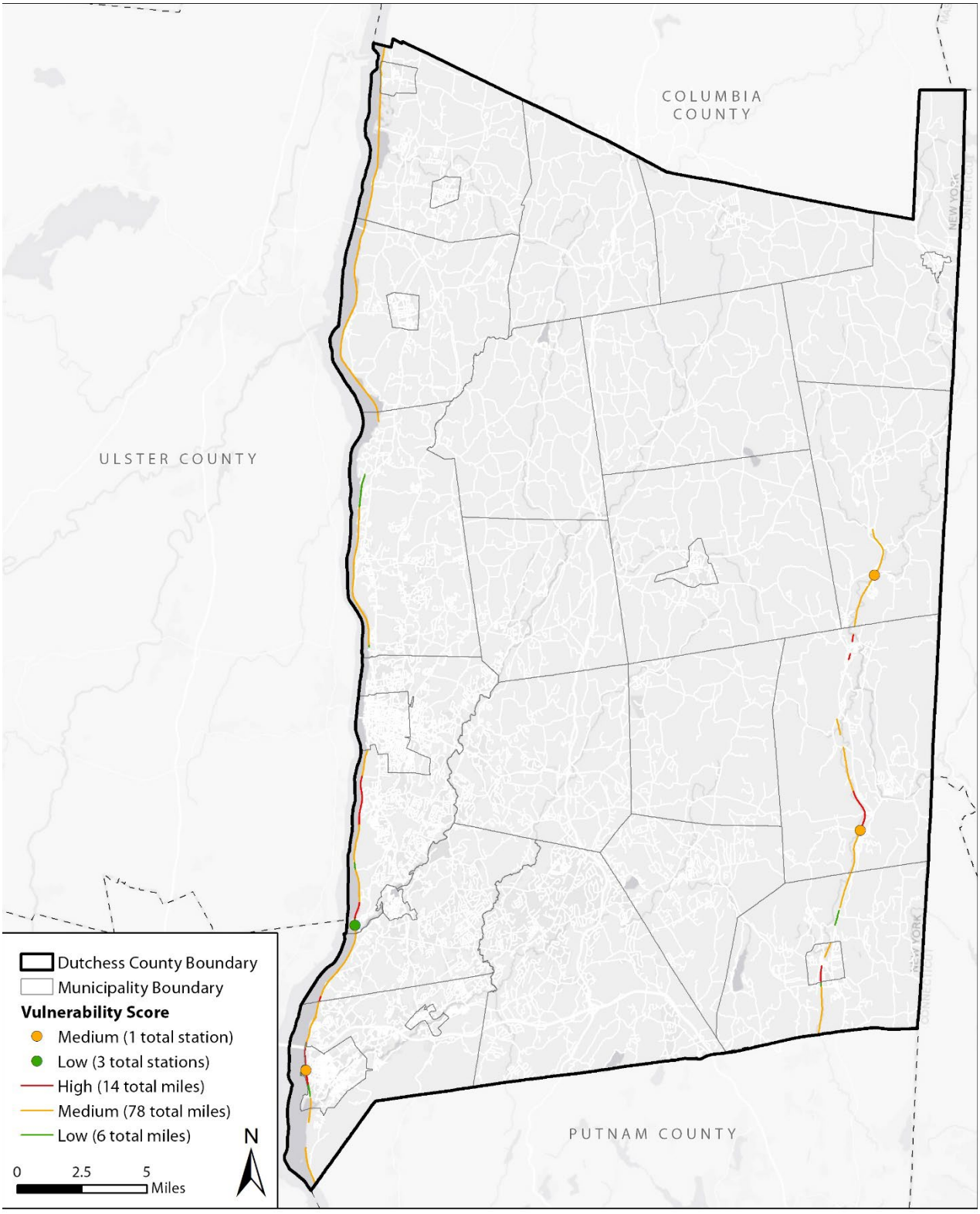


FIGURE 8. FINAL VULNERABILITY SCORES FOR RAIL LINES & STATIONS AND FLOODING

Rail Trails

Rail trails can become unpassable and dangerous for users if flooded, especially if portions wash out or debris accumulates. Erosion and embankment failure may occur if flooding is severe. Of the 48 miles of rail trails assessed, three miles (7%) received a high vulnerability score for flooding, and 23 miles (47%) received a medium vulnerability score. Most rail trail mileage (42%) is not exposed to flooding and therefore not vulnerable. Highly vulnerable rail trail segments are in the towns of North East (46%), Millerton (28%), and Poughkeepsie (26%).

None of the three miles of rail trail segments with high vulnerability to flooding are in areas with high transportation equity scores.

Figure 9 shows a map with the final vulnerability scores for rail trails and flooding.

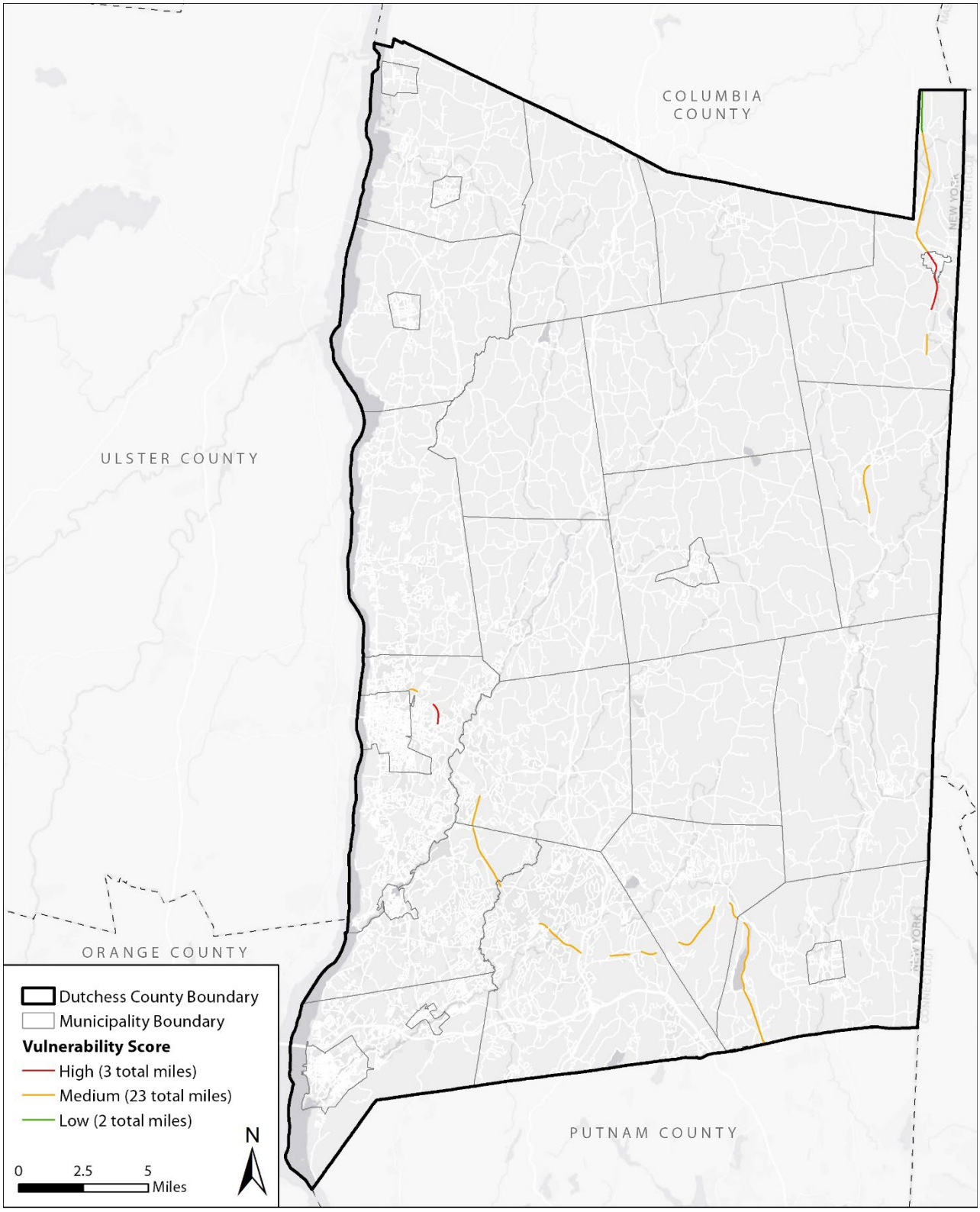


FIGURE 9. FINAL VULNERABILITY SCORES FOR RAIL TRAILS AND FLOODING

Landslides

The Dutchess County's 2016 Hazard Mitigation Plan (HMP)[28] stated that landslides are not a hazard of concern due to them being rare. However, if a landslide event were to occur, it could have a significant impact. In addition, climate change is projected to increase the number of heavy precipitation events and the incidence of freeze thaw events, which could increase the likelihood of landslides in the future.

Landslide vulnerability was assessed for roads, bridges, rail lines, and rail stations. Most of these assets have low or no vulnerability. Figure 10 summarizes the number of assets (in miles or count as appropriate) that received a high landslide vulnerability score. These assets emerge as priorities for further analysis and future investments to reduce landslide vulnerability.

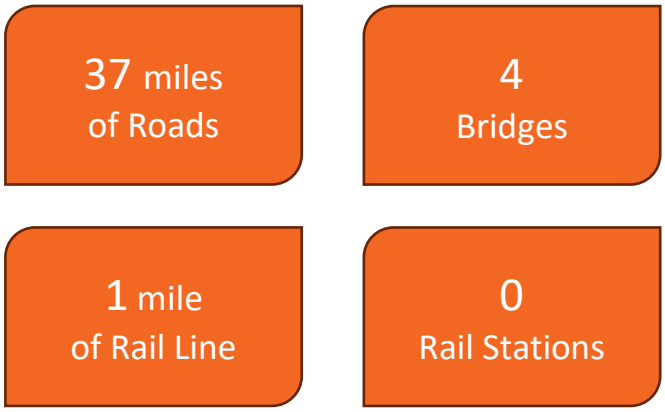


FIGURE 10. SUMMARY OF ASSETS WITH HIGH LANDSLIDE VULNERABILITY

Roads

Landslides can cause physical damage to road surfaces and cause service disruptions. Out of the 3,055 miles of road assessed, 37 miles (1%) received a high vulnerability score for landslides and 77 miles (3%) received a medium vulnerability score. Most highly vulnerable roads are in the towns of Fishkill (22%), Amenia (18%), Dover (11%), LaGrange (10%), and East Fishkill (10%).

Of the 37 miles of high vulnerability roads, 59% are high volume. None are in an area with a high transportation equity score.

Figure 11 shows a map with the final vulnerability scores for roads and landslides.

[28] Dutchess County Department of Emergency Response. 2016. Hazard Mitigation Plan. https://www.dutchessny.gov/Departments/Emergency-Response/Hazard-Mitigation-Plan.htm

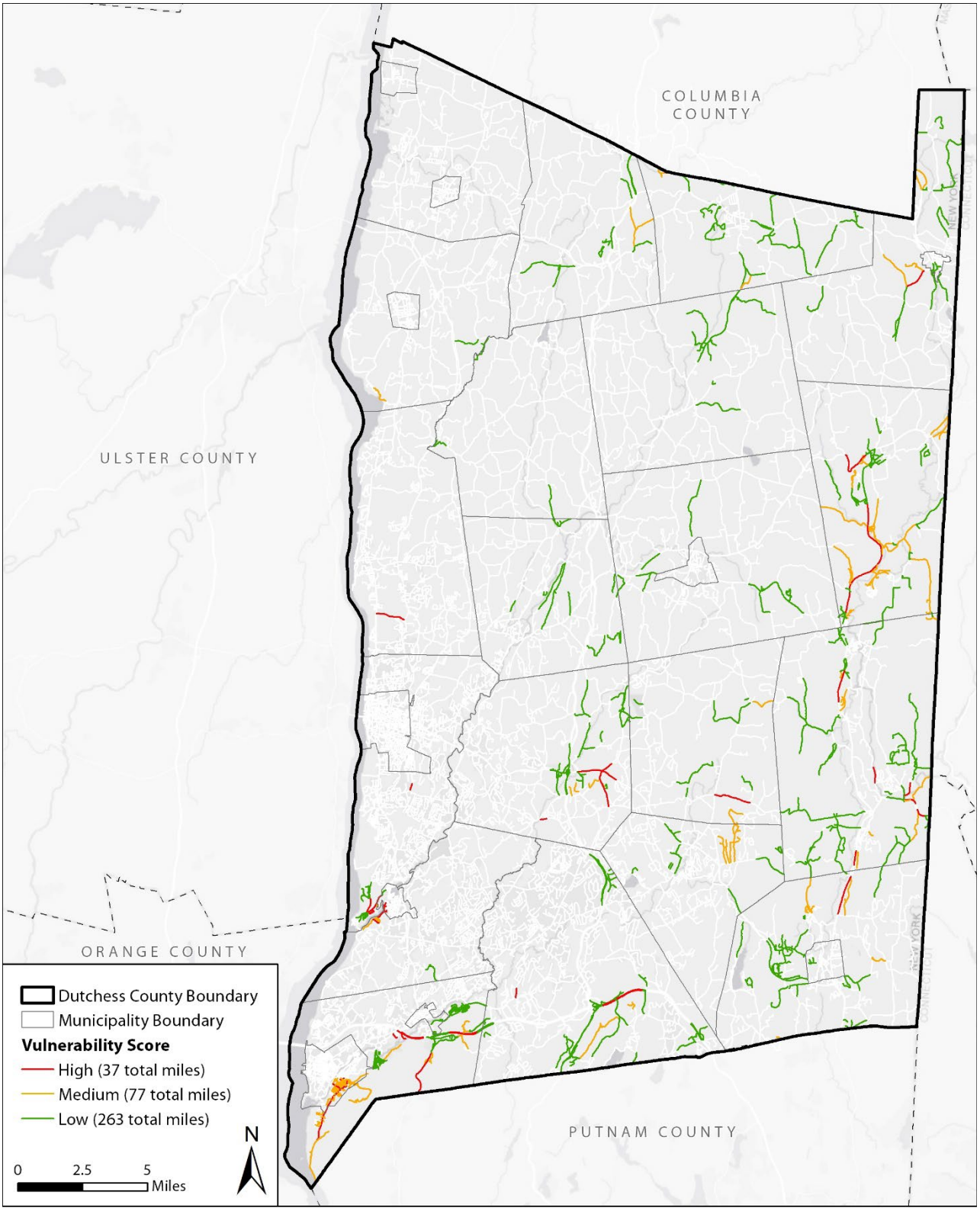


FIGURE 11. FINAL VULNERABILITY SCORES FOR ROADS AND LANDSLIDES

Bridges

Landslides can cause physical damage to bridges and impact their support structures, making them unstable and leading to service disruptions. Of the 366 bridges assessed, four (1%) received a high vulnerability score for landslides (listed in Table 22), and seven (2%) received a medium vulnerability score. Of the four bridges with high vulnerability to landslides, two are on high-volume roads. None are in an area with a high transportation equity score.

TABLE 22. BRIDGES THAT RECEIVED HIGH VULNERABILITY SCORES FOR LANDSLIDES

Bridge Owner	Municipality	Bridge BIN	Road Carried	Feature Crossed	High Volume
NYSDOT	Amenia	1016750	Route 22	Wassaic Creek	No
NYSDOT	Amenia	1032510	Route 22	Clear Creek	Yes
NYSDOT	Dover	1027210	Route 55	Deuel Hollow Brook	No
NYSDOT	Fishkill	1016740	Cary Road	Interstate 84	Yes

Figure 12 shows a map with the final vulnerability scores for bridges and landslides.

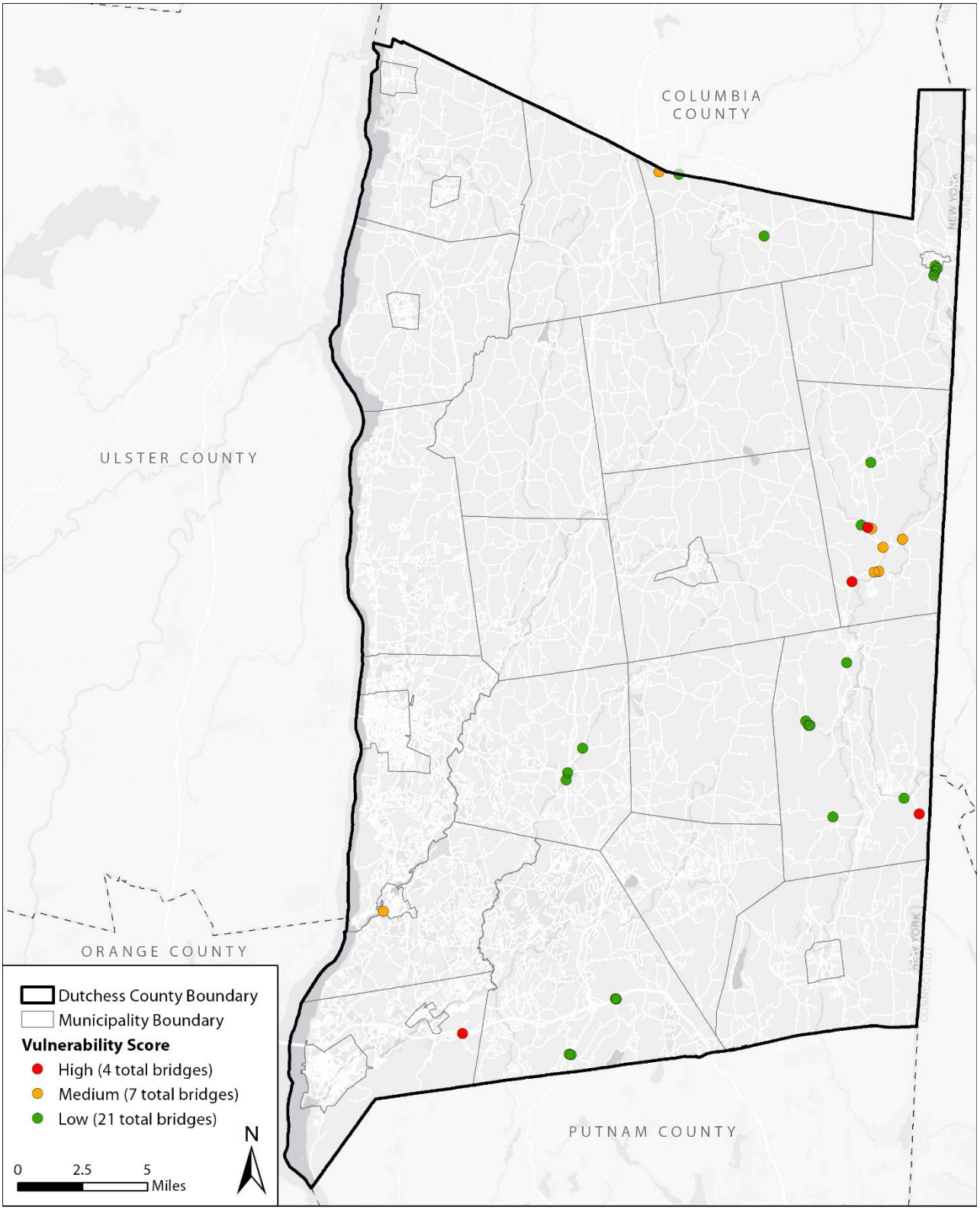


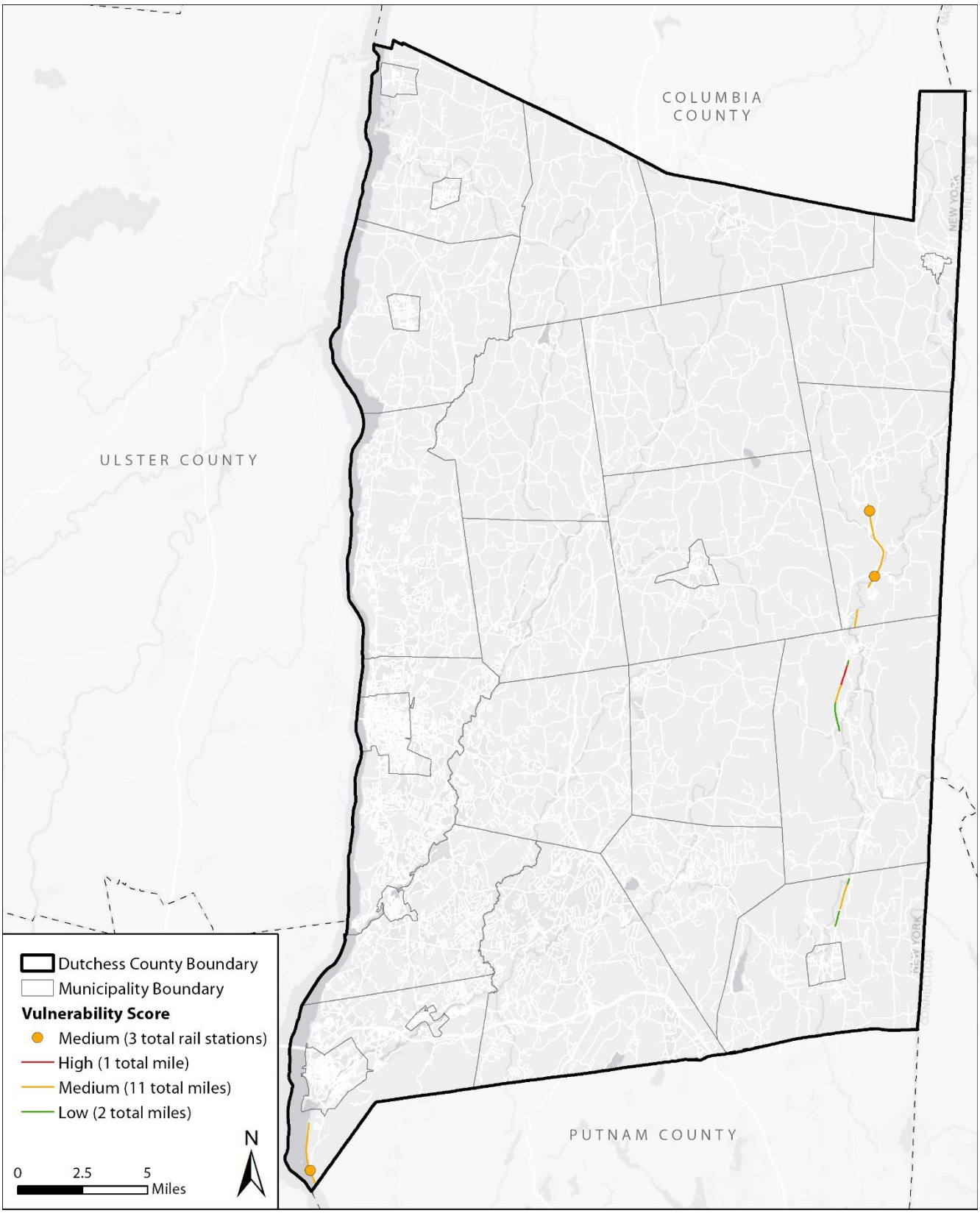
FIGURE 12. FINAL VULNERABILITY SCORES FOR BRIDGES AND LANDSLIDES

Rail Lines & Stations

Landslides can block rail lines and cause physical damage to stations and rail equipment, leading to service disruptions. Of 126 miles of rail lines assessed, one (1%) mile received a high vulnerability score for landslides and 11 (9%) received a medium vulnerability score. Erosion along rail lines on sloped terrain has been a frequent issue in Dutchess County. The Harlem Line is the most vulnerable: nearly one mile has high vulnerability and seven miles have medium vulnerability, mostly located near the Wassaic, Ten Mile River, and Dover Plains stations. The Hudson Line has zero miles with high vulnerability, but five miles with medium vulnerability.

Of 11 rail stations, none received a high vulnerability score and three received a medium vulnerability score: Breakneck Ridge (flag stop), Ten Mile River, and Wassaic.

Figure 13 shows a map with the final vulnerability scores for rail lines and stations and landslides.



Landslide Vulnerability for Rail Lines & Stations

FIGURE 13. FINAL VULNERABILITY SCORES FOR RAIL LINES & STATIONS AND LANDSLIDES

Next Steps

The completion of the Phase 2-Asset Level analysis serves as an essential piece of Resilient Ways Forward and its results will inform the strategies and recommendations in the final adaptation plan. Specifically, the Phase 2 results provide state, county, and local government and transportation agencies with a clearer picture of where their infrastructure and services are most vulnerable to our changing climate. This information will not only help them prioritize future resilience investments, but also assist them with their current capital programming. In accordance with federal guidelines for a Resilience Improvement Plan (RIP)[29], the follow-on final adaptation plan will use the results of both Phase 1 and Phase 2 to develop a mix of adaptation strategies that will include:

- **A toolbox of physical adaptation strategies** that will summarize ways to address climate change risks. These adaptation strategies will be evaluated for their pros and cons using multiple criteria, such as effectiveness at reducing vulnerabilities, impact on focus equity communities, and capital and maintenance costs.
- **Policy-based adaptation strategies** for consideration by state, county, and local government, and agencies to promote resiliency across the transportation system.
- **Climate change-informed design guidelines** that can be used by transportation agencies and asset owners to reduce climate change-related vulnerabilities to infrastructure.
- **A list of prioritized projects/locations** that should be addressed to build resiliency.
- **An implementation and monitoring plan** to ensure that the recommended adaptation strategies are carried forward.

[29] FHWA. PROTECT Program Overview. https://www.fhwa.dot.gov/environment/protect/.

Appendix: High Vulnerability Assets

This appendix lists assets with high vulnerability scores of 2.5 or higher, unless otherwise noted in a footnote.

Flooding

Roads

TABLE 23. TOP ROAD SEGMENTS WITH HIGH VULNERABILITY SCORES FOR FLOODING[30]

Road	Owner	Municipality	GIS ID	Miles	Flood Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
N Clinton St	Local	Poughkeepsie City	1690	0.04	3	3	3	3	**3.0**
N Clinton St	Local	Poughkeepsie City	3362	0.11	3	3	3	3	**3.0**
N Clinton St	Local	Poughkeepsie City	10661	0.04	3	3	3	3	**3.0**
N Hamilton St	Local	Poughkeepsie City	3524	0.04	3	3	3	3	**3.0**
N Hamilton St	Local	Poughkeepsie City	4477	0.04	3	3	3	3	**3.0**
N Hamilton St	Local	Poughkeepsie City	4506	0.06	3	3	3	3	**3.0**
N Hamilton St	Local	Poughkeepsie City	8577	0.07	3	3	3	3	**3.0**
N Hamilton St	Local	Poughkeepsie City	9219	0.02	3	3	3	3	**3.0**
N Hamilton St	Local	Poughkeepsie City	10120	0.06	3	3	3	3	**3.0**
Washington St	Local	Poughkeepsie City	1466	0.04	3	3	3	3	**3.0**
Mill St	State	Poughkeepsie City	3037	0.08	3	3	3	3	**3.0**
Mill St	State	Poughkeepsie City	16735	0.05	3	3	3	3	**3.0**
Mill St	State	Poughkeepsie City	16984	0.11	3	3	3	3	**3.0**
Catharine St	Local	Poughkeepsie City	4311	0.17	3	3	3	2	**2.9**
Clinton Sq	Local	Poughkeepsie City	1504	0.03	3	3	2	3	**2.9**
Clinton Sq	Local	Poughkeepsie City	6735	0.03	3	3	2	3	**2.9**
Cottage St	Local	Poughkeepsie City	13471	0.09	3	3	3	2	**2.9**
Garden St	Local	Poughkeepsie City	11516	0.09	3	3	3	2	**2.9**
Mansion St	Local	Poughkeepsie City	432	0.07	3	3	3	2	**2.9**
Mansion St	Local	Poughkeepsie City	4468	0.08	3	3	3	2	**2.9**

[30] Only roads with a final score of 2.8 and above were included in this table due to the number of road segments with high vulnerability (over 700).

Road	Owner	Municipality	GIS ID	Miles	Flood Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
Mansion St	Local	Poughkeepsie City	12838	0.07	3	3	3	2	**2.9**
N Hamilton St	Local	Poughkeepsie City	5731	0.10	3	3	2	3	**2.9**
N Hamilton St	Local	Poughkeepsie City	7216	0.37	3	3	3	2	**2.9**
Smith St	Local	Poughkeepsie City	10995	0.05	3	3	3	2	**2.9**
Verazzano Blvd	Local	Poughkeepsie City	15018	0.31	3	3	3	2	**2.9**
Maple St	State	Poughkeepsie City	8611	0.08	3	3	2	3	**2.9**
Maple St	State	Poughkeepsie City	12256	0.01	3	3	2	3	**2.9**
Maple St	State	Poughkeepsie City	15599	0.14	3	3	2	3	**2.9**
Route 9	State	Poughkeepsie City	14706	0.37	3	3	2	3	**2.9**
Route 9	State	Poughkeepsie City	16989	0.17	3	3	2	3	**2.9**
Maple St	State	Poughkeepsie City	431	0.13	3	3	2	3	**2.9**
Maple St	State	Poughkeepsie City	4172	0.02	3	3	2	3	**2.9**
W Main St	State	Village of Wappingers Falls	3117	0.01	3	2	3	3	**2.9**
E Main St	State	Village of Wappingers Falls	9260	0.04	3	2	3	3	**2.9**
W Main St	Local	Beacon City	10052	0.05	3	2	3	2	**2.8**
Balding Av	Local	Poughkeepsie City	12723	0.05	3	3	3	1	**2.8**
Brookside Av	Local	Poughkeepsie City	10049	0.31	3	3	3	1	**2.8**
Catharine St	Local	Poughkeepsie City	14409	0.10	3	3	3	1	**2.8**
Conklin St	Local	Poughkeepsie City	255	0.15	3	3	3	1	**2.8**
Cottage St	Local	Poughkeepsie City	6437	0.04	3	3	3	1	**2.8**
Elm Pl	Local	Poughkeepsie City	6119	0.05	3	3	3	1	**2.8**
Fallkill Pl	Local	Poughkeepsie City	6302	0.02	3	3	3	1	**2.8**
Garden St	Local	Poughkeepsie City	14321	0.03	3	3	2	2	**2.8**
Gifford Av	Local	Poughkeepsie City	15488	0.25	3	3	3	1	**2.8**
High St	Local	Poughkeepsie City	15745	0.08	3	3	3	1	**2.8**
Little Smith St	Local	Poughkeepsie City	13684	0.04	3	3	3	1	**2.8**
Mansion St	Local	Poughkeepsie City	655	0.03	3	3	2	2	**2.8**

Road	Owner	Municipality	GIS ID	Miles	Flood Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
Mansion St	Local	Poughkeepsie City	3571	0.05	3	3	2	2	**2.8**
Mansion St	Local	Poughkeepsie City	11939	0.09	3	3	2	2	**2.8**
Mansion St	Local	Poughkeepsie City	12560	0.05	3	3	2	2	**2.8**
Mill St	Local	Poughkeepsie City	7284	0.08	3	3	2	2	**2.8**
N Bridge St	Local	Poughkeepsie City	1657	0.16	3	3	3	1	**2.8**
N White St	Local	Poughkeepsie City	4646	0.07	3	3	2	2	**2.8**
Smith St	Local	Poughkeepsie City	59	0.08	3	3	2	2	**2.8**
Smith St	Local	Poughkeepsie City	1511	0.02	3	3	2	2	**2.8**
Smith St	Local	Poughkeepsie City	12678	0.03	3	3	2	2	**2.8**
Smith St	Local	Poughkeepsie City	12757	0.02	3	3	2	2	**2.8**
Thompson St	Local	Poughkeepsie City	7170	0.09	3	3	3	1	**2.8**
W Oakley St	Local	Poughkeepsie City	5473	0.12	3	3	3	1	**2.8**
Winnikee Av	Local	Poughkeepsie City	15182	0.10	3	3	2	2	**2.8**
Zimmer Av	Local	Poughkeepsie City	15427	0.04	3	3	3	1	**2.8**
Family Partnership Driveway	Private	Poughkeepsie City	5403	0.07	3	3	3	1	**2.8**
Crum Elbow Rd	County	Hyde Park	897	0.35	3	1	3	3	**2.8**
Crum Elbow Rd	County	Hyde Park	6798	0.23	3	1	3	3	**2.8**
E Market St	County	Hyde Park	14069	0.10	3	1	3	3	**2.8**
Route 22	State	Dover	16166	0.29	3	2	2	3	**2.8**
Main St	State	Fishkill	3726	0.01	3	1	3	3	**2.8**
Main St	State	Fishkill	14563	0.12	3	1	3	3	**2.8**
Route 9G	State	Hyde Park	10107	0.18	3	1	3	3	**2.8**
Route 9G	State	Hyde Park	16019	0.74	3	1	3	3	**2.8**
Violet Av	State	Hyde Park	1118	0.04	3	1	3	3	**2.8**
Violet Av	State	Hyde Park	1729	0.10	3	1	3	3	**2.8**
Violet Av	State	Hyde Park	5087	0.03	3	1	3	3	**2.8**
Violet Av	State	Hyde Park	6657	0.19	3	1	3	3	**2.8**

Road	Owner	Municipality	GIS ID	Miles	Flood Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
Violet Av	State	Hyde Park	11594	0.09	3	1	3	3	**2.8**
Route 376	State	Wappinger	5066	0.90	3	1	3	3	**2.8**

Bridges

TABLE 24. BRIDGES WITH HIGH VULNERABILITY SCORES FOR FLOODING

Bridge BIN	Owner	Municipality	Road Carried	Feature Crossed	Flood Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
1026860	NYSDOT	Town of East Fishkill	Route 52	Gayhead Pond	3	1	2	3	**2.7**
2342910	Local	Town of Dover	Nellie Hill Road	Wells Brook	3	2	2	1	**2.6**
3343130	County	Town of Fishkill	Washington Avenue	Fishkill Creek	3	1	1	3	**2.6**
2223040	Local	Town of Pawling	West Main Street	Pawling Creek	3	1	1	2	**2.5**
3343280	County	Town of LaGrange	County Road 21	Jackson Creek	3	1	0	3	**2.5**
3358430	County	Town of LaGrange	Degarmo Road	Wappinger Creek	3	1	0	3	**2.5**
3358440	County	Town of LaGrange	Degarmo Road	Wappinger Creek	3	1	0	3	**2.5**
3343240	County	Town of LaGrange	Stringham Road	Sprout Creek	3	1	1	2	**2.5**
1005370	NYSDOT	Town of Red Hook	Route 9	Sawkill Creek	3	1	0	3	**2.5**

Culverts

TABLE 25. CULVERTS WITH HIGH VULNERABILITY SCORES FOR FLOODING

Culvert BIN	Culvert Owner	Road Carried	Feature Crossed	Municipality	Flood Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
C821084	NYSDOT	Spackenkill Road	Casper Creek	Poughkeepsie	3	2	0	3	**2.6**
C830111	NYSDOT	State Route 376	Stream off Lake Walton Preserve	East Fishkill	3	1	0	3	**2.5**
B-16	County	Beekman Poughquag Road	Whaley Lake Creek	Beekman	3	1	1	2	**2.5**
WP-35	County	All Angels Hill Road	Stream off Sprout Creek	Wappinger	3	1	0	3	**2.5**

Rail Lines

TABLE 26. RAIL LINE SEGMENTS WITH HIGH VULNERABILITY SCORES FOR FLOODING[31]

Rail Line	Owner	GIS ID	Miles	Flood Score	Transportation Equity Score	Key Destination Score	Final Score
Hudson Line	Consolidated Rail Corp	19	0.91	3	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	136	0.91	3	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	210	0.91	3	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	146	0.04	3	2	1	**2.9**
Hudson Line	Consolidated Rail Corp	147	0.05	3	2	1	**2.9**
Hudson Line	Consolidated Rail Corp	20	0.12	3	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	137	0.12	2	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	143	0.12	3	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	211	0.12	2	2	3	**2.9**

[31] No rail stations received a high vulnerability score for flooding.

Rail Line	Owner	GIS ID	Miles	Flood Score	Transportation Equity Score	Key Destination Score	Final Score
Hudson Line	Consolidated Rail Corp	135	0.20	3	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	209	0.39	3	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	18	0.40	3	2	3	**2.9**
Hudson Line	Consolidated Rail Corp	51	0.89	3	3	1	**2.7**
Hudson Line	Consolidated Rail Corp	242	0.89	3	3	1	**2.7**
Hudson Line	Consolidated Rail Corp	152	0.21	3	3	1	**2.7**
Hudson Line	Consolidated Rail Corp	45	0.51	3	3	1	**2.7**
Hudson Line	Consolidated Rail Corp	236	0.51	3	3	1	**2.7**
Harlem Line	Metropolitan Transportation Authority	434	0.24	3	2	2	**2.7**
Hudson Line	Consolidated Rail Corp	33	0.70	3	2	1	**2.6**
Hudson Line	Consolidated Rail Corp	224	0.70	3	2	1	**2.6**
Hudson Line	Consolidated Rail Corp	44	0.16	3	3	0	**2.6**
Hudson Line	Consolidated Rail Corp	235	0.16	3	3	0	**2.6**
Hudson Line	Consolidated Rail Corp	26	0.20	3	2	1	**2.6**
Hudson Line	Consolidated Rail Corp	217	0.20	3	2	1	**2.6**
Hudson Line	Consolidated Rail Corp	47	0.33	3	3	0	**2.6**
Hudson Line	Consolidated Rail Corp	151	0.33	3	3	0	**2.6**
Hudson Line	Consolidated Rail Corp	238	0.33	3	3	0	**2.6**
Harlem Line	Metropolitan Transportation Authority	399	0.62	3	1	2	**2.6**
Harlem Line	Metropolitan Transportation Authority	409	0.65	3	2	1	**2.6**
Harlem Line	Metropolitan Transportation Authority	418	0.75	3	2	1	**2.6**
Harlem Line	Metropolitan Transportation Authority	412	0.07	3	2	1	**2.6**

Rail Line	Owner	GIS ID	Miles	Flood Score	Transportation Equity Score	Key Destination Score	Final Score
Harlem Line	Metropolitan Transportation Authority	413	0.13	3	2	1	**2.6**
Harlem Line	Metropolitan Transportation Authority	431	0.26	3	2	1	**2.6**
Harlem Line	Metropolitan Transportation Authority	7	0.55	3	2	1	**2.6**

Rail Trails

TABLE 27. RAIL TRAILS WITH HIGH VULNERABILITY SCORES FOR FLOODING

Rail Trail	Municipality	GIS ID	Miles	Flood Score	Transportation Equity Score	Key Destination Score	Final Score
Dutchess Rail Trail	Poughkeepsie	20	0.82	3	2	2	**2.7**
Harlem Valley Rail Trail	Millerton	5	0.09	3	1	2	**2.6**
Harlem Valley Rail Trail	Millerton	50	0.32	3	1	2	**2.6**
Harlem Valley Rail Trail	Millerton	61	0.50	3	1	2	**2.6**
Harlem Valley Rail Trail	North East	48	1.46	3	1	2	**2.6**

TABLE 28. ROADS WITH HIGH VULNERABILITY SCORES FOR LANDSLIDES

Road	Owner	Municipality	GIS ID	Miles	Landslide Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
Market St	Local	Village of Wappingers Falls	2034	0.05	3	2	3	1	**2.7**
Market St	Local	Village of Wappingers Falls	11124	0.05	3	2	3	1	**2.7**
McKinley St	Local	Village of Wappingers Falls	11038	0.21	3	2	3	1	**2.7**
I 84 W	State	Fishkill	4821	0.88	3	1	2	3	**2.7**
Sheafe Rd	Local	Poughkeepsie	4699	0.66	3	2	1	2	**2.6**
Market St	Local	Village of Wappingers Falls	6675	0.04	3	2	2	1	**2.6**
Alexander Ln	Local	Village of Wappingers Falls - Wappinger	15656	0.18	3	2	2	1	**2.6**
Market St	Local	Village of Wappingers Falls - Wappinger	14260	0.12	3	2	2	1	**2.6**
Palen Rd	County	East Fishkill	11463	0.36	3	1	1	3	**2.6**
Wolcott Av	State	Beacon City	5605	0.09	3	1	1	3	**2.6**
Wolcott Av	State	Beacon City	7174	0.12	3	1	1	3	**2.6**
Wolcott Av	State	Beacon City	8202	0.24	3	1	1	3	**2.6**
Wolcott Av	State	Beacon City	10414	0.02	3	1	1	3	**2.6**
Wolcott Av	State	Beacon City	10847	0.08	3	1	1	3	**2.6**
Wolcott Av	State	Beacon City	11659	0.03	3	1	1	3	**2.6**
Wolcott Av	State	Beacon City	12393	0.16	3	1	1	3	**2.6**
Route 22	State	Dover	7699	0.55	3	2	0	3	**2.6**
Route 22	State	Dover	16085	1.25	3	2	0	3	**2.6**
I 84 E	State	East Fishkill	544	0.60	3	1	1	3	**2.6**
I 84 E	State	East Fishkill	13638	1.10	3	1	1	3	**2.6**
I 84 W	State	East Fishkill	5865	1.13	3	1	1	3	**2.6**

Road	Owner	Municipality	GIS ID	Miles	Landslide Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
I 84 W	State	East Fishkill	10883	0.58	3	1	1	3	**2.6**
Route 9	State	Fishkill	1639	0.25	3	2	0	3	**2.6**
Route 9	State	Fishkill	8715	0.28	3	2	0	3	**2.6**
Route 9	State	Fishkill	8927	1.26	3	2	0	3	**2.6**
I 84 E	State	Fishkill	1116	0.86	3	1	1	3	**2.6**
I 84 E	State	Fishkill	1167	0.56	3	2	0	3	**2.6**
I 84 E	State	Fishkill	12014	0.55	3	2	0	3	**2.6**
I 84 W	State	Fishkill	910	0.57	3	2	0	3	**2.6**
I 84 W	State	Fishkill	13027	0.54	3	2	0	3	**2.6**
Route 55	State	LaGrange	5667	0.65	3	1	1	3	**2.6**
Route 82	State	LaGrange	4843	0.47	3	1	1	3	**2.6**
Route 22	Local	Amenia	12743	0.24	3	1	0	3	**2.5**
Route 22	Local	Amenia	14279	0.11	3	1	0	3	**2.5**
Route 22	Local	Amenia	15045	0.01	3	1	1	2	**2.5**
Route 44	Local	Amenia	16018	0.12	3	1	1	2	**2.5**
Depuyster Av	Local	Beacon City	536	0.03	3	1	1	2	**2.5**
Depuyster Av	Local	Beacon City	1170	0.05	3	1	1	2	**2.5**
E Main St	Local	Beacon City	4888	0.05	3	1	1	2	**2.5**
E Main St	Local	Beacon City	7727	0.06	3	1	1	2	**2.5**
Howland Av	Local	Beacon City	2587	0.05	3	1	1	2	**2.5**
Howland Av	Local	Beacon City	2862	0.12	3	1	1	2	**2.5**
Howland Av	Local	Beacon City	3127	0.07	3	1	1	2	**2.5**
Howland Av	Local	Beacon City	8592	0.15	3	1	1	2	**2.5**
Howland Av	Local	Beacon City	9997	0.12	3	1	1	2	**2.5**
Washington Av	Local	Beacon City	518	0.08	3	1	1	2	**2.5**
Route 55	Local	Dover	13342	0.08	3	2	0	2	**2.5**
Route 55	Local	Dover	16135	0.16	3	2	0	2	**2.5**
Pump House Rd	Local	Fishkill	14168	0.50	3	1	2	1	**2.5**

Road	Owner	Municipality	GIS ID	Miles	Landslide Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
Route 9D	Local	Fishkill	13308	0.02	3	1	1	2	**2.5**
Route 9D	Local	Fishkill	14189	0.08	3	1	1	2	**2.5**
Route 9D	Local	Fishkill	15117	0.01	3	1	1	2	**2.5**
Van Steuben Rd	Local	Fishkill	12458	0.26	3	1	2	1	**2.5**
Route 82	Local	LaGrange	13047	0.35	3	1	0	3	**2.5**
Route 82	Local	LaGrange	13952	0.93	3	1	0	3	**2.5**
Route 22	Local	Pawling	16075	1.52	3	1	0	3	**2.5**
Channingville Rd	Local	Poughkeepsie	6320	0.29	3	2	1	1	**2.5**
Channingville Rd	Local	Poughkeepsie	10763	0.08	3	2	1	1	**2.5**
Channingville Rd	Local	Poughkeepsie	11711	0.41	3	2	1	1	**2.5**
Channingville Rd	Local	Poughkeepsie	15302	0.11	3	2	1	1	**2.5**
Donny Dr	Local	Poughkeepsie	6390	0.09	3	2	1	1	**2.5**
Iris Ct	Local	Poughkeepsie	2984	0.03	3	2	1	1	**2.5**
Phyllis Rd	Local	Poughkeepsie	186	0.06	3	2	1	1	**2.5**
Phyllis Rd	Local	Poughkeepsie	7723	0.21	3	2	1	1	**2.5**
Phyllis Rd	Local	Poughkeepsie	8148	0.07	3	2	1	1	**2.5**
Marlorville Rd	Local	Wappinger	11410	0.29	3	1	2	1	**2.5**
Dog Tail Corners Rd	County	Dover	4588	0.63	3	2	0	2	**2.5**
Old State Route 22	County	Dover	7991	0.62	3	2	0	2	**2.5**
Saint Andrews Rd	County	Hyde Park	2514	1.12	3	1	0	3	**2.5**
Noxon Rd	County	LaGrange	258	0.25	3	1	0	3	**2.5**
Cedar Av	County	Poughkeepsie	4498	0.25	3	2	0	2	**2.5**

Road	Owner	Municipality	GIS ID	Miles	Landslide Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
Wingdale Mountain Rd	County	Union Vale	6860	1.45	3	1	1	2	**2.5**
Creek Rd	County	Wappinger	207	0.38	3	2	1	1	**2.5**
Route 44	State	Amenia	6792	0.30	3	1	1	2	**2.5**
Route 44	State	Amenia	17040	1.19	3	1	1	2	**2.5**
Route 22	State	Amenia	694	0.02	3	1	0	3	**2.5**
Route 22	State	Amenia	3043	0.02	3	1	0	3	**2.5**
Route 22	State	Amenia	3750	0.46	3	1	0	3	**2.5**
Route 22	State	Amenia	4484	0.86	3	1	1	2	**2.5**
Route 22	State	Amenia	4616	0.70	3	1	0	3	**2.5**
Route 22	State	Amenia	5091	0.42	3	1	0	3	**2.5**
Route 22	State	Amenia	7600	1.21	3	1	1	2	**2.5**
Route 22	State	Amenia	8639	0.09	3	1	1	2	**2.5**
Route 22	State	Amenia	11587	0.01	3	1	0	3	**2.5**
Route 22	State	Amenia	11593	0.78	3	1	0	3	**2.5**
Wolcott Av	State	Beacon City	2145	0.14	3	1	0	3	**2.5**
Wolcott Av	State	Beacon City	2961	0.06	3	1	0	3	**2.5**
Wolcott Av	State	Beacon City	8755	0.13	3	1	0	3	**2.5**
Wolcott Av	State	Beacon City	9969	0.04	3	1	0	3	**2.5**
Wolcott Av	State	Beacon City	10109	0.05	3	1	0	3	**2.5**
Route 55	State	Dover	3334	0.11	3	2	0	2	**2.5**
Route 55	State	Dover	6787	0.35	3	2	0	2	**2.5**
Route 55	State	Dover	11531	0.24	3	2	0	2	**2.5**
Route 9D	State	Fishkill	1094	0.70	3	1	1	2	**2.5**
Route 9D	State	Fishkill	4878	0.11	3	1	1	2	**2.5**
Route 9D	State	Fishkill	6455	0.38	3	1	1	2	**2.5**
Route 9D	State	Fishkill	8860	0.11	3	1	1	2	**2.5**
Route 55	State	LaGrange	5483	0.96	3	1	0	3	**2.5**
Route 82	State	LaGrange	2954	0.17	3	1	0	3	**2.5**
Route 22	State	North East	10688	0.90	3	1	1	2	**2.5**

Bridges

TABLE 29. BRIDGES WITH HIGH VULNERABILITY SCORES FOR LANDSLIDES

Bridge BIN	Primary Owner	Municipality	Road Carried	Feature Crossed	Landslide Score	Transportation Equity Score	Key Destination Score	Traffic Score	Final Score
1032510	NYSDOT	Town of Fishkill	Cary Road	I 84	3	2	0	3	**2.6**
1016740	NYSDOT	Town of Amenia	Route 22	Clear Creek	3	1	0	3	**2.5**
1016750	NYSDOT	Town of Amenia	Route 22	Wassaic Creek	3	1	1	2	**2.5**
1027210	NYSDOT	Town of Dover	Route 55	Deuel Hollow Brook	3	2	0	2	**2.5**

Rail Lines

TABLE 30. RAIL LINE SEGMENTS WITH HIGH VULNERABILITY SCORES FOR LANDSLIDES[32]

Line	Owner	GIS ID	Miles	Landslide Score	Transportation Equity Score	Key Destination Score	Final Score
Harlem Line	Metropolitan Transportation Authority	427	0.82	3	2	1	**2.6**

[32] No rail stations received a high vulnerability score for landslides.