Brandywine Flood Study Summary Report

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PREPARED BY

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This document is a summary report of the Brandywine Flood Study's full technical report. That report and its associated appendices contain all the data and analysis referenced here. Please refer to the full report for additional details and supplementary information.

Acknowledgements

The Brandywine Conservancy, Chester County Water Resources Authority and University of Delaware Water Resources Center would like to acknowledge the following organizations for their partnership in preparing the Brandywine Flood Study report. The following organizations have contributed to the data and content provided in this report as well as participated in the flood studies technical committee and outreach:

- Arcadis
- Chester County, Pennsylvania
- City of Wilmington, Delaware
- Delaware County, Pennsylvania
- Gannett Fleming
- Geodesy, Inc.
- Meliora Design
- New Castle County, Delaware
- Stroud Water Research Center
- United States Geological Survey
- West Chester University

It is important to recognize there are a multitude of projects being conducted in the Brandywine watershed throughout Delaware and Pennsylvania through a variety of nonprofit, government, academic and private organizations. The Brandywine Flood Study is an important piece of a broader and multi-faceted effort to reduce flooding and its impact on the communities in the Brandywine River Watershed.

The report team would like to acknowledge Chester County, PA, Delaware County, PA, Federal Emergency Management Agency (FEMA), National Oceanic and Atmospheric Administration (NOAA) and Pennsylvania Emergency Management Agency (PEMA) for its funding support of the Brandywine Flood Study.

Chapter 1: Flooding in the Brandywine – A Call to Action

The Brandywine Creek, which traverses through southeastern Pennsylvania and northern Delaware, has always had an incredible impact on the local landscapes and communities. Hundreds of years ago, industries established themselves along the banks of the Brandywine and its tributaries to harness its power. Townships and cities settled around those industrial hubs and continued to grow and expand even as the use of hydropower declined. Today, these streams provide natural character and numerous ecosystem services to their communities. Yet, flooding along these waterways has the potential to endanger lives, disrupt economic activities, and cause extensive damage.

Communities along the Brandywine Creek and its tributaries are no stranger to the threat of rising waters. Many residents across the region can vividly recall hurricanes, tropical storms, and other major rain events that disrupted their lives in one way or another. The devastation caused by Hurricane Ida in 2021 brought renewed attention to flood mitigation efforts in the Brandywine watershed. That storm served as the main catalyst for this study to better understand the factors that contribute to and exacerbate flooding in the watershed, as well as identify actionable steps communities can take to reduce flood risks.

Planning for flooding along the Brandywine Creek and its tributaries has been an ongoing exercise for decades. Major floods in 1920, 1933, 1942, 1955, 1972, and 1973 were referenced in plans that ultimately resulted in the construction of five regional flood control facilities within the upper portions of the watershed. These include:

- Robert G. Struble, Sr. Dam and Regional Flood Control Facility - built in 1971 on the East Branch Brandywine Creek in Honey Brook Township.
- Marsh Creek Reservoir and State Park - built in 1973 on Marsh Creek in the East Branch Brandywine watershed in Upper Uwchlan Township.
- Beaver Creek Regional Flood Control Facility - built in 1975 on Beaver Creek in the East Branch Brandywine watershed in East Brandywine Township.
- Barneston Regional Flood Control Facility - built in 1983 on the East Branch Brandywine Creek in Wallace Township.
- Hibernia Regional Flood Control Facility - built in 1994 on Birch Run in the West Branch Brandywine Creek watershed in West Caln Township.

Together, these structures provide 5.5 billion gallons of total flood storage capacity to protect thousands of lives and properties downstream. This amount of water could fill the entire Lincoln Financial Field stadium, home of the Philadelphia Eagles, seven times.

Struble Lake in Chester County, PA

However, as storms become more frequent and intense and development continues throughout the watershed, the challenge of flooding continues. According to the National Oceanic and Atmospheric Administration (NOAA) Storm Events Database, since 1996 (two years after the construction of the final regional flood control facility), flood events have resulted in two deaths and more than $56 million in property damage in Chester County, PA. The remnants of Hurricane Ida alone, which occurred September 1-2, 2021, caused nearly $45 million in damage to private property and public infrastructure in southeastern Pennsylvania and northern Delaware. Several communities within the watershed are still actively recovering from Ida.

To address these longstanding challenges, the Chester County Water Resources Authority (CCWRA), Brandywine Conservancy & Museum of Art (BC), University of Delaware Water Resources Center (UDWRC), and Delaware County, PA have conducted a flood study of the Brandywine Creek and its tributaries in Chester County, PA and the state of Delaware. This study builds upon the 2017 Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) updates and flood zone maps revisions for the region by incorporating updated land use data and climate model projections with hydrologic and hydraulic computer modeling.

The project analyzes the Brandywine Creek during intense storm and flooding events in order to produce an actionable suite of flood mitigation recommendations. This report provides a summary of the research and community outreach conducted, along with proposed implementation strategies to address future intense storm events and flooding throughout the watershed.

The Brandywine Flood Study included the following key elements:

1) *Flood Working Group:* Identify representatives from the public (focus on municipal governments), private, and nonprofit entities to serve on a Flood Working Group to inform

and advise on the initiative. Conduct public outreach meetings. Develop a website to organize and distribute GIS data.

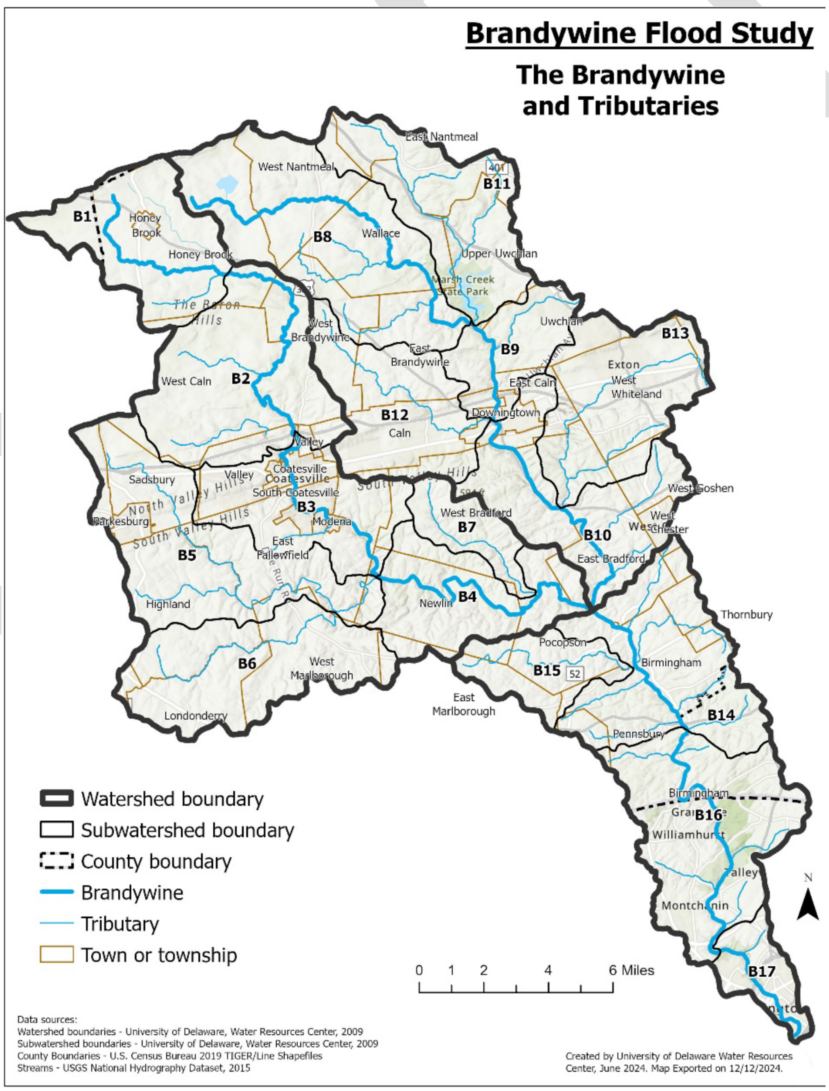
2) *Flood Identification:* Identify and map chronic flooding areas through the review of literature from FEMA, US Army Corps of Engineers (USACOE), U.S. Geological Survey (USGS), Delaware Department of Natural Resources and Environmental Control (DNREC), Pennsylvania Department of Environmental Protection (PADEP), CCWRA, and the media. Conduct field reconnaissance to field survey and map flood areas.
3) *Storm Event Analysis:* Develop a series of storm events using historical records at precipitation gages in Chester County to analyze hydrologic and hydraulic models. Use historical storm event analysis to develop storm events representing potential increases in intensity and duration of future events for the models.
4) *Hydrologic Model:* Utilize U.S. Department of Agriculture (USDA) Technical Release 55 (TR-55) hydrologic models and ArcView GIS to delineate watersheds/subwatersheds, incorporate USGS stream gages, stream/storage routing, and conduct existing/proposed (i.e., with flood solutions) conditions modeling for the 2-, 10-, 50-, 100-, 500-, 1000-year, and storm of record flood frequency scenarios. The scenarios incorporated projections related to climate change and the potential effects of future development throughout the watershed.
5) *Hydraulic Model:* Conduct field survey and utilize existing USACOE HEC-RAS hydraulic models and FEMA flood profiles for the mainstem, east and west branches, and tributaries of the Brandywine Creek to evaluate existing flooding conditions and perform proposed future conditions modeling.
6) *Flood Relief Analysis:* For areas with chronic flooding or significant obstructions, perform flood control analysis using hydrologic/hydraulic models and assess opportunities for structural and non-structural mitigation projects.
7) *Public Engagement:* Solicit public input on flooding hot spots, areas of concern, and ideas for future solutions through multiple avenues, including live and pre-recorded presentations, web-based surveys, an interactive flood mapping tool, and community listening sessions in key areas throughout the watershed.
8) *Municipal Outreach:* Meet with staff and officials from each municipality in the watershed to gather feedback on localized flooding challenges as well as ongoing/planned efforts to address them.

This study was funded through grants from FEMA, and Chester and Delaware Counties in Pennsylvania. The primary authors of this report are CCWRA, BC, and UDWRC. Multiple project partners have contributed significantly to the report by providing data, feedback, mapping support, written content, and technical review at all stages of the project. In addition to the primary authors, the Brandywine Flood Study partners include the Stroud Water Research Center, West Chester University, and Meliora Design. The Brandywine Flood Study Technical Advisory Committee includes government officials, nonprofit organizations, and private entities who provided continuous feedback and expertise throughout the project. Community members throughout the Brandywine provided the project team with meaningful input and have contributed significantly to inform and advise the project. This report was made possible by the robust support of this broad network of engaged stakeholders.

Chapter 2: Current Watershed Conditions

The Brandywine watershed is one of the most historic small watersheds in the nation. It is part of the ancestral homelands of the Lenni Lenape, nestled within two of the original thirteen U.S. colonies. The area boasts a rich agricultural heritage and is home to early mills which helped to power the American Industrial Revolution. The watershed spans 325 square miles (sq. mi.), of which 303 sq. mi. (93%) are in Pennsylvania and 23 sq. mi. (7%) are in Delaware. It is currently home to more than 265,000 people (U.S. Census 2020).

The Brandywine Creek is comprised of three main branches: the Main Stem, running from the mouth at Wilmington, Delaware, north into Pennsylvania; the East Branch, from Pocopson through the Borough of Downingtown to the headwaters east of the Borough of Honey Brook in Chester County Pennsylvania; and the West Branch, running through the City of Coatesville to the headwaters south of Honey Brook. The watershed includes tributaries which define 17 distinct sub-watersheds.



The Brandywine watershed begins near the Welsh Mountains along the northern border between Lancaster and Chester Counties, at an elevation of over 1,000 feet. From its headwaters, the Brandywine Creek flows for more than 40 miles down to its confluence with the Christina River in Delaware.

For thousands of years, the watershed's rolling hills and stream valleys have been part of the ancestral homelands of the Lenni Lenape. Later in its history, the watershed supported colonial populations, who took advantage of the fertile soils and ample waterpower for farms and mills. The area played an important role in the American Revolution, as the location of the Battle of the Brandywine. Industrialization in this region of the country began in the early 1800s with the development of textile and powder mills along the Brandywine Creek fall-line, and later with steel mills in the central Great Valley at Coatesville. Today, a mix of residential, commercial, and industrial development forms the basis for growing communities and significant economic activity.

As of the 2020 U.S. Census there were more than 265,000 residents in the Brandywine watershed, with 222,000 (84%) residing in Pennsylvania, and nearly 43,000 (16%) in Delaware. The population is concentrated in the urbanized central portion of the watershed, particularly in the areas surrounding the Borough of West Chester and along the Great Valley corridor, and in the City of Wilmington near the mouth of the Brandywine. The more rural areas in the headwaters near Honey Brook, and the West Branch below Coatesville are less densely populated. The population of the watershed has been steadily growing in recent decades, reflecting trends in Chester, Delaware, and New Castle Counties. Between 2010 and 2020 the watershed saw a net increase of nearly 15,000 residents (5.9%) including a 1.7% increase (700 people) in Delaware and a 6.8% increase (14,000 people) in Pennsylvania.

Land use in the Brandywine watershed is roughly equally divided among developed, agricultural, and forested areas. Agriculture predominates in the norther portion of the watershed, near the headwaters of the East and West Branches. Urban development is focused in the Great Valley along the Route 30 corridor, and around the City of Wilmington, while less dense mixed residential and commercial development occurs in the suburban areas beyond those urbanized centers.

Land use has a large effect on water quality of waterways, and of volume of stormwater runoff. Areas of highly developed land will tend to generate more runoff, resulting in water quality impacts and flooding potential. Impervious cover in the watershed occurs at the highest levels where there is concentrated residential, commercial, or industrial development. The urbanized areas around West Chester, the Route 30 corridor in the Great Valley, and in Wilmington thus have the greatest amount of imperviousness. The sub-watersheds of the former two areas have seen increases in imperviousness of between 12% and 17% in the period 2001 to 2021, while Wilmington has experienced a 45% increase in imperviousness over the same period.

Chapter 3: Historic Flooding Challenges

Records of flooding in the Brandywine Valley date back to January 1839 (USACOE, 1963). During that winter storm, the main stem of the Brandywine rose dramatically and all but two of the bridges across the creek were swept away. Since then, dozens of flood events have impacted communities across the watershed. Tropical Storm Agnes produced over seven inches of rain on the area between June 20-25, 1972 and resulted in a flood crest elevation of 167.0 feet in Brandywine Creek at Chadds Ford, PA. Prior to Agnes, the previous flood of record occurred on March 5, 1920 and had a crest elevation of 165.5 ft. Agnes was considered the highest flood of record in the watershed until Hurricane Ida in 2021.

In response to these severe storms (as well as growing water supply demands and drought concerns), in the 1950s, local, state, and federal partners active in the watershed collaborated on the development of the Brandywine Watershed Work Plan. The most significant outcomes of the plan's implementation include the construction of five major flood control structures in the upper reaches of the watershed. These facilities were completed between 1971 and 1996. While these structures provide significant protection for downstream communities during storms, they are not a cure-all, particularly as they only manage water from the drainage area above the structure itself. Since the final flood control structure was built in the mid-1990s, numerous floods have negatively impacted communities across the watershed. These include, but are not limited to:

- Hurricane Floyd in September 1999
- Multiple severe storms in July 2003
- Tropical Storm Henri in September 2003
- Tropical Depression Ivan in September 2004
- Tropical Depression Frances in September 2004
- Hurricane Jeanne in September 2004
- Hurricane Katrina in September 2005
- Severe storms in June 2006
- Hurricane Irene in August 2011
- Tropical Storm Lee in September 2011
- Hurricane Sandy in October 2012
- Hurricane Ida in September 2021

Hurricane Ida made landfall in Louisiana on Sunday August 29, 2021, with winds of up to 150 miles per hour (mph). The storm's remnants reached the Brandywine watershed three days later on Wednesday, September 1, 2021. Rainfall intensity varied throughout the watershed as well as over the course of the day when Hurricane Ida passed over the watershed. Ida dropped 7.3 inches of rain at the City of Coatesville and 8.2 inches at Downingtown Borough over the duration of the storm. However, most of the rainfall occurred in a 6-hour window. The maximum rainfall recorded in the 6-hour timeframe at the USGS gage in Modena Borough exceeded NOAA's estimate for the 1,000-year

What does the term "100-year flood" really mean?

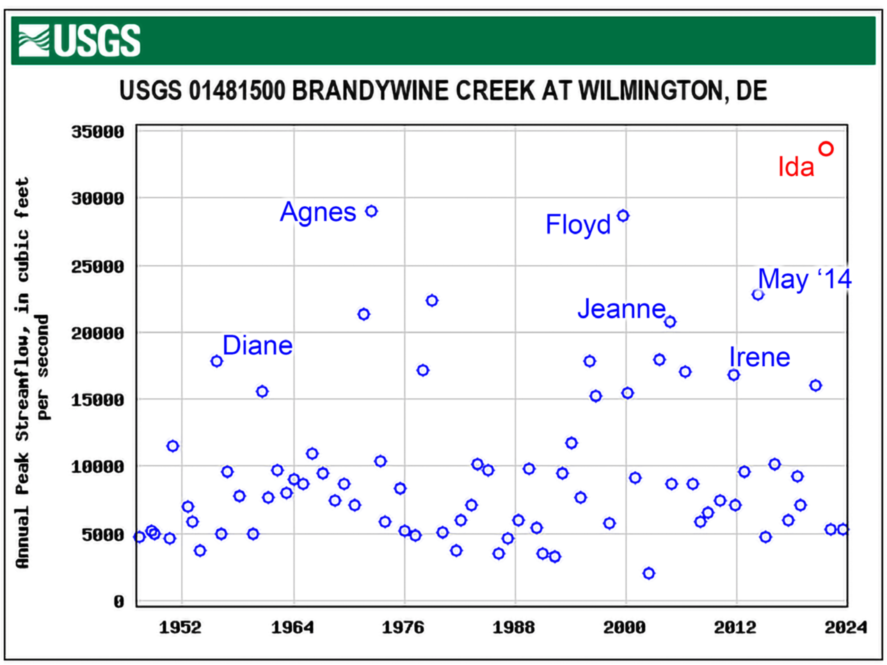
It doesn't actually refer to a flood that can happen only once every 100 years.

Instead, it is the level of flooding that has a 1% chance (or once out of 100 times) of occurring in any given year.

Sometimes, this is referred to as the "1% Annual Chance" flood. This term can be used interchangeably with the "100-year" flood or storm.

storm (6.93 inches in 6 hours). Most other sites in the upper Brandywine Creek watershed exceeded the 200-year event.

While rainfall totals during Ida were less in the lower Brandywine watershed, flooding in the upper reaches was exacerbated by the inherently steep Piedmont topography, which creates a funnel-like shape in the watershed closer to the Pennsylvania/Delaware state line. Floodwaters overtopped the USGS gage at Chadds Ford in the early morning hours of September 2, 2021. USGS used high water marks and other data to determine that Ida's peak discharge at that location was roughly 49,000 cfs. Based on this estimate, this would represent approximately an 800-year flood event (Stuckey et.al., 2023) and the highest flood recorded at the site in two centuries. While the wider, flatter floodplains in southern Chester County were able to attenuate some of the flood waters, the peak flow in the City of Wilmington reached 33,700 cfs on September 2, 2021. This is the highest flood discharge on record along the Brandywine Creek at Wilmington dating back to 1946, surpassing Hurricanes Agnes (29,000 cfs) in 1972 and Floyd (28,700 cfs) in 1999.



Since 1947, the Brandywine Creek at Wilmington, DE never exceeded 22,000 cfs until Hurricane Agnes in 1972 which resulted in flood flows of 29,000 cfs. However, flood flows from Hurricane Ida set a new recorded and were esimated by the U. S. Geological Survey to be 33,700 cfs.

Source: U. S. Geological Survey, Peak Streamflow for the Nation, USGS 01481500 Brandywine Creek at Wilmington, DE
https://nwis.waterdata.usgs.gov/nwis/peak?site_no=01481500&agency_cd=USGS&format=html

The results of this storm were catastrophic for many communities in the central and lower portions of the watershed. In some cases, individual recovery efforts are still ongoing. These impacts were the catalyst for this study, to provide recommendations for communities to be better protected and prepared for future storms.

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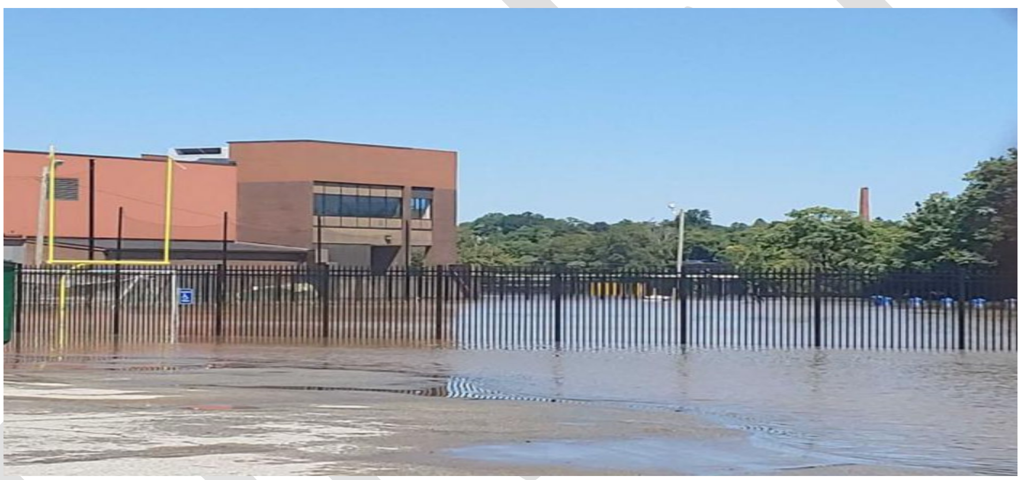
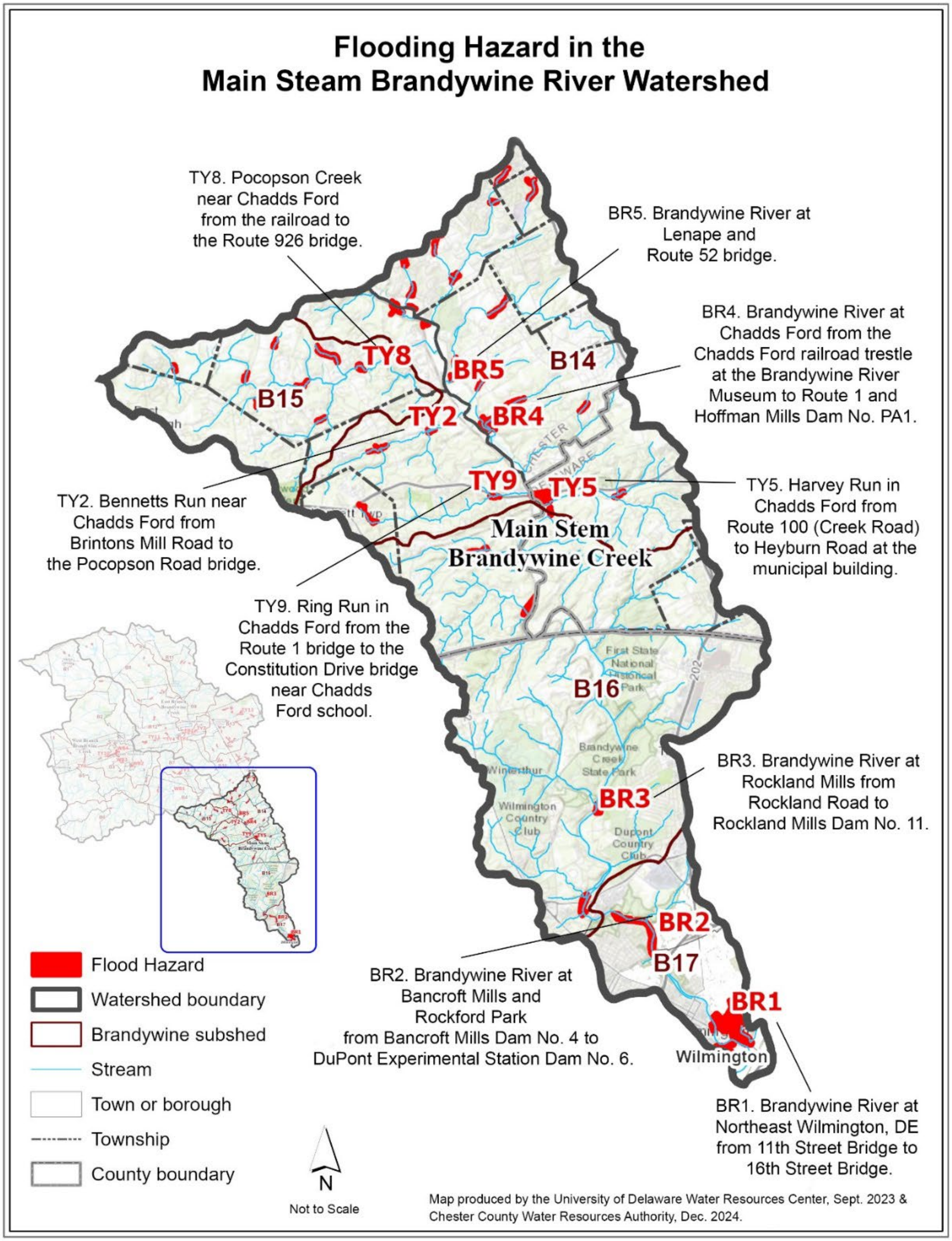
Hurricane Ida (September 2, 2021) high water mark at Howard High School in Wilmington, DE

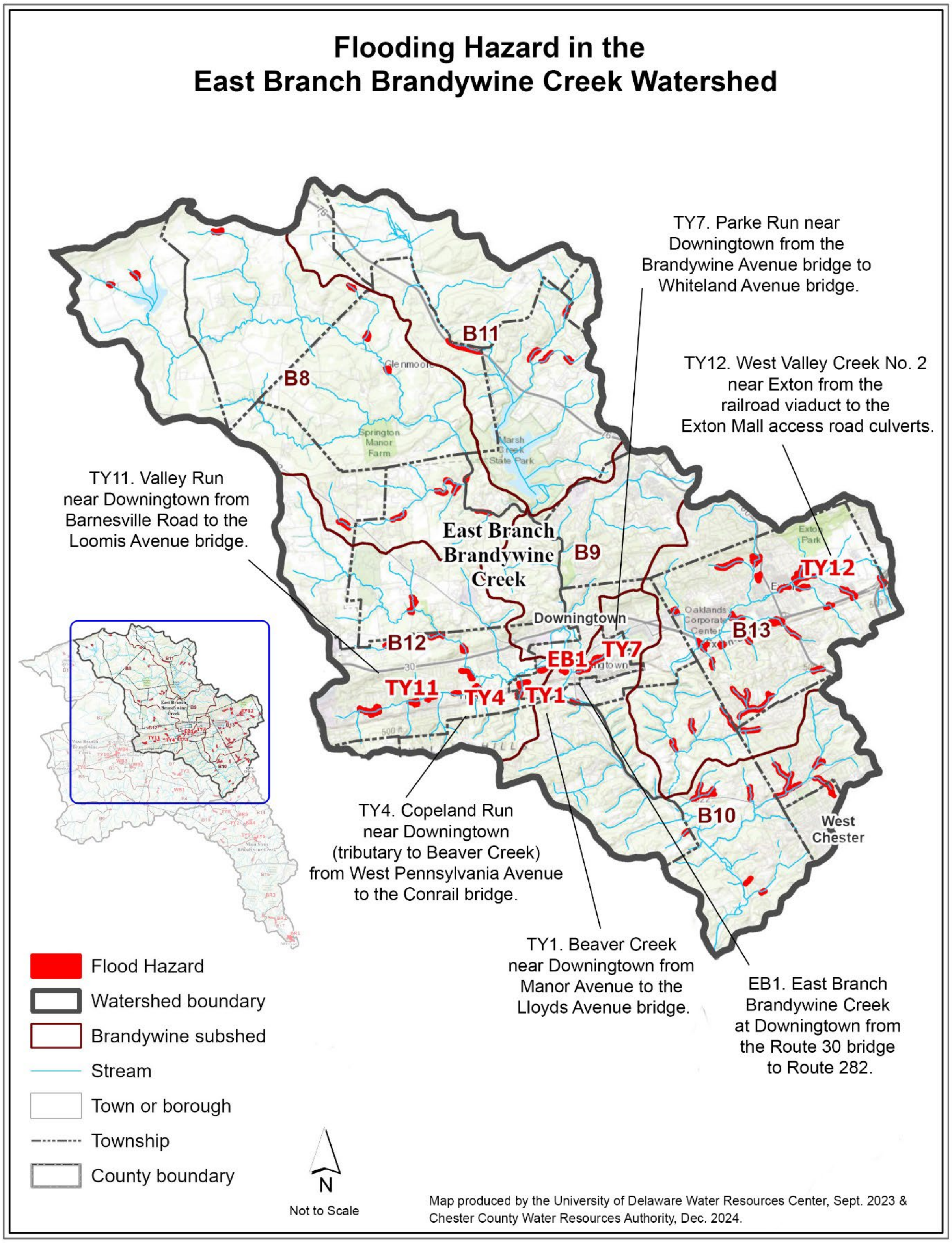


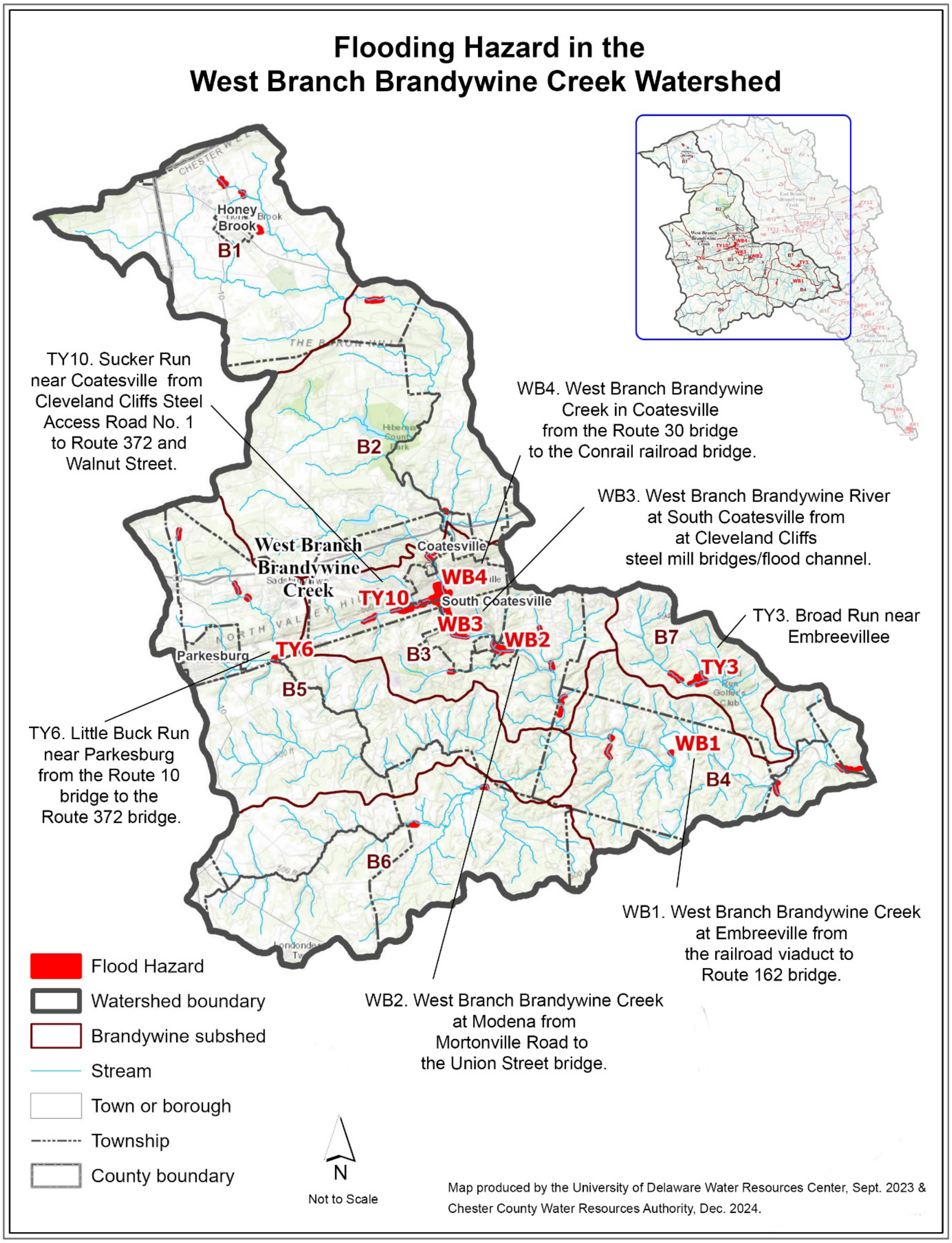
Hurricane Ida (September 2, 2021) high water mark at Brecks Mill Dam in Wilmington, DE

Areas of Recurrent Flooding

The Brandywine Creek and its tributaries typically experience out-of-bank flooding approximately once every three to five years. Areas of recurrent flooding have been identified through examining the FEMA floodplain maps and profiles, news media reports, and published reports by the USCOE, USGS, and others. The analysis identified twenty-two specific flood hazard areas – five along the mainstem of the Brandywine (BR), five along the East Branch (EB) and West Branch (WB), and twelve sites along the tributaries (TY).


Flooding Hazard in the
Main Steam Brandywine River Watershed
TY8. Pocopson Creek near Chadds Ford from the railroad to the Route 926 bridge.
BR5. Brandywine River at Lenape and Route 52 bridge.
BR4. Brandywine River at Chadds Ford from the Chadds Ford railroad trestle at the Brandywine River Museum to Route 1 and Hoffman Mills Dam No. PA1.
TY2. Bennetts Run near Chadds Ford from Brintons Mill Road to the Pocopson Road bridge.
TY5. Harvey Run in Chadds Ford from Route 100 (Creek Road) to Heyburn Road at the municipal building.
TY9. Ring Run in Chadds Ford from the Route 1 bridge to the Constitution Drive bridge near Chadds Ford school.
BR3. Brandywine River at Rockland Mills from Rockland Road to Rockland Mills Dam No. 11.
BR2. Brandywine River at Bancroft Mills and Rockford Park from Bancroft Mills Dam No. 4 to DuPont Experimental Station Dam No. 6.
BR1. Brandywine River at Northeast Wilmington, DE from 11th Street Bridge to 16th Street Bridge.
TY8
BR5
B14
B15
TY2
BR4
TY9
TY5
Main Stem
Brandywine Creek
B16
BR3
BR2
B17
BR1
Wilmington
First State National Historical Park
Brandywine Creek State Park
Winterthur
Wilmington Country Club
Dupont Country Club
202
Flood Hazard
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
Not to Scale
Map produced by the University of Delaware Water Resources Center, Sept. 2023 & Chester County Water Resources Authority, Dec. 2024.


Flooding Hazard in the
East Branch Brandywine Creek Watershed
TY7. Parke Run near Downingtown from the Brandywine Avenue bridge to Whiteland Avenue bridge.
TY12. West Valley Creek No. 2 near Exton from the railroad viaduct to the Exton Mall access road culverts.
TY11. Valley Run near Downingtown from Barnesville Road to the Loomis Avenue bridge.
TY4. Copeland Run near Downingtown (tributary to Beaver Creek) from West Pennsylvania Avenue to the Conrail bridge.
TY1. Beaver Creek near Downingtown from Manor Avenue to the Lloyds Avenue bridge.
EB1. East Branch Brandywine Creek at Downingtown from the Route 30 bridge to Route 282.
B8
B9
B10
B11
B12
B13
TY1
TY4
TY7
TY11
TY12
EB1
East Branch Brandywine Creek
Downingtown
West Chester
Glenmoore
Springton Manor Farm
Marsh Creek State Park
Oaklands Corporate Center
Exton Park
Flood Hazard
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
Not to Scale
Map produced by the University of Delaware Water Resources Center, Sept. 2023 & Chester County Water Resources Authority, Dec. 2024.


Flooding Hazard in the
West Branch Brandywine Creek Watershed
TY10. Sucker Run near Coatesville from Cleveland Cliffs Steel Access Road No. 1 to Route 372 and Walnut Street.
WB4. West Branch Brandywine Creek in Coatesville from the Route 30 bridge to the Conrail railroad bridge.
WB3. West Branch Brandywine River at South Coatesville from at Cleveland Cliffs steel mill bridges/flood channel.
TY3. Broad Run near Embreevillee
TY6. Little Buck Run near Parkesburg from the Route 10 bridge to the Route 372 bridge.
WB1. West Branch Brandywine Creek at Embreeville from the railroad viaduct to Route 162 bridge.
WB2. West Branch Brandywine Creek at Modena from Mortonville Road to the Union Street bridge.
Honey Brook
B1
B2
B3
B4
B5
B6
B7
West Branch Brandywine Creek
Coatesville
South Coatesville
Parkesburg
TY10
TY6
TY3
WB1
WB2
WB3
WB4
Flood Hazard
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
Not to Scale
Map produced by the University of Delaware Water Resources Center, Sept. 2023 & Chester County Water Resources Authority, Dec. 2024.

Chapter 4: Engaging the Public and Key Watershed Stakeholders

From the commencement of the study, robust public engagement was a priority to ensure that the public's experience was documented and incorporated. The study aimed to offer a diversity of engagement options to receive feedback directly from within the communities that experience flooding impacts.

Aligned with the existing local efforts to address flooding within the community, multiple locations around the watershed were identified so that public meetings were easily accessible by community members. Public meetings were held in the City of Coatesville, Downingtown Borough, Chadds Ford Township, and the City of Wilmington. These sessions combined informational presentations with active listening and information gathering from attendees.

Additional methods of encouraging public engagement in the planning process included:

- **Public Outreach Events** – Attendance and promotion of the flood study to over 1,000 individuals at over 30 partner events throughout the bi-state region incorporated presentations, flyers, QR codes, active tabling, focused meetings and targeted discussion regarding the Brandywine Flood Study and access to the Public Survey and Interactive Flood Map.

- **Flood Study Website** –The study launched a website that has been an essential tool for keeping partners and the public informed and updated throughout the study. The Brandywine Flood Study website (www.brandywine.org/conservancy/brandywine-flood-study) (Appendix 7) includes: links to the Public Input Survey and the Interactive Flood Map; frequently asked questions (FAQs); link to the Flood Study Communications Toolkit; previous and upcoming public meetings; among other information and resources.

- **Flood Study Communications Toolkit** – the bundle of resources includes everything that partners and the public may need to promote and increase engagement with the study from residents and on social media, including a general information flyer, a flood study survey flyer with a QR code that links directly to the survey, a sample flood study article, and flood study graphics including partner logos and a geographic coverage map.

- **Survey for Public Engagement and Feedback** – A 22-question survey was distributed by partners in public platforms such as Facebook, the Brandywine Flood Study website, five public meetings, and 35 public outreach events. The survey garnered 175 responses, and select questions were extracted and developed into posters for interaction with attendees at the public meetings. The survey results and comments are included in the Appendix 6 of the full report.

Only **28%** report having flood insurance coverage

79% have had flooding greatly affect their ability to travel for work, recreation, and essential services

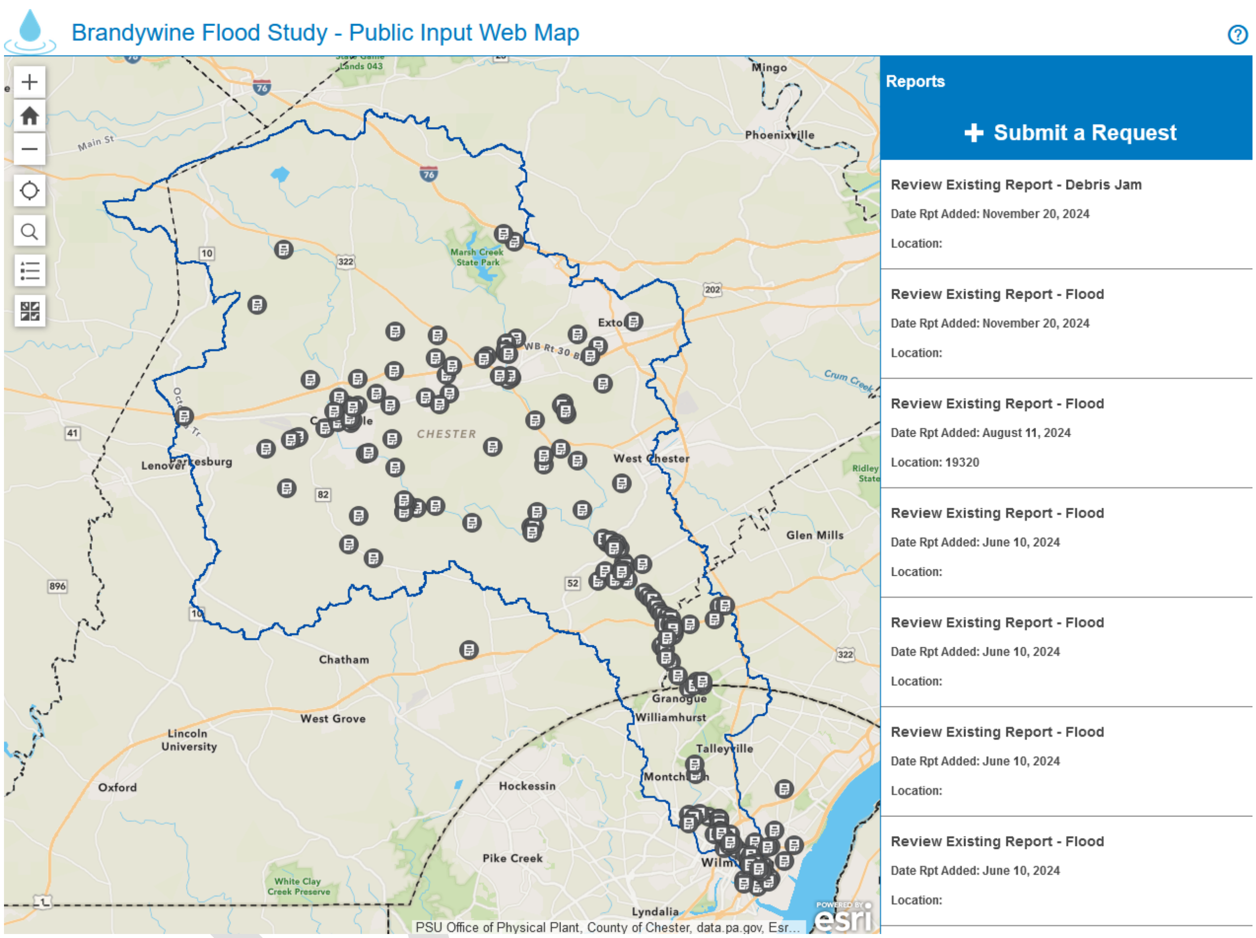
51% have experienced property damage due to flooding

26% have experienced flood damage to their homes and **37%** experienced damage to other private property

More than 66% have experienced some degree of financial losses due to flooding

95% are worried about increased frequency and/or intensity of future flooding

- **Interactive Public Input Web Map** – Available on the Brandywine Flood Study website, the interactive map provides a platform for community members to report and view flood-related issues in the Brandywine watershed. Users can mark locations of concern, such as flood damage, infrastructure problems, or environmental impacts, on a shared map. Users can also directly add photos, videos and comments to the locations marked. This tool encourages collaboration and transparency by integrating public observations into the flood study, helping prioritize mitigation efforts (Appendix 6).



- **Media and Press Coverage** – Flood study efforts were supported by significant coverage from 20 local and regional media outlets, highlighting the study's crucial role in addressing flooding issues in the region and emphasizing the collaborative nature of the study between local governments, conservation organizations, and academic institutions.

- **Advisory Committee** – Assembled at the start of the project, the committee was open to anyone interested, and meetings were regularly attended by representatives and specialists from: municipalities, community groups, conservation organizations, county departments, federal and state agencies, water utilities, consultants, and other stakeholders. The Advisory Committee participants were engaged in their capacity as technical experts and stakeholders.

- **Municipal Outreach –** Forty five municipalities, which included flood study partners meeting with municipal staff from multiple departments, including executive and legislative officials, directors of public works, directors of emergency services and engineers, were engaged in the planning process. Outreach meetings, conducted from September 2023 through December 2024, included a set of guiding questions regarding specific impacts and locations of flooding for individual and recurrent flood events in order to identify potential solutions, resulted in the municipal inventory and assessment reports (Appendix 1).

Through vigorous and sustained efforts to engage the public and gain insight into localized flooding impacts, the flood study survey, Interactive Flood Map, ongoing public meetings, and continued initiatives to participate in public events, this study engaged with over 1,500 individuals to gather public comments and reports across all mediums. All findings from the public engagement efforts are included in Appendix 6. Below is a summary of selected public comments by prominent themes.

Communication and Safety

- Increased local notification systems and frequency of notifications before and during severe precipitation events.
- Uniform, simplified messaging about flood forecasts, risks, etc.
- More tools to make historical and projected flood information available, meaningful, and actionable for the general public.
- Additional support to emergency services to assist vehicles in unsafe flood situations.
- Additional and more rapid installation of barricades, signage, and communication prior to and during flood events of blocked or closed roadways.

"I found ReadyChesCo to be a valuable resource for getting updates and communications particularly in regards to flood prediction and extreme weather. I would like to encourage DelCo to deploy a similar system."

Structural Solutions

- Green stormwater infrastructure installed where impervious surfaces cannot be removed (roadways and existing development), coupled with education, signage and green stormwater infrastructure and landscaping installation guides for home and business owners.
- Ensuring disadvantaged communities are not left behind in future flood mitigation efforts.
- Evaluation and repair of municipal stormwater and sewer infrastructure systems.
- Evaluation, repair, and retrofits made to roadways, bridges and culverts that experience frequent flooding.

"Storm water management must include adequate, functioning stormwater retention basins."

Non-Structural Solutions

- Additional municipal comprehensive planning and required review of stormwater management plans with each development application.
- Prioritization of open space preservation in headwater regions as well as flood prone areas.
- Addition of flood-specific zoning ordinances and ensure compliance from proposed and existing development.

"Can we require developer regulations to be more stringent than the current 100-year flood maps?"

The feedback collected throughout the planning process underlines the interconnectedness of individual, community, and systemic responses in addressing flooding challenges. It also highlights the public's desire for collaborative, cost-effective, and environmentally sustainable solutions.

Chapter 5: Structural Recommendations

To address the scope and breadth of flooding challenges in the Brandywine watershed, a variety of structural solutions are necessary. Potential solutions vary in terms of scale, complexity, capacity, and expense, but each can play a role in mitigating the impacts of flooding in local communities. Once in place, structural solutions typically provide relatively immediate relief from flood risk to both people and property by physically manipulating the way water moves through the landscape. However, it is important to note that many of the structural solutions described here must be considered in terms of timeframe for implementation and their potential impacts both up and downstream, as to whether alleviation of flooding in one community may or may not exacerbate flooding in another.

The types of structural flood mitigation projects considered in this study include:

- Floodplain restoration
- Flood mitigation dry ponds
- Replacement, rehabilitation, or removal of bridges, culverts, or dams
- Modifications to existing flood control facilities and reservoirs
- Stormwater basin retrofits

Potential flood mitigation strategies were identified in each of the categories listed above. Generally, flood storage capacity and peak flow rate reduction were the primary factors that determined the study's recommendation for each project. Each category of structural solutions incorporated additional evaluation criteria, including existing and potential future risk to vulnerable populations and historically marginalized communities. The details for the project sites investigated are further discussed in the sections below. Additional local stormwater mitigation measures are recommended, however initial analyses were not included in this study.

Floodplain Restoration

Floodplains are nature's buffer zones between waterways and adjacent lands. They provide space for streams to rise and spread out of their channels, naturally slowing and storing flood waters. They also offer numerous other ecological benefits, including wildlife habitat, pollution filtering, and carbon sequestration. However, development in and around floodplains over the past hundred years has greatly compromised their functionality.

Plum Run in the lower Brandywine Creek watershed prior to restoration (photo courtesy of the Brandywine Red Clay Alliance)

Plum Run after restoration by the Brandywine Red Clay Alliance in 2021 (photo courtesy of the Brandywine Red Clay Alliance)

Two-dimensional (2D) HEC-RAS models were utilized to identify relatively flat and wide floodplain areas that may attenuate the flood waters along stream reaches, providing substantial flood storage. Along the 52.5 miles of the Brandywine and its tributaries, the floodplain area technically has 16.5 billion gallons of storage capacity.

The project team identified and assessed numerous sites in the watershed for floodplain restoration potential. Factors used to determine potentially viable projects included existing upstream structures, estimated cost of grading and hauling floodplain material, and downstream peak flow and volume reduction estimates. Where available, the models used bathymetry data, bridge and dam geometry from FEMA effective HEC-RAS models. The table below shows findings from initial analyses at these sites. Detailed results for each site can be found in Appendix 8.

Initial Analysis of Potential Floodplain Restoration Sites

Site	Municipality	Watershed	Concept	Determination
Brandywine Conservancy properties	Chadds Ford Township, PA	Brandywine Creek	Floodplain restoration/Legacy dam removal	Recommended
Mary Street Riparian Corridor	Downingtown Borough, PA	Beaver Creek	Floodplain/ Streambank restoration	Further analysis recommended
Valley Run/Beaver Creek Confluence	Caln Township, PA	Beaver Creek	Floodplain/Stream restoration	Further analysis recommended
Brandywine Picnic Park	East Bradford and Birmingham Townships, PA	Brandywine Creek (mainstem)	Floodplain restoration/ Storage capacity improvements	Not recommended - minimal impact
Johnsontown Park	Downingtown Borough, PA	East Branch Brandywine	Floodplain/Stream bank restoration	Not recommended - minimal impact
Parkside Soccer Fields	Downingtown Borough, PA	East Branch Brandywine	Floodplain/Stream bank restoration	Not recommended - minimal impact
Manor Road/Kings Highway	City of Coatesville, PA	West Branch Brandywine	Floodplain restoration/storage capacity improvements	Not recommended - minimal impact

Flood Mitigation Dry Ponds

Dry ponds, or detention basins, can detain flood waters to reduce peak flow rates. Typically for stormwater management, these basins capture water from storm events and then release water slowly to a stream or other waterbody or into the stormwater drainage system. A dry basin can capture and detain stormwater runoff to delay much of the runoff from reaching the stream during the rain event.

Several potential dry pond sites were identified and analyzed to determine their effectiveness for flood benefits. The following table summarizes the results from initial analyses at these sites. Details for each site can be found in Appendix 8 of the full report.

Initial Analysis of Potential Flood Mitigation Dry Ponds				
Site	**Municipality**	**Watershed**	**Concept**	**Determination**
Chester County Public Safety Training Campus	South Coatesville	West Branch Brandywine	Flood storage capacity improvements	Not recommended - minimal impact
Ingleside Golf Course	Caln	Beaver Creek	Flood storage capacity improvements	Not recommended - minimal impact
Route 113 clover leaf	Downingtown/East Caln	Beaver Creek	Flood storage capacity improvements	Not recommended - minimal impact
Paradise Valley Nature Area	East Bradford	Valley Creek	Flood storage capacity improvements/ diversion	Not recommended - minimal impact
East Fallowfield Park	East Fallowfield	Dennis Run	Flood storage capacity improvements	Not recommended - minimal impact
West Branch near Valley Station Road	Coatesville	West Branch Brandywine	Dry dam/flood storage capacity improvements	Not recommended - minimal impact
Buck Run near Laurel Forge Road	Newlin	Buck Run	Dry dam/flood storage capacity improvements	Not recommended - infeasible

Evaluation of Existing Flood Control Facilities

Historic floods along the Brandywine in the first half of the 20th century drove initial flood control strategies identified in the Brandywine Watershed Work Plan. Beginning in the 1950's, the Brandywine Creek Watershed Work Plan included 12 flood control projects and other conservation measures:

- Seven multi-purpose reservoirs (five for both flood control and water supply)
- Five flood control only projects
- Forested and agricultural actions to increase infiltration and reduce sedimentation

Chambers Lake/Hibernia Dam at Hibernia County Park in West Caln Township is a multi-purpose dam that provides flood control, water supplies and recreation.

After several amendments to the Plan, only five projects were constructed in the Upper Brandywine Watershed between 1970-1994:

1. Struble Dam - Flood Control, Fishing
2. Barneston Dam - Flood Control
3. Marsh Creek Dam - Water Supply, Flood Control, Recreation, Flow Augmentation
4. Beaver Creek Dam - Flood Control
5. Chambers Lake/Hibernia Dam on Birch Run - Water Supply, Flood Control, Recreation

This study conducted an initial assessment of additional flood storage potential at these five existing dams. Beaver Creek Dam and Chambers Lake/Hibernia Dam completed rehabilitation projects to meet current Pennsylvania Dam Safety standards in 2020 and 2022, respectively, and as the dams currently restrict discharge up to the 100-year storm, additional modifications to the structures were not identified during this study.

Beaver Creek Dam – Change of Operation to Provide Additional Flood Storage

Beaver Creek Dam was operated from 1992 to 2020 with an impoundment of approximately 7.2 million gallons within an 11-acre sediment pool. During rehabilitation work on the dam from 2021 to 2022, the reservoir was drained. As of 2024, the Chester County Water Resources Authority, has submitted an application to the Pennsylvania Department of Environmental Protection (PADEP) to change the operation of Beaver Creek Dam to a dry dam. This change in operation to a dry dam will provide additional flood storage upstream of the dam embankment where the normal impoundment has been dewatered. The change in operation also provides environmental benefits for wetlands and native wildlife habitat.

Beaver Creek Dam in East Brandywine Township before (with a 7.2 million gallon pool) and after (operating as dry dam with no permanent pool) the rehabilitation project, completed in 2022.

Barneston Dam Rehabilitation

Barneston Dam, one of the five flood control dams in the Upper Brandywine Creek watershed, is located in Wallace Township across the East Branch Brandywine Creek. The dam was built in 1983 by CCWRA and USDA Soil Conservation Service, now the Natural Resources Conservation Service (NRCS). Barneston Dam is owned and operated by CCWRA and provides flood protection for residents in Chester County.

- Current Conditions and Capacity - Barneston Dam is 43 feet high and is maintained as a "dry" dam, which means there is no lake or impoundment behind the dam during normal, sunny days. However, the dam detains flood waters flowing to the upper portion of East Branch Brandywine Creek during storm events that drain are constricted by the small size of the culvert spillway at Barneston Dam. This principal spillway is a four foot by four-foot box culvert at the same elevation as the stream.

  The dam has two additional spillways, a 240-feet wide concrete drop spillway approximately 33.5 feet above the stream, and a vegetated auxiliary spillway that is 39.5 feet above the stream. The flood storage pool to the crest of the concrete drop spillway is approximately 1,520 acre-feet (or 495 million gallons). From 1983 through 2024, there has never been any flow through these overflow spillways – all flood waters have been detained and routed through the four feet by four feet box spillway.

Barneston Dam in Wallace Township on the East Branch Brandywine Creek is a dry dam with a standard weir control on the auxiliary spillway

- <u>Potential Rehabilitation to Increase Flood Storage</u> - An initial engineering review and modeling evaluation identified an opportunity to reconstruct the 240-feet wide concrete drop spillway with a labyrinth weir with can provide additional flood storage between the 50-year and 100-year storm. By modifying the concrete drop spillway, the elevation of the weir may be elevated by a few feet to provide additional storage for large storms while still meeting state and federal regulations for dam safety. While Barneston Dam will remain a dry dam, this type of spillway modification may provide additional flood storage at Barneston Dam for storms between the 50-year and 500-year events.

A labyrinth weir constructed at Lake Williams Dam in York, PA (photo courtesy of Gannett Fleming)

- Potential Benefit – Based on initial modeling, the benefit of making this modification is to reduce the flood waters passing through Barneston Dam during very large storm events in the upper East Branch Brandywine Creek watershed. This modification will not reduce flood waters downstream of the dam for smaller storms, such as the 5-year, 10-year or 25-year events. However, for very large storms, the 50-year, 100-year, and 500-year storm events, this modification could either fully control or at least delay any additional flood waters continuing in the East Branch Brandywine Creek.

Summary Analysis of Proposed Labyrinth Weir Spillway and Drop Spillway Structure						
Parameter	**50-year Event**	**100-year Event**	**200-year Event**	**500-year Event**	**6-hour PMP Event**	**12-hour PMP Event**
Peak Outflow - Existing Drop Spillway (cfs)	598	1,297	2,229	3,871	28,667	29,457
Peak Outflow - Labyrinth Weir Spillway (cfs)	419	435	1,086	2,790	29,569	30,188
Relative Difference in Outflow	-30.1%	-66.5%	-51.3%	-27.9%	3.2%	2.6%

- Rehabilitation Process - Federal legislation, known as the Watershed Protection and Flood Prevention Act (PL-566), authorizes NRCS, who is the federal sponsor for Barneston Dam, to work with local communities and watershed project sponsors to address public health and safety concerns and potential environmental impacts of aging dams. NRCS provides technical and financial assistance in planning, designing, and implementing watershed rehabilitation projects. The first step in a Rehabilitation Project is to conduct a Planning Study to evaluate needs, objectives, and alternatives for potential rehabilitation of the dam.

Review of Other Dams and Reservoirs

Additional review is proposed for dam modification potential and/or operations at Struble Lake, Marsh Creek Reservoir, and Rock Run Reservoir. Struble Dam is owned and operated by Chester County Water Resources Authority, while the lake is managed by Pennsylvania Fish and Boat Commission. Marsh Creek Reservoir and Dam are owned and operated by the Pennsylvania Department of Conservation and Natural Resources. Rock Run Reservoir, owned and operated by Pennsylvania American Water Company, is a water supply reservoir. The project team will coordinate with the responsible agencies for review of dam operations.

Under the Brandywine Watershed Work Plan, several flood control projects were not built for various reasons including modifications or combinations of proposed projects, funding, and balancing flood control and water supply uses. Three tributaries in the Brandywine Watershed have been identified as flood prone during this study.

While the Work Plan's proposed Icedale Dam on the upper West Branch was not built (Chambers Lake/Hibernia Dam was built instead), a smaller dam was ultimately constructed on the site. This dam, which is owned by the Pennsylvania Fish and Boat Commission, has been breached for several years and West Brandywine Township is in the process of replacing the bridge just downstream from the dam. This study conducted initial assessments of the flood control potential at the dam, and while no currently viable opportunities were identified, future analysis may be warranted.

Preliminary data collection identified Sucker Run and Buck Run as flood prone tributaries. Detailed analyses were not included as part of this study, so further analyses for both tributaries are recommended.

Bridges, Culverts, and Dams – Stream Crossings

With the abundance of streams in the Brandywine watershed are the numerous bridges, culverts, and dams along the Brandywine and tributaries that may increase water surface elevations during large storm events. As the water infrastructure may require replacement or repair due to aging past their useful lives, natural hazard damage, or other factors, it provides opportunities for flood mitigation by evaluating potential to reconstruct inadequately-sized bridges and culverts or detain flood waters.

This study identified bridges, culverts, and dams throughout the watershed that hypothetically raise flood elevations for the 10-, 50-, 100-, and 500-yr flood, generally because the hydraulic openings of these structures may be too small to convey these design flows. In many cases, flood levels may backup upstream, overtop bridge decks, and take transportation arteries out of service. Addressing inadequately sized infrastructure generally requires rebuilding the structures with larger waterway openings, or removing them entirely.

The analysis examined close to 300 bridges, culverts and dams along the mainstem, East and West Branches of the Brandywine, and tributaries in Pennsylvania. As shown in the following table, of the 291 structures reviewed, 172, or 60%, were found to be undersized and/or insufficient, resulting in increased flood levels that negatively impact nearby and downstream communities. While some of the remaining 119 structures may be technically undersized to pass larger flood volumes, they may not create additional risk to people or buildings, and were not considered a priority for retrofitting. In fact, in some cases, these obstructions, typically in undeveloped areas, may provide flood control benefits for downstream communities by holding back and slowing the movement of flood waters.

Inadequately sized bridges, culverts, and dams in the Brandywine watershed			
Reach	**Total # of Bridges/ Culverts**	**# of Undersized Bridges/Culverts**	**% Undersized**
Mainstem Brandywine Del.	25	8	32%
Mainstem Brandywine Pa.	8	5	62%
East Branch Brandywine	37	20	54%
West Branch Brandywine	37	24	65%
Beaver Creek	16	9	56%
Brandywine Tributaries	168	106	63%
Total	**291**	**172**	**60%**

This study identified inadequately functioning infrastructure in the Brandywine watershed that are recommended to be prioritized for retrofits, reconstruction, or removal which include the following:

Main Stem Brandywine in Delaware

RM 7970. US Rte 13 Northeast Blvd raises the 100 yr and 500 yr flood elevation by 1.9 ft and 2.9 ft
RM 19996. Bancroft Mills Dam No. 4 raises the 100 yr and 500 yr flood elevation by 4.8 ft and 4.9 ft
RM 24490. DuPont Exp. Sta. Dam No. 6 raises the 100 yr and 500 yr flood elevation by 5.2 ft and 2.3 ft
RM 7.3. Rockland Road raises the 100 yr and 500 yr flood elevation by 4.5 ft and 5 ft

Main Stem Brandywine in Pennsylvania

RM 22413. Chadds Ford railroad viaduct raises the 100 yr and 500 yr flood elev. by 3.3 ft and 0.7 ft
RM 23660. US Rte. 1 Bridge raises the 100 yr and 500 yr flood elev. by 2.4 ft and 0.7 ft
RM 23743. PA Dam No. 1 at Hoffman's Mills raises the 100 yr and 500 yr flood elev. by 2.2 ft and 0.6 ft
RM 44561. Rte 52 bridge at Lenape raises the 500 yr flood elev.by 1.4 ft

East Branch Brandywine

RM 30958. Harmony Hill Road bridge raises the 50- and 100-yr flood elev. by 1.7 ft and 1.3 ft
RM 39913. Route 322 bridge raises the 100 yr and 500 yr flood elevation by 0.7 ft and 1.0 ft
RM 46852. Bus. Route 30/Lancaster Pike bridge raises the 10 yr and 50 yr flood elev. by 0.7 ft and 0.9 ft
RM 47407. Pennsylvania Ave. Bridge elevates the 100 yr and 500 yr flood elevation by 1.1 ft and 1.1 ft
RM 50557. Rte 282 bridge in Downingtown elevates the 100 yr and 500 yr flood elev. by 2.0 and 1.8 ft
RM 52186. US Rte 30 bridge above Downingtown raises the 100 yr and 500 yr flood elev. by 1.6 and 0.9 ft
RM 101800. Rte 282 bridge elevates the 100 yr and 500 yr flood elevation by 2.9 ft and 4.3 ft

West Branch Brandywine

RM 38567. Brandywine Railroad bridge elevates the 100 yr and 500 yr flood elev. by 2.0 ft and 8.1 ft
RM 40378. Embreeville Road/ raises the 100 year and 500 year flood elevation by 2.5 ft and 5.3 ft
RM 71551. Mortonville Road railroad bridge raises the 100 yr and 500 yr flood elevation by 2.8 ft and 1.3 ft
RM 73143. Union Street bridge in Modena raises the 10-yr and 50 yr flood elev. by 1.0 ft and 0.6 ft
RM 79889. Pipeline crossing in S. Coatesville raises the 100 yr and 500 yr flood elev. by 0.5 ft and 0.9 ft
RM 79956. First Street bridge raises the 100 year and 500 yr flood elevation by 1.3 ft and 1.4 ft
RM 81718. Cleveland Cliffs railroad bridge raises the 10 yr and 100 yr flood elev by 1.5 ft and 1.9 ft
RM 83283. Private Drive bridge raises the 50 yr and 100 yr flood elev. by 0.9 ft and 0.8 ft
RM 84010. Railroad Bridge raises the 50 year and 100 year flood elevation by 1.7 ft and 1.4 ft
RM 84755. Railroad Bridge raises the 50 yr and 100 yr flood elevation by 1.7 ft and 1.3 ft

RM 85003. Access Rd. bridge to Cleveland Cliffs elevates 100 yr and 500 yr flood elev.by 1.2 ft and 1.0 ft
RM 85175. Footbridge at Coatesville raises the 100 yr and 500 yr flood elevation by 1.2 ft and 0.7 ft
RM 86712. Bus. Rte 30 bridge in Coatesville elevates 100 yr and 500 yr flood elev. by 1.1 ft and 4.2 ft
RM 87569. Pedestrian path bridge elevates the 100 yr and 500 yr flood elevation by 3.4 ft and 1.9 ft
RM 87799. Coatesville dam elevates the 100 and 500 yr flood elevation by 0.7 ft and 1.6 ft
RM 88244. Eigencrest Rd. bridge raises the 100 yr and 500 yr flood elevation by 1.5 ft and 1.7 ft
RM 88570. Brandywine Railroad bridge elevates the 100 yr and 500 yr flood by 7.7 ft and 6.5 ft
RM 90014. Brandywine Railroad bridge raises the 100 yr and 500 yr flood elevation by 1.7 ft and 4.4 ft
RM 91123. Brandywine Railroad bridge raises the 100 yr and 500 yr flood elevation by 0.6 ft and 3.4 ft
RM 107051. Wagontown Road bridge elevates the 100 yr and 500 yr flood elevation by 4.4 ft and 4.6 ft

Beaver Creek
RM 1388. Manor Ave. bridge raises the 100 yr and 500 yr flood elevation by 1.0 ft and 2.1 ft
RM 6510. The Lloyd Ave. bridge raises the 100 yr and 500 yr flood elevation by 1.5 ft and 1.6 ft
RM 118. The Fisherville Road bridge elevates the 100 yr and 500 yr flood elevation by 3.6 ft and 3.4 ft
RM 2755. Private Driveway bridge raises the 100 yr and 500 yr flood elevation by 2.0 ft and 3.0 ft

Beaver Run
RM 10450. Fairview Road bridge raises the 100 yr and 500 yr flood elevations by 1.5 ft and 1.0 ft

Bennetts Run
RM 880. Brandywine Railroad bridge raises the 100 yr and 500 yr flood elevation by 2.5 ft and 1.0 ft
RM 4960. Chandler Road bridge raises the 100 yr and 500 yr flood elevation by 2.0 ft and 2.0 ft
RM 6720. Pocopson Road bridge raises the 100 yr and 500 yr flood elevations by 1.0 ft and 1.0 ft
RM 10920. Pocopson Road bridge raises the 100 yr and 500 yr flood elevations by 2.0 ft and 2.0 ft
RM 11880. Parkersville Road bridge raises the 100 yr and 500 yr flood elevations by 2.0 ft and 2.0 ft

Birch Run. No. 1
RM 9400. Martins Corner Road bridge elevates the 100 yr and 500 yr flood elevations by 3.0 ft and 2.5 ft

Birch Run No. 2.
RM 10340. Birch Run Road Bridge raises the 100 yr flood elevation by 1.5 ft
RM 12340. The dam raises the 100 yr flood elevation by 3.0 ft.
RM 12700. The Access Road bridge raises the 100 yr flood elevation by 2.5 ft

Boot Road Run.
RM 1600. Springton Lane Bridge raises the 100 yr and 500 yr flood elevation by 2.0 ft and 2.0 ft
RM 6200. Green Hill Road bridge raises the 100 yr and 500 yr flood elevation by 4.0 ft and 4.0 ft

Buck Run
RM 12700. Doe Run Road bridge raises the 100 yr and 500 yr flood elevations by 5.0 ft and 6.0 ft
RM 16600. Springdale Road bridge raises the 100 yr flood elevation by 9.0 ft and 500 yr flood elevation by 9.0 ft
RM 21200. Railroad Bridge raises the 100 yr and 500 yr flood elevations by 4.0 ft and 6.0 ft
RM 25100. Buck Run Road bridge raises the 100 yr and 500 yr flood elevations by 4.0 feet and 6.0 ft
RM 32300. The Railroad bridge raises the 100 yr and 500 yr flood elevations by 8.0 ft and 10.0 ft
RM 34800. West Glen Rose Road bridge raises the 100 yr and 500 yr flood elevations by 2.0 ft and 2.0 ft

Colebrook Run
RM 4500. Private Driveway bridge raises the 100 yr and 500 yr flood elevations by 2.5 ft and 2.0 ft
RM 5000. US Route 30 bridge raises the 100 yr and 500 yr flood elevations by 2.5 ft and 2.0 ft
RM 8050. Colebrook Road Bridge raises the 100 yr and 500 yr flood elevations by 4.5 ft and 4.5 ft

Copeland Run
RM 1150. West Pennsylvania Avenue Bridge raises the 100 yr and 500 yr flood elevations by 2.5 ft and 2.5 ft
RM 1950. West Lancaster Avenue bridge raises the 100 yr and 500 yr flood elevations by 2.5 ft and 3.5 ft
RM 2700. West Prospect Avenue bridge raises the 100 yr and 500 yr flood elevations by 1.0 ft and 3.5 ft
RM 3000. Railroad Bridge raises the 100 yr and 500 yr flood elevations by 14.0 ft and 15.0 ft

Cossart Run
RM 2360. Private Road bridge raises the 100 yr and 500 yr flood elevations by 1.5 ft and 1.5 ft

Craigs Run
RM 3100. Fairville Road bridge raises the 100 yr and 500 yr flood elevations by 5.0 ft and 5.0 ft

Doe Run
RM 9450. Doe Run Road bridge raises the 100 yr and 500 yr flood elevations by 1.5 ft and 1.5 ft
RM 16750. North Chatham Road bridge raises the 100 yr and 500 yr flood elevations by 2.5 ft and 2.0 ft
RM 19400. Springdale Road bridge raises the 100 year and 500 yr flood elevations by 6.5 ft and 4.5 ft
RM 33050. Creek Road bridge raises the 100 year and 500 yr flood by 1.0 ft and 1.5 ft

Indian King Run
RM 500. South Whitford Road bridge raises the 100 yr and 500 yr flood elevations by 1.5 ft
RM 7050. US Rte 30 bridge raises the 100 yr and 500 yr flood elevations by 3.0 ft and 3.5 ft
RM 7360. Railroad bridge raises the 100 yr and 500 yr flood elevations by 3.0 ft and 2.5 ft

Little Buck Run
RM 3300. Route 10 bridge raises the 100 yr and 500 yr flood elevations by 2.0 ft and 2.0 ft
RM 5000. Route 372 bridge raises the 100 yr and 500 yr flood elevations by 2.5 ft and 3.5 ft
RM 6250. Main Street bridge raises the 100 yr and 500 yr flood elevation by 5.0 ft and 6.5 ft
RM 7150. Route 10 bridge raises the 100 yr and 500 yr flood elevations by 1.0 ft and 6.0 ft
RM 8700. The north Church Street bridge elevates the 100 yr and 500 yr flood elevations by 2.5 ft and 2.0 ft.
RM 850. Abandoned Railroad bridge raises the 100 yr and 500 yr flood elevations by 1.5 ft and 2.5 ft
RM 1100. The railroad bridge elevates the 100 yr and 500 ft elevations by 1.5 ft and 2.5 ft
RM 2750. Chestnut Road bridge raises the 100 yr and 500 yr elevations by 2.0 ft and 1.0 ft

Pocopson Creek
RM 200. The Railroad bridge raises the 100 year and 500 yr flood elevation by 2.0 ft and 1.0 ft

Radley Run
RM 2500. The Railroad bridge elevates the 100 yr and 500 yr elevations by 2.0 ft and 1.0 ft
RM 3300. The Knolls Road bridge elevates the 100 yr and 500 yr flood elevations by 8.0 ft and 7.5 ft

Ring Run
RM 850. Chadds Ford School Rd bridge elevates the 100 yr and 500 yr flood elevation by 1.5 ft and 1.5 ft
RM 4100. US Route 1 bridge raises the 100 yr and 500 yr flood elevations by 4.0 ft and 4.0 ft
RM 4600. Legend Lane bridge elevates the 100 yr and 500 yr flood elevations by 3.0 ft and 2.0 ft
RM 4900. Constitution Drive bridge raises the 100 yr and 500 yr flood elevations by 3.5 ft and 2.0 ft

Rock Run
RM 700. Pedestrian Bridge raises the 100 yr and 500 yr flood elevations by 0.5 ft and 1.0 ft
RM 4000. Private Road bridge raises the 100 yr and 500 yr flood elevations by 3.0 ft and 1.5 ft

Shamona Creek
RM 180. Struble Trail footbridge raises the 100 yr and 500 yr flood elevations by 6.5 ft and 5.0 ft
RM 260. Footbridge raises the 100 yr and 500 yr flood elevations by 1.5 ft and 1.0 ft

Shiloh Run
RM 840. Conrail bridge raises the 100 yr and 500 yr flood elevations by 16.5 ft and 18.0 ft

Sucker Run
RM 3400. Access Road No. 2 elevates the 100 yr and 500 yr flood elevations by 3.5 ft and 3.5 ft
RM 4200. Access Road No. 3 elevates the 100 yr and 500 yr flood elevations by 6.0 ft and 7.5 ft
RM 7300. Railroad Bridge elevates the 100 yr and 500 yr flood ovations by 1.0 ft and 2.0 ft
RM 8750. South Park Avenue bridge raises the 100 yr flood elevation by 1.0 ft
RM 9400. Grove Avenue bridge elevates the 100 yr and 500 yr flood elevations by 1.5 ft and 1.0 ft
RM 10500. Route 372 bridge elevates the 100 yr and 500 yr flood elevations by 1.5 ft and 1.5 ft
RM 11800. Mount Carmel Street bridge raises 100 yr and 500 yr elevations by 3.0 ft and 3.0 ft
RM 13500. Red Road bridge elevates the 100 yr and 500 yr flood elevations by 3.0 ft and 3.0 ft

Taylor Run
RM 100. Highland Rd. bridge raises the 100 yr and 500 yr flood elevations by 5.5 ft and 6.0 ft

Two Log Run
RM 2700. Private road bridge raises the 10 yr and 50 yr flood elevations by 2.0 ft and 1.5 ft

Trib to East Branch Brandywine
RM 1000. Creek Road elevates the 100 yr and 500 yr flood elevations by 2.0 ft and 2.0 ft
RM 2200. Off Creek Road bridge elevates the 100 yr and 500 yr flood elevations by 2.0 ft and 1.5 ft

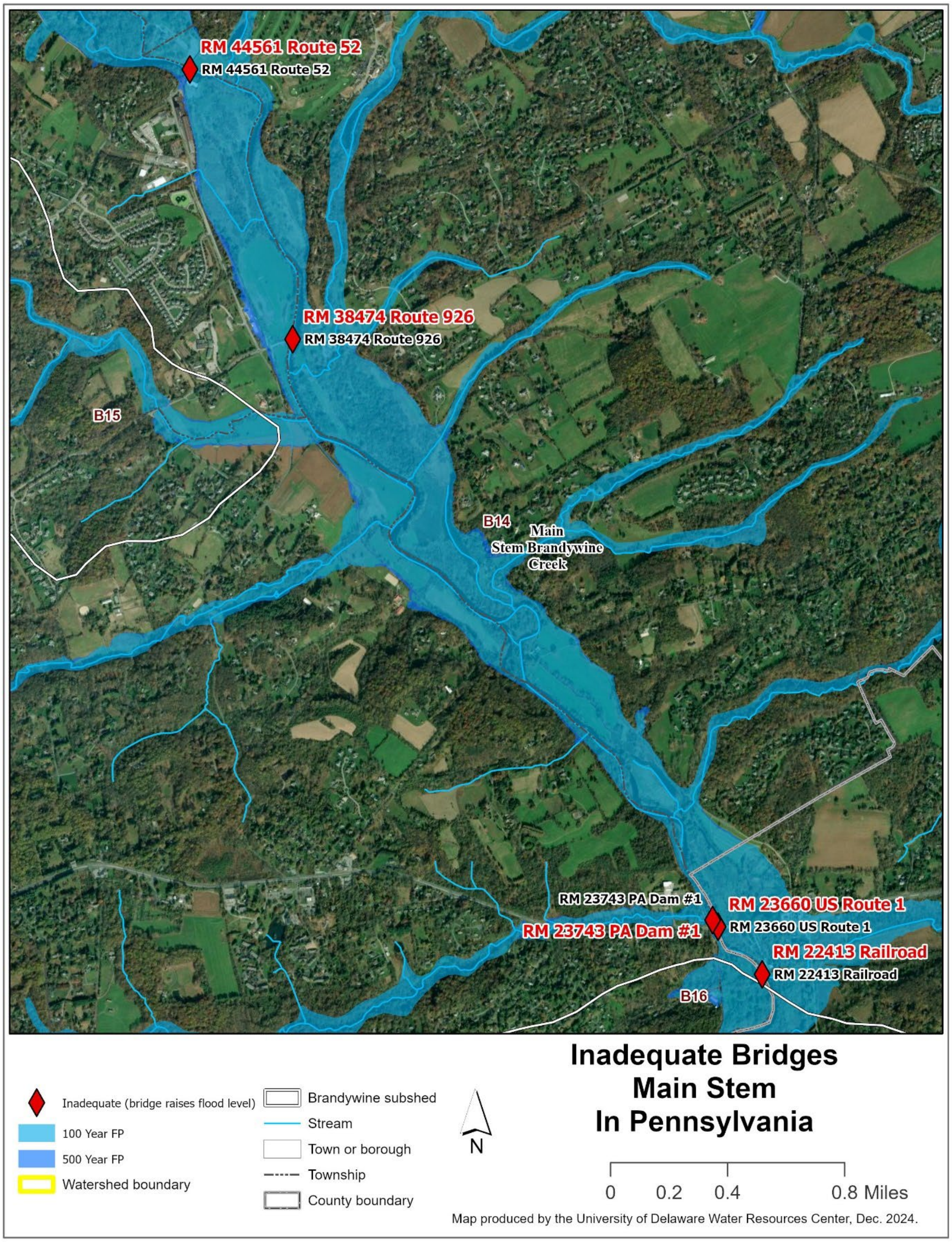
Trib to West Branch Brandywine
RM 1000. Private Road bridge elevates the 100 yr and 500 yr flood by 1.5 ft and 1.5 ft
RM 2600. Stillwater lane bridge raises the 100 yr and 500 yr flood elevation by 1.0 ft and 1.5 ft

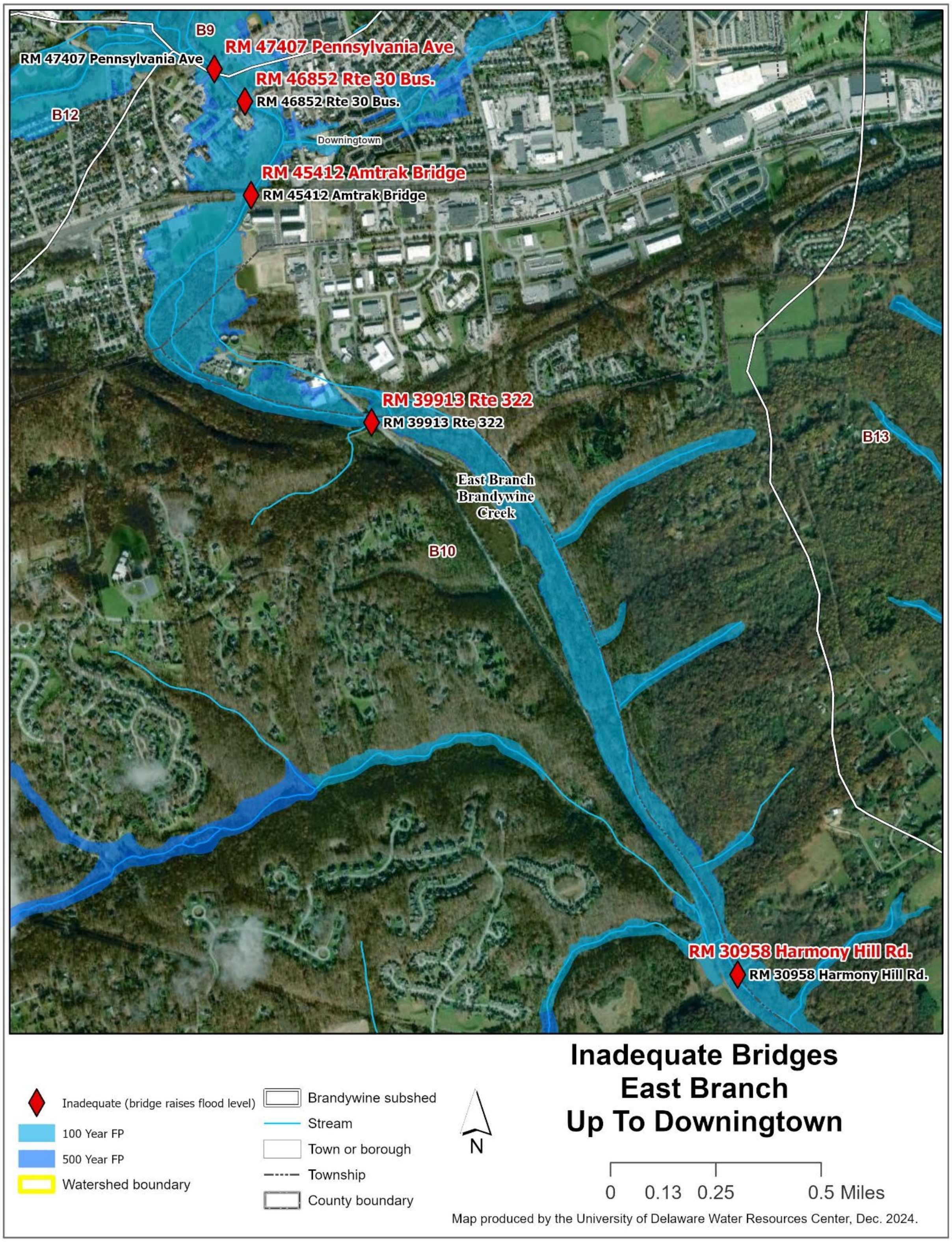
Valley Run
RM 4000. Bondsville Road bridge elevates the 100 yr and 500 yr elevations by 3.5 ft and 3.0 ft
RM 5100. Thornridge Drive Bridge elevates the 100 yr and 500 yr flood elevations by 1.0 ft and 1.0 ft
RM 8700. Bailey Road bridge elevates the 100 yr and 500 yr flood elevations by 2.0 ft and 2.0 ft
RM 9200. George Carlson Blvd bridge raises the 100 yr and 500 yr flood elevations by 2.0 ft and 2.5 ft
RM 10400. George Carlson Blvd. bridge raises the 100 yr and 500 yr flood elevations by 4.0 ft and 5.5 ft
RM 12400. Barleysheaf Road bridge elevates the 100 yr and 500 yr flood elevations by 1.5 ft and 2.0 ft
RM 13300. Loomis Avenue bridge elevates the 100 yr and 500 yr elevations by 1.0 ft and 1.0 ft
RM 14500. Setzer Avenue bridge elevates the 100 yr and 500 yr flood elevations by 1.0 ft and 1.0 ft

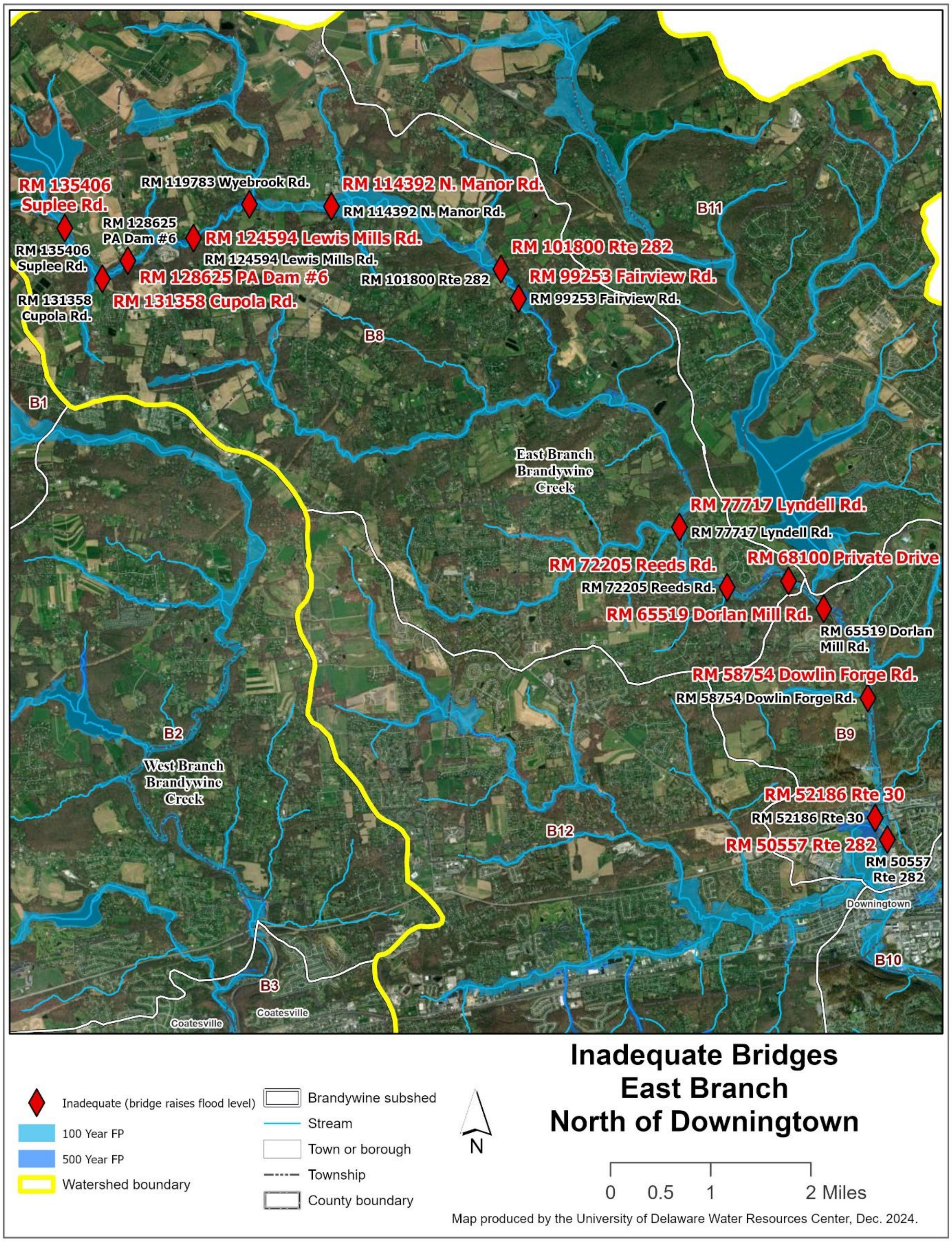
Valley Creek (East Branch Brandywine)

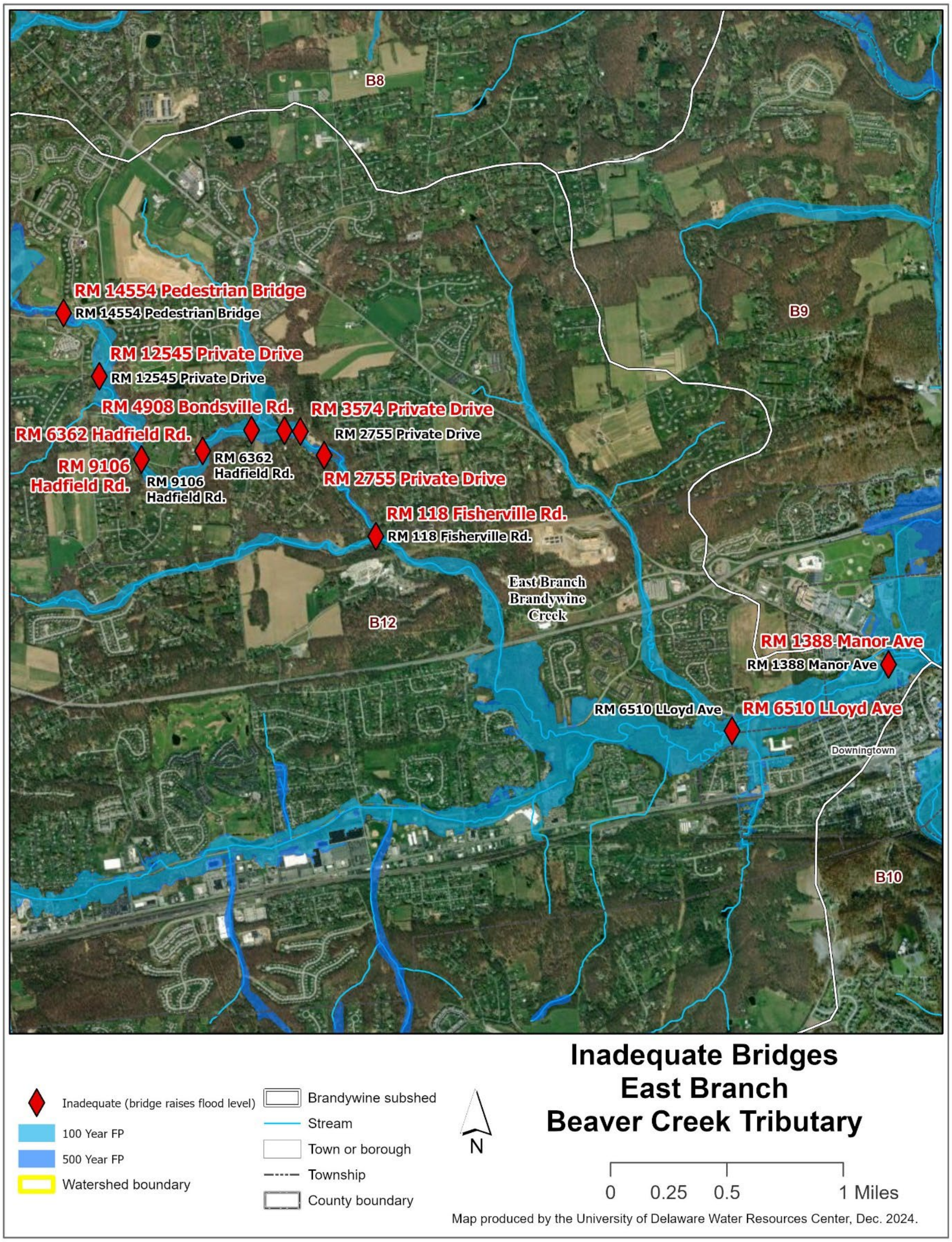
RM 13300. Route 100 bridge elevates the 100 yr and 500 yr elevations by 1.5 ft and 1.0 ft
RM 14100. Route 30 bridge elevates the 100 yr and 500 yr flood elevations by 1.0 ft and 1.0 ft
RM 14600. Exton Mall access bridge elevates the 100 yr and 500 yr flood elevations by 1.0 ft and 3.0 ft
RM 17500. Valley Road bridge elevates the 10 yr flood elevation by 2.0 ft
RM 17700. Locust Lane bridge elevates the 100 yr and 500 yr flood elevations by 1.0 ft and 0.5 ft
RM 18900. Ship Road bridge raises the 100 yr and 500 yr flood elevations by 2.0 ft and 2.0 ft
RM 20200. Exton Mall Access bridge raises the 100 yr and 500 yr flood elevations by 1.5 ft and 1.5 ft
RM 20400. Exton Mall Access Road bridge raises the 100 yr and 500 yr flood elevations by 1.0 ft and 1.0 ft
RM 21000. Chester Valley Trail bridge elevates the 100 yr and 500 yr flood elevations by 9.0 ft and 8.5 ft
RM 21500. Railroad Bridge raises the 100 yr and 500 yr flood elevations by 5.5 ft and 6.5 ft
RM 23500. Church Farm Lane bridge elevates the 100 yr and 500 yr flood elevations by 3.0 ft and 3.0 ft
RM 24600. Valley Creek Blvd. bridge elevates the 100 yr and 500 yr flood elevations by 4.5 ft and 5.0 ft

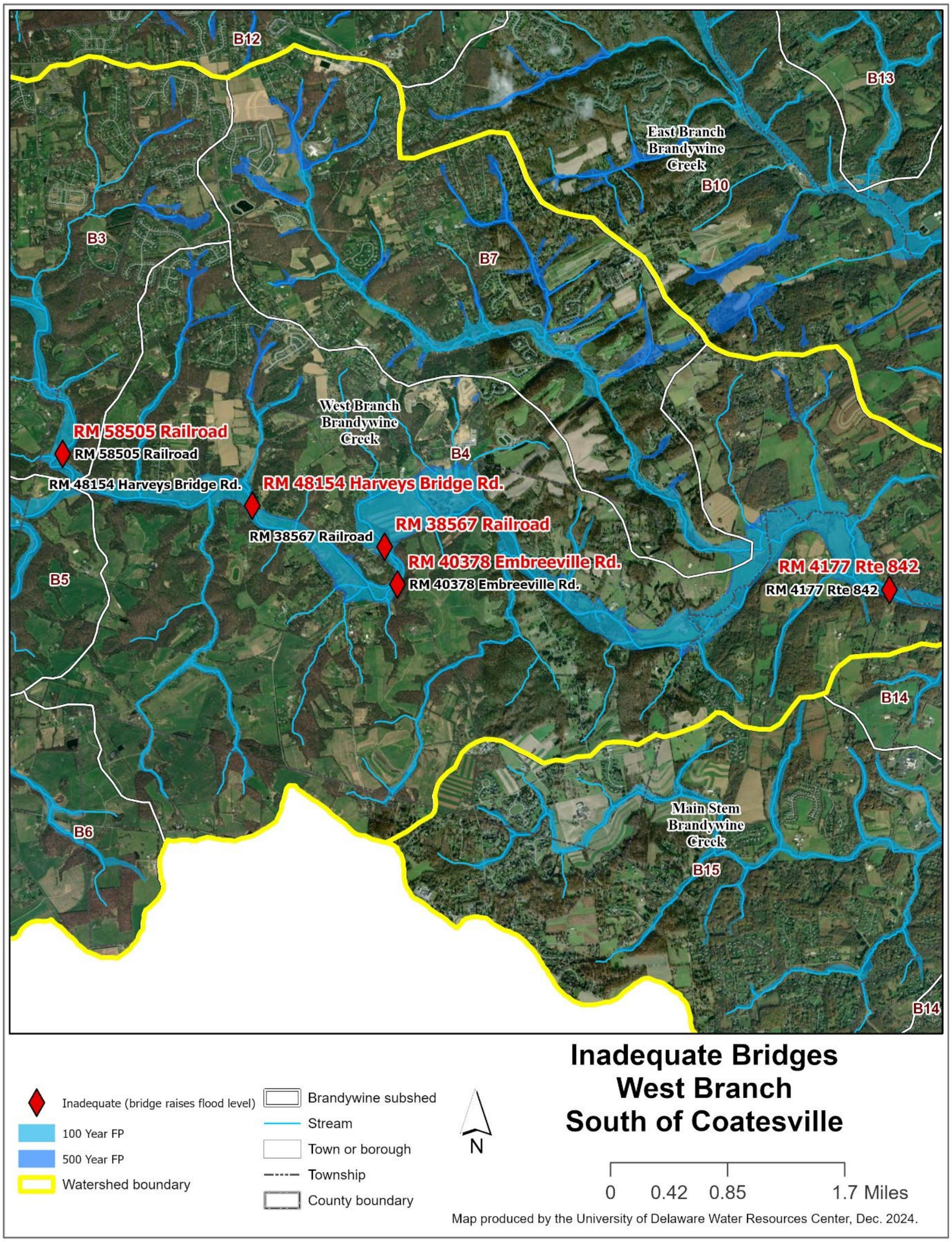

RM 7.3 Rockland Road
RM 7.3 Rockland Dam #11
RM 7.3 Rockland Dam #11
RM 7.3 Rockland Road
B16
Main Stem Brandywine Creek
RM 22976 Rockford Falls Dam #5
RM 22976 Rockford Falls Dam #5
RM 24490 DuPont Exp. Sta.Dam #6
RM 19996 Bancroft Dam #4
RM 19996 Bancroft Dam #4
RM 24490 DuPont Exp. Sta.Dam #6
B17
RM 16692 Footbridge
RM 16692 Footbridge
Wilmington
RM 9929 Jessup St./16th St. Bridge
RM 9929 Jessup St./16th St. Bridge
RM 7970 US Rte 13/NE Blvd
RM 7970 US Rte 13/NE Blvd
Inadequate Bridges
Main Stem
In Delaware
Inadequate (bridge raises flood level)
100 Year FP
500 Year FP
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
0
0.25
0.5
1 Miles
Map produced by the University of Delaware Water Resources Center, Dec. 2024.

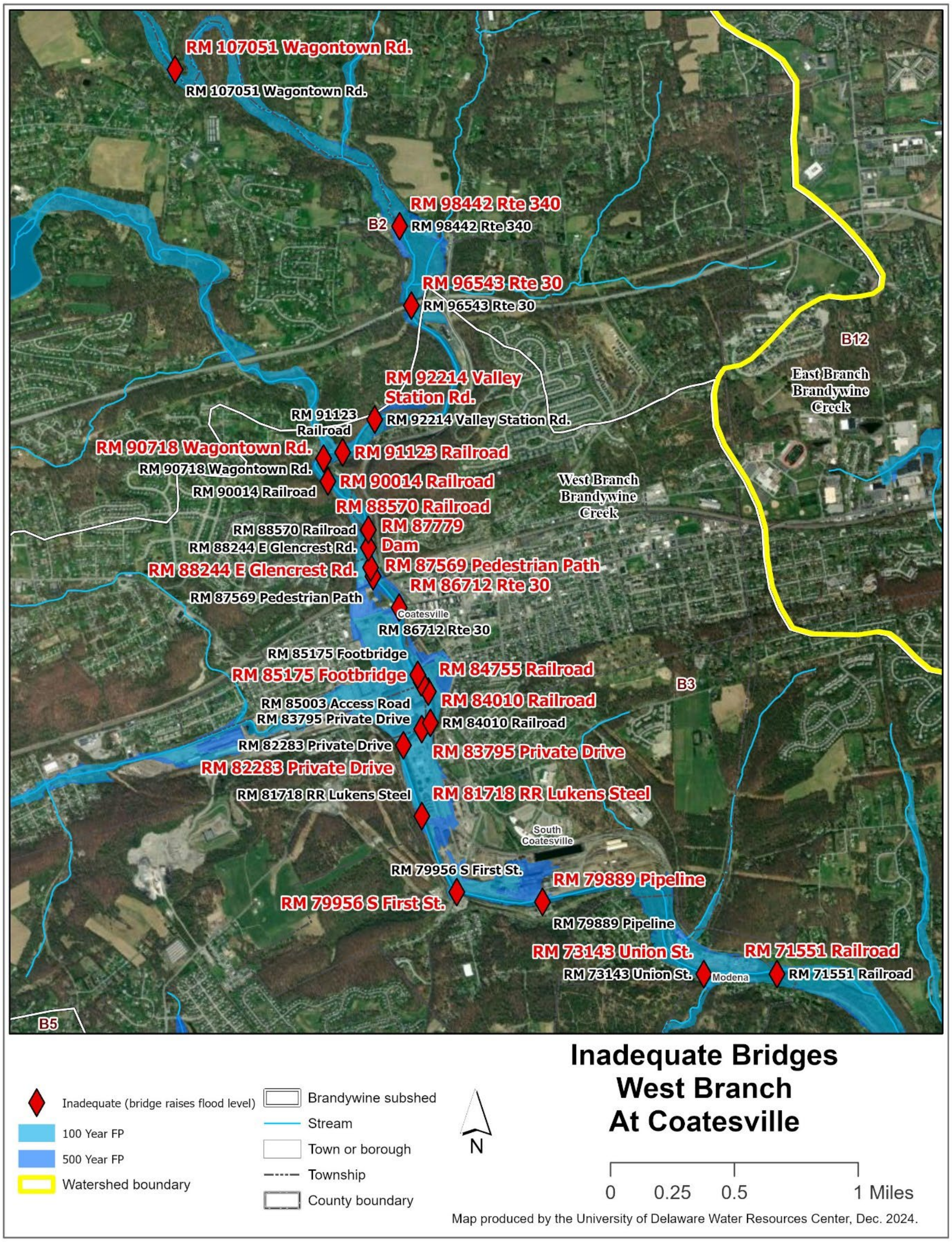

RM 44561 Route 52
RM 44561 Route 52
RM 38474 Route 926
RM 38474 Route 926
B15
B14
Main Stem Brandywine Creek
RM 23743 PA Dam #1
RM 23660 US Route 1
RM 23743 PA Dam #1
RM 23660 US Route 1
RM 22413 Railroad
RM 22413 Railroad
B16
Inadequate Bridges Main Stem In Pennsylvania
Inadequate (bridge raises flood level)
100 Year FP
500 Year FP
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
0 0.2 0.4 0.8 Miles
Map produced by the University of Delaware Water Resources Center, Dec. 2024.


B9
RM 47407 Pennsylvania Ave
RM 47407 Pennsylvania Ave
RM 46852 Rte 30 Bus.
RM 46852 Rte 30 Bus.
B12
Downingtown
RM 45412 Amtrak Bridge
RM 45412 Amtrak Bridge
RM 39913 Rte 322
RM 39913 Rte 322
B13
East Branch Brandywine Creek
B10
RM 30958 Harmony Hill Rd.
RM 30958 Harmony Hill Rd.
Inadequate (bridge raises flood level)
100 Year FP
500 Year FP
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
Inadequate Bridges
East Branch
Up To Downingtown
0
0.13
0.25
0.5 Miles
Map produced by the University of Delaware Water Resources Center, Dec. 2024.


RM 135406 Suplee Rd.
RM 119783 Wyebrook Rd.
RM 114392 N. Manor Rd.
RM 114392 N. Manor Rd.
RM 128625 PA Dam #6
RM 124594 Lewis Mills Rd.
RM 124594 Lewis Mills Rd.
RM 135406 Suplee Rd.
RM 128625 PA Dam #6
RM 101800 Rte 282
RM 101800 Rte 282
RM 99253 Fairview Rd.
RM 99253 Fairview Rd.
RM 131358 Cupola Rd.
RM 131358 Cupola Rd.
B11
B8
B1
East Branch Brandywine Creek
RM 77717 Lyndell Rd.
RM 77717 Lyndell Rd.
RM 72205 Reeds Rd.
RM 72205 Reeds Rd.
RM 68100 Private Drive
RM 65519 Dorlan Mill Rd.
RM 65519 Dorlan Mill Rd.
RM 58754 Dowlin Forge Rd.
RM 58754 Dowlin Forge Rd.
B9
B2
West Branch Brandywine Creek
RM 52186 Rte 30
RM 52186 Rte 30
B12
RM 50557 Rte 282
RM 50557 Rte 282
Downingtown
B10
B3
Coatesville
Coatesville
Inadequate (bridge raises flood level)
100 Year FP
500 Year FP
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
Inadequate Bridges
East Branch
North of Downingtown
0 0.5 1 2 Miles
Map produced by the University of Delaware Water Resources Center, Dec. 2024.


B8
B9
B12
B10
RM 14554 Pedestrian Bridge
RM 12545 Private Drive
RM 4908 Bondsville Rd.
RM 3574 Private Drive
RM 2755 Private Drive
RM 6362 Hadfield Rd.
RM 9106 Hadfield Rd.
RM 118 Fisherville Rd.
East Branch Brandywine Creek
RM 1388 Manor Ave
RM 6510 LLoyd Ave
Downingtown
Inadequate Bridges
East Branch
Beaver Creek Tributary
Inadequate (bridge raises flood level)
100 Year FP
500 Year FP
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
0 0.25 0.5 1 Miles
Map produced by the University of Delaware Water Resources Center, Dec. 2024.


B12
B13
East Branch
Brandywine
Creek
B10
B3
B7
West Branch
Brandywine
Creek
B4
RM 58505 Railroad
RM 58505 Railroad
RM 48154 Harveys Bridge Rd.
RM 48154 Harveys Bridge Rd.
RM 38567 Railroad
RM 38567 Railroad
RM 40378 Embreeville Rd.
RM 40378 Embreeville Rd.
RM 4177 Rte 842
RM 4177 Rte 842
B5
B14
B6
Main Stem
Brandywine
Creek
B15
B14
Inadequate (bridge raises flood level)
100 Year FP
500 Year FP
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
Inadequate Bridges
West Branch
South of Coatesville
0
0.42
0.85
1.7 Miles
Map produced by the University of Delaware Water Resources Center, Dec. 2024.


RM 107051 Wagontown Rd.
RM 98442 Rte 340
B2
RM 96543 Rte 30
B12
East Branch Brandywine Creek
RM 92214 Valley Station Rd.
RM 91123 Railroad
RM 90718 Wagontown Rd.
RM 90014 Railroad
West Branch Brandywine Creek
RM 88570 Railroad
RM 87779 Dam
RM 88244 E Glencrest Rd.
RM 87569 Pedestrian Path
RM 86712 Rte 30
Coatesville
RM 85175 Footbridge
RM 84755 Railroad
B3
RM 85003 Access Road
RM 84010 Railroad
RM 83795 Private Drive
RM 82283 Private Drive
RM 81718 RR Lukens Steel
South Coatesville
RM 79956 S First St.
RM 79889 Pipeline
RM 73143 Union St.
Modena
RM 71551 Railroad
B5
Inadequate (bridge raises flood level)
100 Year FP
500 Year FP
Watershed boundary
Brandywine subshed
Stream
Town or borough
Township
County boundary
N
Inadequate Bridges
West Branch
At Coatesville
0
0.25
0.5
1 Miles
Map produced by the University of Delaware Water Resources Center, Dec. 2024.

Stormwater Reduction Measures

Stormwater runoff contributes to local flooding during both small and large storm events. Local improvements and investments made in each municipality may provide benefits to nearby neighborhoods as well as downstream communities. The project team has compiled stormwater infrastructure geospatial data of municipalities in the Brandywine Creek watershed to identify potential flood mitigation measures to better protect residents living along the Brandywine Creek in Pennsylvania and Delaware. For this study, understanding the current state of local stormwater management, specifically existing infrastructure, is a critical component to the identification of flood mitigation opportunities.

Stormwater infrastructure includes Best Management Practices (BMPs) like detention basins, wet ponds, infiltration facilities, stormwater inlets, pipes, and outfalls. These features convey, reduce peak flowrates and quantity, and control stormwater runoff before it is released to surface waters throughout the drainage area. Stormwater infrastructure is typically constructed during land development and is regulated by local municipalities in accordance with state law.

For this study, data collection focused on stormwater basin data from various available sources to compile a comprehensive geodatabase of all stormwater basins in the Brandywine Creek watershed. Attributes for basins in the data set include ownership, area, depth, storage volume, age, and condition (where available). This study was not able to collect comprehensive information on subsurface infrastructure (storage area, inlets, pipes, and outlets), but future data collection is strongly recommended to better understand how stormwater is conveyed through existing infrastructure to the stream and impacts local flooding.

Stormwater Basin Retrofits

A desktop analysis identified 1,232 stormwater basins in the Brandywine watershed. These were primarily concentrated in areas that have been developed over more recent decades and therefore, subject to local stormwater management regulations. In total, it is estimated that these basins have a collective maximum capacity of 5.4 million cubic feet, or about 40 million gallons.

That volume is equal to roughly 1% of the capacity of the existing five major flood control facilities in the upper watershed. Therefore, it is unlikely that investments in storage capacity upgrades to these smaller, distributed systems would have any measurable impact on regional flooding. However, in certain areas, retrofitting existing stormwater basins may make very meaningful contributions to localized flood reduction efforts, particularly in areas near the smaller, flood-prone tributaries to the larger mainstem, East Branch, and West Branch stretches of the Brandywine Creek.

The project team plans to work with municipalities to further identify potential stormwater basin retrofit projects, specifically in areas with localized flooding concerns. In addition, municipalities should regularly inspect their stormwater basins, and all stormwater infrastructure, to ensure they are functioning as designed. Faulty or failing basins have the potential to exacerbate community flooding issues, so frequent monitoring and timely repair is important.

Finally, many older developments and communities lack critical stormwater infrastructure, as they were constructed prior to the adoption of stormwater management regulations. Especially in these areas, redevelopment presents opportunities to install stormwater infrastructure that will help address runoff-related challenges, such as flooding.

Reducing Impervious Cover

Rainfall runs off impervious cover contributing to increased stormwater and local flooding. Removing impervious surfaces and replacing with either natural vegetation or pervious pavement/pavers can help reduce the amount of stormwater runoff.

Drainage Improvement Projects

Municipalities are responsible for maintenance of their stormwater drainage system. Inspection of inlets, catch basins, manholes, pipes, and related stormwater infrastructure helps to identify malfunctioning components of the stormwater collection system. Incorporating additional factors, such as useful life estimates and local flood frequency can help municipalities prioritize stormwater infrastructure in need of repair or replacement.

Backflow Prevention Device Installation

During heavy storm events, stormwater infrastructure that is outdated to meet current capacity, under-designed, improperly maintained, or simply overwhelmed for extreme storm events may experience floodwaters backing up through the system, resulting in localized flooding. For example, this can happen when flood elevations in the stream are higher than stormwater outfalls. Backflow prevention devices, like gates, flaps, or valves, may be installed at various points within the stormwater system to prevent backwater from contributing to flooding.

Chapter 6: Non-Structural Recommendations

Along with structural solutions to mitigate flood damage, there are non-structural solutions that help to achieve maximum flood mitigation and prevention benefits to the community and the natural landscape of the Brandywine watershed during flood occurrences. Non-structural flood solutions include mitigation measures that do not require a physical structure, such as a levee or dam, and exist in many forms and can be led by many different entities. Some strategies may be more appropriate for areas with significant development, and others better suited for areas with more open space and undeveloped land.

Non-structural Solutions in Developed Areas

In urban and suburban areas, much of the landscape, especially along waterways, is already developed. While this may present challenges for implementing larger scale structural projects, non-structural solutions offer communities the opportunity to reduce flood risks through policy, planning, public education, and emergency management efforts. Many of the non-structural solutions recommended in this study for developed areas are actively utilized by municipalities throughout the Brandywine watershed. So, expanding these efforts by incorporating new techniques, best practices, and information may be the lowest hanging fruit for many communities to implement.

Emergency Preparedness Planning

As flooding is often unpredictable, robust emergency preparedness planning is a critical tool to ensuring that first responders and emergency management personnel are adequately equipped to respond as waters rise during severe storm events.

Each municipality, within its jurisdiction, is responsible for emergency management, response, and recovery, including developing and updating the local disaster emergency management plan. For flood hazards, these plans should:

- Give special attention to roadways and access points that may be cut-off by flood waters, preventing emergency services from reaching those in need.
- Identify bridge crossings and low-lying roads are particularly vulnerable.
- Determine communities bisected by a waterway may require two emergency response plans: one for each side of the stream, in the event that first responders are unable to cross from one side to the other. Care should be taken to identify these potential problem sites, along with concrete steps to maneuver around them during a flood event.
- Ensure emergency response plans, evacuations routes, and related resources are easily accessible by the public and promoted regularly throughout communities prior to an emergency.

In addition, municipalities should consider:

- Conducting flood simulation tabletop exercises, where local officials and the public run through protocols and procedures to train for addressing real world crises.

- Proactively closing flood-prone roads during a storm to keep the public safe. Less than two feet of rushing water can carry away the average car, and many drivers are likely to underestimate both water depths and the risks they pose. In high hazard areas where cones or standard barricades might not be enough to dissuade drivers, some communities have installed roadway closure gates.
- Participating in the development process of, and subsequently adopting, the County Hazard Mitigation Plan. Identifying areas of recurrent flooding and mitigation opportunities in hazard mitigation plans opens the door for communities to access funding, both before and in the aftermath of a flood event.

Public Alerts and Readiness

Early warnings ahead of major storms play a critical role in protecting and saving lives. Existing resources that can connect the public to flood alerts and preparedness information include:

- **ReadyChesCo** – Severe weather and flood alerts are sent out through the ReadyChesCo system. In Chester County, the County's Department of Emergency Services offers the ReadyChesCo program, where individuals can register for free to receive emergency and non-emergency alerts for their community.
- **FloodTools** – The Chester County Water Resources Authority hosts a web-based "Flood Tools" portal (www.chesco.org/floodtools) with current and forecasted flood conditions across the County. One of the portal's features includes instructions and links for individuals to sign up for rainfall and stream height and flow alerts for their area based on data directly from the local USGS monitoring network.
- **Ready.gov** – Officials and disaster assistance personnel recommend individuals and families assemble an emergency kit and have an established plan for what to do in a variety of emergency situations. In the case of a flood, this may mean being without electricity for a period of time or evacuating to higher ground. The U.S. Department of Homeland Security maintains the www.ready.gov website, which includes information on what to include in an emergency kit and how to develop an emergency plan.

Flood Insurance

Flood insurance through the National Flood Insurance Program (NFIP) can help individuals recover losses and rebuild their lives after flood events. Those with federally backed mortgages and other loans may be required a flood insurance policy on their property, and it's sensible for anyone owning property with an elevated risk of flooding to consider getting a policy. Municipal officials and community organizations can help educate the public on the value of flood insurance and dispel related common myths. For example, NFIP flood insurance is available for anyone (including renters), regardless of whether their property is located within Special Flood Hazard Areas (SFHA).

Enforcing and Enhancing Local Floodplain Regulations

All municipalities in Pennsylvania are required to participate in NFIP and adopt local floodplain ordinances. These ordinances are critical tools to helping build safer, more resilient communities. Floodplain ordinances require municipalities to:

- Designate a Floodplain Administrator to oversee the implementation of the local floodplain management program and enforcement of the ordinance
- Adopt flood maps, as developed by FEMA, which define the official SFHAs, to identify boundaries within which floodplain regulations are enforced
- Develop and implement a floodplain permitting program requiring permits for all development activities (including grading/earth moving, small scale projects, etc.) within the floodplain

- Identify construction standards specific to structures and development within the floodplain
- Enforce code requirements for new structures and for structures determined to be "substantially improved" (where the market value of improvements to a structure is greater than or equal to 50% of the value of the structure) or "substantially damaged" (where the market value of necessary repairs to a structure after it is damaged is greater than or equal to 50% of the value of the structure).

Communities may choose to implement higher standards to further reduce local flood risk such as:

- Increased freeboard requirements in construction standards
- Cumulative substantial improvement rules
- Compensatory storage requirements to offset fill placement in the floodplain

Communities who elect to adopt higher standards may be eligible to participate in FEMA's Community Rating System (CRS) program. This program points to a municipality for activities and regulations that go beyond the minimum requirements, which translate to lowered NFIP insurance premiums for their residents.

Structural Elevations, Floodproofing, and Property Buyouts

Structures built in the floodplains along the Brandywine Creek include industrial sites, commercial businesses, and residences. A good portion of these structures and the people who rely upon them tend to be the most vulnerable to damages from flood events. The table below lists the total acres within the 100-year floodplain (FEMA designated Special Flood Hazard Area Zones A, AE, AE Floodway, and AO), along with the number of parcels and structures greater than 400 square feet, by municipality.

Development in the 1% Annual Chance (100-year) Floodplain by Municipality					
Municipality	**County**	**State**	**Total Acres**	**# of Parcels**	**# of Structures (> 400 sq. ft)**
Birmingham Township	Chester	PA	646.2	215	43
Caln Township	Chester	PA	479.6	324	95
Charlestown Township	Chester	PA	0.0	0	0
Coatesville City	Chester	PA	107.5	83	32
Downingtown Borough	Chester	PA	269.7	433	172
East Bradford Township	Chester	PA	1309.7	501	103
East Brandywine Township	Chester	PA	413.6	213	33
East Caln Township	Chester	PA	132.8	30	5
East Fallowfield Township	Chester	PA	553.9	187	30
East Marlborough Township	Chester	PA	79.7	78	5
East Nantmeal Township	Chester	PA	516.2	70	3
East Whiteland Township	Chester	PA	8.1	6	1
Highland Township	Chester	PA	319.1	85	16

Development in the 1% Annual Chance (100-year) Floodplain by Municipality					
Municipality	**County**	**State**	**Total Acres**	**# of Parcels**	**# of Structures (> 400 sq. ft)**
Honey Brook Borough	Chester	PA	0.0	0	0
Honey Brook Township	Chester	PA	1473.5	276	47
Kennett Township	Chester	PA	41.8	42	4
Londonderry Township	Chester	PA	271.6	54	8
Modena Borough	Chester	PA	58.6	82	34
Newlin Township	Chester	PA	976.4	261	70
Parkesburg Borough	Chester	PA	33.6	40	9
Pennsbury Township	Chester	PA	499.8	153	24
Pocopson Township	Chester	PA	772.2	240	70
Sadsbury Township	Chester	PA	346.2	155	33
South Coatesville Borough	Chester	PA	75.6	16	23
Thornbury Township	Chester	PA	22.0	16	3
Upper Uwchlan Township	Chester	PA	947.7	272	35
Uwchlan Township	Chester	PA	76.4	60	11
Valley Township	Chester	PA	144.5	213	49
Wallace Township	Chester	PA	500.4	130	10
West Bradford Township	Chester	PA	491.5	136	34
West Brandywine Township	Chester	PA	484.3	207	18
West Caln Township	Chester	PA	591.4	126	13
West Chester Borough	Chester	PA	12.0	89	26
West Fallowfield Township	Chester	PA	7.4	3	0
West Goshen Township	Chester	PA	205.3	253	38
West Marlborough Township	Chester	PA	662.5	92	25
West Nantmeal Township	Chester	PA	569.9	153	18
West Sadsbury Township	Chester	PA	32.3	8	0
West Vincent Township	Chester	PA	17.1	6	3
West Whiteland Township	Chester	PA	803.7	565	194
Westtown Township	Chester	PA	33.9	14	2
Bethel Township	Delaware	PA	8.0	2	0
Chadds Ford Township	Delaware	PA	436.0	134	40
Concord Township	Delaware	PA	10.6	18	1
Caernarvon Township	Lancaster	PA	0.0	0	0
Salisbury Township	Lancaster	PA	38.0	11	5
New Castle County	New Castle	DE	528.1	95	52
Wilmington	New Castle	DE	433.9	487	270
TOTAL			**16442.1**	**6632**	**1707**

Sources:
FEMA Flood Map Service Center, https://msc.fema.gov/portal/advanceSearch
DVRPC, https://catalog.dvrpc.org/dataset/impervious-surfaces-2015-chester-county
DVRPC, https://catalog.dvrpc.org/dataset/impervious-surfaces-2015-delaware-county

Lancaster County, https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=1257
New Castle County GIS Services, https://apps-nccde.hub.arcgis.com/

Two main options for increasing the resilience of buildings already located with the floodplain are structural elevation and floodproofing. For residential properties, the standard protocol is to elevate the house above the base flood elevation (also known as the 100-year flood height). Structural elevation may be achieved in several forms, including elevating the building up on fill or abandoning the bottom floors. For non-residential structures, floodproofing is an acceptable strategy by dry floodproofing (where materials are used to make the exterior of a building watertight) or wet floodproofing (where flood damage-resistant materials are used to minimize damage in the lower portion of a structure, which is intentionally allowed to flood). Structural elevation and floodproofing have numerous benefits, however, they do not entirely eliminate the risk to life and property. For example, an elevated home might keep the residents high and dry, but first responders may still be cut off from accessing them when the land around the structure floods.

For homes subject to frequent, hazardous floods, some communities have chosen to pursue voluntary property buyouts. In these cases, the municipality offers the owner of the flood-prone property to pay fair market value, then the site is completely cleared. This eliminates future risk to loss of life from flooding at the site, and when coupled with floodplain restoration, can even reduce potential flood damage to nearby areas.

Unfortunately, despite the benefits, buyout programs is not without downsides. Many residents may be unwilling to participate, and those who do, may choose to move out of the municipality, which has potential ramifications for the tax base and overall fabric of the community. It can also be an expensive process, although there are several federal and state programs that can provide funding to support property buyouts (particularly after disaster declarations). Ultimately, it is up to the community to weigh the risks and benefits of a buyout program before initiating one.

Municipalities should conduct a comprehensive analysis of residential structures within the delineated 100-yr floodplain and consult with the affected property owners. The analysis should assess the value and structural soundness of the building to determine whether they are fit for elevation or floodproofing, compared to the persistent flood risks and NFIP claims.

Strengthening Steep Slope Protection Ordinances

Steeper slopes generate more stormwater runoff than flatter areas, leading to flooding and problems with erosion. Most municipalities in Chester County have protective ordinances that restrict some or all development activities on slopes with a 15% or higher grade. However, even less steep slopes can generate significant runoff that can damage infrastructure and create risks for the public. To address this issue, a model ordinance should be developed to identify additional stormwater management protections and/or development restrictions for slopes with grades of 10-15%.

Public Education and Engagement

Consistent education and outreach are needed on "blue sky" days to help community members prepare for flood events. Popular ready-made campaigns include the National Weather Service's "Turn Around, Don't Drown®" program, which educates the public on the dangers of trying to drive through floodwaters. NWS offers numerous resources, including emergency sign templates, available online for public use (www.weather.gov/safety/flood-turn-around-dont-drown).

Through the NFIP, FEMA has a High Water Mark Initiative aimed at encouraging community awareness of flood risk and mitigation opportunities through historic high water mark signage (https://www.fema.gov/flood-maps/products-tools/high-water-mark-initiative). In places like Washington D.C. and Carson City, Nevada, communities have gone one step further, enlisting the help of artists to visually depict the impact of floods through public art installations like murals and sculptures. A program like this could be replicated in the Brandywine Watershed with relative ease, as the USGS recorded high watermarks at bridges along the mainstem and the East and West branches of the Brandywine during Hurricane Ida (Table 7.2). For instance, the recorded high watermarks at the US Route 13 bridge in northeast Wilmington (RM 7970) was 9.7 ft and at US Route 1 in Chadds Ford (RM 23,660), the Ida high watermark was found at 171.6 ft. Installing Hurricane Ida high water mark signs or art pieces at some of these locations could serve as a reminder to the public about the historic high water experienced during the largest flood along the Brandywine and its tributaries in two centuries.

Non-structural Solutions in Less Developed Areas

In areas with more limited development, a variety of strategies exist to utilize open space as a natural flood mitigation tool to slow, spread, and store floodwaters. Protecting these lands is critical, as development on these lands may exacerbate future flooding. While a complete development moratorium is not permitted under state law, local governments should consider implementing zoning ordinances and adopting policy changes that limit and/or heavily regulate development within floodplains or other flood-prone areas (Northwest Hydraulic Consultants Ltd. (NHC, 2021). In addition, there are opportunities for local governments and conservation organizations to protect open spaces for public and private use, as an effective tactic in protecting communities from flooding, as it prevents development in flood-prone areas and allows landscapes to absorb and slow the flow of water (Open Space Institute (OSI), 2020).

Protecting and enhancing natural floodplains is one of the most cost-effective methods for managing flood risk in downstream communities. Reiterating, that the floodplains of Brandywine Creek and its branches have 16.5 billion gallons of potential storage capacity.
The most impactful opportunities for flood storage and open space conservation are typically found in areas where the floodplain is minimally developed, wide, and mildly sloped. Examples of this in the Brandywine watershed include the stretch of stream between Chadds Ford and Lenape Park, where the floodplain ranges from 1700 to 2600 feet wide, and along the East Branch below Embreeville, where the landscape is roughly 900 feet wide.

There is a long legacy of land preservation in the Brandywine watershed by municipalities and conservation organizations. Presently, roughly a third of the watershed in Chester County is permanently preserved as open space or agricultural land. This has been achieved primarily through the use of fee simple land and conservation easement acquisitions, both of which are described in detail in the following sections. A combination of land conservation and active land management can support natural systems which are extremely effective in mitigating flood risk and creating healthier ecosystems.

Fee Simple Acquisition

Fee simple acquisition entails the outright purchase of a parcel of land. Ownership of the land allows a conservation organization more flexibility in how it is managed. Deed restrictions can be placed on the land to prevent certain types of development and protect sensitive environments within the parcel. These restrictions can also limit future land use to prevent commercial, agricultural, or disruptive recreational activities. It can allow for land management techniques that may be prohibited in other forms of land conservation for wetland and floodplain restoration, such as dredging. While fee simple acquisition may be more effective in quickly protecting and managing flood-prone land, it is usually more costly, as the owning entity must have enough funding to make the purchase and provide all equipment and labor necessary for the management and maintenance of these lands.

Conservation Easements

For more than six decades, conservation easements have protected land within the Brandywine Watershed and have helped mitigate flooding within the region. A conservation easement is a legal agreement between a landowner and a conservation organization or government entity that protects the conservation values of a parcels of land in perpetuity. Conservation objectives can vary from uninterrupted public views of open space to the presence of rare habitat types. Conservation easements can be used to protect many aspects of a landscape, such as its scenic value, a sensitive ecosystem, agricultural soils, and others by extinguishing some of the development rights held by the original owner and limit the allowable activities, uses, and improvements of the landscape.

Once a conservation easement is executed, it can be extremely difficult to make any changes to it. This is very important, as it protects the land from any future landowners who may intend to develop or use the property for other means. However, it can also create difficulties in adequately protecting the land under the easement. Landscapes are dynamic, and more recently are subject to rapid, climate driven change.

It has been noted in various studies, conservation easements or fee acquisition of landhave not been used previously to preserve land specifically for its ability to mitigate flood hazards, even though both of these tools easily provide a means to this goal. While there are flood mitigation benefits that occur along with other conservation values protected in easements, there is a lack of targeted flood-related language (OSI, 2020, p.4). For this reason, it is important to consider the ways in which conservation easements can be written, amended, or restructured in a way that would more effectively protect flood prone land. The full report and Appendix 9 include details on easement language to promote flood mitigation through these tools.

River Corridor Easements

Another method to protect flood-prone lands is through an altogether different kind of conservation easement. The Vermont Rivers Program, under the Vermont Agency of Natural Resources, works to protect flood-prone land through River Corridor Easements (RCEs). (Vermont Agency of Natural Resources Department of Environmental Conservation (VTDEC), n.d.). While the adoption of a new kind of easement may seem daunting to many conservation organizations and other easement holders, this easement language has seen notable success in Vermont, where flooding has created decades long safety, environmental and agricultural issues. Details for river conservation easement language can be found in Appendix 9.

Developing Municipal Open Space Funds

An extremely useful tool that many municipalities in the region already employ to fund both land acquisition and easements is municipal open space funding programs. These programs are implemented by local governments through a small increase in Earned Income Taxes. An example of this can be seen in Elk Township (Chester County, PA), which, in 2006, proposed an open space funding referendum and passed by a vote of township residents. The referendum allowed a 0.5% Earned Income Tax increase for resident wage earners to be used to fund the purchase of agricultural lands and open space in the township (Brandywine Conservancy, 2016). Between 2006 and 2016, the township's protected lands grew from 14% to 37% and raised about $90,000 each year, at very little cost to individual residents.

Open space funds allow municipalities to prioritize their own land conservation goals, such as prime agricultural soils or recreational spaces. Hence, municipalities may use open space funds to protect lands for other public benefits, such as flood mitigation. Overall, the implementation of an open space fund is an effective tool that municipalities may use for flood management initiatives.

Chapter 7: Moving into Implementation

Study Limitations and Recommendations

While this study involved a robust assessment of flood hazards and potential mitigation opportunities within the Brandywine Watershed, it is not without its limits such as:

- results included in this report are based on best available data, public/partner input, and computer modeling software used;
- study partners worked with available HEC-RAS models from FEMA, which were not available for many of the smaller tributaries; and
- generally speaking, the scale of analysis was based on subwatersheds and not at an individual site/project scale.

Structural recommendations included in this study are conceptual in nature and project design was not within the scope of this study. For this reason, the development of cost estimates for mitigation projects was also omitted. Engineering designs and their associated site analyses will need to be completed as projects are selected for implementation. Future partners for implementation are welcome to the available data and models used in this study, which can be accessed through the Chester County Water Resources Authority.

Fortunately, further analyses of potential localized mitigation projects are currently underway in several areas of the watershed. Ongoing studies in the City of Coatesville, Downingtown, and Wilmington will likely produce additional sites to supplement those identified in this study. The Flood Study partners are committed to supporting these efforts as they come to fruition.

Roles for Implementation

Achieving full implementation of this study's potential will require engagement from individuals, municipalities and organizations throughout the watershed. This section outlines potential implementation roles for different stakeholders based on the recommendations outlined in Chapters 6 and 7 of the full report. While not exhaustive, this list is meant to serve as a starting point for those looking to reduce flood risks in their communities.

Chester County Water Resources Authority

- Begin the preliminary stages of design and preparation for the rehabilitation of Barneston Dam in the East Branch Brandywine watershed to comply with updated state requirements and improve flood storage capacity
- Coordinate with County Facilities to assess opportunities for impervious cover reduction and stormwater control/flood storage projects on County-owned properties within the watershed
- Identify opportunities to support municipalities with the implementation of floodplain ordinances and participation in the FEMA Community Rating System (CRS)

- Maintain operations of Struble Lake, Beaver Creek Dam, and Hibernia Dam to ensure ongoing flood control benefits for downstream communities
- Maintain the FloodTools website to provide public information on current and forecasted flooding conditions

County Departments of Emergency Services/Emergency Management

- Coordinate with municipalities throughout the watershed to identify and incorporate flood hazards and projects into the updated County Hazard Mitigation Plans
- Support municipal and multi-municipal emergency preparedness and planning efforts
- Support municipal and multi-municipal grant applications for pre-disaster mitigation funding
- For Chester County, continue to broadcast storm and flood alerts to subscribers of the Ready ChesCo alert system

Municipalities

- Inspect, maintain, rehabilitate, and upgrade stormwater infrastructure to improve flood storage capacity
- Prioritize replacement or upgrades of municipally owned bridges, culverts, or other obstructions identified in Chapter 6 to reduce local flood risks
- Identify properties in the floodplain subject to high risk to life and damages and consider offering voluntary property buyouts
- Work with the County Planning Commission/Department and/or regional metropolitan planning organization to submit bridge repair and replacement projects to the state Transportation Improvement Program (TIP) list
- Participate in the County's Hazard Mitigation Plan update process and adopt the plan upon its completion to ensure future eligibility for state and federal hazard mitigation funding
- Review community emergency response plans to ensure they account for major flood scenarios, especially in streamside communities or those bisected by waterways
- Educate community members on flood preparedness tools and resources like Ready ChesCo and Chester County's FloodTools website
- Educate municipal staff, elected officials, and the public about the importance of proper enforcement of the local floodplain ordinance
- Consider participation in the FEMA CRS program to reduce local flood insurance premium costs and encourage residential participation in the NFIP

PennDOT/DelDOT

- Prioritize replacement or upgrades of state-owned bridges, culverts, or other obstructions identified in Chapter 6 and design beyond the 100-year storm to reduce long-term local flood risks
- Inspect, maintain, rehabilitate, and upgrade stormwater infrastructure to improve flood storage capacity

Conservation Organizations

- Prioritize parcels with natural floodplains for preservation
- Explore floodplain restoration on owned and/or eased lands to improve flood storage, particularly in areas where floodplains are flat, wide, and vertically disconnected from the stream channel
- Educate municipal representatives and the public about the importance of floodplain protection
- Provide technical assistance for municipalities, homeowners associations, and others on issues related to stormwater management, riparian buffers, etc.
- Coordinate with academic and local government partners as opportunities arise to seek funding for project implementation

Community Groups

- Help identify strategies to improve community preparedness and prevention, including accessing and interpreting information about flooding before and after storm events
- Elevate local concerns about the impacts of flooding to municipal and county officials, including areas of chronic flooding, barriers to individual or community resilience, etc.
- Coordinate with municipalities to support waterway cleanups to reduce litter and debris that can contribute to flooding obstructions
- Coordinate with county, state, and federal disaster response efforts after a flood to improve the efficiency of recovery efforts

Individuals

- Sign up for early warning alerts, like those provided by Ready ChesCo, USGS, or the National Weather Service
- Maintain a personal emergency preparedness kit and be aware of local evacuation routes
- For property owners and renters, consider purchasing federal flood insurance for properties within the designated floodplain and close to waterways with flood potential (even if they are not along streams with a mapped floodplain)
- Consider elevating structures within the floodplain to reduce flood risk
- Be aware of and prepared to comply with substantial improvement and substantial damage requirements in the local floodplain ordinance as they apply to properties in the special flood hazard area
- Remember to never drive or walk through floodwaters, even if they do not seem too deep

Potential Funding Opportunities for Implementation

Funding is often one of the largest hurdles to implementing flood mitigation and risk reduction strategies. Fortunately, there are local, state and federal grant funding opportunities that communities can pursue to offset the costs of these efforts. For some non-flood related grants, flood protection and mitigation may be incorporated as a secondary or co-benefit to the primary focus of the grant (e.g., habitat restoration or infrastructure repair). Chapter 8 in the full report highlights potential grant funding opportunities that may be relevant in the implementation of this study's recommendations.

Final Thoughts

Anywhere there is water, there is the potential for flooding. Even with unlimited financial and technological resources, it would be impossible to eliminate all flood risks. However, the Flood Study partners are confident that implementation of the recommendations laid out in this report can meaningfully reduce future flood risks to communities throughout the Brandywine watershed. The partners are committed to supporting municipalities, stakeholders, and others in implementing these strategies, and to continually assessing new opportunities to reduce localized and regional flooding in the future.