SEPTEMBER 2022

Community Guide to Assessing Non-Tidal Flood Impacts in Maryland

PREPARED AND PRESENTED BY

V. Beth Kuser Olsen, Ph.D.
Earth System Science Interdisciplinary Center (ESSIC)
University of Maryland
College Park, Maryland

PREPARED FOR

Maryland Department of Natural Resources
Chesapeake and Coastal Service

Research Team

V.Beth Kuser Olsen, Ph.D.
Principal Investigator
Earth System Science Interdisciplinary Center (ESSIC)
University of Maryland, College Park

Deborah McKinley
Environmental Engineer
Project researcher

Mariel D. Friberg, Ph.D.
Project Collaborator
NASA Universities Space Research Association Postdoctoral Fellow

Phillip R. Stratton
Project Liaison
Maryland State Climatologist's Office

Funding

This guide was developed as part of the Chesapeake Bay Implementation Grant (CBIG) project, "Development of a Community Guide to Assessing Non-Tidal Flood Impacts in Maryland." This project has been funded wholly or in part by the United States Environmental Protection Agency (EPA) under assistance agreement CB96336601 to the Maryland Department of Natural Resources. The contents of this document do not necessarily reflect the views and policies of the EPA, nor does the EPA endorse trade names or recommend the use of commercial products mentioned in this document.

photo by V. Beth Kuser Olsen (c)2022

Acknowledgements
This guide was developed in collaboration with
Megan Granato
Director, Center for Restoration Finance
Chesapeake and Coastal Service
Maryland Department of Natural Resources

We would like to thank the Maryland communities and the engineering firms that participated in the development of this guide. The contributions they made form the basis of many of the recommendations and strategies in this document.

Low Impact Development Center, Inc
Beltsville, Maryland
Rauch Engineering, Inc.
Easton, Maryland
EA, Engineering, Science, and Technology, Inc.
Hunt Valley, Maryland
Weston and Sampson Engineers
Portsmouth, New Hampshire

Greenbelt Homes. Inc., Maryland (GHI)
GHI Board of Directors
GHI Management and Technical Services Department
GHI Stormwater Management Task Force
GHI Woodlands Committee
GHI Communications and Marketing Committee

The City of Aberdeen, Maryland, Department of Public Works
The City of Greenbelt, Maryland, Department of Public Works

Permissions

Material on this website may be used for educational purposes free of charge. The recommended citation for the complete guide is:

Kuser Olsen, V. Beth. (2022, September). *Community Guide to Assessing Non-Tidal Flood Impacts in Maryland*. Maryland Department of Natural Resources. Available online at https://dnr.maryland.gov/ccs/coastsmart/Pages/grants.aspx

The recommended citation for specific sections of the guide should follow this format:

Kuser Olsen, V. Beth. (2022, September). [Title of the section of the guide]. In *Community Guide to Assessing Non-Tidal Flood Impacts in Maryland*. Maryland Department of Natural Resources. Available online https://dnr.maryland.gov/ccs/coastsmart/Pages/grants.aspx

The recommended citation for specific photos within the guide should follow this format:

[name of photographer: Kuser Olsen, V. Beth or Murtha, Xianoyu Bi]. (2022, September). In *Community Guide to Assessing Non-Tidal Flood Impacts in Maryland,* [page number within the guide where photo is located]. Maryland Department of Natural Resources. Available online at https://dnr.maryland.gov/ccs/coastsmart/Pages/grants.aspx

Thank you for following this policy. If you have any further questions, contact Dr. Beth Olsen at bolsen@umd.edu

Contents

Introduction

Why Maryland's non-tidal regions need this guide

Maryland is facing a wide variety of consequences from climate change. In response to the mounting scientific evidence of the effects of these changes on regional climate, Maryland has been a leader in developing and implementing mitigation and adaptation strategies. To date, the emphasis has been on understanding and reducing the vulnerability of coastal and Chesapeake Bay communities. These areas have been hardest hit, with the combination of increased frequency and intensity of winter/spring precipitation, sea-level rise, and increased storm surge[1]. However, the non-tidal regions of Maryland, inland systems from the upper reaches of Chesapeake Bay tributaries to the Appalachian Mountains are also affected by climate changes. These regions are experiencing a climate that is trending warmer and wetter, with an increased frequency of winter/spring precipitation. Maryland's annual mean precipitation has been above average for the past two decades. The state's climate is generally expected to continue trending warmer and wetter over the next century, accompanied by an increase in extreme precipitation events.[2,3]

Floods become disasters when people and property intersect the path of flood waters. Flood risk is a measure of the probability that flood waters will inundate an area. In non-tidal regions, providing information on flood risk specific to local communities is difficult because natural factors that influence the precipitation patterns and flow of water once it reaches the ground vary widely. The main atmospheric determinant of flood risk is the intensity, duration, and frequency of precipitation over an area. The greater those factors, the greater the risk. When the precipitation hits the ground, hydrological and hydraulic components of the surface landscape influence the behavior of the stormwater. These include factors such as topography, soil type, bedrock geology, and proximity to rivers, streams and wetlands. The localized precipitation trends and variation across the surface landscape result in microclimates. In addition to the natural microclimate in which a community is located, rural, suburban and urban sites differ in anthropogenic factors such as proportion of impervious surfaces, engineered drainage areas, and presence/absence and type of vegetative cover. Each microclimate has unique characteristics that influence flood vulnerability. During the development of a community flood resiliency plan, engineers model stormwater behavior and identify the community's high-risk areas. Highly flood-vulnerable locations are found where a critical infrastructure or vulnerable population cluster is geospatially located in the same place as an area identified by the model as high flood risk. Reducing flood vulnerability, increases resiliency. Flood resiliency is the ability of an individual, business, or community to socioeconomically recover quickly and completely following a flood event. These are the locations where communities need to concentrate efforts

---

[1]Stratton 2018: Stratton, Phillip. "Sea Level Rise in Maryland," Maryland State Climatologist Office, 2018. [Online]. Available: https://www.atmos.umd.edu/~climate/ClimateChange/slr.php [Accessed 10 August 2019].

[2]Runkel, *et al.* 2017: J. Runkel, K. Kunkel, D. Easterling, B. Stewart, S. Champion, R. Frankson and W. Sweet, "Maryland State Summary," National Oceanic and Atmospheric Administration, 2017.

[3]EPA 2015: United States Environmental Protection Agency (EPA), "Climate Change in the United States: Benefits of Global Action," United States Environmental Protection Agency, Office of Atmospheric Programs, 2015.

to lower flood risk by utilizing best stormwater management practices to mitigate the flooding. Building resiliency is often associated with a community's ability to recover following a major flood event, but chronic, low-impact flooding can also affect resiliency. A well-designed community-wide flood resiliency plan places its focus on reducing overall long-term vulnerability. It plans for a resilient future by mitigating anticipated flood impacts likely to result from the largest floods as well as the small, chronic flooding issues. Stormwater management that requires substantial capital investment and specialized expertise to operate and maintain will need to be financed through the community's budgetary process. However, there are many aspects of stormwater management that can be undertaken by individual community members and business owners. The sum of many small, inexpensive projects can be equivalent to a single large, expensive project in its contribution to reducing flood vulnerability and building community-wide resiliency. For a flood resiliency plan to work, the entire community needs to be engaged in making it happen. That includes community government leaders, staff, businesses, and the general citizenry.

Why it is important to have a community flood resiliency plan

A community flood resiliency plan provides a tool for gathering and organizing information for the purpose of designing a systematic approach to building flood resiliency. Reducing flood vulnerability prior to anticipated flood events is the key to resilience and developing a plan to build resiliency is the first step.

Many non-tidal communities are interested in gaining a better understanding of their local flood patterns so they can implement measures to reduce their vulnerability. In addition, they want to know what flooding issues to anticipate in the future with continuing changes in precipitation trends, increases in extreme precipitation events**,** and precipitation variability due to climate change. These issues include flooding and erosion due to heavy rainfall and spring snow melt, and decreased effectiveness of soil absorption due to extended periods of drought**.** Though the specifics in timing and magnitude may be uncertain due to a wide range of variables, an urgent response is clearly crucial to minimizing both the costs and risks of climate change.[4,5,6] Small communities, with limited public works maintenance and emergency preparedness budgets, are particularly vulnerable to the hazards of climate change.

[4]IPCC 2018: Intergovernmental Panel on Climate Change (IPCC), "Summary for Policymakers," in Global Warming of 1.5°C, 2018.

[5]AAAS 2014: American Association for the Advancement of Science (AAAS), "What We Know: The reality, risks, and response to climate change," 2014. [Online]. Available: http://whatweknow.aaas.org/wp-content/uploads/2014/07/whatweknow_website.pdf [Accessed 10 August 2019].

[6]AGU 2014: American Geophysical Union (AGU), "Human-Induced Climate Change Requires Urgent Action," 2014. [Online]. Available: http://sciencepolicy.agu.org/files/2013/07/AGU-Climate-Change-Position-Statement_August-2013.pdf. [Accessed 10 August 2019].

What our guide offers

The *Community Guide to Assessing Non-Tidal Flood Impacts in Maryland* is a best-practices guide for community flood resiliency planning specifically designed for use by small, incorporated cities, towns, villages, cooperatives, and home-owner associations in the non-tidal regions of Maryland. It provides an overview of non-tidal flood hazards; strategies, tools, and resources available to help assess the impacts of non-tidal flooding in local communities; and descriptions of successful approaches to building resiliency to these flood-related hazards that have been developed by other local communities. The guide provides step-by-step preparation for stormwater management, including:

1. How to take a system-wide approach to your community flood resiliency plan.
2. What requires employing experts/specialists to accomplish the tasks involved in designing and developing your flood resiliency plan.
3. What is involved in grant proposal preparation and the search for funding sources.
4. Prior preparation you will need to accomplish before developing your flood resiliency plan.
5. How to attract the best engineering firms at affordable bids.
6. How to stay within your community's budget and get what you need.
7. What to expect from the engineering firm your community hires.

Although developed for small communities, this guide may also be useful to state, county, and Baltimore City planners. Other groups, such as consultants, realtors, and landscape architects, may find the information helpful. The guide may serve as a model for local non-tidal communities in other states, particularly those in the Mid-Atlantic region, in developing and implementing climate change adaptation strategies.

Research Methodology for developing our guide.

This project is a joint endeavor between the University of Maryland (UMD) Earth System Science Interdisciplinary Center (ESSIC) under the direction of ESSIC research scientist, Dr. V. Beth Kuser Olsen, and the Maryland Climatologist Office, a service of the UMD Atmospheric and Oceanic Sciences Department. The UMD partners worked closely with the Maryland Department of Natural Resources (MDNR) to produce this best-practices guide for community flood resiliency planning for local government officials, planners, and engineers to use in addressing their non-tidal flooding issues. To develop the guide, we selected three Maryland local governments that recently completed community flood resiliency plans funded through Chesapeake Bay Implementation Grants (CBIG). The selected CBIG-funded resiliency plans include:

- "Lower Ward 1 Resilient Stormwater Systems Planning Study" for the City of Hyattsville, Prince George's County,
- "Town of Hebron Stormwater Management Master Plan: Analysis, Design and Green Infrastructure Planning," Wicomico County, and
- "Climate Adaptation and Resilience Plan for the City of Aberdeen," Harford County.

In all three case studies, the primary focus of the project was to develop a flood resiliency plan for a portion or the entirety of the local government's jurisdiction to manage current and future flood risk in a systematic, watershed-level context. The purpose was to provide a plan for community decision-makers that was tailored to the specific needs of their jurisdiction designed

to increase community resiliency by reducing community vulnerability to current and anticipated future flooding patterns; and contribute to the overall improvement of water quality in the Chesapeake Bay. We reviewed their plans to learn (1) what local data and other background materials needed to be gathered and organized prior to developing a community-wide resiliency plan, (2) what resources are publicly available to communities that are useful for local plan development, (3) what flood risk assessment models were used to simulate local precipitation patterns and stormwater behavior to identify flooding 'hot spots' in the community, and (4) what flood risk reduction options were recommended. We then interviewed the local governments' Flood Resiliency Plan Project Managers and the engineering firms that worked with them to develop the community's flood resiliency plan. The interviews were designed to provide further details on the information we gathered from our review of the completed plans and to provide insight into what obstacles were faced, what efforts were successful, what efforts were not successful, and how the plans are being used. The engineering firms discussed lessons learned from their point of view. The local governments' project managers assessed the quality and value of the plan from their perspective.

In a separate step, we selected a pilot project community that was interested in developing a flood resiliency plan but had not yet done so. Our pilot community was Greenbelt Homes Incorporated (GHI), located within the jurisdiction of the City of Greenbelt. GHI is the largest housing cooperative in Prince George's County with 1600 households in the community. This provided an opportunity to test proof-of-concepts and refine the approach and design of our guide by asking community staff and community volunteer organizations working on stormwater management issues the following questions about stormwater projects:

- What information is needed for making the best decisions in project selection and development?
- What resources are publicly available to communities for decision-making?
- What requires employing experts/specialists to accomplish the preparatory work?
- What preparation is most efficiently and effectively handled by an engineering firm rather than community staff or volunteers?

The results of the study's interviews and pilot project community discussions are incorporated into the *Community Guide to Assessing Non-Tidal Flood Impacts in Maryland*.

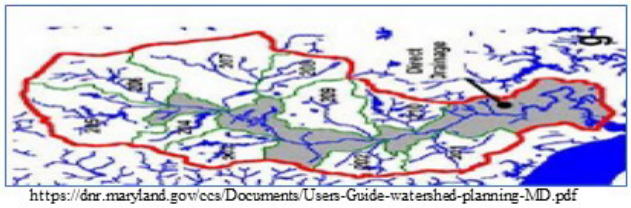
Don't wait – challenges are not unsurmountable - develop a community-wide flood resiliency plan now!

Step 1: Initiate a successful flood resiliency project

Set community-specific goals.

Develop the project scope.

Take a system-wide approach.



https://dnr.maryland.gov/ccs/Documents/Users-Guide-watershed-planning-MD.pdf

Key actions

1. Gather and organize community data and documents.
2. Conduct site visits to verify or refine the data.
3. Use stormwater models to produce scenarios illustrating current and future flood risk and vulnerability.
4. Select appropriate stormwater best management practices (BMP)s for the community.
5. Using the modeling results, evaluate new construction or retrofitted existing stormwater management infrastructure for potential flood risk reduction.
6. Produce a guidance outline for reevaluating community flood risk and vulnerability as changes occur due to further climate change, changes in land use, and other factors.

When first thinking about developing a flood resiliency project, you will need to make several preliminary decisions about the work to be done. This section will help you think through the project's goals, scope, and approach.

Set goals for developing your community's resilience

Before embarking on a plan, set goals your community envisions as the key factors in flood management and overall resiliency. Each community has unique socioeconomic characteristics and unique flooding issues, which your goals should take into account. By setting goals before the start of the planning process, they will serve as your overarching guide to decision-making during the development of the plan. Typical goals of a flood resiliency plan are to:

1. increase community resiliency by reducing community vulnerability to current and anticipated future flooding patterns,
2. design for long-term, multiple-project implementation, and
3. contribute to the overall improvement of water quality in the Chesapeake Bay.

These can serve as a starting point for your community but should be modified based on your community's needs and priorities.

Develop the project scope

The project scope serves as the blueprint of actions that will be taken to achieve the goals. When developing the scope, consider these questions:

1. What vulnerabilities will the project address? What do we already know about these vulnerabilities, and what do we want to know about them? Do they exist now, and/or are they anticipated to exist in the future?
2. How are these vulnerabilities likely to be impacted by climate change?
3. What geographic area do we want to focus on? For guidance, see "Take a system-wide approach to your community flood resiliency plan" below.
4. When considering future conditions, what planning timeframe should we use?
5. Who are the key stakeholders that should be involved? Consider government staff, residents, businesses, non-profits, volunteer groups, etc. How can we ensure that the stakeholders that participate adequately represent the diversity within our community?
6. How and when will public outreach and engagement be performed, and how will we integrate public feedback into the project? What are the roadblocks to meaningful and equitable engagement that we will need to overcome?
7. Do we have sufficient capacity to develop this project internally? If not, what are the capacity gaps? What partners could help fill those gaps?
8. If capacity gaps cannot be filled by partners, can we hire consultants? What services should the consultant provide?
9. What is an appropriate timeline for the project?
10. What deliverables do we want the project to develop? How would those deliverables be used?

11. What role do elected officials play in the project during both development and implementation? Will any step of this process require review and approval?

This list is not exhaustive but will help you start to think through the "who, what, where, when, and why" of the project scope.

Take a system-wide approach to your community flood resiliency plan

Water does not heed political boundaries. As a result, we recommend that you take a watershed-level approach when defining your plan's target geography. A watershed is an area of land where all precipitation, including rainfall and snowmelt, flows from a geographic high point, such as a ridge, hilltop, or mountaintop, into a common body of water, such as a stream, river, bay, or ocean. These are referred to as common outflows. However, a watershed may also drain into a low area that is geographically confined, such as a pond, lake, or wetland. A geographic high point that separates two watersheds is called the drainage divide. The lower elevation in a watershed is called the drainage basin or catchment. Watersheds can be as small as a puddle or large enough to encompass all the land that drains water into rivers that drain into the Chesapeake Bay, where it enters the Atlantic Ocean. All of Maryland's non-tidal regions, except the westernmost section of the Appalachians in Garrett County, are part of the Chesapeake Bay watershed. A community's flood resiliency plan needs to consider the entire watershed, including sections that may be in adjacent political jurisdictions.

Key actions to developing a successful flood resiliency plan

Every resilience plan is going to be different. However, there are key actions that are commonly taken during resilience plan development. These actions are listed below and can serve as a starting point as you think through the tasks for your specific project.

1. Gather all available information useful in evaluating current flood risk at the watershed level within your community. For guidance on how to do this, see Step 4 within this document.
2. Conduct site visits to verify or refine the available information (e.g., maps, infrastructure drawings, etc.).
3. Use stormwater models to produce scenarios illustrating current and anticipated future flood risk and to identify locations of greatest vulnerability.
4. Consider how both gray and green infrastructure could be appropriate for managing flood risk and vulnerability at specific locations within your community and provide benefits to the overall water quality in the Chesapeake Bay. Gray stormwater infrastructure refers to hardened engineered structures that affect stormwater behavior, such as drainpipe systems and stone levees. Green stormwater infrastructure works with natural or nature-based features to manage stormwater behavior. Raingardens and the inclusion of natural wetlands as a component of stormwater management are examples of green infrastructure.
5. Evaluate how the construction of new stormwater management facilities and/or gray infrastructure could ameliorate the potential flood risk shown in the modeling results. Also consider if existing systems and facilities could reduce flood risk through maintenance, repair, retrofit, or expansion.

6. Produce a guidance outline for community planners and stormwater managers to fortify your community's resiliency by improving your ability to reevaluate flood risk on a systematic level as changes occur in flood risk and vulnerability due to further climate change, changes in land use, and other factors. Guidance documents sometimes provide prioritized lists of flood reduction approaches with corresponding cost estimates. Some plans even include concept-level diagrams of high-priority projects. The more detailed the plan, the more easily you will be able to transition into implementation. However, available funds may be a limiting factor.

Step 2: Assemble the internal project team

- **Evaluate internal capacity**
- **Select a Flood Resiliency Plan Development Project Manager**
- **Select an Outreach and Engagement Specialist**
- **Form a Flood Resiliency Plan Preparation Task Force**

Small local governments typically have few staff members, each of whom performs an array of crucial services. As a result, smaller governments are not likely to have the staff capacity needed to develop a resiliency plan entirely in-house. This was the case for all three projects we evaluated. All the case studies employed a team approach in which the local government project managers worked together with the hired engineering firms to (1) develop a plan that supports the goals set by the community, (2) locate a source of funding to assist with the expenses of developing a comprehensive resiliency plan, and (3) write the proposal for funding. When engaging in an informal collaboration with a firm that may later be considered for related contractual work, be sure community personnel follow all procurement regulations.

Evaluate internal capacity

During scope development you began to think through who needs to be involved in the project as well as their roles and responsibilities. You also began to think through what could be accomplished in-house, as well as what would require the procurement of consultant services. In the case studies we evaluated, the governments found that developing an overall systematic approach to a flood resiliency plan requires experts and/or specialists in the following areas:

1. Grant-writing.
2. Design and construction of green-gray combination stormwater management systems.

Community outreach and engagement.

However, this will vary based on the capacity of each particular community. Continue to think through the skills and abilities that can be contributed by community staff, the contributions that could be made by partnering organizations, and the services that will need to be procured.

The local community initiating the project will play a crucial role throughout its duration. To do so most effectively, there are several key roles that will need to be filled. These roles can take several forms but are described in this section as a Flood Resiliency Plan Development Project Manager, Community Outreach and Engagement Specialist, and Resiliency Preparation Task Force members.

Select your community's Flood Resiliency Plan Development Project Manager

In all our case studies, the engineering firms emphasized that a key criterium in their decision to engage in the local community project was the trust they had in key personnel to (1) provide an efficient, timely response to requests for community information, (2) provide as much background data as the community had available, and (3) provide periodic feedback to ensure the plan was geared toward meeting their community's goals. The success of the projects in our case studies were, in large part, attributed to this highly productive collaboration.

In advance, select a community point-of-contact that will serve as the community's Flood Resiliency Plan Project Manager during the process of developing your community's plan. Their duties include:

1. Coordinating all prior preparation, including the search for funding, oversight of grant-writing, the search for a high-quality engineering firm, organization of community background materials, and compilation of local data.

2. Collaborating with the engineering firm hired to design and develop the plan.
3. Serving as liaison between the engineering firm and the rest of the community staff, community governance body, interested community organizations, and the citizenry at large.
4. Overseeing review of the final report and coordinating implementation of the follow-up projects recommended.

The qualifications of the Flood Resiliency Plan Project Manager include:

- Experience with applying science-based decision-making.
- General understanding of the engineering hydraulics of stormwater management systems, including the community's drainage pipe systems.
- General understanding of the importance of natural and nature-based features, including forest and wetland ecology, in stormwater management.
- Familiarity with integrating gray and green best practices into storm water management infrastructure projects.
- Experience with oversight of stormwater management projects.
- Commitment to best practices in operating, maintaining, and improving the community's stormwater infrastructure.
- Understanding of community-wide and project-specific budgeting processes.
- Familiarity with basic geographic information systems (GIS) applications.
- Interest in community outreach and engagement in the field of stormwater management.

Select your community's Outreach and Engagement Specialist

In our study, the engineering firms and the pilot project community staff and volunteer stormwater management committees emphasized the need for engaging all segments of the community in the development of the resiliency plan. All considered establishing early lines of communication as essential to the success of the plan development. Prior to designing the flood resiliency plan, the engineering firms developed an outreach approach and interactive activities with:

- Community staff
- Community governance bodies (city council/town commissioners)
- General community citizenry

The pilot project community staff and volunteer stormwater management committees emphasized the need for the community to train a member of staff or hire a new staff member with combined expertise in a systematic, watershed-based approach to stormwater management and expertise in community outreach and engagement methodology to navigate the social science aspects of stormwater management, especially in addressing the concerns of the overall community membership. Questions that need addressing included:

- Are we really addressing the problems that community members are experiencing?
- How many members are having problems and how often?
- Who do they approach for help with these?
- Do they feel they are being heard?

In advance of hiring an engineering firm to design and develop the flood resiliency plan, select a community Outreach and Engagement Specialist who will serve as your

community's liaison between the engineering firm your community employs, community governance leaders and staff central to community decision-making, and the general public during the process of developing your community's flood resiliency plan. Consider this to be a permanent responsibility since community outreach and engagement will be essential to the implementation of the plan's recommendations. For more detail on the role of your community's Outreach and Engagement Specialist, see "Appendix 1: Community Outreach and Engagement Specialist's Guide to communicating flood vulnerability and building resiliency."

The duties of the community Outreach and Engagement Specialist include:

1. Increase public access to flood risk and vulnerability information, particularly with reference to the recent and anticipated future local climate changes. Be prepared to update this information with new data as natural factors that influence the precipitation patterns and land-use patterns that influence the flow of stormwater vary over time.
2. Make use of presentation methods and venues that provide information access to all demographic groups represented in the community. Repeat the presentation of information in multiple formats and at multiple times.
3. Engage the public in the decision-making process, starting with the community's consideration of the need to design and develop a resiliency plan.
4. Keep the community updated on the progress of the plan as it develops. Be prepared to explain the rationale for including procedures and analytical tools, such as stormwater modeling, in the development of the plan.
5. Following the development of the resiliency plan, bring the public back into the decision-making process as the community considers action to take on the plan's recommendations. Bring feedback from the community at large back to your governance body and staff for their consideration before they begin their discussion of the prioritization of follow-up projects. Bring the decisions of governance and staff back to the public. Include full explanations of how their priority list was developed and the rationale on which the list is based.
6. Introduce flood risk and flood vulnerability reduction options available on the level of the individual homeowner or renter, and local businesses.
7. Develop effective methods for initiating action by individuals to reduce their flood vulnerability.
8. Test the efficacy of your methodology throughout the process. Make changes where needed.

Qualifications of the community Outreach and Engagement Specialist include:

- Expertise in community outreach and engagement methodology.
- Excellent communication skills, especially in the ability to listen and provide appropriate feedback to all members of the community.
- Experience with applying science-based information to public engagement and educational activities.
- Expertise in a systematic, watershed-based approach to stormwater management, including an understanding of the general function of green and gray stormwater management systems.
- Aptitude for engaging the public enthusiastically and sincerely with sensitivity to demographic inclusiveness. Consideration of equity issues and inclusiveness are important for the success of community resiliency projects.

Form a Flood Resiliency Plan Preparation Task Force

This is a working group with specialized skills for accomplishing the task of gathering and organizing all existing community data and documents relevant to stormwater management. Set a finite time frame for accomplishing the task and outline the specific deliverables expected of the task force. As the name implies, when the task is completed, the task force is dissolved. Long-term, the community will need a curator of these files. These will require updating as new data and documents become available. Some of this information will also be useful for other purposes, such as community long-term planning, budgeting, and emergency preparedness for hazards other than flooding. It is best if at least one member of the task force, as well as the long-term curator of the organized information, be community staff employees. If some aspects of the skillset needed to complete the task force team are not available in-house, consider recruiting volunteer(s) from the community with those skills or hiring a temporary employee to fill that role. If your community is recognized as having historical significance, you may want to search for an institution or organization interested in preserving and curating the original documents that are of historical value. There is not likely to be external funding available to cover the other tasks to be accomplished in this phase of the process. For the task force, select individuals with the following skills:

- Institutional knowledge of the community's existing stormwater management system.
- Multi-media organizational and curating skills, like those of librarians, archivists, curators, and museum workers.
- Technical skills in digitizing information. Minimum skills include working with electronic word processors, spreadsheets, and scanners. Ideally, skills include familiarity with electronic databases and GIS technology.

You may only need a task force of one if a single individual has all these skills. Otherwise, include the minimum needed to cover all areas of expertise. The tasks will take time to complete, so be prepared to provide temporary reallocation of normal duties for staff asked to participate or provide over-time compensation. For the permanent position of curator of the organized information, the staff member will need to be permanently relieved of normal duties equivalent in magnitude to compensate for the extra duties of information curator.

Evaluate volunteer capacity

If community volunteers are sought to fill these positions, caution should be taken to be sure that volunteers are not over-burdened with time-consuming tasks. It is recommended that community staff be either trained or new individuals employed to take on the largest bulk of the tasks and that volunteer experts/specialists be asked to engage in short-term tasks that require manageable time commitments. As you review the sections of our guide that provide details about the requirements of each step in the preparation, design, and development of the resiliency plan, think about the human resources available in your community and decide which require employing external experts and specialists and which can be handled in-house.

Review your goals and scope

Now that you have your internal team assembled, plan for the team to review the initial goals and scope. You may find that the project intent has changed through the process of selecting individuals to participate and because of the knowledge and insight they have already shared. Work within the team to update the goals and scope as necessary until all team members approve

them. Doing so will create buy-in for the process and help orient everyone to the work to be completed.

Step 3: Secure Funding

Small municipalities are not likely to have the staff capacity needed to develop a flood resiliency plan entirely in-house.

Take a team approach - work together with a hired engineering firm to

(1) develop a plan that supports the goals of the community,

(2) locate a source of funding, and

(3) write the proposal for funding.

Be prepared to do as much of the groundwork as possible to lessen the burden of proposal development that relies mainly on the expertise of the external engineering firm.

Developing a strong flood resiliency plan that reflects the needs and goals of the community will require adequate funding. Small governments are unlikely to have the funds needed to develop the plans in their existing budgets. Fortunately, grant funds can be secured to support these types of projects. To make full use of this guide, your community will need to seek grant funding or have a continuously maintained budget large enough to accommodate the costs of designing and developing a flood resiliency plan, and capital improvements, operations, and maintenance for the follow-up projects your flood resiliency plan recommends.

In most cases, small communities do not have the expertise to write the proposal for grant funding without substantial input from the engineering firm. However, without external funding support, most communities do not have enough unallocated funds in their budget to afford to provide financial support for grant-writing. In the case studies, the engineering firms and community staff engaged in an informal collaboration to locate funding and write the grant proposal prior to initiating a formal contract to develop their flood resiliency plan. The community submitted the proposal. Once the grant was awarded, formal contracts were drawn between the community and the engineering firms detailing the responsibilities of each party. When developing these types of relationships, be sure community staff and volunteer personnel follow all procurement regulations. These regulations will also help guide whether funding should be secured before a firm is engaged, or vice versa.

Communities need to be prepared to do as much of the groundwork as possible to lessen the burden of proposal development that relies mainly on the expertise of the engineering firm. Experts and specialists in grant-writing and community outreach and engagement can be community staff personnel, community volunteers, or subcontractors. It is important to remember that a grant writer may not have technical expertise in stormwater management systems nor specialized experience with community outreach and engagement methodology. These experts and specialists will be needed in addition to a grant-writer. If your community has selected staff members to serve as the Resiliency Plan Development Project Manager and the Outreach and Engagement Specialist, they can contribute the technical expertise needed in the grant proposals. If, in addition to the expertise for which they were hired, they also have experience with grant-writing, they may be able to perform that task as well. An alternative is to add these tasks to those your community includes in the scope of services provided by the engineering firm. However, keep in mind this will increase the cost of the services and that their expertise is centered on stormwater management, not grant-writing or community engagement. Your community may find that employing these specialists separately or training staff to handle these areas of expertise will provide greater value for the money spent.

Get to know potential funding organizations

Engage in efforts to establish relationships with various potential funding agencies. Look for events sponsored by your county or other agencies designed to connect community leaders in stormwater management with potential funding agencies actively seeking to support projects in your county. These events often include various grant organizations giving presentations on what they offer, followed by a question-and-answer session. The funding organizations also offer online webinars and in-person events about their upcoming grant opportunities, as well as workshop training sessions providing information on how to advance stormwater management projects in your community. These activities provide face-to-face interaction between the community stormwater management leaders and potential funders.

MDNR provides funding support to local Maryland communities to assess their flood risks and design and implement mitigation projects through its Community Resilience Program (CRP). Although funding support has been available to address coastal flood hazards for over fifteen years, the support for non-tidal flooding has only been in place for five. A combined consideration of water quality and quantity is a key tenant to MDNR's CRP, which encourages local governments to consider green infrastructure and nature-based approaches as part of a resilience strategy. For more information on MDNR CRP, visit https://dnr.maryland.gov/ccs/coastsmart/Pages/grants.aspx For more information on state funding within the CRP that can support the design and implementation of natural and nature-based resilience projects, see https://dnr.maryland.gov/ccs/Pages/Resiliency-through-Restoration.aspx

A good strategy for your community is to start by learning more about funding agencies and organizations that offer grants to cover all or part of the cost of designing and developing your community's flood resiliency plan, such as MDNR CRP. Visit their websites and, if possible, meet with their representatives in-person. Learn what it is your community needs to do to qualify and pay close attention to proposal submission requirements and deadlines. Once your community completes a flood resiliency plan, meet with funding agencies and organizations that offer grants to cover all or part of the cost of designing and constructing the best management practices recommended in your resiliency plan as follow-up projects.

Step 4 Gather and organize community data and documents

- **Historical maps, plats, drawings, and descriptive documents**
- **Institutional knowledge from community staff**
- **Assessment of existing stormwater infrastructure**
- **Staff & community reports of chronic flooding issues**
- **Newspaper articles on local flood events**
- **Property lines and property ownership data**
- **Economic indicators useful in identifying highly vulnerable areas**
- **Community stormwater management education programs and materials**

In our study, all engineering firms, and pilot project community staff and volunteer stormwater management committees stressed the advantages of having local data and other background materials gathered and organized prior to proposing a community-wide flood resiliency plan. All engineering firms involved in the case studies reported collaborating with community personnel and seeking information from other sources to gather and organize all local information needed prior to initiating work on the flood resiliency plan. Most reported that the local information was not centrally located. Therefore, gathering the data and documents will likely require searching many possible locations to retrieve all materials. Digitize your documents and data. For details on digitization recommendations, see "Appendix 2: Digitize your documents and data." and "Appendix 3: Keep documents and data secure and private." All noted that if community personnel do this in advance of contacting external engineers, this will make a community more attractive to an engineering firm interested in partnering with key community stormwater management personnel and potentially lower the bid estimates a community receives from engineering firms for the scope of work outlined in a proposal. Prepare a list of titles of the reports, datasets, and other documents your community gathers and organizes in advance. Include a reference to this list in the Request for Proposals so that the engineering firms know what materials are organized and readily available for their immediate use.

Basic data and background materials that are your responsibility

Historical maps, plats, drawings, and descriptive documents

In most cases, historical records will be found in several locations. Gather these in one file and prepare them for scanning. If your community was established more than a few decades ago, the originals may be in fragile condition. Have at least one member of the Flood Resiliency Plan Preparation Task Force skilled in handling and preserving historical documents.

Community reports of past and current stormwater issues

This category includes regulatory documents and weblinks related to local, county, state, and federal stormwater regulations the community is mandated or recommended to follow; the documentation the community provides to the regulatory agents to show compliance; and internal reports that include stormwater management information, such as yearly reports of stormwater issues addressed or budgetary allocations toward stormwater maintenance and capital improvements.

Collect information from community staff with institutional knowledge

Interviewing community staff with substantial institutional knowledge about present and past historical flood events and chronic stormwater issues in the community is essential. Documentation of past and current procedures taken by staff to resolve or mitigate these stormwater issues is also important. Community staff with institutional knowledge know the intricacies of a town's drainage systems. They know where the chronic problems are and what type of precipitation events trigger the problems. They know what procedures are generally followed to solve or mitigate the issues and which chronic issues remain largely unresolved.

Smaller communities often have only part-time staff and/or high turn-over, situations that are not conducive to a successful project. Retirement of long-term employees whose institutional knowledge leaves with them is also a problem. All engineering firms made use of historical data on past local flood events gathered from local community documents and from interviews with community storm management personnel with institutional knowledge. Two approaches to gathering information in advance would be useful to the engineering firm hired to design your community's flood resiliency plan:

1. Interview staff, both present and retired, with substantial institutional knowledge about present and past stormwater issues. Record the information they provide in written electronic format. If they agree, audio record the interviews. The audio can then be transcribed to text utilizing computer software designed for that purpose. This will preserve their exact words for future reference, rather than relying only on the interviewer's notes.
2. Map the information that can be geolocated by the staff with knowledge of the trouble spots. Include with the map the specific characteristics of each problem spot. If another person is marking the locations on a map, have the interviewee with the firsthand knowledge check the map for accuracy. Marking the spots on a paper map that has accurate locations for reference points, such as roads and buildings, will be useful. Identifying the points in a GIS formatted map would be even more useful to the engineers.
3. Ask the knowledgeable staff for permission to provide their contact information to the engineering firm if the firm would like to discuss stormwater management with them further.

Community assessment of existing stormwater infrastructure

The pilot project community staff stated one of the first steps in approaching stormwater management is to assess the overall system that presently exists. This includes:

1. Assessment of the condition of existing storm drainage infrastructure.
2. Identification of weaknesses in the system.
3. Documentation utilizing drawings, maps, photos, and written reports.

This is best accomplished by staff with substantial institutional knowledge of the storm drainage infrastructure. Alternatively, the task can be contracted to an engineering firm with expertise in design and construction of storm drainage infrastructure. The engineers in the case studies agreed that this is important and performed this task prior to beginning design and development of the community's resiliency plan. They made visual observations of the community and recorded the geolocation and condition of all existing stormwater management installations, including both gray and green infrastructure.

Other staff-reported stormwater incidents

Collect staff documentation of chronic community flood issues, including drainpipe system weaknesses, changes in surface grade that affected stormwater behavior, and other problems noted by staff. This information may be found in different departments and be recorded in different formats. Gather and organize all past information in one location. In addition to written documentation, map the trouble spots identified. Include with the map the specific characteristics of each problem. Marking the spots on a paper map that has accurate locations for reference points, such as roads and buildings, will be useful. Identifying the points in a GIS formatted map would be even more useful. Setup a system for automatically funneling all future staff-reported stormwater incidents into the new organizational format. This will minimize the effort needed to access this information in the future.

Community members' reports of chronic flooding issues

In our study, all engineering firms, pilot project community staff, and volunteer stormwater management committees emphasized the importance of engaging the full community in the resiliency planning process. In their decision-making process, all utilized information provided by the general citizenry about chronic flooding issues. Sources of this information varied. Included were complaints delivered to staff, presented to members of the volunteer groups working on stormwater issues, brought to the attention of members of the local governance body, posted on unofficial community Facebook® groups and other social media platforms, and submitted to the community newspaper's "letters to the editor." One of the engineering firms tried using the county "311" call data to add to their information on citizen reports referencing local flooding incidents. At the time, the "311" system did not have the data organized in a way that made it practical to sort flood-related issues from other call topics. However, they noted that this may be a useful source in the future. Check with your local jurisdiction to learn whether "311" data is organized in a searchable format. "911" data is another potential source of citizen-initiated flood reporting. Community engagement early in the process is essential to the long-term success of a resiliency plan. If the community feels they are heard and their concerns are being addressed, they will trust the process and are more likely to support the recommendations included in the plan.

Some sectors of the community that are important to the development of community-wide flood resiliency may not be represented by the methods of communication described above. The methods above focus on the "squeaky wheels." While this approach is an important part of a process that listens to the concerns of the general community, these forums may not be utilized by all sectors of the community. Some may consider these options too confrontational. Those who communicate in a language other than English may not feel comfortable using these platforms, which are usually English-only forums. To include a broader sector of the community, alternative outreach approaches are needed. An example of a more collaborative forum for reporting local flooding issues are mobile apps such as *MyCoast: Maryland* (https://mycoast.org/md) that place the emphasis on a brief description of a real-time flood event and mark its geolocation. *MyCoast: Maryland* is a portal to collect and analyze pictures and data relating to flooding caused by precipitation or coastal events. Information collected through this site is used to visualize the impacts of flood events, to enhance awareness among decision-makers and residents, and to encourage action to reduce flood risks. To document the effect and impact of precipitation-based and stormwater flooding, participants click on the "Maryland Storm Reporter" link (https://mycoast.org/md/pluvial). The description can be a photograph and a few words. The spotlight is not on the person reporting the incident, but on the "citizen science" approach to gathering flood event data. As the database grows, its value as a tool for guiding communities developing a flood resiliency plan will be enhanced. Communities could design their own version of photo-documenting local flood events utilizing Google Earth® (http://earth.google.com). Caution should be taken to protect personal identity such as location of a residence. This can be done by using the privacy setting available in Google Earth®. See important information in "Appendix 3: Keep data and documents secure and private." Engineering firms in one of our case studies made use of paper street maps presented to community staff and the general citizenry and asked them to circle areas where they had observed chronic flooding issues. This method provided a comfortable forum for responses from

those with and without technological experience. Combining several different community outreach and engagement activities will promote a more inclusive, complete overview of flood issues important to the entire community. To test how well your community's efforts accomplish this, use ground-truthing after heavy rainstorms to find areas not reported that are regularly flooding.

Reports of chronic flooding issues from members of the community will likely be patchy and incomplete at the time of hiring an engineering firm to design your community-wide flood resiliency plan but this information will still be useful to the engineers. Gather all records in one file to be used in the plan development process.

Newspaper articles on local flood events

Archived local and regional newspaper articles on local flood events will add to the historical records gathered in the above sections. Include photos as well as written descriptions.

Accurate property lines and property ownership data

Accurate property lines and property ownership data are important. Online information is not always up-to-date. The accuracy of this information is of particular importance for estimating the amount of time and the costs of implementing the recommended follow-up flood mitigation and resiliency-enhancing projects. All other characteristics of a proposed project being equal, those that are located on city/town-owned property will be easier to implement than those that are located on private land or land owned by other political jurisdictions, those with utility or other rights-of-way easements, and those that overlap multiple property boundaries. When a project overlaps boundaries, accurate property lines and property ownership data provide the information needed to negotiate memoranda of understanding prior to the start of a project. In addition to flood resiliency planning, this information is useful to communities for other purposes, such as clarification of road and sidewalk maintenance responsibilities and long-term planning.

Gathering the data and documents will likely require searching many possible locations to retrieve all materials. Sort the data chronologically to capture changes in property lines and jurisdictional boundaries over time. Select the most up-to-date records for use in developing your flood resiliency plan. This is the information the design firm will need. In a separate folder, store the obsolete historical records. This information may be useful for other purposes such as documentation of the community's history.

Economic indicators useful in identifying highly vulnerable areas

Some flood-vulnerable sectors of the community that are important to the foundation of a community's economic resiliency are not easily mapped or modeled. This includes sectors that are not clustered but spread randomly throughout the community, which may be the case for households lacking connectivity to broadband internet and/or cellular service, and sectors that identify demographically sensitive information on individuals, such as non-English speakers, lower-wage earners, and racially or ethnically distinct groups. The U.S. Census Bureau (USCB) collects demographically sensitive information on individuals but publishes the data in aggregated blocks to protect personal identifiable information. It is unlikely that a local community's jurisdictional boundaries will match the boundaries of one or more USCB blocks.

Therefore, consider other methods of inclusion of these community sectors in the planning process. For more details on these sectors of the community, see "Appendix 1: Community Outreach and Engagement Specialist's Guide to communicating flood vulnerability and building resiliency."

Highly flood-vulnerable locations are found where a critical infrastructure or vulnerable population cluster is geospatially located in the same place as an area identified by the model as high flood risk. These are the areas where the community needs to concentrate efforts to lower flood risk by installing stormwater management projects to mitigate the flooding. By doing so, the community reduces its flood vulnerability and increases its resiliency. Gather this information in advance for use by the engineers when they are ready to prioritize recommended sites for future stormwater management projects. Identify and geolocate infrastructure critical to economic continuity during flood emergencies and resilience following the emergency. For purposes of developing a community flood resiliency plan, include only critical infrastructure within or partially within the community's jurisdictional boundaries. Economic indicators are grouped into two major categories, Continuity of Operations and Continuity of Government critical infrastructure, and facilities and housing clusters socioeconomically important to community resilience following a flood emergency. Continuity of Operations and Continuity of Government critical infrastructure include:

- Cellular and internet communications
- Utilities
- Backup generators
- Community maintenance facilities
- Community vehicle storage facilities
- Public and community-owned vehicle fuel stations
- Critical public safety and emergency health care facilities
- Food distribution facilities
- Commerce transit routes.

Facilities and housing clusters socioeconomically important to community resilience following a flood emergency include:

- Clusters of affordable housing
- Assisted living facilities
- Educational facilities.

For greater detail on infrastructure included in each of these subcategories, see "Table 1: Infrastructure critical to economic continuity during flood emergencies" and Table 2: Facilities and housing clusters socioeconomically important to community resilience following a flood emergency." Identify and geolocate each. At the minimum, provide the addresses of each. Record "none" if your community does not have a listed infrastructure. This will indicate to the engineering firm designing your flood resiliency plan that they do not need to spend time looking for that item. Add any items important to your community that are not listed. In addition to the list of addresses for each, the value of the information would be enhanced by providing geospatial context. Marking the location of each on a paper map that has accurate locations for reference points, such as roads and buildings, will be useful. Identifying the points in a GIS formatted map would be even more useful. Some of these items may be security sensitive. See important information in "Appendix 3: Keep data and documents secure and private."

Table 1: Infrastructure critical to economic continuity during flood emergencies

Continuity of Operations and Continuity of Government critical infrastructure	Geolocation (address, map icon, or contact information for the company that has the information. Record "none" if this information is not available.)
• Cellular and internet communications:	
○ Cell towers	
○ Publicly accessible Internet hotspots	
○ Publicly available recharging stations for cell phones, laptops, tablets, and other mobile personal communication devices	
• Utilities:	
○ Electric lines and substations	
○ Gas lines, compressor stations, and gate stations	
○ Sewer and water lines	
○ Stormwater drainage systems	
• Backup generators	
• Community maintenance facilities	
• Community vehicle storage facilities	
• Public and community-owned vehicle fuel stations	
• Critical public safety and emergency health care facilities:	
○ Fire and ambulance stations and fire hydrants	
○ Police stations	
○ U.S. military-readiness facilities	
○ Hospitals	
○ Mobile healthcare unit storage and maintenance facilities	
○ Local public transit vehicle storage and maintenance facilities	
○ Emergency shelters:	
- Community emergency shelters	
- Hotels	
• Food distribution facilities:	
○ Grocery stores	
○ Food storage facilities	
○ Emergency food distribution centers	
○ Community kitchens	

• Commerce transit routes:	
○ Interstate highways	
○ State highways	
○ Local roads	
○ Railways	
○ Bus transit routes	
○ Port facilities	
○ Airports	

Table 2: Facilities and housing clusters socioeconomically important to community resilience following a flood emergency

Socioeconomically important factors	Geolocation (address, map icon, or contact information for obtaining the information. Record "none" if this information is not available)
Clusters of affordable housing:	
○ Resident-owned homes	
○ Rental homes and apartments	
Assisted living facilities:	
○ Child and eldercare facilities	
○ Long term care assisted living facilities	
Educational facilities:	
○ Primary and secondary schools	
○ Universities	
○ Libraries	
○ Vocational training centers	

Community Emergency Response Team

Your community will need to create and continually update a list of contact information for those needed to operate and maintain the economically important infrastructure indicators described above. See "Table 3: Chart for listing emergency service providers" for some examples to include. Tailor the list to your community and complete the descriptions of service providers. Where applicable, include emergency phone numbers for reaching the service providers. If your community has a Federal Emergency Management Agency (FEMA) Community Emergency Response Team (CERT), work with them to develop and maintain this list. If your community does not have a CERT, consider establishing one. The FEMA CERT program educates volunteers about disaster preparedness for the hazards that may impact their area and trains them in basic disaster response skills, such as fire safety, light search and rescue, team organization, and disaster medical operations. The program offers a consistent, nationwide approach to volunteer training and organization that professional responders can rely on during disaster situations, allowing them to focus on more complex tasks. CERT will be able to utilize the critical infrastructure list and contact information for the associated service providers for more than just flood-related emergencies, including extreme heat and winter storm events.

Table 3: Chart for listing emergency service providers

This is a list of those needed to operate and maintain economically important infrastructure indicators useful to community flood risk/vulnerability managers in identifying highly vulnerable areas. Some examples are included. Tailor the list to your community and complete the descriptions of service providers. Where applicable, include emergency phone numbers for reaching the service providers.

Continuity of Operations and Continuity of Government critical infrastructure	Service providers
• Cellular and internet communications:	
○ Cell towers	Cellular service companies and cell tower repair personnel, emergency mobile cellular communications services
○ Publicly accessible internet hotspots	Internet service companies and their repair personnel, security personnel for internet network storage facilities, emergency mobile internet communications services
○ Publicly available recharging stations for cell phones, laptops, tablets, and other mobile personal communication devices	
• Utilities:	
○ Electric lines and substations	Line-repair personnel, emergency communications services and substation operators
○ Gas lines, compressor stations, and gate stations	Gas distribution system-repair personnel, emergency communications services
○ Sewer and water lines	Sewer-system repair personnel, water line-repair personnel, emergency communications services
○ Stormwater drainage systems	Local community personnel with knowledge of the stormwater drainage system, system-repair personnel, emergency communications services
• Backup generators	Emergency generator operation specialists
• Community maintenance facilities	Facilities security personnel, emergency maintenance dispatch centers and repair personnel
• Community vehicle storage facilities	
• Public and community-owned vehicle fuel stations	

• Critical public safety and emergency health care facilities:	
o Fire and ambulance stations and fire hydrants	
o Police stations	
o U.S. military-readiness facilities	
o Hospitals	
o Mobile healthcare unit storage and maintenance facilities	
o Local public transit vehicle storage and maintenance facilities	
o Emergency shelters:	
- Community emergency shelters	
- Hotels	
• Food distribution facilities:	
o Grocery stores	
o Food storage facilities	
o Emergency food distribution centers	
o Community kitchens	
• Commerce transit routes:	
o Interstate highways	
o State highways	
o Local roads	
o Railways	
o Bus transit routes	
o Port facilities	
o Airports	
Socioeconomically important factors	Service providers
Clusters of affordable housing:	
o Resident-owned homes	
o Rental homes and apartments	
Assisted living facilities:	
o Child and eldercare facilities	
o Long term care assisted living facilities	
Educational facilities:	
o Primary and secondary schools	
o Universities	
o Libraries	
o Vocational training centers	

Community stormwater management education programs and materials

Gather any stormwater management educational materials, records of past and present programs, such as workshops, and website links that your community previously developed or procured from other sources and shared or presented to staff or the general public.

How to use the Flood Resiliency Plan Preparation Task Force information to greatest advantage

By gathering and organizing all the information described above, the task force's duties are now complete. Before disbanding the group, review the information described in the guide section below, "What to expect from the engineering firm your community hires." If any of the datasets or other materials included in that section can be feasibly handled by the task force, they may choose to gather and organize that information, and add it to the earlier set of documents. In our study, all engineering firms, pilot project community staff, and volunteer stormwater management committees stressed the advantages of having local data and other background materials gathered and organized prior to proposing a community-wide flood resiliency plan. However, in our study, the engineering firms included this step as part of the plan development process. By completing these tasks in advance of soliciting engineering firms, your community is more attractive to an engineering firm interested in bidding on the project and there is potential for lowering the bid estimates your community receives from the firms for the scope of work outlined in a proposal they submit. If writing a Request for Proposal (RFP), include what data and materials your task force has readily available for the engineering firm's immediate use in the work they will be doing to design and develop the plan. Also state specifically what your community expects the engineering firm to provide. State in the RFP what your community's Flood Resiliency Plan Development Project Manager is planning to contribute in services and collaboration during the process of completing the plan. The clearer you are on what your community is providing and what you expect from the engineering firm, the more likely it is your community will receive well-defined proposals from engineering firms and more reasonable bid amounts.

Your community can also highlight the accomplishments of the Flood Resiliency Plan Preparation Task Force when soliciting potential funding organizations. This will make your community more attractive as a potential award recipient.

Step 5: Hire a Consulting Engineer Firm

- Proven record of expertise and competence as demonstrated in previous stormwater management-related projects;
- Demonstrated familiarity with stormwater issues common to the region and its local communities, including an understanding of the changing trends and projections for future flood hazards related to climate change;
- Expertise with stormwater modeling technology, including ability to scale to a resolution appropriate for a local community;
- Demonstrated efficiency in execution of the project through the use of a pre-established template;
- Ability to listen to the goals and concerns of the community and adapt the project objectives to meet those needs;
- Willingness of the engineering firm to collaborate with community personnel to assist in locating funding sources and writing the proposal.

Assuming that your local government does not have the capacity to develop the plan in-house, you will need to hire a consulting firm. As a reminder, your government's procurement policies should be followed and will help to guide the order in which firms are engaged and funding proposals are developed. The primary criteria in choosing an engineering firm with which to collaborate on local community stormwater management projects are the engineering firm's (1) proven record of expertise and competence as demonstrated in previous stormwater management-related projects; (2) demonstrated familiarity with stormwater issues common to the region and its local communities, including an understanding of the changing trends and projections for future flood hazards related to climate change; (3) expertise with stormwater modeling technology, including ability to scale to a resolution appropriate for a local community; (4) demonstrated efficiency in execution of the project through the use of a pre-established template; (5) ability to listen to the goals and concerns of the community and adapt the project objectives to meet those needs; and (6) willingness of the engineering firm to collaborate with community personnel to assist in locating funding sources and writing the proposal. This section provides guidance on how to select a high-quality firm to participate in your project.

Find engineering firms that do work in your community's general location.

Check with neighboring communities that have a flood resiliency plan in place and ask about their experience with the engineering firm they hired. Talk to them in-person or check their community website to see what the plan included. Visit some of their completed projects immediately following large rainstorms to observe how well the systems are functioning. Older installations will provide you with more information than newly installed projects. Most system malfunctions or underperforming system components, if there are any, will be revealed over time. Check the engineering firm's website to get an idea of the type and quality of their work. The engineering firms in our study were multi-faceted. In addition to working with local communities to develop resiliency plans, they work on green-gray stormwater management projects, large and small.

Get to know local engineering firms

In all three case studies, the community stormwater managers and the primary engineering firms involved were familiar with one another's expertise and competency in the field of stormwater management at the community level. This prior interaction was essential to the establishment of trust between community managers and the engineering firms. Our case study and pilot project community staff as well as the pilot project community volunteer stormwater management committees recommended employing a high-quality engineering firm to design and develop the flood resiliency plan. The communities did not feel they had time or human resources to devote to the development of the plan in-house and thought the engineering firm was better qualified to provide the expertise needed. However, they emphasized that community staff with appropriate engineering background in both green and gray stormwater management systems are needed to select a high-quality engineering firm and oversee the progress and quality of the work. Among the engineering firms' primary criteria in choosing to engage in local community projects was that the community's Flood Resiliency Plan Project Manager be well-educated and experienced in the field of stormwater management.

Another advantage to soliciting an external expert to review and evaluate a community's stormwater management practices is that their perspective brings 'fresh eyes' to the subject. An external evaluator can 'see' the big picture and sometimes catch areas of weakness that those

who have been closely involved in the details sometimes miss. An external firm would ideally come to the task free of personal bias.

The best engineering firms to employ for the design and development of a flood resiliency plan are those familiar with both gray and green stormwater management and who have experience integrating the two. Green infrastructure considerations, along with traditional gray stormwater installations, can yield a better alternative that addresses the flooding issue and adds value by providing water quality protection for the watershed. There are well-established engineering firms with long histories of successful high-quality gray stormwater projects, but some may not have experience with green stormwater infrastructure projects. Green stormwater technology is relatively new and best management practices are evolving. There are many relatively new companies offering services in the field of green stormwater infrastructure, but they may not have expertise in the design and installation of gray infrastructure. Some companies have staff expertise in both. There are also companies that formed partnerships to work jointly on projects, one company bringing gray infrastructure expertise to the project and the other bringing skills in green infrastructure. Companies and/or partnerships that bring both sets of skills to a project are highly recommended for a flood resiliency plan development project and for the follow-up projects that will be recommended in the plan.

How to attract the best engineering firms at affordable bids: Stay within your community's budget and get what you need

In our study, all the engineering firms acknowledged that small communities have budgetary limitations and are limited in resources available to increase their budget. They designed plans based on the best available data and best available modeling software that stayed within their community's budget. The engineers recognized the economic hardship placed on small communities that are interested in establishing digitized baseline data and would like to maintain a high quantity and quality of field data, but do not have the budget to do so. Staff training in the use of sophisticated planning methodology and modeling tools, and cost of the related software are beyond the reach of a typical community budget. To lessen the burden on the local budget, the engineering firms made use of non-conventional, cost-free resources, such as conducting interviews with community staff having institutional knowledge of historical flood events and chronic local flooding issues, reports of chronic flooding issues from members of the community, and online archived regional and local newspaper articles on past major rain events. They also optimized the utilization of cost-free federal, state, and county data useful to the community, such as the FEMA digitized Flood Insurance Rate Maps (FIRMs); United States Geological Survey (USGS) digitized topographical data; U.S. Department of Agriculture Natural Resources Conservation Service online soil survey; high-quality, accessible digitized data for evaluating hydraulic and hydrological components from the Maryland State Highway Administration and Maryland Department of Planning Land Use/Land Cover Database; and Maryland county or District of Columbia precipitation data on non-tidal rainfall. These datasets usually needed to be 'fine-tuned' by adjusting the scale to match the high resolution needed for use by a small community, but the time and labor saved by utilizing these robust datasets was substantial.

The engineering firms recognized that the follow-up projects recommended in the flood resiliency plan would need to be spread over multiple years to accommodate both the limited community budget and the limited human resources on staff who are tasked with stormwater management project oversight. Small communities usually have only one, or sometimes only a part-time staff person with the educational background, practical skills, and experience working with green-gray stormwater infrastructure project installation. To assist the communities with long-term budget planning and project scheduling, the engineering firms included qualitative cost-benefit estimates for the recommendations in the flood resiliency plan.

In our study, all engineering firms and local governments' project managers that responded to our interview request indicated the plans delivered a high-quality product within the community's budget.

Follow your procurement policies when hiring a consulting engineer firm

It is important to follow your organization's procurement policies when selecting and contracting a firm to provide services. Regardless of the process used, engage your internal project team in the selection process. Members of the team may have insights or experiences that can help you make the best choice. When describing the project and/or preparing a RFP, tailor your materials to the goals and scope that you developed in Step 1.

When issuing the contract, consider the checkpoints that will be used to evaluate progress and integrate them into the services to be provided. For example, you may want to require that drafts be shared for comment at particular development milestones, that update meetings be held with the internal team on a set schedule, or other approaches to help ensure robust communication during the entire contract.

If you issue an RFP to solicit firms, it is a good practice to include contact information for your community Flood Resiliency Plan Development Project Manager and Outreach and Engagement Specialist in the RFP so that the engineering firms bidding on the project know that your community has in place a point-of-contact with the appropriate expertise needed to answer technical questions they may have while writing their proposal and estimating their costs for the project. This also communicates to the potential engineers that your community will be providing key personnel to collaborate with them during the flood resiliency plan design and development to (1) provide an efficient, timely response to requests for community information, (2) provide as much background data as the community has available, and (3) provide periodic feedback to ensure the plan is geared toward meeting your community's goals.

Communities attract the best engineers by marketing their potential contributions to the project

There are many local communities interested in hiring high-quality engineering firms familiar with both gray and green stormwater management and who have experience integrating the two. Therefore, in economic terms of supply and demand, it's a supplier's market! Engineering firms traditionally advertise the expertise and the services they provide. This is not a traditional role for most communities. They are more accustomed to writing and announcing an RFP or Request for Bids (RFB), receiving many responses from companies, evaluating the merits of each, and choosing the one perceived to provide the highest quality deliverables at the most reasonable cost. In the present climate (pun intended!) the companies qualified to provide high-quality

deliverables that combine gray and green technology in a stormwater management project are positioned to choose the communities that offer the best work environment. The engineering firms in the case studies recommend the community promote the attributes they bring to the project by including this information in the RFP or RFB.

Demonstrate how your community will contribute to a successful and enjoyable collaboration. The case study communities provided staff with the credentials, work ethic, and enthusiasm that contributed to a successful and enjoyable project. All three have a full-time staff member with engineering and/or architectural backgrounds and credentials. Not all communities have staff with that level of education and expertise. Smaller communities often have only part-time staff. The case study community staff (1) were well-educated and experienced in the field of stormwater management; (2) were experienced with the use of GIS technology, including the GIS interactive platform available through Environmental Systems Research Institute® (ESRI), with some relevant data previously digitized; (3) had a long history of institutional knowledge; (4) had a previous record of efficient, timely response to requests for community data not available from other sources; (5) expressed a strong interest in the flood resiliency plan development; and (6) were perceived by the engineering firms to have the ability to follow through with the project recommendations and the interest in doing so.

Engineers' primary criteria in choosing a community with which to work

The engineering firms' primary criteria in choosing to engage in local community projects are:

1. Community staff that are well-educated and experienced in the field of stormwater management;
2. Community staff experienced with the use of GIS technology, including the GIS interactive platform available through ESRI, with in-house availability of ESRI programs and relevant community documents previously digitized in the ESRI system serving as an additional attractive quality;
3. Community staff with a long history of institutional knowledge;
4. Community staff with a previous record of efficient, timely response to requests for community data not available from other sources;
5. High-quality, accessible data available for evaluating local hydrological and hydraulic components;
6. High-quality localized data available on historical precipitation;
7. A community that demonstrated the ability to finance a project to develop a comprehensive stormwater management plan and/or collaborate meaningfully to the development and submission of grant proposals to fund the project fully or partially:
8. Community key personnel that express a strong interest in the project, with general citizenry enthusiasm serving as an additional attractive quality: and
9. The engineering firm's perception that the community had the ability to follow through with the project recommendations and the interest in doing so.

Establish early lines of communication

Once your community has hired the engineering firm, it is important to determine how communication will be managed. In all the case studies, the engineering firms and the local governments' project managers worked together in an informal collaboration to develop a set of

goals important to the community's stormwater management and overall flood resiliency plan. Most importantly, they made time to periodically meet with community project managers to review the plan development to be sure the plan objectives were on-target to meet the community's needs. Since your community already has your key personnel, the Flood Resiliency Plan Development Project Manager and the Outreach and Engagement Specialist in place, your community can expect this aspect of the plan design and development to go smoothly.

Step 6: Implement the Project

Data compilation

- **Hydrological**
- **Hydraulic**
- **Floodplain**
- **Precipitation**

Model selection

- **Precipitation modeling – design storm scenarios**
- **Storm drain infrastructure vulnerability assessment**
- **Non-tidal riverine systems models - dynamic precipitation and stormwater behavior simulations**
- **Modeling Socioeconomically vulnerable flood hotspots**

Choosing appropriate stormwater best management practices (BMP)s for the community

Case study commonalities

Our interviews with the case study engineering firms provided detail and insights into the design process they utilized in developing flood resiliency plans for their communities. Each community had a unique set of goals and objectives as the focus of their plans:

- The primary focus of the City of Hyattsville's "Lower Ward 1 Resilient Stormwater Systems Planning Study" was to take a portion of the city where redevelopment is less prevalent, evaluate its existing stormwater infrastructure, and identify potential green and gray stormwater infrastructure improvements to manage flood risks and improve water quality.
- The "Town of Hebron Stormwater Management Master Plan: Analysis, Design and Green Infrastructure Planning" had a three-pronged focus: 1) study existing conditions (map water flow paths, understand the existing stormwater hydrology, create stormwater models); 2) analyze data (perform stormwater retrofit inspections, identify target areas); and 3) develop a conceptual retrofit plan design, including calculating anticipated pollution reductions.
- The "Climate Adaptation and Resilience Plan for the City of Aberdeen" served as a guide to current and future decision-makers in protecting the natural and built environment, residents and visitors, the economic base, and the quality of life of citizens.

Although each community had their unique goals and objectives, the engineers' approaches to designing their plan had a number of characteristics in common. These common techniques for a plan design could prove useful to your community in learning what to expect from the engineering firm your community hires. In our case studies, all engineering firms chose to model stormwater flow during a hypothetical design storm scenario or series of scenarios under various storm settings. Assessments based on the modeled scenarios were the foundation of the design of the flood resiliency plan. All emphasized the need to collect as much baseline data as possible from the most reliable sources available before modeling stormwater behavior in the community. All model input data required digitization prior to use in the model. In some cases, ESRI digitization at the appropriate resolution was shelf-ready for the engineering firms' use. Where data was not yet digitized, the engineering firms included digitization as one of their project tasks. Digitized data available prior to the project proposal development was an important consideration for all engineering firms in determining whether they would consider doing the project and the cost quoted for their project deliverables. All relied on input data reflecting the hydrology and hydraulic conditions on the ground, and the trends in precipitation in the atmosphere to model outcomes that simulated realistic stormwater flow specific to the local conditions. All emphasized the importance of ground-truthing to verify or adjust the input data to reflect the real conditions observed. All included as components of ground-truthing:

- "Boots on the ground," preferably immediately after a large rainstorm. This was performed by engineering firm staff or subcontractors.
- Interviews with local community key personnel with substantial institutional knowledge about present and past stormwater issues in the community.
- Interaction with community citizens to identify areas of flood concern they wanted to see addressed.

The engineering firms placed importance on providing explanations of why flooding is occurring, in general, and in specific locations. Reasons for flooding included:

- Climate change
- Land use changes

- Changes in grade of slope – small and large
- Poorly designed stormwater management system
- Poor maintenance of the stormwater management system

Because small changes could result in major shifts in stormwater flow, the engineers stressed that models cannot easily show behavior on this scale. In all case studies, they explained the purpose of the models used in the analyses and the level of reliability of the model output based on the quality of input data, quantity of input data, and other factors. This information was shared with community representatives and included in the final report.

Data compilation

Our case studies centered on two themes as the most essential components of a successful project:

1. The importance of close collaboration between the engineering firms and the community stakeholders, including staff, city/town governing bodies, and the citizens of the community.
2. The availability of accurate and precise local flood baseline data to support the accuracy of the model analyses. The flood analysis models require local data that meet quantity and quality thresholds.

As one of the first steps of project implementation, the engineering firm will work with the project team to compile information. The starting point for this effort will be the community data and documents you compiled during Step 4. In addition to the information you will be providing, the engineering firm will likely need to acquire additional data from a variety of resources. One of the case studies had accessible high-quality resources to meet these requirements at the county level (Prince George's County databases) and state level (Maryland State Highway data on roads and drainage systems, and Maryland Department of Planning 2007 Land Use/Land Cover Data). Another case study relied mainly on data compiled previously in a community comprehensive plan developed by the city planning commission, city council, and city staff; and from a county-wide regional report authored by the same engineering firm in a previous year. The third case study relied mainly on data compiled previously in community reports, data previously compiled in a proprietary model designed by the engineering firm, and fresh data collected as part of the flood resiliency plan development. The engineering firms emphasized that adequate non-tidal data for evaluating local flood risk, both current and climate-change related future expectations, was essential to the success of a flood resiliency plan. Access points for up-to-date sources of associated meta data are also needed. These are not always available online. All engineering firms reported challenges to accessing high-quality, quantitative data.

There are several types of data that the engineering firm will integrate into the project to understand how water moves through the project area, as described below:

Hydrological components

Hydrological components are natural or nature-based features that affect stormwater behavior. The following were included in the baseline data of all three case studies:

1. Topography
2. Soil types
3. Natural drainage areas that facilitate infiltration of stormwater
    a. Permanent streambeds and natural ponds

   b. Floodplains (See section below, “Floodplain data”)
4. Natural buffers that slow the velocity of stormwater runoff
   a. Mature woodlands (tree canopy)
   b. Other natural buffers

Hydraulic structures

Hydraulic structures are engineered structures that affect stormwater behavior. The following were included in the baseline data of all three case studies:

1. 1. Impervious surfaces, such as paved roadsSemi-impervious surfaces, such as gravel roads
2. Engineered drainage areas
   a. Engineered swales associated with road, building, and parking lot construction
   b. Stream channelization
   c. Stormwater drainage systems, including stormwater pipes and culverts channeled directly into natural streams leadingto the Chesapeake Bay
   d. Stormwater runoff containment systems, including piped systems and constructed wetlands such as raingardens

Floodplain data

All engineering firms utilized FEMA FIRMs of the 1% annual and 0.2% annual flood risk. Resources used to access FEMA maps varied. FEMA maps were scaled appropriately for the size of the case study communities. However, each engineering firm ‘fine-tuned’ the FEMA maps to provide greater accuracy. Case studies were located in the Piedmont geological region, the Coastal Plain geological region, and at the interface between the Piedmont and Coastal Plain regions. All engineering firms ground-truthed the FEMA floodplain delineations. Ground-truthing showed FEMA floodplain delineations for the Piedmont region “made sense for critical upland floodplains.” Because the Coastal Plain region tends to have minimal topographical variation (the terrain is very flat), ground-truthing for the case study located completely in the Coastal Plain was considered essential to getting the exact delineations corrected. The Prince George’s County website was rated by the engineering firms working in that county as excellent for county FEMA FIRMs. The Prince George’s County website was the source of much of their other data as well, though the engineers reported that some of the online information was outdated and/or records were difficult to access.

Precipitation data

Precise, accurate estimates of present and anticipated future precipitation trends on a local scale were emphasized by all engineering firms as critical in being able to assess what the design requirements should be for future stormwater infrastructure as well as to assess the adequacy of existing systems, and for modeling stormwater behavior. For details on how the challenges of obtaining adequate quantity and quality precipitation data were overcome, see the section below, “Precipitation modeling – design storm scenario development.”

“Boots on the ground” – ground-truthing ensures accuracy and precision

The engineering firms and the pilot project community staff emphasized the importance of ground-truthing in verification of the accuracy and precision of the data prior to entering the information into the models for analyses. Ground-truthing is defined as the verification process that takes samples from the site and compares these measurements to the computer simulated measurements to ensure the accuracy and precision of the computer model. In each case study,

"boots on the ground," preferably immediately after a large rainstorm, was performed by engineering staff or subcontractors. The flood resiliency plan cannot be based solely on theory. The engineers need to see all components of a site. Some characteristics may not be 'seen' in a model or map. "Boots on the ground" is particularly important where the terrain is very flat. Reliable contour lines are essential. A miscalculation of several inches could make a substantial difference in the accuracy of a model simulation of stormwater behavior.

Fieldwork is also needed to assess the overall stormwater management system that presently exists. This includes:

1. Assessment of the condition of existing storm drainage infrastructure.
2. Identification of weaknesses in the system.
3. Identification and geolocation of outfall points, inlet depths, pipe slopes, existing green infrastructure, and other components of a drainage area.

Model selection for data analyses

In our case studies, all engineers placed emphasis on:

1. Designing a flood resiliency plan based on the best available data and best available modeling software that stayed within their local government's budget.
2. Selecting the most appropriate stormwater models available to produce scenarios illustrating current and anticipated future flood risk. There are many good models being developed, but most are not yet scaled for use by local governments.
3. Making use of the modeled scenarios and background information to identify locations of greatest flood vulnerability.

Multiple models were utilized by the engineers. All simulated dynamic precipitation and stormwater behavior using non-tidal riverine systems models. Input for the riverine system modeling required prior modeling of precipitation trends, including both historic and anticipated future scenarios. In addition, two of the three case studies described models utilized to assess stormwater infrastructure vulnerability.

Modeling approaches were described in each of the flood resiliency plan final reports, some in more specific detail than others. Mathematical assumptions, model limitations, and the level of reliability of the model's output based on the quality of input data, quantity of input data, and other limiting factors were clearly stated in all final reports for the precipitation models. For the case studies that provided specific modeling methodology for assessing stormwater infrastructure vulnerability and non-tidal riverine system flood behavior, model assumptions were clearly stated. All provided the rationale for using the models and information on the deliverables the local community could expect to result from the modeling analyses.

Precipitation modeling – design storm scenario development

In the storm drain infrastructure vulnerability assessment models and non-tidal riverine systems models, the precipitation data are one component of the simulations of various design storm scenarios. "Design storms" are defined as an estimate of rainfall intensity in inches per hour based on local rainfall data. Storms are generally analyzed for several duration periods and frequencies. Duration refers to how long a rain event lasts. Frequency refers to the statistical rate of occurrence in an area and is classified in terms of the probability a storm of that design would occur annually, such as a near 100%, 50%, 10%, 2%, or 1% annual chance of occurrence. Design storms are applied in a hydrologic model to estimate rates and volumes of runoff. Storms are

generally analyzed for several duration periods and frequencies. In each case study, this was accomplished by modeling scenarios for 24-hour storm events, with various return frequencies. For the state's current stormwater design standards, see Maryland Department of Environment "Stormwater Design Manual, Unified Stormwater Sizing Criteria" (https://mde.state.md.us/programs/Water/StormwaterManagementProgram/Documents/www.mde.state.md.us/assets/document/chapter2.pdf) This document was utilized in all three case studies.

In two of the case studies, there was not enough precipitation data at the local level to execute a precise precipitation trend analysis. These cases required statistical downscaling to evaluate the changes to local storm frequency expected in the future. In both cases, the methodology in the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 was utilized. For trusted resources on non-tidal areas, the engineering firms accessed nearby political jurisdictions having robust data on non-tidal rainfall. Because these datasets were available at a larger scale, Maryland county (Baltimore and Harford Counties) or District of Columbia (*Climate Ready D.C.* report), statistical downscaling using the methodology in NOAA Atlas 14 was used to evaluate the changes to local storm frequency expected in the future. In addition, one case study used historical and daily bias-corrected downscaled data obtained from the Scripps Institution of Oceanography (https://gdodcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html). The other case study gathered data on individual storm events obtained from the NOAA National Centers for Environmental Information (NCEI – formerly known as the National Climatic Data Center - NCDC) Storm Events Database (https://www.ncdc.noaa.gov/stormevents). This publicly available large-scale precipitation dataset lacks the precision and accuracy needed for meaningful decision-making at the local level. The NOAA NCEI Storm Events Database does not provide data binned at the block level. The NOAA NCEI data need to be interpolated for small areas. This is done using the "Flood Factor." Although the NOAA NCEI data are not precise, the information provides a useful overall view. In addition to these historical records, field data on rainfall were collected by the engineering firms or subcontractors to complement the historical sources.

For the case study without access to a large-scale source of robust precipitation data, rainfall data available at the local subbasin level within the local government's jurisdiction were compiled and entered directly into the precipitation model to calculate design storm duration and frequency periods.

Challenges

All the engineers in our study emphasized that flooding problems are localized. Therefore, publicly available large-scale precipitation datasets and trend analyses lack the precision and accuracy needed for meaningful decision-making at the local level. All engineers commented on the need for access to a minimum level of local data in both quantity and quality to support the accuracy of the model results. All emphasized the importance of local rainfall data to get the precision needed for the scope of the problem. All made use of historical data on past local flood events gathered from local documents and from interviews with the local governments' storm management personnel with institutional knowledge to supplement the local rainfall data. All reported they were able to gather sufficient data for the study.

Storm drain infrastructure vulnerability assessment

All the case studies referred to storm drain infrastructure vulnerability assessments. These provide a better understanding of the local flooding impacts in terms of extent and depth of flooding and determine how they can be mitigated. Two case studies provided specifics on the modeling used. The third study provided general references. For the two providing details on the modeling methodology, both utilized the United States Department of Agriculture Natural Resources Conservation Service (NRCS) Unit Hydrograph method to assess the capacity of the existing infrastructure to handle the regulated design storm and how this capacity would change based on future land use conditions. The NRCS Unit Hydrograph method is designed for computing watershed or drainage area stormwater runoff rates, volumes, and hydrographs. It uses a hypothetical design storm and an empirical nonlinear runoff equation to compute runoff volumes and a dimensionless unit hydrograph to convert the volumes into runoff hydrographs. The key component of the NRCS runoff equation is the NRCS Curve Number, which is based on soil permeability, surface cover, hydrologic condition, and antecedent moisture. A complete description of the NRCS Unit Hydrograph methodology can be found in the NRCS National Engineering Handbook Section 4 – Hydrology (https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/). The NRCS WinTR-55 computer program, which provides a more accurate analysis of the hydrology of small watershed systems can be downloaded, including programs, sample data, and documentation, from https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=stelprdb1042901.

Non-tidal riverine systems models - stormwater management models simulate dynamic precipitation and stormwater behavior

All engineering firms utilized non-tidal riverine systems models to simulate dynamic precipitation and stormwater behavior, such as flow rates and directional flow patterns. Because these are dynamic models, geospatial attributes of data are needed. All firms recognized ESRI shape files or raster files as standard GIS formats and all were able to make use of ESRI files for their stormwater management models. Three of the four engineering firms converted all files to ESRI prior to modeling. The fourth firm used a proprietary model designed by the firm that accepted other digitized formats in addition to ESRI files. All firms considered the availability of a GIS-trained local community staff person to be an asset to the efficient completion of the flood resiliency project.

Two case studies provided specifics on the non-tidal riverine systems model used. The third study provided general references. For the two providing details on the modeling methodology, one case study used a proprietary product based on the Storm Water Management Model (SWMM) developed by the EPA, and the other provided analyses using proprietary software developed in-house by the project engineering firm.

EPA SWMM, a Microsoft Windows®-based desktop program, is open source, public software and is free for use worldwide (https://www.epa.gov/water-research/storm-water-management-model-swmm). The engineering firms purchased a proprietary product developed by a private company that is based on the EPA SWMM - version 5 basic model with advanced functions developed by the private company. They used the water quantity module to determine weak

spots in the local government's stormwater system. The engineers compared the model's results with known problem areas identified by the city and found the model identified the same problem areas. The engineers noted that the EPA SWMM model is a very good modeling tool for water quantity analyses, but not economically practical for water quality analyses within a typical local government's budget. They noted that EPA SWMM has a water quality module available that has the potential to be a very good modeling tool, but a large quantity of input data is needed, which is very expensive to collect.

The engineering firm that used proprietary software developed in-house described their platform as an open-source data search engine that assembles collected information into a single location (the platform). The software tool was utilized to integrate with project-specific design, construction, and as-built utility data. The technology was used to track progress and interpolate data points for incorporation into a larger design solution. Models of 1, 2, 10 and 100-year flood events were generated in the project report. Based on modeling highest flow and flood rates, it targeted areas of the town that would have the greatest benefit from remediation measures. It created a three-dimensional pipe network analysis model, and associated catchments compatible with other dynamic stormwater analysis software publicly marketed. The engineering firm will run hard copies for town records. Its proprietary software is available to towns on a subscription basis that can be used by community personnel for a convenient access portal to town records and for use as a basis for future updates to their flood resiliency plan.

Ground-truthing for the models

The engineering firms emphasized the importance of ground-truthing in verification of the accuracy and precision of the data prior to entering the information into the model for analysis. All engineering firms did field visits to gather data for the model. All noted that existing digital sources were not always reliable. Sometimes this was because the data were out-of-date. Climate change in precipitation trends and changes in land use are examples of data that changes over time and needs to be verified before entering the information in a model. Accuracy of existing sources depends on the source. Some sources have good digital tools, but they are not yet fully mature. Models are for precise, clean systems, which are rarely encountered in real life. All models require mathematical assumptions to function analytically. All assumptions need to be clearly described so that the limitations of the model are understood. All engineering firms did so in the flood resiliency project's final report. In the real-life situation, some modeling assumptions may over or under-weight components of the model. Modeling is best considered as a two-phased process. First, fix and maintain the stormwater management system according to recommendations that emerge from the modeling scenarios. Give the system time to work. Then re-visit the system by conducting follow-up fieldwork. During the follow-up field review, note any areas where real stormwater behavior differs from that described in the model. Correct the model by entering the new field data gathered and reviewing previous mathematical assumptions in the model for possible changes needed based on the new field observations.

Modeling flood vulnerability

Highly flood-vulnerable locations are found where a critical infrastructure or vulnerable population cluster is geospatially located in the same place as an area identified by the model as high flood risk. In Step 4 section, "Economic indicators useful in identifying highly vulnerable areas" your Resiliency Preparation Task Force gathered and organized information that identified critical infrastructure and vulnerable population clusters. By utilizing stormwater

management models, the engineers will identify the geolocations where these economic indicators intersect areas of flood risk. These are the points at which your community is most vulnerable. Socioeconomic vulnerability falls into three categories:

1. Socioeconomically vulnerable flood hotspots

These are located where a critical infrastructure or vulnerable population cluster is geospatially located in the same place as an area identified by the model as high flood risk. These are the areas where the community needs to concentrate efforts to lower flood risk by installing stormwater management projects to mitigate the flooding. By doing so, the community reduces their flood vulnerability and increases their resiliency.

2. Potential future hotspots for socioeconomic vulnerability

There may be areas of high flood risk that are located away from the vulnerable spots, such as deep in a forested area. Many of these are likely functioning as natural stormwater containment areas. These locations need to be flagged for protection from development so that they are preserved as part of the community's stormwater management system; and do not become a flood-vulnerable location as the result of land-use changes or further changes in the climate.

3. Relatively flood-safe socioeconomic factors

There may be critical infrastructure and vulnerable population clusters geospatially located in areas of low flood risk according to the model scenarios of present and anticipated future flood risk. These can be labeled as low priority areas in terms of expenditures for stormwater management upgrades to the community system.

Choosing appropriate stormwater best management practices (BMP)s for the community

All engineering firms in our case studies provided examples of green and gray stormwater BMPs presently available that would be appropriate for managing flood risk and vulnerability at specific locations within the community and provided information about the potential benefits to the overall water quality in the Chesapeake Bay. All engineering firms researched BMPs to identify those that may be applicable to their community as remediation measures. Green stormwater BMPs are continually evolving as new approaches are developed and tested for efficacy. All engineers continually update their inventory of options as new BMPs become available. Resources utilized included the 2018 American Society of Civil Engineers Manual of Practice (MOP) for resilient infrastructure, "Climate-Resilient Infrastructure: Adaptive Design and Risk Management (MOP 140)" (Full text is available to researchers for educational purposes upon request at https://www.researchgate.net/publication/339953671_Climate-Resilient_Infrastructure_Adaptive_Design_and_Risk_Management_MOP_140) and the Prince George's County "Green Map" that has publicly available data on BMPs previously implemented in the county. The county records documenting previously installed BMPs are not as comprehensive as information on infrastructure associated with drinking water. The engineers attributed this difference to the focus of Maryland Department of the Environment Municipal Separate Storm Sewer System (MS4) permits on water quality and not on permitting BMPs for stormwater management. (Information on Maryland MS4 permits is available at https://mde.maryland.gov/programs/water/stormwatermanagementprogram/pages/storm_gen_permit.aspx). The engineers noted that not all BMPs are applicable to a given location with a specific set of flood management needs. The BMPs recommended need to match the real

topographical and hydrological characteristics of the terrain. For example, in the Piedmont, Valley-and-Ridge, and Appalachian Mountain Regions, most BMPs are designed to drain surface stormwater quickly. However, on the Eastern Shore of Maryland where the terrain is very flat, there is not enough natural slope to do this. Therefore zero-grade drainage systems, such as a series of retention ponds, are needed. These provide containment for stormwater immediately following a rainstorm and hold it until there is time for it to slowly seep into the ground. The engineer's recommendations included in a community's flood resiliency plan were tailored to the location. They also made visual observations of the community and recorded the geolocation and condition of all existing stormwater management installations.

The engineers stated that a flood resiliency plan needs to emphasize the type and costs of maintaining BMPs and recommend methods for funding these expenses. When making recommendations for mitigating flood vulnerability and building resiliency, the engineers recommended including a qualitative cost-benefit analysis and consider whether the recommendation can feasibly be accomplished within a community's budget. The communities seldom have extra funds to hire new staff or subcontractors to construct and maintain expanded infrastructure. They often do not have the equipment or human resources to do so. The flood resiliency plan needs to emphasize the BMP type and costs of construction and maintenance and recommend methods for funding the projects.

All engineering firms recommended including a maintenance plan for the flood resiliency plan's suggested BMPs. They emphasized the need to include the cost of maintenance in community budgets for both present and future stormwater management infrastructure. They suggested setting up a schedule and estimate of the cost of long-term maintenance. Also recommended were potential methods for raising the funds to cover maintenance costs and debt services to cover costs of replacement and new construction.

For examples of the types of recommended BMPs and details of the other information introduced in this guide, see the final reports produced in each of our case studies:

Final reports

- City of Hyattsville, Maryland "Lower Ward 1 Resilient Stormwater Systems Planning Study" available at https://lowimpactdevelopment.org/wp-content/uploads/2019/10/Hyattsville-CS-Study-093019-FINAL-sm.pdf
- "Town of Hebron Stormwater Management Master Plan: Analysis, Design and Green Infrastructure Planning" available upon request.
- "Climate Adaptation and Resilience Plan for the City of Aberdeen" available upon request.

Step 7: Integrate the project results

Disseminate the plan

Implement staff and budget adjustments to accommodate both green and gray stormwater management components

Have a clear community-wide plan for financing stormwater management systems

Now that your project has been developed, it is integral to ensure that it doesn't "sit on a shelf." This section will present different options to help you integrate it into your organization's operations.

Disseminate the plan

Once the plan has been finalized, share it widely. If your elected officials were not already part of the plan development process, share it with them and schedule briefings to review the key findings, as possible. Implement a communications strategy to raise public awareness that the planning process has been successfully completed. Your Outreach and Engagement Specialist should put together an approach that includes website updates, social media posts, development of "one pagers" to highlight key findings, and presentations at local group meetings.

Implement staff and budget adjustments to accommodate both green and gray stormwater management components.

There are substantial differences between green and gray infrastructure projects in terms of (1) distribution of costs over time; (2) the need to source green maintenance assignments to staff with the appropriate skills; and (3) the costs of training staff in the operation and maintenance of green infrastructure. Initial installation costs for gray infrastructure are typically higher because they have more costly hardened structural components. Using green infrastructure to supplement or replace gray infrastructure typically has lower initial costs, but higher on-going maintenance costs.

Operational and maintenance procedures require a different set of skills for green versus gray stormwater management projects. Most small communities have staff with skills in maintaining hardened stormwater management systems, such as storm drainpipe systems, but often do not have staff with a background in maintaining green infrastructure. Training of present staff in the installation, operation, and maintenance of green infrastructure or hiring new staff personnel with these skills is needed to widen the breadth of knowledge of staff. Assess your community's ability to accommodate both green and gray components in your stormwater management system and establish a plan and schedule for adjusting your budget and staff expertise to provide support for implementing best management practices (BMPs) in stormwater system design.

Have a clear community-wide plan for financing stormwater management systems

A community plan for long-term, sustainable financing of stormwater management includes capital investments, operation costs, and maintenance costs. In our study, all engineering firms recommended including a maintenance budget for the community flood resiliency plan's suggested BMPs. They emphasized the need to include long-term maintenance costs in community budgets for both present and future stormwater management infrastructure. They suggested potential methods for raising the funds to cover maintenance costs and debt services to cover costs of replacement and new construction. An example would be to charge a local stormwater utility fee. It is not traditional to think of stormwater management in the same way as drinking water and sewer systems, so efforts to educate elected officials and the general community citizenry would be needed. The EPA has charts available to calculate what communities can afford. See the following for more information: https://www3.epa.gov/npdes/pubs/region3_factsheet_funding.pdf and

https://www.epa.gov/sites/production/files/2015-10/documents/guidance-manual-version-2x-2.pdf For an example budget, rate, and fee escalation schedule for a hypothetical Chesapeake Bay community, see "Paying for Stormwater Management in Chesapeake Bay Communities: Policy Recommendations" available online at https://static1.squarespace.com/static/5942af072994ca6253840fc1/t/597a85e29f7456ddab53843e/1501201891539/Strategic+Stormwater+Fee+Structuring+-+6-30-17.pdf

When soliciting grant funding for design of a community-wide flood resiliency plan and for individual follow-up projects, provide information in your grant proposal about your community's plan for long-term, sustainable financing of stormwater BMPs that includes capital investments, operation costs, and maintenance costs. This demonstrates your community's ability to follow through with the flood resiliency plan recommendations and your interest in doing so.

Pricing for operational and maintenance costs, in addition to capital improvement costs, associated with plan recommendations should be a required item in the scope of work you develop with the engineering firm so that your community has a realistic idea of the full cost of a project.

Conclusion: Don’t wait – challenges are not unsurmountable!

While all engineering firms in our study reported challenges, the recommendation was, "Don't wait" – challenges are not unsurmountable, especially when developing a community-wide resiliency planning study, as was the case for these projects. All recommended developing the stormwater management resiliency plan using "good-enough" data rather than to take no action while waiting for better data. All reported sufficient data were available for the assessments and stormwater modeling needed to develop the plan. All recommended using qualitative descriptions of relative flood risk or vulnerability, such as "high," "medium" or "low," rather than using numbers, such as percentages, because the data is not of high-enough quality to support quantitative evaluations. All recognized that greater precision will be needed later, during the design process for site-specific gray/green infrastructure projects. Selection of these site-specific project proposals can use the community-wide planning study qualitative information to justify their location and application of stormwater best management practices.

These themes were expressed by all engineering firms in our case studies and highlighted as "*Strategies that stand out as contributing most to a successful project"* by at least one:

1. Open sharing of data at all levels of government and easily accessible data for use by engineering firms and local communities.
2. "Boots on the ground" – ground-truthing is essential to verification of the accuracy and precision of the input data and model analysis outputs.
3. Acknowledgment of the fact that small communities have budgetary limitations and are limited in resources available to increase their budget. A plan must be designed to stay within your community's budget.
4. Selection of appropriate best management practices (BMPs) for your community, including:
    - Suitability to the topography and other hydrological attributes of the area.
    - Costs of construction and maintenance that are feasible for your community's budget.
5. Inclusion of the cost of maintenance in your community's budget for present and future stormwater management infrastructure.

To get started, a good strategy for your community is to first complete all tasks described above that your community can accomplish independent of external assistance. Once this information is gathered and organized, seek more information about funding agencies and organizations that offer grants to cover all or part of the cost of designing and developing your community's flood resiliency plan, such as the MDNR CRP. See the Step 3 section, "Get to know potential funding organizations" for details on CRP, links to the CRP websites, and details on other potential funding sources.

Now your community is set to approach high-quality engineering firms familiar with both gray and green stormwater management and have experience integrating the two. Choose from the firms that do work in your community's locale. Let the potential engineers know that your community will be providing key personnel to collaborate with them during the flood resiliency plan design and development to (1) provide an efficient, timely response to requests for community information, (2) provide as much background data as the community has available, and (3) be a full partner in the collaborative process to ensure the plan is geared toward meeting your community's goals. Once a good match is found between your community and a high-quality engineering firm, work together in an informal collaboration to develop (1) an overall flood resiliency plan that addresses the set of goals important to the community's stormwater

management, (2) locate a source of funding to assist with the expenses of developing a comprehensive flood resiliency plan, and (3) write and submit a proposal for funding. When funding is awarded, your community is ready to formally contract the engineering firm to take the lead in designing and developing your flood resiliency plan. When engaging in an informal collaboration with a firm that may later be considered for related contractual work, be sure community personnel follow all procurement regulations.

When your community completes a flood resiliency plan, meet with funding agencies and organizations that offer grants to cover all or part of the cost of designing and constructing the best management practices recommended in your flood resiliency plan as follow-up projects. With each follow-up project your community completes, your resiliency to future flood events increases.

Appendix 1: Community Outreach and Engagement Specialist's Guide to communicating flood vulnerability and building resiliency

For a flood resiliency plan to work, the entire community needs to be engaged in making it happen. That includes community government leaders, staff, businesses, and the general citizenry. Interconnecting the efforts of all these sectors through communication and education is the role of a Community Outreach and Engagement Specialist. They serve as the liaison between community leaders and staff making decisions about stormwater management, and the overall community membership who are the main beneficiaries of a well-designed system.

Introduce yourself to the community

Provide the rationale for the establishment of your position including the value your position brings to the community, briefly highlight the expertise you bring, and provide an overview of what you plan to accomplish. Be sure access to this introduction is available to as many of the diverse groups represented in your community as possible. If people feel included from the start of your tenure, they are more likely to continue to collaborate with you as you move through the process of providing information on the community's flood vulnerability and how to build resiliency. Provide your introduction on as many platforms as are readily available and accessible in your community. Try to bring as many of the diverse groups as possible together in the same 'room' when you give your introduction. This encourages collaboration across sectors of the community that can sometimes feel segregated from one another. This all-inclusive introduction helps each group understand that "we're all in this together" and that community decision-making is designed to include all perspectives within the community.

Before announcing your introduction, do a rapid assessment of the diversity that characterizes your community. Past studies show that certain segments of the population may be underrepresented at community flood risk management meetings. Factors that may influence individual participation rates include income, ethnicity, education, gender, age, and home ownership. Make a list of community volunteer organizations that express interest in local stormwater management issues. You will not be advocating for these groups' individual missions or agenda. The lists of demographic groups and volunteer organizations provide a framework for you to use as a guide to be sure your general presentation platforms are including as many sectors of the community as possible. Some communities maintain internal documentation of demographic groups in their community and information on local volunteer organizations. Start there. If community-level information is not available, make use of the demographic information in the USCB blocks that overlap your community's jurisdictional boundaries. Compile a list of interested volunteer organizations as you become aware of them.

To be as inclusive as possible on your platforms, choose a variety of media such as a page on the community's official website, press releases for the local newspaper, and a townhall-style meeting that includes both in-person and virtual meeting room accommodations. On all communication platforms where it is feasible, include access in the major languages spoken in the community, and written and audio versions of the materials. Try to reach each group on at least one of your platforms.

In a recent study, the importance of presenting information multiple times in multiple ways on flood risk, vulnerability, and strategies for increasing resiliency was significant. The study

measured learning outcomes before and after a flood risk management meeting for understanding risk and available risk reduction options and found that all participants learned a significant amount during the meeting. However, presentation of information at a single meeting was not able to close the gap between those with prior knowledge and those learning the information for the first time during the meeting. The take-away message is that information needs to be presented multiple times through multiple methods to gain the greatest understanding and adoption of actions to reduce flood vulnerability.

Measure the effectiveness of your communication methodology

Collect pre-engagement indicators that can be re-visited later to measure the efficacy of your communication methods, including how you disseminate information and what you use to initiate community-wide action to increase resiliency. Locate available data to use as pre-engagement measures of what your community previously knew about their flood risk and vulnerability, and what actions they have taken or made plans to put in place prior to your arrival. This will be useful for knowing what information will be new to them and what will be review; and measuring these indicators again as you progress through the process, so you have an idea of how well you are communicating on the various platforms. Examples of easy measurements to put in place are to include a site visit counter on your webpage and tally the number of participants attending your meetings. This tells you how many are accessing the information. Measuring learning outcomes, intent to take risk-reduction actions, and actions implemented is more difficult. Avoid designing and soliciting responses to surveys, online, in the mail, or in-person. Unfortunately, the high volume of survey use, particularly online, has resulted in survey fatigue. Asking participants to complete a survey before and after engaging on one or more of your platforms will not provide a randomized sample since some sectors of the community are likely to be more inclined to complete the survey than others, and those with survey fatigue may be less inclined to access your information later because they want to avoid being asked to complete a survey again. However, many communities have surveys on file, and some repeat the survey periodically. If these are available, review them to see if any of the questions and responses could be used as indicators of the efficacy of your communication platforms. Another indicator available is to visually observe and take inventory of the risk-reduction options in place in the community. Periodically check to see if more have been installed. Also useful are records of the number of flood insurance policies that have been issued to community homeowners, renters, and businesses. Test the efficacy of your methodology throughout the process. Make changes where needed.

Engage the community in collaborative discussions

The core of communication about flood risk, vulnerability, and strategies to build resilience are collaborative discussions in townhall-style meetings that include both in-person and virtual meeting room accommodations. Your other communication platforms will serve as methods of announcing these collaborative events and providing resources to further reinforce the information provided and ideas generated during the collaborative discussions. Collaborative meetings bring participants into the process of assessing risk when community decision-making begins. The disadvantage of this approach is that early involvement of so many participants slows the initial process. The advantage is that conflict resolution and consensus-building are introduced early in the planning process when the plan design is most flexible and can most easily take these issues into consideration. This increases the chance the plan will be accepted in the final stage by all stakeholder groups. For our purposes, stakeholders are defined as those who

both reap the benefits and pay the costs of implementing a community flood resiliency plan. Collaborative learning allows participants to formulate their own set of questions, emphasizing their personal wants and needs related to flood vulnerability Decision-making involves consideration of multiple competing objectives and criteria. Ranking of these is unique for each individual and for each community as a whole. After considering various alternatives, the participants decide which options have the greatest merit. This is referred to as multi-criteria decision analysis.

Information presented in brochures and on websites is an inexpensive means of disseminating information because it is not as labor-intensive as in-person meetings. However, it requires initiative on the part of community members to seek out the information. Lecture-style teaching places information delivery on the lecturer, increasing the likelihood that the audience will receive it, but this method is found to be limited in its effectiveness. Conversely, collaborative learning in which information is disseminated using a method that emphasizes participant-centered problem-solving teams with a facilitator to guide the discussions has been effective in a number of studies. As your community's Outreach and Engagement Specialist, you will facilitate the participant-centered discussions. Choose a physical space for your meetings that provides a high-quality environment for the in-person participants and high-quality internet connectivity for your online participants. Have at least one other staff member assist with the internet connectivity. The quality of the flood risk management meeting facilities has a significant effect on the intent of participants to take action to reduce their risk following a meeting. The higher the quality of the facilities, the greater the intent to initiate risk-reduction action on the part of participants. Consider the following factors when choosing your physical location to maximize the efficacy of your meetings:
well-maintained buildings where air conditioning is comfortable,
visibility of the presentation is good for all participants,
acoustics are good for projecting the voice of the meeting facilitator throughout the room, and
the wireless internet connection is consistently reliable.

Maintain a science-based exchange of information

Outreach and Engagement Specialists ensure that knowledge is transferred from the science and engineering experts in flood risk management to the community and its individual members using the most effective method of communication available. Bring your community stormwater management planners into the collaborative discussions with the general public. In a recent study, when local government planning representatives were present at the community meetings, increases in knowledge of risk reduction options were significantly higher. The representatives answered questions about the availability and feasibility of local flood risk reduction options the meeting participants were considering.

Some participants may enter the discussions with preconceived ideas or information they associate with flooding issues that are not supported by science-based evidence. As the meeting facilitator, keep the focus of the discussion on science-based information. If unsupported concepts are introduced by a participant, respectfully decline to engage in a discussion of those concepts. A simple, nonjudgmental statement such as, "For the purposes of today's discussion, we're going to focus on evidence-based information" is often enough to steer the group discussion back on track. Social media forums, such as unofficial online community groups, are more susceptible to these distractions during the development of group discussions then is the

case in an official flood risk management meeting. For this reason, it is best to avoid engaging in the discussions on these unofficial forums. Instead, post helpful, science-based information on your community's official website or other official social media.

Utilize visualizations that realistically illustrate the community's flood risks, vulnerability, and risk-reduction options

Utilize realistic visualizations during your collaborative discussions to stimulate discussion; to keep the focus on science-based information; and to minimize conflicts between stakeholders that have differing perspectives on the best practices in flood risk management. Examples include local photos, audio-visual recordings, and modeling scenarios of stormwater behavior under various precipitation conditions. Whenever possible, utilize photographs that show locations and events within your community to illustrate the concepts you present. These might include locations where flooding occurs, flood risk-reduction options presently in place in the neighborhood, and images of damage from flooding that occurred previously in the community and could be prevented by implementing one or more of the risk-reduction options available. If local photographs are not available, make use of photos from nearby communities with similar characteristics. Audio-visual recordings can be a powerful method of illustrating real-time flooding at various locations in your community and showing the real stormwater behavior in action as it is occurring. These model scenarios, audio-visual recordings of real-time flood events in the neighborhood, and photos that jog memories of past events facilitate brain-storming sessions and promote understanding of the consequences of a variety of choices The other interesting role realistic visualizations serve is that of conflict-resolution facilitator. Different stakeholder groups often come to the table with preconceived ideas associated with a flooding issue, the benefits and costs from their isolated perspective, and fixed solutions they plan to promote. As participants share their ideas for solutions, conflicts may arise. These conflicts may result from false assumptions about how the physical system works or may be caused by differences in values or interests. Actively engaging the participants in realistic visualization allows them to witness their assumptions being tested and helps to reduce conflicts based on misinformation. By focusing attention on delivering ideas through the visualizations, conflicts take on a less personal perspective. The illustration of various scenarios under different decision-making criteria allows all participants to visually observe the mutual consequences. This can reduce misconceptions about the distribution of costs and benefits among participants and build empathy among groups. Through this learning process, participants are given the opportunity to broaden their perspectives, which can facilitate consensus-building among groups with diverse interests. The collaboration between groups from the very beginning of the process to its completion, and the transparency throughout the process, builds trust among participants and trust in official policymakers overseeing the project. Be cognizant of copyright laws regarding fair-use regulations when using photos or audio-visual recordings from external sources or making yours available to others. For more details on privacy issues that need to be addressed, see Appendix 3: Keep data and documents secure and private.

Reach out to everyone

When communicating information about flood vulnerability, the intent is to reach out to all sectors of the at-risk population and engage them in risk-reduction measures. In our study, all engineering firms, and pilot project community staff and volunteer stormwater management committees emphasized the importance of engaging the full community in the flood

resiliency planning process. A recent study examined the demographics of flood risk management meeting participants in the United States Mid-Atlantic region and found most demographic sectors of the population were reached during the meetings. However, a multivariate analysis showed there was often much less diversity within the individual communities. For example, some community meetings were represented primarily by low-income, African American females. Others were represented mainly by middle-aged, white males with bachelor's degrees. The message from these findings is that to capture all demographically diverse sectors of the community, it is important for Outreach and Engagement Specialists to identify locations within their community where demographically distinct clusters of residents may be found and be sure the information reaches all. Past studies show that racially segregated minority communities receive significantly fewer benefits associated with high-quality environmental planning. However, racially segregated minority communities are interested in environmental issues—demonstrated by their equal participation in flood risk management meetings. In local communities that tend to be segregated, seeking to include all demographically distinct sectors of the community simultaneously in participatory meetings may alleviate this environmental injustice. While the communities participating in flood risk management meetings were representative of the regional population's racial and gender composition, there were some significant differences when each demographic characteristic was analyzed independently. These results showed the study participants were significantly older, better educated, from households earning more than $35,000 (USD 2013) per year, English-only speakers, and more likely to own a home than the USCB data indicate for the region's population. To communicate flood risk information to those segments of the population that may be underrepresented, outreach methods need to be developed for young adults aged 18−44, those without a college education, those with incomes below $35,000, home renters, and speakers of languages other than English.

The low representation of participants aged 18−20 could be due to the high mobility of this age group. Many are in temporary housing while attending college and may show less interest in attending local flood risk management meetings. Low interest in risk reduction measures may also be due to the 'invincible' attitude attributed to this age group, thinking they can survive a flood without much prior preparation. The significantly low participation rates for the 21−44-year age group may be associated with this group being of child-bearing age. In one recent study of those communities in which the USCB census information indicated childcare would be needed by some families, the community organizers did not arrange for childcare to be available during the flood risk management meetings. Since there was no significant difference in gender attendance, the availability of childcare didn't disproportionately impact women versus men. It is particularly important to reach this group since young children are highly vulnerable to morbidity and mortality during flood events. The 18−44-year age group is also more likely to be in the early stages of their careers, in which they may have less flexibility in scheduling their work time around community meetings than is the case for older individuals, who are either at a more advanced stage in their career or are retired and may have more flexibility. The elderly are well represented at flood risk management meetings, particularly by those living independently in homes they own. In the communities participating in flood risk management meetings, 95% of participants older than 64 years of age owned their homes. This is good news because this segment of the population is highly vulnerable to the effects of flooding events.

Meeting participants without a college education and those with yearly household incomes below $35,000 (USD 2013) have been underrepresented in community flood management meetings. A lack of education can result in less awareness of the programs and associated meetings on flood risk management due to illiteracy. Those with less education may not feel qualified to participate in community decision-making and defer to community members with more education to attend meetings and contribute to community decisions. Those with low household income lack the resources to purchase high-quality, risk-protected land and the retrofits that make staying on risk-prone ground less hazardous. This lack of resources may lead to the perception that a meeting on risk reduction is irrelevant. Other barriers to attendance for low-income households may include the cost of childcare, elder care, and transportation to the meeting. Low-wage earners also tend to have jobs that are less flexible. resulting in an inability to attend meetings scheduled during their work hours. These segments of the population are particularly vulnerable during floods. Their participation may increase if meetings were held in a familiar venue that offers a greater level of comfort, such as community buildings at which they often congregate for other activities.

Whether an individual owns or rents their home may affect participation in flood management meetings. In several studies, the demographics in community meetings showed that homeowners were well represented but few renters were attending. Therefore, renters were not receiving the information they need to make fact-based decisions on reducing their flood risk.
Renters may think of flood insurance as a tool useful only to those who own their real estate property. However, flood insurance is available to cover the flood-damaged contents of a home and the cost of alternative housing while the structural damage is repaired. Temporary alternative housing, such as hotel accommodations, may be more expensive than rent paid for regular housing. Therefore, both types of flood insurance could be useful to renters. In a U.S. nationwide survey conducted by FEMA in 2012, almost 31% of households believed that flood damage was covered by their homeowner's or renter's policy. Since most of these policies do not cover damage resulting from floods, many think they are insured when they are not.

The segment of the population for whom their primary language is not English is underrepresented at flood management meetings. This is a growing sector in the U.S. according to the USCB. 2013 data showed that one in five, 21%, of U.S. residents spoke a non-English language at home. Spanish was the non-English language most frequently spoken at home, followed by Chinese. Receiving English-only information about meetings and other activities in brochures, websites, meeting announcements, and other communications, and lack of translators during the meetings may be a language barrier to attendance. In the U.S, how well a person speaks English may indicate how well they communicate with public officials and other service providers. People who do not have a strong command of English and do not have someone in their household to help them on a regular basis are defined by USCB as "linguistically isolated." In 2013, of those who spoke a foreign language at home, 41% were linguistically isolated. With this trend toward an increased number of households speaking English as a second language or speaking no English, the absence of these groups in community flood risk management meetings indicates that more effective methods of communicating flood risk to this sector are needed.

Those with disabilities are disproportionately affected by disasters, with a mortality rate two to four times higher than people without disabilities. In one study where community organizers

chose the facilities at which flood risk management meetings were conducted, only half of the communities located their meetings in facilities that met the accessibility requirements outlined in the *Americans with Disability Act (ADA)* of 1990. One unobtrusive way to help improve participation may be to ensure that the meeting place is easily accessible to mobility-impaired individuals and make sign language interpreters available upon request. One dilemma that arises is that some historic communities and some low-income communities may not have a public facility that is ADA-compliant. However, sign language interpreters could easily be made available to provide communication assistance for those who are hearing impaired.

Individuals who perceive their social status to be different from other meeting participants may avoid attending because they predict the experience will be unpleasant. Household income, ethnicity, gender, and education can contribute to perceived differences in social status. However, most demographic sectors of the community can be reached and encouraged to attend flood risk management meetings with careful advanced planning.

Agenda for collaborative meetings

Set your agenda for each meeting to reflect the progression of your community's plan for developing resilience. The agenda needs to provide the framework for each meeting. The details will be participant-driven during the collaborative discussion. Stay flexible and adapt the specifics to meet the needs of the participants during the meeting discussions. Here is a basic list of successive meetings:

1. Engage the public in the decision-making process, starting with the community's consideration of the need to design and develop a flood resiliency plan.
2. Keep the community updated on the progress of the plan as it develops. Be prepared to explain the rationale for including procedures and analytical tools, such as stormwater modeling, in the development of the plan.
3. Following the development of the flood resiliency plan, bring the public back into the decision-making process as the community considers action to take on the plan's recommendations. Bring feedback from the community at large back to your governance body and staff for their consideration before they begin their discussion of the prioritization of follow-up projects. Bring the decisions of governance and staff back to the public. Include full explanations of how the priority list was developed and the rationale on which the list is based.
4. Provide updates on follow-up projects recommended in the flood resiliency plan as each is designed, funded, and implemented.
5. Introduce flood risk and flood vulnerability reduction options available on the level of the individual homeowners or renters, and local businesses.
6. Develop effective methods for initiating action by individuals to reduce their flood vulnerability.

Meeting protocol for introducing flood risk-reduction options

1. Initially, select four to seven risk-reduction options to include in the presentation.
2. Whenever possible, include photographs that show locations within your community where these options are presently in place or where damage from flooding had occurred that could be prevented by implementing one or more of the risk-reduction options. The list of options included in the presentation will vary depending on the level of flood risk associated with your community. Where the stormwater management models show very low risk of floods,

emphasize options such as preparing emergency kits for sheltering in place and locating emergency evacuation routes that would be unlikely to flood. In communities where the models show very high risk of flooding, the discussion includes the purchase of flood insurance and introduces some of the more costly options such as raising structures to two-three-foot freeboard above FEMA base flood elevation. Freeboard is the space between the expected flood height and the lowest horizontal component of the structure.

3. Give participants the opportunity to discuss possible risk-reduction options that were not introduced initially in the presentation that are of interest to them.
4. Facilitate participants' discussion of the costs and benefits associated with implementing the risk reduction options presented.
5. Give each participant the opportunity to suggest which risk-reduction options, if any, they recommend the community and/or individual participants implement and how they recommend the implementation be accomplished.
6. Summarize the conclusions of the group.
7. Follow-up with interactive activities to compliment the decisions made during the collaborative meetings and provide specific opportunities to learn more about how to implement the risk-reduction options that the participants decided to recommend the community undertake.

Complement the collaborative learning sessions with interactive activities

Some minor, localized, yard-specific flood issues could be mitigated by action(s) undertaken by individuals in your community. The most important component to initiating action is community member education. The educational materials need to be prepared and presented by experts/specialists. Examples include a do-it-yourself workshop on how to construct small stormwater management projects or a community-sponsored group consultation with a specialist or expert, such as flood insurance representatives. Topics might include how to design, construct, and maintain yard swales; the importance of topsoil and its proper use; a presentation or community walking tour introducing plants that absorb stormwater; and a presentation or walking tour showcasing natural and nature-based features (green infrastructure) members could enhance or install to reduce flooding in their yards. Other concepts may feature ways to increase the water quality of the Chesapeake Bay watershed and the local watersheds within your community. Examples include a presentation or walking tour discussing methods of reducing the need for the application of fertilizers or a parent-child snow-shoveling outdoor workday where both learn where to place shoveled snow, so it melts into the soil and not down the storm drain.

References

Aberman, N. L., Ali, S., Behrman, J., Bryan, E., Davis, P., Donnelly, A., & Okoba, B. (2015). *Climate change adaptation assets and group-based approaches: Gendered perceptions from Bangladesh, Ethiopia, Mali, and Kenya* (Discussion Paper 01412). Retrieved from International Food Policy Research Institute website: http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/128950

Adger, W. N., Kelly, P. M., & Ninh, N. H. (2001). Environment, society and precipitous change. In W. N. Adger, P. M. Kelly & N. H. Ninh (Eds.), *Living with environmental change: Social vulnerability, adaptation and resilience in Vietnam* (pp. 3−18). London, UK: Routledge.

Americans with Disabilities Act of 1990. Pub L 101−336. 104 Stat 327.

Atreya, A., Ferreira, S., & Michel-Kerjan, E. (2015). What drives households to buy flood insurance? New evidence from Georgia. *Ecological Economics*, 117, 153−161.

Castro, C. P., Sarmiento, J. P., Edwards, R., Hoberman, G., & Wyndham, K. (2017). Disaster risk perception in urban contexts and for people with disabilities: Case study on the city of Iquique (Chile). *Natural Hazards*, 86(1), 411−436.

Claes Fornell International Group (2010). *FEMA citizen questionnaire*. PennWell Corporation.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate E., & Webb J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, 18(4), 598−606.

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, 84(2), 242−261.

Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster resilience indicators for benchmarking baseline conditions. *Journal of Homeland Security and Emergency Management*, 7(1).

Cutter, S. L., Mitchell, J. T., & Scott, M. S. (2000). Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Annals of the Association of American Geographers*, 90(4), 713−737.

Dino, S. and Wayne, B. (2007). Interactive visualization for the active learning classroom. *Proceedings of the 38th SIGCSE technical symposium on Computer science education.* Covington, Kentucky, USA, ACM.

Devetak, I., M. Hajzeri, S. A. Glažar and J. Vogrinc (2010). The Influence of Different Models on 15-years-old Students' Understanding of the Solid State of Matter. *Acta chimica slovenica* 57(4): 904-911.

Federal Emergency Management Agency (2011). *Answers to questions about the national flood insurance program* (FEMA F-084). Retrieved from https://www.fema.gov/media-library-data/20130726-1438-20490-1905/f084_atq_11aug11.pdf

Federal Emergency Management Agency (2013). *2012 Public survey findings on flood risk*.

Finan, T. J. and D. R. Nelson (2009). Decentralized planning and climate adaptation: toward transparent governance. Adapting to Climate Change: Thresholds, Values, Governance. W. N. Adger, I. Lorenzoni and K. L. O'Brian. Cambridge, Cambridge University Press**:** 335-349.

Glaeser, B., & Glaser, M. (2010). Global change and coastal threats: The Indonesian case. An attempt in multi-level social-ecological research. *Human Ecology Review,* 17(2), 135−147.

Hiranandani, V. (2016). Disability in humanitarian emergencies in India: Towards an inclusive approach. In M. Gill & C. J. Schlund-Vials (Eds.), *Disability, human rights and the limits of humanitarianism* (pp. 101−118). London, UK: Routledge.

Huang, I. B., Keisler, J. and Linkov, I. (2011). Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends. *Science of the Total Environment* 409, 3578-94.

Hvistendahl, M. (2012). Gender and violence. *Science*, 336(6083), 839−840.

Ibarrarian, M. E., & Ruth, M. (2009). Climate change and natural disasters: Economic and distributional impacts. In M. Ruth and M. E. Ibarrarian (Eds.), *Distributional impacts of climate change and disasters: Concepts and cases* (pp. 46−66). Northampton, MA: Edward Elgar.

IWR (2009). Shared Vision Planning Method, U.S. Army Corps of Engineers Institute of Water Resources (IWR).

Interagency Performance Evaluation Task Force (IPET) (2009). Performance evaluation of the New Orleans and southeast Louisiana hurricane protection system *Final Report* (IPET),(I-IX), March 2007 to June 2009.

Kuser Olsen, V. Beth, Gerald E. Galloway Jr., Matthias Ruth. 2018. "The demographics of public participation access when communicating environmental risk" *Human Ecology Review* 24(1): 115-134.

Kuser Olsen, V. Beth, Bahram Momen, Stacy M. Langsdale, Gerald E. Galloway Jr., Lewis (Ed) Link, Kaye L. Brubaker, Matthias Ruth, Robert L. Hill. 2016. "An approach for improving flood risk communication using realistic interactive visualization" available online at http://onlinelibrary.wiley.com/doi/10.1111/jfr3.12257/pdf *Journal of Flood Risk Management*. doi: 10.1111/jfr3.12257.

Larkin, S., Fox-Lent, C., Eisenberg, D. A., Trump, B. D., Wallace, S., Chadderton, C. and Linkov, I. (2015). Benchmarking agency and organizational practices in resilience decision making. *Environment, Systems, and Decisions* 35:185-195.

Mayberry, M.R., M.W. Crocker and Knoeferle, P. (2009). Learning to Attend: A Connectionist Model of Situated Language Comprehension. *Cognitive Science* 33(3): 449.

Maskiewicz, A.C., Griscom, H.P., Welch, N.T. (2010). Using active-learning strategies to address student misunderstandings of global climate change. *The Ecological Society of America 95th Annual Meeting,* Pittsburgh, Pennsylvania, The Ecological Society of America.

Miller, G. (2012). Getting minds out of the sewer. *Science*, 337(6095), 679−680.

Muggleton, S. H. (2006). "Exceeding Human Limits." Nature **440**: 409-410.

Ploetzner, R., S. Lippitsch, M. Galmbacher, D. Heuer and S. Scherrer (2009). "Students' difficulties in learning from dynamic visualisations and how they may be overcome." Computers in Human Behavior **25**(1): 56.

Patt, A. G., Daze, A., & Suarez, P. (2009). Gender and climate change vulnerability: What's the problem, what's the solution? In M. Ruth and M. E. Ibarrarian (Eds.), *Distributional impacts of climate change and disasters: Concepts and cases* (pp. 82−102). Northampton, MA: Edward Elgar.

Saporito, S., & Casey, D. (2015). Are there relationships among racial segregation, economic isolation, and proximity to green space? *Human Ecology Review,* 21(2), 113−132.

Schwamborn, A., H. Thillmann, M. Opfermann and D. Leutner (2011). "Cognitive load and instructionally supported learning with provided and learner-generated visualizations." Computers in Human Behavior **27**(1): 89.
Sclove, R. (2010). Reinventing technology assessment: A 21st century model. Retrieved from http://www.loka.org/documents/reinventingtechnologyassessment1.pdf
Suarez, P., Ribot, J.C. and Patt, A.G. (2009). Climate information, equity and vulnerability reduction. *Distribution Impacts of Climate Change and Disasters: Concepts and Cases.* M. Ruth and M. E. Ibarrarian (ed). Northampton, Edward Elgar: 151-165.
Szalay, A. (2006). "Science in an Exponential World." Nature **440**(413-414).
Tomblin, D., Worthington, R., Gano, G., Farooque, M., Sittenfeld, D., & Lloyd, J. (2015). Informing Nasa's asteroid initiative: A citizen's forum. Final results report. Retrieved from Expert and Citizen Assessment of Science and Technology website: https://ecastnetwork.files.wordpress.com/2015/09/nasa-asteroid-initiative-citizen-forum-full-report.pdf
van den Belt, M. (2004). Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building. Washington, Island Press.
van den Belt, M. J. (2000). Mediated modeling: A collaborative approach for the development of shared understanding and evaluation of environmental policy scenarios, with case studies in the Fox River Basin, Wisconsin and the Ria Formosa, Portuga. Ph.D., University of Maryland.
Vogel, J.J., Vogel, D.S., Cannon-Bowers, J.A.N., Bowers, C.A., Muse, K. and Wright, M. (2006). Computer gaming and interactive simulations for learning: a meta-analysis. *Journal of Educational Computing Research* 34(3): 229.
United States Census Bureau (2010). *American fact finder: Community facts*. Retrieved from https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
United States Census Bureau (2013). *American community survey*. Retrieved from https://www.census.gov/programs-surveys/acs/
Worthington, R., Cavalier, D., Farooque, M., Gano, G., Geddes, H., Sander, S., Sittenfeld, D., & Tomblin, D. (2012). Technology assessment and public participation: From TA to pTA. Retrieved from Expert and Citizen Assessment of Science and Technology website: https://ecastnetwork.files.wordpress.com/2013/01/ecast-report-ta-to-pta-rev1.pdf

Appendix 2: Digitize your documents and data

All engineering firms in our study, and many of the study's pilot project community staff and volunteer stormwater management committees emphasized the need for data to be digitized in a geographic information systems (GIS) platform, rather than as static files such as a portable document format (pdf) or hard copies. Because the stormwater management models simulate dynamic precipitation and stormwater behavior, such as flow rates and directional flow patterns, geospatial attributes of data are needed. All engineering firms recognized ESRI shape files or raster files as standard GIS formats and all were able to make use of ESRI files for their stormwater management models. Three of the four engineering firms in our study converted all files to ESRI prior to modeling. The fourth firm used a proprietary model designed by the firm that accepted other digitized formats in addition to ESRI files. All engineering firms considered the availability of a GIS-trained community staff person to be an asset to the efficient completion of the flood resiliency project. In the case studies, the engineering firms did not expect the communities to have their files in ESRI format prior to the start of the development of the flood resiliency plan. However, if your community can do so, this would (1) make your community more attractive to an engineering firm interested in partnering with key community stormwater management personnel and (2) potentially lower the bid estimates your community receives from engineering firms for the scope of work outlined in a proposal.

If your community does not have the ability to digitize your data in ESRI GIS, you can at least convert all data and other materials to electronic formats. For many historic documents and community reports, pdf files are likely the best commonly available format. Photographs can be digitized using the Joint Photographic Experts Group (jpeg) format. Low resolution will be acceptable for this planning process. Common formats for drawings and other diagrams are Computer aided design and drafting software (CADD) or pdf. For itemized lists or charts of data, Microsoft Excel® spreadsheets are preferred rather than a word processing format. In some cases, the engineering firm will be able to upload the spreadsheets directly into their database and/or GIS modeling system.

Appendix 3: Keep data and documents secure and private

For all original hard copies produced prior to the availability of electronic software:

1. Electronically scan in pdf or other static electronic format to assure a permanent record of the documents. (This step provides protection from loss of information should the original documents be destroyed by fire, flood, or other disaster.)
2. Sort documents and datasets into descriptive categories, including a category for those applicable to stormwater management decision-making.
3. Store all original documents in one location, preserving the filing system established when sorted. Choose a location that is as safe as possible from theft and environmental fluctuations that may damage the originals. Ideally, the location will be locked; temperature and humidity controlled; ultra-violet light-protected; and vermin-proof, including protection from mammals (mice and others), arthropods (paper mites, starch-eating wood-boring insects, and others), and fungus (mildew and others).
4. Store the scanned documents in two separate electronic locations, preserving the filing system established when sorted. One location will serve as the main location and the second as the backup.
5. Keep the files in electronically secure locations, including using password-protected storage and processing devices, and dual access authorization. It is best to avoid storing these on the community's website where it is difficult to prevent security breaches. If the community's website is utilized by community members as a source of local information, consider placing a firewall between the public version of the website and the site community members can access. Have community members use a password and other security measures to gain access. It is best to limit access to members of staff that need to use the documents in their work. However, be sure that at least two staff members always have access to the files. It may be advantageous to make certain documents publicly accessible, such as to highlight community achievements or publicly display documentation of the community's history. In such cases, do so following thoughtful consideration of any possible security or privacy concerns. For example, consider redacting names, addresses, and other personal identifiable information before release to the public. If photos show identifiable images of a person or their personal residence, ask their permission to publish before doing so. Data tagged to geolocations have the potential to cause unintended consequences. For example, many of the tagged geolocations useful in developing a flood resiliency plan identify stormwater problem areas. If these locations are publicly available, nearby property values could be negatively affected.

For electronic originals:

1. Store a copy in their original format.
2. For written documents, store a second copy as a file converted to a format that preserves the original formatting style and provides document searchability, such as a searchable pdf. For written itemized lists, convert to Microsoft Excel® if possible.
3. For electronic drawings and architectural models, store in original format.
4. For photographs, audio recordings, and audio-visual video, store high-resolution items in a separate file. For flood resiliency planning purposes, high-resolution photos will not be needed. Because these often require a large amount of storage space and slow the

processing time when merging documents, save a compressed or low-resolution copy with the other stormwater management-related files.

5. For datasets, convert to Microsoft Excel® if possible.
6. For any data, photographs, maps, or other documents with geospatial attributes, convert to ESRI GIS if your community has that ability.
7. Sort documents and datasets into the descriptive categories established above for the non-electronic original documents. Add additional categories if needed. For flood resiliency planning purposes, the category applicable to stormwater management decision-making will be utilized.
8. Store copies of the documents in two separate electronic locations and keep the files in electronically secure locations, as described above for the non-electronic original documents.