# A Guide to Assessing Green Infrastructure Costs and Benefits for Flood Reduction

**National Oceanic and Atmospheric Administration (NOAA)**
**Office for Coastal Management**

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# Introduction

The purpose of this guide is to provide a process that communities can use to assess the costs and benefits of green infrastructure to reduce flooding. The guide takes a step-by-step, watershed-based approach to documenting the costs of flooding; projecting increased flooding and associated costs under future land use and climate conditions; and calculating benefits and costs of reducing flooding with green infrastructure over the long term. The guide is based on the experiences of three communities in the Great Lakes region (Duluth, Minnesota; Toledo, Ohio; and Green Bay, Wisconsin). To ensure transferability to different types of watersheds and communities, the methods were applied to the He'eia watershed in Hawai'i. Valuable transferability insights from the He'eia watershed partners have been incorporated.

This process guide outlines a six-step process, with specific tasks associated with each step.

1. Define the Flooding Problem
2. Assess Flooding Scenarios without Green Infrastructure
3. Identify How a Flood Reduction Target Can Be Met with Green Infrastructure
4. Assess Flooding Scenarios with Green Infrastructure
5. Estimate Benefits and Costs
6. Identify and Communicate the Desired Green Infrastructure Strategy

Key considerations, recommended expertise, and case study examples are highlighted for practical implementation tips and lessons learned. Finally, key resources are provided at the end of this guide.

# HOW TO USE THIS GUIDE

Communities should use this guide as a framework that can be adapted for their own purposes to inform planning-scale assessments and spark discussion about green infrastructure options to mitigate flooding and provide other watershed benefits. By following the guide's six steps for developing a green infrastructure strategy, including estimation of associated costs and benefits over a chosen planning horizon, communities can demonstrate the cost-effectiveness of implementing green infrastructure projects. This guide does not compare costs between traditional gray and green infrastructure. It should also be noted that there is always a level of uncertainty associated with the use of models and future flooding predictions; the models and predictive tools used here are intended for planning-scale levels of effort. More detailed analyses are recommended for site-specific green infrastructure design.

# KEY TERMS

**Acre-feet** – A volumetric measurement of the number of acres covered by one-foot depth of water.

**Design storm** – Examples of a design storm (also referred to as a storm event) are the 1-year, 24-hour storm event, or the 100-year, 24-hour storm event. The year designation represents a recurrence interval and indicates the probability that a storm will occur during any given year. A 1-year storm has a 100 percent chance of occurring in any given year. A 100-year storm has a 1 percent chance of occurring in any given year. The hour designation (e.g., 24-hour) is the assumed duration of the storm event.

**Ecosystem services** – A positive benefit (direct or indirect) that living and non-living components of the environment provide to a community.

**Flood-depth grid** – A set of data points that shows the depth of flooding that will occur in a location given a specific amount of precipitation.

**Green infrastructure (GI)** – Stormwater management techniques and practices that mimic natural hydrologic functions and incorporate landscape features to store or treat runoff. Green infrastructure incorporates the natural environment to provide multiple benefits and support resilient communities. Green infrastructure can include site-specific management practices as well as watershed-scale techniques such as land preservation and the restoration of wetlands and floodplains that naturally store water and reduce runoff.

**Hazus** – Software package developed and freely distributed by the Federal Emergency Management Agency (FEMA) that estimates property (e.g., buildings) damages from natural disasters.

**Hydrology and hydraulics (H&H)** – Hydrology is the study of water flow through the water cycle. Hydraulics is the study of water flow in channels and pipes. The combination of hydrology and hydraulics provides a complete look at how water behaves as it moves through the landscape and drainage structures. H&H modeling predicts parameters such as peak flow, runoff volumes, velocities, and surface water flood elevations, which allow users to assess how water moves through a watershed.

**Peak discharge** – The highest flow rate at a location for a specific precipitation event (usually measured in cubic feet per second).

# Framework

| STEP 1: Define the Flooding Problem | STEP 2: Assess Flooding Scenarios without Green Infrastructure | STEP 3: Identify How a Flood Reduction Target Can Be Met with Green Infrastructure | STEP 4: Assess Flooding Scenarios with Green Infrastructure | STEP 5: Estimate Benefits and Costs | STEP 6: Identify and Communicate the Desired Green Infrastructure Strategy |
|---|---|---|---|---|---|
| 1. Choose a watershed study area | 1. Gather data | 1. Select a flood reduction target | 1. Model current and future flooding if the flood reduction target is met with green infrastructure | 1. Estimate green infrastructure option unit costs and strategy cost | 1. Finalize a green infrastructure strategy |
| 2. Characterize flooding issues and causes | 2. Model current and future flooding | 2. Identify green infrastructure options | 2. Quantify current and future flood damages if the flood reduction target is met with green infrastructure | 2. Estimate green infrastructure strategy benefits and co-benefits | 2. Communicate the green infrastructure strategy and plan next steps |
| 3. Determine what's at risk | 3. Quantify current and future flood damages | 3. Determine how much storage the green infrastructure options can provide | | 3. Annualize costs and benefits over a specific time frame | |
| **Output:** Definition of the problem and study parameters | **Output:** Financial impacts of flooding under current and future scenarios without a green infrastructure strategy | **Output:** Preliminary green infrastructure strategy for meeting the flood reduction target | **Output:** Impacts of flooding under current and future scenarios with a green infrastructure strategy | **Output:** Annualized net benefits | **Output:** Implementation of green infrastructure strategy |

# Background

The steps outlined in this process guide were developed based on three pilot studies conducted in the Great Lakes region and a community workshop conducted on the He'eia watershed in Hawai'i. The table below presents a summary of each study. Throughout the guide, case study examples from these locations illustrate steps and tasks of the process (for full case studies, see "Pilot Studies").

| LOCATION | FLOODING CHARACTERISTICS | GREEN INFRASTRUCTURE OPTIONS | COSTS AND BENEFITS |
|---|---|---|---|
| **Silver Creek Watershed in Toledo, Ohio** | • Flat terrain<br>• Highly developed<br>• Frequent street and basement flooding during small (e.g.,<br>• 2-year storm) events<br>• Mostly building and infrastructure damage | • Bioswales<br>• Acquisition of tax-forfeited land for flood storage<br>• Blue roofs<br>• Permeable pavement<br>• Retention ponds<br>• Widen drainage channels<br>• Redevelopment requirements for stormwater control/offsets | • 20-year horizon: damages reduced by $700,000 ($38,000 annually)<br>• 50-year horizon: benefits exceeded costs by $70,000<br>• Benefits: limited to Hazus |
| **Chester Creek Watershed in Duluth, Minnesota** | • Watershed divided by a steep bluff with flat, mostly undeveloped upper watershed<br>• High velocity flash flooding in lower watershed as creek flows through narrow ravine during large (e.g., 100-year) events<br>• Damages to infrastructure and recreational assets | • Bioretention<br>• Blue roofs<br>• Permeable pavement sidewalks<br>• Underground storage<br>• Tree trenches<br>• Retention ponds<br>• Extended detention wetlands<br>• Open space preservation<br>• In-stream velocity-reduction<br>• Development/redevelopment requirements for stormwater control/offsets | • 20-year horizon: damages reduced by $1.63 million ($89,000 annually)<br>• 50-year horizon: benefits exceeded costs by $490,000<br>• Benefits: avoided damage to land, property, recreational assets; avoided cost of maintaining stormwater system |
| **Lower Fox River Basin in Green Bay, Wisconsin** | • Hilly, largely agricultural and undeveloped watershed<br>• Riverine overbank flooding<br>• High development potential | • Preserve flood-prone land in the watershed<br>• Fee simple purchase<br>• Easements | • 15-year horizon: annualized costs of $0.5 to $5.1 million depending on land conservation scenario<br>• Estimated benefits: $2.6 million annually (Hazus) |
| **He'eia Watershed in Oahu, Hawai'i** | • Headwaters receive large amounts of rainfall<br>• High peak discharges<br>• Heavy sediment transport<br>• Impacts on coastal fishpond and coral reefs | • Restoration of ancient loi kalo (taro patches) for flood mitigation, sediment reduction, and food supply<br>• Removal of non-native mangrove vegetation<br>• Restoration of wetlands<br>• Restoration of upland forest in the headwaters | • Not yet assessed |

1. Choose a watershed study area

2. Characterize flooding issues and causes

3. Determine what's at risk

**Output:** Definition of the problem and study parameters

# STEP 1: *Define the Flooding Problem*

Step 1 consists of three tasks for defining the problem and study parameters. In the first task you must decide where to focus efforts, so start by defining your study area and the flooding problem. In the second task, you will determine the specific types of flooding problems and their causes. The third task involves identifying who and what is affected by flooding.

## TIPS FOR A SUCCESSFUL START

Understand early on what you have and what you need in order to develop and implement a successful green infrastructure strategy.

- Hold a workshop with key stakeholders to kick-start discussions and brainstorm ideas for the assessment.
- Publicize early successes during the assessment to build momentum.
- Stay engaged with stakeholders throughout the process.

From the outset of Step 1 and throughout steps of the assessment process, it is critical to engage knowledgeable stakeholders who represent different perspectives (e.g., public officials, business groups, watershed, community and user groups, and academia). They can contribute information, expertise, and political support. Consider forming a work group (typically 10-20 people) to provide input and feedback for every step of the process. Community buy-in will be needed to implement solutions and to invest funds, so make sure the right partners are engaged from the beginning. Periodic community briefings for the general public are also recommended.

Stay focused on solving the defined flooding problem and set the assessment up for success by outlining tasks that fit available resources and timelines. Resist "scope creep" by noting good ideas that can be integrated later on, as resources and time permit.

**Key Question:** *What type of flooding problem is this assessment trying to solve?*

**Key considerations:**

- Clearly define the scope of the assessment (list costs and benefits you want to consider, geographic area, time frame)
- Engage a proactive and interested group of assessment team participants, stakeholders, and members of the public with varied backgrounds
- Identify data, information, and expertise that you have and don't have early on in the process

**Recommended expertise:**

- Mapping and GIS
- Hydrology, engineering, stormwater management
- Planning
- Knowledge of the watershed(s)
- Flood management

## TASK 1: *Choose a watershed study area*

Using selection criteria (see the table below), pick a watershed with flooding problems for your study area. Criteria can be used to rank multiple watersheds numerically (e.g., scale of 1-5) or more subjectively (e.g., high, medium, low).

**SAMPLE CRITERIA FOR WATERSHED SELECTION**

| Criteria | Considerations |
|---|---|
| **Community interest** | Are there engaged stakeholders who have an interest in identifying and implementing solutions in the watershed? |
| **Land use** | Is future land use (and change in impervious surfaces) likely to increase flooding? Are there opportunities to shape future land use decisions? |
| **Restoration** | Are there any existing or planned restoration efforts, including drainage improvements or wetlands or open space plans that could be leveraged for green infrastructure? |
| **Economic factors** | Are there significant costs associated with past flooding events? Are there highly valued resources within the watershed (e.g., recreation, ecological resources, cultural heritage, fisheries, scenic, or other public values)? |
| **Land accessibility and ownership** | Are there sites where green infrastructure could be installed (roof tops of businesses/ industries, publicly owned land, tax forfeit property, wetland expansion sites)? Does the community have existing or potential easements in which green infrastructure could be located? |
| **Historic flood damage** | Are the causes of historical flooding known and well documented? |
| **Water quality** | Are there water quality issues (e.g., erosion/sedimentation, combined sewer overflows, temperature) that could benefit from green infrastructure? |
| **Existing green infrastructure** | Are there successful existing green infrastructure practices in the watershed that can be implemented at a larger scale? |
| **Existing data** | Are there good data and information available about the watershed that will be needed to conduct the assessment? |

*TIP: Consider starting with a watershed that will significantly benefit from green infrastructure to show success. But be careful not to pick the most challenging watershed if capabilities are not in place to tackle the challenge!*

Select your study area by choosing one or more watersheds to assess based on the information you have collected. Keep your stakeholders, timeline, and budget in mind when narrowing your focus. Conduct a gap analysis early in the process by developing an inventory of data that are needed vs. data that are available. Make all data accessible to stakeholders. Obtain or develop map(s) of your watershed that identify physical, hydrologic, political, and topographic features. It is critical to obtain enough information to fully understand the hydrology and hydraulics (H&H) of your watershed. Keep in mind that assessments may include watersheds that extend beyond municipal boundaries.

**Toledo Case Study**: *In Toledo the 4,746-acre Silver Creek watershed was selected because future land use was anticipated to change and there was information from a previous study that could be used to inform the assessment.*

Meet with stakeholders to brainstorm and discuss key data needs. Understanding the features of your watershed and the information that you have or don't have will help you prioritize data-gathering needs and set realistic goals. Consider cost sharing, leveraging, and partnering among stakeholders to overcome budget challenges. Ensure that the flooding problem is clearly defined for all stakeholders who may be approaching the assessment from different viewpoints.

**He'eia Case Study:** *Stakeholders in the 2,800-acre He'eia watershed met for a one-day workshop and successfully used this guide as a framework to brainstorm a green infrastructure watershed assessment. Participants identified the need for an information-sharing session to identify data gaps early in the process and more economic information on ecosystem services, which was the main driver in the He'eia watershed.*

## TASK 2: *Characterize flooding issues and causes*

Identify specific characteristics of flooding in your chosen watershed. Determine what type of flooding you are experiencing.

**Duluth Case Study:** *Flooding in the 4,275-acre Chester Creek watershed was mostly due to infrastructure inadequately conveying the volume of runoff flowing through it. Runoff volumes significantly increased because of commercial development in headwater areas, which funneled into a steep, narrow channel. The 100-year storm event was the chosen threshold for assessing damage.*

- Overbank – Flooding that occurs when water overtops the banks of waterways.
- Flash – A major precipitation event that occurs quickly and overwhelms drainage capacity.
- Coastal – Flooding that occurs from storm surge, extreme waves, or high tide.
- Surface – Flooding that occurs when water ponds in flat, poorly drained, or low-lying areas.
- Groundwater – A rising water table that floods basements, without surface flooding.

Identify the scenarios that cause flooding issues and what storm threshold causes flooding damage. Some communities experience flood damages only during 100-year storm events, while others experience flooding from smaller but more frequent storms. Consider the following to determine your "threshold" event:

- Does flooding typically occur after a certain amount of precipitation?
- Are citizen flooding complaints tracked? Is there a trend between complaints and the type of storm event?
- Are there public works records describing when and where infrastructure damage occurs? Are there records of costs associated with flooding events?
- Does damage occur rarely during large storm events or frequently during small storm events?

Characterize the landscape and runoff patterns to understand how runoff moves through the watershed and to identify potential problem areas.

- What are the land cover, topography, and other characteristics that impact flow?
- Where does the bulk of runoff originate?
- What are the impediments to flow (narrow channel, undersized culverts)?

## TASK 3: *Determine what's at risk*

Identify community assets at risk in the watershed. Defining risks allows you to understand the damages that can be monetized (e.g., structural damage, business closures) vs. those that will be harder to quantify (e.g., loss of access to a hiking trail). Be sure to capture risks that are unique to your watershed, including ecosystem services within the watershed. Understanding ecosystem services impacted by flooding early on will strengthen the economic analysis in later steps.

CS **Duluth Case Study:** *Unique assets at risk within the Chester Creek Watershed included a historic site and a park that provided year-round recreational benefits.*

**Sample Assets and Risks**

| ASSET | RISK |
|---|---|
| **Buildings and infrastructure** | Damage to and loss of roads, bridges, water/sewer/stormwater systems, sidewalks, and property and buildings, including residences |
| **Ecological resources** | Siltation, damage to and loss of habitat for fisheries and wildlife |
| **Land and waterways** | Erosion, scouring, mudslides, and associated property loss and damage |
| **Businesses, schools, public services, and utilities** | Disruption, closures, power outages, utility damage, loss of service, loss of access, agriculture and aquaculture losses |
| **Recreation** | Loss, damage, lack of access, closure of facilities, and damage to natural areas |
| **Cultural assets** | Damage to or loss of historical sites, cultural resources, tribal lands |

## OUTPUT: Definition of the Problem and Study Parameters

**Study Area** + **Flooding Issues and Causes** + **Assets at Risk** = **Problem Identification and Study Parameters**

After completing Step 1 you should have a clear sense of the flooding problem, project scope, focus area, information that is needed vs. available, and assets at risk. The tasks in Step 1 form the basis for the rest of the assessment, so it is important to be thorough and set your team up for success!

*TIP: Synthesize the information from Step 1 into a one-page information sheet to communicate the purpose and scope of the assessment to the public. Include examples of past successful green infrastructure projects.*

1. Gather data

2. Model current and future flooding

3. Quantify current and future flood damages

**Output:** Financial impacts of flooding under current and future scenarios without a green infrastructure strategy

# STEP 2: *Assess Flooding Scenarios without Green Infrastructure*

Step 2 establishes the "business as usual" scenario. It will help answer the question: What are the costs of flooding now and in the future if we don't implement a green infrastructure strategy? Step 2 will model flooding and quantify flood damages within the watershed under current and future land use and climate (precipitation) conditions. Projecting future flooding impacts will help you understand and plan for the consequences of future precipitation changes and future land use decisions.

In the first task, you will gather data to determine the current and future conditions within the watershed. You will also designate the timeframe for your assessment and the type of storm events you want to model. You will use the data gathered for current and future land use and precipitation in the second task to perform hydrology and hydraulics modeling for current and future flooding scenarios. Modeling multiple storm events (e.g., 2-, 10-, 25-, 50-, 100-year storms) is recommended to provide a range of impacts. In the third task, you will perform an economic analysis that will quantify the costs associated with flooding under current and future conditions without green infrastructure. The overall goal of this step is to determine which assets are damaged and the cost of those damages under current and future flooding.

**Key Question:** *What are flooding impacts now and in the future without a green infrastructure strategy?*

**Key considerations:**

- Planning horizon time frame (at least 20 years, and preferably 50 years)
- Current and future precipitation and land use and cover type
- Data inputs for successful modeling

**Recommended expertise:**

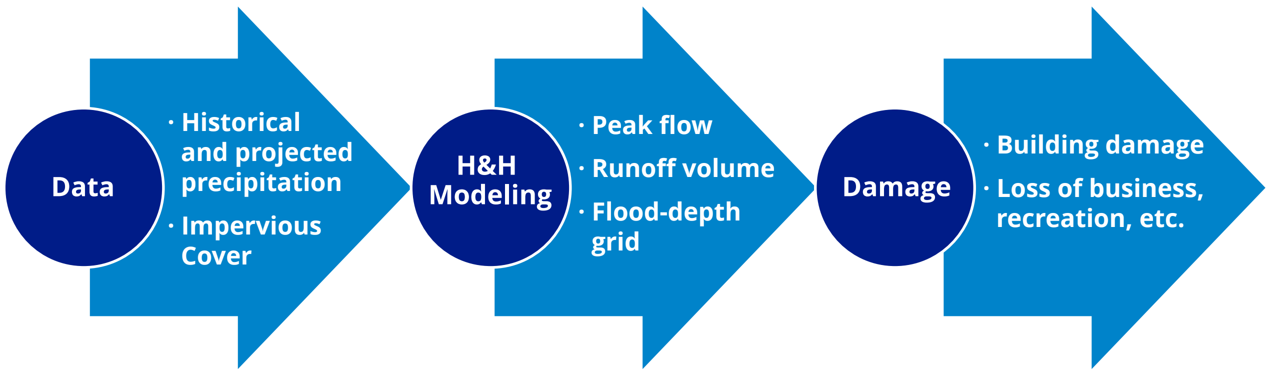
- Planners and local experts in land use, zoning, and mapping (green infrastructure)
- Economists
- Hydrologists, hydrology and hydraulics modelers

## TASK 1: *Gather data*

Establish your assessment window by defining the year that represents your "future" condition (e.g., 50 years from now). This is an important component of your economic and hydrologic analyses. Planning horizons typically range anywhere from 20 to 100 years. A 50-year horizon is advised when assessing the cost-effectiveness of green infrastructure options, since the benefits of properly maintained green infrastructure continue beyond a typical 20-year planning horizon.

CS

**Duluth and Toledo Case Studies:** *A future year of 2035 was chosen because the team had projected future precipitation data for 2035. In hindsight the team felt a longer horizon would have more accurately reflected the green infrastructure benefits and annualized costs. EPA and NOAA assessment tools were used to gather current and future precipitation data. Based on the available data, a U.S. Geological Survey regression equation was used for hydrology modeling and U.S. Army Corps' River Analysis System was used for hydraulic modeling.*




Gather maps and data for both current and future conditions:

- Physical characteristics – topography, soils, waterways, wetlands and floodplains, historic flood elevations, watershed boundaries.
- Current and future land use and zoning – impervious areas, open space, private vs. publicly owned land; residential, business, industrial use; stormwater system, building footprints.
- Inventory of local ordinances, regulations, and plans – stormwater policies and regulations, zoning regulations, master plans, sustainability plans.
- Hydrology and hydraulics (H&H) – stream flow (from gages), existing H&H data and past studies, models that have been used in the watershed, precipitation data.[1]

Gather economic data that will be used to monetize damages to your assets. Identify areas where economic data are lacking. A cost-benefit analysis will still be beneficial even if you don't have all the data; simply note what data are missing and use well-informed, explicit assumptions. Types of economic data include

- Historic flood damage data (from local officials or FEMA insurance claims).
- Recreational use data (from local recreation department or recreation area manager).
- Fisheries or other natural resource data (from state or local natural resource managers).
- Infrastructure cost (capital, operation/maintenance) data (from local engineering office).
- Business disruption data (from local chamber of commerce).

## TASK 2: *Model current and future flooding*

Determine which H&H models to use (there are many) based on the desired outputs, your assessment goals, available data, previous models used in the assessment area, and the type of model recommended by the person performing the modeling. Keep in mind that the watershed-scale

**1** EPA's Climate Resilience and Awareness Tool (CREAT) provides historical and projected future precipitation (http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm); also see TP-40 and Atlas 14 (www.nws.noaa.gov/oh/hdsc/currentpf.htm) analyses described in this process guide are intended for planning purposes rather than for site-level, design-scale green infrastructure. H&H modeling outputs include peak discharges, peak velocities, and flood-depth grids within your watershed. Flood-depth grids allow you to see locations and depths of flooded areas given your design storms and timeframe.

Use the input data for current conditions to perform H&H modeling for current land use and current precipitation scenario. Performing H&H modeling for current conditions provides baseline flood depths for the range of storm events in the watershed.

CS

**Duluth Case Study:** *Based on H&H modeling, the peak discharge for the 100-year, 24-hour storm under current conditions was 1,530 cubic feet per second (CFS) and the peak velocity was 9.62 feet per second (ft/s). Under future conditions with increased impervious cover and precipitation the peak discharge was 1,735 CFS and the peak velocity was 9.87 ft/s.*

Future land use and future precipitation are two main variables that will influence future flooding. Some data inputs will remain the same (e.g., drainage area) but others need to be changed to represent future conditions. Flood impacts of future land use are calculated via a "build out" analysis, where additional impervious surfaces from future development are incorporated into the model. Use the input data for future conditions (increased precipitation, increased impervious surface) to re-run H&H modeling for the future scenario.[2] Modeling future conditions provides flood depths that take into account precipitation and land use changes over the assessment timeframe.

## TASK 3: *Quantify current and future flood damages*

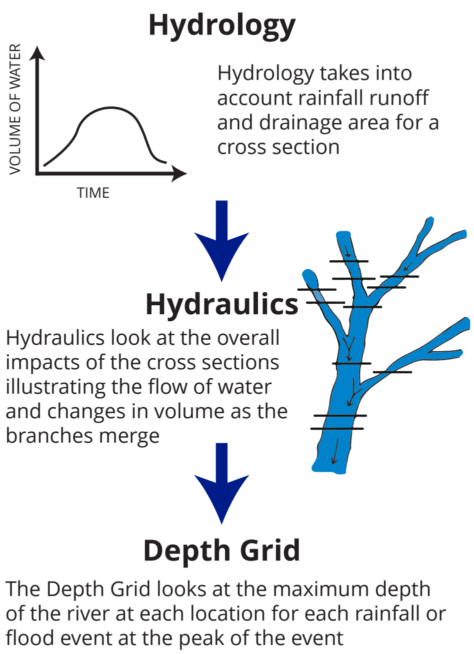
CS

**Toledo Case Study:** *Hazus was used to quantify building damage during current and future flood events. For the 100-year, 24-hour storm event the Hazus building damage in the Silver Creek watershed was estimated to be $738,300 for the current scenario and $980,800 for the future scenario.*

Use the H&H modeling outputs to estimate damages from current and future flooding in "business as usual" scenarios without a green infrastructure strategy. Different economic assessment or modeling approaches may be appropriate depending on the type of damages being assessed. Economic assessments may be performed using spreadsheets or software depending on what makes sense for your community and the resources you have available. An example of an economic assessment model is Hazus,[3] which uses flood-depth grids generated from an H&H model, structure inventories, and standard depth-damage curves to estimate damages to buildings and their contents. The figure is an example of a visual Hazus output. Each Hazus run focuses on the damages associated with a storm event of a particular size; results from multiple Hazus model runs for storms of different magnitudes

**2** Examples of publicly available models and tools (also see "Key Resources"):
EPA's National Stormwater Calculator estimates the annual amount and frequency of runoff from a specific site. The user inputs land cover data and (for Step 3) selects the types of green infrastructure they want to install – *www2.epa.gov/water-research/national-stormwater-calculator*.
EPA's Storm Water Management Model (SWMM) hydrology-hydraulic model can be used for a single event or long-term simulation of runoff quantity and quality from primarily urban areas – *www2.epa.gov/water-research/storm-water-management-model-swmm*.
U.S. Army Corps of Engineers, Hydrologic Engineering Centers provide hydrology (HEC-HMS) and hydraulic (HEC-RAS) engineering analysis models and tools – *www.hec.usace.army.mil.*

**3** More information on Hazus can be found at *www.fema.gov/hazus*.




are used to compute the expected annual damages (EAD), representing the losses that can be expected to result from storms of any size in a single year.[4]

Some types of losses are not assessed by Hazus (e.g., damages to streets, sidewalks, storm sewers and other public infrastructure, reduced visitation at public parks). These losses can be assessed independently of the Hazus model and added to EAD estimates derived from Hazus results. For example, to estimate reduced recreational benefits you would need to estimate (1) the reduced use attributed to flooding and (2) the monetary value associated with usage. Monetary values can be estimated using data on expenditures or by using values developed in other studies via the benefit transfer method.[5]

In order to fully analyze damage, remember to consider the costs that might not be easy to monetize. Some impacts are easily quantified because they have a clear monetary value. Other impacts are less easily quantified or may be expressed in units other than dollars (e.g., days of recreation loss). These types of impacts may require a qualitative assessment, but still need to be included because they are important in portraying a complete picture of the flooding damages.

## OUTPUT: Financial Impacts of Flooding under Current and Future Scenarios without a Green Infrastructure Strategy

**Data** + **H&H for Current and Future Flooding** + **Damages for Current and Future Flooding** = **Current and Future Flood Impacts**

After modeling current and future flooding and estimating damages for both scenarios, you will have a clear understanding of the damages and costs incurred without mitigation provided by a green infrastructure strategy. These “business as usual” scenarios establish a baseline of current damages and estimated future damages based on predicted land use and precipitation changes.

4 EAD computations are used to account for the continuous nature of both storm severities and probabilities of storms occurring. In essence, EAD calculations smooth damages across discrete storm severities (e.g., 2-year, 5-year).

5 Benefit transfer method is used to estimate economic values by transferring available information from one location to another. For example, values for recreational fishing in one state can be estimated by applying recreational fishing values from a study conducted in another similar state.

1. Select a flood reduction target

2. Identify green infrastructure options

3. Determine how much storage the green infrastructure options can provide

**Output:** Preliminary green infrastructure strategy for meeting the flood reduction target

# STEP 3: *Identify How a Flood Reduction Target Can Be Met with Green Infrastructure*

Step 3 focuses on selecting green infrastructure options that together make up a strategy to provide the flood storage needed to meet your flood reduction target. The first task is to choose a quantifiable flood reduction target (i.e., what amount of flood reduction do you want to achieve?). Associated with your target will be a volume of runoff that needs to be stored or reduced to meet your goal. The second task is to select green infrastructure options that will achieve the target. The third task assesses where and how various options can be used to reach the flood reduction target. The goal of Step 3 is to establish a flood reduction target and design a green infrastructure strategy to meet the target.

- Green infrastructure option – An individual green infrastructure practice (e.g., bioretention, permeable pavement, green roof, constructed wetland) or policy (bylaw, ordinance).
- Green infrastructure strategy – The compilation of green infrastructure options (site-specific and watershed scale) that meet the flood reduction target for a watershed.


*Source: NOAA and Minnesota Sea Grant*

## Key Question: *What flood reduction target am I trying to reach and how can I get there with green infrastructure?*

**Key considerations:**

- What is a realistic target for reducing flooding? Ten percent? Twenty percent?
- How much runoff needs to be stored to meet the target?
- Where can green infrastructure be implemented?
- What types of green infrastructure will work and are supported in the watershed?

**Recommended expertise:**

- Local stakeholders familiar with the watershed
- Stormwater management/green infrastructure design experts and engineers
- green infrastructure/mapping support

## TASK 1: *Select a flood reduction target*

Select a quantifiable flood reduction target for your assessment. This target is the amount of runoff that needs to be managed (reduced or stored) in order to protect assets at risk. Identify one design storm (e.g., 100-year, 24-hour storm event) that most commonly causes significant damage or is a threshold for when damage occurs. Pick a flood reduction value (e.g., a 10 percent reduction in peak discharge from your design storm) which, if achieved, would reduce damage to assets. If resources are available, choose to compare a few flood reduction values to see how the damages change with different levels of storage. Use the chosen flood reduction value to determine a storage volume that will be managed in the watershed. This is your flood reduction target.

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**Toledo Case Study:** *In order to pick a flood reduction target for Silver Creek, the team calculated the storage that was required to reduce the peak discharge of the 100-year storm event by 10 percent. Flood Storage Volume = (1,255 ft3/sec - 1,130 ft3/sec) (3 hours) (60 sec/min) (60 min/hr) (acre/43,560 ft2) = 31 acre-feet. To reduce peak flooding by 10 percent over 3 hours, 31 acre-feet of storage would be needed.*

Consider how effectively a flood reduction target will mitigate current and future flooding. Providing flood storage may reduce flooding significantly under current conditions, but the impact may be negligible in 30 years if flooding is expected to increase. You may need a more aggressive target now to realize benefits in the future.

## TASK 2: *Identify green infrastructure options*

Devise a list of green infrastructure options and associated benefits that will provide flood storage or reduce runoff to meet your flood reduction target. Consider diverse options (green infrastructure policies, site-specific approaches, watershed approaches) to allow for flexibility in implementation and potentially reduce costs (see table below). Green infrastructure policies are beneficial because they institutionalize green infrastructure as common practice in a community. Policies are especially important if redevelopment and future land use will increase flooding. Site-specific green infrastructure options do not typically provide as much storage as watershed-scale green infrastructure options; however, their high implementation feasibility makes them an essential component of a green infrastructure strategy. Benefits include groundwater recharge, habitat, aesthetics, water quality, reduced runoff, reduced peak discharges, and reduced reliance on (and costs associated with) gray infrastructure.

CS

**He'eia Case Study:** *The priority green infrastructure option for this coastal watershed was reinstating traditional taro patches to provide flood storage along with cultural value and ecosystem services.*

| EXAMPLES OF GREEN INFRASTRUCTURE OPTIONS | |
|---|---|
| **Policies** | Regulations, bylaws, and stormwater fees aimed at reducing impervious surfaces, requiring more onsite stormwater management and providing revenue for green infrastructure implementation. |
| | Grants and incentives to promote and fund the use of green infrastructure. |
| | Buy out properties in flood-prone areas. |
| | Zoning changes: land use changes; preserving open space; restricting development intensity or pervious surface; shifting development away from flood-prone areas and into areas suitable for development (e.g., transfer of development rights). |
| **Site-specific approaches** | Bioretention, pervious pavement, green/blue roofs, stormwater infiltration devices, curb cuts, tree planting/tree boxes, rainwater harvesting. |
| **Watershed approaches** | Living shorelines, floodplain restoration, riparian buffers, "daylighting" culverted streams, land preservation, land restoration, wetlands and floodplain restoration and creation. |

Reaching your flood reduction target and developing a feasible green infrastructure strategy will likely require a selection of combinations of green infrastructure options based on

- Cost (both capital costs and operation and maintenance costs).
- Space constraints, land availability, existence of opportunities (large roof areas for green/blue roofs).
- Strategic location of storage to maximize impact on downstream flooding.
- Ability to leverage other opportunities (grants, planned stormwater capital projects, private investments, road improvement projects).

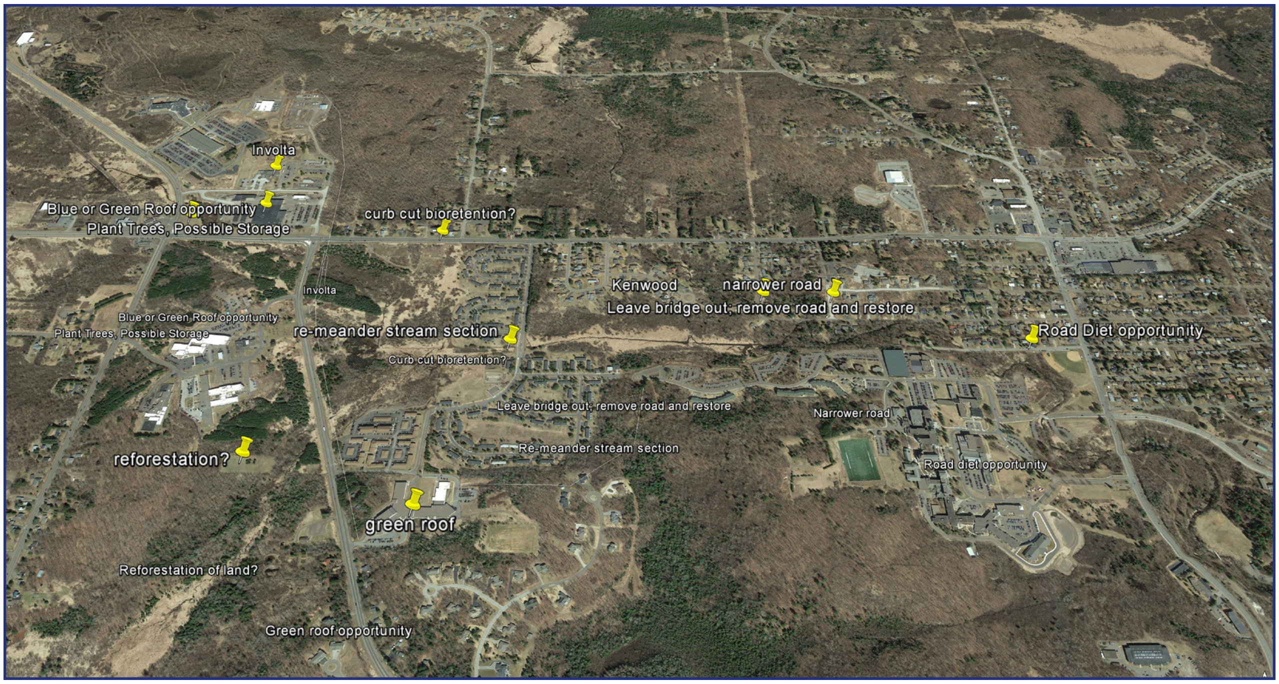
Develop a list of green infrastructure options that are generally supported by stakeholders and provide the best solutions to meet your flood storage target. Consider watershed constraints, technical feasibility, hydrologic impact, and community acceptance when narrowing down the final list of options.

*TIP: Look for opportunities to locate green infrastructure in visible areas, in conjunction with other public amenity improvements such as bike paths.*

## TASK 3: *Determine how much storage the green infrastructure options can provide*

Identify where your green infrastructure options can be implemented. Use aerial imagery and maps to identify locations in the watershed where it is feasible to implement your list of options.

- Are there areas where green infrastructure storage practices can be implemented on a large scale?
- Where can green infrastructure be located to maximize downstream flood reduction benefits?
- Are there heavily developed areas generating lots of runoff with opportunities for onsite green infrastructure (e.g., large commercial roofs where green/blue roofs or curb cuts could be installed)?
- Are there areas with planned capital improvement projects that could incorporate green infrastructure (e.g., roads or sidewalks where bioswales or permeable pavement could be incorporated)?




*Locations of green infrastructure options as identified by participants in Duluth during a mapping exercise*

*TIP: Use participatory mapping, a process where community participants mark up a map (using GIS software or hard copy) for input on possible locations for green infrastructure in the watershed. This gives a sense of possible flood storage locations without establishing priorities for implementation.*

Develop a green infrastructure strategy consisting of a variety of options that add up to your flood reduction target. Developing the strategy will likely be an iterative process involving different combinations of green infrastructure options until you determine the right balance to achieve the flood reduction target. If your green infrastructure options add up to more than your target, then you can drop the less desirable options or adopt a more aggressive target. If your green infrastructure options do not provide enough storage to meet your target, then you will need to change the strategy or reduce the target.

## OUTPUT: Preliminary Green Infrastructure Strategy for Meeting the Flood Reduction Target

**Storage Target** + **GI Options** + **GI Storage** = **Preliminary GI Strategy**

At the end of Step 3 you should have a clear understanding of the flood reduction you want to achieve and what green infrastructure options are feasible to meet the reduction target. The compilation of your green infrastructure options is your preliminary green infrastructure strategy, which you will assess and revise until a final strategy is determined.

1. Model current and future flooding if the flood reduction target is met with green infrastructure

2. Quantify current and future flood damages if the flood reduction target is met with green infrastructure

**Output:** Impacts of flooding under current and future scenarios with a green infrastructure strategy

# STEP 4: *Assess Flooding Scenarios with Green Infrastructure*

This step assesses how current and future flood damages change if a green infrastructure strategy is implemented to meet your flood reduction target. Step 4 modeling mirrors Step 2, but includes the addition of storage from your green infrastructure strategy.

The first task is to model flooding scenarios under current and future conditions with the addition of flood storage from your green infrastructure strategy. The second task is to perform an economic analysis that will quantify the costs associated with flooding under current and future conditions if a flood reduction target is met by implementing a green infrastructure strategy. The benefit of your strategy will be measured by the difference in flooding costs with and without the flood storage provided by green infrastructure implementation. Note that the Step 4 output will provide watershed-scale results, not a site-specific analysis.

| | |
|---|---|
| **Step 2** | Hydrology and hydraulics (H&H) modeling for current conditions without a green infrastructure strategy |
| | H&H modeling for future conditions without a green infrastructure strategy |
| **Step 4** | H&H modeling for current conditions with a green infrastructure strategy |
| | H&H modeling for future conditions with a green infrastructure strategy |

**Key Question:** *What impacts does flooding have now and in the future if a flood reduction target is met with a green infrastructure strategy?*

**Key considerations:**

- The parameters used to perform H&H modeling for current and future scenarios without green infrastructure must be the same as those used to perform H&H modeling for current and future scenarios with green infrastructure.
- Coordinate with your H&H modeler early in the process to determine how you will represent the flood reduction target or storage in your models.

**Recommended expertise:**

- Planners and local experts who have knowledge of land use, zoning, runoff calculations and mapping (GIS expertise suggested)
- Economists
- H&H modelers

## **TASK 1:** *Model current and future flooding if the flood reduction target is met with green infrastructure*

Perform H&H modeling to quantify the impacts of flooding under current and future conditions if flooding is mitigated with green infrastructure. This H&H modeling must mimic the one completed for Step 2, with the exception that your flood reduction target will be incorporated into the model. Watershed boundaries should not change. The H&H modeling outputs will be the same as those obtained in Step 2: peak discharges, peak velocities, and flood-depth grids within your watershed. However, with additional flood storage, the peak discharges, peak velocities, and flood depths should be less compared to the scenarios in Step 2. The outputs from this step will allow you to see where flooding occurs and at what depth when a green infrastructure strategy is implemented, compared to the absence of a green infrastructure strategy for flood mitigation.

CS

**Duluth Case Study:** *Based on H&H modeling, the peak discharge for the 100-year, 24-hour storm under current conditions if the 76 acre-feet flood reduction target was met was 1,224 CFS (20% decrease) and the peak velocity was 9.53 ft/s (1% decrease). Under future conditions if the 86 acre-feet flood reduction target was met the peak discharge was 1,388 CFS (20% decrease) and the peak velocity was 9.56 ft/s (3% decrease).*

## **TASK 2:** *Quantify current and future flood damages if the flood reduction target is met with green infrastructure*

Use the H&H modeling outputs to estimate damages from current and future flooding with a green infrastructure strategy that meets your flood reduction target.[6] This analysis is the same as Step 2, Task 3. Revisit the assets at risk identified in Step 1 and see where they fall on your mapped flood-depth grid when you reduce flooding by meeting your reduction target through a green infrastructure strategy. Identify the assets that are damaged and affected during current and future flooding. Avoided damages are considered benefits from an economic perspective.

6 Note that the cost of green infrastructure strategy implementation is not a component of this task and will be addressed in Step 5.

| STRUCTURAL DAMAGE ASSESSMENT FOR THE TOLEDO CASE STUDY | | | |
|---|---|---|---|
| **Silver Creek Scenario (all 100-year storm event data)** | Number of Buildings Damaged | Maximum Single Building Damage ($) | Total Damage for all Buildings ($) |
| **Current flooding without a green infrastructure strategy** | 253 | $52,000 | $738,300 |
| **Current flooding with a green infrastructure strategy** | 159 | $53,200 | $453,700 |
| **Future flooding without a green infrastructure strategy** | 293 | $67,300 | $980,800 |
| **Future flooding with a green infrastructure strategy** | 179 | $53,500 | $527,500 |

Similar to Step 2, estimate other benefits such as reduced recreational losses with a green infrastructure strategy by considering (1) the reduction in usage attributed to flooding and (2) the monetary value associated with reduced usage. From an economic perspective, recreational losses that are avoided with a green infrastructure strategy are considered benefits.

Green infrastructure also produces other benefits, or "co-benefits," such as wildlife habitat, open space, aesthetics, increased property values, and improved water quality. Assigning a dollar value to these benefits can be more difficult; however, as in Step 2, remember to describe the full range of benefits even if they cannot be easily monetized.

CS

**Duluth Case Study:** *The community used the Chester Creek watershed for numerous recreational activities such as hiking, skiing, and snow shoeing. Incorporating a green infrastructure strategy in Chester Creek reduced flooding impacts, leading to fewer days of recreational activity loss, which could be monetized as a benefit.*

## OUTPUT: Impacts of Flooding under Current and Future Scenarios with a Green Infrastructure Strategy

Current and Future Flooding with a GI Strategy + Current and Future Flood Damage with a GI Strategy = **Current and Future Flood Impacts with a GI Strategy**

After performing flood and economic analyses for current and future flood scenarios with a green infrastructure strategy, you will have a clear understanding under each scenario about how implementing a strategy reduces flood damages compared to a "business as usual" scenario.

1. Estimate green infrastructure option unit costs and strategy cost

2. Estimate green infrastructure strategy benefits and co-benefits

3. Annualize costs and benefits over a specific time frame

**Output:** Annualized net benefits

# STEP 5: *Estimate Benefits and Costs*

Through Steps 2 and 4, you identified the damages and costs associated with four flooding scenarios (current and future flooding scenarios without and with a green infrastructure strategy). Compiling all of the costs and benefits associated with achieving your target through a green infrastructure strategy will allow you to choose the right combination of options that maximizes benefits relative to costs.

The first task is to estimate the unit cost of each green infrastructure option that will be used to meet your flood reduction target. Once you determine unit costs for green infrastructure options, you can estimate a total green infrastructure strategy cost. The second task is to estimate the benefits of your strategy. When estimating benefits it is important to include damages avoided as well as co-benefits and ecosystem services benefits. While the cost of green infrastructure is generally an upfront expense, the benefits of green infrastructure options continue over a long period of time, repeated with every storm event for which green infrastructure provides mitigation. For this reason, the economic assessment of green infrastructure strategies should consider annual benefits and costs over a long period of time. This allows you to determine the point at which you "break even"—the point where accrued benefits exceed accrued costs. The third task annualizes costs and benefits of the green infrastructure strategy over your chosen time frame. The overall goal of this step is to gain a sense of what the annualized net benefits would be for your green infrastructure strategy, which will allow you to make adjustments to the strategy to ensure that your plan maximizes the benefits that are important to your community.

**Annualized costs and benefits** – An estimate of costs considered on an annual basis. The present value (PV) of a stream of costs and benefits is annualized to determine the average cost-benefit per year over a given time frame.

**Benefit transfer** – The process of estimating the values of ecosystem services in a desired location by using information from studies in a different location or context.

**Discounting** – A process to determine the value of a cost or payment in the future. A dollar is worth more today than in the future (due to its capacity to earn interest and inflation over time). Future values are discounted to determine how much they are worth today.

**Expected Annual Damages (EAD)** – The average value of expected losses, computed as a function of the value of losses and the probability of those losses occurring.

**Present value (PV)** – The PV calculation discounts costs or benefits in future years and aggregates the costs and benefits across years. The PV represents the current value of future benefits.

**Unit Costs** – The costs per unit of storage (e.g., cubic feet or acre-feet) that includes both implementation (capital) costs and long-term operation and maintenance costs.

**Key Question:** *What are the annualized costs and benefits of green infrastructure?*

**Key considerations:**

- Research and obtain relevant and up-to-date green infrastructure cost information
- Network with other communities for cost information
- Consider both capital and operation and maintenance costs
- Associate the cost of green infrastructure with a specific flood mitigation benefit; for example, cost per acre-foot of flood storage will enable you to compare relative cost effectiveness across your green infrastructure options

**Recommended expertise:**

- Economists to help annualize costs, estimate ecosystem services, and estimate co-benefits
- Practitioners with knowledge of costs, how to reduce them, and potential funding sources
- Ecosystem service expertise

## TASK 1: *Estimate green infrastructure option unit costs and green infrastructure strategy cost*

Assign unit costs to green infrastructure options. Green infrastructure costs vary widely across geographic regions and have generally decreased with increased demand. For this reason, it is important to adjust unit costs based on current costs and local conditions. Unit costs can be estimated using information from Appendices A and C in the *Economic Assessment of Green Infrastructure Strategies for Climate Change Adaptation: Pilot Studies in the Great Lakes Region Great Lakes* or, preferably, recent sources reflecting similar geographic conditions.

*Tip: Contact communities that have had experience implementing green infrastructure; they may be your best source of information.*

| DULUTH AND TOLEDO CASE STUDY: RELATIVE CAPITAL COST PER CUBIC FOOT OF FLOOD STORAGE PROVIDED ($/CF) | |
|---|---|
| **Most Expensive** | Underground Storage |
| | Bioretention |
| | Permeable Pavement |
| | Blue Roof |
| | Retention Pond |
| **Least Expensive** | Extended Detention Wetland |

Estimate the cost of each green infrastructure option in your green infrastructure strategy. The cost of each option can be estimated by multiplying unit costs by the units of storage to be provided. Remember that costs should include both the initial cost of implementing the green infrastructure option and the future cost of maintaining the option for the selected scenario. Ensure that you use the same units (either cubic feet of storage or acre-feet of storage) for all assessed options. Costs can be reduced significantly by economies of scale. A large-scale green infrastructure option that provides a lot of flood storage will likely be less expensive than several small-scale options.

CS

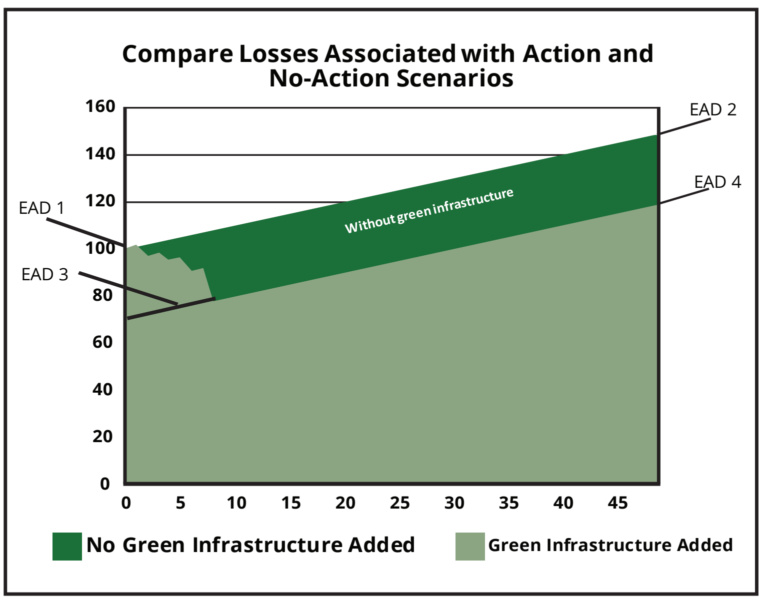
**Duluth Case Study:** *It was estimated that an extended detention wetland had a capital unit cost of $1.30/CF of storage provided. If Duluth wanted to implement 1 acre-foot of flood storage with extended detention wetlands it would cost them ($1.30/CF storage) x (43,560 SF/acre) x (1 acre-foot) = $56,628.*

*Tip: Techniques to reduce costs include integrating green infrastructure into projects that are planned or underway (e.g., road improvements), taking advantage of loan or grant programs, and leveraging private sector funds.*

Estimate the cost of the overall green infrastructure strategy. The cost of your strategy can be estimated by summing the total cost of all green infrastructure options needed to provide the storage volume to meet the flood reduction target.

## TASK 2: *Estimate green infrastructure strategy benefits and co-benefits*

Estimate the benefits of your green infrastructure strategy. The total benefit of a green infrastructure strategy is the sum of all benefits (e.g., damages avoided from reduced flooding) and co-benefits (the ecosystem services provided by natural features). It is important to remember that natural features and ecosystem services that are created or preserved by green infrastructure have value to your community and should be included as benefits.




The primary benefits are represented by the difference in flood losses, with and without green infrastructure. Benefits are simply the difference between damages estimated in Step 2 (business as usual) and damages in Step 4 (green infrastructure strategy implementation).

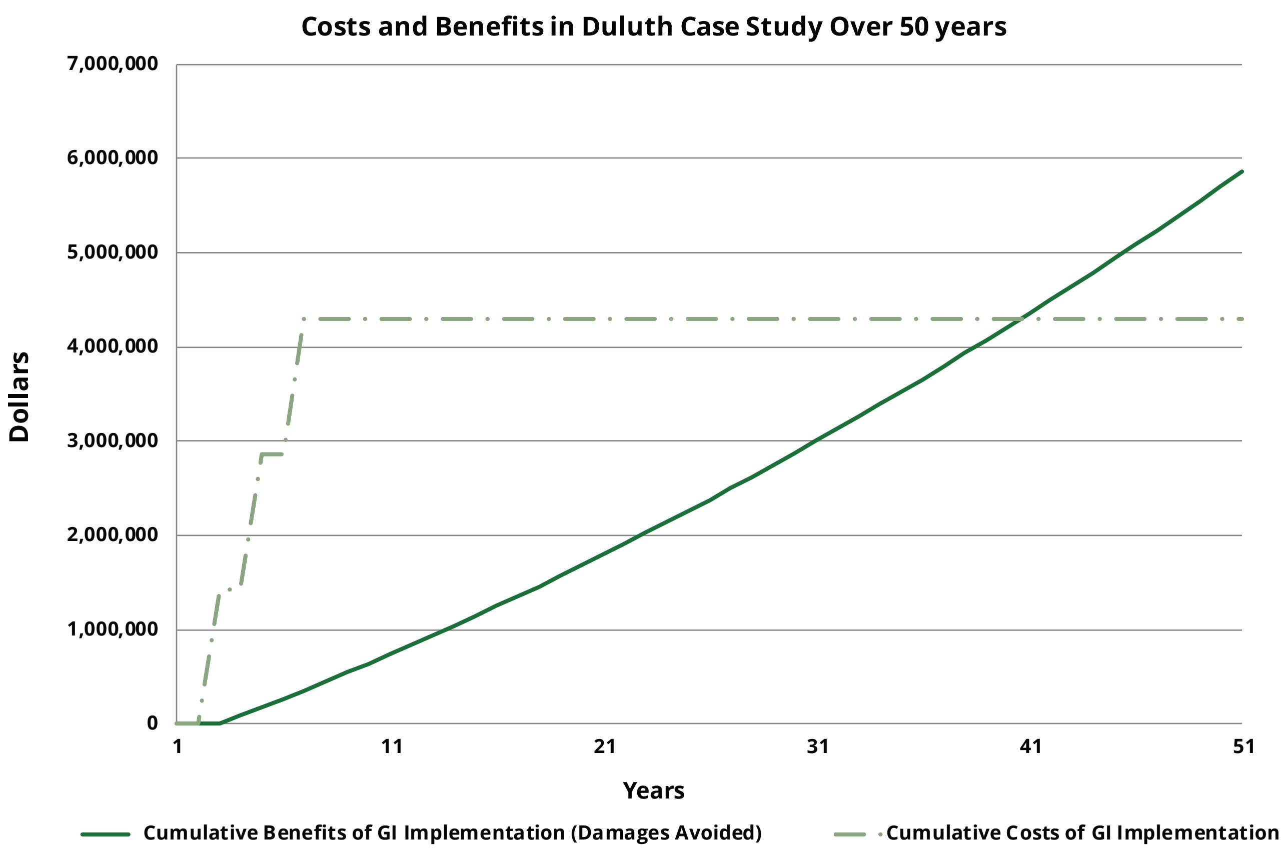
Expected annual damages (EAD) without green infrastructure are represented by line EAD 1 to EAD 2 in the figure. Damages are shown to increase over time, which can be the result of development, increased precipitation associated with climate change, or both. Line EAD 3 to EAD 4 shows the addition of a green infrastructure strategy and a reduction in damage. The effects of some green infrastructure options are often not fully realized with initial implementation as seen in the first 5 years in the figure. For this reason, the difference between EAD with and without green infrastructure increases over time. In this illustration, the beneficial effects of green infrastructure are fully realized after year 10, but this is likely to vary from project to project, and could occur sooner.

The true value of green infrastructure is typically greater than what can be monetized because the value of co-benefits is hard to express in monetary terms. It is important to identify all co-benefits (e.g., habitat, open space, aesthetics, increased property values, improved water quality) that result from green infrastructure implementation. The co-benefits that can't be monetized should be described and included in the decision-making process.

Estimate the value of your co-benefits and ecosystem services. The co-benefits and ecosystem services of green infrastructure may be difficult to monetize but have great value in a watershed and to a community. To try to place a value on ecosystem services, the benefit transfer method may be used. This method uses economic values for ecosystem services in one location to approximate the value in a different location. For example, the value of coral reefs in one area could be applied to monetize the value of coral reefs in another similar location.

## **TASK 3:** ***Annualize costs and benefits over specific time frame***

Discount the calculated benefits and costs. In order to make a fair comparison of costs (which are paid in the early years of a project) and benefits (which are realized year by year over a number of decades) the dollar values have to be converted to "present value" terms through "discounting." Since a dollar invested today could yield far more than a dollar in, say, 10 or 20 years, an interest rate is used to discount future dollars to a present value, which shows what future benefits and costs are worth today.



**Duluth Case Study:** *Benefits and costs were annualized over a 50-year time horizon. Costs were estimated to be $4.17 million per year and benefits to be $4.68 million per year. Therefore, benefits exceed costs and the project is considered worthwhile.*

Distribute the present value across the years of analysis. This will produce the average benefit or cost in each year, referred to as an annualized benefit or annualized cost.

## OUTPUT: Annualized Net Benefits

GI Costs + GI Benefits + Annualize Costs and Benefits = **Annualized Net Benefits**

At the end of this analysis you can determine your annualized net benefits by subtracting annualized costs from annualized benefits. Since the majority of green infrastructure costs occur in the early years of the project, it is important to take a long-term perspective (e.g., 20 to 50 years) in decision-making. The value of green infrastructure benefits adds up over time. In the case of Duluth, the benefits exceeded the costs after around 40 years. It is important to note that, even when an investment is a great idea over the long term, it can take years to recoup the initial cost. Shortsighted planning can lead to missed opportunities to put a community in a better, safer position for years to come.

**Fox River Case Study:** *A 2011 study on the East River sub-basin near Green Bay, Wisconsin, found that preventing future development of 7,400 acres of flood-prone land could reduce future flood losses by $2.6 million annually. However, the cost of acquiring the land exceeded benefits by about 200% ($5.1 million, annualized). Alternative scenarios included purchasing easements, targeting parcels that accounted for the highest share of future flood losses, and targeting less expensive parcels. These methods combined were estimated to protect 86 percent of the acreage at less than 10 percent of the cost of acquiring all flood-prone parcels (average annual cost of $500,000).*

1. Finalize a green infrastructure strategy

2. Communicate the green infrastructure strategy and plan next steps

**Output:** Implementation of green infrastructure strategy

# STEP 6: *Identify and Communicate the Desired Green Infrastructure Strategy*

Step 6 focuses on assessing all of the information and outputs gathered during previous steps and taking action to communicate and implement a green infrastructure strategy.

The first task in this step is to finalize a green infrastructure strategy by comparing the costs and benefits of your preliminary strategy and revising the options to best fit the needs of your watershed. Taking a full look at how your green infrastructure strategy will change flooding, and its associated costs and benefits, may lead to strategy adjustments. There is no perfect green infrastructure strategy. The "best" or "right" implementation strategy depends on community acceptance, opportunities to implement, funding, land availability, and other factors such as cost. In addition, your green infrastructure strategy may need to change over time.

The second task is to communicate the results of your assessment to stakeholders in a meaningful way to ensure support for a long-term implementation plan. Long-term implementation and planning will likely involve meetings and continued coordination with stakeholders.

**Key Question:** *What green infrastructure strategy provides the best results for my watershed and how do I communicate that information?*

**Key Considerations:**

- The best green infrastructure strategy may not be the one with the lowest cost per unit of flood storage—remember to consider the value benefits that aren't easily monetized

**Recommended Expertise:**

- Economists with experience in infrastructure return on investment
- GIS analysts
- Engineers
- Political strategy, marketing, and communications experts

## TASK 1: *Finalize a green infrastructure strategy*

Assess the information you have compiled. Look at the outputs and information generated from Steps 1 through 5. The outputs will provide information to inform your green infrastructure strategy assessment and any revisions. Assess the flooding damages, costs, benefits, co-benefits and feasibility of your green infrastructure strategy. There may be options that need to be adjusted or a target that needs to be changed once you are able to look at the entire package of information generated to formulate the green infrastructure strategy.

Work with others (businesses, land owners, town departments) to discuss feasible implementation plans and strategies. The goal is to finalize a strategy that will work. Secure the support of partners. Adjust the green infrastructure strategy as needed to reduce costs, to increase all benefits (e.g., avoided damages and improved ecosystem services), and take advantage of implementation opportunities. Mix and match your green infrastructure options to see how different strategies compare. This process may take several iterations with different combinations of green infrastructure options in order to reduce costs while achieving the flood reduction target.

Remember the benefits that can't be monetized. The "best" green infrastructure strategy for your community may not be the one with the highest annualized net benefits or lowest green infrastructure implementation unit cost. Co-benefits and ecosystem services may not be fully reflected in an economic assessment. Be sure to include qualitative benefits as you finalize a green infrastructure strategy. Also keep in mind that the marginal costs of projects can be reduced if implemented in conjunction with other capital projects (e.g., drainage improvements, road repair, or park and open space design).

Finalize your desired green infrastructure strategy. Based on your assessment and coordination with stakeholders, make adjustments to your preliminary green infrastructure strategy and reassess the outputs from various strategies as needed to establish a final green infrastructure strategy that meets the needs of your community.

## TASK 2: *Communicate green infrastructure strategy and plan next steps*

Communicate to stakeholders and the public. Consider hosting workshops, technical briefings, field trips, and open houses to discuss the green infrastructure strategy and key findings from the analysis. Be sure to brief public officials whose support you'll need for funding and implementing projects and provide them with visible leadership roles along the way.

Take next steps and plan for green infrastructure strategy implementation:

- When you have a final green infrastructure strategy, communicate your results!
- Prepare simple, easy to understand visuals to convey key messages that resonate with your audiences.
- Compile a list of potential partners for implementation. Form an implementation work group (which may be different from the planning work group) to develop an implementation schedule and meet periodically to stay on track.
- Compile a list of potential funding sources and link them to specific green infrastructure projects.
- Be prepared to take advantage of implementation opportunities as they arise, and develop specific plans for locations of green infrastructure options within the hydrologic context of your overall watershed.
- Get design-level projects in the "pipeline" to take advantage of funding when it materializes.
- Look for opportunities to locate green infrastructure in visible areas, in conjunction with other public amenity improvements such as bike paths.
- Seek public-private partnerships; engage the development and business community for support and be sure to recognize their contributions publicly.
- Get the community involved, through scouting groups, school groups, and others. Consider bulk ordering rain barrels or naming green infrastructure features through an "adopt a bioswale" program or other attention-getting promotional ideas. Give implemented green infrastructure a local identity.
- Identify and start implementing pilot projects to show

- progress and success (recognizing that boutique projects are good for building public awareness and support, but larger-scale projects are needed to reach flood reduction targets).
- Document and publicize green infrastructure when it is implemented to make your successes visible.
- Track costs and benefits of all implemented green infrastructure projects for future planning.

CS

**He'eia Case study:** *Green infrastructure is not a term commonly used in the He'eia watershed; instead, green infrastructure practices are specifically named (e.g., "taro patch"). Consider naming your green infrastructure (e.g., "blue sedge bioswale") to personalize and contextualize your green infrastructure.*

## OUTPUT: Implementation of Green Infrastructure Strategy

**Final GI Strategy** + **Communication** = **Implementation**

At the end of these steps, you should have a green infrastructure strategy that suits your community needs and a path forward for implementation.

# Pilot Studies

Economic Assessment of Green Infrastructure Strategies for Climate Change Adaptation: Pilot Studies in the Great Lakes Region (*http://coast.noaa.gov/digitalcoast/publications/climate-change-adaptation-pilot*)

The Role of Land Use in Adaptation to Increased Precipitation and Flooding: A Case Study in Wisconsin's Lower Fox River Basin (*www.rff.org/RFF/Documents/RFF-Rpt-Kousky.pdf*)

# Key Resources

- *Economic Assessment of Green Infrastructure Strategies for Climate Change Adaptation: Pilot Studies in the Great Lakes Region* (*http://coast.noaa.gov/digitalcoast/publications/climate-change-adaptation-pilot*)
- *Enhancing Sustainable Communities with Green Infrastructure* (*www.epa.gov/smartgrowth/green-infrastructure.html*)
- Climate Resilience Evaluation and Awareness Tool (CREAT) (*http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm*)
- Digital Coast website (*www.coast.noaa.gov/digitalcoast/*)
- *Green Infrastructure Guide for Water Management* (*www.unepdhi.org/-/media/microsite_unepdhi/publications/documents/unep/web-unep-dhigroup-green-infrastructure-guide-en-20140814.pdf*)
- Hazus Guide (*www.fema.gov/Hazus-software/Hazus-quick-reference-guide*)
- National Stormwater Calculator (*www2.epa.gov/water-research/national-stormwater-calculator*)
- Storm Water Management Model (SWMM) hydrology-hydraulic model (*www2.epa.gov/water-research/storm-water-management-model-swmm*)
- *The Role of Land Use in Adaptation to Increased Precipitation and Flooding: A Case Study in Wisconsin's Lower Fox River Basin* (*www.rff.org/RFF/Documents/RFF-Rpt-Kousky.pdf*)
- *What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure* (*www.coast.noaa.gov/digitalcoast/publications/adaptation*)
- U.S. Army Corps of Engineers, Hydrologic Engineering Center, hydrology (HEC-HMS) and hydraulic (HEC-RAS) engineering analysis models and tools. (*www.hec.usace.army.mil*)

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