United States Environmental Protection Agency

FLOOD RESILIENCE

A Basic Guide for Water and Wastewater Utilities

Select a menu option below.
First time users should start with the Overview.

Overview

Approach

Mitigation Options

Pilot Project

FLOOD RESILIENCE

A Basic Guide for Water and Wastewater Utilities

September 2014
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Overview (page 1 of 3)

FLOODS AND UTILITIES

Flooding is one of the most common hazards in the United States, causing more damage than any other severe weather-related event. It can occur from tropical storms, hurricanes, swollen rivers, heavy rains, tidal surges, spring snowmelt, levee or dam failure, local drainage issues and water distribution main breaks.

Impacts to drinking water and wastewater utilities can include loss of power, damage to assets and dangerous conditions for personnel. As storms become more frequent and intense and as sea levels rise, flooding will be an ongoing challenge for drinking water and wastewater utilities.

Click Next to learn more about flood resilience and mitigation.

Overview (page 2 of 3)

WHAT IS FLOOD RESILIENCE AND MITIGATION?

For the water sector, "flood resilience" refers to the ability of water and wastewater utilities to withstand a flooding event, minimize damage and rapidly recover from disruptions to service.[1] Utilities can build resilience by implementing mitigation measures. A mitigation measure can be an emergency planning activity, equipment modification/upgrade or new capital investment/construction project. Examples of mitigation measures include:

- Emergency response plan
- Barriers around key assets
- Elevated electrical equipment
- Emergency generators
- Bolted down chemical tanks

Implementing these mitigation measures requires financial investment by the utility; however, flood mitigation could prevent costly damage and enable the utility to provide more reliable service to customers during a disaster. To help pay for flood mitigation measures, a utility can also apply for federal disaster mitigation funds.

Mitigation Success Story in Alabama

During major flooding, power outages at the Geneva Water Works resulted in sewer backups. Geneva County received a FEMA Hazard Mitigation Grant to procure an emergency backup generator and fuel tank as well as to elevate critical motors and blowers. Two years later, Geneva experienced another major flood, but this time the system was unaffected.

[1] For more information on resilience, see Presidential Policy Directive 21 (accessed August 21, 2014).

Click Next to learn more about this Guide and to watch a video on flood resilience.

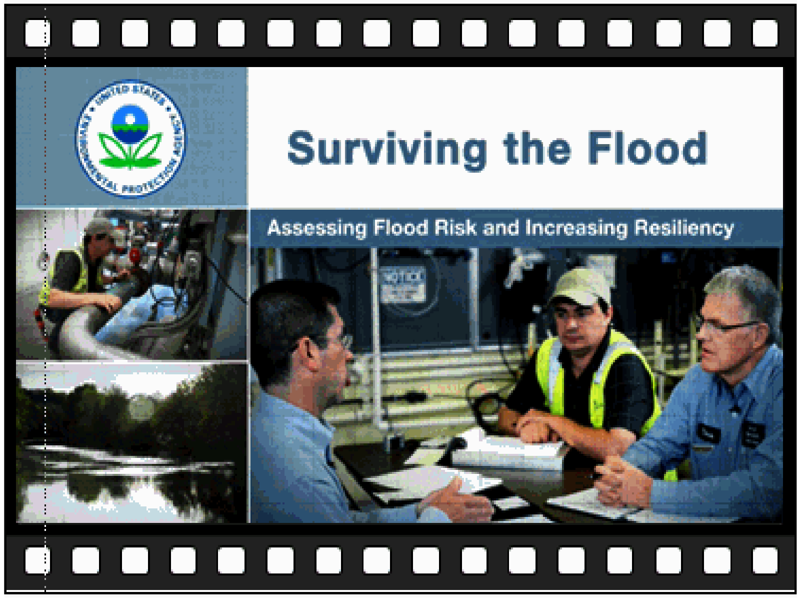
Previous | Main Menu | Next

Overview (page 3 of 3)

ABOUT THIS GUIDE

The U.S. Environmental Protection Agency (EPA) developed this guide to help drinking water and wastewater utilities become more resilient to flooding.[1] In the approach, the utility would examine the threat of flooding, determine impacts to utility assets and identify cost-effective mitigation options. This approach was successfully tested during a pilot project at a small drinking water system, the Berwick Water Department (BWD), in Berwick, Maine. Click on the video to learn why and how BWD assessed their resilience to flooding.

This guide is particularly useful for small and medium utilities. It provides easy-to-use worksheets with corresponding videos (based on the Berwick pilot). To increase your resilience to flooding, consider your utility's priorities and available resources. Although this guide focuses on flood resilience, the same approach can be applied to enhancing resilience to other hazards (e.g., earthquakes, tornadoes).



Click on the image to view the video.

You have completed the Overview.
Click Next to continue to the 4-Step Approach.

[1] For more on EPA's Water Security tools and resources, visit http://water.epa.gov/infrastructure/watersecurity/.

Approach to Flood Resilience

4-STEP PROCESS

There are four basic steps involved in increasing your utility's resilience to flooding.[1]

STEP 1	STEP 2	STEP 3	STEP 4
Understand the Threat of Flooding	Identify Vulnerable Assets & Determine Consequences	Identify & Evaluate Mitigation Measures	Develop Plan to Implement Mitigation Measures

Click on each step above and:
- Read the step description
- Watch the corresponding video
- Complete a worksheet and fill in accompanying blank tables with your utility data

WORK WITH A TEAM

To help you through this process, work with a team of your partners and stakeholders. This team could include your utility staff (e.g., operators, supervisors, field staff), other partners from local government (e.g., town engineer, public works staff, floodplain managers, emergency response personnel) and state government (e.g., primacy agency staff, hazard mitigation officers). It will be helpful to hold a kick-off meeting with this team to discuss goals and responsibilities to complete the assessment and implement mitigation measures. The four steps should be completed sequentially; however, they do not have to be completed all at once. Complete the steps as time and resources permit.

[1] This basic approach is consistent with other water sector guidelines and standards, including ANSI/AWWA G440-11: Emergency Preparedness Practices, ANSI/AWWA G430: Security Practices for Operations and Management, AWWA M-19 Emergency Planning for Water Utilities, JAWWA J100-10 Risk and Resilience Management of Water and Wastewater Systems and the Vulnerability Self-Assessment Tool (VSAT).

Approach to Flood Resilience

STEP 1
Understand the Threat of Flooding

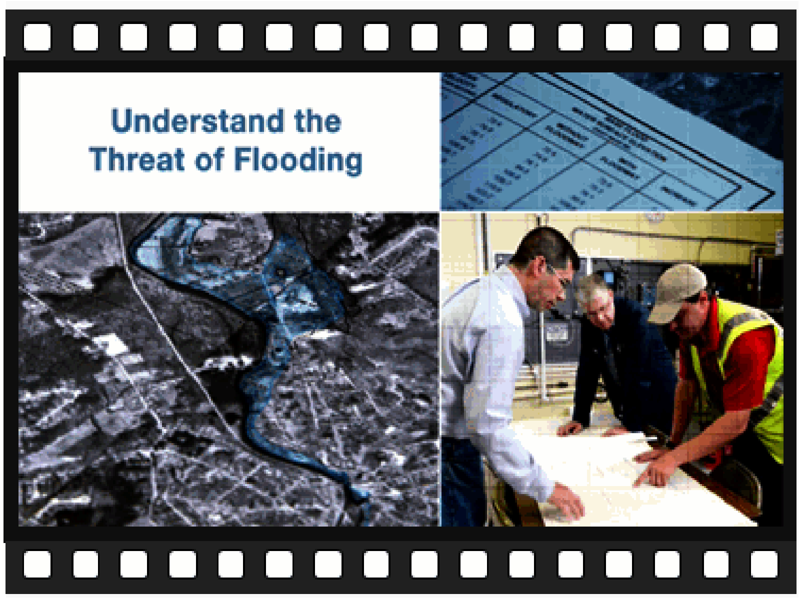
STEP 2
Identify Vulnerable Assets & Determine Consequences

STEP 3
Identify & Evaluate Mitigation Measures

STEP 4
Develop Plan to Implement Mitigation Measures

STEP 1: UNDERSTAND THE THREAT OF FLOODING

Flooding depends on various factors including rainfall, topography, river-flow, drainage and tidal-surge. The threat of flooding is based on the likelihood that such a flooding event will occur. Learn how the Berwick Water Department (BWD) evaluated their threat of flooding from the video. Also, the Federal Emergency Management Agency (FEMA) is a resource to help you. FEMA produces maps of a "100-year flood" (a flood event that has a one percent chance of occurring in a given year) and a more catastrophic "500-year flood" (a flood event that has a two tenths of a percent chance of occurring in a given year). Click on the Step 1 worksheet icon below so that you can document the flooding threat and obtain FEMA *Flood Maps*.



Click on the image to view the video.

STEP 1 Worksheet

Click here to document the threat of flooding to your utility.

Worksheet

Worksheet

STEP 1: Worksheet (page 1 of 2)

To better understand the threat of flooding, your utility should first examine historical flooding data and review Federal Emergency Management Agency (FEMA) *Flood Maps*. Below are instructions for evaluating the threat of flooding at your utility.

The tables below have sample data. Use the blank tables (double click icon) to input your utility's data.

1.1 Have you reviewed utility records of past flooding events?

☐ Yes ☐ No

If no, review how past flooding events have threatened your utility. Use various sources, including utility records, newspapers, websites and hazard mitigation experts, to collect previous flooding data. Enter your utility's past flooding information into Table 1.

EXAMPLE OF COMPLETED TABLE 1 – PAST FLOODING EVENTS

Event Information (e.g., Date, Name, Type*, Flood Elevation)	**Description of Damage** (Operational, Public Health and Economic Impacts)
April 2007, "Patriot's Day Storm," Nor'easter, 238.5 ft	Collapsed water storage tank and damage to pump stations and chemical storage. Operated on backup power generator. Boil water notice issued for several days. Financial impacts were roughly $100,000.

** Tropical storm, hurricane, spring thaw/snowmelt, levee failure, etc.*

1.2 What potential sources of flooding could impact your utility?

☐ Swollen rivers/streams ☐ Flash floods ☐ Levee/dam failure

☐ Spring thaw ☐ Coastal flooding ☐ Non-natural causes (e.g., main breaks)

1.3 Have you obtained FEMA Flood Maps?

☐ Yes ☐ No

If no, go to the Map Service Center to find FEMA *Flood Maps*, categorized by community. *Flood Maps* show areas that will be affected by both 100-year and 500-year floods. A "100-year flood" is a flood event that has a one percent chance of occurring in a given year. A "500-year flood" is a flood event that has a two tenths percent chance of occurring in a given year. Click on the icon to learn more about interpreting a *Flood Map*. If your *Flood Map* is not up to date, talk with your local community planning department or floodplain manager.

Guide to Interpreting FEMA Flood Maps

1.4 Identify which floodplains your utility systems are located within.

Locate your utility systems, such as intake, treatment, distribution, storage tank and pump stations, on your community's *Flood Map* to determine which floodplains they are located within. Summarize your findings in Table 2.

Worksheet

STEP 1: Worksheet (page 2 of 2)

EXAMPLE OF COMPLETED TABLE 2 - UTILITY SYSTEMS WITHIN FLOODPLAIN

Utility System	100-year Floodplain Flood Reaches Elevation (237 ft)	500-year Floodplain Flood Reaches Elevation (240 ft)
Intake (235 ft)	✓	✓
Treatment (238 ft)		✓
Distribution/Collection (237 ft)	✓	✓
Storage Tank (252 ft)		
Pump Stations (238 ft)		✓

Note: Changes in climate and land use can affect a utility's flooding threat. For a more advanced evaluation, EPA's Climate Resilience Evaluation and Awareness Tool (CREAT) can provide data on projected changes of extreme precipitation events and sea-level rise by location.

1.5 What flooding threat do you want to prepare for?

Using your utility's information from Table 2, decide which flood threat will be the focus for protecting your utility. Select the flooding level that you would like to address.

☐ 100-year flood Elevation ____________ ft

☐ 500-year flood Elevation ____________ ft

☐ Other: ________ Elevation ____________ ft

(e.g., add elevation for climate change impacts or freeboard[1] for local building requirements)

Note: A recent FEMA publication[2] recommended elevating critical infrastructures above the 500-year flood elevation. This level of protection may be necessary to obtain federal funding.

To illustrate how a utility might make this decision, below are three potential options based on the sample data in Table 2 above.

- **Option A: Select 100-year flood.** The utility is unwilling to tolerate a one percent probability of a flood that would damage its intake and distribution systems. The utility is not concerned about the more remote possibility of a 500-year flood at this time.
- **Option B: Select 500-year flood.** Although the utility will have some impacts from a 100-year flood, the intake and distribution systems are generally well protected. However, the entire facility, including a new expensive treatment system, would be a total loss with a 500-year flood.
- **Option C: Select 100-year flood plus 2 feet.** The facility has assets located along the coast and experienced two floods in the last 5 years that approached this elevation and caused significant disruption to service.

[1] Freeboard is a safety factor expressed in feet above a flood level for purposes of floodplain managers.

[2] "Reducing Flood Effects in Critical Facilities," FEMA RA2 (accessed August 21, 2014).

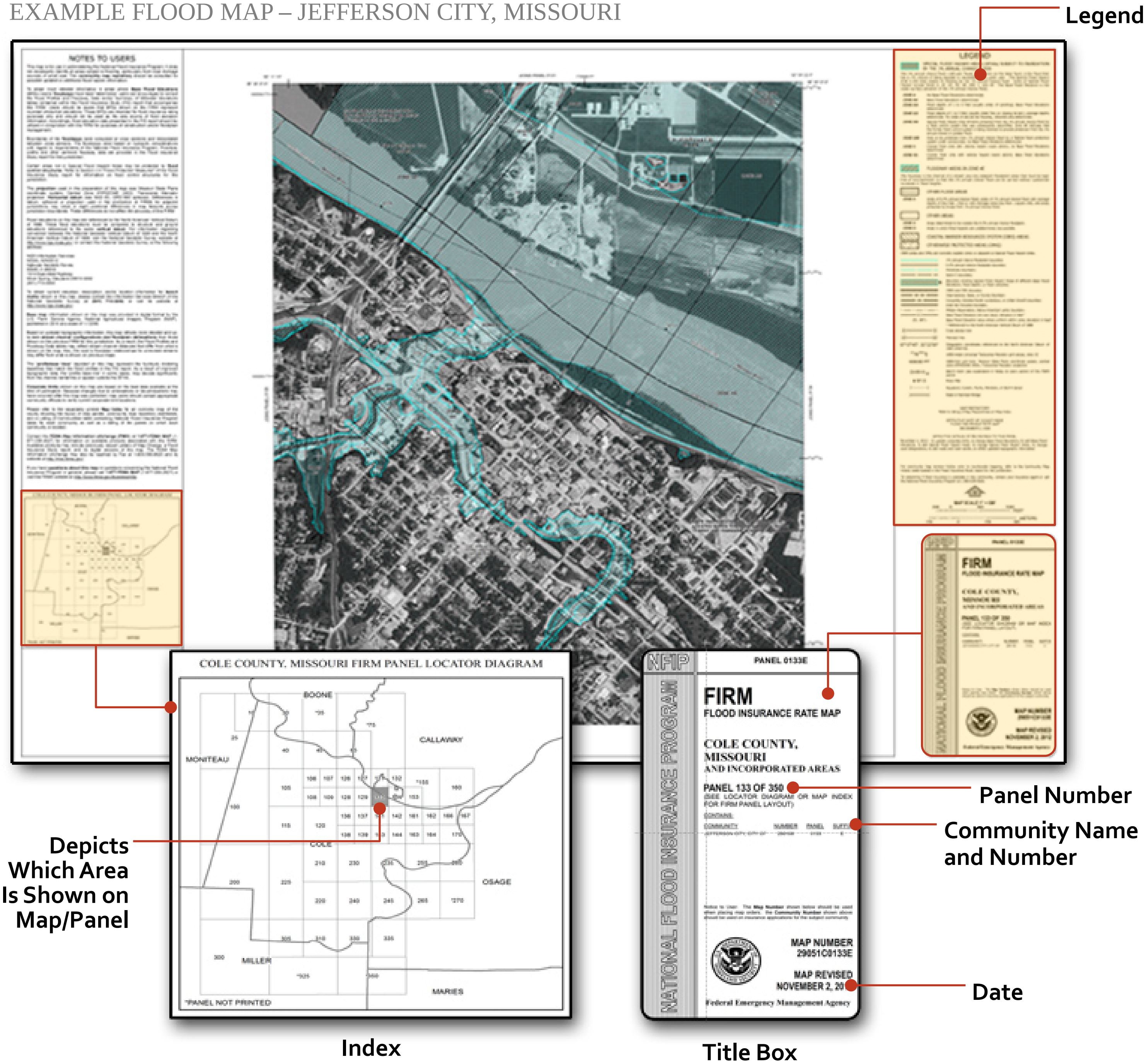
Return to Step 1 Worksheet

Interpreting FEMA Flood Maps (page 1 of 2)

FLOOD MAP

Flood Map is the common term used to refer to a Flood Insurance Rate Map (FIRM) developed by FEMA. Local and state governments use these maps to understand the threat of flooding and to devise hazard mitigation plans (including possible projects) to mitigate the effects of flooding in their communities. *Flood Maps* can be obtained through FEMA's [Map Service Center](). To identify your relevant *Flood Map*, enter the address of your facility or vulnerable asset(s). An example map including legend, index and title box is provided below.

EXAMPLE FLOOD MAP – JEFFERSON CITY, MISSOURI



Interpreting FEMA Flood Maps (page 2 of 2)

FLOOD MAP

The figure below presents a close-up view of the *Flood Map* shown on the previous page. Water and wastewater utilities can use *Flood Maps* to determine if their facility locations (e.g., treatment, culverts, water storage) are in a 100-year flood zone, a 500-year flood zone or outside of a 500-year flood zone. Although the format and content may differ, information on a *Flood Map* includes:

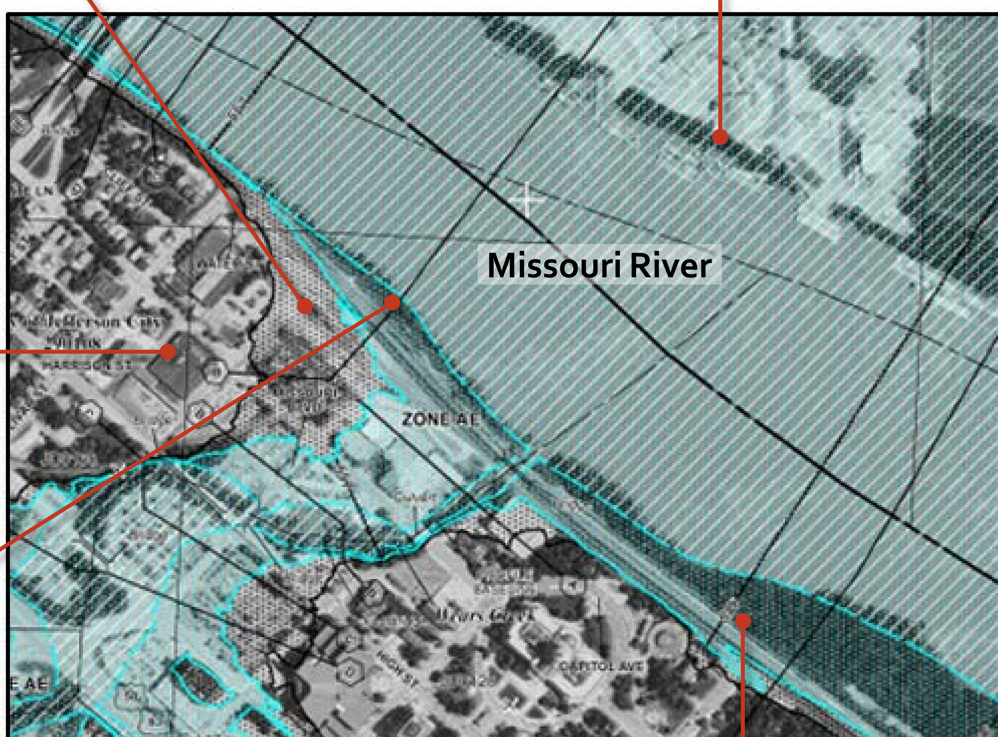
- Common physical features, such as major highways, lakes, railroads and waterways
- Areas subject to a 100-year flood (one percent annual chance of such flooding), also known as Special Flood Hazard Areas (SFHAs) and base flood areas
- Areas subject to a 500-year flood (two tenths percent annual chance of such flooding)
- Areas outside of the 500-year flood zone
- Base flood elevation (BFE) or depths
- Flood insurance risk zones

To illustrate how to interpret a *Flood Map*, a hypothetical water utility building is shown.

CLOSE-UP OF EXAMPLE FLOOD MAP

OTHER FLOOD AREAS
ZONE X Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot with drainage areas less than 1 square mile; and areas protected by levees from 1% annual flood chance.
Includes areas in the 500-year floodplain

FLOODWAY AREAS IN ZONE AE
The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.



Hypothetical Water Utility Building located outside of the 500-year flood zone.

Special Flood Hazard Areas (SFHAs) Subject to inundation by the 1% annual chance of flood.
Depicts areas in the 100-year floodplain

Base Flood Elevation line and value.

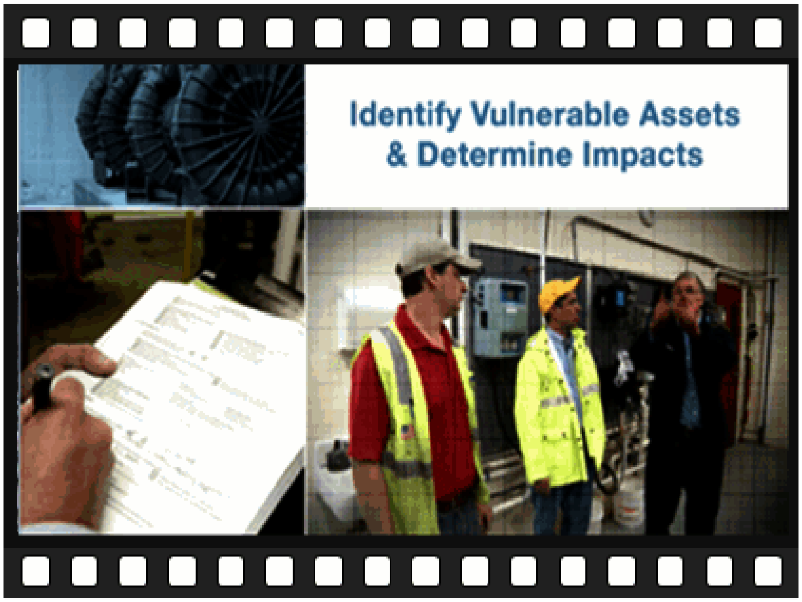
More information on how to read a Flood Map can be found at
http://www.floodsmart.gov/floodsmart/pages/flooding_flood_risks/understanding_flood_maps.jsp.

Approach to Flood Resilience

STEP 1 Understand the Threat of Flooding → **STEP 2** Identify Vulnerable Assets & Determine Consequences → **STEP 3** Identify & Evaluate Mitigation Measures → **STEP 4** Develop Plan to Implement Mitigation Measures

STEP 2: IDENTIFY VULNERABLE ASSETS & DETERMINE CONSEQUENCES

Often located in low lying areas, water and wastewater utilities are particularly vulnerable to flooding. Water and debris can inundate the facility, thereby damaging equipment and structures and causing power outages. Such impacts can lead to various consequences including costly repairs, disruptions of services, hazardous situations for personnel and public health advisories. In this step, identify the assets that are vulnerable to flooding and determine the resulting consequences to those assets and to overall utility operations. Using this information and your judgment, determine the assets/operations that you will need to protect from flooding.



Click on the image to view the video.

Click the video to learn how BWD identified vulnerable assets and determined consequences to their utility. Use the worksheet below to conduct Step 2. It includes a checklist to inspect your utility and determine elevations of assets/operations. It is important to understand how your drinking water or wastewater utility may be impacted by flooding events so that you can identify appropriate mitigation actions to eliminate or reduce asset damage and prevent service disruptions.

STEP 2 Worksheet

Worksheet

Click here to identify assets that are vulnerable to flooding and determine consequences.

Worksheet

STEP 2: Worksheet (page 1 of 2)

To identify which key utility assets/operations are vulnerable to flooding, you should conduct an on-site inspection to locate assets and document elevations. Compare these elevations with the threat elevations in the FEMA *Flood Map*. The assets/operations that are vulnerable to flooding and that result in significant consequences for the utility are candidates for mitigation and protection. Below are instructions for evaluating vulnerabilities of assets and the resulting consequences at your utility.

The tables below have sample data. Use the blank tables (double click icon) to input your utility's data.

2.1 Measure elevations of utility assets to determine vulnerability to flooding.

Conduct on-site inspections of your utility system and then determine the elevation for each critical asset/operation. To assist you, use the On-Site Asset Inspection Form found in the blank tables. Summarize the elevation data for all assets/operations in the vulnerability columns in Table 3.

- Write in the asset/operation (column 1)
- Measure the height of the asset/operation above the floor (column 2)
- Determine the elevation of the floor (above sea level) using as-built design drawing or layouts
- Determine asset elevation (column 3) by adding floor elevation and asset height above the floor
- Write in flood threat elevation into column 4 (from Step 1.5)
- Compare asset elevation (column 3) to flood threat elevation (column 4) and determine which assets/operations are vulnerable to flooding (column 5)

Tip:

• During the inspections, consider flood water entry points. For example, assets/operations below ground may be vulnerable due to leaks from first-floor flooding.

• Although an asset may be located within a floodplain, it may not be vulnerable to flooding if, for example, it is built on an elevated platform or within a bermed area.

2.2 Determine consequences based on replacement costs and impacts to facility operations.

Assuming that an asset/operation is flooded, determine the consequences. Estimate replacement costs for assets based on the best available data, vendor costs or Recommended Practices.[1] Record this in column 6 of Table 3 and characterize impacts to the utility operations in column 7.

2.3 Determine priority need for mitigation to improve flood resilience.

For each asset/operation, use your judgment to determine the priority need for mitigation measures. Base your decision on both the vulnerability of the asset/operation to flooding (column 5) and the consequences for the utility (columns 6 and 7) in Table 3. Enter your judgment into column 8.

Tip: In the example table, note that the automatic transfer switch has a high consequence to the utility, but is located above the flood threat elevation, so the switch ultimately has a low priority for mitigation.

[1] AACE Recommended Practice 17R-97: Cost Estimating and Budgeting: Class 5 – Process Industry Planning Level estimate http://www.aacei.org/non/rps/17R-97.pdf (accessed August 21, 2014).

Worksheet

STEP 2: Worksheet (page 2 of 2)

EXAMPLE OF COMPLETED TABLE 3 – SUMMARY OF VULNERABLE ASSETS, CONSEQUENCES OF FAILURE & PRIORITY FOR MITIGATION

Vulnerability					Consequences		Priority for Mitigation[5]		
1	2	3	4	5	6	7	8		
Asset/ Operation	Height of Asset Above Floor (ft)[1]	Elevation of Asset (ft)[2]	Elevation of Flood Threat (ft)[3]	Vulnerable to Flooding? (Yes/No)[4]	Replacement Costs ($) for Asset	Impact to Facility Operations from Asset Failure	Low (✓)	Moderate (✓)	High (✓)
Raw Water Pump	0.5	238.5	240	Yes	20,000	Inability to feed raw water to the process tanks will render the facility **inoperable.**			✓
Air Compressor	0.75	238.75	240	Yes	15,000	Inability to provide high air pressure will limit the operation of pneumatic valves on the treatment process systems. This will render facility **inoperable.**			✓
Automatic Transfer Switch	2.5	240.5	240	No	5,000	If water damaged the Automatic Transfer Switch, the facility would be **inoperable.**	✓		
Electrical Outlets	2.5	240.5	240	No	5,000	The outlets for general use are **not critical** to facility operations and they are located above the 500-year flood elevation.	✓		

[1] The distance between the floor and the bottom of the utility asset.
[2] Elevation of the asset = elevation of floor (in this example, 238 ft based on design drawing of utility) plus height of asset above floor (column 2).
[3] In this example, elevation of flood threat for the 500- year flood is 240 ft (obtained from Step 1.5).
[4] If elevation of flood (column 4) is higher than elevation of asset (column 3), then yes.
[5] Based on qualitative judgment considering both vulnerability and consequences.

Approach to Flood Resilience

STEP 1	STEP 2	STEP 3	STEP 4
Understand the Threat of Flooding	Identify Vulnerable Assets & Determine Consequences	Identify & Evaluate Mitigation Measures	Develop Plan to Implement Mitigation Measures

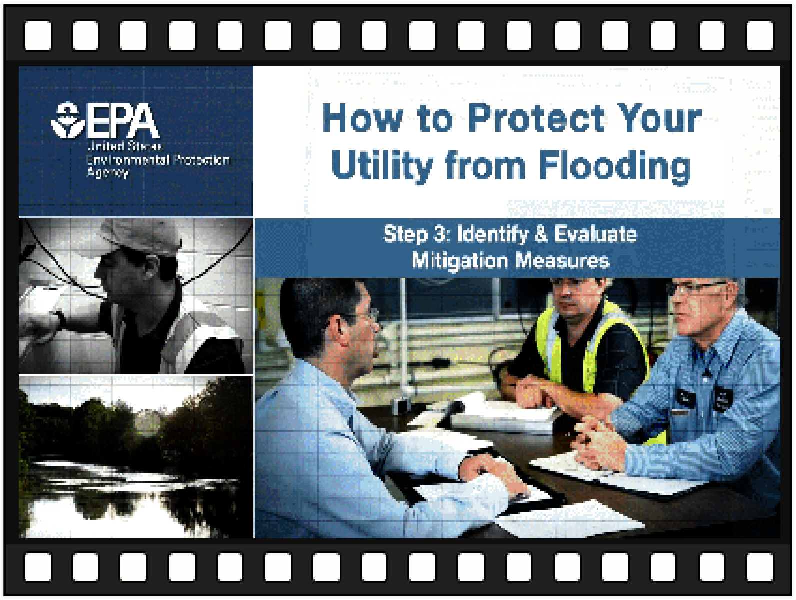
STEP 3: IDENTIFY & EVALUATE MITIGATION MEASURES

First, identify possible mitigation measures that can protect the key vulnerable assets and operations prioritized in Step 2. Then, evaluate which mitigation measures make sense to pursue and implement.

A mitigation measure can be any emergency planning activity, equipment modification or new capital construction project. Examples of each include:

- Emergency procedure to top off water storage tanks in advance of flooding.
- Bolting down chemical tanks and elevating equipment.
- Constructing flood barriers and installing backup generators.

Click the video to learn how BWD identified and evaluated appropriate mitigation measures. Click on the worksheet icon below to conduct Step 3.



Click on the image to view the video.

STEP 3 Worksheet

Worksheet

Click here to identify and evaluate mitigation measures.

Worksheet

STEP 3: Worksheet (page 1 of 5)

To improve your utility's flood resilience, you should identify and evaluate which mitigation measures to pursue based on cost, effectiveness and practicality. It is possible that some mitigation measures could be implemented at little to no cost to your utility. Below are instructions for evaluating mitigation measures at your utility.

The tables below have sample data. Use the blank tables (double click icon) to input your utility's data.

3.1 What are your utility's requirements to maintain a minimum level of service during a flood?

Enter capacities/requirements to maintain a minimum level of service at your utility into Table 4. See below for an example of Table 4 completed with sample data. This information may help you choose mitigation measures that can sustain your minimum level of service.

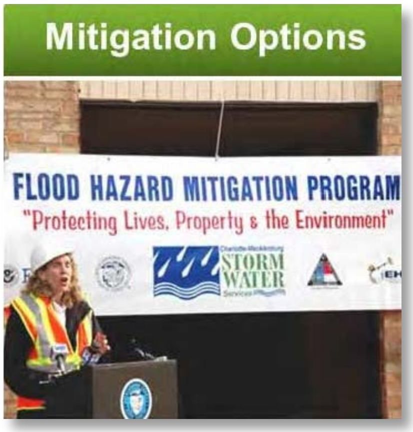
EXAMPLE OF COMPLETED TABLE 4 –
CAPACITIES/REQUIREMENTS TO MAINTAIN A MINIMUM LEVEL OF SERVICE

Sample Asset/Operation	Capacity/Requirements
Finished Water	3,500 gpd
Chemical and Fuel	500 lbs chlorine/day
Electricity	Varies
Water Pressure at Treatment Plant	60 psi
Pressure of Booster Pumps	80 psi

TIP: The level of service required following a flood event may differ from "normal" demands.

3.2 What flood mitigation measures can prevent damage to key assets and disruptions to critical operations?

For assets/operations that have a moderate or high priority for mitigation (column 8 in Table 3), you may consider consulting with a team of operators, mitigation officers, town engineers, neighboring utilities, vendors, etc., to identify potential options. Click the icon to help you identify mitigation measures.



Mitigation Options

TIP: General examples include waterproofing, elevating or upgrading equipment; using flood control methods to modify runoff and managing stormwater through green infrastructure.

Worksheet

STEP 3: Worksheet (page 2 of 5)

3.2 What flood mitigation measures can prevent damage to key assets and disruptions to critical operations? (cont'd)

Populate the first two columns in Table 5 with mitigation measures that you propose for each asset/operation. FEMA also provides some guidance for selecting mitigation measures to protect against flooding.[1]

TIP: Consider listing several possible mitigation measures for a specific asset or operation (e.g., multiple rows for one asset/operation).

3.3 Evaluate mitigation measures.

Evaluate the mitigation options based on various criteria including effectiveness, practicality and cost. Descriptions of these sample criteria are in Matrix 1. Also, your utility might want to consider other factors such as:

- Availability of funding from federal/state sources,
- Selecting a mitigation strategy that addresses a group of similar assets/operations (e.g., pumps for raw water and pumps for intake water) or
- Bundles of mitigation measures that can better address a flooding threat (e.g., bundle sandbags and water-proof doors).

For each mitigation measure, use your professional judgment to classify the criteria as low, medium or high. In columns 3–5, rate each criterion and, in column 6, write your thoughts in evaluating the mitigation option. Finally, in column 7, provide your recommendation. For each mitigation measure, complete columns 3–7 in Table 5.

[1] Selecting Appropriate Mitigation Measures for Floodprone Structures, FEMA 551 (2007), Section 7-2, Technical Considerations (available at http://www.fema.gov/library/viewRecord.do?id=2737 [accessed August 21, 2014]).

Worksheet

STEP 3: Worksheet (page 3 of 5)

MATRIX 1 – DESCRIPTIONS OF EVALUATION CRITERIA

Priority Evaluation Criteria		
Effectiveness	**Practicality**	**Cost**
This evaluates the ability of a mitigation measure to increase resilience. For the water sector, "flood resilience" refers to the ability of water and wastewater utilities to withstand a flooding event, minimize damage and rapidly recover from disruptions to service. This can be measured against the requirement for a minimum level of service (see Table 4).	This is a measure of the ease to implement the mitigation option. For example, consider whether the mitigation option requires ongoing operations and maintenance or special training or certification.	Consider replacement costs for the asset, up-front costs for the mitigation measure, operations and maintenance costs as well as indirect costs such as staff training. Sources of cost estimation include vendors, trade publications or industry standards. Consider whether the mitigation measure can be implemented internally or if it requires outside contractor assistance. Also, consider calculating net present value costs and compare the costs of the mitigation measures to the costs of replacing flood-damaged equipment and the costs of disrupted operations, as outlined in Table 3.

Other Evaluation Criteria		
Funding Sources	**Single Mitigation Solution for Groups of Assets**	**Bundle Mitigation Strategies**
Consider the likelihood of applying and receiving federal funding for the mitigation measure. Be aware that for FEMA Hazard Mitigation Grants, you need to use FEMA's more comprehensive Benefit-Cost Analysis Tool to assess mitigation costs.	You may want to consider a mitigation strategy for a group or bundle of assets/operations that are threatened in the same way. For example, several critical pumps (raw water, backwash and finished water) that are co-located at similar elevations could be considered a single group of assets that need protection. It may be more cost effective to protect all the pumps with a retaining wall rather than invest in submersible versions of the pumps.	Sometimes, combinations or bundles of mitigation measures can better address a flooding threat. Often, such bundles can be provided at a lower cost. For example, you may want to bundle sandbags and water-proof doors to provide complementary reliable protection.

Worksheet

STEP 3: Worksheet (page 4 of 5)

EXAMPLE OF COMPLETED TABLE 5 –
IDENTIFY & EVALUATE MITIGATION MEASURES FOR POWER SUPPLY

Mitigation Measures		Evaluation Criteria			Recommendation	
1	2	3	4	5	6	7
Assets/ Operations	Possible Mitigation Measures	Effectiveness (Low, Med, High)	Practicality (Low, Med, High)	Estimated Cost ($)	Evaluation of Mitigation Measure	Recommend Mitigation Measure (Yes/No)?
Power Supply	Procure emergency generator	High	Medium	Medium-High: $100K; Cost-Benefit analysis indicated a 7-year return on investment	Significant benefit over current situation – highly effective. Would propose to bundle the procurement of a generator and fuel agreements to ensure power resilience in floods. FEMA mitigation can fund generators so we will plan to apply.	Yes
Power Supply	Establish agreements with suppliers to fuel generator	High	High	Low: $5K	Initial conversation with vendors looked promising. Bundled with generator procurement. Influenced by high effectiveness and low cost.	Yes
Power Supply	Procure vehicle to obtain/ distribute fuel for generator	Medium	Low	Medium: $30K plus costs for operations & maintenance	Strongly influenced by low practicality. There is no need for fuel truck beside emergencies and it may require hazmat driver certification. Also, the vendor agreed to stage a fuel vehicle in advance of hurricanes.	No

Worksheet

STEP 3: Worksheet (page 5 of 5)

EXAMPLE OF COMPLETED TABLE 5 –
IDENTIFY & EVALUATE MITIGATION MEASURES FOR PUMPS

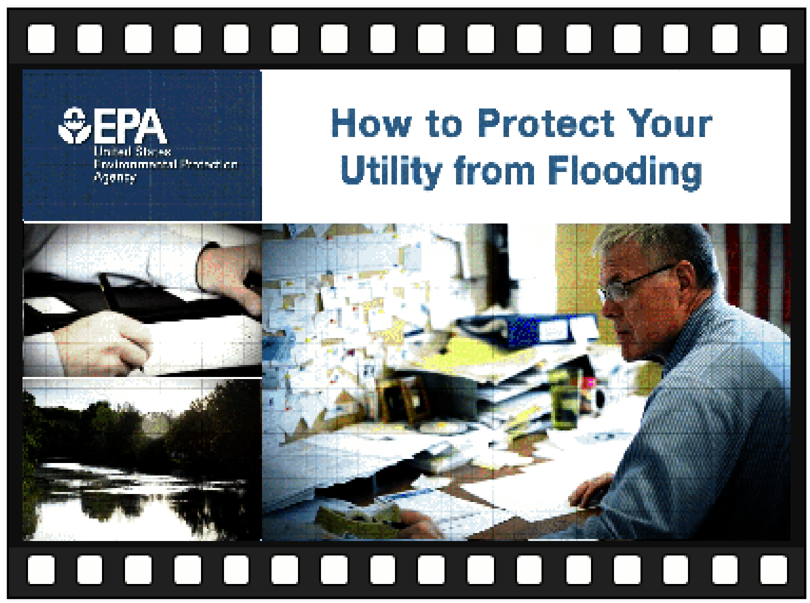
Mitigation Measures		Evaluation Criteria			Recommendation	
1	2	3	4	5	6	7
Assets/ Operations	Possible Mitigation Measures	Effectiveness (Low, Med, High)	Practicality (Low, Med, High)	Estimated Cost ($)	Evaluation of Mitigation Measure	Recommend Mitigation Measure (Yes/No)?
Pumps (raw, finished, backwash)	Replace with submersible pumps	Medium	Medium	High: $150–216K for six pumps ($25K/pump to replace or $36K/pump to upgrade to submersible)	High cost because there are six pumps at similar vulnerable elevation; medium practicality because would also need to upgrade electrical panel. Look for other short term fixes.	No
Pumps (raw, finished, backwash)	Increase capacity for sump pump	Medium	High	Low: $7K	Larger sump pump capacity may give staff additional time to plan for mitigation efforts. Low cost is attractive.	Yes
Pumps (raw, finished, backwash)	Install watertight doors and sand bags for waterproofing	Medium	High	Low-Medium: $20K	Relatively easy to install water proofing, but relies on labor for heavy lifting. Worthwhile given that preventing water from entering building protects six pumps totaling more than $150K in replacement costs.	Yes

Approach to Flood Resilience

STEP 1	STEP 2	STEP 3	STEP 4
Understand the Threat of Flooding	Identify Vulnerable Assets & Determine Consequences	Identify & Evaluate Mitigation Measures	Develop Plan to Implement Mitigation Measures

STEP 4: DEVELOP A PLAN TO IMPLEMENT MITIGATION MEASURES

Your utility will need to develop a plan to implement mitigation measures to reduce or eliminate asset damage and service disruptions during flooding. The plan should be revisited periodically and address actions, schedule, funding, responsibilities, etc. For example, flood mitigation measures that involve major capital and infrastructure investments should be integrated into the utility's overall scheduling in the asset management planning process (e.g., phasing in flood-resistant pumps). Click on the video to learn how BWD developed a plan to implement mitigation measures. To help your utility complete Step 4, click the worksheet icon below.



Click on the image to view the video.

STEP 4 Worksheet

Click here to develop a plan to implement mitigation measures.

Worksheet

Worksheet

STEP 4: Worksheet (page 1 of 2)

Now that you have selected mitigation measures, develop a plan to implement them. Below are instructions for developing an implementation plan at your utility.

The tables below have sample data. Use the blank tables (double click icon) to input your utility's data.

4.1 Develop an implementation plan for selected mitigation measures.

Develop a plan, with specific timeframes, to implement your recommended mitigation measures (identified in Table 5). Consider coordinating with the following contacts: Utility Board, Local Government, Emergency Management Agencies, State Hazard Mitigation Officer, Other Utilities and Vendors.

Decide when and how to implement mitigation measures

- [ ] Identify if the mitigation measure is to be implemented in the short-term (requiring less planning and resources, yet filling an urgent need), medium-term or long-term (requiring more planning/resources and protecting your utility from more intense events).
- [ ] Determine when your utility will be making other planning decisions (e.g., updating capital improvement plans or conducting capacity building) and incorporate mitigation activities into these decision-making processes.
- [ ] Consider general operations and maintenance activities that are planned (e.g., replacing equipment at the end of their life cycles) and how they might factor into the timeline for implementing mitigation measures.

Use Table 6 to structure the plan.

EXAMPLE OF COMPLETED TABLE 6 –
PLAN TO IMPLEMENT SELECTED MITIGATION MEASURES

Mitigation Measure	Actions to Implement Mitigation Measure & Timeline for Completion	Total Time to Implement	Lead Individual or Agency	Funding Source
Emergency Generator and Fuel Vendor Agreement	• Develop proposal that outlines basic engineering plans and cost/benefit analysis for generator; include costs for operations, maintenance, fuel (within 2 months) • Talk to power utility about priority restoration of electricity as well as possibility of generator (within 2–3 months) • Talk to fuel vendors to establish agreements (within 2–3 months) • Take proposal to town managers for preliminary approval to pursue (4 months) • Work with local mitigation official and explore idea of getting Federal Emergency Management Agency (FEMA) Mitigation Funds for generator perhaps bundled with other measures, etc. (4 months to 1 year)	1 year	Operations and Finance	Capital Funding and FEMA Hazard Mitigation Grant Program

STEP 4: Worksheet (page 2 of 2)

4.2 Explore funding sources for mitigation measures.

- [ ] Internal utility capital improvement funding.
- [ ] Local/State funding/bonds.
- [ ] Federal funding: EPA's tool Federal Funding for Utilities – Water/Wastewater – in National Disasters (Fed FUNDS) provides comprehensive information on funding programs from various federal agencies including FEMA, EPA, the U.S. Department of Agriculture (USDA), the U.S. Department of Housing and Urban Development (HUD) and the Small Business Administration (SBA). For example, because of flooding from Hurricane Sandy, EPA's State Revolving Funds have refocused efforts on encouraging flood resilience for both water and wastewater utilities. To access Fed FUNDS, click the icon below.

Federal Funding for Utilities – Water/Wastewater – In National Disasters (Fed FUNDS)

Tip: Utilities applying for FEMA Hazard Mitigation Grants must use FEMA's Benefit-Cost Analysis Tool to evaluate the cost-effectiveness of the mitigation measure.

4.3 Follow your implementation plan.

- [ ] Implement measures according to the adopted implementation plan.
- [ ] Update emergency response plans based on new mitigation measures and procedures to maintain operations.
- [ ] Evaluate the actual effectiveness of mitigation measures and reassess mitigation decisions/approaches.

You have completed Step 4.
Return to the Main Menu to explore other sections of this Guide.

Mitigation Options

IDENTIFY MITIGATION MEASURES

This guide provides two ways to identify mitigation measures:

1. **Practical Mitigation Measures**. Click the clipboard icon for a one-page list of practical mitigation measures to help your utility prevent flood water intrusion, protect assets/operations if flooding does occur and ensure power reliability.

Practical Mitigation Measures

2. **Mitigation Options for Specific Assets/Operations**. Click the photographs of assets/operations at drinking water (DW) and wastewater (WW) utilities and get tables of flood mitigation measures for those assets/operations. The tables also provide relative costs for various mitigation options.

DW Assets

Water Intake, Distribution and Storage

Booster Stations and Other Pumps

Drinking Water Treatment Plant

DW & WW Assets

Buildings

Chemical and Other Storage

Instrumentation and Electrical Controls

Power Supply

WW Assets

Lift Stations

Headworks

Wastewater Treatment Plant

Remember, before you select the mitigation measures to implement, know the vulnerabilities of the assets/operations and the costs and effectiveness of those mitigation measures (Step 3 Worksheet). You may be able to relocate certain assets/operations outside of the floodplain. Also, find out if your local government requires critical infrastructures to elevate assets to certain heights (e.g., 2 feet above 100-year floodplain).

Practical Mitigation Measures for Flood Resilience

PREVENT INTRUSION OF FLOOD WATER

- Implement a program to keep all drains and culverts clear of debris to reduce possible flooding.
- Use sandbags to make a quick and low-cost barrier to minor flooding. Have sand and bags available.
- Install backflow preventers on low-lying overflow pipes to protect finished water.

Sandbags to prevent intrusion of water

PROTECT ASSETS AND OPERATIONS

- Secure or elevate chemical and other tanks to prevent them from floating away, releasing contents or damaging other equipment.
- Plan to move vehicles to high ground. Develop alternative methods to access the facility if entry is blocked by high flood waters or debris.
- Elevate or relocate instrumentation, electrical controls, computers and records.
- Fill finished water storage tanks to full capacity if a flooding event is anticipated.
- Maintain sufficient supplies of chemicals and fuel in anticipation of supply disruptions during a flood.

Wellhead above 100-year flood

ENSURE POWER RELIABILITY

- Contact your local power utility and local emergency management agency to plan for priority restoration of power to your water or wastewater utility.
- Ensure backup power for pumps, treatment facilities and remote units. Purchase, rent or borrow generators (e.g., through mutual aid). Install connections to enable your utility to rapidly hook up generators to your system.
- Make sure generators, electrical connections and fuel supplies are protected from flooding (e.g., elevated, easy to access).
- Arrange for priority access to fuel supplies (e.g., vendor contract).

Elevated Emergency Generator

Mitigation Options

BUILDINGS (page 1 of 2)

- ☑ Drinking water
- ☑ Wastewater

It is important for drinking water and wastewater utilities to protect their buildings and other structures from floods. This includes any entryways, both obvious (e.g., doors, windows, floor drains) and not so obvious (e.g., wiring conduits, overflow drains, cracks) where water can enter structures. Significant damage can result from flood waters entering a building; water can damage or destroy the structure, process equipment, communications and controls, records and field and administrative equipment. Flood waters can also restrict access to the facility. These impacts could result in loss of service for your customers and significant repair costs for the utility. Utilities should establish emergency monitoring and warning systems (alarm systems where possible), emergency preparedness protocols and evacuation procedures for all buildings and facilities.

See the following checklist for potential flood mitigation options for your utility buildings.

✓	Mitigation Options for Buildings	Cost
	1. Prevent buildings from flooding.	
☐	a. Caulk and/or seal wall and floor penetrations.	$
☐	b. Install backflow prevention devices on sewers, drains and other buildings.	$
☐	c. Install waterproof protection (e.g., removable/semi-permanent structures, sealed doors, shields) for building entry points (e.g., windows, doors, garages).	$$
☐	d. Install floodwalls, levees or berms around buildings.	$$$
	2. Protect critical components if buildings do flood.	
☐	a. Train staff how and when to shut down and start up power and gas supplies, electrical controls, operating systems and other equipment in system facilities.	$
☐	b. Identify locations outside the flood zone where utility equipment (e.g., heavy equipment, vehicles, replacement parts, backup generators, pumps) can be stored safely, permanently or temporarily, to prevent damage from flood waters or debris.	$
☐	c. Have an alternative access plan in case normal access to buildings is blocked. Consult with other entities (e.g., Department of Transportation) to consider alternate road/transportation options (e.g., watercraft).	$

Mitigation Options

BUILDINGS (page 2 of 2)

☐	d. Elevate or relocate equipment (e.g., computers, desks, work benches) to prevent damage if water does enter the facility (i.e., move control centers and/or laboratories to a second floor).	$$-$$$
☐	e. Maintain a cache of spare parts.	$-$$$
3. Maintain operations when the electrical grid is down.[1]		
☐	a. Maintain a generator above flood levels.	$$
4. Maintain continuity of operations during flooding.		
☐	a. Regularly backup electronic and paper files outside the flood zone either on-site (e.g., an upper floor) or off-site. Include all permits and compliance documentation, designs and as-built drawings, process diagrams, operations and maintenance (O&M) records, standard operating procedures, process and equipment manuals, material safety data sheets, asset management data, purchasing records, operations data, customer records and other critical information.	$
☐	b. Have the capability to operate remotely in case buildings are inaccessible.	$$$
☐	c. Establish interconnections or other partnership opportunities to share resources with neighboring water utilities.	$$-$$$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

$ - Little to no cost. Some internal level of effort required, but no contractor support needed.
$$ - Moderate cost/complexity. Likely involves contractual costs.
$$$ - High cost/complexity. Will require one or more contractors to implement this option.

[1] See Mitigation Options (Power Supply)

Mitigation Options

CHEMICAL AND OTHER STORAGE

- ☑ Drinking water
- ☑ Wastewater

After a flooding event, adequate supplies of chemicals and fuel are vital to maintain utility operations during the days and weeks that follow. Chemicals are needed for continued treatment of water and wastewater and fuel is needed to run equipment including emergency generators. Flooding may impact these resources in several ways. Deliveries of chemicals and fuels can be disrupted if access to the facility is restricted due to high flood waters or debris. Without necessary chemicals or fuels, utility service could be disrupted for a prolonged period of time. Storage tanks are also at risk of being damaged from a flooding event. For example, chemical or fuel tanks that are not properly secured can be carried away, damaged or ruptured, potentially resulting in leaks and spills that may contaminate utility assets and the environment.

See the following checklist for potential flood mitigation options for your utility chemical and other storage.

✓	Mitigation Options for Chemical and Other Storage	Cost
☐	a. Elevate or relocate tank platforms above flood levels (e.g., 100- and/or 500-year flood) or install physical barriers around the tanks.	$-$$$
☐	b. Secure tanks to platforms (i.e., bolt tanks down).	$
☐	c. Install larger capacity chemical storage tanks to ensure a sufficient supply through and beyond an emergency until the supply chain is restored.	$
☐	d. Establish emergency contract provisions with various fuel vendors and chemical suppliers and inform them of estimated fuel/chemical needs (type, volume and frequency).[1] Work with your local emergency management agency to prioritize chemical/fuel needs.	$$
☐	e. Ensure chemicals and fuels are topped off in advance of a potential flood.	$-$$
☐	f. For systems that work on groundwater well supply, procure or get access to a portable chlorinator.	$-$$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

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[1] See Mitigation Options (Power Supply)

Mitigation Options

INSTRUMENTATION AND ELECTRICAL CONTROLS

- ☑ Drinking water
- ☑ Wastewater

Instrumentation, electrical controls and electrical wiring are critical components of drinking water and wastewater treatment processes and should be protected from flood damage to prevent a potential service interruption. Motor Control Units (MCUs) may be co-located with the equipment they monitor/control or they may be located in a central control room. Typically, MCU clusters are co-located with the pumps and other equipment that they control. With some modification they can be made more resilient to flooding. Supervisory Control and Data Acquisition (SCADA) systems also may be at risk of failure during a flood. Loss of SCADA systems can impact operations and data collection in operations centers, treatment facilities, processes and remote locations in distribution and collection systems such as valve chambers and pump stations. Utilities should be able to monitor and control operations manually if instrumentation and controls are off-line due to flooding impacts.

See the following checklist for potential flood mitigation options for your utility instrumentation and electrical controls.

✓	Mitigation Options for Instrumentation and Electrical Controls	Cost
	1. Protect instrumentation and electrical controls from flood damage.	
☐	a. Elevate individual instrumentation/controls, control centers and MCUs or relocate to remote locations outside of the flood zone.	$$
☐	b. Maintain a cache of spare parts to restart operations as soon as possible.	$-$$
☐	c. Purchase and have available portable equipment if permanent equipment becomes disabled.	$$
☐	d. Train staff to shut down electrical equipment and controls (e.g., SCADA systems, computers, field instruments) prior to a flood to minimize damage.	$$
☐	e. Replace instrumentation and control enclosures with waterproof models.	$-$$$
	2. Maintain continuity of operations (e.g., redundant controls at another location) if instrumentation and controls are damaged by a flood.	
☐	a. Have redundant controls at another location and/or remote access capabilities.	$$
☐	b. Train staff and plan for manual operation of your water system.	$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

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$$$ - High cost/complexity. Will require one or more contractors to implement this option.

Return to Mitigation Options

Mitigation Options

POWER SUPPLY (page 1 of 3)

- ☑ Drinking water
- ☑ Wastewater

Floods often result in power outages that have major implications for drinking water and wastewater utilities. Without a backup solution, outages can disrupt service leading to boil water advisories, sewer backups or the discharge of raw sewage. To ensure continued service in the event of a power outage, a utility should consider a number of different strategies (e.g., backup generators, alternative/auxiliary source of power, energy efficient equipment) to run the critical components of its system keeping in mind that the minimum level of service required after a flood may differ from "normal" demands. Deciding on a strategy requires that you identify and evaluate your facility's sources, reliability, redundancies and critical power needs. To get started, use the EPA's publication Is Your Water or Wastewater System Prepared? What You Need to Know About Generators (EPA 901-F-09-027, September 2009).

See the following checklist for potential flood mitigation options for your utility power supply.

✓	Mitigation Options for Power Supply	Cost
	1. Long before a flood, take measures to reduce the duration of power outages.	
☐	a. Prepare a list of key utility facilities (e.g., intake works, pump stations, treatment facility) that require critical power restoration and include the physical locations of the facilities and their corresponding power company account numbers. Provide this information to the power company during an outage to expedite electricity restoration.	$
☐	b. Talk with your local emergency management agency and local power utility to increase the priority of power restoration for your utility's facilities.	$
☐	c. Working with the power utility, consider installation of two independent power feeds to your utility, elevating substations and/or ways to avoid downed power lines.	$$
☐	d. Establish more reliable connection to power source (e.g., install substation expressly for your utility or a dedicated feeder between the power station and the treatment plant).	$$$
	2. Secure backup generators.[1]	
☐	a. For your electrical requirements, document the size and type of backup generator that you need including voltage, phase configuration, horsepower/amperage, fuel, etc.	$

[1] Regularly test/service backup generators and ensure that permanent/mobile generators are elevated or outside of flood zone.

Return to Mitigation Options

Mitigation Options

POWER SUPPLY (page 2 of 3)

☐	b. Have pump stations wired to accept a portable generator. Ensure that "quick connect" capability is installed and ready, and that on-site personnel are trained.	$
☐	c. Arrange to get portable generators in an emergency by maintaining a call list of multiple vendors that rent portable generators, entering into an agreement with a particular vendor or joining a mutual aid network (e.g., Water/Wastewater Agency Response Network [WARN]) to allow sharing of backup generators. During widespread flooding events, demand and competition for portable generators will be high.	$
☐	d. Procure and install your own portable or permanent generators. Consider multi-fuel generators.	$$$
3. Secure a source of fuel for backup generators.[1]		
☐	a. Fill fuel storage tanks in anticipation of flooding.	$
☐	b. Establish an agreement with your fuel supplier and provide estimates of fuel needs (e.g., volume and frequency) in the event of a power outage. Also, secure a list of alternative fuel suppliers. Maintain communication with your local emergency management agencies for priority in getting fuel supplies.	$
☐	c. Install fuel tanks on your utility's vehicles and train staff in moving the utility's fuel in an emergency.	$$
☐	d. Perform an energy audit of your facility to identify energy saving opportunities via operations and equipment modifications. Implement recommendations of the audit (e.g., replace equipment with energy efficient models) to extend the life of your backup power supply.	$$
☐	e. Install additional and/or larger fuel storage tanks.	$$
4. Install an alternative energy system.		
☐	a. Install solar panels or wind turbines to reduce dependence on the electrical grid and to potentially supplement your backup power supply (ensure your utility has the proper technical switches).	$$$
☐	b. Install cogeneration units and/or a waste heat recovery system at wastewater treatment plants to reduce or eliminate dependence on the grid.	$$$
5. Prepare/protect electrical connections/equipment.		
☐	a. Train staff to shut down electrical equipment (e.g., Supervisory Control and Data Acquisition [SCADA] systems, computers, field instruments) prior to a flood event to minimize potential damage from flood waters.	$
☐	b. Develop "start and connect" checklists specific to each piece of equipment.	$

[1] Regularly inspect/service fuel storage tanks and ensure that permanent/mobile fuel tanks are elevated or outside of flood zone.

Mitigation Options

POWER SUPPLY (page 3 of 3)

	c. Equip generators and motors with disconnect fittings that can be removed before a flood and then restored.	$
	d. Evaluate existing electrical panels to determine the best method of connecting external portable generators to the facility or to individual pieces of equipment.	$
	e. Replace/upgrade electrical connections/motor controls/junction boxes with watertight panels.	$$
	f. Relocate or elevate electrical vaults and service panels outside of the flood zone.	$$$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

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Return to Mitigation Options

Mitigation Options

WATER INTAKE, DISTRIBUTION AND STORAGE (page 1 of 3)

☑ Drinking water

Flooded rivers and lakes can pose threats to source water intake structures by clogging them with excess silt/debris or by physically damaging them with debris. Flood waters that do enter the intake may carry increased contaminant loads and/or turbidity levels that may impact water treatment plant processes. Distribution system piping and appurtenances that are underground, along culverts and under bridges can be washed out by fast and high flowing flood waters. Finished water storage tanks also can be damaged by the force of flood waters.

Groundwater sources also may be prone to damage. Flood waters can overtop wellheads, causing damage to the casings as well as contaminating the well water. Shallow wells near a flood zone can be contaminated even if the wellhead itself has not been overtopped. Distribution lines for groundwater sources can be equally vulnerable to flooding.

See the following checklist for potential flood mitigation options for your utility surface or groundwater intakes, distribution systems and storage facilities.

SURFACE WATER UTILITIES

✓	Mitigation Options for Surface Water Utilities	Cost
1.	**Prevent structures from flooding.**	
☐	a. Relocate or elevate pump house and distribution system appurtenances that are in the flood zone.	$$$
2.	**Protect critical components if intake, distribution and storage of finished water do flood.**	
☐	a. Protect or reinforce surface water intake structures from floating debris, erosion and siltation to prevent damage or blockages during floods. Install jetty or breakwater to divert debris/silt away from structure. Install/upgrade screen at the intake to prevent debris blockages.	$$
☐	b. Waterproof, relocate or re-enforce distribution system appurtenances (i.e., fire hydrants, valve vaults) susceptible to flooding or damage from debris.	$$
☐	c. Install submersible pumps or waterproof pump motors.	$$
☐	d. Ensure that distribution lines across streams are sufficiently below streambed.	$$-$$$

Mitigation Options

WATER INTAKE, DISTRIBUTION AND STORAGE (page 2 of 3)

3. Maintain delivery of safe drinking water during flooding. [1]		
☐	a. Sign up for U.S. Geological Survey (USGS) alerts for stream and river gauges: • WaterAlert – Select gauges of interest, and USGS will send an email/Short Messaging Service (SMS; i.e., text) message when parameters exceed user-defined thresholds. • WaterNow – Receive current conditions for water data at a specific gauge directly to your mobile phone or email.	$
☐	b. Install monitoring equipment upstream of intakes to provide an early warning of raw water conditions (e.g., turbidity, flow) if no state or federal monitoring is available. Adjust the treatment process as necessary (e.g., chemical addition, residence time) to account for higher contaminant loading or increased turbidity.	$$
☐	c. Have an alternative access plan in case normal access to intake structure and/or pump house is blocked. Consult with other entities (e.g., Department of Transportation) to consider alternate road/transportation options (e.g., watercraft).	$
☐	d. Establish a plan to fill finished water storage tanks to capacity prior to a storm event.	$
☐	e. Stock spare parts to repair damaged equipment.	$-$$
☐	f. Explore interconnections or other partnership opportunities to share resources or facilitate emergency public water supply services with neighboring water utilities.	$$-$$$

GROUNDWATER UTILITIES

✓	Mitigation Options for Groundwater Utilities	Cost
1. Prevent well field/pump house from flooding.		
☐	a. Procure temporary flood barriers (e.g., sandbags) for use in minor floods.	$
☐	b. Re-grade land surrounding well field so that it slopes away to prevent flood water from flowing toward the wells. Ensure that the casing terminates at least twelve inches above grade. Also, extend well casings above the flood zone.	$-$$
☐	c. Relocate or elevate well field pump houses that are in the flood zone.	$$$

[1] See Mitigation Options (Drinking Water Treatment Plant)

Mitigation Options

WATER INTAKE, DISTRIBUTION AND STORAGE (page 3 of 3)

2. Protect critical components if groundwater intake and supply do flood.		
☐	a. Seal the top of well casings, waterproof well caps that are in the flood zone and extend vents above the flood zone elevation.	$
☐	b. Periodically evaluate the integrity of surface seals outside casings and check that there has been no soil settling or that no cavity has developed around the outside of well casings where surface water would be able to flow down to the aquifer.	$
☐	c. Install submersible pumps or waterproof pump motors and other equipment.	$$
3. Maintain delivery of safe drinking water during flooding. [1]		
☐	a. Plan to fill water storage tanks to capacity prior to a storm event.	$
☐	b. Have an alternative access plan in case normal access to wellhead/pump house is blocked. Consult with other entities (e.g., Department of Transportation) to consider alternate road/transportation options (e.g., watercraft).	$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

$ - Little to no cost. Some internal level of effort required, but no contractor support needed.
$$ - Moderate cost/complexity. Likely involves contractual costs.
$$$ - High cost/complexity. Will require one or more contractors to implement this option.

[1] See Mitigation Options (Drinking Water Treatment Plant)

Return to Mitigation Options

Mitigation Options

BOOSTER STATIONS AND OTHER PUMPS (page 1 of 2)

☑ Drinking water

Flood waters can severely damage pumps, thereby impacting the entire drinking water system from intake through distribution. Similarly, loss of facility power could render pumps inoperable without adequate backup power. Vulnerable water facility control systems include pump controls, variable frequency drives, electrical panels, motor control centers and Supervisory Control and Data Acquisition (SCADA) systems.

See the following checklist for potential flood mitigation options for your utility booster station/pumps.

✓	Mitigation Options for Booster Stations and Other Pumps	Cost
1. Prevent booster stations from flooding.		
☐	a. Procure temporary flood barriers (e.g., sandbags) for use in minor floods.	$
☐	b. Install permanent physical barriers (e.g., flood walls, levees, sealed doors).	$$
2. Protect critical components if booster stations do flood.		
☐	a. During upgrades or design of new equipment, develop capability to temporarily remove and safely store vulnerable components in advance of a flood.	$-$$$
☐	b. Waterproof, relocate or elevate motor controls, variable frequency drives, computers and electrical panels to a higher elevation by constructing platforms or integrating controls into existing buildings or infrastructure on-site.	$$
☐	c. De-energize systems prior to flooding to mitigate damage to electrical components.	$
☐	d. Replace non-submersible pumps with submersible pumps, if cost effective.	$$-$$$
☐	e. Replace standard electrical conduits with sealed, waterproof conduits. Replace electrical panels with submersion rated enclosures.	$$$
☐	f. Install sump pumps for below-ground facilities. Although not typically used to protect against flooding events, sump pumps may provide additional time to take other mitigation measures.	$
☐	g. Replace a below-grade booster station with an above-grade station elevated higher than the flood stage.	$$$

Mitigation Options

BOOSTER STATIONS AND OTHER PUMPS (page 2 of 2)

3. Maintain pumping operations when the electrical grid is down.[1]		
☐	a. Store temporary or replacement pumps out of the flood zone.	$
☐	b. Install energy efficient equipment to increase the longevity of the fuel supply for backup generators.	$$
☐	c. Replace pumps with diesel driven or dual-option counterparts.	$$
☐	d. Consider options for procuring generators (permanent or portable) or an alternative energy supply.	$$
4. Maintain pumping operations.		
☐	a. Maintain a call list of multiple vendors that can provide “pump around” services in an emergency or enter into an agreement with one.	$
☐	b. Procure extra portable pumps or specialized parts to repair damaged pumps. Consider stockpiling major components of specialized high capacity pumps.	$$-$$$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

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$$ - Moderate cost/complexity. Likely involves contractual costs.
$$$ - High cost/complexity. Will require one or more contractors to implement this option.

[1] See Mitigation Options (Power Supply)

Mitigation Options

DRINKING WATER TREATMENT PLANT (page 1 of 2)

☑ Drinking water

Flood waters may inundate a treatment facility and wash out open tanks and filter beds, damage mechanical equipment, render electrical power and controls useless, spoil finished water storage, deposit debris on-site or wash contaminants into the treatment process. Flood waters may also alter source water chemistry and turbidity, posing treatment challenges to utilities that continue to operate during a flood. For example, residence times may need to be significantly longer following a flood to attain safe drinking water standards due to high turbidity and the potential influence of contaminants in the flood waters.

See the following checklist for potential flood mitigation options for your utility treatment plant.

✓	Mitigation Options for Drinking Water Treatment Plant	Cost
	1. Prevent structures from flooding.	
☐	a. Install physical barriers to protect the entire facility from flooding (e.g., flood walls, levees) or be able to deploy temporary systems that achieve the required protection.	$$-$$$
☐	b. Install green infrastructure within or beyond the boundaries of the treatment plant to attenuate, divert or retain flood water and storm surges.	$$-$$$
☐	c. Install flood water pumping systems and/or channel/culvert systems to collect and divert flood water away from treatment processes.	$$
	2. Protect critical components if the treatment plant does flood.	
☐	a. During upgrades or design of new equipment, develop capability to temporarily remove and safely store vulnerable components before a flood when there is enough advanced notice to do so.	$-$$$
☐	b. Install saltwater-resistant equipment and storage tanks (e.g., for chemicals and fuel).	$$
☐	c. Waterproof electrical components (e.g., pump motors, monitoring equipment) and circuitry.	$$
☐	d. Elevate, relocate or cap individual assets to prevent damage from flood waters; vertically extend the walls of a treatment structure (e.g., basin, tank, filter) above flood stage; and/or flood-proof/seal structures to prevent seepage of flood water into the treatment train.	$$$

Mitigation Options

DRINKING WATER TREATMENT PLANT (page 2 of 2)

☐	e. Replace motorized and electrical equipment with submersible equipment (e.g., submersible pumps).	$$$
3. Maintain delivery of safe drinking water during flooding.		
☐	a. Monitor the quality of raw water entering the treatment plant and be prepared to adjust the treatment process as necessary (e.g., chemical addition, residence time) to account for higher contaminant loading or increased turbidity.	$
☐	b. Purchase portable, handheld testing equipment to serve as a backup to permanent mounted testing equipment that may be inoperable during a flood.	$
☐	c. Develop process guidelines or models to understand potential water quality changes, adjustments that may have to be made to attain drinking water standards and the potential costs of changes in treatment.	$$
☐	d. Explore interconnections or other partnership opportunities to share resources or facilitate emergency public water supply services with neighboring water utilities.	$$-$$$
4. Maintain operation of treatment plant if electrical grid is down. [1]		
☐	a. Install energy-efficient equipment to increase the longevity of the fuel supply for backup generators.	$$
☐	b. Replace motorized equipment with diesel-driven or dual-option counterparts.	$$
5. Increase storage capacity in preparation for floods.		
☐	a. Consider filling finished water storage tanks to capacity prior to a storm event to maximize storage if service is interrupted or if the utility is damaged.	$
☐	b. Install larger capacity chemical storage tanks to ensure a sufficient supply through and beyond an emergency until the supply chain is restored.	$$
☐	c. Determine if increased finished water emergency storage capacity would be beneficial (as opposed to water age/quality concerns).	$$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

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$$$ - High cost/complexity. Will require one or more contractors to implement this option.

[1] See Mitigation Options (Power Supply)

Mitigation Options

LIFT STATIONS (page 1 of 2)

☑ Wastewater

Lift stations are typically located at the lowest points in gravity-fed sewer systems and are therefore prone to flooding. Lift stations are also vulnerable to power outages. When lift stations lose power and do not have adequate emergency power, untreated sewage can back up into homes and businesses, flood streets or run off into local waterways. This presents a serious threat to public health and the environment. Utilities should analyze various lift station failure scenarios (using flood stage in the flood zone for hydraulic calculations) and determine potential impacts to help inform mitigation decisions. Mitigation decisions will also depend on the type of lift station (e.g., wet or dry well), location (above or below grade), existing enclosure and ancillary equipment (e.g., minimal electrical/mechanical control equipment versus grit chambers, screens, electrical panels and other equipment).

See the following checklist for potential flood mitigation options for your utility lift stations.

✓	Mitigation Options for Collection System Lift Stations	Cost
	1. Prevent lift stations from flooding.	
☐	a. Procure temporary flood barriers (e.g., sandbags) for use in minor floods.	$
☐	b. Extend vent lines above anticipated flood stage to prevent floodwater from entering the lift station.	$-$$
☐	c. Install gates and backflow prevention devices on influent and emergency overflow lines to prevent inundation of the lift station by the collection system and the overflow.	$
☐	d. Install permanent physical barriers (e.g., flood walls, levees, sealed doors).	$$
☐	e. Install green infrastructure to attenuate or divert flood water and storm surges away from lift stations.	$$
	2. Protect critical components if lift stations do flood.	
☐	a. Install unions in the conduit system to reduce the time required to repair damaged sections.	$
☐	b. During upgrades or design of new equipment, develop capability to temporarily remove and safely store vulnerable components before a flood when there is enough advanced notice to do so.	$-$$$

Mitigation Options

LIFT STATIONS (page 2 of 2)

☐	c. Waterproof electrical components, controls and circuitry.	$$
☐	d. Relocate or elevate electrical components (e.g., motors, switchgears, motor control centers, cathodic protection systems, exhaust fans, etc.) above the flood stage.	$$
☐	e. Replace vulnerable components with a submersible option (e.g., pumps, flow meters, gate/valve operators, etc.).	$$$
☐	f. Replace a below-grade lift station with an above-grade station elevated higher than the flood stage.	$$$
3. Maintain lift station operations when the electrical grid is down. [1]		
☐	a. Consider options to procure generators (permanent or portable), increase fuel storage capacity or install an alternative energy supply. The generators should be elevated above the flood stage, have automated controls and be sized appropriately. On-site fuel storage should also be elevated and secured to prevent floatation.	$$
☐	b. Install energy efficient equipment to increase the longevity of the fuel supply for backup generators.	$$
☐	c. Replace pumps with diesel driven or dual-option counterparts.	$$
4. Have a means of bypassing normal lift station operations when necessary.		
☐	a. Maintain a call list of multiple vendors that can provide “pump around” services in an emergency or enter into an agreement with one.	$
☐	b. Procure portable pumps to restore operation of a damaged lift station following an event.	$$
☐	c. Implement a regionalization project to enable diversion of wastewater flows to an alternate system for emergency wastewater collection and conveyance.	$$$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

$ - Little to no cost. Some internal level of effort required, but no contractor support needed.
$$ - Moderate cost/complexity. Likely involves contractual costs.
$$$ - High cost/complexity. Will require one or more contractors to implement this option.

[1] See Mitigation Options (Power Supply)

Mitigation Options

HEADWORKS (page 1 of 2)

Wastewater

The headworks includes the structures and equipment at the beginning of the wastewater treatment plant, such as gates and flow controls, metering equipment, pumps, mechanical screens and grit removal systems. This equipment is often at a lower elevation compared to the rest of the facility, increasing its vulnerability to flooding. If the headworks is off-line due to flooding, the rest of the plant would be inoperable. A failure of the headworks without a relief or bypass may also create backwater effects on the collection system that could flood streets and basements. Utility operators should identify how a headworks failure would affect the collection system and wastewater treatment plant performance using flood water elevations in the flood zone for hydraulic calculations and then implement the appropriate mitigation measures.

See the following checklist for potential flood mitigation options for your utility headworks.

✓	Mitigation Options for Headworks	Cost
	1. Protect critical headworks components from flooding.	
☐	a. Install nonelectrical backup controls where possible (e.g., float switches for pumps).	$
☐	b. During upgrades or design of new equipment, develop capability to temporarily remove and safely store vulnerable components before a flood when there is enough advanced notice to do so.	$-$$$
☐	c. Upgrade mechanical screens to prevent debris blockages and hydraulic restrictions in anticipation of higher than normal sand, grit, trash and debris loading during and immediately after a flood event.	$$
☐	d. Waterproof or elevate motor control units, instrumentation and controls, electrical panels, variable frequency drives and other systems.	$$
☐	e. Elevate pump and screen motors and other process mechanical/electrical equipment above flood stage.	$$
☐	f. Replace dry well pumps with submersible pumps; consider increased capacity needed during storm/flood events.	$$

Mitigation Options

HEADWORKS (page 2 of 2)

2. Maintain headworks operation when the electrical grid is down.[1]		
☐	a. Secure backup power supply for the headworks. Consider installing a generator just for the headworks or procuring a mobile generator with sufficient output for the same purpose.	$$
☐	b. Replace motorized equipment with diesel driven or dual-option counterparts.	$$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

$ - Little to no cost. Some internal level of effort required, but no contractor support needed.
$$ - Moderate cost/complexity. Likely involves contractual costs.
$$$ - High cost/complexity. Will require one or more contractors to implement this option.

[1] See Mitigation Options (Power Supply)

Mitigation Options

WASTEWATER TREATMENT PLANT (page 1 of 2)

☑ Wastewater

Wastewater treatment plants are typically located at low elevations and near a receiving water body, which may pose a significant flood risk to a facility. Coastal facilities face additional risk from storm surges and saline flood waters that can corrode storage tanks, circuitry and equipment.

Flood waters can wash out primary and secondary clarifiers, aeration tanks and chlorine contact chambers, as well as upset bioreactors. Other impacts from flood waters include damage to mechanical and electrical equipment/controls, interference with biosolids handling and disposal systems as well as washing of contaminants into the treatment train. Treatment plants that are still operational during a flood need to be prepared to accommodate higher flow rates and increased pollutant loads.

See the following checklist for potential flood mitigation options for your utility treatment plant.

✓	Mitigation Options for Wastewater Treatment Plant	Cost
	1. Prevent treatment plant from flooding.	
☐	a. Install physical barriers to protect the entire facility from flooding (e.g., flood walls, levee, sealed doors) or be able to deploy temporary systems that achieve the required protection.	$$
☐	b. Install green infrastructure within or beyond the boundaries of the treatment works to attenuate, divert or retain flood water and storm surges.	$$
☐	c. Install flood water pumping systems and or channel/culvert systems to collect and divert flood water.	$$
☐	d. Correct infiltration and inflow problems to reduce flows to the treatment works in a flood.	$$$
☐	e. Separate combined sewers to reduce flows to the treatment works in a flood.	$$$
☐	f. Construct a large storage tank to store overflows for future treatment (e.g., a large-capacity combined sewerage overflow (CSO) tunnel).	$$$
	2. Protect critical components if treatment plant does flood.	
☐	a. Secure air tanks to prevent floatation if flooded.	$
☐	b. During upgrades or design of new equipment, develop capability to temporarily remove and safely store vulnerable components before a flood when there is enough advanced notice to do so.	$-$$$

Return to Mitigation Options

Mitigation Options

WASTEWATER TREATMENT PLANT (page 2 of 2)

☐	c. Install saltwater resistant equipment and storage tanks (e.g., for chemicals and fuel), if near a coastline/brackish water.	$
☐	d. Waterproof electrical components (e.g., pump motors) and circuitry.	**$$**
☐	e. Elevate, relocate or cap individual assets (e.g., blowers, chemical/fuel/air tanks, instrumentation/controls) to prevent damage from flood waters; vertically extend the walls of a treatment structure (e.g., clarifier, basin, tank) above flood stage and/or flood-proof/seal structures to prevent seepage of flood water into the treatment train.	$$$
☐	f. Replace motorized and electrical equipment with submersible equipment (e.g., submersible pumps).	$$$
☐	g. Have an alternative access plan in case normal access to the treatment plant is blocked. Consult with other entities (e.g., Department of Transportation) to consider alternate road/transportation options (e.g., watercraft).	$
3. Maintain treatment plant operations when the electrical grid is down[1] and/or access routes are blocked.		
☐	a. Install larger capacity chemical and fuel storage tanks to ensure a sufficient supply through and beyond an emergency until the supply chain is restored.	$
☐	b. Install energy efficient equipment to increase the longevity of the fuel supply for backup generators.	$$
☐	c. Replace motorized equipment with diesel driven or dual-option counterparts.	$$
☐	d. Consider options for procuring backup generators or an alternative energy supply.	$$
4. Have a means of bypassing normal treatment plant operations when necessary.		
☐	a. Install an external connection to the facility's compressed air system to allow a temporary, portable air compressor to be used if the main air compressor becomes disabled.	$
☐	b. Procure portable pumps or maintain a call list of multiple vendors that can provide "pump around" services in case part of the treatment train is off-line.	$$
☐	c. Implement a regionalization project to enable diversion of wastewater flows to an alternate system for emergency wastewater collection and treatment services.	$$$

Cost Key (*Provides relative costs of mitigation measures - actual costs may differ for your utility)*

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$$ - Moderate cost/complexity. Likely involves contractual costs.
$$$ - High cost/complexity. Will require one or more contractors to implement this option.

[1] See Mitigation Options (Power Supply)

Pilot Project at a Small Drinking Water Utility

BERWICK, MAINE

A small drinking water utility in Berwick, Maine was concerned about flooding events from a nearby river. In May 2006 and April 2007, the Berwick Water Department (BWD) was impacted by two consecutive 100-year storms. In both instances, road access to the BWD facility was cut off by high flood waters. BWD was concerned that it may be vulnerable to more intense floods in the future.

At the request of BWD, utility operators and EPA engineers conducted a pilot resilience project to evaluate the flooding risk and determine what actions could improve the utility's resilience to flooding. EPA and BWD staff carried out the four steps described in the selection, Approach to Flood Resilience.

Using FEMA floodplain information and incorporating future uncertainties such as land use changes, urban development and climate change, BWD characterized the impact of three flood levels (100-year flood, 500-year flood, and a 500-year flood plus 2 feet freeboard). Critical assets that needed to be protected from flooding included process pumps; heating ventilation and air conditioning (HVAC), instrumentation and electrical controls as well as chemical storage tanks. The utility operators and engineers estimated the costs to repair/replace flooded assets and determined the potential impacts to operations.

Finally, the BWD operators and engineers identified mitigation options to protect their systems and provided recommendations to their management. Short-term mitigation options included placing sandbags at utility entryways, installing backflow preventers on low lying overflow pipes, securing or elevating tanks to prevent floating and ensuring adequate finished water storage prior to storm events. Many of the mitigation options were low cost or would have other benefits to operations. EPA helped BWD develop a plan that calls for implementing certain measures in the short-term to address immediate utility needs. The plan also allows for flexibility in applying other measures when additional utility resources become available and when conditions require increased flood protection. Since the assessment, BWD has secured an alternate access road so staff can enter the plant if the main road is inundated during a flood.

Quotes from Berwick Water Department

"When you realize that a flood could come and bring [your workable plant] all to an end in a couple of hours, and you'd be down for potentially weeks, that makes you ...want to know, what can I do to avoid this?"

"I'd be implementing some planning and some low cost alternatives right away, and then looking at the big budget picture for other things."

"Think ahead. Make plans now. Reduce the risk, and you'll be happy in the end."