FLOODING MITIGATION

TOOLBOX

Flood Resiliency Tools for Residents & Businesses

CITY OF VIRGINIA BEACH
Public Works

theRippleEffect
VIRGINIA BEACH FLOOD PROTECTION PROGRAM

PUBLIC WORKS ENGINEERING STORMWATER EXTENSION

JULY 2025

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Introduction and Purpose

This document is designed to educate residents and business owners in Virginia Beach to become more prepared for flooding by providing the tools, technical information and support to create a flood-resilient community. Each parcel in the city brings a unique set of challenges: the layout of the site, how the water was originally designed to enter and leave the parcel, and the development of adjacent areas. Likewise, each flooding situation is unique: differences in flooding caused by rainfall or inundation (further explained on page 6), the duration of the flooding event, and downstream factors can all change between flooding events.

The Stormwater Extension Program is in place to help residents and business owners address flooding issues on their property. The City of Virginia Beach Department of Public Works (PW) is tasked with maintaining stormwater flow within the City's right-of-way (ROW) through construction projects and studies (PW Engineering) and through maintenance and inspection (PW Operations). As part of PW Engineering, the Stormwater Extension Program (SEP) increases the City's ability to provide flood mitigation strategies tailored to individual situations. The limits of the program are discussed on page 4 of this toolbox, but essentially the program is in place to inform residents and businesses on how to improve their flooding situation while not increasing the flooding to any neighboring or downstream parcels.

As part of the National Flood Insurance Program (NFIP), the City of Virginia Beach is required to enact and enforce a floodplain ordinance. Any improvements carried out must fully comply with the requirements of the City's ordinances and any other permitting laws. Flooding, along with associated regulations, engineering concepts and mitigation strategies can be very confusing and can quickly become overwhelming; while the Extension agent is the primary contact and will be able to help navigate these topics, there are resources available from the City to help answer questions which may arise.

Welcome from the Director

Virginia Beach is a city defined by water, and while we celebrate the recreational and commercial uses of our great shared resource, we also must be mindful of the effects of flooding. That mindset of preparation and mitigation is key to the continued success of our community. The Flooding Mitigation Toolbox will serve as another method to empower residents and business owners to thrive in the years and decades to come. It is our belief that this toolbox and the Stormwater Extension Program will, in the words of the Sea Level Wise report, "...maintain and improve the quality of life for residents and ensure a vibrant future for the City of Virginia Beach."

Sincerely,

LJ Hansen, P.E.

Director of Public Works

How to Use This Toolkit

This toolbox contains 17 flood mitigation strategies available for residents and businesses to consider and decide which is right for their specific situation. All variables in these tables are based on averages, and unique situations may arise which can change any variable. It is the responsibility of the resident and/or businesses to determine whether a professional is required to perform any part or all of any mitigation strategy. Each mitigation strategy follows the same format:

Sample Mitigation Strategy Table (Tree Planting):

Flooding Type	Cost	Action	Lifespan	Maintenance Level	Planning Review	Difficulty
Rainfall	$	Passive	Multi-decade	Medium	No	2/5

Flooding Type

The strategy is designed to mitigate:

- Rainfall: Excess rain is unable to clear out because drains are blocked or there is no clear path to the drain.
- Inundation: Flooding caused by water rising from nearby waterways.
- Both: Flooding caused by either/both rainfall and inundation.

Cost

The estimated cost based on an average implementation; the general ranges are:

- $: $0-$1,000
- $$: $1,000-$5,000
- $$$: $5,000-$10,000
- $$$$: $10,000-$25,000
- $$$$$: $25,000 +

Action

Does the strategy require action to be taken before and during a flood event?

- Active: Yes, the parcel owner must act before flooding to be protected.
- Passive: Protection is always in place, no action is needed before flooding.
- Both: Some protection in place, but the parcel owner still needs to take action.

Lifespan

The average lifespan of the strategy. Individual specifics may shorten or lengthen lifespan.

Maintenance Level

Estimated amount of preventative maintenance to ensure success:

- Low: Maintenance needed every six months or longer.
- Medium: Maintenance needed every one to six months.
- High: Maintenance needed every time flooding occurs.

Planning Review

Will the City's Planning Department need to review the plans and/or issue permits before work begins? It is best to check with Permits and Inspections if there is ever any question if a permit is needed.

Difficulty

An estimate of level of skill needed to perform the work successfully on a scale of 1 to 5, with a 1 being ideal for do-it-yourself homeowners, and a 5 being exclusively in the professional field. Individual skills and site specifics may skew the difficulty higher or lower.

Program Allowances and Limitations

Allowances

The Stormwater Extension Program is designed to give residents and businesses the tools to mitigate flooding issues outside of the right-of-way (ROW). The City's Stormwater Extension agent will work with the parcel owner to look at potential flooding issues, including but not limited to blocked drainage paths, inadequate existing drainage facilities, maintenance levels on drainage facilities, site topography, changes or alterations from planned and/or permitted work, and other physical factors impacting the parcel, and offer strategies to relieve flooding. In some cases, there may not be a strategy or combination of strategies that will completely eliminate flooding; however, every effort will be made to mitigate flooding impacts.

Feel free to discuss any questions, comments or concerns about any strategy with the Stormwater Extension agent. Often, there are many factors that go into recommending a particular strategy or set of strategies. In the long term, these flooding strategies will work best if you understand the reasoning behind the strategy and the way the strategy helps lessen the impact of flooding. Written communication (particularly email) is preferred. This will allow a record to be maintained of interactions between the Stormwater Extension agent and you.

Limitations

All improvements proposed by the Stormwater Extension agent may be subject to approval by the Department of Public Works, Planning Department, other City departments, or by state and/or federal agencies. It is incumbent on the property owner or business to ensure these approvals are granted (typically in the form of a permit) and to ensure the work is carried out properly. Working with a licensed contractor and/or engineer is strongly encouraged for most strategies.

All flood mitigation projects are required to comply with the Americans with Disabilities Act (ADA) accessibility mandates. All entities subject to Title III of the ADA are responsible for checking ADA requirements and ensuring compliance.

The City of Virginia Beach is not responsible for the financing, installation, maintenance, ADA compliance or any other aspect of any mitigation strategy proposed or installed. The ultimate success of any parcel-specific flooding mitigation strategy is based on the parcel owner understanding the purpose and limitations of the strategy. The implementation of any mitigation strategy is at the homeowner's or businessowner's risk.

Definitions

This section defines terms and abbreviations used throughout this guide. If there are any questions, feel free to ask the Stormwater Extension agent for further clarification on these, or any other terms. See reference documents on page 42 for more information.

100-Year Flood

A flood which has a 1% chance of happening in any given year. This does not mean the flood will only occur once in 100 years. It may even happen multiple times per year. This is also known as the base flood. See reference 1.

Base Flood Elevation (BFE)

The elevation water will rise to in the 100-year flood, measured in NAVD88. This is the basis for flood insurance rates. See reference 1.

FEMA

Federal Emergency Management Agency - Federal agency tasked with overseeing the NFIP.

FIRM

Flood Insurance Rate Map - Map created by FEMA to determine and display flood risk. The NFIP requires the City, financial institutions and insurance providers to use the FIRM to determine flood risk.

Floodway

Channel of a watercourse and adjacent land that must be reserved to discharge the base flood without increasing water elevation more than a height determined by the community. See reference 2.

Freeboard

Additional building elevation above the BFE. This can mean lower flood insurance premiums and better preparation for sea level rise. Freeboard is required in some areas of Virginia Beach and varies based on location. See reference 3.

NFIP

National Flood Insurance Program - FEMA administered program to provide cost-effective flood insurance and to limit taxpayer burden for disaster relief payments. See reference 1.

NAVD88

North American Vertical Datum of 1988 - Datum for measuring elevations on the surface of the Earth. This datum replaced the NGVD29 datum. NAVD88 is the standard in Virginia Beach.

Special Flood Hazard Area (SFHA)

Areas shown on the FIRM as being subject to flooding in the 100-year flood. Note: Zone X (shaded and unshaded) are not considered an SFHA but are included here for convenience. Only zones found in developed areas of Virginia Beach are included. See reference 1.

Zone A

Subject to the 100-year flood, but no BFEs are determined.

Zone AE

Subject to the 100-year flood with BFE determined. This is the elevation water levels are expected to rise to during the 100-year flood.

Zone VE

Coastal flood area with velocity hazard (wave action) with BFE determined.

Shaded X

Areas with a 0.2% chance of a flood happening in a given year (500-year flood).

Unshaded X

Areas outside of the 0.2% chance flood area.

Substantial Damage

Damage of any origin to a structure when the cost of restoring the structure would equal or exceed 50% of the market value of the structure before damage occurred. See reference 4.

Substantial Improvement

Reconstruction, rehabilitation or other improvement of a structure, the cost of which equals or exceeds 50% of the market value before the start of construction. See reference 4.

Explanations

This section covers more complex concepts used throughout this guide, as well as provides insight into the forces at play when flooding occurs.

Rainfall Flooding

Temporary collection of water on a normally dry area of land due to inability of the water to drain effectively. Typically, the key to alleviate flooding in these situations is to improve the existing drainage system by increasing pipe size, increasing the number of pipes, adding or widening ditches, or regrading the ground to move water more efficiently.

Inundation Flooding

Flooding that occurs due to waterways becoming overfilled with water. This can be caused by excess rainfall, tidal action, wind action, storm surge and other factors. Typically, the strategy to this type of flooding is to either block the water at a certain point to prevent flooding upstream of that point or to elevate key elements of a parcel (structure, parking, utilities etc.) above typical inundation levels.

Flood Insurance

Flood insurance provides peace of mind that when a flood occurs, the property is insured and will be taken care of financially once flood levels recede. Flood insurance takes 30 days to go into effect, so it must be bought proactively. The City of Virginia Beach participates in the NFIP program to ensure residents have access to the fairest rates possible.

Public Works

The Department of Public Works administers the Stormwater Extension Program to assist parcel owners to find strategies for their specific flooding issues. Public Works is the primary department dealing with flooding through the design, construction, and maintenance, studies into the causes of flooding, inventories the City's drainage structures, and administers the Capital Improvement Program (CIP) projects to provide flood relief.

Planning Department

The City's Planning and Community Development Department (referred to as the Planning Department in this document) has two main roles when it comes to the toolbox: environmental planning and permitting. The environmental office works with individuals in buffer and shoreline areas. The permits and inspections group physically checks work performed to ensure it complies with the City's ordinances for floodplain management as well as general building and development codes.

Flood Protection Program (FPP)

The FPP is a decade-long Capital Improvement Project designed to combat flooding along with the effects of sea level rise. These projects are administered by Public Works and, when complete, will be able to shut off tidal inundation and remove excess rainfall through pump stations in certain neighborhoods. The strategies suggested in this program will be evaluated against the goals of the FPP to gauge the effectiveness of the proposed strategy pre- and post-FPP.

Public vs. Private Drainage

The City is tasked with using public funds to move public stormwater within the public ROW and public drainage easements. Whether rain falls within the ROW or runs off private property into the ROW, it becomes the responsibility of the City - even if the pipes or ditches that convey the water downstream are on private property. When private runoff flows from one parcel to another, it is incumbent on all parcel owners involved to work together to ensure positive drainage.

Easements

An easement is an agreement between a property owner and another party to allow for access for a given reason. Virginia Beach uses easements to note areas of land that must be protected to allow for drainage structures and ditches to be installed and maintained. Only drainage structures and ditches that carry public runoff are maintained by the City using public funds.

Flooding Type	Rainfall
Cost	$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	No
Difficulty	2/5

Tree Planting

Flood-resistant trees help absorb rainfall and hold soil together to prevent erosion.

Trees and shrubs at Redwing Park help soak up rainwater that runs off the event field and prevent soil erosion into Malbon Swamp.

This stand of mature pines was planted over 25 years ago along West Landing Road and has successfully reduced flooding in the area.

Trees along the shore of Stumpy Lake prevent erosion, slow water velocity and absorb excess runoff from the golf course.

Description

Planting trees in low-lying areas can help absorb excess runoff. In addition to mitigating rainfall flooding, trees provide cooling shade in adjacent areas during hot weather, a natural habitat for wildlife, and can improve property values. Trees are a long-term investment and will continue to provide flood protection for years to come, as well as preventing erosion by helping to hold soil together. Trees grow at different rates depending on the species, and a mix of tree types may be needed for short- and long-term mitigation. No permits are needed to plant trees; however, Home Owner Associations (HOAs) may have rules regarding location and species.

Concerns

Depending on the age of the transplanted tree, it may take years for the tree to be able to absorb excess runoff. During extreme rain events such as hurricanes, tropical storms and nor'easters, there may be so much runoff the tree (or trees) cannot absorb enough water to prevent flooding. Winds associated with extreme storm events may cause branches or the entire tree to come down. As living beings, trees are susceptible to disease and can become damaged or die. Leaves and other debris may be blown into neighboring yards.

Maintenance

Trees tend to be low maintenance, however deciduous trees lose their leaves in the fall and may blow into neighboring property, diches, storm pipes and other areas, which will need to be cleared. Limbs may be damaged and need to be pruned.

Ideal Species

Below are six species identified for both providing good runoff absorption as well as being native to the area. Other species might also provide flood mitigation, and the Stormwater Extension agent or a professional arborist will be able to help evaluate different choices.

For dry ground subject to ponding:

- Eastern Red Cedar (Juniperus virginiana)
- Loblolly Pine (Pinus taeda)
- White Oak (Quercus alba)

For lower, wet ground made worse by ponding:

- Bald Cypress (Taxodium distichum)
- Overcup Oak (Quercus lyrate)
- Black Willow (Salix nigra)

Insurance and Grants

Planting trees will not affect flood insurance rates. Ask the Stormwater Extension agent about the availability of grants to purchase trees, because some programs may charge.

Extension Information

The Stormwater Extension agent will work with you to find the right variety of tree, suggest locations for planting, and answer any questions you may have about the trees.

Flooding Type	Inundation
Cost	$$-$$$$
Action	Passive
Lifespan	Multi-year
Maintenance Level	Low
Planning Review	Yes
Difficulty	4/5

Living Shoreline

Native wetlands plants designed to reduce inundation flooding and improve water quality.

Living shoreline with riprap and a variety marsh, salt meadow, salt panne, and upland plants along the Elizabeth River near Interstate 64.

Low marsh shoreline installed in Thalia Creek east of Princess Anne High School.

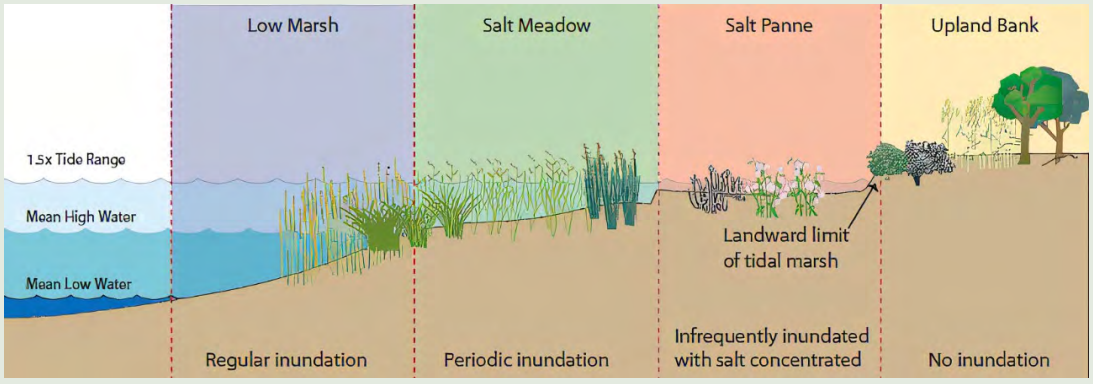


Diagram of marsh inundation zones, courtesy of Virginia Institute of Marine Science.

Description

A living shoreline provides flood protection by reestablishing and encouraging the growth of native plants. These plants slow water down during inundation events, provide a habitat for aquatic life, and improve water quality in a natural way. There are a variety of planting options, and plants must be tailored to the site based on several factors, including: depth of water, normal tidal range, desired access to the water from the property, and regulatory concerns. Having professional help for regulatory compliance, design and construction is strongly advised, because a Joint Permit Application (JPA) is required to be submitted to the Virginia Marine Resource Commission (VMRC). The cost to implement a living shoreline will vary greatly by the amount of planting, length of the shoreline, and the distance into the water the plants are to go.

Concerns

Any work in the waterways of Virginia Beach will invite attention from neighbors, recreational and commercial users of the waterway, regulatory officials, and other interested groups. There are many factors about modifying a shared natural resource, such as a waterway, which may make it difficult to get the desired result. One of the largest potential issues of installing a living shoreline is ensuring the ability to plant far enough out in the water to get the desired flood mitigation result. Regulatory officials and professionals can help make that determination.

Maintenance

The goal of a living shoreline is to largely be self-reliant and ecologically stable; however, coastal storms may cause plants to be dislodged, which can cause flooding during the storm. Invasive or unwanted species of plants may also try to establish themselves in a living shoreline; a guide of native and invasive plants may help determine if a plant should be removed.

Alternatives

Regulations from the Commonwealth of Virginia now require living shorelines in lieu of bulkheads. See reference 15 for more information. Bulkheads are more difficult to maintain in the long run, cause a loss in biodiversity, and increase water velocity, all of which can lead to further environmental degradation.

Ideal Species

The Virginia Institute of Marine Science (VIMS) has a website dedicated to living shoreline plants based on salt and brackish marsh, freshwater marsh and other native plants. See reference 7 for more information.

Resources

There are a number of resources available for guidance on living shorelines, several of which are listed in the reference section at the end of this guide. Reference 5 describes topics in coastal North Carolina; while regulatory and permit requirements are different in Virginia, this resource offers good background into the concept of a living shoreline.

Insurance and Grants

Planting a living shoreline will not affect flood insurance rates. Ask the Stormwater Extension agent about the availability of grants for a living shoreline, because these programs frequently change.

Extension Information

The Stormwater Extension agent will work with you to find the best method of marsh planting and answer questions you may have about the plantings.

Flooding Type	Rainfall
Cost	$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	No
Difficulty	1/5

Rain Barrel

Small rain collection systems attached to downspouts to retain runoff.

Open top rain barrel at the Virginia Beach Farmers Market. Note the screen covering the top, the spigot at the bottom, and the cinderblock foundation to provide stability.

A rain barrel constructed from a recycled plastic drum. Note the screen at the intake and hose at the bottom for gardening.

A cistern installed at Kellam High School. These use the same principle as a rain barrel, just on a much larger scale.

Description

Rain barrels provide an excellent means for capturing excess runoff from a house, garage or other structure to lessen the burden on the stormwater system. Often aesthetically pleasing and complementary to many architectural styles in Virginia Beach, rain barrels are an easy way to help limit runoff while also providing a source of non-potable (non-drinkable) water for a number of uses around the home and garden. Rain barrels have a small footprint and are particularly suited for sites where the house or primary structure covers a high percentage of the parcel.

Concerns

Rain barrels, when full of water, will be heavy. It is essential that the foundation and/or soil under a rain barrel be sturdy and stable enough to handle that stress. The barrel should be monitored for leaks, which may indicate a breakdown in the material used to construct it that could lead to a structural failure. Filter screens should be used at intake points to screen out leaves, frogs, rodents and other debris. Rain barrels are an attractive habitat for mosquitos, and water should be emptied or agitated regularly if mosquitos are able to enter the barrel.

Legality

A rumor that often pops up concerns rain barrels being illegal in Virginia; this is simply not true. There is no legal limit on rain barrels, aside from the condition that the water is not to be used for drinking, cooking or other situations where non-potable water should not be used (reference 16). This rumor may stem from the western United States where local, state, tribal and federal governments may limit water storage for the purpose of conservation.

Cistern

A cistern is the same concept as a rain barrel, but on a much larger scale. Typically, the primary purpose of a cistern would be to capture as much water as possible for an industrial or commercial purpose; runoff capture for flood abatement would be a secondary goal. Kellam High School on West Neck Road has made extensive use of cisterns to capture rainwater for sports field irrigation, as well as reducing the volume of runoff to West Neck Creek in southern Virginia Beach. For more information see reference 8.

Insurance and Grants

Rain barrels will not affect flood insurance rates. The City's Agriculture Department, local nonprofits, and home improvement stores frequently offer programs about building and installing rain barrels. Ask the Stormwater Extension agent about the current availability of programs, because these programs frequently change.

Extension Information

The Stormwater Extension agent will work with you to find the best location and tips to make rain barrel installation a success and answer questions you may have about rain barrels.

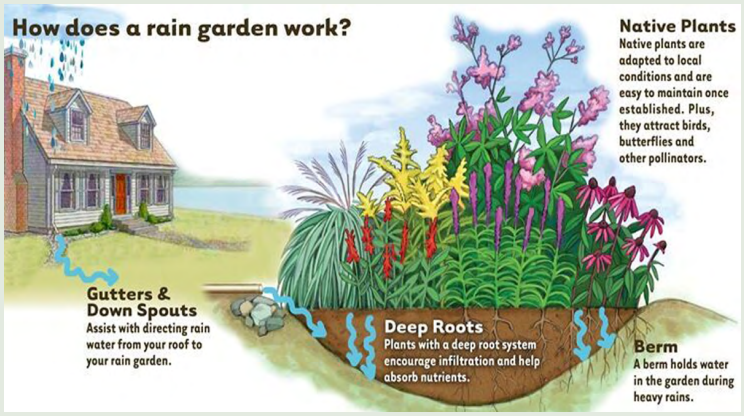
Flooding Type	Rainfall
Cost	$$-$$$$
Action	Passive
Lifespan	Multi-year
Maintenance Level	Medium
Planning Review	Possibly
Difficulty	3/5

Bio-Retention Beds & Rain Gardens

Specifically designed flower and planting beds to absorb and treat runoff.

Rain garden at the Virginia Beach Famers Market, featuring native plants attractive to pollinators.

Bio-retention bed with rain garden at Redwing Park designed to support dry ground plants.



Rain garden diagram, courtesy of Virginia Department of Wildlife Resources.

Bio-retention bed with rain garden at Redwing Park designed to support marsh plants.

Description

Bio-retention beds and rain gardens are specially designed planting beds that maximize the amount of rain and runoff that can be absorbed, treated and infiltrated into the soil or into the air as evaporation. Aesthetically pleasing and an oasis for bees, birds, butterflies and other pollinators, bio-retention and rain gardens have become extremely popular in urban and suburban areas to try to restore a piece of the native habitat. For runoff reduction and flood storage, a professional landscape architect may be needed to determine the optimal location for the bed, the depths and types of soil, and the ideal plant species. The size, plantings, soil mixture and other factors will determine the ultimate cost of this strategy. If land disturbance area is greater than 2,500 square feet, a review by the Planning Department may be needed.

Concerns

Bio-retention beds and rain gardens will require upkeep and maintenance to the same degree, or higher, than most typical flower beds. Native plants are strongly encouraged, and the use of pesticides and herbicides is strongly discouraged. This will increase the time and effort to maintain the beds from invasive weeds. Homeowner Associations (HOA) may have regulations prohibiting planting rain gardens and bio-retention beds.

Stormwater Management

In some newer construction, houses are being built with bio-retention beds as part of the stormwater management plan for the site. These beds may fall under the City's Municipal Separated Storm Sewer System (MS4) permit, administered by the Public Works Engineering Regulatory Compliance office, because these beds must be maintained to provide cleaner runoff. Bio-retention beds installed under the Stormwater Extension program will not fall into this category.

Mosquito Control

Those with concerns about the use of mosquito control chemicals around pollinator plants can request a red tag for their mailbox to alert the mosquito control driver to turn off the spray, as he or she passes by on evening spray routes. Residents can contact Public Works Operations at 757-385-1470 to request a tag for their mailbox.

Insurance and Grants

Bio-retention beds and rain gardens will not affect flood insurance rates. Local non-profits may provide information and referrals to landscape professionals who will be able to help plan the best plantings. Ask the Stormwater Extension agent about the current availability of programs, as these programs frequently change.

Extension Information

The Stormwater Extension agent will work with you to find the best location and tips to make your garden a success, and answer questions you may have about bio-retention beds and rain gardens.

Flooding Type	Rainfall
Cost	$$$$
Action	Both
Lifespan	Multi-decade
Maintenance Level	High
Planning Review	Yes
Difficulty	5/5

Berm with Sump Pump

Earthen or concrete wall around all or part of a parcel to prevent inundation flooding.

Low rise walls, like the poured concrete one shown above, can be used to lessen the footprint of a berm. However, further engineering will be needed to ensure the strength of the wall. Image courtesy of FEMA.

House protected by a permanent berm. Even with vegetation, seepage will enter the protected area. Photo courtesy of FEMA.

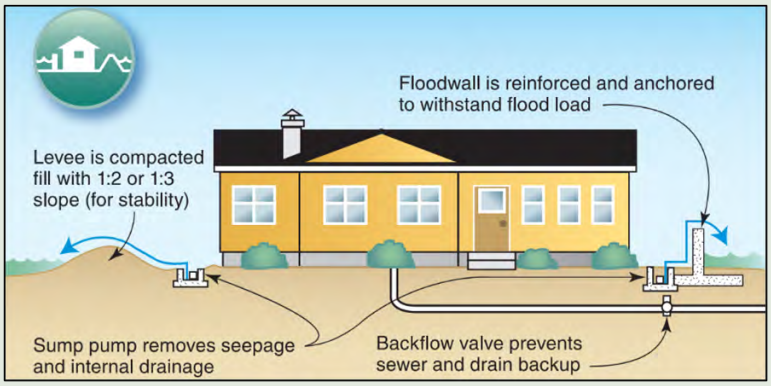


Diagram showing earthen (left) and concrete (right) berms, as well as the need for sump pumps. Diagram courtesy of FEMA.

Description

A berm (also known as a levee or dike) is a protective mound of earth or human-made material, such as concrete, acting as a barrier between a source of inundation flooding and property to be protected. Berms are a particularly attractive method of floodproofing, because they totally stop the ability of the water to flood the area they are designed to protect. A sump pump is required inside a berm to remove water during and after a storm event. The design and construction of the berm, as well as operating and maintenance costs of the sump pump, will all need to be factored into the total cost of this strategy.

Concerns

Berms come with a number of challenges, the largest being the consequence of the berm failing and water entering the previously protected area. The two main causes for a breach would be a fault in the construction (unsuitable soil, voids or decay in the soil, loss of vegetation holding soil together) or through overtopping (water flowing over the top of the berm, eroding soil, causing more flow, eroding more soil in a cycle). The sudden rush of water caused by a breach can damage the structure and trap people inside, potentially leading to an evacuation, often at the height of the flooding event. An additional concern may be impacts to adjoining properties. The risk of additional flooding to others should be evaluated in the planning stages, and all possible efforts must be taken to avoid this.

Sump Pump

A sump pump is essential for this type of strategy in order to remove water from inside the berm caused by seepage or rainfall. Pumps requiring electricity to operate will also need a generator in the event of a power outage during the flood event. Pumps require periodic maintenance and should be sized appropriately for the area they are expected to protect.

Rim Elevation

The elevation of the top of the berm (the rim) must be high enough to provide protection to the base flood elevation and additional freeboard for good measure. As discussed above, overtopping is catastrophic, and every effort should be made in the planning stages to minimize the chance of this.

Access

To access the area inside the berm, pedestrians and vehicles will either have to go over the top or through an opening that can be flood proofed (typically by stoplogs). The angle of the walls and height of the berm will help decide the ideal access strategy.

Floodplains and Fill

Floodplain management requirements may treat a berm as fill, therefore Planning will review the site plan to determine whether a berm has an impact on the floodplain.

Insurance and Grants

Constructing a berm will likely not impact flood insurance, however it is strongly suggested you contact both your flood insurance and homeowners' insurance provider(s) to determine impacts to premiums. Feel free to contact the Stormwater Extension agent for grant information; however, there are not many grants to cover this type of strategy.

Extension Information

The Stormwater Extension agent will be able to provide some technical assistance for planning a berm; however, calculations, surveys, and design work should be done by a licensed professional engineer.

Flooding Type	Both
Cost	$$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Low
Planning Review	Yes
Difficulty	4/5

Regrading

Moving existing soil or adding additional soil to fill low areas of a parcel.

Lynnhaven Parkway between Salem High School and Indian River Road was built in phases, eastbound (right) being built first in 1984. In 1988 the road was widened with the westbound lanes (left) being graded about 4 feet higher than the existing lanes. This prevented the westbound lanes from flooding in Hurricane Matthew (2016) while the eastbound lanes did flood.

Description

Regrading the soil within a lot, or bringing in additional soil, can be used to eliminate low areas prone to flooding. For the purposes of this toolbox, regrading a parcel only applies to the grounds surrounding the structure. Regrading a parcel generally will not protect any structure and should only be used to increase usable yard area and reduce ponding. In some cases, just a small amount of earth will need to be moved requiring a low amount of effort, disturbance, and changes to the drainage. In situations where a large amount of soil is being moved, however, there is an increased chance that the proposed improvements will require a Planning review, permitting and inspections. Of all the flooding strategies offered in this program, regrading the soil generally has the lowest amount of long-term maintenance.

Concerns

The main concern with regrading a parcel is the possibility of erosion during and immediately after regrading. Soil erosion causes the downstream drainage system to become sedimented, decreasing the amount of runoff it can carry and causing more upstream flooding. Erosion also removes the very soil used to regrade the lot, thereby creating a material and financial loss for the parcel owner. Silt fences and seeding should be incorporated to lessen the impact of erosion from the site.

Drainage

Changing the elevation of a parcel will also likely change the way in which it drains. Careful attention should be paid during heavy rain events to: where the water drains, where the water is pooling, and where the high points in the yard are located. A best practice for regrading is to keep the same drainage pattern after regrading, so that the same outfall paths are receiving roughly the same amount of runoff.

Permits

Permits will be needed if the total area being disturbed is greater than 2,500 square feet. See reference 9. Any fill within a floodplain will have to be reviewed by Planning to ensure the fill does not cause an increase in flood elevation or velocity. In the southern part of the city, fill may be restricted in areas designated as a Floodplain Subject to Special Restrictions. The Planning Department will be able to provide further guidance.

Hauling

If additional soil is to be brought to the site, a hauling permit may be needed. In general, a hauling permit will be required if more than 337 cubic yards of fill will be hauled using the City's roads, see reference 10. The Planning Department will be able to provide further guidance.

Insurance and Grants

Regrading a lot will likely not affect flood insurance rates. There are not likely to be many grants available for this type of work, but feel free to contact the Stormwater Extension agent to check whether they may be available.

Extension Information

The Stormwater Extension agent will be able to produce topographic maps of the parcel, suggest areas where fill can be added and where it can be taken from, and offer advice to ensure positive drainage.

Flooding Type	Inundation
Cost	$$
Action	Active
Lifespan	Multi-year
Maintenance Level	High
Planning Review	No
Difficulty	1/5

Temporary Barriers

Physical barriers used to keep flood waters from entering a structure.

A water filled temporary barrier surrounding a house, in place before flood waters rise. Image courtesy of FEMA

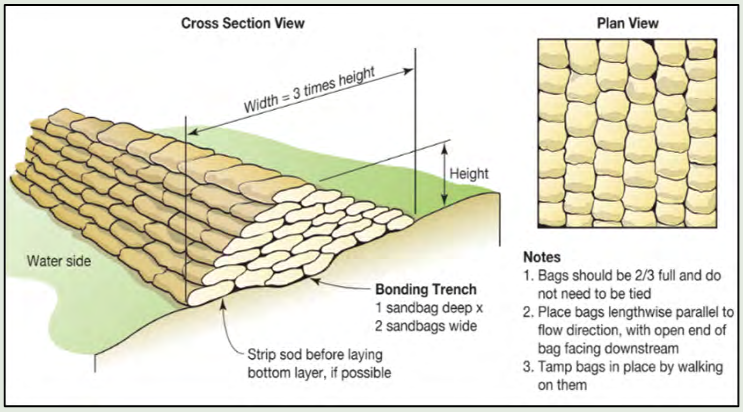


Diagram of the proper installation method for a multi-layer sandbag wall. Diagram courtesy of FEMA.

A gel filled boom type temporary barrier available from most home improvement stores. This is ideal for quick install and shallow water levels.

Description

A temporary barrier provides a physical means of keeping water from entering a structure. Primarily for inundation situations, these barriers work in a similar way to berms (discussed on pages 15-16) by not allowing water to move overland from a nearby source of flooding. The main difference between the two is that while a berm is permanent and usually protects the structures(s) as well as part of the yard, a temporary barrier is, by definition, temporarily deployed before the start of a flooding event and generally will only protect the primary structure on a parcel.

Concerns

No matter the design, all temporary barriers have the same flaw; they must be fully in place before flooding begins. This can be especially difficult during the preparation for a hurricane or tropical storm; these are high-stress situations with many different factors weighing on the parcel owner and installing a barrier can be rushed, inviting failure later on. Similar to the consequences of failure of a berm (page 16), if a temporary barrier were to fail, there would be a sudden rush of water with the potential to damage the structure, which may need to be evacuated during the flood event. Seepage is also a concern; the longer a temporary barrier is in place, the more water will seep through leading to some shallow flooding within the protected area. A sump pump will be needed to remove seepage and any rain that will fall between the structure and the barrier, depending on the type of barrier deployed.

Water Level Forecasts

Temporary barriers must be able to provide protection to the expected highest water level forecast during a storm. In tidal areas of the city, tide forecasts are issued for Crab Creek at Lynnhaven Inlet. Local variation due to fetch, storm surge and rainfall will cause water levels to vary, usually higher than forecast for Crab Creek. Currently, there are no official forecasts for water levels in the southern watershed of the City making it difficult to gauge the effectiveness of barriers during flood events in the Back Bay and North Landing watersheds.

Fresh Water vs. Salt Water

Water-filled temporary barriers use the force of water within the barrier to counteract the force of the water outside the barrier causing the flooding. Water-filled barriers are an effective tool for protecting a structure, but it is critical to fill the barrier with salt/brackish water and not fresh water. Fresh water has a lower density than salt/brackish water, and the barrier will float when the two come in contact. Virtually all inundation flooding in Virginia Beach is from salt/brackish water sources. See section 8-3 of reference 13 for more information.

Rainfall Uses

Temporary barriers can also be used for rainfall, particularly to keep water from entering openings vulnerable to runoff (typically garage doors or other at-grade doors). Heavy rain from hurricane and tropical storm events can be planned for, however pop-up thunderstorms can drop devastating amounts of rain in a short period with little to no warning. This is an example of the problem of having the barrier in place before the flooding starts. In the long term, the other strategies in this toolbox should be explored to mitigate these types of flooding events.

Insurance and Grants

Temporary barriers will not affect flood insurance rates. Grants are not likely to be available for this strategy, but feel free to check with the Stormwater Extension agent for availability.

Extension Information

The Stormwater Extension agent will help identify the types of barriers available on the market, their usefulness in regard to your site, and sources for information regarding real-time flood and water level forecasts.

Flooding Type	Rainfall
Cost	$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	Possibly
Difficulty	3/5

French Drain

Permeable pipes designed to allow runoff to soak into the ground.

An example of a French drain installation with two perforated pipes surrounded on all sides by gravel. Note: most French drain installations use a layer of filter fabric between the soil and gravel at the bottom, sides and over top of the pipes to keep the pipes and gravel clear of soil, extending the life of the strategy.

This French drain includes a wye fitting to connect another downspout into the underground system. Since part of this system is against the foundation of the structure, solid wall pipe should be used here instead of perforated pipe.

Description

A French drain is a single or a connected system of perforated pipes designed to carry runoff underground to be absorbed directly into the soil. An added benefit to a French drain system is lawns, trees, and gardens can all benefit from the additional water in the soil. Pipes are typically made of either polyethylene (PE) (sometimes referred to as high density polyethylene or HDPE) or polyvinyl chloride (PVC) with perforations along the pipe to allow water to soak into the ground. Typical installation will require a layer of filter fabric wrapped around the pipe. This is used to screen out loose soil and roots, then a course of gravel or other stone to bed the pipe.

Concerns

A French drain will be able to cope with most run-of-the-mill rain events, however there is a good chance it will be overwhelmed in larger rain events such as hurricanes, tropical storms, and even heavy downpours no matter how large the system is. Cleanouts should be installed along the system to allow the pipes to be cleaned periodically. The pipes should be planned out in such a way that vehicles will not drive over the pipes unless they are specially shielded or designed to handle traffic. For parcels with septic systems, the septic drain field should be as far as possible from any French drain line.

Soil Types

There are three main types of soil: loam, sand and clay. Virginia Beach has a mix of loamy and clay soils with some pockets of sandy soil, typically in low-lying areas and near the ocean. Loamy soil is ideal for a French drain, because it easily allows the water to be absorbed. Sandy soils will also allow for a decent amount of absorption; however, sand can easily infiltrate the pipe reducing overall usefulness. Clay soils do not absorb water well, and when mixed with sand will make a French drain ineffective. Soil types may vary across a parcel. It is ideal to take several soil samples along the planned path of the French drain to ensure the soil can absorb water well.

Popup Overflows

Popup overflows are a device for the end of a French drain that allows for excess water that cannot be absorbed to leave the pipe and runoff as sheet flow. These can only be installed in areas where the pipe has enough slope for the hydraulic head to force the water out the pipe end. This drainage should be directed toward the right of way whenever possible.

Maintenance

Similar to any toolbox concept, maintenance is key to ensure the longevity of the strategy. Being underground, it can be very difficult to gauge how well the system is working and whether the pipes are beginning to become clogged. The best way to do this is to be proactive: when the French drain is first installed, purchase a rain gauge and keep track, either on paper or mentally, of how many inches of rain will cause the system to be overwhelmed. If the system is being overwhelmed in smaller rain events, it is likely time to have the system cleaned. This is where having cleanouts (as mentioned above) comes in handy.

Insurance and Grants

French drains will not affect flood insurance rates. Grants may be available for this strategy, but feel free to check with the Stormwater Extension agent for availability.

Extension Information

Home improvement stores and local nonprofits may offer courses on how to install French drains and rent equipment to make installation easier. Since this strategy involves digging into the ground, you must call Miss Utility at 811 to have any underground conduits and pipes staked out before any digging takes place.

Flooding Type	Rainfall
Cost	$$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	Yes
Difficulty	4/5

Permeable Pavers

Paver stones designed to allow the infiltration of runoff.

Interlocking concrete pavers installed at Lake Smith/Lake Lawson Natural Area.

Monolithic concrete parking adjacent to cellular grid pavers allowing for more parking accessible to all users at Little Island Park.

Cellular grid pavers installed at Little Island Park in Sandbridge. Note the grass growing in the cells - this will help reduce runoff even further.

Description

Permeable pavers are a strategy for parcels with a large area of impervious surface creating runoff. By replacing the impervious surface with permeable pavers, rainfall can work its way into the soil and less runoff will be sent to the storm systems. In addition to helping with flood reduction, permeable pavers also help to capture pollutants by locking them into the soil rather than running off. For commercial properties, the use of permeable pavers as a best management practice may result in reduced stormwater fees. Permeable pavers are considered impervious within the Chesapeake Bay Resource Protection Area (CBRPA), and Chesapeake Bay Preservation Board approval may be required for this strategy. There are many types of permeable paver designs for use in different traffic areas (vehicular traffic, parking, foot traffic, etc.) and a licensed engineer or contractor should be able to help find the right strategy for the parcel. Costs will vary due to parcel specifics, such as the land area being converted to pavers, other site work needed to ensure maximum efficiency and drainage, and the types of pavers being used.

Concerns

Similar to French drains (pages 21 and 22), the underlying type of soil must be able to absorb water, soil primarily composed of clay will not be able to absorb runoff as well as loamy or sandy soils. In areas being retrofitted from impervious pavement to permeable pavers, the soil under the pavement may be compacted from the original construction and years of use. In this case, the soil will likely have to be replaced to allow for proper infiltration.

Accessibility

Per the Department of Justice: As a reminder, whatever surface material is selected the individual, organization or entity must comply with the Americans with Disabilities Act (ADA) accessibility requirements.

Maintenance

Like all the strategies offered in this toolbox, permeable pavers require maintenance. Vehicular traffic, tree debris, and sheet flow are all factors that will influence how often the pavers need to be cleaned. Typically, a street sweeper, vacuum sweeper, or even a leaf blower will be able to clear the debris from the pavers, however occasional power washing and replacement of gravel may be needed. The supplier of the pavers should include or have available a maintenance schedule.

Insurance and Grants

Permeable pavers will not affect flood insurance rates. Grants are sometimes available for this type of work. Check with the Stormwater Extension agent for availability.

Extension Information

It is strongly advised that anyone interested in permeable pavers, particularly commercial sites, retain an engineer to ensure the design, permitting and construction are handled properly. The Stormwater Extension agent will be able to assist in rudimentary information about area disturbed, feasibility of permeable pavers, and soil conditions at the site.

Flooding Type	Both
Cost	$$$$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	Yes
Difficulty	5/5

Structural Elevation

Raising a flood-prone structure above the base flood elevation (BFE).

This house, located in the Lynnhaven Colony neighborhood, was raised several feet bringing the lowest floor above the BFE for the area. While not as dramatic as a house having an entire level added underneath, just a few feet can make a big difference in flooding.

Description

Structural elevation is the act of raising a house or business to a higher elevation, usually within the same footprint. When most people think of raising a house, they think of houses that have an entire level added underneath the structure. While this is a popular method, elevating by just a few feet can make a dramatic difference in flood risk, flood insurance rates and peace of mind. Elevating a structure is an attractive method for flood mitigation because it has the highest guarantee of keeping a structure flood-free when compared to other flood-proofing methods. However, the largest drawback is the cost and disruption to daily life during construction. No decision for a flood mitigation strategy should be rushed, but especially with structural elevation, all parties involved should come together and weigh the pros and cons of elevation.

Concerns

One of the largest and most overlooked concerns is temporary housing during construction. Typically, residents will not be able to enter the structure in any way during the elevation process; occupants will have to essentially move out during construction. Another major concern is the long-term accessibility of the structure. As people grow older, they may find it harder to go up and down stairs to get in the front door. The original construction quality of the structure should also be evaluated (typically by the engineer and/or contractor) to ensure the house will hold together while being raised and when potentially exposed to more wind. All home systems (electrical, plumbing, etc.) must be brought up to current code standards to be eligible for FEMA grants.

BFEs and Freeboard

Any structural elevation is pointless unless the first floor is elevated to or above the base flood elevation (BFE) for the area. In Virginia Beach, there is a good chance that when elevating a structure, there will also have to be an additional freeboard elevation above the BFE. This protects the parcel owner in the long run as sea levels rise and storms get more severe, as well as helping to lower flood insurance rates even further.

Maintenance

Depending on the method to raise the structure, there may be an elevated crawl space under the first floor. It is incumbent on the homeowner to check this space periodically for damage and vermin, as well as making sure flood waters can pass underneath the structure. Typical household chores will also become more difficult once the structure is elevated. Simple things such as cleaning the gutters, power washing and washing windows will become more difficult.

Aesthetic

Efforts should be made during the planning stages to use materials complementary to the structure and the neighborhood to not disrupt the aesthetics of the area. Screening plants, fences and other techniques can be used to help modifications blend into the feel of the neighborhood, especially in established or historical areas.

Insurance and Grants

Flood insurance may be reduced once an updated FEMA elevation certificate is complete and on file with the insurance agent. Feel free to contact your flood insurance provider to inquire about the changes in flood insurance rates based on elevating to the BFE plus freeboard, and additional feet above that. Grants are available from FEMA and other organizations to help offset the costs of structural elevation. In Virginia Beach, the Office of Emergency Management handles these requests.

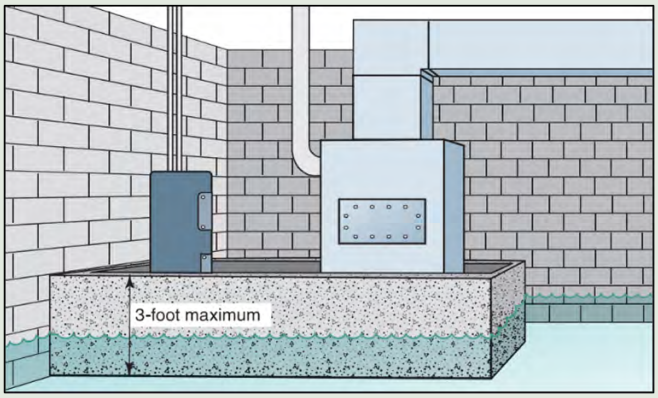
Extension Information

The Stormwater Extension agent will be able to help gather information about flooding on your parcel, connect you with resources in the City as well as other levels of the government, and answer questions you may have about the process.

Flooding Type	Both
Cost	$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	Possibly
Difficulty	4/5

Equipment Elevation

Raising key mechanical systems and appliances to reduce risk from flooding.



Equipment protected by a concrete floodwall. Three foot is the maximum recommended height for stability and access. Diagram courtesy of FEMA.

HRSD's Arctic Ave pump station was designed to keep equipment above flood levels. Note the height of the maintenance doors, and the stairs up to the main door.

HVAC system elevated and anchored to the side of an elevated house. This will protect the equipment from flooding but will be more difficult to maintain. Image courtesy of FEMA.

Description

Appliances and home systems are major investments that must be protected to avoid financial hardship. Most appliances such as washers, dryers, freezers, refrigerators, water heaters, and furnaces require electricity or a pilot light to operate; flood waters can destroy the electronic components of the machine, extinguish a pilot light causing a gas leak, and generally leave the appliance ruined with just a few inches of water. Home systems such as furnaces, HVAC units and associated duct work, electrical systems, and cable/fiber runs can be more difficult to elevate; but if damaged by flooding, can be more expensive and require total replacement.

Concerns

The main concern with elevating equipment is knowing what the homeowner can do and what should be done by a professional. The sections below will help give some ideas of the variables to consider, and feel free to ask the Stormwater Extension agent for guidance.

Cost

Of all the strategies proposed in this guide, elevating equipment has the biggest cost range based on the specific improvement for a home. For example, if a washer and dryer are in a flood-prone garage, building a wooden platform and steps up is a straightforward weekend project; materials are available from any home improvement store and will likely come in under $500. On the other hand, moving duct work from a crawl space to an attic will require professional help and will likely require Planning review, coming in at a higher cost. It is important to keep in mind that the cost savings of proactively protecting assets will outweigh the costs, time delays, and misery of post-flood clean up, repair and replacement.

DIY vs. Contractor

As stated in the Cost paragraph, some equipment raising ideas can be carried out by a homeowner, whereas some will likely need, or even require, a licensed professional. If there is doubt about whether a DIY project should be attempted, feel free to ask the Stormwater Extension agent, a trusted friend or neighbor, or reach out to a professional to get a quote.

Permits

A recurring theme of elevating equipment is the variability of the strategy, tailored to a specific home. Generally, a building permit will be required if a contractor is modifying the electrical or plumbing systems in some way. The Stormwater Extension agent will be able to give some guidance on the permitting process; however, it is encouraged to contact Planning directly or through the contractor to ensure the best answer.

Maintenance

Similar to the maintenance discussion in the section on elevating a structure on page 26, maintenance of the home system or appliance being raised could become more difficult; although with proper planning maintenance, may become easier. For example, if a crawlspace had ductwork with an air return at floor level, it could be susceptible to flood damage. If the ductwork were moved to the attic, the air return may be put in the ceiling, making it difficult to change the filter. With a maintenance mindset in the planning stage, it may be possible to work with the contractor to have the air return lower for easier maintenance.

Insurance and Grants

Flood insurance will likely not be affected by elevating equipment; however, check with your homeowner's insurance to see if it will credit your efforts to protect home systems. Grants may be available for some work. Check with the Stormwater Extension agent for grants as opportunities change frequently.

Extension Information

The Stormwater Extension agent will be available to offer guidance on projects and will help with determining the ideal elevation equipment should be raised to, as well as guidance on DIY or professional projects.

Flooding Type	Both
Cost	$$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	Yes
Difficulty	4/5

Wet Floodproofing

Allowing flood water to pass under living spaces using flood vents to minimize damage.

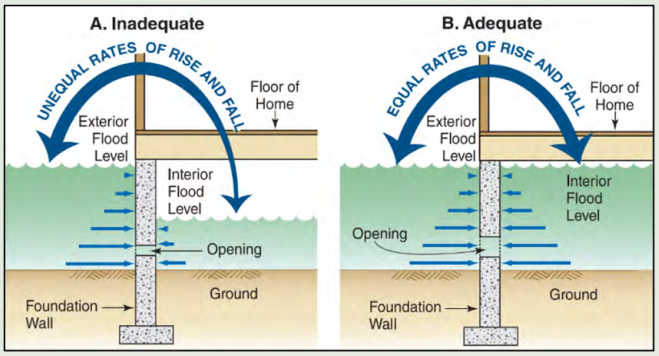


Diagram showing the importance of sizing of flood openings correctly to reduce pressure to the foundation. Diagram courtesy of FEMA.

This house uses flood vents (visible on the right) as well as wood lattice screening on the front to keep the crawlspace open for floodwaters to enter and exit freely. Utility pipes (water especially) should be shielded from cold temperatures if lattice screening is used. Image courtesy of FEMA.

Flood vents in a residential building. Flood vents can be very low key and can be out of view behind flower beds and other plants; however, access to the vents must be maintained. Image courtesy of FEMA.

Description

Wet floodproofing allows floodwaters, especially those moving quickly, to flow through non-living spaces like garages and crawlspaces under the living spaces of a home without applying undue pressure to the structure. This strategy is ideal for buildings that face flooding where the water does not rise high enough to enter the living area. Hydrostatic force (the weight of water pushing against the side of the structure) can cause damage to, or the failure of, the foundation. Equalizing the pressure by allowing the water to flow in and out of the foundation is essential. Hydrodynamic force (the force applied by flowing water from creek flow, tidal action or wave action) can cause structural failure with even less water present.

Concerns

Wet floodproofing is popular where flooding does not enter the living areas of the structure because the living area is above the base flood elevation. Hurricanes, flash floods and wave action can cause water levels to rise quickly and go past the level that wet floodproofing can offer protection. Flood vents should be checked regularly to ensure they can open during a flood and have not become damaged due to animals, wear or the weather. Garage doors without flood vents do not count as flood vents, because they are not automatically activated and rely on electricity to function in normal operation.

Slab Structures

The core concept of wet floodproofing is allowing water to flow under the living areas of a structure. A slab home is constructed with living spaces at grade. There is no path for water under the structure. Therefore, slab structures are not eligible for wet floodproofing.

Flood Vents

Flood vents are openings in the foundation that allow water to enter and leave the crawlspace. There are some wet floodproofing examples where the owner has simply left openings in the wall with no covering; however, this is not advised due to the risk of creatures living under the structure. Automatic vents are available online, and at some home improvement stores. There must be at least two openings (one each on different walls) in the structure within 1-foot of grade to allow for equilibrium to be reached as quickly as possible, and the number of additional openings can be found using this formula: 1 square inch (sq in) of opening per 1 square foot (sq ft) of enclosed area subject to flooding. Example 1: 1,280 sq ft house ÷ 128 sq in = 10 openings needed. Example 2: 2,000 sq ft house ÷ 128 sq in = 15.62, rounded up = 16 openings needed. No matter the decimal, the number will always be rounded up, see reference 1 for more information. 128 sq in is used for the opening size because the standard cinderblock is 8 inches by 16 inches, or 128 sq in.

Raising Equipment

Wet floodproofing will only protect the living areas of the structure. Flood-prone garages will still flood; using the information covered in the Raising Equipment section (pages 27-28), appliances and home systems in the garage can be raised to further mitigate damage from floods.

Insurance and Grants

Wet floodproofing will improve flood insurance premiums only if the strategy is installed correctly according to the regulations. Professional help is strongly advised to ensure optimal flood insurance discounts. Grants may be available to help install wet floodproofing. Check with the Stormwater Extension agent for the availability of programs.

Extension Information

The Stormwater Extension agent will be able to help put together rudimentary calculations and estimates of openings needed, as well as any other questions you may have about implementing wet floodproofing.

Flooding Type	Both
Cost	$$$
Action	Both
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	No
Difficulty	5/5

Dry Floodproofing

Placing barriers in vulnerable structural openings to block flood waters.

Dry floodproofing using multiple aluminum stoplogs held in place with a guiderail. Image courtesy of FEMA.

A dry floodproofed business with an aluminum shield in the doorway. The gaskets used between the rough brick and foundation stone surface and the guide rails will need to be inspected and replaced when it wears out. Image courtesy of FEMA.

Cinderblock building retrofitted with a poured concrete wall on the exterior, with openings that can be sealed off using flood barriers in front of both teal doors. Image courtesy of FEMA.

Description

Dry floodproofing involves putting physical barriers in structural openings (doors, windows, vents etc.) to completely block any paths for flood water to enter a structure. Dry floodproofing uses the same overall theory as a berm (page 15-16) or a temporary barrier (page 19-20) which is to block the water before it can enter a structure. Dry floodproofing can only be installed on structures that constructed from brick or poured concrete; wood framed structures, including those with a brick veneer, cannot be dry floodproofed due to the risk of collapse from hydrodynamic and hydrostatic forces as well as the risk of water infiltrating through seams of the structure, see reference 13. Because of these construction specifics and the considerations listed below, dry floodproofing will not be recommended as a flood mitigation strategy for residential structures regardless of flood zone, but may be incorporated in commercial and industrial structures. The Planning Department will determine whether a floodproofing certificate is required.

Concerns

As with temporary barriers and berms, the main concern is failure of the flood control barrier during a flood event. Unlike with a berm or barrier, there would not be additional strain on the building from the rush of water, however there would be constant pressure applied to doors, windows and other openings. A failure of one of these would allow water to rush in, bringing with it glass from the broken window/door, pieces of the dry floodproofing itself, and other debris from the flood waters. Buoyancy force would also be applied to the building, and foundation damage can result, see reference 13.

VE Zones

Additional water velocity and wave action can severely damage dry floodproofing measures leading to catastrophic failure. In 2021, FEMA issued a technical bulletin clarifying that the NFIP regulations do not allow dry floodproofing in V (including VE) zones, see reference 12. Reference 11 describes how Hurricane Ian in 2022 caused multiple failures of dry floodproofing measures throughout Florida, most notably at the Fort Myers Beach Town Hall, where anchor bolts were ripped from concrete walls by waves and surge.

Structural Considerations

The walls of a dry floodproofed structure must be able to withstand the lateral force of water being applied to the structure. Poured cement walls and brick/cinderblock construction will be able to best withstand this force. Openings in the walls (doors, windows, etc.) will have to have guide rails for flood shutters/stoplogs installed. The guide rail must be anchored into suitably strong construction to transfer the force of the water to the structure.

Substantial Damage and Improvement

Dry floodproofing cannot be used to bring a substantially damaged structure into compliance with the NFIP. An alternative to dry floodproofing would be to raise the structure or other strategies offered in this guide geared toward inundation mitigation.

Flood Depth

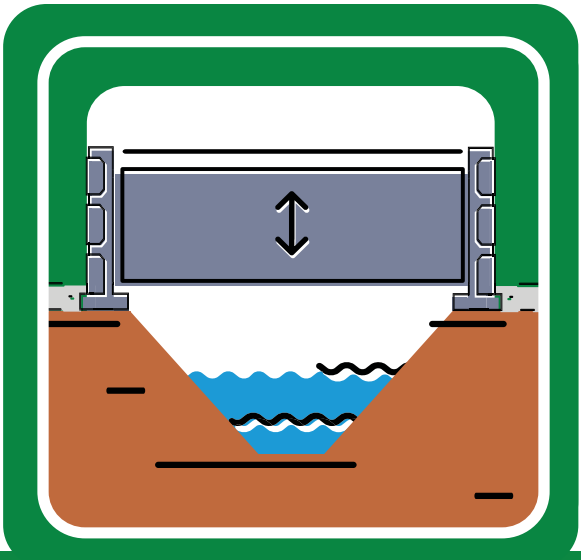
The expected depth of flooding is critical to determining whether dry floodproofing is viable for a site. The BFE for the site is a good benchmark, as well as adding at least 1 full foot of additional freeboard for protection.

Insurance and Grants

Dry floodproofing will not affect flood insurance rates and is heavily regulated by the NFIP. There are not likely to be many grants for dry floodproofing, but feel free to check with the Stormwater Extension agent.

Extension Information

The Stormwater Extension agent can help identify the BFE for your site, recommend different methods for dry floodproofing, as well as provide resources concerning flood forecasts and other information.



Flooding Type	Inundation
Cost	$$$$
Action	Active
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	Yes
Difficulty	4/5

Sluice Gate

Open air water control valves in ditches to shut off the flow of inundation.

Sluice gates, like this one installed along Flanagans Lane, are typically attached to a headwall and are lowered to stop the flow water into a stormwater system. Simpler gates may consist of a board lowered into place by hand.

Description

A sluice gate is a vertically moving valve designed to regulate the flow of water in a channel. The City uses automated gates at several locations to shut off vulnerable areas from the effects of inundation flooding, with more planned as part of the ongoing Flood Protection Program (FPP). On a much smaller scale, a sluice gate can be installed in a ditch where inundation water is flowing from the source and threatening a parcel. Operating a sluice gate requires an understanding of the water and weather systems that effect water level, and the ability to recognize when to open or close the valve. A major drawback to a sluice gate is when faced with both rainfall and inundation, a choice must be made on which force will cause more flooding, and sometimes there is no way to avoid flooding. The cost to implement a sluice gate will vary based on the size of the ditch and the amount of earth- and site-work needed to ensure the gate is able to withstand the force of the water.

Concerns

When considering a sluice gate, it is important to gauge the impact it will have on surrounding properties. In rural areas, ditches tend to serve as property lines, so both property owners should agree to and understand the principles of a sluice gate, as well as other property owners upstream and downstream of the ditch that will be affected by a gate. The depth of the ditch is a critical design factor; if the water can continue to rise and overflow through adjacent ground, this will make the sluice gate ineffective and potentially lead to a flash flood situation. The quality of the soil in the area of the gate will also affect the installation, potentially requiring additional fill or concrete work to ensure the gate is properly seated.

Maintenance

Sluice gates require ongoing maintenance to ensure they will operate properly during a flood event. Most maintenance will be limited to simply cleaning the area around the gate to ensure debris does not get stuck in the seat of the gate and it has a tight seal when closed. More intense activities may include lubricating the valve stem and operating gears. The valve manufacturer should provide, or have available, a maintenance schedule.

Rainfall

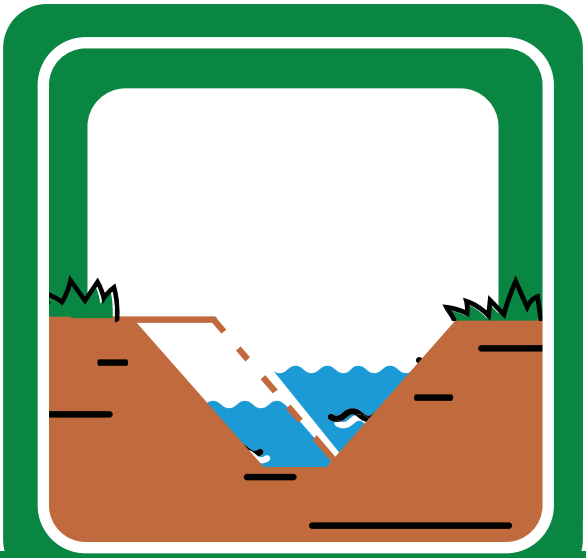
While we are seeing an increase in “sunny-day” inundation flooding events, most inundation flooding will be part of a storm bringing rain into the situation. Closing off the drainage path will resolve the water backflowing into the ditch, but it will also not allow for the rainfall to runoff. In these situations, the parcel owner must decide which type of flooding will be worse, and act in the best interest of themselves as well as the best interest of others along the ditch.

Insurance and Grants

Installing a sluice gate will not affect flood insurance rates. There are not likely to be many grants for this mitigation strategy, but feel free to check with the Stormwater Extension agent.

Extension Information

The Stormwater Extension agent will be able to help identify properties both upstream and downstream of the proposed sluice gate to determine which parcels will be affected by the gate.



Flooding Type	Rainfall
Cost	$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	Possibly
Difficulty	2/5

Ditch Cutting and Cleaning

Cleaning existing ditches and adding new ditches to direct water efficiently to the outfall.

City crews cleaning out the roadside ditch on Old Pungo Ferry Road, working from the top of the image toward the bottom. Smaller ditches can be cleaned using hand tools, but larger ditches and more heavily sedimented ditches may require heavy equipment.

Description

Adding ditches or swales encourages positive flow that will move runoff away quicker. This strategy is ideal for larger parcels that experience ponding that may last for hours or even days after a rain event; the ditches will direct this water away when the soil cannot absorb any more rain. The dimensions of the ditch will depend on the site conditions; however, in many cases, only a small ditch will need to be cut into the soil that can be mowed without adding extra difficulty. Cleaning ditches will also encourage positive flow, whether it is cleaned by the parcel owner or by a professional. Over time, it is natural for ditches to become sedimented and lose the capacity to move runoff; recognizing when this occurs and taking action to correct sedimentation is a simple way to ensure proper stormwater flow. Costs will vary based on the complexity of the task, the machinery used, and the length of the ditch being cut or cleaned.

Concerns

Adding and cleaning ditches along a property line will require consultation and coordination with neighboring property owners to ensure everyone is on the same page, and that this does not increase flooding elsewhere. The parcel owner should understand the topography of the parcel, where ponding is occurring, and where the water is trying to outfall before beginning to add ditches or swales. Miss Utility will need to mark potential underground utilities before digging occurs; it can be reached at 811. When cleaning a ditch, the entire ditch should be cleaned to ensure there is a smooth and steady bottom to the ditch; sharp drops will lead to erosion which will increase sedimentation downstream.

Design

The Public Works Design Standards Manual (PWDSM) requires both new and recut ditches must be no deeper than 18 inches from the ditch bottom to the surrounding ground. The sides of the ditch must be no steeper than 3:1 horizontal to vertical (for example: a 1-foot deep ditch would need sides 3-feet wide from the bottom of the ditch to the surrounding ground). For more information, see reference 14.

Maintenance

Newly cut ditches should be designed to ensure the property owner is able to maintain them as easily as possible. Wide bottoms and shallow slope sides will make mowing easier but may require a footbridge or culvert to cross and take up more area on the parcel. On the other hand, a narrow ditch with steep sides may require a string trimmer to maintain but have less of a footprint on the site. Ultimately, these ditches will need to be cleaned as sediment settles in the ditch. Stabilization is required for new or recut ditches; typically this can be accomplished with grass, however other materials such as wetlands plantings or riprap may be used.

Sediment Control

When digging or cleaning a ditch, special attention must be paid to the amount of loose sediment entering the receiving water. As sediment travels downstream, it will collect and create blockages adding additional flooding to the upstream parcels. Sediment also contains nutrients that encourage the growth of harmful algae downstream, depleting oxygen levels and decreasing the health of the city's waterways. Silt fencing, stilling basins and check dams are simple ways to help prevent excess sediment runoff.

Insurance and Grants

Adding and/or cleaning ditches will not affect flood insurance rates. There may be grants available to improve drainage for parcel owners; check with the Stormwater Extension agent to see if there are any available.

Extension Information

The Stormwater Extension agent will be able to offer guidance on the topography of the parcel, and where the ditches should be directed toward to ensure proper drainage.

Flooding Type	Rainfall
Cost	$$-$$$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Low
Planning Review	Possibly
Difficulty	4/5

Private Drainage System

Drainage system directing runoff underground to the outfall.

Contractors installing storm pipe in a trench. This type of installation will be common on larger sites, typically commercial and industrial.

Smaller residential storm inlets and pipes can be purchased at many home improvement stores. These will be easier to install and maintain but may be overwhelmed in heavy rain events.

Description

Adding a drainage system to a residential or commercial property is a strategy that, if properly planned and engineered, can greatly reduce flooding from rainfall. Drainage systems are common throughout the city; they typically consist of inlet structures which collect runoff, manhole structures which allow pipes to change direction, pipes which move stormwater between structures and the outfall, and finally the outfall where the stormwater leaves the system and flows into a ditch, lake, canal, pipe system or other receiving water. In a residential setting, a drainage system may be very similar to, or even incorporate the design of, a French drain by using small pipes to move water to the outfall. Non-residential parcels will likely have a more robust system with VDOT and/or City standard structures, 12-inch or larger drainage pipes, and potentially a stormwater management facility. Costs for a private drainage system will vary between commercial and residential implementations, as well as for the size of the system, the depth of the pipes, and if a stormwater management facility must also be installed.

Concerns

Private drainage systems will require occasional maintenance to ensure there is no debris restricting or blocking flow in the pipes and structures. Sites with more loose surfaces (rock, gravel, sand, etc.) and those with more leaf litter will require more frequent cleaning. Runoff volume will increase where the pipe discharges the stormwater, which can cause erosion and sedimentation. Riprap should be used to reduce flow velocity and the outfall should be carefully monitored for the first few big rain events to ensure damage is not being done to the receiving waterway.

Design

The design of any stormwater system must comply with the Public Works Design Standards Manual (PWDSM), regardless of whether it is conveying public or private runoff. Other mitigation strategies covered in this guide, particularly French drains and dry wells, do not necessarily have to meet the standards of the PWDSM because they do not connect or convey runoff to the larger stormwater system. However, a private drainage system is specifically designed to connect to other systems, and therefore will have to meet requirements (see reference 14 for more information). A Planning review is required if the land disturbance exceeds 2,500 square feet, or if there is a direct connection to the City's drainage system.

City Connection

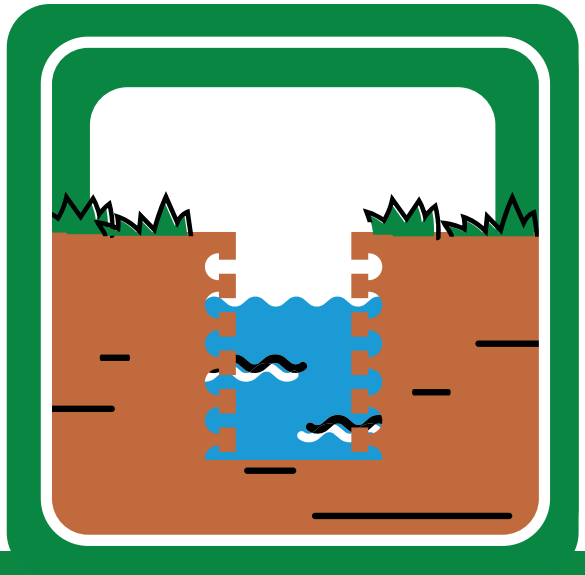
In some cases, the best way to improve a flooding situation is to connect to an existing City-owned drainage system. While any plan to build a private drainage system must be reviewed by the DSC, connecting directly to the City's system will require additional review by the Department of Public Works to ensure the system can handle the additional runoff. For smaller systems, typically residential, it may be possible for the outfall of the system to punch through the curb and drain directly into the gutter. These plans should also be submitted to DSC and the punch-through must comply with the PWDSM Appendix B standard drawing B-16 or B-17, see reference 14. Connection to the City drainage system may require an encroachment agreement.

Insurance and Grants

Adding a private drainage system will not affect flood insurance rates. Grant programs may exist to assist to improve drainage systems. Ask the Stormwater Extension agent about the availability of programs.

Extension Information

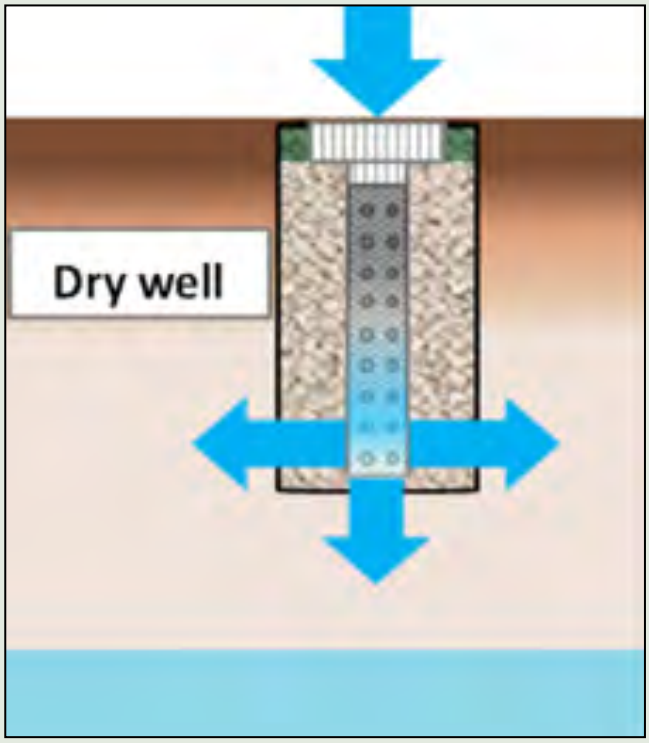
Every parcel in the city is different, and the potential design of a private drainage system will depend on the characteristics unique to the site. The Stormwater Extension agent will be able to help provide guidance on the size and scope of the system needed.



Flooding Type	Rainfall
Cost	$$$
Action	Passive
Lifespan	Multi-decade
Maintenance Level	Medium
Planning Review	No
Difficulty	5/5

Dry Well

Stormwater inlet designed to infiltrate water directly into the soil.



Cutaway view of a drywell showing a perforated vertical chamber which allows water to infiltrate through the surrounding gravel into the earth. Diagram courtesy of California OEHHA.

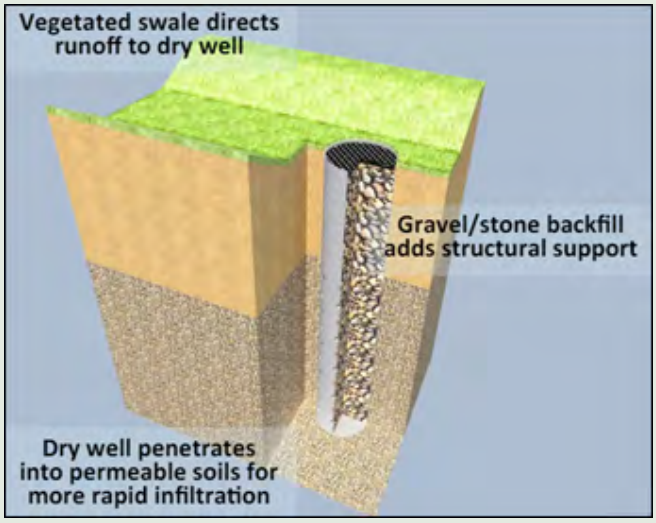


Diagram showing how a small swale can be used in conjunction with a dry well to focus runoff into the well. Diagram courtesy of California OEHHA.

Description

A dry well is a storm inlet, typically a drop inlet with a flat cast iron grate, which does not connect to a larger stormwater system. Instead, the inlet will have a gravel base to allow stormwater to infiltrate into the soil. There are cases where multiple dry wells have been connected together with permeable pipes to help spread the area of infiltration. Dry wells are an ideal strategy for areas with a noticeable depression in the soil and where other strategies, particularly ditches, are not practical. Dry wells will typically be able to handle more runoff than a French drain, as well as having a smaller footprint.

Concerns

The diameter of the inlet, the land area being drained, and the ability of the soil to absorb water will all affect how the dry well is able to mitigate flooding. The larger the area being drained, the more runoff will enter the inlet and the quicker it will fill. The water will slowly infiltrate into the soil, but there is an expectation for flooding during extreme rain events, and when back-to-back rain events occur.

Maintenance

Over time, leaf debris and sediment will enter the inlet and cause two problems: less ability for runoff to infiltrate into the soil leading to stagnant water in the inlet, and less storage capacity in the inlet leading to more flooding in less severe rain events. Preventative maintenance is the key to avoiding these situations; more frequent cleaning will be necessary, particularly in areas with heavy tree cover and/or soils prone to erosion due to lack of grass or other ground cover. Maintenance should only be carried out by the parcel owner if they feel comfortable opening the lid and have access from ground level to the bottom of the inlet, otherwise a professional should be used.

Groundwater Elevation

Groundwater elevations, also known as the water table, vary geographically and during the time of year, with the highest elevation typically in late winter/early spring, and the lowest in the late summer/early fall. Groundwater elevations will affect the ability of a dry well to absorb water, and the invert (bottom) of the inlet should be higher than the highest groundwater level experienced in the area. The Stormwater Extension agent will be able to pull data from nearby monitoring wells and help determine the approximate invert; however, it is strongly recommended that the seasonal high groundwater elevation be determined at the site. Because of groundwater elevations, dry wells will not be a viable strategy in some parts of Virginia Beach.

Mosquito Concerns

Dry wells will hold some amount of water, and this can become an attractive breeding ground for mosquitos. Special attention should be paid to dry wells, particularly in the summer, to make sure they do not become mosquito haunts. Simply agitating the water with a stick will be enough to destroy eggs, but in some cases chemical pesticides may need to be used.

Insurance and Grants

A dry well will not affect flood insurance rates. Grants may be available to homeowners to build dry wells. Ask the Stormwater Extension agent about the current availability of programs.

Extension Information

The Stormwater Extension agent will be able to help determine the approximate depth of the dry well based on groundwater monitoringawells, placement of a dry well based on the topography of the site, and whether there are other strategies that can be used in conjunction with a dry well.

Mitigation Strategy Table

This table is the combined attributes of all the strategies covered in the toolbox. Use this to compare strategies and focus ideas based on these variables.

CONCEPT:	USEFULNESS:	COST:	ACTION:	LIFESPAN:	MAINTENANCE LEVEL:	PLANNING REVIEW:	DIFFICULTY:
Tree Planting	Rainfall	$	Passive	Multi-decade	Medium	No	2 / 5
Living Shoreline	Inundation	$$-$$$$	Passive	Multi-year	Low	Yes	4 / 5
Rain Barrel	Rainfall	$	Passive	Multi-decade	Medium	No	1 / 5
Bio-Retention Beds / Rain Garden	Rainfall	$$-$$$$	Passive	Multi-year	Medium	Possibly	3 / 5
Berm w/Sump Pump	Inundation	$$$$	Both	Multi-decade	High	Yes	5 / 5
Regrading	Both	$$$	Passive	Multi-decade	Low	Yes	4 / 5
Temporary Barriers	Inundation	$$	Active	Multi-year	High	No	1 / 5
French Drain	Rainfall	$$	Passive	Multi-decade	Medium	Possibly	3 / 5
Permeable Pavers	Rainfall	$$$	Passive	Multi-decade	Medium	Yes	4 / 5
Structural Elevation	Both	$$$$$	Passive	Multi-decade	Medium	Yes	5 / 5
Equipment Elevation	Both	$$	Passive	Multi-decade	Medium	Possibly	4 / 5
Wet Floodproofing	Both	$$$	Passive	Multi-decade	Medium	Yes	4 / 5
Dry Floodproofing	Both	$$$	Both	Multi-decade	Medium	No	5 / 5
Sluice Gate	Inundation	$$$$	Active	Multi-decade	Medium	Yes	4 / 5
Ditch Cutting and Cleaning	Rainfall	$$	Passive	Multi-Decade	Medium	Possibly	2 / 5
Private Drainage System	Rainfall	$$-$$$$	Passive	Multi-decade	Low	Possibly	4 / 5
Dry Well	Rainfall	$$$	Passive	Multi-decade	Medium	No	5 / 5

References and Further Reading

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All photos courtesy of City of Virginia Beach, unless otherwise noted.

CITY OF VIRGINIA BEACH
Public Works

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VIRGINIA BEACH FLOOD PROTECTION PROGRAM

The Stormwater Extension Program helps residents and business owners find ways to mitigate flooding.

For more information, contact:
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757-385-1690

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