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FLOOD RESILIENT RESIDENTIAL RETROFITS HANDBOOK

A practical guide for implementing flood resiliency measures in existing structures

PARTNERS FOR ACTION

Clean Foundation

Partners for Action

Partners for Action (P4A) is an initiative in the Faculty of Environment at the University of Waterloo that brings together governments, researchers, businesses, and communities to better understand flood risk. It was launched in 2015 with founding sponsorship and thought leadership from Co-operators and Farm Mutual Re. P4A promotes community-level flood resiliency as a pathway toward climate action (focusing on awareness and preparedness), climate adaptation and climate justice. It developed FloodSmartCanada.ca, a bilingual site with flood prevention resources and flood maps, and produces applied research and tools, policy work on managed retreat, a study on inclusive risk communication, and a database of multi-hazard resilient retrofits– which aim to help inform and catalyze equitable resilience. Partners for Action is the creator and steward of **climateresilientretrofits.ca**, an online resource hub containing multi-hazard databases and research pertaining to resilient home retrofits for climate change adaptation.

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Clean Foundation

Clean Foundation promotes green solutions for today – and supports the environmental leaders of tomorrow. Clean Foundation is a Nova Scotia-based independent, non-governmental environmental charity that began in 1988. Clean Foundation's passion is providing the knowledge, tools and inspiration needed to encourage the actions that lead to positive environmental change. Clean Foundation supports the fair transition to a cleaner economy and greener society. To achieve this, Clean Foundation works collaboratively with their many partners to: reduce energy poverty, promote social equity and support historically marginalized communities, develop the clean economy workforce, protect the natural environment, and educate and promote action on climate change. Clean Foundation's Resilient Home Retrofits Program is funded by Halifax Regional Municipality, the Province of Nova Scotia's Climate Change Plan, and the Town of New Glasgow.

Clean Foundation

FLOOD RESILIENT RESIDENTIAL RETROFITS

Clean Foundation is piloting a flood resiliency retrofit program for homeowners in Halifax and New Glasgow, Nova Scotia. This program is designed to build homeowner knowledge of flooding and insurance and to address capacity and financial barriers to enable homeowners to reduce their flood risks.

Critical to the program are home assessments and the need to work with contractors to build awareness and understanding of how to install retrofits that reduce household flood risks. Contractors need to know how to comply with regulations and how to follow best practices, with regard to stormwater management and ensuring that the building envelope is effectively sealed. However, there is a general lack of consensus on what to do and how best to do it. In addition, guidelines and standards are often written using highly technical language that is not user-friendly for homeowners or contractors that install flood risk reduction measures. Furthermore, there are not necessarily clear standards available for all relevant retrofit measures, such as basement work and eavestrough installations.

To address these concerns, Clean Foundation has engaged Partners for Action to produce a plain language, semi-technical manual of household flood resilient retrofits for contractors and homeowners to enable consistency in installation and at the same time, confidence in the work done in terms of whether it meets relevant standards and reflects recommended best practices.

This handbook is designed to support homeowners or contractors in understanding and implementing measures to enhance the flood resilience of single-family residential properties. Drawing from expertise in flood resilience and practical knowledge from experienced contractors, this handbook provides a step-by-step guide to improve the resiliency of single-family residential properties against flooding.

For more information about Clean Foundation's programs, visit their website:

www.cleanfoundation.ca

For more information about the research informing this report, visit the Climate Resilient Retrofits website developed by the Partners for Action team:

www.climateresilientretrofits.ca

https://uwaterloo.ca/partners-for-action/

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Credits

Writers & researchers

Benedictus Haryanto
Sumana Mitra
Felicia Watterodt
Herry Chen

Project lead

Sharmalene Mendis-Millard

Editors

Felicia Watterodt
Sheridan Hill

Content drawn from research done by

Devon Jones, *for P4A's Climate Resilient Retrofits Database (2023)*

Subject matter expertise & content

Jesse Galati

Content reviewers

Patrick Larter
Alexia Héroux

Report design

Felicia Watterodt

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Disclaimer

Although the information provided in this guide references experts who have worked directly with these flood risk reduction solutions, it is important to note that this handbook is provided for general information purposes only and is not a replacement for following the advice or instruction of a contractor or a retrofit expert who can be on-site and assess the unique conditions and challenges of a property or assess the specific product/materials you choose. The exact products or strategies needed to address the hazard conditions your property faces, and the precise steps to follow and the authorities to contact may vary. The exact steps to follow or authorities you may need to reach out to may also vary. Check with your municipality, contractor, and local not-for-profits that promote flood resiliency, like Clean Foundation in Nova Scotia and Reep Green Solutions in Ontario, for resources and advice.

When planning for a flood-resilient home retrofit, consider both conditions at time of installation and expected conditions for your property in the future. Look up your local flood susceptibility and exposure maps (e.g., on **HealthyPlan.City**; **FloodSmartCanada.ca**) and learn more about how rainfall, sea levels and other variables are changing for your area at **ClimateData.ca**.

This handbook provides a collection of solutions and related local building standards and guidelines. However, the instructions do not replace the details found in the codes, by-laws, and technical guides mentioned. For additional details and up-to-date information, please see the technical guides referenced in this publication. If unsure of how to proceed with a retrofit project, it is best to enlist the services of a licensed and insured professional.

Clean Nova Scotia Foundation (operating as Clean Foundation), Partners for Action and each of their respective partners, affiliates, successors, agents, directors, officers, employees, volunteers, and contractors assume no responsibility or liability for:

- any direct, indirect, incidental or consequential loss or damage that any person may sustain as a result of the information in, or anything done in or omitted to be done in reliance on, this handbook;
- any personal injury or bodily injury, including death, and any loss or damage whatsoever, whether caused by flooding or otherwise to insured or uninsured structures and/or property, that any person may sustain as a result of the information in, or anything done in or omitted to be done in reliance on this handbook;
- the failure of retrofits due to environmental changes, material defects, or installation errors; and,
- any failure to comply with local or national laws, codes, or standards.

The guidance provided in this handbook is current to its publication date. Future users should take care to verify whether there may have been changes or amendments subsequent to the publication date.

Users of this handbook are solely responsible for meeting all legal and regulatory requirements. This handbook serves as a general guide and is not a substitute for professional or legal advice.

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1. INTRODUCTION

1.1. How to use this handbook

1.1.1. Purpose

This handbook offers a series of installation procedures, instructions, and key considerations that pertain to strategic flood resiliency retrofits for single-family homes. It is intended to be used by contractors, people experienced with do-it-yourself (DIY) renovations, and homeowners who want to know what questions to ask. This work aims to provide key steps within the retrofitting process to help ensure that the retrofit functions as intended. Each retrofit page outlines what to consider during installation, and how to maintain and utilize the measure. The hope is that this handbook serves as a practical reference guide, with information synthesized from established experts in the flood risk management field combined with insights from contractors and their real-world experiences.

The authors encourage readers to explore any locally available incentives, subsidies, grants, and retrofit programs, such as **Clean Foundation's *Resilient Home Retrofit Pilot Project.***

Please refer to the provided disclaimer on page IV.

Key terms:

ADAPTATION:

An action taken to respond to changing climatic conditions in an effort to improve one's ability to withstand current and future adverse conditions.

RESILIENCE:

The ability to withstand an adverse event and maintain normal operation/function and/or to recover from an adverse event back to pre-event normal.

RETROFIT:

The installation of an upgrade, typically to one's house.

1.2. The need for resilient retrofits

1.2.1. Why it matters

As climate change intensifies, with extreme weather events becoming more frequent and severe, building resilience is more important than ever. It is widely recognized that climate change will lead to an increase in the frequency, intensity, and unpredictability of flooding across Canada. The country's exposure to flood risks is also expected to grow as new housing and infrastructure continue to be developed (**Insurance Bureau of Canada, 2022**).

Ensuring that residential buildings are retrofitted and equipped to withstand extreme weather, including severe storms and flooding, is essential. The accelerating pace of climate- and weather-related damage is taking a toll on buildings, roads, railways, and other critical infrastructure across Canada (**Ness et al., 2021**).

Canadian homeowners, insurers, and governments are struggling to keep up with the mounting costs of climate change. Catastrophic insured losses, defined as events resulting in more than $25 million in claims due to extreme weather, surged significantly between 1983 and 2021 (**Bakos et al., 2022**). From 1983 to 2008, annual insurance losses averaged between $250 million and $450 million, but from 2009 to 2021, this average rose sharply to $1.96 billion per year (**Bakos et al., 2022**). To put these losses into perspective, the average cost of repairing a flooded basement is approximately $43,000; yet this excludes the cost of replacing furniture, electronics, and other personal items (**Moudark & Feltmate, 2019**).

Flooding can be a highly impactful and traumatic event for individuals and families. Flood disasters can result in short- and long-term displacement, disruptions to work and family life, adverse health impacts, the loss of irreplaceable personal belongings, and financial setbacks. In addition to home-scale retrofits, another preparedness measure that homeowners can take is checking with their insurance provider to understand what losses are and are not included in their coverage.

Without strengthened adaptation and resilience measures, flood damage to homes and buildings in Canada could increase fivefold in the coming decades and tenfold by the end of the century, potentially reaching $13.6 billion in annual costs (**Ness et al. 2021**, *as cited in* **Sparling et al. 2024**). Yet, according to the Canadian Climate Institute, implementing proactive adaptation measures can produce a return on investment of $13 to $15 in accrued future economic benefits and loss avoidances for every dollar spent today (**Sawyer et al., 2022**). Not only this, but investment in climate-resilient materials has immense potential to reduce damages (**Ness et al., 2021**).

1.3. Flood risk in Atlantic Canada

1.3.1. Hurricane Fiona // 2022

In Atlantic Canada and Quebec, Hurricane Fiona contributed to making 2022 the third-worst year for insured losses in Canadian history (**Insurance Bureau of Canada, 2023**). When Hurricane Fiona made landfall in Nova Scotia, the historic event marked the lowest recorded pressure of any tropical or non-tropical storm to reach north of the US Gulf Coast (**Henson & Masters, 2022**). This was significant because the lower a storm's pressure, the more intense it is. When Hurricane Fiona struck Eastern Canada, the storm produced heavy rainfall, powerful winds, and damaging storm surges, with the easternmost Maritime regions bearing the brunt of the severe winds and rainfall (**Mitchell, 2022**). Tree and structure damage, coastal flooding, and significant erosion ensued, which is reflected in the $800 million in insured damages resulting from the event (**Insurance Bureau of Canada, 2023**).

Left: High winds caused by Hurricane Fiona resulted in significant loss and damage, including this home in Port aux Basques, Newfoundland and Labrador.

Photo credit:
Rene Roy/ Wreckhouse Press via the Associated Press, 2022

Right: Coastal storm surges from Hurricane Fiona lifted this house located near Marshville, Nova Scotia from its foundation and carried the structure nearly 15 metres away.

Photo credit:
Shaina Luck / CBC News, 2023

1.3.2. Flooding // 2023

During the following spring and summer of 2023, Nova Scotia yet again experienced a deluge of flood events. In July 2023, the Town of New Glasgow faced significant flooding due to heavy rainfall that overwhelmed drainage systems (**Snoddon, 2023**). Streets were submerged, transportation networks were disrupted, and numerous homes and businesses were damaged. The flooding created chaotic conditions, requiring extensive emergency response efforts, and leaving a trail of infrastructure damage in its wake (**Snoddon, 2023**).

1.3.3. Hurricane Beryl // 2024

In July 2024, the impact of Hurricane Beryl was particularly devastating for Nova Scotians. The remnants of the storm caused flash flooding in the Annapolis Valley, where over 100 millimetres of rain fell during the span of only a few hours (**Patil, 2024**). This sudden deluge resulted in severe flooding, particularly in the Wolfville area, where a child tragically lost their life after being swept into a water-filled ditch (**Patil, 2024**). The flooding damaged roads, bridges, and homes, and led to multiple evacuations and rescue operations across the Digby, Annapolis, Kings, and Hants counties (**Patil, 2024**).

Right: Flash flooding during Hurricane Beryl affected many residents and businesses, including this restaurant in Cornwallis, Nova Scotia.

Photo credit:
Frank & Dora's Restaurant / Facebook via CTV News, 2024

2.1. Context

2.1.1. Riverine and pluvial flooding

Not all flooding happens in floodplains. Anyone can be impacted by pluvial/overland flooding, which occurs when groundwater and stormwater management systems cannot absorb all the rainwater that falls. In Canada, both annual and seasonal precipitation are projected to increase as a result of climatic changes, particularly in the spring and winter, with more rain than snow and increased and/or variable spring runoff (**Zhang et al., 2019**).

These changes are already underway. During the period of 1948 to 2012, Canada experienced an overall rise in average annual precipitation totals, with northern regions seeing the largest relative increase (**Environment and Climate Change Canada, 2017**). Additionally, significant precipitation growth has already occurred in other regions of the country, including in eastern Manitoba, western and southern Ontario, and the Maritimes (**Environment and Climate Change Canada, 2017**). In the Halifax region, the total annual amount of precipitation in the form of rain, drizzle, snow, and sleet is projected to increase by 79 millimetres during the period of 2021 to 2050, and by 131 millimetres between 2051 and 2080 (**Sustainability Solutions Group, n.d.**).

2.1.2. Coastal flooding

Coastal flooding occurs as the combined result of sea level rise, storm surges, land subsidence and other mechanisms of coastal erosion, and wave effects. Much of the Canadian coastline is expected to experience the effects of sea level rise in the coming decades, with the Atlantic Canada, the Fraser Lowlands in British Columbia, and the Beaufort Sea in the Arctic being the most susceptible (**James et al., 2014**).

In some areas of Atlantic Canada, rising sea levels are expected to surpass the global average for 2100 as a result of land subsidence (**Zhai et al., 2023**). Land subsidence, or sinking, is currently occurring at a rate of 15 centimetres per century in Nova Scotia, increasing the risks associated with sinkholes and coastal flooding (**Municipal District of Lunenberg, n.d.**). Additionally, reduced sea ice cover is expected to produce increased wave activity and larger storm surges along the Atlantic coastline, particularly when and where open water is most prevalent (**Zhai et al., 2023**).

Visit **climatedata.ca** for up-to-date projections and maps.

2.2. Building impacts

- Inundation of building basement or lower levels
- Damage to building materials or building contents
- Erosion at the building foundation
- Damage to structure from hydrostatic pressure and/or impact loading
- Increased corrosion of building materials
- Potable water scarcity
- Limited or restricted building access
- Capacity of drainage systems exceeded (i.e., wastewater and/or stormwater)

2.3. Resilient home retrofits for flood protection

2.3.1. How do these retrofits help keep homes dry?

ENVELOPE—ROOF

Eavestroughs and Downspouts:

- Install or repair eavestroughs and downspouts, directing water away from the building to an area with better drainage, and ensure these remain clear through regular seasonal maintenance. Downspouts should discharge onto permeable surfaces, such as gardens, at a slope so that the water flows away from the foundation. Ideally, water should discharge at least 3 metres/10 feet away from the foundation, but this may not always be possible.

ENVELOPE—WALLS

Sealant System:

- Use permanent (e.g., cement) or temporary (e.g., polyethylene film) treatments to prevent water from seeping through outside walls into the home. Sealants may include cement, asphalt, polyurethanes, or epoxies.

ENVELOPE—FOUNDATION

Backfill Capping:

- Install an impermeable cap on top of the backfill zone to reduce the risk of water infiltrating the foundation. This can be a clay layer, a low-permeability membrane, or an insulation board that is sloped away from the building foundation. The end goal is to prevent water from flowing into the backfill zone that surrounds the foundation.

French Drain / Weeping Tile:

- Direct surface water or groundwater away from a specific area, such as a home's foundation, through a drain and/or gravel-filled trench that includes a perforated or slotted pipe that is wrapped in a filter sock or equivalent.

Catchment Basins:

- Manage stormwater runoff through the installation of a catchment basin, of a capacity that is appropriate for the local flood risk, and keep clear of debris through routine maintenance. Ensure that water slopes away from the house and road. Catchment basins can be installed in the yard or at the bottom of a reverse slope driveway (i.e., a driveway that slopes downward at a lower elevation than the street).

ENVELOPE—WINDOWS & DOORS

Window Well Cover:

- Window well covers are placed over window wells to prevent water from pooling within the wells and from draining into the foundation.

MECHANICAL, ELECTRICAL, PLUMBING (MEP) SYSTEMS

Backflow Valve:

- Install a backflow valve to reduce the risk of sewage systems backing up into the home's sanitary and/or storm sewer lateral or branch lines. These valves close during backwater events, reducing the risk of sewage overflowing into the home.

Sump System:

- Install a sump system to pump groundwater and discharge from the home's foundation, reducing the risk of basement flooding. Sump systems are mechanical water-pumping systems generally located in a pit below the basement level.

Disconnect Direct Connections:

- Disconnect the direct connections to storm and sewer systems in areas at high risk of sewer back-up (e.g., foundation drains/weeping tiles, downspouts), as the additional water in the sewer system can lead to flooding.

Elevate and Secure HVAC Components:

- Move HVAC components—such as ductwork, condensers, air handlers, and electrical components—above the designated design flood level, the minimum elevation to which a structure should be floodproofed. Elevate and secure any exterior components to protect against potential damage from flood stress.

LANDSCAPING / OUTSIDE AREA

Swales:

- Drain stormwater from the property into local catchments through the use of a swale — a shallow, sloped drainage channel.

Site Grading:

- Grade, or reshape, the land around the home's foundation to direct water away from the structure. Site grading efforts should be combined to create swales when subdivisions are being newly constructed, or with two homes that are close together.

Berms:

- Construct a berm— a hill of compacted dirt with a slope of 1:2 or 1:3 for stability.

Flood Walls:

- Construct a flood wall in areas with insufficient space to construct a berm. A flood wall is an anchored and reinforced wall that is able to withstand the force of floodwaters.

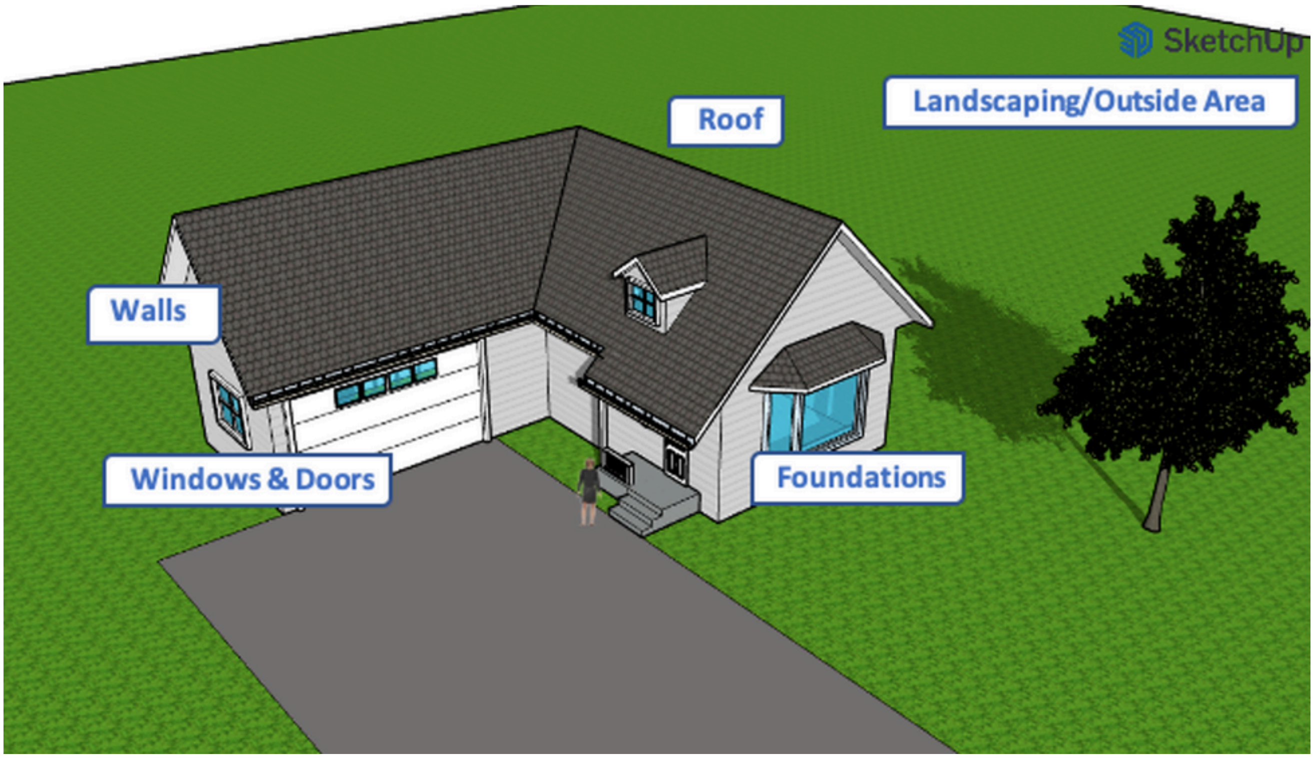
Rain Gardens:

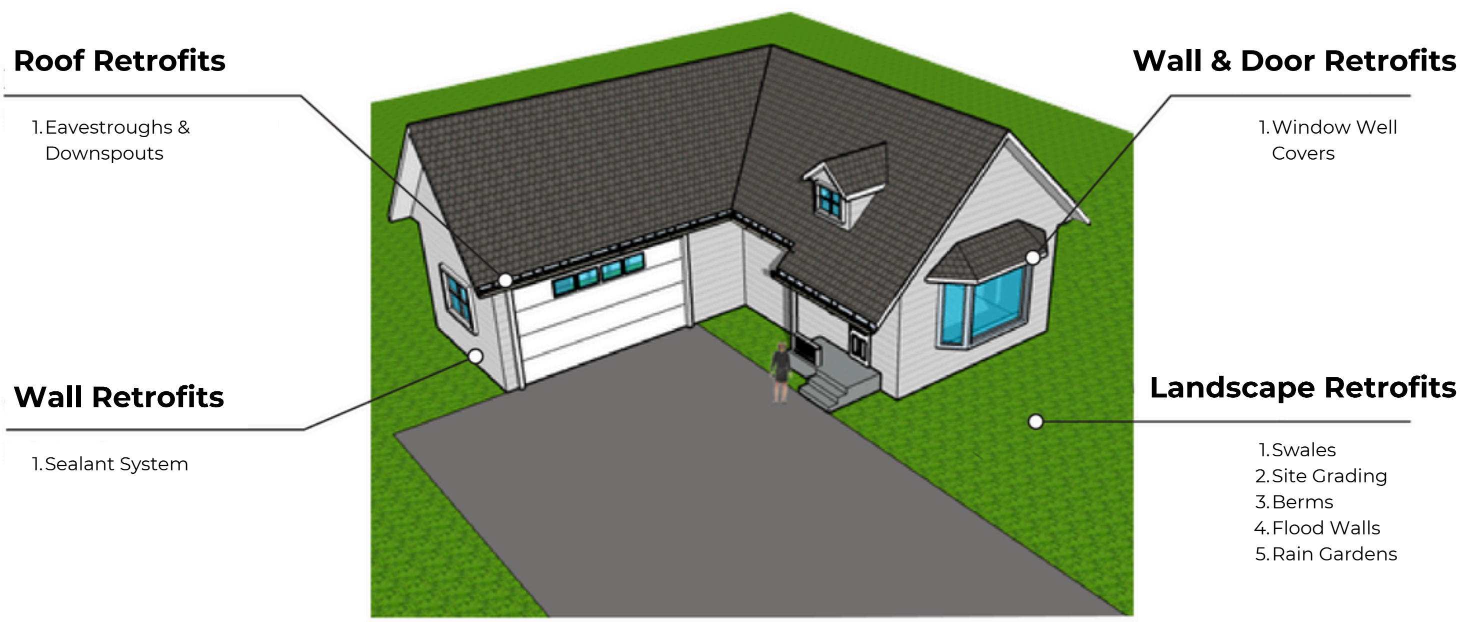
- Improve site drainage by installing a rain garden. Also called bio-retention systems, rain gardens are shallow, excavated areas where soil is replaced by materials that take in water at higher rates, and topped with native, erosion-resistant vegetation. Rain gardens are best suited to lower-volume rain events.

2.4. Building components

The following figures provide a visual overview of the exterior and interior building components where flood-resilient retrofits can be implemented.

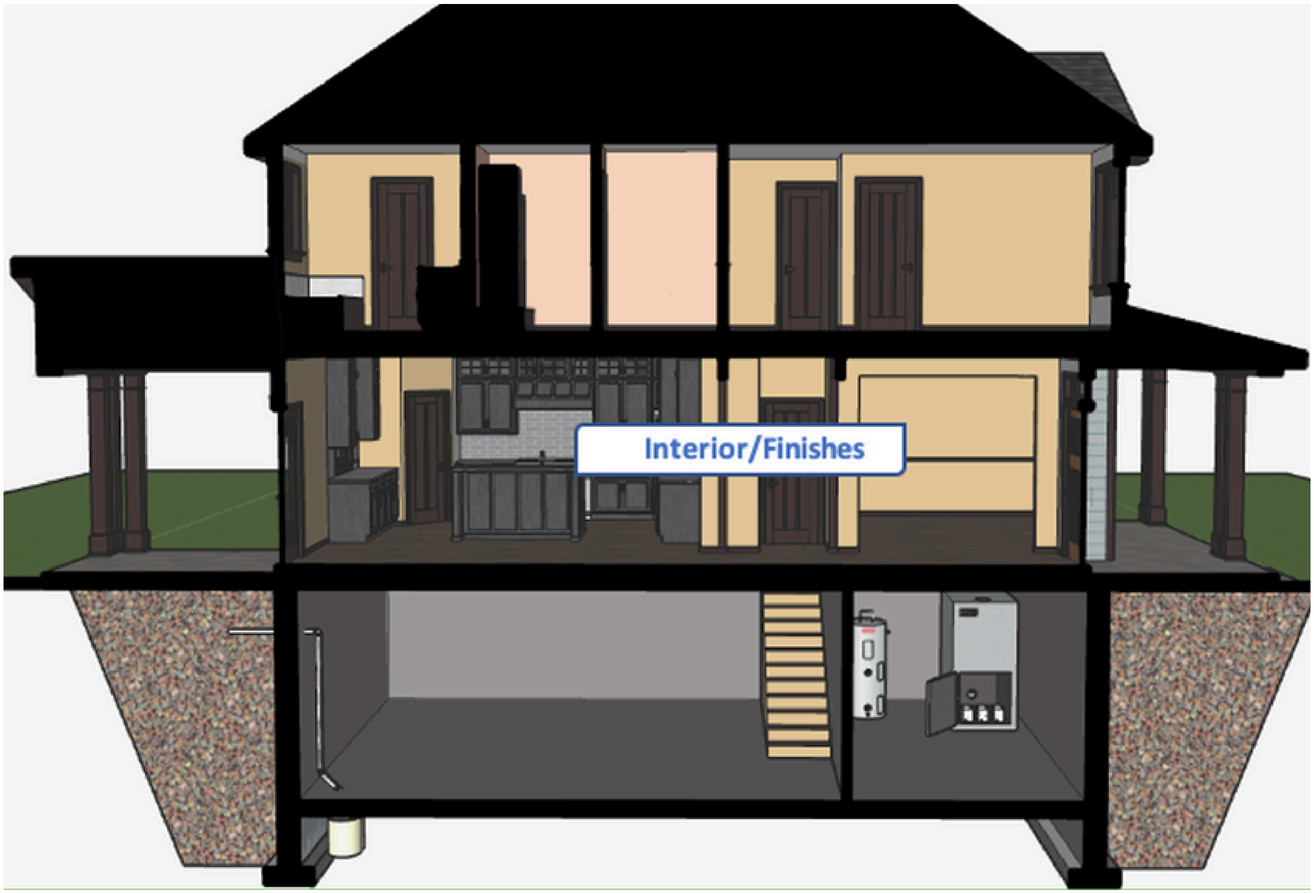
2.4.1. Exterior components

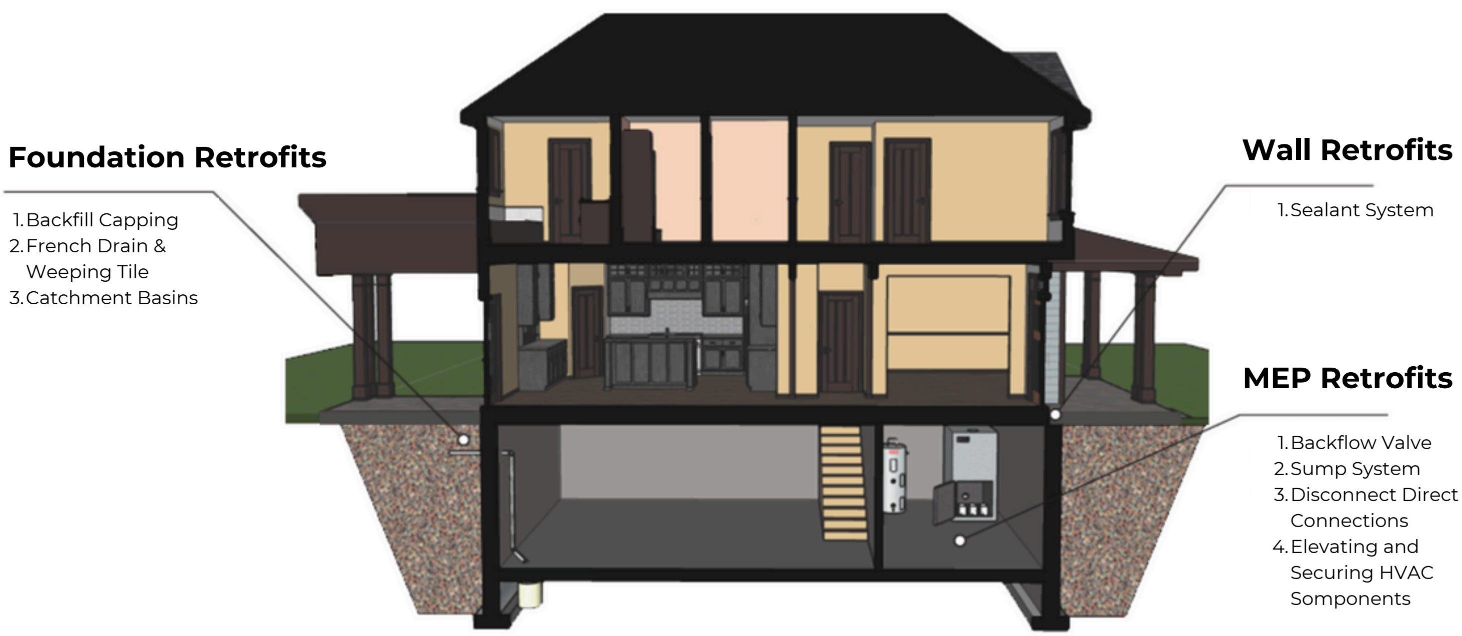




Above: Exterior interventions may include retrofits to the walls, foundation, windows, doors, and roof, as well as landscape improvements.

2.4.2. Interior components





Above: Interior interventions are concentrated around interior finishes, such as retrofits made to the walls, foundation, or mechanical, electrical, and plumbing system.

3.1. Eavestroughs and downspouts

3.1.1. Overview

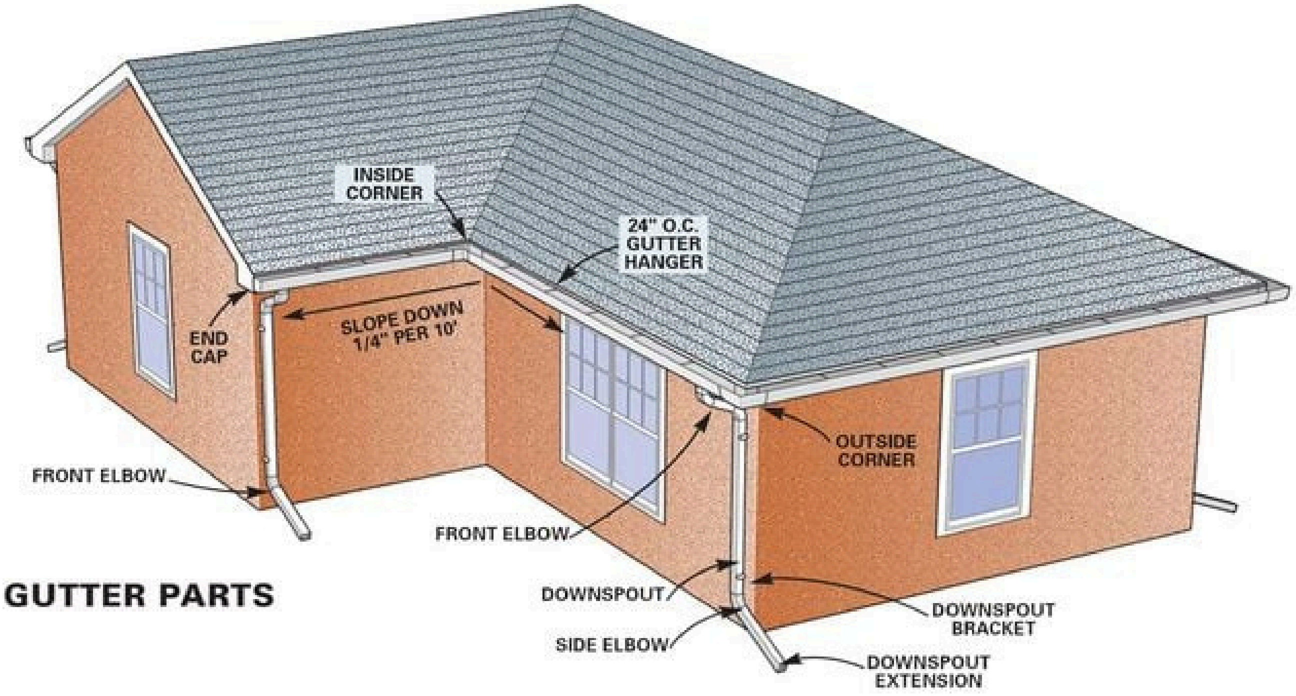
How this retrofit helps reduce flood risks:

Eavestroughs

Commonly known as a gutter, eavestroughs collect and direct the flow of water and rooftop debris toward the downspout to prevent building damage.

Downspouts

Also known as downpipes, downspouts convey the water collected by the eavestroughs towards acceptable drainage areas away from the building foundation.



Above: Schematic of eavestrough (gutter) and downspout components (**Family Handyman, 2024**).

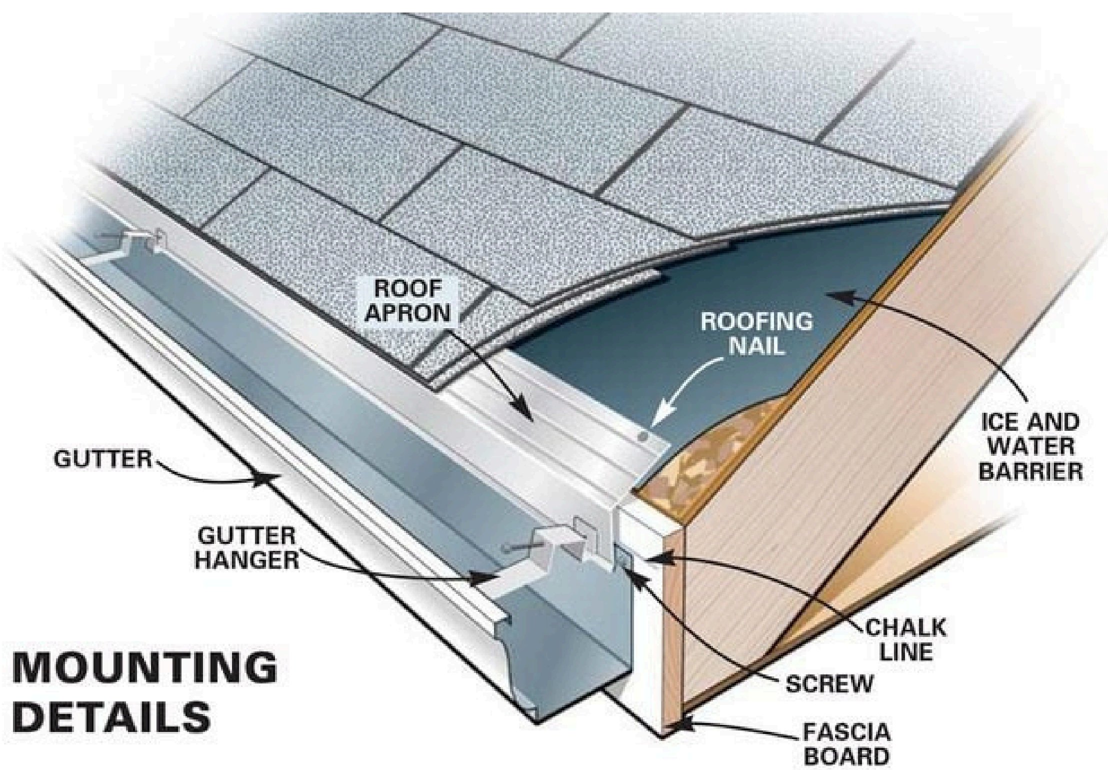
3.1.2. Design parameters: Eavestroughs

SLOPE:

- An eavestrough must gradually slope downwards towards the point where it connects with the downspout.
- A 2% to 4% slope—meaning a 1/4 to 1/2 inch drop for every 10 feet of length—is recommended (**Lutz, 2024**; **Sandink et al., 2021**).

SIZING:

- Most residential properties typically use eavestroughs with a width of 5 to 6 inches; however, larger and steeper roofs will benefit from having wider eavestroughs (**D'Angelo & Sons, 2023**).
- According to **D'Angelo & Sons** (**2023**), when determining which size of eavestrough is appropriate for the home, consider the following:
  - The roof **pitch (steepness)**;
  - The **rainfall intensity** for the local area—if future climate projections are unavailable, historic rainfall data can be used;
  - The **water flow**, or drainage capacity, of the roof—calculated as a function of the pitch, rainfall intensity, and total drainage area; and
  - The **drainage capacity** of gutters and downspouts, meaning the amount of water that each component is able to handle—calculated using the gutter height and the size and number of downspouts.



Above: Eavestrough mounting components (**Family Handyman, 2024**).

3.1.3. Installation guide: Eavestroughs

1) Mark the highest and lowest points of the eavestrough on the fascia

a. The highest point of the eavestrough should be located slightly below the edge of the roof, or approximately 3/4 inches below the shingles (**Lutz, 2024**).
b. The lowest point of the eavestrough will be placed either opposite of the high point on the fascia or at the downspout location (**Lutz, 2024**).
c. Ensure the high and low points are designated such that the 2% to 4% slope is maintained (**Lutz, 2024**; **Sandink et al., 2021**).

2) Trim the eavestrough and attach the end caps

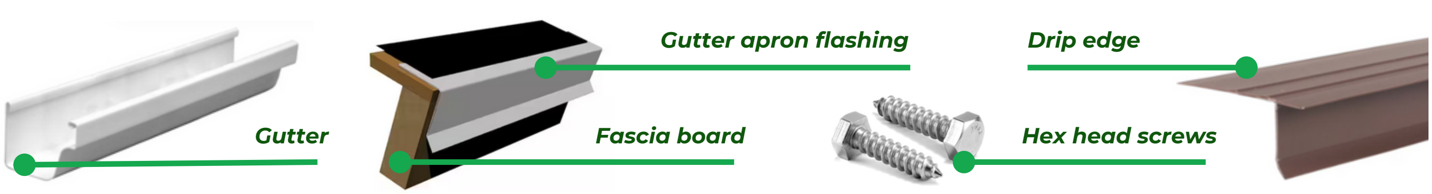
a. Aviation/tin snips, a hacksaw, or a power saw can all be used to cut the eavestrough components into the necessary lengths (**Family Handyman, 2024**).
b. It may be necessary to install two separate lengths of an eavestrough, in which case the two lengths should overlap by 8 inches (**Family Handyman, 2024**).
c. Attach the end caps at the square-cut end of the eavestrough using pop rivets or outdoor corrosion resistant screws (**Family Handyman, 2024**; **Lutz, 2024**).
d. Seal the rivets and each end-cap with a waterproof sealant/caulk to ensure the joints are watertight.

3) Cut the downspout holes

a. Downspouts should be installed at a ratio of one downspout per 20 feet of eavestrough length; however, wider eavestroughs with a higher capacity for volume can have downspouts up to every 50 feet of length (**Building America Solution Centre, n.d.-a**). For areas expected to experience higher volumes of rainfall in shorter time periods, additional capacity may be required.

4) Hang the eavestrough

a. When hanging, start from the middle of the eavestrough, moving to the end.
b. It is advisable to also install gutter apron flashing or a drip edge to ensure that the fascia and the roof decking are shielded from moisture damage and to prevent rot (**Petersen & Hayes, 2023**).
c. Screw the gutter to the fascia board with 1-1/4” stainless steel hex head screws through the back of the gutter (**Family Handyman, 2024**).
d. Install a gutter apron flashing under the shingles to prevent water from flowing backward behind the gutter. Secure the gutter apron flashing with one-inch roofing nails at intervals of two feet, and overlap the sections by approximately two inches (**Family Handyman, 2024**).
e. Install gutter hanging straps at two-foot intervals by screwing through the back of the gutter into the fascia board (**Family Handyman, 2024**). Hanging straps are used to support the front edge of the gutter (**Family Handyman, 2024**).



Helpful tips:

Above: When marking the chalk lines and outline below the roof edge, check that the bubble in the spirit level touches the outer measurement line at a 2%-4% grade (**Family Handyman, 2024**; **Kelsey, 2024**).

Above: When attaching the downspout elbows, start with the underside (**Family Handyman, 2024**).

3.1.4. Installation guide: Downspouts

1) Fasten the downspout to the eavestrough

a. Begin by connecting the upper pipe elbow to the bottom of the eavestrough at the eavestrough outlet (**Family Handyman, 2024**).
   - Fasten using sheet metal (self-tapping) screws or rivets.

b. Ensure that the elbow is directed toward the wall where the downspout will be installed (**Family Handyman, 2024**).

2) Measure and assemble the components

a. Place a second pipe elbow against the wall, then measure the distance between the two elbows, adding an extra 3 inches (1-1/2”) on each side for overlap (**Family Handyman, 2024**).

b. If necessary, crimp one end of the cut section to match the water flow direction and fit snugly into the elbow or pipe (**Family Handyman, 2024**).

c. Rest the elbows against the wall and measure the distance from the bottom elbow to the ground (**Family Handyman, 2024**).

d. Deduct 14 inches from the measured distance to allow sufficient space to install the lower pipe elbow and downspout (**Family Handyman, 2024**).

e. Attach the short section (i.e., the cut piece of the downspout or extension pipe) to the elbows using 1/4” hex head sheet metal screws or an equivalent (**Family Handyman, 2024**).

3) Install wall straps and extensions

a. Secure the downspout to the wall by installing straps at three-foot intervals along the length of the downspout (**Family Handyman, 2024**).

b. Attach the downspout extension by fitting it into the existing long pipe going up the wall and have it be supported by the ground.

3.1.5. Key considerations and actions to avoid risk

Discharge and Extensions:

- For downspout extensions:
  - Extensions should have a minimum grade of 30 degrees relative to the ground surface (**City of Edmonton, n.d.**).
  - Discharge points should extend at least 6 feet (1.8 metres) from the home’s foundation (**Sandink, 2009**).
  - If site conditions prevent proper extension, then the discharge points must be located, at a minimum, past backfill zones (**Sandink, 2009**).

- The key to proper water drainage is ensuring that the eavestrough maintains a downward slope of 2% to 4% (**Savage et al., 2021**).

Discharge and Extensions Continued:

- In the **Canadian Standards Association's Z800-18 (R2023): *Guidelines on basement flood protection and flood risk reduction***, the following is noted:
  - Downspouts should discharge over a permeable surface or to other drainage conveyance or discharge.
  - Downspouts should not discharge directly onto walkways, sidewalks, patios, or driveways. In the winter, this poses the risk of freezing and can create a potential slipping hazard.
  - Downspouts should not discharge towards neighbouring properties, as this can elevate flood risks for adjacent homes.
  - Downspouts should not discharge directly into municipal storm or sewer systems unless authorized by local bylaws.

Personal Safety:

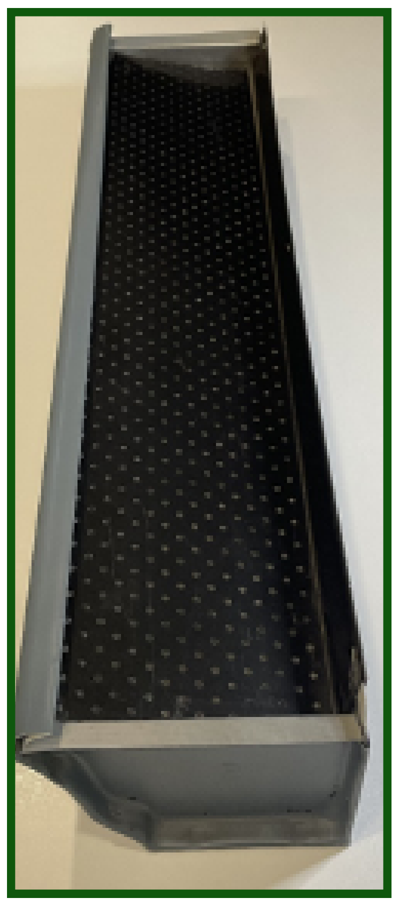
- With all retrofit measures mentioned in this handbook, installers should take into account appropriate personal safety precautions, including but not limited to wearing personal protective gear, engaging in working at heights training, and utilizing fall prevention and fall arrest systems when necessary.

Eavestrough Guards:

- 'Leaf guards' or 'gutter guards' can be installed on top of the eavestrough to prevent leaves and other debris from clogging up the gutters (**Glover, 2024**).

- Leaf guards are specially designed to keep leaves out and are recommended if the property is located in a flood- or wildfire-prone area (**University of California, n.d.**).
  - For wildfire-prone areas, ensure that the leaf guards are made from metal (**University of California, n.d.**).

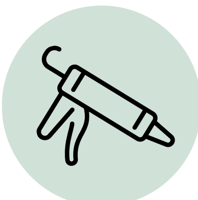
Left: A gutter guard is recommended to prevent debris build-up (Photo courtesy of **Clean Foundation**).



4.1. Sealant system

4.1.1. Overview

How this retrofit helps reduce flood risks:



Sealant system

Use sealants, barriers, or treatments to seal cracks in walls and at wall intersections. Examples of sealant systems options include cement, polyethylene film, epoxies, and waterproof boards. The choice of sealant should depend on the location of the crack, the surrounding surface material, and any other situational factors. Polyethylene film is a good choice if the building does not already have a dedicated moisture barrier.

4.1.2. Installation guide: Polyethylene film (Interior)

1) Preparation

a. Measure out the vapour barrier material and cover the area that needs sealing.
b. Cut the material to the necessary dimensions using a utility knife (**Fastener Systems, 2023**).
c. To help maintain a proper seal, ensure that there is a minimum overlap of 12 inches between the seams of the cut material (**Fastener Systems, 2023**).
d. After filling the caulk gun with a vapour barrier caulking material (e.g., acoustical sealant), make a 45-degree cut at the end of the tube (**Fastener Systems, 2023**).

2) Apply caulking along barrier seams

a. Caulk the walls, floor, and around windows and doors at the edges and overlaps of the vapour barrier (**Fastener Systems, 2023**). Ensure that the caulk is applied in a continuous motion to maintain a consistent, solid bead of caulk (**Fastener Systems, 2023**).

NOTE: For flat surfaces, vapour barrier sheathing tape can also be used to seal edges, overlaps, and sheet seams.

Helpful tips:

If installing over a mud or earthen floor:

- Put down a layer of drainage stone, such as gravel, over the floor.
- Place the vapour barrier over the top.

If installing over a crawl space:

- When fastening the vapour barrier material for the floor, use a vapour barrier sealant or rubberized butyl tape to secure it to the wall at a height of 6 inches above the ground (**Nichols, 2024**).
    - Where possible, secure the vapour barrier with landscape fabric stakes to secure it in place (**Nichols, 2024**). Seal and reinforce these penetrations to prevent leaks and rips. This will enable the barrier to remain in place during any future maintenance that requires entry within the crawlspace (**Nichols, 2024**).
- Place rubber mats down after installation to create a softer surface to position on and to make future maintenance activities easier (**Nichols, 2024**).

Above: Vapour barrier installed over a crawlspace (**Grandbrothers, n.d. via Getty Images/iStockphoto**).

Above: Vapour barrier installed over a crawlspace that has been correctly sealed (Photo courtesy of **Clean Foundation**).

4.1.3. Installation guide: Foundation water management

1) Prepare the site

a. Excavate the area surrounding the foundation. For exterior walls, remove enough soil to uncover the footing base (**Drycrete Waterproofing, n.d.**).

NOTE**:** Do not excavate below the foundation footing and take caution not to damage any utility pipes and lines coming from or around the property. Follow proper safety protocols and always call local authorities before digging.

b. Clean the foundation walls to ensure good adhesion and a proper seal (**Drycrete Waterproofing, n.d.**).

- Wire brushes can be used to remove dirt from the wall surface (**Drycrete Waterproofing, n.d.**).
- Identify and repair any existing damages to the foundation. If significant damages are encountered, consult with a structural engineer.

2) Apply the waterproofing membrane to the outside foundation

a. Dimple boards, liquid-applied coatings, and rubber- or asphalt-based sheet membranes designed for concrete foundation water management repairs are suitable for use (**Drycrete Waterproofing, n.d.**; **Savage et al., 2021**).

3) Backfill the soil around the foundation

a. Backfill the excavated site, ensuring that the soil covers the foundation walls and footing (**Drycrete Waterproofing, n.d.**).

b. Take measures to prevent any damage to the waterproofing membrane during and after installation (**Drycrete Waterproofing, n.d**.).

Left: An example of a foundation perimeter sealed with a dimple board (**Waterproof Magazine, 2018**).

4.1.4. Sealing cracks (interior or exterior)

1) Seek a professional assessment

a. A professional should first inspect any cracks along the foundation to assess the severity and the structural risk of the crack.

2) If the crack is <u>not</u> considered to be a structural risk:

a. Seal the crack using a product designed for concrete foundation cracks, like epoxy or cement.

3) If the crack is severe and deemed to be a structural risk:

a. Hire a professional engineer to identify the cause of the crack, assess how the crack may impact the structural foundation, and provide recommendations for further action.

Helpful tip:

Have a professional inspect any suspected cracks on the interior or exterior walls and foundation before undergoing any further work.

Above: A crack on the interior wall (**Schroeder, 2021**).

4.1.5. Key considerations and actions to avoid risk

Vapour Barrier:

- Assess the compatibility between the sealant, the vapour barrier material, and any site-specific needs (**Fastener Systems, 2023**).
    - Prioritize materials that are malleable, durable, moisture-resistant, and capable of providing an airtight seal (**Fastener Systems, 2023**).
- According to **Fastener Systems** (**2023**), common materials include:

- **Polyurethane:** This material is relatively pliable and sturdy, and is well-equipped to withstand weather-related stress and temperature fluctuations. Polyurethane is ideal for maintaining the structural integrity of the vapour barrier and is relatively easy to apply on flat surfaces.

- **Acoustical sealant:** Because acoustical sealants are designed for soundproofing, the material is optimal for creating an airtight seal, while still remaining flexible after curing.
- **Butyl rubber caulk:** This sealant material is ideal for sites where moisture levels are relatively high, such as in the washroom.

Foundation Perimeter:

- All temporary excavations should be carried out in accordance with the requirements of relevant work safety codes and regulations, including under the supervision of a qualified engineer, where required.
- Ensure that any piping or utility lines coming from and around the property are not damaged throughout the excavation and backfilling process.
    - **Call for locates:** Contacting the relevant utilities companies or municipalities where works are being completed will help to inform operators of potential risks.

Applying Sealant:

- In general, whenever a sealant is being applied, ensure that:
  - The sealant is compatible with the substrate surface.
  - The substrate surface is clean of dirt and free of any sort of moisture, including frost. Cleaning can be done with a broom or wire brush.
- When selecting a sealant, it is important to consider adhesion, and how this may differ between sealant types depending on the material of wall and floor surfaces (**Gagne, 2024**).
- Ensure that the product selected is suitable for the materials it is being used for and follow the manufacturer's guidance.
  - Conduct a test for adhesion before beginning any type of sealant system work (**Fastener Systems, 2023**), as well as periodically as the sealant cures, to ensure that the sealant is properly adhering (**Snell, 2024**).
- Joint movement should be accounted for in the placement of the sealant and the amount applied (**Gagne, 2024**).
  - When applying sealant to gaps and joints, use a backing material (e.g., backing rod, bond breaker tape) to prevent three-sided adhesion (**Snell, 2024**).
  - Improper installation can lead to a loss of cohesion and adhesion, whereby the sealant loses its elasticity and cannot move with the surface materials as they expand and contract (**Trisco Systems Inc., 2015**).
  - If too much sealant is applied, joint movement can become restricted, while not enough sealant can weaken the integrity of the seal (**Gagne, 2024**).

If testing reveals inadequate adhesion, this could be because of:

- "Contaminated or expired sealant or primer;
- Improper substrate cleaning;
- Incorrect primer selection;
- Improper join configuration;
- Poor priming techniques;
- Three-sided adhesion (i.e., the absence of or incorrect installation of backing material);
- Excessive substrate movement;
- [The] presence of bond breaking material(s) at bond lines (e.g., moisture, frost, incompatible coatings); and/or
- Incomplete fill of sealant into the joint" (**Snell, 2024**).

For further guidance on performing a **Field Adhesion Test**, refer to **ASTM International's** (**2020**) ***C1521-19 Standard practice for evaluating the adhesion of installing weatherproofed sealant joints***.

5. FOUNDATION

5.1. French Drain / Weeping Tile

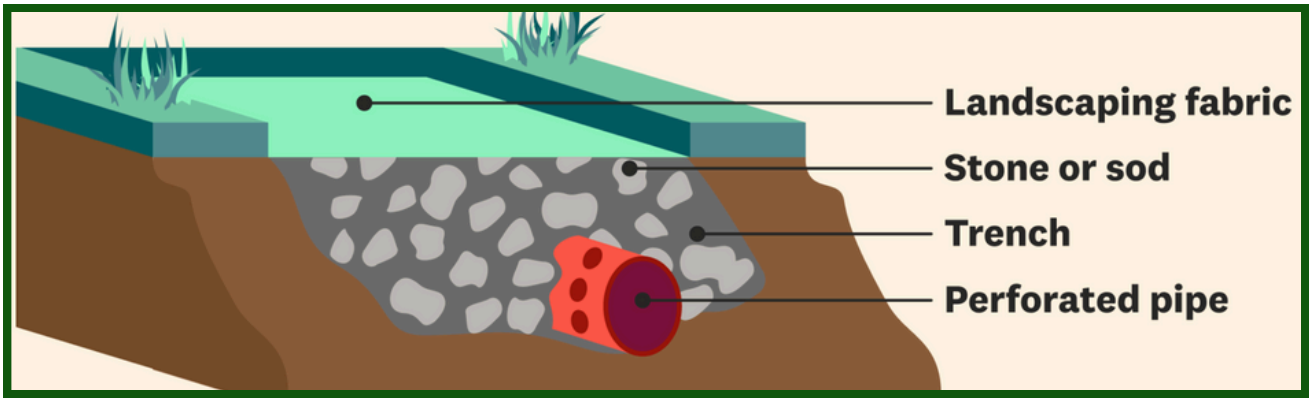
5.1.1. Overview

How this retrofit helps reduce flood risks:

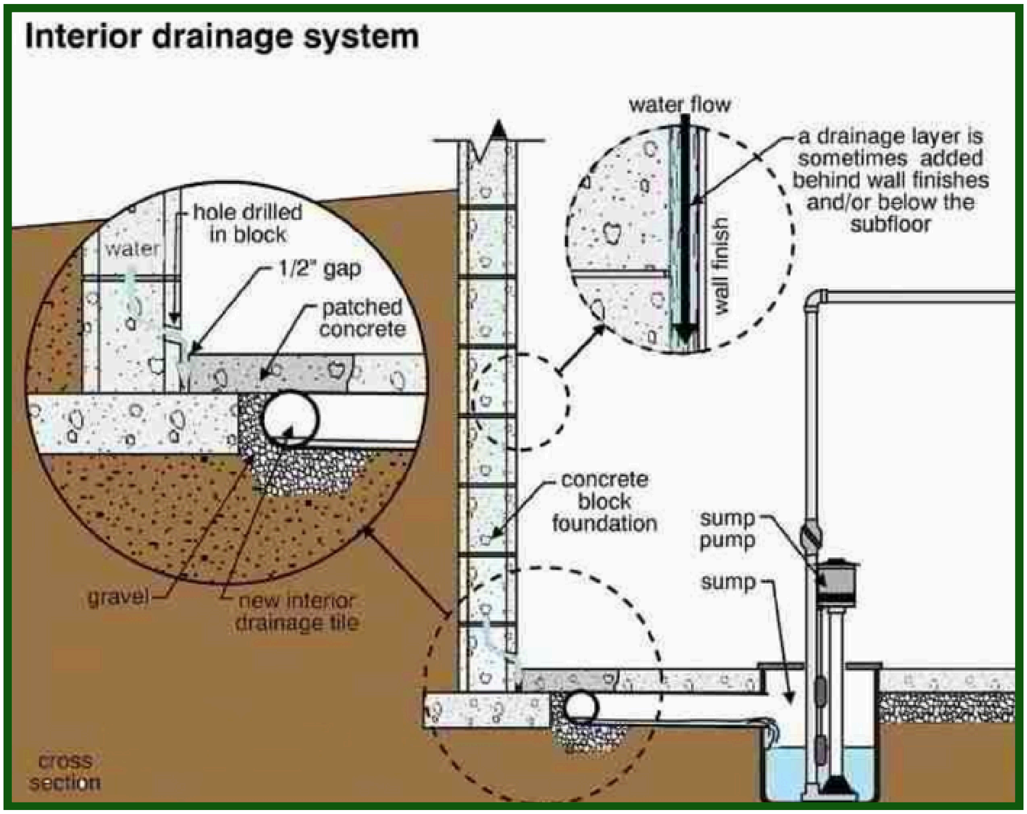
French Drain / Weeping Tile

These two terms are often used interchangeably, but it is important to distinguish that a French drain functions as an exterior perimeter drainage system, while a weeping tile functions as an interior perimeter drainage system (**Canadian Home Inspection Services [CHIS], n.d.**; **Federal Emergency Management Agency [FEMA], 2012**; **OntarioAgra, n.d.**). Both systems operate similarly, in that they involve underground perforated pipe that surrounds the foundation of a home, collecting and managing drainage (**FEMA, 2012**; **Sandink, 2009**).

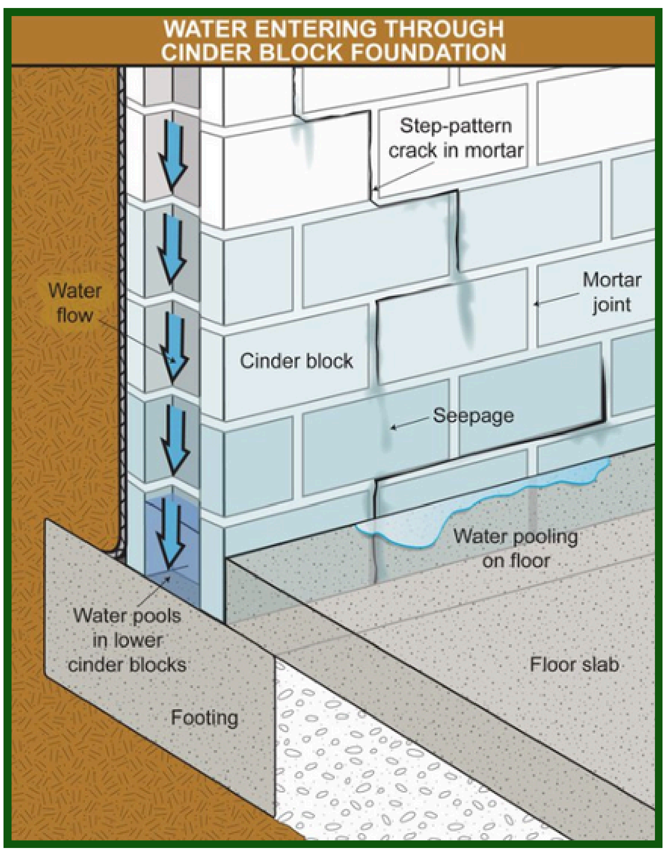
Note: Either system may sometimes be referred to as a perimeter drain, foundation drain, or curtain drain (**MacRae, 2024**).



Above: Components of a French drain system (**Brancanto, 2024**).



Above: Components of a weeping tile, or interior drainage, system installed up against the building's footing (**CHIS, n.d.**).



Above: How water enters through the home's foundation (**CHIS, n.d.**).

5.1.2. Design parameters: French drain / weeping tile

When designing and installing a French drain / weeping tile system, consider the following:

SLOPE:

- There should be a 1% slope (i.e., a 1/8-inch drop for every 1 foot of length) to ensure adequate drainage (**MacRae, 2024**; **National Diversified Sales, n.d.-a**).

TRENCH:

- The trench should be 0.5 to 1 foot deep, and about 1 foot wide, to accommodate the pipe, gravel, and subsequent soil infill (**FEMA, 2012**).

LOCATION:

- Ensure that the selected area can meet slope and trench parameters.
- ***Weeping tile specific:*** It may not be feasible to have the weeping tile surround the entirety of the foundation, depending on the surrounding area and terrain of the home.

INFILL:

- ***French drain specific:*** A combination of gravel and rocks should be used to fill in the trench, followed by a layer of topsoil or even additional stone. Smaller rocks and gravel should be placed closer to the pipe, followed by the larger pieces closer to the surface (**National Diversified Sales, n.d.-a**).
- ***Weeping tile specific:*** Concrete should be repoured equal to the amount excavated, such that the basement floor is the same height and level all around.

MATERIALS:

Two types of drainpipes are readily available in the market:

***Black perforated drainpipe*:** This pipe is commonly used as a cheaper, easier to install, and more flexible option. The material can be cut to the exact needed length. However, this type of drainpipe is prone to infiltration by sediment and soil particles and destruction by roots and can be crushed by debris (**Commercial Industry Supply, 2019**). Typically, the pipe comes with a 'sock' to help reduce the infiltration of debris.

40-gauge PVC perforated drainpipe: This type of pipe has holes drilled every 2 inches at the bottom that are placed facing down and is slightly more expensive to purchase and install. However, this kind of pipe stays rigid and firm and is also easier to clean and maintain by using ports. These ports are usually small openings or capped ends that can be opened to insert cleaning tools, such as high-pressure water jets, to remove blockages and debris from the inside of the pipe (**Commercial Industry Supply, 2019**).

5.1.3. Installation guide: French drain / weeping tile

1) Identify and mark the best location, as per the design parameters above

a. The two endpoints and overall length can be marked with spray paint or any other tools at your disposal.
b. Drainage area(s) should be identified and should not feed into neighbouring properties (**Sandink, 2009**).

2) Measure the grading—exterior specific

a. The grade can be measured by marking stakes at the two endpoints and tying a string between them. This will help with measuring the current grading of the site and ensuring that a 1% slope is achieved (**National Diversified Sales, n.d.-a**).

3) Dig the trench to the appropriate depth, width, and slope

a. The minimum depth of the trench should be no shallower than 0.5 to 1 foot deep (**MacRae, 2024**). However, for best results in cold climates, situating pipes below the frost level, at a depth of 3 to 4 feet, is recommended to reduce the risk of freezing, which can create drainage issues (**Lambourne, 2023**).
b. The trench should be approximately 1 foot wide (**MacRae, 2024**).

4) Install filter fabric and add a layer of rock/gravel

a. Line the trench with filter fabric, as well as a 3-inch-deep layer of small rocks or gravel, to prevent clogging (**Engel, n.d.; Home Depot, 2024**).

5) Lay the pipe

a. The pipes should then be laid with the drainage holes facing downwards (**MacRae, 2024**; **National Diversified Sales, n.d.-a**).
b. Ensure the 1% slope is achieved as the pipes are connected, or the water will not drain through the pipes (**Von Gerl, 2023**).
c. Either use the excess filter fabric or an additional layer to fold over the drainpipe to protect the pipe (**National Diversified Sales, n.d.-a**).

6) Cover the pipe and fill in the trench

- ***French drain specific:*** Add another layer of rocks or gravel, so that there is approximately 9 inches of space between the top of this layer and the ground surface level (**FEMA, 2012**).
  - The remaining infill is up to the homeowner's discretion and can either be a layer of topsoil or additional gravel/rocks.

- ***Weeping tile specific:*** Leave the rock/gravel layer for one day to settle, before repouring concrete (**Urban Water, 2023**).
  - The amount of concrete poured should equal the amount of concrete excavated at the beginning.
  - Ensure that the basement floor is level and at the same height as it was prior to excavation.

5.1.4. Key considerations and actions to avoid risk

Water Infiltration:

- French drains should be installed at a depth that ensures that water infiltration is captured and directed to flow away from the foundation.
- While the exact conditions of the home may vary, the French drain/weeping tile should be installed such that "water infiltration is captured and directed to flow away from the foundation" (**Association of State Floodplain Managers, 2022b**).

Drainage:

- Drainage for either system should not be directed toward any neighbouring properties.
- Ensure compliance with any floodplain bylaws or water discharge regulations.
- Ensuring a minimum 1% slope (1-inch drop for every 10 feet of length) prevents the risk of standing water and allows for continuous drainage (**Von Gerl, 2023**). Where conditions allow, a greater slope of 2%-4% is recommended.
- To ensure appropriate drainage capacity, "choose a perforated pipe with a diameter suitable for the anticipated volume of water" (**Urban Water, 2023**).
- ***French drain specific:*** Avoid having downspouts connect directly to the French drain. This helps reduce the risk of clogging (**Urban Water, 2023**). *Refer to Section 5.3: Catchment Basins for more options.*
- Both the gravel layer and especially the perforated pipe should be wrapped in filter fabric. This prevents soil intrusion which could inhibit drainage (**Engel, n.d.**; **Home Depot, 2024**). Avoid wrapping filter fabric directly around the perforated pipes; instead, ensure that there is a gravel or rock layer in between. This will help reduce the risk of clogging (**Master Drain, 2023**; **Pro Fabric Supply, 2020**).
- It is recommended to first place the fabric in the trench to ensure there is enough to cover the trench all the way up the walls. Fill the trench with a few inches of gravel, before laying the drainage pipe. Fill the trench with the remaining gravel and wrap the remaining fabric over top of the gravel layer.
- Use clean and washed gravel as well as angular stones to ensure adequate water filtration and structural support of the drainage system (**Urban Water, 2023**).

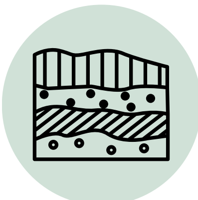
Durability:

- Make note of nearby large trees, as their roots may extend and damage the pipes. Consider using root barriers as a means of protection (**Urban Water, 2023**).

5.2. Backfill Capping

5.2.1. Overview

How this retrofit helps reduce flood risks:



Backfill Capping

Capping the backfill zone prevents water from permeating and penetrating through the building foundation, reducing the risk of water damage.

5.2.2. Installation guide: Backfill capping

1) Cap the backfill with an impermeable surface sloped away from the foundation, such as:

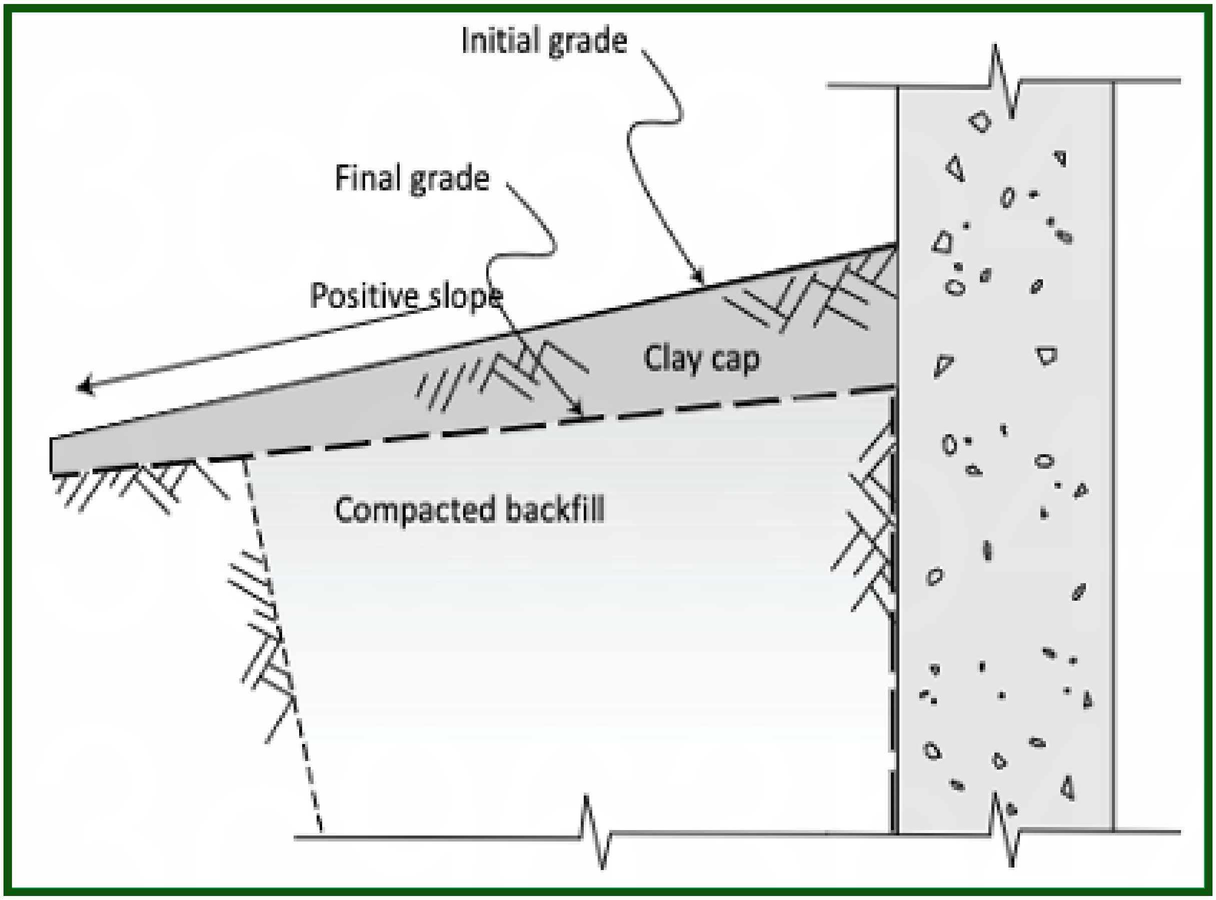
a. A fine-grained, low-permeability cohesive soil, such as clay (**Canadian Standards Association, 2018**).

b. A membrane or insulation board of low permeability is placed just below the ground with a paved surface over top (**Canadian Standards Association, 2018**).

- National Research Council Canada recommends beginning with a woven/sheet polyethylene or geotextile membrane over the top of the initial backfill, which prevents plant growth between the pavers (**Swinton & Kesik, 2008**).
- A 1-inch-thick sand layer should then be applied, which will enable the paved surface cap to level and adjust over top of the backfill (**Swinton & Kesik, 2008**).
- Use shorter lengths of pavers to allow for adjustments to the grading in the future (**Swinton & Kesik, 2008**). This is important for maintaining proper slope.

2) Grade the surface

a. The initial grade next to the foundation should be exaggerated to compensate for long-term backfill settling so that the final grade, after settling, has a 2% to 5% downward slope away from the foundation (**Canadian Standards Association, 2018**).



Above: Schematic of backfill cap. Note that the initial grade is exaggerated to ensure that the settled backfill retains a 2% to 5% downward slope. This image depicts the cap extending beyond the backfill zone, although this is not necessary. The key is ensuring a proper slope while covering the backfill zone (**Canadian Standards Association, 2018**).

Right: Weed growth in between pavers can reduce effectiveness. In addition, notice the short lengths of pavers used. This allows for adjustments, if the grading or other elements of the cap need to be shifted (**World of Stones, 2023**).

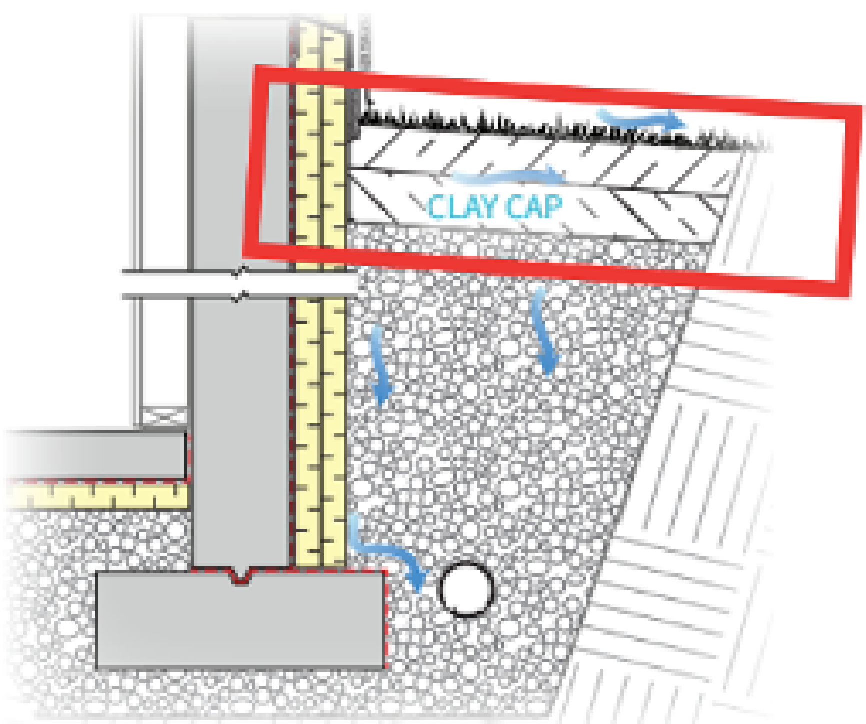
5.2.3. Key considerations and actions to avoid risk

Clay Cap:

- If installing a clay cap, ensure that it is "roughly 4 inches thick, and sloped at a minimum of 2% away from the building" (**Savage et al., 2021**).

Backfill Settling:

- The need for an intermediary sand layer or an exaggerated grade is of primary concern for newer homes where the backfill has not yet settled (**Canadian Standards Association, 2018**).
- For older buildings with backfill that have already settled or been previously compacted, it is still crucial that the chosen backfill cap is graded such that the 2% to 5% downward slope is preserved (**Canadian Standards Association, 2018**).
- It is common for footings/foundations to sit below 3.9 feet (1.2 metres) from grade to prevent freeze heave, which can affect the soil around the foundation and damage the foundations. This depth changes depending on the soil conditions and the location.



Above: A clay cap should be 4 inches thick. A paved surface can also be used to cap the backfill, but this should be done over a 1-inch-thick sand layer (**Canadian Standards Association, 2018**).

5.3. Catchment Basins

5.3.1. Overview

How this retrofit helps reduce flood risks:

Catchment Basins

A catchment basin is an underground box or "basin" made of plastic or concrete. It is typically set into the ground at a low point on the property. On top of the basin sits a grate whereby water runoff enters the basin. The drainage pipe slopes away from the building or home. Catchment basins "catch" and drain debris to prevent downstream pipes from clogging and to prevent yards from flooding. The recommendations herein are general and not exhaustive; users are encouraged to consult with experts to address unique challenges.

Left: A catchment basin. Note that the drainage pipe and trench need to provide sufficient space for gravel and concrete to be poured around the catchment basin for stability (**Rooterworx, 2021**).

Right: A small wooden wall around the outlet pipe can help secure the gravel and limit the spread of weeds which can disrupt drainage capacity (**Wallender, 2024**).

5.3.2. Installation guide: Catchment basins

1) Plan the location

a. Identify the lowest point of the driveway or yard where water tends to accumulate (**Savage et al., 2021**).
b. Ensure there is a proper slope of about 1% (1/8 inches for every 1 foot) towards the catch basin for efficient water flow (**National Diversified Sales, n.d.-b**).

2) Excavate the area

a. Mark the area where the catch basin will be installed.
b. According to the **Industry Training Authority BC** (**2023**), "a hole slightly deeper and larger than the catch basin itself should be dug. This will allow the placement, compaction, and levelling of bedding material under the basin."

3) Prepare the base

a. Add a gravel layer at the bottom of the hole to aid in drainage.
b. Compact the gravel to create a stable base for the catch basin to rest on and avoid using large stones that could damage the drainage pipe.

4) Lay the drainage pipe

a. Dig a trench from the catchment basin to the desired drainage point, such as a grassy low point along the property and away from the foundation. The trench should be deep and wide enough to accommodate the size of pipe used, while also maintaining a 1% to 2% slope from the basin to the selected drainage point (**National Diversified Sales, n.d.-b**).
   - 3 to 4-inch PVC pipes are recommended **(Industry Training Authority BC, 2023**; **Wallender, 2024**).

b. The ideal drainage point should:
   - Avoid direct connections to the municipal storm sewer or sanitary system unless explicitly permitted by local regulations;
   - Not feed into neighbouring properties; and
   - Allow for the trench feeding into the drainage point to maintain proper slope.

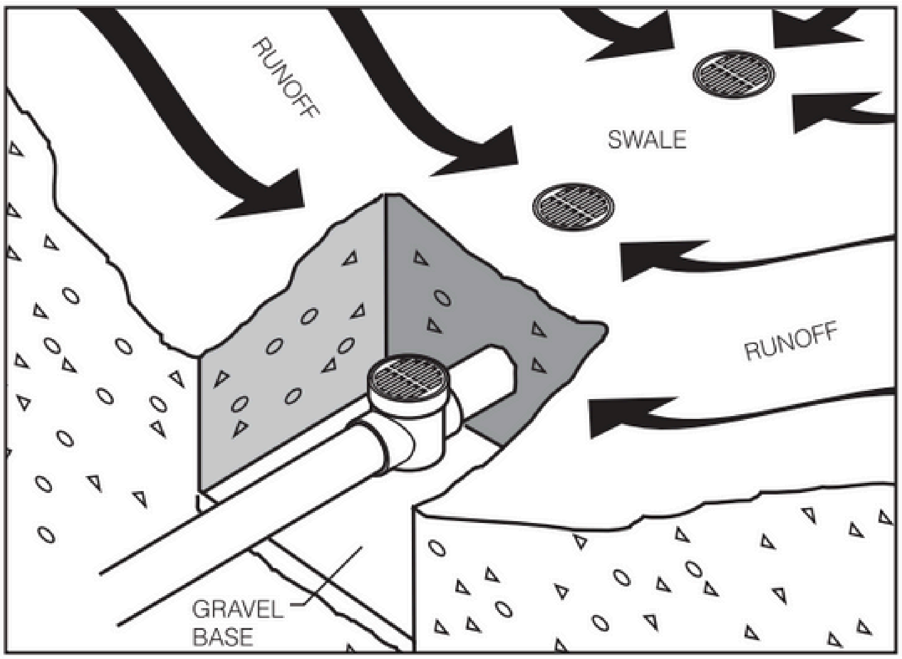
c. Lay the drainage pipe in the trench, connecting it to the catch basin. Ensure that the outlet pipe is above the lower part of the catchment basin so that debris settles instead of becoming stuck in the outlet pipe.

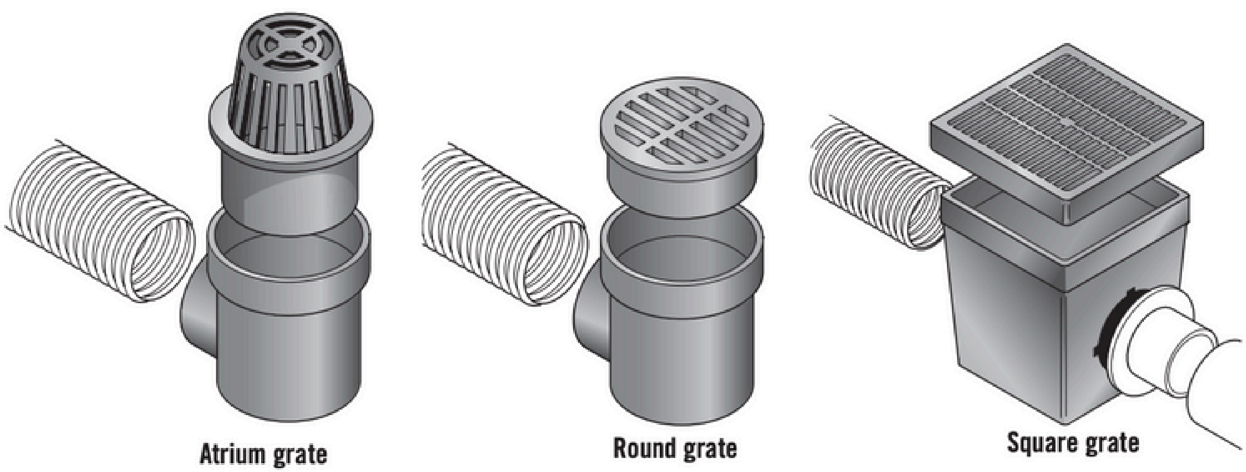
5) Install the grate

a. Depending on the system's design (e.g., landscaping versus hardscaping), this step may either occur before or after backfill (**G&G Concrete and Construction Inc., 2024**; **National Diversified Sales, n.d.-b**).
b. When backfilling or pouring concrete, tape over the grate openings to prevent debris from entering (**National Diversified Sales, n.d.-b**).
c. Grates should sit 1/4 to 1/8 inch below the ground's surface (**National Diversified Sales, n.d.-b**).

6) Backfill and secure the trench

a. Backfill around the catchment basin and the drainage pipe, adding gravel to enhance stability and drainage (**Industry Training Authority BC, 2023**; **Wallender, 2024**).
b. Cover the trench with soil, ensuring that the pipe remains sloped correctly. Compact the soil to prevent settling (**Industry Training Authority BC, 2023**).
c. If necessary, pour concrete around the catch basin to secure it in place or, if installed on a reverse slope driveway, to ensure a smooth transition with the driveway surface (**Industry Training Authority BC, 2023**; **National Diversified Sales, n.d.-b.**). Allow the concrete to cure as per the manufacturer's instructions.





Above: **Top—**Multiple basins may be necessary, depending on the property size and water flow characteristics (**National Diversified Sales, n.d.-b**). **Bottom—**Atrium and round grates are most common within landscaping applications, while square grates are typically used in tandem with concrete, pavers, and pavement (**National Diversified Sales, n.d.-b**).

Reverse slope driveway specific:

What is a reverse slope driveway?

A reverse slope driveway is when the driveway slopes downwards towards a lower-level garage, as opposed to towards the street (City of Toronto, 2024). Because of this, reverse slope driveways pose a heightened risk of basement flooding, and require the installation of a catchment basin to ensure that stormwater is able to properly drain into municipal drainage systems (City of Toronto, 2024).

Above: A reverse slope driveway (Reddit/Homeimprovement).

Key considerations:

- According to the City of Toronto (2022), catchment basins capturing water from reverse slope driveways should be **properly connected** to municipal stormwater management systems and be accompanied by the following installations:
  - "a **flap gate backwater valve** installed at 2% slope directly downstream of the private catch basin, so that no storm water may back up from the city storm sewer into the private catch basin; and
  - a **sump pump**, located in the overflow sump, to discharge any stormwater which has collected in the catch basin while the above-noted flap gate backwater valve has closed to prevent a backup of stormwater."
- The drainage inlet of the catch basin, as well as the sump system and pipes, should be sufficient to accommodate runoff from, at minimum, a 1-in-100-year rainfall event (City of Toronto, 2022).

When excavating for a catch basin:

- The basin should be located right at the bottom of the reverse slope, where the driveway meets the garage.
- Ensure that the hole is deep enough for the basin to sit flush with the driveway surface (Vodaland, 2023).

5.3.3. Key considerations and actions to avoid risk

Type of basin

- The exact type of basin selected for installation may vary in shape and size, depending on the homeowner's discretion, as well as the appropriate conditions and needs of the property. This may impact the size of pipes required to fit into the basin.

- Basins can be constructed on either a gravel, sand, or concrete base (**National Diversified Sales, n.d.-b**).

Sanitary and sewer systems

- If the catchment basin must be connected to municipal storm sewer systems:
  - Ensure that downspouts are disconnected and do not directly discharge into the catchment basin. Downspouts should instead drain over the surface of the lot (**Canadian Standards Association, 2018**).
  - It is recommended that the catchment basin be installed in combination with a sump system and backwater valve (**Canadian Standards Association, 2018**).

Connections

- A catchment basin can act as a drainage point for other foundation drainage systems such as a French drain / weeping tile or sump system.

Outlet pipe

- If the catchment basin is designed to drain into a grassy low point along the property, apply a small layer of small rocks or gravel to help facilitate drainage (**Wallender, 2024**).

- A small, boxed wall made of wood can be built around the gravel to keep it in place and prevent weed growth around the outlet pipe (**Wallender, 2024**).

- All components should be secured together using a PVC primer and a medium-bodied fast-setting PVC solvent cement (**National Diversified Sales, n.d.-b**).

Additional drainage

- To reduce the potential for standing water in the basin bottom, holes can be drilled, given that the base is gravel, allowing water to drain out (**National Diversified Sales, n.d.-b**).

Maintenance and inspection

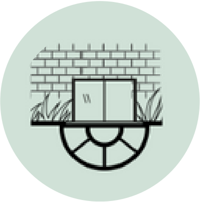
- Reverse slope driveway pipes should be inspected regularly, and the catchment basin should be maintained to remain free of blockages.

6. WINDOWS & DOORS

6.1. Window Well Cover

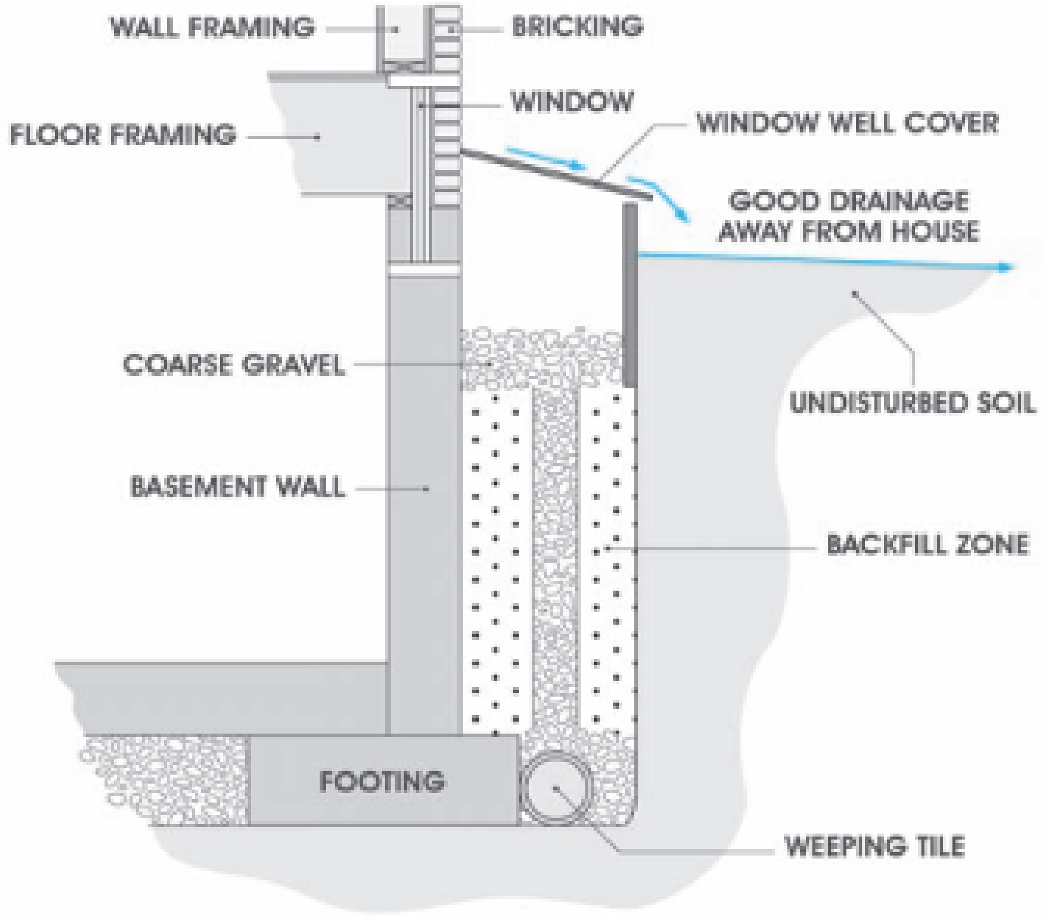
6.1.1. Overview

How this retrofit helps reduce flood risks:



Window Well Cover

Window well covers are placed over window wells to prevent water from pooling within the wells and from draining into the foundation. An effective window well cover diverts water away from the foundation/backfill zone. An added benefit for properties with French drains / weeping tiles is that it reduces the load on foundation drainage systems (**Sandink, 2009**)



Above: A diagram of a connected window well system (**Sandink, 2009**).

6.1.2. Installation guide: Window well covers

1) Position the cover

a. Center and align the window well cover with the edges of the window well, ensuring the back edge is snug against the house (**Gregory, 2023**).
b. Pressing the back edge against the house, centre the cover over the window well.

<u>Note</u>**:** *Ignore Steps 2-3 if the cover has pre-drilled holes*

2) Measure out the drill holes

a. On both sides of the cover, measure 4 to 6 inches from the back edge that is against the house and mark those locations with painter's tape (**Gregory, 2023**).
b. With the same tape, mark where the edge of the window well touches the cover (**Gregory, 2023**).
c. For non-egress windows, measure, tape, and mark the covers at the sides and in the front (**Gregory, 2023**).

3) Drill screw holes

a. Place a 2-inch by 4-inch scrap piece of wood beneath the cover plastic, placing it under one of the marked tape pieces. This will help to prevent damage to the cover while drilling (**Gregory, 2023**).
b. Drill a hole slightly larger than the diameter of the screws supplied with the cover (**Gregory, 2023**).

4) Fasten the clips

a. Fasten the clips to the cover, such that the prongs can grab the edges (**Gregory, 2023**).

5) Test the fit

a. Test-fit the cover on the window well. Check to make sure the cover does not shift or bend in the clips while in place (**Gregory, 2023**).
b. Any cuts or trims that must be made to the window well cover should be kept to a minimum to preserve the integrity of the cover and prevent bending (**Gregory, 2023**).

<u>Note</u>: When installing window well covers, it is important to also consider the egress routes available to occupants in the event of an emergency, such as a home fire or other hazardous event. If permanently attaching a solid cover, ensure that there are alternative escape routes from basement rooms.

6.1.3. Key considerations and actions to avoid risk

Sufficient structural support:

- Homeowners with small children or pets may wish to select a window well cover model capable of supporting weights of up to 45 kilograms, or 100 pounds.

Slope:

- The window well cover will not adequately prevent water from entering the window well if it is not sloped properly, such that water can drain away from the foundation or backfill zone.
- The drainage area that the window well cover feeds into should also be sloped downward, away from the foundation/backfill zone.
    - ***For more information***, see *Section 8.2: Site Grading.*

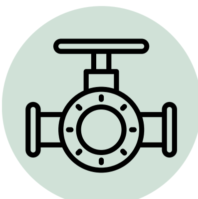
Above: An example of a window well cover (**Home Depot, n.d.**).

7. MECHANICAL, ELECTRICAL, PLUMBING (MEP) SYSTEMS

7.1. Backwater Valve

7.1.1. Overview

How this retrofit helps reduce flood risks:



Backwater valve

A backwater valve is located in a home's sanitary and/or storm sewer lateral or in the branch lines located in a home's basement. Backwater valves act as a one-way barrier, allowing wastewater to flow from the home. During a backwater event, such as a flood, these valves close, reducing the risk that sewage will return up the branches and/or laterals and into homes (**GreenBuilding Canada, 2024**; **Institute for Catastrophic Loss Reduction [ICLR], n.d.-a**).

Note: Although backwater valves are commonly referred to as "backflow" or "check" valves, this is incorrect terminology, as backflow and check valves function for different intended purposes (**ICLR, n.d.-a**).

7.1.2. Types of backwater valves

Not all backwater valves are created equally. A variety of models exist in the marketplace, with the main variations being their gate features (**ICLR, n.d.-a**). The **Institute for Catastrophic Loss Reducation** (**n.d.-a**) recommends choosing either an open, electro-pneumonic valve, automatic, or extendable backwater valve.

In addition, the National Research Council Canada advises that the following standards be consulted when selecting a backwater valve (**Sandink et al., 2021**):

- ***ASME A112.14.1-2003 –*** *Backwater Valves*
- ***ANSI/CAN/UL/ULC 1201:2016 –*** *Sensor Operated Backwater Prevention Systems*
- ***CAN/CSA B1800-15 –*** *Thermoplastic Non-pressure Piping Compendium*

Common valve models

According to the ***Institute for Catastrophic Loss Reduction*** *(****n.d.-a****):*

***Recommended* by experts:**

- ***Open backwater valve:*** These are installed on the main lateral line, where it connects to municipal sewage systems. Open backwater valves contain a gate that remains in the 'open' position, allowing for gases to ventilate and wastewater to exit, while preventing backflow.
- ***Electro-pneumonic valve:*** This is a newer device which uses electronic sensors to detect a backwater event. In response, the valve automatically inflates a 'bladder' to seal the pipes, and deflates this seal once the event passes. Because this unit is electronic and self-monitoring, rather than mechanical, it requires less user maintenance. It includes internal sensors that monitor system components, including battery health (intended to last for 1 week in the case of a power outage).
- ***Automatic backwater valve:*** In recent years, some manufacturers have developed automatic backwater valves with a normally open design, which requires a lesser slope and less intrusive installation (i.e., requires a smaller hole) as compared to traditional backwater valves, which require the removal of larger sections of basement flooring. The valve is installed in main lines and automatically shuts when reverse flows or sewer and septic backups occur (**Backwater-Valves.com, n.d.**).
- ***Extendable backwater valve*:** Another recent addition to the market is extendable valves, which work similarly and may either be installed within the basement or on the sewer lateral located outside of the home. Such bypassing can allow users to install the valve without removing concrete flooring, and to easily access maintenance.

***Not recommended* by experts:**

- **Gate valves:** Gate valves are an older technology that is no longer widely used in Canada. Gate valves require that the homeowner is present to manually install the gate and/or switch the valve from 'off' to 'on' before a backflow event occurs, which is not feasible for most users.
- **Inline check valves:** These one-way devices are still commonly used in Canada, but typically remain in the 'closed' position and thus, are unsuitable for use on main sanitary lines. A downside of inline valves is that this device prevents the ventilation of sewage gases, as typically required by plumbing codes. Furthermore, these are difficult to access for routine maintenance and are prone to clogs via drain snakes, which can damage the unit.
- **Plug-type valves:** These are installed directly into basement floor drains, and thus are not advised due to the risk of having sewer backup pressure build up beneath the basement, leading to cracks and structural damages.

7.1.3. Installation guide: Backwater valves

1) Ensure appropriate slope for valve type

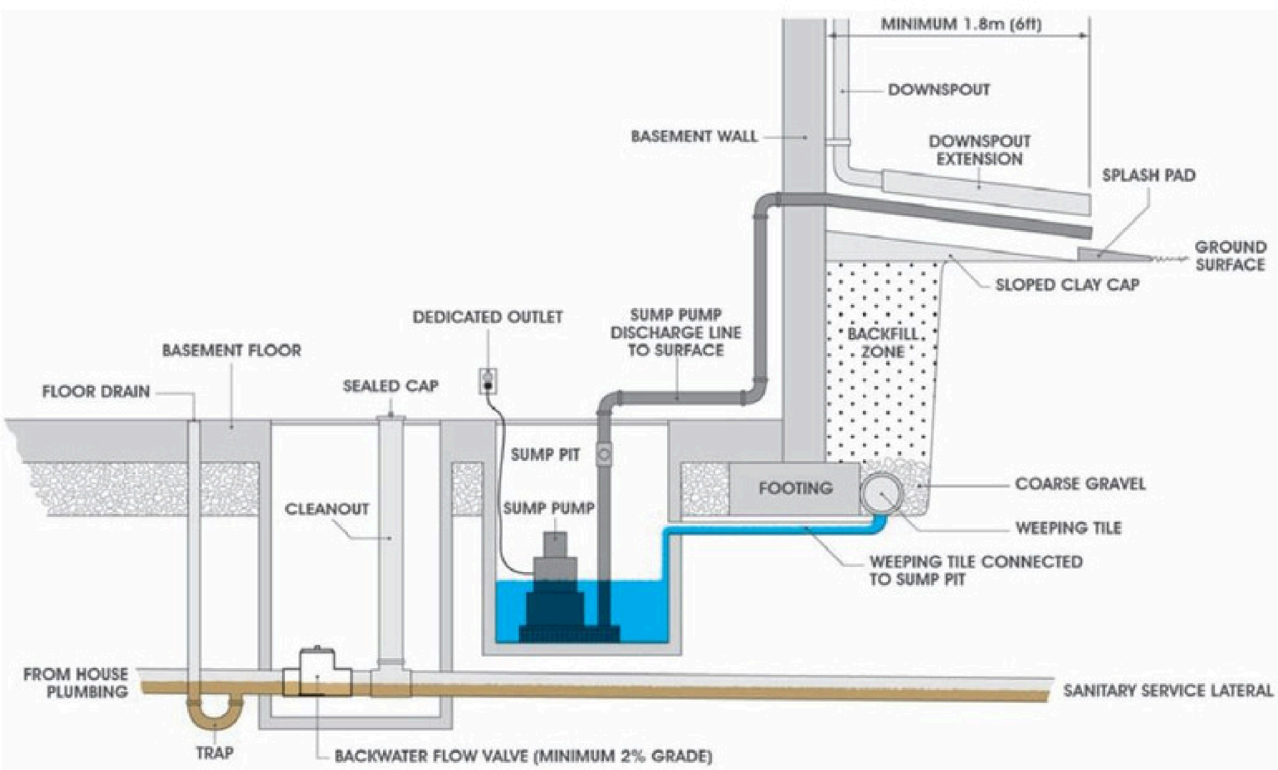
a. Backwater valves should be installed with a slope of 1:48, or approximately 2% (**Backwater-Valves.com, n.d.**). This minimum downward slope is necessary "to allow wastewater to properly exit the house and drain into the municipal system and to allow the backwater valve to work properly" (**ICLR, n.d.-a**).

b. While some model installations may work best during new home construction to achieve the 2% slope, a section of the sewer lateral can be cut out to accommodate and connect the valve (**Canadian Standards Association, 2018**).

c. Installation often requires that cement flooring be taken up, averaging 4 to 5 feet, to achieve proper slope characteristics for the pipes running to the valve (**Canadian Standards Association, 2018; ICLR, n.d.-a**).

2) Install the valve per the manufacturer's instructions

a. It is important to follow the manufacturer's specifications for placement and grading (**ICLR, n.d.-a**). If backwater valves are installed incorrectly or in the wrong location, the valve may be ineffective in providing protection from backwater events, lead to sewage pressure building up beneath the foundation, or cause sewage to drain instead into the foundation—elevating the risk of structural damages and flooding (**ICLR, n.d.-a**).



Above: The minimum 2% grade allows for any sewer backflow to float the backwater gate upwards and close the valve (**Sandink, 2009**).

7.1.4. Key considerations and actions to avoid risk

Sewer lateral:

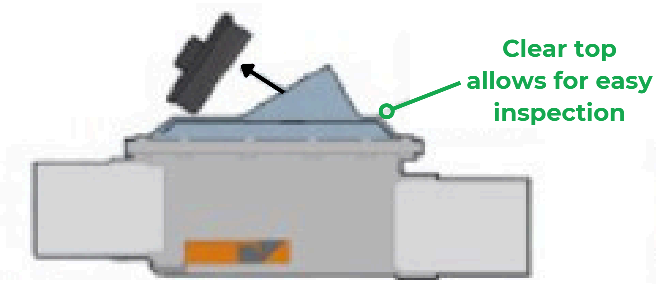
- ***Installing on a sewer lateral:*** The **Canadian Standards Association** (**2018**) states that only an open backwater valve should be used for installation on a sewer lateral. This ensures proper ventilation of sewer gases and prevents the buildup of sewer backup pressure (See Z800-18).
- ***Pre-installation considerations:*** It is important to assess the potential impact of tree roots on the sewer lateral, as tree root intrusion can cause pipe fractures, leading to inflow and infiltration issues (**ICLR, n.d.-a**).

Valve failure:

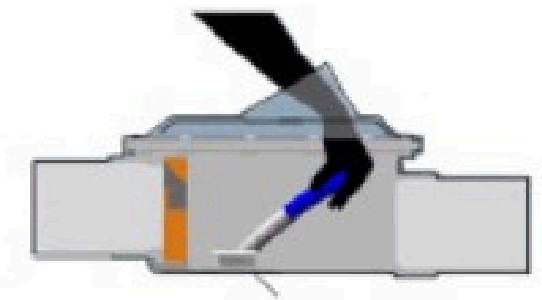
- ***Avoid flat or reverse slopes:*** The backwater valve pipeline should not be installed on flat or reversed slopes, as this can cause debris to accumulate on the valve components (**ICLR, n.d.-a**).
- ***Check the valve O-ring***: Make sure the valve's O-ring is securely in place, and that the valve itself is not glued or cemented (**ICLR, n.d.-a**).
- ***Ensure proper sealing:*** There should be no leakage between the valve and its connection to the sewer lateral pipes (**ICLR, n.d.-a**).
- ***Avoid corrodible materials:*** For new installations, avoid using cast iron or other materials prone to corrosion, as these can increase the risk of clogs around the valve hinges (**ICLR, n.d.-a**).

Maintenance:

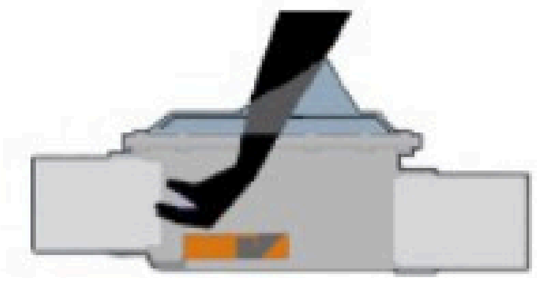
- ***Keep the valve area clear:*** Avoid placing heavy objects on top of the valve location, as this could obstruct access for maintenance (**ICLR, n.d.-a**).
- ***Understand the manufacturer's requirements:*** To prevent backwater valve failure after installation, homeowners must be aware of the necessary maintenance requirements as per the manufacturer's instructions (**ICLR, n.d.-a**).
- ***Seek professional help if needed:*** Homeowners are advised to consult a professional plumber if they are unsure about how to properly maintain or repair the valve (**ICLR, n.d.-a**).



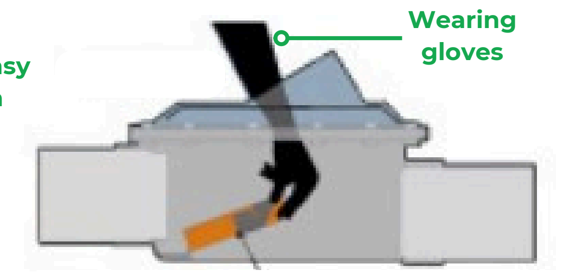
1. Remove cleanout cap and inspect with a flashlight



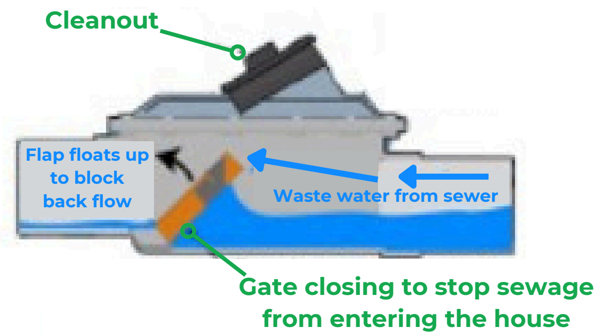
2. Inspect for debris build-up and clean if debris is found



3. Inspect and replace O-ring if necessary



4. Ensure valve gate moves freely



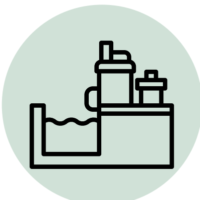
5. Properly reinstall cleanout plug when maintenance and inspection are completed

Above: The backwater valve should be accessible for maintenance and cleaning. Valves often are equipped with a translucent top which allows the user to visually inspect for clogs and other debris. Routine maintenance involves inspecting the gate to ensure that the flap moves freely and clearing any debris that has built up inside the unit (**Sandink, 2009**).

7.2. Sump Systems

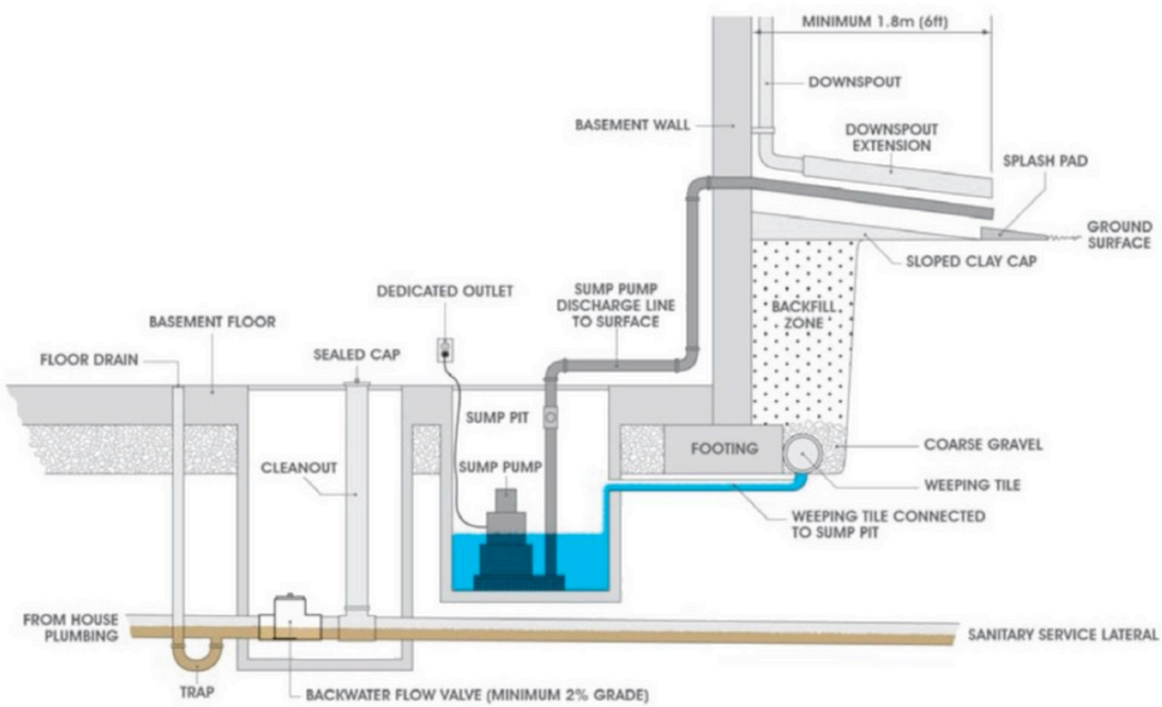
7.2.1. Overview

How this retrofit helps reduce flood risks:



Sump Systems

Also referred to as a sump pit, sump pump, or auxiliary power system, a sump system works to drain any water that might seep into a building's foundation. In the event of a power failure, auxiliary or backup power systems help keep the pumps running and basements dry. Systems should be accompanied by alarms in case the sump stops working, as well as backup batteries in case the power goes out during a storm. It is best practice to use a dedicated circuit and a ground-fault circuit interrupter (GFCI) switch for the sump system.



Above: Schematic depicting a sump pump system (**Sandink, 2009**).

According to the Institute for Catastrophic Loss Reduction "when weeping tiles are disconnected from sewer laterals, a sump-pit and sump-pump must be installed. The sump pump is used to pump water from the weeping tiles to the lot's surface. In some cases, municipal governments may recommend using a sump pump to pump weeping tile water to the municipal sewer system" (**Sandink, 2009**).

7.2.2. Design parameters: Sump systems

SUMP PITS

LOCATION:

- A sump pit should be located no further than 4 feet from the exterior wall (**Sandink et al., 2021**).
- When determining the sump pit location:
    - Determine if there are any structural footings that would interfere with installation (**FEMA, 2012**).
    - Coordinate with existing drainage systems.
        - Sump systems are typically connected to a French drain / weeping tile system.
        - Locating the sump pit so that it acts as a drainage point for such a system is ideal.
    - A consistent power source should be nearby, such as a power outlet. It is best practice to use a dedicated circuit and a GFCI switch for the sump system.

SIZING:

- The **City of Winnipeg** (**2022**) recommends a sump pit size of 30 inches wide by 30 inches high, if possible. It should be no less than 18 inches wide (**City of Winnipeg, 2022**).

MATERIAL:

- The sump pit should be made of fibreglass or heavy-duty plastic, such as polyethylene or polypropylene (**Sandink et al., 2021**).

Left: An example of a fibreglass sump pit (**Superior Cleaning Equipment Inc., n.d.**).
Right: An example of a polyethylene sump pit (**AK Industries Inc., n.d.**).

SUMP PUMPS

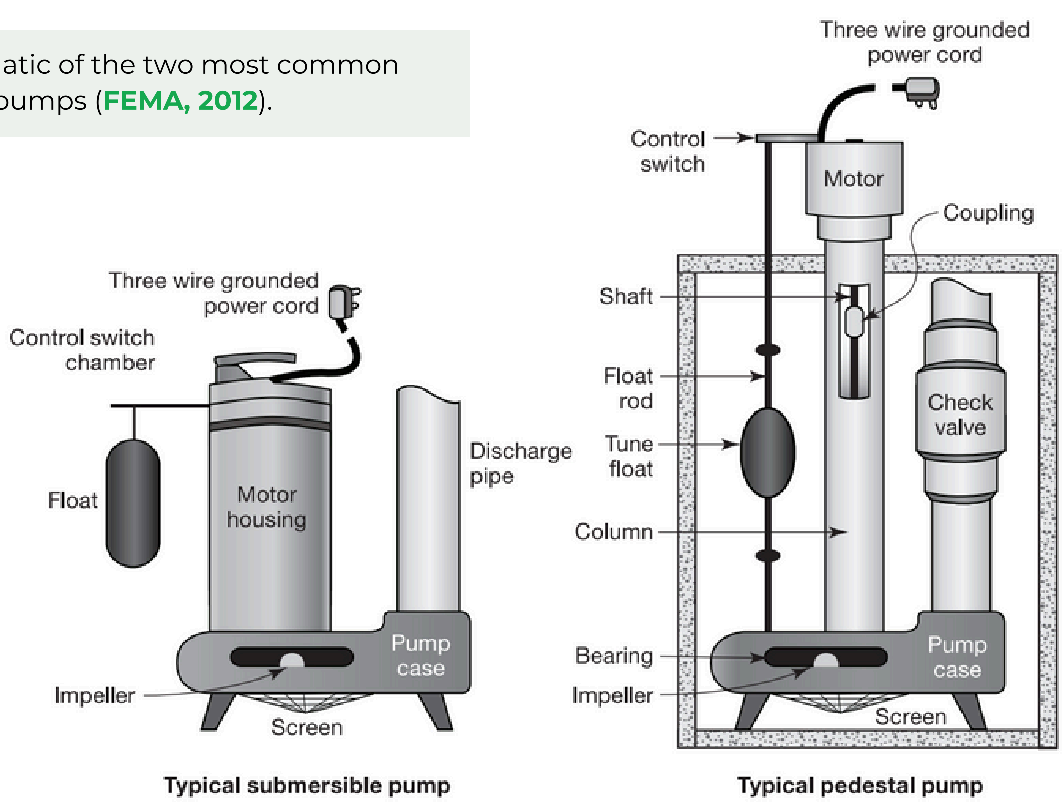
OPERATING CAPACITY:

- National Research Council Canada recommends that a sump pump be capable of:
  - Operating 10 start and stop cycles per hour;
  - Operating continuously for up to 336 hours; and,
  - Exhibiting no excessive wear after 1,000 total cycles (**Sandink et al., 2021**).

PUMP TYPE:

- The most common types of sump pumps are:
  - **Submersible pump**
    - This type operates with a watertight motor that directly connects to the pump case, which rests at the bottom of the sump pit (**FEMA, 2012**). When water rises to a certain point such that the float is triggered, the pump activates and begins to discharge water out of the sump pit (**Sandink et al., 2021**).
  - **Pedestal pump**
    - This type operates with an open motor attached to the pump case via a pipe column (**FEMA, 2012**). A shaft inside this column is what connects the motor to the pump impeller (**FEMA, 2012**). Just like with a submersible pump, the pump is activated when water rises to a certain point, triggering the float (**Sandink et al., 2021**).

Right: A schematic of the two most common types of sump pumps (**FEMA, 2012**).



7.2.3. Installation guide: Sump systems

1) Select the right location for the sump pit

a. Most sump systems are installed with the sump pit located inside the home in the lowest portion of the basement. Make note of the previously mentioned design parameters when determining the location.

b. Ensure that the selected location does not interfere with any utility lines or pipes (**City of Moncton, n.d.**).

2) Excavate a hole for the sump pit

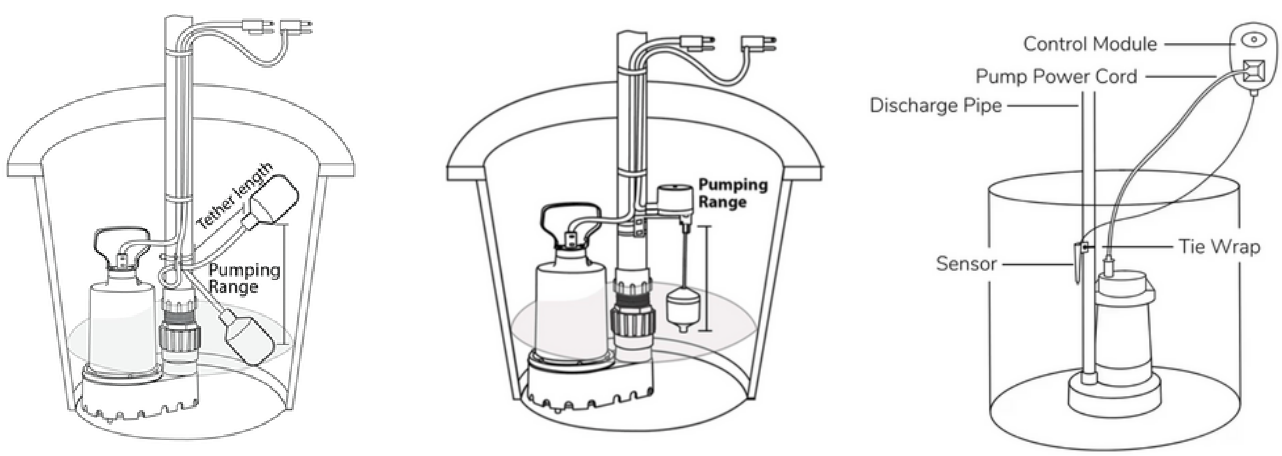
a. The excavated area should be about 6 inches deeper and 10 inches wider than the sump pit (**FEMA, 2012**). Fill this extra space with coarse gravel and stones, compacting it such that the bottom is level (**FEMA, 2012**).

3) Place the sump pump into the sump pit

a. Test that the float switch can rise and fall freely, as this is a crucial part of ensuring that the pump turns on (**Drain Express, n.d.**).

b. According to **Drain Express** (**n.d.**), there are three main types of float switches available on the market:

- **Tethered float switch:** The switch is connected to the sump pump via a tether and becomes activated when the water rises to a certain level. Tethered float switches are best suited to larger sump pits.
- **Vertical sump pump float switch:** The switch moves along a vertical rod, floating at the surface and activating at a certain water level. Vertical sump pump float switches are recommended for narrow sump pits.
- **Electronic sump pump float switch:** The switch is non-mechanical, meaning that components do not move with the water. Instead, a sensor is used to monitor water levels and activate the pump. These are the costliest options.



Left: An example schematic of a *tethered float switch* (**Superior Pumps, n.d.**).
Middle: An example schematic of a *vertical float switch* (**Superior Pumps, n.d.**).
Right: An example schematic of an *electronic float switch* (**Sump Pumps Direct, n.d.**).

4) Connect the French drain / weeping tile to the sump pit

a. The pipe connection should be attached in such a way that a 1% slope is maintained between the French drain / weeping tile and the sump pit.

5) Attach the drainage pipeline to the designated discharge area

a. The **City of Moncton** (**n.d.**) recommends PVC pipes with a diameter of 1-1/4 inches, and National Research Council Canada recommends an absolute minimum diameter of 1-1/8 inches (**Sandink et al., 2021**).

b. Minimize the length of the drainage pipes and the number of turns needed to reach the discharge area, as longer pipes and 90-degree angle turns can strain the sump pump and cause friction loss (**Utilities Kingston, n.d.**; **Zoeller, 2023**).
   - Using two 45-degree angle pipe elbows, rather than one 90-degree angle elbow, is recommended for corner fittings (**Sandink et al., 2021**).
   - Ensure that the positioning of the drainage pipes does not pose a tripping hazard (**Sandink et al., 2021**).
   - Ensure that the drainage pipes are located away from electrical equipment and other utilities to reduce risks from leaks (**Sandink et al., 2021**).

c. Install a check valve along the drainage pipeline, attached to the top of the sump pump.
   - Check valves and other discharge pipe components will need to be routinely inspected and maintained, so it is important to ensure that these systems are easily accessible and removable (**Sandink et al., 2021**).

d. National Research Council Canada recommends drilling a relief hole—ranging in diameter from 1/8-inch to 3/16-inch diameter—in the floor between the pump discharge and the check valve (**Sandink et al., 2021**). The purpose of this relief hole is to release trapped air and prevent air lock (**Sandink et al., 2021**).
   - Drill the relief hole at about a 45-degree angle to ensure water does not spray out of the sump pit (**Werner, n.d.**).

e. Ensure that the discharge area extends at a minimum of 6 feet (1.8 metres) from the property foundation and onto a splash pad (**Sandink et al., 2021**).

Right: Splash pads are concrete installations that direct water away from the home's foundation so that the water is not being taken up again by the sump system (**City of Edmonton, n.d.**). The **City of Edmonton** (**n.d.**) recommends a size of 30 x 107 centimetres, and that the splash pad drains onto a permeable surface, such as "sod, topsoil, or gravel" where not connected to municipal storm sewers.

6) **Test the sump pump by plugging it in and filling the sump pit with water**

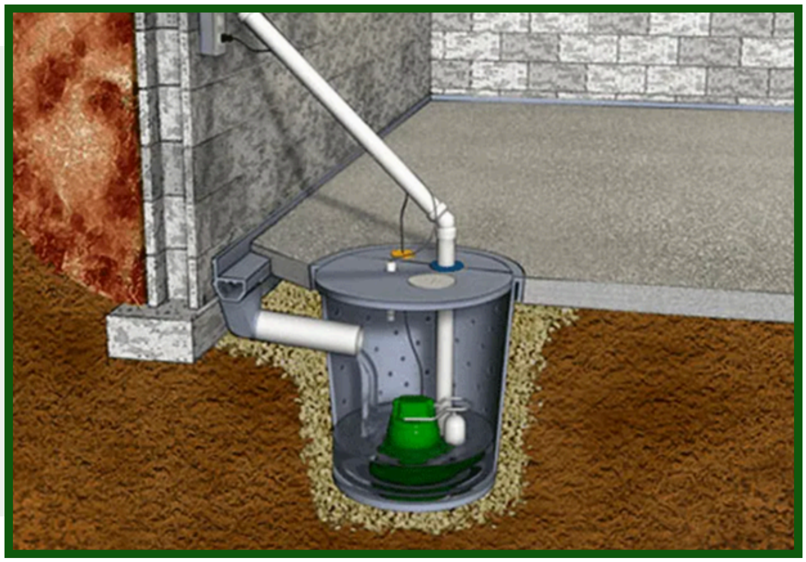
a. Ensure that the float is rising, that the pump itself has turned on, and that water is being pumped (**ICLR, n.d.-b**). Inspect the drainage pipeline for any leaks and check to ensure water is discharging away from the home's foundation (**ICLR, n.d.-b**).

7) **Place the cover over the sump pit and cover the hole**

a. ***Interior specific:*** Conceal the exposed edges around the sump pump by applying a layer of concrete, ensuring that the mixture is the consistency of peanut butter. Ensure that the lid remains clear of concrete (**Clement et al., 2024**).

b. ***Exterior specific:*** Add a 1-inch layer of smooth stones around the lid (**Sandink et al., 2021**).

Right: When digging the sump pump hole (basin), ensure that there is enough space for both the sump tank and the gravel lining over which the tank will be placed on (**Plumbwize, n.d.**).



Left: Seal the sump pump hole with concrete such that only the sump pump lid is visible. Also note that the drainage pipes all remain as close to the walls as possible, so as not to take up excessive basement space (**Family Handyman, 2024**).

7.2.4. Key considerations and actions to avoid risk

Backup Power:

- Sump systems should be provided with an adequate backup such as a battery backup power, backup pumps, and a backup generator located on the building exterior (**ICLR, n.d.-b**).
    - It is ***NOT*** recommended to utilize the flow of a potable water distribution network for energy in the sump system, as this poses a severe and unnecessary threat to the municipal drinking water system (**Sandink et al., 2021**). Additionally, because water-powered sump pumps require water pressure, these will not work during power outages for homes on well water (**Water Commander, n.d.**).
    - Install a check valve on backup sump pumps (**Sandink et al., 2021**).

Sump Pump Cover:

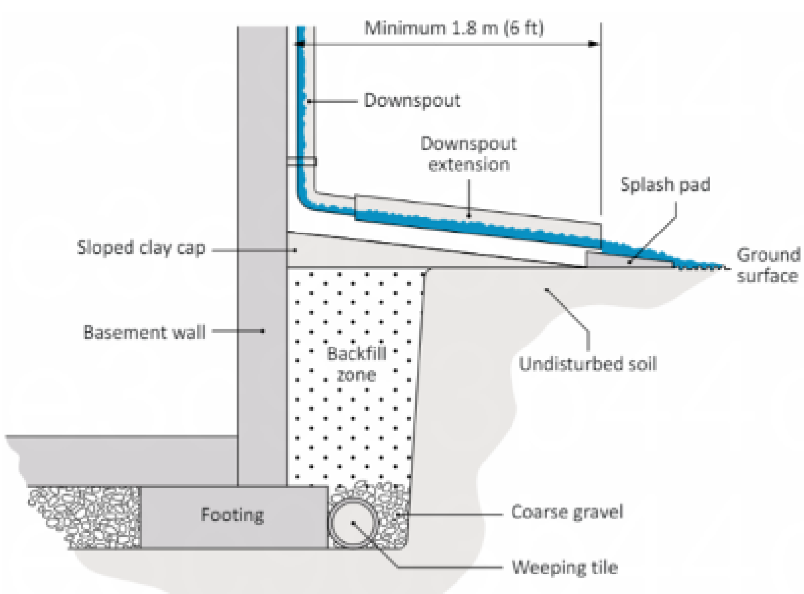
- Sump pump covers should be designed to withstand the weight of occupancy loads and to remain closed in the event of floods (**Sandink et al., 2021**).

Sump Pump Discharge:

- Install a check valve on the discharge line that is located as close to the sump pump as possible (**Sandink et al., 2021**).

- The drain for the discharge pipes should be extended to 6 feet away from the building foundation to prevent the recycling of water through the foundation drainage/sump system (**Canadian Standards Association, 2018**; **Sandink, 2009**; **Sandink et al., 2021**).
    - If a distance of 6 feet is not possible for the property, ensure that the discharge point is beyond the line of excavation and backfill, and not directed back towards the foundation or any neighbouring properties.

Right: Discharging at least 6 feet away from the home's foundation ensures that the drainage does not simply cycle back into the foundation/ backfill area (**Sandink, 2009**).



Frost and Ice:

Sump pump systems, and especially any exterior discharge lines and water pipes, should be protected from frost or ice. There are several methods to reduce freezing:

- ***Insulation:*** Measure the wall surrounding the sump basin and fit an insulating material around the system to keep cold air out (**Davis & Green, 2024**). Insulation materials include foam board insulation and air bubble insulation (**Davis & Green, 2024**). Similarly, wrap exterior drainage pipes in an insulant, such as foam pipe insulation or a heat tape barrier, to retain heat.
- ***Depth:*** Pipes should be buried at a depth of 4 to 5 feet beneath the surface, allowing the dirt around the pipe to trap in heat (**Eakes, 2016**).
- ***Heating systems:*** Heated sump pit systems exist on the market. These are more expensive units, but allow the homeowner to regulate the temperature within the sump system using a thermostat (**Heatline, 2024**). Similarly, heating cables designed for this application can be installed either within or on top of the sump pump drainage pipe, as well as around the tank and inside drainage tiles (**Heatline, 2024**).
- ***Battery backup systems:*** Installing a battery-operated backup system can help to ensure that the sump pump continues to run in the event of a power outage, which can help to prevent freezing. Backup batteries can be enclosed in a waterproof "marine" case and should be designed for use within a sump system (**Davis & Green, 2024**).
- ***Maintain a low water flow:*** Because still water is more likely to freeze than running water, maintaining a slow trickle of water moving throughout the system can help prevent ice build-up (**Davis & Green, 2024**; **Wentworth Plumbing, 2016**). Homeowners can attach a garden hose to the sump pump and allow it to run periodically (e.g., a few hours in the day) to keep water moving within the tank; however, caution must be taken to ensure that this process is well-monitored, as too high of water flow has the potential of overwhelming the pumps or causing basement flooding (**Davis & Green, 2024**).

Left: The sump system discharges into the wider exterior pipe. Leaving a gap in between can prevent drainage backup if the wider exterior pipe freezes (**Maxwell, 2024**).

Frost and Ice Continued:

- ***Slope:*** Ensuring a sufficient slope at the bottom of the sump pit can also help to prevent freezing, allowing water to drain efficiently, rather than run the risk of pooling (**Davis & Green, 2024**). When installing a sump system, manually dig out a slope and/or use a sloped bottom liner (**Davis & Green, 2024**). Slope can be tested by running water through the system and assessing the drainage characteristics (**Davis & Green, 2024**).

- ***Routine maintenance:*** When sump pumps are overburdened, the system is more susceptible to freezing (**Davis & Green, 2024**). Ensuring that gutters and downspouts are free of leaves and other debris, and ensuring that the property has sufficient overall drainage, will help to reduce the workload of the pump motor by redirecting water away from the home, rather than being captured by the sump system (**Davis & Green, 2024**). Additionally, water damage and leaks in basements and crawl spaces can contribute to increased pump activity (**Davis & Green, 2024**).

- ***Pipe distance:*** Sump systems that discharge from an interior pipe into a wider exterior pipe should have a gap between the two. Increasing this distance can help to prevent water in the discharge line from freezing (**Davis & Green, 2024**).

- ***Freeze guard:*** This device can be installed to monitor water temperature within the discharge line, turning the pump off if it detects water that is too cold (**Basement Systems, 2024**).

- ***Colour:*** Using black pipes can also help to retain heat and prevent freezing.

Above: A freeze guard device can be installed to allow water to leave the discharge line in the case of freezing or blockage, rather than entering the sump basin when the pump is not working (**Basement Systems, 2024**).

7.3. Disconnect Direct Connections

7.3.1. Overview

How this retrofit helps reduce flood risks:

Disconnect direct connections to sewer systems

Disconnect direct connections to sewers in areas at risk of sewer back-up—such as a French drain, weeping tile, or downspouts. This can reduce the risk of sewer water backflowing into the house during heavy precipitation or flood events and reduces the load on municipal stormwater management/sewer systems (**City of Anderson, n.d.**).

7.3.2. Installation guide: Disconnecting direct connections

The exact procedure for disconnecting any sort of drainage system that leads to a sewer system will vary. Seeking the help of a professional is recommended if not familiar with the system or technology. Common types of direct connections include:

French drain / weeping tile

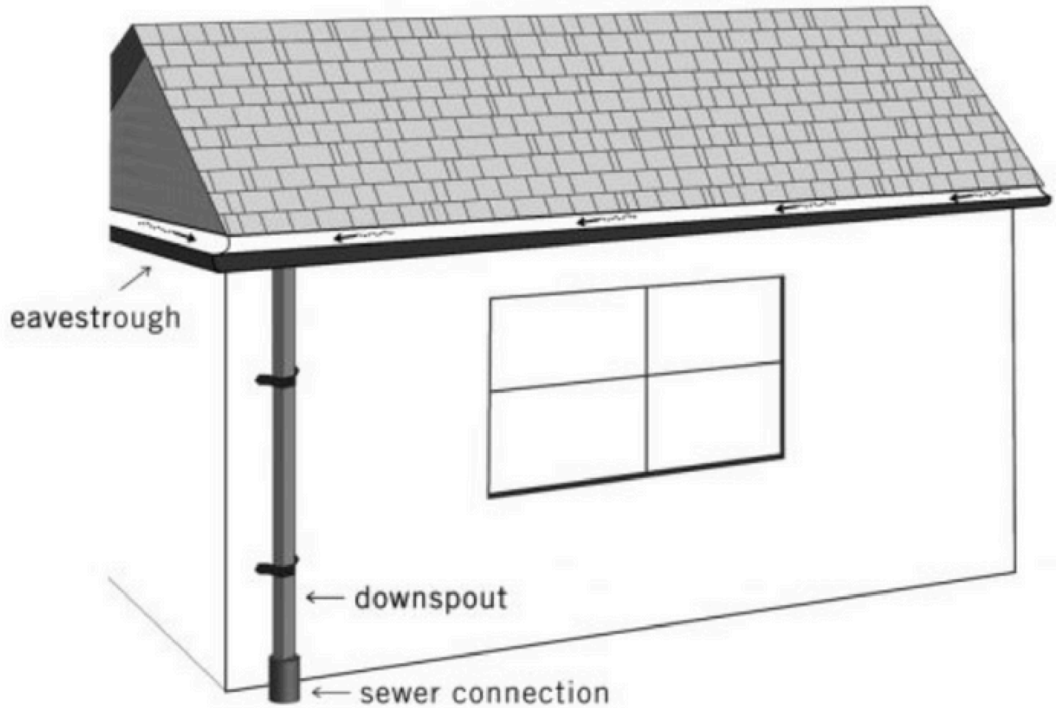
- Excavate the area where the French drain / weeping tile is connected to the municipal sewer system. This may be through a floor drainpipe but can vary depending on the property (**Basement Technologies, 2024**).
- Remove the pipe connection and install a new pipe that reroutes the drainage from the French drain / weeping tile to a new drainage area, such as a sump system (**Basement Technologies, 2024**).

Downspouts

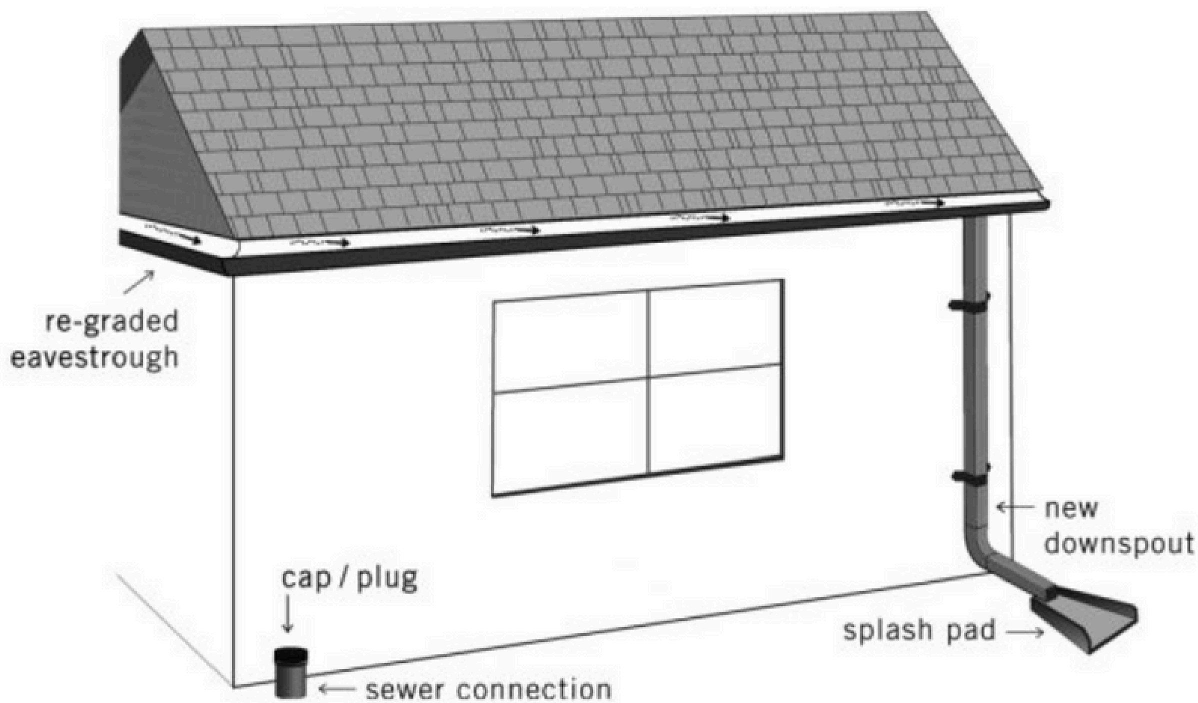
- A downspout direct connection will be one where the downspout feeds directly into an underground pipe (**City of Toronto, n.d.**; **Sandink, 2009**).
- Use a fine blade hacksaw to cut the downspout at 9 inches above where the standpipe meets the ground (**City of Toronto, n.d.**).
- Cap the exposed underground pipe using a polyvinyl chloride (PVC) cap.
- Insert the downspout into an elbow, then attach a downspout extension that will discharge water away from the property foundation (**City of Toronto, n.d.**).
- The extension should discharge a minimum of 6 feet away from the foundation (**Sandink, 2009**).

Catchment basins

- Excavate the area where the catchment basin is connected to the sewer system.
- Remove the direct pipe connection and install a new pipe that reroutes the drainage from the catchment basin to a new drainage area. This can be a lower elevation, grassy area of the property.



Above: A connected downspout is pictured here. Note the direct connection to the municipal sewer system (**Toronto and Region Conservation Authority, 2018a**).



Above: A disconnected downspout is pictured here. Note that the downspout discharges away from the home's foundation and that the sewer connection is securely plugged (**Toronto and Region Conservation Authority, 2018a**).

7.3.3. Key considerations and actions to avoid risk

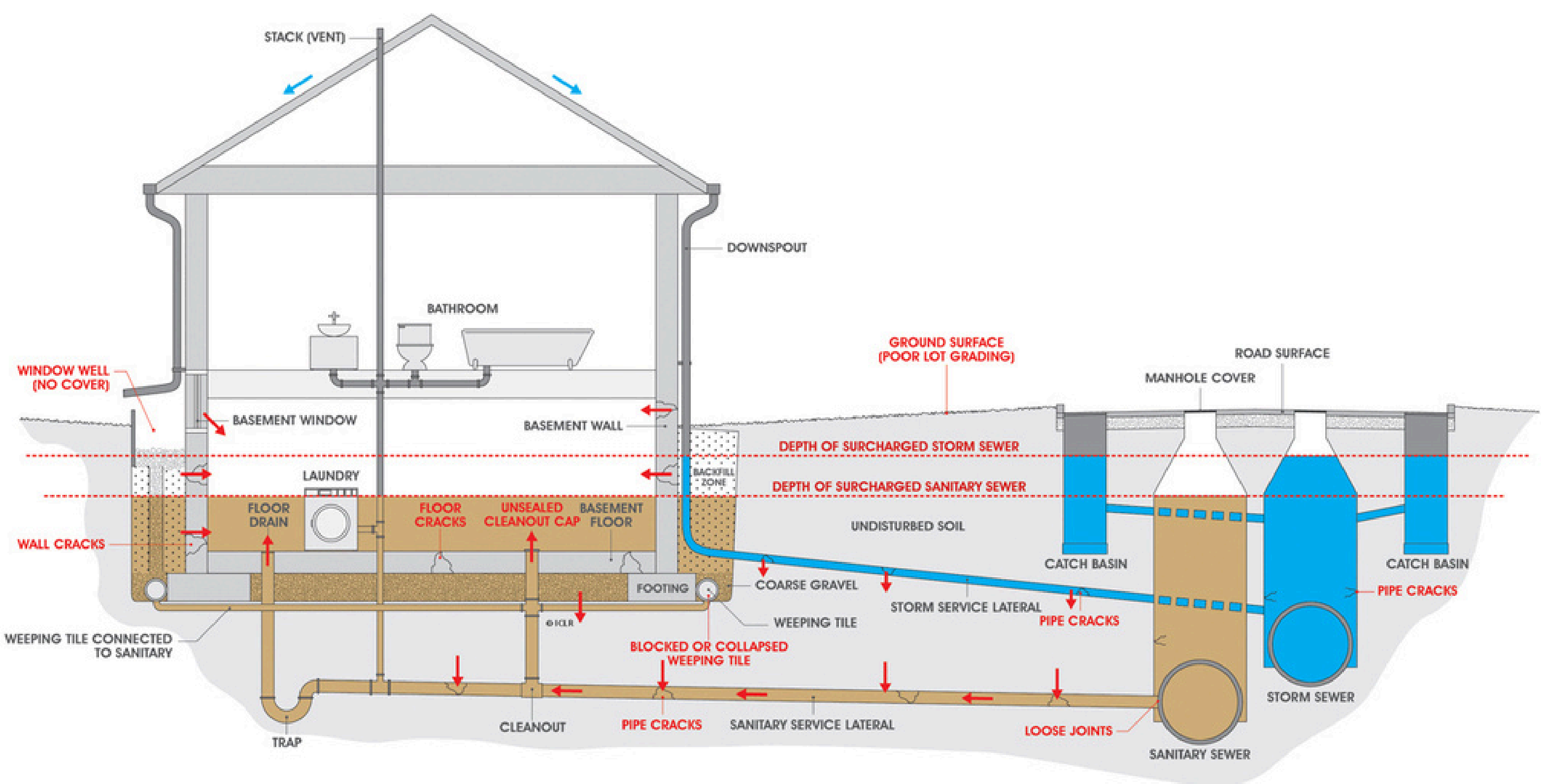
Redirecting discharge:

- For any direct connection that has been disconnected, the new drainage area should:
  - Not feed into neighbouring properties, and
  - Be directed away from the property foundation.

- A splash pad can be placed at the end of a downspout extension to both help drain the water and prevent erosion (**City of Toronto, n.d.**).

Storm sewer lateral:

- In some places across Canada, downspouts are connected to storm and/or sanitary systems. If disconnecting the storm sewer connection, ensure that the storm sewer lateral is severed as close to the municipal storm sewer as possible to reduce the risk of sewer backup (**Canadian Standards Association, 2018**).

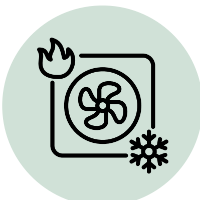


Above: An example of a home that has both storm sewer and sanitary sewer connections (**Sandink, 2009**). In this case, the catch basins, site grading, backfill, and weeping tiles all feed into the direct connections. The recommended practice would be to disconnect them all (**Canadian Standards Association, 2018**). Also note that the poor grading and lack of backfill capping exacerbate the risk of sewer overwhelm (**Sandink, 2009**).

7.4. Elevating and Securing Heating, Ventilation and Air Conditioning (HVAC) Components

7.4.1. Overview

How this retrofit helps reduce flood risks:



Elevating HVAC components

Elevating HVAC components above the design flood level and securing any exterior exposed elements, such as air conditioning units, can reduce the risk of damage from extreme rain and wind.

7.4.2. Installation guide: Elevating and securing the HVAC

Utility units should be either relocated to the main floor or above, or raised above the basement floor. For smaller units (e.g., air conditioning units), this means a minimum elevation of 1 to 2 feet. For larger equipment (e.g., furnaces, hot water tanks), a minimum elevation of 2 to 8 inches is recommended. When relocation or elevation is not possible, installing waterproof barriers around HVAC equipment can be another solution (**Federal Emergency Management Agency [FEMA], 2017**).

- **Electrical service boxes/panel boards**
- **Furnaces**
- **Hot water heaters**
- Other **major appliances**, such as washers and dryers

The exact procedure for elevating and securing HVAC components will vary depending on the specific component in question. The **Federal Emergency Management Agency** (**2017**) categorizes HVAC components into two categories:

- ***Primary components:*** These are the components of any given HVAC system that are necessary for the system to operate.
    - Examples include boilers, air handling units, and condenser units.

- ***Secondary components:*** These are components of any given HVAC system that can lose function without the system losing full operation.
    - Examples include convectors, radiators, and ducts.

7.4.3. Key considerations and actions to avoid risk

Fire Safety:

- Heating oils, fuel oils, and any flammable gas containers and tanks that are attached to, underneath, or located near the building should be sufficiently secured and anchored to resist the force of floodwaters and for fire safety (**FEMA, 2018**).

Adequate Support:

- According to **Building America Solutions Center** (**n.d.-c**), the following precautions should be taken when elevating HVAC equipment:
  - "Elevated surfaces must be able to adequately support and anchor the weight of the HVAC equipment; and
  - If not placed on a balcony cantilevered from the building, outdoor elevated HVAC equipment should be supported by piles, masonry, or a concrete structure that extends below the expected depths of erosion, scour, and frost." Appropriate brackets designed for mounting equipment may be required, depending on the set-up.
- HVAC equipment can also be elevated on a balcony (**FEMA, 2017**).
- Whatever elevation method is chosen, it is important that both the structure itself and the anchors are designed to withstand the force of floodwaters and winds (**FEMA, 2017**).

Condensation:

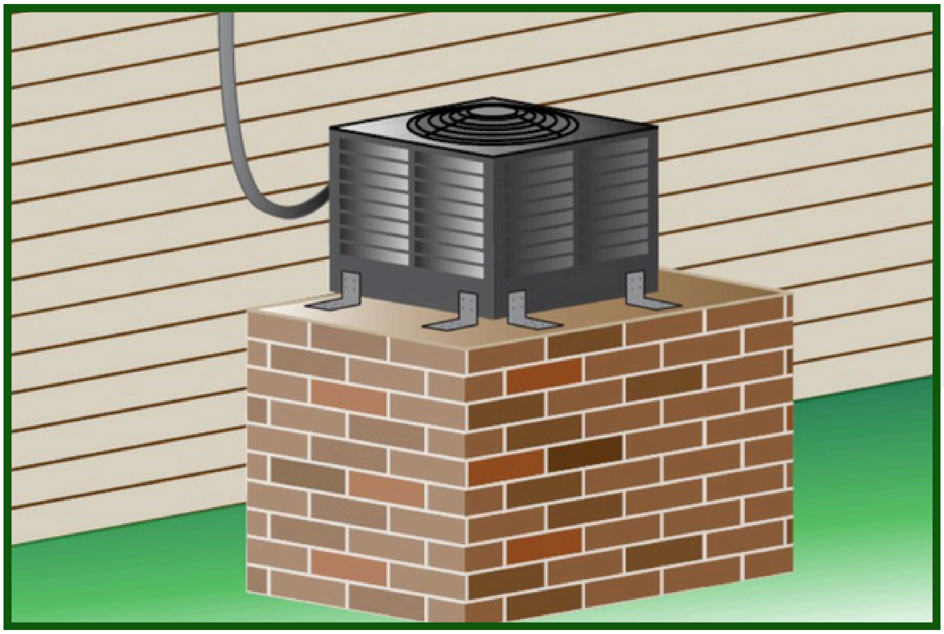
- Ensure exhaust vents are properly elevated and ducts are sloped upwards from the exhaust vent to maintain airflow and ensure proper drainage (**Building America Solution Centre, n.d.-c**).

Clearance:

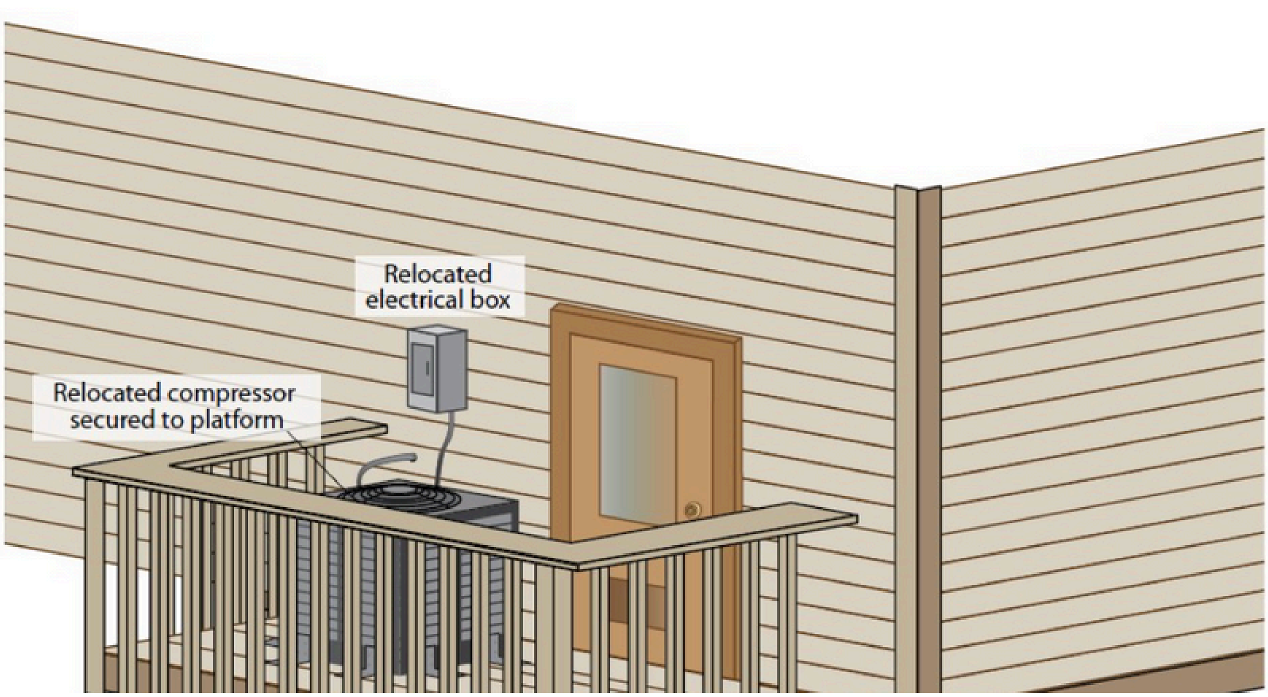
- HVAC equipment should have an above-and-side clearance of 36 to 56 inches (**Building America Solution Centre, n.d.-c**).
- When elevating combustion equipment, perform a safety test to ensure that there is adequate airflow and venting (**Building America Solution Centre, n.d.-c**).
- Upgrading to sealed-combustion, direct-vented equipment is also recommended if feasible to do so at the same time as raising equipment (**Building America Solution Centre, n.d.-c**).

Maintenance:

- Ensure that HVAC equipment remains accessible for routine maintenance. Check with the local utility company to cross-reference any restrictions that may prohibit the elevation or relocation of HVAC equipment (**FEMA, n.d.**).



Left: An example of HVAC equipment being elevated on a raised structure (**FEMA, 2017**).



Above: An example of HVAC equipment being elevated on a balcony (**FEMA, 2017**). Note that the doorway provides access for routine maintenance.

8. LANDSCAPING

8.1. Swales

8.1.1. Overview

How this retrofit helps reduce flood risks:

Swales

A swale is a shallow, sloped, and vegetated channel that collects and drains water runoff. The channel slopes and flat bottom help to drain and absorb water from other drainage systems, such as downspouts or sump systems (**Cambridge City Council, n.d.**). More complex swales might include lining, underdrains, and filter strips to support channel retention and the filtering of pollutants, though these are primarily used in municipal infrastructure and not in a residential context (**Cambridge City Council, n.d.**; **Five Counties Salmonid Conservation Program, 2022**; **Larrey-Lassalle et al., 2024**).

Types of swales:

There are two main types of swales:

- ***Wet swale:*** A wet swale incorporates marshy conditions and shallow pools of water to function like a miniature wetland and filter out environmental contaminants (**Cambridge City Council, n.d.**; **Federal Highway Administration, 2018**). This design is more suitable for areas with a relatively high water table, or with poor soil permeability (**Larrey-Lassalle et al., 2024**). Note that a wet swale runs the risk of creating mosquito breeding areas in urban areas (**Larrey-Lassalle et al., 2024**).

- ***Dry swale:*** Dry swales are more common in residential settings than wet swales (**Larrey-Lassalle et al., 2024**). The swale design incorporates the use of permeable soils and an underdrain, which provides relatively quick stormwater infiltration and conveyance (**Larry-Lassalle et al., 2024**). Dry swales may incorporate check dams, which reduce the speed of water entering the swale and promote infiltration (**Aukland Council, n.d.**; **Larry-Lassalle et al., 2024**).

Left: An example of a swale with a wet base. Swales that contain vegetation are called **bioswales** (**Newton, 2024**).

Right: An example of a swale with a dry base. Swales without planted vegetation are called **grass swales** (**Sustainable Technologies, 2023**).

Left: The blue arrows denote a gradually sloped **filter strip**. This directs runoff to a filter drain and/or swale (**Cambridge City Council, n.d.**).

8.1.2. Design parameters: Swales

There are many factors to consider when designing and installing a swale, including:

LOCATION:

- A swale should be located in an area along the property where it is able to transport water away from the building foundation and towards a suitable drainage area, such as a grassy low point or even an existing garden bed (**Melbourne Water, n.d.**).
- Ensure that the beginning of the swale is located beneath downpipes (**Melbourne Water, n.d.**).
- Check with the local government to ensure that any existing drainage plans are not affected by the intended swale location (**Sandink, 2009**).

DESIGN:

- The exact size and length of the swale is dependent on the size and conditions of the property, as well as the homeowner's discretion.

- The Environmental Protection Agency [EPA] recommends that regardless of size, swales should meet the following criteria:
  - The side slopes of the swale channel should be no more than 3:1, or 33% (e.g., 3 inches of depth for every 1 inch of length) (**EPA, 2021**; **Larrey-Lassalle et al., 2024**).
  - The slope of the swale channel itself should be around 2% to 4%—or 1/4 – 1/2 inches of depth for every 1 foot of length (**EPA, 2021**).
  - The shape should resemble a trapezoidal or triangular formation (**EPA, 2021**; **Melbourne Water, n.d.**).
  - The swale should not be built over or within the proximity of any utility lines, septic services, or piping (**EPA, 2021; Melbourne Water, n.d.**).

SOIL PERMEABILITY & WATER TABLE:

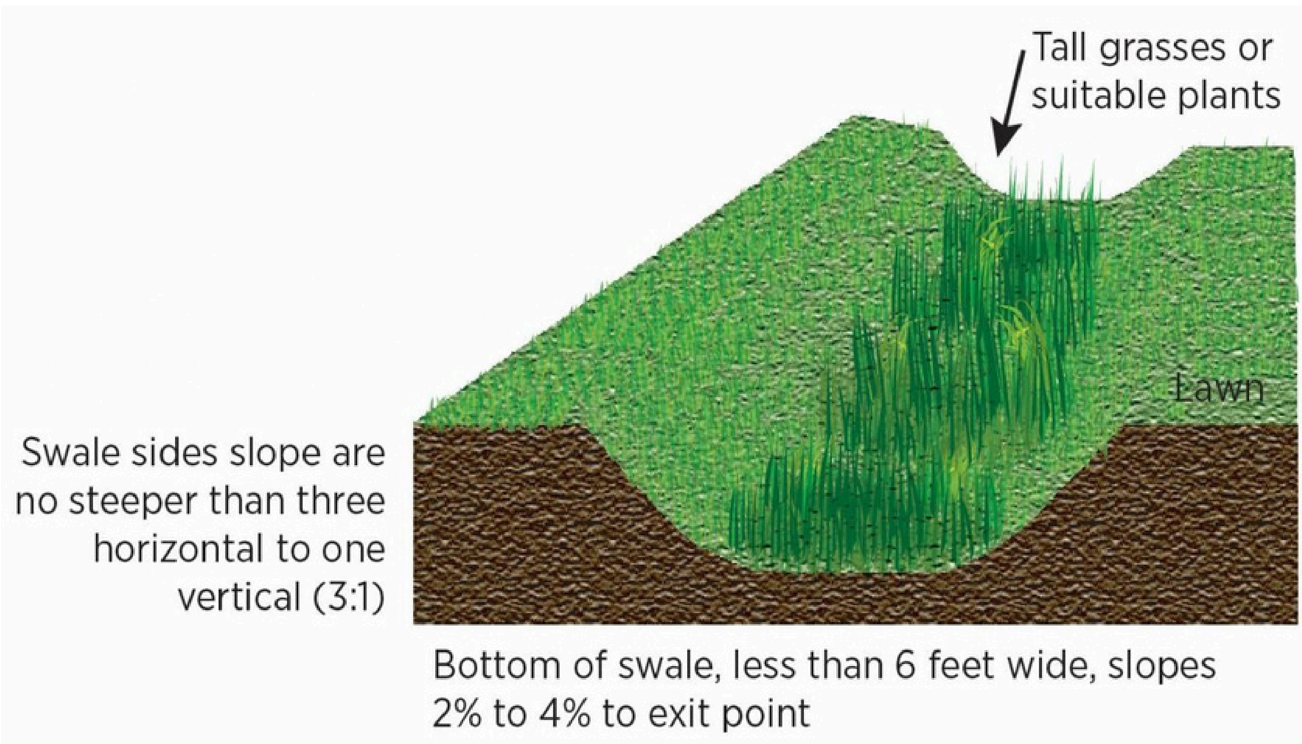
- Soil permeability and the water table level in the desired swale site will determine the suitable swale type and its design characteristics.
  - For soils with low permeability or in areas with a relatively high water table, a wet swale may be a preferable choice over a dry swale (**Larrey-Lassalle et al., 2024**).

- Planting vegetation along and within the swale channel enhances water infiltration capacities and helps to filter contaminants from the runoff (**Federal Highway Administration, 2018**; **Larrey-Lassalle et al., 2024**).

- Vegetated swales may incorporate an aggregate bed which is covered by a non-woven geotextile fabric; however, this approach is more costly than a traditional grass swale (**Larrey-Lassalle et al., 2024**).

STORMWATER DIVERSION:

- During swale construction, a temporary downpipe diversion may be necessary to reduce the risk of flooding (**Melbourne Water, n.d.**). Consult a plumber to determine the "depth and location of the stormwater outlet for the overflow" (**Melbourne Water, n.d.**).
- If a stormwater surface pit or catch basin is located on the property, the swale can be designed to convey stormwater from the diverted downpipe (**Melbourne Water, n.d.**).
- Ensure that the swale does not discharge runoff onto neighbouring properties (**City of Burlington, 2020**).



Above: Swales are trapezoidal channels dug to receive stormwater overflow, with specific vegetation planted to improve aesthetics, filter stormwater runoff, and prevent erosion (**Building America Solution Center, n.d.-b**).

8.1.3. Installation guide: Swales

1) Excavate the site

a. Excavate along the designated location to form the swale channel.
   - **Melbourne Water** (**n.d.**) recommends excavating to a maximum depth of 11 to 12 inches, while the **City of Burlington** (**2020**) recommends a minimum depth of 6 inches (150 millimetres) and a maximum depth of 11 inches (300 millimetres).
     - Consult with municipal guidelines, drainage plans, and regulations.
     - Note that the exact depth may need to be adjusted depending on the conditions of the property soil and the depth of the water table. The key is to ensure that the slopes are maintained as noted below.
   - **Building America Solutions Center** (**n.d.-b**) recommends a maximum width of 6 feet.

b. Ensure that the side slopes do not exceed a 3:1 ratio (depth/vertical to length/horizontal) (**City of Burlington, 2020**; **Ekka et al., 2021**; **EPA, 2021**).

c. Ensure that the base of the channel is wide enough for lawnmower access and that it is graded downwards away from the foundation at a 2% to 4% slope (**EPA, 2021**; **Larrey-Lassalle et al., 2024**).

d. Do not compact the soil at the base of the channel, as it acts as a filter for water flow (**Building America Solution Center, n.d.-b**; **EPA, 2021**).

2) Connect the swale to the drainage area

a. While the swale itself is meant to act as a drainage area, its excavation should still lead from a water inflow point to a designated outflow area. This can be a rain garden, catchment basin, or simply a vegetated low point along the property away from the foundation (**Building America Solution Center, n.d.-b**).

b. Again, ensure that the entirety of the swale from the initial inflow to the designated outflow maintains a slope of 2% to 4%. Additional excavation or refilling may be necessary.

3) Infill the excavated channel

a. Infill the excavated area such that a minimum of 4 inches of topsoil can be added while maintaining the necessary side and base channel slopes (**EPA, 2021**; **Melbourne Water, n.d.**).
   - The topsoil layer will allow for the planting of native plants and vegetation.
   - Ensure that the topsoil layer is not compacted and that it is free of impermeable clays to allow water to properly infiltrate.

b. Depending on how loose the topsoil is, a layer of smooth rocks and gravel can be lined around the excavated channel to prevent erosion prior to adding the topsoil (**Building America Solution Center, n.d.-b**; **Melbourne Water, n.d.**; **Savage et al., 2021**). A layer of geotextile fabric can be laid out beneath the rocks if desired (**Melbourne Water, n.d.**).

c. It is best to consult a professional engineer to determine the best way to stabilize the swale and preserve its function.

4) Cover with vegetation

a. A combination of tall and stiff grasses, along with other native plants, will work best to manage water infiltration (**Ekka et al., 2021**).
b. Plant vegetation such that the entire length and width of the swale is covered.
   - **Melbourne Water** (**n.d.**) recommends a ratio of six plants per square meter, although this will also be dependent on the plant type.
   - Ensure the surface is watered regularly to facilitate healthy plant growth.
c. ***Wet swale specific:*** A wet swale will need to incorporate permanent, shallow pools of water and utilize wetland vegetation (**Larrey-Lassalle et al., 2024**).

8.1.4. Key considerations and actions to avoid risk

Maintenance:

- Avoid applying fertilizer, sand, or salt around the swale (**EPA, 2021**).
- ***Dry swale specific:*** Dry swales that are exclusively grassed (i.e., no native plants utilized) should be mowed to a height of 3 to 6 inches (**Anne Arundel County Department of Public Works, 2023**; **EPA, 2021**).

Vegetation:

- It is ideal to plant a diversity of native, perennial plants and grasses that can tolerate both wet and dry conditions (**Melbourne Water, n.d.**).

Underdrain:

- An underdrain system may be incorporated. This would consist of a perforated pipe system lined with filter fabric underneath the base channel of the swale (similar to a French drain / weeping tile) (**Building America Solutions Center, n.d.-b**).
  - A professional engineer can assist in determining whether this is necessary.

Erosion:

- Check dams are rock/gravel structures placed along the downstream end of a swale (**Ekka et al., 2021**). These can be added to help minimize erosion and sediment loss and should be built in a way that does not inhibit the flow of water through the swale channel (**Ekka et al., 2021**).
- While establishing plant cover, erosion control matting can be added to prevent erosion and enhance longevity (**Lake Superior Streams, n.d.; New Jersey Department of Environmental Protection, 2014**).
- Using shallow slopes, direct the sheet flow of surface water towards the side of the channel (**Larrey-Lassalle et al., 2024**). Flow spreading devices, like check dams, can help to reduce water velocity, especially for swales with concentrated/single inflow points (**Larrey-Lassalle et al., 2024**).
- Inspect regularly for signs of erosion, especially after heavy rainstorms (**Anne Arundel County Department of Public Works, 2023**).

8.2. Site grading

8.2.1. Overview

How this retrofit helps reduce flood risks:

Site Grading

Site grading is the reshaping of land around the property foundation in a way that helps to passively move and direct water away from the home's structure.

Note: A swale can be described as a specific type of site grading that specifically creates a depression in the ground for water drainage. Site grading is a more general activity that can be done in different ways to support drainage along different areas of the home. Site grading can vary greatly depending on the exact scope and purpose of the grade.

8.2.2 Installation guide: Site grading

The exact steps required for site grading will vary depending on the nature and purpose of the project. Note that the act of site grading may be done when installing any other retrofits, especially sump systems, swales, berms, catchment basins, and rain gardens. Many retrofit projects require a slope sufficient for drainage, which will often require some sort of site grading.

If done in isolation, the two most common forms of site grading are:

- **Back-to-front grading**
  - The rear lot line acts as the high point of elevation on the property, directing surface water to flow from the rear lot toward the front of the property (**City of Winnipeg, n.d.**). This type of grading is recommended for houses built on hillsides or mountains where the home already sits on a back-to-front slant (**Swinton & Kesik, 2008**).
- **Split-site grading**
  - The house is the highest point of the lot with water draining forwards toward the street and backwards toward the rear line (**City of Winnipeg, n.d.**). This type of grading is the most common and is suitable for houses built on flatter land (**Swinton & Kesik, 2008**).

Above: A schematic of back to front grading (**City of Winnipeg, n.d.**).

Above: A schematic of split side grading (**City of Winnipeg, n.d.**).

8.2.3. Key considerations and actions to avoid risk

Drainage:

- A minimum downward slope of 2% will adequately transport water away from the building (**Sandink, 2009**; **Savage et al., 2021**).
- The 2% slope should extend 10 feet past the building foundation or, at a minimum, extend beyond the backfill zone (**Savage et al., 2021**).
- Site grading should direct surface drainage away from window wells, exterior stairwells, decks, and driveways to minimize flood risks. Site grading should be done in such a manner that water does not pool along the property.
- Site grading should not direct drainage directly into neighbouring properties. Incorporating a swale in between houses that can direct and control drainage may be necessary (**City of Brampton, n.d.**). If a shared swale cannot be excavated in between adjacent properties, homeowners may be required to construct internal swales on their own property (**City of Brampton, n.d.**).

Above: The illustrations show a shared swale on the property line between the two houses. On the left, a split-side grade is shown, while on the right is a back-to-front grade (**City of Brampton, n.d.**).

8.3. Berms

8.3.1. Overview

How this retrofit helps reduce flood risks:

Berms

A berm is a raised hill of compacted, dense sediment that can control the velocity and flow rates of water. Berms can act as a barrier to resist the force of flood waters. Note that berms are sometimes referred to as levees or even dikes (**Alberta Water, 2023**). Berms are more commonly used in a residential context and are constructed with earth-fill and grass. Levees and/or dikes can be more complex structures used for managing stormwater/floods at a municipal scale.

8.3.2. Design parameters: Berms

There are many factors to consider when designing and installing a swale, including:

LOCATION:

- Both a professional engineer and the local jurisdictional authority should be consulted before any excavation occurs.
  - Understand that a berm functions by redirecting water away from the property, which can have implications on neighbouring properties and municipal storm sewer capacity (**Investment Agriculture Foundation, 2022**).
  - The type and density of soil around the property and the home's foundation will affect the amount of seepage that may occur.
  - A berm is a hill of compacted sediment. Understanding the risk of seepage is key in preventing erosion along other critical areas of the property and in reducing the chance of the berm collapsing.
- Provincial and municipal regulations may dictate specific requirements that prevent a berm from being located too close to designated drainage basins or watercourses.

FILL:

- The fill used to construct the berm should be impermeable and stone-free. A minimum of 10% clay material is recommended (**Government of New Brunswick, n.d.**).
- Avoid wet, fine-grained, highly organic soils, and highly expansive clays (**FEMA, 2012**).
- To support the growth of grass and vegetation, a minimum of 6 inches of topsoil is recommended (**Government of New Brunswick, n.d.**).

SLOPE:

- If the soil around the property and foundation is predominantly clay-based, a 3:1 base-to-height slope ratio on the land side of the berm is recommended (**FEMA, 2012**; **Government of New Brunswick, n.d.**).
- If the soil around the property and foundation is predominantly sandy, a 5:1 base-to-height slope ratio on the land side of the berm is recommended (**FEMA, 2012**).
- A 2.5:1 floodwater side slope is recommended to minimize the potential for erosion and to increase the stability of the berm (**FEMA, 2012**).

8.3.3. Installation guide: Berms

1) Excavate the berm site

a. Mark out the border of the desired site of the berm.
b. Excavate the topsoil within the border outline. Any excavated soil can be saved for refilling the berm.

2) Fill and compact the layers of the berm

a. Begin pouring the selected fill into the excavated area, layer by layer and compacting each time. No single layer should exceed a thickness of 6 inches before compacting (**FEMA, 2012**; **Government of New Brunswick, n.d.**).
b. The **Federal Emergency Management Agency** (**2012**) recommends constructing the height of the berm to be 5% higher than designed, which will allow the soil to settle, although this is dependent on the exact type of fill used.

3) Apply topsoil, taking care to maintain proper slope

a. Ensure that there is enough space so that a minimum of 6 inches of topsoil can be applied, all while maintaining the required slope (**FEMA, 2012**).

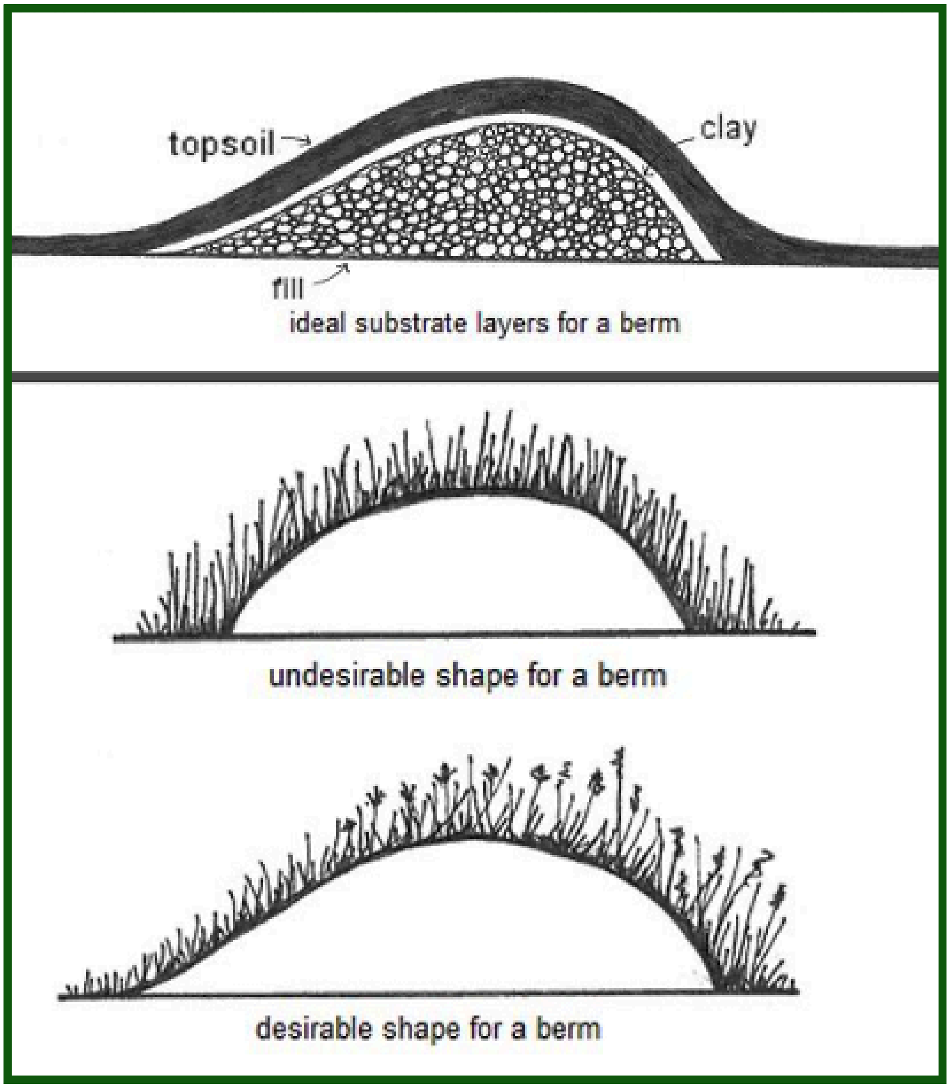
8.3.4. Key considerations and actions to avoid risk

***Maintenance*:**

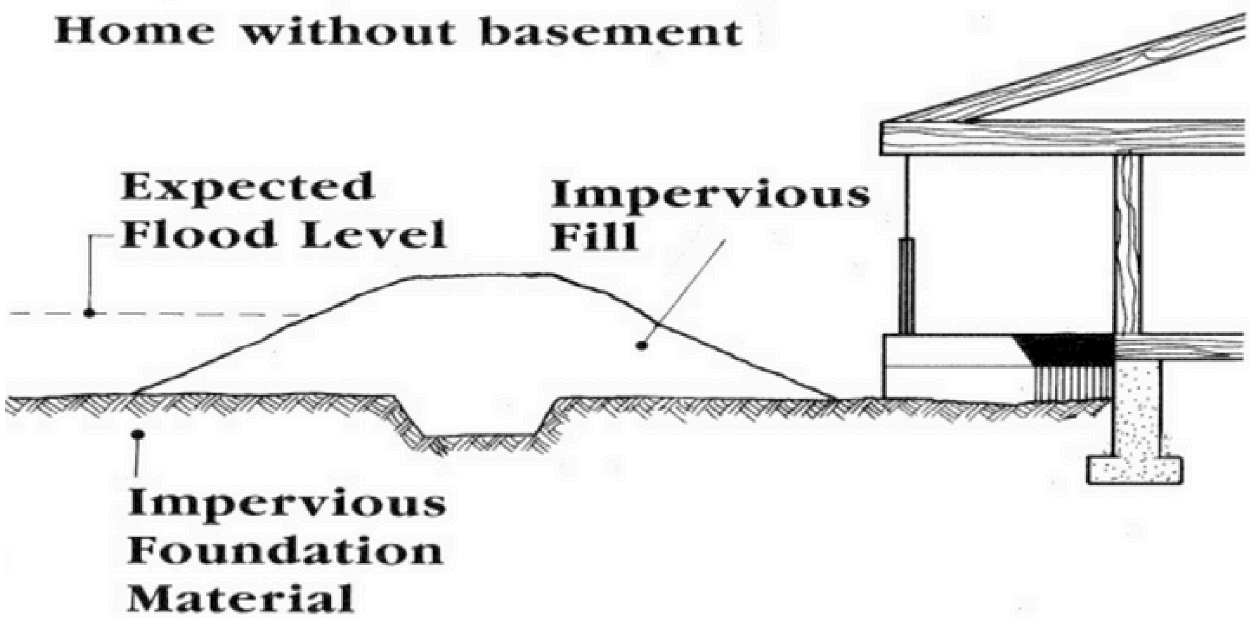
- After installation, regular inspections should be performed to ensure that the drainage of snowmelt and water has not been disrupted by debris or erosion of the berm (**Investment Agriculture Foundation, 2022**).
- If excessive pooling is identified, the berm should be dispersed and rebuilt (**Government of New Brunswick, n.d.**).

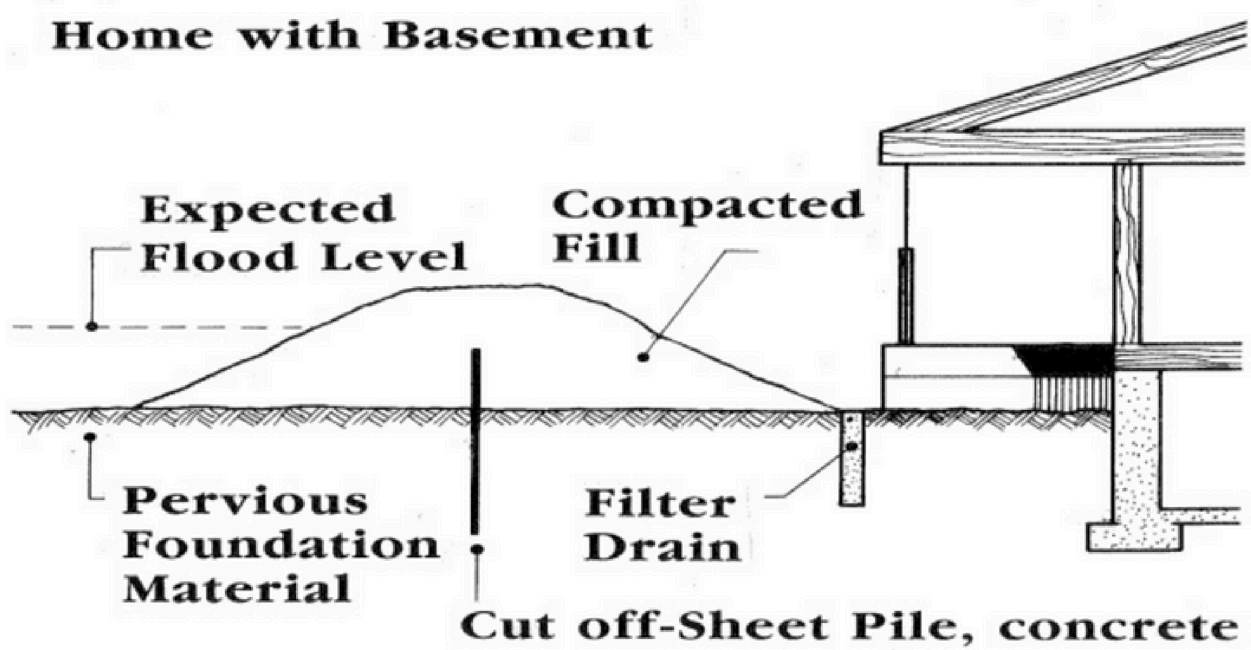
Soil:

- Beginning construction in summer or early fall is recommended so that the soil is drier and more workable (**Government of New Brunswick, n.d.**).
- Consider the permeability of the soil around which the berm is being built. Sandy soil is highly pervious to water, which can undermine the berm's ability to resist water forces and may result in seepage underneath.
    - As a method of reducing the risk of water seepage from the berm, cut-off walls or filter drains can be placed beneath the soil layer, in between the berm and the property foundation (**Government of New Brunswick, n.d.**).



Above: Leave a foot of space between the infill and the border outline of the berm, to allow for the layer of topsoil (**Government of New Brunswick, 2019**). Note that this image incorporates a clay layer, although this is not necessary if the sediment fill is already impermeable or consists of clay (Photo: **Don's Notes, 2017**).



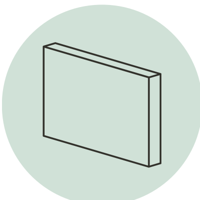


Above: According to the **Government of New Brunswick** (**2019**), "an important consideration in the design of a berm is the ability of the soil to permit the passage of water. If the soil is porous, seepage into the basement of the nearby home is possible. The use of cutoff walls, or blanket drains, beneath the berm is one way to prevent such seepage."

8.4. Flood wall

8.4.1. Overview

How this retrofit helps reduce flood risks:



Floodwall

A flood wall is an anchored and “reinforced wall able to withstand hydrostatic and hydrodynamic pressure” (**FEMA, 2007**). Flood walls are usually only considered in areas without sufficient space to build a berm. This may also be called a retaining wall or a perimeter-engineered barrier (**Association of State Floodplain Managers [ASFPM], 2022a**).

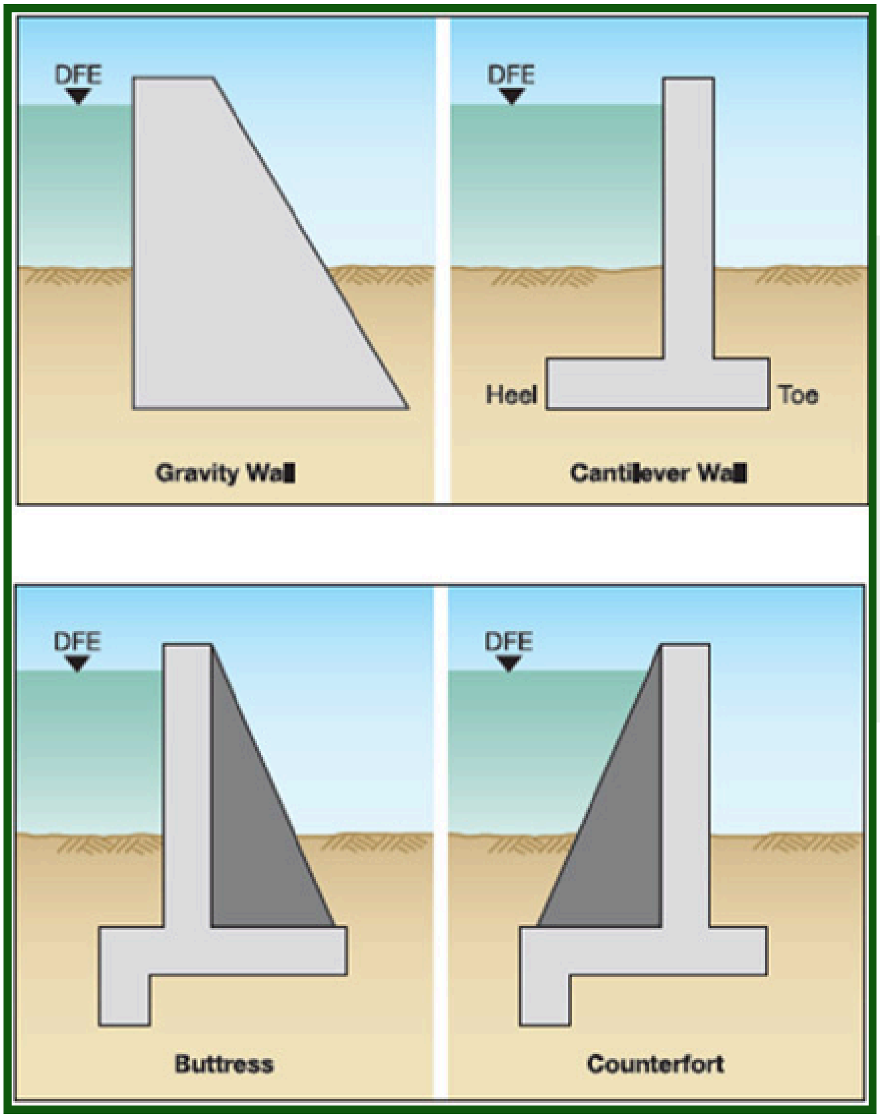
Flood walls are usually constructed using reinforced concrete, and can range from 1 to 5 feet in height (**ASFPM, 2022a**). The size and scale of the flood wall can be designed and altered to protect the entire building or to prevent water from entering specific openings, such as garages, doors, and windows (**ASFPM, 2022a**).

Design will vary depending on the desired scope and purpose. Flood walls may involve either automatic (i.e., ‘passive’) or manual closure mechanisms (**ASFPM, 2022a**).

8.4.2. Types of flood walls

According to **FEMA** (**2012**), the main types of flood walls are:

- ***Gravity flood wall:*** This is the simplest type of flood wall, although it requires a lot of concrete. The stability of this type of flood wall is reliant on the pure weight of the concrete base.
- ***Cantilever flood wall:*** This type of flood wall is cheaper to design and construct, and is most commonly used for residential structures. Cantilever flood walls are designed using a concrete wall that is reinforced by a steel bar.
- ***Counterfort flood wall*:** The supporting walls are hidden under water or soil for this type of flood wall. It is also rarely used in residential structures.
- ***Buttress flood wall:*** The concrete buttress is located on the opposite side of the retaining water side. It is not as commonly used due to the amount of usable space it takes up and is similar in design to a counterfort floodwall.



Left: The main types of flood walls are shown. In this diagram, DFE (Design Flood Elevation) refers to the highest flood elevation that a retrofitting method is designed to protect against (**FEMA 2012**).

8.4.3. Installation guide: Flood walls

To install, a professional engineer will first need to perform an analysis to provide an exact plan for construction, operation, and maintenance.

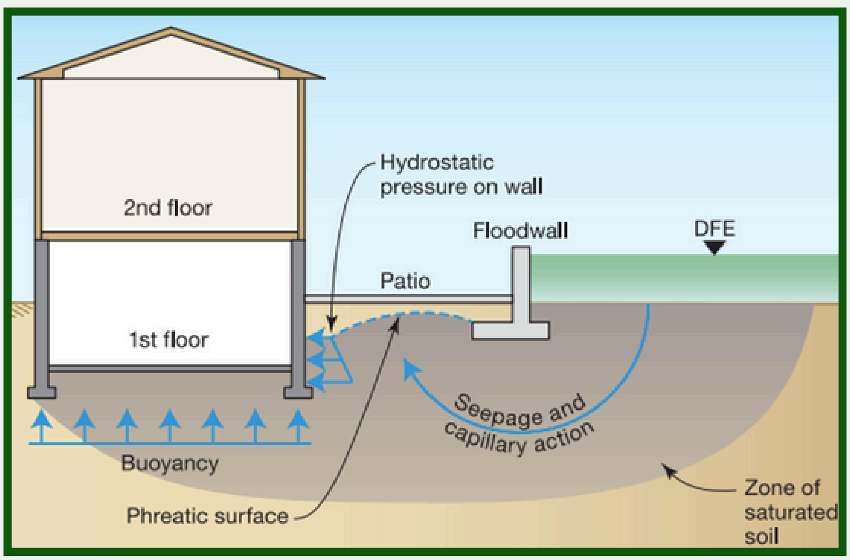
8.4.4. Key considerations and actions to reduce risk

Vegetation:

- Landscaping materials, such as vegetation and stone aggregate, can be used to prevent erosion and scour (**FEMA, 2012**). However, when planting vegetation around the flood wall, it is important to consider how roots and tree growth may impact the structure and to consult a local landscape architect (**FEMA, 2012**).

Seepage:

- For below-grade foundation structures, the risk of seepage underneath the flood wall can create saturated soil pressures that the existing foundation may not be able to withstand (**FEMA, 2012**).
- Installing a foundation drainage system (i.e., French drain, sump system) can help to alleviate the flow of water seepage underneath the flood wall (**FEMA, 2012**).
- To prevent seepage along the floodwall structure, "all expansion and construction joints within the floodwall [must] be constructed with appropriate water stops and joint sealing materials" (**FEMA, 2012**).
- Additionally, there is often a gap, or 'expansion joint,' between the flood wall and the exterior home structure (**FEMA, 2012**). To prevent leakage, seal the gap with waterproof materials, such as bulb-type water seals, high-density caulking, and bituminous expansion material (**FEMA, 2012**). The chosen filler should be designed to withstand expansion and contraction from freeze-thaw cycles (**FEMA, 2012**).



Left: This image shows the risk of increased hydrostatic pressure that can be applied to buildings with below-grade foundations. Floodwaters create a zone of saturated soil underneath the flood wall. Adding a drainage system along the foundation, such as a sump system or French drain, can help alleviate this risk (**FEMA, 2012**).

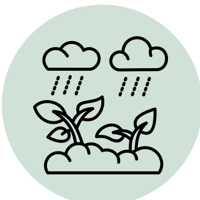
Annual inspection:

- The flood wall's structural integrity should be inspected annually. **FEMA** (**2012**) recommends completing a visual inspection that includes the following checklist:
  - "General flood wall observations involving: wall cracking (length, width, locations), deteriorated mortar joints, misalignments, chipping, etc.;
  - Sealant observation, including displacement, cracking, and leakage;
  - Overall general characteristics of the site, including water ponding/leakage, drain(s), and drainage and site landscaping;
  - Operation of the sump pump, generator/battery, and installation of any closures;
  - Testing of drains and backflow valves."

8.5. Rain gardens

8.5.1. Overview

How this retrofit helps reduce flood risks:

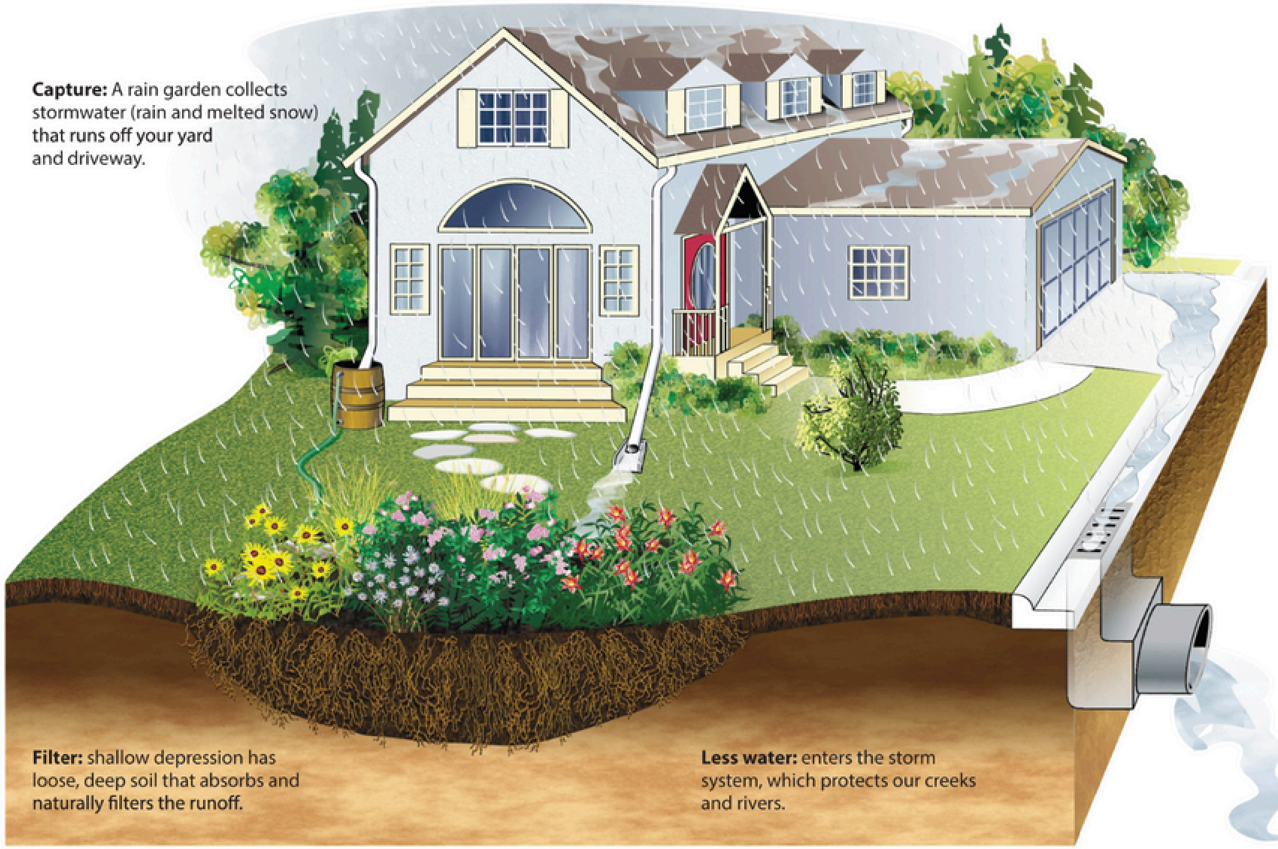


Rain gardens

Rain gardens—sometimes called bioretention systems—are shallow, excavated areas comprised of "loose, deep soil that absorbs and naturally filters the runoff" (**Toronto and Region Conservation Authority [TRCA], 2018b**). Existing lawn is replaced by soil and other materials, including native vegetation, that are able to take in water at higher rates (**TRCA, 2018b**). Rain gardens are best suited for lower-volume rain events, and tend to drain within 12 to 48 hours (**Groundwater Foundation, 2022**).

***Note*:** Rain gardens are versatile in design, and can be adapted to suit a homeowner's individual needs and preferences (**TRCA, 2018b**). Rain gardens can range in size from property-wide landscaping to being incorporated at a smaller scale throughout pockets of available space within the yard (**TRCA, 2018b**).

Left: An example of a residential rain garden (**TRCA, 2018a**).



Above: A schematic of a rain garden. Note that water is being directed from the downspouts and rain barrels towards the rain garden (**City of Calgary, n.d.**) Rain barrels are another useful stormwater management installation. These collect and store rainwater from the roof, and can be used to water gardens and lawns (**TRCA, 2018a**).

The many added benefits of rain gardens

According to the **Toronto Region and Conservation Authority** (**2018b**), in addition to reducing flood risks and improving stormwater drainage, rain gardens provide added benefits, such as:

- Minimizing erosion and retaining soil
- Filtering pollutants from water runoff
- Recharging groundwater systems
- Attracting pollinators

8.5.2. Design parameters: Rain gardens

When designing and installing a rain garden, consider the following factors:

SITE FEASIBILITY:

- The rain garden should be located a minimum of 10 feet (3 metres) away from the building to ensure that water does not infiltrate into the home's foundation (**Chicago Botanic, 2003**; **TRCA, 2018b**).
- Rain gardens require relatively flat terrain with a slope of 1% to 5% (**City of Richmond Hill, 2024**; **TRCA, 2018b**).
- ***Inflow:*** The garden should be located downhill from a source of water to feed into the garden space, such as a downspout, French drain, or rain barrel (**Chicago Botanic, 2003**; **City of Richmond Hill, 2024**; **TRCA, 2018b**).
- ***Overflow:*** Likewise, the garden should be uphill (no steeper than a 1-5% slope) from a grassy area to direct overflow (**Chicago Botanic, 2003**).
- The rain garden should be clear of any underground utility lines or tree roots (**Canadian Mortgage and Housing Corporation, 2011**).

SOIL TYPE:

- A soil test can be done by digging a 6-inch (15-centimetre) hole and filling it with water (**City of Richmond Hill, 2024**). If after 24 hours, the water has not fully dissipated into the ground, the soil is not suitable (**Chicago Botanic, 2003**, **City of Richmond Hill, 2024**).
- This can be amended by replacing the soil within the designated site with 'rain garden soil.'
    - ***If replacing clay:*** Use a 60% sand / 40% compost mixture (**Reep Green Solutions, 2024**).
    - ***If replacing sandy or loam soil:*** Use a 60% existing soil / 40% compost mixture (**City of Richmond Hill, 2024**; **Reep Green Solutions, 2024**).

PLANT TYPE:

- Native plants that can tolerate both flooding (from large storms) and drought (low rainfall periods) conditions should be selected for the rain garden for maximum resilience (**Chicago Botanic, 2003**; **Reep Green Solutions, 2024**). This should be a mixture of shrubs, flowers, and grasses (**TRCA, 2018b**).

SIZING:

- It is recommended that the total surface area of the rain garden equal 1/10th to 1/6th of the size of the drainage area (**Reep Green Solutions, 2024**; **Princeton Hydro, 2021**).

8.5.3. Installation guide: Rain gardens

1) Mark out the area

a. Mark out the designated area for the rain garden with a shovel using ground paint or wooden stakes.
b. The area through which the water will reach the rain garden, as well as the water overflow areas, should also be marked.
c. For a more technical guide, including calculations, refer to the following resources: **Iowa Stormwater Education Partnership, 2021**; **Pacific Water Research Centre, 2023**; **Southeast Michigan Council of Governments, 2008**.

2) Excavate

a. The rain garden should then be dug to a depth of about 3 feet (85 to 100 centimetres) (**City of Richmond Hill, 2024**).
b. Do not compact the soil while excavating. Avoid standing inside the hole or placing down heavy objects.

3) Add in the soil mixture

a. Add the rain garden soil mix to the excavated garden area, filling approximately 70% of the hole, or to a depth of 2 feet (60 centimetres) (**City of Richmond Hill, 2024**; **Reep Green Solutions, 2024**).
b. Leave approximately 10 inches of space (25 centimetres) of space to accommodate vegetation, mulch, and rainwater (**City of Richmond Hill, 2024**; **Reep Green Solutions, 2024**).
c. When filling with the rain garden soil, tamp down the area using a shovel or feet every few layers (approximately every 8 inches or 20 centimetres) (**City of Richmond Hill, 2024**).

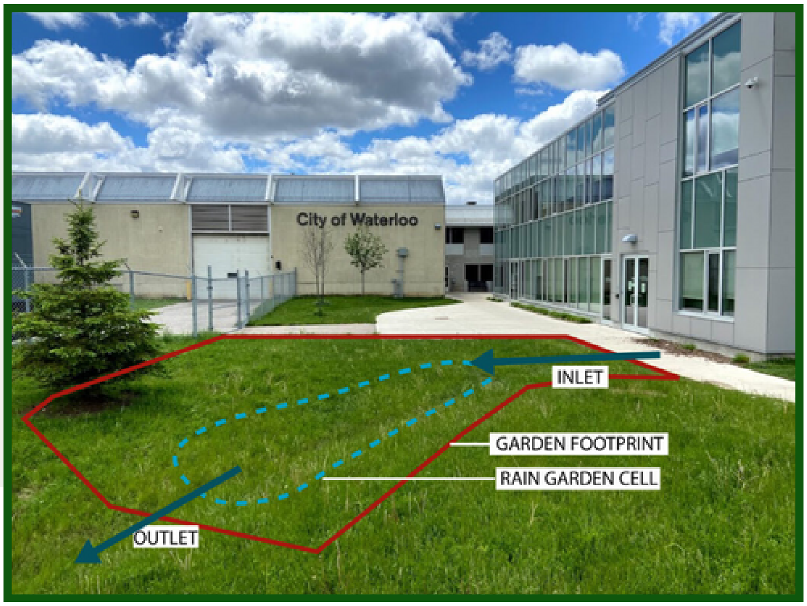
4) Create an inflow inlet and overflow channel

a. Create an inlet, the area whereby water enters the rain garden from a water source, such as a downspout, overflow pipe, infiltration trench, or French drain (**City of Richmond Hill, 2024**).
b. Create an overflow, the channel for water to exit the rain garden in the event of excess water. Although the soil will typically absorb water during normal conditions, heavy rainfall events can lead to heavy saturation, requiring an outlet to redirect any excess water (**City of Richmond Hill, 2024**).
c. ***Inflow Inlet:*** An inlet can be designed by placing small stones around the area through which the rain garden will connect to the water source (**City of Richmond Hill, 2024**). This will help to minimize soil erosion and slow down water flow (**City of Richmond Hill, 2024**).
d. ***Overflow Channel:*** The overflow should be located on the downhill side of the rain garden, directing excess water towards a second garden or an open area of lawn (**Reep Green Solutions, 2024**). Again, small stones should be placed at the outlet (**City of Richmond Hill, 2024**).

5) Plant garden variety

a. Plant the rain garden, ensuring the chosen plants do not reach too deep into the soil.
b. Plants will need to be watered every few days until established, a process that typically takes about 4 weeks (**Reep Green Solutions, 2024**). Watering is most effective in the early morning and evening, and it is important not to overwater, as this can reduce soil and plant health (**TRCA, 2018b**).
c. Fill excavated soil around the plants so that vegetation is held in place.
d. Apply a mulch layer no deeper than 2 to 4 inches (10 centimetres) (**TRCA, 2018b**). Mulch is beneficial in reducing weed cover, protecting against drought and erosion, and enhancing water filtration and absorption (**TRCA, 2018b**). Maintain the mulch layer and check annually to ensure adequate depth (**TRCA, 2018b**).

Right: In this sample photo, the rain garden has been designed such that the inlet can direct water runoff from the building into the lawn area towards the overflow outlet (**Reep Green Solutions, 2024**).



Left: Line the inflow inlet and overflow channel with landscaping fabric and stones (**Reep Green Solutions, 2024**).

8.5.4. Key considerations and actions to reduce risk

Drainage:

- Soil erosion and debris can gradually clog the soil mix and reduce drainage effectiveness. The inlet and overflow areas should be inspected for debris clogs, such as leaves, sticks, and other blockages, a minimum of twice a year (**TRCA, 2018b**).

Soil:

- Check regularly to ensure that there is no exposed soil in need of additional mulch (**TRCA, 2018b**; **Reep Green Solutions, 2024**).
- Dead plants should be replaced, and fertilizer should not be applied (**TRCA, 2018b**).
- To protect the soil and add a decorative element to the rain garden, add a covering of rocks around the inlet and outlet areas (**Reep Green Solutions, 2024**; **TRCA, 2018b**).

Plant type:

- The use of native plants is strongly recommended, as these will be best suited for the local climate.
- Consulting a local horticulturist or biodiversity expert to help identify suitable native plants that are both appropriate for the local environment and work well in a rain garden.
    - In Nova Scotia, the following resources are recommended:
        - K.C. Irving Environmental Science Centre & Harriet Irving Botanical Gardens, Acadia University.
        - **Nova Scotia Wild Flora Society** (**n.d.**): *Gardening with native plants.*
        - **New Brunswick Invasive Species Council & Nova Scotia Invasive Species Council** (**2023**): *Grow me instead.*

Left: This inlet and outlet use rocks to guide and direct the flow of water (**Reep Green Solutions, 2024**).

Bylaws, Building Codes, & Standards

Laws & bylaws

What documents apply, and how are these enforced or applied to buildings?

Discharge, stormwater, and water use bylaws/ regulations
E.g., Halifax Water Regulations

- Municipality-specific laws that must be abided by
- For flood risk measures, the most relevant bylaws will be those concerning water use and discharge.

Standards

What documents apply, and how are these enforced or applied to buildings?

CSA Z800-18: Guidelines on Basement Flood Protection

- Outlines guidelines on flood protection, specifically focusing on basements and foundations.

CSA A23.1-19: Concrete Materials and Methods of Concrete Construction

- Outlines guidelines for all concrete designs which cover foundations and walls.

Building codes

What documents apply, and how are these enforced or applied to buildings?

Nova Scotia Building Code Regulations

- Outlines disclosures for sewage, water, electrical, mechanical and structural systems for new buildings, and alterations or reconstructions for existing buildings.

What regulations and guidelines most affect buildings in Halifax?

Buildings in Halifax must comply with the ***Nova Scotia Building Code Regulations***, which are based on the ***National Building Code of Canada***. The National Building Code of Canada is a model code, meaning that it guides the provincial guidelines.

Key takeaways from the Nova Scotia Building Code Regulations

When does the code apply?

- Building codes apply for all new construction. Building codes also apply to “alteration, reconstruction, demolition, removal, relocation, occupancy and change of occupancy classification of existing buildings.”
- If unsafe conditions are reported to a building official or observed during an inspection, the building codes apply to the necessary work.
- If a building was damaged by a natural hazard or fire, the building code applies to the reconstruction.

When does the code not apply?

- Municipally owned structures for public use that qualify as:
  - “Sewerage, water, electrical, telephone, rail or similar systems located above, below or on an area that is dedicated or deeded for public use;”
  - “Public utility towers and poles, television and radio or other communication aerials and towers, except for loads resulting from those located on or attached to buildings;” and
  - “Structures that are not buildings including but not limited to: flood control structures, dams for public water supply, hydroelectric dams and their related structures.”
- Mechanical or other equipment and appliances not specifically regulated by the Code.
- Above-ground or below-ground bulk storage tanks are not regulated under Part 6 of the National Building Code or the National Farm Building Code.
- Free-standing signs and fences.
- Auxiliary small structures that do not require construction.
- Small buildings below a certain size.
- Retaining walls or exterior steps not attached to, and forming part of, a building’s construction.
- Manufactured and modular homes have some exceptions.

How are the Nova Scotia Building Code Regulations applied and enforced?

- Building codes are enforced through legislation, including the ***Nova Scotia Building Code Act***.
- Professionals, such as architects, constructors, professional engineers or interior designers, have an obligation to design within the building code.
- Owners are responsible for their building meeting the code.
- Construction that does not comply with the building code will be given a building permit by the municipality and may face legal action such as fines.

FOR COMPLETE DETAILS, VISIT THE FOLLOWING:

- **Nova Scotia Building Code Regulations**
  https://novascotia.ca/just/regulations/regs/bcregs.htm
- **National Building Code of Canada**
  https://nrc.canada.ca
- **Nova Scotia Building Code Act**
  http://nslegislature.ca/legc/statutes/buildcod.htm

References

Chapter 1: Introduction

Bakos, K., Feltmate, B., Chopik, C., & Evans, C. (2022, February). *Treading water: Impact of catastrophic flooding on Canada's housing market.* Intact Centre for Climate Adaptation, University of Waterloo. https://www.intactcentreclimateadaptation.ca/wp-content/uploads/2022/04/UoW_ICCA_2022_02-Treading-Water_Flooding-and-Housing-Market.pdf

Henson, B., & Masters, J. (2022, September 24). Fiona sets Atlantic Canada reeling; Ian forms in Caribbean. *Yale Climate Connections.* https://yaleclimateconnections.org/2022/09/fiona-sets-atlantic-canada-reeling-ian-forms-in-caribbean/

Insurance Bureau of Canada. (2022, January 18). Severe weather in 2021 caused $2.1 billion in insured damage. http://www.ibc.ca/qc/resources/media-centre/media-releases/severe-weather-in-2021-caused-2-1-billion-in-insured-damage

Insurance Bureau of Canada. (2023, January 18). Severe weather in 2022 caused $3.1 billion in insured damage – making it the 3rd worst year for insured damage in Canadian history. http://www.ibc.ca/ab/resources/media-centre/media-releases/severe-weather-in-2022-caused-3-1-billion-in-insured-damage-%E2%80%93-making-it-the-3rd-worst-year-for-insured-damage-in-canadian-history

Mitchell, K. (2022, September 26). Kalin's Call: Storm summary for record-setting Fiona. *CTV News.* https://atlantic.ctvnews.ca/kalin-s-call-storm-summary-for-record-setting-fiona-1.6084984

Moudrak, N., & Feltmate, B. (2019, January). *Weathering the storm: Developing a Canadian standard for flood-resilient existing communities.* Intact Centre on Climate Adaptation, University of Waterloo. https://www.intactcentreclimateadaptation.ca/wp-content/uploads/2019/01/ Weathering-the-Storm.pdf

Ness, R., Clark, D.G., Borque, J., Coffman, D., & Beugin, D. (2021). *Under water: The costs of climate change for Canada's infrastructure.* Canadian Climate Institute. https://climateinstitute.ca/reports/under-water/

Patil, A. (2024, July 11). Parts of Nova Scotia ravaged by heavy rains and flash flooding – again. *CBC News.* https://www.cbc.ca/news/canada/nova-scotia/beryl-remnants-rain-flooding-in-parts-nova-scotia-1.7261255

Sawyer, D., Ness, R., Lee, C., & Miller, S. (2022). *Damage control: Reducing the costs of climate impacts in Canada.* Canadian Climate Institute. https://climateinstitute.ca/wp-content/uploads/2022/09/Damage-Control_-EN_0927.pdf

Snoddon, R. (2023, August 8). Is flash flooding more frequent in the Maritimes this summer? *CBC News.* https://www.cbc.ca/news/canada/nova-scotia/weather-ryan-snoddon-flash-flood-1.6930339?cmp=newsletter_CBC%20Nova%20Scotia_1639_

Sparling, E., Eyzaguirre, J., & Wale, J. (2024, January). *Turning the tide: How flood risk transparency can drive equitable outcomes in Canada.* Canadian Climate Institute. https://climateinstitute.ca/wp-content/uploads/2024/01/Turning-the-tide.pdf

Sustainability Solutions Group. (n.d.). Halifax Regional Municipality: Climate adaptation baseline report. https://cdn.halifax.ca/sites/default/files/documents/about-the-city/energy-environment/Adaptation%20Baseline%20Report_0.pdf

Chapter 2: Building impacts

Environment and Climate Change Canada. (2017). *Climate data and scenarios: synthesis of recent observation and modelling results.* Government of Canada. https://publications.gc.ca/collections/collection_2016/eccc/En84-132-2016-eng.pdf

James, T.S., Henton, J.A., Leonard, L.J., Darlington, A., Forbes, D.L., & Craymer, M. (2014). *Relative sea-level projections in Canada and the adjacent mainland United States.* Geological Survey of Canada, Open File 7737. https://doi.org/10.4095/295574

Municipal District of Lunenberg. (n.d.). What is land subsidence? https://engage.modl.ca/36890/widgets/153759/documents/106253

Sustainability Solutions Group. (n.d.). *Halifax Regional Municipality: Climate adaptation baseline report.* https://cdn.halifax.ca/sites/default/files/documents/about-the-city/energy-environment/Adaptation%20Baseline%20Report_0.pdf

Zhai, L., Greenan, B.J.W., & Perrie, W. (2023). The Canadian Extreme Water Level Adaptation Tool (CANEWLAT). Canadian Technical Report of Hydrography and Ocean Sciences 348, Fisheries and Oceans Canada. https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41093720.pdf

Zhang, X., Flato, G., Kirchmeier-Young, M., Vincent, L., Wan, H., Wang, X., Rong, R., Fyfe, J., Li, G., & Kharin, V.V. (2019). "Chapter 4: Changes in temperature and precipitation across Canada." In E. Bush & D.S. Lemmen (Eds.), *Canada's changing climate report* (pp.112-193). Government of Canada: Ottawa, Ontario. https://changingclimate.ca/CCCR2019/

Chapter 3: Building envelope—Roof

Building America Solution Center. (n.d.-a). Gutters and downspouts. https://basc.pnnl.gov/resource-guides/gutters-and-downspouts#edit-group-description

Canadian Standards Association. (2018). *Z800-18: Guideline on basement flood protection and risk reduction.* https://www.csagroup.org/store/product/Z800-18/

City of Edmonton. (n.d.). *The homeowner's guide to lot grading and drainage: How to identify problems and maintain your home's drainage systems.* https://www.edmonton.ca/sites/default/files/public-files/documents/PDF/Homeowners_Guide.pdf

D'Angelo & Sons. (2023, July 21). What size of gutters and downspouts do you need? https://dangeloandsons.com/what-size-gutters-and-downspouts-do-you-need/

Family Handyman. (2024, October 4). How to install and replace gutters. https://www.familyhandyman.com/project/how-to-install-gutters/

Glover, E. (2024, May 8). 5 reasons to install gutter guards. *Forbes Home.* https://www.forbes.com/home-improvement/gutter/reasons-to-install-gutter-guards/

Lutz, A. (2024, October 24). Understanding gutter slope and how to measure it. *Architectural Digest.* https://www.architecturaldigest.com/reviews/gutters/slope-of-gutters

Sandink, D. (2009, June). *Handbook for reducing basement flooding.* Institute for Catastrophic Loss Reduction. https://www.iclr.org/wp-content/uploads/PDFS/handbook-for-reducing-basement-flooding.pdf

Sandink, D., Robinson, B., Dale, N., & Oktrutney, P. (2021). *Practical guidance for private-side drainage systems to reduce basement flood risk: Addressing critical information gaps.* Prepared by Institute for Catastrophic Loss Reduction for National Research Council Canada. https://doi.org/10.4224/40002662

Savage, K., Meeha, D., Finch, G., & Higgins, J. (2021). *Builder guide to site and foundation drainage: Best practices for part 9 buildings in British Columbia.* BC Housing Research Centre. https://www.bchousing.org/publications/Builder-Guide-to-Site-and-Foundation-Drainage.pdf

Petersen, M., & Hayes, K. (2023, September 27). Do I need a gutter apron? *Fine Homebuilding #319.* https://www.finehomebuilding.com/2023/09/27/do-i-need-a-gutter-apron

University of California. (n.d.). *Homeowner's wildfire mitigation guide: Gutters.* Division of Agriculture and Natural Resources. https://ucanr.edu/sites/Wildfire/Roof/Edge_of_Roof_Issues/Gutters_785/

Weatherseal Roofing. (n.d.). *Gutter apron vs. drip edge: What's the difference and why does it matter?* https://www.weathersealnj.com/post/blogpost-2-the-difference-between-gutter-apron-and-drip-edge

Chapter 4: Building envelope—Walls

ASTM International. (2020). *C1521-19 Standard practice for evaluating adhesion of installing weatherproofed sealant joints.* https://www.astm.org/c1521-19r20.html

Drycrete Waterproofing. (2023, November 19). How to waterproof house foundations from the outside. https://drycretewp.com/how-to-waterproof-house-foundations-from-the-outside/

Fastener Systems. (2023, November 2). Vapor barrier caulk. https://www.fastenersystems.com/blog/vapor-barrier-caulk

Gagne, B. (n.d). How to apply sealant. *Tremco Construction Projects Group.* https://blog.buildmeetsworld.com/how-to-apply-sealant

Nichols, L.M. (2024, July 3). How to install a vapor barrier in crawlspace. *Family Handyman.* https://www.familyhandyman.com/article/vapor-barrier-crawl-space/

Savage, K., Meeha, D., Finch, G., & Higgins, J. (2021). *Builder guide to site and foundation drainage: Best practices for part 9 buildings in British Columbia.* BC Housing Research Centre. https://www.bchousing.org/publications/Builder-Guide-to-Site-and-Foundation-Drainage.pdf

Schroeder, D. (2021, July 25). The foundation crack that should get more attention. *Schroeder Engineering.* https://www.schroederkc.com/blog/diagonal-cracks

Snell, S. (2024). Eliminate costly rework with the field adhesion test. *Build Meets World.* https://blog.buildmeetsworld.com/eliminate-costly-rework-with-the-field-adhesion-test

Trisco Systems, Inc. (2015, November 16). Sealants: Failures and installation considerations. https://triscosystems.com/sealants-failures-installation-considerations/

Waterproof Magazine. (2018, April 9). Dimple drain sheets. https://www.waterproofmag.com/2018/04/dimple-drain-sheets/

Chapter 5: Building envelope—Foundation

Association of State Floodplain Managers. (2022b). Install an exterior French drain. *Reduce Flood Risk.* https://www.reducefloodrisk.org/mitigation/install-an-exterior-french-drain/

Brancato, K. (2024, June 14). What is a French drain and how does it work? *Angi.* https://www.angi.com/articles/what-is-a-french-drain.htm

Canadian Home Inspection Services. (n.d.). Interior weeping tile drainage system. https://www.canadianhomeinspection.com/home-reference-library/basement-wall-structure-components/interior-weeping-tile-drainage-system/

Canadian Standards Association. (2018). *Z800-18: Guideline on basement flood protection and risk reduction.* https://www.csagroup.org/store/product/Z800-18/

City of Moncton. (n.d). *The homeowner's guide to flood protection.* https://www5.moncton.ca/docs/emergency/Flood_Protection_Manual.pdf

City of Toronto. (2022, September). *Design criteria for sewers and watermains* (2nd Ed.). https://www.toronto.ca/wp-content/uploads/2022/10/8f8d-ecs-specs-dcm-design-criteria-sewers-satermains-Sep2022.pdf

City of Toronto. (2024). Toronto Water Technical Reviews for reverse slope driveways. https://www.toronto.ca/services-payments/water-environment/managing-rain-melted-snow/toronto-water-technical-reviews-for-reverse-slope-driveway/

Commercial Industry Supply. (2019, March 20). White solid PVC vs black corrugated pipe for French drain installation. https://www.commercial-industrial-supply.com/resource-center/white-solid-pvc-vs-black-corrugated-pipe-french-drain-installation/

Engel, A. (n.d.). How to install a French drain. *This Old House.* https://www.thisoldhouse.com/plumbing/21328906/french-drain-installation

Federal Emergency Management Agency. (2012, January). E*ngineering principles and practices for retrofitting flood-prone residential structures* (3rd ed). FEMA P-259. https://www.fema.gov/sites/default/files/2020-08/fema259_complete_rev.pdf

G&G Construction Inc. (2024, June 13). Installing a concrete catch basin. https://www.gandgconcrete.com/how-to-install-a-concrete-catch-basin/

Home Depot. (2024). How to install a French drain. https://www.homedepot.com/c/ah/how-to-install-a-french-drain/9ba683603be9fa5395fab9012cc2665

Industry Training Authority BC. (2023). *Block A: Sewers.* Pressbooks. https://opentextbc.ca/plumbing3a/chapter/describe-the-installation-of-catch-basins/

Lambourne, B. (2023, June 17). French drains in cold climates. *French Drain Guys.* https://frenchdrainguys.com/french-drains-in-cold-climates/

MacRae, G. (2024, May 13). Weeping tile vs French drain: Which is better for you? *GJ MacRae Foundation Repair.* https://wetbasements.com/weeping-tile-vs-french-drain/

Master Drain. (2023, July 15). How to install a French drain in your yard: Tips and tricks for successful French drain installation. https://masterdrain.ca/how-to-install-a-french-drain-in-your-yard-tips-and-tricks-for-successful-french-drain-installation/

National Diversified Sales. (n.d.-a). French drain installation.
https://www.ndspro.com/french-drain-installation-guide/

National Diversified Sales. (n.d.-b). Principles of exterior drainage: Short course.
https://wenatcheehomeinspection.com/wp-content/uploads/2021/12/principles-of-exterior-drainage.pdf

OntarioAgra. (n.d.). The importance of French drains and how to install them.
https://www.ontarioagra.ca/french-drain-installation/

Pro Fabric Supply. (2020, October 9). 7 common French drain mistakes and how to avoid them.
https://www.profabricsupply.com/blogs/articles/7-common-french-drain-mistakes-how-to-avoid-them

Rooterworx. (2021, April 8). Importance of catch basin installation for backyard gardens.
https://www.rooterworx.ca/catch_basin_garden

Sandink, D. (2009, June). *Handbook for reducing basement flooding.* Institute for Catastrophic Loss Reduction. https://www.iclr.org/wp-content/uploads/PDFS/handbook-for-reducing-basement-flooding.pdf

Savage, K., Meeha, D., Finch, G., & Higgins, J. (2021). *Builder guide to site and foundation drainage: Best practices for part 9 buildings in British Columbia.* BC Housing Research Centre.
https://www.bchousing.org/publications/Builder-Guide-to-Site-and-Foundation-Drainage.pdf

Swinton, M.C., & Kesik, T.J. (2008). *Site grading and drainage to achieve high performance basements.* Institute for Research in Construction, National Research Council Canada. https://doi.org/10.4224/40002808

Urban Water. (2023). French drain–ultimate design guide UK 2023.
https://urban-water.co.uk/french-drain-design-guide/

Vodaland. (2023, May 15). How to install a catch basin.
https://vodaland-usa.com/blogs/news-and-article/how-to-install-a-catch-basin

Von Gerl, B. (2023, May 18). Weeping tile: What is it and do I need it? *Reno Assistance*.
https://www.renoassistance.ca/en/french-drains/weeping-tile-things-you-need-to-know/

Wallender, L. (2024, March 13). What is a catch basin? How to install one in your yard. *The Spruce*.
https://www.thespruce.com/how-to-install-a-catch-basin-for-yard-drainage-5080372

World of Stones USA. (2023, March 28). 5 ways to prevent weed growth between paving stones.
https://worldofstonesusa.com/blogs/all/prevent-weed-growth-paving-stones

Chapter 6: Building envelope—Windows & Doors

Gregory, B. (2023, February 10). How to install a window well cover. *Lowes*. https://www.lowes.com/n/how-to/install-a-window-well-cover

Home Depot (n.d). Basement window well cover. https://www.homedepot.ca/product/maccourt-basement-window-well-cover/1000121598

Sandink, D. (2009, June). *Handbook for reducing basement flooding*. Institute for Catastrophic Loss Reduction. https://www.iclr.org/wp-content/uploads/PDFS/handbook-for-reducing-basement-flooding.pdf

Chapter 7: Mechanical, Electrical, and Plumbing (MEP) Systems

American National Standards Institute, Standards Council of Canada, Underwriters' Laboratories Inc., & ULC Standards. (2016). *ANSI/CAN/UL/ULC 1201:2016: Sensor operated backwater prevention systems.* https://canada.ul.com/wp-content/uploads/sites/11/2016/12/ANSI-CAN-UL-ULC-1201-2016-EN.pdf

American Society of Mechanical Engineers. (2003). *ASME A112.14.1-2003: Backwater valves.* https://www.asme.org/codes-standards/find-codes-standards/a112-14-1-backwater-valves

Backwater-Valves.com. (n.d.). How to install a backwater valve: Installation retrofit in non-new construction. https://www.backwater-valves.com/Backwater-Valve-Installation-Sticker.asp

Basement Systems. (2024). IceGuard sump pump discharge line system. https://www.basementsystems.com/basement-waterproofing/basement-waterproofing-products/iceguard-discharge-line-system.html

Building America Solution Centre. (n.d.-c). Outdoor HVAC equipment elevated and secured for resistance to floods, earthquakes, and high winds. https://basc.pnnl.gov/resource-guides/outdoor-hvac-equipment-elevated-and-secured-resistance-floods-earthquakes-and-high#edit-group-description

Canadian Standards Association. (2015). *CAN/CSA B1800-15: Thermoplastic non-pressure piping compendium.* https://www.csagroup.org/store/product/2423252/

Canadian Standards Association. (2018). *Z800-18: Guideline on basement flood protection and risk reduction.* https://www.csagroup.org/store/product/Z800-18/

City of Anderson. (n.d.). Downspout disconnection program. https://www.cityofanderson.com/237/Downspout-Disconnection-Program

City of Edmonton. (n.d.). Splash pads: Commercial and multi-family. https://www.edmonton.ca/business_economy/commercial_lot_grading/splash-pads

City of Toronto (n.d). Mandatory downspout disconnection. https://www.toronto.ca/services-payments/water-environment/managing-rain-melted-snow/basement-flooding/mandatory-downspout-disconnection/

City of Winnipeg (2022). Sump pit installation guidelines. https://legacy.winnipeg.ca/ppd/Documents/Brochures/Sump-Pit-Installation-Guidelines.pdf

Davis & Green. (2023). How to keep your sump pump from freezing. Dgelectrical.com. https://dgelectrical.com/how-to-keep-your-sump-pump-from-freezing/

Drain Express. (n.d.). How does a sump pump float switches work and how to maintenance them for long-term reliability. https://drainexpress.ca/how-does-a-sump-pump-float-switches-work-and-how-to-maintenance-them/

Eakes, J. (2016, December 19). How do I keep a shallow sump pump from freezing outdoors. *Ask Eakes.* https://joneakes.com/jons-fixit-database/1282-How-do-I-keep-a-shallow-Sump-drain-from-freezing-outdoors

Federal Emergency Management Agency. (n.d.). "Chapter 8: Protecting service equipment." In *A homeowner's guide to retrofitting* (pp. 143-149). https://www.fema.gov/pdf/rebuild/mat/sec8.pdf

Federal Emergency Management Agency. (2012, January). *Engineering principles and practices for retrofitting flood-prone residential structures* (3rd ed). FEMA P-259. https://www.fema.gov/sites/default/files/2020-08/fema259_complete_rev.pdf

Federal Emergency Management Agency. (2017, February). Protecting building utility systems from flood damage (2nd ed.). FEMA P-348. https://www.fema.gov/sites/default/files/2020-07/fema_p-348_protecting_building_utility_systems_from_flood_damage_2017.pdf

Federal Emergency Management Agency. (2018). *2018 International Building Code: A compilation of flood resistant provisions*. https://www.fema.gov/sites/default/files/2020-08/fema_2018-i-codes-flood-provisions.pdf

Green Building Canada. (2024, August 22). *A guide to backwater valve installation.* https://greenbuildingcanada.ca/backwater-valve-installation/

Heatline. (2024). *How to prevent a frozen sump pump discharge line.* https://heatline.com/ideas/how-to-prevent-a-frozen-sump-pump-discharge-line/

Institute for Catastrophic Loss Reduction. (n.d.-a). *Focus on backwater valves.* https://www.iclr.org/wp-content/uploads/PDFS/focus-on-backwater-valves.pdf

Institute for Catastrophic Loss Reduction. (n.d.-b). *Focus on sump pump systems.* https://www.iclr.org/wp-content/uploads/PDFS/Sump_pump_booklet.pdf

Maxwell, R. (2024, October 4). How to install a sump pump. *Family Handyman.* https://www.familyhandyman.com/article/how-to-install-a-sump-pump/

Sandink, D. (2009, June). *Handbook for reducing basement flooding.* Institute for Catastrophic Loss Reduction. https://www.iclr.org/wp-content/uploads/PDFS/handbook-for-reducing-basement-flooding.pdf

Sandink, D., Robinson, B., Dale, N., & Oktrutney, P. (2021). *Practical guidance for private-side drainage systems to reduce basement flood risk: Addressing critical information gaps.* Prepared by Institute of Catastrophic Loss Reduction for National Research Council Canada. https://doi.org/10.4224/40002662

Toronto and Region Conservation Authority. (2018a, July 18). How to set up a rain barrel and harvest rainwater. https://trca.ca/news/set-up-rain-barrels-harvest-rainwater

Utilities Kingston. (n.d.). Sumps and sump pumps. https://utilitieskingston.com/Wastewater/BasementFlooding/Protect/Sumps

Water Commander. (n.d.). Pros and cons of water-powered sump pumps. https://www.watercommander.com/articles/water-powered-sump-pump-pros-and-cons

Wentworth Plumbing. (2016, December 9). Tips to avoid a frozen sump pump. https://wentworthplumbing.ca/blog/avoid-a-frozen-sump-pump/

Werner, A. (n.d.). Do sump pumps need weeping holes? *Real Seal Basement Waterproofing and Foundation Repair.* https://www.therealsealllc.com/blog/do-sump-pumps-need-weep-holes/

Zoeller. (2023, September 15). 5 ways to properly size your sump pump. https://www.watercommander.com/articles/water-powered-sump-pump-pros-and-cons

Chapter 8: Landscaping

Alberta Water. (2023, September 7). *Flood mitigation: Berms.* https://albertawater.com/flood-mitigation/berms/

Anne Arundel County Department of Public Works. (2023, April). *How to maintain your grass drainage swale.* https://www.aacounty.org/sites/default/files/2023-04/Grass_Swale_Maintenance_FINAL.pdf

Association of State Floodplain Managers. (2022a). Construct a floodwall barrier. *Reduce Flood Risk*. https://www.reducefloodrisk.org/mitigation/construct-a-floodwall-barrier/

Aukland Council. (n.d.). *Swales and filter strips: Operation and maintenance guide.* https://www.aucklandcouncil.govt.nz/environment/looking-after-aucklands-water/stormwater/docsmaintenanceguides/swales-filter-strips-operation-maintenance-guide.pdf

Building America Solution Center (n.d.-b). Swales, drains, and site grading for stormwater control. https://basc.pnnl.gov/resource-guides/swales-drains-and-site-grading-stormwater-control#edit-group-description

Cambridge City Council. (n.d). Swales and filter strips. https://www.cambridge.gov.uk/media/5464/suds-design-and-adoption-guide-part-7.pdf

Chicago Botanic. (2003). *Rain gardens: A how-to manual for homeowners.* https://www.chicagobotanic.org/downloads/wed/WI_DNR_homeowners.pdf

City of Brampton. (n.d.). *Residential surface draining: Lot grading guidelines.* https://www.brampton.ca/EN/residents/Roads-and-Traffic/Permits-and-Applications/Documents/Residential%20Surface%20Drainage%20Lot%20Grading%20Guidelines.pdf

City of Burlington. (2020, May 21). *Stormwater management design guidelines.* https://www.burlington.ca/en/planning-and-development/resources/Urban-Design-Guidelines/Stormwater-Management-Design-Guidelines.pdf

City of Calgary. (n.d.). *Rain gardens in Calgary.* https://www.calgary.ca/planning/water/rain-garden-calgary.html

City of Richmond Hill. (2024, June). *Build your own rain garden! A resident guide.* https://www.richmondhill.ca/en/resources/Rain-Gardens/Build-Your-Own-Rain-Garden-FINAL.pdf

City of Winnipeg. (n.d). *Residential lot grading*. Water and Waste Department. https://legacy.winnipeg.ca/waterandwaste/drainageFlooding/lotGrading/lotDrainage.stm

Ekka, S.A., Rujner, H., Leonhardt, G., Blecken, G.T., Viklander, M., & Hunt, W.F. (2021). Next generation swale design for stormwater runoff treatment: A comprehensive approach. *Journal of Environmental Management 279 (1):* 111756. https://doi.org/10.1016/j.jenvman.2020.111756

Environmental Protection Agency. (2021, December). *Stormwater best management practice: Grassed swales*. https://www.epa.gov/system/files/documents/2021-11/bmp-grassed-swales.pdf

Federal Emergency Management Agency. (2007, March). *Selecting appropriate mitigation measures for floodprone structures.* FEMA 551. https://www.fema.gov/sites/default/files/2020-08/fema_551.pdf

Federal Emergency Management Agency. (2012, January). *Engineering principles and practices for retrofitting flood-prone residential structures* (3rd ed). FEMA P-259. https://www.fema.gov/sites/default/files/2020-08/fema259_complete_rev.pdf

Federal Highway Administration. (2018, December). *The stormwater practitioners guide.* Department of Transportation. https://highways.dot.gov/sites/fhwa.dot.gov/files/docs/federal-lands/construction/27396/cfl-stormwater-guide.pdf

Five Counties Salmonid Conservation Program. (2022). *Convey water in swales.* https://www.5counties.org/handbook_conveyswales.html

Government of New Brunswick. (2019, November). *Floodproofing: Protect your home and contents against flooding.* Department of Public Safety & Department of Environment and Local Government. https://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Flooding-Inondations/Floodproofing.pdf

Groundwater Foundation. (n.d.). *All about rain gardens.* https://groundwater.org/rain-gardens/

Investment Agriculture Foundation. (2022). *Landscape level approaches to mitigate flood impacts for farms and ranches.* BC Climate Change Adaptation. https://www.bcclimatechangeadaptation.ca/app/uploads/SP05-Flood-Toolkit-Landscape-Level-Approaches-to-Mitigate-Flood-Impacts-for-Farm-and-Ranches.pdf

Iowa Stormwater Education Partnership. (2021, March). *Iowa rain garden design and installation guide* (3rd ed.). https://iowastormwater.org/wp-content/uploads/Iowa-Rain-Garden-Design-and-Installation-Guide-Third-Edition-Web-March-2021.pdf

Lake Superior Streams. (n.d.). *Grassed swales.* https://www.lakesuperiorstreams.org/stormwater/toolkit/swales.html

Larrey-Lassalle, P., Cannavo, P., Bouzouidja, R., & Musy, M. (2024). *Swale.* Climate Change Adaptation Resource Centre. https://ww.adaptation-changement-climatique.gouv.fr/sites/cracc/files/inline-files/Swale.pdf

Melbourne Water. (n.d.). *Instruction sheet: Building a swale.* Victoria State Government. https://melbournewater.com.au/raingardens

New Brunswick Invasive Species Council & Nova Scotia Invasive Species Council. (2023, July). *Grow me instead: New Brunswick and Nova Scotia edition.* https://nsinvasives.ca/wp-content/uploads/2023/07/CCIS-NSISC-Grow-Me-Instead-Guide_2023_EN_web.pdf

New Jersey Department of Environmental Protection. (2014, September). "Chapter 9.1.2: Grass swales." In *New Jersey stormwater best management practices manual.* https://dep.nj.gov/wp-content/uploads/stormwater/archived_nj_swbmp_9.12.pdf

Newton, E. (2024, February 23). Designing effective vegetated swales for roadside runoff. *Stormwater Solutions.* https://www.stormwater.com/erosion-control/vegetation-management/article/53096731/designing-effective-vegetated-swales-for-roadside-runoff

Nova Scotia Wild Flora Society. (n.d.). *Gardening with native plants.* https://nswildflora.ca/links/naturalization/

Pacific Water Research Centre. (2023, April 5). *User manual: Surrey rain garden project.* Simon Fraser University. https://www.sfu.ca/content/sfu/pwrc/resources-list/how-to-build-a-rain-garden/_jcr_content/main_content/download/file.res/Rain%20Garden%20Design%20Guide.pdf

Princeton Hydro. (2021, September 28). *How to build a rain garden in 10 steps.* https://princetonhydro.com/how-to-build-a-rain-garden-in-10-steps/

Reep Green Solutions. (2024). *A beginner's guide to building a rain garden.* https://reepgreen.ca/a-beginners-guide-to-building-a-rain-garden/

Sandink, D. (2009, June). *Handbook for reducing basement flooding.* Institute for Catastrophic Loss Reduction. https://www.iclr.org/wp-content/uploads/PDFS/handbook-for-reducing-basement-flooding.pdf

Sandink, D., Robinson, B., Dale, N., & Oktrutney, P. (2021). *Practical guidance for private-side drainage systems to reduce basement flood risk: Addressing critical information gaps.* Prepared by Institute of Catastrophic Loss Reduction for National Research Council Canada. https://doi.org/10.4224/40002662

Savage, K., Meeha, D., Finch, G., & Higgins, J. (2021). *Builder guide to site and foundation drainage: Best practices for part 9 buildings in British Columbia.* BC Housing Research Centre. https://www.bchousing.org/publications/Builder-Guide-to-Site-and-Foundation-Drainage.pdf

Southeast Michigan Council of Governments. (2008). *Low impact development manual: A design guide for implementers and reviewers.* https://www.swmpc.org/downloads/lidmanual.pdf

Sustainable Technologies. (2023, October 26). Swales. https://wiki.sustainabletechnologies.ca/wiki/Swales

Swinton, M.C., & Kesik, T.J. (2008). *Site grading and drainage to achieve high performance basements.* Institute for Research in Construction, National Research Council Canada. https://doi.org/10.4224/40002808

Toronto and Region Conservation Authority. (2018b, August 14). *A complete guide to building and maintaining a rain garden.* https://trca.ca/news/complete-guide-building-maintaining-rain-garden/