5C Program's Stormwater Management Guide

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0 Intro to Low Impact Development

What is Low Impact Development?

Low Impact Development (LID) is a collection of methods (aka Best Management Practices or BMPs) that preserve natural resources and collect and clean stormwater runoff to protect and improve water quality and availability. One of the main principles is to simulate natural drainage patterns and incorporate vegetation and natural materials into stormwater facilities. The Puget Sound Partnership defines LID as “a stormwater and land use management strategy that strives to mimic pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation and transpiration by emphasizing conservation, use of on-site natural features, site planning, and distributed stormwater management practices that are integrated into a project design.” LID may also be referred to as Green Infrastructure, Green Development Practices, or Alternative Storm Water Management Systems.

There are over 200 best management practices (BMPs) that may be used to improve watershed health[1]. BMPs may fall into two categories:

Non-structural BMPs

These are restoration and protection practices often employed during the early planning phase, but may also appear during other project phases. This includes choosing low impact techniques over conventional ones and also selecting natural approaches over ones that require more physical structures.

- Relative Effectiveness: High
- Relative Cost: Low

Figure 1 Choose good materials and avoid polluting ones (like this copper downspout).

Figure 2 This berm, made of compost instead of ordinary loose soil, is highly effective at reducing sediment transport off-site and can be installed by hand or machine.

Figure 3 Compost amended soils restore compacted soils and can be used to reduce water demand in gardens or lawns.

[1] For a checklist of best management practices, visit http://www.greengirlpdx.com/Publications.htm#c

Structural BMPs

These are mitigation strategies or facilities designed to reduce impact from either past or future development.

- Relative Effectiveness: Low to Moderate
- Relative Cost: High

Figure 4 Pervious concrete infiltrates rainfall at the source.

Figure 5 Contained planters intercept, then evaporate, rainfall and are a cost-effective way to beautify anyplace.

Figure 6 Ecoroofs intercept & evaporate rainfall and greatly extend roof life.

Figure 7 Rain gardens are great alternative to mange runoff when it can't be prevented.

Why Use Low Impact Development?

In undeveloped areas, very little rainwater or snowmelt runs off the land like it does in urbanized towns and cities. Trees, plants, and soil capture much of the precipitation, and some of it evaporates back into the air. Most of the precipitation that doesn't evaporate or get captured by vegetation soaks into the ground where soil and microbes remove pollutants naturally. The water slowly recharges streams, wetlands and groundwater. Very little runs off, except in very large storms. The natural terrain acts like a sponge.

This natural hydrologic cycle is radically altered when land is developed and the way it has been for decades is changed. Typical development clears the land of vegetation and covers it with hard surfaces such as roads, parking lots, and rooftops. Construction and foot traffic compact soils, so that even landscaped areas can generate unnaturally high runoff volumes. Storm drains are installed to get water out of the way by sending it

Figure 8. Water quality is important to the life that lives in streams; but humans, too rely on clean water for drinking and recreation.

Figure 9. As long as excess runoff volume is piped to streams, erosion from streambank scouring will continue to impair water quality.

into local streams or injecting it underground without treatment. Development dramatically increases runoff volumes. Even when controlled by detention basins, this causes flooding, damages fish and wildlife habitat, and delivers pollutants such as oils and pesticides to local waterways. The decreased infiltration results in: less cool, clean groundwater to recharge streams in the dry summer months; and in a reduction in water availability throughout the watershed.

LID practices may be incorporated into existing as well as newly built developments in a community. They increase groundwater supplies and reduce the negative water quality impacts to streams and fish habitat, flooding, and in many cases, the cost of stormwater treatment and infrastructure. They are aesthetically pleasing and have been shown to increase real estate values.

Which BMPs Should I Use & How?

The 5C Program offers technical guidance on a number of different practices. (See *"Navigating the 5C Program's Stormwater Management Guidance".)* The reason for a particular design element in this guidance may not be apparent immediately; but, it's "that way" because it supports long-term water quality and watershed restoration[2]. In order for them to work properly, stormwater BMPs must be installed and maintained according to the design specifications. So to avoid unintended consequences, the project team, which might include the owner, designer(s), contractor(s)/construction crew, maintenance staff and others as appropriate, all need to do their part in properly implementing the practices you choose. The table below shows the types of practices that are generally applicable to different stormwater runoff sources. Each BMP has additional applicability criteria related to slopes, soils, setbacks, and geometry and is included in the guidance documents provided by the 5C Program.

[2] For additional information on how changes to facility designs are likely to impact function, see pdfs under the column heading "Additional sustainability & design considerations for modifying details" under each set of facility detail design at http://extension.oregonstate.edu/stormwater/swamp-lid-details

Applicability

The following table illustrates which types of stormwater runoff thatseveral BMPs can manage:

	BMPs	Stormwater Runoff Surface Types			
		Rooftops	Roadways	Sidewalks	Compacted & Semi-pervious Landscape Areas
Structural BMP	Rain Gardens	X	X	X	X
	Vegetated Filter Strips	X	X	X	X
	Pervious Concrete		X	X	
	Rainwater Harvesting	X			
	Convey Stormwater without a Pipe	X	X	X	
Non-structural BMP	Minimize Impervious Area	X	X	X	
	Runoff Area Disconnection		X	X	
	Tree Preservation & Planting		X	X	X
	Restore Soil				X
	Native Plants				X

Combining Practices

Numerous practices may be combined into endless combinations depending on natural conditions on-site, stakeholder and designer preferences, and budget. As you can see, some practices can be applied to runoff from an array of surfaces while others only manage one or two kinds of surfaces. So combining practices is probably the best and most cost-effective way to manage stormwater on your site.

Figure 10 A daylit stream, a rain garden, porous pavement, and native plants all work together to protect water resources on and off site.

Figure 11 Even a single practice like this rain garden will need additional BMPs implemented (erosion control) to be really effective long-term.

5C Program
Five Counties Salmonid Conservation Program

Navigating the 5C Program's Stormwater Management Guidance

This summary outlines the available guidance on stormwater management through the 5C Program to help ensure that you have all the information you need to plan, design, construct, and maintain best management practices. You can navigate the material in a few different ways: by topic, by specific practice, or by the function you want to achieve.

By Topic

Guidance is organized by overarching topic. In each fact sheet, we've strived to create easy-to-understand text and illustrations on implementation, cost considerations, and relative benefits to watershed and water conservation efforts. In the table below, guidance is ordered by relative cost for new development. In retrofits, where stormwater management is not required, managing stormwater with Low Impact Development (LID) or even with conventional approaches will require an initial investment. However, there are many benefits of stormwater management that are not easy to quantify in dollars. Certain practices, such as those that capture stormwater, can actually save money in the long-term. In some case, effectiveness will probably be the driving factor for decision-making.

Best Management Practices (BMPs)

	Title	Content Description	Relative Cost	Effectiveness*
1	*Minimize Impervious Area*	Learn how to minimize impervious area in new and existing development.	Low	High
2	*Disconnect Impervious Areas*	Learn how to manage: roof runoff by disconnecting your downspouts; and pavement runoff with vegetated filter strips.		High
3	*Restore Disturbed Soils*	Landscape areas can generate a surprising amount of runoff, carrying pollutants like pesticides, fertilizers, and herbicides to downstream waterways. Learn how to uncompact your soil, permanently, to reduce maintenance and watering demand.		High
4	*Build a Rain Garden*	Learn how to design, construct, and maintain a rain garden.		Low to High
5	*Build A Rain Barrel*	Rain barrels are a great way to raise awareness of water conservation and will provide some water quality treatment. Learn how to build your own from scratch to reuse rainwater for outdoor uses.		Low
6	*Harvest Rainwater with a Cistern*	Get more information on rainwater harvesting systems designed to re-use water inside or out using cisterns.	High	Low to High

* This rating refers to the effectiveness of stormwater management. These techniques offer other benefits such as water conservation with a good rate of effectiveness.

Supplemental Information		
7	*Test Your Soils*	Learn how to test your soils to reduce installation & maintenance costs and improve the effectiveness of bioretention facilities (e.g., rain garden, vegetated filter strip).
8	*Site Bioretention for Infiltration*	Reducing runoff volumes is the best way to preserve and restore watershed health. Learn how to find the right place for your rain garden, vegetated filter strip, or disconnected downspout.
9	*Find Native Plants in Your Area*	Not all plants are created equal. Native plants provide superior watershed protection, habitat value, and are resilient. Learn how to navigate the USDA's PLANTS database to find native plants in your county.
10	*Amend Soils for Bioretention*	Learn how to best prepare your native soils for directing runoff to them for stormwater infiltration.
11	*Convey Water in Swales*	Learn how to convey water around your site using overland flow instead of pipes.

Implement Specific Practices

If you’re already pretty familiar with using best management practices or have something in mind already for other reasons, refer to the table below to see which guidance topics you’ll need to gather before starting your project.

I want to:	Because it will be good for:	Guidance documents you’ll need (listed generally in the order of implementation):
Minimize impervious area.	Water quality & energy savings	Essential:**1** Optional if area remaining will be garden instead of lawn: **9**
Remove some unneeded existing pavement (aka depaving).	Water quality & energy savings	Essential: **1, 3, 9** Optional if impervious pavement will drain to depaved area, see vegetated filter strip: **2, 10**

Disconnect my downspout.	Water quality	Essential: **8, 2** Optional if replacing lawn with garden at mouth of disconnection**: 9, 10**
Disconnect my pavement (aka vegetated filter strip).	Water quality	Essential: **8, 2, 10, 9**
Restore my soil.	Water quality & water conservation	Essential: **3** Optional if resulting area will be garden instead of lawn: **9**
Build a rain garden.	Water quality	Essential: **8, 7, 4, 10, 9** Optional if conveying water to or away from rain garden with overland conveyance instead of a pipe: **11**
Build a swale.	Water quality	Essential: **11, 10, 9**
Harvest rainwater in rain barrels	Water quality & water conservation	Essential: **5**
Harvest rainwater in a cistern.	Water quality & water conservation	Essential: **6**

Functional Checklist Approach

If you have some idea of what practices you'd like to use, but would like to explore additional approaches, then use this checklist approach below. Available resources are listed by how they work to protect watershed health. If best management approaches perform more than one function, they're listed in all relevant categories. Guidance that is essential or optional for implementation is listed with numbers corresponding to the topics table above.

	Essential	Optional
Step 1: Evaluate existing site to prevent runoff.		
☐ Assess natural areas.		
☐ Perform infiltration testing to find areas of high and low infiltration rates.	7	
☐ Protect sensitive areas.	8	
☐ Depave unneeded areas of pavement.	1, 3, 9	2, 10

	Essential	Optional
Step 2: Evaluate proposed site to prevent runoff.		
☐ Miminize impervious areas.		
☐ Share driveways.	1	9
☐ Share parking spaces.	1	9
☐ Minimize parking space dimensions and driveway widths.	1	9
☐ Minimize building footprints.	1	9
☐ Minimize setbacks.	1	9
☐ Cluster development.	1	9
Step 3: Prevent pollution of runoff.		
☐ Restore disturbed soils.	3	9
Step 4: Intercept rainfall.		
☐ Depave unneeded areas of pavement.	1, 3, 9	2, 10
☐ Restore disturbed soils.	3	9
☐ Contained planters	2, 9	
Step 5: Mitigate runoff volume.		
☐ Infiltrate.		
☐ Infiltration rain garden	8, 7, 4, 10, 9	11
☐ Disconnect a downspout	8, 2	9, 10
Step 6: Reduce pollutants in runoff.		
☐ Miminize impervious areas.		
☐ Share driveways.	1	9
☐ Share parking spaces.	1	9
☐ Minimize parking space dimensions and driveway widths.	1	9
☐ Minimize building footprints.	1	9
☐ Minimize setbacks.	1	9
☐ Cluster development.	1	9
☐ Depave unneeded areas of pavement.	1	9

Essential **Optional**

☐ Intercept and evaporate.		
☐ Contained planters	2, 9	
☐ Restore disturbed soils.	3	9
☐ Infiltrate.		
☐ Infiltration rain garden	8, 7, 4, 10, 9	11
☐ Infilration vegetated filter strip	8, 2, 10, 9	
☐ Intercept and use.		
☐ Harvest rainwater in a barrel.	5	
☐ Harvest rainwater in a cistern.	6	
☐ Convey and treat.		
☐ Vegetated swale	11, 10, 9	
☐ Filtration rain garden	4, 10, 9	11
☐ Filtration vegetated filter strip	2, 10, 9	11

1 Minimize Impervious Areas

An impervious area is one that does not allow water or other fluids to pass through or be absorbed. Minimizing impervious pavement protects on-site water quality and reduces runoff, which protects off-site water quality. Impervious cover is considered by many to be equivalent to some types of common pollutants. Oils and other pollutants that have built up on impervious surfaces when it's not raining are released during storms-- even very small, frequent storms – polluting waterways and may create slick roads and driveways.

New Developments

The planning and zoning codes of many jurisdictions will govern, and in some cases will require minimums for, the amount of total impervious areas in your watershed. But, there are a number of ways to minimize impervious pavement in new developments that may be applied in your neighborhood as well.

- On private property, reduce pavement widths to:
  - Sidewalks: 3'
  - Driveways: 8 – 10'
- Share parking spaces with a neighbor. In commercial districts, it may be possible to share parking with a church or other organization that has different peak hours from your land use.

Figure 1. Consider stepping stones instead of pouring a sidewalk.

- Eliminate unneeded pavement. The strip between the tires of cars often doesn't need to be paved. To preserve permeability in this middle strip, don't compact the soil and place 12" of clean, open-graded (all the same size) gravel. See Figure 2.
- Don't exceed front setbacks required by your city or town. The closer a building is to the street, the shorter the driveway and sidewalk to it. See Figure 3.
- Share a driveway with your neighbor. In some cases, especially for buildings far from the road, doing so can be very effective. Usually, the driveway is owned by one person and the adjoining property owner is granted an access easement. See Figure 4.
- Minimize building footprints. A two-story house is better for the watershed than ranch style house of the same total square footage. See Figure 5.

Figure 2. Lawn tends to get compacted when not properly designed and will not grow in the place where you most often park your car.

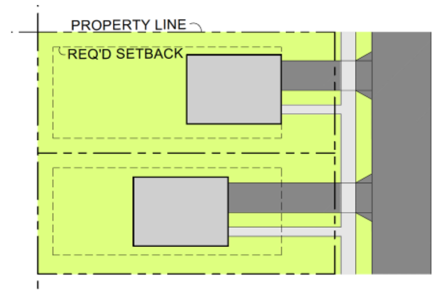

Figure 3. Exceeding setbacks generates additional paved sidewalks and driveways.

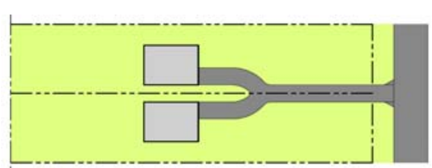

Figure 4. Share a driveway.

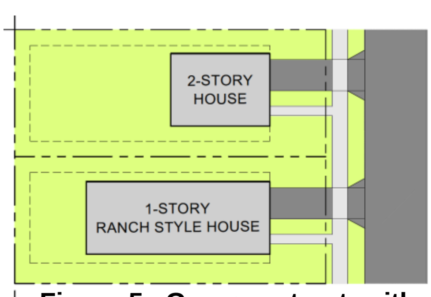

Figure 5. Go up, not out, with your floor plan.

Figure 6. The driveway leading up to this two-car garage is kept narrow as it winds through the yard.

- Minimize driveway widths to a multiple car garage by flaring out the pavement in front of the garage. A depth of 20 feet will provide adequate space to maneuver. See Figure 6.
- In subdivisions, corporate campuses, etc., cluster development. Locate buildings and other features requiring road access in one place to reduce impervious area. This practice will also save money on constructing utilities such as water and sewer pipe.
- Opt for pervious instead of impervious (conventional) concrete. Pervious concrete is a way to allow rainfall to soak into the ground where it falls instead of generating runoff. This is achieved by ensuring that every layer of pavement (subsurface soils, base rock, and surface) is permeable. Siting, design, construction, and maintenance of pervious surfaces is different from that of conventional concrete. For more information on this approach, visit the National Ready Mix Concrete Association (NRMCA) website at http://nrmca.org/GreenConcrete/default.asp. Installation of pervious concrete differs significantly from conventional concrete, so use a contractor certified by the NRMCA. For certified contractors in California, visit http://www.nrmca.org/Education/Certifications/Pervious_Contractor.htm.

Figure 7: Pervious pavement (left side) and traditional impervious pavement (right side). Areas of pooled water are seen on the impervious surface.

Cost Considerations

In new developments, minimizing impervious pavement is a cost-saving or at least cost-neutral approach. Developers save money twice: 1) for every square foot of pavement they don't build, they save money on excavation and grading, compaction, materials, & labor; and 2) they can install a smaller, less expensive stormwater facility. In jurisdictions where no stormwater facility is required, this practice could be cost-neutral, assuming money is spent on soil amendments and landscape plantings instead of pavement.

Depaving Existing Hard Surfaces

Figure 8. Many small unused pavement areas add up to a lot of unnecessary pavement in a watershed.

It's likely that there are many little paved areas throughout the watershed that no one needs or uses, but when viewed altogether are impacting water quality downstream. Tearing out pavement and replacing it with landscaped areas – depaving – is an effective means of restoring your watershed. A good time to do this is when pavement gets worn and needs to be replaced anyway.

Deconstruction & Restoration

Below are some important factors when planning or considering a depaving project:

- Check local building or development services department to find out what codes may apply to your project. A permit may be needed if parking will be reduced or work is performed in the public right-of-way. Water quality rules will also usually come into play when excavating more than a certain threshold of dirt and materials.
- Where does runoff currently flow on-site? If it flows to the proposed depaved area, see additional information on vegetated filter strips in "*2 Disconnect Impervious Areas".*
- Locate underground utilities. Call 811 to get your utilities lines marked (even on private property).
- Consider current land use and take appropriate cautions with contaminated soils. Soils that smell bad or look funny may be contaminated. It's a good idea to contact your local Natural Resources Conservation Service (NRCS) http://offices.sc.egov.usda.gov/locator/app?agency=nrcs for advice or ask an environmental scientist or engineer to help plan your project or find an alternative place to depave.
- Look up local noise regulations and think about which time(s) of day your project is likely to create noise.
- If you decide to depave areas of your property, keep the following in mind:
    - Safety comes first. Depave, a non-profit organization http://depave.org/learn/how-to-depave/ has some great, detailed guidance on planning considerations, safety equipment, and more. Ignore their information on plant species, which may not grow in your region or may be invasive. Invasive plants are very hard to manage and harm local plants and the watershed. See "*9 Find Native Plants in Your Area*".
    - Depaving is messy. Implement erosion prevention and sediment control measures (e.g., covers for exposed soil; wattles). Avoid sediment fences, which aren't very effective at controlling fine soil particles like clay and silt.
    - Think about what you will do with the materials you remove (pavement and any rock below). Asphalt, concrete, and rock can be recycled or reused. However, avoid re-using crushed concrete in stormwater facilities, which can make runoff more basic in pH level and impact your soil.

Figure 9. Volunteers learn about the connection between impervious pavement and water quality as they work to remove asphalt at a school.

- At a minimum, the soils you expose should be amended with compost at a minimum. See “*3 Restore Disturbed Soils”* for more information. Depending on the pavement and rock depth removed, clean topsoil may need to be brought in so that the landscape area can meet and match existing grades.
- Revegetate the area with native grasses and grass-like plants, flowers, and shrubs. Trees may be planted if they will be planted in at least 240 square feet of soil that is at least 3’ deep.
- Mulch the area with 2 – 3 inches of clean organic mulch that has no weed-seed or pollutants. Avoid yard waste if you use pesticides or accept it from others. Avoid wood chips and sawdust since this will rob the soil of nitrogen.

Cost Considerations

Depaving will always be more expensive than doing nothing, but your watershed is probably already impacted from the pavement that exists. Only addressing new development is usually not enough to significantly improve water quality – especially in urbanized areas. Many depaving projects to date have been done with volunteer labor, as a way of raising awareness about the connection between impervious pavement and watershed health. There are still costs associated with using volunteer labor including materials (e.g. imported soils, compost, erosion control, and vegetation) and services (e.g. waste removal and equipment rental). If volunteer labor will not be used, heavy equipment such as a backhoe will likely be the most cost-effective approach.

Maintaining Pervious Areas

- Maintenance for unpaved areas is the same as conventional landscape. Remove weeds twice a year.
- Replenish compost in gardens to a depth of 2-3 inches and lawns 1 inch every year.

Irrigation During 2-3 Year Establishment Period

To establish perennial plants, you’ll need to irrigate more in the first year and less in subsequent years. In addition, plants benefit from changing irrigation with the seasons. After summer starts and the rains stop, water a little. Increase water volume as the dry season continues. Taper off irrigation as the rains start to come back. Depending on your area and rainfall patterns, irrigation may be needed from May to October.

The volume of water and frequency of watering varies with the type of plant. See “*9 Find Native Plants for Your Area*” for information on preferred growing locations and watering needs. Some rules of thumb:

- Trees: 5-10 gallons, once/week
- Shrubs: 3-5 gallons once/week
- Groundcover: 1-2 gallons, once or twice/week
- Perennial herbs: ½ gallon, twice/week

If the planted areas are surrounded by pavement or conventional (hot) roofs, some irrigation beyond the establishment period will probably be needed. You may reduce your water demand by hand watering, using efficient irrigation systems (drip), and harvesting rainwater. To make hand watering faster/easier, find a 1-2 gallon container, poke a few small holes in the bottom, and place it next to the stem of the plant. Fill the container as many times as needed. This quickly delivers ideal volumes without causing erosion. For more information on rainwater harvesting, see *“5 Build a Rain Barrel”* and *“6 Harvest Rainwater in Cisterns”*.

Figure 10. Establishing vegetation in a depaved area.

Permits

Permitting varies, so check with your local jurisdiction's building or development services department to find out what codes may apply to your project. If information in this guidance conflicts with your jurisdiction's requirements or approach, then follow their guidance instead.

Bibliography

Information on depaving was copied and adapted from the following source:
Depave. (n.d.). Retrieved from Depave. From Parking Lots to Paradise.: http://depave.org/

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2 Disconnect Impervious Areas

Rainfall over an impervious area (one that does not allow water or other fluids to pass through or be absorbed) tends to quickly end up in storm drains, which often make their way into a creek, or discharge directly in a creek. The best way to restore watershed health is to prevent runoff in the first place. For more information, see *"1 Minimize Impervious Area".* Aside from that, disconnecting impervious areas from storm drains and creeks is a simple, cost-effective way to reduce runoff volume and protect your watershed. Contained planters, downspout disconnection for roofs, and vegetated filter strips for ground level impervious areas (sidewalks, driveways, roads) are three ways to reduce runoff from small areas.

Contained planters placed over existing impervious areas, on the ground or roof, intercept rainfall and then evaporate it back. When runoff does occur, it moves through two different forms: sheet flow (aka overland flow) and concentrated flow. Sheet flow occurs first, when rain falls on roof or pavement and "sheets" across the surface. Eventually, sheet flow may arrive at either a roof gutter or a curb and becomes concentrated flow. Design and management of both sheet and concentrated flows must be carefully done to prevent erosion, which in turn protect water quality.

Figure 1 Downspout disconnection can be a simple and easy way to restore watershed health. If this were a new tree, this configuration would function well. But the health of this existing tree, which established under drier conditions, may be impacted by the additional water.

Siting for Infiltration

Downspout disconnection and vegetated filter strips rely on the ability of the soil to absorb and filter runoff. Infiltration facilities, if not sufficiently separated, both horizontally (i.e. setbacks from infrastructure) and vertically (with enough depth to allow proper function), from various conditions have the potential to cause damage. For more information, see *"8 Site Bioretention for Infiltration".*

Downspout Disconnection

Many modern houses in developed areas have a gutter and downspout assembly that conveys all the runoff from their roof into a public storm drain. This storm drain probably outlets to a natural area, where pollutants from the roof and the additional runoff volumes collected impact water quality. Disconnecting the downspout means directing runoff from your downspouts to a landscape area instead of allowing your water to flow directly to a creek via the storm drain. In many rural areas, where pipe infrastructure is limited, downspout disconnection is common practice.

Figure 2 This LDPE downspout extension is next to a slab footing of a garage. A non-perforated section on the right provides adequate setback for a garage slab, while the left half has holes that spread runoff out, preventing erosion. Compost amended soil below and a few inches of mulch added every year to the path surface, make this a no maintenance "facility".

Design

Since downspouts are usually attached to a building wall, if you have a basement and not pier or post footings, the first step is to cut the downspout and attach an extension on it that will convey stormwater safely away to a landscape garden or lawn area. Since water in soil can move twice as fast horizontally as vertically and easily flood the basement, water should be moved at least 10 feet away from any basement walls or other sensitive infrastructure.

Don’t put a downspout outlet in an area that is too small to drain the water properly. A landscape area at least half the size of the roof area draining to the downspout is a rule of thumb that should work in most soils. Smaller areas may work in fast draining soils like sand.

There are many kinds of downspout extensions available, some of which can be found at your local hardware store. Or you can use a piece of downspout laid on its side. A lined conveyance swale is another alternative; see *“11 Convey Water in Swales”* for more information.

Beyond the 10-foot setback, there are a number of ways to safely disperse and infiltrate runoff at the end of your downspout:

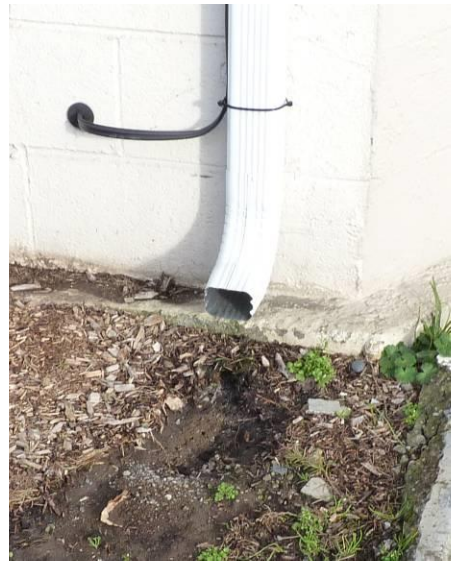

Figure 3 Placing a downspout this close to a slab is not ideal. It would require a vertical liner to be placed at least a few inches deeper than the slab section (including rock). If erosion like this occurs, spread the flows out and/or plant some vegetation at the mouth.

Water can be deposited directly into the yard. However, erosion from this concentrated flow is likely. If you’ve tried this simple approach, but there is erosion, spread it out using the suggestions that follow. Vegetation is great at holding soil, but too much vegetation at the mouth of a simple downspout extension could cause water to back up and flood the basement anyway. Downspout extensions (Figure 2) – perforated at the end – will prevent erosion by slowing flows and spreading them out over a larger area.

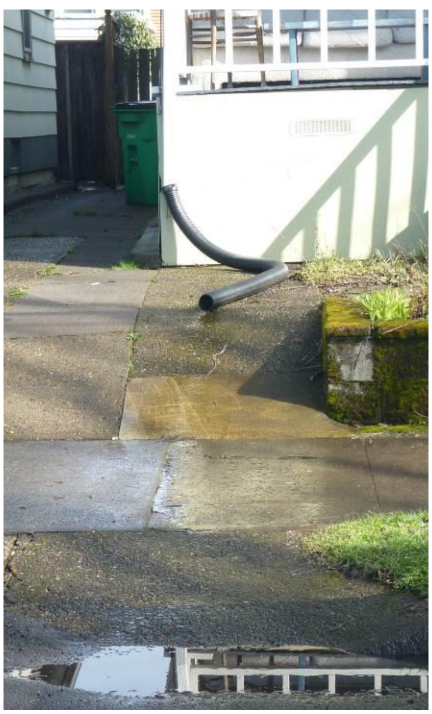

Figure 4 Avoid disconnecting your downspout to impervious areas. This has as little benefit to the watershed and could create safety hazards (e.g., puddle at the bottom of the driveway).

Specifications

Gutters, downspouts, extensions and other components used to move stormwater around the site should be durable and non-polluting. Plastic, like all petroleum products, are broken down by UV light and microbial action in soil. Choose materials that are UV and rust resistant. Avoid copper, galvanized steel, and iron. Water moving over these materials picks up portions of the metals that pollute ground and surface waters. Stainless steel, high density polyethylene (HDPE), low density polyethylene (LDPE), and aluminum are some good alternatives.

Construction

Steps for disconnecting:

1. If your downspout connects to the sewer system directly via a pipe, measure the existing downspout from the top of the standpipe. Make a

Figure 5 Avoid disconnecting your downspout onto a short hill like this. Instead, attach your downspout to a level spreader (described below) and turn the rest of the yard into a vegetated filter strip.

mark at least 9 inches above the standpipe. A standpipe is the pipe leading into the below-ground storm drain.

2. Cut the existing downspout with a hacksaw at the mark. Remove the cut piece.

3. Plug or cap the standpipe. Do not use concrete or other permanent sealant.

4. Attach an elbow to the newly cut downspout by inserting the elbow over the downspout. Then use at least two sheet-metal screws to secure the two pieces.

5. Measure and cut the downspout extension so that when it is attached, it will direct flow to an area that won't cause flooding (see Design above). Fit the extension over the elbow and attach it with sheet-metal screws.

6. Since the extension does not connect directly to the standpipe or leads into a rain garden, use a splash block, gravel, or a flow spreader to prevent soil erosion.

7. Remember that each section should funnel into the one below it. All parts should be securely fastened together with sheet-metal screws.

Maintenance

Be sure to maintain your gutter system. Inspect it regularly for leaks, sagging, holes, or other problems. Inspect annually and clear debris from gutters, elbows, and other connections before the rains arrive. If you find erosion, spread the flow out along areas of similar elevation (i.e. don't direct water downhill) using a perforated spreader or other means.

If you find that water isn't infiltrating into your landscape area or lawn and you're meeting the above criteria, the area was probably compacted and impermeable. (There are no or very few voids in the soil where water can go.) In this case, restore soils by amending them with compost. For more information, see *"3 Restoring Disturbed Soils"*. Considering vegetating the area with tall grasses, shrubs, and the like, which will help preserve the long-term permeability of the soil and reduce maintenance. Choose native species that will tolerate moist conditions (like that of the slope area of a rain garden) and the other natural conditions at your site. For more information, see *"9 Find Native Plants for Your Location".*

Vegetated Filter Strips

A vegetated filter strip (VFS) is an area covered in vegetation (grass and/or plants) that receives sheet flow runoff from impervious surfaces, which are located at ground level.

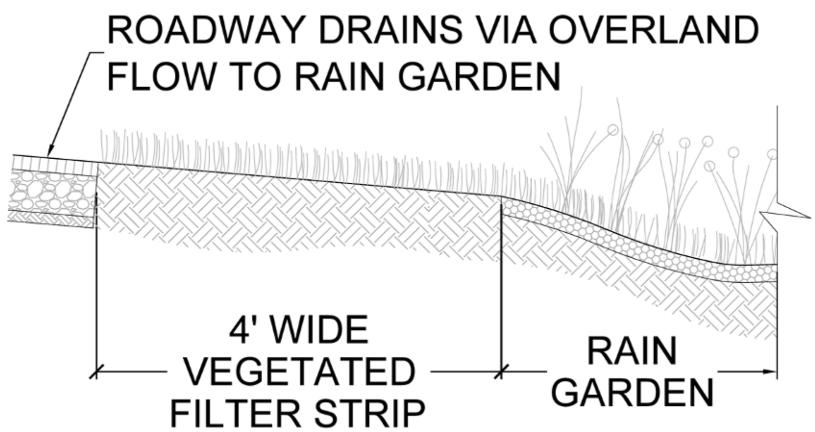

Figure 6 Vegetated filter strips are sometimes used as pretreatment to settle sediment to protect other facilities from clogging.

This guidance is for small areas with sheet flow only. More complex design and calculations are required for other conditions. Consider building a rain garden if the design criteria below cannot be met. For more information, see *"4 Build a Rain Garden".*

Design

VFS design is defined the width of the landscaped area and the width of the impervious area sheet flowing into it (aka contribution area). The following design criteria apply:

- Use a VFS for contribution areas no wider than 60'.
- The VFS must abut (be located directly next to) the contribution area.
- The width of the VFS should be at least half the width of the contribution area. This may not be necessary if you will perform stormwater modeling to assist in your design.
- Ensure that water actually will flow evenly into the VFS and not be blocked. For existing pavement, observe an area in the rain or run a hose on it to see where water flows. Use a level spreader if needed (Figure 8).
- Limit the slope/grade of the VFS in any direction to 10% total.
- Vegetate with native plants that tolerate moderately wet conditions and will find other natural conditions agreeable. For more information on choosing native species, see *"9 Find Native Plants for Your Location".*

Construction

The steps to construct a VFS are:

1. Begin construction only when the contribution area is stabilized and temporary erosion and sediment control measures are in place. The strip should be installed at a time of the year when it is most likely to establish without irrigation. However, temporary irrigation may be needed in periods of little rain.
2. Amend the soil to a depth of 18" per guidance in *"10 Amend Soils for Bioretention"*.
3. Carefully grade the VFS area. Accurate grading is crucial for filter strips. Even the smallest irregularities may concentrate sheet flow and cause erosion.
4. Seed, sod, or plant more substantial native vegetation. If sod is used, place tiles tightly to avoid gaps, and stagger the ends to prevent a channel from forming along the strip. Use a roller on sod to prevent air pockets from forming between the sod and soil but never compact with a vibratory compactor or heavy equipment.
5. Stabilize seeded filter strips with appropriate, permanent soil stabilization methods, such as erosion control matting or blankets.
6. Irrigate or hand water for a 2-3 year establishment period, see maintenance section in "*1 Minimize Impervious Areas*". Irrigation after this can be done during especially hot periods when plants are at risk, but regular watering after the establishment period will invite weeds and be more work to maintain.

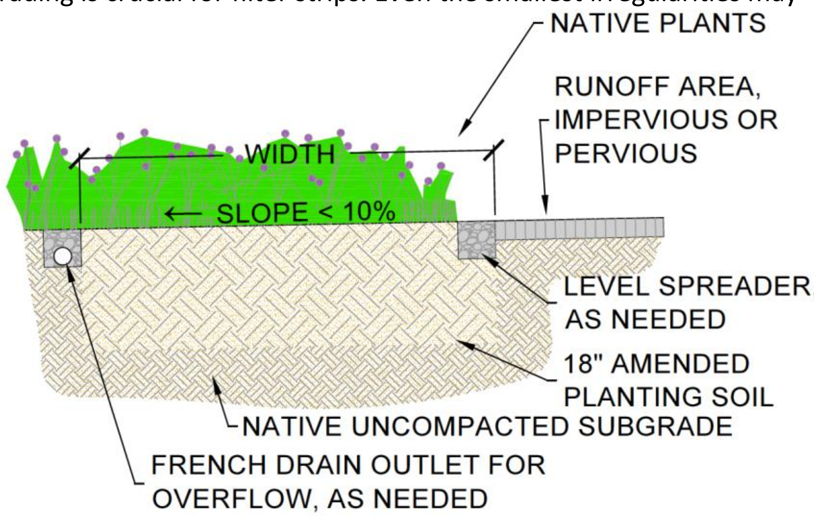

Figure 7 A typical vegetated filter strip receiving overland flow.

7. Once the filter strip is sufficiently stabilized after one full growing season, remove temporary erosion and sediment controls.

Figure 8 Another accidental vegetated filter strip. The parking lot sheds runoff to the left towards the grassy area. A lack of curbs and additional drainage means all the runoff from the parking lot stays on-site.

Maintenance

As with other vegetated best management practices, filter strips must be properly maintained to ensure their effectiveness. In particular, it is critical that there be even sheet flow throughout the life of the filter strip. Field observations of strips in urban settings show that their effectiveness can deteriorate due to lack of maintenance, inadequate design or location, and poor vegetative cover. Compared with other vegetated stormwater management practices, filter strips require only minimal maintenance efforts, many of which may overlap with standard landscaping needs.

Specific activities that should be performed on at least a quarterly basis (if no other time period is suggested below) include:

- Look for and remove sediment and debris at the top of the VFS after every storm event greater than one inch during the establishment period (2-3 years) and after that at least quarterly. Very small sediment accumulation (depths of less than 1/8 inch) can block or re-route runoff, causing channelization and erosion. During the fall, this may need to be done more often.
- Throughout the entire area of the VFS, sediment and debris should be removed when buildup exceeds two inches in depth. Perform this during the dry season.
- If erosion is observed (i.e. rills and gullies, channelization) stabilize with erosion control matting, and either seed or place sod in the area. For channels less than 12 inches wide, filling with crushed gravel, which allows grass to creep in over time, is acceptable. For wider channels (greater than 12 inches), regrading and reseeding may be necessary. Small bare areas may only require overseeding (i.e. casting seed over whatever is already there). If erosion cannot be stabilized long-term by the methods described so far, install a level spreader as described below.
- If pools of standing water are observed along the slope, regrade the area so that ponding will not occur. In no case should standing water be tolerated for longer than 48 to 72 hours. If no visible sediment is clogging the area, soils have been compacted. Fold a few inches of compost into the top 6" of soil, form a smooth surface, and revegetate.
- If a filter strip exhibits signs of poor drainage, periodic soil aeration (for grassed facilities) or liming may help to improve infiltration.
- Grass cover should be mowed to maintain a height of 4-6 inches. Mowers often have a setting that allows them to be set high. The deeper the roots, the better the function.
- Remove invasive plants (i.e. weeds) on a semi-annual basis: once in May and once in Sept. Native vegetation should cover at least 85 percent of the vegetated filter strip at all times. Re-vegetate as needed.
- Consider adding signage and low fencing or other messaging to alert pedestrians and drivers to the location of the VFS.

Cost

The cost of constructing VFS includes grading, sodding (when applicable), installing vegetation, and, if proposed, constructing a level spreader. Depending on whether seed or sod is applied, enhanced vegetation use, or design variations such as check dams, construction costs may range anywhere from no cost (assuming the area was to be grassed regardless of use as runoff treatment) to thousands of dollars per acre. The annual cost of maintaining filter strips (mowing, weeding, inspecting, litter removal, etc.) generally runs from $100 to $1,400 per acre (2008 costs from Southeast Michigan for commercial sites) and may overlap with standard landscape maintenance costs. Maintenance costs are highly variable, as they depend on frequency, local labor rates, proper construction of the original facilities, and most importantly, preventative maintenance.

Additional VFS Applications

Vegetated filter strips have traditionally been used by farmers to prevent precious soil resources from being lost. However, VFSs have also been used:

- As sediment pretreatment for other stormwater management facilities
- By transportation agencies to treat and infiltrate highway runoff
- Instead of rain gardens where high bedrock, groundwater tables or fragipan (non-infiltrating soil layer) exist

Level Spreader

Often, a piece of pavement is not as smooth or regular as it appears. Even very small dips and inconsistencies can concentrate sheet flow, causing erosion through the formation of channels. A level spreader, installed at the line between the contributing pavement area and the VFS, is a way to ensure that water spreads out over the entire length of the VFS, reducing erosion and maintenance and improving function.

Construction

Construction is simple:

1. Excavate a 9-inch wide by 6-inch deep trench the entire length of the vegetated filter strip.
2. Place an impermeable liner vertically along the downstream side (VFS side, not pavement side) of the trench. As long as you don’t place any liner on the bottom of the level spreader facility, your VFS should still be properly sized.
3. Place clean, uniformly graded (i.e. all the same size) crushed aggregate in the trench. If crushed aggregate is not aesthetically pleasing, first place 4” of crushed rock then top with 2” of pea gravel.

Specifications

- Any crushed aggregate where all the pieces are about all the same size (i.e. uniformly graded) will work for this application.
- Avoid rounded river rock mined from waterways, which causes erosion in the stream channel where the material is removed and impacts water quality. There are other alternatives. Over geologic time periods, rounded river rock can be deposited far from a waterway where it can be mined. This source of rock is better for protecting overall watershed health.
- Install liners per manufacturer recommendations. For filtration facilities or any other purpose, use:

Figure 9 Crushed aggregate can be as aesthetically pleasing as rounded river rock and does a better job at protecting water quality.

- 30 to 60 mil (mm) EPDM rubber (ethylene propylene diene monomer)
- bentonite clay mat
- 30 to 60 mil (mm) LDPE (Low density polyethylene) plastic (aka pond liners)
- Avoid asphalt products, which are subject to degradation from soil microbes. Avoid PVC (poly vinyl chloride) which is more polluting than the EPDM, LDPE, and bentonite clay.

Contained Planters

Contained Planters are an easy way to disconnect impervious area and improve aesthetics anywhere. Put a potted plant anywhere there is unused pavement or a roof. Acting much like green roofs, contained planters can reduce annual runoff by 40% to 60% from the area on which they are placed.

Design

Container Materials

The container can made of anything you like as long as it can drain from the bottom. Since these will be outside year-round, consider durability.

Figure 10 Contained planters are a common beautification project that can have real benefits to the watershed when placed over impervious surfaces.

Soils

Consider using a native soil or an amended native soil instead of store bought potting soil because:

- Having adapted over geologic times, native plants are usually healthier and thrive better in native soil.
- Potting soil is designed to over-nourish plants. As rainfall runs quickly through potting soil, it leaches nutrients out, which will be carried downstream to impact water quality.
- Potting soil is sterile. Plants benefit from microbes, mushroom roots (mycorrhizae), and larger soil animals like beetles, which move and process nutrients and preserve permeability. If you do use potting soil, throw a handful of organic (dark colored) soil into the pot.
- Potting soil is usually less dense than native soil, which makes it less resistant to temperature swings and won't reduce runoff as much.

If your native soil is clay and the water table isn't too high, you could successfully put a native plant right into the clay soils with no amendments and it would do fine. This is done in watershed restoration projects all the time. However, since you'll be disturbing all the structure of the soil to put it into a container and since clay isn't that easy to work with, you may consider amending it with compost.

If your soil is sandy, folding in some compost and even a little clay will help slow water as it passes through. The soil will hold more water for the plant later as well.

For any kind of soil, you might consider mycorrhizal treatments to make your plantings more resilient and to reduce water demand. Most plants in the Five Counties region (and outside it) have co-evolved with this mushroom root material. You can buy these amendments as pellets or water soluble powder. Mushroom roots interact with the plant roots by feeding on the plant's waste and by bringing the plant nutrients, thereby expanding the effective root area of the plant by many fold. Plants receiving this kind of amendment consistently grow bigger and faster than plants without it.

For contained planters on roofs with adequate structural integrity, you may want to consider purchasing engineered lightweight soil mixes. Lightweight mixes are usually 80 – 90% lightweight stone, like pumice or expanded shale. Look for a mix with amendments that include mycorrhizal fungi, biota, and a natural carbon source like jute that will degrade slowly over time. Some mixes have water holding pellets that will reduce water demand. Green roof practitioners in Europe are successfully using native soils on roofs. If your roof can take the extra weight, this would be ideal for a contained planter. Again, consider the wetted weight of your soil when determining structural capacity. Before placing contained planters on roofs, make sure that the roof is strong enough to support the container, the soil, the mature plants, and the weight of the water that will temporarily be filling the voids of the soil. If the container gets clogged for some reason, the roof must be able to withstand the weight for a potentially long period of time. If living in cold climates, consider the snow load as well. Check with the local county building department for snow load information for roofs.

Plant Choices & Soil Depth

All kinds of plants are suitable for use in contained planters, although perennials that won't require much irrigation after an establishment period of 2 – 3 years are preferred. Take care to avoid the numerous invasive plants (i.e. noxious weeds) such as periwinkle (vinca minor or major), English ivy, and yellowflag iris that may be sold at your nursery. For more information on plant choices and needs, see *"9 Finding Native Plants in Your Area"*.

Generally, the more soil, the better it will be for the plant. Provide enough soil at the start so that at maturity, roots have access to the soil volume they need. Too little soil can stunt the size of the plant. However, this is sometimes used as a landscape design approach. For instance, a Ponderosa Pine in a small container will stay small and will survive, but may be high maintenance.

For plants to reach full maturity and be low maintenance, soil depth requirements vary with the plant type. Soil depth rule of thumb minimums are as follows:

Figure 5 These benches were created to intercept some rainfall and seat people on the terrace.

- Grasses: 12". Generally, the roots of grasses and grass-like plants will be as deep as the plant is tall.
- Shrubs: 18", but 24" is preferable.
- Trees: 36", but depending on the species, trees also need a minimum volume of soil, 400 to 1,000 cubic ft. Since tree roots don't usually extend much beyond 3 ft, the minimum area needed is 133 to 333 square ft.
- Vegetables would be fine in these containers, but rooting depth probably varies widely, so search the internet for guidance. Consider the

size and weight of vegetables when designing your project.

Construction

Find a suitably sized, sturdy container. Fill it with soil. Put your plant in it. It's almost as simple as that.

Correct Planting Techniques

Plants from nurseries can often be root-bound in their pots. If the roots aren't loosened and unwound, the roots will continue to twist around in the hole you planted them in instead of growing downwards and outwards. Another key to low maintenance plant establishment is to ensure that the roots have good contact with the soil.

To properly plant potted plants:

1. Fill your container up with soil to the desired depth leaving an inch or two to the top of the container.
2. Dig a hole twice the size of the pot the plant comes in. Keep the soil pile nearby and clear of leaves and other surface debris.
3. Take note of where the potting soil level is compared to the stem of the plant. Many plants have a different color and texture on the section that sits below the soil than on the sections that sit above ground.
4. Gently shake the potting soil off as much of the roots as possible. The nutrition from the potting soil has probably been exhausted.
5. For balled and burlapped trees, the soil may be left in. However, ensure that burlap or any other confining material will not impede root growth by removing at least the bottom half of the material.
6. Loosen the roots.
7. Taking some of the soil you dug out, create a mound at the bottom of the hole and lightly tamp it down.
8. Drape the plant roots around the mound so that they're touching the mound on the bottom and pointing downwards. There are two kinds of roots, larger structural roots and tiny feeder roots, which is where the plant "drinks" and "eats". In pot-bound plants, some roots may be really long and will just continue winding around the other plant roots. If they're feeder roots, shorten them by pulling them off to be a similar length as the other roots. A few of the bigger structural roots can be cut, but it's better to dig a deeper hole and get them pointed downward.
9. As you backfill the hole by pushing soil in around the tops of the roots, hold the plant so that the point at which the plant came out of the soil in its original pot will be the place where the final grade of soil in the contained planter will be (level of soil on the

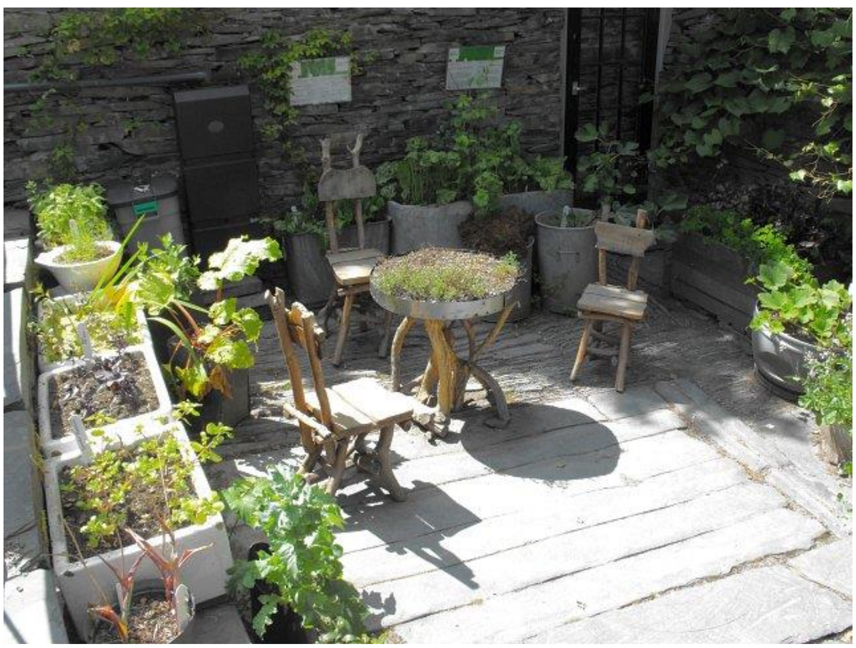

Figure 6 At the Center for Alternative Technology in Wales, sinks, baths, cisterns and roofing slates are reused to create planters for their patio.

stem is the same). Plants that are too deep may drown or the stem may rot. Plants that are too high may not have enough feeder roots in the soil to survive.

10. When finished, tamp down the soil. If the container is very large, step around the stem of the plant. This, combined with previous steps, will ensure good root contact with the soil.
11. Place an organic mulch that meets the specifications in *"3 Restore Disturbed Soils"* to a depth of 2 to 3". For woody stems on shrubs or trees, push the mulch a few inches away or the stems could rot.

Maintenance

Since contained planters are above ground, depending on the soil, they may be more subject to freezing and may drain faster than the soil around plants that are in the ground.

Maintenance of contained planters is similar to that of conventional landscape:

- Remove weeds twice a year.
- Replenish compost to a depth of 2-3 inches annually.
- Irrigate per the following guidance.

Establishment Period Irrigation

Irrigation of contained planters is easy if you followed step 1 (Correct Planting Techniques) during construction. Since the container will allow water to pond over the plant, it'll be faster than watering a garden.

To establish perennial plants, you'll need to irrigate more in the first year and less in subsequent years. In addition, plants benefit from changing irrigation with the seasons. After summer starts and the rains stop, water a little. Increase water volume as the dry season continues. Taper off irrigation as the rains start to come back. Depending on your area and rainfall patterns, irrigation may be needed from May to October.

The volume of water and frequency of watering varies with the type of plant. See "*9 Find Native Plants for Your Area*" for information on preferred growing locations and watering needs. Some rules of thumb:

- Trees: 5-10 gallons, once/week
- Shrubs: 3-5 gallons once/week
- Groundcover: 1-2 gallons, once or twice/week
- Perennial herbs: ½ gallon, twice/week

After the 2 – 3 year establishment period, irrigation should not be needed. However, contained planters will be placed over and presumably will be surrounded by impervious pavement or conventional (hot) roofs. This setting will probably require occasionally irrigation beyond the establishment period. You may reduce your water demand by hand watering, using efficient irrigation systems (drip), and harvesting rainwater. To make hand watering faster/easier, find a 1-2 gallon container, poke a few small holes in the bottom, and place it next to the stem of the plant. Fill the container as many times as needed. Having a bunch of them already placed around the plants allows you to quickly move from one plant to another without having to wait for the water to soak in. This quickly delivers ideal volumes without causing erosion. For more information on rainwater harvesting, see *"5 Build a Rain Barrel"* and *"6 Harvest Rainwater in Cisterns"*.

Fertilizing

Avoid P-K-N (potassium –phosphorus – nitrogen) as these are common pollutants found in waterways and will easily dissolve in water, flow out of the container bottom onto an impervious surface, and likely into a pipe that drains to a waterway. Replenishing the 2-3" of organic compost every year will provide adequate nutrition slowly and safely. Grasses are self-fertilizing, since 30% of their roots die off every year.

Permits

Permitting varies, so check with your local jurisdiction's building or development services department to find out what codes may apply to your project. Retrofits using these practices will likely not require permits, but new development likely will. In addition, where stormwater management is required, clarify relevant calculations such as detention to confirm where you can subtract areas where you will install stormwater management practices from the total project area that you may have to detain or otherwise treat.

If information in this guidance conflicts with your jurisdiction's requirements or approach, then follow their guidance instead.

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3 Restore Disturbed Soils

Disturbed soils (i.e. any soil in a town, city, or other historically populated area) tend to get compacted by vehicular or, in the case of clayey soils, even foot traffic. Compaction reduces spaces in the soil where water can infiltrate, which has several impacts to water quality & availability[1].

- Rain falling on compacted soil can no longer be absorbed and conveyed downhill in the soil, but instead runs off, carrying pollutants with it.
- Plant establishment depends on roots' access to air and water in spaces within the soil (voids).
- Landowners often respond to unhealthy plants by applying chemicals like pesticides, herbicides, and fertilizers and by watering more.

Figure 1. Compost amendment of disturbed soils reduces long-term maintenance and irrigation, reducing or eliminating the need for pesticides and herbicides.

In studies done by Washington State University Extension Services, simply ripping/disturbing, without folding in compost, allows the soil to slump back into a compacted state. These studies found that when disturbed soils were properly amended with compost and finished in lawn or shrubs in a landscape area, the areas responded to rainfall events as if they were 50% - 80% forested, respectively, and remained permeable (allow water to soak in) over time. This method of soil restoration in developed areas is recommended to regain greater stormwater functions, provide increased treatment of pollutants and sediments, and minimize the need for some landscaping chemicals, thus reducing pollution through prevention[2]. The practice of amending these soils is a simple, cost-effective practice for restoring and preserving the long-term permeability of compacted soils. The practice is also a great way to conserve water.

Cost Benefits

Real estate agents estimate that the landscape is about 5-10% of the total sales price of a house. This practice can cost as little as $1,000/lot during construction[3]. Long-term irrigation demand can be cut by 50% with a payback period of 3-7 years, which is a selling point for landowners. Stockpiling topsoil for use later as an ingredient in the compost amendment can save money in hauling costs.

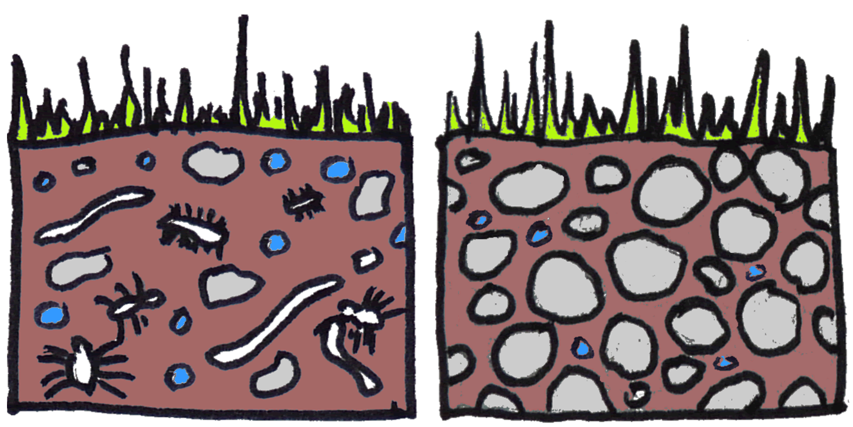

Figure 2. Left: Beneficial soil animals, from tiny microbes to beetles and larger fauna, chemically break down some pollutants and provide nutrition to plants. As they move through the soil, they protect long-term permeability and promote soil formation. Right: Compacted soils have fewer to no voids to store air and water needed to sustain soil animals.

Where to Amend

Compost amended soils should be used anywhere soils have been disturbed and where a future landscape area is proposed. Compost amendment should not be performed under tree canopies or other established landscape areas to be preserved since the tilling process will damage roots. Any kind of soil will benefit from compost amendment, but in particular, watersheds with clay will benefit the most.

Design

For all proposed landscape areas inside the disturbed area (clearings, parking, roads, pathways, re-grading), till compost into the top few inches of native soils. The ideal organic content is 10% for landscaped beds. A lower target rate for turf areas of 5% is recommended since a higher organic content could make mowing more difficult. The document "Building Soil[4]" includes great detail on methods to calculate the appropriate depth of compost to use to achieve these percentages, but the following guidance is a method that can easily applied, without calculations or lab testing, to any kind of soil (sandy, clay, silty, etc).

To amend proposed landscaped beds:

- Till or scarify soil 12" deep.
- Place 3" of compost and till into 5" of soil (a total amended depth of about 9.5", for a settled depth of about 8").
- Rake beds to smooth and remove surface rocks larger than 2" in diameter.
- Mulch planting beds with 2 – 3" of organic mulch.

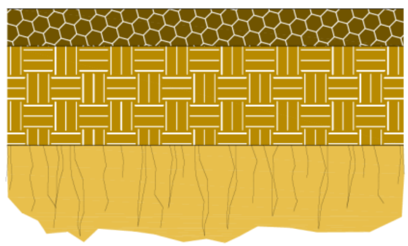

Figure 3. For lawn or landscaped garden, the same cross section (layers) of loosened and amended soils apply.

To amend proposed turf areas that will be mowed:

- Till or scarify 12" deep.
- Place 1.75" of composted material and roto-till into 6.25" of soil (a total amended depth of about 9.5", for a settled depth of about 8").
- Water or roll to compact to 85% of the maximum density there would be in dry conditions. Rake to a level surface and remove surface woody debris and rocks larger than 1" diameter.

To amend native soils for rain gardens and vegetated filter strip areas, see *"4 Build a Rain Garden"* and *"2 Disconnect Impervious Areas"*.

Compost Specification

When amending soils, care should be taken to ensure that compost is clean and free of weeds, pollutants, or other harmful materials that may impact plant health and water quality.

Organic compost should have the following properties:

- Weed seed and pollutant free.
- 100% of material shall pass a ½" screen.
- pH between 5.5 and 7.0. If the pH isn't quite right, it may be lowered by adding iron sulfate and sulfur or raised by adding lime or recycled, ground gypsum board.

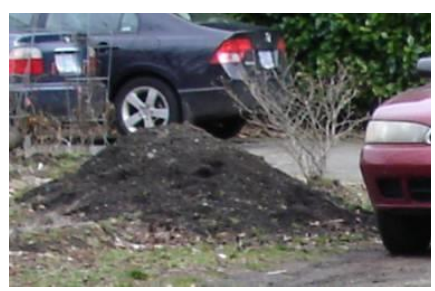

Figure 3. Compost should be dark and fully composted (in other words, smell like earth, not ammonia).

- Carbon nitrogen ratio of 35:1.
- Organic matter content between 40 and 50%.
- Fully decomposed. Earthy is good. Avoid compost that smells like ammonia.

Organic compost may consist of the following:

- Mushroom Compost. The used bedding material from commercial mushroom production.
- Local nursery or garden supply's stock of organic compost. There is US Compost Council Seal of Testing Assured (STA) compost. Visit http://compostingcouncil.org/participants to find a participating supplier near you. The STA program is no guarantee of quality, only that the compost has been tested and those test results are available for review.

Organic compost may NOT be:

- Composted Yard Debris. This is because excessive pollutants, mostly herbicides, pesticides, and fertilizers, have historically been found in these materials. "Cides" can kill beneficial soil life, reduce stormwater benefits, and increase maintenance.
- Peat Moss. Peat moss is extracted from wetlands; this has negative impacts on the watershed from which the peat moss was removed.

Conveyance

Compost amended areas are considered self managing. Grading plans should show a 2% minimum slope away from buildings for a minimum distance of 10' in landscape areas to ensure adequate drainage during large storms, which are expected to generate runoff. This is a common rule of thumb and shouldn't change the grading design from that of a conventional stormwater approach. If compost amended landscape areas drain to a structured outlet such as an area drain and pipe, size the infrastructure to adequately convey even the very large, perhaps infrequent, storm flows safely away.

Figures 4 & 6. A range of construction equipment (tiller, cat mounted ripper, tractor-mounted disc, etc) or simply shovels and rakes may be used depending on the extent of the area to be amended.

Construction

Soils should be amended at the end of construction or at least at the completion of concrete work. Protect areas from compaction and erosion afterward with fencing and signage as needed[5]. Minimize erosion by covering soil with mulch and planting right away.

Maintenance

Maintenance of compost amended soils is the same as any landscape area. It should be possible to irrigate less and reduce or eliminate the use of fertilizers, herbicides and pesticides. Keep soil in landscaped garden areas covered with 2-4" of compost by mulching once a year. Aerate turf areas and top-dress with fine mulch[6].

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[1] EPA Stormwater Menus of BMPs website http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=97&minmeasure=1 This references:
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4 Build a Rain Garden

Rain Gardens are shallow depressions (bowl-shaped or linear) that treat stormwater with soil and plants though ponding (aka bioretention). To protect water quality and create a low maintenance facility, a rain garden should be built in the right place. For more information, see *"8 Site Bioretention for Infiltration".*

Figure 1 A rain garden can be a beautiful landscape amenity that protects water quality, too.

Choosing the Right Rain Garden Configuration

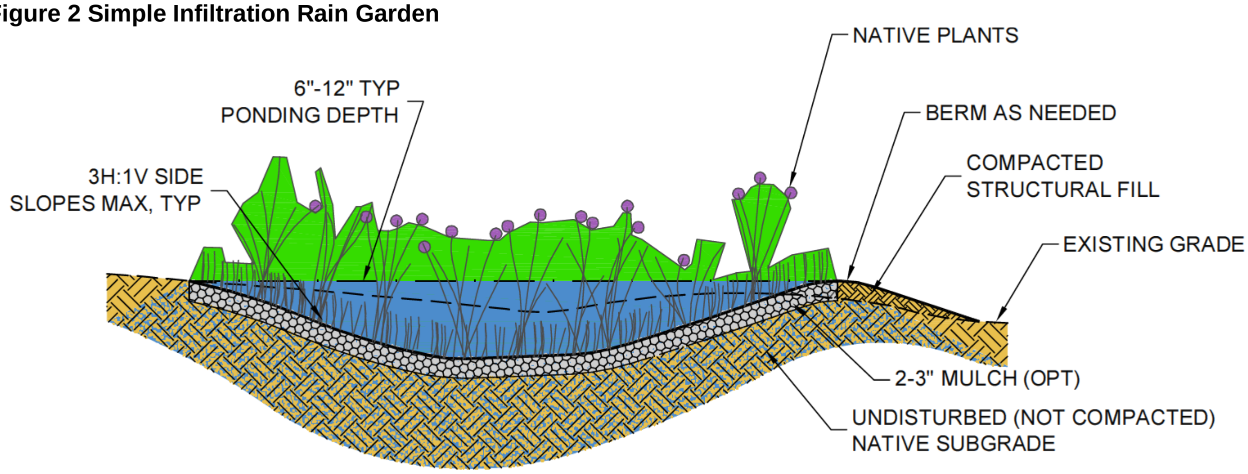
Rain gardens have a range of complexity, from very simple to highly engineered. Let's take a tour of some details and in what situations you will probably want to use them. Rain Gardens should not be built in soils with an infiltration rate (how well they absorb and allow water to pass through) of less than 0.5 inch/hour. See Figure 2 below for an illustration. Other constraints on your site may limit the use of rain gardens; see *"8 Site Bioretention for Infiltration".* Guidance here refers to native infiltration rates of soils. Infiltration testing is essential for the proper design and functioning of rain gardens. For more information on infiltration testing and soil texture analysis, see *"7 Test Your Soil"*.

Simple Infiltration Rain Garden

A simple infiltration facility per Figure 1 below may be used when all of the following criteria are met:

- Native soils infiltrate between 0.5 and 12 inches/hour AND
- In a large storm or in the case of a clogging failure, when water flows over the berm and/or low point of the facility, it will not cause damage to any structures downhill AND
- In a large storm or in the case of a clogging failure, water will not back up to flood any nearby structures uphill.

Figure 2 Simple Infiltration Rain Garden



Infiltration Bioretention with Area Drain

An area drain per Figure 2 should be added to the facility when:

- Native soils infiltrate between 0.5 and 12 inches/hour AND
- In a large storm or in the case of a clogging failure, when water flows over the berm and/or low point of the facility, it MAY cause damage to any structures downhill OR
- In a large storm or in the case of a clogging failure, water MAY back up to flood any nearby structures uphill.

Area drains and piping are available at your local hardware store. A 12” x 12” box for the area drain will be sufficient for rain gardens managing less than 10,000 square feet of drainage area, as described below. A plumbing permit will probably be required to install the area drain and overflow pipe and to connect the pipe to an approved disposal point, such as a public pipe in the right-of-way or a waterway. Connection to an underground perforated pipe will require a permit for a Class V Underground Injection Control (UIC) through the California Department of Conservation, see http://www.consrv.ca.gov/dog/general_information/Pages/class_injection_wells.aspx for more info.

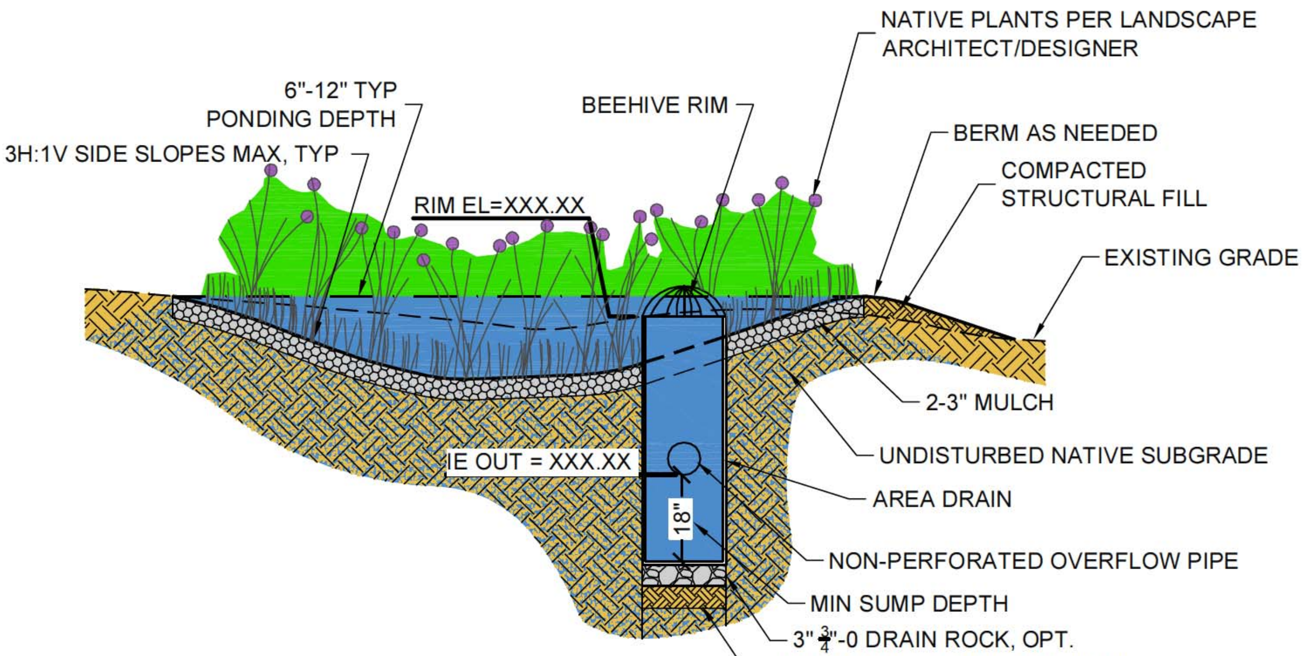


Figure 3 Infiltration Rain Garden with Area Drain

Infiltration Rain Garden with Amended Planting Soil

Soil should be amended to a minimum depth of 18 inches when:

- Native soils infiltrate at 1 inch/hour or slower. Soil amendments are needed to increase the storage capacity (and therefore the infiltration capacity) of the facility (see Figure 4).
  [Note: This approach is most often used in tight clay soils to provide more voids in the soil for water storage. It does not change the infiltration rate of the facility. In making calculations or decisions, use the soil infiltration rate of the original, unamended soil.] OR
- Native soils infiltrate 12 inches/hour or faster. Soil amendments are needed to slow water flow to achieve adequate retention time in the soil for water quality treatment OR

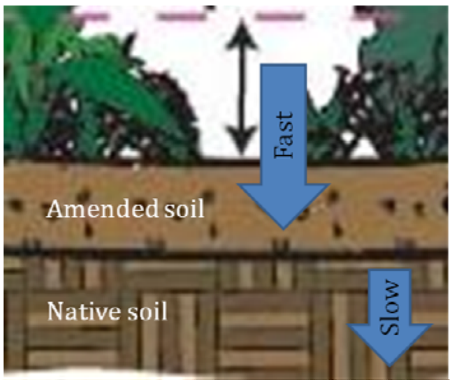


Figure 4 Use the infiltration rate of the slowest soil under the rain garden for calculations.

- A simple rain garden or rain garden with area drain configuration was planned, but the soil was accidentally compacted during construction.

Soil may also be amended when:

- You believe that the plants will be healthier with amendments OR
- A faster draining soil is beneath a slower draining surface soil and you wish to decrease the footprint of your facility by being able to access the faster draining soil (see Figure 5).

For more information, see *"10 Amend Soils for Bioretention".*

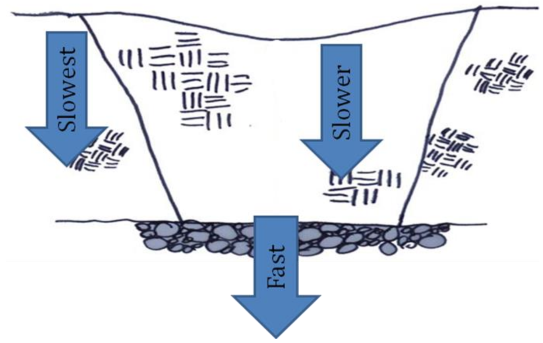


Figure 5 Amended soils can sometimes reduce the size of a facility when faster draining soil is found within a few feet below grade. Since the slowest native soils are no longer draining the rain garden, the slower infiltration rate may be used for sizing.

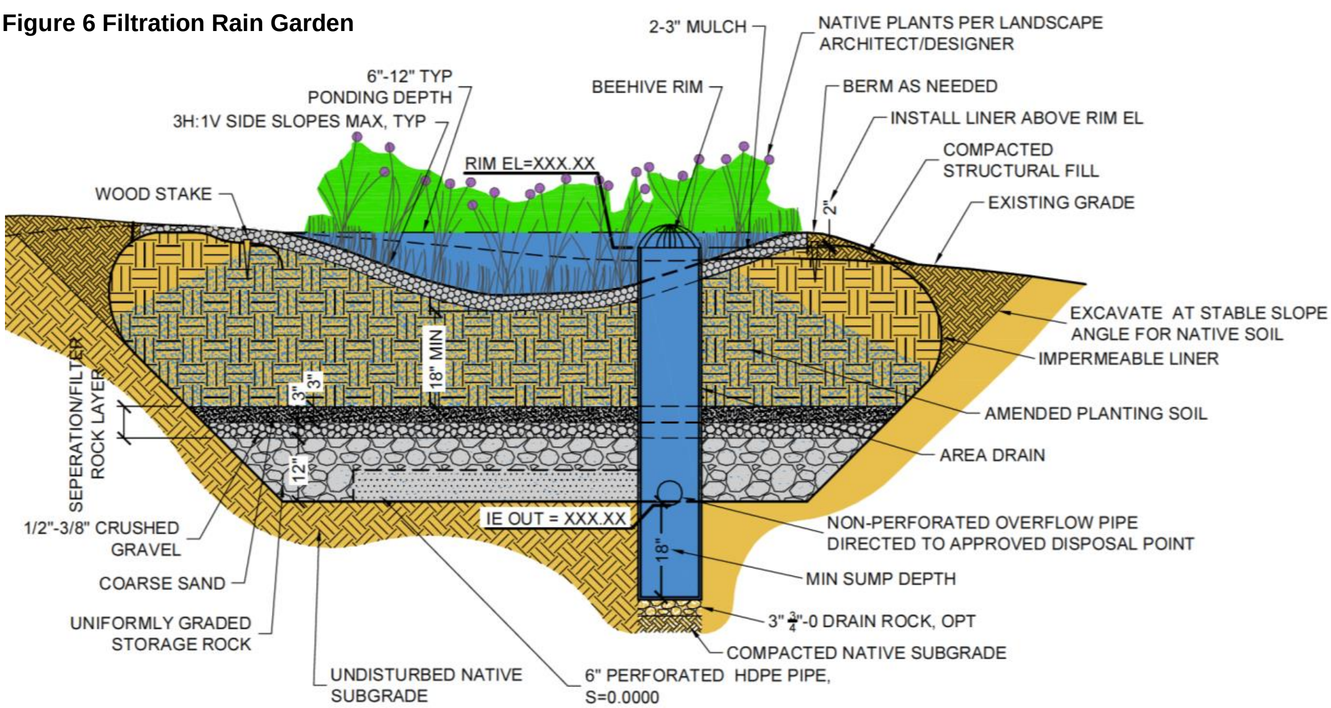
Filtration Rain Garden

A lined filtration facility (see Figure 6) may be chosen when siting criteria for infiltration cannot be met (See *"8 Siting Bioretention for Infiltration")*. However, these are not very effective at protecting watershed health and can be very expensive. Consider other practices in other fact sheets provided by the Five Counties Salmonid Conservation Program before choosing a filtration rain garden (see "*Navigating 5C Resources*").

The installation of a liner causes a series of additional, unavoidable costs:

- Since water can't flow out the bottom of the facility into the surrounding soil, a perforated pipe at the bottom of the facility must be included. This insures that the facility will drain out and be empty in 30 hours for the next storm. Evaporation alone would never empty a facility out in time. In addition, plants are unlikely to survive in a constantly wet/inundated condition.
- Since you must have a perforated pipe at the bottom, you must have a way to place it in gravel so it doesn't

Figure 6 Filtration Rain Garden



get clogged. This requires gravel at the bottom (i.e. rock separation & uniformly graded rock storage).

- An area drain isn't necessarily required if an alternative overflow allows water to flow out of the facility at the top and over the surface of the land in a way that won't damage infrastructure up or downhill of the facility. However, a cleanout is required, at a minimum, to access the perforated pipe in case it gets clogged.
- Since you must have all the items mentioned above, then excavation is required to a depth of 3.5 to 4.5 feet, depending on ponding depth.

Designing Rain Gardens

Once you've chosen the right type of facility, you're ready to design it in detail.

Facility Elements

There are a few crucial design elements:

- All points at which water may overflow (berm and/or low point, the rim of the area drain, and/or check dams) must be at least as high above the bottom of the facility as the desired ponding depth (typically 6" – 12").
- There is no shape requirement for rain gardens. They can be designed as square or rectangular with 5' minimum rounded corners, circular, oblong, or irregular.
- Rain garden's maximum side slopes should be 3 horizontal to 1 vertical (often written as 3H:1V or just 3:1). Slopes steeper than 3H:1V usually need to be compacted, which will limit infiltration area to the bottom section of the facility instead of the top and will also make it hard to establish plants.
- Since 3:1 side slopes are needed, there are minimum widths and areas for each depth as shown in Table 1.
- Maximum ponding depth should be 12". Facilities in low infiltration soils (0.5 – 1.0 inch/hour) will pond much less than this.

Ponding Depth [inches]	Minimum Width [ft]	Min Area [ft2]
6	3	9
7	3.5	12.3
8	4	16
9	4.5	20.3
10	5	25
11	5.5	30.3
12	6	36

Table 1 Minimum Rain Garden Geometry

- The minimum depth of any required soil amendment should be 18 inches. For more information on amending soils, see *"10 Amend Soils for Bioretention".*

Sizing Rain Gardens

While there are many elements that dictate the size of a rain garden, following this guidance, to size a rain garden in the Five Counties area, you only need to know:

- The infiltration rate of your native or amended planting soil. See *"7 Test Your Soil"* AND
- The drainage area (see next section).

Finding Your Drainage Area

Decide which impervious and pervious areas you'd like to manage using a rain garden. Measure the areas and add them together to give you the square feet of surface area to be treated. See Figure 7 for an example. The rain falling on the part of the roof outlined in red drains into downspout H1 and could be directed into a rain garden.

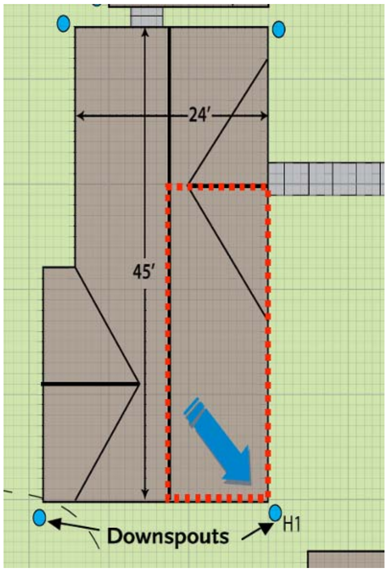


Figure 7 Map out all the different areas where a rain garden can go. Then calculate the area that can be drained there.

Width of Surface Area x Length of Surface Area = Area (square feet)

Example: roof area draining to downspout H1 is 30' x 12' = 360 square feet of roof area.

Applying Sizing Factors

We've done the engineering and modeling for you. Now, all you have to do is multiply the drainage area you just found by the right sizing factors below.

Table 2 Rain Garden Sizing Factors

Infiltration Rate (inches/hour)	Sizing Factor
Under 0.5	not applicable
0.5 – 0.9	0.09
1.0 – 1.4	0.05
1.5 – 1.9	0.04
2.0 – 5.9	0.03
6.0 – 11.9	0.02
12.0 and over	0.01

Example: For a roof area of 360 square feet and an infiltration rate of 2.7 inches/hour, your rain garden should be 10.8 square feet (360 ft2 x 0.03 = 10.8 ft2). Remember that it has to be constructed with 3:1 side slopes, so for a 10.8 ft2 rain garden, you need a ponding depth of at least 7" according to Table 1.

Figure 8 This sump settles sediment from roofs and pavement and makes it easy to remove.

Sizing Factors for Regions with Seasonally Frozen Ground

If the soil in the facility is frozen, then it's probably snowing, not raining. However, there will be a time when it's raining and the ground is still frozen, of course. At this time, soaking a rain storm into the soil will be impossible. We recommend that rain gardens in these regions be large enough to store the entire volume of runoff from a site for the water quality storm, which constitutes the most frequent, most polluted flows. For these regions, use ponding depth of 12" and build the facility to be 15% (Sizing Factor = 0.15) of the contribution area.

Pretreatment

Treat stormwater before it enters a facility by settling out sediment and trapping trash in order to extend the life of the facility and reduce maintenance times. This is done by concentrating potential clogging agents into one place for easy removal. Where stormwater enters a facility in a concentrated fashion (i.e., everything except what flows in sheets over the surface – aka overland), use a sump (see Figure 8). A 4' wide vegetated filter strip of grass (with less than 5 percent slope) can be used to treat overland flows (see "*2 Disconnect Impervious Areas"*).

Figure 9 This 4" ABS pipe will convey water from this building into a rain garden. Pipes like these must be laid at a slope dropping about 1 inch for every 10 feet so water flows away from the building but does not build up too much speed by the time it arrives. Per the Plumbing Code, they must be buried at least 12" to the top of the pipe.

Conveyance

If needed, direct stormwater to and from bioretention facilities with piping per Plumbing Code requirements (see Figure 9 for example). Stormwater may also flow directly into or out of facilities via overland flow, along a curb, or in a conveyance swale (see "*11 Conveyance Swales"*). Overflow structures such as area drains should direct excess stormwater to an appropriate disposal point as approved by your County's building or development services.

Gutters, downspouts, extensions, rain chains (see Figure 10), area drains, and other components used to move stormwater around the site should be durable and non-polluting. Plastic, like all petroleum products, is broken down by UV light and microbial action in soil. Choose materials that are UV and rust resistant. For conveyance, avoid these materials, which contain pollutants (listed in parentheses):

- Copper (copper)
- Galvanized steel (zinc)
- Iron (rusted iron)

Water moving over or through these materials picks up soluble (dissolved) portions of the metals that pollute ground and surface waters.

Better materials to use for conveyance include:

- Stainless steel
- High density polyethylene (HDPE)
- Aluminum

Rain Gardens on Slopes

Check dams are sometimes used in linear shaped facilities to pond water and prevent erosion on slopes.

- The top elevation of the check dam should not be so high that water cannot overtop it and flow into the next cell but also not so low that the design ponding depth is not achieved.
- On slopes exceeding 5%, install check dams made of:
    - Concrete
    - Stone
    - Piled crushed rock (may not be appropriate where vandalism is likely).
- Avoid using the following materials for check dams:
    - Metals, except stainless steel
    - Crushed concrete
    - Bare compacted clay or soil
    - Wood

These contribute a variety of pollutants to stormwater after it enters the facility.

Underdrains

Underdrains are perforated pipes, usually located at the very bottom of a facility, that ensure water drains within a reasonable period of time to

Figure 10 Copper rain chains are a popular, yet polluting, means of slowing water flow. Copper in very small amounts is toxic to fish and other aquatic life. Because it's soluble (can be dissolved) in water, it can't be treated by a rain garden.

keep the plants alive or to ensure the facility is ready for the next storm. Keep the following in mind:

- Underdrains are necessary in filtration facilities.
- Underdrains should not be wrapped in geotextile fabric. Instead, a rock separation layer (as shown on the figures above with underdrains) should be used. Geotextile fabric placed under soil is likely to clog and cause a failure.
- Access to underdrains should be provided via a cleanout or outlet structure (such as an area drain or catch basin).

Plantings

The interaction of soil, plants, and the beneficial microbes that concentrate on plant roots is what ultimately removes or reduces pollutants -- the more plants, the more treatment. A large variety of plants have been used successfully in rain gardens. The USDA PLANTS Database is a helpful tool to find plants appropriate for your area. For a tutorial on using the USDA PLANTS Database, see *“9 Find Native Plants in Your Area”*.

Figure 11 A variety of vegetation types can be used in rain gardens. Here, grasses, shrubs and trees are used.

Use the following criteria to choose plantings:

- Plants native to California and preferably to your county. In most cases, non-native seeds and rhizomes/roots can greatly impact the habitat potential and water quality of downstream waterways.
- Don’t plant non-natives, invasives, or noxious weeds. For a list of invasive and noxious weeds, visit http://plants.usda.gov/java/noxious?rptType=State&statefips=06. Seeds disperse downstream during flooding in natural wetlands. These plants will not function in the same way, hydrologically or ecologically, as natives. Some invasives, such as perwinkle (vinca minor or major), English ivy, and yellowflag iris may be sold at your local nursery. However, invasives cost American farmers and consumers billions of dollars a year in management and lost crop yields.
- Any type of native plant – grass, sedge, rush, flowers and other forbs, trees – will be ecologically beneficial.
- Consider safety and “eyes on the street”/”neighborhood watch” benefits when locating taller, dense shrubs.

A dense mix of plantings, thoughtfully placed, in bioretention facilities is critical to successful stormwater function, prevents erosion and weed invasion, and enhances aesthetic value. Use the following minimum criteria.

- Per 100 square feet of rain garden, place:
  - 115 herbaceous plants, 1’ on center spacing, ½-gallon container size OR
  - 100 herbaceous plants, 1’ on center spacing, ½-gallon container size and 4 shrubs, 2’ on center, 1-gallon container size
- Per 300 square feet of rain garden, consider placing 1 tree, 2-gallon container size by 2 feet tall.
- Place plants throughout the facility, but especially in the bottom of the facility. Avoid a dry creek bed look. This approach will effectively treat the small, frequent storms that have ponding depths so shallow that the water may never reach the plants on the side slopes.
- Consider the plants’ spread (i.e. width) and height at maturity or you may find yourself excessively pruning in the future.

Considerations for Your Setting

Put the right plant in the right place. Many microclimates mixing sun/shade, windy/protected (from wind), and dry/wet are likely to be created by a small site with a building and a few trees on it. In addition, a rain garden will have its own microclimates. For instance, rain gardens have three zones of moisture: the bottom, wettest area; the drier middle; and the driest top. See Figure 12 at right.

Figure 12 Avoid bark mulch. It floats, carrying pollutants adhered to its surface to downstream waterways.

High Summer Temperatures: In areas where temperatures are higher than 90 degrees Fahrenheit, some plants in sunny locations with fast-draining soils will need supplemental irrigation—at least for the first two or three years while roots are becoming established.

Cold Winter Temperatures: Many plants can tolerate freezing temperatures. Choose plants adapted to these conditions. Plants may not establish new roots well in frozen soils. Plan to construct and plant your garden early enough in the late summer to allow for plants to become established.

High Wind: Strong winds can dry out and damage plants any time of the year. Provide for shelter, or plan your plant selections to take account of the wind damage. Additional water may be necessary during the summer months, when drying winds can be most damaging for newly established rain garden plants.

Sandy Soils: Some beach homes are built on fossilized sand dunes. Soils on and around these geologic features will drain extremely rapidly, often in excess of 2 inches per hour, making a rain garden unnecessary or impractical. Furthermore, the additional water from a rain garden built on a fossilized dune may cause it to slump or even collapse. We do not recommend constructing a rain garden under these conditions.

Semi-Arid & Fire-Prone: If you live in a fire-prone area, avoid using plants in your rain garden that are flammable. Plants with dry material (such as leaves or needles) and those with fine structure, aromatic leaves, loose bark, or resinous sap tend to be flammable. Consult your local University of California Cooperative Extension office for more information and a list of fire-resistant plants.

These semi-arid regions have long, dry summers with very little rainfall. Depending on your plant choice, it may be necessary to irrigate your rain garden two to three times each summer to keep the plants healthy, attractive, and fire-resistant.

Mulch

Mulch, 2-3 inches deep, is often used to completely cover the soil and prevent erosion or weed intrusion. Acceptable materials include:

- Wood chips
- coarse compost on bottom and sides
- fine compost on sides

Materials to avoid include:

- Bark dust or bark chips. Bark floats, polluting downstream waterways and making lawn overflow areas difficult to mow.
- Sawdust or grass clippings. These will break down quickly, robbing the soil of nitrogen.

Constructing Rain Gardens

Like all stormwater management facilities, care must be taken to properly construct rain gardens. Mistakes in construction can lead to unintentional damage to the facility (i.e., clogging) or to long-term maintenance challenges (i.e., plant replacement).

Amending Soils

Never fold sand alone into clayey soils. With insufficient quantities of sand, doing this is likely to cement the soil, creating a barrier to water and infiltration. See *"8 Amend Soils for Bioretention"* for more information on construction techniques for soil amendment.

Figure 13 Delineate the rain garden with a hose, strings, stakes, or marking paint. Call 811 to locate utilities.

Infiltration Rain Gardens

To properly construct an infiltration rain garden:

1. Call 811 to locate private utilities on your site to make sure your work will not impact them. For setbacks and other considerations, see "*8 Site Bioretention for Infiltration".*
2. Delineate the rain garden (see Fig 13). Fence off the infiltration area with a cyclone fence (if possible) or orange construction fence (see Fig 14) to prevent vehicular and foot traffic that will compact soils and reduce the infiltration rate of the native soils.
3. Install temporary erosion control such as erosion control fabric, temporary seeding, biobags, wattles, and compost berms. Make sure any erosion control method you choose is weed-seed free. Avoid plastic, especially plastic mesh, where possible since amphibians and other animals are harmed by it.
4. When excavating with machinery, use track equipment and/or excavate from the sides of the infiltration area (see Fig 15).
5. Amend the soils as desired or required (see previous section) especially if the soil has been compacted despite your best efforts.
6. Protect native soils and amendments from rain exposure by covering with jute or other natural, breathable material or by waiting until the last moment to expose soils. If soils are exposed to rain, fine soil particles will be picked up and moved around. This may clog the native soils beneath creating a layer naturally impervious to water. In clayey soils, this can be difficult to fix. If soils don't clump, rake the surface to loosen soil before proceeding. If soils do clump, follow compost guidance in *"8 Amend Soils for Bioretention"*.

Figure 14 These native soils clogged due to rain exposure and possibly foot traffic during construction. Clayey soils this wet are difficult to unclog since they clump. You probably need to wait for it to evaporate before amending. If left like this, the facility won't infiltrate and plants are likely to die from poor drainage.

7. Rake or compost amend a rain garden that was dug by hand since foot traffic in the facility area is probably unavoidable.
8. Plant the facility and protect it from stormwater flows for 3 months after planting using sand bags to block flows or piping around the facility. This will help plants to establish and prevent erosion.
9. Mulch, if desired. While plants are small, mulch can make weeding easier, but it can also float out of the facility, carrying pollutants downstream with it. Remember to make your rain garden that much deeper, so your desired ponding depth is not decreased by mulch.
10. Unblock inlets to allow stormwater flows to enter the facility 3 months after planting.
11. Remove temporary erosion control if soil is stabilized.
12. Water plants as needed through dry months for a minimum establishment period of 2 years.

Filtration Rain Gardens

To properly construct a filtration rain garden (see Figure 6 above for a helpful picture):

Figure 16Avoid foot or vehicular traffic before, during, and after construction. This backhoe is excavating from outside the rain garden.

1. Install temporary erosion control such as erosion control fabric, temporary seeding, biobags, wattles, and compost berms according to product directions. Make sure any erosion control method you choose is weed-seed free. Avoid plastic, especially plastic mesh, where possible since amphibians and other animals are harmed by it.
2. Overexcavate 30 inches beyond the desired ponding depth. If stockpiling soil for another use, cover with a breathable fabric to prevent erosion and protect it against the clogging action of rain.
3. Install the outlet structure (i.e. area drain, catch basin) or cleanout and non-perforated/solid pipe to the approved discharge point using standard construction techniques.
4. Install impermeable liner of either 30 to 60mm (mil) low density polyethylene (LDPE) or bentonite clay mat per manufacturer guidance. If a plastic liner will be used, make sure that it's a single, solid piece of plastic big enough to be installed underneath the entire facility area. Overlapping plastic sheets will not adequately prevent infiltration of water. If you choose to line the facility with a bentonite clay mat, installation is relatively simple. Make sure that the liner is installed high enough –at a height equal to the depth of water that may be ponded in any storm, not just the design storm. Attach the liner to the outlet structure with the appropriate adhesive or mechanically.
5. Place a 6” or 8” diameter perforated HDPE (high density polyethylene) underdrain pipe on the bottom of the facility and connect it to the outlet structure.
6. Place 12” of clean, open-graded (i.e. all the same or very similar size) 1.5” to 1” diameter crushed gravel throughout the bottom of the facility.
7. Place 3” of clean, open-graded ½” to 3/8” diameter crushed gravel over the rock placed in Step 6.
8. Place 3” of clean, open-graded coarse sand over the rock placed in Step 7.
9. Create or buy an amended planting soil mix that allows water to infiltrate at a rate between 2” to 12”/hour.
10. Place the amended planting soil in two lifts, saturating each lift with water to lightly compact it (i.e.85% compaction). Boot packing or light tamping may also be used but never apply vibratory compaction.
11. Place a final lift as needed to reach desired elevations.

12. Plant the facility and protect it from stormwater flows for 3 months after planting using sand bags to block flows or piping around the facility. This will help plants establish and prevent erosion.
13. Mulch, if desired. While the plants are small, mulch can make weeding easier, but it can also float out of the facility, carrying pollutants downstream with it. Remember to make your rain garden that much deeper, so your desired ponding depth is not decreased by mulch.
14. Unblock inlets to allow stormwater flows to enter facility 3 months after planting.
15. Remove temporary erosion control if soil is stabilized.
16. Water plants as needed through dry months for a minimum establishment period of 2 years.

Planting Techniques

Proper planting techniques can greatly reduce maintenance. Plants from nurseries can often be root bound in their pots. If the roots aren't loosed and unwound, the roots will continue to twist around in the hole you planted them in instead of growing downwards and outwards; this will eventually starve them. Another key to low maintenance plant establishment is to ensure that the roots have good contact with the soil.

To properly plant potted plants:

1. Dig a hole twice the size of the pot. Keep the soil pile nearby and clear of leaves and other surface debris.
2. Take note of where the potting soil level is compared to the stem of the plant. Many plants have a different color and texture on the section that sits below the soil than on the sections that sit above ground.
3. Gently shake the potting soil off as much of the roots as possible. The nutrition from the potting soil has probably been exhausted.
4. For balled and burlapped trees, the soil may be left in. However, ensure that burlap or any other confining material will not impede root growth by removing at least the bottom half of the material.
5. Loosen the roots.
6. Taking some of the soil you dug out, create a mound at the bottom of the hole and lightly tamp it down.
7. Drape the plant roots around the mound so that they're touching the mound on the bottom and pointing downwards. There are two kinds of roots, larger structural roots and tiny feeder roots, which is where the plant "drinks" and "eats". In pot-bound plants, some roots may be really long and will just continue winding around the other plant roots. If they're feeder roots, shorten them by pulling them off to be a similar length as the other roots. A few of the bigger structural roots can be cut, but it's better to dig a deeper hole and get them pointed downward.
8. As you backfill the hole by pushing soil in around the tops of the roots, hold the plant so that the point at which the plant came out of the soil in its original pot will be the place where the final grade of soil

Figure 3 The more plants and the more variety of plants in a rain garden, the better the rain garden is likely to function.

in the contained planter will be (level of soil on the stem is the same). Plants that are too deep may drown or the stem may rot. Plants that are too high may not have enough feeder roots in the soil to survive.

9. When finished, tamp down the soil. Step around the stem of the plant. This, combined with previous steps, will ensure good root contact with the soil.
10. Place an organic mulch that meets the specifications in “*3 Restore Disturbed Soils”* to a depth of 2 to 3”. For woody stems on shrubs or trees, push the mulch a few inches away or the stems could rot.

Figure 18Since weeds need water in the summer but the right natives won’t, substantial irrigation beyond the establishment period will increase weeds and maintenance.

Rain Garden Care & Maintenance

Proper maintenance is required to ensure proper functioning and especially that water is able to enter the facility at all times of the year. Observing the facility during a variety of rain events will help you see where water is and isn’t flowing. Maintenance requirements are typical of vegetated areas; structures like sumped catch basins are typical of conventional infrastructure maintenance. Watering and weeding may be needed frequently within the first 1 to 3 years during California’s very dry summers, but this should taper off dramatically if you choose plants that require little to no watering after establishment.

Establishment Period Irrigation

To establish perennial plants, you’ll need to irrigate more in the first year and less in subsequent years. In addition, plants benefit from changing irrigation with the seasons. After summer starts and the rains stop, water a little. Increase water volume as the dry season continues. Taper off irrigation as the rains start to come back. Depending on your area and rainfall patterns, irrigation may be needed from May to October.

The volume of water and frequency of watering varies with the type of plant. See “*9 Find Native Plants for Your Area*” for information on preferred growing locations and watering needs. Some rules of thumb:

- Trees: 5-10 gallons, once/week
- Shrubs: 3-5 gallons once/week
- Groundcover: 1-2 gallons, once or twice/week
- Perennial herbs: ½ gallon, twice/week

After the 2 – 3 year establishment period, irrigation should not be needed. However, contained planters in developed settings will probably require occasionally irrigation beyond the establishment period

You may reduce your water demand by hand watering, using efficient irrigation systems (drip), and harvesting rainwater. To make hand watering faster/easier, find a 1-2 gallon container, poke a few small holes in the bottom, and place it next to the stem of the plant. Fill the container as many times as needed. Having a bunch of them already placed around the plants allows you to quickly move from one plant to another without having to wait for the water to soak in. This quickly delivers ideal volumes without causing erosion. For more information on rainwater harvesting, see “*5 Build a Rain Barrel*” and “*6 Harvest Rainwater in Cisterns*”.

Recommended Rain Garden Maintenance

Inspect the facility a minimum of 4 times per year and perform needed maintenance as follows:

- Contribution areas should not add pollutants to runoff in excessive amounts.
  - Pavement and roofs should not be treated with polluting materials such as moss poisons (mossicides) or coal tar sealants.
  - Landscape areas and lawns should be maintained with integrated pest management, using hand pulling and other means first and herbicides, pesticides and mossicides last.
- Downspout pipes or other inlets should maintain a calm flow of water entering the facility.
  - Erosion sources should be identified and controlled when soil is exposed or erosion channels are forming. Rip rap or other effective material should be placed around the point where water is discharged into the facility to slow the water and prevent erosion.
- Sediment and debris should be removed from:
  - The pretreatment sump
  - The facility's surface, being careful not to damage vegetation. Accumulated sediment should be removed if it is more than 1" thick or if it is damaging vegetation.
  - The facility's outlet (i.e., overflow drain or conveyance swale).
  - Inlets. Because the storms in the Five Counties area for which you would design your facility are frequent and small, flows are very shallow. Some kinds of inlets (see Figure 19) may block water from coming into the facility at very small depths (less than 1/8").

Figure 19 Because of a small amount of sediment and possibly too much vegetation right at the mouth of the inlet, the smallest, most frequent, and dirtiest flows are bypassing the inlet.

Debris and soil from rain gardens is not considered hazardous and can be disposed of in the landfill.

- Slopes should be stabilized and planted using appropriate erosion control measures when soil is exposed or erosion channels are forming.
- Maintain the design ponding depth by:
  - Repairing any structural elements that may leak from cracks or worn sealant.
  - Maintaining the design elevation of check dams.
- Topsoil should allow stormwater to percolate uniformly through the rain garden.
  - If the facility does not drain within 48 hours, scrape 1" of soil out of the facility and replace with amended planting soil that meets the specifications described in *"8 Amend Soils for Bioretention"*. Test the ability of the facility to infiltrate water in order to confirm drainage.
  - If facility still does not drain after scraping 1", you may try scraping another 1" deeper.

Figure 20 Curled soil often suggests a facility has clogged and ponded water, possibly excessively.

Figure 4 Instead of string trimming dead material from grasses, pull the dead material out by hand. String trimming impairs the function of a rain garden and increases the probability of clogging.

- If facility still does not drain after scraping the top 2”, till and replant the facility.
- Debris that inhibits infiltration of water should be removed routinely (no less than quarterly), or when it is discovered.

- Vegetation should be healthy and dense enough to filter stormwater while protecting underlying soils from erosion. Mulch should be replenished until vegetation is established and shades the bottom of the facility.
  - Fallen leaves and debris from plants should be removed. But don’t string trim grasses, which will inhibit deep rooting and increase the probability of clogging (see Figure 21). Grasses may be raked.

Nuisance plants (i.e. those blocking the inlet) and non-native and invasive vegetation (such as weeds, Himalayan blackberries and English Ivy) should be removed when discovered.

- Dead vegetation and woody material should be removed so that it makes up less than 10% of the rain garden surface area. Vegetation should be replaced within 3 months, or immediately if required to maintain a cover density of at least 90%.and control erosion where soils are exposed.

- Spill prevention measures should be taken when handling substances that can contaminate stormwater. Releases of pollutants should be corrected as soon as they are noticed.

Permits

Permitting varies, so check with your local jurisdiction’s building or development services department to find out what codes may apply to your project. Retrofits using rain gardens will likely not require permits, but new development likely will as part of the larger project permitting. In addition, where stormwater management is required, clarify relevant calculations such as detention to confirm where you can subtract areas where you will install stormwater management practices from the total project area that you may have to detain or otherwise treat.

If information in this guidance conflicts with your jurisdiction’s requirements or approach, then follow their guidance instead.

Bibliography

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5 Build a Rain Barrel

A rain barrel is a simple rainwater collector that captures and stores a portion of the runoff from a roof downspout for non-potable, exterior uses, such as irrigation. Rain barrels come in a wide variety of materials, designs, and colors. Common sizes for residential use are 55 gallons and 90 gallons. They are usually installed on the ground next to buildings.

Benefits

Using rain barrels to temporarily store and reuse rainwater can conserve drinking water by providing a chlorine-free water source that your plants will prefer. You will also save money on your water bills each year. Rain barrels are a great way to remind you of the advantages of conserving water given the many ways you use it throughout your day.

Unfortunately, due to their small size as compared to the average roof and average rainfall and patterns in the Five Counties area – 6 months on, 6 months off – some pollutants from your roof may be captured in your rain barrel. In the Five Counties area, average annual rainfall ranges between 10 to 120 inches of rain per year. This means that for every 1,000 square feet of roof area, 6,000 to over 73,000 gallons of runoff may be generated annually. Because of their capacity, rain barrels will not provide enough reduction in annual runoff to significantly protect water resources. In order for rainwater harvesting to be used as a stormwater management facility, a much larger cistern system is needed. Rain barrels are an easy and great place to start and will still save water and money.

Siting

To determine if a rain barrel is right for your property, the first step is to identify your site's drainage conditions. Answer the questions below as you walk around your property.

Where would you like to locate your rain barrel?

Install your rain barrel based on where you will use the water in your yard. Keep in mind that it may be possible to rehang the gutter and move the downspout to a more convenient location. The rain barrel is usually located at the base of one of the downspouts draining your roof gutter.

Since a rain barrel is its own impervious surface and would, in most places in the Five Counties area, fill up just from rain falling into it over the course of a single year, when possible place it on an existing impervious area like sidewalks and driveways instead over a landscaped area that provides its own form of stormwater management for your property.

Where does that downspout currently drain?

The downspout you will divert to your rain barrel probably drains into a standpipe or to your yard. This is the stormwater discharge point and is the same location where the rain barrel overflow should go.

Design

Rainwater collection using a rain barrel for residential, external, non-potable uses such as irrigation, does not require a county permit, but there are still design considerations to follow.

Overflow

All rainwater collection systems must have an overflow to a safe disposal location. A 55-gallon rain barrel captures only a small fraction of annual rainfall, even from small roof areas. Even if you have multiple rain barrels connected together, you still should have an overflow to a safe discharge location.

If your rain barrel overflows into the standpipe, be sure the overflow pipe is attached and sealed to the standpipe opening. If the downspout to be connected to your rain barrel currently drains to an area in your yard like a rain garden or downspout disconnection area where runoff infiltrates into the ground (surface infiltration), the overflow from your rain barrel should also discharge to that location. If the downspout currently drains to a standpipe and you wish to change your overflow disposal to surface infiltration in your yard, see *“Navigating the 5C Program’s Stormwater Management Guidance”* to find the right guidance documents (e.g. rain garden, disconnect impervious areas).

Safety Considerations

Your rain barrel must be secured on a firm, level surface. A full 55-gallon rain barrel weighs over 400 lbs.; so tipping is a risk if it’s unsecured or on uneven ground. If water in your barrel is likely to freeze, expansion may cause the bottom to bow outwards, which may also be a tipping hazard.

- The barrel should be a food-grade, structurally sound container made to hold liquid. Some containers, such as trash cans, are not designed to withstand the pressure of the water. If re-using a barrel, check for odors that indicate that it may have been used to store chemicals or toxic substances. If it smells strange, avoid using it.
- The barrel should have a lid and a sturdy fine mesh covering all openings to prevent small animals and mosquitoes from getting inside (1-millimeter or smaller mesh to keep out mosquitoes).
- The water from the rain barrel should never be used for drinking, cooking, or other potable uses.
- Your rain barrel should overflow to a safe discharge point.
- If you use a moss-control product on your roof, be sure to use a control product that is garden- and waterway-safe. Look for products containing soaps, fatty acids, or ferrous sulfate. Avoid products with zinc sulfate.
- If you plan to change your downspout to a rain chain, choose stainless steel or fired clay/pottery. Avoid copper, galvanized steel, and iron. Rain moving over these materials picks up soluble portions (those that can be dissolved in water) of the metals that pollute water and can harm fish and other aquatic life.
- The barrel should be opaque, not clear/see-through. Algae is likely to grow in a clear barrel and become a maintenance issue. Paint that will adhere to plastic should be available at a local store.

Larger or more complex systems

More complex rainwater collection systems have a much larger storage container (a cistern), and/or use pumps to move water to desired locations. Some use their captured rain water indoors for toilet flushing. These projects involve factors beyond what is applicable to simple rain barrels, such as plumbing and electrical work, soil excavation, or concrete foundations and other structural components. For rainwater collection projects of this scale, you should consult a professional to review design, construction, and safety considerations. For more information about rainwater harvesting for indoors or using cisterns, see *”6 Harvest Rainwater in Cisterns”*.

Construction

Many nurseries and yard supply stores sell fully assembled rain barrels. But you can get a regular barrel and convert it into a rain barrel yourself. Assemble your tools and supplies, then follow the construction steps below.

Tools

- drill
- inch hole saw for overflow pipe (see Figure 1)
- one-inch spade bit for spigot
- tin snips or heavy-duty scissors
- adjustable wrench
- utility knife
- safety glasses

To disconnect your downspout to your rain barrel:

- tape measure
- hacksaw
- drill
- screwdriver or nut driver
- pliers or crimpers

Figure 1 Hole saw

Materials

- One 55 to 90-gallon food grade plastic, opaque barrel (can be found at local restaurant suppliers, nurseries, or gardening supply stores, or online)

Find the following items at most plumbing or hardware stores:

- hose spigot with 3/4 inch threaded inlet and 3/4 inch male hose end
- two 3/4 inch galvanized locknuts to secure spigot from the inside of the barrel
- four 1-inch (opening) washers to provide rigid surface to fasten hose bib
- Teflon tape
- silicon adhesive or outdoor caulking
- two 8"x 8" x 12" concrete or wooden blocks
- window screen mesh: 1)enough to cover the barrel opening; and 2) small enough mesh to exclude mosquitoes (1-millimeter or smaller mesh)
- downspout elbow to route the downspout to the barrel
- clincher strap (attaches downspout and barrel to house); a water heater strap rated for outdoor use can be used to secure the barrel
- small pieces of wood blocking to use behind clincher strap (if necessary)
- any additional materials necessary for the overflow location (see *Overflow* section above)
- 1/4" #6 sheet metal screws for downspout
- 3/4" screws for clincher strap
- 2" overflow pipe fittings

Construction Steps

1. Build an Inlet

Create an opening with fine screening through which the rain barrel will collect water from the downspout elbow. This can be a single screened opening large enough to accommodate the downspout elbow (as shown in the photo at the top of this guide), or a series of smaller screened openings directly in the top of the barrel.

2. Build an Overflow

Drill a hole near the top of the barrel to accommodate an overflow pipe that is at least 2 inches in diameter. If the overflow pipe elbow seals and seats securely, it can be threaded directly into the barrel opening. If not, it should be secured with washers on both sides of the barrel and a nut on the inside. Use Teflon tape around the threads and a bead of silicon caulking around the opening to ensure a tight seal.

3. Provide a Foundation

Create a raised, stable, level base (like concrete blocks) for the rain barrel to sit on. You might want to test stability by filling the rain barrel with water before attaching to your structure. A full rain barrel is very heavy and tipping is a risk if it's unsecured (unstrapped) or on an uneven surface.

4. Redirect the Downspout

Be sure that the steps above are complete and that the rain barrel is where you want it. Put the barrel into place to make sure you know where the top of it will sit. Cut the downspout with a hacksaw so that the elbow will sit just above the rain barrel inlet. Attach the elbow over the downspout with a screw and secure the downspout to the house with the strap. Be sure that the end of the downspout goes on the inside of the elbow section to avoid leaks.

5. Attach Barrel

Set up the barrel beneath the elbow and secure the barrel to the house with a water heater strap rated for outdoor use. Cut and attach the overflow pipe to the overflow elbow and direct to the existing discharge location.

6. Build an Outlet

Drill a hole 4 – 6" above the bottom of the empty barrel to attach the drain spigot. Placing the spigot a little too high will create a place in the bottom of your rain barrel for dirt and other debris that comes off your roof. If the spigot seals and seats securely, it can be threaded directly into the barrel opening. If not, it should be secured with washers on both sides of the barrel and a nut on the inside. Use Teflon tape around the threads and a bead of silicon caulking around the opening to ensure a tight seal.

7. Use the Water

After a rainfall, fill a watering can using the bottom spigot or attach a hose to use the water where it's needed.

Maintenance

Simple maintenance of your rain barrel can prevent problems.

- Clean gutters at least twice a year, more often if you have trees near your roof.
- Make sure gutters are tilted to direct water to downspouts and fix low spots or sagging areas along the gutter line with spikes or place new hangers as needed.
- Make sure roof flashing directs water into the gutter.
- Make sure all parts are securely fastened together and the rain barrel is securely fastened to the building.
- Clean out the rain barrel and check for leaks at least once a year. Caulk any gutter, downspout, barrel, and overflow leaks and holes.
- Check and clear downspout elbows, rain barrel screening, and overflow to prevent clogging.
- Make sure the rain barrel remains securely screened to prevent mosquito entry. Mosquitoes can also be controlled by adding a few goldfish to your barrel every so often.
- If overflow is to a surface infiltration area (e.g. rain garden or downspout disconnection area), monitor the overflow area and regrade the soil if necessary to make sure that water drains away from structures and does not flow onto pavement, sidewalks, or neighboring properties.

6 Harvest Rainwater with a Cistern

A rainwater harvesting system captures stormwater runoff, often from a rooftop, and stores the water for later use. Water from a rainwater harvesting system can be used to water gardens or wash cars —even when water restrictions prevent the use of municipal water for those purposes. The harvested rainwater can even be treated and piped inside for potable drinking needs.

Rainwater harvesting systems can improve the environment by capturing nutrients and other pollutants from rooftop runoff, preventing them from contaminating surface waters. Moreover, the nutrients in rooftop runoff, such as nitrogen and phosphorus, can help plants grow when the captured water is used for irrigation. By using harvested rainwater for purposes that don't require treated drinking water, we reduce the demand on municipal water supplies. When harvested rainwater is used inside for flushing toilets or drinking, the system can offer a significant reduction in runoff since water is being used year-round as it falls.

Rainwater harvesting has been practiced for thousands of years. However, recent concerns over water supplies and the environment have prompted many homeowners to consider using rainwater harvesting systems. While advanced systems are available from consultants and vendors, a homeowner can construct a simple system for home use with a basic understanding of its components and function.

A rainwater harvesting system consists of four main components (Figure 1):

- The gutter system collects runoff from the rooftop and directs it into the cistern (aka water storage tank).
- The cistern stores runoff for later use.
- The overflow pipe allows excess runoff to leave the cistern in a controlled manner.
- The outlet pipe, sometimes connected to a pump, draws water from the bottom of the cistern for use.

Figure 1 Basic rainwater harvesting system components.

Consider all of these components and how they work together before installing a rainwater harvesting system. The cistern is the primary component, so select and locate it based on where you will use the harvested rainwater. Remember that local plumbing codes might affect the installation. Periodic maintenance will be required.

Siting

The primary consideration and constraint in selecting a cistern location is the position of the gutter downspouts. Although there is some flexibility in routing gutter pipes to various locations, it is generally easiest and most cost effective to place the cistern near an existing downspout (Figure 2). When possible, locate the cistern near the site where water will be used.

Transporting water over long distances will increase pump requirements. Before deciding where to locate a cistern, contact your local utilities companies (dial 811) to locate any underground pipes or cables that might be affected by a cistern or its structural support. Because cisterns can be incredibly heavy when filled with water, avoid placing the cistern over any buried pipes, septic tanks, or drain fields that may not support the load exerted by it. (Your local health department can provide assistance if you have a septic system and have difficulty locating it.) Do not locate an underground cistern immediately next to a building, because excavation and installation could damage or compromise the foundation.

Figure 2 Above-ground cistern located at the corner of a house near existing downspouts.

Design

Cistern Materials

The cistern may be ordered and shipped directly to the location where it will be installed. Due to the large size and weight of many cisterns, delivery charges can be substantial. Many online retailers sell tanks that can be used for rainwater harvesting. Some companies focus specifically on rainwater harvesting systems. Homeowners can also find tanks at local stores that sell agricultural, lawn and garden, or industrial supplies. Select a cistern based on its material, size, whether it will be installed above- or below-ground, and where it will be located.

Cisterns can be constructed from a variety of materials. The most commonly available cisterns are made of plastic, fiberglass, or metal. If the rainwater harvesting system will be used to supply drinking water, special cistern materials are required. If cistern-stored water is to be used for drinking water purposes, please consult a water-harvesting vendor and local drinking water ordinances for advice on what materials to use. Only certain resins are approved by the FDA for storing potable water. Use of other materials may leach harmful chemicals into the stored water supply that cannot be easily removed by subsequent water treatment.

Plastic

Plastic cisterns are generally less expensive than other materials and don't require assembly. But they may not be the best option when aesthetics are a priority. Their appearance can be improved with wraps made of wood or other materials. Plastic cisterns can be moved into place without much difficulty. They are relatively lightweight, and the plastic material can be easily cut or drilled with standard tools to install the necessary valves and fittings.

Translucent or light-colored materials may permit algae growth within the cistern. Plastic tanks are relatively easy to paint or decorate. Paint or other coatings can be used to prevent algae growth. Check with your local store to make sure you are purchasing long pasting paint that will adhere long term to the type of plastic you will be coating.

Metal

Metal cisterns are often adapted from grain bins. Their basic appearance is generally preferred to plastic cisterns. Metal cisterns are typically assembled from sections of corrugated galvanized metal, and a plastic liner is installed inside the cistern (Figure 3). Because a liner is needed, it may be difficult for an inexperienced installer to construct a metal cistern.

Figure 3 Metal cistern being constructed.

Above Ground or Below?

Several factors should be considered when deciding whether a rainwater cistern will be installed above or below ground. Above-ground cisterns are typically easier to install than below-ground because excavation for the cistern is not necessary. Below-ground cisterns have limited accessibility after installation, making it difficult to repair leaks or other problems. Due to their increased structural requirements and potential floatation concerns (discussed below in the special considerations section), below-ground cisterns are generally more expensive than are above-ground types. (Do not place a plastic cistern manufactured for above-ground use in the ground because it will collapse.)

Unlike an above-ground cistern where some low pressure needs and casual uses are possible without a pump, the use of a pump is required to obtain water from an underground cistern. Additionally, some pumps may not be appropriate for an underground cistern because the pump must be installed below the water level or be capable of providing adequate suction lift. A submersible pump or jet pump designed for shallow wells is a suitable option for pulling water from an underground cistern. Pump selection is discussed in detail on this website: http://www.bae.ncsu.edu/topic/waterharvesting/Pump4Cisterns2006.pdf publication "*Choosing a Pump for Rainwater Harvesting* (AG-588-08)". The main advantage of below-ground cisterns is that they don't occupy valuable space in a yard.

Special Considerations for Underground Cisterns

Because of the potential structural and safety concerns, it is important to comply with all underground cistern installation instructions and regulations.

- Before beginning an underground cistern installation, contact your local utilities companies (dial 811) to locate any underground pipes or cables.
- Depending upon the specific underground cistern being installed, sand, pea gravel, or crushed stone backfill material may be required. Follow the cistern manufacturer directions and specifications.
- Consult the cistern directions to determine the required specifications for backfill material, excavation depths, and the depth of soil required over the cistern.
- Potential floatation concerns: In areas where the water table can rise above the bottom of the underground cistern (see *"7 Test Your Soil"*), special consideration is required to ensure that the cistern is properly anchored against any potential buoyancy (floatation) and is structurally suited to handle these additional forces.

- An underground tank must be properly vented to the open air above ground to prevent the buildup of pressure or vacuum within the tank. Vents are often incorporated into a tank or can be attached as a basic fitting.

Water Treatment

Any Use

Any use will benefit from a first flush diverter to dispose of the first 10 gallons of roof runoff. Many people think of roofs as clean, but this varies with air quality. Even in rural areas, particulates, mercury, feces, and many other pollutants are likely to be deposited on the roof. There are a number of first flush devices on the market that automatically empty. Early ones were simply a standpipe with a small, slow-draining hole drilled into a cap in the bottom. But these clog easily, so for reduced maintenance find a diverter that incorporates a ball valve, a cleanout at the bottom for debris, and a drain that's a little higher, at least, than the cleanout.

Irrigation

If you plan to use your harvested rainwater for irrigation, you don't have to worry about pollutants like nitrogen and phosphorus; these will be good for your garden. Other pollutants, including hydrocarbons from asphalt shingles, will be treated by microbial degradation or physical filtration. Other pollutants, such as the soluble portion of zinc from a galvanized metal roof, are unlikely to significantly affect your garden. Many people irrigate their vegetable gardens straight from a rain barrel – even without a first flush diverter – with no ill effects. In fact, your plants will appreciate chlorine-free water!

Potable Uses

If harvested rainwater will be used for any use indoors – even if you just want to flush your toilets – health code often specifies the kind of roofing material (e.g. metal) that may be used in addition to meeting a certain standard for potable water. A treatment train (series of structures) to remove different pollutants is usually required. The most common residential treatment train includes a large and then a small screen to keep out larger debris, a sand filter for smaller debris, and an ultraviolet (UV) light to remove bacteria. Larger commercial cisterns might have additional equipment such as pressure tanks.

Sizing a Cistern

The size of the rainwater cistern can have the greatest impact on system cost and performance. Several factors must be considered, including the area of contributing rooftop, rainfall patterns, and anticipated usage.

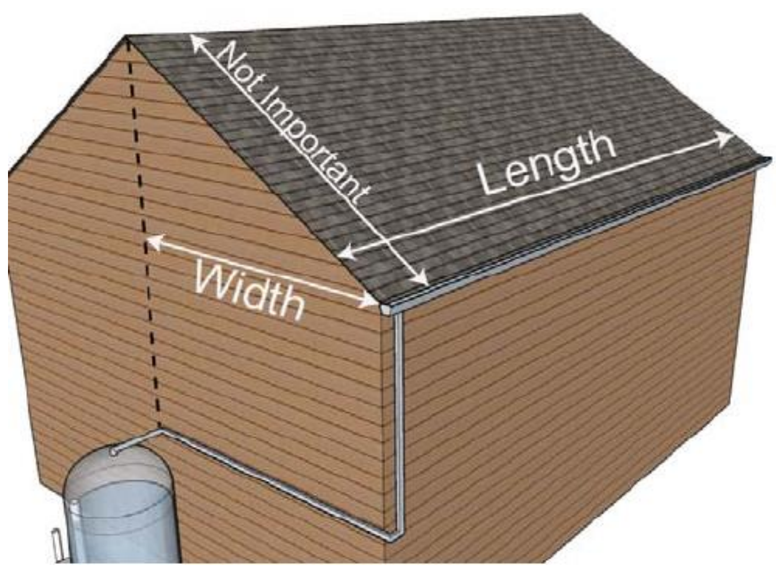


Figure 4 Contributing roof area measurements.

Determining Contributing Rooftop Area

Examine the location of downspouts that will drain to the cistern in order to estimate the rooftop area. Note the slope/angle of the gutter, and visualize what area of the rooftop will drain to each downspout. When measuring the rooftop area, it is important to measure the roof's horizontal projection (the distance you would go if you were to walk on the ground from the edge of the roof where the gutter sits to the peak of the roof), ignoring the pitch of the rooftop (Figure 4). Because the roof's slope is not a factor in the area measurements, the contributing area can usually be estimated by measuring the area of the roof at the ground or foundation level.

Rainfall Patterns

Due to the rainfall patterns in the Five Counties area – 6 months on, 6 months off – a cistern for irrigation, depending on the size of your garden, might be thousands of gallons. Although public water demand will be reduced, this may still not reduce runoff enough to benefit downstream waterways, depending on the size of your roof. A cistern that serves indoor needs will fill and empty much more frequently, reducing water bills and significantly reducing runoff. In addition, this cistern will be much smaller and cost-effective. In the 6 months when there's not much rain, your cistern may empty. Because of this, a valve is required that allows the household to switch to another water supply.

"The Texas Manual on Rainwater Harvesting" has some great guidance and tools on some more complicated calculations you can perform to optimize your tank size seasonally for your water demand. However, rainfall patterns and your budget are likely to limit the size of your cistern, such that it will definitely be empty at some point during the long, natural (and unnatural) droughts in the Five Counties area. To get a rough estimate of annual runoff volume from your roof, lookup the average annual rainfall for your area by Googling "average annual rainfall" and the closest city or town, and convert that number to feet per year rather than using inches per year. See Equation 1 below for an example. You will also need to apply a reduction factor depending on the type of roof you have and whether you will have lower runoff (as with a rough roof like composite) or higher runoff (as with a smooth roof like metal) and whether or not you're using a first flush diverter, which decrease harvest volume by 10 gallons per downspout during every rainfall (see Table 1).

Table 1 Reduction Factors

Roof Texture	Reduction Factor without First Flush Diverter	Reduction Factor with First Flush Diverter
Rough	0.85	0.80
Smooth	0.95	0.90

Finally, multiply the modified average annual rainfall amount by your roof area. The number you calculate will be in cubic feet, so multiply that by 7.48 gallons/cubic foot to get the amount of runoff in gallons you are looking to capture each year. Even on small roofs, residents in most of the Five Counties area will find that their roof is likely to generate much more runoff than they expected.

Equation 1
Example calculation to approximate annual runoff volume:
Homeowner in Crescent City, CA:
Average annual rainfall = 75 inches/year divided by 12 inches (to convert to feet) = 6.25 feet/year
Roof area = 1250 square feet
Roof type = asphalt shingles or rough type
First flush diverter? = yes
Reduction Coefficient from Table 1 = 0.80
Average annual roof runoff = 6.25 [ft/yr] x 0.80 x 1250 [sf] x 7.48 [gal/cf] = 46,750 gal/yr

Anticipating Water Use
Estimating how much water will be used from the rainwater harvesting system is *crucial* to selecting an appropriate cistern size. One of the best ways to estimate water usage for irrigation is to use a simple garden water meter and record how much water is being used for tasks that will be replaced with harvested rainwater. Garden water meters that measure the number of gallons flowing through a hose or other device are available from a variety of retailers for about $10. Water usage in your house is already measured by your water company, so take a look at your bill to find your average annual demand.

Cistern Structural Support
In some cases, the weight exerted by the cistern and the water it holds may require more structural support than the soil that is in the ground now can provide. Soils are generally estimated to support at least 2,000 pounds per square foot, but you should check with your jurisdiction or a professional for your local soils. Based on the cistern's volume, footprint (the square footage it occupies), and the density of water, you can determine whether additional structural support for a cistern is necessary. The load exerted by the cistern can be calculated using Equation 2 (below). If the calculated load is greater than the load bearing capacity of the soil (2,000 pounds per square foot), some type of structural support will be required. Structural support for an above-ground cistern could consist of a concrete or gravel pad installed using standard building design practices. Alternatively, a cistern with a larger footprint or smaller volume could be selected to reduce the cistern load.

Sand, stone, or gravel backfill and anchoring—or even the use of a poured concrete pad—may be required to ensure that even an underground cistern won't settle. Be sure to follow the manufacturer's instructions and any local regulations when installing an underground cistern.

Equation 2
Calculation of the cistern load to determine if there is a need for structural support:

$$\text{Cistern Load} = \frac{\text{Capacity [gal]} \times (8.35 \text{ [lb/gal]} + \text{Cistern Weight [lb/gal]})}{\text{Cistern Footprint Area [sf]}}$$

Cistern Weight: The weight of an empty *plastic* cistern can be approximated as 0.3 lb/gal if the specific weight is unknown.
Footprint Area: Area of the cistern in contact with the ground.

EXAMPLE
A 1,000-gallon plastic cistern has a diameter of 7.25 feet (radius is half, which is 3.625 ft). Determine if additional structural support is required, assuming soil bearing capacity is at least 2,000 pounds per square foot.
Cistern Footprint Area = $\Pi r^2 = 3.14 \times (3.625)^2 = 41.3$ square feet

$$\text{Cistern Load} = \frac{1{,}000 \text{ [gal]} \times (8.35 \text{ [lb/gal]} + 0.3 \text{ [lb/gal]})}{41.3 \text{ [sf]}} = 210 \text{ lb/sf}$$

which is less than 2000 lb/sf, so no additional support needed

Conveyance
Gutters, Downspouts, and Pipes
An existing gutter system can be easily modified to direct rainwater into a cistern. In most cases, some type of gutter screen or filter is needed to prevent debris from entering the system. Although more expensive, screens installed across the length of the gutter are less likely to clog and cause gutter overflows than filters located only at the downspout. Metal gutter downspouts and fittings are available from home improvement stores and can be used to route rainwater into a nearby cistern. Remember that metal downspouts are generally attached to a

building and may require additional structural support when spanning any substantial distance to a cistern. Corrugated plastic pipes are an alternative to metal downspouts that may make installation easier and require less structural support. To prevent mosquitoes from breeding within the cistern, any open pathways to the captured water should be covered by 1-millimeter or smaller mesh screen.

Several approaches can be used to direct more water to a rainwater harvesting system. The easiest and safest way to contribute more water is to pipe water from multiple existing downspouts into the cistern. Using this approach provides water from more areas of the rooftop without the risk of exceeding the capacity of either the downspout or gutter. In locations where it is not practical to direct water from multiple downspouts into the cistern, it may be possible to modify the gutter system so that more water is directed to a single downspout.

Standard gutter systems are designed to efficiently remove water from the rooftop and gutter through numerous downspouts. Any modifications to the gutter system without careful consideration can result in overflows or structural failure. Per the Plumbing Code, gutters should convey water for the 100-year, 1-hour storm event (the same event used for sizing the cistern overflow). Carefully consider Tables 2 and 3 below before modifying gutters to direct water into a cistern. Table 1 lists the maximum rooftop area that can be safely drained by various gutter and pipe configurations, while Table 2 lists the maximum roof area that can be drained by a downspout.

Maximum Allowable Horizontal Projected Area in Square Feet (Tables 2 & 3)

Table 2: For Vertical Piping (Downspouts)

Pipe Diameter [in]	Maximum Roof Area [sf]
2	1,440
3	4,400
4	9,200
5	17,300
6	27,000
8	58,000

Table 3: For Horizontal Piping (Gutters & Pipes)

	Pipe Slope [in/ft]		
	1/8 (~ 1%)	1/4 (~2%)	1/2 (~4%)
Pipe Diam [in]	Maximum Roof Area [sf]		
3	1,644	2,320	3,288
4	3,760	5,300	7,520
5	6,680	9,440	13,360
6	10,700	15,100	21,400
8	23,000	32,600	46,000

Outlet

To draw water from the cistern, some type of faucet or outlet pipe must be installed. Although a valve located near the bottom of the cistern can be used to pull water from the cistern for small uses, such as filling watering cans, a pump is necessary to supply adequate pressure for many other uses. Pump selection is discussed in detail in detail on this website publication: *Choosing a Pump for Rainwater Harvesting (AG-588-08).*

Figure 5 Bulkhead fitting installed at the base of a cistern.

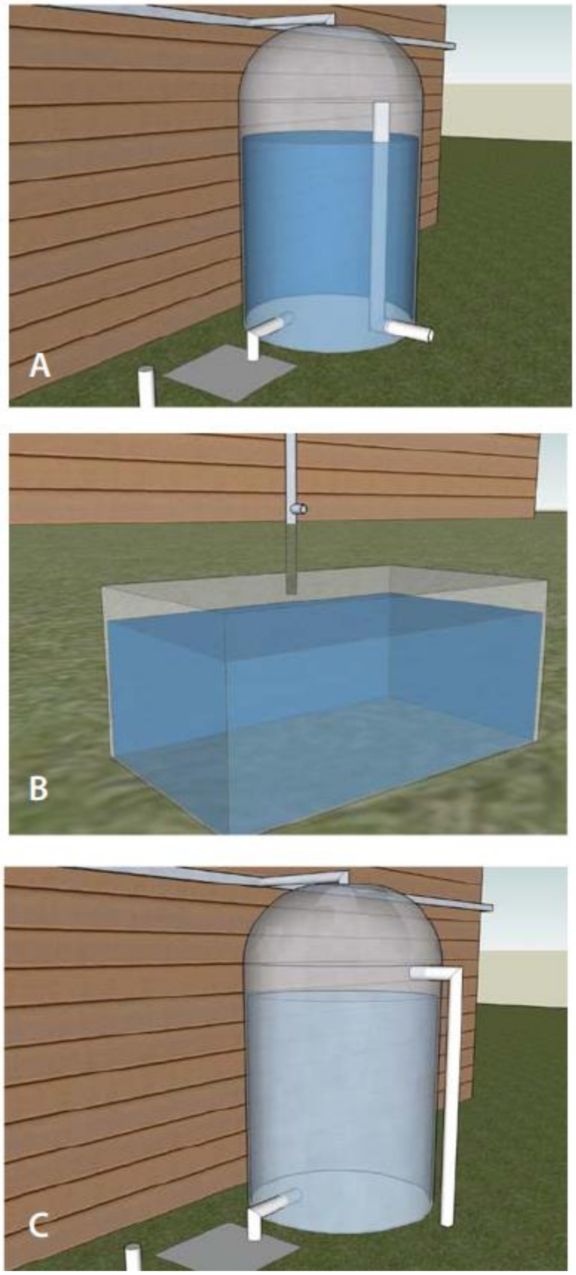


Figure 6 A, B, C. Basic overflow configuration

The outlet should be installed at least 6 inches above the bottom of the cistern to provide room for sediment storage. Because the outlet connection will be subject to substantial water pressure, a bulkhead fitting is necessary to prevent any leaks. Install a bulkhead fitting by drilling a hole into the cistern and threading the fitting through the hole (Figure 5). Because installing a bulkhead fitting requires access from the inside of the tank, it is often worth the extra expense to have the bulkhead fitting installed by the cistern vendor.

Emergency Overflow

Some type of overflow or bypass is required to release water when the cistern has reached its capacity. The cistern overflow must handle the same flow as the gutter system, per the California Plumbing Code. Install the overflow near the top of the tank, leaving several inches between the overflow and top of the tank for storage during intense storms. A bulkhead fitting installed near the top of the tank will provide a sturdy connection point for the overflow pipe. However, these fittings can be expensive, especially for large diameters. Because an overflow connection at the top of the tank will not be submerged under pressure and a perfect seal with the cistern wall is not necessary, a variety of PVC fittings can be adapted to connect the overflow pipe. If the overflow is routed internally through the bottom of the tank, as shown in Figure 6A, a bulkhead fitting is required to prevent leaks. For underground cistern installations as shown in Figure 6B, the overflow can be installed with a t-fitting on the pipe carrying water from the gutter to the cistern. For both above- and below-ground cisterns (example shown in Figure 6C), it is important to protect, armor, or reinforce the soil around the overflow outlet to prevent erosion.

Water Supply Plumbing Codes

Because widespread public interest in rainwater harvesting systems is a relatively recent development, many plumbing codes do not currently address the use of harvested rainwater. Plumbing codes are constantly evolving. Consult your local building or development services department to determine which plumbing fixtures (such as tubs, toilets, and sinks) can legally be supplied with harvested rainwater and what specific regulations apply. Many of the restrictions associated with plumbing codes can be avoided by maintaining entirely separate plumbing networks or using harvested rainwater for outdoor purposes only. Regardless of the plumbing network, any faucet or fixture supplied by the rainwater harvesting system must be properly labeled with its source. Harvested rainwater contains pathogens and other pollutants at levels that pose health concerns if drunk. Installing signs or labels that warn of these health concerns is important to prevent any potential hazards (Figure 7).

Maintenance

With routine maintenance, rainwater harvesting systems should provide a sustainable, non-potable water supply for many years. Over time, sediment carried by incoming runoff will be deposited within the bottom of the cistern and may require removal. Using a first-flush diverter or sediment trap will reduce the amount of sediment going into the cistern (Figure 8). In most cases, a 6-inch sediment storage zone at the bottom of the cistern should provide years of sediment storage. If sediment buildup is a concern, install a valve at the bottom of the cistern to regularly drain the sediment-laden water. Due to the risk of drowning and exposure to toxic gases, a homeowner should never enter a cistern for maintenance or any other purpose.

Check gutter connections every three to four months and after intense rainfall to check for any damage. Clean gutters of leaves and debris as needed and at least seasonally. Check mosquito screens periodically to ensure they are in place and not blocked by debris. Maintain any pumps or filters used in the rainwater harvesting system according to the manufacturer's recommendations.

Figure 7 Stickers remind users that untreated cistern water is not safe to drink without treating.

Figure 8 Rain barrel for landscape watering. Note the leaf guard over the gutter screen and strainer basket, which are used to reduce clogging and maintenance.

Rain Barrels

Rain barrels are less expensive alternatives to large rainwater harvesting systems and can be used to meet small outdoor water demands. A rain barrel is typically constructed from a 55-gallon container and has the same main components as a large rainwater harvesting system, including a gutter connection, overflow, and outlet valve or faucet (Figure 1). Because 55-gallon barrels are used to store and transport a variety of materials, used barrels are inexpensive to obtain. But they may require special cleaning, depending on their previous use. The relatively small size of a rain barrel usually does not merit the cost of installing a pump because gravity flow is generally adequate to fill a hand watering can. Although a rain barrel does not provide enough water to irrigate a lawn, it can be used to store water for hand-watering plants in a small garden area. To build a simple variation of a rainwater harvesting system for outdoor use only, see *"5 Build a Rain Barrel"*.

Photo & Document Credits

This document was adapted (but mostly lifted word for word) with permission from William Hunt, Ph.D, P.E. from the Urban Waterways *"Rainwater Harvesting: Guide for Homeowners"* (AG-588-11), North Carolina Cooperative Extension Service, N.C. State University.
Figure 1: NC Cooperative Extension. Figure 2: LSU Ag Center. Figures 3 – 7: NC Cooperative Extension. Figure 8: Dennis Slota.

7 Test Your Soil

Infiltration Testing

An infiltration test will help you determine the soil's capacity to absorb and percolate water down into the lower layers. The ability of soil to drain water is one of the most important considerations for understanding the site.

You may use an infiltration test like this to:

- Size a new rain garden
- Test existing facilities
- Find the fastest infiltration rate on your site (in areas that meet appropriate setback requirements as described in *"8 Site Bioretention for Infiltration").*

Testing is not needed for filtration facilities, which are lined to prevent water from entering the native soil.

Existing soil or geologic maps can be used in the initial steps to evaluate the site's potential for infiltration, but should never be used alone. Ground truthing with infiltration tests very often reveals different conditions in different places on the site at different depths.

Timing & Location

Tests should not be conducted:

- in the rain
- within 24 hours of a storm greater than 1/2 inch (check your local weather report, place a rain gauge in your yard, or check NOAA's website for recent rainfall: http://water.weather.gov/precip/)
- when the ground is frozen.

The test measures the soil's ability to infiltrate water in a very small and specific area. If the proposed facility has a large area, multiple measurements within the area are suggested to properly assess the site's suitability.

In new development, infiltration tests should be performed across the proposed development area prior to placing structures on the ground. This provides the opportunity to install drainage facilities on optimal soils and geology to reduce their size and cost. If buildings are proposed on high infiltration soils and facilities proposed in lower infiltrating soils, plans can be modified to improve stormwater management and decrease cost. The earlier in the site development process that infiltration tests are conducted, the better. Regardless of soil type, the infiltration rate will be needed to select and design facilities.

In retrofits, where you have a limited area to choose from, it's ideal to test directly over or as close to the proposed facility.

Number of Tests

The number of infiltration tests for large sites varies widely depending on local regulations. More tests will be needed if there are many different types of soil conditions across the site. In urban sites, where soils may have been disturbed a number of times over many years, soil conditions may vary greatly over small distances.

Safety

Call 811 prior to digging if there is any possibility of underground wires or pipes at your test site. Make sure the bottom of the rain garden is at least 3 feet above the high groundwater table (where you would find water if digging a hole in the soil during the wet season). Contact your local water district, County Planning Department, local well drilling company, local Resource Conservation District, landscape contractors, or others to determine depth to groundwater at your site. If you cannot find any information on depth to groundwater at your site, you can drive a 1" steel pipe into the ground and insert a metal tape rubbed with chalk into the pipe to determine the ground water level. All relevant Occupational Safety and Health Administration (OSHA) regulations should be observed. If a hole big enough to climb in (i.e. test pit) is deeper than 4', the sides must be graded back to a gentle slope of 3H:1V or if walls are vertical, shoring (reinforcement to prevent collapse of the walls) is required. "Excavation should never be left unsecured and unmarked, and all applicable authorities should be notified prior to any work".

Figure 1 Anyone can perform an infiltration test with commonplace tools.

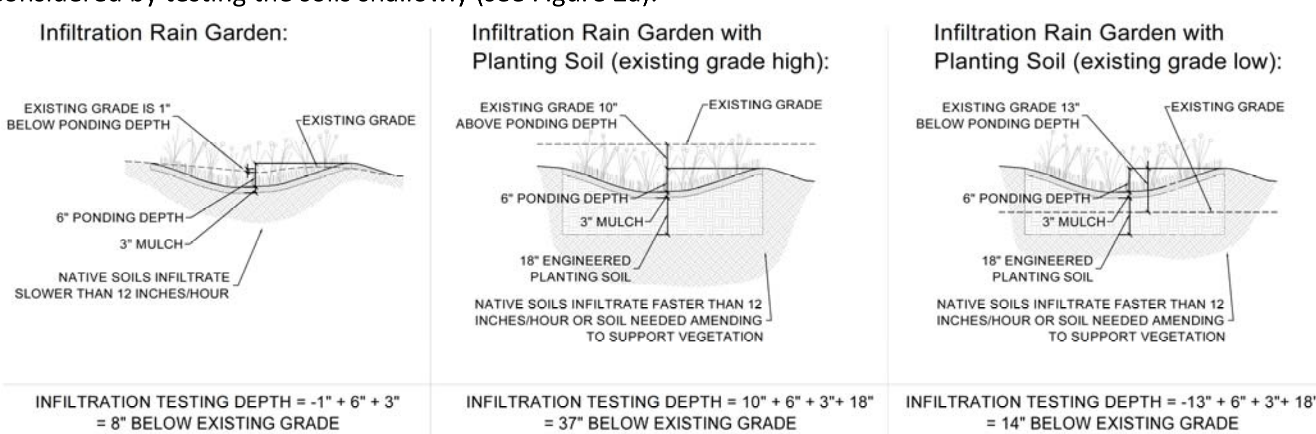
Equipment Needed

To perform an infiltration test, you will need:

- Shovel and/or post-hole digger
- Yardstick or ruler
- Water source
- Some clean gravel (if you are in clay soils)
- Pencil
- Paper
- Watch or timer
- Watering can (optional)

Testing depth

Infiltration testing should be performed at the depth where you expect the bottom of the facility to be located; however, consider the possibility that infiltration testing will determine the depth and location of excavation needed . Soils just 6" below existing grade may be suitable for infiltration and have enough nutrients to support plant growth. In this case, a very simple facility that doesn't replace or amend the native soils should be considered by testing the soils shallowly (see Figure 2a).



Figures 2a, 2b, 2c Infiltration testing depth will vary with type of facility and other siting considerations.

Test Infiltration

A simplified 'falling head' test is described as follows.

1. Dig a test hole with a post hole digger or a larger area with a shovel. The width/area of the hole doesn't matter. Dig a hole to the expected depth of the rain garden as discussed above.
2. If you don't know how to identify clay soils, perform a ribbon test as described in a section below.
3. If soils are clayey, scrape the sides of the hole a little (i.e. scarify). Remove the scraped material in the bottom of the hole and place an inch or so of clean gravel at the bottom; otherwise, the tiny clay particles will be suspended in the water to form an impermeable sheen around the sides and bottom of the hole.
4. Fill the hole with water gently to a depth of water expected if the rain garden filled to the rim. You can mark this depth by sticking a pencil or nail into the side of the hole. Record the exact time you stop filling the hole (if soils are fast draining, measure time down to the second) and the time it takes to drain completely.

Figure 3 A shovel was used to dig most of the way then a 6" diameter post hole digger was used to reach the proposed bottom elevation of a rain garden. Measure the drop in water from a known, stable marker.

5. Refill the hole again and repeat step 2 two more times. The third test will give you the best measure of how quickly your soil absorbs water when it is fully saturated, as it would be during a rainy period of the year or during a series of storms that deliver a lot of rainfall in a short period of time. The average infiltration rate should decrease with each round. If it doesn't, repeat the test a few feet away.
6. Divide the distance that the water dropped by the amount of time it took for it to drop. For example, if the water dropped 6 inches in 12 hours, then 6 divided by 12 equals 1/2 inch per hour of infiltration. If the slowest infiltration rate measured of the three trials is less than 1/2 inch per hour, then you should dig another 3 to 6 inches deeper and repeat the above steps to see if there's a faster draining soil beneath your test holes. This will help to minimize the depth of the rain garden and reduce the cost of excavation and replacing native soil with amended planting soil (See *"4 Build a Rain Garden"* and "*10 Amend Soils for Bioretention").* Repeat this process at various depths down to another 2 feet, or until you have at least 1/2 inch per hour infiltration.

Confirm Vertical Separation

7. Voids in the soil convey water down and away from the site like a big, slow-draining underground pipe. Adequate depth of dry soil beneath an infiltration facility ensures that the facility won't damage important structures by backing up and flooding them. (See *"8 Siting Bioretention for Infiltration"*.) Now that infiltration testing is done, look for bedrock or other impermeable subsurface layers that may delay infiltration. Dig the hole another 2 feet of depth from the bottom of the proposed rain garden. If the soil is pretty consistent all the way down then one criteria for vertical separation is met.
8. Now look for a seasonal high groundwater table by digging a hole to an additional one foot of depth. If the hole doesn't fill up with water, then groundwater levels are sufficiently deep and the second vertical separation criterion is met.
9. Fill the hole back up.

Interpret Your Results

To infiltrate, all other siting criteria in “*8 Site Bioretention for Infiltration”* must be met.

If:
- Your infiltration rate is less than 1/2 inch per hour AND
- vertical separation criteria cannot be met,

test other possible locations (preferred) or use a lined filtration facility to prevent flooding and protect groundwater resources.

If:
- Your infiltration rate is less than 1/2 inch per hour AND
- vertical separation criteria can be met,

test other possible locations (preferred) or install an underdrain in your infiltration facility per *“4 Build a Rain Garden”.*

If:
- your infiltration rate is greater than 1/2 inch per hour AND
- vertical separation is confirmed,

then this location is suitable for a rain garden or other infiltration facility. (Porous pavements are not specifically addressed in this guidance, but it’s worth noting that soils infiltrating at 1/10 inch per hour or greater are suitable for porous pavement since porous pavements manage rainfall, not runoff.)

If:
- your infiltration rate is greater than 12 inches/hour,

then this location is suitable for a rain garden or other infiltration facility. However, consider replacing the first 18” of native soil with an engineered 3-way mix as described in *“10 Amend Soils for Bioretention”.*

Installing a rain garden or other infiltration facility in soils with rates exceeding 12 inches/hour is not recommended because the facility may pollute groundwater resources. This is because runoff may not be retained in the soil long enough before it joins the groundwater table.

If:
- your hole caves while or after pouring water in AND
- the infiltration rate slows to nothing,

then this location is probably not suitable for an infiltration rain garden. Soils that behave like this will be a mix of sand and clay; redirecting runoff from large areas into the relatively small rain garden area will cause this kind of soil to become cement-like. Test other possible locations (preferred) or use a lined filtration rain garden.

Ribbon Testing

As indicated above, to properly install an infiltration facility, you need to approximately identify the soil texture of your existing native soils, which may range from more sandy to more clayey.

Determine soil texture

1. Take a handful of the soil you have excavated from your infiltration test. Pulverize it in your hand and remove any bits of organic matter or obvious rocks.
2. Wet it with a small amount of water and rub it between your thumb and index finger. Don't saturate it until it is runny mud. You might feel stickiness, grittiness, or smoothness. The grittier the feel, the more sand is present in your soil. The slicker the soil, the more clay in it. Smooth soils are sometimes an indicator of a fine silt or loam. Discard the soil.

Figure 4 Soil texture assesses organic content and soil type. Step 3 is shown here.

3. Next, take another sample in your hand. Wet it until it has the consistency of dough. You should be able to form a ball that holds together with the soil in your palm. If you cannot get the ball to form, then your soil is very sandy. In most soils, however, you should be able to create a rough ball (see picture below).

4. Knead the soil together between your thumb and fingers and attempt to form a ribbon. As you build the ribbon, it will either hold together or break off.

Figure 5 Step 4 of the ribbon test.

Interpret Your Results

If the soil forms a ribbon:

- less than 1 inch in length before it breaks, the soil is sandy or silty.
- 1 to 2 inches in length before it breaks, the soil is clayey (i.e. has some clay).
- greater than 2 inches before it breaks, the soil is clay. You may find that the infiltration rate is so low that, depending on the available area, you'll need to install an underdrain beneath your infiltration facility per *"4 Build a Rain Garden"*.

Bibliography

Emanuel, Robert, Derek Godwin and Candace Stoughton. The Oregon Rain Garden Guide. Stormwater Management Manual. Salem, OR: Oregon State Univesity, 2010.

Cahill, Maria & Derek Godwin. Infiltration Testing. Fact Sheet. Salem, OR: OSU Extension, 2011.

Photo Credits

Figure 1 – 3: Maria Cahill
Figure 4 -5: Gina Emanual

8 Site Bioretention for Infiltration

Figure 1. This father and son are bug-hunting in an urban stormwater facility. Many factors come into play in choosing a location.

Siting a rain garden, downspout disconnect, or a vegetated filter strip is critical to improve watershed health and reduce construction and maintenance costs. These facilities fall into a larger category of stormwater facilities often called “bioretention”. These practices are described in “*2 Disconnect Impervious Areas*” and “*4 Build a Rain Garden*”. ***To simplify the rest of this discussion, the word bioretention will be used to refer to guidance that applies to rain gardens, downspout disconnection, vegetated filter strips and similar vegetated stormwater practices.***

Infiltration vs. Filtration Facilities

There are two types of bioretention: infiltration and filtration. Infiltration facilities allow stormwater to flow into the native soils and mimic the natural movement of water (aka hydrology) of the pre-developed site. Filtration facilities are lined, which prevents on-site absorption and downward passage of water. When these facilities are located in native soils infiltrating less than 0.5 inch/hour, they are likely to have standing water for excessive periods. Stormwater passes through an engineered soil mix, hits the liner, and flows into a pipe or other approved discharge point, such as a waterway. Both approaches remove pollutants on-site, but since filtration facilities don’t imitate the hydrology of pre-development conditions, additional runoff volumes cause damage to downstream waterways, impacting water quality, habitat, and availability. In some studies, lined facilities have only slowed flows by 13 minutes, offering questionable detention protection from flooding. ***For these reasons, a filtration facility should only be used as a last resort. Finding the right place for an infiltration facility should be a priority.***

Test Your Soils

Infiltration testing to see how well soils drain should be conducted where your bioretention will be located. Sometimes when there are a few possible locations, designers will run a few tests to find the optimal infiltration rate that will reduce the size and cost of the facility. For more information, see *“7 Test Your Soils”.*

Criteria for Siting for Infiltration

Regardless of whether building a new project or retrofitting existing sites, all bioretention facilities have the potential to flood property and cause damage. However, infiltration facilities, if not sufficiently separated from various conditions, both horizontally (i.e. setbacks from infrastructure) and vertically (with enough depth and layers to allow proper function), have greater potential to cause damage.

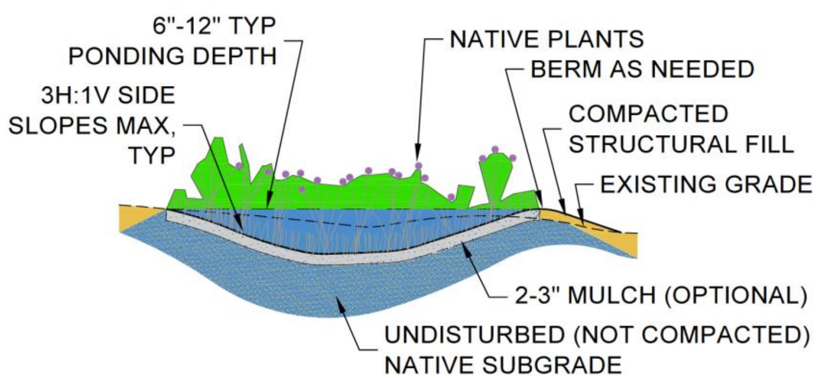


Figure 2 Infiltration from bioretention, such as from this rain garden, must be placed in a proper location to avoid the potential to flood basements and other critical structures.

To prevent property damage from flooding, move runoff safely away (convey) to an infiltration location:

Horizontal Setbacks

- 10’ from a footing, foundation, or the top of a wall.
- 5’ from the property line.
- 100’ from slopes ≥ 10% below the bioretention feature. Add 5’ of setback for each additional slope percent up to 30%. For example, for a 15% downslope, you need 125’ of setback. Avoid installing an infiltration facility near slopes greater than 30%.
- 5’ from underground pipes. Call 811 to locate utilities on private property.
- 0’ from slabs footings or pavement. (A vertical liner extending at least 6” beyond the pavement section should be used so infiltrating water doesn’t undercut and cause a structural failure of the pavement.) 0’ from pier footings or the bottom of a site (not building) wall.

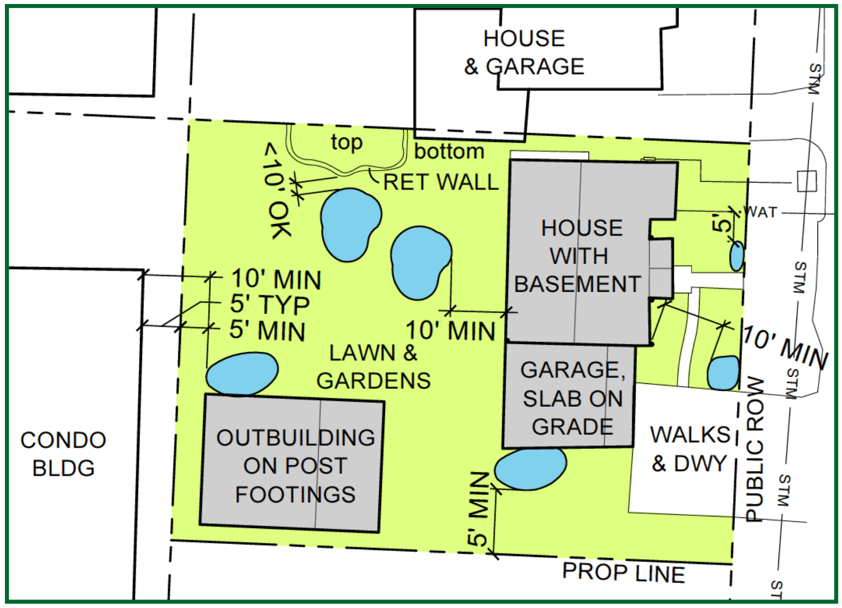


Figure 3 Horizontal setbacks from buildings and foundations are needed for rain gardens and vegetated filter strips. Other important setbacks listed below may apply to your site.

Vertical Separation

- 3’ from the bottom of the facility to the top of the high groundwater table.
- 2’ from the bottom of the facility to the top of bedrock, fragipan (an impervious subsurface layer), or other impermeable material.

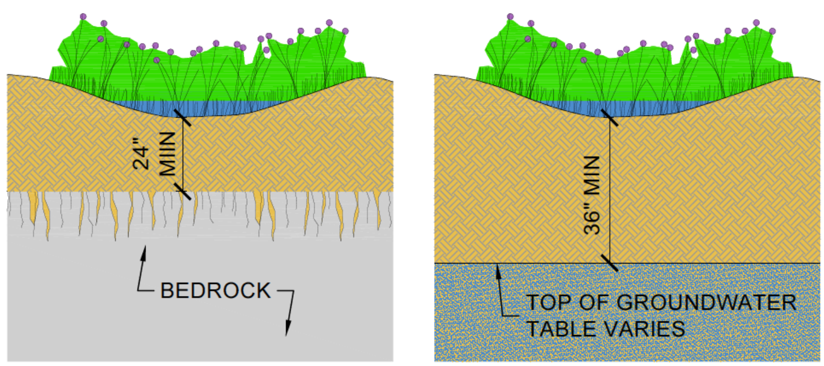


Figure 4 Enough separation from certain subsurface conditions, like bedrock or groundwater, is critical to the function of infiltration facilities.

Additional general siting criteria:

- Native soils must infiltrate at a minimum of 0.5 inches/hour.
- Never place facilities in 25-year floodplains or other sensitive areas such as wetlands, riparian areas and buffers, or habitat.
- For runoff from vehicular areas, never place infiltration facilities in wellhead protection areas or within a horizontal distance of 2 times the depth of any nearby wells.
- Never place over septic systems.
- Never place under the drip lines of trees to be preserved.
- Never place in contaminated soils or groundwater.
- Facilities are usually not placed on new (less than 5 years old) fill.

- Consider overhead lines when choosing vegetation types. For example, don’t plant a tree that’s going to be 100’ tall at maturity under an overhead utility that’s only 30’ above your facility.
- For disconnected downspouts, place 3’ from public sidewalks.

Depending on the situation, it may be possible to exceed some of the above guidelines. However, to do that a geotechnical engineer licensed in the State of California must investigate and provide a stamped report allowing alternative setbacks and/or vertical separations.

Filtration (i.e., lined) bioretention should be used instead of infiltration facilities:

- Where horizontal setbacks, vertical separation, & additional general siting criteria for infiltration as described above cannot be met.
- In potential stormwater hotspots such as vehicle fueling, industrial loading, unloading, and material storage areas.
- On slopes exceeding 10% or in landslide or unstable areas.

Avoiding Flood Damage

Regardless of facility size or storm size managed, all bioretention facilities must have a safe overflow that conveys water away from buildings and other sensitive infrastructure (such as electrical boxes) via the surface of the land. Never direct stormwater overflows towards neighboring private properties. Overflows should be directed to a public street, pipe, or other discharge point approved by your county.

Permits

A permit may not be needed to choose a site for bioretention, but check with your jurisdiction’s building or development services department. If information in this guidance conflicts with your jurisdiction’s requirements or approach, then follow guidance provided by them instead.

Bibliography

Godwin, Derek, Maria Cahill and Marisa Sowles. Rain Gardens. Fact Sheet. Salem, OR: OSU Extension, 2011.

Photo Credits

Figures 1-4: Maria Cahill, Green Girl Land Development Solutions.
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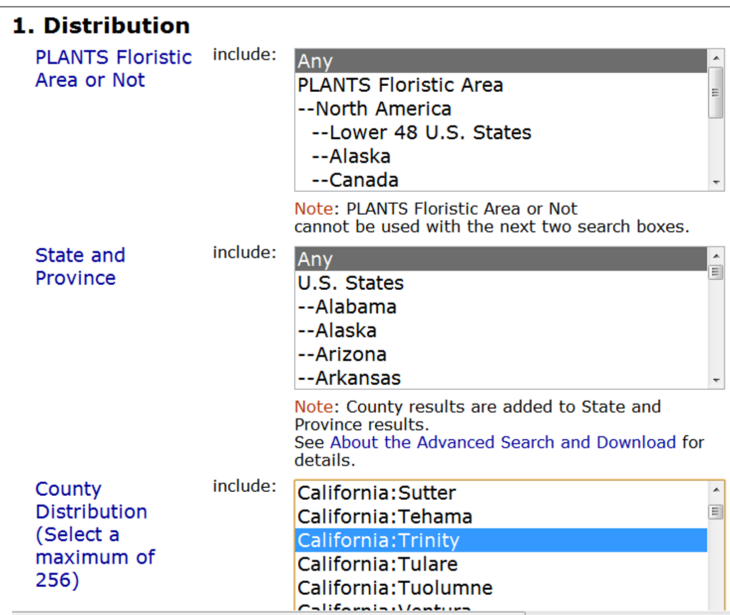
9 Find Native Plants in Your Area

The USDA has excellent online guidance for finding plants native to your state and even your county. The following tutorial includes screen shots to help you use their website to identify suitable plants for your project. You may want to visit a nearby native plant nursery to see what's available. If no native plant nursery is nearby, you'll have to look up what is available in your area with this database.

Always avoid invasive plants. Some of these, such as perwinkle (vinca minor or major), English ivy, and Yellowflag iris may be sold at your local nursery. For more information, visit the California Invasive Plant Council's website: http://www.cal-ipc.org/ip/management/plant_profiles/.

<table>
<tr><th>Tutorial Directions & Related Information</th><th>What To Look For OR What You'll See</th></tr>
<tr><td>1. Go online to the USDA PLANTS Database at: plants.usda.gov</td><td rowspan="2">
</td></tr>
<tr><td>2. In the upper left hand corner click on "Advanced Search".

(For better viewing, the left navigation bar has been cropped from the rest of the screen shots.)</td></tr>
<tr><td>3. We're going to pick and choose a few different items on the "Advanced Search and Download" web page. Not all search options need attention. For any of these scroll menus, you may have to click outside the box (in white space) to get your choice to "stick".

Start by scrolling down under "1. Distribution" to "County Distribution" and choose your county. In this example, we chose California: Trinity.</td><td>
</td></tr>
</table>

4. Scroll down under "2. Taxonomy" to "National Common Name" and click the checkbox to the right that says "Display"	National Common Name include: Display Wild cards are permitted.
5. Scroll down under "3. Ecology" to "Duration" and choose "Perennial"	**3. Ecology** Duration include: Any Annual Biennial Perennial
6. Go to the next item under "3. Ecology" to "Native Status" and choose "-- L48 Native"	**3. Ecology** Duration include: Any Annual Biennial Perennial Growth Habit include: Any Forb/herb Graminoid Lichenous Native Status include: Any Native to PLANTS Floristic Area --North America Native --L48 Native --AK Native --CAN Native
7. Scroll down (or up) to the "Display Results" button and click on it.	Display Results Review Selections or Sort Report Display Results runs the entire search, Parts A and B
8. A list (partially shown here) of all plants native to Trinity County in California with their common names is generated:	**Scientific Name** — **Common Name** *Abies lowiana* — Sierra white fir *Abies magnifica* — California red fir *Acer circinatum* — vine maple *Acer glabrum* — Rocky Mountain maple *Acer glabrum var. torreyi* — Torrey maple *Acer macrophyllum* — bigleaf maple *Achillea millefolium* — common yarrow *Achillea millefolium var. occidentalis* — western yarrow

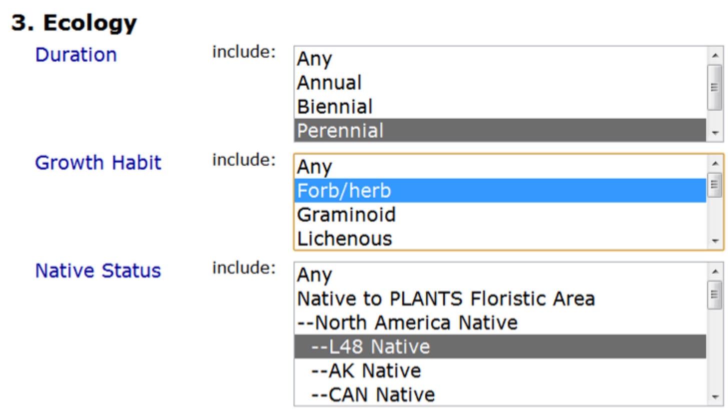
9. To narrow the search to certain types of plants, like shrubs and trees, click on the "Back" button or back arrow of your internet browser (see next step & figure).

Selections that might be appropriate to plant in a rain garden or your landscape area are:

- Forb/herb (flowering plants that aren't grasses, sedges, & rushes)
- Graminoid (grasses, sedges, & rushes)
- Shrub
- Subshrub
- Tree
- Vine

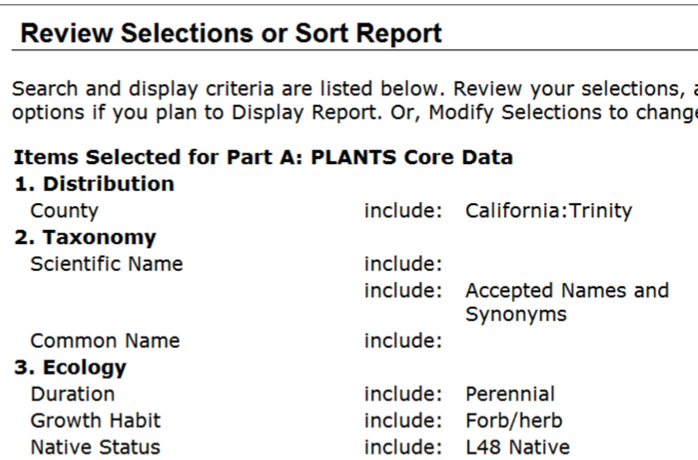
10. Scroll down to "3. Ecology" and "Growth Habit".

For this example, choose "Forb/herb". (To choose more than one selection at a time in any of these lists, hold down the "Ctrl" button on your computer while scrolling and clicking. Once you're done selecting, you can double check your selections by letting go of the Ctrl button and scrolling around to see if more than one selection is highlighted.)

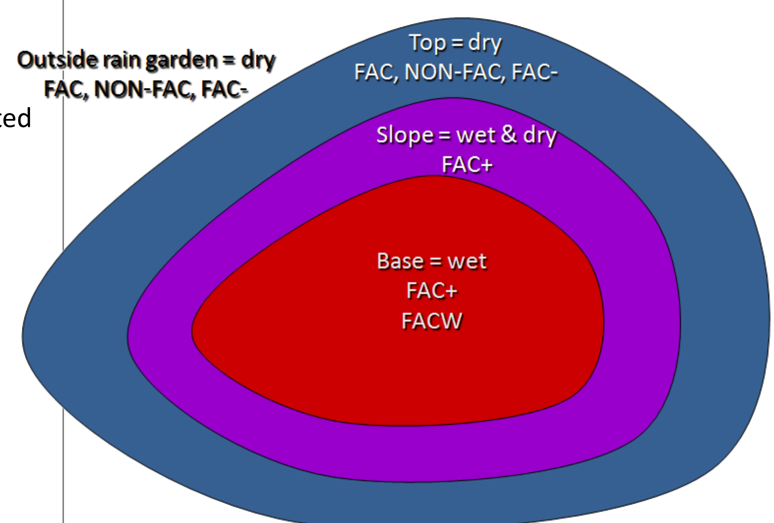


11. Your previous choices should still be selected. Scroll down to "Review Selections or Sort Report" button in the middle or bottom of the page and click this to see what criteria you've entered so far.

12. After you click, you'll see all your criteria listed.



13. Now click the “Display Results” button at the bottom of this page.	Display Results Review Selections or Sort Report Display Results runs the entire search, Parts A and B
14. This list (partially shown) is narrowed to native, perennial flowering plants in Trinity County in California.	**Scientific Name** — **Common Name** *Achillea millefolium* — common yarrow *Achillea millefolium var. occidentalis* — western yarrow *Aconitum columbianum* — Columbian monkshood *Aconitum columbianum ssp. columbianum* — Columbian monkshood *Actaea rubra* — red baneberry *Actaea rubra ssp. arguta* — red baneberry
15. To narrow your search to find plants appropriate for different moisture zones, scroll to “4. Legal Status” and look for “National Wetland Indicator Status” as follows: Click the back button on your browser twice to the “Advanced Search and Download” page. Scroll to “4. Legal Status” and under “National Wetland Indicator Status”. Holding down the Ctrl button throughout, choose “-- FACW (Facultative Wetland)”, then scroll down and click on “-- FAC+ (Facultative +)”. The different moisture zones of a rain garden (base, slope, top) can be correlated to National Wetland Indicator Status[1] as shown in this rain garden diagram:	National Wetland Indicator Status include: --FACW+? (Possibly Facultative Wetland+) --FACW (Facultative Wetland) --FACW? (Possibly Facultative Wetland) --FACW- (Facultative Wetland-) National Wetland Indicator Status include: --FACW+? (Possibly Facultative Wetland+) --FACW (Facultative Wetland) --FACW? (Possibly Facultative Wetland) --FACW- (Facultative Wetland-)



[1] Per conversation with Rob Emmanuel, Ph.D. Clean Water Services in Hillsboro, OR

16. Let’s review our choices by clicking on the “Review Selections or Sort Report” button.	**Review Selections or Sort Report** Search and display criteria are listed below. Review your selections, options if you plan to Display Report. Or, Modify Selections to chanç **Items Selected for Part A: PLANTS Core Data** **1. Distribution** County include: California:Trinity **2. Taxonomy** Scientific Name include: include: Accepted Names and Synonyms Common Name include: **3. Ecology** Duration include: Perennial Growth Habit include: Forb/herb Native Status include: L48 Native **4. Legal Status** National Wetland Indicator Status include: FACW - Facultative Wetland, FAC+ - Facultative
17. Click on the “Display Results” button at the bottom of this page.	Display Results Review Selections or Sort Report Display Results runs the entire search, Parts A and B
18. You’ll see all the flowering, native, and perennial plants native to Trinity County, CA that are appropriate for the wettest zones of a rain garden.	**Scientific Name** — **Common Name** *Aconitum columbianum* — Columbian monkshood *Angelica arguta* — Lyall's angelica *Apocynum cannabinum* — Indianhemp *Apocynum sibiricum* *Aralia californica* — California spikenard *Arnica amplexicaulis* — clasping arnica

Links to Plants Native to Your County

We’ve done *some* of the sorting for you. The links below will give you a list of perennial plants native to your county and will indicate whether they are a forb/herb (flowering plants that aren’t grasses, sedges, and rushes), graminoids (grasses, sedges, & rushes), tree, shrub, subshrub, or vine. Wetland status is indicated in the list, but has not been narrowed to any particular status (i.e. FAC+, FAC, etc). Even if you are looking in your county, it is important to keep in mind your elevation, aspect (how much shade the area will get), and other factors unique to your home’s location that will affect your plants and trees.

Del Norte: http://tinyurl.com/6vqk42f
Humboldt: http://tinyurl.com/c46nbuz
Mendocino: http://tinyurl.com/ctu4l62
Siskiyou: http://tinyurl.com/77vjcj9
Trinity: http://tinyurl.com/6pz3tym

Bibliography

Tutorial created from USDA PLANTS Database website: http://plants.usda.gov/

Photo Credits

All figures except rain garden in step 15 are screenshots of the USDA PLANTS Database website: http://plants.usda.gov/.

Rain garden figure in step 15 based on graphic from Candace Stoughton.

10 Amend Soils for Bioretention

Bioretention is the practice of using plants and soil to manage stormwater. Examples include rain gardens, swales, and vegetated filter strips. Soil plays a major role in watershed function, because it conveys rainfall through voids (i.e. air pockets), delivering that water to waterways hours, days, or even weeks after a rainfall event. Healthy soil not only contains critical nutrients to support plant life, but also has sufficient voids for water *and* air, which are needed by microbe-sized and larger soil animals. Healthy soil critters means healthy plants and long-term permeability (ability of water to enter), which results in stormwater facilities that are less likely to clog than those without plants and healthy soil.

To install a rain garden or vegetated filter strip, many guidance documents will ask or require you to remove the first 12” – 18” of soil and replace it entirely with an engineered soil mix. This is an expensive and not very efficient approach in most cases. Many designers and jurisdictions have excellent results when they simply amend the native soils.

This guide will step you through that process to ensure that your bioretention facilities are protecting water quality. Soils outside your stormwater facility may also benefit from soil restoration. For more information, see *“3 Restore Disturbed Soils”*.

Design

Never fold sand alone into clayey soils. With insufficient quantities of sand, doing this is likely to cement the soil, creating a barrier to water and infiltration.

To ensure adequate water quality treatment, healthy soil that infiltrates water at a good rate (not too fast and not too slow) is needed for a depth of 18”. For more information on how to perform an infiltration test on your native soils, see “7 *Test Your Soils”*.

Construction

Steps to amend native soils are as follows:

1. Remove the top 12 inches of soil where your infiltration facility will be. Leftover materials can be used in compost piles or DIY projects or disposed. If you would like to use it as fill, consult with a geotechnical engineer licensed in the State of California to make sure that the material is suitable for its intended use.
2. **For soils infiltrating 1 inch/hour or slower:** Amend 6” of native soil with a mix of one part imported organic compost and one part gravelly sand, such that there are equal parts compost, sand, and native soil (aka three-way mix).
3. **For soils infiltrating 12 inches/hour or faster:** Amending soils to drain slower can be tricky and potentially expensive. Most designers will send a soil sample to a laboratory and request a “recipe” of what to mix in and in what quantities. A more cost-effective solution is to simply replace the first 18” of native soil with an engineered soil mix (see Figure 1 and specifications below).
4. Till the mix thoroughly together on-site, using a portable soil mixer, hand-digging, or roto-tilling at multiple depths.

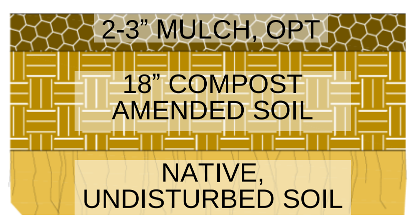


Figure 1 To ensure proper water quality treatment, an 18” layer of healthy soil is needed in all bioretention facilities.

5. Place mix in 9 – 12 inch depths (aka lifts) and spray water over the entire lift to speed up settlement and achieve final desired elevations.
6. If building a rain garden, test the infiltration rate of the facility (how well it absorbs and allows water to pass through). It should be capable of infiltrating water without ponding more than 30 hours on the surface. If ponding occurs, organic compost and sand must be added and re-tilled until the infiltration rate improves. More information is found in “*4Build a Rain Garden*”.

Specifications

Compost

Care should be taken to ensure that compost is clean and free of weeds, pollutants, or other harmful materials that may impact plant health and water quality.

Organic compost should have the following properties:

- Weed seed and pollutant free.
- 100% of material should pass a ½” screen.
- pH between 5.5 and 7.0. If the pH isn't quite right, it may be lowered by adding iron sulfate and sulfur or raised by adding lime or recycled, ground gypsum board.
- Carbon nitrogen ratio of 35:1.
- Organic matter content between 40 and 50%.
- Fully composed. Earthy is good. Avoid compost that smells like ammonia.

Organic compost may consist of the following:

- Mushroom Compost. The used bedding material from commercial mushroom production.
- Local nursery or garden supply’s stock of organic compost. There is US Compost Council Seal of Testing Assured (STA) compost. Visithttp://compostingcouncil.org/participants to find a participating supplier near you. The STA program is no guarantee of quality, only that the compost has been tested and those test results are available for review.

Organic compost may NOT be:

- Composted Yard Debris. This is because excessive pollutants, mostly herbicides, pesticides, and fertilizers, have historically been found in these materials. “Cides” can kill beneficial soil life, reduce stormwater benefits, and increase maintenance.
- Peat Moss. Peat moss is extracted from wetlands; this has negative impacts on the watershed from which the peat moss was removed.

Gravelly Sand

Gravelly sand should be free of organic material, contaminants, and hazardous materials, and should conform to the following size composition category (gradation), which you can compare against the gradation provided by your quarry’s material:

U.S. Sieve Size	Percent Passing
2-inch	100
3/4-inch	70-100
1/4-inch	50-80
No. 40	15-40
No. 200	0-3

Mixing
Mix soil and amendments to a homogeneous (i.e. all the same) consistency. Do not mix compost, sand, and native soil in the rain or wet conditions. Even in dry weather, soils and amendments themselves should not be overly wet.

Storage
Protect and cover stored stockpiles of organic soil mix in a manner that prevents them from becoming:
- wet from rain, stormwater runoff, leaks, or other sources of water, or
- contaminated by fine soil or other undesirable materials.

Placement
Place amended soil mix in rain gardens and stormwater planters in lifts/layers not exceeding 6 inches in loose thickness. After all lifts have been placed, grade soil to finish grades as specified on the plans. Do not over compact soil mix with mechanical equipment after placement. After following the construction steps above, soils have already been water compacted.

Engineered Soil Mix
Engineered Soil Mix (aka 3-way mix or bioretention soil mix) should have the following properties:
- Free of contaminants & hazardous materials
- 60% Loamy sand
- 40% organic compost
- Organic matter content from 8-10% by weight
- 2 – 5% mineral fines
- Cation exchange capacity (CEC) greater than 5 millequivalents/100 grams of dry soil
- Minimum long-term hydraulic conductivity of 1 inch/hour per ASTM D2434 at 85% compaction per ASTM D2668
- Conform to the following gradation:

U.S. Sieve Size	Percent Passing
3/8-inch	100
#4	95-100
#10	75-90
#40	25-40
#100	4-10
#200	2-5

- Meet specifications above for organic compost, mixing, storage, & placement.

Mulch
Wood chips or coarse compost (not bark dust or chips) can be used in a layer a minimum of 2-inches thick over the amended soil mix and between the plantings to completely cover the soil and prevent erosion or weed intrusion. After plants have established and soil is covered, mulching is probably not needed for erosion control or weed suppression.

Figure 1 Avoid bark mulch. It floats, carrying pollutants adhered to its surface to downstream waterways.

Post-Construction Facility Infiltration Testing
To test a recently constructed or existing bioretention facility:
1. Wet the surface of the rain garden with a sprinkler or hose until saturated. The full scale of small rain gardens or cells separated by check dams(<100 square-feet in surface) area can be tested at once. For large rain gardens, vegetated filter strips, and swales, use isolated falling head tests (minimum 2 per 100 square feet of area). For instructions on how to perform a falling head test, see *"7 Test Your Soils"*.
2. Fill the testing area to a depth of 4-inches and track the time it takes for the water to completely draw down.

3. Repeat test 3 times. If the water in any of the tests fails to draw down in less than an hour, add compost and gravelly sand to the mix and re-till.
4. Repeat this procedure until favorable test results – see *"7 Test Your Soils"* – are achieved.

Permits

A permit is probably not needed to perform infiltration testing. But, check with your jurisdiction's building or development services department. If information in this guidance conflicts with your jurisdiction's requirements or approach, then follow their guidance instead.

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Emanuel, Robert, Derek Godwin and Candace Stoughton. The Oregon Rain Garden Guide. Stormwater Management Manual. Salem, OR: Oregon State Univesity, 2010.

Godwin, Derek, Maria Cahill and Marisa Sowles. Rain Gardens. Fact Sheet. Salem, OR: OSU Extension, 2011.

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Photo Credits

Figures 1 & 2: Maria Cahill

11 Convey Water in Swales

Vegetated swales are linear, channeled depressions containing vegetation in the landscape that convey runoff from a variety of surfaces. Swales are sometimes referred to as fancy ditches, which is about right. As runoff passes through the swale, some water infiltrates into the soil. But the primary function of these facilities is to convey runoff slowly and treat it. Plants will enhance this, but are not absolutely necessary, for conveyance.

Siting

Conveyance swales will probably be most often used by homeowners to move runoff from a downspout to someplace else in their yard, like a rain garden. Conveyance swales are a great substitute for pipes. The slopes cause water to flow in the direction you'd like to move your runoff.

Figure 1. A vegetated swale can be an aesthetically pleasing way to convey water around a site and protect downstream waterways.

The amount of runoff that might infiltrate as it moves along the swale will vary with the centerline slope of the swale (the difference in elevation between the top/start and bottom/mouth of the swale). Steeper swales convey water faster and infiltrate (absorb and allow water to pass through) less than shallow swales. Regardless, anywhere a swale is used near a building or the top of wall, it should be lined for the first 10' to prevent basement flooding or wall destabilization. See *"8 Site Bioretention for Infiltration"* for appropriate setbacks needed for infiltration.

After water has been conveyed to a point where infiltration is appropriate, an unlined swale, which is much easier to construct, may be used (see Figures 2 & 3). Even a small infiltration area to reduce runoff a little bit will still be beneficial to downstream waterways.

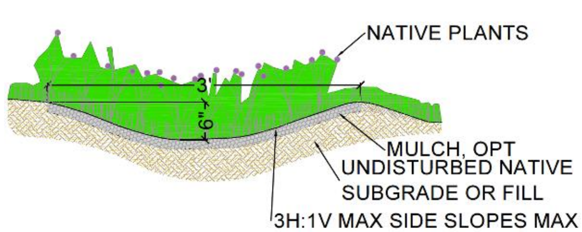

Figure 2 Vegetated conveyance swale for areas suitable for infiltration (absorption and conveyance of water)

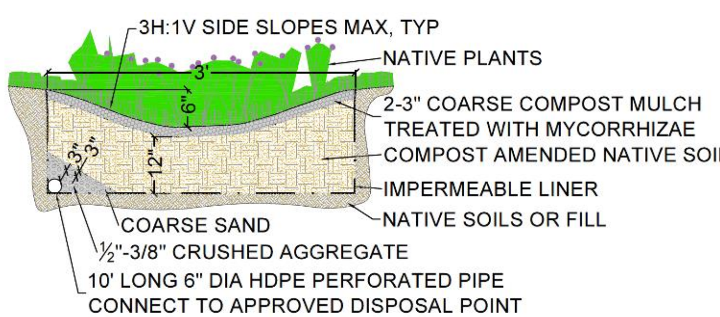

Figure 3 Vegetated conveyance swale with liner for areas not suitable for infiltration (absorption and conveyance of water)

Design

Swale design can be complicated and requires an understanding of open channel hydraulics (see Figures 2 & 3). The width and depth of a swale needed to convey runoff depends on storm intensity, rainfall distribution, runoff contribution area and length, roughness, slopes of the sides, and channel shape. Following the guidelines offered here, your channel is likely to be over-designed, but will safely convey runoff away from structures.

Erosion

Erosion is a problem in everybody's yard and varies with soil type. It's also a problem in everyone's watershed. Sediment causes cloudy (aka turbid) water that reduces water quality and habitat value. When runoff is concentrated with a downspout or pipe and deposited at the top of a conveyance swale with soil in the bottom (instead of concrete, for instance), erosion is much likely and the speed at which water flows must be controlled. To control erosion, longitudinal swale slope (steepness of the channel from the top/start and bottom/mouth of the swale) should be limited to a maximum of 5% and a stilling basin (aka energy dissipater) should be used where a concentrated point of water is deposited from a pipe.

Vegetation & Soil Depth

Swales can be planted with a variety of plant types, but trees are probably not practical for the relatively small swales used at the residential scale. For lined swales, providing enough soil for rooting depth is important for long-term plant health, which in turn, reduces water demand and the need for fertilizers (a common pollutant in our waterways). For grasses, the rule of thumb is that they need a rooting depth equal to how tall they will be allowed to grow. So, for lawns mowed to a height of 3", rooting depth is about 3", but for grasses that will not be mowed, like the numerous attractive native grasses, a rule of thumb is to provide a minimum of 12" of soil. Short shrubs can get by on 18" of soil, but tall shrubs need 24".

In unlined swales, soil depth will probably not be limited. However, some sites may have a shallow depth of soil over rock fill. Dig down a foot or two to confirm that there's a suitable depth and quality (10% organic matter is ideal) of soil. If not, amend soils or replace with amended planter soil per guidance provided in *"10 Amend Soils for Bioretention".*

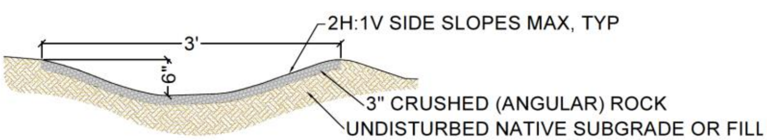

Figure 1. Rock swale for areas suitable for infiltration

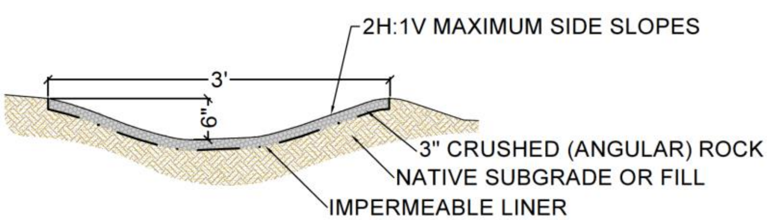

Figure 5 Rock swale for areas not suitable for infiltration

Rock Swales

Rock swales are an easy and cost-effective way to move water around a site. Avoid rounded river rock mined from waterways, which causes down-cutting and erosion in the stream channel and other biological and water quality impacts to the stream it was taken from. Over geologic time periods, rounded river rock might be deposited far from a waterway where it can be mined. This upland source of rock is better for protecting overall watershed health. A safer, less impactful way to go is to use crushed, angular aggregate.

Liner Specifications

Liners for filtration facilities or any other purpose should be:

- 30 to 60 mil (mm) EPDM rubber (ethylene propylene diene monomer)
- bentonite clay mat
- 30 to 60 mil LDPE (Low density polyethylene) plastic (aka pond liners)

Install liners per manufacturer recommendations.

Avoid:

- asphalt products, which are subject to degradation from soil microbes.
- PVC (poly vinyl chloride) which is more polluting than alternatives.

Cross Section

The shape of the swale impacts how much water can be conveyed. Use a parabolic shape (imagine a trench roughly in the shape of a soft V or the end of an egg) as shown in all the figures in this guidance. A 3H:1V (horizontal:vertical) side slope is best for plant establishment and therefore will reduce erosion. Plants on steeper slopes have difficulty rooting. Considering the variation in flows that could occur, we recommend a minimum 3' wide swale. With this 3' width, 3:1 side slopes dictate a maximum possible depth of 6".

Swale Depth

In many storms, you may not see much water running down your swale. However, there's always a big storm coming in the future and all conveyance systems, whether open channel or piped, must be designed for such a storm. The standard convention is to design for a 100 year storm. A minimum depth of 3" should be provided, but over time, you may find that a greater depth (and therefore, a greater width) is needed. It does not hurt to start with a depth greater than 3" so long as the side slope ratios and other considerations are followed.

Construction

Unlined Swales

Unlined swales are the easiest to construct:

1. Dig the shape and depth of the swale that you'd like, based on the guidance discussed above. If native soils will be exposed to rain before the next step, clay particles may clog the surface. So keep native soils covered with (weed seed-free) straw, compost, or jute fabric. This can be left in place if planting or removed if lining with rocks.
2. Plant the bottom with vegetation per the guidance in *"4 Build a Rain Garden"* or line with a 3" minimum depth of rocks.
3. Direct runoff to the top of the swale by disconnecting your downspout per *"2 Disconnect Impervious Areas".* If using a vegetated swale, wait 3 months before introducing runoff to give the plants time to establish; erosion will be less likely.

Figure 6. This vegetated conveyance swale will be partially lined, which is why it's so deep.

Lined Swales

Lined swales are a little more difficult to construct.

To build a lined vegetated swale:

1. Use erosion control methods such as biobags, wattles, or compost berms downhill of the excavation to prevent sediment from leaving your property while you dig.

2. Since a liner must be placed at the bottom and up the sides, over-excavate a trench the size and shape of the swale you'd like, plus another 12" to 24" of depth (depending on the guidance offered above on vegetation type). Set soils you remove to the side of the trench (Figure 6).
3. Line the bottom and sides of the trench with an impermeable material (Figure 7). If plastic, lay down a single, continuous piece. If using bentonite clay mats, seal the edges together as directed by the manufacturer. Try to get the sides of the trench as vertical as possible before installing the liner. In clays, this will be easy but sandy soils, more difficult. Vertical slopes will help ensure that there aren't very shallow soil depths along the top edges of the swale.

Figure 7. A single sheet of EPDM is being laid in the bottom to a minimum distance of 10' from the house.

Figure 8. Since the bottom of the lined swale will empty into native soil, the bottom of the swale must also slope away from the building. Otherwise, plant roots won't dry out between waterings and rainfall events or plants won't be healthy.

4. The swale must drain out the bottom to keep the plants alive (see Figure 8).
   - If swale length exceeds liner length, then make sure: 1) the bottom of the swale slopes down, away from important infrastructure and 2) that water will run along the interface between the liner and the soil and into the native soil at the end of the liner. Once water reaches native soil, it should infiltrate.
   - If swale length is the same length as the liner length needed, then place a 10' long perforated pipe (with cleanout or other maintenance access) at the lowest elevation on top of the liner. Connect this perforated pipe to a non-perforated pipe on the other side of the swale. You'll have to cut the liner at that connection point, so make sure that you use the appropriate cement, wet/dry glue, or other method to seal the liner-pipe interface. By placing the pipe in the corner, it will be easier to cover the pipe with a rock separation layer per the detail in Figure 3. Substituting a geotextile sock around the perforated pipe will result in clogging.
5. Amend soils (use what you dug up and set aside) per *"10 Amend Soils for Bioretention"* (see Figure 9). A portion of the soil will not be needed, since amendments will have bulked up the soil and the shape of the swale will have also reduced the volume needed.
6. Place soil back over the liner. (Figure 9).
7. Reuse leftover soil somewhere else. If stockpiling, to prevent sediment from leaving your property by wind or water, place: 1) biobags, wattles, or a compost berm around the bottom of the pile and 2) jute fabric over the top, using weights to hold it in place.
8. Cut excess liner material at the surface.

Figure 9. A few inches of compost and a sprinkling of a soil restoration product with mycorrhizae and biota (Permamatrix used here) were placed over native soils, then shoveled together and into the swale.

9. Vegetate the bottom of the swale with plants per guidance in *"4 Build a Rain Garden".*
10. Wait 3 months before directing runoff to the swale, to give plants time to establish and to reduce erosion.
11. Disconnect your downspout per *"2 Disconnect Impervious Areas"* into the top of the swale.

To build a lined swale with rocks:

1. Use erosion control methods such as biobags or wattles downhill of the excavation to prevent sediment from leaving your property while you dig.
2. Since a liner must be placed on the bottom and up the sides, over-excavate a trench the size and shape of the swale you'd like plus another 3" of depth. Set soils you remove to the side of the trench.
3. Line the bottom and sides of the trench with an impermeable material. If plastic, lay down a single, continuous piece. If using bentonite clay mats, seal the edges together as directed by the manufacturer.
4. Reuse leftover soil somewhere else. If stockpiling, to prevent sediment from leaving your property by wind or water, place: 1) biobags, wattles, or a compost berm around the bottom of the pile; and 2) jute fabric over the top, using weights to hold in place.
5. Place 3" of rock on top of the liner (see Figure 10).

Figure 10. Rock swale conveys water from a downspout

Maintenance

Maintenance of vegetated swales is similar to maintenance of other landscapes.

- Pull weeds. Avoid herbicides and opt for integrated pest management techniques like hand pulling. "Cides" are common pollutants found in our waterways and groundwater.
- Maintain a minimum cover over the swale of 85%. If vegetated, replace plants as they die and consider that other varieties (e.g. native) may be needed. If rock lined, push rock back into place.
- Look for erosion. Maintaining cover should help, but if erosion continues, use a method to slow flows, like a stilling basin (aka energy dissipater) or a check dam.

- For vegetated swales: If water sits on top, or otherwise seems to not be infiltrating, the surface may be clogged. This isn't a problem for conveyance, but is a problem for the plants, which need access to air and water.
  - If the facility does not drain within 48 hours, scrape the top 1" layer of soil out of the facility and replace with amended planting soil, which meets the specifications provided. Test the ability of the facility to infiltrate water in order to confirm drainage.
  - If facility still does not drain after scraping 1", you may try scraping another 1" deeper.
  - If facility still does not drain after scraping the top 2", till and replant the facility.
  - Debris that inhibits infiltration of water should be removed routinely (no less than quarterly), or when it is discovered.

Fertilizing

Avoid P-K-N (potassium –phosphorus – nitrogen) as these are common pollutants found in waterways and will easily dissolve in water, flow out of the swale bottom onto an impervious surface and likely into a pipe that drains to a waterway. Replenishing the 2-3" of organic compost every year will provide adequate nutrition slowly and safely. Grasses are self-fertilizing, since 30% of their roots die off every year.

Cost Considerations

A lined swale will be more expensive than an unlined swale. Compared to installing a pipe, conveyance swales can be much less expensive. The most commonly used pipe material is plastic, which is flexible so it needs certain subgrade treatments for proper installation. Cost savings over a pipe are in excavation, subgrade compaction, base rock for plastic pipes, and piping. The cost of vegetated swales may be similar to pipes if potted plants are bought; seeding is much less expensive.

Permits

Water quality swales have been used for many years in the Five Counties area and may require a permit. Conveyance swales, such as described here, will probably not need a permit unless you're using a lined swale and need to install plumbing to drain it out the bottom. In any case, check with your County's building or development services department to see if a permit is needed. If information in this guidance conflicts with your jurisdiction's requirements or approach, then follow their guidance instead.

Bibliography

Cahill, Maria, and Derek Godwin. Swales. Fact Sheet. Salem, OR: OSU Extension, 2011.

Photo Credits

Figure 1: 5C Program, Sandra Pérez
Figures 2- 10: Maria Cahill