Rain Gardens:
Design, Implementation, and Maintenance Considerations

KERR WOOD LEIDAL
consulting engineers

ACKNOWLEDGEMENTS

Technical writing assistance for *Rain Gardens: Design, Implementation and Maintenance Considerations* was provided by Kellie Garcia of Insight Environmental Consulting Ltd., Kelowna, British Columbia.

Chris Johnston, David Lee, Craig Kipkie, David Zabil and Joan Carter of Kerr Wood Leidal Associates Ltd. (KWL) provided the background information for the paper and guided the writing process.

All photos and diagrams are credited to KWL.

EXECUTIVE SUMMARY

Rain gardens can be useful tools for rainwater management and have been constructed throughout the world, Lower Mainland, and other areas of British Columbia. Unfortunately, improper design and implementation or inadequate maintenance has resulted in many gardens not reaching their full potential or failing all together. Failed examples can lead to setbacks in widespread implementation, so it is important to share experiences of what works and what needs improvement.

Through experience and observation over the past decade, Kerr Wood Leidal Assoicates (KWL) staff has identified ten design considerations and ten implementation and maintenance considerations that require additional attention to maximize the usefulness and productivity of rain gardens and ensure that they meet stormwater criteria. It is important to note that the considerations covered in this paper are not intended to represent all facets of rain garden design, implementation and maintenance. There are other aspects to consider; however, these are the most common considerations that are currently being overlooked or not dealt with appropriately.

The top ten design considerations covered in this paper are:

1. **Rainwater design criteria:** It is important to understand the standard design criteria available and choose something to work with.
2. **Impervious to rain garden area ratio:** Make sure the rain garden is not capturing too much impervious area or the plantings will not survive, the garden will turn to mud, and its infiltration capabilities will be lost.
3. **Overflow drain height and soil selection:** Carefully select the growing medium to ensure its infiltration rate matches the amount of water and sediment that will be coming into the rain garden. Use temporary surface ponding to store excess water during a major high intensity convective storm.
4. **Use of underdrains:** Use an underdrain system in low permeable soils to ensure sufficient oxygen remains in the growing medium.
5. **Depth of rain garden:** Ensure that the depth of the rain garden below the impervious surface is sufficient enough that it will not need to be dug out for 20 to 25 years.
6. **Curb-edge material:** Grass buffers are very efficient at trapping sediment and should not be used as a filter strip between asphalt and rain gardens.
7. **Trees:** Trees do not work well in rain gardens because the leaves and needles can smother vegetation and reduce infiltration rates.
8. **Direction of infiltrated water:** Use a trench dam to contain infiltrated water if there is a utility trench bisecting the rain garden that could create an unwanted drainage route.

9. **Native soil infiltration rates:** Rain gardens can be used in native soils such as clay, glacial till and rock because rain gardens are intended to capture the small storms.
10. **Depth of rock trenches:** As a general rule, the rock trench depth should not be more than 0.85 metres below the bottom of the growing medium or generally 1.6 metres below the surface.

The top ten implementation and maintenance considerations covered in this paper are:

1. **Construction phasing:** The rock trench, perforated drain, and overflow should be constructed at the same time as other subdivision utilities. Growing medium and plantings should be installed after building construction is complete and before the second lift of asphalt.
2. **Proper soil specification:** Proper soil properties are critical to meeting surface infiltration rates and ensuring healthy plants for the long term.
3. **Weed control:** Seed germination will most likely be an issue if using an onsite soil mix. A composting process under controlled conditions can be used to generate heat and kill seeds. Ground wood mulch can also be used to control weeds.
4. **Binding of soil layers during construction:** The sand layer above the rock trench and filter fabric may need to be scarified prior to placing the growing medium. Sand layers are optional, and may be used in some situations depending on the degree of clay/silt in the growing medium mix.
5. **Interim sediment and drainage control – minor storms:** It is critical to establish areas to capture sediment from minor storm events that occur during construction of the rain garden.
6. **Interim drainage management – major storms:** Major drainage paths during construction need to be considered in case of a major storm.
7. **Builder management:** Builder and trades need to be educated on building site management and the impact their activities can have on rain gardens and other stormwater measures.
8. **Maintenance responsibility:** Responsibility for ongoing maintenance should be clearly outlined using a restrictive covenant, boulevard maintenance bylaw, local area improvement agreement or other means.
9. **Road maintenance:** City staff or contractors need to be educated regarding snow removal, sanding and salting practices near rain gardens.
10. **Performance monitoring and warranty period:** Be sure to determine that the rain garden is working properly before the end of the warranty period.

Engineers, biologists, landscape architects, soil physicists and other specialists need to work together to ensure rain gardens are designed to maximize their usefulness for the process they are being applied to. It is hoped that the recommendations in this paper are used by the industry, leading to a greater success rate and acceptance of rain gardens and more and more being used in developments throughout North America.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Rain gardens can be very useful tools for rainwater management and have been constructed throughout the world, Lower Mainland, and other areas of British Columbia. Unfortunately, improper design and implementation or inadequate maintenance has resulted in many gardens not reaching their full potential or failing all together.

Through experience and observation over the past decade, Kerr Wood Leidal Associates (KWL) staff has identified ten design considerations and ten implementation and maintenance considerations that require additional attention to maximize the usefulness and productivity of rain gardens and ensure that they meet stormwater criteria. These considerations are presented in this paper.

It is important to note that the considerations are not intended to represent all facets of rain garden design, implementation and maintenance. There are many more aspects that must be considered. This paper identifies the most common considerations that are being overlooked or not dealt with appropriately and provides recommendations on how things can be done better.

Since rain gardens offer a significant tool in the rainwater management arsenal, and failed examples can lead to setbacks in widespread implementation, it is important to share experiences of what works and what needs improvement.

1.1 What is a Rain Garden?

A rain garden is a planted depression that holds rainwater runoff from impervious urban areas like roofs, driveways, walkways, parking lots, and compacted lawns and allows it to infiltrate into the soils.

Rain gardens can sometimes be confused with bioswales. Both are vegetated, but the difference is that bioswales are sloped and are mainly used for conveying water from one location to another whereas a rain garden is designed to absorb a majority of the water it captures.

1.2 What are the Basic Components of a Rain Garden?

A rain garden has six basic components: growing medium, vegetation, rock trench, perforated drain, above ground storage zone, and overflow. The purpose of the growing medium is to support plant growth and retain water to field capacity of the soil. Vegetation promotes the regeneration of the infiltration surface and supports evaporation and transpiration processes. A rock trench, which is optional for high permeable soils, stores infiltrated water and releases it after a storm event. The perforated drain, again optional for high permeable soils, protects plant roots from flooding, preserves oxygen levels in the growing medium, and safely directs interflow from infrequent events to the collection system. The above ground storage zone provides storage volume to retain rainwater from high intensity rainfall events until the growing medium is able to infiltrate the water. The overflow protects property and infrastructure from both high intensity rainfall events that overwhelm the rain garden infiltration rate and rain on frozen ground conditions. The overflow safely takes the water away to a nearby designated location.

1.3 How does a Rain Garden Work?

As water from impervious surfaces drains into the rain garden, it first fills up the voids in the growing medium. In the warmer months, rainwater will evaporate and transpirate from the garden. When the surface soil becomes saturated during wetter months, the water infiltrates to the rock trench and begins to fill it up. In larger storm events, the water moves out from the rock trench and through the perforated drain, which safely conveys the water away from the rain garden to a designated location. Figure 1 provides a visual representation of a functioning rain garden. Figure 2 is a photo of a rain garden in the Lower Mainland region of British Columbia.

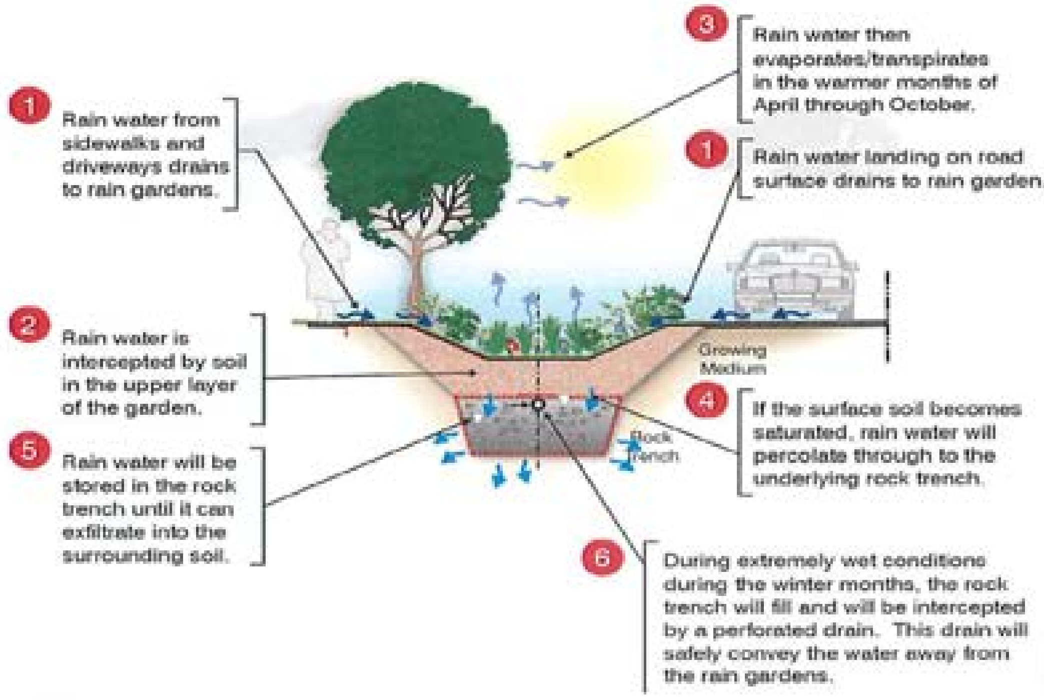


Figure 1: Diagram showing how a rain garden works.

Figure 2: Rain garden in the Silver Ridge development, Maple Ridge, British Columbia.

1.4 What are the Benefits of a Rain Garden?

When rain falls on the impervious surfaces in urban centres and rural neighbourhoods, it flows faster and in greater amounts than it would have under natural conditions, significantly increasing runoff and reducing infiltration. This increased rate of runoff can contribute to flooding, road damage, stream erosion, and landslides. Runoff also collects pollutants and sediment as it flows over the landscape. Excess fertilizers and herbicides, pet waste, soap from car washing, oil and grease from leaking engines, zinc from tires, and copper from brakes are just some contaminants that can be found in runoff.

Rain gardens filter pollutants from runoff and disconnect impervious surfaces from storm sewers. By doing so, rain gardens can reduce flood risk and erosion in creeks and streams, protect fish habitat and water quality, and create a barrier for point source pollution. Rain gardens can also recharge aquifers and provide habitat for beneficial insects, birds and wildlife.

2.0 TOP 10 DESIGN CONSIDERATIONS

The ten design considerations covered in this section include:

1. Rainwater design criteria
2. Impervious to rain garden area ratio
3. Overflow drain height and soil selection
4. Use of underdrains
5. Depth of rain garden
6. Curb-edge material
7. Trees
8. Direction of infiltrated water
9. Native soil infiltration rates, and
10. Depth of rock trenches.

2.1 Rainwater Design Criteria

It is important to understand the standard design criteria available and choose something to work with.

In British Columbia, there are several criteria available that can be used to guide the design of a rain garden. Fisheries and Oceans Canada released criteria in 2001 that provide guidance on protecting aquatic habitat. Stormwater Planning – A Guidebook for British Columbia[1], released in 2002, lays out criteria for the protection of aquatic habitat and reduction of erosion. As well, there are several other municipal criteria throughout British Columbia that can be used. Table 1 shows typical design criteria components.

Table 1: Typical design criteria components.

Volumetric Reduction	Rate Control	Water Quality	Major Storms
Capture a set amount of rain	*Slow any runoff down*	*Reduce suspended solids*	*Provide safe passage*

Volumetric reduction is the most important criteria for rain garden design. It involves capturing a certain amount of rain and infiltrating it so that the water does not reach the storm sewer.

There are several computer models that can be used to guide the rain garden design process (see Table 2).

[1] www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/guidebook/pdfs/stormwater.pdf

Table 2: Examples of computer models that can guide the rain garden design process.

Model Name	Description	For More Information
Water Balance Model	A practical, web-based tool that allows comparison of multiple scenarios of rainwater management solutions under different land use, soil, and climate conditions.	www.waterbalance.ca
EPA SWMM	A dynamic rainfall-runoff-subsurface runoff simulation model used for single-event to long-term (continuous) simulation of the surface/subsurface hydrology quantity and quality from primarily urban/suburban areas. Can be used to explicitly model the hydrologic performance of specific types of low impact development controls, such as porous pavement, bio-retention areas (e.g., rain gardens, green roofs, and street planters), rain barrels, infiltration trenches, and vegetative swales.	www.epa.gov/nrmrl/wswrd/wq/models/swmm/
PCSWMM	The graphical decision support system for the US EPA SWMM program. It incorporates a modern, powerful GIS engine that works seamlessly with the latest GIS data formats, and provides intelligent tools for streamlining model development, optimization and analysis in a comprehensive range of applications.	http://www.chiwater.com/Software/PCSWMM.NET/index.asp
XPSWMM	A model that simulates natural rainfall-runoff processes and the performance of engineered systems. It also simulates flow and pollutant transport in engineered and natural systems including ponds, rivers, lakes, floodplains and the interaction with groundwater.	www.xpsoftware.com/products/xpswmm/

Manual calculation methods can also be used to design rain gardens. The basic premise of calculating the volume that the rain garden needs to capture is the use of an intensity, duration and frequency (IDF) curve (see Figure 3). Every region has an IDF curve.

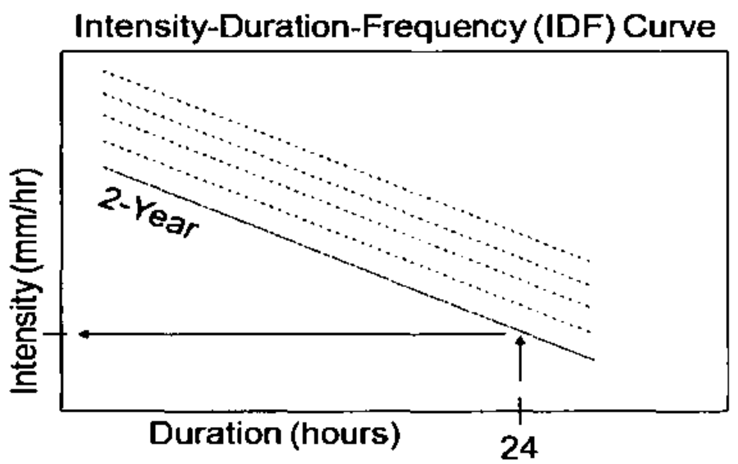
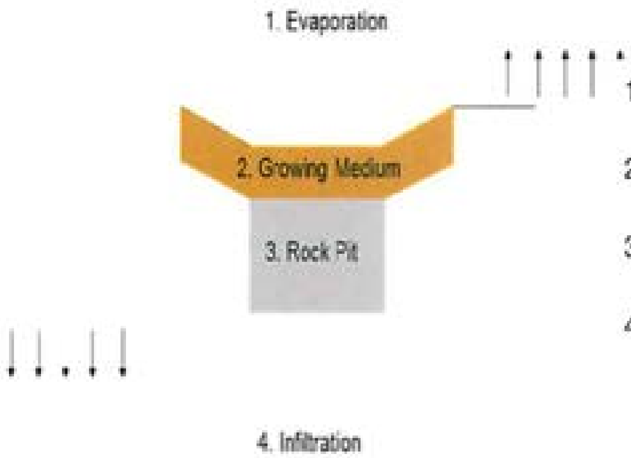


Figure 3: Example of an Intensity-Duration-Frequency (IDF) Curve.

To calculate capture rainfall amount, first identify the intensity at 24-hour duration for a 2-year storm. Multiply that number by 24 hours to get the millimetres of rain that will fall in a 24-hour period. Multiply that number by 50% if using the Stormwater Guidebook criteria or 72% if using the DFO criteria. This represents the proxy for a 6-month storm, which is approximately 90% of the storms that occur in the Lower Mainland[2]. Other regions will vary slightly.

To determine the input volume in cubic metres, multiply the capture rainfall amount by the tributary area.

Next, determine the capture volume of the rain garden[3], which is the sum of:



1. 24 hour evaporation multiplied by surface area
2. Volume of growing medium multiplied by (field capacity minus wilting point)
3. Volume of rock pit multiplied by available water content
4. 24 hour infiltration multiplied by surface area

EXAMPLE CALCULATION FOR THE DESIGN OF A RAIN GARDEN

Location: small parking lot in Port Moody
Area of parking lot: 21 m x 25 m
Area of rain garden: 3 m x 25 m

Rainfall capture amount:
2-year rainfall event = 76.8 mm
6-month rainfall event = 76.8 mm (2-yr, 24 hr) x 72% = **55.3 mm**

Input volume:
21m x 25m x 55mm rain = **29.0 m^3**

Continued on next page...

[2] Stormwater Management Manual for the Puget Sound Basin, State of Washington, Department of Ecology, 1991

[3] Input volume should equal capture volume. Assume dry soils (i.e., moisture content at wilting point)

EXAMPLE CALCULATION FOR DESIGN OF A RAIN GARDEN, CONTINUED

Capture volume:

Evaporation Volume = Rain Garden Area x Evaporation Rate
Evaporation rates can be collected by measuring temperature of the air, relative humidity and ground temperature. The value of 1 mm/day is an average for Metro Vancouver during the winter months.
Evaporation Volume = 3m x 25m x 1mm/day = **0.075 m^3**

Growing Medium Volume = Rain Garden Area x Porosity x (Field Capacity – Wilting Point)
The porosity describes the amount of air or voids within the soil as a fraction. The porosity is dependent on the soil particle sizes and gradation. Values of 0.35 to 0.45 are typical for sandy soils. The field capacity minus wilting point describes the total available water to the plants in the growing medium.
Growing medium = 3m x 25m x 0.45 x (0.25 - 0.05) = **6.75 m^3**

Rock Trench Volume = Rain Garden Area x Trench Depth x Voids Ratio
The voids ratio describes the amount of voids within the soil as a fraction and is dependent on soil particle size, gradation and density (typical values for sand range from 0.3 to 0.5). In this calculation the value used is 0.35.
Rock Trench Volume = 3m x 25m x 0.8m x 0.35 = **21.0 m^3**

Infiltration Volume = Rain Garden Area x Infiltration Rate
The infiltration rate is determined using in-situ percolation tests of the native soil. For this example, the value of 1 mm/hr is taken from soil information as found in the Silver Ridge development where a layer of sandy loam from 300 mm to 600 mm thick, with sandy/gravel sections.
Infiltration Volume = 3m x 25m x 1 mm/hr x 24 hr = **1.8 m^3**

Reference: Craig Kipkie, KWL. - "Silver Ridge: Low Impact Residential Development" Annual CWRA National Conference in Toronto, Ontario June 4-7, 2006.

The values pertaining to soil characteristics used in this example are based on field observations and typical values are for conceptual design purposes. For detailed design of rain gardens it is good practice to determine these values after conceptual design by field and lab tests of soils and apply factors of safety to refine the design since soil characteristics vary from site to site.

In this example, most of the volume is in the rock trench because the soils have a very low permeability. Some water is also in the growing medium. Very little water will infiltrate or evaporate within the first 24 hours of the rainfall event. Depending on the severity of the event, the water may take 1 to 14 days to leave the rock trench due to the low permeability of the soil. To drain the rock trench quicker, the design can incorporate a wider footprint than the growing medium, to allow for more surface area for infiltration.

Note: The assumption made in this calculation is that the rock trench and the growing medium are dry, at wilting point. This will most often be the case in spring, summer and fall but may not be in the winter. As wetter conditions and consecutive storm events occur in the winter, chances are that in pre-developed conditions the water would have moved through the soil. The rain garden is mimicking natural conditions while slowing the water down by moving it through a perforated drain.

2.2 Impervious to Rain Garden Area Ratio

Make sure the rain garden is not capturing too much impervious area. Otherwise, the plantings will not survive; the garden will turn to mud; and its infiltration capabilities will be lost.

Quite often, rain gardens are designed to capture too much impervious area relative to the receiving garden area. When too much sediment travels to the rain garden the vegetation does not have time to regenerate itself and eventually dies. A mud plume forms and continues to grow until eventually the garden loses its capability to infiltrate water.

The ratio of impervious area relative to garden area depends on the amount of traffic that uses the impervious surface. The ratios tend to be higher in areas with very little traffic and lower in parking lots, collector roads and loading areas because more pollutants are generated.

If site specific information is available, it is recommended that these ratios be refined as based on the field observations and soil tests. Suggested maximum ratios of impervious area to rain garden area are[4]:

Parking <1car/d use = 40:1
Parking >1 car/d use = 20:1
Collector road use = 30:1
Loading areas use = 20:1
Low traffic or roof areas use = 50:1

2.3 Overflow Drain Height and Soil Selection

Carefully select the growing medium to ensure its infiltration rate matches the amount of water and sediment that will be coming into the rain garden. Use temporary surface ponding to store excess water during a major high intensity convective storm.

The growing medium in a rain garden can consist of native soils (amended as necessary) or a mix from a local distributor. Regardless, careful thought must be put into selecting a growing medium that has an infiltration rate to match the incoming rainfall intensities without limiting vegetation growth. Section 3.2 provides more detail on proper soil selection.

[4] These maximum ratios are based on empirical observations and ability of the vegetation to handle flows and pollutants.

Temporary surface ponding, achieved by including an overflow drain, can be used to store excess water during a major storm so it has more time to infiltrate. The overflow drain height can be determined through calculations that take into account the rainfall intensities that exceed the infiltration capacity of the rain garden soil (Figure 4).

Figure 4: The overflow drain height should be set to allow for temporary ponding during high intensity events.

The maximum ponded level is typically set between 150 mm to 300 mm so that the ponded water can draw down within 24 to 48 hours.

2.4 Use of Underdrains

Use an under drain system in low permeable soils to ensure sufficient oxygen remains in the growing medium.

Water may pond in the rain garden above the growing medium during high intensity storms. However, the growing medium will still have oxygen in the soil provided either the native infiltration rate of the surrounding soil is high or a perforated drain is incorporated below the growing medium. Unless the plantings were selected specifically to handle oxygen deprived soils, the rain garden should have an underdrain to handle these situations so the growing medium remains oxygenated. Underdrains are particularly important in low permeable soils.

2.5 Depth of Rain Garden

Ensure that the depth of the rain garden below the impervious surface is sufficient enough that it will not need to be dug out for 20 to 25 years.

The rain garden needs to be designed so that it can handle the amount of sediment that will accumulate over a 20 to 25 year period. If set too shallow, the rain garden will need to be dug out in 5 to 10 years, which involves removing all of the plantings, digging it down, and putting the plantings back in. The approximate amount of sediment that will enter the rain garden per year and the associated rise in the rain garden invert can be calculated.

A typical residential road generates 1,200 kg/ha/yr of sediment[5]. This translates to approximately one mm/year rise in sediment in the rain garden invert based on area.

2.6 Curb-Edge Material

Grass buffers are very efficient at trapping sediment and should not be used as a filter strip between asphalt and rain gardens.

Grass is extremely effective at trapping sediment. When it is used as a filter strip between asphalt and a rain garden it quickly turns into a new curb as sediment builds in the strip. Use gravel, river rock, sedums or plantings as a transition buffer to keep water and sediment travelling into the invert of the rain garden (Figure 5).

Figure 5: Non-erodible material should be used as a buffer between the asphalt and the rain garden (left photo). Do not use grass (right photo).

[5] This number depends on the area and how much snow removal, sanding and graveling are conducted on the street.

2.7 Trees

Trees do not work well in rain gardens because the leaves and needles can smother vegetation and reduce infiltration rates.

Trees are often used in residential subdivisions to line the roads and beautify the neighbourhood. If the street trees are above the rain garden problems will arise. Deciduous trees will drop their leaves and no matter how motivated the homeowner or municipality is, the leaves will eventually smother and kill the plantings and inhibit the infiltration capabilities of the garden (Figure 6). Plant trees on the other side of the street or at either end of the rain garden to avoid these issues.

Figure 6: Trees should be avoided in or near rain gardens because leaves and needles can smother vegetation and reduce infiltration.

2.8 Direction of Infiltrated Water

Use a trench dam to contain infiltrated water if there is a utility trench bisecting the rain garden that could create an unwanted drainage route.

It is important to ensure that water collecting in a rain garden does not have an escape route, such as a utility trench, that could carry the water away from the rain garden to the foundation of a nearby house or to a trench dam where it could build up pressure and burst a nearby road. If a utility trench bisects the rain garden be sure to put in a trench dam to control the infiltrated water. This is particularly important in lower permeable soils.

2.9 Native Soil Infiltration Rates

Rain gardens can be used in native soils such as clay, glacial till, and rock because rain gardens are intended to capture the small storms.

Rain gardens can be used in low permeable soils, including clay, glacial till, and rock, because rain gardens are designed to focus on the small storms, not the large infrequent storms.

Generally, the saturated hydraulic conductivity of clay is 0.7 to 1.0 mm/hour and glacial till is 0.9 to 1.6 mm/hour. These rates are based on measurements conducted in developed areas where soil has been disturbed. Rates will most likely be different in a pre-development area. An infiltration test on the native soils is a good starting point to determine what they can handle. A double ring infiltrometer can be used onsite to quickly gather data to determine infiltration rates. This test estimates the vertical movement of water through the bottom of the test area

2.10 Depth of Rock Trenches

As a general rule, the rock trench depth should not be more than 0.85 metres below the bottom of the growing medium or generally 1.6 metres below the surface.

If the rock trench is dug too deep infiltration may be inhibited and can drop off dramatically as you reach depths where the soil has been disturbed by utility trenches or fissures have occurred.

Figure 7: When communities are built, utility trenches are constructed and perforate the site. If the rain garden trench extends too far below the invert of the major utility trenches, the theory is that infiltration rates will tend to decrease.

3.0 TOP 10 IMPLEMENTATION AND MAINTENANCE CONSIDERATIONS

The ten implementation and maintenance considerations covered in this section include:

1. Construction phasing
2. Proper soil specification
3. Weed control
4. Binding of soil layers during construction
5. Interim sediment and drainage control – minor storms
6. Interim drainage management – major storms
7. Builder management
8. Maintenance responsibility
9. Road maintenance, and
10. Performance monitoring and warranty period.

3.1 Construction Phasing

The rock trench, perforated drain, and overflow should be constructed at the same time as other subdivision utilities. Growing medium and plantings should be installed after building construction is complete and before the second lift of asphalt.

Construction phasing is a critical component in the successful implementation of a rain garden in a subdivision. Ideally, the rock trenches, perforated drains, and overflows will be constructed at the same time as the other utilities for the subdivisions (Figure 8).

Figure 8: The rock trench, perforated drain and overflow should be constructed at the same time as other subdivision utilities.

It is very important to ensure that the newly installed rock trenches, perforated drains, and overflows are protected during construction of the buildings and roads. The use of a sacrificial soil layer and poly sheeting should be considered (Figure 9). The rock trench is an integral part for storing the runoff coming into the ground, and if it is not protected, it is tempting for developers to use it as a stock pile area. The foundation of the rain garden can also be damaged by rainfall events during construction if it is not protected.

Figure 9: The rock trench should be protected with a sacrificial soil layer and poly sheeting while roads, driveways, sidewalks, and buildings are constructed. Once covered, the depression can be used as a settling facility for lot runoff then removed once the lot is completed. 2 x 4s can be used on top of the poly to assist in the location of the poly upon removal of the sacrificial material.

Growing medium and plantings should be put in after the roads, driveways, sidewalks, and houses are finished (Figure 10) but before the second lift of the asphalt. The reasoning for this is that during construction, there are often stockpiles of excavated and other material on the lots, and this material may get into the garden and smother the plants (Figure 11). Also, rain gardens do not have barrier curbs, just panel curbs that allow the runoff and construction sediment from vehicle traffic to enter the garden, so the second lift of asphalt provides a lip that directs the flow along the road and into the rain garden. Therefore, it is better if the second lift of asphalt is put in once the rain garden is functioning and ready to handle runoff.

Figure 10: Growing medium and plantings should be put in after buildings are complete (but before the second lift of asphalt).

Figure 11: Growing medium and plantings should not be put in before building construction is complete because stockpiled material may get into the garden and smother the plants.

3.2 Proper Soil Specification

Proper soil properties are critical to meeting surface infiltration rates and ensuring healthy plants for the long term.

Quite often, native soils from the development site are used as growing medium for the rain garden. This can be detrimental because native soils are most often not the right specification for drainage. In most cases, native soils do not contain enough sand to be used as they are for a rain garden.

There are two options for selecting soil with the right specification for drainage – amending native soils onsite or importing an appropriate soil mix from an off-site source.

A soil physicist should be consulted to test the soil and provide correct mix proportions if amending soil onsite. This is an important and worthwhile step that is not hard to complete. Mix proportions are not usually complicated. In fact, they may be as simple as adding one bucket of sand to two buckets of soil or two buckets of sand to on bucket of soil and the mixing can be done on site.

Alternatively, MMCD soil mix for "Low Traffic Lawn Areas, Trees and Large Shrubs" with a minimum saturated hydraulic conductivity of 20 mm/hr can be specified and brought to the site.

3.3 Weed Control

Seed germination will most likely be an issue if using an onsite soil mix. A composting process under controlled conditions can be used to generate heat and kill seeds. Ground wood mulch can also be used to control weeds.

Weed control is a very important consideration, especially if using an onsite soil mix that probably contains weed seeds. Once the seeds germinate, the issue can very easily get out of control with weeds growing throughout the rain garden and degrading the plantings. A germination test should be conducted on the onsite soil mix before using it as growing medium for the rain garden.

Seeds in the soil can be killed by heat. A full composting process under controlled conditions will often raise the temperature high enough to kill the seeds.

Mulch can also be used to inhibit weeds. Ground wood mulch is the best option. Do not use not use bark chips because they will float or sawdust/chips because they remove nitrogen. Use a 50mm to 75mm layer of mulch. Too deep a layer risks black liquor runoff associated with biochemical oxygen demand.

3.4 Binding of Soil Layers during Construction

The sand layer above the rock trench and filter fabric may need to be scarified prior to placing the growing medium. Sand layers are optional, and may be used in some situations depending on the degree of clay/silt in the growing medium mix.

The length of time between completing the rock trench and adding the layer of growing medium can affect the performance of a rain garden. The sand layer below the growing medium can potentially form a semi-impermeable crust if it is subjected to rain then drying. This would cause ponding of any water that tries to infiltrate into the rock trench.

If a crust has formed, the sand layer will need to be scarified prior to placing the growing medium. Scarified simply means scratching the surface so that the growing medium and sand layer can intermix and infiltration can take place (Figure 12).

Figure 12: The sand layer may need to be scarified before adding the growing medium to the rain garden.

3.5 Interim Sediment and Drainage Control – Minor Storms

It is critical to establish areas to capture sediment from minor storm events that occur during construction of the rain garden.

As with any construction site, interim sediment and drainage control is critical during construction of the rain garden. Material is being excavated and stored on impervious surfaces so when rain falls and runoff occurs there is the potential for these sediments to be picked up and taken to receiving waters.

Control methods include establishing temporary sediment capture areas at low points (Figure 13) and using the rain garden depression as a sediment trap, as long as rock trench and perforated drain are protected. If the second lift of asphalt has not gone in yet, minor flows can be contained along the panel curb and directed to the road surface (Figure 14)

Figure 13: A low area with an outlet being used for sediment control at a construction site.

Figure 14: Minor flows can be contained along the panel curb prior to the second lift of asphalt.

3.6 Interim Drainage Management – Major Storms

Major drainage paths during construction need to be considered in case of a major storm.

Subdivisions with rain gardens are different than traditional subdivisions because there are usually no catch basins or barrier curbs. The majority of the systems that will be used to infiltrate water into the ground (e.g., rock pits, absorbent landscape, and rain gardens) will not be functional during the construction phase so there could potentially be more runoff.

The site needs to be prepared for a major storm event even though the probability of a 5 to 10-year storm occurring during construction period is low because if it happens, the results can be disastrous. The roads can be used as a conveyance system (provided the second lift asphalt is not in place). Temporary measures such as sandbags or other measures can be used to help with flow redirection, so that building areas are not overwhelmed. Major flows can be directed to the site's sedimentation pond at the downstream end of the system (Figure 15). The pond needs to be sized large enough to hold major events out of the construction ground conditions, which will potentially have more runoff.

Figure 15: A sediment pond at a construction site.

3.7 Builder Management

Builder and trades need to be educated on building site management and the impact their activities can have on rain gardens and other stormwater measures.

Once the developers have put in the utilities, panel curbs, first lift of asphalt, and foundation for the rain garden (i.e., rock trench, perforated drain and overflow), it is time for the builders and trades people to start on the houses, finish the second lift of asphalt, landscape the lots, and put the growing medium and plants in the rain garden.

Home builders need to be educated on the potential impacts of their activities on rain gardens and other stormwater measures. "No-go" areas should be clearly marked using signage and/or an orange fence around the rain garden depression area.

Roof gutters should not be installed until the site has been landscaped and the rain garden planted. Removal of the sacrificial soil layer and poly sheeting and planting of the rain garden should be done only when building is fully completed. This can be difficult due to timing and requires the developer, builder, and trades people to all work together.

If 2x4s were placed on top of the poly layer below the sacrificial soil, they would assist in locating the poly sheets upon removal of the sacrificial soil layer. The idea is that an excavator will hit the 2x4s instead of the perforated drains.

3.8 Maintenance Responsibility

Responsibility for ongoing maintenance should be clearly outlined using a restrictive covenant, boulevard maintenance bylaw, local area improvement agreement or other means.

During the warranty period, which is generally 2 to 3 years, the developer (public areas) and/or builder (on-lot) will be responsible for maintenance of the rain garden. This includes watering, plant and soil maintenance and weed control (twice annually – spring and fall).

After warranty period there are some options for ongoing maintenance. These include registering a restrictive covenant; implementing a city-wide boulevard maintenance bylaw; assigning city staff responsibility; and signing a local area improvement agreement amongst homeowners and others.

A restrictive covenant is a legal document registered with the Land Title Office that outlines the property owner's maintenance responsibilities. It can include a penalty clause that enables the District or City to conduct maintenance if a homeowner has not and then recover the costs through property taxes or some other means.

For example, in the Silver Ridge residential development a restrictive covenant was implemented, and it states: "The Grantor covenants and agrees that it shall ensure that any landscaping on the boulevard, whether planted by the owner, a previous owner, an occupier or previous occupier of the real property, or by the District, is maintained to a standard that a reasonable property owner would use in the care of his or her landscaping on his or her own property."

Slightly less formal is the boulevard maintenance bylaw. A boulevard is defined as the area that runs along an individual's property, such as a sidewalk or landscaped area between the property line and the street. In this case, it would include rain gardens. Maintenance typically includes care of the vegetation, watering all landscaping, removal of weeds and correcting hazardous or potentially hazardous situations.

For example, the City of Coquitlam's "Boulevard Maintenance Bylaw" requires residents and property owners to keep their boulevards safe and clean. The bylaw provides guidelines for caring for vegetation on boulevards, including:

Do ...

- Water all landscaping and vegetation regularly
- Remove harmful weeds
- Correct hazardous or potentially hazardous situations, and
- Report vegetation growing around power, cable or telephone wires to your local utility company.

Don't ...

- Let grass on the boulevard exceed 15cm (5.9in) in height
- Use pesticides on City property and boulevards
- Damage boulevards, trees, shrubs, plants, bushes, hedges, fences or street lighting
- Cut trees without obtaining the consent from the City arborist, and
- Let rocks, gravel, pebbles, bark mulch or other loose landscaping or surfacing materials escape and fall onto any sidewalk or roadway.

It is generally not advisable for city staff to take responsibility for rain garden maintenance. However, there may be public areas or "perceived" public areas that the city may need to maintain. These areas should be kept to a minimum. The basic premise is that the hours spent by a homeowner maintaining a rain garden should be less than those spent maintaining a lawn in the same area.

A local area improvement agreement is a memorandum of understanding that determines maintenance responsibility between different groups. This is the model that the City of Seattle uses for the High Point Community. Their memorandum of understanding contains a map that clearly shows where the maintenance responsibility lays with the homeowner association, the limited partnership (rental housing) or the rights-of-way association. It gives a good understanding and it sets it straight at the beginning about who is responsible for what so there are no questions asked through the years of rain gardens maintenance.

3.9 Road Maintenance

City staff or contractors need to be educated regarding snow removal, sanding and salting practices near rain gardens.

Road maintenance near a rain garden requires different considerations than in an area with traditional curbs and sidewalks.

Since rain gardens do not have barrier curbs, snow plows need to be extra careful not to plow over them. If rain gardens will be used for snow storage or if the area has snow that lasts through the winter season (e.g., Whistler), this should be anticipated during the design process, and plants should be selected accordingly.

Street sweeping can prolong the life of a rain garden because it often reduces the amount of sediment that ends up in the garden. The type of sweeper and timing is important. High efficiency street sweeping at regular intervals will be far more effective then low efficiency sweeping once a year. Street sweeping is particularly important in colder areas with high sanding activity.

Regular inspection is required to ensure sheet flow is not being impeded causing concentrated flow. If there is a sand build-up at the curb edge, water will flow along the curb edge to the next lowest area. This will channel all of the flow into one area of the garden and could jeopardize the impervious/pervious ratio and kill the vegetation.

The top layer of the growing medium and the plantings may have to be replaced when the road surface is redone, which is 20 to 25 years.

3.10 Performance Monitoring and Warranty Period

Be sure to determine that the rain garden is working properly before the end of the warranty period.

Various inspection and testing methods can be used to monitor the performance of the rain garden. Continuous flow, rainfall and water quality monitoring is the best way of measuring performance. But, it is expensive process to install the stations and time-consuming to analyze the data. Pilot studies and research projects are the best means to do this type of monitoring.

Simpler and less expensive inspection methods can also be used. They include:

- **Test 1 - Water quantity inspection:** During a dry soil period, put a chalk line or a cork in the downstream outlet and observe whether water flowed at a rainfall event. Water should not flow below design rainfall intensity levels and capture target.

- **Test 2 - Water quality inspection:** If the water quantity objective above is met, a large percentage of the water quality targets will also likely be met. Test 2 is not required if test 1 is passed.

- **Test 3 - Standing water inspection:** There should be no standing water in the rain garden after a 24 hour storm.

- **Test 4 -Vegetation inspection:** There should not be a vegetation wall forming at the interface with the flat panel curb. The vegetation of the rain garden should be healthy and abundant. Most surfaces should be covered with vegetation in 3 years.

- **Test 5 - Impervious/Pervious ratio check (I/P Ratio):** There should not be any mud forming in the rain garden, and there should be no build-up of mud or other materials within the garden. If a mud plume is forming, it will likely consume the entire garden in a few years.

4.0 CONCLUSION

Rain gardens can be useful tools for rainwater management. Unfortunately, improper design and implementation or inadequate maintenance has resulted in many gardens not reaching their full potential or failing all together. Failed examples can lead to flooding and property damage, high maintenance costs, and setbacks in widespread implementation.

This paper shares a decade of experience and observations of KWL's staff regarding what works and what needs improvement in the design, implementation and maintenance of rain gardens. The recommendations in this paper can be used by engineers to maximize the usefulness and productivity of rain gardens and ensure they meet stormwater criteria, leading to a greater success rate and acceptance of rain gardens and an increase in their use in developments throughout North America.

5.0 RESOURCES AND REFERENCES

Stormwater Planning: A Guidebook for British Columbia
www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/guidebook/pdfs/chapter7.pdf

Building a Rain Garden Brochure, Capital Regional District
www.crd.bc.ca/watersheds/lid/documents/RainGardenBrochure.pdf

Rain Garden Handbook for Western Washington Homeowners, Washington State University www.crd.bc.ca/watersheds/lid/documents/Raingarden_handbook.pdf

Stormwater Source Control Design Guidelines Part IV, Metro Vancouver
http://www.metrovancouver.org/about/publications/Publications/Storm_Source_Control_Part IV.pdf

Rain Gardens: Improve Stormwater Management in Your Yard, Canadian Mortgage and Housing Corporation
www.cmhc-schl.gc.ca/en/co/maho/la/la_005.cfm

Rain Gardens: A How To Manual for Homeowners, University of Wisonsin
http://learningstore.uwex.edu/Assets/pdfs/GWQ037.pdf

Bioretention (Rain Gardens), US Environmental Protection Agency
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=72

Stormwater Management Manual for the *Puget Sound Basin*, State of Washington, Department of Ecology, 1991.

Craig Kipkie, KWL - "Working From the Source Towards Sustainable Water Management" Annual CWRA National Conference in Toronto, Ontario June 4-7, 2006.

City of Coquitlam, Home Owner Responsibilities, 2011
http://www.coquitlam.ca/Residents/My+Property/Good+Neighbour/Home+Owner+Responsibilities.htm

Low Impact Development Manual for Michigan
http://library.semcog.org/InmagicGenie/DocumentFolder/LIDManualWeb.pdf

Master Municipal Construction Document, Volume II.