LID RESEARCH PROJECT FOR BLUFFDALE CITY
Project ID: CEEn_2017CPST_007

by

ROTC Plus One Engineering
Jeremy Fowler / Project Manager
Steven Evans / Team Lead
Ryan Selee
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A Capstone Project Final Report

Submitted to

Dan Tracer
Bluffdale City Engineering

Department of Civil and Environmental Engineering
Brigham Young University

4/13/2018

Executive Summary

PROJECT TITLE: LID Implementation Study
PROJECT ID: CEEn-2016CPST-007
PROJECT SPONSOR: Bluffdale City
TEAM NAME: ROTC Plus One Engineering

The ROTC Plus One Engineering Group completed and presented to Bluffdale City a manual detailing various methods for implementing Low Impact Development (LID) requirements in the city. The manual includes fourteen entries of applicable LID methods, with their respective descriptions, applications, advantages, limitations, maintenance requirements, cost, pollutant removal efficiencies, and construction methods. The manual also includes a summary table summarizing the different aspects of each LID as a quick reference guide. The manual also includes a simple diagram to help aid in decision-making when implementing LID.

The ROTC Plus One Engineering group consists of team members Steven Evans, Wade Bozeman, and Ryan Selee, with Jeremy Fowler serving as project manager.

The engineering group met each week, and each team member worked approximately eight hours each week researching various LID methods, preparing the manual, and documenting sources. The group determined the practicality, limitations, maintenance requirements, effectiveness, and proper implementation of various LID and then selected fourteen LID that were appropriate for use in Bluffdale. Throughout the course of the project, the engineering team met with Bluffdale about once each month to report progress and solicit feedback from the sponsor.

The Bluffdale LID Manual is included as Appendix B of this report.

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Introduction

This project was planned in response to new legislation from the Utah Department of Environmental Quality, particularly the following passages:

"For new development or redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, the program shall include a process to evaluate and encourage a Low Impact Development (LID) approach which promotes the implementation of BMPs that infiltrate, evapotranspire or harvest and use storm water from the site to protect water quality. By March 1, 2019, the program shall include a process which requires the evaluation of an LID approach for new development or redevelopment projects that disturb greater than or equal to one acre including projects less than one acre that are part of a larger common plan of development or sale. Structural controls may include green infrastructure practices such as rainwater harvesting, rain gardens, permeable pavement, and vegetated swales. If an LID approach cannot be utilized, the Permittee must document an explanation of the reasons preventing this approach and the rationale for the chosen alternative controls on a case by case basis for each project."

-Utah Department of Environmental Quality

"By March 1, 2019, new development or redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale must manage rainfall on-site, and prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 90th percentile rainfall event."

-Utah DEQ

Bluffdale City seeks to comply with this new regulation, and so asked ROTC Plus One Engineering to complete a manual on LID that can be used to aid the implementation of LID in the city. This Manual is included as Appendix B of this report. Low Impact Development approaches aim to mimic the natural hydrology (pre-development) of a development. LID uses various land planning and design practices and technologies (including methods to infiltrate, evapotranspirate, harvest and reuse, and treat stormwater runoff) to simultaneously conserve and protect natural resource systems and reduce infrastructure costs. LID still allows land to be developed, but in a cost-effective manner that helps mitigate potential environmental impacts. Implementing LID allows us to develop sustainably, planning and preparing for the future.

Schedule

10/25/2017 – Initial Meeting with Bluffdale City

12/19/2017 – Follow-up meeting with Bluffdale City (by phone)

01/08/2018 – Complete Studying of EPA LID regulations and begin intensive LID research

01/24/2018 – Update with Bluffdale City

01/29/2018 – Complete initial study of each LID. Determine which are applicable in Bluffdale.

02/07/2018 – Update with Bluffdale City

02/19/2018 – Complete study of LID infiltration methods. Determine which areas of Bluffdale contain soils suitable for infiltration LID methods.

02/21/2018 – Update with Bluffdale City

03/05/2018 – Complete Analysis of Pollutant Removing Filters

03/07/2018 – Update with Bluffdale City

03/19/2018 – Complete Research of each remaining applicable LID method

04/02/2018 – Update with Bluffdale City

04/09/2018 – Complete report and prepare presentation

04/12/2018 – Present in BYU Seminar

04/17/2018 – Present Completed Report to Bluffdale Development Review Committee

Assumptions & Limitations

Team will provide work for this Capstone project "as is" using best practices and with best effort. Project results cannot be construed as work performed by licensed professionals and cannot be used as "stamped deliverables" without first being reviewed, approved and stamped by a qualified and relevant license professional engineer.

This project included assumptions for standard costs and pollutant removal rates for various LID methods. These assumptions were based on information provided by manufacturers, University studies, City and County Stormwater Manuals, and studies by the Environmental Protection Agency, the Army Corps of Engineers, and other agencies. The sources of each of these assumptions are stated in the LID Manual created by the engineering group in the References section of each LID entry. These costs and pollutant removal rates are based on the best available information and reasonably represent reality, but cannot be construed as exact amounts. Cost and pollutant removal rates will vary with each project.

Design, Analysis & Results

The project was carried out as planned and a manual on LID was prepared for Bluffdale City. The manual consists of 14 LID methods that can be implemented in Bluffdale. The selection of LID depends on space, slope, soil, size, water table location, and cost factors. Table 1 below summarizes the purpose, effectiveness, pollutant removal, runoff reduction, cost, maintenance, and permit requirements for each of the 14 LID studied.

Table 1:Summary of Each LID

LID	Purpose	Treated Contaminants	Treatment Effectiveness	Runoff Reduction	Cost	Maintenance	Permit Required
Bioretention Basins	Retention, treatment, infiltration, and evapotranspiration	TSS, Phosphorous, Nitrogen, Copper, Zinc, Nitrates	Excellent	High	Moderately High	Bi-monthly (weeding)	No
Bioswales	Treatment, reduce velocities, and partial infiltration	TSS, Phosphorous, Nitrogen	Fair	Low	Moderate	Frequent (mowing)	No
Dry Wells	Storage and infiltration	TSS, Phosphorous, Nitrogen	Fair	Medium	Moderately High	Periodically	Yes
Hydrodynamic Separators	Treatment	TSS, Petroleum	Fair	-	Moderately High	Semi-annually	No
Infiltration Trenches	storage and infiltration	TSS, Phosphorous, Nitrogen, Zinc	Fair	Medium - High	Moderately High	Monthly	Yes
Popup Emitters	Disperse rooftop runoff	-	-	Low	Low	Yearly	No
Porous Pavement	Infiltration and treatment	TSS, Zinc, Petroleum	Good	High	High	Semi-annually	No
Rain Capture	Storage of rooftop runoff	-	-	High	Moderate	Yearly	Yes
Rain Gardens	Retention, treatment, infiltration, and evapotranspiration	TSS, Phosphorous, Nitrogen, Copper, Zinc, Nitrates	Good	Medium - High	Moderate	Bi-monthly (weeding)	No
R-Tanks	Storage, treatment and infiltration	TSS, oil and grease	Good	High	High	Yearly	Yes
Stormtech	Storage, treatment and infiltration	TSS, oil and grease	Good	High	High	Yearly	Yes
Tree Filters	Treatment, partial storage, evapotranspiration	TSS, Nitrogen, Zinc, Petroleum	Excellent	Medium	Moderate	Bi-monthly (weeding)	No
Vegetative Filter Strips	Treatment, reduce velocities, and partial infiltration	TSS, Phosphorous, Nitrogen	Good	Low	Low	Frequent (mowing)	No
Wetlands	Treatment, storage, and infiltration	TSS, Phosphorous, Nitrogen, Nitrates, Zinc, Petroleum	Excellent	High	Moderately High	Bi-monthly (weeding)	No

In addition to the table, more specific characteristics of each LID were detailed in the LID Manual, which includes sections on LID Overview, Application, Construction, Cost, Pollutant Removal, and Maintenance Requirements. Each LID entry in the manual also includes an easy to access summary section, which quickly displays the overview, advantages, limitations, cost, pollutant removal rates, and maintenance for each LID. A sample of the entry in the LID Manual for Bioswales is displayed on the following two pages as Figure 1.

LID Summary

Bioswales

Overview

Swales remove pollutants, reduce velocities, and partially infiltrate runoff as water is conveyed to further storm water structures.

Advantages

Swales are cheap and easy to construct.

Swales can effectively pre-treat water before entering other LID structures.

Limitations

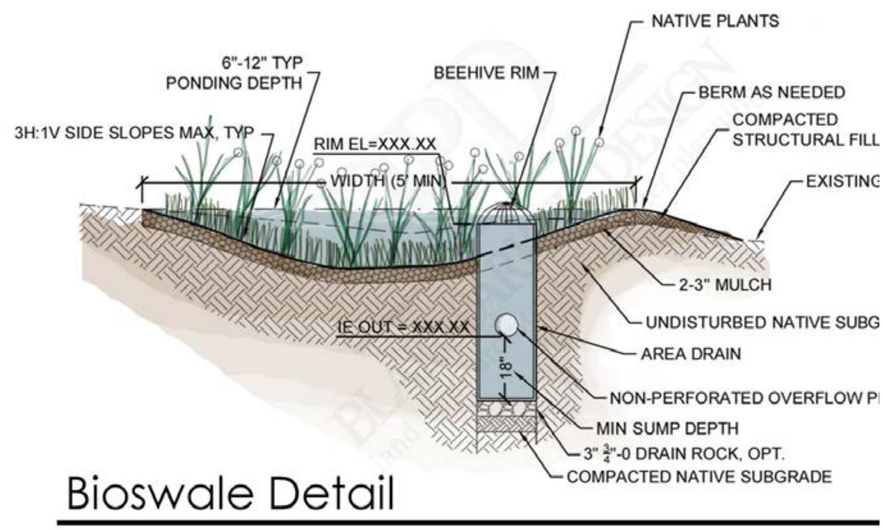
Not appropriate in high water table areas.

Impractical in areas with steep slopes or very flat grades.

On steeper slopes, check dams, filter berms, or weirs should be included to reduce velocity and encourage infiltration.

Bioswales

Overview: Vegetated channels and grassed swales can be used in lieu of traditional curb and gutter and subsurface piping to convey storm water runoff. Swales consist of a shallow trough-like vegetated depression underlain by at least 24 inches of permeable soil, with side slopes not exceeding 3:1 slope. The swale should include dense, low-growing native vegetation that is water-resistant, drought tolerant, and provides substantial pollutant removal. Simple grass swales are less expensive, but provide far less infiltration and pollutant removal than vegetated swales. Unlike conventional systems, vegetated swales slow the erosive velocity of the storm water, increase time of concentration, filter pollutants such as sediment, and infiltrate a portion of the runoff volume. Swales and channels are low-cost when compared to conventional conveyance systems. The inlet and outlet structures of swales should be carefully designed to prevent erosion, scouring, and the accumulation of standing water for more than 48 hours.



Typical Bioswale Cross-Section

Application: Bioswales can be effectively used to initially treat and convey runoff to bioretention areas or infiltration structures, and are applicable in residential, industrial, and commercial settings, as well as along highways, roads, or parking lots. Swales are impractical for areas with very flat grades or steep slopes, and should be used to serve an area of less than 10 acres, with slopes no greater than 5% and no less than 1% (University of Florida IFAS Extension, 2008). Swales with slopes exceeding 3% should include filter berms, check dams, or weirs perpendicular to the flow to reduce flow velocity, facilitate storage volume, and extend treatment and infiltration time (PA DEP (Pennsylvania Department of Enviornmental Protection), 2006). Vegetated swales should not be installed in areas with high water tables where groundwater reaches the bottom of the swale.

LID Summary

Bioswales

Cost

$4.50-$8.50 per linear foot for a 15 ft wide swale.

$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	81%
Total Phosphorous (TP)	10-65%
Total Nitrogen (TN)	-
Copper (Cu)	-
Zinc (Zn)	88%
Petroleum Hydrocarbons	82%

Maintenance

Swales should be inspected for bare areas and reseeded as necessary.

Vegetation must be irrigated during dry periods

Construction: Vegetated swale construction should occur only after upstream erosion and sediment control measures are in place in order to prevent clogging of the swale by silts. First, the swale should be rough graded, avoiding excessive compaction. Where substantial compaction occurs, or in poor draining soils, the first 18 inches of soil should be removed and replaced with a blend of topsoil and sand to promote infiltration and plant growth (PA DEP (Pennsylvania Department of Enviornmental Protection), 2006). Check dams should then be installed as required. The swale should then be fine graded and then seeded and vegetated. Vegetation should consist of dense, drought and salt tolerant, water-resistant plants such as Western Wheatgrass or Salt grass (Pratt, 2018).

Cost: In general, vegetated swales are considered a low-cost LID. A fifteen feet wide vegetated swale will typically cost from $4.50-$8.50 per linear foot (Pennsylvania DEP), significantly cheaper than curb and gutter.

Pollutant Removal: The University of New Hampshire reports reduction of 81% total suspended solids (TSS), 82% total Petroleum Hydrocarbons in the Diesel Range (TPH-D), and 88% Total Zinc (Zn) for vegetated swales. The same study found that stone (or rip-rap) swales reduce 50% TSS, 33% TPH-D, and 64% total Zn (University of New Hampshire Stormwater Center (UNH), 2009). Pollutants are removed by the vegetation and by contact with the soil in slower sheet flow.

Maintenance: Swales should be periodically inspected to ensure the successful establishment of plants and grasses. Any bare areas should be reseeded and appropriate erosion control measures should be taken if erosion channels begin forming. Check dams should be monitored and inspected for signs of erosion or channelization. During dry periods, swale vegetation should be watered. If swales convey parking lot or roadside runoff, mulching and/or soil aeration may be required in the spring to restore soil structure and moisture capacity and to reduce the impact of deicing agents (PA DEP (Pennsylvania Department of Enviornmental Protection), 2006).

References

PA DEP (Pennsylvania Department of Enviornmental Protection). (2006). *Pennsylvania Stormwater Best Management Practices Manual.* Harrisburg, Pennsylvania: Pennsylvania Department of Environmental Protection.

Pratt, M. S. (2018). *Range Plants of Utah.* Logan, UT: Utah State University Extension.

University of Florida IFAS Extension. (2008). *Florida Field Guide to Low Impact Development.*

University of New Hampshire Stormwater Center (UNH). (2009). *Biannual Report.* Durham, NH.

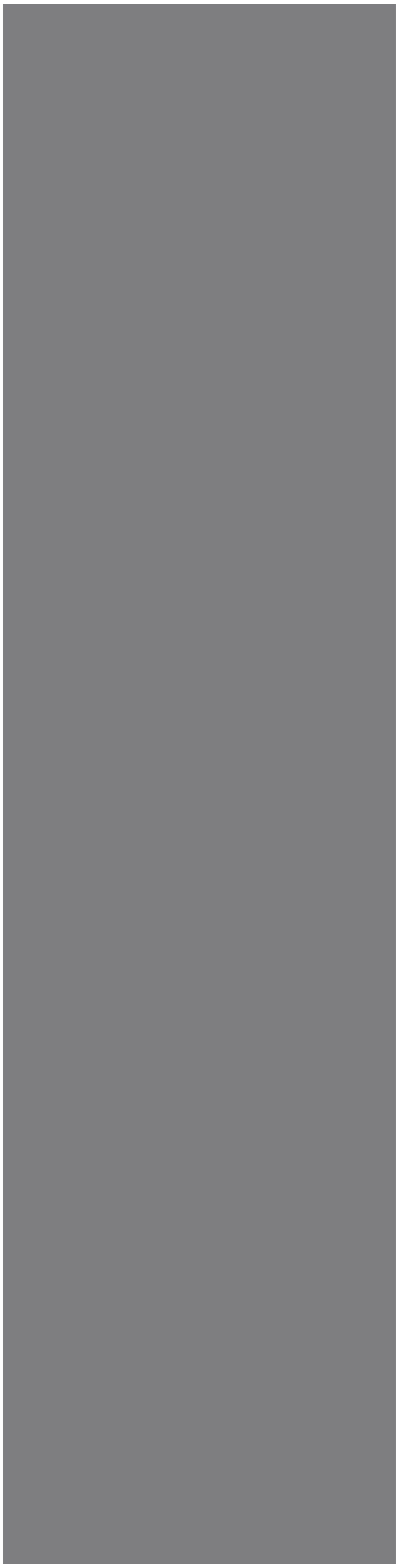


Figure 1:Sample Entry in LID Manual

The manual also included a flowchart to aid in LID implementation. The flowchart is displayed below in Figure 2.

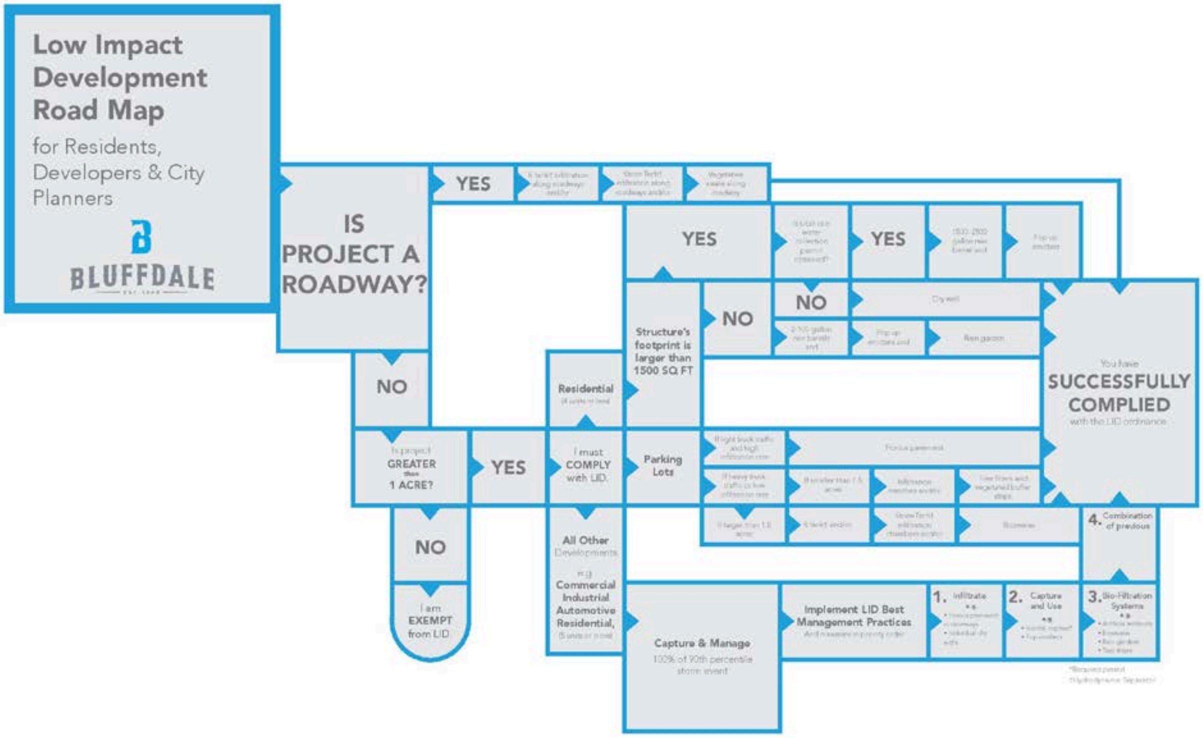


Figure 2: LID Flowchart

The results of this LID study indicate that LID can be effectively implemented in Bluffdale, Utah. Determination of the proper LID method for each situation is based on site and development parameters, including native terrain, soil permeability, proximity to wells, water table elevation, slope, development size, potential pollutants, sediment loading, and development type. LID can be implemented in nearly every situation, but may require some creativity and flexibility. Implementation of LID requires careful planning and coordination from engineers, planners, and contractors.

Lessons Learned

This project included several challenges. One challenge was difficulty finding examples of LID in Salt Lake County. LID is relatively new in Utah, so it was difficult to find examples of effective use in climate and soils similar to those in Bluffdale. We were able to find some examples of LID in Daybreak, Utah and we were able to study LID in other areas of the country with some similar characteristics and then combine those findings together to apply it to Utah. For example, the Los Angeles area has similar summers to Utah, with high temperatures, very little precipitation, and large amounts of clay soils. Meanwhile, Minnesota has harsh, snowy winters, even more severe than Utah's. We researched LID implementation in both areas and combined elements of each for use in Utah, since both of these areas have some characteristics similar to Utah and some that are very different.

Another challenge that we faced was finding good cost estimates for each LID. One way that we resolved this issue was by speaking with representatives who had constructed these LID. For example, we talked with C. Hales, a representative from Advanced Drainage Systems, to obtain a good cost estimate for StormTech Infiltration Chambers. The cost estimate given to us matched well with estimates we had found from other sources.

Conclusions

The ROTC Plus One Engineering Group learned a great deal from this project. Before this project, we had almost no experience with LID and really did not have any idea how to effectively implement LID anywhere, let alone in Utah. After hours of research and preparing manuals and tables, we gained confidence and now feel much more comfortable with LID. We have concluded that LID is a great development practice that should be implemented quickly to preserve the environment. LID limits stormwater pollution and stormwater runoff, which can damage ecosystems, increase erosion, and increase contamination. LID is a great way to reduce the impact of development on the environment, preserving the natural hydrology of a site. Implementing LID will help Bluffdale to grow sustainably into the future.

Recommendations

We recommend that Bluffdale require developers to implement LID methods in all developments within the city. We envision that our LID Manual will be used to aid developers and to provide them with ideas for implementing LID in planned developments. By no means is the LID Manual an exhaustive detailed listing of all methods for reducing stormwater runoff and pollutant loads. The manual is meant to provide a basic overview of several methods that are applicable in Bluffdale. Effective implementation of LID requires creativity and requires attention to the topography, soil characteristics, land use, and development type of each site. There are no one size fits all solutions for LID, and not every possible solution can be tabulated in a manual.

We envision that Bluffdale can provide potential developers with a copy of the LID Manual as they prepare and submit plans to the city for approval of the development. The developers can use the manual as a guide to decide, in conjunction with the city, which of the LID they will implement to meet the requirements of reduced runoff and pollutant loading.

As more LID are implemented in the city, we suggest that the estimated costs section of the manual be updated according to actual costs incurred during development in Bluffdale. Currently, most of the LID have not been implemented in Bluffdale, so costs have been estimated by compiling actual costs and cost estimates from other areas of the country and trying to fit them to local circumstances. As more LID are used around Bluffdale, cost estimates will become more accurate, and these should be added to the manual.

Appendix A

Steven Evans

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801-900-1715 • stevenwevans2@gmail.com

EDUCATION

Brigham Young University Provo, UT

- BS Civil and Environmental Engineering April, 2018
- Cousework in transportation, hydraulics, soil mechanics, structural analysis, GIS, groundwater modeling, and computer programming.
- 3.97 GPA.

WORK EXPERIENCE

Provo City Engineering Provo, UT
Intern January, 2017 – Present

- Assisted Provo's engineers in design and drafting using AutoCAD Civil 3D.
- Assisted in GIS mapping, and pavement management using ArcMap.
- Assisted in surveying, traffic studies, traffic modeling (using Synchro), and utility marking.
- Prepared concept designs, concept maps, cost estimates, and bond estimates.
- Prepared bid documents, bid tabs, and traffic reports.
- Reviewed and signed off on plans during the building permit process.

BYU Department of Mathematics Provo, UT
Grader August, 2016 – January, 2017

- Worked for Doctor Chahal grading multi-variable calculus and proofing his tests.

Provo Parks and Recreation Provo, UT
Laborer April – August, 2016

- Mowed and maintained the grass at twenty parks throughout the city of Provo.

B D Stearns Concrete Construction Lebanon, OR
Laborer June – August, 2012

- Constructed and leveled forms according to plans; placed rebar; poured concrete.

VOLUNTEER EXPERIENCE

Provo Parks and Recreation Provo, UT
Coach 2017

- Volunteered coaching youth soccer. Held practices, coached games, and communicated with participants and parents.

The Church of Jesus Christ of Latter-day Saints Louisville, KY
Missionary 2013 - 2015

- Greatly improved my interpersonal and communication skills through teaching, giving community service, and training other missionaries.

SKILLS / AWARDS

- Experienced in AutoCAD Civil 3D, ArcMap, GIS, Microsoft Office, C++, and Revit.
- Experience surveying using a total station and survey grade GPS.
- Learning MODFLOW groundwater modeling and Synchro traffic modeling software.
- 2012 Citizenship Award- given to a Senior who exemplifies the highest traits of good citizenship.

Ryan Selee

1080 W 100 N, Provo, UT 84601 | (360) 984-8524 | selee.taylorryan@gmail.com

Education

BS Civil and Environmental Engineering, Brigham Young University — *JUN 2018*
Minor in Military Science — *Provo, Utah*

- Relevant Course Work: Water Resources Management, Hydraulic Engineering, Transportation Engineering, Structural Engineering, Engineering Applications of GIS

Skills & Accomplishments

Surveying, AutoCAD, Revit, ArcGIS, Eagle Scout, and Army ROTC Scholarship Recipient

Experience

Cadet, Army Reserve Officer Training Corps (ROTC) – BYU Battalion — *AUG 2013 – Present*, *Provo, Utah*
- Led peer teams of 4 to 48 cadets in rotational leadership roles
- Conducted event planning, organization, and execution as a team
- Trained 90 cadets in radio operations and land navigation

Intern/Assistant Platoon Leader, 3-13th Battalion/210th Field Artillery Brigade — *JUL 2016 - AUG 2016*, *Camp Casey, Korea*
- Tracked maintenance of communications systems for 32 vehicles
- Led a logistics exercise involving 30 people and 8 tons of supplies
- Prepared the mobilization task calendar for a group of 90 people

Cadet, Leadership Development Course — *JUN 2016 –JUL 2016*, *Fort Knox, Kentucky*
- Completed confidence courses as an individual and in a team to include rappel tower, obstacle course, and unit run
- Led 36 peers in rotational leadership roles for 16 days of field training

Custodian, Brigham Young University — *MAY 2015 – AUG 2015*, *Provo, Utah*
- Prepared 5 apartments per shift for new resident arrivals
- Nightly cleaned the university administration office building

Activities Support, Brigham Young University — *JAN 2014 – APR 2014*, *Provo, Utah*
- Set up and took down university sports complexes for events
- Maintained university sports equipment and facilities

Rancher, Self-employed — *JAN 2008 –AUG 2013*, *Battle Ground, Washington*
- Constructed and maintained livestock shelter and fence
- Raised 11 sheep and 6 cows to market ready
- Marketed and sold the livestock at auction or open market

- **Wade R. Bozeman**
- 407 E 100 N
- Nephi, UT 84648
- Telephone (707) 718-5503
- Email: wdbozeman@gmail.com

- **OBJECTIVE**
- Demonstrate competency and qualifications for completion of Capstone Project.

- **QUALIFICATIONS**
- Knowledgeable in the classroom and the field. Surveying/navigation and GIS competent. Currently enrolled in advanced Environmental Engineering course.

- **EDUCATION**
- BRIGHAM YOUNG UNIVERSITY: B.S. expected Jun. 2018. Civil Engineering Major. Aerospace Studies Minor. Successfully completed relevant courses in soils, GIS, and surveying, among others.

- **EXPERIENCE**
- US FOREST SERVICE: Range Aid. Applied herbicide to noxious weeds, fenced riparian areas, performed range health assessments, located stray cows, operated ATVs and UTVs, rode and ensured care of horses and mules, and checked on compaction and erosion in soils. Worked as wildland firefighter when needed.

- BRIGHAM YOUNG UNIVERSITY: Teaching Assistant. Educated students in AutoCad and Revit computer programs. Graded assignments, administered test reviews, and gave students an introduction to the Civil Engineering Program (This is a beginning level course).

- **ACHIEVEMENTS AND AWARDS**
- Eagle Scout Award Recipient.
- Various awards from the Air Force ROTC program at BYU, including for leadership and physical fitness.

- **ACTIVITIES**
- 4th year Cadet: Air Force ROTC.
- Student member: American Society of Civil Engineers.

- **REFERENCES**
- Von Black, Range Technician: (435) 686-4531
- More Available upon request.

Appendix B

Bluffdale City Low-Impact Development Manual

Prepared by BYU Capstone team: Wade Bozeman, Steven Evans, and Ryan Selee

Printed on April 16, 2018

Executive Summary

Low-Impact Development (LID) is a stormwater management practice where the main goal is to reduce runoff by mimicking natural hydrologic processes. This is desirable for the preservation of the non-engineered landscape, reduction of surface water pollution, and more efficient use of rain water. Additionally, Low-Impact Development will be made mandatory as of March 1, 2019 by the Utah Department of Environmental Quality. These four reasons create a great incentive to utilize LID.

The General Permit for Discharges for Small Municipal Separate Storm Sewer Systems (MS4s) from the Utah Department of Environmental Quality Division of Water Quality states,

> *By March 1, 2019, new development or redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale must manage rainfall on-site, and prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 90th percentile rainfall event.*

This requirement can be fulfilled in Bluffdale City by the proper implementation of the 14 LID techniques discussed in this report. This report includes the discussion of Stormtech Infiltration Chambers, R-Tank Modular Units, Infiltration Trenches, Dry Wells, Bioswales, Vegetated Filter Strips, Tree Filters, Bioretention Basins, Rain Gardens, Pop-up Emitters, Rainfall Capture, Constructed Wetlands, Porous Pavements, and Hydrodynamic Separators.

The techniques described in this report vary in design, purpose, and effect, and all can play a big role in LID implementation in Bluffdale City. Not all techniques need be used on every site, and on most sights some of the LID techniques will not be applicable. This report provides a general overview of the 14 most applicable LID practices to Bluffdale City; however, before installing any of the following techniques an applicable expert, or experts, should be consulted, such as a licensed civil engineer knowledgeable in the area(s) of question.

Introduction

This manual was created in response to new legislation from the Utah Department of Environmental Quality, particularly the following passages:

> *For new development or redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, the program shall include a process to evaluate and encourage a Low Impact Developmnet (LID) approach which promotes the implementation of BMPs that infiltrate, evapotranspire, or harvest and use storm water from the site to protect water quality. By March 1, 2019, the program shall include a process which requires the evaluation of an LID approach for new development or redevelopment projects that disturb greater than or equal to one acre including projects less than one acre that are part of a larger common plan of development or sale. Structural controls may include green infrastructure practices such as rainwater harvesting, rain gardens, permeable pavement, and vegetated swales.*
>
> -Utah Department of Environmental Quality

> *By March 1, 2019, new development or redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale must manage rainfall on-site, and prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 90th percentile rainfall event.*
>
> -Utah Department of Environmental Quality

Under the direction of Bluffdale City, a group of senior students in Civil Engineering at BYU complete a BYU Capstone project to prepare this manual for Bluffdale City detailing several different Low Impact Development (LID) methods applicable in Bluffdale, Utah. This manual is to aid in the implementation of LID in the city. Low Impact Development approaches aim to mimic the natural hydrology (pre-development) of a development by using various land planning and design practices and technologies (including methods to infiltrate, evapotranspirate, harvest and reuse, and treat stormwater runoff) to simultaneously conserve and protect natural resource systems and reduce infrastructure costs. LID still allows land to be developed, but in a cost-effective manner that helps mitigate potential environmental impacts.

This manual includes entries on fourteen different LID methods, and includes an Appendix with a summary table of characteristics of each LID, and a simple chart to guide initial decision-making.

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LID Summary
Storm Tech Chambers

Overview
Temporarily stores and infiltrates storm water. Most appropriate underneath parking lots, roadways, or athletic fields.

Advantages
Capable of retaining 90th percentile storm on-site.

Isolator row isolates pollutants and reduces maintenance requirements

Underground construction preserves surface space.

Limitations
Not appropriate in high water table areas.

Requires underdrain in low permeability soils.

Requires pre-treatment.

Must be registered with the DEQ when used in commercial settings.

StormTech Infiltration Chambers

Overview: Storm Tech Chambers are manufactured by Advanced Drainage Systems (ADS) and are designed primarily to be used for temporary storage and infiltration under parking lots and roadways. These injection-molded polypropylene chambers are embedded underground in a layer of clean, crushed, angular stone. Storm water is collected and should be routed over vegetated filter strips or swales, or through a ADS HDPE Water Quality Unit to remove sediment, grease, and oil. The StormTech system should include a manhole with a high flow diversion weir upstream of the chambers. This manhole diverts flow and provides maintenance access to a single row of fabric wrapped StormTech chambers known as the isolator row. Sediment accumulates in this single row rather than the entire system, drastically reducing maintenance costs. The isolator row and remaining chambers store and infiltrate the storm water as the water percolates through the clean stone into the underlying soils. Additional storage is also provided in the pore space of the bedding stone. This system is very useful because the entire system is buried underground, preserving land for development purposes.

Prescott, Everett J. "Storm Water Solutions." Waterworks Services & Products for Professionals, EJP, 19 Oct. 2016, www.ejprescott.com/blog/storm-water-solutions-the-stormtech-sc-160lp-water-detention-chamber.

Application: Storm Tech Chambers should not be used in areas where the seasonally high water table is within two feet of the infiltration chamber in order to prevent contamination of groundwater (North Carolina Division of Water Quality (NCDWQ), 2007). Depending on soil characteristics and design size, the system may require underdrains, which are constructed by installing perforated pipe in the gravel bedding near the top of the infiltration chambers, which directs storm water downstream to further storm water management structures. As the storm water accumulates and reaches the storage capacity of the system, it will drain via the underdrain, preventing system failure. The Storm Tech filtration system is best suited to locations where space is at a premium, as it increases available space for development (University of New Hampshire Stormwater Center (UNH), 2009).

Construction: When used in a commercial setting, Storm Tech chambers are considered a Class V UIC Storm Water Drainage Well. Owners of all UIC Class V

LID Summary

Storm Tech Chambers

Cost

$4.50-$6.00 per cubic feet of water storage.

$$$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	80%
Total Phosphorous (TP)	60%
Total Nitrogen (TN)	-
Copper (Cu)	90%
Zinc (Zn)	90%
Petroleum Hydrocarbons	90%

Maintenance

System should be inspected twice each year.

Isolator Row should be cleaned out by JetVac when sediment reaches 3" depth.

wells are required by federal and state regulation to submit inventory information. This submittal includes an inventory review fee at the time of initial inventory submission for each subclass of Class V injection well at each facility location (Utah Department of Enviornmental Quality, 2018).

The area must be excavated and lined with a nonwoven geotextile fabric to prevent fines intrusion into the angular stone. A layer of nominal ¾ to 2-inch clean, crushed, angular stone is placed over the entire bottom surface of the bed to a minimum thickness of 6". Storm Tech Chambers are laid out over the stone bed, including an isolator row wrapped in woven geotextile, and an access manhole containing a high flow weir, which diverts the first flows to the isolator row. Embedment stone is placed around the chambers to a minimum cover of 6" over the top of the chambers and then covered with nonwoven geotextile. Granular fill material is placed over the geotextile such that a minimum cover of 18" is achieved. Care should be taken during construction not to drive heavy equipment over the chambers before the required coverage is achieved.

Cost: Typical cost to install a Storm Tech infiltration system is approximately $4.50-6.00 per cubic foot of runoff storage. This includes materials, excavation, backfill, and labor costs (Hales, 2018)

Pollutant Removal: The ADS HDPE Water Quality Units and Isolator row remove 80% of total suspended solids and 80% of oil and grease (Advanced Drainage Systems (ADS), 2018). The University of New Hampshire found that the isolator row filters out significant amounts of Phosphorous, Suspended Sediment, Suspended Solids, Turbidity, and Zinc (University of New Hampshire Stormwater Center (UNH), 2009). These pollutants are captured in the isolator row and Water Quality Unit. Additional treatment occurs as the water percolates through the underlying soil.

Maintenance: Storm Tech recommends that the isolator row be inspected every six months for the first year and then annually for following years. If inspection reveals that sediment has accumulated to a depth of 3 inches, cleanout should be performed by JetVac. Storm Tech recommends that the length of the isolator row be limited to 175 feet.

References

Advanced Drainage Systems (ADS). (2018, March 29). *ADS HDPE Water Quality Unit (WQU)*. Retrieved from ads-pipe.com: https://www.ads-pipe.com/products/water-quality/ads-hdpe-water-quality-unit-wqu

Hales, C. (2018, March 8). ADS Products. (S. Evans, Interviewer)

North Carolina Division of Water Quality (NCDWQ). (2007). *Stormwater Best Management Practices Manual.* Raleigh, NC.

University of New Hampshire Stormwater Center (UNH). (2009). *Biannual Report.* Durham, NH.

LID Summary

R-Tank Units

Overview

Used to store and infiltrate or harvest and reuse storm water. Most appropriate underneath parking lots, roadways, or athletic fields.

Advantages

Capable of retaining 90th percentile storm on-site.

More spatially efficient than Storm Tech Chambers.

Easy installation.

Limitations

Not appropriate in high water table areas.

Requires underdrain in low permeability soils.

Requires pre-treatment.

More difficult to maintain than Storm Tech Units.

Must be registered with the DEQ when used in commercial settings.

R-Tank Modular Units

Overview: R-Tank modular units are manufactured by ACF Environmental and are a space-efficient method for storing and infiltrating runoff underground. R-Tanks may be used either for infiltration or for storage and irrigation use, but storage and reuse is limited in Utah (see entry on Rainfall Capture). The modular units are 95% void space, which is used to store water. The exterior of the units is 90% permeable, which allows infiltration; the rate of infiltration is dependent on the conditions of the native soils. It is highly recommended to install ACF's Trash Guard Plus Pretreatment device (a relatively inexpensive, simple element that captures sediment, debris, and floatables) in the inlet to the R-Tank system in order to prevent the accumulation of fines, grease, and oils, which could clog the system. This underground system is a valuable asset because it is constructed entirely underground, preserving the surface for usable space.

"Rainwater Collection System Archives -." RSS, www.greening-solution.com/tag/rainwater-collection-system/. R-Tank Modular Unit Installation

Application: R-Tank modules should not be used for infiltration in areas where the seasonally high water table is within two feet of the infiltration chamber in order to prevent groundwater contamination (North Carolina Division of Water Quality (NCDWQ), 2007). R-tanks may require an underdrain depending on soil characteristics and system sizing. The underdrain should be installed using a perforated pipe near the ceiling of the R-tanks that will drain excess water as the system reaches capacity, carrying the excess downstream to further storm drain structures. R-Tanks are effective under parking lots, streets, and fields.

Construction: When used in a commercial setting, R-Tanks are considered a Class V UIC Storm Water Drainage Well. Owners of all UIC Class V wells are required by federal and state regulation to submit inventory information. This submittal includes an inventory review fee at the time of initial inventory submission for each subclass of Class V injection well at each facility location (Utah Department of Enviornmental Quality, 2018).

During construction, the area must be excavated with a minimum 2-foot perimeter around the R-tanks and a minimum of 4-inches below the R-tanks. For

LID Summary

R-Tank Units

Cost

$4.50-$6.00 per cubic feet of water storage.

$$$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	80%
Total Phosphorous (TP)	60%
Total Nitrogen (TN)	50%
Copper (Cu)	90%
Zinc (Zn)	90%
Petroleum Hydrocarbons	

Maintenance

System should be inspected every 6 months during first year and annually during subsequent years.

System should be flushed when sediment accumulates to 6" depth.

Trash Guard Plus must be cleaned 4 times each year.

infiltration, the base of the excavation should not be compacted, but must support a minimum of 2,000 psf (ACF Environmental, 2017). The minimum 4-inch base should consist of coarse sand or washed angular stone, placed and rolled but not compacted. The excavation should be lined with a geotextile fabric to prevent fines intrusion into the modules. If the system will be used for rainwater harvesting, it should be wrapped in impermeable fabric. Inlet, maintenance, and (where applicable) outlet pipes are constructed by cutting the plate of the R-tank to allow the fitting of the pipe to the system. Maintenance ports should be installed such that the distance between ports does not exceed 50 feet. The perimeter of the excavation should be backfilled with a free draining backfill to minimum 95% compaction to ensure stability. In all load bearing applications, a geogrid is required to be placed 12" above the R-Tank (ACF Environmental, 2017). The R-Tanks should have a minimum of 20" of cover of free draining backfill (ACF Environmental, 2017). The inlet to the R-Tank system should include devices to remove sediment and debris before entering the infiltration tanks, such as ACF's Trash Guard Plus, which is installed at the inlet structure and prevents sediment and debris from entering the system.

Cost: Typical cost to install an R-Tank system is approximately $5.00-7.00 per cubic foot of runoff storage. This includes materials, excavation, backfill, and labor costs (Hales, 2018).

Pollutant Removal: Infiltration through the R-Tank system effectively filters out significant amounts of suspended solids, suspended sediment (80%), phosphorous (60%), Nitrogen (50%), and heavy metals (over 70%) (Minnesota Pollution Control Agency, 2000). Most of this treatment occurs as the water infiltrates into the subsurface and percolates through the soil. Sufficient water table and bedrock depth is required to facilitate proper treatment.

Maintenance: R-Tanks should be inspected very six months for the first year of operation, and then annually during subsequent years. The R-Tank System should be back-flushed once sediment accumulation has reached 6" or 15% of the total system height (ACF Environmental, 2017). To back-flush the R-Tank, water is pumped into the system through the Maintenance Ports as rapidly as possible. The turbulent action of the water moving through the R-Tank will suspend sediments which may then be pumped out. The ACF Trash Guard Plus functions well, but is susceptible to clogging, and should be inspected 4 times each year to remove accumulated sediment and debris.

References

ACF Environmental. (2017). *R-Tank Infiltration Systems.*

ACF Environmental. (2017). *R-Tank Installation Guide.*

ACF Environmental. (2017). *R-Tank Operation, Inspection, and Maintenance.*

Hales, C. (2018, March 8). ADS Products. (S. Evans, Interviewer)

Minnesota Pollution Control Agency (2000).*Protecting Water Quality in Urban Areas: Best Management Practices for Dealing with Storm Water Runoff from Urban, Suburban and Developing Areas of Minnesota*. St Paul, MN.

LID Summary

Infiltration Trenches

Overview

Temporarily stores and infiltrates storm water. Most appropriate for low pollutant level runoff.

Advantages

Capable of retaining 90th percentile storm on-site.

Effectively filters and infiltrates runoff from small areas with low loads.

Easy to fit into most site plans.

Limitations

Not appropriate in high water table areas.

Requires underdrain in low permeability soils.

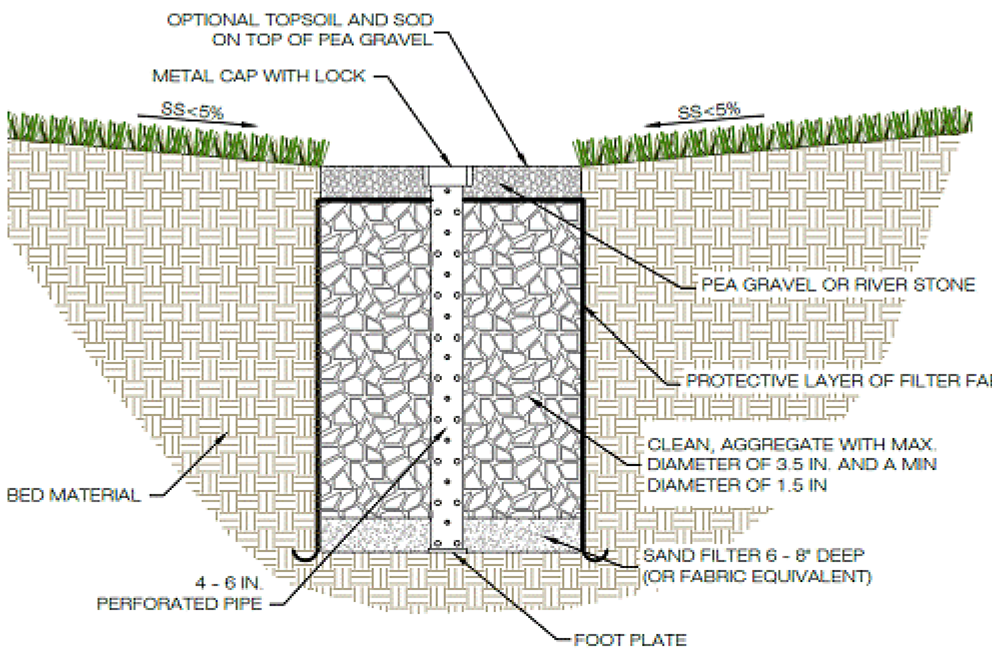
Not appropriate in areas with high pollutant or sediment loads, or steep slopes.

Should be installed in conjunction with a vegetated filter strip or swale.

Must be registered with the DEQ when used in commercial settings.

Infiltration Trenches

Overview: Infiltration trenches consist of an excavation filled with washed angular stone (and may include perforated pipe), surrounded by a geotextile fabric to prevent fines intrusion. The stone trench generally contains about 40% void space, which is used to temporarily store runoff before it infiltrates into the subsurface or continues downstream through an appropriate overflow outlet. Infiltration trenches often include perforated pipe, which increases the capacity of this LID. Infiltration trenches should include swales, filter strips or other pretreatment devices to remove silt and debris to prevent clogging of the pore space.



VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 8 INFILTRATION PRACTICES, www.vwrrc.vt.edu/swc/april_22_2010_update/DCR_BMP_Spec_No_8_INFILTRATION_Final_Draft_v1-8_04132010.htm.

Application: Infiltration trenches should not be used where the bottom of the trench is within 2 feet of the seasonally high water table (to ensure significant head for infiltration and to prevent groundwater contamination). A geotechnical engineer should be consulted before installing an infiltration trench near a steep slope, or in close proximity to building foundations or drinking water wells. (Virginia DEQ, 2011) (Metropolitan Council of the Twin Cities Area, 2001). Infiltration trenches are most effective for infiltrating water from rooftop runoff or from small impervious surfaces with light sediment loads and minimal oil and grease buildup (small parking lots). They should not be used to drain pervious areas since pervious areas will contribute silts which will clog the system. Infiltration trenches are viable options where the measured soil permeability rate exceeds ½ inch per hour (Virginia DEQ, 2011).

Construction: When used in a commercial setting, infiltration trenches are considered a Class V UIC Storm Water Drainage Well. Owners of all UIC Class V wells are required by federal and state regulation to submit inventory information. This submittal includes an inventory review fee at the time of initial

LID Summary

Infiltration Trenches

Cost

$4.00 per cubic feet of water storage.

$$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	80-100%
Total Phosphorous (TP)	40-60%
Total Nitrogen (TN)	40-60%
Copper (Cu)	-
Zinc (Zn)	80%
Petroleum Hydrocarbons	-

Maintenance

Trenches should be cleared of debris and obstructions regularly.

Observation wells should be installed to monitor drawdown.

inventory submission for each subclass of Class V injection well at each facility location (Utah Department of Enviornmental Quality, 2018).

During construction, the trench site should be excavated to an appropriate depth and lined with a filter fabric to prevent fines intrusion and encourage pollutant removal. The subgrade should not be compacted. The trench should include an observation well (vertical perforated pipe with a lid at the surface) so that water levels and infiltration rates may be monitored. The base of the excavation should consist of a 6-8” thick sand filter beneath the backfill of washed angular stone. The stone layer may include perforated pipe, which will create additional void space, increasing system capacity. The stone should be covered with a permeable filter fabric and then a layer of pea gravel or river stone. This LID should include a pretreatment structure such as a grass channel or filter strip, a grassed swale, or a sediment forebay. These devices help remove silts from the stormwater, preventing clogging of the infiltration trench, and reducing maintenance requirements. When used to drain small parking lots, the system should be designed such that sheet flow runs of the pavement over a vegetated filter strip onto the infiltration trench, where it will fill the pore space and infiltrate into the subsurface.

Cost: Typical cost to install an infiltration trench is approximately $4.00 per cubic foot of runoff storage. This includes materials, excavation, backfill, and labor costs (Southeastern Wisconsin Regional Planning Commission (SWRPC), 1991).

Pollutant Removal: The Department of Environmental Resources (DER) reports that infiltration trenches filter out 80-100% of TSS, 40-60% total Phosphorous, 40-60% total Nitrogen, 80-100% Zinc, and 80-100% Lead (Department of Environmental Resources: The Prince George's County, Maryland, 2007). The Pennsylvania DEP reports that infiltration trenches filter 85% TSS, 85% TP, and 30% NO3 as the stormwater infiltrates through the base of the trench and percolates through the soil (PA DEP (Pennsylvania Department of Enviornmental Protection), 2006).

Maintenance: Infiltration trenches must be cleared of obstructions, debris, and trash on a regular (monthly recommended) basis. The trench observation well should be checked after storm events to ensure that water is draining from the system. The area should be checked for erosion around the inflow in order to avoid silt clogging of the system.

References

Department of Environmental Resources: The Prince George's County, Maryland. (2007). *Bioretention Manual.*

Metropolitan Council of the Twin Cities Area. (2001). *Bioretention Manual.* Minneapolis, MN: Barr Engineering Company.

PA DEP (Pennsylvania Department of Enviornmental Protection). (2006). *Pennsylvania Stormwater Best Management Practices Manual.* Harrisburg, Pennsylvania: Pennsylvania Department of Environmental Protection.

Virginia DEQ. (2011). *Infiltration Practices.*

LID Summary
Dry Wells

Overview
Temporarily stores and infiltrates storm water. Most appropriate for residential rooftop runoff.

Advantages
Capable of retaining 90th percentile storm on-site.

Underground construction preserves land for other uses.

Takes up little space.

Limitations
Not appropriate in high water table areas.

Requires an overflow structure that drains to public storm water.

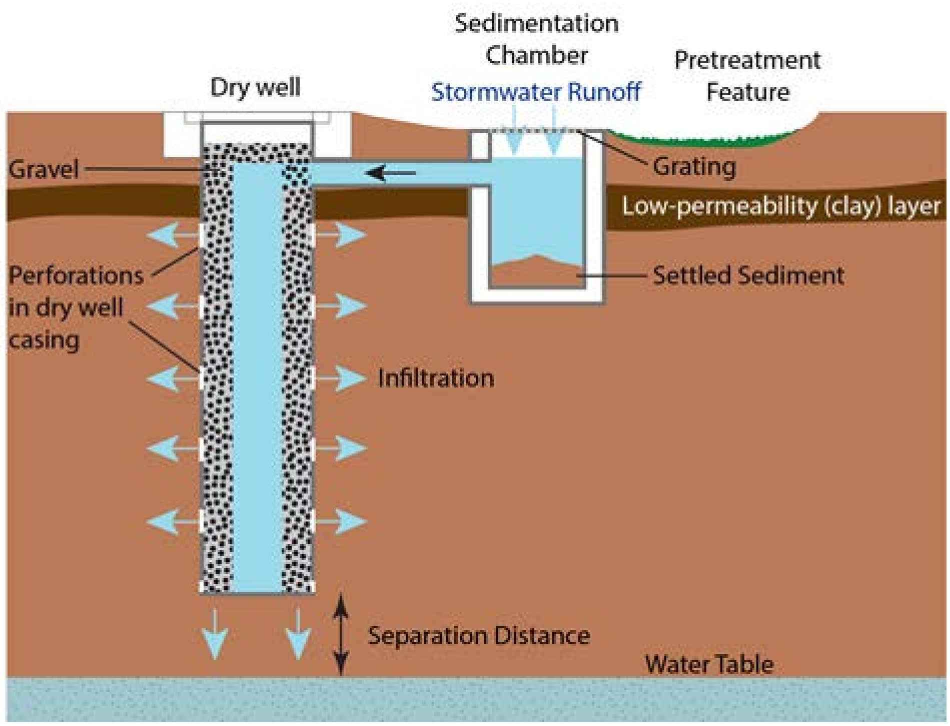
Not appropriate in areas with high pollutant or sediment loads.

Should not be used in soils with low permeability.

Must be registered with the DEQ when used in commercial settings.

Dry Wells

Overview: Dry wells are excavated pits filled with aggregate stone or perforated pipe to hold water until it can infiltrate into the ground. They should be designed with emergency overflow structures that drain to public storm water conveyances to accommodate runoff from major storms. Dry wells should be installed near the downspouts from roofs in order to infiltrate rooftop runoff into the ground. Dry wells are generally designed for smaller stormwater volumes, and thus are most applicable to residential settings.



"Dry Wells for Stormwater Management." American Geosciences Institute, 6 Apr. 2018, www.americangeosciences.org/critical-issues/factsheet/dry-wells-stormwater-management.

Application: Dry wells have a very small footprint and so can be used effectively in areas with limited space. Dry wells are mid-range cost and can be used to temporarily store and infiltrate storm water, providing groundwater recharge. Dry wells are appropriate for soils with an infiltration rate of at least 0.3 inches/hour (County of Los Angeles Department of Public Works, 2014). Dry wells should not be used in areas where the seasonally high water table is within 2 feet of the bottom of the well (to prevent groundwater contamination), or beneath the drip line of trees (trees will drop leaves and other debris which could clog the system). A geotechnical engineer should be consulted before placing dry wells near foundations or wells. Dry wells are ideal for infiltrating rooftop runoff. The dry well infiltration system should include pretreatment devices such as leaf guards, filter strips, vegetated swales, or sediment forebays to remove sediment and debris, which could clog the system. Dry wells can be designed as entirely gravel, or consisting of perforated metal, plastic, or concrete pipe surrounded by gravel, which allows for more storage space.

Construction: If used in a commercial setting**,** dry wells are considered a Class V UIC Storm Water Drainage Well. Owners are required by federal and state regulation to submit inventory information, which includes an inventory review

LID Summary
Dry Wells

Cost
$300-$5,000 per residential dry well.

$$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	90%
Total Phosphorous (TP)	60%
Total Nitrogen (TN)	55%
Copper (Cu)	-
Zinc (Zn)	-
Petroleum Hydrocarbons	-

Maintenance
Dry wells should be monitored for erosion and for the accumulation of sediment or debris.

Observation wells should be installed to monitor drawdown.

fee at the time of initial inventory submission for each subclass of Class V injection well at each facility (Utah Department of Enviornmental Quality, 2018).

Dry wells must include a geotextile fabric above, beneath, and around the system in order to prevent fines intrusion and system clogging. The well consists of 6 inches of sand at the base, which will serve as a preliminary filter for water infiltrating from the well. Above the sand layer is several feet of clean, washed gravel, which should have a void ratio of approximately 40%. Dry wells can be designed to receive storm water either from above the well through a layer of pea gravel and then geotextile, or through a subsurface pipe. If a subsurface pipe is used, the pipe must include a fine mesh screen to prevent fines from entering the well and clogging storage pore space. Dry wells should also include a perforated monitoring pipe in order to monitor infiltration and water levels in the system. As appropriate, the dry well should include an overflow structure to pass flow from large storm events downstream.

Cost: Dry wells are a relatively cheap LID option. A 5 ft deep, 5 ft diameter dry well filled with stone could store approximately 40 cubic feet of water (300 gallons). This would store the runoff from approximately 500 square feet of roofing during a 1” storm event. If a plastic, metal, or concrete storage chamber was used for increased storage, the well would have significantly larger capacity. Depending on the size, type of well, and material used, dry well costs can range from $300-$5,000. The city of Portland, OR estimates costs for a dry perforated pipe dry well between $1,200 and $1,500 per well (Department of Environmental Services).

Pollutant Removal: Studies indicate that dry wells effectively reduce 90% of runoff, and remove 90% TSS, 55% TN, and 60% TP (Winer, 2000). These pollutants are filtered out by the ground as the water percolates down through the soils to the water table.

Maintenance: One advantage of dry wells is that they require minimal maintenance. Observation wells should be regularly inspected after storm events to ensure that water drains and infiltrates out of the system. The area around the well should also be checked for erosion, and sediment or debris accumulation. Any sediment or debris should be removed and eroded areas should be repaired. System performance can be enhanced, and maintenance reduced, by placing gutter guards or screens on top of roof downspouts to filter out leaves and sediment before the stormwater reaches the dry well.

References
County of Los Angeles Department of Public Works. (2014). *Low Impact Development Standards Manual.* Los Angeles, CA.

Department of Environmental Services. (n.d.). *Stormwater Solutions Handbook.* Portland, OR.

Winer, R. (2000). *National Pollutant Removal Performance Database for Stormwater Treatment Practices. 2nd Edition.* Elliot City, MD: Center for Watershed Protection.

LID Summary
Bioswales

Overview
Swales remove pollutants, reduce velocities, and partially infiltrate runoff as water is conveyed to further storm water structures.

Advantages
Swales are cheap and easy to construct.

Swales can effectively pre-treat water before entering other LID structures.

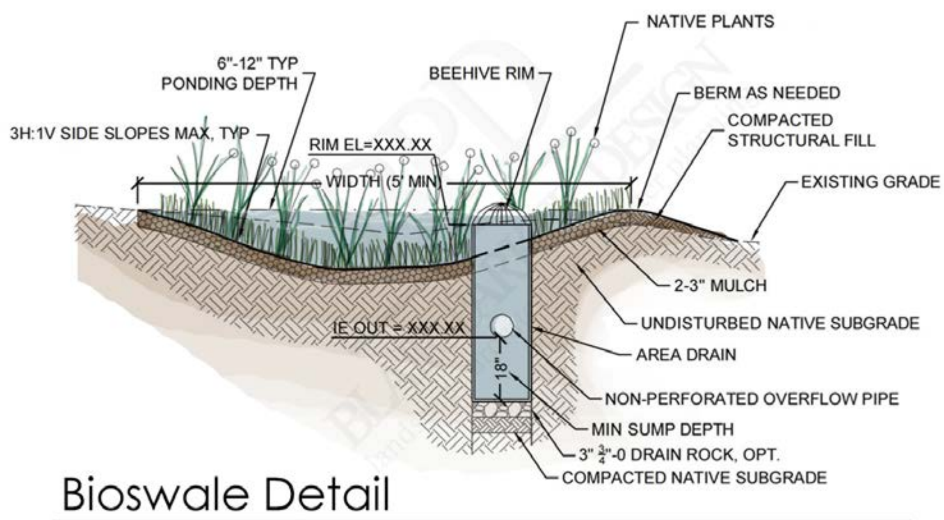
Limitations
Not appropriate in high water table areas.

Impractical in areas with steep slopes or very flat grades.

On steeper slopes, check dams, filter berms, or weirs should be included to reduce velocity and encourage infiltration.

Bioswales

Overview: Vegetated channels and grassed swales can be used in lieu of traditional curb and gutter and subsurface piping to convey storm water runoff. Swales consist of a shallow trough-like vegetated depression underlain by at least 24 inches of permeable soil, with side slopes not exceeding 3:1 slope. The swale should include dense, low-growing native vegetation that is drought tolerant, can handle subsidence, and provides substantial pollutant removal. Simple grass swales are less expensive, but provide far less infiltration and pollutant removal than vegetated swales. Unlike conventional systems, vegetated swales slow the erosive velocity of the storm water, increase time of concentration, filter pollutants such as sediment, and infiltrate a portion of the runoff volume. The inlet and outlet structures of swales should be carefully designed to prevent erosion, scouring, and the accumulation of standing water for more than 48 hours.



"20140613 Bioswale Detail." Blair Parker Design Landscape Architecture, www.blairparkerdesign.com/wordpress/sustainable-site-design/20140613-bioswale-detail/.

Application: Bioswales can be effectively used to initially treat and convey runoff to bioretention areas or infiltration structures, and are applicable in residential, industrial, and commercial settings, as well as along highways, roads, or parking lots. Swales are impractical for areas with very flat grades or steep slopes, and should be used to serve an area of less than 10 acres, with slopes no greater than 5% and no less than 1% (University of Florida IFAS Extension, 2008). Swales with slopes exceeding 3% should include filter berms, check dams, or weirs perpendicular to the flow to reduce flow velocity, facilitate storage volume, and extend treatment and infiltration time (PA DEP (Pennsylvania Department of Enviornmental Protection), 2006). Vegetated swales should not be installed in areas with high water tables where groundwater reaches the bottom of the swale.

Construction: Vegetated swale construction should occur only after upstream erosion and sediment control measures are in place in order to prevent clogging of the swale by silts. First, the swale should be rough graded, avoiding excessive compaction. Where substantial compaction occurs, or in poor draining soils, the

LID Summary

Bioswales

Cost

$4.50-$8.50 per linear foot for a 15 ft wide swale.

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Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	81%
Total Phosphorous (TP)	10-65%
Total Nitrogen (TN)	40%
Copper (Cu)	-
Zinc (Zn)	88%
Petroleum Hydrocarbons	82%

Maintenance

Swales should be inspected for bare areas and reseeded as necessary.

Vegetation must be irrigated during dry periods.

first 18 inches of soil should be removed and replaced with a blend of topsoil and sand to promote infiltration and plant growth (PA DEP (Pennsylvania Department of Enviornmental Protection), 2006). Check dams should then be installed as required. The swale should then be fine graded and then seeded and vegetated. Vegetation should consist of dense, drought and salt tolerant, water-resistant plants such as Western Wheatgrass or Salt grass (Pratt, 2018).

Cost: In general, vegetated swales are considered a low-cost LID. A fifteen feet wide vegetated swale will typically cost from $4.50-$8.50 per linear foot (Pennsylvania DEP).

Pollutant Removal: The University of New Hampshire reports reduction of 81% total suspended solids (TSS), 82% total Petroleum Hydrocarbons in the Diesel Range (TPH-D), and 88% Total Zinc (Zn) for vegetated swales. The same study found that stone (or rip-rap) swales reduce 50% TSS, 33% TPH-D, and 64% total Zn (University of New Hampshire Stormwater Center (UNH), 2009). The American Water Resources Associtaiton found that swales remove 40% of TN (Koch, 2014). Pollutants are filtered by the vegetation and by contact with the soil in slower sheet flow. Wider, milder sloped swales will provide higher filtration rates. Sediment, pollutants, and suspended solids settle out of the stormwater as the vegetated swales slow velocities and increase time of concentration. Increased contact time between the stormwater and the plants and soils will enhance filtration.

Maintenance: Swales should be periodically inspected to ensure the successful establishment of plants and grasses. Any bare areas should be reseeded and appropriate erosion control measures should be taken if erosion channels begin forming. Check dams should be monitored and inspected for signs of erosion or channelization. During dry periods, swale vegetation should be watered. If swales convey parking lot or roadside runoff, mulching and/or soil aeration may be required in the spring to restore soil structure and moisture capacity and to reduce the impact of deicing agents (PA DEP (Pennsylvania Department of Enviornmental Protection), 2006).

References

Koch, B J. (2014). Nitrogen Removal by Stormwater Management Structures. *Journal of American Water Resources Association.* (2014). Vol 50, no. 6

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LID Summary

Vegetated Filter Strips

Overview

Filter strips slow erosive velocities, remove sediment and pollutants, and partially infiltrate runoff. They are well-suited for low-density development areas.

Advantages

Filter strips effectively pre-treat runoff before entering infiltration or conveyance structures.

Filter strips are cheap, easy to construct, and require little maintenance.

Limitations

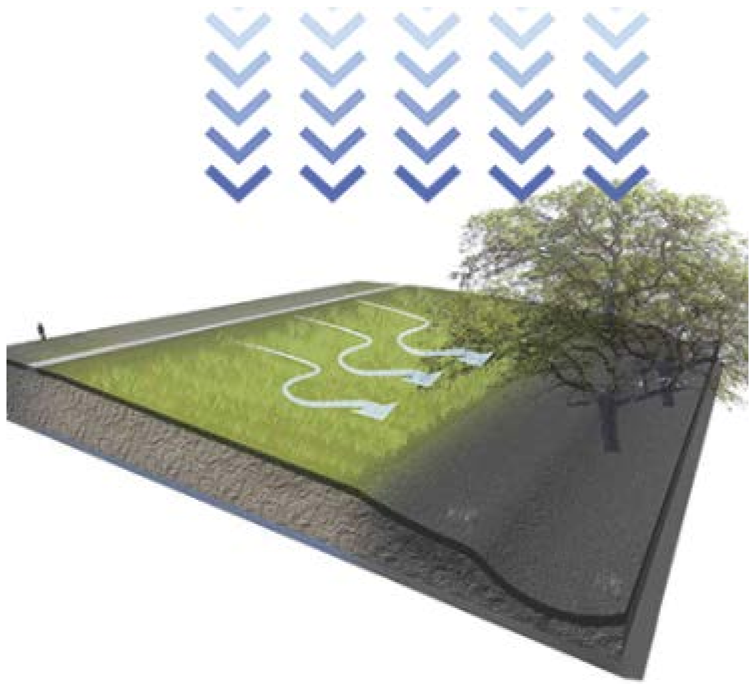
Not suitable for steep slopes.

Requires other LID structures to meet on-site retention requirements.

Requires irrigation.

Vegetated Filter Strips

Overview: Vegetated filter strips are low sloped vegetated strips bordering parking lots or other impervious areas, used to slow erosive velocities and filter sediment and pollutants. Vegetated filter strips are well suited for low-density developments or areas with less concentrated amounts of runoff. They function by using soil and vegetation to remove pollutants from stormwater runoff, and often are incorporated to pre-treat and remove sediment before water enters infiltration devices such as bioretention areas, infiltration trenches, or vegetated swales.



Low Impact Development (LID) Toolbox - Houston-Galveston Area Council (H-GAC), www.h-gac.com/community/low-impact-development/lid-toolbox.aspx.

Application: Vegetated filter strips are used to minimize flow velocities and filter sediments and associated nutrients, and other pollutants from sheet flow runoff from impervious surfaces. Usually, a vegetated filter strip is used as a pretreatment component to reduce sediments and particulate pollutant load before runoff reaches the primary stormwater BMP (best management practice), such as bioretention, vegetated swale, or infiltration trench; the dense vegetation, grasses and/or woody plants, of the filter strip slows runoff to allow for sediments and particulates to settle out (U.S. Army Corps of Engineers Engineer Research and Development Center, 2013). Vegetated filter strips are best suited for low density developments where space is not a premium. Advantages of filter strips include easy installation, little maintenance requirements, and reduced peak flow during small storm events. Filter strips are not suitable for steep slopes, can be susceptible to erosion in high flows, and require irrigation.

Construction: Vegetated filter strips should be constructed such that the filter strip receives water as sheet flow. Channelized flow will erode and scour the filter strip and limit pollutant removal efficiency. Filter strips should include a narrow, shallow gravel trench on their receiving end to spread runoff into sheet

LID Summary

Vegetated Filter Strips

Cost

Filter strips are comparable in price to traditional landscaping costs.

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Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	70%
Total Phosphorous (TP)	45%
Total Nitrogen (TN)	40%
Copper (Cu)	-
Zinc (Zn)	-
Petroleum Hydrocarbons	-

Maintenance

Debris or sediment should be removed to prevent blocking of flow.

Filter strips should be mowed as needed and irrigated during the dry season.

flow, dissipate energy, and minimize erosive potential (County of Los Angeles Department of Public Works, 2014). Filter strips consist of uncompacted moderately permeable soils evenly graded (to prevent channelization) on lateral slopes (parallel to the pavement edge) of less than 4% and slopes (parallel to flow) of less than 5% (County of Los Angeles Department of Public Works, 2014). The surface layer should consist of compost mixed with native soils, vegetated with dense native grasses.

Cost: Vegetated filter strips are a low cost LID, comparable in price to traditional landscaping costs.

Pollutant Removal: Filter strips function best when flow is evenly spread in a thin layer over the surface amidst the vegetation. Generally, filter strips can remove 70% TSS, 40% TN, and 45% TP (Winer, 2000). Filter strips can effectively infiltrate and reduce runoff during small storm events, but do not generally reduce significant amounts of runoff during large storm events.

Maintenance: Maintenance of vegetative filter strips includes removal of debris or sediment from the level spreader in order to prevent blocking of flow. Filter strips should be mowed as needed and irrigated during the dry season. Filter strips should be repaired if damaged by erosion, or if channels begin to form. Channelization compromises the purpose of this LID by reducing the surface area of interaction between the stormwater runoff and the plants and soil, which provide treatment and reduce runoff velocity.

References

County of Los Angeles Department of Public Works. (2014). *Low Impact Development Standards Manual.* Los Angeles, CA.

U.S. Army Corps of Engineers Engineer Research and Development Center. (2013). *Army Low Impact Development Technical User Guide.* Office of the Assistant Chief of Staff for Installation Management.

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LID Summary
Tree Filters

Overview
Tree filters filter, evapotranspirate, and infiltrate storm water runoff.

Tree filters can be effectively used in small spaces to treat relatively large impervious areas.

Advantages
Capable of significant runoff volume reduction.

Require very little space. Easily incorporated into site plans.

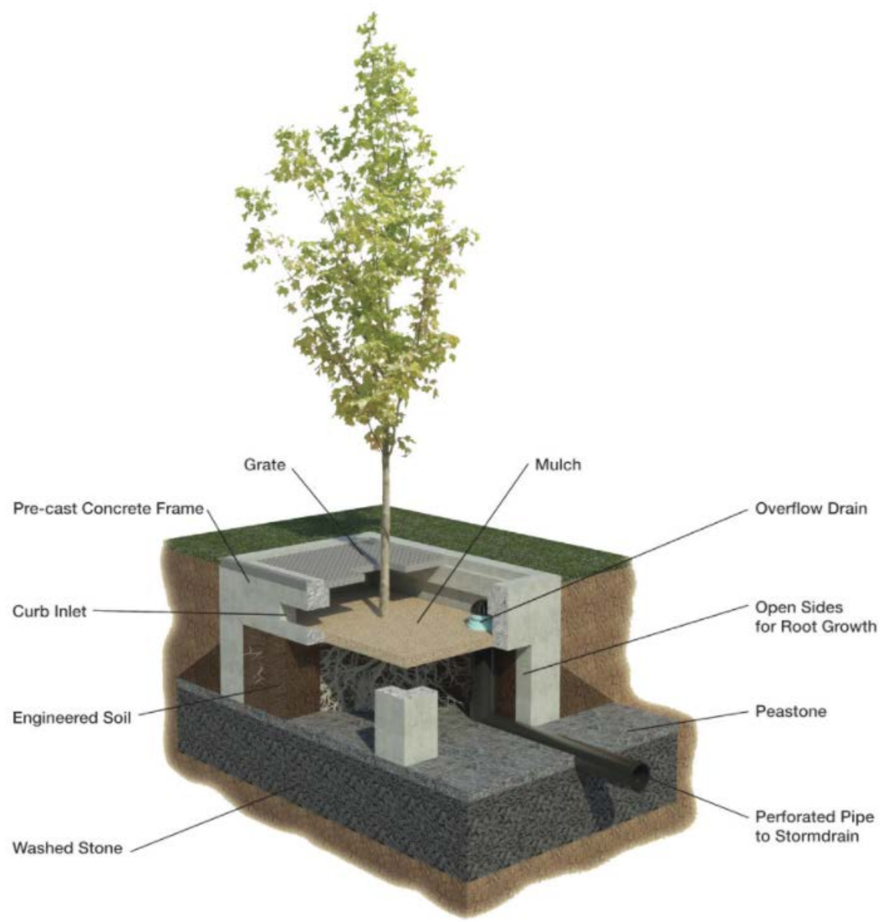
Effective pollutant removal.

Limitations
Trees requires supplemental irrigation.

Must be designed well to allow for growth of the tree root structure.

Tree Filters

Overview: Tree filters consist of a curb inlet that flows into the root space of a decorative planter tree. These trees appear no different than traditional street planter trees, but provide additional benefit by filtering stormwater and reducing runoff volumes. Tree filter designs vary widely, from single tree structures to tree trenches, where multiple trees in a line are connected by underground infiltration, which maximizes filtration and runoff reduction. Though small, tree filters are able to treat a surprising amount of runoff, and are able to completely handle the runoff from most small storm events (University of New Hampshire Stormwater Center (UNH), 2016). Tree filters are a relatively simple, spatially efficient, aesthetically pleasing LID that treats, filters, evapotranspirates, and partially infiltrates stormwater runoff.



Niantic River Watershed, www.nianticriverwatershed.org/our-programs/water-quality-management/stormwater-management/current/.

Application: Tree filters are extremely useful in urban, down-town, or dense residential areas where little open space is available for other LID. “They can be installed in open-bottomed chambers in locations where infiltration is desirable, or in close-bottomed chambers if infiltration is impossible (clay soils) or undesirable (high groundwater or contaminated soils). These chambers can include lateral openings or be combined with structural cells to provide soil and space for root growth under sidewalks and other pavements.” (University of New Hampshire Stormwater Center (UNH), 2016) They are very effective for the removal of many common pollutants.

LID Summary

Tree Filters

Cost

$3,000 - $20,000 per tree filter box.

$$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	90%
Total Phosphorous (TP)	-
Total Nitrogen (TN)	40%
Copper (Cu)	-
Zinc (Zn)	78%
Petroleum Hydrocarbons	99%

Maintenance

Trees must be irrigated during dry seasons.

Trees should be weeded and sediment should be removed as needed.

Construction: Tree filters are installed directly behind curb inlets and should be designed to overflow to the storm drain. After excavation, an open sided (to allow for root growth) concrete box is installed, which includes the inlet to the system. The tree is planted in the box amidst soils engineered for infiltration and plant growth. These soils typically include a mixture of sand, organic material, and top soil, which will allow for infiltration and healthy tree growth. A layer of mulch should be installed over the uncompacted engineered soils. The tree filter box should include an overflow pipe that will allow runoff to quickly drain if water accumulates too high in the box.

Cost: The cost of tree filters ranges from roughly $3,000 to more than $20,000 for the pre-manufactured tree filter box, planting of the tree, and placing of the soil and aggregate.

Pollutant Removal: "Physical, chemical and biological processes allow for pollutant removal sustainability. The primary treatment mechanisms used in tree box filters are inert and reactive filtration, coupled with various inter-storm treatment processes such as microbial- and phytoremediation. The majority of particulates or particulate-bound contaminants are filtered by the mulch surface, with the engineered filter media below primarily responsible for dissolved contaminant removal. Contaminant degradation and assimilation by microbes and plants provide adsorption site regeneration. Ponding space above the mulch allows for the capture of trash and debris." (Stormwater Equipment Manufacturers Association, 2015)

Maintenance: Maintenance is generally simple: removing litter, raking, and removal of sediments on the filter media. In Utah, stormwater will not be sufficient to irrigate the tree filter and supplemental irrigation will be required in order to maintain healthy trees.

References

Stormwater Equipment Manufacturers Association. (2015). Tree Box Filters. *StormwaterAssociation*, 1.

University of New Hampshire Stormwater Center (UNH). (2016). *Annual Report.* Durham, NH.

LID Summary
Bioretention Basins

Overview
Bioretention basins are shallow depressions filled with engineered soils and vegetation used to retain, treat, and infiltrate water.

Advantages
Capable of retaining 90th percentile storm on-site.

Bioretention basins remove pollutants and infiltrate and evapotranspirate water.

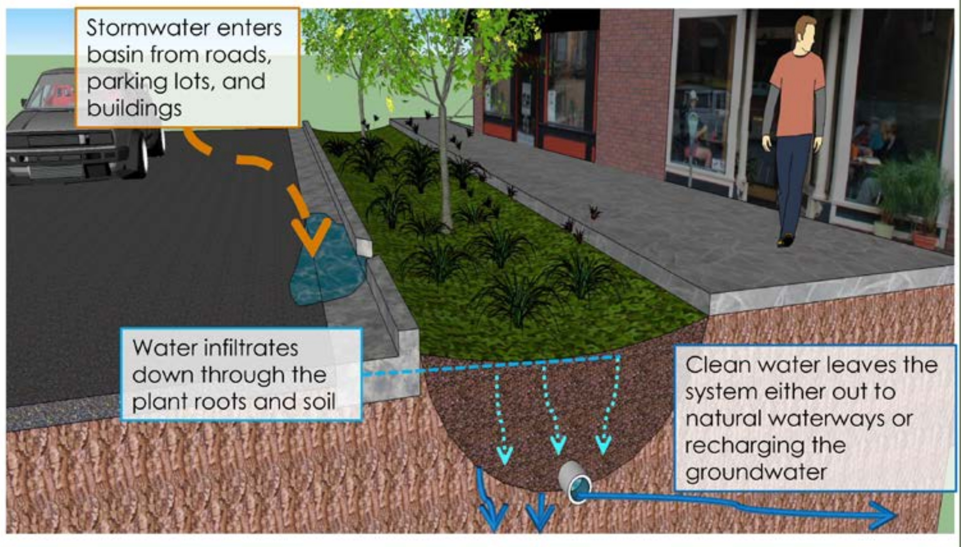
Limitations
Not appropriate in high water table areas.

Bioretention basins should be designed to drain water within 24 hours to prevent mosquito breeding.

Underdrains should be used in low permeability soils.

Bioretention Basins

Overview: Bioretention areas are shallow, topographic depressions filled with engineered soils and vegetation that retain, treat, and infiltrate water. These can be used in all different types of developments. In residential developments, the basin should be located a distance away from houses to increase flow paths and treat runoff from rooftops and driveways.



"TourGuide." Stops, tourguide.cal.msu.edu/stops/view/51a7aaf4-0c14-4451-bd21-6cc92308e069.

Application: Bioretention basins can be used on a wide variety of scales, from a small parking lot to suburban parks to treating roadway runoff. In areas where a large runoff area is treated, it is recommended to also include other treatment measures before the water reaches the bioretention basin, for example vegetated strips and swales. These will help capture sediment and reduce the frequency of maintenance on the bioretention basin (University of Florida IFAS Extension, 2008). Bioretention areas should ideally receive runoff as sheet flow to minimize erosion and maximize pollutant removal. If the basin is going to treat pollutant from significant sources, bioretention basins should not be installed in areas with a high water table, as this could lead to pollution of the ground water. Sufficient depth of the water table is needed to ensure enough contact time between stormwater and soil to filter out pollutants.

Construction: When constructing a bioretention basin, if groundwater levels are well below the basin bottom and the soils are well drained (class A or B), an under drain is not required. However, in areas where soils have low conductivity, excavating the site, lining with geotextile fabric, and installing an underdrain in a gravel bed is the first step in construction. A thin 6" layer of sand should be over the gravel layer, with approximately two feet of planting soil (consisting of sand, organics, and minimal fines) over the sand (New Jersey Department of Environmental Protection, 2009). If an underdrain is not used, the bioretention basin should include two feet of planting soil to support vegetation. Vegetation should ideally include native plants, avoiding woody shrubs and large trees, which would shade the area too heavily and limit infiltration and evapotranspiration (University of Florida IFAS Extension, 2008).

LID Summary
Bioretention Basins

Cost
$3.00-$15.00 per square foot.

$$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	69%
Total Phosphorous (TP)	65%
Total Nitrogen (TN)	40%
Copper (Cu)	99%
Zinc (Zn)	90%
NO3-N	75%

Maintenance
Mulch should be replaced every 2-3 years.

Planter must be weeded regularly and cleared of debris, vegetative litter, and sediment deposits.

Bioretention basins should ideally be placed in a natural low spot with good infiltration rates. Planners should strive to design bioretention and other LID structures to limit disturbance of the natural terrain and to take advantage of beneficial elements of the natural topography. When designing the basin, ponding depth (calculated based on inflow rate, ponding volume available, and soil characteristics) should not exceed 12 inches (for various reasons, including safety, plant inundation, and drainage). The system should include an overflow drain to limit ponding to the appropriate depth. The duration of ponding should not exceed 24 hours to prevent mosquito infestations and other hazards. The retention basin should be built at least 10 feet from any building to avoid moisture around the buildings foundation, and away from any septic system.

Cost: Typical costs for bioretention areas are from $3-$15 per square foot (depending on current soil conditions, locations, etc.). Bioretention basins make up for their cost by significantly reducing costs for storm drain pipes, inlets, and detention ponds. Bioretention areas can also be used as landscape elements (University of Florida IFAS Extension, 2008).

Pollutant Removal: Pollutant removal is one of the main selling points of a bioretention basin. Between the vegetation and engineered soils, most pollutants will be filtered or absorbed as the water travels through. During testing in North Carolina, it was found that bioretention basins reduced Total Nitrogen by 40%, NO3-N by 75%, Total Phosphorous by 65%, Zn by 90%, Cu by 99%, Pb by 81%, and Total Suspended Solids by 69% (North Carolina Division of Water Quality (NCDWQ), 2007).

Maintenance: If not maintained properly, the storage capacity of the bioretention basin can be compromised as silts accumulate and clog the system. In order to maintain it, regular inspections must occur, with the inspector looking for signs of erosion, sediment deposits, and vegetative litter (human litter can also negatively affect the capacity of a bioretention basin). Mulch should be replaced every 2-3 years (mulch helps prevent erosion, filter pollutants, limit weed growth, and increase plant health). New plants may occasionally need to be replanted, and weeds may need to be pulled. Gravel can be considered around plants to reduce growth of unwanted vegetation (University of Florida IFAS Extension, 2008). The bioretention area must be irrigated and weeded to maintain healthy vegetation. Maintenance can be minimized by incorporating swales, filter strips, or sediment forebays to capture sediment before it enters the bioretention basin.

References
New Jersey Department of Environmental Protection. (2009). *New Jersey Stormwater Best Management Practices Manual: Bioretention Systems.*

North Carolina Division of Water Quality (NCDWQ). (2007). *Stormwater Best Management Practices Manual.* Raleigh, NC.

University of Florida IFAS Extension. (2008). *Florida Field Guide to Low Impact Development.*

LID Summary
Rain Gardens

Overview
Rain Gardens treat rooftop runoff through pollutant removal, evapotranspiration, and infiltration.

Effective for residential and non-residential roofs.

Advantages
Rain gardens can be used to effectively treat and capture rooftop runoff.

Aesthetic appeal.

Rain Gardens do not require pre-treatment.

Simple design.

Limitations
Requires supplemental irrigation during dry periods between storms.

May require soil amendments in clay soils with low permeability.

Rain Gardens

Overview: Rain gardens are constructed near roof downspouts and consist of shallow depressed areas with layers of compost or mulch and native plants used for evapotranspiration. Studies indicate that rain gardens can function well even in clay soils if they are designed properly to avoid clogging, using proper plants, and using soil amendments as necessary to improve permeability. Rain gardens are effective for pollutant removal, infiltration, and evapotranspiration. Rain gardens are similar in function to bioretention basins, but on a smaller scale, often serving just one building or household.

"What Is a Rain Garden?" Kitsap Conservation District, 18 July 2016, kitsapcd.org/programs/raingarden-lid/rgbasics.

Application: In a new residential development, rain gardens will typically be constructed to treat, infiltrate, and evapotranspirate rooftop runoff from individual housing units. Rain gardens can also be used in other non-residential settings to treat and evapotranspirate rooftop runoff. Rain gardens should be combined with the overall landscaping plan, and be aesthetically pleasing. Rain gardens function very similarly to a bioretention basin but on a smaller scale.

Construction: Rain gardens are very similar to bioretention basin, but on smaller and less complex scale. Put simply, a rain garden is a "depressed area in the landscape that collects rain water from a roof, driveway or street and allows it to soak into the ground" (Environmental Protection Agency, 2018). Rain gardens are typically constructed near rooftop downspouts. Runoff typically enters the garden via a stone, concrete, or rip rap spillway at the base of the downspout, which will slow erosive flow, dissipate energy, and diffuse the water over a larger area. Runoff could also be routed to the garden over a filter strip or swale, which would provide initial pollutant removal and reduce sediment load on the rain garden. A rain garden for an individual home does not need to have an underdrain, nor any other complex features, but sandy soil with a high infiltration rate does help with infiltration. A typical rain garden should include vegetation in a surface layer of mulch, over a two-foot-thick layer of planting soil

LID Summary

Rain Gardens

Cost

$3.00-$4.00 per square foot for residential developments.

$10.00-$40.00 per square foot for commercial roofs.

$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	69%
Total Phosphorous (TP)	65%
Total Nitrogen (TN)	40%
Copper (Cu)	99%
Zinc (Zn)	90%
NO3-N	75%

Maintenance

Mulch should be replaced every 2-3 years.

Planter must be weeded regularly and cleared of debris, vegetative litter, and sediment deposits.

composed of sands, topsoil, compost and organics, over a thin layer of pea stone or gravel, which rests on the uncompacted native soil (or amended soils in clay areas). Vegetation should include decorative but hardy plants that provide water purification and aesthetic appeal.

Cost: Due to their simple design, rain gardens really cost no more than many other decorative landscaping features, and cost should not be considered to be prohibitive in its implementation. A general rule of thumb is that residential rain gardens average about $3 to $4 per square foot, depending on soil conditions and the density and types of plants used (Coffman, 1999). Commercial, industrial and institutional site costs can range between $10 to $40 per square foot, based on the need for control structures, curbing, storm drains and underdrains.

Pollutant Removal: as stormwater enters the rain garden, the plants and the mulch layer filter it first. This layer generally filters heavy metals and suspended solids. As the water begins infiltrating and runs through the soil and through the plant's roots, more pollutants are filtered and absorbed by the roots. Some of the stormwater pollutants (such as Nitrogen, Phosphorous, and Nitrates) are essential nutrients for the plants. Rain gardens filter and absorb pollutants similarly to bioretention basins, with reductions of Total Nitrogen by 40%, NO3-N by 75%, Total Phosphorous by 65%, Zn by 90%, Cu by 99%, Pb by 81%, and Total Suspended Solids by 69%. (North Carolina Division of Water Quality (NCDWQ), 2007)

Maintenance: Rain garden maintenance is similar to maintenance for a simple planter garden. Similar to the bioretention basin, rain gardens need to occasionally be weeded, and cleared of leaf litter and other biomass that might inhibit its ability to absorb water. Large accumulation of sediment or debris can cause clogging, which compromises the system. Rain gardens must be irrigated during dry seasons to maintain healthy vegetation. Rain gardens should also be mulched to prevent weed growth, to reduce erosion, to enhance filtration of pollutants, and to increase plant health(North Carolina Division of Water Quality (NCDWQ), 2007).

References

Coffman, L. R. (1999). Low Impact Development: An Innovative Approach to Stormwater Management. *Proceedings of the 26th Annual Water Resources Planning and Management Conference ASCE.* Tempe, AZ: WRPMD.

Environmental Protection Agency. (2018, April 5). *Soak Up the Rain: Rain Gardens*. Retrieved from EPA.gov: https://www.epa.gov/soakuptherain/soak-rain-rain-gardens

North Carolina Division of Water Quality (NCDWQ). (2007). *Stormwater Best Management Practices Manual.* Raleigh, NC.

LID Summary

Pop-up Emitters

Overview

Pop-up emitters disperse stormwater over an area of the lawn so that it can effectively infiltrate.

Advantages

Simple, cheap design and implementation.

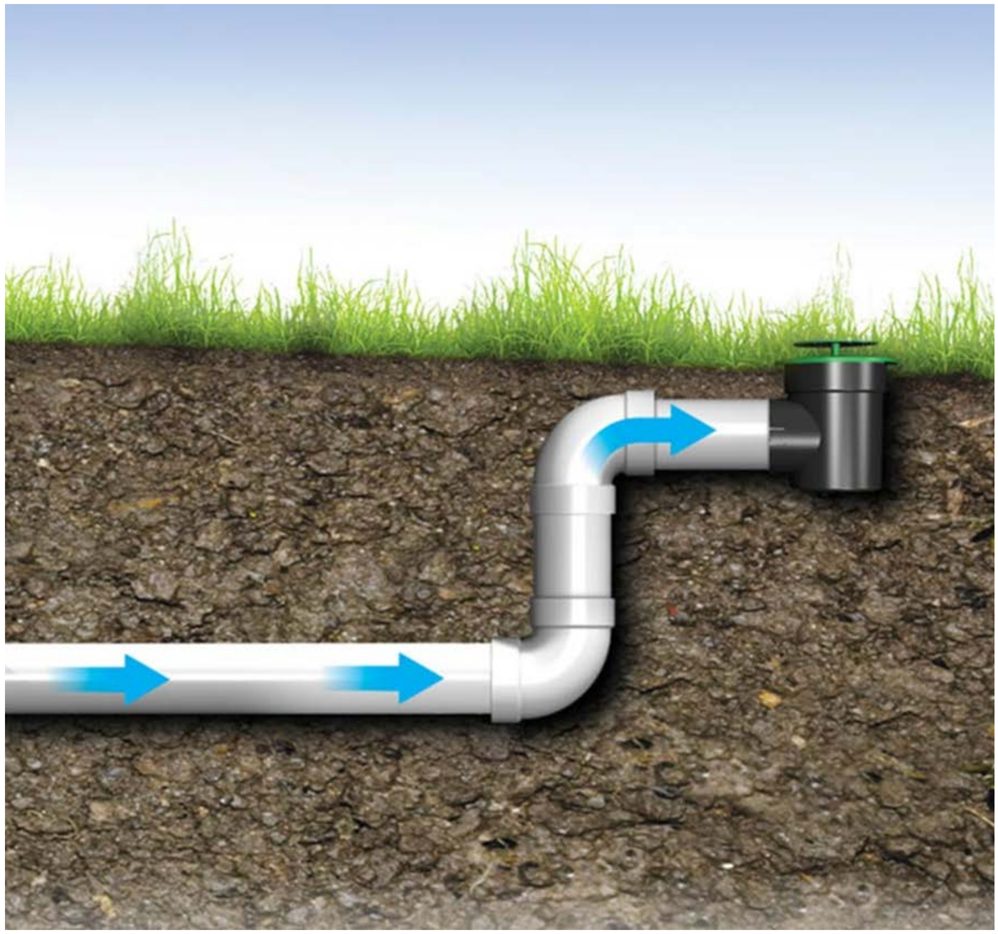
Water is treated as it seeps through the lawn into the underlying soils.

Limitations

Pop-up emitters may not function well in freezing temperatures.

Pop-up Emitters

Overview: Pop-up emitters disperse rainwater from rooftop gutters throughout the lawn. PVC pipe runs from the roof downspout to the pop-up emitter, which pops up as pressure increases, spreading the water over an area of the lawn. These emitters are useful for soils with poor drainage.



NDS Water Management, www.ndspro.com/sustainable-stormwater-solutions.

Application: Best used in combination with water storage system (rainwater collection) so that rainwater may be utilized during dry times. If legally limited to 200 gallons of water storage (a possible situation given Utah's rainwater collection laws) an overflow can be implemented so that during a storm event that exceeds the 200-gallon capacity, water still flows through the pop-up emitters and saturates the lawn, rather than becoming heavy runoff.

Construction: Installed similarly to an ordinary sprinkler system, with lower cost and lower maintenance parts. Rooftop runoff is routed through underground PVC pipe to the pop-up emitters. As runoff increases, pressure builds in the pipe and the emitter pops up and disperses water throughout a small area of the lawn.

Cost: This system is very low cost. Dispersing rooftop runoff using pop-up emitters would cost approximately $200-$300 for a single family home.

LID Summary

Pop-up Emitters

Cost

$200-$300 per home.

$

Pollutant Removal

Pop-up emitters do not remove pollutants, but their outflow will be filtered as it infiltrates into the lawn.

Maintenance

Make sure that the pop-up emitters do not freeze shut during the winter months.

Pollutant Removal: The emitter itself does not remove any pollutants. This system captures rooftop runoff, which is lightly polluted. Pollutants will be filtered as the water dispersed from the emitter percolates downward through the soil in the lawn.

Maintenance: Maintenance will be minimal. No pump will be needed, as water pressure produced by elevation will be used to disperse the water throughout a small area of the lawn, regardless of whether the water originates directly from roof runoff or longer term storage tanks. Unlike an ordinary sprinkler system, a small leak is not a huge deal, as the water will still infiltrate into the soil in accordance with this LID. The only concern is freezing. If water pools up in the emitter, the emitter may freeze shut.

References

NDS. (2018, April 5). *ndspro.com*. Retrieved from Pop-up Emitters: https://www.ndspro.com/pop-up-emitters

LID Summary
Rainfall Capture

Overview
Store rooftop runoff in rain barrels or cisterns.

Advantages
Reduces irrigation costs by storing and reusing water.

Easy installation.

If registered with the state, the entire rooftop runoff from a 90th percentile storm event can be stored on-site.

Limitations
Persons registered with the Utah Division of Water Rights may collect and store no more than 2,500 gallons of rainwater.

Unregistered persons may collect and store no more than 200 gallons.

Rainfall Capture

Overview: Utah allows for the direct capture and storage of rainwater on land owned or leased by the person responsible for the collection. According to Senate Bill 32 (2010), a person registered with the Division of Water Rights may collect and store no more than 2,500 gallons of rainwater. 2,500 gallons is more than sufficient to retain the rooftop runoff from a single family home during the 90th percentile storm. If unregistered, no more than two containers may be used, and the maximum storage capacity of any one container shall not be greater than 100 gallons. It is important to remember that when a property exchanges ownership, the new owner must register with the Utah Division of Water Rights in order to legally utilize rainwater harvesting. Registration is a simple process and can be done by visiting the following website:

https://waterrights.utah.gov/forms/rainwater.asp

"Rainwater Harvesting Systems Installed." Above Ground Large Water Tank/Cistern Installations, Examples, Pictures - GradyBarrels, www.gradybarrels.com/tank_installs.html.

Application: A properly installed and utilized rainwater capture system can effectively eliminate runoff in a 90th percentile storm event, with a modest 1500 square foot roof (about average) producing 561 gallons of runoff in Bluffdale. A large home with a 3000+ square foot roof could still have runoff effectively managed with just a 1500-gallon tank. Large businesses and office buildings however, may struggle to capture all roof runoff with a 2500-gallon tank, with the maximum roof size being approximately 6700 square feet. Even if a structure is larger than that, however, rainwater storage is still a viable option as it will take load off of other LIDs that have been implemented in the area, all while being put to good use irrigating when it is dry. All water collected on a property may only be used on that property.

LID Summary

Rainfall Capture

Cost

2500 gallon tanks cost from $850 to $1,400.

100 gallon tanks cost approximately $100-$200.

$$

Pollutant Removal

Cisterns and rain barrels do not remove pollutants.

Maintenance

Stored water must be used or released between storm events.

Rooftop gutters must be cleared periodically.

Construction: Construction would be very simple compared to other LID options. All that would have to be done is install a tank of appropriate size (based on roof area), ensure that rain gutters all flow into the storage tank, and connect the storage tank to a pump (or just keep it elevated) and connect that to the home's sprinkler system.

Cost: For an average household, a 2500-gallon tank is approximately $850-$1,400, a 1500-gallon tank would cost approximately $750, and a 100-gallon tank typically costs $100-$200. Utilizing rainwater for irrigation or other non-potable uses will reduce future water consumption and irrigation costs.

Pollutant Removal: Cisterns and rain barrels do not remove pollutants. Water stored in these containers is suitable for irrigation, flushing toilets, washing cars, and various other uses, but should not be used for drinking water.

Maintenance: Water stored in the barrels and cisterns must be used or released between storm events to make room for further storage. Just like any house, the gutters will need to be cleared periodically. The tank may also need to be occasionally cleaned, and sprinklers serviced, but these are largely maintenance issues to be expected with the ownership of any home.

References

Rainwater Harvesting. Utah State Senate Bill 32 (2010).

Register for rainwater harvesting at:
https://waterrights.utah.gov/forms/rainwater.asp

LID Summary

Constructed Wetlands

Overview

Wetlands can be used in high water table areas to filter pollutants, to retain and infiltrate water, and to create a wetland habitat.

Advantages

Capable of retaining 90th percentile storm on-site.

Wetlands effectively remove many pollutants.

Wetlands enhance the ecosystem of the area.

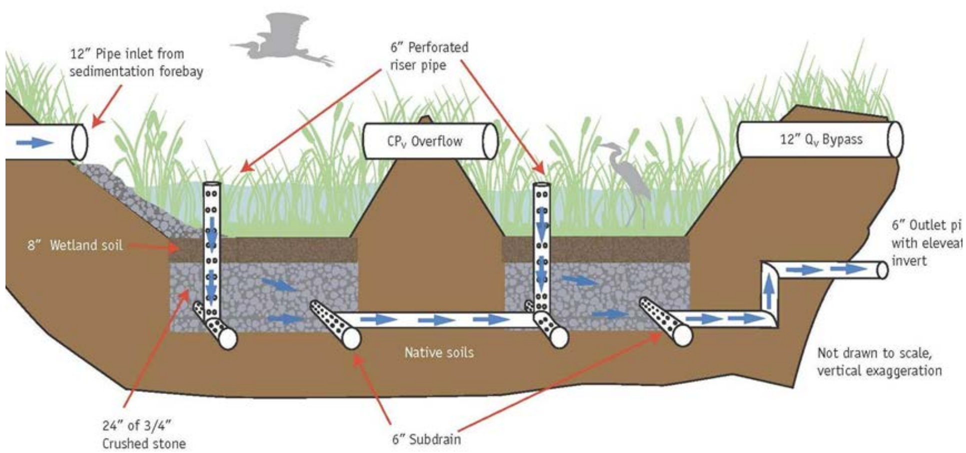
Limitations

Wetlands can be used in low-lying areas with a high water table.

Wetlands can create issues with mosquitoes.

Constructed Wetlands

Overview: Wetlands can be used in high water table areas, creating land that is permanently wet and vegetated accordingly. These remove pollutants and provide recreation and aesthetic appeal. They also serve as detention basins for storm water. Wetlands have shown to be very effective at pollutant and solids removal, removing 93% of Total Suspended Solids, 90% of inorganic Nitrogen,90% of Zinc, and 60% of Phosphorus (University of New Hampshire Stormwater Center (UNH), 2016). These pollutants are filtered and absorbed by micro-organisms in the plants and soils of the wetland, and by the vegetation. This shows that not only are wetlands great for capturing storm water, but also for cleaning it and putting it to good use in the natural ecosystem. It is important to note, however, that they are not quite as efficient during spells of cold weather when plants and water freeze, but still function well.



"Subsurface Gravel Wetlands for Stormwater Management." The Stormwater Report, 3 Jan. 2013, stormwater.wef.org/2012/07/subsurface-gravel-wetlands-for-stormwater-management/.

Application: Wetlands are best applied in areas with ground water near the surface. In the case of Bluffdale, this would likely limit storm water wetland creation to areas near the Jordan River. The design of the artificial wetlands must be heavily considered to meet the desired effects. Often these wetlands have a secondary purpose of aesthetic appeal or recreation that benefits the local community. This benefit can be marginalized if unwanted waterfowl flock to the area, disturbing city dwellers not used to the noise that they can make. The bigger problem can be mosquitoes, who could turn the area into a breeding ground, harassing residents in the general vicinity.

Medium-fine texture soils (such as loams and silt loams) are best to establish vegetation, retain surface water, permit groundwater discharge, and capture pollutants. At sites where infiltration is too rapid to sustain permanent soil saturation, an impermeable liner may be required. Where the potential for groundwater contamination is high, such as runoff from sites with a high potential pollutant load, the use of liners is recommended. At sites where bedrock is close to the surface, high excavation costs may make constructed stormwater wetlands infeasible. (State of New Jersey, Department of Environmental Protection, 2004)

LID Summary

Constructed Wetlands

Cost

Cost varies widely by soil type, wetland design, and plant selection but should be around $20,000 per acre treated.

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Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	93%
Total Phosphorous (TP)	60%
Total Nitrogen (TN)	90%
Copper (Cu)	-
Zinc (Zn)	90%
Petroleum Hydrocarbons	90%

Maintenance

System should be inspected twice each year.

Isolator Row should be cleaned out by JetVac when sediment reaches 3" depth.

Construction: You must be careful not to overbuild or underbuild your storm-water wetland. Considerations should include ground-water level, anticipated runoff inflow, and local geology and geography. Once this information is determined, you must decide the best type of wetland for your area (pond, marsh, or a mixture of the two), and a method to convey overflows downstream in a safe and stable manner. (State of New Jersey, Department of Environmental Protection, 2004) The diagram at the beginning of this section shows a very simplified model on how this can be carried out. Vegetation must also be carefully selected to avoid the introduction of noxious and invasive weeds, and to improve the aesthetics of the local community.

Cost: Cost varies widely, depending largely on the size and location of the wetlands. As mentioned in the "application" section, certain soil characteristics could make stormwater wetlands cost prohibitive. Overall costs include excavation, site formation, structural components, site restoration, and maintenance. (Minnesota Pollution Control Agency, 2017)

Pollutant Removal: Wetlands are home to chemical, physical, and biological processes that filter and break down pollutants. Wetlands provide long stormwater residence time, which leads to substantial pollutant reduction rates, including 93% of Total Suspended Solids, 90% of inorganic Nitrogen, 90% of Zinc, 60% of Phosphorous, and 90% total Petroleum Hydrocarbons in the Diesel Range (TPH-D), and 88% Total Zinc (Zn) (University of New Hampshire Stormwater Center (UNH), 2009).

Maintenance: Maintenance includes debris removal at least twice a year, invasive plant removal as needed, sediment removal every 1 to 5 years, erosion repair as needed, gate and valve operation, semiannual inspections, and mowing as often as 4 times per year. Costs can add up, and vary widely depending on location. (Minnesota Pollution Control Agency, 2017) If maintenance is not done regularly, unsightly and smelly algae blooms can frequent the wetlands, especially in areas with high nutrient runoff.

References

Minnesota Pollution Control Agency. (2017). *Minnesota Stormwater Manual.* Minneapolis: State of Minnesota.

State of New Jersey, Department of Environmental Protection. (2004). NJ Stormwater Best Management Practices Manual. *Stormwater in New Jersey*, 45.

University of New Hampshire Stormwater Center (UNH). (2009). *Biannual Report.* Durham, NH.

LID Summary

Porous Pavements

Overview

Porous pavements allow water to infiltrate down through the pavement into the ground, rather than pooling on the surface.

Advantages

Capable of retaining 90th percentile storm on-site.

Drastically reduced storm water pipe and structure costs.

No additional space requirements.

Effective pollutant removal.

Limitations

Not appropriate in high water table areas.

Requires underdrain in low permeability soils.

Not appropriate for surfaces with truck traffic.

Porous Pavements

Overview: Porous pavements allow infiltration in places that would typically generate large amounts of runoff from traditional pavements. Porous pavement comes in three different varieties: porous concrete, porous asphalt, and pavers. These permeable pavements can replace or compliment traditional pavements. Porous pavements are placed on top of high void space aggregate to clean, capture, and infiltrate runoff.

Application: Permeable pavements can be used for parking lots, sidewalks or walkways, shoulders, driveways, or other low-volume, low-speed uses. It is recommended pavements are not installed in areas with a speed limit exceeding 35 mph, as permeable pavements have lower load bearing capacities, and there is increased likelihood of aggregate breaking off the surface in permeable pavements (Stiffler, 2012). Permeable pavements should not be used in areas with extreme truck traffic or where toxic waste is likely to be spilled to include fueling stations (Federal Highway Administration (FHWA), 2015). The soil requirements are infiltration rates of .1 – 10 inches/hour, and the seasonally high water table should be at least two feet beneath the base of the excavation. In cases where the pavement is designed to receive runoff from impervious areas, gravel or vegetative filter strips should be used to settle out fines from the stormwater before it flows onto the pavement, and the ratio of drained unpaved to paved area should not exceed 5:1 to prevent clogging (National Asphalt Pavement Association (NAPA)). Porous pavements should have a barrier in between or be at least 10 feet away from untreated foundation walls, and should be at least 100 feet from municipal water wells (Federal Highway Administration (FHWA), 2015).

Construction: See the individual pavement segments below for separate details. One similarity with all of the porous pavements is the need for geosynthetic fabrics. The geosynthetics are place along the infiltration boundaries to keep fines out of the reservoirs beneath the porous pavements.

Cost: Porous concrete costs about $2.00 - $6.50 per square foot, porous asphalt costs around $1.00-$3.00 per square foot, and interlocking pavers cost about $5.00-$10.00 per square foot (Virginia DCR, 2011). Generally, a permeable pavement will cost about 20% more than its impermeable counterpart (e.g. porous asphalt costs 20% more than standard asphalt) (Stiffler, 2012).

Pollutant Removal: According to the University of New Hampshire Stormwater Center, pervious pavements are effective at removing suspended solids, hydrocarbons, and zinc, and partially effective at removing Phosphorous (University of New Hampshire Stormwater Center (UNH), 2016). Asphalt, concrete, and permeable paver surfaces all effectively filter out pollutants. Filtration occurs by mechanical processes as the water percolates downward. Bacteria and other organisms also break down hydrocarbons and other pollutants in the pavement and stone reservoir.

LID Summary

Porous Concrete

Cost

Porous concrete costs \$2.00-\$6.50 per square foot.

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Pollutant Removal

Porous Concrete

Removal Efficiencies	
Total Suspended Solids (TSS)	97%
Total Phosphorous (TP)	-
Total Nitrogen (TN)	50%
Copper (Cu)	75%
Zinc (Zn)	75%
Petroleum Hydrocarbons	99%

Maintenance

The surface must be swept at least twice per year and kept clear of debris and silts.

Surface should be monitored for ponding, which indicates clogging.

Porous Concrete

Construction: Porous concrete is a mix of coarse aggregate, Portland cement, and water, with little to no sand. The void space is between 15% and 25% which allows infiltration. The coarse aggregate should be ASTM sizes 7, 8, 67, or 89. An open-graded aggregate subbase reservoir should be at least 6 inches thick beneath the porous concrete. It is important to ensure that the porous concrete does not become saturated while in use because freeze-thaw will destroy it. To avoid this, provide sufficient storage in the subbase reservoir, or an overflow path. The Federal Highway Administration provided two tables covering the design of permeable concrete (Federal Highway Administration (FHWA), 2012).

Property	Common Value / Range
Plastic Concrete	
Slump	N/A
Unit weight	70% of conventional concrete
Working time	1 hour
Hardened Concrete	
In-place density	100 to 125 lb/ft^3
Compressive strength	500 to 4,000 lbf/in^2 (typ. 2,500 lbf/in^2)
Flexural strength	150 to 550 lbf/in^2
Permeability	2 to 18 $gal/ft^2/min$ (384 to 3,456 ft/day)

Mix Constituent or Design Parameter	Range
Coarse aggregate	2,000 to 2,500 lb/yd^3
Cementitious materials	450 to 700 lb/yd^3
Water-to-cementitious ratio	0.27 to 0.34
Aggregate-to-cementitious ratio (by mass)	4 to 4.5:1

Porous concrete has a higher initial cost than pervious asphalt, but porous concrete has been shown to be more durable and last longer without repairs than pervious asphalt (Custom Concrete, 2016). Permeable concrete also has a larger weight bearing capacity than pervious asphalt (Su-Lin Terhell, 2015). Because of its higher strength, permeable concrete may be used in low-traffic roads and parking lots. Permeable concrete also provides benefit by reducing the heat island effect (University of New Hampshire Stormwater Center (UNH), 2016).

LID Summary

Porous Asphalt

Cost

Porous Asphalt costs $1.00-$3.00 per square foot.

$$$$

Pollutant Removal

Porous Asphalt

Removal Efficiencies	
Total Suspended Solids (TSS)	99%
Total Phosphorous (TP)	60%
Total Nitrogen (TN)	-
Copper (Cu)	-
Zinc (Zn)	75%
Petroleum Hydrocarbons	99%

Maintenance

The surface must be swept at least twice per year and kept clear of debris and silts.

Surface should be monitored for ponding, which indicates clogging.

Porous Asphalt

Construction: Porous asphalt is an asphalt pavement with a high percentage of air voids. It should have 16% - 22% air voids, an asphalt content of 5.75% minimum, and a drain down test maximum of .3% (TechBrief 009) (National Asphalt Pavement Association (NAPA)). Beneath the asphalt there needs to be a stabilizing coarse and a subbase reservoir. The subbase reservoir should be a single size aggregate with 40% air voids. Overflow options should be provided to keep the water level from rising above the top of the recharge basin. Between the subbase and the asphalt there should be a 1-inch-thick stabilizing layer that allows the asphalt to be compacted (TechBrief 009). The stabilizing coarse should be stone size AASHTO No 1, 2, or 3 (National Asphalt Pavement Association (NAPA)).

Porous asphalt is significantly cheaper to install than permeable pavers or porous concrete. Asphalt has a lower load bearing capacity than concrete, and should generally be used only in very low traffic situations, such as shoulders, parking stalls, or over flow parking lots (Custom Concrete, 2016). Porous asphalt does not reduce temperatures, but may actually increase temperatures compared to standard asphalt (National Center of Excellence on Smart Innovations, 2012). Because of its good drainage, porous asphalt is much less susceptible to pothole formation than traditional pavement.

Pavers

Construction: LID pavers systems consist of permeable or impermeable pavers in open-graded aggregate on top of several open-graded aggregate reservoirs. Typical pavers should be 3 1/8 inches thick for vehicular pathways and 2 3/8 inches thick for pedestrian pathways (Federal Highway Administration (FHWA), 2015). The joints should be the same size aggregate as the bedding course, which should be 2 inches thick, typically ASTM 8, 89, or 9. Below the bedding coarse, there is a transitional reservoir. This layer is to structurally transition from the bedding coarse to the subbase reservoir. This layer should be 4 inches thick of ½ to 1-inch diameter stones. The last layer is the subbase reservoir. This layer is only needed for water storage until infiltration is complete, so the thickness depends on how much water needs to be stored for infiltration. The subbase reservoir is an open-graded aggregate of size 2 inches to 3 inches (Federal Highway Administration (FHWA), 2015).

Permeable pavers have a higher initial cost than pervious asphalt, but permeable pavers have been shown to be more durable and last longer without repairs than pervious asphalt (Custom Concrete, 2016). Permeable pavers can be used for small or micro-sized paving jobs. Pavers can be installed in small-scale settings where porous asphalt or concrete may be impractical, such as patios, small walkways, or individual sidewalks. Pavers are able to handle vehicle loads when designed with the proper supporting base material. One concern with pavers is that snow plows may catch on the pavers, damaging the pavement and/or the plow. Because of this concern, plow blades should be raised slightly when plowing over pavers.

LID Summary

Permeable Pavers

Cost

Permeable Pavers cost between $5.00-$10.00 per square foot.

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Pollutant Removal

Permeable Pavers

Removal Efficiencies	
Total Suspended Solids (TSS)	95%
Total Phosphorous (TP)	65%
Total Nitrogen (TN)	82%
Copper (Cu)	90%
Zinc (Zn)	90%
Petroleum Hydrocarbons	99%

Maintenance

The surface must be swept at least twice per year and kept clear of debris and silts.

Surface should be monitored for ponding, which indicates clogging.

Cracks between pavers should be weeded.

Maintenance: New porous pavements or pavers should be inspected several times in the first few months after construction and at least annually thereafter. The goal of these inspections is to check for sediment build-up and clogging. Inspections should be conducted after major storms to check for surface ponding that might indicate possible clogging. It is important that sand or abrasives are not used for de-icing, as these will clog the pore space of the surface. It is recommended that vacuum sweeping be performed at least twice a year to remove accumulated clogging. In environments where larger amounts of fine materials are present, the frequency should be increased accordingly (National Asphalt Pavement Association (NAPA)). Porous pavements may reduce de-icing and snow removal maintenance requirements by allowing water to infiltrate rather than ponding.

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LID Summary

Hydrodynamic Separators

Overview

Hydrodynamic separators are filtration units used to remove particles, floatables, grease, and oil from runoff.

Advantages

Separators take up little space and can effectively remove some pollutants from runoff.

Easy maintenance.

Can be used for pre-treatment for LID such as Storm Tech, R-Tanks, or bioretention.

Limitations

Hydrodynamic separators may not effectively remove very small particles or dissolved pollutants.

Hydrodynamic Separators

Overview: Hydrodynamic separators are filtration units that use the flow of the water around steel or concrete walls within the unit to remove particles and floatables including oil and grease. Hydrodynamic separators are pre-designed units available for purchase in Utah from companies including Amcor, AquaShield Inc, Bayersaver Technologies, Contech Engineered Solutions, Hydro International, Crystalstream Technologies, and Rinker Materials.

Domareki, Bridget. "Downstream Defender." Hydro International, 18 Oct. 2017, www.hydro-int.com/en/products/downstream-defender.

Application: Hydrodynamic separators are useful for filtration and pretreatment purposes. Separators are installed just after the curb inlet, and help capture hydrocarbons, oil, grease, and other floatables, enhancing the quality of water flowing further downstream.

Construction: Depending on the manufacturer, hydrodynamic separators may be precast, or cast in place. The area should be excavated and bedding and backfill material used according to requirements for standard manholes or catch basins. Pipe inlets and outlets are attached to the separator structure.

Cost: The cost varies by size, shape, and company; however, a 4-foot diameter, cylindrical hydrodynamic separator has an average 74 cubic foot capacity and costs $8,400, according to research done by Crystalstream Technologies (Crystalstream Technologies, 2012).

Pollutant Removal: Hydrodynamic Separators utilize a combination of swirl concentration and indirect screening to screen, separate, and trap debris, sediment, and hydrocarbons from stormwater runoff (Contech Engineered Solutions, 2018). Stormwater enters through the inlet flume, where it is guided into the separation chamber, where water velocities create a swirling vortex, shearing debris off the screen and forcing floatables to the center. Sediment and

LID Summary

Hydrodynamic Separators

Cost

One separator costs typically $8,400 to implement.

$$$

Pollutant Removal

Removal Efficiencies	
Total Suspended Solids (TSS)	80%
Total Phosphorous (TP)	-
Total Nitrogen (TN)	-
Copper (Cu)	-
Zinc (Zn)	-
Petroleum Hydrocarbons	some

Maintenance

System should be inspected twice each year.

Maintenance should be performed according to manufacturer specifications.

floatables in the center settle into an isolated sump, where they remained until removed during maintenance (Contech Engineered Solutions, 2018). Pollutant removal depends on the product, but the research done by Stantec Consulting Inc. for the Utah Department of Transportation in 2005 gives a general idea (Stantec Consulting Inc., 2005).

Company*	Hydrodynamic Separator Name	System Type	Pollutant Removed	Flow Control	TSS Removal	Free Oils	Emulsified Oils
Amcor	Oil Water Separator	Off-Line, w/flow bypass	Oils	weir	10-15 PPM Effluent Conc	N/A	N/A
Aqua-Swirl™ Concentrator	Aqua-Swirl™ Concentrator	Off-Line, w/flow bypass	Off-Line, w/flow bypass	orifice/weir	90%	some	none
Baysaver, Inc.	Baysaver	In-Line, w/flow bypass	sediments & floatable particles	trapezoidal weir	60 to 80%	some	none
CDS Technologies, Inc.	Continuous Deflection Separator (CDS)	Off-Line, w/flow bypass	sediments & floatable particles	orifice	84 - 52%	some	none
		In-Line	sediments & floatable particles	orifice	84 - 52%	some	none
Hydro International	Downstream Defender	In-Line, w/flow bypass	sediments & floatable particles	-	84%	some	none
Practical Best Management (PBM)	Crystal Stream Oil/Grit Separator	Limited space	sediments	NA	95%	significant	none
Stormceptor	Stormceptor	In-Line, w/flow bypass	sediments & floatable particles	orifice	80%	some	none
		two units in series	sediments & floatable particles	orifice/weir	80%	some	none
Vortechnics, Inc.	Vortechs System	In-Line, w/flow bypass	sediments & floatable particles	orifice/weir	80%	some	none
	VortSentry	In-Line, w/flow bypass	sediments & floatable particles	orifice	80%	some	none

NA = Not Available, N/A = Not Applicable

* All information presented in this table is based on manufacturers' published documents as of 3/04

Maintenance: Maintenance should be carried out according to manufacturer specifications. Generally, maintenance is minimal; the system should be inspected twice each year (minimum), and cleaned out using a vacuum truck when the level of sediment in the sump reaches 75% of sump capacity.

References

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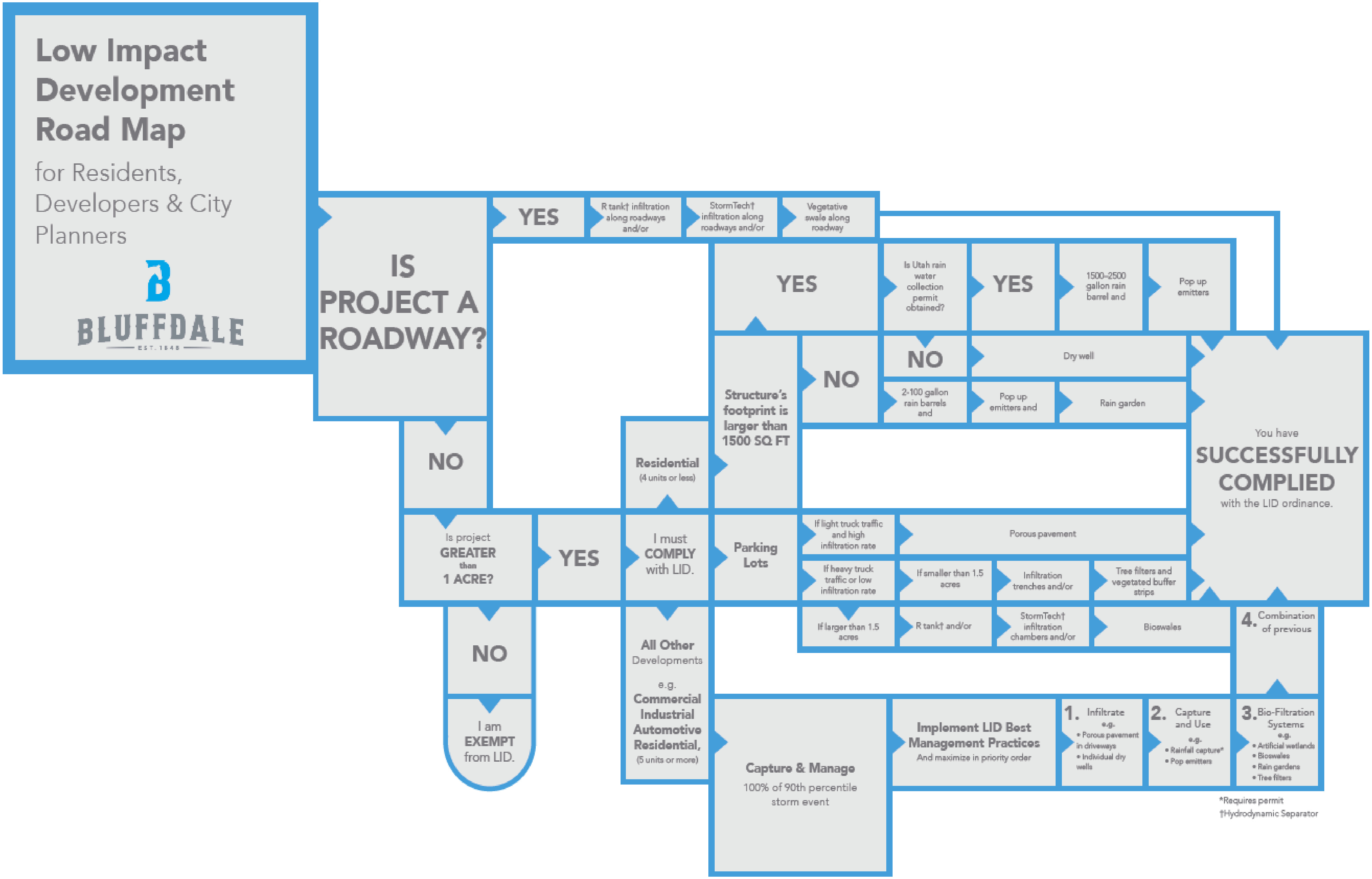
Appendix: Summary Tables and Diagrams of LID

LID	Purpose	Treated Contaminants	Treatment Effectiveness	Runoff Reduction	Cost	Maintenance	Permit Required
Bioretention Basins	Retention, treatment, infiltration, and evapotranspiration	TSS, Phosphorous, Nitrogen, Copper, Zinc, Nitrates	Excellent	High	Moderately High	Bi-monthly (weeding)	No
Bioswales	Treatment, reduce velocities, and partial infiltration	TSS, Phosphorous, Nitrogen	Fair	Low	Moderate	Frequent (mowing)	No
Dry Wells	Storage and infiltration	TSS, Phosphorous, Nitrogen	Fair	Medium	Moderately High	Periodically	Yes
Hydrodynamic Separators	Treatment	TSS, Petroleum	Fair	-	Moderately High	Semi-annually	No
Infiltration Trenches	storage and infiltration	TSS, Phosphorous, Nitrogen, Zinc	Fair	Medium - High	Moderately High	Monthly	Yes
Popup Emitters	Disperse rooftop runoff	-	-	Low	Low	Yearly	No
Porous Pavement	Infiltration and treatment	TSS, Zinc, Petroleum	Good	High	High	Semi-annually	No
Rain Capture	Storage of rooftop runoff	-	-	High	Moderate	Yearly	Yes
Rain Gardens	Retention, treatment, infiltration, and evapotranspiration	TSS, Phosphorous, Nitrogen, Copper, Zinc, Nitrates	Good	Medium - High	Moderate	Bi-monthly (weeding)	No
R-Tanks	Storage, treatment and infiltration	TSS, oil and grease	Good	High	High	Yearly	Yes
Stormtech	Storage, treatment and infiltration	TSS, oil and grease	Good	High	High	Yearly	Yes
Tree Filters	Treatment, partial storage, evapotranspiration	TSS, Nitrogen, Zinc, Petroleum	Excellent	Medium	Moderate	Bi-monthly (weeding)	No
Vegetative Filter Strips	Treatment, reduce velocities, and partial infiltration	TSS, Phosphorous, Nitrogen	Good	Low	Low	Frequent (mowing)	No
Wetlands	Treatment, storage, and infiltration	TSS, Phosphorous, Nitrogen, Nitrates, Zinc, Petroleum	Excellent	High	Moderately High	Bi-monthly (weeding)	No


Low Impact Development Road Map
for Residents, Developers & City Planners
BLUFFDALE
EST. 1848
IS PROJECT A ROADWAY?
YES
R tank† infiltration along roadways and/or
StormTech† infiltration along roadways and/or
Vegetative swale along roadway
NO
Is project GREATER than 1 ACRE?
NO
I am EXEMPT from LID.
YES
I must COMPLY with LID.
Residential (4 units or less)
Structure's footprint is larger than 1500 SQ FT
YES
Is Utah rain water collection permit obtained?
YES
1500–2500 gallon rain barrel and
Pop up emitters
NO
Dry well
NO
2-100 gallon rain barrels and
Pop up emitters and
Rain garden
Parking Lots
If light truck traffic and high infiltration rate
Porous pavement
If heavy truck traffic or low infiltration rate
If smaller than 1.5 acres
Infiltration trenches and/or
Tree filters and vegetated buffer strips
If larger than 1.5 acres
R tank† and/or
StormTech† infiltration chambers and/or
Bioswales
All Other Developments
e.g.
Commercial
Industrial
Automotive
Residential, (5 units or more)
Capture & Manage
100% of 90th percentile storm event
Implement LID Best Management Practices
And maximize in priority order
1. Infiltrate
e.g.
• Porous pavement in driveways
• Individual dry wells
2. Capture and Use
e.g.
• Rainfall capture*
• Pop emitters
3. Bio-Filtration Systems
e.g.
• Artificial wetlands
• Bioswales
• Rain gardens
• Tree filters
4. Combination of previous
You have SUCCESSFULLY COMPLIED with the LID ordinance.
*Requires permit
†Hydrodynamic Separator