Student Engineering Associates
University of Utah
Department of Civil & Environmental Engineering
201 Presidents Circle
Salt Lake City, Utah 84112

Ms. Laura Hanson
Dr. David Eckhoff
Jordan River Commission
Multi Agency State Office Building, 3rd Floor
within the Division of Water Quality
195 North 1950 West
P.O. Box 91095
Salt Lake City, Utah 84109-1095
December 6, 2012

RE: Guidance Document for Stormwater Management in the Jordan River Corridor

Dear Ms. Hanson and Dr. Eckhoff,

Student Engineering Associates (SEA) is eager to submit the Guidance Document for Stormwater Management in the Jordan River Corridor.

This document contains design information regarding stormwater control measures for appropriate stormwater management solutions in a fact sheet format for three different application spaces: site, roadway, and end-of-pipe. In addition, model design examples were evaluated and designed considering limitations, effectiveness and cost for five selected locations including a parking lot, a major street, and three stormwater outfall examples. Finally, preliminary guidance at the watershed scale is provided through modeling and simulation analysis and implementation challenges are identified and guidance provided related to ordinances, public education, financing, and professional training.

The project has been completed on schedule and within budget expectations. If you have any questions or concerns, please do not hesitate to contact any member of the Project Management (PM) team.

Prepared For: Laura Hanson and David Eckhoff
Prepared By: SEA

Sincerely,

SEA Project Management team

John Vogelsang	Tyler Jepsen	Jeff Huber
John.Vogelsang@utah.edu	Tyler.Jepsen@gmail.com	hubjefm@gmail.com
Manager	Engineer	Engineer

Guidance Document for Stormwater Management in the Jordan River Corridor




Prepared For:

JORDAN RIVER COMMISSION

Prepared By:

CIVIL & ENVIRONMENTAL ENGINEERING

STUDENT ENGINEERING ASSOCIATES

SEA

December 2012

The Jordan River Commission

JRC

Project Management
John Vogelsang (PM)
Tyler Jepsen
Jeff Huber

Site Controls
Chris Cooper (TL)
Chad Anderson
Courtney Fleming

Roadway Controls
Jason Recker (TL)
Sam Brown
Jeff Bunker

End-of-Pipe Controls
Kevin Rubow (TL)
Sam Bell
C.J. Coggins

Stream Restoration
Kevin Croshaw (TL)
Nikolai Halverson
Jacqueline Pacheco

Constructed Wetlands
Christopher York (TL)
Daniel Tracer
Kenneth Achter

Watershed Modeling
Travis Christensen (TL)
Ruixi Chen
Jason Dao

Ordinance, Education and Funding
Ryan Hazelwood (TL)
Abbie D'Evelyn
Jeff King

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Name	Organization
Laura Hanson	Jordan River Commission
David Eckhoff	Jordan River Commission
Steve Burian	University of Utah
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Ty Harrison	Ecological Restoration Consultant
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Leslie Chan	SLC Parks and Recreation
Emy Maloutas	Parks and Public Lands Program Director
Dan Potts	Salt Lake County Fish and Game Association
Charles “Torch” Elliot	University of Utah
Lawrence Reaveley	University of Utah
Michael Fazio	Bluffdale City Engineer
Ross Jones	Jordan River Corridor resident
Adriaan Boogard	Jordan River Corridor resident

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Executive Summary

Student Engineering Associates (SEA) has completed a Guidance Document for Stormwater Management in the Jordan River Corridor. The Jordan River Corridor is defined as a one-mile wide zone with the Jordan River at its center. Lack of environmental regulation in the past has caused the Jordan River to deteriorate to an unacceptable state. Stormwater has been identified as major contributor to the Jordan Rivers' impaired status. Because of this, stormwater management is a critical component for the restoration and protection of the Jordan River. This document seeks to assist planners in creating stormwater solutions that balance social, economic, and environmental needs. The objectives of this guidance document are to:

1. Compile information on appropriate Stormwater Control Measures (SCMs) including advantages and disadvantages, selection guidance, and design criteria;
2. Provide design examples for five different stormwater control measures aimed at guiding the engineer through the process of designing these SCMs;
3. Provide concise fact sheets for each corresponding design;
4. Provide performance and cost analysis results for watershed scale installation of SCMs, and;
5. Present direction and implementation guidance to address the challenges and opportunities related to ordinances, education, and financing.

Information on SCMs for site development, roadway, and end-of-pipe applications were compiled to provide planners with a simple method to select stormwater control measures. Design examples were created for five sites. The design examples in this document are:

- Parking Lot Example: A bioretention system treating runoff from a parking lot
- Roadway Example: A bioswale treating stormwater runoff from a roadway
- Developed Outfall Example: A Continuous Deflective Separation (CDS) system treating runoff from a developed stormwater outfall.
- Stream Restoration Example:
- Undeveloped Outfall Example:

For a parking lot, a bioretention system was designed, by using the included selection guidance and design criteria, five example sites (one parking lot, one roadway, and three stormwater outfalls representing different types of site conditions) were chosen to demonstrate the application of the guidance document. Designs of alternatives were used to quantify costs and benefits, as well as social, environmental and economic metrics used in a decision analysis to identify and recommended the best alternatives for each type of site.

At the site development scale, rainwater harvesting, pervious concrete, and bioretention were considered. Bioretention was identified as one of the recommended alternatives. For roadway applications, a sand filter, bioswale and gutter filter were evaluated, with a bioswale being the most recommended alternative. For our developed site example, a settling basin, cartridge

filters, and a pre-manufactured Continuous Deflective Separation (CDS) system were analyzed, with a CDS system as the recommended alternative. For an undeveloped outfall example an extended stormwater wetland and a subsurface gravel wetland system were both analyzed, resulting in the extended stormwater wetland being the best alternative. Finally, for a stream restoration design, an in-line detention basin, as well as an off-line detention basin was evaluated with the in-line detention basin being selected as the recommended alternative.

An important part of this phase of the project was the analysis of watershed scale implementation trade-offs and optimal implementation rate. This process was completed using U.S. EPA Storm Water Management Model (SWMM) computer modeling and simulation combined with cost analysis and assessment of other criteria. A SWMM model was developed for the Red Butte Creek watershed located in Salt Lake City, Utah. An analysis framework has been defined to determine the current quantity and quality of stormwater exiting the watershed. This was accomplished by gathering data such as average ground slope, pervious surface area, Manning's roughness coefficients, and land use. The data was then entered into SWMM. Once the model was developed and calibrated, SCMs could be added to the watershed to determine their efficiency, with respect to improving the water quality, and to help determine the reduced water quantity exiting the watershed. The analysis of determining the optimum combination of SCMs has been performed to demonstrate the overall effectiveness of combined systems.

The final aspect of the document is the creation of an implementation plan. This includes providing recommended strategies to change current ordinances, identifying and creating descriptions of programs for public education and professional training, and identifying and analyzing potential financing strategies such as raising taxes, utilizing available grant programs, implementing fines for stormwater misconduct or a hybrid of each, to support stormwater management in the Jordan River Corridor. The strategies for changing current ordinances included adopting a successful program from another community, compiling local ordinances into one document, and creating a draft guideline. The development of the public education program included looking at creating a pamphlet, poster, or a brochure. For the development of a professional training program, options include a website, developing a book, and holding seminars. The recommended alternative for this portion was creating a website to educate design professionals.

The hope for this document is that it be used as a helpful resource that will contribute to the overall improvement of the Jordan River corridor. It is SEA's intent to provide guidance that will enable planners, designers, and other decision makers select and design stormwater management programs to help restore and protect the Jordan River.

Volume I

1|Introduction

The goal of this guidance document is to provide the JRC and affiliates, with information and criteria that will help implement SCMs along the Jordan River watershed to improve the Jordan River water quality, biodiversity and aesthetic appeal. The objectives are to:

1. Identify and describe SCMs for (1) residential, commercial, and industrial sites, (2) roadways, and (3) major stormwater outfalls servicing mixed land uses.
2. Apply SCM selection guidance and design criteria for the three types of locations listed previously to selection guidance matrix's to determine optimum SCM.
3. Demonstrate example designs that can be used as guidance, to design SCMs for a particular location.
4. Provide watershed scale implementation rate and combination guidance using stormwater management modeling.
5. Present guidance for implementing stormwater management practices that address development ordinance modification, public education, professional training, and financing.

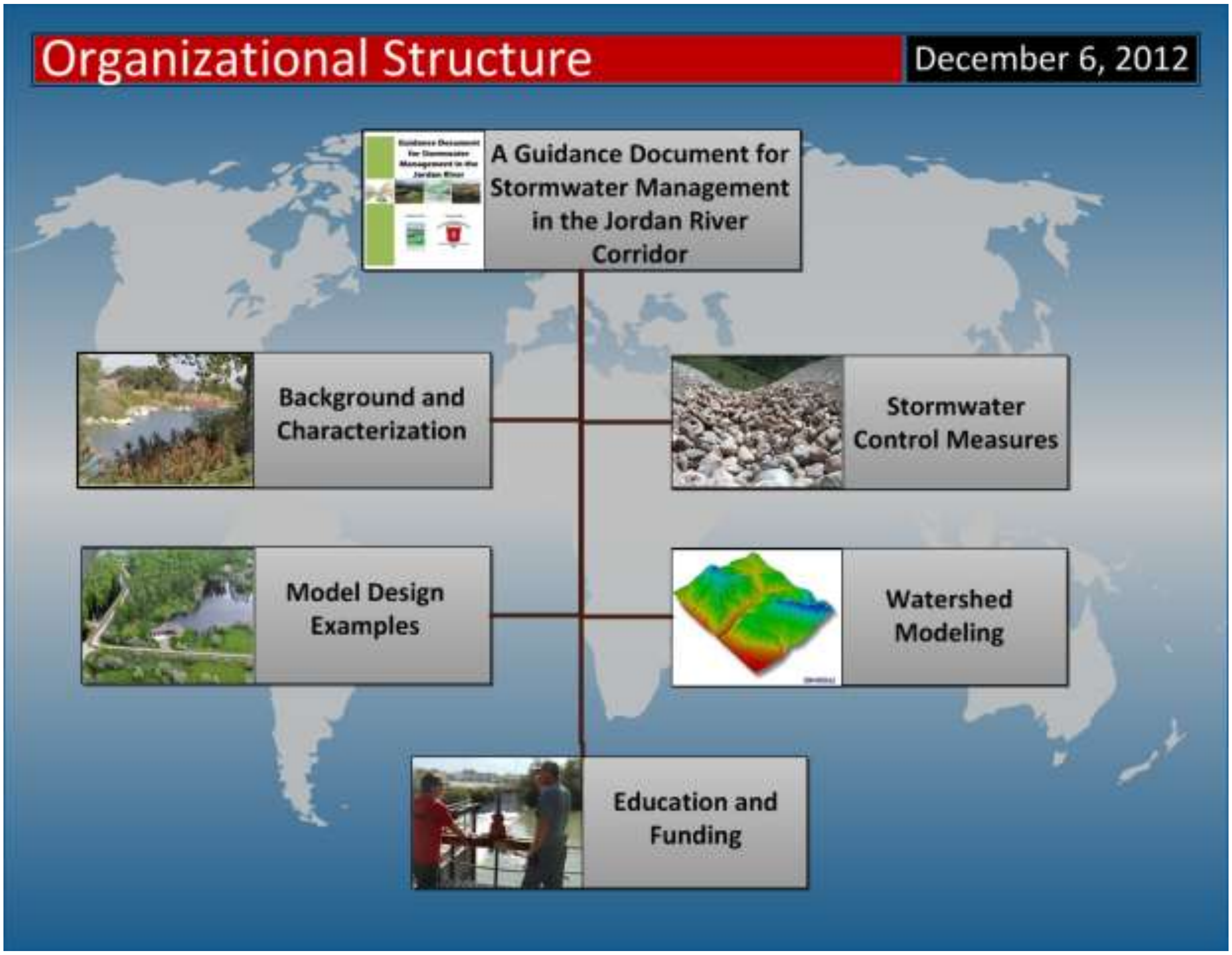
Volume I & II of this guidance document contributes to the first and second objectives listed above by providing detailed information about SCMs for residential, commercial, and industrial sites. Volume II is the form of fact sheets which are SCMs. Once alternatives are selected from Volume II, section 3 of Volume 1 on selection guidance matrix will be used to determine optimum alternative.

Volume III are example designs created for the Jordan River. This section goes through the process of designing five different SCMs for five different locations. This helps with the third objective of this guidance document

Stormwater management modeling is evaluated in the fifth section of Volume I, contributing to the fourth objective by providing guidance for SCM implementation and optimal design.

The final section of Volume I, in this guidance document contributes to the final objective by providing guidance regarding ordinances, education, and funding

Figure 1-1 shows the basic organizational structure for the Guidance Document for Stormwater Management in the Jordan River Corridor. The structure can also be used in creating guidance documents for other rivers. Important sections are listed below. This structure has SCMs and example design in separate volumes because of the sheer size. The remaining sections listed below are contained in volume I.



2|Background

The Jordan River originates at the outlet of Utah Lake and flows 51 miles to the north where it terminates at Burton Dam. The Jordan River watershed incorporates all of Salt Lake County and some of the most densely populated areas of Utah. The Jordan River watershed comprises the downstream end of the Provo/Jordan River Basin and is one of three river basins that contribute 92 percent of inflow to the Great Salt Lake with the Jordan River contributing approximately 13 percent. [1] Figure 2-1 shows the Jordan River watershed and the many streams that are discharged into the river.

Figure 2-1 Jordan River. (Source: Salt Lake City Public Utilities G.I.S. Division)

Precipitation in the form of rain and snow varies widely across the Jordan River basin due to the effect of topography on regional and local weather patterns. Weather patterns in the Jordan River Basin are typical of the Intermountain West and are characterized by four distinct seasons. Much of the annual precipitation falls as snow in the Wasatch Mountains and contributes high runoff and stream flow during the spring thaw. Annual precipitation levels range from 12 to 16 inches on the valley floor to over 60 inches near mountain peaks [2].

There are several sources of flow to the Jordan River.

- Utah Lake – the existing outlet from the lake is the original surface water source for the Jordan River.
- Tributaries – gauged and ungauged.
- Permitted Discharges – effluent from wastewater treatment plants.
- Stormwater – surface runoff from collection systems that discharge via direct outfalls or larger storm drains and tributaries that receive stormwater and eventually enter the Jordan River.
- Diffuse Runoff – surface runoff outside of stormwater catchments that contribute sheet flow into the Jordan River.
- Irrigation Diversions and Return Flows – flows diverted to irrigation canals and the return of unused irrigation water discharging from canals to the Jordan River.
- Groundwater.

The Jordan River is currently on the state's 303(d) list of impaired waters for failing to meet water quality standards set forth by the United States Environmental Protection Agency (EPA). Areas of impairment include: low dissolved oxygen levels, excess total dissolved solids, high temperature, excess *E. coli* contamination, and excess salinity.

Low dissolved oxygen levels inhibit desired aerobic organisms such as the Bonneville cutthroat trout, Utah Lake sculpin, and Western Pearlshell mussel. If the dissolved oxygen becomes too low, undesired nuisance species can become prevalent such as algae and the common carp. Low dissolved oxygen levels are caused by aerobic processes within the river, such as the decomposition of organic materials. The amount of dissolved oxygen the river can hold decreases as salinity and temperature increase [3].

Dissolved solids are solids that will pass through a filter 2.0 micrometer or smaller nominal average pore size. Excess dissolved solids can damage vegetation when used for irrigation [3]. Native vegetation, such as sagebrush, juniper, and grasses, have health issues when high dissolved solids water sources.

E. coli is a bacteria that is present in the stomachs of all warm-blooded animals. In excess levels, it can cause intestinal and other illnesses. According to the 2008 Total Maximum Daily Load (TMDL) study, the exact source of the contamination is not known [4]. This contamination must be addressed in order to meet the JRC's vision for the river.

The TMDL document was drafted with the intention of analyzing the overall health of the Jordan River. Its goal is to identify problem areas, and the sources of these problems. The document was created with the help of the JRC in an effort to devise a plan to improve the Jordan River and its surrounding areas.

This guidance document will specifically address the low dissolved oxygen levels and excess salinity that are heavily contributed by stormwater runoff. The runoff picks up organic materials, such as yard clippings and leaves, and also inorganics such as de-icing salt, which can affect all forms of life within the river's ecosystem. Higher levels of salt can kill off native species, while also promoting the growth of invasive species. The river has a loading capacity of 1,373,630 kg/yr Total Organic Matter. The current load is 2,225,523 kg/yr Total Organic Matter [4]. Several alternatives will be designed to address this issue.

Stormwater discharge within the Jordan River is regulated by the Utah Division of Water Quality (DWQ). The EPA delegated the DWQ in accordance with the Clean Water Act to regulate the Jordan River. There are 17 communities/organizations that are permitted to discharge water into the Jordan River. These include: Bluffdale, Draper, Herriman, Holladay, Lehi, Midvale, Murray, Riverton, Salt Lake City, Salt Lake County, Sandy, South Jordan, South Salt Lake, Taylorsville, the Utah Department of Transportation (UDOT), West Jordan, and West Valley.

Table 2-1 provides a detailed list of total acreage contributing to stormwater discharge into the Jordan River, broken down by municipality.

Table 2-1 Stormwater catchment areas that contribute stormwater flow to the Jordan River

Stormwater catchment areas that contribute stormwater flow to the Jordan River			
Jurisdiction	**Serviced Area Discharging Directly to the Jordan River[1]**	**Serviced Area Discharging to Tributaries**	**Total Area Contributing Stormwater Discharge**
Bluffdale		239	239
Davis County	4,776	13,104	17,881
Draper City		4,816	4,816
Lehi	3,483		3,483
Midvale	372		372
Murray	2,428	987	3,415
Riverton	124	1,176	1,299
Salt Lake City	6,776	8,214	14,991
Sandy	3,786	2,003	5,789
South Jordan	200	805	1,005
South Salt Lake	477	1,848	2,325
UDOT	397	16	413
West Jordan	5,670	801	6,471
West Valley	6,375		6,375
Total	34,866	34,009	68,876

[1] Direct discharge to the Jordan River includes stormwater catchments that discharge to stormwater collection drains flowing to the Jordan River.

Organic matter enters the Jordan River when stormwater flows across developed, impervious surfaces such as rooftops, streets, parking lots, sidewalks, and gutters. Surrounding plants and animals are also large contributors of organic matter. Raised levels of organic matter occur in the months of March-June during spring runoff when stormwater flows are at their highest. This is also because organic loads have accumulated during the previous fall and winter. The organic matter levels typically decrease during summer because stormwater flows have washed away excess organic matter buildup [1].

Sources of organic matter in the Jordan River include: organic loads to headwater reaches of tributary streams, leaf litter and other organic matter entering the river from trees and vegetation that line the riparian corridor, the portion of organic matter contributed by Utah Lake that is not influenced by anthropogenic inputs, and naturally occurring levels of soil erosion and stream channel dynamics.

There are a total of 13 stream channels that feed into the Jordan River, as shown in 2-2, including seven perennial and six intermittent streams. These tributary stream channels allow organic matter to enter the Jordan River. When overflow stormwater enters these channels directly or indirectly, it contributes additional organic matter.

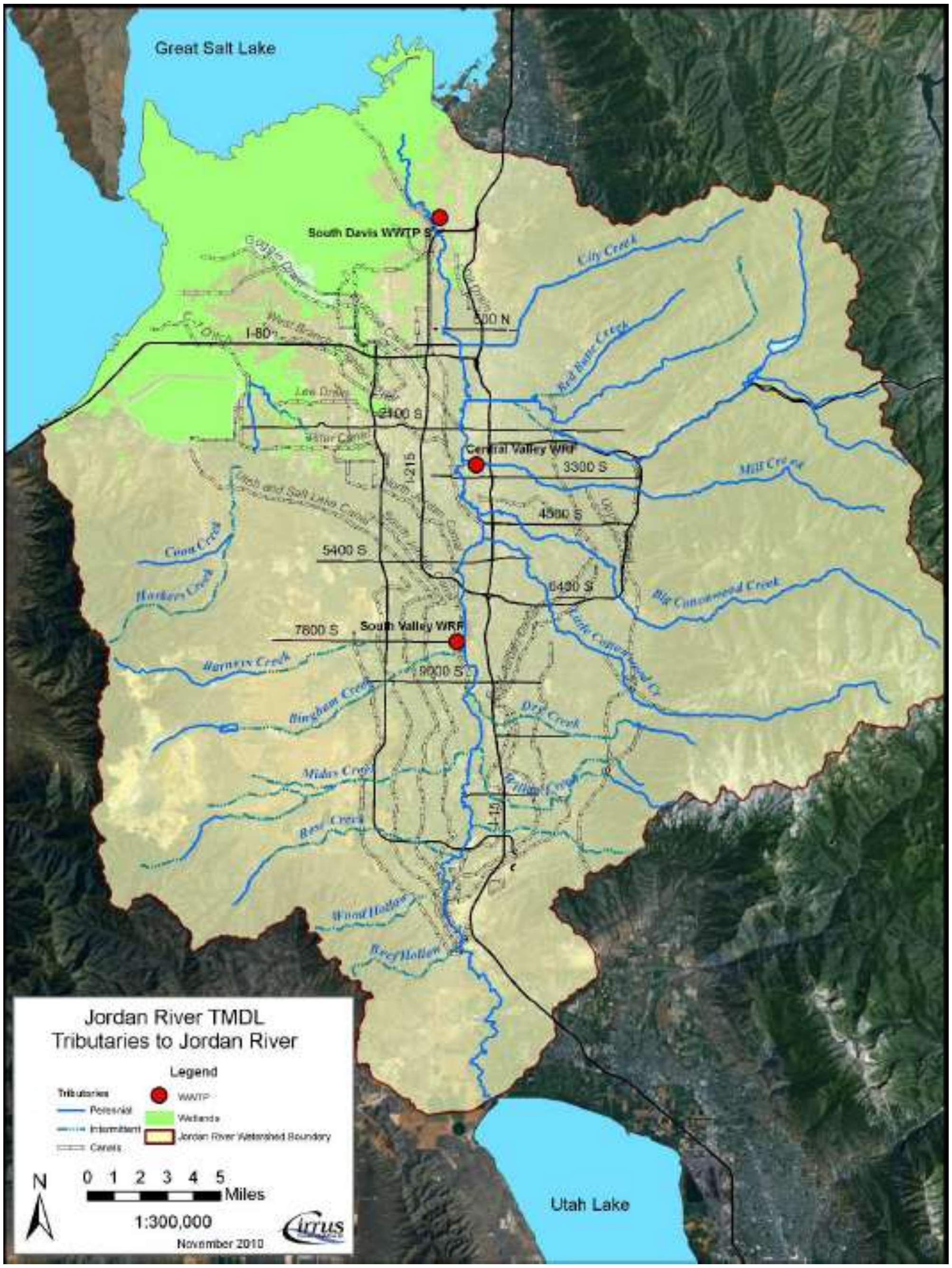


Figure 2-2 Tributaries to the Jordan River. (Source: www.waterquality.utah.gov)

Diffuse runoff, which is surface runoff from areas where there is no stormwater catchment, flows directly into the Jordan River in several locations. Organic matter that is small enough can be carried by surface runoff into the river. Table 2-2 shows acreage from each municipality that contributes diffuse runoff into the Jordan River.

There are many sections of the Jordan River that are impaired due to low levels of Dissolved Oxygen (DO). Because the river is on a 303(d) list, additional test data has been collected to further assess what actions need to be taken.

Table 2-2 Areas contributing diffuse runoff directly to the mainstream Jordan River

Areas contributing duffuse runoff directly to the mainstem Jordan River									
Municipality	**DWQ Segment**								**Total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
Bluffdale						446	519	13	978
Davis County	241								241
Draper City						483			483
Lehi								1,031	1,031
Midvale					157	182			339
Murray				475	14				489
North Salt Lake	425								425
Riverton						506			506
Salt Lake City	2	419	522	3					946
Salt Lake County	596	220		64					880
Sandy						41			41
Sandy City						140			140
Saratoga Springs								407	407
South Jordan						715			715
South Salt Lake				281					281
Taylorsville				323					323
Utah County								890	890
West Jordan					134	263			397
West Valley				290					290
Total	1,264	639	522	1,436	305	2,776	519	2,341	9,802

The Jordan River has experienced many changes since the Salt Lake Valley was developed. Throughout the 1960s and into the 1970s the Jordan River continued to be used as a waste disposal canal for area slaughterhouses, packing plants, mineral reduction mills, and laundries. The Provo-Jordan River Parkway Authority was created in 1973 with the purpose of enhancing the natural quality of the river. It was tasked with developing parks and recreational facilities, water conservation projects, and flood control measures. The water had improved by 1976, with noticeably lower levels of industrial pollution. The Jordan River area is becoming more of a recreational area now, as it is used for jogging, equestrian riding, fishing, and canoeing. It also has sections that are used for flying model airplanes and golfing [5]. No longer a river of waste and refuse, the Jordan River has emerged as an area of opportunity for community improvements. Blueprint Jordan River is a modern effort to develop a publically supported vision for the future of the entire river corridor. The Blueprint Jordan River project aims to make the river an amenity for our region and contains over 100 projects to achieve the overall vision [6].

Past and current projects include the Jordan River Parkway, which is a system of trails and parks that will run the entire 50 mile length of the river. Various sections include jogging and walking paths, playgrounds, bird refugees, equestrian trails and a motocross facility. The parkway has not yet been established along the entire length of the river. Completed projects along the river include:

- Jordan River State Park
- Salt Lake City section from 1000 North to 1700 South
- South Salt Lake and West Valley City section
- Murray/Taylorsville section
- Midvale and West Jordan section
- Sandy and South Jordan section
- Draper and Bluffdale section
- Utah County section

Current projects include:

- Best management practices for Riparian Corridor Conservation and Development (JRC)
- Jordan River Parkway Trail Map (completed/developing)
- The Jordan River Technical Library (in process, JRC)
- The Jordan River Parkway Trail Completion (in process, multiple parties involved)

Recently, emphasis on the Jordan River has highlighted some of the Jordan River trail development and has found success by implementing restorative and conservative measures along the Jordan River. One particular project on 7800 South has implemented a constructed wetland that filters the stormwater before discharging to the Jordan River. The project was funded by Salt Lake County and Region VIII EPA and completed by CH2MHill. This project, along with many others, has found huge success and this document will help continue the efforts to improve the Jordan River. Water quality improvement is one of the goals that the JRC hopes to accomplish along the Jordan River. Implementing SCMs along the Jordan River will help reduce the pollutants and organic matter that are dumped into the river thereby improving water quality.

3|Stormwater Control Measures

3.1 Fact Sheets

Fact sheets are a short hand version of SCMs. Fact sheets describe applicable SCMs; reports their advantages and disadvantages, provides selection guidance, and presents design objectives and criteria. Designers please see volume II for all facts sheets. There are three control types for facts sheets. They are site controls, roadway controls and end-of-pipe controls. Site controls are defined for this Guidance Document as all SCMs applied in an upland setting and not to control roadway runoff. For example, site SCMs may be applied to parking lots and building rooftops. Because a major fraction of the developed land surface in the Jordan River Corridor is covered by parking lots and rooftops, this site control application is included as a defined SCM category here and later in the report as a case study application.

The main emphasis of roadway controls SCMs is runoff pollution associated with stormwater that runs off bridges and roads. As stormwater flows over these surfaces it picks up dirt, dust, automotive liquids, heavy metals, organic matter, bacteria, and debris. These contaminants are then carried to the nearest body of water. The overall goal of the JRC and SEA is to improve the water quality and habitat surrounding the Jordan River. In order for this goal to be met, roadway controls must be implemented. The following alternatives are SCMs that are specifically relevant to roadway pollution. The following section will analyze the various roadway alternatives for their advantages, disadvantages, design objectives, and design criteria. From this analysis, these alternatives will be put into a selection guidance matrix. The selection guidance matrix will rate each of these alternatives based on: GWT restrictions, reduction of peak discharge, first flush, and removal of specific pollutants, maintenance requirements, and retrofit availability. From this selection guidance matrix, the three highest rated alternatives will be chosen for an in-depth analysis at the selected site.

End-of-pipe controls have been evaluated for different SCMs options to improve stormwater quality prior to discharge into the Jordan River. The primary functions of SCMs are peak flow reduction by means of increased infiltration and water quality improvement. Stormwater quality can be improved through the removal of TSS, organic matter, nutrients, pollutants, and debris. The possible design alternatives for end-of-pipe controls are constructed wetland, wet pond, detention basin, and mechanical treatment facility.

Table 3-1 List of all Fact Sheets in Volume II

Control Type	Fact Sheets
Site Controls	Green Roof
	Rainwater Harvesting
	Pervious Pavement
	Bioretention
	Oil/Grit Separators
Roadway Controls	Gutter Filter
	Sand Filter
	Bioswale
End-of-Pipe Controls	Constructed Wetland
	Wet Pond
	Detention Basin
	Mechanical Treatment Facility

3.2 Selection Guidance Matrix for Site Controls

3.2.1 Selection Guidance Matrix Criteria

The following section defines the criteria that are in the selection guidance matrix. Each site control SCM will be weighed against these definitions in the selection matrix. The selection matrix is a quick tool for readers to see what SCMs handle the following criteria.

1. **Groundwater Table Restrictions**: Ground water table (GWT) restrictions are determined if a particular SCM has any design restrictions in relation to groundwater levels. If the design has limitations due to the GWT it has restrictions.
2. **Peak Discharge:** Peak Discharge is when stormwater discharge rate is at its greatest point during a given storm. This discharge rate is increased with impervious surfaces thus altering pre-development discharge rates. With an increase in peak discharge there is a decrease in base flow, the effect of this are streams get deeper, steeper, wider and transport higher levels of contaminants along with increased rates of erosion.
3. **Runoff Volume:** Runoff volume is a volumetric reading of water flowing during a given storm. This volume is increased with impervious surfaces as the water cannot infiltrate. Rural runoff water is one of the leading sources of water pollution in the United States. When there is an increase in runoff volume, which is caused by urbanization, less water is capable of natural infiltration thus increasing pollutant loading.
4. **Stormwater Hotspots:** The Center for Watershed Protection defines a stormwater hotspot as “an urban land use or activity that generates higher concentrations of hydrocarbons, trace metals, toxicants that are found in typical stormwater runoff.”
5. **First Flush:** First flush is the initial surface runoff of a rainstorm. First flush stormwater is typically more concentrated compared to the remainder of the storm. It is these high concentrations of urban runoff that result in high levels of pollutants.

6. **Trash:** Trash consists of any macroscopic floatables. This includes the typical garbage not properly disposed of, pop cans, water bottles, paper and plastic, etc.
7. **Organic Matter:** Organic matter comes from once-living organisms. It is capable of decay, a product of decay, or is composed of organic compounds.
8. **Nutrients:** Nutrients of concern are phosphorous and nitrogen, these can be found in lawn and crop fertilizers. When water bodies receive abundance supply of nutrients algae blooms, die-off and decompose thus reducing the dissolved oxygen.
9. **Oil and Grease:** Roadways and parking lots tend to accumulate oil and grease that wash away with stormwater. SCMs that handle water from these sources should treat or collect oil and grease from the water, usually by biological or mechanical means.
10. **Total Suspended Solids:** This category indicates a SCMs ability to decrease the TSS in the stormwater. Suspended solids are particulates that can cause turbidity thus decrease the sun's rays for water penetration. This will reduce photosynthesis and cause a lower daytime release of oxygen into the water. Turbidity is also a sign of erosion which is cause by high peak and volume runoff.
11. **Retrofit Availability:** Retrofit availability refers to the addition of new technology or features to an older system. If the storm control measure can be implemented into existing infrastructures, it will be considered retrofit available.
12. **Low Maintenance Requirements:** Low maintenance requirement gauges the ease of maintenance. If maintenance has to be done more than four times per month it cannot be considered low maintenance. Regardless, all systems should be checked following any storm, which is not included in the decision.
13. **Seasonal Resistance:** Seasonal resistance is a measure of whether the SCM is affected by seasonal changes. If seasonal weather changes have a negative effect on the design's efficiency, it cannot be considered seasonal resistant.
14. **Durability:** Durability is a measure of whether the storm control design is capable of handling everyday use and if maintained correctly will survive its designed life span.

3.2.2 Selection Guidance Matrix

Table 3-2 Site Controls Selection Guidance Matrix

	Site-Control SCMs				
Criteria	**Bioretention**	**Pervious Pavements**	**Green Roof**	**Oil/Grit Separator**	**Rainwater Harvesting**
Groundwater Table Restriction	Yes	Varies	Yes	Yes	No
Reduce Peak Discharge	Yes	Yes	Yes	No	Yes
Reduce Runoff Volume	Yes	Yes	Yes	No	Yes
First Flush	Yes	Yes	N/A	Yes	Varies
Hot Spot Loading	Varies	No	No	Yes	Varies
Trash	Yes	No	No	Yes	No
Organic Matter	Yes	Varies	Yes	Yes	Yes
Nutrients	Yes	Varies	Varies	No	Varies
Oil and Grease	Yes	Varies	N/A	Yes	Varies
TSS	Yes	Varies	Yes	Yes	Varies
Retrofit Availability	Yes	No	Varies	Varies	Yes
Low Maintenance Requirements	Yes	Yes	Yes	No	Yes
Seasonal Resistance	Yes	Varies	No	Yes	Yes
Durability	Yes	Yes	Yes	Varies	Yes

3.2.3 Scoring Criteria Justification

The following section outlines the justification behind the scoring of the selection guidance matrix for each SCM design alternative. This will help clarify why each SCM got marked with a "yes" or a "no" in respect to each criterion in the guidance matrix.

3.2.3.1 Green Roof Selection Guidance

1. ***Groundwater Table Restriction***. Green Roofs do not increase infiltration of stormwater. In fact, green roofs reduce stormwater runoff from roofs which will reduce infiltration in some cases. As such, the depth of the water table does not influence the selection of green roofs.
2. ***Reduces Peak Discharge***. In summer, green roofs may retain 70-90 percent of precipitation that falls on them. In winter, green roofs retain 20-40 percent of precipitation that falls on them [7]. EPA recommends that developers can assume 50 percent of rainfall stormwater will be absorbed [8]. Researchers in Central Florida found that for a 1-inch 10-minute storm, green roofs reduced the rate of peak discharge by a rate of 50 percent [9].

3. ***Reduces Runoff Volume.*** Research suggests that green roofs may reduce the volume of stormwater runoff by 25 to 50 percent [8], [9]. When a green roof is used in conjunction with cisterns, runoff volume may be reduced by as much as much as 87 percent [9].
4. ***First Flush.*** It may be reasonably assumed the green roof acts as a filter, limiting the amount of debris and organic matter that is discharged from the building. Because debris and organic matter are the most common pollutants contained in first flush runoff from roofs, it may also be assumed that green roofs are effective at reducing first flush pollution.
5. ***Hot Spot Loading.*** Because roofs are not considered hot spot sources for stormwater pollution, green roofs are not applicable to the reduction of hot spot loading [10]
6. **Trash.** Roofs do not generally contribute trash to stormwater runoff. As such, the use of green roofs is not applicable to reducing trash loading in stormwater runoff.
7. ***Organic Matter.*** Data is not available on the efficiency of vegetated green roofs at removing organic matter from runoff. However, it is reasonable to assume that runoff from conventional roofs may contain organic matter. It is also reasonable to assume that the soil in the vegetated green roof acts as a filter, removing most, if not all, of organic matter from runoff.
8. ***Nutrients.*** Researchers have found that due to the use of compost in green roof soils, the concentrations of nitrogen and phosphorous in water discharged from green roofs is higher than water discharged from other roofs [9], [11]. However, green roofs also reduce the total runoff volume from the roofs. Because of this, the total masses of nitrogen and phosphorous contributing to stormwater pollution may be lower than for other roofs [9]. As a result, the effectiveness of green roofs at removing nutrients from stormwater is a function of the soil and fertilizer used, as well as the evapotranspiration from the roof.
9. ***Oil and Grease.*** It is reasonable to assume that oil and grease are not normally contained in discharge from rooftops. Because of this, oil and grease removal is not applicable to green roofs.
10. ***Total Suspended Solids.*** Green roofs do not have a statistically significant effect on the concentration of TSS in stormwater discharge. However, because the total volume of stormwater runoff is decreased, the total mass pollution of TSS is lower for green roofs than for conventional roofs [12].
11. ***Retrofit Availability.*** According to the EPA, the majority of flat roofs are already designed so that green roofs may be added without structural modification. This makes green roofs an acceptable retrofit option for buildings with flat roofs. However, the feasibility of using green roofs for retrofit of sloped roofs varies. In all cases, analysis must be performed by a structural engineer to determine whether green roofs may be used for retrofit applications [8].
12. ***Low Maintenance Requirements.*** During the first season after green roof installation, green roofs need to be monitored regularly. After the first season, green roofs need to be maintained in the same manner as any landscaped area. For extensive green roofs, this may mean weeding and fertilizing once per year, as well as watering in case of drought [8].

13. ***Seasonal Resistance.*** In cold climates, such as Utah, green roof soil may become frozen during the winter, limiting the pollutant removal of vegetated green roofs [13]. Because of this reduction in effectiveness, vegetated green roofs cannot be considered resistant to seasonal change.
14. ***Durability.*** Green roofs reduce the amount of UV light that come into contact with a roof's waterproofing membrane. Additionally, they mitigate the climate extremes that negatively affect the roof's waterproofing membrane. As such, the use of green roofs may extend the life by as much as twenty years [14].

3.2.3.2 Rainwater Harvesting

1. ***Groundwater Table Restriction.*** Rainwater harvesting (RWH) is compatible with high GWT, thus it is not restricted. Above-ground rain barrels can be used regardless of the water table and when underground cisterns are partially under the water table buoyancy calculations must be included in the design to ensure that the tank does not float when empty [15].
2. ***Reduce Peak Discharge.*** Rain barrels and cisterns reduce peak discharge as they can be sized to handle any target volume of rainwater but they are usually sized so that only up to 90 percent of annual rainfall is harvested and used [15].
3. ***Reduces Runoff.*** Because harvesting rainwater temporarily stores runoff for later use, it reduces runoff volume [15].
4. ***First Flush.*** RWH is intended to store and reuse water from most storms. However, some systems use a diverter that specifically directs first flush runoff into storm drains so that the harvested water cleaner, thus systems varies based upon design.
5. ***Hot Spot Loading.*** If harvesting rooftop water, hotspot loading is not applicable. If collecting first flush, it can handle hotspot loading but if the water is diverted it will, thus RWH varies in respect to hot spot loading.
6. ***Trash.*** RWH systems usually screen water to prevent trash from entering the system as it is difficult to remove, thus it does not remove trash from entering open water channels.
7. ***Organic Matter.*** Organic matter usually becomes trapped in the screens use to filter debris, the rainwater harvesting does eliminate organic matter from enter open water channels.
8. ***Nutrients.*** Water collected in cisterns and rain barrels is reused to water plants and can be pumped to be used as toilet water in order to conserve potable water. This water is used the same regardless of what nutrients it carries so the nutrient removal varies depending upon the reuse of the collected water.
9. ***Oil and Grease.*** If the collected water is reused as irrigation it will still enter open water channels, but if it is filtered it will not, thus the removal of oil and grease varies.
10. ***Total Suspended Solids.*** TSS will settle in the RWH system thus eliminate it from runoff.
11. ***Retrofit Availability.*** Rain barrels are retrofit available because they can be installed above ground or below any existing surface.
12. ***Low Maintenance Requirements.*** Rain barrels and cisterns must be cleaned out periodically because TSS and some organic matter settles in the tanks. Generally,

cisterns and rain barrels need to be cleaned out yearly and gutters need to be kept clear.

13. ***Seasonal Variability.*** With some minor design modifications, they can be applied in many climatological and geologic situations, as well in arid or cold climates regions.
14. ***Durability.*** Rain barrels and cisterns typically do not undergo wear and they have a very long usable lifetime.

3.2.3.3 Permeable Pavement

1. ***Groundwater Table Compatibility.*** A high GWT may cause runoff to pond at the bottom of the permeable pavement system. Therefore, a minimum vertical distance of 2 feet must be provided between the bottom of the permeable pavement installation (i.e., the bottom invert of the reservoir layer) and the seasonal high water table [16].
2. ***Reduce Peak Discharge.*** Pervious pavement can reduce peak discharge rates allowing stormwater to percolate into the ground.
3. ***Reduce Runoff Volume.*** With proper design mixes of pavement, interconnected void spaces will reduce stormwater runoff [17].
4. ***First Flush.*** Pervious pavement should not be on stormwater "hotspots" with high pollutant loads because stormwater cannot be pretreated prior to infiltration [17].
5. ***Hot Spot Loading.*** It is not appropriate for stormwater hotspots where hazardous materials are loaded, unloaded, stored, or where there is a potential for spills and fuel leakage as permeable pavement is not intended to treat these conditions [16].
6. ***Organic Matter.*** Varies studies rate the efficiency of organic matter removal to be the 80^{th} percentile.
7. ***Nutrients.*** Studies have shown pervious pavement has a 52 percent average removal rate of Nutrients.
8. ***Trash.*** Pervious pavement is not capable of screening trash.
9. ***Oil and Grease.*** According to the National Asphalt Pavement association, studies indicate high removal rate for oil and grease.
10. ***Total Suspended Solids.*** Studies have shown pervious pavement has a 90 percent average removal rate of TSS.
11. ***Retrofit Availability.*** Porous pavement cannot be used for retrofitting.
12. ***Low Maintenance Requirements.*** Pervious pavements require substantially less long-term maintenance and repair. Expensive maintenance for potholes repairs and asphalt resurfacing are virtually illuminated [17].
13. ***Seasonal Variability.*** Pervious asphalt has been found to work well in cold climates as the rapid drainage of the surface reduces the occurrence of freezing puddles and black ice. Melting snow and ice infiltrates directly into the pavement facilitating faster melting [17].
14. ***Durability.*** Pervious pavement has proven to outlast all common paving materials. Lifespan for conventional pavement parking lots is typically 15 years where as porous pavement parking lots can have a life span of more than 30 years because the reduced freeze/thaw cycle [17].

3.2.3.4 Bioretention System

1. ***Groundwater Table Restriction.*** Bioretention should be separated from the ground water to ensure that the GWT does not directly interact with the bioretention soil media. This design restriction prevents possible ground water contamination [16].
2. ***Reduce Peak Discharge.*** Bioretention is a temporary storage for runoff, which allows water the needed time for infiltration; this SCM helps maintain predevelopment peak discharge rates [16].
3. ***Reduce Volume Runoff.*** Acting as a deposit for runoff storage, bioretention cells reduce a site's overall runoff volume by restricting the runoff from direct channel loading [16].
4. ***First Flush.*** First flush will be captured with pretreatment measure if implemented; as well first flush can be captured in the depression of the bioretention design [18].
5. ***Storm Water Hot Spots.*** Bioretention areas can be used to treat stormwater hot spots as long as an impermeable liner is used at the bottom of the soil media [16].
6. ***Organic Matter.*** Bioretention will collect and store organic matter as it gets trapped in the planted vegetation but will have to be removed periodically to be efficient in organic matter trapping.
7. ***Nutrients.*** Phosphorous removal is between 67 and 87 percent. And Nitrogen removal is around 49 percent. Both are removed in the soil media [18].
8. ***Trash.*** Trash will collect in bioretention systems by getting trapped in vegetation and/or settling in the depression.
9. ***Oil and Grease.*** Removal of oil and grease are around 70 percent, although some studies have shown efficiencies greater than 98 percent. This is accomplished with the soil media [18].
10. ***Total Suspended Solids.*** TSS removal rate is between 80 percent and 90 percent depending upon the thickness of the soil planting bed and the type of vegetation grown in the bed. This is accomplished with the soil media [18].
11. ***Low Maintenance.*** Effective bioretention system performance requires regular and effective maintenance. This can be accomplished by any yard maintenance worker. If maintained regularly, the work is easy and is considered low maintenance (EPA, 2012).
12. ***Retrofit Availability.*** Bioretention can be used as a stormwater retrofit by modifying existing landscaped areas. In highly urbanized areas, this is one of the few retrofit options that can be employed [19].
13. ***Seasonal Variability.*** With some minor design modifications they can be applied in many climatological and geologic situations, as well in arid or cold climates regions [19].
14. ***Durability.*** Bioretention systems are durable based on proper vegetation plantings for the climate. All structural components must be inspected for subsidence, erosion, and deterioration annually; otherwise bioretentions have a 20 year life span [19].

3.2.3.5 Oil and grit Separator Selection Guidance

1. ***Groundwater Table Restriction.*** Oil and grit separators do not infiltrate water into the ground table. Therefore, there is no GWT for oil and grit separators [20].
2. ***Reduce Peak Discharge.*** Oil and grit separators do not affect peak discharge [10].
3. ***Reduce Runoff Volume.*** Oil and grit separators do not affect runoff volume [10].

4. ***First Flush.*** Because oil and grease are most commonly first flush pollutants, water quality inlets are effective at treating the first flush [21].
5. ***Hot Spot Loading.*** Because of the effectiveness of oil and grit separators at removing oil and grease, they are suitable for hot-spot loading areas, such as gas stations, vehicle maintenance locations, and vehicle storage areas [10], [22].
6. ***Trash.*** It is recommended that water quality inlets be designed with trash filters between the sedimentation chamber and the oil separation chamber. When these filters are used, oil and grit separators have been found to be effective at removing trash [23].
7. ***Organic Matter.*** Organic matter is often contained in the sediments that are removed from discharge. As such, a properly designed and maintained oil and grit separator may remove between 20 and 40 percent sediments from stormwater discharge [22]. It has also been found that approximately 80 percent of the sediment collected by water quality inlets is organic matter [24].
8. ***Nutrients.*** Oil and grit separators are ineffective at removing nutrients from stormwater, except when this removal is directly related to sediment removal [22].
9. ***Oil and Grease.*** Sediments trapped in water quality inlets tend to have high hydrocarbon contents. In addition, oil and grit separators have been found to be effective at separating oil and grease from stormwater [22]. The median oil and grease removal effectiveness of a properly-designed oil and grit separator has been found to be 51 percent [24].
10. ***Total Suspended Solids.*** According to the Metropolitan Washington Council of Governments, a properly designed and maintained oil and grit separator can remove between 20 and 40 percent of sediments in discharge. It should be noted that this data comes from a 1992 study of over 100 water quality inlets. The EPA also cites a 1995 study of a single oil and grit separator. This 1995 study found that the oil-grit separator actually increased the amount of TSS and nutrients in the stormwater [24]. Because of the small sample size of the 1995 study, it is not considered in this document.
11. ***Retrofit Availability.*** The applicability of oil and grit separators in retrofits is dependent stormwater volume to be treated and the space available. Some companies design oil and grit separators that may be placed with relative ease. If a larger separator is needed, retrofit may require extensive construction [23].
12. ***Low Maintenance Requirements.*** Maintenance of oil and grit separators can be cumbersome. As a minimum, it is recommended that water quality inlets are inspected at the beginning of each season and after each storm event. It is recommended that oil-grit separators be cleaned a minimum of two times during the wet season, and it has been shown that more frequent cleaning can increase the efficiency of these inlets. Maintenance can also be cumbersome because the oil collected from the separators must be disposed of separately from normal trash. Finally, if a vacuum truck is not purchased, an outside company must be hired to bring in a truck [21], [20].
13. ***Seasonal Variability.*** Little seasonal variation has been found in the pollutant removal efficiencies of oil and grit separators [25].

14. ***Durability.*** A properly designed and maintained oil and grit separator can be expected to last for 35 years or longer [22].

3.3 Selection Guidance Matrix for Roadway Controls

3.3.1 Selection Guidance Matrix Criteria

1. **Groundwater Table Restrictions.** GWT restrictions pertain to the particular alternative if it could affect the GWT. Meaning if the design has any affect or limitations it has restrictions.
2. **Reduce Peak Discharge.** Peak discharge is the maximum flow for a design storm that occurs in a certain period of time. The discharge increases with the surface being more impervious. To receive a “yes” the peak discharge must be reduced greatly. To receive a “varies”, the peak discharge needs to be reduced. To receive a “no”, the peak discharge will not be affected.
3. **First Flush.** First flush is the first runoff of any storm. First flush carries a most of the trash and debris.
4. **Trash.** Trash is any non-organic material that can be floatable or non-floatable that can be thrown in a trash can.
5. **Organic Matter.** Organic matter comes from dead organisms. It is capable of decay and is a product of decay. In large amounts can lower the amount of oxygen in the water to dangerous levels for living organisms.
6. **Nutrients.** Nutrients of phosphorous and nitrogen are the main focus. They are commonly found in lawn and farm fertilizers. These nutrients cause algae to grow and greatly reduce the amount of dissolved oxygen in the water.
7. **Oil and Grease.** Roadways and parking lots collect oil and grease from vehicles. These contaminants are very harmful to the living organisms in the Jordan River.
8. **Total Suspended Solids.** Suspended solids are particulates that can cause turbidity thus decrease the sun’s rays for water penetration. This will reduce photosynthesis and cause a lower daytime release of oxygen into the water.
9. **Metals/Toxins.** Metals and toxins are just that metals or any non-metal material that is toxic to living organisms.
10. **Bacteria.** Bacteria focused on will be E. coli or fecal coli form.

- **Retrofit Availability.** Retrofit availability refers to the ability to adapt an existing system or implement a new system. If the alternative can be implemented into an existing infrastructure it will be considered retrofit availability.
- **Low Maintenance Requirements.** Low maintenance requirement gages the ease of maintenance. If the SCM in place requires outside resources for routine maintenance and/or general maintenance has to be done more than four times a month it cannot be considered low maintenance. Either way all systems should be checked following any storm, which is not included in the decision.

3.3.2 Selection Guidance Matrix

Table 3-3 Roadway Controls Selection Guidance Matrix

	Roadway Stormwater Control Measures (RSCM)				
Criteria	**Gutter Filter**	**Sand Filter**	**Bioswale**	**Catch Basin**	**Soil Amendments**
Groundwater Table Restrictions	No	Yes	No	No	No
Reduce Peak Discharge	No	Varies	Yes	No	Varies
First Flush	Yes	Yes	Yes	Yes	No
Trash	Yes	Yes	Yes	Yes	No
Organic Matter	No	Yes	Yes	Yes	Yes
Nutrients	Varies	Yes	Yes	Yes	Yes
Oil and Grease	No	Yes	Yes	Yes	No
TSS	Yes	Yes	Yes	Yes	Yes
Metals/Toxins	No	Yes	Yes	Yes	Yes
Bacteria	Yes	Yes	No	Yes	Yes
Retrofit Availability	Varies	Varies	Varies	Yes	No
Low Maintenance Requirements	Varies	Varies	Varies	Varies	Yes

3.3.3 Scoring Criteria Justification

The following Guidance Document section outlines the justification behind the scoring of the selection guidance matrix for each SCM design alternative.

3.3.3.1 Gutter Filter Selection Guidance

1. **Groundwater Table Restriction**. Gutter filters do not have any considerable GWT restrictions.
2. **Reduces Peak Discharge**. Gutter filters can provide low reductions in the peak discharge rate from all storms up to the design rainfall intensity because of percolation through the filter medium.
3. **First Flush.** Gutter filters are capable of filtering the increased pollutants associated with the first flush of stormwater.
4. **Trash.** Gutter filters will filter out the larger debris such as trash.
5. **Organic Matter.** Gutter filters target oxygen depleting substances.
6. **Nutrients.** Gutter filters can filter nutrients to a degree. If nutrient removal is required other alternatives should be considered.
7. **Oil and Grease.** Gutter filters do not have the capability of filtering oil and grease.
8. **Total Suspended Solids.** Gutter filters target TSS substances.
9. **Metals/Toxins.** Gutter filters are incapable of filtering metals and toxins.

10. **Bacteria.** Gutter filter targets fecal coliform.
11. **Low Maintenance Requirements.** Accumulated trash and large debris on the grate surface should be removed every 7 to 14 days. This can be done in conjunction with street sweeping. Removal of debris that has accumulated in the void space between the gravel layer and grate should be done four times a year.
12. **Retrofit Availability.** Gutter filters retrofit capabilities vary on the existing road surface. Gutter filters can be retrofitted to pre-existing road if: road is straight, closed-section roadway and is on the shoulder or break down lane.

3.3.3.2 Sand Filter Selection Guidance

1. **Groundwater Table Restriction**. The bottom of the sand filter should be two to four feet above the seasonally high GWT.
2. **Reduces Peak Discharge**. Sand filters do not significantly impact the peak discharge flow rate.
3. **First Flush.** Bioswales are capable of filtering the increased pollutants associated with the first flush of stormwater.
4. **Trash.** Sand filters will filter out the larger debris such as trash.
5. **Organic Matter.** Sand filters target oxygen depleting substances.
6. **Nutrients.** Sand filters are capable of filtering a significant amount of nutrients.
7. **Oil and Grease**. Oil and grease substances are filtered from the effluent water.
8. **Total Suspended Solids.** Sand filters target TSS substances.
9. **Metals/Toxins**. Sand filter target metal and toxic substances.
10. **Bacteria.** Sand filter targets fecal coliform bacteria.
11. **Low Maintenance Requirements.** Accumulated trash and large debris should be removed every 7 to 14 days. The top layer must be raked to break up surface clogging four times per year. Accumulated sediment must be vacuumed from the sand filter two times per year.
12. **Retrofit Availability.** Sand filters are appropriate for sites with limited open space.

3.3.3.3 Bioswale Selection Guidance

1. **Groundwater Table Restriction.** The minimum distance from the swale invert to bedrock or to the seasonally high water table is two feet.
2. **Reduces Peak Discharge**. By providing storage mechanisms, swales are effective at reducing the peak discharge rate.
3. **First Flush:** Sand filters are capable of filtering the increased pollutants associated with the first flush of stormwater.
4. **Trash.** Bioswales will filter out the larger debris such as trash.
5. **Organic Matter.** Bioswales are capable of filtering oxygen depleting substances.
6. **Nutrients.** Bioswales are capable of filtering a significant amount of nutrients.
7. **Oil and Grease.** Bioswales can filter oil and grease without use of a separator.
8. **Total Suspended Solids.** Bioswales target TSS substances.
9. **Metals/Toxins**. Bioswales target metal and toxic substances.
10. **Bacteria.** Bioswales do not filter bacterial substances.

11. **Low Maintenance Requirements.** The primary maintenance requirement for swales is to inspect the treatment area for sediment and debris and to do routine mowing.
12. **Retrofit Availability.** Bioswales can be installed in selection site that has a minimum of: one percent slope, bottom width of two to eight feet and maintains one foot vertical and five feet horizontal clearance from the swale to any storm drain.

3.3.3.4 Catch Basin Selection Guidance

1. **Groundwater Table Restriction.** Catch basins do not have any GWT restrictions.
2. **Reduces Peak Discharge.** Catch basin controls do not decrease peak discharge flow rate.
3. **First Flush.** Catch Basins are capable of filtering the increase of large debris and TSS associated with the first flush of stormwater.
4. **Trash.** Catch basins target Floatables and debris such as trash.
5. **Organic Matter.** Catch basins are capable of filtering organic matter from the effluent.
6. **Nutrients.** Catch basins are capable of filtering a significant amount of nutrients.
7. **Oil and Grease.** Catch basins are capable of filtering oil and grease.
8. **Total Suspended Solids.** Catch basins target TSS substances.
9. **Metals/Toxins.** Catch basins are capable of filtering metals and toxins.
10. **Bacteria.** Catch basins are capable of filtering bacterial substances.
11. **Low Maintenance Requirements.** The primary maintenance activities are to remove accumulated trash and sediments and inspect the basin and controls for deterioration and operation.
12. **Retrofit Availability.** Catch basins should be installed in closed-section roadways and in site locations with the largest possible volume.

3.3.3.5 Soil Amendments Selection Guidance

1. **Groundwater Table Restriction.** Soil amendments do not have any considerable GWT restrictions.
2. **Reduces Peak Discharge.** Soil amendments can help reduce the peak discharge rate from all storms by enhancing the water retention and infiltration properties of native soils.
3. **First Flush.** Soil amendments do not have the capabilities of handling first flush properties associated with stormwater.
4. **Trash.** Soil amendments are not capable of filtering large debris such as trash.
5. **Organic Matter.** Soil amendments are capable of filtering organic matter from the effluent.
6. **Nutrients.** Although soil amendments may increase the total concentration of nutrients, they can decrease the mass of pollutants transported downstream because of the runoff volume can be significantly reduced. Soil amendments also target removal of nutrients such as phosphorus.
7. **Oil and Grease.** Soil amendments are not capable of filtering oil and grease.
8. **Total Suspended Solids.** Soil amendments target removal of TSS substances.
9. **Metals/Toxins.** Soil amendments are capable of filtering metals and toxins from the effluent.

10. **Bacteria.** Soil amendments filter bacterial substances from effluent.
11. **Low Maintenance Requirements.** Routine inspection of amended soils should evaluate factors that may decrease the soil's infiltration capacity, aeration and organic content.
12. **Retrofit Availability.** Soil amendments are not available for retrofit.

3.4 Selection Guidance Matrix for End-of-Pipe Controls

3.4.1 Selection Guidance Matrix Criteria

1. **Groundwater Table Restrictions.** GWT restrictions are determined if a particular SCM has any design restrictions in relation to groundwater levels. If the design has limitations due to the GWT it has restrictions.
2. **Peak Discharge.** Peak discharge is when the stormwater discharge rate is at the greatest point during a given storm event. The discharge rate is increased from the addition of impervious surfaces within a watershed. The effect of this are increased levels of erosion and greater transport of contaminants.
3. **Runoff Volume.** Runoff volume is a volumetric reading of water flowing during a given storm. This volume is increased with impervious surfaces as the water cannot infiltrate. Rural runoff water is one of the leading sources of water pollution in the United States. When there is an increase in runoff volume, which is caused by urbanization, less water is capable of natural infiltration thus increasing in pollutant loading.
4. **First Flush.** First flush is the initial surface runoff of a rainstorm. The concentrations of contaminants within the first flush are typically greater than compared to the remainder of the storm.
5. **Total Suspended Solids.** TSS refers to the quantity of organic and inorganic material that is suspended in the stormwater. Suspended solids are particulates that can cause turbidity thus decrease the sun's rays for water penetration. This will reduce photosynthesis and cause a lower daytime release of oxygen into the water. Turbidity is also a sign of erosion which is cause by high peak and volume runoff.
6. **Organic Matter.** Organic matter is natural material in the stormwater that decomposes to result in lower dissolved oxygen content within the water. Plant life such as leaves and lawn clippings are major contributors to organic matter.
7. **Nutrients.** Nutrients of concern are phosphorous and nitrogen, these can be found in the typical lawn and crop fertilizers. When water bodies receive an abundance supply of nutrients algae bloom, die-off and decompose thus reducing the dissolved oxygen.
8. **Trash.** Trash or debris is collected and transported within stormwater runoff. Trash removal will increase the aesthetics for the Jordan River.
9. **Retrofit Availability.** Retrofit availability refers to the addition of new technology or features to an older system. If the storm control measure can be implemented into existing infrastructure it will be considered retrofit available.
10. **Requires Small Footprint.** The amount of land required to implement a SCM is dependent on the volume of stormwater to be treated. If a SCM has a land requirement of greater than 1000 square feet it cannot be considered a small footprint.

11. **Low Maintenance Requirement.** Low maintenance requirement gages the ease of maintenance. If the SCM requires general periodic maintenance it cannot be considered low maintenance.
12. **Seasonal Variability.** Seasonal resistance is a measure of whether the SCM is affected by seasonal changes. If seasonal weather change has a negative effect on the design to where it does not operate as intended, it cannot be considered seasonal resistant**.**

3.4.2 Selection Guidance Matrix

Table 3-4 Selection Guidance Matrix for End-of-Pipe Control Measures

	End-of-Pipe Stormwater Control Measures			
Criteria	Constructed Wetland	Wet Pond	Detention Basin	Mechanical Treatment Facility
Groundwater Table Restriction	Yes	Yes	Yes	No
Reduce Peak Discharge	Yes	Yes	Yes	No
Reduce Peak Runoff Volume	Yes	Yes	Yes	No
First Flush	Yes	Yes	Yes	Yes
TSS	Yes	Yes	Varies	Yes
Organic Matter	Yes	Yes	Varies	Yes
Nutrients	Yes	Yes	Varies	Varies
Trash	Yes	Yes	Yes	Yes
Retrofit Availability	No	Varies	Varies	Yes
Requires Small Footprint	No	No	No	Yes
Low Maintenance Requirement	Yes	Yes	Yes	No
Seasonal Variability	Yes	Yes	Yes	No

3.4.3 Scoring Criteria Justification

This section outlines the scoring justification for the selection guidance matrix for each of the end-of-pipe controls possible design alternatives. The compatibility to the selection guidance criteria for each of the end-of-pipe control SCMs is listed above in Table 3-3.

3.4.3.1 Constructed Wetlands Selection Guidance

1. **Groundwater Table Restrictions.** The GWT level will affect the infiltration rate for a constructed wetland. High GWT will result a reduction of storage capacity for the wetland.
2. **Reduce Peak Discharge.** Constructed wetlands serve as temporary storage and infiltration for stormwater which will reduce peak discharge.
3. **Reduce Peak Runoff Volume.** Constructed wetlands can store a large volume of stormwater which will reduce the peak runoff.
4. **First Flush.** First flush will be captured within the constructed wetland. Contaminants will settle out of the stormwater and pollutants will be consumed through biological uptake.

5. **Total Suspended Solids.** Suspended solids will settle out of the stormwater following Stokes Law, where largest particles settle first. Constructed wetlands with a longer drawdown time will remove a greater amount of TSS.
6. **Organic Matter.** Constructed wetlands will collect and allow organic matter to decompose. The concentration of organic matter will affect the eutrophic state of the wetland and promote algae blooms.
7. **Nutrients.** Plant life will consume excess nitrogen and phosphorus from the stormwater.
8. **Trash.** Trash or floatable debris can be collected at the inlet of a constructed wetland by means of screens or grating. The trash will need to be removed periodically to prevent stormwater flow obstruction.
9. **Retrofit Availability.** Due to the large land requirements for a constructed wetland, retrofit availability is limited in an urbanized area.
10. **Requires Small Footprint.** Due to the shallow depth, constructed wetlands are one of the most land intensive options for SCMs.
11. **Low Maintenance Requirements.** Schedule yearly maintenance for removal of debris and sediment from the forebay and outlet structures. Constructed wetlands require low maintenance.
12. **Seasonal Variability.** Cold climates reduce the contaminants removal of wetlands because plant life is dormant.

3.4.3.2 Wet Ponds Selection Guidance

1. **Groundwater Table Restrictions.** Wet ponds are typically constructed with an impermeable layer to restrict contaminates entering the GWT.
2. **Reduce Peak Discharge.** Wet ponds serve as temporary storage and infiltration for stormwater which will reduce peak discharge.
3. **Reduce Peak Runoff Volume.** Wet ponds can store a large volume of stormwater which will reduce the peak runoff. In arid climates, high evaporation rates will reduce the volume of stored water.
4. **First Flush.** First flush will be captured within the deep pool of the wet ponds.
5. **Total Suspended Solids.** Suspended solids will settle out of the stormwater following Stokes Law, where largest particles settle first. Deep pools within wet ponds give an increased hydraulic residence time which will remove a greater amount of TSS.
6. **Organic Matter.** Wet ponds will collect and allow organic matter to decompose. The concentration of organic matter will affect the eutrophic state of the pond and promote algae blooms.
7. **Nutrients.** Wet ponds contain less vegetation when compared to a constructed wetland, and will consume a lower amount of nutrients from the stormwater.
8. **Trash.** Trash or floatable debris can be collected at the inlet of a wet pond by means of screens or grating. The trash will need to be removed periodically to prevent stormwater flow obstruction.

9. **Retrofit Availability.** Retrofit availability is limited in an urbanized area, because of their comparatively large land area and drainage area requirements, to allow for adequate turnover.
10. **Requires Small Footprint.** Wet ponds typically require one to two acres of land.
11. **Low Maintenance Requirements.** Schedule yearly maintenance for removal of debris and sediment from the forebay and outlet structures. Wet ponds require low maintenance.
12. **Seasonal Variability.** Cold climates can cause freezing of the inlet or outlet structures, which can impede the flow of stormwater.

3.4.3.3 Detention Basin Selection Guidance

1. **Groundwater Table Restrictions.** The level of the GWT will affect the infiltration rate for a detention basin. If the detention basin intercepts the GWT, it may result in a loss storage volume and difficulty in maintaining the basin bottom.
2. **Reduce Peak Discharge.** Detention basins serve as temporary storage and infiltration for stormwater which will reduce peak discharge. Staged outlet structures can be used to regulate discharge rates.
3. **Reduce Peak Runoff Volume.** Detention basins can be designed to store a large volume of stormwater to reduce the peak runoff volume for flood and erosion control.
4. **First Flush.** First flush can be captured within the forebay of the detention basin.
5. **Total Suspended Solids.** Detention basins can achieve a 60 percent TSS removal rate with a 24 hour detention time [7].
6. **Organic Matter.** Detention basins will retain some of the organic matter, but small percentage of the organic matter will decompose.
7. **Nutrients.** Low amount of nutrients can be removed by a detention basin.
8. **Trash.** Trash or floatable debris can be collected at the inlet of a detention basin by means of screens or grating. The trash will need to be removed periodically to prevent stormwater flow obstruction.
9. **Retrofit Availability.** Detention basins can be retrofitted to existing developments if area permits.
10. **Requires Small Footprint.** Detention basins typically require one to two acres of land.
11. **Low Maintenance Requirements.** Schedule yearly maintenance for removal of debris and sediment from the forebay and outlet structures. Detention basins require low maintenance.
12. **Seasonal Variability.** Cold climates can cause freezing of the inlet or outlet structures, which can impede the flow of stormwater.

3.4.3.4 Mechanical Treatment Facility Selection Guidance

1. **Groundwater Table Restrictions.** Mechanical treatment facilities are typically constructed as concrete vault; therefore the GWT has little restrictions on the design.

2. **Reduce Peak Discharge.** Mechanical treatment facilities typically do not reduce peak discharge. Their primary function is the improvement of stormwater quality and has little effect on the quantity.
3. **Reduce Peak Runoff Volume.** Mechanical treatment facilities typically do not reduce peak runoff volume. Their primary function is the improvement of stormwater quality and has little effect on the quantity.
4. **First Flush.** First flush can be captured and removed from the stormwater by means of baffles, screens, and filters.
5. **Total Suspended Solids.** A CDS treatment system can achieve an 80 percent removal efficiency of TSS based on an average particle size of 63 micron [8].
6. **Organic Matter.** The treatment facility can capture 100 percent of organic matter greater than 2.4 millimeters [8].
7. **Nutrients.** Low amounts of nutrients can be removed through mechanical treatment.
8. **Trash.** Trash or floatable debris can be removed from the stormwater by mechanical treatment.
9. **Retrofit Availability.** Most mechanical treatment facilities can be adapted to existing stormwater sewer systems.
10. **Requires Small Footprint.** Mechanical treatment facilities require the least amount of land requirements for the end-of-pipe SCMs.
11. **Low Maintenance Requirements.** Monthly inspection of the treatment facility should be conducted within the first year of installation to develop a maintenance schedule. Removal and disposal of collected sediment and trash is required. Mechanical treatment facilities typically have high maintenance requirements.
12. **Seasonal Variability.** Cold climates typically do not affect mechanical treatment facilities, due to the subgrade installation. Seasonal high flow rates can be accommodated with a diversion weir to bypass excessive flow rates.

4|Example Designs

The objective of the example design section of this Guidance Document is to provide a detailed analysis of different alternatives from the selection guidance matrix for each of the design locations. There are five locations that have multiple options for improving the Jordan River. The first location, focused on site controls evaluated bioretention, rainwater harvesting, and permeable pavement designs for implementation in a parking lot example located at the ORP on the University of Utah campus. A bioswale, sand filter, and gutter filter were designed for implementation for a roadway site example located at 4500 South and 600 West. For a developed outfall example evaluating end-of-pipe controls, a settling basin, cartridge filters, and a Continuous Deflective Separation treatment system were designed for a location at 1300 South 900 West. The constructed wetlands example consists of an extended stormwater wetland and subsurface gravel wetland system located in Bluffdale near 14600 South Redwood Road. Finally, the stream restoration examples that were designed were an in-line detention basin as well as an off-line detention basin. Each of the designs are supplemented with drawings and cost estimates to help evaluate the feasibility of each alternative. The alternatives were then placed into a decision analysis and weighed against social, economic, and environmental criteria to quantitatively provide a recommendation. A map and summary of each location and design alternatives are shown in Figure 4-1 and Table 4-1 below.

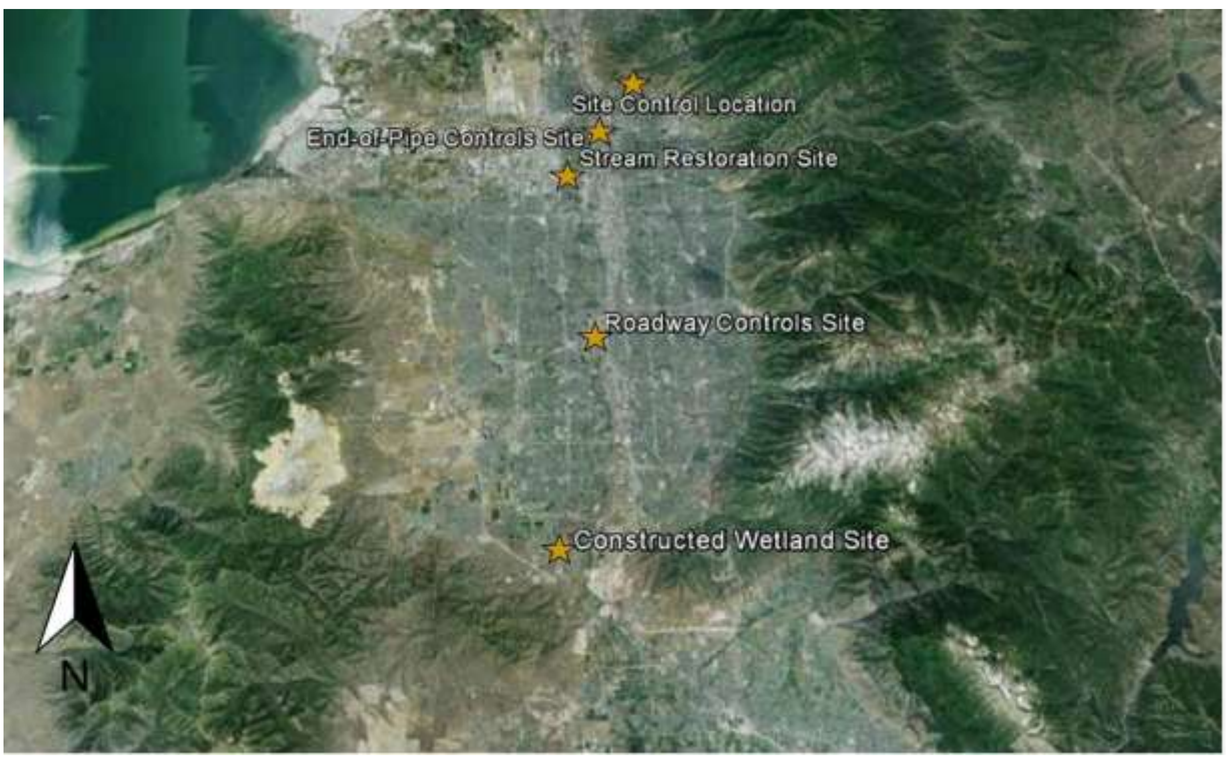


Figure 4-1 Map of Model Design Locations (Source: www.earth.google.com)

The following Example designs are contained in Volume III.

Table 4-1 Detailed Information of Example Designs

Example Design	Example Type	Location	SCM
1	Parking lot	2140 East and 300 South	Bioretention
2	Roadway site	4500 South and 600 West	Bioswale
3	Developed outfall	1300 South and 900 West	Mechanical Treatment Facility
4	Stream Restoration	900 South	Off-line detention basin
5	Constructed Wetland	14600 south Redwood Road	Extended stormwater wetland

5|Watershed Modeling

The objective of the watershed modeling section is to present the data and methods necessary to create a model representative of an actual watershed. SCMs can then be added to the model to determine their impact and effectiveness of managing stormwater. This section is written to demonstrate the process that a designer would go through to perform a watershed analysis. To illustrate this process the Red Butte Creek Watershed location and characteristics, the data gathered to create a map in ArcGIS, how the model of the watershed was created in EPA modeling program Storm Water Management Model (SWMM), and how the analysis and addition of SCMs was performed. SWMM was chosen for the analysis because it has the capability to model both stormwater quality and quantity, it is a free software package, and it has a large amount of support from users on the internet. A working knowledge of SWMM is essential to perform the watershed analysis described in this section, SWMM tutorials can be found on the EPA's website in the SWMM User's Manual. This process may be followed with any watershed to assess the current stormwater properties of a watershed, such as discharge rate and quality, and to determine the effectiveness of potential SCMs.

Figure 5-1: Red Butte Creek Watershed

5.1 Watershed Description

The first step necessary is to define the boundaries and extents of the watershed to be analyzed. The boundries of watersheds can be defined by physical features such as mountains or manmade features such as stowm sewer pipe networks or dams. Finding as much information relative to the watershed such as flow data from any rivers or pipes, release data from dams, or special systems which may divert into or away from the watershed.

The Red Butte Creek watershed is located near the University of Utah and covers an area of approximately 1300 acres starting at the Red Butte Creek Dam and ending at 1600 East where the Red Butte Creek goes underground. These parameters were chosen because water release data is available from the Central Utah Water Conservancy District who manages the dam for this area. In addition, Salt Lake County has a stream guage which measures the flow rate of water at 1600 East. The boundary of the watershed was delineated in accordance to the model previously developed by Salt Lake County. The model was for the entire county, but also contained delineated sub-basins such as the Red Butte Creek watershed. The watershed for this analysis is much smaller than the Salt Lake County's because the county model starts above the Red Butte Dam and it ends at Liberty Park, the data for which is not readily accessible.

The watershed contains a diverse landscape including a vegetated and non-vegetated mountainside, open green space, paved roads, prairie fields, and public and private buildings. Figure 5-1 shows the delineated watershed for Red Butte Creek with the dam at the top of the river and the watershed's end at approximately 1600 East. This location was selected because data is readily accessible and there are diverse ground coverings that are found throughout the Jordan River Watershed. Figure 5-2 below shows the elevation profile of the watershed starting at the Red Butte Creek Dam and ending at 1600 East. The watershed has a total length of three miles, an average slope of six percent, and has a total elevation change of 887 feet.

Figure 5-2: Elevation Profile of the Red Butte Creek Watershed

Figure 5-3: Soil Classification of the Red Butte Creek

The map depicted on the left in Figure 5-3, is the soil data of the Red Butte Creek watershed. This information was used to estimate the amount of water that will infiltrate the soil and how much will runoff will flow off the land surface and ultimately into the Red Butte Creek. The outline of the wateshed can be seen as a fadded blue below the soil classifications.

The average ground slope, soil properties, watershed boundaries were determined and added to the ArcGIS map which was created. These properties and characteristics are ensential for creating an accurate model in SWMM.

5.2 ArcGIS Map

In order to create a model of the Red Butte Creek Watershed a map of the watershed was first developed using the geographic information system (GIS) software ArcGIS developed by Esri. ArcGIS is useful for compiling geographic data and analyzing mapped information. Version 10.0 of ArcGIS was used to create the map of the watershed. While ArcGIS is not required to create a watershed model, it has the capability to display many elements at once such as roads, buildings, storm sewer pipe networks, streams, dams, soil properties, drainage areas and homes.

Figure 5-4: Divisions of the Red Butte Creek Watershed

Analyzing the watershed to determine land use and development will be required to create the SWMM model in the next section.

The Red Butte Creek Watershed map in Figure 5-1 can be divided into three sections: the mountainside, the University of Utah, and the residential zone, which can be seen in Figure 5-4. Each of these sections has similar ground slopes, land use, and pervious area. The mountainside is approximately 1071 acres and the land is undeveloped. The University of Utah has an area of 500 acres and is contains large buildings, parking lots, and open spaces. The residential zone covers approximately of 179 acres of the watershed and contains a large number of homes. Determining the exact impervious area for all the ning to complete. The solution for this was to sample a couple of residential parcels, and extrapolate the land use data over the entire residential zone.

Data determined using the GIS map, such as areas of pervious and impervious surfaces, region soil types, and elevation data are crucial in creating the SWMM watershed model that is discussed in the next section.

5.3 SWMM Model

SWMM version 5.0 was used to create the watershed model. SWMM is a dynamic rainfall runoff simulation model used for both single and long term hydrologic events. The program can calculate both stormwater quantity and quality from these storm events. This section will discuss how a model representative of a watershed can be built and calibrated and how SCMs can be added into the model.

5.3.1Model Construction

Figure 5-5: Sub-basins of the Red Butte Creek Watershed

SWMM has the capability to import images into the work space, this enables the designer to visualize the locations of sub-basins and controls easier. To create the model in SWMM sub-basins need to be defined with parameters such as pervious area and land slope, rain gauges need to be inserted with design storms or actual data, and an outlet needs to be set up.

For the Red Butte Creek Watershed the map created in ArcGIS was exported into SWMM so that the boundaries of the watershed could be properly defined. The watershed was broken down into sub-basins, which are smaller areas within the watershed with similar characteristics, and can be seen in Figure 5-5. Each sub-basin has similar land slope, land use, and percent impervious ground cover; the developed sub-basins are also divided according to networks of storm sewers. These storm sewers drain into the Red Butte Creek at various points on the river. Due to these storm sewers the area north of the creek is not included because the storm sewers remove any water to a different watershed in Salt Lake City.

Each sub-basin required the input of several parameters such as Manning's roughness coefficient for both the pervious and impervious ground coverings, average slope of the basin, and the percent of impervious and pervious land. The Manning's roughness coefficient was determined from the engineering toolbox for urban areas of both pervious and impervious areas. The average slope of each sub-basin was determined using the elevation profile tool in

Table 5-1: Properties of Individual Sub-basins of the Red Butte Creek Watershed

Sub-Basin	1	2	3	4	5	6	7	8	9
Area (acres)	281.2	790.1	111.8	24.8	169.7	61.1	201.4	8.2	156.2
Manning's Roughness Coefficients									
Impervious Ground Area	-	-	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Pervious Ground Area	0.015	0.015	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Average Ground Slope	28.9	32.0	2.2	2.8	0.4	1.1	2.4	0.3	0.4
Percent Impervious (%)	0.2	0.01	26.9	27.3	38.3	49.0	41.8	38.3	38.3
Percent Pervious (%)	99.8	99.99	93.1	92.7	61.7	51	58.2	61.7	61.7

Google Earth, a total of five measurements were taken in each sub-basin and the results were averaged to determine the averaged slope. The percent of pervious and impervious land was calculated using the ArcGIS map, all the buildings, roadways, and other impervious surfaces were defined and an area calculator was able to determine the area within each sub-basin. The values for each sub-basin are found in Table 5-1, shown above.

5.3.2 Model Calibration

Once the parameter and boundaries for the model were constructed in SWMM it was calibrated to ensure that the model accurately represented the current system. Using rainfall data from NOAA, stream gauge data from Salt Lake County, and Red Butte Dam release data from the Central Utah Water Conservancy District the model was adjusted to these values. Using the law of conservation of mass, an assumption was made that the water exiting the

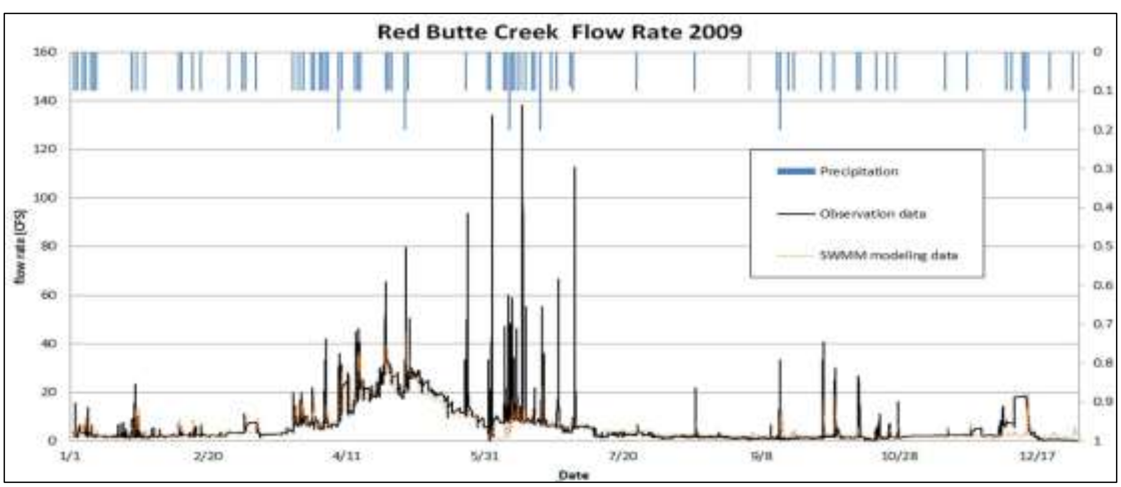


Figure 5-6 Red Butte Creek Calibration Data

watershed at 1600 East was made up of only the water discharged from the dam as well and rainwater from the storm sewers. While there are other sources of water contributing to the outflow at 1600 East, such as water from sprinklers and individual discharge, for the size of the this watershed these additional sources were assumed to be negligible. Based upon these assumptions the amount and percentages of impervious area was adjusted and drainage areas were resized to produce discharge values that match those of the current system during rainstorms and dry periods. Figure 5-6 above shows the actual discharge data for the creek versus the discharge data the SWMM model produced.

The graph also shows the precipitation, which was taken from a rain gauge near the Red Butte Creek Dam located just above the watershed. The output from the model closely represents the actual storm water discharge with the exception of a few instances. This acceptable because most of the data matches that of what is actually occurring in the watershed. The differences can be attributed to seasonal variations not taken into account by the model such as snowmelt. Snowmelt from mountains attributes greatly to the water in the Red Butte Creek during the spring and the fall.

5.3.3 Low Impact Development Parameterization

Once the watershed model has been created and calibrated SCM controls can be added to the watershed. SWMM refers to SCM controls as low impact development (LID); the terms SCM and LID are used interchangeably throughout the following sections. Within SWMM, the LID Control Editor requires parameters to define the qualities for certain control types: pavement, bio-retention, rain barrels, and underground cisterns. Within each type, there were a number of parameters including but not limited to surface slope, thickness, and permeability.

After the Red Butte Watershed SWMM model was built and calibrated, the next step was to create stormwater controls to test in the model. The LID parameters were acquired using standards from the SWMM User's Manual, SEA Design Teams, and research of systems currently in place in other locations. The defined parameters for each LID control are included in Tables 7-4 & 7-5 in Appendix B.

5.4 Basis of Design

The basis of design for watershed modeling sets specific guidelines which implemented SCMs shall meet. Each individual SCM within the watershed is not expected to meet the criteria below, but as a whole the SCMs must meet the specified criteria. The basis of design consists of requirements and specifications for stormwater quantity, peak discharge, and quality. Local regulatory agencies within cities, counties, and states typically have requirements for stormwater discharge and quality, this was the case for the Red Butte Creek Watershed and the design specifications are found below.

5.4.1 Stormwater Quantity

The volume of stormwater discharged from the post-development Red Butte Creek Watershed shall be reduced by 80 percent for total volume discharge over one year's time. The implemented stormwater control measures must not allow the discharge of too much stormwater from the watershed and shall prevent downstream flooding.

5.4.2 Stormwater Peak Discharge

Reducing the peak discharge of stormwater that is discharged from the watershed during a rain event is a key component of the analysis. Stormwater controls placed throughout the watershed shall contain the stormwater runoff from a 10 year 24 hour storm event and prevent flooding. Reducing the peak discharge of post-development watershed by 80 percent would be ideal but is not required.

5.5 SCMs Analysis

With a working model and basis for design, the next step is to evaluate how well certain SCMs perform at a watershed level. This requires two steps: single SCM analyses and combinatory analyses to determine which single SCMs are most effective and what combinations will reduce peak flow and total volume to desired amounts respectively.

5.5.1 Single SCM Analysis

Single SCMs analyzed included bioretention, underground cisterns, pervious pavements, and rain barrels. These particular SCMs are in the category of LID controls. Each LID control was evaluated at 25, 50, 75, and 100 percent of reasonable implementation. Reasonable implantation can be interpreted as realistic adoption of the controls. For instance, the Red Butte Creek watershed contains a total of approximately 220 acres of pavement. It would be unrealistic to expect for all pavements in an area to be converted into pervious pavements. At the high end, if an area decides to adopt pervious pavements fully; approximately 21 percent of pervious pavements might be installed. This results in a realistic value of 48 acres of pervious at 100 percent implementation. The analysis of pervious pavement was done at 12, 24, 36, and 48 acres of coverage. Presented below in Figure 5-7 and Figure 5-8 are comparison charts for how particular LID controls performed in terms of reduction of peak discharge and volume.

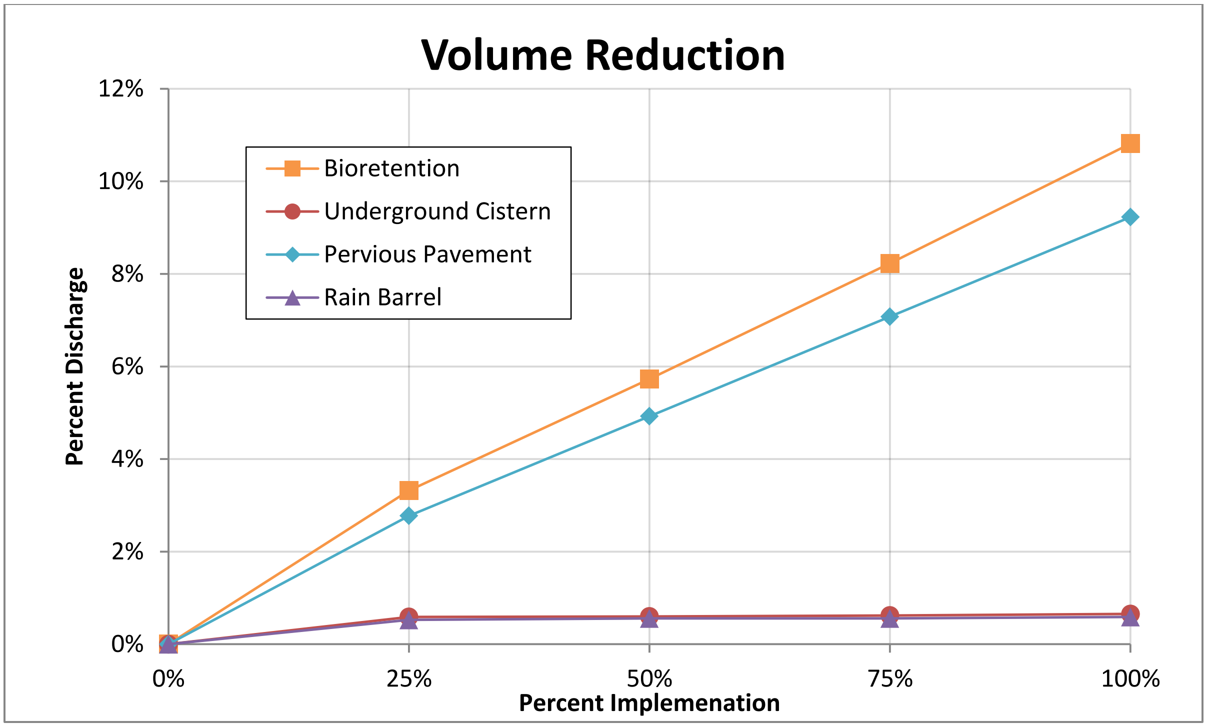


Figure 5-7: Single LID controls volume reduction for the Red Butte Creek watershed

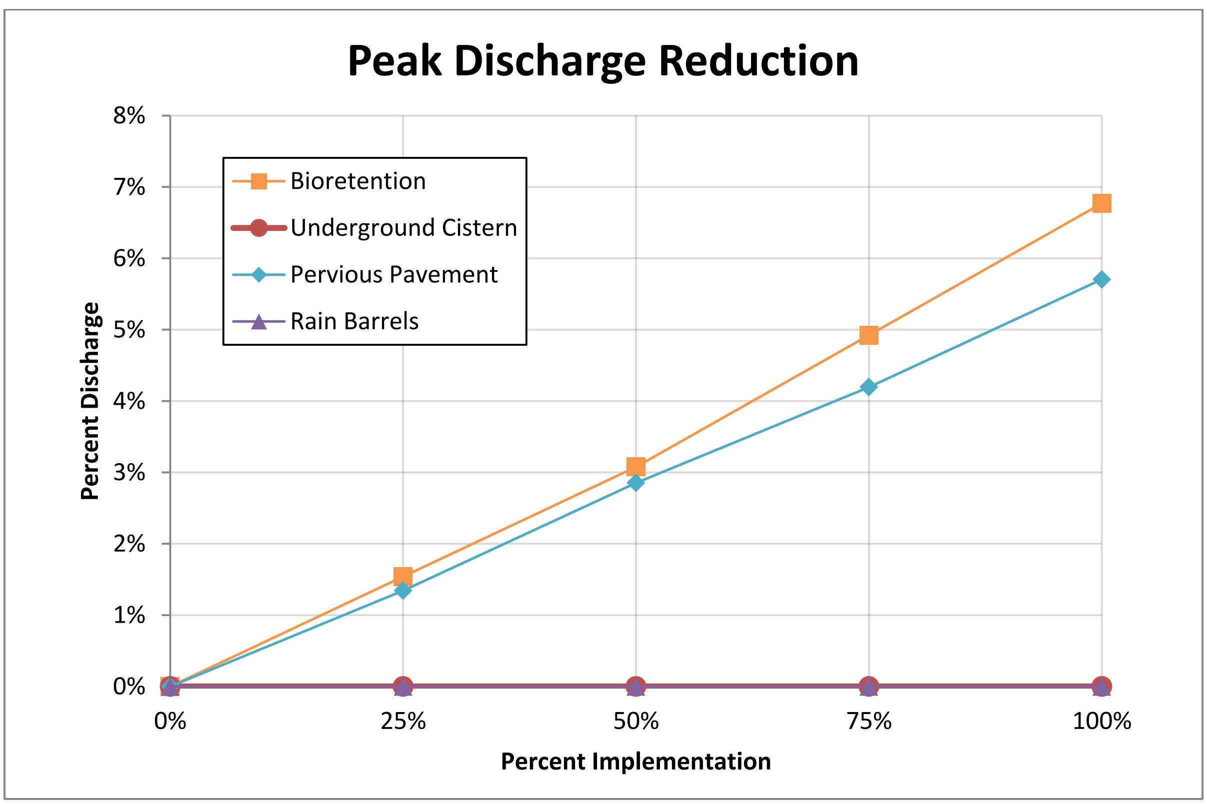


Figure 5-8: Single LID controls peak discharge reduction for the Red Butte Creek watershed

5.5.2 SCM Combinations Analysis

Once the effectiveness of the individual SCMs has been determined the designer can begin to create combinations of the SCMs and determine their effectiveness in managing stormwater. The number of SCMs can be modified within reason to increase performance. The controls can be modified in the text document associated with the model created in SWMM. Making changes to the text document and reopening the SWMM file will save the designer time when optimizing the number of controls necessary.

For the Red Butte Creek Watershed five different types of SCMs were placed in the post-development Red Butte Creek Watershed: bioretention, pervious pavement, rain barrels, retention ponds, and underground cisterns. A combination of controls was created that represented the maximum number of controls that could be reasonably placed within the watershed. The combination consisted of covering ten percent of the pervious area within the watershed with bioretention. This was selected because bioretention can be used in small and large areas and could have various applications throughout the watershed. Twenty five percent of the paved surfaces were converted to pervious pavement; this is a very generous amount but was based upon converting approximately one half of the parking lots to pervious pavement. Rain barrels were placed at every house and building within the watershed. Salt Lake County permits the use of two 100 gallon containers to collect rainwater, assuming that the county provided the rain barrels this could be a reasonable amount. Underground cisterns were placed in every large building on the University of Utah campus with a capacity of 2500 gallons; there are currently no regulations for underground rainwater harvesting.

Once the SCM controls were placed in all of the developed sub-basins of the watershed the model was run with rainfall data from an entire year to evaluate the total discharge. The discharge was compared to the discharge prior to the installation of the SCM controls. The Red Butte Creek Watershed experienced a total volume discharge reduction of 13.0 percent. Each SCM was then reduced by a factor 75, 50, and 25 percent of the initial amount to determine the relationship number of controls to performance. The results showed a linear decreasing trend, as the numbers of SCMs in the watershed were reduced by a given factor the performance was also reduced by the same factor.

The basis of design requires a reduction of 80 percent reduction in the total one year volume discharge. To increase the volume reduction in the watershed five retention basins were added to the largest sub-basins prior to entering the Red Butte Creek. The retention basins were modeled to allow infiltration through a layer of loam and had an average loss due to infiltration of approximately 15 percent. The retention basins were designed to have 3:1 side slope (3 horizontal feet for every one vertical foot), a depth of ten feet, and a top width of 200 feet by 200 feet, which resulted in a total volume of approximately 325,000 cubic feet. A circular one foot diameter drain that flowed into the creek was placed at the bottom of the retention basin and a weir was installed at the top of each basin and was sized to ensure that flooding did not occur over the one year simulation or during the 10 year 24 hour SCS design storm. The weirs ranged from a 20 feet by one foot deep to 10 feet by one half foot deep.

The retention basins allowed for an additional reduction of the total yearly volume discharge of 49.2 percent. The retention basins and SCMs together were able to reduce the total yearly volume discharge by 62.2 percent from 152.2 million gallons to 57.6 million gallons per year. While the reduction of 62.2 percent does not meet the required reduction of 80 percent, the reduction is near the maximum that can be attained for the Red Butte Creek Watershed. Additional SMCs and retention basins cannot be added due to space constraints, local regulations, and/or feasibility. This is important to take into account, while some SCM's may be very effective, it may be very hard to find space in retrofit application for installation, this is the case with retention basins, due to their size and depth there are few locations in which installation is feasible.

The combination of SCMs and retention basins were able to contain the 10 year 24 hour SCS design storm and reduce the peak discharge from the watershed by 36.9 percent. The SCMs attributed to a reduction in peak discharge of 2.6 percent and the retention basins attributed to a reduction of 34.3 percent, which can be seen in Figure 5-9 and Figure 5-10 below. LID Controls are effective in reducing total volume runoff but are not as effective for peak discharge which is why retention basins are required. Retention basins enable the discharge of stormwater to be slowed and spread out over a longer period of time which in turn reduces the peak discharge rate.

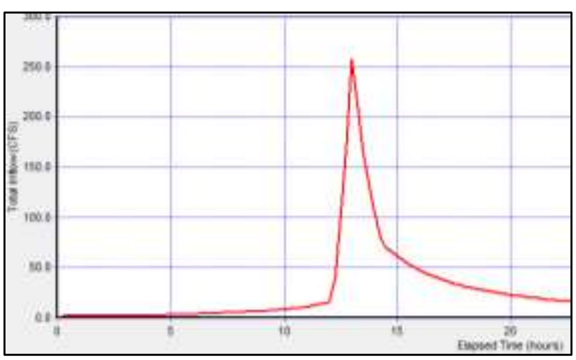


Figure 5-9: Peak Discharge (No SCMs or Retention Basins)

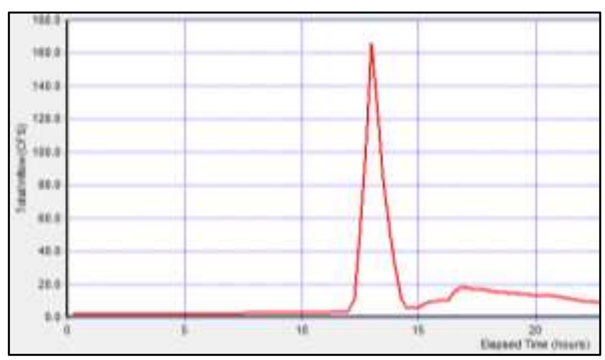


Figure 5-10: Peak Discharge with SCMs and Retention Basins

5.6 Cost versus Performance

SWMM was selected because the relationship between controls and performance can be determined quickly by running the model. Mitigating stormwater runoff has costs associated with it, and presented here is an approximation of how much it will cost to implement the combination of controls in previously mention in Section 1.5. The idea is to define a relationship between costs and performance. Using alternative's cost analysis from SEA Design Teams and personal research into average values for LID controls and total cost was evaluated for SCM implementation to the Red Butte Creek watershed. A post-construction present cost breakdown at 100 percent implementation is provided below in Table 5-2. Cost estimates for each of the controls were provided by the SEA team with the exception of bioretention which was found on the EPA's website.

Table 5-2: Red Butte Creek SCM Controls Cost Breakdown.

SCM	Unit Cost	Single SCM Size	Control Cost	Number of Controls	SCM Total
Bioretention	\$9.00 / ft^2	2000 ft^2	\$18,000.00	1,743	\$31,374,000.00
Pervious Pavement	\$4.25 / ft^2	500 ft^2	\$2,125.00	981	\$2,084,625.00
Underground Cistern	\$1.66 / gallon	2,500 gallon	\$4,150.00	4,189	\$17,384,350.00
Rain Barrels	\$0.73 / gallon	200 gallon	\$146.97	88	\$12,933.36
Retention Basin	\$0.90 / ft^3	325,000 ft^3	\$292,500.00	5	\$1,462,500.00
				Total	\$52,318,408.36

Additional cost breakdown for commercial and residential areas is provided in Table 7.1 of Appendix B. 52 million dollars is the cost for 100 percent implementation over a 1,800 acre area of land that includes mountainside, commercial, and residential zone. If applied to other area the cost may increase or decrease with less or more mountainside coverage respectively. The relationship between the total costs is linear with the percentage of all controls implemented. If only 25 percent of all controls are implemented, the total cost for the watershed is 25 percent of the cost at 100 percent implementation. Performance however is not a linear relationship and provided above in Figure 5-11 depicting the relationship between relative cost and performance.

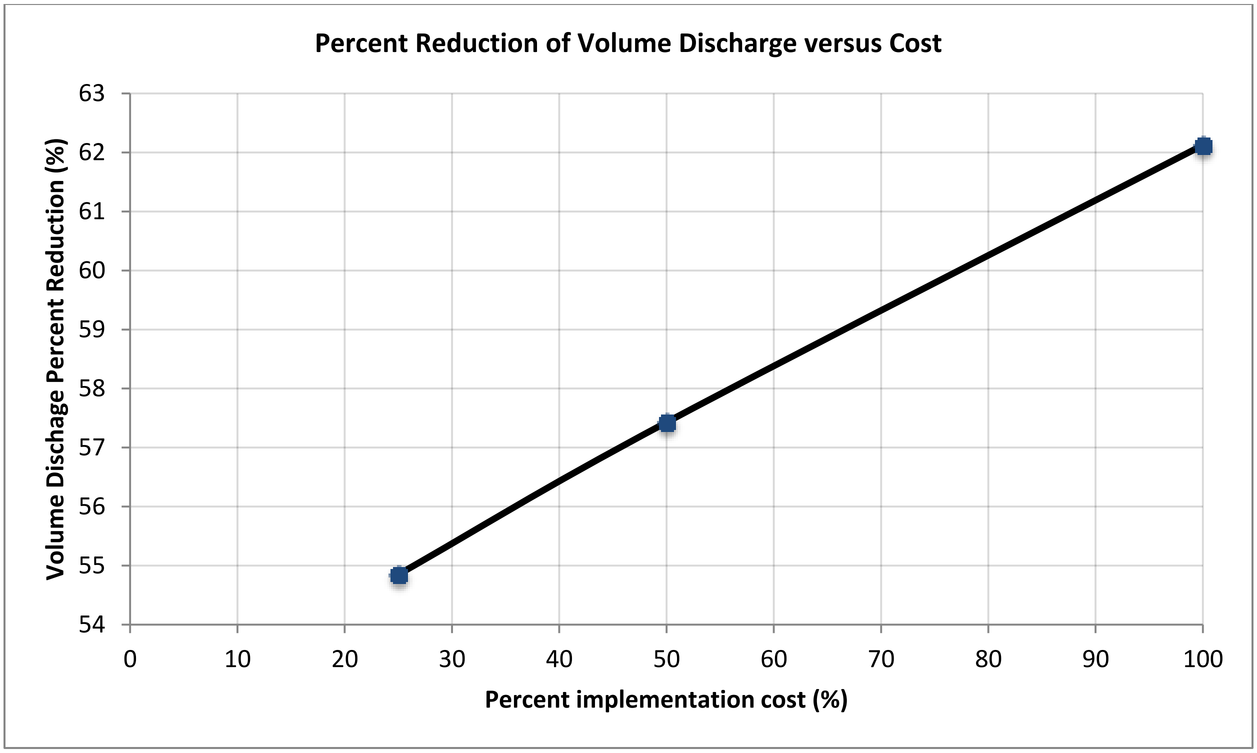


Figure 5-11: Cost versus Performance

5.7 Conclusion

From the stormwater analysis which has been performed for the Red Butte Creek Watershed it can be seen that SWMM is powerful modeling program. SWMM can be used in applications ranging from large to small scale watersheds and can predict within reason total volume and peak discharges for various types of simulations. SWMM is a great tool to quickly determine the performance of several different types of SCMs in a given watershed. It can also be used to perform very in depth analyses which were not covered in this section such as effect and performance of stormwater sewers and locations of specific SCMs and retention basins.

SWMM is also capable of modeling stormwater quality which was not simulated for this project due to time constraints. The SWMM User's Manual discusses in detail how stormwater quality can be modeled and visualized. The capabilities of SWMM are vast but utilizing all of them requires a lot time and uses more computing resources. It is possible to model more than the five SCMs that were used from the LID Control Editor. Almost any type of SCM can be placed in a watershed using the sub-basin tool to create the area and define the parameters. More experience is required to perform this function but it is possible.

As you can see SWMM is an efficient tool and once a functional knowledge of the program is attained a model of a watershed to be analyzed can be developed quickly. This program is recommended for use in developing model watersheds in urban areas that require stormwater analysis and the implementation of SCMs and retention basins.

6| Ordinance, Education, and Funding

6.1 Stormwater System Funding

6.1.1 Revenue Generation

One of the major hurdles to implementing SCMs is finding a way to generate enough revenue to build them. This two-step process involves determining the amount of revenue needed and then developing a funding method. The most popular method for funding stormwater systems is implementing a stormwater utility fee. In some cases this revenue stream is supplemented by acquiring grant money and/or diverting money from other sources like property taxes. In the following sections SEA has estimated a total cost and cost per household to implement a proper amount of stormwater control measures.

6.1.2 Land Use and Population Projections

To calculate the number of SCMs needed for the Jordan River Corridor, watershed modeling data was extrapolated to represent Salt Lake County. Once the watershed modeling data was extrapolated and pricing information was gathered regarding the individual designs, a unit price in today's dollars was determined for various types of land use. The land use estimations (Table 6-1) are based on the 2030 projections by the Salt Lake County Watershed – Water Quality Stewardship Plan [28]. It should be noted that Salt Lake County data was used because most cities along the Jordan River Corridor are in Salt Lake County.

Table 6-1 Land Use Projections and Unit Cost

2030 Land Use		Acres	Cost per Acre	Total Cost
Forest	39.3%	202630.8	$0	$0
Residential	32.2%	166023.2	$34,064	$5,655,392,798
Parks/Open Space	6.7%	34545.2	$0	$0
Industrial	6.6%	34029.6	$27,762	$944,741,766
Public/Institutional	4.2%	21655.2	$19,665	$425,849,508
Transportation	1.8%	9280.8	$315	$2,920,329
Commercial Other	0.2%	1031.2	$32,775	$33,797,580

The cost per acre (Table 6-1) for residential and commercial land use was calculated using a combination of watershed modeling data, Water Quality Stewardship Plan data, and engineering judgment. Watershed modeling data for residential and commercial areas yielded the cost per acre breakdown in Table 7-1 of Appendix B.

To relate the industrial, public/institutional, and transportation land use categories, the Water Quality Stewardship Plan's guidance regarding impervious land percentages (Table 6-2) was used to relate area with similar characteristics. For example, since commercial sites have similar characteristics to industrial sites, the cost to treat an industrial site is similar to the cost to treat a commercial site. To account for the differences in impervious error, an adjustment factor was applied to the cost for a commercial site to generate the cost estimate for an industrial site. Full description of the values used can be found in Table 7-2 of Appendix B.

Table 6-2 Percent Land Impervious [28]

Public/Institutional	51%
Commercial &Transportation	85%
Industrial	72%
Residential	32%
Open Space	12%
Forest/Wetlands	9%

The total cost was then broken down to show the cost per household using projected population data for the cities of Salt Lake County [28]. The population estimate was then divided by U.S. Census data regarding the average number of people per household in the Salt Lake County [29]. The city-by-city breakdown can be found in Table 7-3 of Appendix B.

6.1.3 Cost per Household

The total cost per household to implement the SCM measures is estimated to be $15,029.59. This number represents the amount of money each household would have to contribute to help install adequate SCMs throughout Salt Lake County for a design year of 2030. This number does not account for any businesses or organizations contributing to the construction of SCMs. In reality, businesses would also be obligated to contribute and lower the cost per household, just like they currently do for all other public utilities.

6.2 Funding Options

One option for generating the necessary revenue is to adopt a fee structure already in place elsewhere. SEA has researched and analyzed three different stormwater utility fee systems for comparison and to make a recommendation. The most prevalent is charging a stormwater utility fee based on impervious area, type of land, and/or some other governing factor. The key for implementing a utility like this is to find a fee structure that is socially acceptable and reasonable for the location. In the following sections three examples of such stormwater utilities are discussed

6.2.1 Non-Local Solutions

The City of Champaign, Illinois is currently looking into implementing a stormwater utility that would be based on the amount of impervious area on a given property. By implementing this fee, the City of Champaign hopes to reduce the amount of flooding and to improve the quality of water that enters their waterways. The users along the waterways would have a fee added on to their monthly utility bill from the city that already includes the sewer and trash collection costs. The reason that their community leaders gave for choosing this option was "the relationship between the fee paid and the services provided." Another reason for why this fee was selected was the "voluntary nature of the fee." If homeowners and businesses along the river reduced the amount of pervious pavement, then that would result in lower fees assessed. It was projected that the city could generate $3.4 million from the fee over a 20 year period. The fees assessed by the city are a flat fee of $4.94 for residential units with less than 6000 square feet of pervious area; a $10.55 fee for properties with 6001 to 8000 square feet of pervious area and any property with more than 8001 square feet are charged a fee of $13.64 monthly. All of this revenue would be put back into improvement plans for the city water system.

Another stormwater utility fee structure that was examined was the City of Orlando, Florida. The system essentially uses a series of yes/no questions outlined in a flowchart to determine the fee for a parcel of land (Figure 6-1). The plan is much more thorough than the basic fee structure outlined by the City of Champaign. Instead of using flat rates for an acreage window, the acreage for the particular type of property is multiplied by a factor. Also, the system not only has fees based on areas, but also a further breakdown of types of properties. If the property area is towards the maximum/minimum allowed for the case, a maximum/minimum fee is also given in the flowchart. This type of system would obviously take thorough knowledge of the area to appropriately delineate the fee structure.

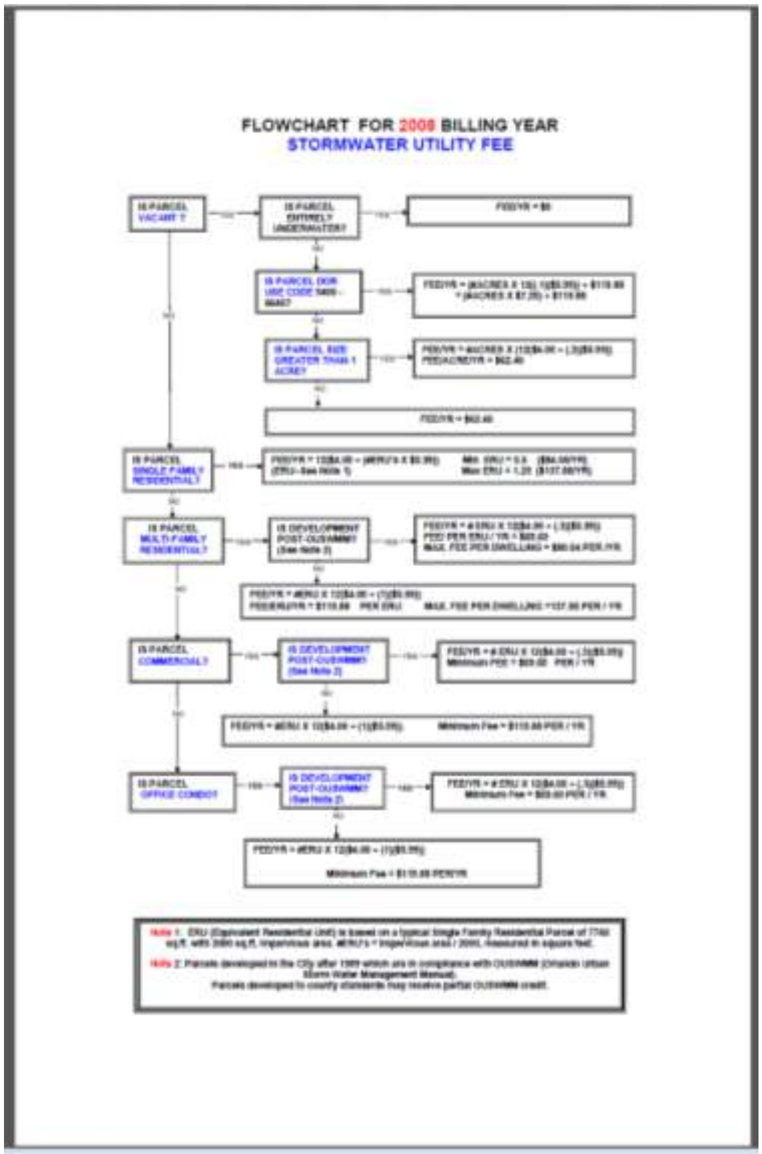


Figure 6-1 Flow Chart for Stormwater Fees [30]

6.2.2 Current Riverton, UT Stormwater Utility

An example of a stormwater utility fee currently in place in the Salt Lake Valley can be found in Riverton, UT. The fee was instituted due to a requirement made by the Environmental Protection Agency (EPA) to increase stormwater quality and reduce pollutants as part of the National Pollution Discharge System, a stipulation of the Federal Clean Water Act. To make the changes necessary to comply with EPA regulations, additional revenue, which is generated by the fee, was needed. Before the fee was implemented there was no direct funding for stormwater. The money needed was diverted from similar services like gas and property taxes. The fee is now being phased in over a four year period which began in fiscal year 2010-2011.

The amount of the fee is determined by the amount of impervious area on the property, or Equivalent Residential Unit (ERU). The initial fee for phase one was $4.00/ERU and will gradually increase to $7.00/ERU in 2013-2014. It is estimated that by 2014 the fee will bring in $1,400,000 annually. This revenue will help pay for maintenance of the stormwater system, streets sweeping, public information and education, and enforcement of regulations [31].

6.2.3 Estimated Cost to Businesses and Homeowners

The best fee structure for Jordan River Corridor would be the Riverton model. The fee structure is already acceptable in the region and would be easy to gain information about. Additionally, for the city of Riverton no additional fee restructuring would be necessary. By using this fee structure, the total cost per household could be broken up into monthly billing increments and included with other municipal utilities.

6.3 Education

6.3.1 Stormwater Education

SEA realizes the importance of an education plan for stakeholders on the use of a best management practices document. By educating stakeholders on the importance of stormwater management, they can best use the document and implement the recommendations. The team selected three alternatives for educating stakeholders: the use of a book, the use of a website, and the use of a scheduled workshop. After conducting research on each of the alternatives presented in the guidance document, SEA has selected a website as the best alternative for a public education plan. Although SEA will not be providing nor conducting any of the programs, SEA does have an outline of information created for the website.

The recommended option for the JRC by SEA is to create a website. By making the information on stormwater management easy to access for stakeholders, local governments, and the general public, it would be the best use of time and resources for the JRC. The website would be divided into eight sections:

- General information
- Hazards with Stormwater
- Invasive Plants and Noxious Weeds Identification
- Proper Disposal and Care for Dead Plant Material
- Native and Ecologically Friendly Plant Identification
- Tips on Maintaining Ecological Stability
- Rules and Regulations
- Current River Data

By having a website, it makes the information easy to follow and find on the website. Also the ease of updating a website would ensure that all parties have access to the latest information on stormwater management. Also each community could have their own section of the website so that stakeholders and citizens could fully understand what is going on in their own community. A community board could also be made so that everyone can see updates and advice for projects along the river.

Although the use of a web site does have many advantages it does come with some drawbacks. It may not be friendly to those in the field because an internet connection maybe hard to find. Another disadvantage would be the learning curve associated with a website format and the fact that someone would need to be in charge of maintaining the website.

6.3.2 Public Awareness and Dissemination

One major component of stormwater management is public involvement. If the public is not informed on the issues going on in the river, and does not do their part in the cleanup, then the river will never return to a healthy state. By the public becoming more involved in the river system, it will lead to a river that is cleaner, more environmentally friendly, and a place for recreational activities. The goal of public awareness is to reach as many people as possible, and be done in an effective manner. The SEA team looked at three alternatives for accomplishing this: an informative distribution pamphlet, a tri-fold brochure, and a poster. By looking at the advantages and disadvantages for each alternative the team selected the informative distribution pamphlet as the best option for the JRC.

The pamphlet can be seen below in Figure 6-2 and in Figure 7-1 of Appendix B and would take up one half of an 8 1/2 by 11 sheet of paper making it roughly 4.25 by 11. It would be one sided for cost purposes and contain information for public information. The poster can be seen in Figure 7-2 of Appendix B and could vary in size. It would be one side and contain similar information as the pamphlet. It would be more appropriate in public settings. The SEA team felt like because of the importance of organic matter in the river system it was most important to focus on that. The pamphlet mainly focuses on how homeowners can reduce organics in the river and why organics are harmful to the river system. The goal of the pamphlet is to inform the public and to get them more involved in the river. By handing the flyer out door to door or working with the public works to get the pamphlet put into a monthly bill then it would reach the highest amount of people.

Figure 6-2 Public Education Handout

This type of distribution compared to the others is a very quick and easy way to get information out to the public. The pamphlet will hopefully grab the reader's attention and give them easy access to the information. These pamphlets are simple and inexpensive to distribute which makes it easy to get out.

The disadvantage to this type of pamphlet is because of its common size many people could just see this as junk mail and throw it away before reading any of the content. The size of the pamphlet may also be a problem because the information that is contained there could be limited.

6.4 Model Ordinance

6.4.1 Ordinance Collection

As stated in the guidance document provided earlier to the JRC, SEA has been working towards the production of a model ordinance that could identify key terms and directives in which a government body could establish for their respective community. However, due to the language and training that is required for such a legal document to be produced, a selected alternative for a complete model ordinance was in the use of a draft outline for a stormwater management plan. This plan would provide necessary guidance for creating a program that would allow each government body to establish their respective goals and ideas instead of providing full documents with specific instructions. The completed outline was generated from current stormwater management plans from communities in the Jordan River Corridor with added information from the guidance principles set forth by the JRC in the publication *Blueprint Jordan River.* The stormwater plans from each city amongst the Jordan River Corridor were analyzed for best practices, and a list was compiled of the most effective and efficient directives. These directives were then combined with the guidance principles set forth in *Blueprint Jordan River* completing the outline.

6.4.2 Model Ordinance

The draft outline is to be used by a government body in writing a stormwater management plan. The intention of the draft is to allow each respective government body to write, update, or enhance their current stormwater management programs. A view of the front page can be seen in Figure 6-3 with the full completed draft outline found in Stormwater Management Program Outline in Appendix B. The draft outline is written with the following format:

Section Heading

Specific Topic to be Addressed

Suggestion of what should be included in the subject matter

Stormwater Management Program Outline

The following is a draft outline to be used by a government body in writing a stormwater management ordinance. The outline was generated from stormwater management plans from communities in the Jordan River Corridor with added information from the guidance principles set forth by the Jordan River Commission in the publication *Blueprint Jordan River*. The intention of this draft is to allow government bodies to write, update, or enhance their current stormwater management plans. The draft outline is written with the following format

Section Heading

Specific Topic to be Addressed

Suggestion of what should be included in the subject matter

Front Matter

Glossary

List of acronyms

Purpose

Abstract summary

Legal Authority

Federal, State, County, and City current regulations and responsibilities

Storm Water Management Plan (SWMP) Coordination

Agency and contact information

SWMP Review and Modification

Date of completion and timeframe of review

Staffing and Resource Allocations

Who is involved within the SWMP and where funding is obtained

Stormwater System Overview

City details to include location, area, water systems, and a percentage of residential, commercial, transportation, parks, and open spaces in city limits

Proposed Program Summary

Short summary of each chapter in document identifying goals and intentions

Stormwater Districts

Establishment of multijurisdictional stormwater districts

Stormwater Management Implementation Plan

Timeline showing completion dates of each project

Figure 6-3 Front Page of Model Ordinance

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7.1 Appendix A – Acronyms and Abbreviations

Division of Water Quality	DWQ
Environmental Protection Agency	EPA
Geographic Information System	GIS
Groundwater table	GWT
Jordan River Commission	JRC
National Oceanic and Atmospheric Administration	NOAA
Outdoor Recreation Program	ORP
Project Management	PM
Rainwater Harvesting	RWH
Storm Water Management Model	SWMM
Stormwater Control Measures	SCMs
Student Engineering Associates	SEA
Total Maximum Daily Load	TMDL
Total Suspended Solids	TSS
Utah Department of Transportation	UDOT
Continuous Deflective Separation	CDS
Dissolved Oxygen	DO
Low Impact Development	LID
Equivalent Residential Unit	ERU

7.2 Stormwater Utility Cost and Population Data

Table 7-1- Residential and Commercial Area Cost Analyses

Residential Area

	Units	Cost Per Unit	Control Per Acre	Cost Per Acre
Bio-Retention	236	18000	1.51	$27,231
Porous Pavement	462	2125	2.96	$6,293
Rain Barrels	573	146.97	3.67	$540
			Total	$34,064

Commercial Area

	Cost Per Unit	Control Per Acre	Cost Per Acre
Bio-Retention	18000	1	$18,000
Porous Pavement	2125	5	$10,625
Rain Barrel	146.97	0	$0
Underground Cistern	4150	1	$4,150
		Total	$32,775

Table 7-2 - Cost Calculation Methodology

2030 Land Use	Calculation Method
Forest	NA
Residential	Residential Cost
Parks/Open Space	NA
Industrial	(72%/85%) * Commercial
Public/Institutional	(51%/85%) * Commercial Cost
Transportation	20% * Porous Pavement Cost
Commercial Other	Commercial Cost

Table 7-3 Population Projections

Municipality	2030 Projected Population	Projected Households	Acres
Alta	NA	NA	2890
Bluffdale	52900	17993	10795
Cottonwood Heights	43991	14963	5754
Draper	46256	15733	13870
Herriman	45686	15539	7993
Holladay	32891	11187	4976
Midvale	44610	15173	3753
Murray	70693	24045	7860

Riverton	51793	17617	8081
Salt Lake City	200051	68045	70556
Sandy	94170	32031	14649
South Jordan	98150	33384	14156
South Salt Lake City	31031	10555	4452
Taylorsville	67119	22830	6953
West Jordan	132730	45146	20695
West Valley	153890	52344	22929
Unincorporated	215603	73334	295210
Total	1381564	469920	515572

7.3 Public Education Materials

Figure 7-1- Public Flyer

Figure 7-2 - Public Poster

7.4 Stormwater Management Program Outline

The following is a draft outline to be used by a government body in writing a stormwater management ordinance. The outline was generated from stormwater management plans from communities in the Jordan River Corridor with added information from the guidance principles set forth by the Jordan River Commission in the publication *Blueprint Jordan River.* The intention of this draft is to allow government bodies to write, update, or enhance their current stormwater management plans. The draft outline is written with the following format

Section Heading

Specific Topic to be Addressed

Suggestion of what should be included in the subject matter

7.4.1 Front Matter

Glossary

List of acronyms

Purpose

Abstract summary

Legal Authority

Federal, State, County, and City current regulations and responsibilities

Storm Water Management Plan (SWMP) Coordination

Agency and contact information

SWMP Review and Modification

Date of completion and timeframe of review

Staffing and Resource Allocations

Who is involved within the SWMP and where funding is obtained

Stormwater System Overview

City details to include location, area, water systems, and a percentage of residential, commercial, transportation, parks, and open spaces in city limits

Proposed Program Summary

Short summary of each chapter in document identifying goals and intentions

Stormwater Districts

Establishment of multijurisdictional stormwater districts

Stormwater Management Implementation Plan

Timeline showing completion dates of each project

7.4.2 Public Education and Outreach Program

Objective

What is the objective of this chapter

Target Audience

Identify who is being addressed

Administration Responsibility

Responsibility in particular to this program

Educational Opportunities to Alert the Public

Displays, information booths, school presentations, websites, community and residential programs, curb markings, newsletters, etc.

Restore Riparian and In-Stream Habitats

Process for restoring riparian system to include boardwalks and interpretive signs

Public Recreational Areas

For example b*ike trails, river play areas, wildlife viewing stations, etc.*

Measurable Goals

Goals for the BMP to implemented and assessed during the permit term

7.4.3Public Involvement/Participation Program

Objective

What is the objective of this chapter

Target Audience

Identify who is being addressed

Administration Responsibility

Responsibility in particular to this program

Public Opportunities

Open houses, volunteer opportunities, service projects, public reporting, etc.

Use of Nature Centers

Directives on use and ability to display public art, have nature tours, and hold outdoor school classrooms

Measureable Goals

Goals for the BMP to implemented and assessed during the permit term

7.4.4Natural Stormwater Controls Program

Objective

What is the objective of this chapter

Administration Responsibility

Responsibility in particular to this program

Use of Wetlands

Creation and maintenance of wetlands to provide flood water storage and habitat and filter water back to the water table

Use of Floodplains

Creation and maintenance of floodplains to provide flood water storage, but are also prime areas for wildlife habitat, urban forests, and recreational greenways

Vegetation Control

Planting of native and adapted species providing habitat and water quality

Use of Buffers

Use of buffers to serve as natural boundaries between the local waterways and existing development to help protect water quality from stormwater runoff

Use of Green Roofs

Directives on whom and when green roofs should be employed

Pavement Runoff

Directives on the type of pavement stormwater control measures to be used. Could include use of permeable pavement, bioswells, and bioretention ponds

Rain Gardens

Directives on whom and when rain gardens should be employed

7.4.5Illicit Discharges and Improper Disposal Program

Objective

What is the objective of this chapter

Administration Responsibility

Responsibility in particular to this program

Storm Drain System Map

A map showing the locations of storm drains

Identification of Illicit Discharges

Listing of illicit discharges

Illicit Discharge Screening Reports

How illicit discharges will be reported

Removal of Illicit Discharges

Environmentally friendly procedures on removal of illicit discharge

Prevention of New Illicit Discharges in Stormwater System

Education, regulations, spill prevention, response procedures, etc.

Investigations, Enforcement, Violation, and Penalties

How illicit discharges will be enforced

Measureable Goals

Goals for the BMP to implemented and assessed during the permit term

7.4.6 Construction Site Stormwater Runoff Control Program

Objective

What is the objective of this chapter

Administration Responsibility

Responsibility in particular to this program

Construction Site Programs

Construction site programs and requirements to reduce pollutants

Stormwater Management Site Permit

Permitting process with requirements for construction operators

Site Inspections

Timeline and process for inspecting construction sites

Contractor Education

How contractors are to informed of stormwater management BMP's

Construction Permit Notification and Documentation

Construction site permit documentation and contractor notification on requirements

Investigations, Enforcement, Violation, and Penalties

How site permits will be enforced

Measureable Goals

Goals for the BMP to implemented and assessed during the permit term

7.4.7 Post-Construction Stormwater Management in New Development and Redevelopment Program

Objective

What is the objective of this chapter

Administration Responsibility

Responsibility in particular to this program

Stormwater Quality Post-Construction Site Permit

A stormwater management permit is required for connections to city

Post-Construction Maintenance

Procedures to ensure long-term operation and maintenance of stormwater controls

Comprehensive Land Use Master Plan

Water quality impacts of new and redevelopment areas

Inspections During and After Construction

Timeline and requirements for inspections on new and redeveloped areas

Investigations, Enforcement, Violation, and Penalties

How stormwater management in new and redeveloped areas will be enforced

Measureable Goals

Goals for the BMP to implemented and assessed during the permit term

7.4.8 Pollution Prevention and Good Housekeeping Program

Objective

What is the objective of this chapter

Administration Responsibility

Responsibility in particular to this program

Training and Education

Training of public employees and road crews

Inventory and Assessment of Facilities

Determination of facility priority ranking based on potential to discharge urban pollutants

Storm Drain System Maintenance

How and when storm drains will be maintained

Flood Control Programs

How will flood control be addressed

Structural Controls and Detention Requirements

Controls to improve stormwater quality and decrease stormwater release rates

Snow Removal and De-Icing Practices

Process for snow removal and de-icing on roads

Street Sweeping

Procedures for removal of debris from streets

Pollution Prevention Practices

Pesticides, herbicides, and fertilizer control

Spill Prevention and Response

How are spills responded to

Measureable Goals

Goals for the BMP to implemented and assessed during the permit term

Appendix B – Watershed Modeling Metadata

Table 7-4 Pervious Pavement LID Parameters

Process Layer	Parameter	Value	Reference
Surface	Storage Depth (in)	4-6	SEA Design Team
	Vegetation Volume Fraction	0	SWMM User Manual
	Surface Roughness (Manning's n)	0.03	See Reference 4.
	Surface Slope (percent)	0.3	SEA Design Team
Storage	Height (in)	6-18	SWMM User Manual
	Void Ratio (Voids/Solids)	0.5-0.75	SWMM User Manual
	Conductivity (in/hr)	1417	See Reference 5
	Clogging Factor	0	SWMM User Manual
Pavement	Thickness (in)	4-6	SWMM User Manual
	Void Ratio	0.12-0.21	SWMM User Manual
	Impervious Surface Fraction	0	SWMM User Manual
	Permeability (in/hr)	14.4-2,000	See Reference 6
	Clogging Factor	0	SWMM User Manual

Table 7-5 Bioretention LID Parameters

Process Layer	Parameter	Value	Reference
Surface	Storage Depth (in)	8	SEA Design Team
	Vegetation Volume Fraction	.2	SEA Design Team
	Surface Roughness (Manning's n)	0.029	See Reference 3
	Surface Slope (percent)	1%	SEA Design Team
Soil	Thickness (in)	30	SEA Guidance Doc
	Porosity,(Volume Fraction)	0.463	SWMM User Manual
	Field Capacity (Volume Fraction)	0.232	SWMM User Manual
	Wilting Point (Volume Fraction)	0.116	SWMM User Manual
	Conductivity (in/hr)	0.13	SWMM User Manual
	Conductivity Slope	10	SWMM User Manual
	Suction Head (in)	3.5	SWMM User Manual
Storage	Height (in)	24	SEA Team
	Void Ratio (Voids/Solids)	0.3	See Reference 3
	Conductivity (in/hr)	0.13	SWMM User Manual
	Clogging Factor	0	SWMM User Manual