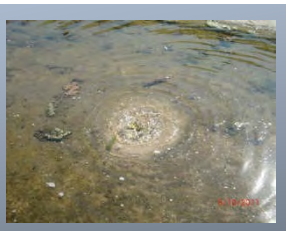

Antelope Creek Watershed Basin Management Plan

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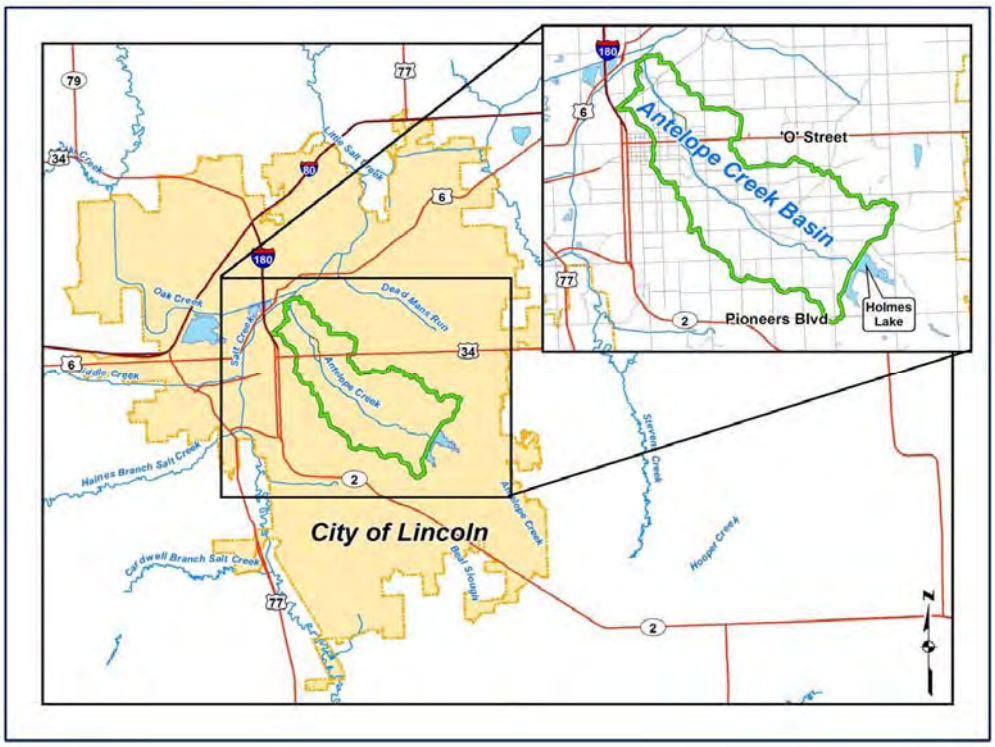
EXECUTIVE SUMMARY

Introduction

The City of Lincoln (City) and Lower Platte South Natural Resources District (LPSNRD) have continued efforts towards developing Comprehensive Watershed Management Plans for the City of Lincoln and future growth areas with the establishment of the Antelope Creek Watershed Basin Management Plan (Basin Plan). The focus of the Basin Plan is improving water quality as compared to past Basin Plans that provided information primarily for flood control and stream degradation projects. The Basin Plan addresses improvement of water quality in a stretch of Antelope Creek that is highly urbanized in the center of Lincoln, Nebraska. The Basin Plan only includes the portion of the Antelope Creek watershed downstream of Holmes Lake (see Figure ES-1).

Figure ES-1: Antelope Creek Location Map



Previously adopted Watershed Master Plans include:

- Beal Slough (2000)
- Southeast Upper Salt Creek (2003)
- Stevens Creek (2005)
- Cardwell Branch (2007)
- Deadmans Run (2007)
- Little Salt Creek (2009)

The Basin Plan boundary totals 4,932 acres, from Antelope Creek's confluence with Salt Creek near the Devaney Sports Center, southeast to Holmes Lake. The watershed includes approximately 7.7 square miles— 5.7 miles of stream with a maximum width of 2 miles, and maximum length of 5 miles.

The City and LPSNRD worked with a team of scientists and engineers during plan development from May 2010 through March 2012. The team was led by EA Engineering, Science, and Technology, Inc. (EA) located in Lincoln, NE. EA worked in cooperation with JEO Consulting Group (JEO) of Lincoln, NE, Wright Water Engineers (WWE) of Denver, CO, and a nationally recognized water quality expert, Dr. Robert Pitt, from the University of Alabama.

In 2007, the Nebraska Department of Environmental Quality (NDEQ) and the United States Environmental Protection Agency (EPA) listed this stretch of Antelope Creek as being impaired due to elevated levels of ammonia and the bacterium *Escherichia coli (E. coli)*. *E. coli* bacteria are commonly found in the intestines of animals and

humans and serve as an indicator of fecal contamination. Antelope Creek was determined to be a Category 5 water body and was listed on EPA's Clean Water Act Section 303(d) list of impaired waters. In response, NDEQ developed a Total Maximum Daily Load (TMDL) in 2007 for Antelope Creek, in order to set goals for pollution reduction levels necessary to remove Antelope Creek from the 303(d) list.

The primary goal of this Basin Plan is to identify sources of pollution, provide alternatives to reduce pollutant loads below EPA criteria, and to provide information to aid in removing this segment from the 303(d) list. Secondary goals include educating the public about water quality, and applying lessons learned from the Basin Plan to other basins within Lincoln, NE and future growth areas.

Although reducing concentrations of *E. coli* in Antelope Creek is a primary focus, the Basin Plan was written comprehensively to address both non-point and point sources and other contaminants found in the Creek. A community-based planning process was used which emphasized public involvement. In addition, the Basin Plan was written with a focus on EPA's Nine Elements of watershed planning.

Public Involvement

The City and LPSNRD emphasized public participation and education as key aspects of the Basin Plan. A public involvement strategy was established so that citizens could participate in public decisions that might affect them, their property, and their interests. Public involvement was also included due to the importance of educating the public on stormwater best management practices (BMPs) and their use by the City as well as by residential landowners. The public involvement process included the following:

- **Advisory Council** – A 12-member group was appointed by the Mayor and is displayed in Table ES-1. The group members' roles and responsibilities included reviewing elements of the Basin Plan, asking questions, raising issues, and sharing information with one another, the public, and the team. The team facilitated three Advisory Council meetings.
- **Core Work Group** – An eight member, technically-based group, including the City of Lincoln Parks and Recreation, Planning, and Public Works, the LPSNRD, and the NDEQ, was established at the beginning of the project to provide technical direction for Basin Plan development. The project team facilitated 11 core work group meetings.
- **Open Houses** – Two open houses were conducted, one in September 2010 and a second in December 2011. Post card invites were sent to 11,000 landowners in the Basin Plan area.
- **Stakeholder Meetings** – Presentations were conducted for multiple stakeholders, including the University of Nebraska–Lincoln (UNL), Witherbee Neighborhood Association (NA), Colonial Hills NA, Homebuilders Association of Lincoln, 40th and A Street NA, and the Lincoln Children's Zoo.
- **Watershed News** – Four newsletters providing information on the Basin Plan development and public education were distributed through mailing to 1,100 key stakeholders in Lincoln.

Picture 1: JB Dixon answers questions at Open House #1

- **City Website** – The City's website provided plan information and announcements, and made materials such as the newsletter available to the public.

Public involvement and input from the Advisory Council, open houses, Core Work Group, and stakeholder meetings were used by the project team during establishment of strategies in the Basin Plan.

Table ES-1. Basin Plan Advisory Council

Representing	Name
Non-profit	Mike Renken, NeighborWorks
Lincoln Public Schools	Scott Wieskamp, Facilities & Management
Business Group	Andrew Campbell, Campbell's Nursery
Business Group	Steve Hill, Assurity
University of Nebraska – Lincoln	Jennifer Dam, Campus Planning
Lincoln Golf Courses	Dale Hardy, Administrator
Lincoln Children's Zoo	John Chapo, President
Neighborhood Group	Tracy Corr, 40th and A Street
Neighborhood Group	Bob Kuzelka, Near South
University of Nebraska – Lincoln	Rachel Herpel, Water Center
LPSNRD	Karen Amen, Board Director
City of Lincoln	Adam Hornung, City Council

Basin Plan Elements

The Basin Plan preparation included several key elements that enabled the project team to review existing information, collect field data, model the watershed, screen potential project locations, conceptualize and prioritize projects, and formulate an implementation strategy. Summaries of each significant Basin Plan element are provided below:

Picture 2: Antelope Creek Open House #1

Basin Inventory

- Completed an inventory to identify critical areas within the watershed with potential to be pollutant sources.
- Completed a bridge inventory to identify locations where animals can directly contribute to pollutant loads within Antelope Creek.

TMDL Assessment

- Assessed the TMDL requirements for Antelope Creek and the data set used to develop the TMDL.

Water Quality Monitoring

- Conducted a visual inspection of dry weather flows contributing to Antelope Creek to identify potential point sources by walking the creek bed and observing more than 220 outfalls.
- Developed and implemented a water quality monitoring program to characterize pollutant distribution in the surface water and sediments.

Source Loading and Management Model for Windows (WinSLAMM)

- Utilized WinSLAMM to evaluate stormwater pollutant loadings specific to storm hydrology and land use conditions in the Basin Plan area.
- Completed a detailed land use inventory of specific locations in the watershed to calibrate WinSLAMM.
- Utilized WinSLAMM to evaluate alternative Best Management Plans (BMPs) throughout the watershed to analyze the effectiveness of different combinations of BMPs.

Best Management Practices (BMPs)

- Conducted a field screening and desktop review of more than 50 sites throughout the watershed to identify potential sites for water quality BMPs.
- Ranked and selected sites in the watershed based upon watershed specific selection criteria to identify the most feasible project locations.
- Conceptualized 13 structural BMP projects, including description, cost, water quality benefits, and pollutant loading estimates.
- Established more than 20 non-structural recommendations including expansion of existing programs and consideration of new programs.

Implementation Strategy

- Developed a long-term implementation strategy to improve water quality in Antelope Creek.

Summary of Findings

The TMDL regulatory driver set by NDEQ, as mandated by the EPA, requires that Antelope Creek attain water quality standards of a full body contact recreational stream during the months of May through September. The two regulated pollutants listed in the 2007 TMDL are ammonia and *E. coli* bacteria. The TMDL also identifies other "pollutants of concern" for the stream, including conductivity, selenium, and chloride. Currently, no TMDL has been developed for these pollutants for Antelope Creek. The activities conducted in preparation of this Basin Plan allowed the Project Team to successfully identify sources of the pollutants, define the magnitude of the problem, and develop Basin Plan recommendations to address the problem. Below is a summary of the Basin Plan findings.

1. **Antelope Creek does not attain the TMDL standard for *E. coli* bacteria.** The *E. coli* standard for the stream established by the EPA is 126 colony-forming units per 100 milliliters (cfu/100 mL) during both dry and wet weather conditions. The recreation season geometric mean concentration of *E. coli* at the confluence with Salt Creek measured by NDEQ in 2004 used to develop the TMDL was 3,433 cfu/100 mL. The 2007 TMDL lists 113 cfu/100 mL as the reduction goal for Antelope Creek. The recreation season geometric mean concentration of *E. coli* at the confluence with Salt Creek measured during the 2010-2011 sampling activities as part of the Basin Plan was 1,511 cfu/100 mL. The project team used the 1,511 cfu/100 mL level in development of the Basin Plan recommendations. This means that a 93% reduction in the *E. coli* pollutant load to Antelope Creek will be necessary to meet the recreational stream standards and TMDL goal at the confluence with Salt Creek.
2. **Other pollutants found in Antelope Creek are not as great of a concern as *E. coli*.** With the exceptions of *E. coli*, conductivity, chloride and selenium, Antelope Creek currently attains all other stream standards assigned to the stream by NDEQ. Based on sampling activities conducted as part of this Plan, ammonia is no longer present in the stream at levels exceeding the current TMDL. Conductivity, selenium, and chloride are currently only listed as pollutants of concern and do not have TMDLs. Groundwater inflows to the stream are expected to be the source of chloride, conductivity, and selenium in the lower portion of Antelope Creek, and are most likely naturally occurring.
3. ***E. coli* bacteria are likely from a diffuse source such as urban wildlife and potentially also from domestic pets.** Pollution sources within a watershed

Picture 3: Antelope Creek near Jim Ager Golf Course

are generally divided into two categories; point sources and non-point sources. Point sources consist of a single site or location from which pollution occurs such as a sewer main break, or a facility discharging pollutants directly into the watershed. Non-point sources are background sources of pollutants that are spread throughout a watershed (*i.e*., wildlife, domestic pets, fertilizers, and urban stormwater runoff that collects bacteria from rooftops or gutters). Sampling of stormwater outfalls to the stream indicated the *E. coli* bacteria source is a non-point source mainly from urban wildlife (*e.g.,* pigeons, raccoons), and potentially from domestic pets. The background level of bacteria naturally occurring in the watershed is unknown. It should be noted that other local urban and rural streams also exhibit high levels of *E. coli*.

4. **Achieving the TMDL standard for *E. coli* will be difficult, costly, and require a long term systematic approach.** Due to the relatively ubiquitous and diffuse nature of such background level pollutants, it is impractical to remove all sources (wildlife and pets), and it is also impractical to treat the entire watershed at the lower end in a similar manner to how wastewater is treated. The diffuse nature of the sources of *E. coli*, will make meeting the standard difficult and costly, and will require a long-term, systematic approach. The estimate of total cost to implement best management practices (BMPs) and projects in the watershed that will achieve the EPA standard for *E. coli* will be approximately $57 million over the 40-year life of this plan. From a regulatory perspective, it is important for the City to proactively implement measures that may help to incrementally reduce *E. coli* loads to the stream.
5. **For the Antelope Creek Basin, the most effective pollution control strategies for diffuse sources of *E. coli* are source controls, stormwater surface runoff volume reduction, and infiltration BMPs.** Source controls, or non-structural BMPs, reduce the source of the pollutant rather than treating the pollutant through a structural BMP. Source controls are usually low-cost and are typically the responsibility of the resident or property owner to implement (*i.e.,* Low/No-phosphorus fertilizers and picking up pet waste). BMPs that achieve stormwater runoff volume reduction ultimately reduce the volume of surface water reaching Antelope Creek, thus reducing the pollutant load. Infiltration BMPs treat stormwater runoff and capture pollutants prior to reaching Antelope Creek.
6. **The levels of pollutants found in Antelope Creek are typical of other urban streams found throughout the United States.** In-stream monitoring of Antelope Creek in 2010 and 2011, and a review of existing water quality data have shown that the problems of Antelope Creek are not unique as compared to other urban streams.

Summary of Recommendations

The ultimate goal of this Basin Plan is to remove Antelope Creek from the Clean Water Act Section 303(d) impaired waters list. Based on the most recent in-stream sampling, this equates to reducing the levels of *E. coli* bacteria in the stream by 93%. Due to the diffuse nature of the pollutant sources within the Antelope Creek watershed and the magnitude of the problem, the process used to achieve this goal could be challenging, costly, and long-term.

Pollution Control Strategies

Two main types of pollution control strategies are recommended; source controls (non-structural programs) and pollutant treatment practices (structural BMPs).

1) Non-structural source control strategies involve controlling the pollutant source in the watershed as much as possible before it has the chance to be mixed with stormwater and enter Antelope Creek. These strategies might include pet waste removal, wildlife management strategies, and Low/No-phosphorus fertilizer programs.
2) Structural BMPs involve constructing projects throughout the watershed to treat the pollutants within the stormwater before reaching Antelope Creek, or within the creek. These include installation of grass swales using native vegetation, rain gardens, enhancing existing wetlands and small tributaries to increase ponding of stormwater (filtration, infiltration, and water retention), use of hydrodynamic separators, and others.

On a watershed basis non-structural source control strategies are generally more cost-effective than structural controls for treating non-point sources of *E. coli* bacteria. However, non-structural source controls alone may not adequately reduce the *E. coli* levels in Antelope Creek by 93%. Structural BMPs may need to be constructed throughout the watershed to provide the additional pollutant removal capacity needed to meet the water quality goal.

General Water Quality Recommendations

To improve water quality in the Antelope Creek Watershed the following actions are recommended:

1. Continue enforcing existing City ordinances to control pollutant sources within the Antelope Creek watershed, such as pet waste ordinances and sediment control.
2. Review existing ordinances and target the development of new ordinances based on the pollutants of concern.
3. Develop and implement wildlife control practices in the Antelope Creek watershed, such as retrofits to bridges to limit roosting/nesting, detour geese away from waterways using landscaping techniques (tall grass/shrubs), etc.
4. Continue and expand preventative maintenance and cleaning activities to minimize future pollutant sources, such as sanitary sewer inspections, street sweeping, and in-stream sediment removal.
5. Continue and expand pollution source control and runoff quantity reduction programs, such as public education programs, Low/No-phosphorus fertilizer program, and the rain garden/rain barrel programs.
6. Develop and implement additional pollution source and runoff volume control programs such as a downspout disconnection program and continue yard waste pickup programs.
7. Implement structural stormwater BMP ordinances for BMPs that would treat frequently occurring rainfall events and reduce surface runoff volumes. The BMPs should be designed to target 90% of all rainfall events (1.25 inches and under) if possible. Such stormwater BMPs could be implemented on new development projects and retrofit projects. There also could be opportunities for demonstration projects with the City and/or LPSNRD as funding is available.
8. Evaluate the feasibility of altering release patterns from Holmes Lake to determine whether more frequent “flushing flows” would benefit water quality in Antelope Creek.
9. Evaluate channel modifications throughout Antelope Creek to minimize sedimentation areas and reduce nuisance algae blooms.
10. Evaluate Lincoln’s Storm Drainage Criteria Manual to ensure it is up to date. The evaluation can be compared to the 2010 version of the Urban Drainage and Flood Control District (UDFCD) manual, or another comparable national manual.
11. Consider concentration of resources into a priority sub-basin. A concentration of resources, such as developing several projects in a smaller sub-basin, would allow the City to more closely evaluate BMP performance. Focusing on a sub-basin is a more practical approach for a diffuse pollution source and is typical of EPA approved water quality plans.

Summary of Implementation Plan and Projected Costs

Reducing the pollutant load into Antelope Creek is a complex and challenging effort that will require the City and LPSNRD to acquire outside financial and technical resources. A cost estimate was established in order to quantify potential financial resources necessary to remove Antelope Creek from the impaired waters list and does not reflect any type of commitment of resources by Basin Plan stakeholders.

Implementation Strategy

The Basin Plan includes a strategy which describes practices to be implemented over the entire watershed for a 40-year period. A total of 8 sub-basins have been identified as a guide for step-by-step implementation to improve water quality overtime. This strategy assumes that projects will be implemented over a 5 year period for each sub-basin. During each phase projects should be evaluated further in regard to water quality, property owner interest, and cost. The implementation strategy includes a process for the City and NRD to follow in order to review progress towards improving water quality using evaluative criteria and monitoring.

Phase One – Antelope Park Sub-Basin

Phase One of the Basin Plan includes implementation of several non-structural control strategies across the entire Antelope Creek watershed and several structural BMPs within a 630 acre sub-basin. The Phase One sub-basin includes Antelope Park from A Street south to Sheridan Boulevard and the Lincoln Children’s Zoo as seen in Figure ES-2.

Although all non-structural BMPs listed in the Basin Plan may be considered, the nine listed below were given higher priority during the planning process and were viewed as being more effective in limiting *E. coli,* sediments, and

nutrient loadings from entering Antelope Creek. The following five non-structural BMP recommendations would be implemented by the City and/or LPSNRD:

1) Retrofitting older bridges and overpasses crossing Antelope Creek to limit bird activity
2) Sanitary Sewer Line Inspection Program Expansion
3) Dry Weather Storm Drainage Screening
4) Enforcement of existing pet waste ordinances
5) Supplying and maintaining additional pet waste containers

The following four non-structural BMPs listed below would be implemented by residents and property owners through programs offered by the City and/or LPSNRD.

1) Low/No-phosphorus fertilizer program
2) Rooftop disconnection incentive program
3) Rain garden program
4) Rain barrel program

In total, 14 demonstrative structural BMPs have been identified to treat stormwater and remove pollutants from Antelope Creek. Five of these 14 structural water quality BMPs have been recommended as part of the Phase One implementation. The location of these proposed projects can be found in Figure ES-3.

To ensure success of both non-structural and structural BMPs, the City and LPSNRD could work together to provide educational opportunities and community outreach to residents and property owners throughout the Basin Plan area. Phase One would conclude with monitoring of water quality at the confluence with Salt Creek to assess the effectiveness of implemented strategies.

The total estimated cost of Phase One is $1.7 million over a 5-year period. Cost estimates are based upon preliminary engineering estimates, a review of City program cost, and several cost assumptions listed in the Basin Plan. Implementations of Phase One actions are dependent upon availability of funding resources and cost share from State/Federal resources and willingness of residents and property owners to participate in non-structural programs. Table ES-2 below displays cost estimates for the structural BMP projects as well as the estimated cost for implementation of non-structural programs as part of Phase One.

Table ES-2. Phase One Antelope Creek Basin Implementation Plan

Basin Plan Watershed	Project Cost
Phase One: Structural BMPs	
P01: Antelope Park: Van Dorn St to Sheridan Blvd	$125,000
P02: Antelope Park: South St to Van Dorn St	$125,000
P03: Antelope Park: SW of 33rd and South St	$125,000
P04: Antelope Park: A Street to South Street	$250,000
P06: Lincoln Children's Zoo	$425,000
Sub-total	**$1.1 million**
Phase One: Non-Structural BMPs	
Basin-wide Non-structural Programs	$550,000
Phase One: Review, Monitoring, plan revision	$50,000
Grand Total	**$1.7 million**

Additional Implementation Phases

It is estimated that all phases would cost approximately $57 million which may be necessary to eventually meet existing regulatory criteria for *E. coli* in Antelope Creek. This cost estimate was established using information in the Source Loading and Management Model for Windows (WinSLAMM), Phase One cost estimates, and historical and current non-structural programs cost. This estimate far exceeds available funding, therefore it is recommended that the City and LPSNRD continue a phased approach, implementing the most cost effective practices in the early years and continuing to evaluate and implement additional practices over a 40-year period. In Phases 2-8 additional

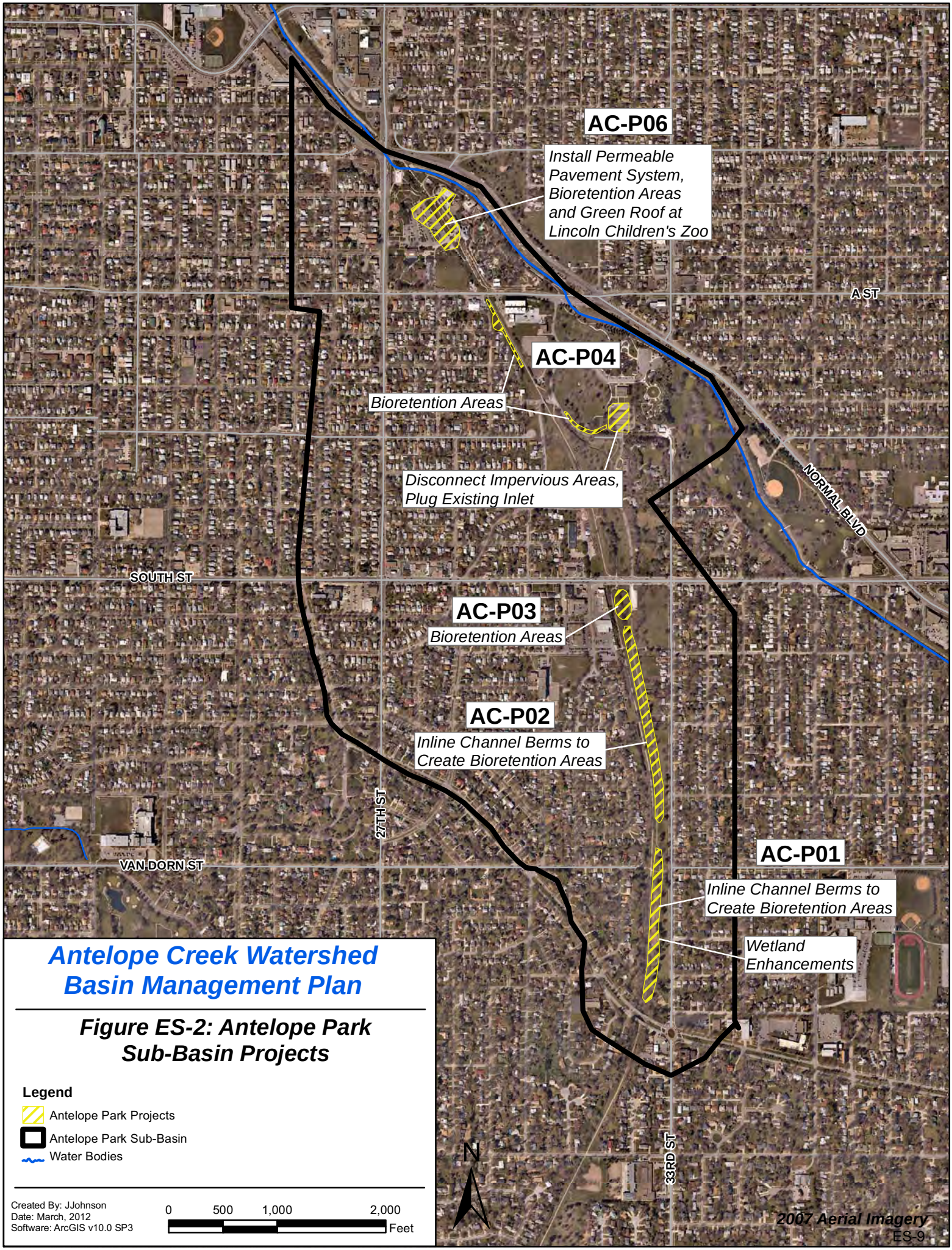
structural water quality improvement projects will be considered for construction within the Antelope Creek watershed.

Conclusion

The project team understands that financial expenditures of this magnitude, to consistently meet the EPA criteria in a recreational stream segment within an urbanized watershed, are somewhat impractical as compared to existing financial resources available. Plan reviews could potentially have large effects on the overall cost estimate based upon the effectiveness of the Phase One project and program implementation. Funding assistance from Federal, state, and local sources are anticipated to be available to provide assistance with funding during implementation of the Basin Plan.

Although the goal of this Basin Plan is to remove Antelope Creek from the impaired waters list, the structural and non-structural BMPs recommended have multiple benefits. These include, but are not limited to: reduction of a wide range of other pollutants, reduced stormwater runoff volume, reduced landscape maintenance, increased stream stability, reduced infrastructure cost downstream, recharging groundwater levels, aesthetics, educational opportunities, increasing the overall health of Antelope Creek, and improving public safety, health, and welfare for Lincoln citizens and visitors.

Together, the City, LPSNRD and Lincoln citizens can work proactively to reduce *E. coli* loads to the stream and implement strategies outlined in the Basin Plan. Successful implementation of strategies outlined in the Basin Plan will allow the City to begin working towards water quality improvements in Antelope Creek as well as other basins in the City.


AC-P06
Install Permeable Pavement System, Bioretention Areas and Green Roof at Lincoln Children's Zoo
A ST
AC-P04
Bioretention Areas
Disconnect Impervious Areas, Plug Existing Inlet
NORMAL BLVD
SOUTH ST
AC-P03
Bioretention Areas
AC-P02
Inline Channel Berms to Create Bioretention Areas
27TH ST
VAN DORN ST
AC-P01
Inline Channel Berms to Create Bioretention Areas
Wetland Enhancements
33RD ST
N
2007 Aerial Imagery
Antelope Creek Watershed Basin Management Plan
Figure ES-2: Antelope Park Sub-Basin Projects
Legend
Antelope Park Projects
Antelope Park Sub-Basin
Water Bodies
Created By: JJohnson
Date: March, 2012
Software: ArcGIS v10.0 SP3
0
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2,000
Feet

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SECTION 1 – INTRODUCTION AND PURPOSE

1.1. Introduction and Purpose

The water quality in a stretch of Antelope Creek contains elevated levels of *E. coli* and other contaminants that have become a concern to the City of Lincoln (City) and the Lower Platte South Natural Resources District (NRD). Working together, the City and LPSNRD have cooperatively developed the Antelope Creek Watershed Basin Management Plan (Basin Plan) for Antelope Creek from Holmes Lake to its confluence with Salt Creek an area of 7.7 square miles. For the purposes of this report the term 'Antelope Creek' only refers to that portion of Antelope Creek downstream/west of Holmes Lake, or approximately along 60th Street.

This Basin Plan differs from past plans that have focused on flood control, stream stability, and erosion. The focus is to improve water quality in Antelope Creek, from Holmes Lake to the confluence with Salt Creek.

The Basin Plan is part of an ongoing effort over the last decade to establish Comprehensive Watershed Management Plans within the corporate limits of Lincoln and future growth areas. A basin by basin approach has been used with preparation of individualized watershed master plans for each basin. By identifying structural and non-structural Best Management Practices (BMPs), each plan, including this Basin Plan, will serve as a tool for the City and LPSNRD staff, as well as other planning and design engineers, to proactively forecast, evaluate, and manage stormwater quality impacts associated with existing and future re-development of the City. The watershed master plans are regularly used to identify future capital improvement projects (CIPs).

An overview of the status of individual comprehensive watershed management plans is presented in Figure 1-1. The City and LPSNRD have adopted master plans for the following basins:

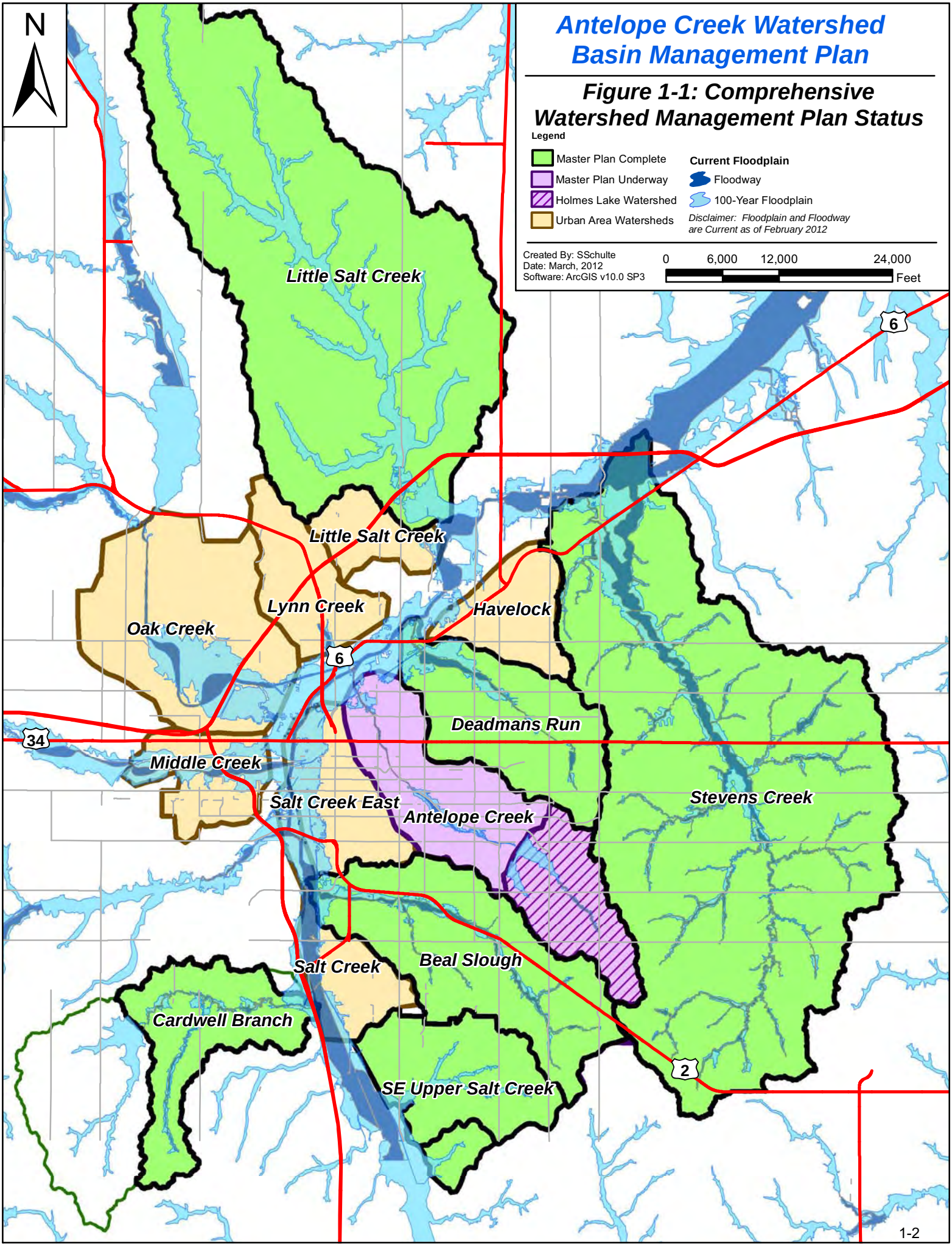
- Beal Slough (2000)
- Southeast Upper Salt Creek (2003)
- Stevens Creek (2005)
- Cardwell Branch (2007)
- Deadmans Run (2007)
- Little Salt Creek (2009)

The previous master planning efforts listed above focused primarily on **water quantity** to address flood management, stream stability, and erosion problems with a secondary focus on **water quality**. This Basin Plan, a continuation of the master planning process, is unique in that its purpose is to determine the source of contaminants impairing the everyday uses of Antelope creek. Antelope Creek watershed is entirely urbanized and has recently had a major project constructed to reduce flooding and stabilize the stream banks (Antelope Valley). The focus of the Basin Plan is to improve water quality in this stretch of Antelope Creek.

The U.S. Environmental Protection Agency (EPA) has established watershed management plan review criteria, the EPA Nine Elements, which will guide development of the Basin Plan. These planning criteria will ensure that the plan is laid out to meet the minimum requirement of the EPA Nine Elements, making the projects and programs eligible for potential Federal, state, and local funding opportunities.

The Basin Plan evaluates and makes recommendations to address several water quality parameters with an emphasis on *E. coli* bacteria, total suspended solids (TSS), and nutrients. By establishing this Basin Plan, the City and LPSNRD will be presented with projects and programs to improve water quality within the basin using stormwater controls. Secondary benefits of stormwater controls include increased aesthetics, use of native vegetation, and others.

Stormwater controls include several structural and non-structural management practices, used both individually and in combination with each other. Practices are intended to improve water quality by limiting the contribution of pollutants (i.e., removal of pet waste) or treating stormwater runoff prior to reaching a water body (i.e., use of a bioretention area). Due to local familiarity with the term best management practice, stormwater controls are generally referred as BMPs for the purposes of this Basin Plan.


Antelope Creek Watershed
Basin Management Plan
Figure 1-1: Comprehensive
Watershed Management Plan Status
Legend
Master Plan Complete
Master Plan Underway
Holmes Lake Watershed
Urban Area Watersheds
Current Floodplain
Floodway
100-Year Floodplain
Disclaimer: Floodplain and Floodway are Current as of February 2012
Created By: SSchulte
Date: March, 2012
Software: ArcGIS v10.0 SP3
0
6,000
12,000
24,000
Feet
N
Little Salt Creek
Little Salt Creek
Lynn Creek
Oak Creek
Havelock
Deadmans Run
Middle Creek
Salt Creek East
Antelope Creek
Stevens Creek
Salt Creek
Beal Slough
Cardwell Branch
SE Upper Salt Creek
6
6
34
2

Regulatory Background

In Nebraska, water quality regulations are administered through the Nebraska Department of Environmental Quality's (NDEQ) Water Quality Division. NDEQ is authorized through the Environmental Protection Agency's (EPA) Clean Water Act of 1972; which requires states, territories, and authorized tribes to identify and establish priority ranking for water bodies. Once these water bodies are identified, NDEQ establishes a Total Maximum Daily Load (TMDL) for the pollutants causing impairments in those water bodies. This is completed through the Water Quality Integrated Report, completed every 2 years by NDEQ, and most recently in April 2010.

NDEQ also administers the National Pollutant Discharge Elimination System (NDPES) permitting program. Activities listed in the Basin Plan are above and beyond NPDES requirements listed in the City's municipal separate storm drainage system (MS4) permit. Activities listed in this Basin Plan are non-regulatory and specific to address water quality issues in Antelope Creek. The City allocates funding separately for projects that support MS4 activities.

Table 1-1. Antelope Creek 2010 Water Quality Integrated Report

Water Body ID	Water Body Name	Recreation	Aquatic Life	Public Drinking Water	Agriculture Water Supply	Industrial Water Supply	Aesthetics	Overall Assessment	2010 IR	Impairments	Parameters of Concern	Comments / Actions
LP2-20900	Antelope Creek	I	I	NA	S	NA	S	I	5	*E. coli,* Selenium, Copper, Chloride, Conductivity	*E. coli,* Selenium, Copper, Chloride	*E. coli* and ammonia TMDL approved 9/07

Source: NDEQ 2010 Water Quality Integrated Report (S=Supported Beneficial Use; I=Impaired)

As seen in Table 1-1 above, this stretch of Antelope Creek has listed impairments to the Aquatic Life and Recreation uses due to *E. coli* bacteria, Selenium, Copper, Chloride, and Conductivity. Parameter violations of Nebraska's Surface Water Quality Standards – Title 117 (NDEQ, 2009) have resulted in a 2010 Section 303 (d) Category 5 listing for this segment of Antelope Creek. While there are currently no state water quality standards for phosphorus and nitrogen in flowing waters, the City will proactively address these pollutants through the implementation of this Basin Plan. Each of the above listed parameters is further detailed in SECTION 4 - TMDL ASSESSMENT.

In order to establish goals for improving the water quality in lakes and streams, NDEQ develops a TMDL, which outlines the maximum loading of certain contaminants a stream or lake can handle before being considered impaired. Antelope Creek's TMDL was approved in September 2007. At that time, listed parameters of concern were Total Ammonia and *E. coli*. During establishment of the Basin Plan each parameter of concern listed in the 2008 and 2010 Water Quality Integrated Report, as well as the two listed in the 2007 TMDL, were evaluated.

Ammonia was removed from the Antelope Creek sampling for this project because recent NDEQ ambient stream monitoring data and data from the first round of Antelope Creek sampling conducted by EA indicated that the ammonia levels previously reported for Antelope Creek were no longer above the water quality criteria. Determining the source of ammonia, and reasoning for the recent reduction in ammonia concentrations, was not included as part of the scope of this project and is unknown.

Nutrients and sediments are not currently contributing to regulatory impairments in Antelope Creek and have been added to the Basin Plan based upon the intentions of the City to holistically address water quality issues.

Basin Plan Project Area

The area addressed in this Basin Plan includes the lower portion of the Antelope Creek watershed below Holmes Lake Dam to its confluence with Salt Creek as illustrated in Figure 1-2. The project area encompasses approximately 7.7 total square miles and has a maximum width of about 2.1 miles. Prior to the Antelope Valley Project, a total of 5.7 miles of stream length existed, including over 0.75 miles that flowed through an underground conduit (23rd and N to 20th and Vine). Several factors brought on by urban development, greatly increased the

peak flow during flood events causing the flood capacity of the underground conduit to no longer be adequate, leading to necessary improvements to reduce the threat of flooding.

As of 2010, major improvements have been made to the creek and surrounding area as part of the Antelope Valley Project including the creation of 0.83 miles of open channel that includes the area through Union Plaza. The new design of Antelope Creek allows high flow events to run through both the underground conduit and the new open channel segment; drastically increasing the capacity of the creek. Before the project, flows that the underground conduit could not carry would flow overland and flood the neighborhood. That floodwater can now flow in the new and improved channel, reducing the floodplain and the threat of flooding. These structural improvements allow for a more effective conveyance of large rainfall events and reduced the existing floodplain to further protect approximately 800 homes and 200 businesses in the project area as illustrated in Figure 1-3. In addition to The Antelope Valley improvements, a significant flood control project was completed in 2011 which increased the flood capacity for a segment of the creek near the Lincoln Children's Zoo. Figure 1-3 represents these improvements.

Approximately 48,500 full-time residents and 8,500 University of Nebraska students live and work within the watershed study area (City Planning Department, 2010). Land use categories describe how property owners utilize the land, such as residential for homes, commercial for businesses, and industrial for manufacturing. The amount of stormwater runoff can vary greatly depending upon the type of land use. The majority of the 4,932 acre project area is residential (44%) with the remaining land use consisting of transportation (roadways, right-of-ways, etc.) (25%), and other various uses (31%). A full breakdown of land uses in the Basin Plan project area is found in Table 3.2.

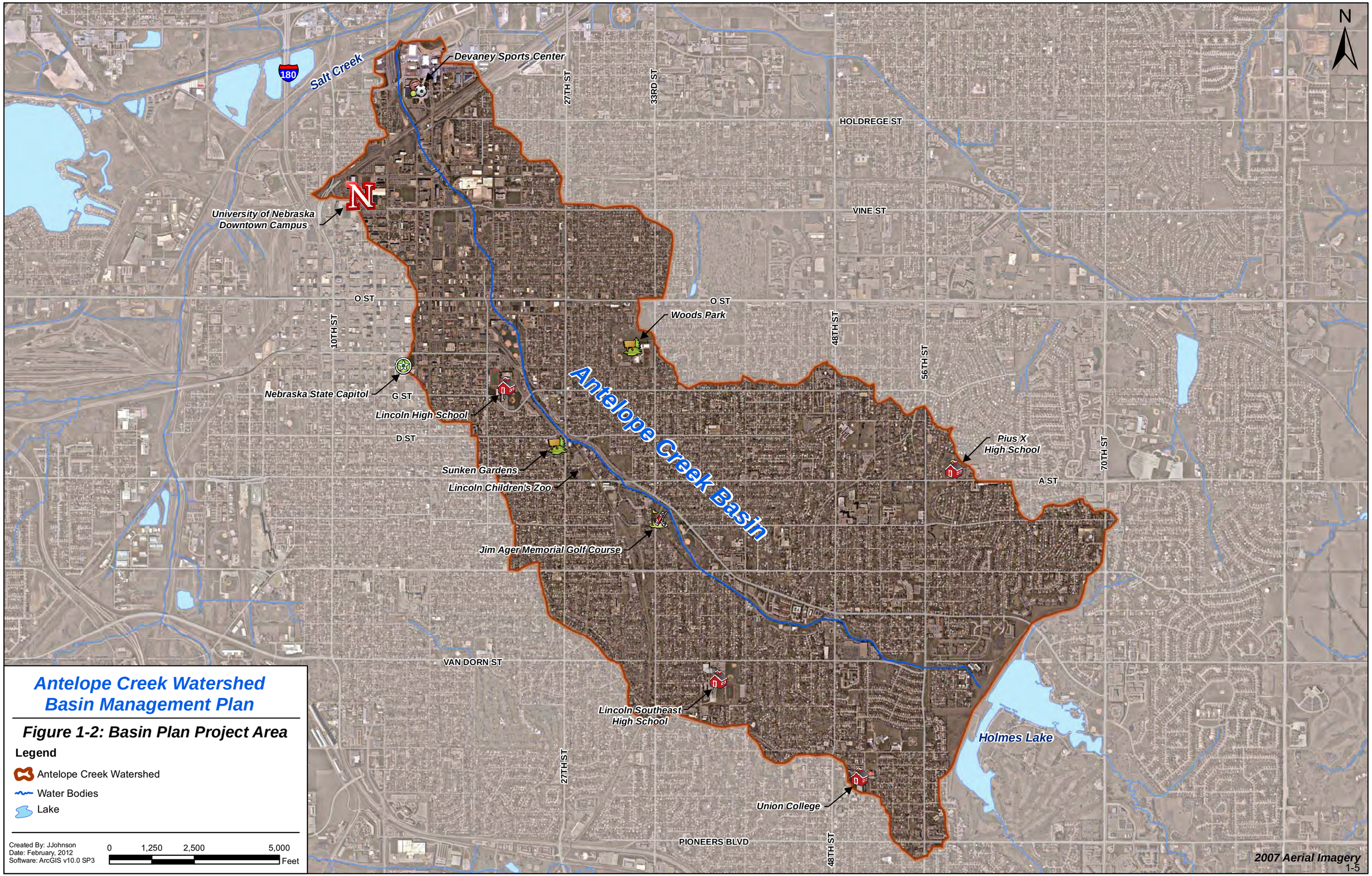
Approximately 48,500 full-time residents and 8,500 University of Nebraska students live and work within the watershed study area.

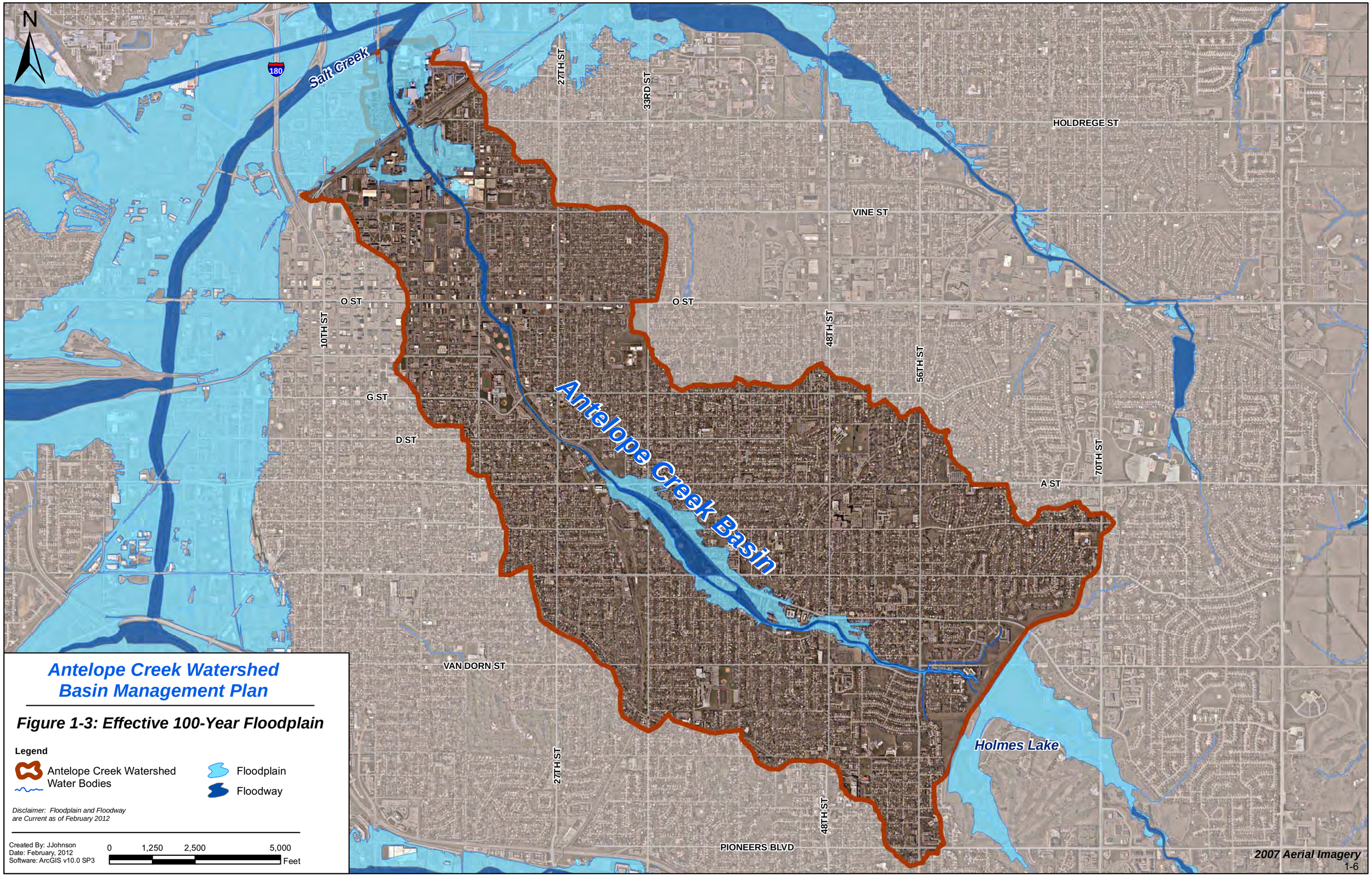
Previous Antelope Creek Watershed Projects

The City and LPSNRD have worked extensively to improve flood control, reduce erosion, and minimize stream degradation in Antelope Creek. Below is a listing of three specific efforts recently completed in or near the Basin Plan area. This list does not include several smaller completed, ongoing, and planned improvements within Antelope Creek Watershed.

Antelope Valley Project—Since 2000, significant changes have occurred in the project area primarily due to the Antelope Valley Project; substantially complete as of 2011. Construction on the Antelope Valley Project has improved flood control, improved transportation, and provided community enhancements. Major projects have been completed adjacent to Antelope Creek including the creation of 0.83 miles of open channel, new bike trails, and pedestrian walkways. Several new transportation routes have been constructed as well as the establishment of a community park, Union Plaza.

Holmes Lake Renovation—In 2005, the City worked with Nebraska Game and Parks Commission (NGPC), NDEQ/USEPA, and Nebraska Environmental Trust to restore and improve the 110 acre lake and enhance the surrounding park area. This project removed sediment, increased the depth of the reservoir, improved sediment entrapment capabilities, and renovated the aquatic habitat of the reservoir. The project extended the recreational life span of the lake by 100 years.


N
Salt Creek
180
Devaney Sports Center
27TH ST
33RD ST
HOLDREGE ST
VINE ST
University of Nebraska
Downtown Campus
O ST
10TH ST
Woods Park
48TH ST
56TH ST
Nebraska State Capitol
G ST
Lincoln High School
Antelope Creek Basin
D ST
Pius X
High School
70TH ST
Sunken Gardens
Lincoln Children's Zoo
A ST
Jim Ager Memorial Golf Course
VAN DORN ST
Lincoln Southeast
High School
Holmes Lake
Union College
PIONEERS BLVD
Antelope Creek Watershed
Basin Management Plan
Figure 1-2: Basin Plan Project Area
Legend
Antelope Creek Watershed
Water Bodies
Lake
Created By: JJohnson
Date: February, 2012
Software: ArcGIS v10.0 SP3
0
1,250
2,500
5,000
Feet
2007 Aerial Imagery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70TH ST
A ST
Antelope Creek Basin
VAN DORN ST
27TH ST
48TH ST
PIONEERS BLVD
Holmes Lake
Antelope Creek Watershed
Basin Management Plan
Figure 1-3: Effective 100-Year Floodplain
Legend
Antelope Creek Watershed
Water Bodies
Floodplain
Floodway
Disclaimer: Floodplain and Floodway
are Current as of February 2012
Created By: JJohnson
Date: February, 2012
Software: ArcGIS v10.0 SP3
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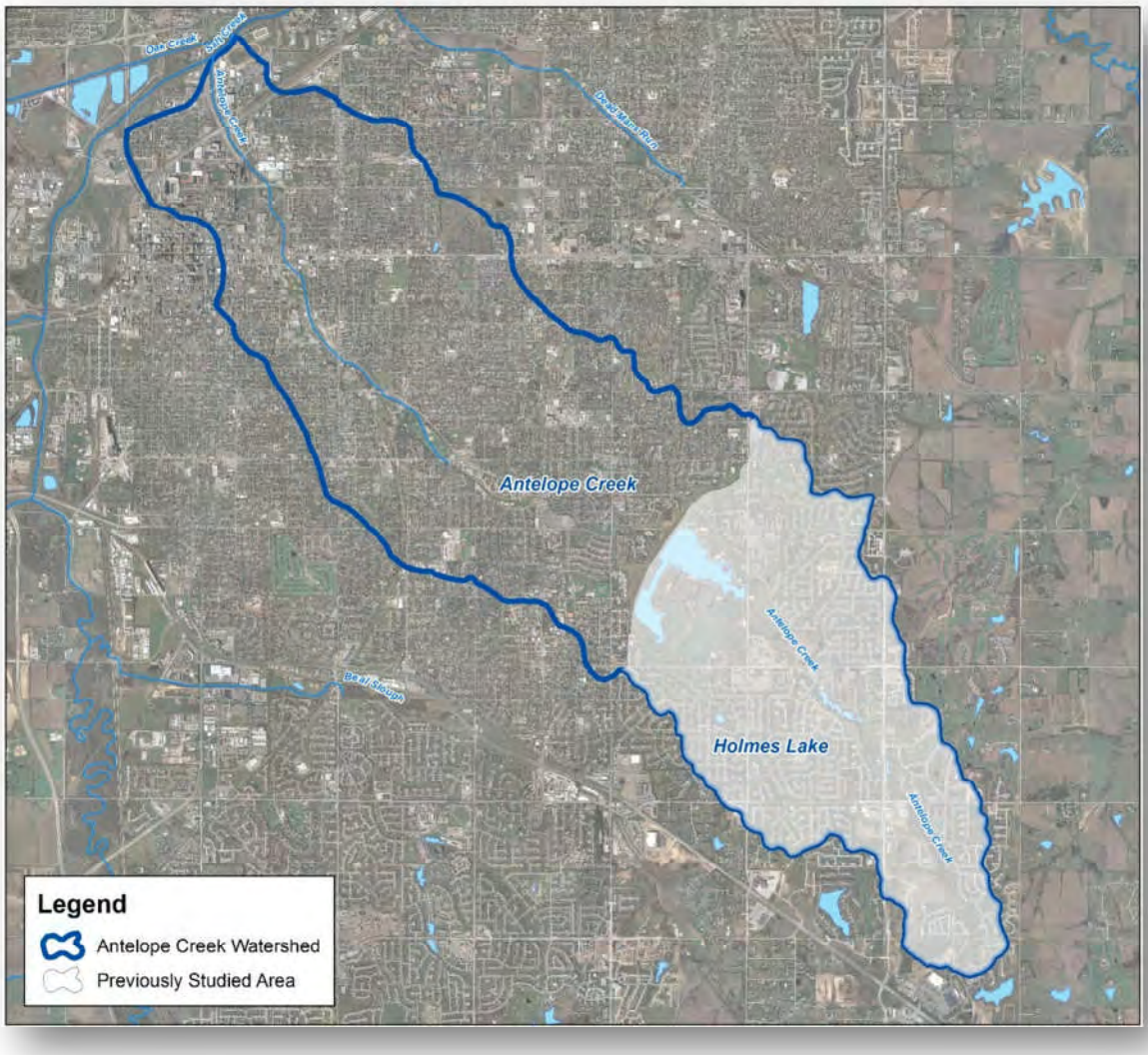
2007 Aerial Imagery

Figure 1-4. Antelope Creek Watershed Planning Areas



Holmes Lake Watershed Plan—The City of Lincoln worked with NDEQ/USEPA to establish a watershed plan for the portion of the watershed above Holmes Lakes, as seen in Figure 1-4 above. The intent of this community-based plan was to reduce the pollution flowing into the newly renovated Holmes Lake. As part of the plan's implementation, a pilot-program was launched by the City in 2007. The City paid for 90% of rain garden cost and property owner paid 10%, free rain barrel installation, and free Low/No-phosphorus fertilizer. A Holmes Park Advisory Committee was established prior to the Holmes Lake renovation in 2003 to reduce the threat of future pollution at Holmes Lake through public education, wetland enhancement, and drainage improvements.

Project Team

The Basin Plan is a joint project led by the City and LPSNRD, with the City serving as the primary sponsor. The City and LPSNRD retained the consulting team led by EA Engineering, Science, and Technology, Inc. (EA) in association with JEO Consulting Group, Inc. (JEO) and Wright Water Engineers, Inc. (WWE). Serving as part of the WWE team, additional expertise for the project was provided by Dr. Robert Pitt, P.E., of the University of Alabama. The consulting team worked directly with a Core Work Group, consisting of staff from City Departments, LPSNRD, and NDEQ, in addition to an Advisory Council consisting of key stakeholders from the project area. Both the Core Work Group and Advisory Council are detailed in SECTION 2 - PUBLIC PARTICIPATION AND EDUCATION.

1.2. Basin Plan Goals and Objectives

Goals and objectives have been established in order to achieve the vision of the City and LPSNRD, which intends to improve the water quality in Antelope Creek. The Basin Plan will allow the City and LPSNRD staff, as well as other planning and design engineers, to proactively forecast, evaluate, and manage stormwater impacts as well as other existing impacts and impacts which could result from future development. Below are primary goals of the Basin Plan:

- Goals—broad based desires, written as statements, of the ultimate result being undertaken
- Objectives—steps or actions performed and assigned to individuals and/or groups, to attain a goal

Goal One: Determine the source of contaminants in Antelope Creek through establishment of the Antelope Creek Watershed Basin Management Plan.

Objectives:

- Basin Inventory—Collect, compile, and evaluate available data within the Antelope Creek Basin utilizing GIS to organize data.
- TMDL Assessment—Evaluate the feasibility of meeting the 2007 TMDL through review and evaluation of the database used to establish the TMDL and compare to other available water quality data.
- Water Quality Monitoring—Conduct water quality sampling to provide additional information regarding spatial and seasonal variation of contaminant levels.
- Pollution Sources—Evaluate relationship between land use and water quality, conduct visual inspection of dry weather flows into Antelope Creek, and identify possible pollution sources within the watershed.

Goal Two: Determine what can be done to reduce levels of each contaminant to maintain or improve the quality of water in Antelope Creek.

Objectives:

- Watershed Pollutant Modeling—Develop a water quality model for evaluation of BMPs. Evaluate structural and non-structural BMPs, their targeted pollutant removal efficiencies, appropriate land use applications, and long-term maintenance requirements.
- Site Screening and Conceptual Design—Identify a site inventory of at least 30 locations within the basin suitable for implementation of various BMPs; evaluate, rank, and prioritize site locations; and create the conceptual design of at least 10 structural BMPs at selected locations throughout the watershed.
- Improvement Projects—Develop capital and non-capital improvement projects and programs to improve water quality.
- Load Reduction–Establish a phased implementation strategy that will outline actions necessary to remove Antelope Creek from the 303(d) list. Include strategies that will limit loading of sediments, nutrients, and bacteria.

Goal Three: Educate the public about water quality and provide awareness of the Antelope Creek Watershed Basin Management Plan**.**

Objective:

- Public Information and Education—Disseminate information and solicit feedback from the public through open house meetings, newsletters, stakeholder meetings, and an advisory council.
- Public Acceptance–Work to achieve at least 50% implementation rate of non-structural stormwater controls amongst property owners and residents.

Goal Four: The City of Lincoln will apply lessons learned during the establishment of the Antelope Creek Watershed Basin Management Plan to other basins within the City and future growth areas.

Objective:

- City-Wide Load Reduction—Develop City-wide recommendations for reducing pollutant load through BMPs for other watersheds within the City.

SECTION 2 – PUBLIC PARTICIPATION AND EDUCATION

2.1. Introduction

The City and LPSNRD have emphasized the importance of public participation and education since the beginning of the Basin Plan effort. To achieve plan goals and fully understand issues throughout the watershed, citizens and stakeholders were informed and given multiple opportunities to provide feedback as part of the planning process. The Basin Plan is expected to be adopted as an approved component of, and will be integrated into, a unified watershed management master plan for the City and projected growth areas.

The public involvement strategy was established so that citizens can participate in public decisions that affect them, their property, and their interests. The public involvement strategy's diverse approach involved a Core Work Group, Advisory Council, two open house events, stakeholder meetings, four newsletters, press releases, news articles, and the City of Lincoln Watershed Department website. A description of each component of the strategy is outlined below.

The public involvement strategy was established so that citizens can participate in public decisions that affect them, their property, and their interests.

2.2. Core Work Group

Technical input from the Core Work Group was vital to establishing the Basin Plan. This group consisted of technical staff representing the City of Lincoln Public Works and Utilities Department, Planning Department, and Parks and Recreation Department, the Nebraska Department of Environmental Quality (NDEQ), LPSNRD, and members of the consultant team. The Core Work Group, listed below in Table 2-1, met 11 times throughout the planning period; most members also attended Open House events and various other progress meetings. The Core Work Group was responsible for reviewing and commenting on Basin Plan components, providing direction for public involvement and education, and adding technical insight to the Basin Plan.

Table 2-1. Basin Plan Core Working Group

Representing	Name	Title
City of Lincoln Public Works	Ed Kouma, PE	Project Manager
City of Lincoln Public Works	Ben Higgins, PE	Senior Engineer
City of Lincoln Public Works	Miki Esposito, JD	Director of Public Works
City of Lincoln Planning	Sara Hartzell	Planner
City of Lincoln Parks and Recreation	Terry Genrich	Natural Resources Manager
LPSNRD	Paul Zillig	Assistant Manager
LPSNRD	JB Dixon	Stormwater Specialist
NDEQ	Mary Schroer	Program Specialist
EA Engineering, Science, and Technology	*Dale Schlautman, PE	Senior Technical Review
EA Engineering, Science, and Technology	*Jon Trombino, PE	Project Manager
EA Engineering, Science, and Technology	*Jonathan Mohr, AICP	Environmental Scientist
JEO Consulting Group, Inc.	*Lalit Jha, PE, CFM, D.WRE	Engineer
Wright Water Engineers	*Jane Clary, LEED AP, CPESC	Senior Environmental Scientist
Wright Water Engineers	*Jonathan Jones, PE, D.WRE	Chief Executive Officer
Wright Water Engineers	*Dr. Robert Pitt, PE, PhD, BCEE, D.WRE	Cudworth Professor University of Alabama

*Consulting team members attended at appropriate times throughout the project

2.3. Advisory Council

"Advisory Council members were asked to review elements of the process, ask questions, raise issues, and share information with one another, the public, and the project team" – Advisory Council's Role

An Advisory Council was established in order to gather input from a diverse set of stakeholders that live and work in the Basin Plan project area. The Advisory Council members were selected based upon recommendations from the Core Work Group, and appointed by Mayor Chris Beutler. Council members were invited to review elements of the process, ask questions, raise issues, and share information with one another, the public, and the project team. The 12-member Advisory Council included representatives from neighborhoods, business owners, and various agencies in the project area as shown in Table 2-2. The Advisory Council met three times during the planning period, including meetings in September 2010, February 2011, and November 2011; brief meeting summaries are provided below. Meeting minutes and sign-in sheets are provided in Appendix B.

Table 2-2. Basin Plan Advisory Council

Representing	Name
Non-profit	Mike Renken, NeighborWorks
Lincoln Public Schools	Scott Wieskamp, Facilities & Management
Business Group	Andrew Campbell, Campbell's Nursery
Business Group	Steve Hill, Assurity
University of Nebraska – Lincoln	Jennifer Dam, Campus Planning
Lincoln Golf Courses	Dale Hardy, Administrator
Lincoln Children's Zoo	John Chapo, President
Neighborhood Group	Tracy Corr, 40th and A Street
Neighborhood Group	Bob Kuzelka, Near South
University of Nebraska – Lincoln	Rachel Herpel, Water Center
LPSNRD	Karen Amen, Board Director
City of Lincoln	Adam Hornung, City Council

Basin Plan Advisory Council Meeting #1

LPSNRD Office, 3125 Portia Street, Tuesday September 14th, 2010 – 5:30 to 7:30 pm

Summary—The Advisory Council's first meeting consisted of introductions, an introduction to the project, a brief presentation about the scope of work, and discussion to gather feedback from the group on the Basin Plan effort.

Basin Plan Advisory Council Meeting #2

LPSNRD Office, 3125 Portia Street, Thursday February 10th, 2011 – 7:30 to 8:30 am

Summary—The group was briefed on the project team's progress, including a summary of the basin inventory, water quality sampling results, and work completed by the consultant team. The group also discussed the game plan for proceeding with stakeholder meetings, the next open house, and schedule for plan completion.

Basin Plan Advisory Council Meeting #3

LPSNRD Office, 3125 Portia Street, Thursday November 29th, 2011 – 7:30 to 8:30 am

Summary— The final meeting provided the Advisory Council with an update of the project through the presentation to be used at the second Open House. The Council also provided feedback on the project overall and helped make changes to the public presentation.

2.4. Open House Events

Citizens and other stakeholders had the opportunity to meet first hand with those working directly on the Basin Plan at two Open House events. The first Open House was held September 2010, at the beginning of the planning process; the second was held towards the end of the project in December 2011. Open house post-card invitations were sent to more than 11,000 property owners in the project area, special interest groups and resource agencies from across the City of Lincoln. Street sign advertising, a press release, the City's website, and announcements at City and LPSNRD meetings were also employed to advertise the Open Houses. Below is a brief summary of each Open House:

Basin Plan Open House #1

Charles Gere Library, 2400 S. 56th St, Thursday September 30, 2010, 5:00 to 7:30 pm

Summary—Nearly 90 citizens attended the first open house which featured a 15 minute presentation showing at 5:30 pm and 6:30 pm. In addition to the presentations, three stations were set-up featuring water quality, best management practices, and floodplain issues. The City provided a rain barrel door prize, information on rain barrels, and a sign-up for rain garden classes. A large table map of the Basin Plan project area was also provided, along with markers, to allow participants a bird's eye view and the opportunity to locate their property or indicate to the project team potential problem areas. The majority of the core working group and members of the Advisory Council attended as well as members of the consulting team which delivered the presentation.

Picture 4: A participant at Open House #1 reviews the Basin Plan area map

The bulk of the audience's questions concerned current pollutants present in Antelope Creek and what they could do to help improve the water quality. Other questions focused on the differences between the Antelope Creek Basin Plan and other plans which had primarily focused on flood control improvements. Sign-in sheets and a meeting summary are provided in Appendix B.

Basin Plan Open House #2

Auld Pavilion, 3140 Sumner, Thursday December 1, 2011, 5:00 to 7:00 pm

Summary—Nearly 40 citizens attended the final Open House that included two 15 minute presentations and three stations with information on the Basin Plan recommendations, both structural and non-structural. One station included information on existing programs of the City and LPSNRD and a rain barrel which was given as a door prize.

2.5. Stakeholder Meetings

Six stakeholder groups allowed the project team to more thoroughly identify issues and expand opportunities to educate those that live and work in the project area. Based upon recommendations of the Advisory Council, the project team reached out to groups that may be impacted by activities recommended in the Basin Plan, such as neighborhood associations, the Lincoln Children's Zoo, and other community organizations. The project area includes portions of 20 neighborhood associations, each of which received a letter offering opportunities to learn about the Basin Plan. Stakeholder group actions are detailed in Table 2-3 below.

Table 2-3. Stakeholder Group Action Summary

Stakeholder	Activity	Date	Notes
Homebuilders Association of Lincoln (HBAL)	Basin Plan article in monthly newsletter	March 2011	The HBAL newsletter is distributed to approximately 750 businesses.
Lincoln Children's Zoo	Meeting with Zoo staff	March 2011	Project team members received an update on existing water quality projects at zoo and discussion of planned activities and projects to be included in the plan
Witherbee Neighborhood Association	Basin Plan article in monthly newsletter and presentation at monthly meeting	July 2011	Project team members Jonathan Mohr and Ed Kouma presented at a monthly meeting July 7, 2011.
Colonial Hills Neighborhood Association	Basin Plan article in monthly newsletter	May 2011	Project team members provided a summary for the monthly newsletter
University of Nebraska-Lincoln	Focus group meeting	June 2011	Project team members Jon Trombino, Jonathan Mohr, Paul Zillig, and Ed Kouma met with six separate department representatives to discuss water quality in Antelope Creek.
40th and A Street Neighborhood Association	Presentation at monthly meeting	October 2011	Project team members Jon Trombino and Ed Kouma presented general information on components of the Basin Plan with an emphasis on what citizens can do to help water quality.

2.6. Newsletter and Website

Watershed News

Four issues of Watershed News, a newsletter used to provide general information on the Basin Plan, were mailed during the project. Newsletters highlighted different components of the Basin Plan in an educational format and were distributed to a list of more than 1,100 individuals representing businesses, community organizations, neighborhood associations, non-profits, and local, state, and Federal agencies throughout the City and the Basin Plan project area. Newsletters were also distributed at each Open House, and made available to the Mayor's roundtable and posted on the City's website. Each volume is summarized below:

- **Volume One, August 2010**—Introduced the Basin Plan, discussed water quality issues present in Antelope Creek, generally described typical BMPs, and invited readers to Open House #1.
- **Volume Two, January 2011**—Focused on stormwater runoff, land-uses and pollutant sources, and included a summary from the first open house.
- **Volume Three, September 2011**—Summarized what we have learned after modeling the watershed and conducting surface water sampling. Discussed source of *E. coli* being non-point from diffuse sources in the watershed.
- **Volume Four, April 2012**—Summarized final recommendations in the Basin Plan for reducing pollutant loads in the watershed and highlighted the implementation strategy. Featured both structural and non-structural solutions.

A copy of each Watershed News newsletter is located in Appendix B.

City Website

The City's website (lincoln.ne.gov: keyword 'watershed') was used to feature an array of information on the Basin Plan. The website included an informative project description, frequently asked questions, information on project team members and Advisory Council, public participation, and newsletters. The website was regularly updated by City staff, and included interactive definitions of key terms and several images.

SECTION 3 – WATERSHED INVENTORY

3.1. Introduction

In order to develop management strategies to improve water quality in Antelope Creek, it is first necessary to understand the stream conditions and watershed characteristics. During the summer and fall of 2010, the project team conducted a watershed inventory to evaluate the factors potentially affecting water quality in Antelope Creek. The inventory included a desktop review of existing information and field surveys to fill data gaps.

3.2. Collection of Existing Information

For planning purposes, the City refers to the upper portion of the watershed as Holmes Lake Watershed, and the lower portion as Antelope Creek watershed.

Desktop review included:

- NDEQ and other historical water quality records
- Hydrologic and hydraulic information
- Available Geographic Information Systems (GIS) data
- Land-use
- Storm drainage system
- Lincoln/Lancaster Comprehensive Plan and other existing planning documents
- Existing water quality projects

Field surveys included:

- Inspection of outfalls for dry weather flows and further investigation of outfalls with dry weather flows
- Characterizing typical land-use areas
- Locating possible illicit connections, nutrient sources, or sediment loadings
- Inventory of bird activity under bridges
- Tour of the Lincoln Children's Zoo
- Tour of the watershed with key members of the project team

3.2.1 Physical Setting

Watershed Size and Boundaries

The watershed for Antelope Creek covers a total of 13.1 square miles (8,389 acres), from approximately 98th and Pine Lake Road, flowing to the northwest through the heart of Lincoln to the confluence of Salt Creek. The watershed includes Holmes Lake, a 112 acre flood control and recreational reservoir located between 56th and 70th Streets and Van Dorn Avenue. For planning purposes, the City refers to the upper portion of the watershed as Holmes Lake Watershed, and the lower portion as Antelope Creek Watershed. The divide between these two sub-watersheds lies on a line across Holmes Lake Dam from approximately 70th and A Street south, to near 56th and Pioneers Boulevard. This Basin Plan only addresses the lower portion of the watershed known as Antelope Creek Watershed.

Picture 5: Sunken Gardens

Antelope Creek Watershed

Antelope Creek watershed was re-delineated to update the previous watershed boundary and provide an accurate boundary for future use. Data used to update the boundary include the existing watershed boundary, storm drain system layout, updated contours provided by Light Detection and Ranging (LIDAR) data, and site walkthroughs. The updated watershed boundary covers approximately 4,932 acres from Holmes Lake Dam downstream to the northwest 5.7 stream miles. The watershed is approximately 2.1-miles wide and nearly 100% urbanized. Significant landmarks located within the watershed include:

- University of Nebraska–Lincoln(UNL) City Campus and Innovation Campus, Bob Devaney Sports Center
- City recreational facilities including Union Plaza, Antelope Park, Jim Ager Memorial Golf Course, and Sunken Gardens
- Lincoln High and Southeast High Schools
- Lincoln Children's Zoo

Topography

Antelope Creek watershed is nearly 100% urbanized, and overall is sloped mildly ranging from 0 to 11%. Antelope Creek, at the outlet of Holmes Lake Dam, is at an elevation of approximately 1,210 feet. The confluence with Salt Creek is at an elevation of approximately 1,122 feet. The highest point in the watershed is just south of 70th and A Street, 1,330 feet. Overall, Antelope Creek bottom has a fairly constant slope along the entire length with an average slope of 0.3%.

Soils

The project area is covered by a variety of soil types typical for most areas in Lancaster County. Soil types for the project area have been summarized in Table 3-1. The soil summary was provided by the USDA and NRCS web soil survey.

Table 3-1. Watershed Soil Types

Map Unit Name	Hydrologic Soil Group	Slope %	Approximate % of Area
Aksarben silty clay loam	C	2 to 6	1.6%
Aksarben silty clay loam	C	6 to 11	0.2%
Burchard clay loam	C	6 to 11	0.1%
Wymore silty clay loam	D	3 to 6	0.6%
Colo-Nodaway silty clay loams	C	Flat	1.0%
Nodaway silt loam	B	(Channelized)	0.2%
Urban land-Judson complex	C	1 to 3	5.7%
Urban land-Kennebec complex	B	0 to 2	20.7%
Urban land-Pawnee-Mayberry complex	D	2 to 6	1.5%
Urban land-Wymore complex	C	0 to 2	2.6%
Urban land-Wymore-Aksarben complex	C	2 to 6	54.0%
Urban land-Crete-Aksarben complex	C	0 to 2	11.2%
Arents, earthen dam	D	NA	0.2%
Water	NA	NA	0.4%

Source: USDA Web Soil Survey

The three predominant soil types are the Urban land-Wymore-Aksarben complex, Urban land-Kennebec complex and the Urban land-Crete-Aksarben complex which comprise about 88% of the total area. The Urban land-Wymore-Aksarben complex is characterized as a gently sloping, well drained silty clay loam. This soil type can generally infiltrate 0.06 to 0.20 in/hr. The Urban land-Kennebec complex is characterized as a flat, moderately well drained silt loam. This soil type can generally infiltrate 0.6 to 2.0 in/hr. The Urban land-Crete-Aksarben

complex is characterized as flat, moderately well drained silty clay. This soil type can generally infiltrate 0.06 to 0.20 in/hr.

Regional Geology

According to the Lancaster County soil survey, the bedrock in Lancaster County is Pennsylvanian and Permian age limestone with interbedded shale and shaley limestone, and interbedded shale and sandstone of the Dakota Group of the Cretaceous age. Exposed Dakota sandstone and shale are present in areas of Antelope Creek including areas near Lincoln Children's Zoo.

Antelope Creek watershed was historically a native prairie dominated by big bluestem, little bluestem, and other grass species. Prior to urbanization and substantial flood control projects, Antelope Creek had a sandstone bottom and several sandstone outcroppings. Antelope Creek remains influenced by groundwater, especially downstream towards the confluence with Salt Creek. Several areas of groundwater seeps were noted during the field survey. Groundwater seeps are more frequent closer to the confluence with Salt Creek, as is evident by the increased base flow near Salt Creek.

3.2.2 Land-Use

Existing Land-Use

The City of Lincoln/Lancaster County Planning Department regularly updates the existing land-uses using a detailed number category within GIS. Land-use categories describe how property owners utilize the land (*i.e.,* residential for homes, commercial for businesses, and industrial for manufacturing). Overall, the watershed consists mostly of residential land-uses that have been in place for more than 50 years. The second most common land-use is for transportation (*i.e.,* uses such as roads, railroads, and Right-of-Ways). Two land-use summaries are provided, including a detailed breakdown (Table 3-2) and a composite breakdown (Table 3-3) based upon standard land-use classifications. Figure 3-1 shows the existing land-uses within the Antelope Creek watershed.

Table 3-2. Detailed Land-Use Summary

Land-Use Type	Land-Use Area (Acres)	% of Project Area	Land-Use Type	Land-Use Area (Acres)	% of Project Area
Single Family Detached	1,854.4	37.60%	Light Industrial	48.8	0.99%
Street/ROW	1,172.4	23.77%	Heavy Industrial	41.7	0.85%
School	372.3	7.55%	Hospital	30.6	0.62%
Park	317.1	6.43%	Rail Road	28.8	0.58%
Commercial	180.0	3.65%	Single Family Attached	24.8	0.50%
Multi Family	145.7	2.95%	Golf Course	22.3	0.45%
Open Space	144.8	2.94%	Dormitory	20.5	0.42%
Duplex	142.3	2.89%	Vacated ROW	11.2	0.23%
Public Owned	132.8	2.69%	Utility Facility	2.5	0.05%
Vacant Land	72.3	1.47%	Commercial / Residential	2.0	0.04%
Parking Lot	57.7	1.17%	Parking Garage	1.9	0.04%
Nursing Home	53.6	1.09%	Stream, Creek, Ditch	1.2	0.02%
Church	49.4	1.00%	Unknown	0.6	0.01%
			TOTAL	**4,932**	**100%**

Source: Lincoln/Lancaster County Planning Department 2010

Table 3-3. Composite Land-Use Summary

Land-Use Type	Total Acres	Percentage of Project Area
Single Family Residential	1,879	38%
Multiple Family Residential	309	6%
Commercial (shopping Areas)	182	4%
Industrial	93	2%
Public/Quasi-Public (schools)	639	13%
Transportation (Roads)	1,261	25%
Park/Recreation/Open space	569	12%
Total	**4,932**	**100%**

Source: Lincoln/Lancaster County Planning Department 2010

Future Land-Use

Due to the majority of the watershed being fully developed, future land-uses matched closely to the existing land-uses according to the Lincoln/Lancaster County future land-use map. Significant changes in land-use had occurred from 2000 to 2011 due to the Antelope Valley Project; which increased the use of land for transportation, recreation, and commercial use in the area. UNL's Innovation Campus, at the site of the former Nebraska State Fairgrounds, was being developed during the development of this Basin Plan. At the time of the planning period, no other significant changes were planned.

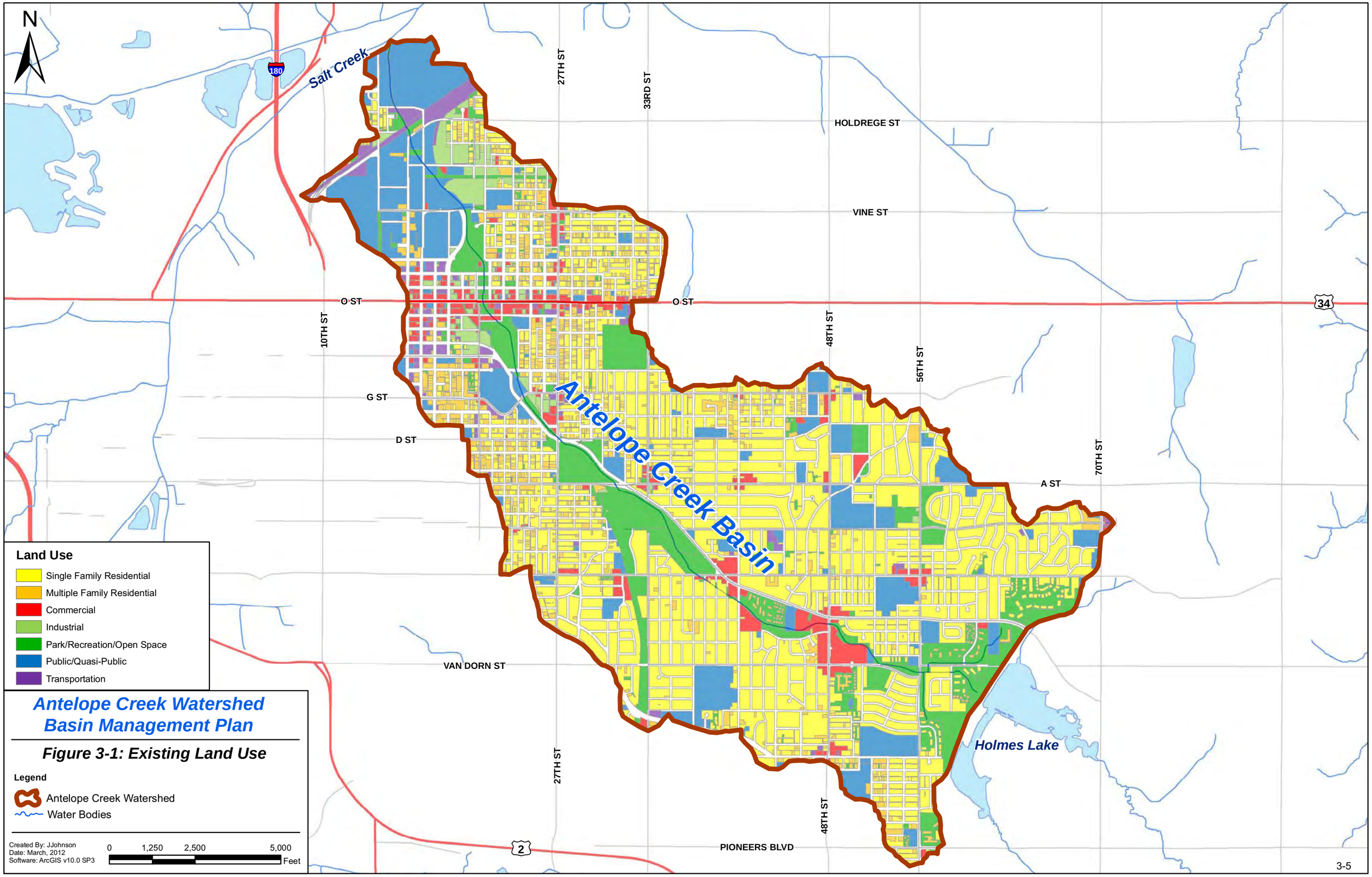
3.2.3 Storm Drainage System

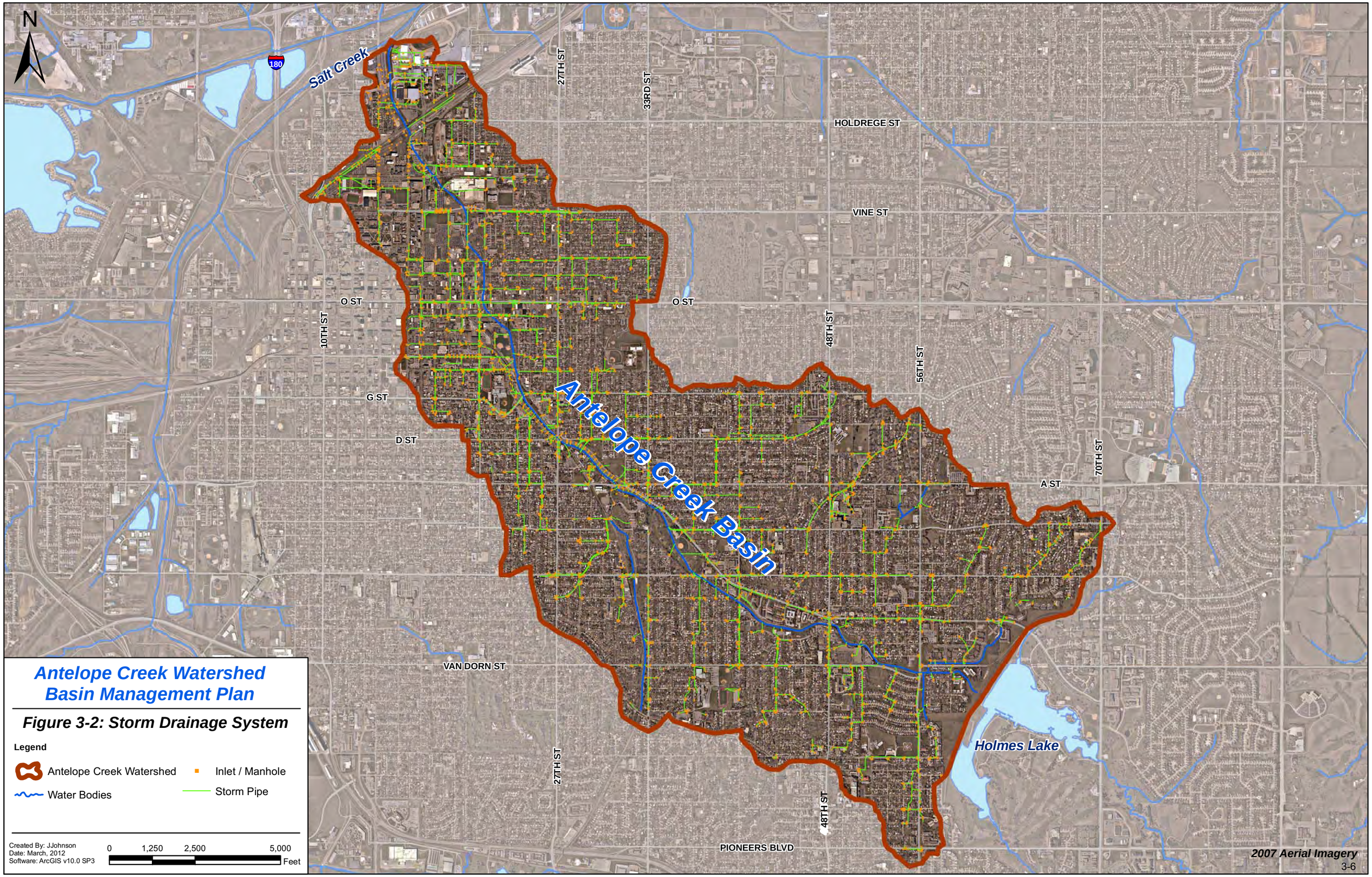
The storm drainage system in the Antelope Creek watershed largely consists of typical curb and gutter, with a few surface drainage tributaries to Antelope Creek. Sheetflow, directly into Antelope Creek, occurs in limited locations along the stream channel. The storm drainage system is typical of an urban area. The system includes approximately 86 miles of storm drain pipe across the watershed. The majority of the system's storm drain pipe is in generally good condition and primarily made up of 15-inch (21.8%), 18-inch (15.3%), and 24-inch (11.7%) reinforced concrete pipe. From Holmes Lake to the confluence of Salt Creek, roughly 3,775 storm drain inlets collect flows discharging to approximately 223 outfalls to Antelope Creek. The outfalls vary in size from 2-inch foundation drains to an 8 foot by 10 foot enclosed conduit outfall.

From Holmes Lake to the confluence of Salt Creek, roughly 3,775 storm drain inlets collect flows discharging to approximately 223 outfalls to Antelope Creek.

Three unnamed tributaries to Antelope Creek exist: one segment through Antelope Park, and two segments that branch off to the north and south near 56th and Van Dorn Street. Figure 3-2 displays the storm drainage system, Antelope Creek, and two tributary segments.

Picture 6: Sediment deposits below an outfall above the labyrinth weir


N
Salt Creek
180
27TH ST
33RD ST
HOLDREGE ST
VINE ST
O ST
O ST
34
10TH ST
48TH ST
56TH ST
70TH ST
G ST
D ST
A ST
Antelope Creek Basin
VAN DORN ST
27TH ST
48TH ST
PIONEERS BLVD
2
Holmes Lake
Land Use
Single Family Residential
Multiple Family Residential
Commercial
Industrial
Park/Recreation/Open Space
Public/Quasi-Public
Transportation
Antelope Creek Watershed
Basin Management Plan
Figure 3-1: Existing Land Use
Legend
Antelope Creek Watershed
Water Bodies
Created By: JJohnson
Date: March, 2012
Software: ArcGIS v10.0 SP3
0
1,250
2,500
5,000
Feet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VINE ST
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56TH ST
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D ST
70TH ST
A ST
Antelope Creek Basin
VAN DORN ST
27TH ST
48TH ST
PIONEERS BLVD
Holmes Lake
Antelope Creek Watershed
Basin Management Plan
Figure 3-2: Storm Drainage System
Legend
Antelope Creek Watershed
Inlet / Manhole
Water Bodies
Storm Pipe
Created By: JJohnson
Date: March, 2012
Software: ArcGIS v10.0 SP3
0
1,250
2,500
5,000
Feet
2007 Aerial Imagery

3.2.4 Hydrologic and Hydraulic Data

Antelope Creek, a tributary to Salt Creek, originates near 91st and Pine Lake Road. Since the completion of the Holmes Lake Dam in 1962, major floods have not occurred; however, some local flooding such as in July, 1967, resulted from several heavy rains. On September 8, 1989 Holmes Lake reached a record high elevation when a storm produced 8 inches of rain in the Antelope Creek watershed. Since the construction of Holmes Lake, additional urban development has taken place in the Antelope Creek watershed between Salt Creek and Holmes Lake Dam, which has increased storm runoff and potential downstream flooding.

Picture 7: The labyrinth weir above Union Plaza is a recently constructed flood control structure installed as part of The Antelope Valley Project

Flows begin at the outfall of Holmes Lake, flowing through an open channel underneath many street bridges, through residential and business neighborhoods, until conveyed underground into an enclosed conduit near 23rd and N Street, just west of Elliott Elementary School. Antelope Creek remains underground between N and Vine Streets, until it leaves the enclosed conduit southwest of the Old Cushman Building on UNL's City Campus near 21st and Vine Street. The final leg meanders in an open channel through the eastern edge of the UNL campus, underneath the Burlington Northern Santa Fe Railway tracks, and continues between North 14th Street and the western edge of Innovation Campus where it empties into Salt Creek south of Cornhusker Highway. Base flow patterns in Antelope Creek are dependent upon the amount of water being released from Holmes Lake, surface water runoff, and groundwater infiltration; these flows travel through the original channel which includes the enclosed conduit. Several groundwater boils are visible in the creek south of Vine Street.

In 2010, the City and LPSNRD completed significant changes to Antelope Creek as part of the Antelope Valley Project due to urbanization of the watershed. Flood control improvements included creation of an open waterway, with gently rising grassy slopes, to carry 100-year flood waters through a one-half block wide linear park, named Union Plaza. Flood control improvements completed in 2010 allow high-flows during flood events to move through the existing box culvert, as well as the newly created open channel passing through Union Plaza. A labyrinth weir located near the entrance of the box culvert controls the amount of water that flows through the existing box culvert. Improvements to the channel narrowed the floodplain such that more than 800 homes, 200 businesses and over 50 acres of UNL's City Campus are no longer threatened by the 100-year flood. The new open linear park waterway is aesthetically designed and attractive to encourage recreational, housing, and business redevelopment.

3.3. Historic Water Quality Data

Sources of water quality data for Antelope Creek include NDEQ, UNL, the City, and EA. Details and discussion on water quality date can be found in SECTION 5 - WATER QUALITY MONITORING. Water quality data for Antelope Creek, from below the Holmes Lake dam to the confluence with Salt Creek, is summarized below:

- NDEQ rotating basin sampling plan data for 2002-2008 collected at Antelope Creek at the State Fairgrounds. This location was included in NDEQ's water quality assessment for 2010 (NDEQ 2010) and was provided in electronic format by NDEQ. (Note: the data set forming the basis of the Antelope Creek TMDLs for ammonia and E. coli was limited to 2002-2004, and is discussed further in SECTION 4 – TMDL ASSESSMENT.)
- NDEQ collected additional monitoring data for Antelope Creek in 2009, also limited to the State Fairground sampling location, and was provided electronically by NDEQ.
- UNL conducted in-stream monitoring at five locations in Antelope Creek, which were visited six times during the summer of 2009. These sites were chosen to assess whether pollutants of concern were entering Antelope Creek from locations such as the State Fairgrounds, the Lincoln Children's Zoo and Sunken Garden, and the Holmes Park Dog Run (upstream of Holmes Lake).
- As part of its NPDES illicit discharge detection and elimination monitoring program, the City conducts a dry weather sampling program of its storm drain system. The program is implemented on a 5 year rotating basis for three groups of sample locations. The most recent sampling results were the 2009 sampling

program, conducted by UNL. From June to August 2009, 51 storm drains were monitored throughout the City. Of these sites, 23 were located in the Antelope Creek watershed.

- NDEQ collected in-stream samples near the Lincoln Children's Zoo for fecal coliform throughout the summer of 1999.
- The City conducted wet weather flow monitoring in other Lincoln watersheds as part of NPDES monitoring in the 1990s and more recently in 2006-2007. Although these samples were not collected within the Antelope Creek watershed, they are still useful in characterizing runoff quality likely to be expected for similar land uses in the Antelope Creek watershed.
- EA completed water quality sampling and sediment sampling as part of the Basin Plan in 2010 and 2011. A variety of parameters were analyzed including *E. coli*, copper, selenium, conductivity, total phosphorus, ammonia, dissolved organic carbons, and general field parameters.

3.4. Existing Water Quality Projects

The City, LPSNRD, UNL, and several businesses and non-profit organizations have planned and implemented "green practices" in the Antelope Creek watershed. Below is a summary of some of the projects that have occurred recently.

- **UNL's 19th and Vine Parking Garage** – Pervious concrete was installed in the north surface parking lot, along with stormwater filtration and reduction system for the parking garage. Rainwater from top parking deck is filtered through site landscape before reaching a perforated drain pipe covered with filter fabric. Stormwater is absorbed by site turf and trees and leftover water is filtered by the fabric before entering storm pipe.
- **UNL's Whittier Research Center** – Installation of 700 square feet of Green Roof.
- **UNL's Abel/Sandoz Dormitories** – Installation of a bioswale south of the building. Native vegetation will infiltrate stormwater prior to running into underground stormwater infrastructure.
- **Rain Gardens –** Approximately 20 rain gardens have been installed within the watershed as part of the City of Lincoln Rain Garden Project.
- **Lewis Field Parking Lot –** This new lot utilizes rain garden islands and pervious pavement to reduce the amount of stormwater runoff and improve water quality.
- **27th and Randolph/F Street (2005 Stormwater Bond) –** The City retrofitted two parking lots located at 27th and Randolph Street (American Legion Park) and 27th and F Street. The parking lot at American Legion Park was retrofitted with a bio-swale in order to capture and treat the first flush during a rainfall event. The parking lot at 27th and F Street was retrofitted with both a rain garden and pervious pavement. The rain garden captures and treats the first flush much like the bio-swale. The pervious pavement was installed beneath the parking stalls and sidewalks, and captures and treats the stormwater that falls on it.

Picture 8: Curb-cut bioswale in the new parking lot at the Parks and Recreation Office

- **Antelope Creek Tributary Restoration (2005 Stormwater Bond) –** This unnamed tributary to Antelope Creek winds through Antelope Park and had severe stream bank erosion that caused damage to trees, trails, a pedestrian bridge, and threatened to damage streets close to the channel bank. This project reduced erosion problems and removed the threat of damage to amenities in the park by adding a winding stream and placing large rocks along sections of the channel.
- **South 48th Green Street –** In 2009, the City began design of a 'green street' on 48th from Pioneers north to Calvert near the divide between Antelope Creek and Beal Slough. This effort included more than 5,000 square feet of bio-swale as a demonstration site intended to receive and treat stormwater runoff. The City intends to monitor effectiveness of the bio-swale over a 2-year period and incorporate it into other areas in the community. Construction on the project began May 2010.

- **Parks and Recreation Department –** The City finished installation of several BMPs at the Parks and Recreation Office Building in 2011 including a parking lot bioswale and rain gardens.
- **Silva cells in Union Plaza –** The City utilized NDEQ funding in 2009 to install silva cell structures in Union Plaza. Silva cells are subsurface framework systems that can be stacked several units deep and topped with a deck to support pavement or other hardscape surfaces and collect stormwater runoff. Trees growing in these structures will utilize stormwater runoff which is designed to infiltrate and be retained prior to entering Antelope Creek.
- **Assurity Life Insurance Company Building –** Assurity Life Insurance Company's new 180,000 square foot office is located on approximately 9.5 acres adjacent to Union Plaza. The site design includes multiple stormwater management practices intended to limit pollutant loading to the adjacent Antelope Creek. Features include native and naturalized landscaping, bioretention gardens/cell, stormwater harvesting/cisterns, pervious pavement, and a green roof system.
- **Lincoln Children's Zoo –** In 2010, the Children's Zoo received Nebraska Environmental Trust funding to improve water and soil management in two highly utilized public areas of the zoo. The project is intended to reduce runoff and increase water quality while enhancing the aesthetic appeal of the space. Surface water will be managed by bio-filtration methods including natural sand filtering, water detention, and large rain garden areas.
- **Groundwater Guardian Green Sites –** The Groundwater Foundation's program recognized good stewards of groundwater by encouraging managers of highly-managed green spaces to implement, measure, and document their groundwater friendly practices. In the project area this includes:
    - Community CROPS – Antelope
    - Madonna Rehabilitation Hospital
    - SE Park District of the City of Lincoln
    - Jim Ager Junior Golf Course
    - Lincoln Children's Zoo
    - First-Plymouth Congregational Church

3.5. Dry Weather Survey

Dry weather flows from the storm drainage system are of potential concern to Antelope Creek; primarily because they may represent ongoing sources of pollution associated with illicit connections, illicit discharges of washwater or other inappropriate discharges to Antelope Creek. During 2010, EA inventoried the City's outfalls to Antelope Creek. Outfalls with dry weather flows were re-visited one week later (no rain during that time) to check for flows again. Of the 223 outfalls, 12 were observed to have flow during dry weather conditions. These 12 outfalls were further evaluated by tracking the flows up through the storm drain system to investigate the source. Table 3-4: Summary of Dry Weather Flows summarizes the known dry weather flows contributing to Antelope Creek. Multiple groundwater seeps were noticed while performing the dry weather flow survey. The frequency of the seeps increased with proximity to Salt Creek. Data collected during the dry weather survey included pipe size, type of flow, odor, algae growth, sediment deposits, and location using a handheld Global Position System (GPS). Natural seeps into the storm drain system are not considered to be illicit discharges. A full analysis of dry weather flow and results from sampling can be found in SECTION 5 - WATER QUALITY MONITORING.

Picture 9: EA staff collecting a dry weather sample in 2011

Table 3-4. Summary of Dry Weather Flows

Outfall Location	Pipe Size (in)	Comments
South of Big "X", Under Pedestrian Bridge	72	Some flow originates from Memorial Stadium.
South of Big "X", Under Pedestrian Bridge	60	Source unknown.
Between Big "X" and Y Street	60x72	50% of flow from near Jorgensen Hall on UNL campus, 50% of flow from surface drains near The Village Dorms on UNL Campus. Both sources are believed to be Air-Conditioning condensate.
17th and Y Street	42	Flow originates from Abel Dorm Air-Conditioning unit.
17th and Y Street	96x126	Source unknown.
North of Vine Street Bridge	48x84	Source unknown.
Under 40th Street Bridge	36	Source traced to Lincoln High School. Source is believed to be Air-Conditioning condensate.
North of Y Street Bridge	72	Source unknown.
South of A Street Bridge	120x60	Source generated between 28th and Arlington, and Jefferson and Arlington (water service line break). This line was repaired in May of 2011, and greatly reduced this dry weather flow.
33rd and Capital Parkway	84x60	Source traced to Tabitha Health Care Services. Source is believed to be Air-Conditioning condensate.
West of Pedestrian Bridge near S. Cotner and Normal Blvd	80x60	Source traced to Bryan LGH Medical Center. Source is believed to be Air-Conditioning condensate.
East of 48th and Normal	60	Source unknown.
East of 48th and Normal	84x60	Flow dissipates upstream. Source is believed to be groundwater infiltration.

Source: EA Engineering Field Survey 2010

3.6. Pollutants and Pollution Sources

A number of potential pollution sources were identified based on the results of the watershed inventory. A summary is provided below. A more detailed description of each pollution source is discussed in SECTION 6 - POLLUTION SOURCES AND CONTROL STRATEGIES.

- **Wildlife and pet waste** – There are 29 bridge crossings in the watershed. Many of the older structures provide opportunities for birds to nest and perch where their droppings may contribute to contaminants in Antelope Creek. Existing habitat in the watershed provides room for wildlife such as raccoons, squirrels, and other feral animals that contribute to pollution sources. Domesticated pets, such as cats and dogs, can also provide a significant source of pollution if waste is not properly disposed.
- **Fertilizers** – Excess nutrients in the stream, which may originate from over-fertilizing, contribute to algal blooms in the water. Improper storage and disposal of fertilizers, over application, or incidental application to impervious surfaces, such as concrete driveway and sidewalks, can lead to nutrients entering Antelope Creek through stormwater runoff.
- **Soil erosion and construction site runoff** – Sediment can enter a stream through natural processes, erosion, or through activities such as construction sites. Sedimentation of a waterway decreases the biological function of the water and is detrimental to aquatic habitat. In addition, sediment picks up nutrients such as nitrogen and phosphorus, and carries them into a waterway, which can create an incubation zone for bacteria growth.

- **Gravel/Sand** – Large amounts of gravel and sand were observed on the downstream side of many bridges. The gravel, primarily applied in the winter to provide better traction, is flushed off parking areas and streets after rain events.
- **Oils and Grease** – Droppings from vehicles include oil and grease. Examples include runoff from maintenance facilities, streets, and parking lots.
- **Heavy Metals** – The source of heavy metals within Antelope Creek are unknown and are not a focus of this management plan.

Picture 10: Bird droppings are commonly found under Antelope Creek bridges

3.6.1 Stormwater Permits

The City of Lincoln and UNL each hold an active municipal separate storm drainage system (MS4) permit, administered through the National Pollutant Discharge Elimination System (NPDES) Program by NDEQ. Each is authorized to discharge to the Salt Creek and receiving waters (including Antelope Creek). Two industrial discharges were noted in the Antelope Creek TMDL, each of which is no longer in use.

3.7. GIS Database

The project team used GIS to manage and organize existing and new geographical information using Arc GIS software. All data was formatted in order to be compatible with existing City GIS data. GIS was used to create plan maps, manage databases, query information, etc. Information includes a variety of datasets such as:

- GPS – used to locate dry weather flows, outfalls, water and sediment sampling locations
- Aerial photography – 2010 color imagery
- Storm drainage system infrastructure
- Lakes and streams
- Hydraulic Unit Code (HUC)
- Existing land-use
- Streets and roads

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SECTION 4 – TMDL ASSESSMENT

4.1. Introduction

The Nebraska Department of Environmental Quality (NDEQ) Water Quality Division develops and prioritizes a biennial list of "impaired" state waters that do not attain water quality standards for designated uses. This list, commonly referred to as the impaired waters list, is developed in accordance with Section 303(d) of the Federal Clean Water Act (CWA). NDEQ obtains state water data as part of the Nebraska Ambient Stream Monitoring and Basin Rotation Networks. The Ambient Stream Monitoring Program consists of 98 fixed station sites distributed throughout Nebraska's 13 designated river basins, with data collected based on NDEQ's sampling rotation. Typically, the sites are co-located with stream gauging stations. Under this program, monitoring is limited to two or three river basins each year with all 13 basins being (partially) examined in a 5-year period.

Once a water body is identified as 'impaired', states are required to initiate the Total Maximum Daily Load process to address these impairments and assign pollutant load allocations to various sources discharging to the stream

Once a water body is identified as "impaired", states are required to initiate the Total Maximum Daily Load process to address these impairments and assign pollutant load allocations to various sources discharging to the stream. Waste load allocations are assigned to point sources such as permitted wastewater and stormwater discharges (*i.e.,* MS4 permits). Load allocations are assigned to non-point and background sources. A margin of safety is also required. The basic form of a TMDL calculation is:

TMDL (Total Maximum Daily Load) = ΣWLA (Waste Load Allocation) + ΣLA (Load Allocation) + MOS (Margin of Safety)

Pollutant contributions in the waste load allocation component of this calculation are reduced through permit requirements and enforced under National Pollutant Discharge Elimination System (NPDES) permits. Pollutant contributions in the load allocation component are typically reduced through non-structural and structural best management practices (BMPs). Municipal separate storm drainage systems (MS4s) are considered point sources. Background contributions such as natural sources are recognized in the load allocation component. The margin of safety component of the TMDL may be based on an assigned quantitative load (explicit) or on a conservative assumption (implicit). Stated differently, an explicit margin of safety requires waste loads and loads to be reduced to reach a target lower than the stream standard, whereas the target for an implicit margin of safety is typically the stream standard.

The following section provides a description of the current Antelope Creek TMDL, a general comparison of the Antelope Creek TMDL to other TMDLs in Lancaster County and the State, information on the primary constituent of concern (*E. coli*), and information on past constituent of concern (ammonia). A summary is included on the basis used for listing these streams as impaired and a brief discussion of other pollutants of concern.

4.2. Antelope Creek TMDL

Antelope Creek was included in the 2010 Nebraska Surface Water Quality Integrated Report as an impaired water body due to excessive conductivity, copper, selenium and *Escherichia coli* (*E. coli*) bacteria. Data collected by NDEQ from 2002-2005 indicated the following impairments to beneficial uses:

- Primary contact recreation — *E. coli* bacteria
- Aquatic life — ammonia, copper, and selenium
- Agricultural water supply — conductivity, chloride

As a result of these listings, NDEQ developed TMDLs for ammonia and *E. coli* in 2007 (NDEQ 2007). No TMDLs were developed for conductivity, selenium, and copper due to uncertainty associated with the limited data set and the potential for changes to the designated uses through completion of a Use Attainability Analysis. In 2010, NDEQ removed ammonia from the 303(d) list and added chloride. Ammonia was removed from the Antelope Creek sampling for this project because recent NDEQ ambient stream monitoring data and data from the first round of Antelope Creek sampling indicated that the ammonia levels previously reported for Antelope Creek were no longer above the water quality criteria. The water quality goals for the TMDL are currently being met for ammonia. As a result, the primary focus of this Basin Plan with regard to existing stream impairments is *E. coli*.

It is important to note that there are no municipal wastewater treatment plant (WWTP) discharges to Antelope Creek, so the primary focus from a waste load allocation perspective is the two stormwater NPDES permits in the basin, which include the City and University of Nebraska–Lincoln (UNL). Two industrial discharges had been permitted but are no longer operational and do not discharge to the Creek. No non-point sources of pollution are specified in the TMDL, although wildlife is identified as a natural source of *E. coli*. Although many TMDLs use an implicit margin of safety in their calculations, the Antelope Creek TMDL includes a clearly defined explicit margin of safety that reduces the water quality target below the stream standard by 10%. For example, the water quality objective for the *E. coli* seasonal geometric mean in the Antelope Creek TMDL is 113 colony forming units per 100 milliliters (cfu/100 mL); which is 10% below the NDEQ's TMDL stream standard of 126 cfu/100 mL.

4.3. State and Local Watershed TMDLs

As of 2010, NDEQ had completed 12 TMDLs for lakes (Table 4-1) and 15 TMDLs for streams (Table 4-2). Multiple stream segments (*e.g.,* 5 to 10 segments) were often included within a single TMDL, so the number of stream segments in the state impaired by *E. coli* with TMDLs completed is about four times higher, totaling approximately 60 segments. Based on the 2010 NDEQ Integrated Report, nearly 70 additional water body segments are listed as impaired for *E. coli*, but TMDLs have not been developed. These *E. coli* listings account for about half of the Nebraska stream impairments requiring TMDLs.

Lancaster County has five stream TMDLs and three lake TMDLs, including Holmes Lake. Antelope Creek and the Lower Platte River (eight segments) have *E. coli* TMDLs, both of which were completed in June 2007. Salt Creek, Wahoo Creek, Deadmans Run, and Oak Creek segments are included in the Lower Platte River *E. coli* TMDL. Segments in the vicinity of Lincoln are shown on Figure 4-1. NDEQ has completed TMDLs for all of the *E. coli* listed stream segments in the Lower Platte River Basin. Adjacent river basins with *E. coli* TMDLs include the Big Blue River Basin and the Nemaha River Basin, both of which include multiple stream segments in each basin TMDL.

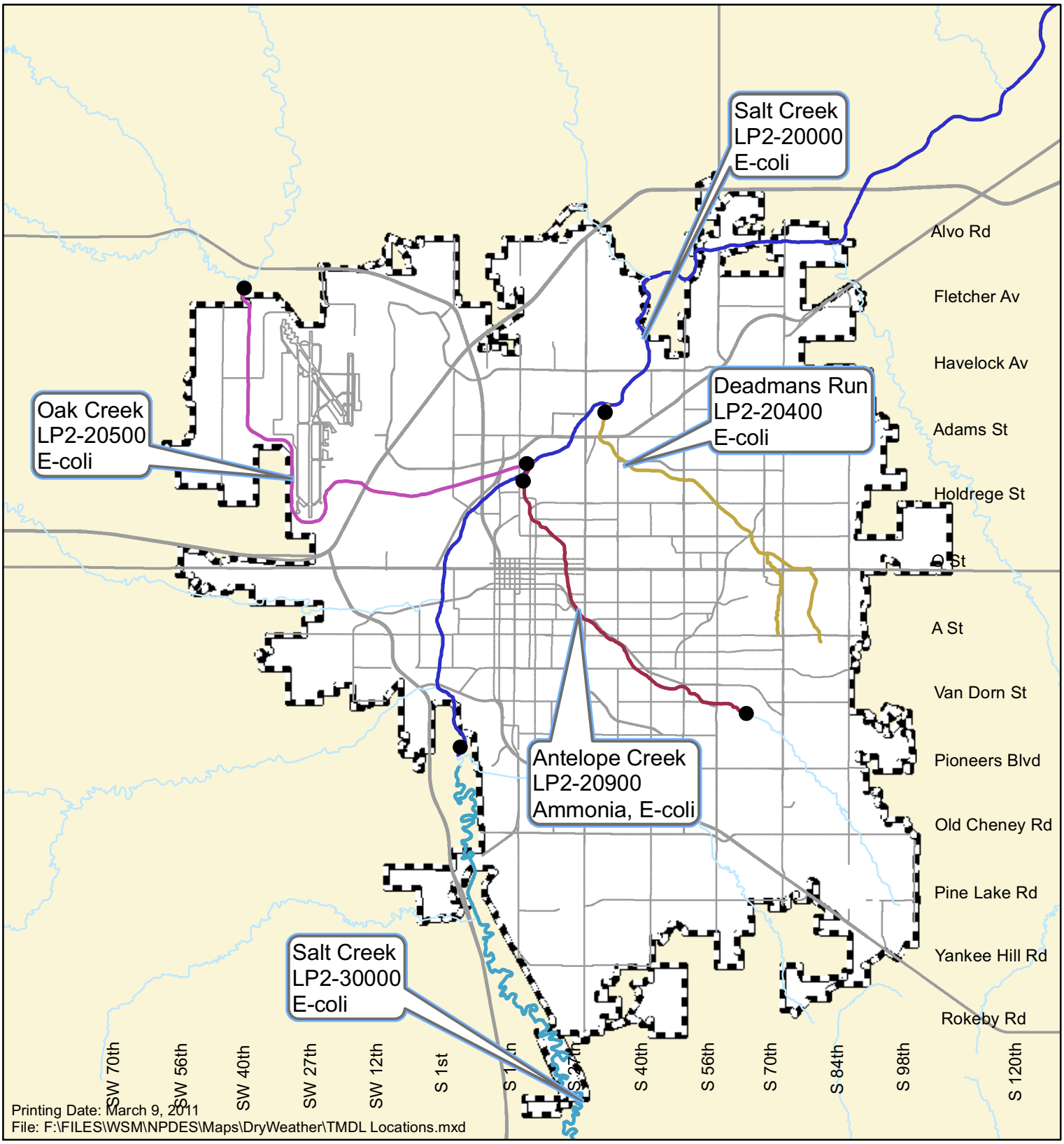
Table 4-1. TMDLs Completed for Nebraska Lakes (NDEQ 2010)

Lake Name	Location (county)	Parameters	Date
Big Indian Lake	Gage County	Sediment and Phosphorus	September-09
Carter Lake	Douglas County	Algae and Turbidity	June-07
Holmes Lake	**Lancaster County**	Sediment and Phosphorus	June-03
Iron Horse Trail Lake	Pawnee County	Phosphorus and Sediment	December-05
Johnson Lake	Gosper County	Fecal coliform	August-04
Kirkman's Cove	Richardson County	Phosphorus	September-02
Lake Ogallala	Keith County	Sulfides and Inst. Oxygen Demand	June-07
Fremont 20	Dodge County	Phosphorus	June-07
Standing Bear Lake	Douglas County	Sediment and Phosphorus	June-03
Wagon Train Lake	**Lancaster County**	Sediment and Phosphorus	September-02
Yankee Hill	**Lancaster County**	Sediment and Phosphorus	August-02
Zorinsky Lake	Douglas County	Sediment and Phosphorus	September-02

Source: Nebraska Department of Environmental Quality 2010

Figure 4-1. State of Nebraska NDEQ TMDL Listed Water Bodies for Lincoln/Lancaster Co. Area

Public Works & Utilities



CITY OF LINCOLN
NEBRASKA
MAYOR CHRIS BEUTLER

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Miles

State of Nebraska NDEQ 2010 - TMDL Listed Water Bodies for Lincoln/Lancaster Co. Area

** Not inclusive of all pollutants of concern*

Legend

Major Streams
TMDL
Other Streams
LP2-20000
LP2-20400
LP2-20500
LP2-20900
LP2-30000

Table 4-2. TMDLs Completed for Nebraska Streams

Stream	Location (county or stream segments)	Parameters	Date
Antelope Creek	LP2-20900, **Lancaster**	*E. coli*; Ammonia	June-07
Middle Creek	LP2-21100, **Lancaster** and Seward	Atrazine	June-07
Shell Creek	LP1-20700, Antelope, Boone, Colfax, Madison and Platte	Atrazine	June-07
Big Blue	Multiple Segments: Gage, Pawnee, Jefferson, Saline, **Lancaster**, Fillmore, Clay, Adams, Seward, York, Hamilton, Hall, Butler, Polk	*E. coli*	February-05
Elkhorn River Basin	Multiple Segments: Antelope, Brown, Boone, Burt, Cedar, Colfax, Cumming, Dixon, Dodge, Douglas, Garfield, Holt, Knox, Madison, Platte, Rock, Stanton, Thurston, Washington, Wayne and Wheeler Sarpy	*E. coli*	September-09
Little Blue River Basin	Multiple Segments: Jefferson, Saline, Fillmore, Clay, Nuckolls, Adams, Thayer, Webster, Kearney, Franklin	*E. coli*	February-05
Loup River Basin	Multiple Segments: Arthur, Blaine, Boone, Brown, Buffalo, Cherry, Custer, Dawson, Garden, Garfield, Grant, Greeley, Holt, Hooker, Howard, Logan, Loup, McPherson, Merrick, Nance, Platte, Rock, Sherman, Sheridan, Thomas, Valley, Wheeler	*E. coli*	December-02
Lower Platte River Basin	Multiple Segments: Boone, Butler, Cass, Colfax, Dodge, Douglas, **Lancaster**, Madison, Platte, Sarpy, Saunders, Seward	*E. coli*	June-07
Middle Platte	Multiple Segments: Platte, Polk, Nance, Merrick, Hamilton, Howard, Hall, Adams, Kearney, Buffalo, Phelps, Gosper, Dawson, Custer, Frontier, Logan, Lincoln, McPherson	Fecal coliform	April-03
Nemaha Basin	Multiple Segments: Cass, Gage, Johnson, **Lancaster**, Nemaha, Otoe, Pawnee and Richardson	*E. coli* & Atrazine	June-07
Niobrara	Multiple Segments: Antelope, Boyd, Box, Butte, Brown, Cherry, Dawes, Holt, Keya Paha, Knox, Morrill, Rock, Sheridan and Sioux	*E. coli*	December-05
North Platte	Multiple Segments: Lincoln, McPherson, Keith, Arthur, Garden, Sheridan, Cheyenne, Morrill, Kimball, Banner, Scottsbluff, Sioux	*E. coli*	September-03
Papillion Creek	Multiple Segments: Douglas, Sarpy and Washington	*E. coli*	September-09
Republican	Multiple Segments: Chase, Dundy, Franklin, Frontier, Furnas, Gosper, Harlan, Hayes, Hitchcock, Kearney, Keith, Lincoln, Nuckolls, Perkins, Phelps, Red Willow, Webster	*E. coli*	February-05
White River	Segment WH1-20000, Dawes, Sheridan and Sioux	*E. coli*	December-05

Source: Nebraska Department of Environmental Quality 2010

A comparison of the Antelope Creek and Lower Platte River Basin *E. coli* TMDLs was completed to assess whether similar approaches were used for development of the TMDLs and to identify common factors that may be contributing to elevated *E. coli* in these basins. Multiple stream segments in the Lower Platte River Basin were addressed in the Lower Platte River Basin TMDL, whereas Antelope Creek is addressed in a separate TMDL. Table 4-3 summarizes several key characteristics for the relevant stream segments, followed by discussion of several of these characteristics.

Table 4-3. Summary of *E. coli* Data Providing Basis of Lower Platte Basin *E. coli* TMDLs

Segment Location	Dominant Land Use	WWTPs: # Discharging to Stream/# in Basin (Descp. if > 0.5 cfs)[1]	Number of Samples[2]	Seasonal Geometric Mean (#/100 mL)	Targeted Reduction	Target (#/100 mL)
Antelope Creek at Lincoln	Urban	0/0	20[3]	3,433	97%	113
Dead Man's Run at Lincoln	Urban	0/0	20	1,404	92%	112
Salt Creek at Lincoln	Urban	2/8 NE Lincoln (15.47 cfs) Theresa St. (44.87 cfs)	20	432	74%	112
Oak Creek at Lincoln	Mixed (Airport/Indust/ Open)	0/1	20	389	71%	113
Salt Creek at Pioneers Blvd: Lincoln	Mixed (Wilderness Park/Open/Res.)	0/2	20	458	76%	110
Platte River at Louisville	Agricultural	5/10	22	314	64%	113
Platte River at North Bend	Agricultural	3/9 Cargill Meats (4.25 cfs) Schuyler (1.08 cfs)	22	750	85%	113
Salt Creek at Greenwood	Agricultural	2/5	21	718	85%	108
Wahoo Creek at Ashland	Agricultural	0/6 Wahoo (1.08 cfs)	22	531	79%	111

Table Notes:
[1]In some cases, a wastewater treatment plant (WWTP) may be present in the watershed, but does not discharge directly to the stream segment.
[2]Data forming the basis of the Antelope Creek and Lower Platte River Basin *E. coli* TMDLs was collected during 2004 under the NDEQ rotating basin monitoring program.
[3]Number of *E. coli* samples identified in the Antelope Creek TMDL is 20; however, 21 samples are present in the NDEQ electronic data set. This minor discrepancy does not substantively affect conclusions regarding *E. coli*.

Key observations resulting from this comparison include:

- Both Antelope Creek and Lower Platte River Basin TMDLs follow similar protocols using Load Duration Curves to target *E. coli* load reductions. This approach is a tool that associates *E. coli* loads with flow conditions and helps target whether the source loading is due to point or nonpoint sources of pollution. This tool provides general information on how to partition the TMDL between waste load allocations and load allocations, but does not provide a detailed assessment of specific sources of pollutant loading within these categories. The Antelope Creek Load Duration Curve shows elevated *E. coli* under both high and low flow conditions, suggesting that nonpoint sources under base flow conditions are likely a contributing factor.
- Both TMDLs are based on relatively limited data sets, with comparable numbers of samples (20-22) for each stream segment addressed.
- Both TMDLs use an explicit margin of safety approach, which results in a target below the stream standard (*e.g.,* 113 cfu/100 mL as opposed to 126 cfu/100 mL). WWTP NPDES permits were allocated based on the stream standard.
- Substantial reductions in *E. coli* are targeted for most of the listed stream segments with reductions in the 64 to 97 percent range.

- In-stream and environmental factors affecting bacteria die-off or growth are not discussed in the TMDLs.
- No combined sewer overflows or sanitary sewer overflows are identified as affecting any of these streams.
- Antelope Creek does not receive WWTP discharges, unlike several of the stream segments in the Lower Platte River TMDL. Based on additional research by EA, the only two permitted industrial discharges noted in the Antelope Creek TMDL are no longer occurring.
- The Antelope Creek drainage basin is located within an urbanized area, whereas several portions of the Lower Platte River TMDL are in undeveloped areas.
- The Lower Platte River TMDL assigns load allocations for non-point sources, whereas non-point sources are not included in the Antelope Creek TMDL. Although wildlife is briefly mentioned in the Antelope Creek TMDL as a natural source, the primary thrust of the TMDL is focused on the MS4 permits, with non-point sources identified as negligible. In the City of Lincoln's MS4 discharge permit, a municipal separate storm drainage system is defined as "a conveyance or system of conveyances including but not limited to roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels designed or used for collecting or conveying stormwater." "Point-source discharges of municipal stormwater and other authorized flows" from these sewers or systems of sewers are the focus of regulation in the discharge permit. It is important to recognize that in Lincoln and other urban areas, there are also sources of pollution to the stream that are not discharged from such stormwater conveyance systems. For example, birds and squirrels that nest in the tree canopy or bridges along the riparian corridor of the stream channel may be sources of *E. coli* that do not originate from the City's storm drainage system. As other examples, many urban areas have foxes, coyotes, raccoons and other mammals that frequent waterways and may contribute to *E. coli* loads. These diffuse sources that are not part of the stormwater conveyance system are best characterized as non-point sources of *E. coli*. Based on observations along Antelope Creek, natural sources (particularly birds) are expected to be potentially significant factors affecting *E. coli* concentrations on Antelope Creek; however, these factors are not discussed in the Antelope Creek TMDL. Additional monitoring is needed to assess the degree to which these nonpoint source factors are affecting Antelope Creek *E. coli* concentrations.
- Land uses among the stream segments vary from agricultural to urban and include segments with and without WWTP discharges to the stream. Several qualitative observations (*i.e.,* without statistical testing) can be made based on a comparison of the factors in Table 4-3. Urban land uses appear to be associated with the highest *E. coli* concentrations, with Antelope Creek and Dead Man's Run having the highest *E. coli* recreation season geometric mean concentrations (1,400-3,400 cfu/100 mL) and other impaired stream segments having geometric mean concentrations in the 300-800 cfu/100 mL range. Presence of WWTP discharges does not appear to strongly affect observed *E. coli* values.
- Basic implementation plans are provided in each TMDL that identify existing regulatory programs as the primary path toward reducing *E. coli* exceedances. For example, the implementation plan sections reference existing NPDES WWTP and stormwater permits, Confined Animal Feeding Operation regulations, and Section 319 nonpoint source management program grant opportunities. Stormwater is addressed in the context of EPA (2002) guidance, which focuses on use of municipal stormwater programs to reduce pollutant loading.

In summary, comparable approaches for development of *E. coli* TMDLs were used by NDEQ for Antelope Creek and Lower Platte River Basin. For the Antelope Creek TMDL, additional exploration of non-point source contributions to *E. coli* is needed, and being completed as part of this Basin Plan. Additionally, the conservative mass balance approach to the TMDL (*e.g.,* not accounting for bacteria die-off) could provide a basis for use of an implicit margin of safety, as opposed to an explicit margin of safety, which has the effect of lowering the stream standard target.

4.4. Pollutants

An overview of the primary pollutant of concern (*E. coli*) for Antelope Creek, including why the pollutant is regulated is discussed below. Other constituents of potential concern are also briefly described including ammonia, which was listed in the 2008 TMDL but is no longer considered a concern based upon the 2010 Nebraska Surface Water Quality Integrated Report. Each pollutant's relationship with land uses in Antelope Creek is further described in SECTION 6 - POLLUTION SOURCES AND CONTROL STRATEGIES.

4.4.1 *E. coli*

EPA uses *E. coli* and enterococcus as indicators of fecal contamination of receiving waters, with *E. coli* recommended for use in freshwater environments. These fecal indicator bacteria are present in the intestines of warm-blooded animals and are easier to identify and enumerate in water quality samples than the broad range of pathogens in human and animal feces. Presence of the *E. coli* subgroup indicates that some degree of fecal contamination to the stream has occurred and that water quality conditions may pose increased risk to human health for those swimming or recreating in a water body. The geometric mean standard of 126 cfu/100 mL of *E. coli* is based on an accepted risk level of eight swimmer illnesses per 1,000 exposures.

In total, 12 of Nebraska's 13 primary watersheds have water bodies that are affected by *E. coli* (or fecal coliform, spanning both rural and agricultural land uses. This statewide perspective is important because it shows that elevated *E. coli* is a common phenomenon in Nebraska streams and that is not limited to urban areas. Nationally, pathogens (as evidenced by elevated fecal indicator bacteria) were the top cause of stream impairments, with over 10,000 stream segments identified as impaired.

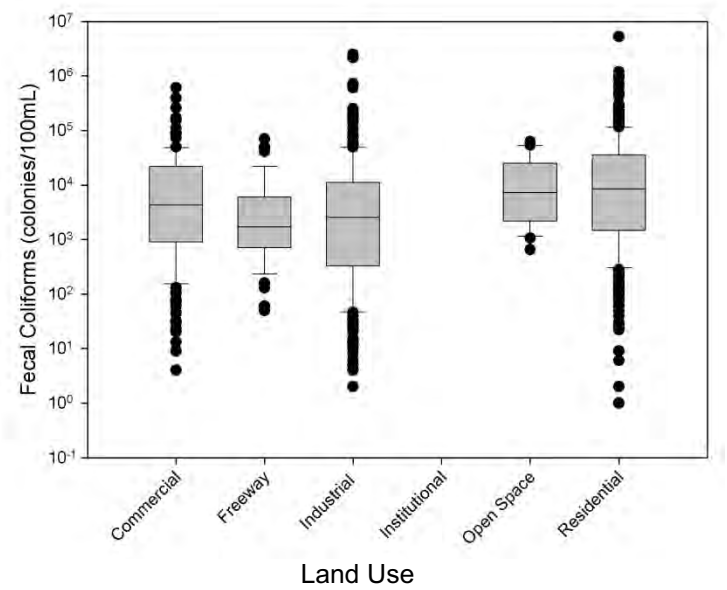
Sources of fecal indicator bacteria in streams vary widely and include animal, human and environmental sources such as:

- Illicit discharges through improper connections to the municipal storm drainage system (*e.g.,* inadvertent plumbing connections of sanitary wastewater to the storm drainage system).
- Municipal and industrial wastewater treatment facilities without adequate treatment processes or improperly functioning treatment systems.
- Malfunctioning on-site wastewater systems.
- Sanitary sewer overflows, combined sewer overflows and sewer line break discharges.
- Urban stormwater runoff, including rain and snowmelt.
- Urban dry weather discharges such as power washing of impervious surfaces with bird droppings and lawn irrigation runoff that collects bacteria from gutters.
- Urban wildlife that inhabits storm drainage systems such as raccoons and rats, along with other wildlife.
- Bird nesting areas under bridges overhanging streams and direct use of water bodies by birds, both in the water and on lawn areas directly adjacent to water bodies.
- Wildlife and domestic animal use of vegetated or open space areas such as parks, golf courses, and urban lawns.
- Agricultural runoff from crops, pasture and confined animal feeding operations (CAFOs).
- Unique source areas with higher animal densities such as zoos, stock show arenas, dog parks, etc.
- Environmental growth and persistence of *E. coli* in stream sediments and algae.

Environmental sources of bacteria have gained increasing attention in recent years. For example, Skinner et al. (2010) summarize recent research indicating that biofilms (*i.e.,* the "slime layer") in storm drainage systems provide a safe environment for enhanced bacterial replication, supply nutrients and water for biofilm bacteria, and offer protection against microbial predators, ultraviolet (UV) light, drying, and disinfectants (citing research by Coghlan 1996, Costerton et al. 1995, Donlan and Costerton 2002, Donlan 2002). Environmental sources of fecal indicator bacteria such as bacteria in sediments present in outfalls and streambeds have also received attention in various studies (*e.g.,* Byappanahalli et al. 2003; Byappanahalli et al., 2006; Davies et al. 1995; Monroe 2009). Other studies have shown plant sources such as decaying kelp along beaches serving as the "perfect incubator for bacterial growth" (Kolb and Roberts 2009).

Regardless of whether the source is natural or human-caused, fecal indicator bacteria concentrations in urban stormwater are typically well above primary contact recreation stream standards, regardless of the land use (Figure 4-2) (Pitt, Maestre and Morquecho 2004).

Figure 4-2. Box and Whisker Plots of Fecal Coliform in Stormwater Data



Note: Primary Contact Recreational Standard for Fecal Coliform =200/100 mL
(Source: Pitt, Maestre, and Morquecho 2004)

To target source controls, more detailed evaluation of sources or activities within various land uses is typically needed, and is discussed further in SECTION 6 – POLLUTANT SOURCES AND CONTROL STRATEGIES. Although some of these sources can be reasonably controlled (*e.g.,* wastewater discharges, illicit connections), other sources are much more difficult to control such as raccoons and other animals in storm drainage systems, beavers, wildlife in open space areas, birds on bridges, and stream and storm drainage system sediments and biofilms. When exploring source of fecal contamination that pose risks to human health, stormwater managers should also be aware that although significant concentrations of fecal indicator organisms are nearly ubiquitous in urban drainage, the relationship between fecal indicators and pathogens is unclear. For example, Schroeder et al. (2002) investigated the presence of human pathogens in urban storm drains in California and concluded, "Pathogens can be found in urban drainage, but there does not appear to be a relationship between the presence of pathogens and the concentration or presence of indicator organisms." (Note: most of the currently available existing epidemiological data are oriented toward contamination from sanitary wastewater sources, as opposed to stormwater sources.)

Currently, water quality criteria do not differentiate risks to human health due to sources of fecal indicator bacteria. Expert panels convened by EPA (2007) and the Water Environment Research Foundation (WERF 2009) have generally agreed that human sources of bacteria are expected to pose a greater health risk than animals and environmental sources, but have also recommended additional research to better quantify this risk. In *Review of Zoonotic Pathogens in Ambient Waters*, EPA (2009) concludes "Contamination of recreational waters with feces from warm-blooded animals poses a risk of zoonotic infection of humans with some of the pathogens in those waters. Although the risk and severity of human illness due to contamination with animal feces and zoonotic pathogens is most likely lower than the risk and severity of illness from treated or untreated human sewage, currently available data are insufficient to quantify the differences." Consequently, EPA requires both natural and human-caused sources of fecal indicator bacteria to be addressed unless an epidemiological study has demonstrated that non-human sources do not pose an increased risk to human health beyond the allowed 8 swimmer illnesses per 1,000 exposures for freshwater settings.

Understanding sources of bacteria is important in selecting appropriate BMPs targeted to these sources. Managing the source should be the first strategy implemented. A variety of guidance and techniques exist for conducting bacteria source tracking, ranging from relatively straightforward illicit discharge screening (CWP and Pitt 2004) to complex microbial source tracking (MST) studies (EPA 2005; WERF 2007). As one example, some communities have had success using quantitative polymerase chain reaction (QPCR) methods for human source

Bacteroides. EPA's Recreational Water Quality Criteria website provides additional information on these techniques (http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/health/recreation/index.cfm).

Data Used to Determine *E. coli* Impairment

The Antelope Creek *E. coli TM*DL is based on *E. coli* data collected by NDEQ in the Lower Platte River basin in 2004. The data set included 21 *E. coli* samples located at "Antelope Creek at State Fair" (Station SLP2ANTLP104) on Antelope Creek. The reported values ranged from 164 to >24,192 cfu/100 mL, with a calculated recreation season geometric mean of 3,163 cfu/100 mL. All sample densities exceeded the 126 cfu/100 mL water quality standard, as well as the 113 cfu/100 mL TMDL target. Additionally, all but one sample exceeded the 576 cfu/100 mL single sample allowable density for infrequently used recreational waters as specified in the Nebraska Water Quality Standards (Title 17, Chapter 4). NDEQ has collected additional data since completion of the TMDL that also show elevated *E. coli* densities.

Although this available data set was adequate for the purposes of identifying the stream segment as impaired for *E. coli*, the single monitoring station on the stream is not adequate to identify sources of *E. coli* or strategies to reduce *E. coli* loading to Antelope Creek. Additionally, the Load Duration Curve in the Antelope Creek TMDL shows exceedances under both high and low flow conditions (NDEQ 2007), therefore elevated *E. coli* on Antelope Creek cannot be simply considered a stormwater issue. To better understand sources of *E. coli* within the basin, additional sampling was included in the development of the Basin Plan. The results of this additional sampling are discussed in SECTION 5 - WATER QUALITY MONITORING.

4.4.2 Ammonia

EPA has established Ambient Water Quality Criteria for Ammonia due to toxicity to fish (EPA 1999). Early life stages of fish are more sensitive than juveniles or adults; therefore, effects are more likely to occur during seasons when early life stages are present. Toxicity of ammonia is dependent on ionic composition, pH, and temperature, with currently applicable EPA criteria calculated based on pH and temperature and applied to total ammonia (EPA 1999). The ionic composition of total ammonia includes the ammonium ion ($NH4^+$) and un-ionized ammonia (NH3), with water quality criteria prior to 1999 focusing on the more toxic un-ionized ammonia form. NDEQ water quality standards are based on total ammonia, consistent with currently applicable EPA criteria.

In "CADDIS: The Causal Analysis/Diagnosis Decision Information System", EPA (2010) describes common sources of elevated ammonia in water bodies:

- Impoundments: Impoundment of water may contribute to elevated ammonia concentrations due to lack of turbulence and mixing, which decrease volatilization of ammonia, resulting in higher ammonia concentrations downstream. Thermal stratification in impoundments can lead to higher concentrations of ammonia in the hypolimnion which, with bottom-release dams, can result in increased ammonia in downstream waters.
- Municipal waste treatment plants: Municipal waste treatment plants without adequate permit limits to control ammonia or treatment plant upsets malfunctions or bypasses due to combined sewer overflows (CSOs).
- Septic seepage and failed package plants: Seepage from failed septic tanks or their leach fields, and discharges from poorly–functioning package sewage treatment plants may contribute significant amounts of ammonia to streams and lakes.
- Industrial point source: Certain industries release ammonia as a byproduct in their waste stream. Although ammonia is regulated in discharge permits for such facilities, increased ammonia concentrations exist where the original system design is inadequate or problems in operation lead to inadequately treated discharges. This is especially an issue for industries that produce ammonia, animated organic matter, or other nitrogenous wastes such as food processing (*e.g.,* poultry, livestock, or seafood), pharmaceutical manufacturing (*e.g.,* fermentation processes), paper mills, and flue gas treatment in coal-fired power plants.
- Agricultural and urban runoff: Runoff and leachate from agricultural, recreational (*e.g.,* golf courses), or residential fertilizer use can directly increase the amount of ammonia in surface water.
- Manure application: Manure containing ammonia and other nitrogenous compounds often is spread on fields and then washed into streams and other water bodies by rain or snow melt. Grazing livestock spread urine and manure on pastures and, where they have access to streams, they apply urine and manure directly to water.

- Concentrated animal feeding operations: Runoff from feedlots and other concentrated animal feeding operations can contain high levels of ammonia and other nitrogenous compounds.
- Aquaculture: Drainage from fish and shrimp farms is high in ammonia if not properly treated.
- Landfills: Leachate from landfills may contain high ammonia concentrations (Mancl and Veenhuizen 1991).
- Atmospheric sources: These sources include NH3 originating from agricultural practices and nitrogen oxide emissions from automobiles and industry (NOAA 2000). These are regionally important sources, but they seldom are indicative of particular impairments.
- Riparian devegetation: The removal of vegetation from the banks of surface waters increases surface water runoff and water temperature and decreases woody debris input. Increased surface water runoff may increase the amount of ammonia directly entering the water body. Increased water temperature enhances the toxicity of ammonia. Reduced turbulence from less woody debris may decrease volatilization and oxygenation.
- High plant production: High algal or plant production can decrease ammonia by assimilation, increase ammonia by nitrogen fixation, or increase pH toxicity due to uptake of CO2, resulting in a shift to more unionized ammonia.

With regard to ammonia concentrations in urban stormwater, Pitt (2005) reports median ammonia concentration of 0.32 mg/L for residential areas, 0.50 mg/L for commercial areas and 0.18 mg/L for open space (non-urban) areas. These concentrations are well below typical calculated total ammonia limits for warm water streams.

In the context of Antelope Creek, no municipal or industrial point sources or animal feeding operations are present and urban stormwater is not typically a major source of ammonia. The occasionally elevated concentrations of ammonia in Antelope Creek may be associated with sporadic sources such as fertilizer application or stagnant water in the stream during low flow conditions. Elevated ammonia has not been identified as an issue at Holmes Lake; therefore, it is not expected to be a significant source of ammonia in the stream.

Data Used to Determine Ammonia Impairment

As is the case for *E. coli*, NDEQ has collected ammonia samples from Antelope Creek as part of the NDEQ Ambient Water Quality Monitoring Network, with grab samples for ammonia collected twice per month during April through September. The Antelope Creek TMDL was based on data collected from 2002 through 2005, which included total ammonia values ranging from 0.08 to 10.07 mg/L. Exceedances of both chronic and acute standards occurred, with 13 out of 64 results exceeding the chronic water quality limits for Antelope Creek. Streams are considered impaired for aquatic life in Nebraska if more than 10 percent of the samples exceed the acute or chronic criteria. Total ammonia stream standards are calculated for each sampling event based on the corresponding ambient pH and temperature conditions present at the time of sample collection. NDEQ collected 29 additional ammonia samples in 2009, with reported total ammonia concentrations ranging from 0.17 to 0.929 mg/L, with none of the reported concentrations exceeding water quality standards. These recent data, which show consistently low ammonia concentrations, suggest that ammonia may no longer be a constituent of concern for Antelope Creek, with elevated concentrations primarily occurring more than 8 years ago.

4.4.3 Other Constituents of Concern

In the Antelope Creek TMDL, copper, selenium and conductivity are identified as potential pollutants of concern, but lacking adequate data for determination of impairment or development of TMDLs. All of these constituents, as well as chloride, are identified in the 2010 Integrated Report as causing impairment of designated beneficial uses (NDEQ 2010). A brief description of each of these constituents follows.

Copper

As described in the Antelope Creek TMDL, the basis for listing Antelope Creek as impaired for copper was 4 of 14 samples exceeding the chronic water quality criteria (NDEQ 2006). Subsequent review of the data revealed 6 of the 14 samples being labeled with an “M” remark code. The “M” code is defined as inconclusive analysis due to matrix interference and suggests the sample be re-collected. NDEQ has made the decision to discard these data; however, the assessment procedures did not explicitly allow exclusion of such data. After removing these data points, the remaining data set had only eight samples with two of those exceeding the stream standard. The assessment of waters with less than 10 data points with one or two values exceeding criteria are considered Category 3 water bodies—insufficient information for a listing determination. Thus, NDEQ determined that no

TMDL was needed and indicated that the correction would be made in the 2008 Integrated Report; however, review of the 2010 Integrated Report still shows the stream as being listed for copper (NDEQ 2010).

Copper is an abundant naturally occurring trace element found in the earth's crust that is also found in surface waters. Copper is a micronutrient at low concentrations and is essential to most plants and animals. At higher concentrations, copper can be toxic to aquatic life depending on the hardness of the stream (*i.e.,* concentrations are more toxic at low hardness values). Industries with copper-bearing discharges include manufacturers of leather and leather products, fabricated metal products, and electric equipment, as well as mining. Municipal effluents may also contribute additional copper loadings to surface waters. Copper is also found in municipal stormwater runoff and has been attributed to the erosion of automobile brake lining material. In Antelope Creek, copper sources would most likely be associated with automobile sources.

Selenium

In the Antelope Creek TMDL, NDEQ notes that several selenium values were labeled with the "M" remark code, similar to copper. Once the remarked data were removed, only seven data points remained with three values exceeding the water quality standards. Chronic and acute stream standards for selenium are 5 ug/L and 20 ug/L, respectively. These standards are provided for protection of aquatic life. Based on the assessment procedures utilized by NDEQ, the data set is suitable for the identification of the impairments; however, the data set is not sufficient to complete the TMDL. Additionally, NDEQ noted forthcoming revisions of selenium criteria based on fish tissue concentrations (EPA 2004). Because the EPA selenium criteria revision was still in draft form and results of the assessment of Antelope Creek selenium using the new criteria had not been completed, NDEQ decided to delay the development of a selenium TMDL until the criteria are finalized. NDEQ further noted that Antelope Creek would remain in Category 5 as impaired by selenium in the Integrated Report. Review of the 2010 Integrated Report still shows the stream as being listed for selenium (NDEQ 2010). Three additional samples collected by NDEQ in 2009 exceeded the chronic selenium criteria but fell below the acute criteria.

Selenium is a naturally occurring element that can be toxic to fish, and birds that consume fish when selenium concentrations exceed water quality criteria. High levels (>0.05 mg/L) of selenium can also cause impacts to livestock such as loss of hair in the mane and tail in horses as well as hoof sloughing. Cattle may have a rough hair coat and exhibit symptoms such as reduced reproductive performance, poor weight gain, or hoof or horn changes or loss and lameness can result in advanced cases. Antelope Creek is classified as an Agricultural B stream. This classification has no standard for acute or chronic levels of selenium.

Elevated selenium concentrations can occur as a result of natural or anthropogenic conditions. In the western U.S., elevated selenium in streams is often due to naturally occurring geologic sources, particularly where streams are gaining flows from groundwater in contact with these geologic formations, or where irrigation had has caused leaching of selenium from these geologic sources. Anthropogenic sources of selenium may also include coal ash piles, petroleum refinery effluents, and runoff or discharges from certain mining activities. In the case of Antelope Creek, in-stream concentrations are expected to be due to naturally occurring selenium in the vicinity of the stream.

Because selenium concentrations would be expected to be higher during low flow conditions when groundwater dominates the flow regime, a well-rounded sampling program reflecting a broad range of flow conditions would be needed to properly characterize selenium concentrations in Antelope Creek. It should be noted that aquatic life criteria for selenium are more stringent than those for agricultural use and can be difficult to meet when natural sources of selenium are present. An alternative may be development of a site-specific standard based on natural conditions.

Conductivity and Chloride

NDEQ conductivity standards are in place for protection of agricultural water supply, with an upper limit of 2,000 umhos/cm between April 1 and September 30. NDEQ standards for chloride are 860 mg/L for single sample maximum or a four-day average concentration of 230 mg/L, with certain site-specific criteria allowed.

In the Antelope Creek TMDL, NDEQ notes that Antelope Creek has been characterized as being "quite salty" and, with the groundwater infiltrating the stream, to have a total dissolved solids concentration of about 30,000 mg/L (NNRC 1973). NDEQ's analysis of the available data shows a statistically significant trend (95% confidence interval) of decreasing conductivity with increasing stream flow. Other streams in the area have similar characteristics and have been classified with the Agriculture Class B beneficial use. Based on this information, NDEQ suggests that excessive conductivity may be a function of the geology or other natural conditions. Rather than complete a TMDL, NDEQ planned to forward Antelope Creek data to the Water Quality Standards

Coordinator for review. Options available include identification of a natural condition and a “Category 4C” assessment, site-specific water quality criteria or a use attainability analysis. Review of the 2010 Integrated Report again shows the stream as being listed as impaired due to elevated conductivity, as well as chloride (NDEQ 2010).

Specific conductance is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids in the water. High specific conductance indicates high dissolved-solids concentration; dissolved solids can affect the suitability of water for domestic, industrial, and agricultural uses. Agriculture is adversely affected by high-specific-conductance water, primarily due to diminished crop yield or failure resulting from saline water. Additionally, livestock and wildlife may be adversely affected by high specific conductance levels in surface water used as a water source. Generally, specific conductance levels in excess of 9,000 µmhos/cm are considered poor for livestock watering.

High conductivity can result from a variety of natural and human sources. Groundwater contains minerals from the aquifer rock material and can have significantly higher specific conductance. Agriculture can also be the cause of increases in the specific conductance of local waters. When water is used for irrigation, part of the water evaporates or is consumed by plants, concentrating the original amount of dissolved solids in less water; thus, the dissolved-solids concentration and the specific conductance in the remaining water is increased. The remaining higher specific-conductance water reenters the river as irrigation-return flow.

4.5. Summary and Conclusions

In summary, NDEQ prepared the Antelope Creek TMDL following procedures used in the river basins throughout the state. Stream impairment and the TMDL are based on limited data due to the responsibility that NDEQ has for monitoring and development TMDLs statewide; inherently restricting the breadth of monitoring on any particular stream. Nonetheless, even with limited data, it is clear that Antelope Creek does not attain Nebraska stream standards for *E. coli*. Conversely, it appears that a TMDL load reduction for ammonia is not needed. TMDLs are not believed to be effective approaches for facilitating reduction in selenium, chloride, and conductivity due to natural conditions. Due to limited data, it remains unclear whether a copper TMDL is warranted. Given that NDEQ considers the Antelope Creek a “phased TMDL”, meaning that it can and should be revised based on the results of additional monitoring, it may be beneficial for the City to suggest revision of the TMDL once data have been synthesized and evaluated from the expanded monitoring program. The primary purpose of revising the TMDL would be to better delineate the City’s responsibility under its waste load allocation (in relation to its MS4 permit) as opposed to natural sources of bacteria that should be included in a load allocation. Other conclusions relative to each constituent of concern include:

Picture 11: Groundwater boils can be found just past the Vine Street Bridge downstream to Salt Creek

- *E. coli:* While it may be possible to implement BMPs to reduce *E. coli* loading to Antelope Creek, it is highly unlikely that the water quality will meet numeric limits for *E. coli* bacteria during all months of the year due to natural contributions of *E. coli* to the stream. In addition to implementing BMPs, it may be beneficial for the City to explore how frequently *E. coli* standards are exceeded in similar streams that have minimal human or agriculture impacts, in order to develop a better sense of what is potentially attainable for Antelope Creek. Although the frequency of *E. coli* standard exceedances in an urban area would be expected to be greater than in a natural area, it would not be realistic to expect urban areas to be “cleaner than” natural areas. In Southern California, such “reference stream” data has been used to shape expectations for bacteria TMDLs.
- Ammonia: Review of existing data for ammonia suggests that a TMDL for ammonia is not needed since additional monitoring data conducted by NDEQ show no ammonia concentrations exceeding the stream standard.
- Copper: Due to the limited data set, it remains unclear whether copper is a pollutant of concern for Antelope Creek. Collection of additional samples would help to determine whether a TMDL for copper is needed.

- Selenium, Conductivity and Chloride: Uncertainty regarding appropriateness of existing designated stream uses and attainability of standards for selenium, conductivity and chloride remain; however, general consensus is that natural sources cause elevated levels of these constituents. As a result, changes of designated uses and/or site specific standards may be more appropriate approaches to resolve impairment listings for these constituents, as opposed to developing TMDLs for these constituents.

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SECTION 5 – WATER QUALITY MONITORING

Water quality monitoring for Antelope Creek involves a combination of historic data and a targeted monitoring effort developed in support of this Basin Plan during 2010-2011. This section summarizes both current and historic water quality monitoring efforts to provide the most comprehensive understanding of water quality conditions in Antelope Creek.

5.1. Overview of Available Water Quality Data

This discussion is divided into two sections: 1) historic data collected by NDEQ and others, primarily over the past 5 to 10 years, and 2) targeted data collected during 2010-2011 to support development of this Basin Plan. Each of these sources is briefly summarized below, followed by a brief overview of water quality evaluation principles applied in Nebraska, and a more detailed discussion of each data source.

In 2010-2011, EA conducted in-stream sampling of four dry weather and three wet weather synoptic sampling events for approximately 11 locations on the stream.

5.1.1 Historic Data (Primarily 2002-2009)

Historic water quality data for Antelope Creek from below the Holmes Lake Dam to Salt Creek at the State Fairgrounds includes the following sources:

- NDEQ rotating basin sampling plan data for 2002-2008 collected at Antelope Creek at the State Fairgrounds. This location was included in NDEQ's water quality assessment for 2010 (NDEQ 2010) and was provided in electronic format by NDEQ. (Note: the data set forming the basis of the Antelope ammonia and *E. coli* TMDLs was limited to 2002-2004, and is discussed further in SECTION 4 – TMDL ASSESSMENT.)
- NDEQ collected additional monitoring data for Antelope Creek in 2009, also limited to the State Fairground sampling location, as provided electronically by NDEQ.
- Summer 2009, University of Nebraska–Lincoln (UNL) in-stream monitoring at five locations on Antelope Creek, as contained in a report by Mohlman et al. (2009).
- Dry weather outfall screening by UNL as part of the City's rotating NPDES illicit discharge detection and elimination monitoring program, also conducted by UNL (Mohlman et al. 2009).
- Historic wet weather flow monitoring in other Lincoln watersheds as part of NPDES monitoring in the 1990s and more recent monitoring in 2006-2007. These data sets are summarized in a thesis at UNL by Vegi (2008).

5.1.2 Recent Data (2010-2011)

In 2010-2011, EA conducted in-stream sampling of four dry weather and three wet weather synoptic sampling events for approximately 11 locations on the stream. At three of these locations, 5-week sequences of samples for fecal indicator bacteria were also collected to support calculation of geometric mean concentrations for *E. coli*. Outfalls (tributaries) to the stream were sampled for two events under dry weather conditions and investigated for signs of dry-weather pollution. In-stream sediment samples were also collected at targeted locations in the stream for two sampling events.

5.2. General Water Quality Evaluation Principles

Water quality assessment procedures used by NDEQ for Nebraska waters are defined in "Methodologies for Water body Assessments and Development of the 2010 Integrated Report for Nebraska" (NDEQ 2009). From a regulatory perspective, water quality data are compared to stream standards assigned by NDEQ to determine whether the stream attains standards. Several principles specified by NDEQ (2009) that are relevant to evaluation and interpretation of recent and historic water quality data include:

- For most constituents, streams are considered impaired if more than 10 percent of samples exceed the acute or chronic standard. A confidence interval of 90 percent is applied to the 10 percent threshold, therefore NDEQ provides a "lookup" table for these impairment thresholds, depending on number of samples collected (*e.g.,* to be identified as impaired, a sample size of 10 requires that three samples exceed the standard). A notable exception to the 10 percent rule is *E. coli*, where a seasonal geometric mean is compared to the stream standard during the recreation season of May 1 to September 30.

- NDEQ focuses water quality assessments on the most recent and representative data. Data and information collected during the past 5-year period are used to initially categorize a water body. That is, after a water body has been placed in a category, only new or newly acquired data and or information (*i.e.,* TMDLs developed) can be used to place a water body in another category. Water bodies are not shifted from category to category solely based upon the age of the data.
- As a guideline, data collected more than 5 but less than 10 years ago, are not used to identify a water body as impaired. In situations where the data is deemed representative of a water body or watershed, the data may be used to place a water body in the appropriate listing category for the Water Quality Integrated Report [NDEQ 2010]. Data older than 10 years cannot be used to determine if a stream was impaired, but that data can still be used for other analytical analysis.
- The 5-year general practice is the initial screening for data sets, however; a secondary review also considers the installation of treatment or controls, hydro-modification, diversion, impoundments or the presence of new or expanded point source discharges. Only data that has been deemed representative should be used in the assessment process.
- Rather than eliminating the "non-detects" from the assessment data, values below detection limits are calculated as 50 percent of the method detection limit.
- Generally, a 10-sample minimum per constituent is targeted for assessment purposes. For data sets with <10 samples, NDEQ follows these guidelines:
    - Assume 10 samples were "targeted" and base the assessment on n=10.
    - For data sets n=3 to n=9; if three data points exceed the applicable water quality standard or goal, the water body should be assessed as having an impaired beneficial use.
    - For data set n=8 or n=9, if no data points exceed the applicable water quality standard or goal, the water body should be assessed as fully supporting the beneficial use.
    - For all other situations with data sets n=3 to n=9, the water body should be included in Category 3, insufficient information to determine beneficial use status.
- Multiple samples collected on the same day from the same segment under static stream conditions, shall be combined and the parameter mean will be calculated and used to represent the segment's water quality condition. Exceptions to this will be when monitoring efforts are designed to evaluate diurnal or temporal impacts related to a specific pollutant source.
- In order to compare some parameter measurements to water quality criteria, additional information is often required. For example, applicable ammonia criteria are dependent upon the water's pH and temperature; many metals require measures of calcium and magnesium to derive water hardness in order to calculate their criteria. When a water quality parameter requires additional information, the guidelines for data assessment (minimum number of samples, quality assurance requirements) also apply to this data. Assessments of water quality information will not be made in the absence of simultaneously collected additional information.
- Considerations relative to natural conditions:
    - Deviations from criteria that are the result of drought or other natural phenomena are not included in the group of waters needing a TMDL.
    - "Category 4C" Water bodies: Water body is impaired, but the impairment is not the result of a "pollutant." This category also includes waters where natural causes/sources have been determined to be the cause of the impairment.
    - For nonpoint source pollutants, data collected under extreme high flows can skew the data set and force managers to establish unrealistic reduction goals to account for infrequent and often unpredictable events. When reporting beneficial use assessments, impairments due to data collected during extreme high flow events should be noted when that information is available.

The discussion of recent and historic data that follows generally follows the principles defined by NDEQ (2009).

5.3. Historic Water Quality Sampling Results

Historic water quality sampling results are available for 1) in-stream locations for Antelope Creek, 2) stormwater outfalls as part of dry weather screening, and 3) storm runoff from various land uses in other watersheds in Lincoln. These results are summarized in the subsections below.

5.3.1 In-stream Water Quality

Dry weather in-stream monitoring data available for Antelope Creek includes these sources:

- **NDEQ Monitoring Program (2002-2008) at State Fairgrounds Site**: For purposes of the 2010 Water Quality Integrated Report for Antelope Creek, the NDEQ data set includes samples collected from 2002 through 2008 referred to as: "SLP2ANTLP104", Antelope Creek at State Fair Park in Lincoln, NE. This site is located at the west entrance to the State Fairgrounds in Lincoln, approx. 0.1 mile east of 14th Street. This sampling location is identified on Figure 5-1. Table 5-1 provides a summary of NDEQ's assessment, as well as some additional descriptive statistics calculated for the purposes of this Basin Plan. The monitoring program can generally be described as monthly for most constituents, with the exception of weekly monitoring of *E. coli* during the recreational season.
- **NDEQ Monitoring Program (2009) at State Fairgrounds Site:** Since completion of the last Integrated Report, NDEQ collected additional samples at Antelope Creek during 2009, as summarized in Table 5-2. These data are generally consistent with the previously collected data summarized in Table 5-1. Constituents of concern, *E. coli*, chloride and selenium exceed stream standards, whereas ammonia does not. Table 5-2 provides data for some additional potential parameters of interest for Antelope Creek such as total phosphorus, TSS, and additional nitrogen constituents which enable a total nitrogen (TN) calculation. Because resuspension of channel sediment can be a source of *E. coli*, it is noteworthy that several of the very high *E. coli* concentrations (*i.e.,* >10,000/100 mL) appear to coincide with higher TSS concentrations; however, the data set is not adequate to draw conclusions regarding this relationship, since *E. coli* is also considerably elevated in several cases with low TSS.
- **University of Nebraska-Lincoln 2009 In-Stream Monitoring at Multiple Locations:** In 2009, UNL conducted additional in-stream sampling for the City at five locations, which were visited six times during the summer of 2009. These sites were chosen to assess whether contamination was occurring from locations such as the State Fair Grounds, the Children's Zoo and Botanical Garden, and the Holmes Park Dog Run (upstream of Holmes Lake). Figure 5-1 identifies these sampling locations, with location ANTLPSC being the same as NDEQ's location SLP2ANTLP104. Tables 5-3 and 5-4 summarize data collected as part of this sampling program.
- **Historic Fecal Coliform Data near the Children's Zoo:** Samples were collected near the Children's Zoo for fecal coliform in 1999, as summarized in Table 5-5. The historic stream standard for fecal coliform was 200/100 mL; therefore, the seasonal geometric mean of 87/100 mL met this standard, although the early summer months exceeded the standard. Overall, the concentrations observed during 1999 at the Children's Zoo were not unusually high.

Building upon data summarized in Tables 5-1 through 5-4, simple scatter plots and other graphical summaries of historic data sets were developed to evaluate water quality trends, as provided in Figures 5-2 through 5-9. Date ranges presented in these summaries vary, depending on the available data. Key observations include:

- *E. coli* was elevated in both 2004 and 2009 NDEQ sampling periods at the State Fairgrounds, with no apparent differences between the 2 years and only a few samples meeting the TMDL limit of 113/100 mL (Figure 5-2). *E. coli* concentrations span several orders of magnitude when evaluated on a monthly basis, with no apparent trend. (April concentrations appear to be lower, but there are fewer samples available for April.) Elevated *E. coli* occurs at a range of flow conditions; elevated concentrations do not appear to be dependent on flow (Figure 5-3) under ambient conditions.
- Based on 2009 sampling by Mohlman et al. at multiple locations on Antelope Creek, there is not a clear upstream to downstream trend, particularly when looking at individual synoptic sample dates. Statistical testing by Mohlman et al. showed no statistically significant differences between sample locations. All sample locations were above the stream standard (126/100 mL) and the TMDL limit (113/100 mL) for all sampling events (Figure 5-4). Nonetheless, some differences between the sites are suggested by visual inspection of the data that may be worth further exploration in future sampling efforts. For example, geometric mean *E. coli* concentrations at the Antelope Creek Park and Children's Zoo locations are more than 10 times the stream standard (Table 5-4), whereas the Fairground location is on the order of five times the stream standard. There is also greater variability (*i.e.,* wider range of values) in the sample results at the Antelope Creek Park and Children's Zoo locations (Figure 5-4). Mohlman et al. also reported that samples in the afternoon had generally higher *E. coli* concentrations than morning samples.
- Mohlman et al. (2009) analyzed samples for surfactants as a potential indicator of detergents associated with illicit discharges. Surfactants greater than 0.25 mg/L are considered an initial benchmark for the presence of

detergents associated with sewage or washwater (CWP and Pitt 2004). Compared to this benchmark, surfactants in the Antelope Creek samples are quite low, averaging 0.09 mg/L. Additionally, all samples were below this benchmark with the exception of one sample taken from Salt Creek (Fairgrounds) and one result taken from Holmes Lake (Dog Park). Surfactant results at these two sites for other sample dates were an order of magnitude lower. *E. coli* and ammonia concentrations for these two dates were not particularly elevated. Therefore, overall, the Mohlman et al. (2009) data does not suggest illicit wastewater or washwater sources based on these in-stream samples.

- Ammonia data show relatively few exceedances of water quality standards over the past 9 years (Figure 5-5), suggesting that additional controls for ammonia may not be necessary on Antelope Creek in order to meet stream standards and TMDL limits. Ammonia concentrations were highest in 2002, 10 years ago, but have been relatively low since then. These results are also confirmed by the Mohlman et al. (2009) sampling that showed attainment of ammonia criteria at all locations (Table 5-4).
- Chloride concentrations are elevated at the State Fairgrounds during all months of the year (Figure 5-6), although lower concentrations are also present during some sampling events during summer months, presumably due to conditions where higher flows are present. As would be expected, chloride and conductivity are highly correlated (Figure 5-7). Generally, conductivity is higher at low flow conditions, which suggests groundwater influence. Supplemental sampling by Mohlman et al. (2009) also suggests a groundwater influence in the lower portion of the stream segment, as evidenced by elevated chloride, selenium and conductivity at the Vine Street and Salt Creek locations (Table 5-4).
- Selenium exceeds the water quality standard and is expected to be associated with naturally occurring groundwater contributions to the stream. As shown in Table 5-4, selenium concentrations tend to be elevated in the lower reach of the stream segment, along with chloride and conductivity, further supporting this hypothesis.
- In NDEQ's 2010 Integrated Report, copper received a Category 3 determination, indicating insufficient data to determine impairment. Nonetheless, three out of nine samples exceeded the stream standard, so the stream is considered potentially impaired by copper (Table 5-1). Mohlman et al. (2009) collected additional samples on 5 days at the NDEQ monitoring location at the State Fairgrounds as well as other locations on Antelope Creek on the same date (Table 5-4). Following NDEQ procedures (NDEQ 2010) to average sampling results collected at multiple locations on the same date results in five additional copper sample events for Antelope Creek; providing a total of 14 sample events to assess impairment. However, the ancillary hardness data required to assess stream standards was not provided in the Mohlman et al. (2009) data set; therefore, NDEQ would likely exclude these data from assessment (per procedures in NDEQ 2010). Nonetheless, for general information, only two of the five additional sampling events (averaging all locations on sample dates) had detectable concentrations of copper, and none of the five events at the Antelope Creek at the Salt Creek sampling location had copper concentrations above detection limits.

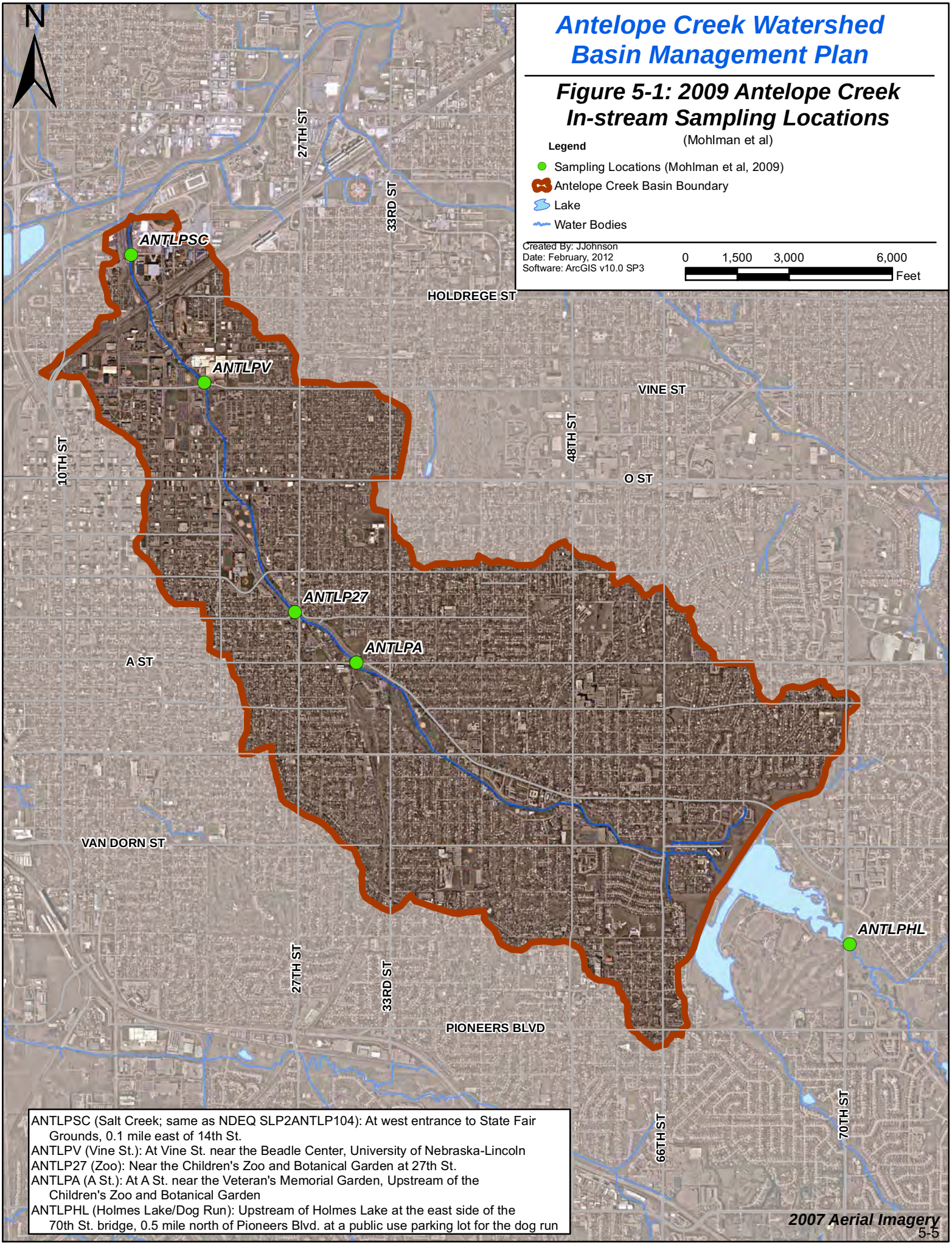

Antelope Creek Watershed
Basin Management Plan
Figure 5-1: 2009 Antelope Creek
In-stream Sampling Locations
(Mohlman et al)
Legend
Sampling Locations (Mohlman et al, 2009)
Antelope Creek Basin Boundary
Lake
Water Bodies
Created By: JJohnson
Date: February, 2012
Software: ArcGIS v10.0 SP3
0
1,500
3,000
6,000
Feet
N
ANTLPSC
ANTLPV
ANTLP27
ANTLPA
ANTLPHL
27TH ST
33RD ST
HOLDREGE ST
VINE ST
48TH ST
O ST
10TH ST
A ST
VAN DORN ST
PIONEERS BLVD
66TH ST
70TH ST
2007 Aerial Imagery
ANTLPSC (Salt Creek; same as NDEQ SLP2ANTLP104): At west entrance to State Fair Grounds, 0.1 mile east of 14th St.
ANTLPV (Vine St.): At Vine St. near the Beadle Center, University of Nebraska-Lincoln
ANTLP27 (Zoo): Near the Children's Zoo and Botanical Garden at 27th St.
ANTLPA (A St.): At A St. near the Veteran's Memorial Garden, Upstream of the Children's Zoo and Botanical Garden
ANTLPHL (Holmes Lake/Dog Run): Upstream of Holmes Lake at the east side of the 70th St. bridge, 0.5 mile north of Pioneers Blvd. at a public use parking lot for the dog run

Table 5-1. Historic Water Quality Data at State Fairgrounds (2002-2008)

Parameter	N (#)	NDEQ Impairment Determination (2002-2008)						Descriptive Statistics			
		Acute Criteria	# Exced-ing Acute Std	Chronic Criteria	# Exceed-ing Chronic Std	Impairment Basis: # samples that must exceed standard	NDEQ Identified as Impaired (Y/N)	Mean	Min	Max	St Dev
Physical (mg/L, unless otherwise noted)											
Temp (C)	113	32.2	0	NA	—	16	No	17.3	3.7	30.1	7.6
DO	109	3/5	3	NA	—	16	No	11.1	4.5	22.8	3.6
pH	112	6.5-9	0	NA	—	16	No	7.58	6.81	8.59	0.35
Conductivity umhos/cm	113	2000	63	NA	—	16	Yes	5947	204	19200	5290
—Seasonal	58	2000	31	NA	—	10	Yes	4561	204	17630	4381
Chloride	113	860	73	230	73	16	Yes	2244	15	6352	1732
Calcium	25	NA	—	NA	—	NA	—	86.0	10.9	145.0	38.3
Magnesium	25	NA	—	NA	—	NA	—	28.0	1.2	48.9	14.9
Flow (cfs)	104	NA	—	NA	—	NA	—	5.2	0.0	100.4	10.9
E. coli (#/100 mL)	21	NA	—	126	NA	NA/Use Geomean	Yes	3163	164	24192	7331
Nutrients (mg/L)											
Ammonia*		—	—	—	—	—	—	—	—	—	—
—Acute	111	Calc.	1	Calc.	0	16	No	1.13	0.05	10.07	1.61
—Chronic	111	Calc.	14	Calc.	0	16	No	1.13	0.05	10.07	1.61
NO3-NO2	113	100	0	—	—	16	No	2.12	0.13	6.02	1.35
Metals (total, µg/L)											
As	30	340	0	16.7	0	6	No	<DL	<DL	<DL	<DL
Cd	11	Calc.	0	Calc.	0	3	No	<DL	<DL	<DL	<DL
Cr	8	Calc.	0	Calc.	0	3	No	<DL	<DL	<DL	<DL
Cu	9	Calc.	0	Calc.	3	3	Yes*	NC	<DL	33.89	NC
Pb	11	Calc.	0	Calc.	0	3	No	NC	<DL	<DL	NC
Hg	11	1.4	0		0	3	No	NC	<DL	<DL	NC
Ni	11	Calc.	0	Calc.	0	3	No	NC	<DL	<DL	NC
Se	22	20	0	5	8	5	Yes	6.08	<DL	13.44	2.01
Ag	11	Calc.	0	—	—	3	No	NC	<DL	1.92	NC
Zn	11	Calc.	0	Calc.	0	3	No	NC	<DL	54.89	NC
Organics (µg/L)											
Atrazine	—	—	—	—	—	—	—	—	—	—	—
—Atrazine	100	330	0	12	1	15	No	NC	<DL	14.52	NC
—Seasonal	25	330	0	12	1	5	No	NC	<DL	14.52	NC
Alachlor	40	760	0	76	0	7	No	NC	<DL	0.90	NC

Parameter	N (#)	NDEQ Impairment Determination (2002-2008)							Descriptive Statistics		
		Acute Criteria	# Exced-ing Acute Std	Chronic Criteria	# Exceed-ing Chronic Std	Impairment Basis: # samples that must exceed standard	NDEQ Identified as Impaired (Y/N)	Mean	Min	Max	St Dev
Metolachlor	100	390	0	100	0	15	No	NC	<DL	1.65	NC

Notes: N = number of samples; DL = detection limit; Calc. = standard calculated based on parameters such as hardness for metals and pH & temperature for ammonia; NR = not reported by NDEQ; NA = not applicable; NC = not calculated for purposes of this report due to large number of non-detects affecting mean and standard deviation.
* = inadequate number samples for determination of attainment.
For *E. coli*, attainment is based on comparison of the seasonal geometric mean to the standard.
Source: (Adapted from electronic data summary provided by NDEQ)

Table 5-2, NDEQ Samples Collected at State Fairgrounds in 2009

Date	NH3	NO3 / NO2	TKN	TN (calc)	TPO_4	TSS	*E. coli*	Cl	Ca	Mg	Na	As	Se
	mg/L						#/100 mL	mg/L				µg/L	
1/13/2009	0.93	3.4	0.52	4.82	0.54	<5	--	5024	168.5	62.4	3656	<5	11.9
2/3/2009	0.78	4.0	1.00	5.79	0.37	<5	--	5952	--	--	--	--	--
3/2/2009	0.66	3.1	0.86	4.66	0.29	<5	--	4924	--	--	--	--	--
4/6/2009	0.63	2.3	1.13	4.09	0.33	46	--	3202	108.5	38.8	2568	<5	6.0
5/4/2009	0.24	1.8	1.14	3.14	0.22	7.5	138	2029	--	--	--	--	--
5/11/2009	0.39	2.1	1.23	3.73	0.23	<5	285	4442	--	--	--	--	--
5/19/2009	0.19	2.2	0.73	3.15	0.51	6	517	3467	--	--	--	--	--
5/27/2009	0.44	0.5	2.11	3.05	0.55	136	> 24192	61	--	--	--	--	--
6/1/2009	0.36	1.6	1.97	3.98	0.37	6	> 24192	2404	--	--	--	--	--
6/9/2009	0.20	1.2	<0.5	1.44	0.65	8	689	2159	--	--	--	--	--
6/15/2009	0.52	1.6	1.48	3.58	0.18	<5	64	2893	--	--	--	--	--
6/22/2009	0.32	0.7	1.61	2.68	0.56	134	> 24192	627	--	--	--	--	--
6/29/2009	0.44	1.1	1.18	2.71	0.26	5	980	1507	--	--	--	--	--
7/6/2009	0.39	1.4	0.99	2.80	0.28	<5	488	2263	--	--	--	--	--
7/13/2009	0.37	2.5	0.64	3.50	0.35	<5	106	3718	--	--	--	--	--
7/20/2009	0.68	1.3	1.94	3.91	0.31	57	14136	562	34.9	7.67	388	<5	<5
7/27/2009	0.39	2.4	0.95	3.72	0.29	<5	56	3124	--	--	--	--	--
8/3/2009	0.45	2.5	0.76	3.71	0.26	<5	49	3628	--	--	--	--	--
8/10/2009	0.28	2.0	1.04	3.30	0.33	32	158	1836	--	--	--	--	--
8/17/2009	0.24	0.3	2.22	2.76	0.34	26.5	649	1038	--	--	--	--	--
8/24/2009	0.35	0.8	1.65	2.82	0.27	16	687	1214	--	--	--	--	--
8/31/2009	0.39	1.5	1.41	3.26	0.26	<5	150	2396	--	--	--	--	--
9/9/2009	0.34	1.1	1.22	2.65	0.27	8.5	192	1824	--	--	--	--	--
9/15/2009	0.19	1.9	0.68	2.76	0.30	<5	159	2675	--	--	--	--	--

Date	NH3	NO3 / NO2	TKN	TN (calc)	TPO4	TSS	*E. coli*	Cl	Ca	Mg	Na	As	Se
	mg/L						#/100 mL	mg/L				µg/L	
9/22/2009	0.46	2.5	1.21	4.15	0.27	<5	> 24192	3096	--	--	--	--	--
9/29/2009	0.44	3.0	0.59	4.06	0.22	<5	139	3966	--	--	--	--	--
10/5/2009	0.31	2.3	0.71	3.28	0.22	<5	--	2479	104.8	35.4	1788	<5	9.3
11/2/2009	0.17	0.6	1.24	1.96	0.18	9	--	695	--	--	--	--	--
12/7/2009	0.64	3.3	<0.5	3.93	0.20	14	--	4818	--	--	--	--	--
Average	0.42	1.9	1.19	3.43	0.33	18.8	619	2690	104.2	36.1	2100	<DL	7.4
Min	0.17	0.3	0.52	1.44	0.18	<DL	49	61	34.9	7.7	388	<DL	2.5
Max	0.93	4.0	2.22	5.79	0.65	136.0	24192	5952	168.5	62.4	3656	<DL	11.9
Count	29	29	27	29	29	29	22	29	4	4	4	4	4

Source: (Adapted from electronic data summary provided by NDEQ)

Table 5-3. In-stream Sampling Locations on Antelope Creek: *E. coli* Results

***E. coli* (#/100 mL)**										
Date	6/04/09 AM	6/04/09 PM	6/17/09	7/7/09	7/22/09	7/29/09	Geo. Mean	Min	Max	St. Dev
Holmes Lake (dog park)	346	358	582	1,096	978	2,094	738	346	2,094	659
A Street (Park)	1,096	732	690	844	1,160	24,200	1536	690	24,200	9512
27th Street (Zoo)	872	256	1,160	1,634	9,680	4,840	1645	256	9,680	3613
Vine Street (UNL)	226	658	358	1,734	358	1,374	597	226	1,734	623
Salt Creek (Fairground)	2,600	872	372	658	384	264	619	264	2,600	882
Geo. Mean	721	521	573	1,115	1,086	2,454				
Min	226	256	358	658	358	264				
Max	2,600	872	1,160	1,734	9,680	24,200				
St. Dev.	859	233	293	427	3645	9106				

Source: Mohlman et al. 2009

Table 5-4. In-stream Sampling Locations on Antelope Creek: Other Constituents

Location	*E. coli*	Surfactants	Ammonia	Total Copper	Chloride	Conductivity	Total Selenium
	#/100 mL	mg/L	mg/L	µg/L	mg/L	mg/L	µg/L
Holmes Lake (dog park)	738 (346-2094)	0.12 (0.02-0.45)	0.09 (<DL-0.20)	< DL	42 (23-55)	742 (652-877)	<DL
A Street (Park)	1,536 (690->24200)	0.10 (0.07-0.16)	0.07 (<DL-0.15)	17 (<DL-46)	40 (15-64)	610 (437-692)	<DL
27th Street (Zoo)	1,645 (256-9680)	0.10 (0.06-0.17)	0.09 (<DL-0.18)	14 (<DL-28)	39 (17-70)	616 (450-731)	<DL
Vine Street (UNL)	597 (226-1734)	0.06 (0.03-0.11)	0.09 (<DL-0.24)	13.9 (<DL-46)	151 (23-535)	895 (490-1272)	9.2 (2.5-16.7)
Salt Creek (Fairground)	619 (264-2600)	0.09 (0.04-0.30)	0.36 (0.13-0.60)	<DL	273 (14-532)	9483 (6050-11840)	6.0 (2.5-16.1)

Notes: Data presented include mean followed by (Minimum – Maximum)
Values below detection limits replaced with ½ of detection limit to calculate statistics
Summary includes six sampling events during the summer of 2009.
DL = detection limit
Grey-shaded cells are sample results suggest influence of groundwater.
Source: Mohlman et al. (2009)

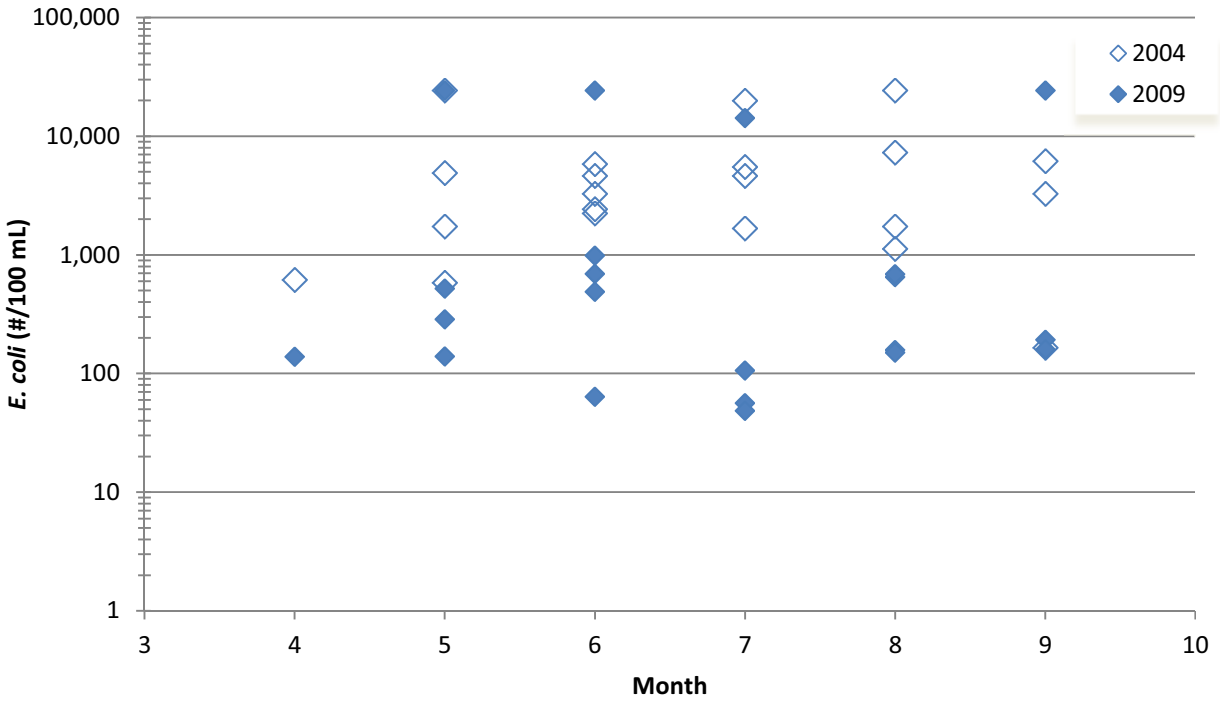
Table 5-5. Historic NDEQ Fecal Coliform Data at Antelope Creek near Children's Zoo

Collection Date	Fecal Coliform (#/100 mL)	Fecal Coliform Monthly Geometric Mean (#/100 mL
5/4/1999	50	253
5/11/1999	1020	--
5/18/1999	200	--
5/25/1999	290	--
5/27/1999	350	--
6/3/1999	670	545
6/8/1999	440	--
6/15/1999	123	--
6/22/1999	190	--
6/29/1999	7000	--
7/1/1999	240	98
7/8/1999	510	--
7/13/1999	22	--
7/20/1999	30	--
7/27/1999	110	--
8/3/1999	11	32
8/10/1999	25	--

Collection Date	Fecal Coliform (#/100 mL)	Fecal Coliform Monthly Geometric Mean (#/100 mL
8/17/1999	4	--
8/24/1999	26	--
8/31/1999	1190	--
9/1/1999	15	11
9/9/1999	260	--
9/14/1999	1	--
9/21/1999	47	--
9/29/1999	1	--
Geometric Mean	87	

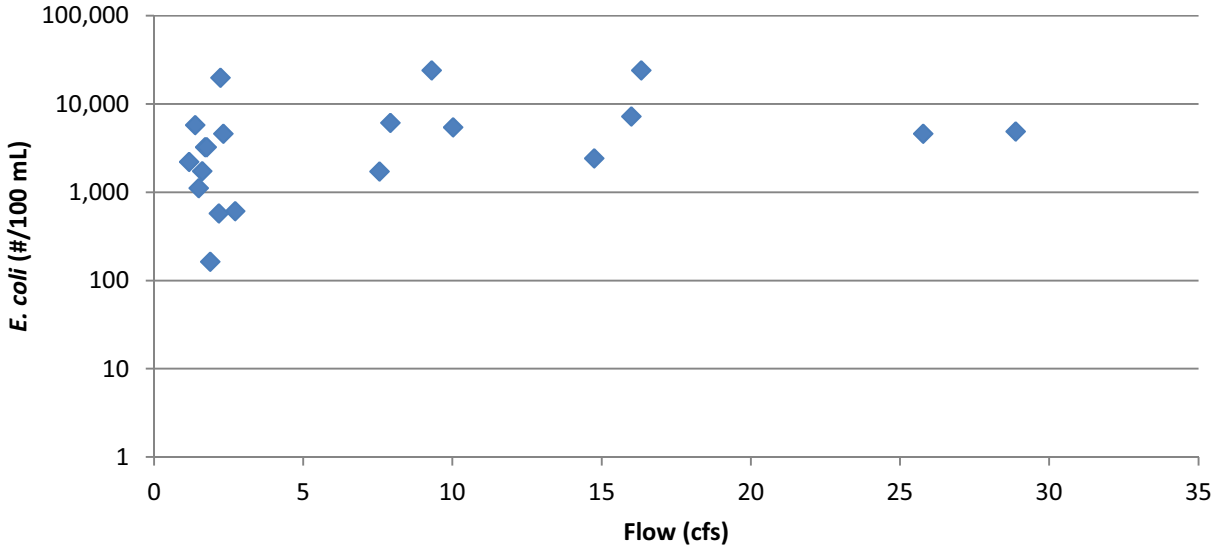
Source: NDEQ

Figure 5-2. Monthly *E. coli* at State Fairgrounds



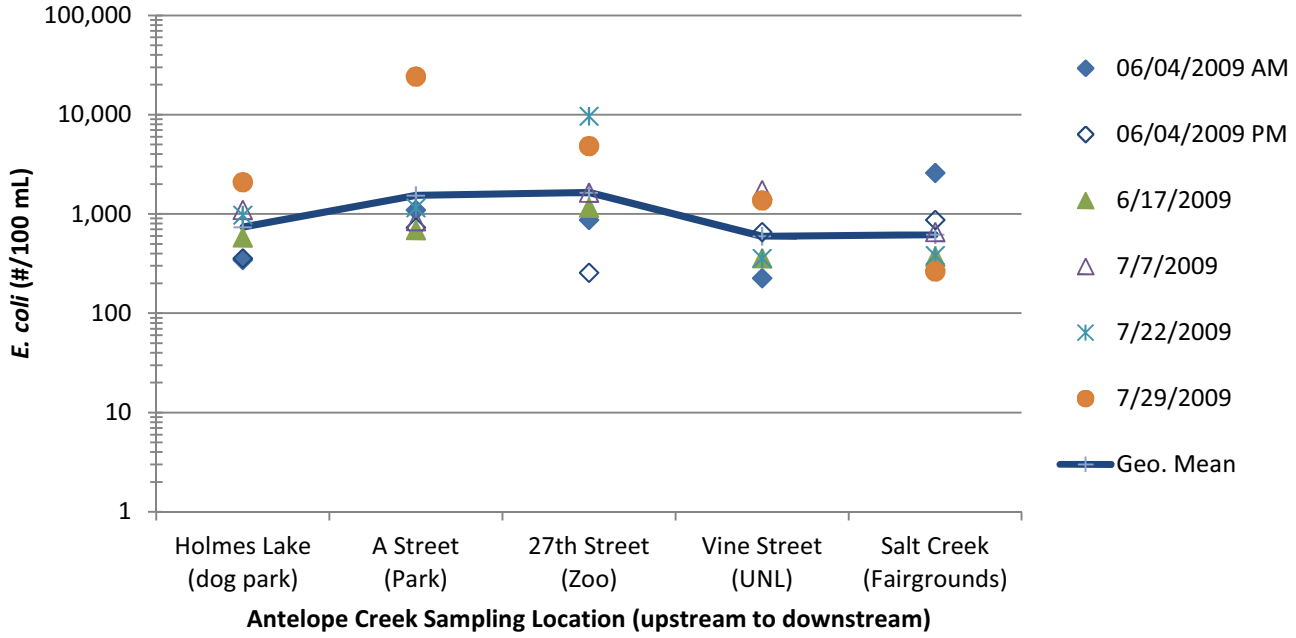
Source: NDEQ 2002-2009

Figure 5-3. *E. coli* vs. Flow Data at State Fairgrounds



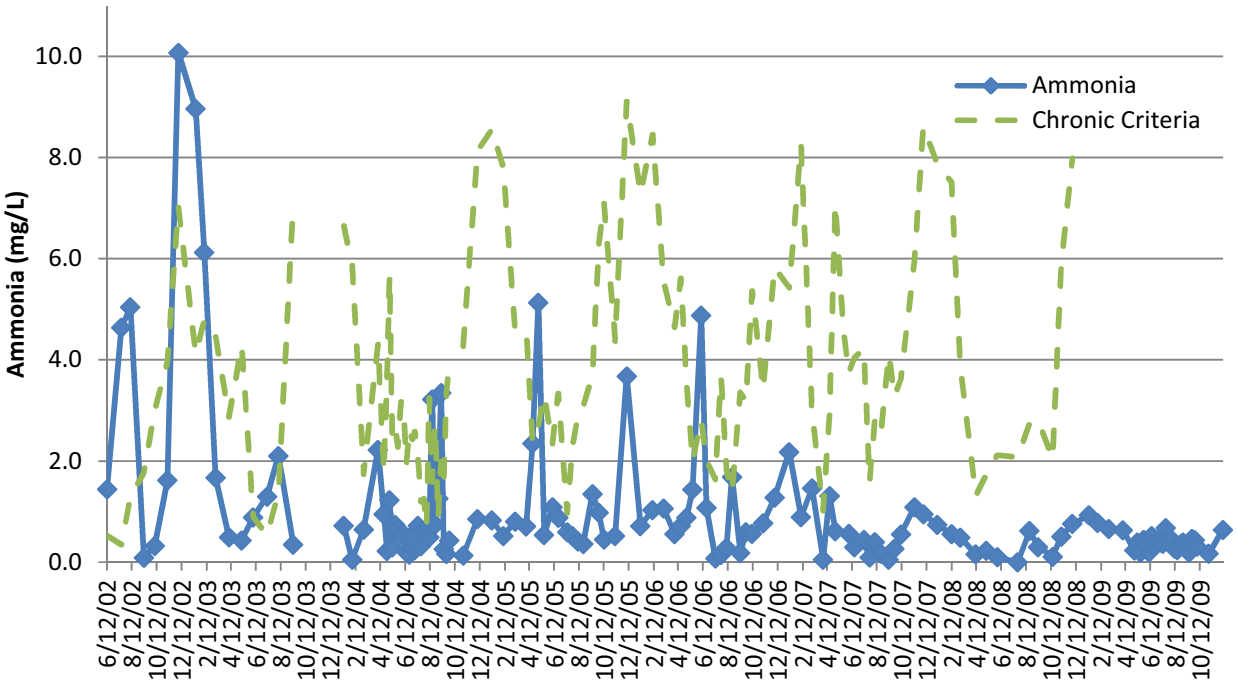
Source: NDEQ 2004

Figure 5-4. *E. coli* Sampling Results on Antelope Creek



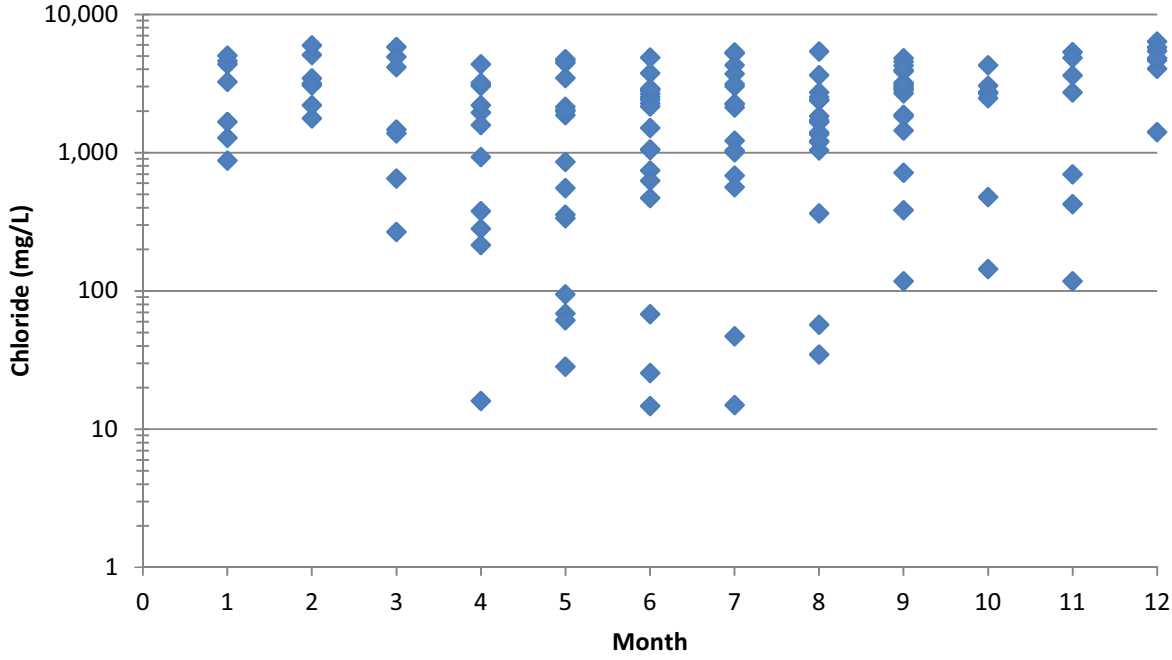
Source: (Mohlman et al., Summer 2009)

Figure 5-5. Total Ammonia at State Fairgrounds



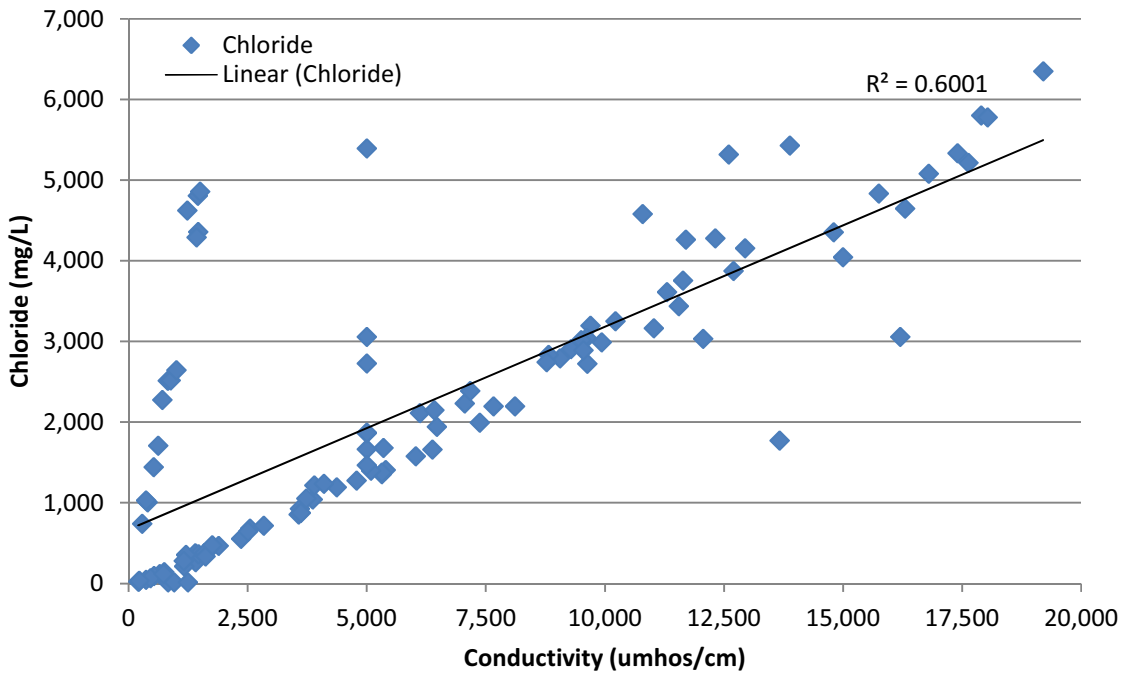
Note: field parameters needed to calculate chronic criteria not provided for 2009
Source: NDEQ 2002-2005

Figure 5-6. Chloride at State Fairgrounds



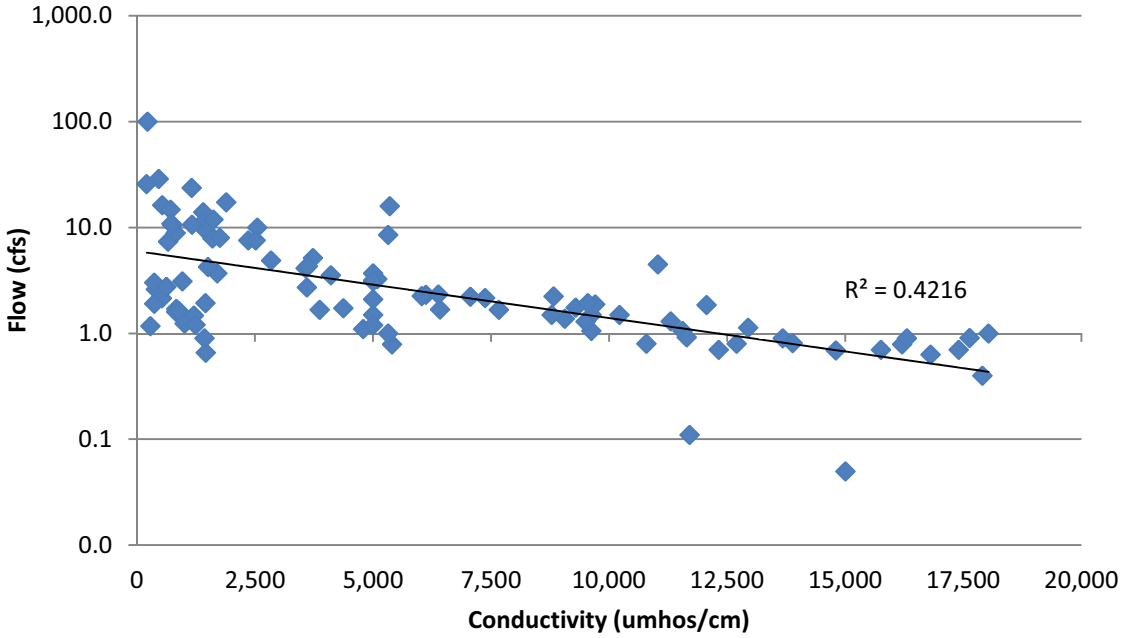
Source: NDEQ 2002-2009

Figure 5-7. Chloride vs. Conductivity at State Fairgrounds



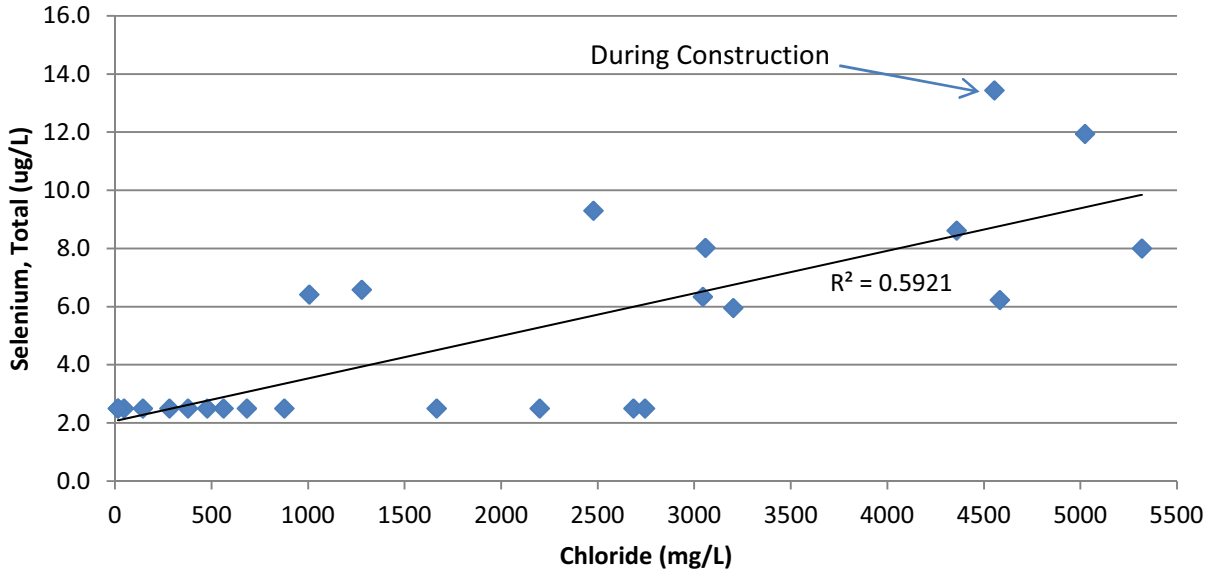
Source: NDEQ 2002-2008

Figure 5-8. Flow Versus Conductivity at State Fairgrounds



Source: NDEQ 2002-2008

Figure 5-9. Selenium vs. Chloride at State Fairgrounds



Note: Detection Limit = 5 ug/L; 1/2 of detection Limit represent non-detects in this plot.
Source: NDEQ 2002-2009

5.3.2 Dry Weather Storm Drainage System Screening

The City conducts a dry weather sampling program of its storm drainage system to identify illicit discharges in the City storm drain system. The program is implemented on a 5 year rotating basis for three groups of sample locations at these intervals: 1) 2000/2005/2010; 2) 2001/2006/2011; 3) 2002/2007/2012, 4) 2003/2008/2013; 5) 2004/2009/2014. For purposes of this Basin Plan, the most recent sampling results were reviewed for the 2009 sampling program, conducted by the University of Nebraska-Lincoln (Mohlman et al. 2009). From June to August 2009, 51 storm drain locations were monitored throughout the City. Of these sites, 23 were located in the Antelope Creek watershed. Key information and observations based on data contained in the Mohlman et al. (2009) report include:

- Twenty-three storm drain locations were sampled, either once in the morning or in the morning and afternoon. Sample duplicates were also collected for five of these sampling events. Ten of the locations had flowing water enabling sample collection.
- Out of the 23 storm drains, five resulted in at least one sample above the *E. coli* stream standard. Follow-up sampling in the afternoon at these five locations resulted in samples below stream standards in three of the cases. The remaining two sites (F-AC-52 and F-AC-55) had *E. coli* above stream standards in both the morning and the afternoon, but other indicators of illicit connections were not present. For example, surfactants were generally low in all samples. The F-AC-52 located had one sample at 2,408/100 mL in the morning and 198/100 mL in the afternoon. At F-AC-55, the morning and afternoon samples, as well as a duplicate sample were on the order of 200/100 mL. Both of these locations are in residential areas upstream of Holmes Lake, so they do not discharge directly to the Antelope Creek segment of interest for purposes of this Basin Plan.
- Only one storm drain (monitoring location (F-AC-39) within Antelope Creek watershed was identified for follow-up sampling during the 2008 monitoring cycle. In the 2009 data set, this site appeared to have normal ranges of constituents.

In summary, available data regarding dry weather discharges from the storm drainage system do not indicate that the storm drainage system is causing the elevated *E. coli* concentrations in Antelope Creek during dry weather conditions.

5.3.3 Stormwater Quality Monitoring

The City has conducted wet weather flow monitoring periodically in support of its NPDES permit at several locations in Lincoln since 1992; however, none of the monitored outfalls are located in the portion of the Antelope Creek Basin covered in this Basin Plan. Vegi (2008) completed a thesis at UNL that summarizes the available wet weather monitoring data for the City, with Table 5-6 providing a summary for several key constituents. The data set included sampling in three watersheds representing three different land use patterns. Site #2 watershed was residential (51 ha), Site #3 was commercial (145 ha), and Site #5 was industrial (20 ha). The analysis data set included wet weather stormwater quality data for 18 events collected as a part of NPDES permit requirement from 1992 to 1999, and additional data collected during 2006 and 2007 for nine rainfall events as part of the thesis study. Although this sampling is outside of the Antelope Creek Basin, it is still useful for calibration of models, as discussed in SECTION 6 - POLLUTION SOURCES AND CONTROL STRATEGIES.

Additionally, Table 5-7 provides data for several fecal indicator bacteria parameters that show elevated bacteria in wet weather flows, consistent with experiences throughout the United States. With regard to bacteria, Vegi (2008) reported a “first-flush” effect for bacteria loads at residential sites. *E. coli* loads from residential sites were found to be higher than commercial and industrial sites

Table 5-6. Comparison of City of Lincoln Wet Weather Event Mean Concentrations (EMCs) to National Urban Runoff Program (NURP) Data Sets

Water Quality Parameter	EMC (mg/L) Value Median (Med.) and Standard Deviation (SD)											
	Residential (Site #2)				Industrial/Mixed (Site #3)				Commercial (Site #5)			
	City Med.	City SD	NURP Med.	NURP SD	City EMC	City SD	NURP EMC	NURP SD	City EMC	City SD	NURP EMC	NURP SD
COD	38	40	**73**	36	43	39	60	38	49	68	57	26
BOD_5	7.4	6.4	10	4.3	7.1	7.9	7.8	5.4	7.4	8.6	9.3	3.2
TSS	115	120	101	167	96	125	78	198	**375**	489	69	148
TKN	1.20	0.74	**1.90**	1.22	**0.95**	0.45	0.50	0.84	0.91	0.68	1.18	0.72
TN	0.71	0.59	0.74	0.69	**1.10**	0.81	0.73	0.56	**0.95**	0.78	0.57	0.40
TDP	**0.76**	0.70	0.14	0.05	0.16	0.30	0.11	0.08	**0.40**	0.43	0.08	0.07
TP	**0.97**	0.81	0.38	0.23	**0.43**	0.44	0.26	0.25	**0.76**	0.42	0.20	0.23
Cu	0.04	0.04	0.03	0.07	0.04	0.04	0.02	0.09	**0.11**	0.09	0.03	0.05
Zn	0.05	0.06	**0.14**	0.15	0.10	0.10	**0.21**	0.14	0.16	0.19	0.23	0.19

Notes: BOLD: When Student t-test showed significant statistical difference between Site Mean Concentration and National Urban Runoff Program (NURP) data. (Source: Vegi 2008)

Table 5-7. Historic Wet Weather Bacteria Data for City of Lincoln (1993)

Date	Site	Storm	Fecal Coliform #/100 mL	Total Coliform #/100 mL	Fecal Streptococcus #/100 mL	Total Streptococcus #/100 mL
7/13	1	#1	1,300,000	4,900,000	4,900,000	4,900,000
7/13	1	repl.	11,000	70,000	490,000	790,000
8/29	1	#2	14,000	130,000	230,000	330,000
9/21	1	#3	1,700	7,000	28,000	28,000
5/30	2	#1	>24,000	>24,000	-0-	-0-
6/23	2	#2	>24,000	>24,000	>24000	>24000
8/13	2	#3	46,000	94,000	>24000	>24000
5/30	3	#1	790	1,300	-0-	-0-
6/23	3	#2	>24,000	>24,000	16,000	>24000
8/19	3	#3	1,400	11,000	17,000	33,000
5/30	4	#1	790	2,400	-0-	-0-
6/23	4	#2	3,500	3,500	16,000	>24000
8/19	4	#3	1,300	3,300	800	23,000
5/30	5	#1	-0-	-0-	-0-	-0-
6/17	5	#2	>24,000	>24000	-0-	-0-
8/19	5	#3	2,000	33,000	130,000	230,000
9/13	5	#4	23,000	23,000	110,000	110,000

(Source: Vegi 2008)

5.3.4 Summary and Conclusions for Historic Monitoring Data

Review of historic data sets for Antelope Creek results in the following conclusions:

Picture 12: EA recorded stream discharge during a wet sampling event in 2011

- Historic data available for Antelope Creek suggest nonpoint sources of *E. coli* during dry weather conditions; however, conclusions regarding sources of *E. coli* based on this data set are limited since the majority of data collected are limited to one location near the State Fair Grounds (Antelope Creek confluence with Salt Creek). Limited monitoring data collected during the summer of 2009 at several additional locations show that *E. coli* was well above stream standards throughout the stream reach during the recreational season. Although there are not significant differences in *E. coli* sample results among monitoring locations, the geometric mean concentrations at A Street (Park) and 27th Street (Zoo) are more than twice the geometric means calculated for other sampling locations. The sample result variation among these sites is also greater than at the other locations.
- Elevated ammonia concentrations appear to be limited primarily to the 2002 time period. Monitoring since that time shows that the stream meets ammonia standards, without additional controls being necessary.
- Chloride, conductivity and selenium are all elevated above stream standards on Antelope Creek. Based on limited samples collected during 2009, these issues appear to be concentrated near the lower portion of the segment near Salt Creek. Groundwater inflows in this reach are expected to be the source of elevated

concentrations of these constituents. These constituents generally appear to be higher during low flow conditions, consistent with groundwater-dominated conditions. Given the guidelines described by NDEQ (2009) regarding natural sources of pollution, these constituents do not appear to warrant further controls since they are likely naturally occurring.

- The copper data set collected by NDEQ is limited to nine samples at the State Fairgrounds location. When supplemented by the sampling gathered by Mohlman et al. (2009), the total sample size at the State Fairgrounds increases to 14 events; however, lack of hardness data limits use of these data to assess attainment of the standard.
- Wet weather conditions on Antelope Creek have not been explicitly monitored. Historic NPDES monitoring in other portions of Lincoln and wet weather monitoring in other parts of the country indicate that urban stormwater would be a source of bacteria loading to streams.
- Since collection of these historic data, significant changes to the stream channel have been implemented due to the Antelope Valley Project. These changes should be considered when comparing historic and recent water quality data.

5.4. 2010-2011 Water Quality Monitoring Activities

In September 2010, the City and LPSNRD sponsored a water quality sampling program for Antelope Creek below Holmes Lake to the confluence with Salt Creek, as documented in “Work Plan: Water Quality Monitoring for Antelope Creek Watershed Basin Management Plan, City of Lincoln” (EA 2010). The purpose of the water quality sampling effort was to investigate, document, and verify potential *E. coli* and ammonia sources in the watershed, provide information needed to assess the current water quality conditions relative to the TMDL, and provide information needed to assess approaches to establishing necessary BMPs to meet the TMDL. For more information on TMDL information relating to Antelope Creek, see SECTION 4 – TMDL ASSESSMENT.

5.4.1 2010-11 Sampling Program Overview

During 2010-2011, EA conducted in-stream sampling for four dry weather and three wet weather synoptic sampling events for approximately 11 locations on the stream between September 2010 and August 2011 (Tables 5-8 and 5-9 and Figure 5-10). Dry weather sampling events were conducted following seven preceding days with no significant rainfall. Wet weather sampling events were conducted within 24 hours of a minimum of 0.5 inch rainfall. At three of these locations (AC-1, AC-4 and AC-9), 5-week sequences of samples for fecal indicator bacteria were also collected to support calculation of geometric mean concentrations for *E. coli*. In-stream sediment samples were also collected at targeted locations in the stream for two of the sampling events, as identified in Table 5-8. Outfalls (tributaries) to the stream were sampled for two events under dry weather conditions and investigated for signs of dry-weather pollution, as summarized in Table 5-10.

Table 5-8. Sampling Dates

Date	Sample Description
9/30/2010	Dry weather sampling (included tributaries)
11/12/2010	Wet weather sampling
1/17/2011	Sediment sampling
5/10/11	Dry weather and sediment sampling
5/20/11	Wet weather sampling
7/1/2011	Dry weather sampling (included tributaries)
7/22/2011	Dry weather sampling
8/8/2011	Wet weather sampling

Source: EA Field Survey 2010-2011

Table 5-9. In-stream Sampling Locations

Location ID	Location	Comment
AC-1	Holmes Lake Outfall	Initial water source for AC study reach
AC-11	Downstream of 56th and Van Dorm	Added May 10, 2011
AC-10	Downstream of 48th and Normal	Added May 10, 2011
AC-2	South Street Bridge	Downstream of AC outfalls
AC-3	"A" Street Bridge	Upstream of the Zoo
AC-4	Upstream 27th Street below sandstone outcrop	Downstream of the Zoo
AC-5	"J" Street Bridge	Flowing water above weir pool
AC-6	Union Plaza	Monitor water quality in Union Plaza
AC-7	Vine Street downstream of tunnel return	Monitor tunnel return water
AC-8	Devaney Bridge at Big "X"	Downstream of large outfalls
AC-9	NDEQ sampling location—SLP2ANTLP104	Confirmation and comparison area for TMDL data

Source: EA Sampling Plan 2010

Table 5-10. Tributary Sampling Locations

Location ID	Location	Outfall Dimension	EA August 2010 Field Comment
Trib-1	East of 48th and Normal	60 inch – round concrete	Flows present, source unknown; source believed to be groundwater infiltration; dry on 7/1/2011.
Trib-2	East of 48th and Normal	80x60 inch – concrete box culvert	Flows present, appear to be diffuse groundwater contributions; dry on 7/1/2011
Trib-3	Antelope Creek Rd. at Eden Park	80x60 inch – concrete box culvert	Flows originate from Bryan LGH Medical Center area; source believed to be air-conditioning condensate
Trib-4	Under 40th Street Bridge	36 inch – round concrete	Flows originate from Lincoln High School vicinity; source believed to be air-conditioning condensate
Trib-5	South of 38th Street	6 inch-vitrified clay	Dry on 9/30/2010 and 7/1/2011
Trib-6	SW of Normal and Sumner	48 inch – round concrete	Dry on 9/30/2010 and 7/1/2011
Trib-7	33rd and Capital Parkway	84x60 inch – concrete box culvert	Flows originate from Tabitha Health Care Services area; source believed to be air-conditioning condensate
Trib-8	South of A Street Bridge	120x60 inch – concrete box culvert	Flows originate between 28th and Arlington, and Jefferson and Arlington (water service line break); Repaired in May of 2011, flow greatly reduced during the July 2011 sampling
Trib-9	Children's Zoo upstream of sandstone outcrop	6 inch – vitrified clay pipe	Dry on 9/30/2010 and 7/1/2011
Trib-10	North of Vine Street Bridge	48x84 inch – concrete box culvert	Flows present, source unknown

Location ID	Location	Outfall Dimension	EA August 2010 Field Comment
Trib-11	17th and Y Street	42 inch – round concrete	Flow originates from Able Dormitory on UNL Campus air-conditioning unit
Trib-12	17th and Y Street	96x126 inch – concrete box culvert	Flows present, source unknown
Trib-13	North of Y Street Bridge	72-inch – round concrete	Flows present, source unknown
Trib-14	Between Big "X" and Y Street	60x72 inch concrete box culvert	50% of flow from near Jorgensen Hall on UNL campus, 50% of flow from surface drains near The Village Dormitories on UNL Campus; both sources are believed to be air-conditioning condensate
Trib-15	South of Big "X"	72 inch – round concrete	Flows present, source unknown
Trib-16	South of Big "X"	60 inch – round concrete	Some flow from Memorial Stadium
Trib-17	Devaney Bridge on Military Rd.	24 inch – round concrete	Flows present, source unknown; dry on 9/30/2010

Source: EA Sampling Plan 2010

Table 5-11. Water Quality Sampling Parameters

Water Quality Parameter Monitored	Rationale/Comment
Field Parameters: pH, conductivity, temperature, and dissolved oxygen (DO)	All sampling events for basic water quality conditions
E. coli	2007 TMDL; primary constituent of interest
Ammonia	2007 TMDL; removed from NDEQ 2010 303(d) list
Selenium	NDEQ 2008 & 2010 303(d) lists; Discontinued prior to 5/10/2011 sampling.
Copper, Dissolved (with hardness data)	NDEQ 2008 & 2010 303(d) lists; Discontinued prior to 5/10/2011 sampling.
Dissolved Organic Carbon	Added beginning 5/10/2011 to evaluate potential relationship with *E. coli.*
Total Phosphorus	Added beginning 5/10/2011 to evaluate potential relationship with *E. coli*.

Source: EA Sampling Plan 2010

The sampling plan was designed to help fill the following data gaps regarding *E. coli* sources on Antelope Creek:

- Provide better spatial resolution (more locations) of *E. coli* concentrations along Antelope Creek to identify trends and locations where significant *E. coli* loads are entering the creek.
- Determine whether dry-weather discharges from stormwater outfalls appear to be sources of *E. coli*, potentially suggesting illicit connections to the storm drainage system.
- Explore whether in-stream sediment appears to be a significant ongoing internal source of *E. coli* in the stream (*e.g.,* serving as a reservoir of *E. coli* that could be resuspended/remobilized).
- Conduct targeted sampling at locations suspected as potential *E. coli* sources (*e.g.,* the Children's Zoo, Holmes Lake, bridge crossings inhabited by birds, etc.).
- Complete field observations to help identify potential sources of *E. coli* such as pigeons at bridge crossings, starlings feeding on insects in exposed stream sediment at the labyrinth weir, and waterfowl in adjacent open space areas (*e.g.,* lawns, golf course).

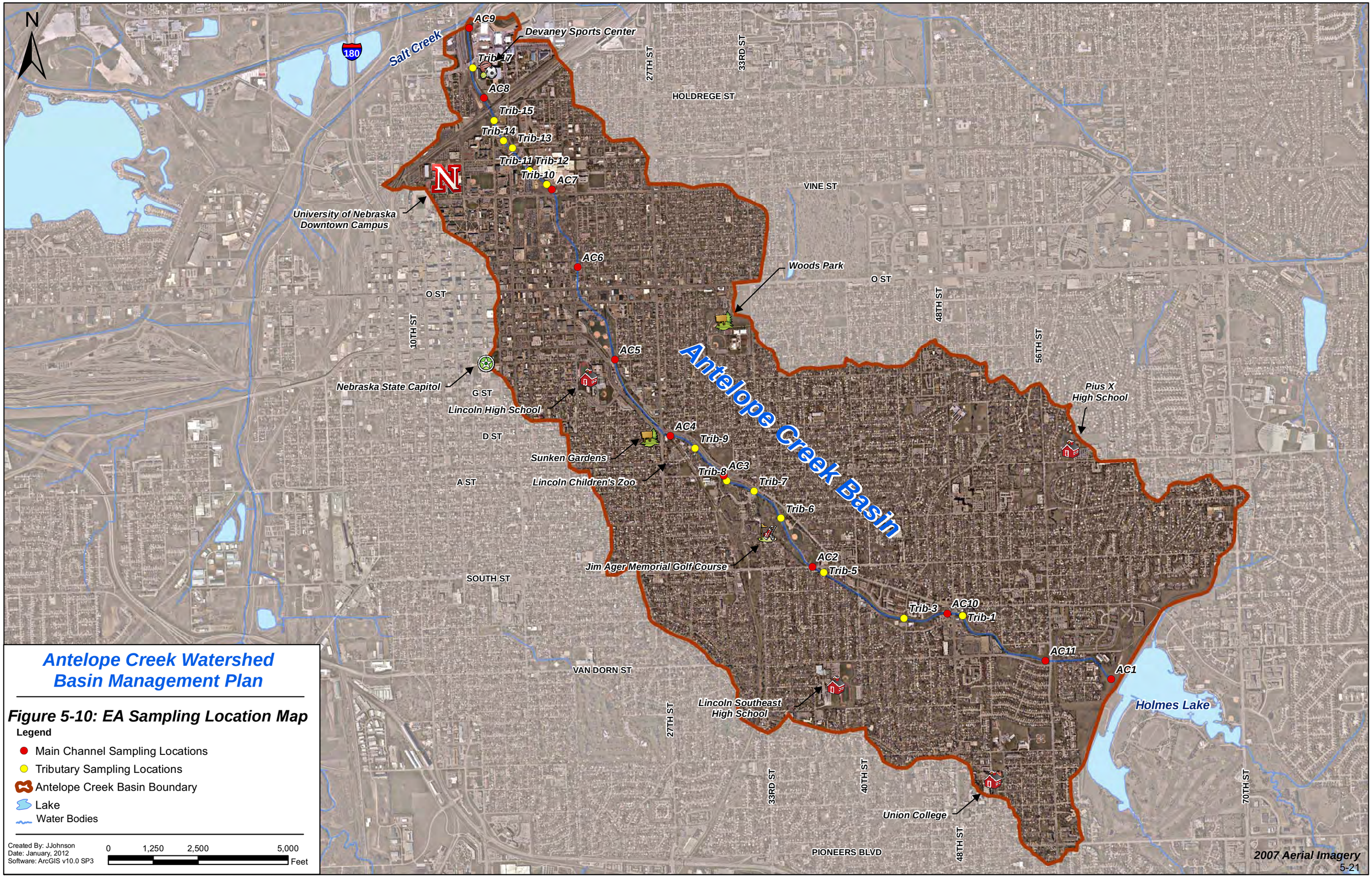
Findings from this sampling program follow for in-stream, outfall and sediment sampling, along with a narrative summary of animals observed along the creek.

5.4.2 In-Stream Sampling Results

No sample location "stands out" as being a particularly problematic source of E. coli.

Dry weather and wet weather sampling results are summarized in Tables 5-12 and 5-13, respectively, Figures 5-11 through 5-17 depict these data graphically (EA Field Data, 2010/11). (Tables and figures are provided at the end of this subsection.) Key observations include:

- Dry weather sample results vary by an order of magnitude or more at most sample locations for the four dry weather sample results. Wet weather sample results are typically an additional order of magnitude higher (*e.g.,* 10^4) and reach the upper quantitation limit of 24,200/100 mL for several samples. These results are within ranges observed in other urban communities.
- *E. coli* exceeds stream standards (126/100 mL) and the TMDL limit (113/100 mL), at all in-stream sampling locations during wet weather events, excluding the sample location below Holmes Lake (AC-1). During dry weather events, *E. coli* also exceeds standards and TMDL limits at most locations excluding the location below Holmes Lake (AC-1). Other than AC-1, rainfall events have much higher *E. coli* than dry weather events, as would be expected. Given these results, the Holmes Lake discharge does not appear to be a significant source of *E. coli* (Table 5-14 and Figure 5-12).
- For the three sites with weekly *E. coli* samples enabling calculation of geometric mean concentrations, the data show in-stream concentrations meeting stream standards below Holmes Lake (AC-1), and being elevated well above the standard for AC-4 (below zoo) and AC-9 (Fairgrounds/Salt Creek) during the recreational season. Geometric mean concentrations for the non-recreational season months (*e.g.,* Nov-Dec 2010, Sept-Oct 2010) tend to be lower, with the November-December geometric mean concentrations attaining the stream standard at all three locations.
- Dry weather *E. coli* concentrations in the stream appear to become elevated in the vicinity of the upper end of the park area upstream of the zoo and generally remain elevated for most of the reach of the stream (Figure 5-11). Although variability in the data set does not enable firm conclusions regarding statistically significant differences between sampling locations, visual inspection of the data suggest that AC-2 to AC-6 may be somewhat more elevated than the lower stream reaches for some of the sampling events (although not necessarily at a statistically significant level). This finding would be consistent with increased wildlife in green space along the creek in this area.
- Wet weather sample results generally increase in an upstream to downstream direction, which would be consistent with storm volumes being added to the creek as it flows toward Salt Creek. No sample location "stands out" as being a particularly problematic source of *E. coli*.
- At the Salt Creek (NDEQ/AC-9) location, which is the only site with a substantial number of samples enabling assessment of changes over time, data collected during 2004, 2009 and 2010/2011 do not suggest that *E. coli* conditions are worsening or improving over time. Visual inspection of the data suggests that *E. coli* concentrations were lower in the 2009 data set relative to the 2004 data set; however, the 2010-2011 data set includes a range of values representative of both 2004 and 2009. As a result, no clear trend over time is present at this sampling location.



Antelope Creek Watershed Basin Management Plan

Figure 5-10: EA Sampling Location Map

Legend

- Main Channel Sampling Locations
- Tributary Sampling Locations
- Antelope Creek Basin Boundary
- Lake
- Water Bodies

Created By: JJohnson
Date: January, 2012
Software: ArcGIS v10.0 SP3

0 1,250 2,500 5,000 Feet

Table 5-12. Antelope Creek Dry Weather Sample Results

Sample Identification	Time Sample Collected				pH				Dissolved Oxygen, mg/L			
Date	9/30/2010	5/10/2011	7/1/2011	7/22/2011	9/30/2010	5/10/2011	7/1/2011	7/22/2011	9/30/2010	5/10/2011	7/1/2011	7/22/2011
Trib 1	0834	--	dry	--	8.3	--	--	--	8.56	--	--	--
Trib 2	0845	--	14:45	--	8.24	--	8.37	--	8.53	--	9.51	--
Trib 3	0912	--	14:15	--	8.22	--	8.15	--	7.3	--	8.67	--
Trib 4	0930	--	14:00	--	8.26	--	8.28	--	8.14	--	9.38	--
Trib 6	--	--	--	--	--	--	--	--	--	--	--	--
Trib 7	1046	--	13:15	--	8.33	--	8.08	--	9.1	--	9.34	--
Trib 8	--	1637	12:52	--	--	--	8.50	--	--	--	10.99	--
Trib 10	1350	--	10:15	--	NR	--	8.20	--	NR	--	8.05	--
Trib 11	1412	--	9:40	--	8.24	--	8.26	--	8.14	--	8.80	--
Trib 12	1423	--	9:50	--	8.19	--	8.19	--	8.83	--	9.43	--
Trib 13	1453	--	9:19	--	7.79	--	7.66	--	7.93	--	9.59	--
Trib 14	1515	--	9:05	--	8.06	--	7.08	--	8.81	--	9.25	--
Trib 15	1543	--	8:38	--	8.18	--	8.73	--	8.36	--	8.65	--
Trib 16	1600	--	8:33	--	8.4	--	8.37	--	8.38	--	10.17	--
Trib 17	--	--	7:55	--	--	--	8.13	--	--	--	10.85	--
Trib 18*	1510	--	--	--	8.06	--	8.06	--	8.81	--	--	--
Filed Blank	1700	--	--	--	Blank	--	Blank	--	Blank	--	Blank	--
Trib 10B Rd	1200	--	--	--	8.06	--	8.06	--	9.25	--	9.25	--
AC 1	0748	14:09	9:45	9:45	7.78	7.29	9.16	9.14	8.10	8.175	8.43	4.23
AC11	--	18:15	10:05	10:05	--	8.12	9.1	8.52	--	8.19	8.26	3.89
AC 10	--	18:00	9:30	9:30	--	8.47	9.13	8.65	--	10.10	11.68	5.04
AC 2	1008	17:34	9:15	9:15	8.4	8.10	9.07	8.11	9.50	6.68	8.89	4.37
AC 3	1134	17:13	9:02	9:02	8.46	8.42	9.13	8.12	12.16	9.25	10.37	5.4
AC 4	1152	17:00	8:50	8:50	8.52	9.10	9.2	8	11.89	10.98	9.9	4.73
AC 5	1234	16:27	8:30	8:30	8.74	9.12	9.21	8.02	12.62	8.90	9.83	4.8
AC 6	1258	16:15	8:13	8:13	8.17	--	8.74	7.72	12.65	--	9.02	3.69
AC 7	1333	16:00	7:55	7:55	7.5	8.56	8.92	7.6	10.00	---	9.11	4.56
AC 8	1624	19:18	7:40	7:40	7.59	8.72	8.7	7.42	12.00	12.83	8.58	3.53
AC 9	1635	19:30	7:20	7:20	7.48	7.56	8.16	7.13	12.87	15.97	7.59	4.7
Duplicate*	1258	16:35	8:30	8:30	8.17	9.12	--	8.02	12.65	8.90	--	4.8

Sample Identification	Temperature, °C				Conductivity				Hardness, mg/L		Selenium, mg/L	
	9/30/2010	5/10/2011	7/1/2011	7/22/2011	9/30/2010	5/10/2011	7/1/2011	7/22/2011				
Date	17.1	--	--	--	413	--	--	--	9/30/2010	5/10/2011	9/30/2010	5/10/2011
Trib 1	18.4	--	18.9	--	463	--	686	--	236	--	< 0.150	--
Trib 2	18	--	21.9	--	902	--	1583	--	276	--	< 0.150	--
Trib 3	18.1	--	20.1	--	991	--	1179	--	356	--	< 0.150	--
Trib 4	--	--	--	--	--	--	--	--	452	--	< 0.150	--
Trib 6	17	--	25.1	--	504	--	701	--	--	--	--	--
Trib 7	--	--	19.8	--	--	--	627	--	192	216	< 0.150	< 0.0050
Trib 8	NR	--	17.8	--	NR	--	795	--	--	--	--	--
Trib 10	20.5	--	20.5	--	1176	--	1142	--	148	--	< 0.150	--
Trib 11	16.8	--	18.4	--	1286	--	1453	--	268	--	< 0.150	--
Trib 12	18.9	--	18.3	--	604	--	737	--	512	--	< 0.150	--
Trib 13	18.6	--	19.9	--	636	--	1414	--	216	--	< 0.150	--
Trib 14	18.6	--	19.5	--	1015	--	892	--	235	--	< 0.150	--
Trib 15	18.1	--	18.3	--	1190	--	1640	--	468	--	< 0.150	--
Trib 16	--	--	15.2	--	--	--	1084	--	623	--	< 0.150	--
Trib 18*	18.6	--	--	--	636	--	--	--	216	--	< 0.150	--
Field Blank	Blank	--	Blank	--	Blank	--	Blank	--	< 5.00	--	< 0.150	--
Trib 10B Rd	16.5	--	16.5	--	526	--	--	--	267	--	< 0.150	--
AC 1	18.80	22.9	27.02	28.9	343.0	595	351	289	114	304	< 0.150	< 0.0050
AC11	--	26.7	27.3	23	--	734	358	328	--	--	--	--
AC10	--	21.0	27.7	27.3	--	650	359	350	--	--	--	--
AC 2	17.90	27.4	28.65	26.7	371.0	902	365	446	141	116	< 0.150	< 0.0050
AC 3	20.00	30.0	28.86	26.3	363.0	830	368	463	141	100	< 0.150	< 0.0050
AC 4	19.90	31.7	28.67	25.9	364.0	642	365	486	145	88	< 0.150	< 0.0050
AC 5	21.40	32.9	27.49	26.1	342.0	783	370	480	137	80	< 0.150	< 0.0050
AC 6	19.40	--	26.31	27.1	308.0	--	380	469	141	52	< 0.150	< 0.0050
AC 7	18.70	23.8	25.67	27.1	380.0	824	386	501	165	64	< 0.150	< 0.0050
AC 8	21.30	23.6	24.23	26	4800.0	1006	1392	610	270	108	< 0.150	< 0.0050
AC 9	21.40	22.7	23.87	23.7	4686.0	---	1278	7510	263	104	< 0.150	< 0.0050
Duplicate*	19.4	32.9	--	26.1	308	783	--	480	137	--	--	--

Sample Identification	Ammonia, mg/L				Total Phosphorus, mg/L		Total Organic Carbon, mg/L		Copper, mg/L		E. coli, #/100ml			
Date	9/30/2010	5/10/2011	7/1/2011	7/22/2011	7/1/2011	7/22/2011	7/1/2011	7/22/2011	9/30/2010	5/10/2011	9/30/2010	5/10/2011	7/1/2011	7/22/2011
Trib 1	< 0.500	--		--	--	--	--	--	< 0.0200	--	140	--	--	--
Trib 2	< 0.500	--	<0.500	--	0.16	--	5.56	--	< 0.0200	--	<1	--	--	'--
Trib 3	< 0.500	--	<0.500	--	1.38	--	9.03	--	0.0624	--	1530	--	110	--
Trib 4	< 0.500	--	<0.500	--	0.189	--	6.34	--	< 0.0200	--	510	--	990	-
Trib 6	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trib 7	< 0.450	<0.500	<0.500	--	--	--	--	--	< 0.0200	< 0.0050	<1	60	670	--
Trib 8	--	--	<0.450	--	0.283	--	5.96	--	--	--	--	--	<1	--
Trib 10	< 0.450	--	<0.500	--	0.257	--	5.73	--	0.0202	--	1860	--	220	--
Trib 11	< 0.500	--	<0.500	--	0.256	--	8.13	--	0.0263	--	<1	--	100	--
Trib 12	< 0.500	--	<0.500	--	0.479	--	3.34	--	< 0.0200	--	60	--	10	--
Trib 13	< 0.500	--	<0.500	--	0.682	--	4.53	--	< 0.0200	--	400	--	960	--
Trib 14	< 0.450	--	<0.500	--	0.299	--	3.48	--	0.0286	--	<1	--	<1	--
Trib 15	< 0.500	--	<0.450	--	0.368	--	3.72	--	< 0.0200	--	60	--	60	--
Trib 16	< 0.500	--	<0.500	--	0.264	--	4.46	--	< 0.0200	--	1610	--	290	--
Trib 18*	< 0.500	--	<0.450	--	0.332	--	4.68	--	0.0291	--	<1	--	600	--
Field Blank	< 0.500	--	--	--	0.188	--	2.61	--	< 0.0200	--	<1	--	10	--
Trib 10B Rd	< 0.500	--	--	--	0.026	--	4.41	--	0.0474	--	<1	--	140	--
AC 1	0.722	< 0.500	<0.500	<0.500	0.163	0.147	8.6	8.07	< 0.0200	< 0.0050	10	20	80	<1
AC11	--	<0.450	<0.500	<0.450	0.168	0.163	8.32	8.14	--	--	--	220	70	170
AC10	--	<0.450	<0.500	<0.500	0.178	0.149	7.44	8.01	--	--	--	<1	80	530
AC 2	< 0.500	< 0.500	<0.500	<0.500	0.187	0.183	8.4	8.25	< 0.0200	< 0.0050	910	210	290	2150
AC 3	< 0.500	< 0.500	<0.500	<0.500	0.18	0.185	8.19	8.33	< 0.0200	< 0.0050	1220	320	250	3660
AC 4	< 0.450	< 0.450	<0.500	<0.500	0.162	0.198	7.63	8.37	< 0.0200	0.00526	890	350	330	9210
AC 5	< 0.500	< 0.500	<0.500	<0.450	0.171	0.193	7.25	8.72	< 0.0200	< 0.0050	390	190	800	3880
AC 6	< 0.500	0.506	<0.450	<0.500	0.193	0.339	7.15	9.84	< 0.0200	< 0.0050	230	--	670	5800
AC 7	< 0.500	< 0.500	<0.500	<0.500	0.177	0.364	7.00	10.8	< 0.0200	< 0.0050	190	10	940	1860
AC 8	0.506	0.525	<0.500	<0.500	0.177	0.309	6.93	10.3	< 0.0200	< 0.0050	380	190	470	3260
AC 9	< 0.500	0.513	<0.500	0.637	0.193	0.265	5.26	2.57	< 0.0200	< 0.0050	250	150	740	5180
Duplicate*	<0.450	--	<0.500	<0.450	0.185	0.166	6.43	7.48	--	--	140	110	530	5800

*Notes Regarding Duplicates
30 Sept 2010 Trib 18 is a duplicate of Trib 14
30 Sept 2010 Duplicate provided for AC 6
10 May 2011 Duplicate provided for AC 5
1 July 2011 Duplicate provided for AC 6
22 July 2011 Duplicate provided for AC 5

Table 5-13. Antelope Creek Wet Weather Sample Results

Sample Identification	Time Sample Collected			pH			Dissolved Oxygen, mg/L			Temperature, °C			Conductivity		
Date	11/12/2010	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011
AC 1	1305	8:20	10:30	6.63	8.49	8.99	9.86	9.90	9.05	8.6	16.6	27.7	668	509	279
AC 11	--	8:48	10:50	--	8.36	8.84	--	9.56	9.22	--	16.4	27.3	--	487	887
AC 10	--	8:58	11:10	--	8.37	8.83	--	9.61	10.65	--	16.3	28.0	--	418	307
AC 2	1227	8:27	11:30	6.81	8.27	8.34	10.60	9.25	8.87	7.2	16.2	28.2	317	464	462
AC 3	1210	9:36	11:45	6.76	8.29	8.50	11.65	9.82	11.23	7.2	16.2	28.7	275	446	465
AC 4	1148	9:51	12:05	6.58	8.30	8.48	12.10	9.77	11.10	7.0	16.3	28.7	261	449	471
AC 5	1123	10:10	12:25	6.67	8.32	8.54	12.50	9.80	11.29	7.1	16.5	29.0	210	442	464
AC 6	1050	10:35	12:40	6.75	7.74	7.68	11.48	9.12	8.19	6.8	17.4	27.8	160	188	235
AC 7	1030	10:55	12:50	6.78	8.10	7.88	11.84	9.49	10.16	7.6	16.5	27.2	186	368	258
AC 8	955	11:12	13:05	6.91	7.97	7.89	11.00	9.15	10.40	7.9	16.5	27.8	1760	353	390
AC 9	925	11:22	13:30	7.12	7.73	7.48	11.78	7.61	12.40	7.8	16.1	27.9	1516	306	2746
Duplicate*	1055	11:05	11:10	--	8.10	8.83	--	9.49	10.65	--	16.5	28.0	--	368	307

Sample Identification	Ammonia, mg/L			Hardness, mg/L	Selenium, mg/L	Copper, mg/L	Phosphorus-Total, mg/L		Total Organic Carbon, mg/L		E. coli, #/100ml		
Date	11/12/2010	5/20/2011	8/8/2011	11/12/2010	11/12/2010	11/12/2010	5/20/2011	8/8/2011	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011
AC 1	< 0.500	<0.50	<0.50	304	< 0.0050	< 0.0050	<0.100	0.184	6.10	8.13	230	80	80
AC 11	--	<0.50	<0.45	--	--	--	<0.100	0.192	13.40	7.94	--	2490	630
AC 10	--	<0.50	<0.50	--	--	--	0.111	0.174	8.86	7.41	--	10120	840
AC 2	< 0.500	<0.50	<0.50	116	< 0.0050	< 0.0050	0.106	0.816	7.47	7.96	6020	4110	1360
AC 3	< 0.500	<0.45	<0.50	100	< 0.0050	< 0.0050	0.113	0.709	7.74	8.18	13000	9810	1280
AC 4	< 0.450	<0.50	<0.50	88	< 0.0050	0.0053	0.114	0.742	7.73	8.07	13000	10470	1560
AC 5	< 0.500	<0.50	<0.45	80	< 0.0050	< 0.0050	0.112	0.655	15.40	8.13	7560	14140	4620
AC 6	0.506	<0.50	<0.45	52	< 0.0050	< 0.0050	1.454	0.200	7.47	9.45	24200	260	17330
AC 7	< 0.500	<0.50	<0.45	64	< 0.0050	< 0.0050	0.163	0.211	8.24	8.72	15540	8670	15540
AC 8	0.525	<0.50	<0.50	108	< 0.0050	< 0.0050	0.192	0.211	8.49	7.4	13000	15540	17330
AC 9	0.513	<0.45	<0.45	104	< 0.0050	< 0.0050	0.208	0.177	6.83	3.91	24200	19870	8170
Duplicate*	<0.500	<0.50	<0.45	56	< 0.0050	0.0095	0.152	0.161	7.51	7.78	24200	17330	890

*Notes for Duplicates:

12 Nov 2010 Duplicate provided for AC 6

20 May 2011 Duplicate provided for AC 5

8 Aug 2011 Duplicate provided for AC 10

- Evaluation of seasonal trends was not an objective of the sampling program, since the stream standard applies during the summer time period (May – Sept), and the majority of the sample events focused on this timeframe. Nonetheless, the November-December sampling events show lower concentrations of *E. coli*, as would be expected during the winter
- Findings for 2010-2011 sample results for *E. coli* are generally consistent with previous work by NDEQ (2004, 2009) and Mohlman et al. (2009).

In summary, available data show both wet weather and dry weather *E. coli* issues; therefore, both wet weather and dry weather management strategies are needed to reduce *E. coli* loading to the stream. Elevated in-stream concentrations generally begin in the AC-2 area at the upper end of the park/greenbelt area and remain generally elevated for most of the stream reach, even though the downstream (AC-9 at the Fairgrounds/Salt Creek) is somewhat lower than the central portion of the stream in the park/greenbelt area.

Findings for ammonia, selenium and copper include:

- Ammonia: Out of 31 wet weather samples only three ammonia results were above detection limits and were in the vicinity of the 0.5 mg/L detection limit. Out of 40 dry weather sample results, only six results were above detection limits, with all but one of these values below chronic (30-day) calculated stream standards and no values above acute stream standards. These results confirm that additional ammonia controls are not necessary to achieve stream standards, consistent with recent NDEQ monitoring in 2009.
- Selenium: All wet and dry weather sample results were below detection limits. (Note the September 30, 2010 sampling event has a relatively high detection limit (0.15 mg/L), but a lower detection limit of 0.005 mg/L was in place beginning in May 2011.)
- Copper: Out of 18 dry weather samples collected during two sampling events, only one sample (5.2 µg/L) was above the detection limit of 5 µg/L. Out of nine wet weather samples collected during one sampling event, only one sample (5.2 µg/L) was above detection limits. Ancillary hardness data was collected along with the copper samples, with samples collected following a Quality Assurance Project Plan (EA 2010). Following NDEQ's procedures to average multiple samples collected on the same date, all three sampling events show copper below the detection limit of 0.005 mg/L. Adding these three events to the nine NDEQ events results in a total of 12 events with three copper exceedances; which demonstrates attainment of the copper standard based on NDEQ procedures (NDEQ 2010). Specifically, the 10 sample minimum for assessment is now met, and for a 12-sample data set, four out of 12 samples would need to exceed the standard for the stream to be identified as impaired. These results remove uncertainty regarding potential impairment due to elevated copper concentrations on Antelope Creek, and attainment of the copper standard is now demonstrated.

Table 5-14. *E. coli* Summary Table (2010-2011)

Date	EA Note	Flow Notes	AC1	AC 11	AC10	AC2	AC3	AC4	AC5	AC6	AC7	AC8	AC9
9/30/2010	Dry #1	--	10	--	--	910	1220	890	390	230	190	380	250
10/8/2010	--	--	20	--	--	--	--	430	--	--	--	--	240
10/15/2010	--	--	50	--	--	--	--	110	--	--	--	--	160
10/22/2010	--	--	10	--	--	--	--	200	--	--	--	--	200
10/29/2010	--	--	540	--	--	--	--	5800	--	--	--	--	180
11/12/2010	Wet #1	Follows 1.72 inch rain	230	--	--	6020	13000	13000	7560	24200	15540	13000	24200
11/19/2010	--	--	1	--	--	--	--	1	--	--	--	--	1
11/22/2010	--	--	1	--	--	--	--	1	--	--	--	--	1
12/3/2010	--	--	20	--	--	--	--	470	--	--	--	--	70
12/10/2010	--	--	--	--	--	--	--	--	--	--	--	--	690
5/10/2011	Dry #2	--	20	220	1	210	320	350	190	NS	10	190	150
5/20/2011	Wet #2	Follows 1.87 inch rain; Salt Creek backwater	80	2490	10120	4110	9810	10470	14140	260	8670	15540	19870
5/27/2011	--	--	140	--	--	--	--	3880	--	--	--	--	650
6/3/2011	--	--	1	--	--	--	--	119	--	--	--	--	84
6/10/2011	--	--	60	--	--	--	--	5480	--	--	--	--	5840
6/17/2011	--	--	60	--	--	--	--	4620	--	--	--	--	2490
7/1/2011	Dry #3	Holmes Lake Flow	80	70	80	290	250	330	800	670	940	470	740
7/8/2011	--	Follows heavy rain est. (2 inch+); Salt Creek backwater	10	--	--	--	--	280	--	--	--	--	2150
7/15/2011	--		130	--	--	--	--	1340	--	--	--	--	280
7/22/2011	Dry #4	Follows light rain (<0.3 inch)	1	170	530	2150	3660	9210	3880	5800	1860	3260	5180
7/29/2011	--	Follows light rain	30	--	--	--	--	6140	--	--	--	--	510
8/5/2011	--	Follows rain (0.45 inch)	4890	--	--	--	--	24200	--	--	--	--	24200

Date	EA Note	Flow Notes	AC1	AC 11	AC10	AC2	AC3	AC4	AC5	AC6	AC7	AC8	AC9
8/8/2011	Wet #3	Follows rain over several days (1.16 inch)	80	630	840	1360	1280	1560	4620	17330	15540	17330	8170
8/12/2011	--	Follows heavy rain	160	--	--	--	--	12040	--	--	--	--	10470
8/19/2011	--	Follows heavy rain (est. 1 inch)	1	--	--	--	--	1400	--	--	--	--	3300
8/26/2011	--	--	10	--	--	--	--	3880	--	--	--	--	1470
9/2/2011	--	--	40	--	--	--	--	1520	--	--	--	--	240
Geometric Mean (all samples)*			27	333	205	1219	1788	959	1966	2145	1319	2343	622
# of Samples (all samples)			26	5	5	7	7	26	7	6	7	7	27
Geometric Mean (May-Sept only)			31	333	205	935	1284	2155	1571	1321	875	1761	1511
# of Samples (May-Sept)			18	5	5	6	6	18	6	5	6	6	18

Note: It is not appropriate to compare differences between sites with substantially differing numbers of samples. Be aware that sites AC1, AC4 and AC9 have more than three times as many samples as other sites in this table.
Source: EA Field Data 2010-2011

Figure 5-11. 2010-2011 Dry Weather Sampling Results for Antelope Creek

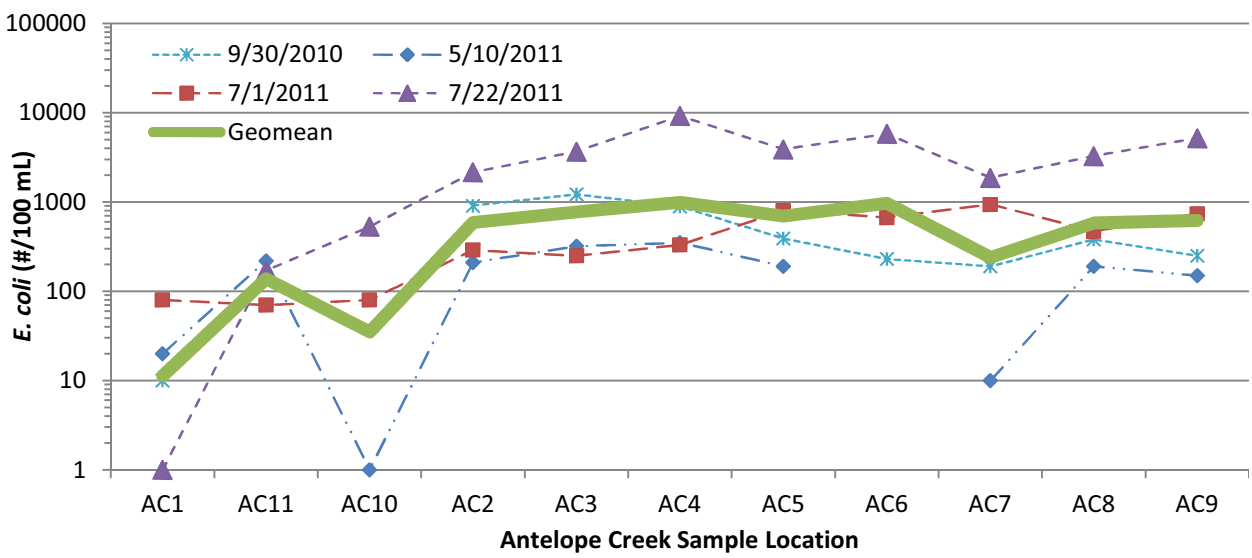


Figure 5-12. 2010-2011 Wet Weather Sampling Results for Antelope Creek

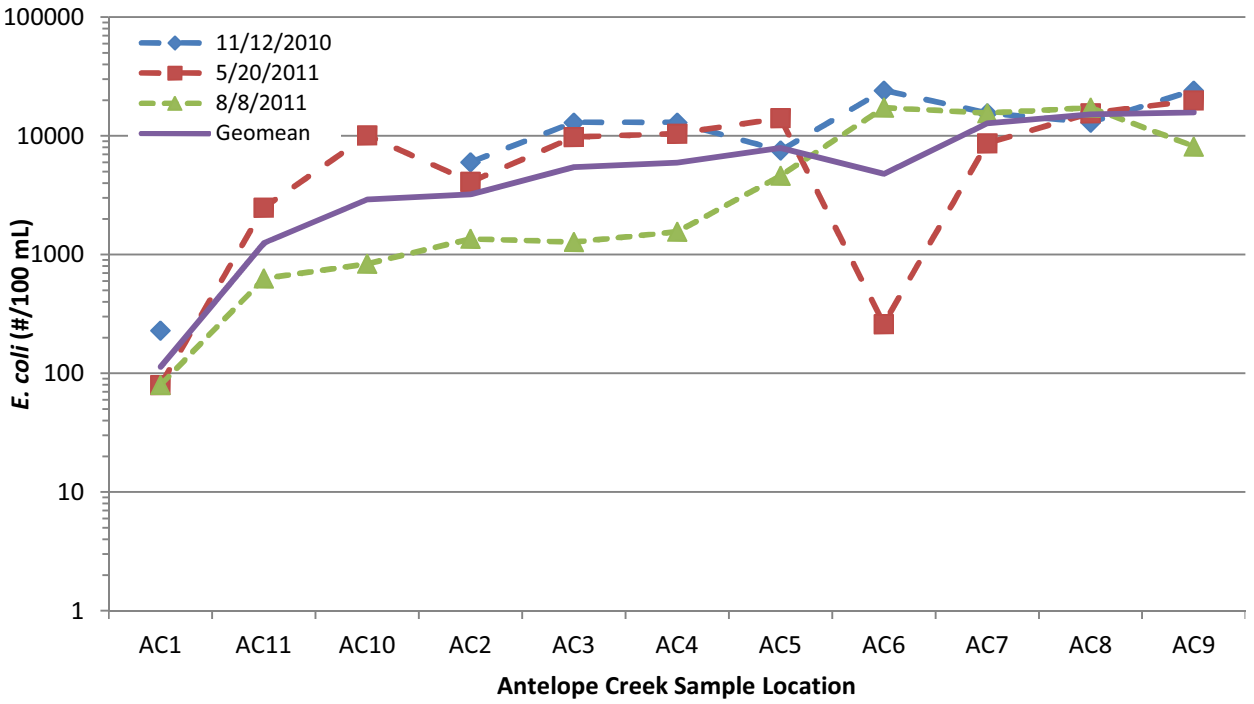
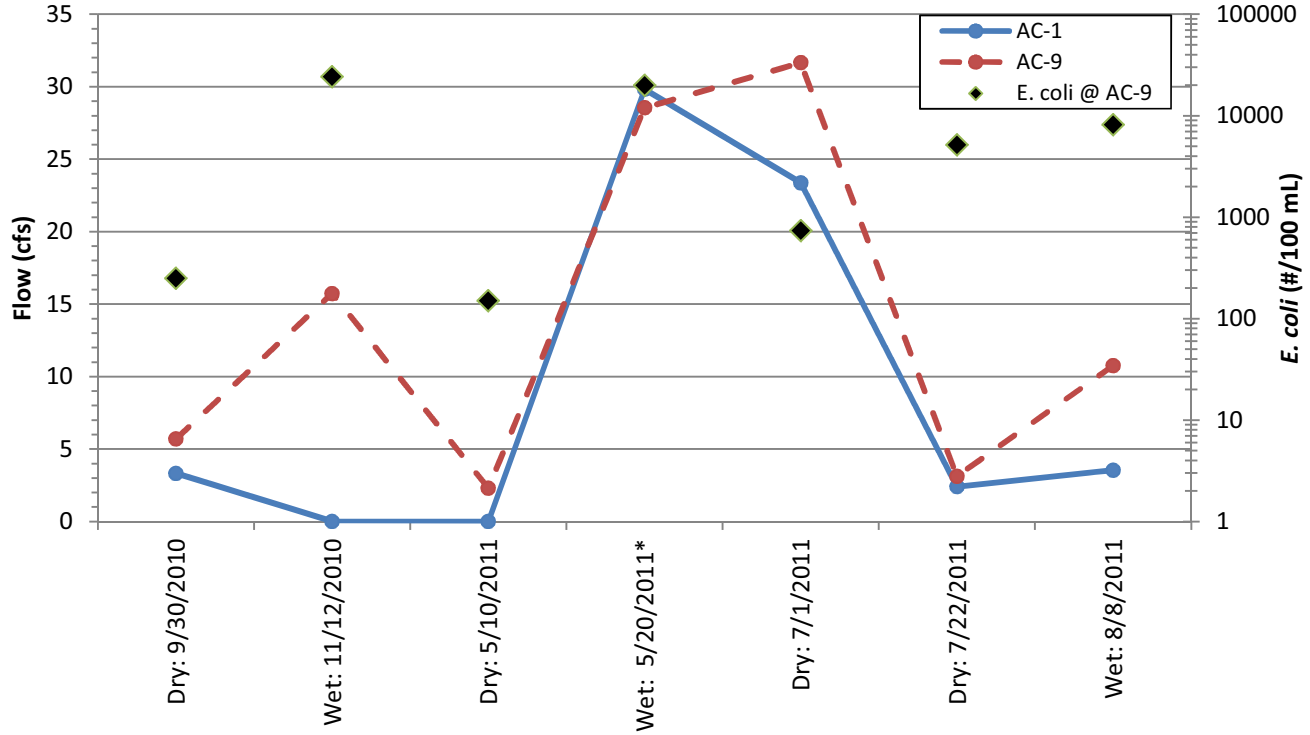


Figure 5-13. Flow Conditions During 2010-2011 Sampling Events

(with *E. coli* @ AC-9 shown on secondary Y-axis)



Note: Wet weather event rainfall amounts include: 11/10/10 = 1.72 inch; 5/20/11 = 1.87 inch; 08/08/11 = 1.16 inch over several days.
* = Wet weather flows on 5/20/11 at AC-9 affected by Salt Creek backwater.

Figure 5-14. Comparison of 2010-2011 Flow Estimates to Other Flow Data Collected on Antelope Creek

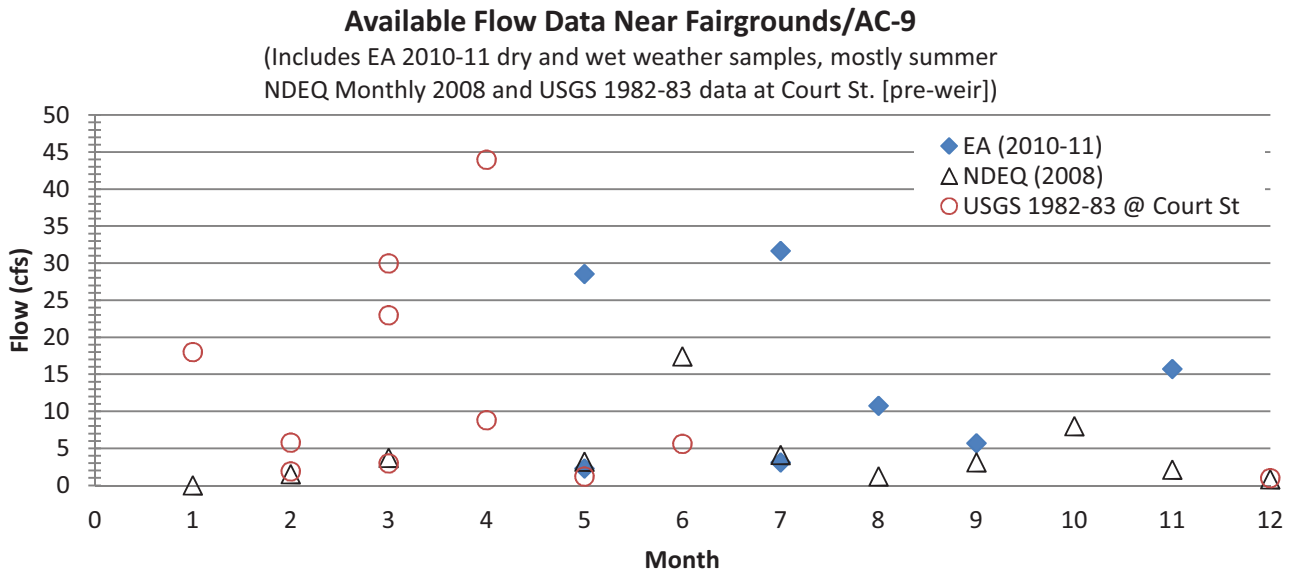
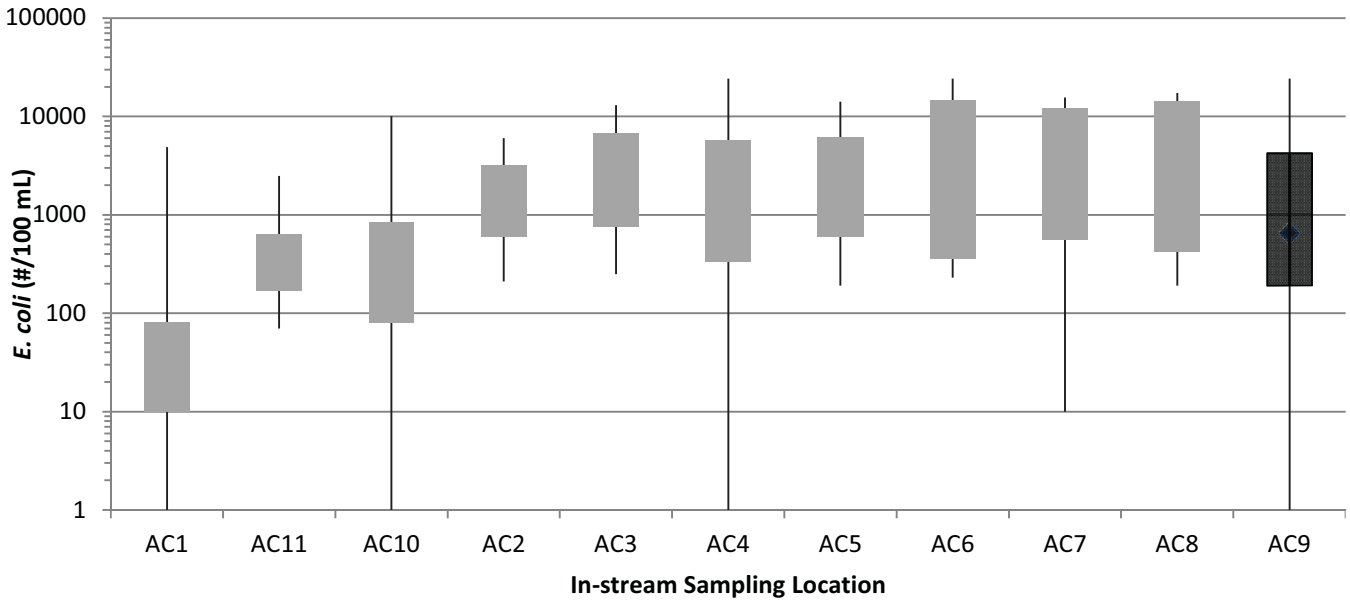


Figure 5-15. 2010-2011 Boxplots of All 2010-2011 Sampling Results for Antelope Creek



Box Plot Key: Diamond = median, Box = 25th-75th percentiles, "whiskers" = minimum and maximum values.
Important Note: Numbers of sampling events are significantly different between monitoring locations, with AC-1, AC-4 and AC-9 have approx. 27 events, whereas most other locations have only 5-7 events.

Figure 5-16. Boxplots of Annual Sampling Results for Antelope Creek at the State Fairgrounds (AC-9)

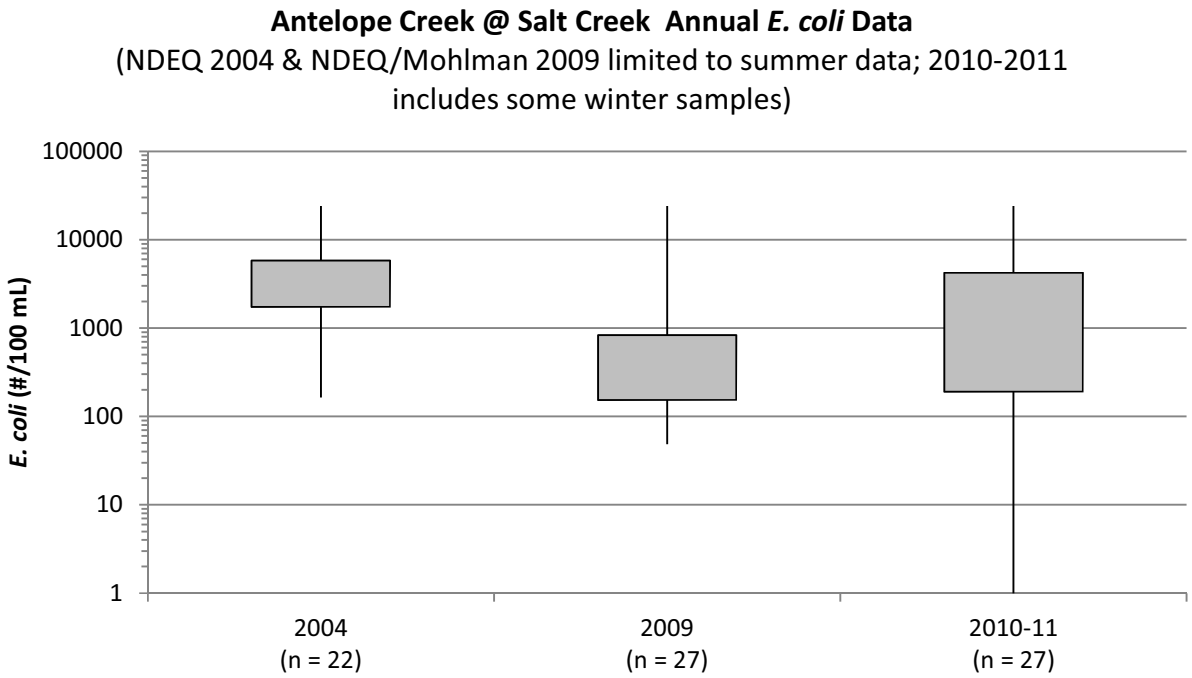
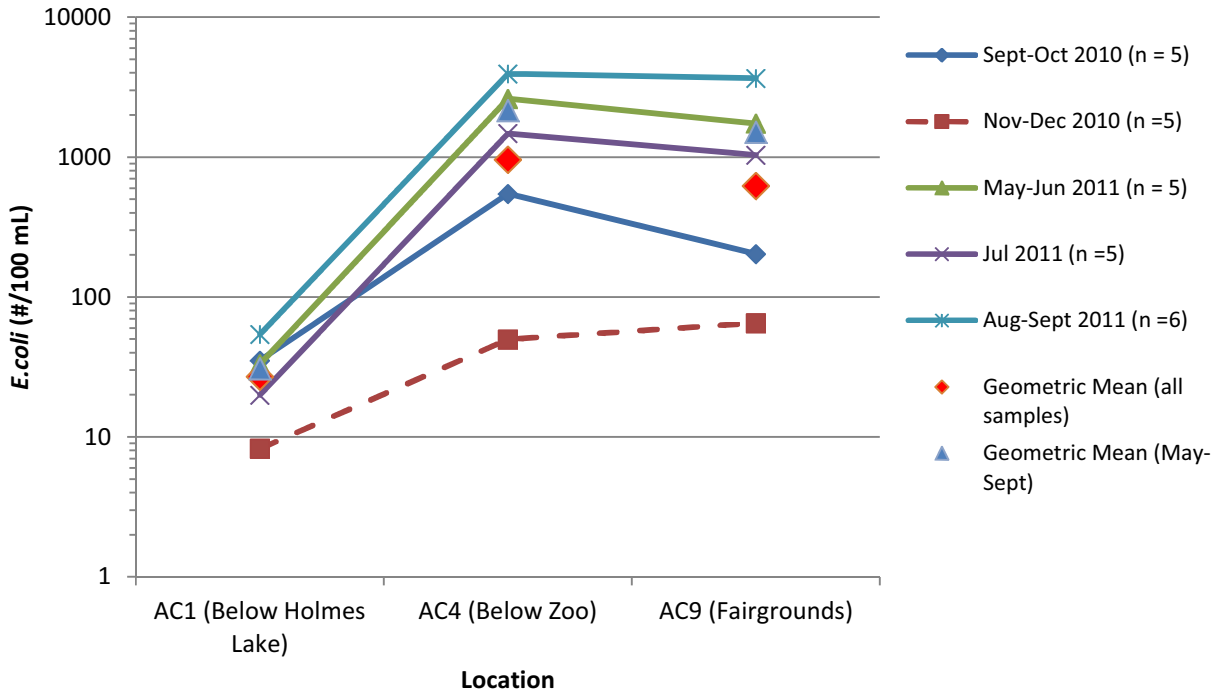


Table 5-15. Geometric Mean Values Calculated for Locations with Weekly Sampling

Date	Geometric Mean Values		
	AC-1 (Below Holmes Lake)	AC-4 (Below Zoo)	AC-9 (Fairgrounds)
Sept-Oct 2010 (n = 5)	35	547	203
Nov-Dec 2010 (n =5)	8	50	65
May-Jun 2011 (n = 5)	33	2615	1736
Jul 2011 (n =5)	20	1476	1033
Aug-Sept 2011 (n =6)	54	3942	3662
Geometric Mean (all samples)	27	959	622
Geometric Mean (May-Sept)	31	2155	1511

Source: EA Field Data 2010-2011

Figure 5-17. 2010-2011 Geometric Mean *E. coli* Concentrations at AC-1, AC-4 and AC-9



Note: Each Value is a Geometric Mean of Weekly Samples Collected over a 30-day Period
Source: EA Field Data 2010-2011

5.4.3 Dry Weather Outfall Investigations and Sampling Results

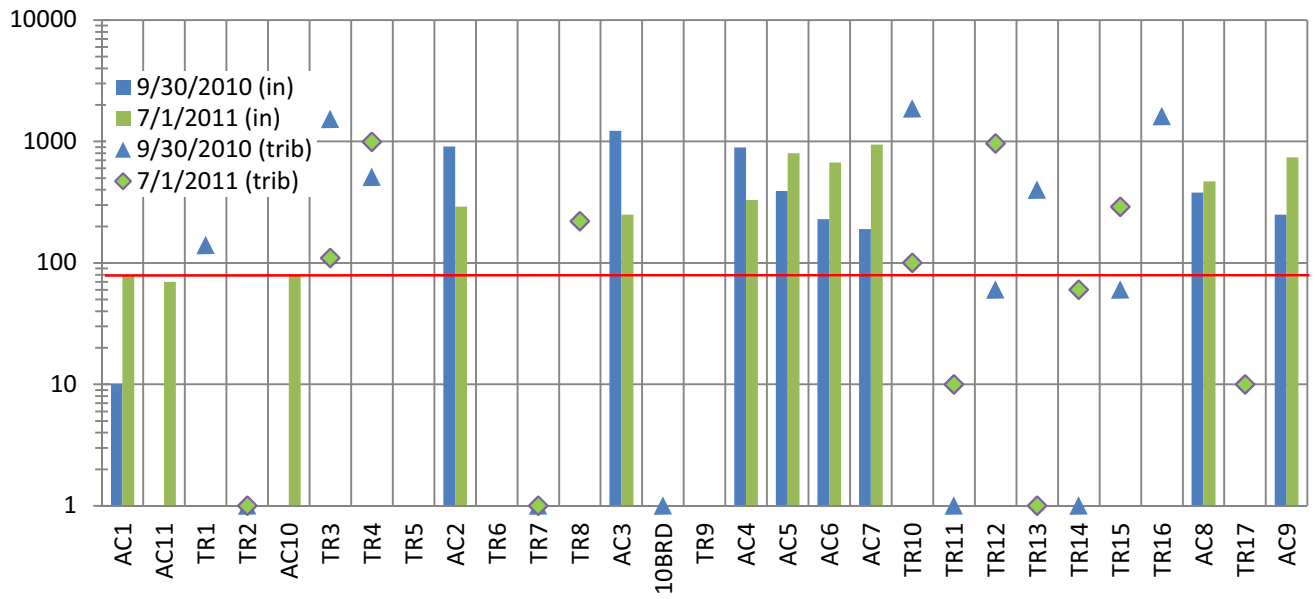
In August 2010, EA completed a dry weather survey of storm drainage system outfalls to the creek. An inventory of these outfalls included basic descriptive information such as size and location, as well as documentation of factors that could suggest potential illicit discharges such as flow, odor, algae and sediment characteristics. Potential natural sources of *E. coli* such as birds and other urban wildlife were also documented, where relevant. Outfalls with dry weather flows were documented during the initial outfall inventory then re-visited one week later (no rain during that time) to re-check for flows. Sites with discharges occurring during both field visits were selected for sampling and further exploration of the origin of the flows. Table 5-10 (in Section 5.1) identifies the outfalls sampled during dry weather conditions on September 30, 2010 and July 1, 2011. Figure 5-18 shows the sampling results for outfall and in-stream locations on these sample dates. (Outfalls are shown as individual markers and in-stream samples are shown as bars.) Key findings include:

- Dry weather flows from most outfalls were relatively minimal, generally below 0.2 cfs (or less than 5% of the flow at AC-1). On September 30, outfall T-2 had flows estimated at 0.4 cfs; however, *E. coli* was not detected at this outfall.
- There are 13 primary outfalls that discharge into the closed conduit adjacent to Union Plaza. The inlet to this conduit is located at the labyrinth weir, with the outlet to the stream located north of Vine Street. EA conducted sampling upstream of the labyrinth weir and downstream of the confluence north of Vine Street. There were no obvious spikes of *E. coli* from the outlet of the closed conduit, which did not merit further investigation. Other general water quality parameters changed due to influences from groundwater. During dry weather conditions, little to no discharge was seen from the closed conduit.
- Visual inspection of outfall for signs of illicit connections generally resulted in observations with low likelihood of illicit connection. Examples of signs of illicit connections could be odor, staining, excessive algae growth, toilet paper, etc. Several outfalls had some algae growth and staining, but not at a level raising suspicion of illicit connections. Evidence of animal presence in several outfalls was also noted.
- For the two dry weather sampling events, the only outfall with *E. coli* above the stream standard for both sampling events was T-4 at 510 and 990/100 mL. Flows at T-4 were very low, less than 0.02 cfs. For all other outfalls, results varied, such as 1) one sample exceeded the standard, but the second sample did not; 2) both sample results were below detection limits, or 3) at least one of the sampling events had no flow. For

locations with *E. coli* above stream standards, the highest concentrations observed were in the range of 1,500-1,800/100 mL. Although these concentrations are an order of magnitude above the stream standard, they are not outside of the range of concentrations associated with transient urban wildlife sources and are lower than concentrations expected to be associated with illicit connections (*e.g.,* 7,000-10,000/100 mL or higher). Combined with field observations that did not show signs of illicit connections, these results suggest that dry-weather discharges from the storm drainage system are not likely to be significant sources of elevated in-stream *E. coli*. Additionally, wildlife, such as raccoons and swallows, was documented to be present in some of the outfalls.

- All outfall samples were below detection limits for ammonia and selenium. Most copper values were below detection limits or in the vicinity of the detection limit (0.02 mg/L). Detected values of copper ranged from 0.0202 to 0.0624 mg/L; however, in-stream concentrations on those dates were below detection limits.

Figure 5-18. 2010-2011 Dry Weather Synoptic Sampling Results for Antelope Creek and Flowing Outfalls



Source: EA Field Data 2010-2011

In-stream Sediment

Recent literature has suggested that fecal indicator bacteria can persist for relatively long periods of time in water body sediments. For this reason, two sediment sampling events were completed and analyzed for fecal indicator bacteria, nutrients (Total Kjeldahl Nitrogen (TKN) and Total Phosphorous (TP)) and Chemical Oxygen Demand (COD) to explore whether sediment may be a potentially significant source of *E. coli* to the stream and to see whether nutrient conditions in the sediment appeared to be potentially related to *E. coli* concentrations. As would be expected, the January samples had low concentrations of bacteria, making it difficult to draw conclusions from this data set (Figure 5-19). The May sediment samples also had generally low concentrations of bacteria, with the exceptions of AC-2 (430 mpn/kg), which is at the South Street bridge, and AC-4 (240 mpn/kg), which is downstream of the zoo. Relationships between nutrients and *E. coli* concentrations in the sediment were not apparent, based on this limited data set.

Based on these results, it is possible that *E. coli* in-stream sediments is contributing to elevated concentration of *E. coli* in the water column, particularly during storms when sediment is resuspended; however, the available data do not suggest that this is a leading or primary cause of elevated *E. coli* in the stream.

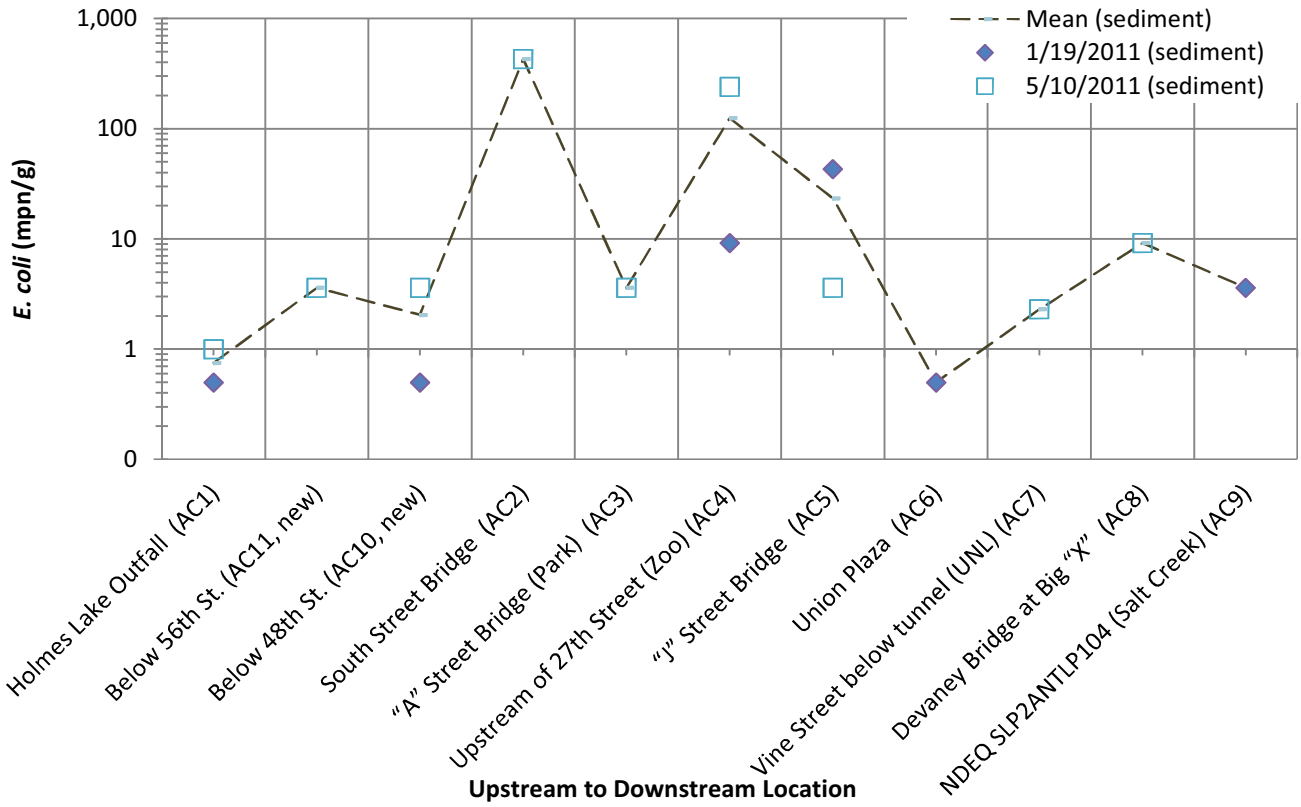
Copper and lead values in sediment samples collected from AC were generally below the levels reported to have observable effects on benthic populations based on data reported in NOAA Technical Memorandum NOS OMA 52, except at AC-4. Concentration for copper and lead at AC-4 are elevated to levels shown to have adverse effects on benthic organisms. Additional data is needed to confirm the value and to evaluate the toxicity.

Table 5-16. 2011 Summary of In-stream Sediment Samples for Antelope Creek

Sample Location	TKN, mg/kg		Phosphorus-Total, mg/kg		COD, mg/kg		Cu mg/kg	Lead, mg/kg	*E. coli*, mpn/g		Entero-bacteriaceae cfu/g		Fecal Coliform, mpn/g	
Date	1/17/2011	5/10/2011	1/17/2011	5/10/2011	1/17/2011	5/10/2011	1/17/2011	1/17/2011	1/17/2011	5/10/2011	1/17/2011	5/10/2011	1/17/2011	5/10/2011
AC 1	48.9	158	82.2	70.5	755	1193	1.3	<5	nd	nd	70	1160	nd	nd
AC 11	—	440	—	177	—	264	—	—	—	3.6	—	610	—	13
AC 10/ 48th Street Bridge	324	109	113	93.6	4092	1280	3.2	9.4	nd	3.6	170	520	2	13
AC 2	—	135	—	156	—	433	—	—	—	430	—	610	—	350
AC 3	—	77	—	79.9	—	713	—	—	—	3.6	—	400	—	8
AC 4	71.8	58	80.2	78.5	305	912	38.8	347	9.2	240	130	930	49	280
AC 5/Weir	1142	166	243	106	11234	476	12	30.2	43	3.6	50	1120	350	2
AC 6/ Union Plaza	931	x	313	x	13883	x	4	6.9	nd	x	30	x	nd	x
AC 7	—	268	—	103	—	1058	—	—	—	nd	—	nd	—	2
AC 8	—	81	—	137	—	1050	—	—	—	9.2	—	40	—	8
AC 9/State Fair Park	652	x	160	x	2906	x	15.3	7.2	3.6	x	nd	x	33	x

Notes: X = no sediment to sample; nd = non-detect; — = not sampled for this event
mg/kg = milligram per kilogram; mpn/g = most probable number per gram; cfu/g = colony forming unit per gram
Source: EA Field Data 2011

Figure 5-19. 2010-2011 Sediment Sampling Results for Antelope Creek



Source: EA Field Data 2010-2011

Animal Sources Observed

Fecal deposition from birds and animals of all sizes can contribute to elevated bacteria concentrations in Antelope Creek. These contributions occur not only from areas immediately adjacent to the creek, but also from the broader watershed, particularly during runoff events. During water quality sampling events, EA staff recorded field observations related to potential animal sources along the creek. Table 5-17 provides a summary of these comments, which document the presence of pigeons, ducks, swallows and raccoons at various times. In particular, locations AC-4 and AC-5 appear to be influenced by pigeons and ducks, respectively. Surveys of animals and birds in other parts of the watershed were not recorded.

Table 5-17. Animals Observed During Sampling Events (2010-2011)

Date	Location	Animal Observations
5/27/2011	AC1	5 turkey vultures on dam
8/26/2011	AC1	Raccoon feces downstream of sampling
5/20/2011	AC2	Starlings sitting on edge of stream (~6)
5/20/2011	AC3	A few swallows nesting under bridge
5/20/2011	AC4	Pigeons downstream of sampling point (many under bridge)
8/19/2011	AC4	20 pigeons flew out from under bridge
9/2/2011	AC4	40 pigeons flew out from under bridge
11/12/2010	AC5	15-20 ducks 200 feet upstream in the stream
5/20/2011	AC5	Mallards swimming upstream (3 families) ~20
7/1/2011	AC5	Birds upstream (6-8), many birds downstream ~20 ducks
5/20/2011	AC8	Pigeons roosting on bridge downstream of sampling point (~6)
5/27/2011	AC9	Several horses east of site training area of former state fairgrounds
6/17/2011	AC9	Washing horse pens at former state fairgrounds
Tributaries/Outfalls		
7/1/2011	T12	A few barn swallow nests with feces piled beneath; raccoon tracks in outfall
7/1/2011	T7	Barn swallows inside (3) + turtle dove

Source: EA Field Survey 2010-2011

5.5. Overall Summary and Conclusions

Both historic and recent water quality and sediment data for Antelope Creek in Lincoln, Nebraska have been summarized and evaluated to support this Basin Plan. Based on sampling by NDEQ (2004, 2009), UNL/Mohlman et al. (2009) and EA (2010/2011), the following observations are provided to support recommendations to improve water quality in the main stem of Antelope Creek.

- Available data for Antelope Creek suggest diffuse sources of *E. coli* under dry weather conditions. Based on available information, it appears that the likely sources of bacteria are urban wildlife such as pigeons under bridges and other birds and wildlife, particularly in the park land and undeveloped areas of the riparian corridor where concentrated animal populations appear more common than other locations in the watershed.
- Although *E. coli* is elevated above stream standards in some dry weather outfall samples, the results do not suggest on-going illicit discharges such as failing sanitary sewer lines or illicit sanitary connections.
- Under wet weather conditions, *E. coli* concentrations are approximately an order of magnitude (10x) higher than dry weather conditions.
- Wet weather *E. coli* concentrations generally increase in a downstream direction, but no particular stream segment appears to be an *E. coli* “hot spot.”
- Sediment samples show that *E. coli* can reside in channel sediments, particularly in the AC-2 and AC-4 sample locations; however, concentrations are not particularly high in the sediments. For this reason, sediment does not appear to be a key source of *E. coli*, although *E. coli* present in sediments may contribute to elevated *E. coli*, particularly under runoff conditions when sediments are scoured and resuspended in the water column.
- Recent sampling data is generally within the range of sample results collected by NDEQ and others for this reach of stream.
- Overall, results suggest that the upper central portion of the stream segment (AC-2 to AC-6) may be an appropriate starting point to focus on non-structural and structural strategies to reduce *E. coli*.
- Based on the cumulative data sets now available, Antelope Creek attains water quality standards for ammonia and copper.
- Selenium, chloride and conductivity appear to be most elevated in the lower portion of the stream segment, with concentrations believed to be influenced by geologic conditions and groundwater contributions to the

stream in this area. Because sources of these constituents are expected to be naturally occurring, they have not been addressed in detail in this analysis.

- Based on the cumulative data set now available, Holmes Lake discharges to Antelope Creek generally attain stream standards for *E. coli*.
- The State Fairgrounds have been moved to another city, and all animal operations, including horse racing, will cease after 2013. The site is now being redeveloped into a private/public sector research campus associated with the University of Nebraska at Lincoln (Innovation Campus). As a result, the State Fairgrounds area is not expected to warrant additional investigation with regard to *E. coli.*

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SECTION 6 – POLLUTION SOURCES AND CONTROL STRATEGIES

6.1. Introduction

In order to develop an effective water quality master plan, it is essential to identify sources of pollutants in a watershed and then evaluate best management practices (BMPs) that can be utilized to reduce pollutant loads and improve in-stream water quality conditions. Sections 3 through 5 of this plan provide specific information regarding existing water quality concerns in Antelope Creek. From a regulatory perspective, the primary concern is fecal indicator bacteria (*E. coli*), with elevated concentrations occurring during both base flow and wet weather conditions. In addition to identifying measures that may reduce *E. coli* loads to the stream, the project team also considered best management practices (BMPs) that would increase the quality of stormwater runoff by reducing other water quality constituents (*i.e.,* solids, nutrients, metals, etc.).

To develop an understanding of sources of pollutant loading to Antelope Creek and BMPs expected to be effective at reducing these loads, Dr. Robert Pitt conducted Windows Source Loading and Management Model (WinSLAMM) modeling for the Antelope Creek watershed.

This section provides a brief overview of pollutant sources in urban runoff, followed by a summary of stormwater modeling results completed for Antelope Creek, and a discussion of structural and non-structural BMPs that may be effective at reducing pollutant loading and improving water quality in Antelope Creek.

To develop an understanding of sources of pollutant loading to Antelope Creek and BMPs expected to be effective at reducing these loads, Dr. Robert Pitt conducted Windows Source Loading and Management Model (WinSLAMM) modeling for the Antelope Creek watershed. This analysis provided useful information for evaluating pollutant loads from various land uses in the Antelope Creek watershed, as well as alternative management strategies and costs for reducing pollutant loads. The WinSLAMM modeling reports can be obtained upon request from the project team, and include the following detailed reports:

- *Lincoln, Nebraska Standard Land Use Characteristics and Pollutant Sources* (Pitt, 4/2011), which describes land use areas, expected stormwater characteristics, and pollutant sources.
- *Lincoln, Nebraska, Retrofit Stormwater Management Options* (Pitt, 7/2011), which provides descriptions of stormwater control practices, an analysis of results including the most suitable controls, and an appendix containing detailed modeling results for all constituents and land uses.

6.2. Pollutants

The chemical and physical characteristic of stormwater runoff change as urbanization occurs; requiring comprehensive planning and management to reduce adverse effects on receiving waters. As stormwater flows across roads, rooftops, and other surfaces, pollutants are picked up and then discharged to streams and lakes. Numerous studies conducted since the late 1970s show stormwater runoff from urban and industrial areas can be a significant source of pollution (EPA 1983; Driscoll et al. 1990; Pitt et al. 2008). Table 6-1 identifies a variety of pollutants and sources often found in urban settings such as solids, nutrients, pathogens, dissolved oxygen demands, metals, and oils.

The increased frequency, flow rate, duration, and volume of stormwater discharges due to urbanization can result in the scouring of rivers and streams, degrading the physical integrity of aquatic habitats, stream function, and overall water quality (EPA 2009). Impacts are site-specific (and watershed-specific) and vary depending on a host of factors. Although historical focus of stormwater management was either flooding or chemical water quality, more recently, the hydrologic and hydraulic (physical) changes in watersheds associated with urbanization are recognized as significant contributors to receiving water degradation. Whereas only a few runoff events per year may occur prior to development, many runoff events per year may occur after urbanization (Urbonas et al. 1989) for sites that have soils that readily infiltrate rainfall, and in the absence of onsite controls that reduce the frequency of post-development runoff. In the absence of controls, runoff peaks and volumes increase due to urbanization (UDFCD 2010).

Table 6-1. Common Urban Runoff Pollutant Sources

Pollutant Category Source	Solids	Nutrients	Pathogens	Dissolved Oxygen Demands	Metals	Oils	Synthetic Organics
Soil erosion	X	X		X	X		
Cleared vegetation	X	X		X			
Fertilizers		X	X	X			
Human waste	X	X	X	X			
Animal waste	X	X	X	X			
Vehicle fuels and fluids	X			X	X	X	X
Fuel combustion						X	
Vehicle wear	X			X	X		
Industrial and household	X	X		X	X	X	X
Industrial processes	X	X		X	X	X	X
Paints and					X	X	X
Pesticides				X	X	X	X
Stormwater facilities without proper	X	X	X	X	X	X	X

Adapted from: Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. 1994. *Fundamentals of Urban Runoff Management: Technical and Intuitional Issues*. Washington, DC: Terrene Institute and EPA.

In the Antelope Creek watershed, the primary source of pollutant loading that can be reduced through implementation of BMPs is expected to be stormwater. Given the complexities of pollutant loading associated with urban land uses, the project sponsors selected a modeling approach based on WinSLAMM to better understand pollutant sources, concentrations, treatment approaches and costs.

6.2.1 WinSLAMM Setup and Scenarios

Lincoln's WinSLAMM model was developed using site specific land-use information from the Antelope Creek watershed collected by the project team. WinSLAMM calculates concentrations, mass discharges, percentage contributions, and control benefits for a broad range of stormwater constituents. The following information and concepts are incorporated into WinSLAMM:

- Soil type (see Section 3.2.1: Physical Setting, for more information)
- Land use area and types
- Local rainfall records
- Development characteristics
- BMPs

The Antelope Creek WinSLAMM modeling effort focused on nine land use categories as seen in Table 6-2. Thirty sites were surveyed within the Antelope Creek watershed to help refine the attributes of the nine land use categories. Attributes of interest included impervious cover types and quantities (many subcategories of impervious area are available in WinSLAMM), landscaping, roofing materials, drainage system information, etc. The surface type in urban areas determines the magnitude of runoff, as well as the amount of pollutants that are conveyed from that area. As an example, pitched roofs are much more efficient in producing runoff than flat roofs. Treated wood, galvanized metals, and other coverings, all affect the concentrations of heavy metals from roofs. Table 6-2 summarizes a few key characteristics of the different land uses in WinSLAMM.

Table 6-2. Typical Land Use Characteristics

Land Use Category	Percent of Roofs that are Directly Connected	Percent Total Directly Connected Impervious Areas (DCIA)	Percent Total Partially Connected Impervious Areas	Percent Total Pervious Areas
Low density residential	12	18	16	66
Med density residential <1960	16	22	20	58
Med density residential 1960-1980	24	18	19	63
Light industry	55	58	27	15
Commercial—strip mall	100	86	0	14
Commercial—shopping center	100	88	0	12
Institutional—school	100	56	0.5	44
Institutional—church	37	44	10	46
Institutional—hospital	80	62	5	33

Source: Pitt 7/2011

6.2.2 WinSLAMM Results – Flow and Pollutant Sources

In *Lincoln, Nebraska Standard Land Use Characteristics and Pollutant Sources* (Pitt, 4/2011), WinSLAMM model results estimating runoff volumes and pollutant loads for various land uses were developed. A summary of these findings is shown in Table 6-3. Results are provided for three general rain event categories: small (<0.5 inches), intermediate (0.5 to 2 inches), and large (>2 inches). See Appendix C of Pitt's April 2011 WinSLAMM report for more detailed results. The results in Table 6-3 are important in terms of identifying the relative contribution of various source areas. Additional discussion based on rain event and source area characteristics follows. Discussions in Section 6.2.2 and 6.2.3 have been established based upon Pitt's WinSLAMM reports completed for the City in 2011.

Rain Event Categories

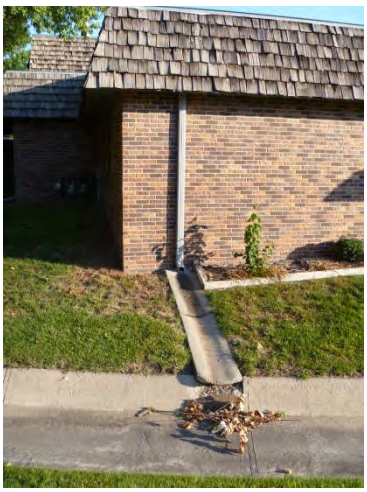
The small rainfall event category generally includes most of the rain and runoff events by number, but produces a small fraction of the annual runoff mass. This category of events is therefore of greatest interest when the number of events is of concern. If stormwater discharges have numeric effluent limits, then the number of runoff events is of the greatest concern, and stormwater control strategies would focus on eliminating as many of the runoff events as practical. By lowering the total number of runoff events, the overall frequency of events discharging stormwater to the stream is lowered. For example, if numeric limits were applied to stormwater discharges, typical numeric standards for bacteria and total recoverable heavy metals would be frequently exceeded. Therefore, runoff volume, bacteria, and heavy metals would be of the greatest interest for removal from the small rain category.

The intermediate rain event category generally includes most of the runoff pollutant discharges by mass; frequently more than 75% of the annual pollutant discharges, by mass. It is therefore desirable to remove as much of the runoff volume as feasible from this rain category. However, site soil and development conditions will typically prevent the elimination of all runoff from this category. Therefore, stormwater treatment will be needed for the constituents of concern for runoff that will be discharged. Flow reduction will always be of interest, but further treatment of stormwater to reduce bacteria, nutrients, and /or heavy metals will also likely be necessary.

The largest rain category includes events that occur less frequently and are generally described as channel-forming; often with significant effects on habitat conditions. These events are the primary focus for drainage design and public safety and rely on basin-wide hydraulic analyses results to determine the most effective stormwater management and drainage options. It is unlikely that pollutant discharges would be of great concern during these large events, as they contribute relatively small fractions of the amortized annual flows, and most treatment methods that could manage these large flows would be costly and inefficient. Thus, these large events are not the primary focus of the Basin Plan, although practices that reduce runoff volumes may still provide some benefit during these larger storms.

Flow Sources

As shown in Table 6-3, most of the flows originate from the directly connected impervious areas (DCIA) such as paved parking lots, roofs, driveways, and streets. However, undeveloped or landscaped areas can contribute large portions of the flows if these areas are very large (such as in the residential areas) and/or if they have “tight” soils, with low infiltration rates. For these areas, the landscaped/undeveloped areas can produce significant flows during large rain events. The goal of most stormwater management programs should therefore be to reduce runoff from the DCIA. However, there are many conditions where large-scale infiltration of stormwater may not be desirable (mainly in areas having severely limited soils that hinder infiltration, shallow groundwater, or other factors that would not adequately mitigate pollutant movement to the groundwater). In most cases, roof runoff, being the least contaminated DCIA source water, should be preferentially infiltrated or used on site for beneficial uses.



Picture 13: Directly connected impervious areas are common throughout the City

In residential areas, the roof runoff comprises about 15% of the total annual runoff amount, mainly because most of the roofs are disconnected (Pitt 4/2011). Streets can comprise the majority of the total flows in residential areas during small to intermediate events. A typical strategy in residential areas would therefore be to apply rain gardens, or otherwise disconnect the roof drainage, for roof runoff control (for currently directly connected roofs). If possible, soil amendments and other strategies to reduce soil compaction to improve infiltration in the landscaped areas can reduce runoff from those areas. Street and driveway runoff are significant flow and pollutant sources. If the area was drained using grass swales, runoff peaks and volumes will be reduced. If drained by conventional curb and gutter, curb-cut bioretention areas could be a retrofit project to significantly reduce runoff (and associated pollutants); particularly for small events. In residential areas having loamy soils that are not compacted and are drained by grass swales, especially if most of the impervious areas are disconnected and drain to pervious areas, no additional or few stormwater controls may be needed. High-density residential areas having larger amounts of impervious areas will normally require additional BMPs.

Runoff from commercial areas primarily originates from paved parking areas, streets, and roofs, unless they are situated in heavy clay soils, where the soils can also be a significant source of runoff. Impervious areas can also be the main sources for many of the pollutants examined, although others such as solids, bacteria and nutrients may be found in higher concentrations in runoff from pervious areas. Commercial areas are often limited on space for development of BMPs that address a single runoff source. A more appropriate approach may be to use a bioretention area that receives runoff from multiple sources such as from roofs and parking areas. Parking areas, islands or the edge of landscaped areas can be retrofitted with infiltration devices for significant runoff volume reductions or for control of critical pollutant source areas such as automobile activity and galvanized metals.

Flows and pollutants in industrial areas originate, primarily, from paved parking and storage areas. Roofs and streets are lesser, but still important sources. Infiltration in these areas is of greater concern as the runoff from industrial areas is more likely to result in groundwater contamination. Critical source area controls (such as media filtration and biofilters using specialized media as part of treatment trains) are often necessary, along with pollution prevention to reduce the exposure of metals, especially galvanized, and other materials. In some industrial areas, stormwater can be used for dust suppression. If the site is relatively large, wet detention ponds could also be located on available land to collect and further treat remaining surface runoff.

Some institutional areas are predominately landscaped, with less directly connected impervious areas and larger landscaped or undeveloped areas for stormwater management. Designing stormwater management features that take advantage of the topography in these areas can result in significant runoff discharge reductions. Most institutional areas in the Antelope Creek drainage basin have large parking areas with long-term parking that could benefit from parking lot islands or perimeter bioretention areas.

Table 6-3: Summary of Major Sources of Flows and Pollutants

	Commercial – Strip Mall	Commercial – Shopping Center	Light Industrial	Institutional - Schools	Institutional - Churches	Institutional - Hospitals	Residential – Low Density	Residential – Medium Density (<1960)	Residential – Medium Density (1960 - 1980)
Flows									
Small	Paved parking (56%) Streets (23%) Roofs (21%)	Paved parking (58%) Roofs (22%) Streets (20%)	Park/stor (55%) Streets (20%) Driveways (19%)	Paved parking (52%) Roofs (32%) Streets (11%)	Paved parking (46%) Streets (33%) Roofs (15%)	Paved parking (63%) Roofs (24%) Streets (11%)	Streets (73%) Driveways (15%) Roofs (12%)	Streets (68%) Driveways (16%) Roofs (16%)	Streets (55%) Roofs (28%) Driveways (16%)
Intermediate	Paved parking (50%) Roofs (30%) Streets (19%)	Paved parking (51%) Roofs (32%) Streets (17%)	Park/stor (53%) Streets (18%) Driveways (14%)	Roofs (42%) Paved parking (41%)	Paved parking (44%) Streets (31%) Roofs (13%)	Paved parking (53%) Roofs (33%)	Streets (60%) Landscaping (15%) Driveways (12%) Roofs (11%)	Streets (59%) Driveways (15%) Roofs (14%) Landscaping (11%)	Streets (47%) Roofs (24%) Driveways (15%) Landscaping (14%)
Large	Paved parking (51%) Roofs (28%) Streets (17%)	Paved parking (52%) Roofs (30%) Streets (15%)	Park/stor (49%) Streets (15%) Driveways (14%)	Paved parking (39%) Roofs (37%) Landscaping (11%)	Paved parking (40%) Streets (24%) Landscaping (15%) Roofs (10%)	Paved parking (51%) Roofs (30%) Landscaping (10%)	Landscaping (40%) Streets (38%) Roofs (14%)	Streets (40%) Landscaping (32%) Roofs (16%) Driveways (11%)	Landscaping (37%) Streets (29%) Roofs (16%) Driveways (11%)
Total Suspended Solids									
Small	Paved parking (83%) Roofs (12%)	Paved parking (84%) Roofs (12%)	Park/stor (78%) Streets (11%) Driveways (10%)	Paved parking (48%) Streets (40%)	Streets (78%) Paved parking (18%)	Paved parking (48%) Streets (46%)	Streets (92%)	Streets (92%)	Streets (90%)
Intermediate	Paved parking (83%) Roofs (13%)	Paved parking (84%) Roofs (13%)	Park/stor (74%) Driveways (12%)	Paved parking (53%) Streets (19%) Roofs (14%)	Streets (56%) Paved parking (30%)	Paved parking (59%) Streets (24%)	Streets (86%)	Streets (88%)	Streets (86%)
Large	Paved parking (64%) Roofs (23%)	Paved parking (66%) Roofs (24%)	Park/stor (87%) Driveways (4%)	Paved parking (47%) Landscaping (30%) Roofs (11%)	Paved parking (37%) Streets (26%) Landscaping (25%)	Paved parking (59%) Landscaping (20%) Streets (10%)	Streets (47%) Landscaping (44%)	Streets (53%) Landscaping (35%)	Streets (48%) Landscaping (40%)
Chemical Oxygen Demand									
Small	Paved parking (67%) Roofs (28%)	Paved parking (67%) Roofs (29%)	Park/stor (73%) Streets (15%) Driveways (10%)	Roofs (42%) Paved parking (37%) Streets (17%)	Streets (56%) Paved parking (25%) Roofs (14%)	Paved parking (46%) Roofs (30%) Streets (22%)	Streets (84%) Driveways (11%)	Streets (71%) Driveways (11%)	Streets (77%) Driveways (11%)
Intermediate	Paved parking (63%) Roofs (31%)	Paved parking (63%) Roofs (32%)	Park/stor (69%) Streets (13%) Driveways (10%)	Roofs (53%) Paved parking (29%)	Streets (37%) Paved parking (32%) Roofs (16%) Landscaping (10%)	Roofs (43%) Paved parking (40%) Streets (10%)	Streets (77%) Landscaping (11%)	Streets (79%)	Streets (73%) Landscaping (10%)
Large	Paved parking (44%) Roofs (42%) Streets (11%)	Paved parking (44%) Roofs (44%) Streets (10%)	Park/stor (81%)	Roofs (44%) Paved parking (26%) Landscaping (24%)	Landscaping (32%) Paved parking (28%) Streets (18%) Roofs (14%)	Roofs (40%) Paved parking (38%) Landscaping (15%)	Landscaping (45%) Streets (40%)	Streets (45%) Landscaping (36%)	Landscaping (41%) Streets (37%) Roofs (10%)
Total Phosphorus									
Small	Paved parking (61%) Roofs (31%)	Paved parking (61%) Roofs (33%)	Park/stor (53%) Streets (24%) Driveways (20%)	Paved parking (43%) Roofs (27%) Streets (16%)	Streets (49%) Paved parking (29%) Driveways (12%) Roofs (10%)	Paved parking (54%) Streets (20%) Roofs (20%)	Streets (88%) Driveways (10%)	Streets (87%) Driveways (10%)	Streets (85%) Driveways (10%)
Intermediate	Paved parking (53%) Roofs (31%)	Paved parking (54%) Roofs (33%)	Park/stor (48%) Streets (22%) Driveways (20%)	Landscaping (30%) Paved parking (25%) Roofs (25%)	Landscaping (39%) Streets (22%) Paved parking (22%)	Paved parking (36%) Landscaping (30%) Roofs (22%)	Streets (58%) Landscaping (36%)	Streets (64%) Landscaping (29%)	Streets (58%) Landscaping (34%)

	Commercial – Strip Mall	Commercial – Shopping Center	Light Industrial	Institutional - Schools	Institutional - Churches	Institutional - Hospitals	Residential – Low Density	Residential – Medium Density (<1960)	Residential – Medium Density (1960 - 1980)
Large	Landscaping (39%) Paved parking (36%) Roofs (25%)	Landscaping (34%) Paved parking (31%) Roofs (28%)	Park/stor (59%) Streets (16%) Driveways (10%) Landscaping (12%)	Landscaping (56%) Paved parking (12%) Roofs (12%)	Landscaping (74%) Paved parking (11%)	Landscaping (62%) Paved parking (20%) Roofs (12%)	Landscaping (81%) Streets (15%)	Landscaping (75%) Streets (20%)	Landscaping (79%) Streets (15%)
Total Kjeldahl Nitrogen									
Small	Paved parking (64%) Roofs (29%)	Paved parking (64%) Roofs (30%)	Park/stor (64%) Driveways (18%) Streets (13%)	Roofs (40%) Paved parking (36%) Streets (19%)	Streets (58%) Paved parking (35%) Roofs (14%)	Paved parking (44%) Roofs (40%) Streets (24%)	Streets (79%) Driveways (14%)	Streets (76%) Driveways (14%)	Streets (69%) Driveways (14%)
Intermediate	Paved parking (58%) Roofs (33%)	Paved parking (58%) Roofs (34%)	Park/stor (56%) Driveways (18%) Streets (10%)	Roofs (46%) Paved parking (25%) Streets (14%) Landscaping (14%)	Streets (35%) Paved parking (25%) Landscaping (18%) Roofs (13%)	Roofs (39%) Paved parking (35%) Landscaping (14%) Streets (11%)	Streets (52%) Landscaping (37%)	Streets (57%) Landscaping (29%)	Streets (49%) Landscaping (34%)
Large	Roofs (38%) Paved parking (34%) Landscaping (19%)	Roofs (41%) Paved parking (35%) Landscaping (16%)	Park/stor (64%) Landscaping (11%) Roofs (10%)	Landscaping (36%) Roofs (30%) Paved parking (18%)	Landscaping (46%) Paved parking (18%) Streets (15%)	Landscaping (37%) Roofs (28%) Paved parking (27%)	Landscaping (78%) Streets (14%)	Landscaping (71%) Streets (18%)	Landscaping (75%) Streets (14%)
Nitrites + nitrates									
Small	Paved parking (48%) Roofs (27%) Streets (25%)	Paved parking (49%) Roofs (29%) Streets (22%)	Park/stor (50%) Streets (24%) Driveways (16%)	Paved parking (43%) Roofs (41%) Streets (12%)	Streets (37%) Paved parking (39%) Roofs (19%)	Paved parking (55%) Roofs (31%) Streets (12%)	Streets (73%) Driveways (12%)	Streets (68%) Roofs (17%) Driveways (13%)	Streets (53%) Roofs (34%) Driveways (13%)
Intermediate	Paved parking (41%) Roofs (37%) Streets (21%)	Paved parking (42%) Roofs (40%) Streets (18%)	Park/stor (50%) Streets (21%) Driveways (14%)	Roofs (52%) Paved parking (33%)	Paved parking (38%) Streets (34%) Landscaping (15%) Roofs (14%)	Paved parking (44%) Roofs (42%) Streets (10%)	Streets (60%) Landscaping (16%) Roofs (14%) Driveways (10%)	Streets (59%) Roofs (17%) Landscaping (12%) Driveways (11%)	Streets (45%) Roofs (28%) Landscaping (14%)
Large	Paved parking (42%) Roofs (36%) Streets (18%)	Paved parking (43%) Roofs (38%) Streets (16%)	Park/stor (55%) Streets (18%) Driveways (12%)	Roofs (46%) Paved parking (31%) Landscaping (11%)	Paved parking (34%) Streets (27%) Landscaping (18%) Roofs (14%)	Paved parking (42%) Roofs (38%) Landscaping (10%)	Landscaping (41%) Streets (36%) Roofs (15%)	Streets (38%) Landscaping (33%) Roofs (19%) Driveways (14%)	Landscaping (38%) Streets (28%) Roofs (25%)
Total Copper									
Small	Paved parking (79%) Roofs (16%)	Paved parking (80%) Roofs (14%)	Park/stor (63%) Roofs (31%)	Paved parking (51%) Streets (28%) Roofs (17%)	Streets (68%) Paved parking (25%)	Paved parking (54%) Streets (33%) Roofs (11%)	Streets (65%) Driveways (17%)	Streets (74%) Driveways (18%)	Streets (53%) Driveways (18%)
Intermediate	Paved parking (77%) Roofs (16%)	Paved parking (78%) Roofs (16%)	Park/stor (52%) Roofs (31%) Streets (10%)	Paved parking (50%) Roofs (28%) Streets (15%)	Streets (50%) Paved parking (37%)	Paved parking (59%) Roofs (20%) Streets (18%)	Streets (74%) Driveways (13%)	Streets (74%) Driveways (13%)	Streets (68%) Driveways (15%) Roofs (10%)
Large	Paved parking (62%) Roofs (25%) Streets (11%)	Paved parking (63%) Roofs (26%) Streets (10%)	Park/stor (58%) Roofs (33%)	Paved parking (52%) Roofs (27%)	Paved parking (45%) Streets (32%) Landscaping (10%)	Paved parking (62%) Roofs (19%) Streets (10%)	Streets (42%) Landscaping (33%) Driveways (13%) Roofs (10%)	Streets (45%) Landscaping (25%) Driveways (14%) Roofs (11%)	Streets (37%) Landscaping (29%) Driveways (14%) Roofs (14%)
Total Lead									
Small	Paved parking (75%) Roofs (22%)	Paved parking (75%) Roofs (23%)	Park/stor (76%) Driveways (16%)	Paved parking (51%) Streets (25%) Roofs (21%)	Streets (66%) Paved parking (26%)	Paved parking (55%) Streets (31%) Roofs (13%)	Streets (75%) Driveways (15%) Roofs (10%)	Streets (73%) Driveways (15%) Roofs (12%)	Streets (65%) Roofs (21%) Driveways (14%)
Intermediate	Paved parking (74%) Roofs (24%)	Paved parking (73%) Roofs (25%)	Park/stor (73%) Driveways (16%)	Paved parking (49%) Roofs (33%) Streets (10%)	Streets (44%) Paved parking (40%)	Paved parking (58%) Roofs (23%) Streets (14%)	Streets (70%) Landscaping (13%) Driveways (10%)	Streets (71%) Driveways (10%)	Streets (65%) Roofs (14%) Landscaping (11%) Driveways (10%)

	Commercial – Strip Mall	Commercial – Shopping Center	Light Industrial	Institutional - Schools	Institutional - Churches	Institutional - Hospitals	Residential – Low Density	Residential – Medium Density (<1960)	Residential – Medium Density (1960 - 1980)
Large	Paved parking (53%) Roofs (40%)	Paved parking (53%) Roofs (42%)	Park/stor (87%)	Paved parking (48%) Roofs (30%) Landscaping (12%)	Paved parking (47%) Streets (21%) Landscaping (17%)	Paved parking (60%) Roofs (23%) Landscaping (10%)	Landscaping (49%) Streets (28%) Roofs (12%) Driveways (11%)	Landscaping (40%) Streets (32%) Roofs (15%) Driveways (12%)	Landscaping (42%) Streets (27%) Roofs (18%) Driveways (11%)
Total Zinc									
Small	Paved parking (68%) Roofs (27%)	Paved parking (68%) Roofs (28%)	Park/stor (76%) Streets (10%)	Paved parking (43%) Roofs (33%) Streets (22%)	Streets (64%) Paved parking (25%) Roofs (10%)	Paved parking (49%) Streets (28%) Roofs (22%)	Streets (80%) Roofs (12%)	Streets (77%) Roofs (14%)	Streets (67%) Roofs (24%)
Intermediate	Paved parking (67%) Roofs (29%)	Paved parking (66%) Roofs (31%)	Park/stor (70%) Roofs (15%)	Roofs (49%) Paved parking (39%)	Streets (45%) Paved parking (37%) Roofs (12%)	Paved parking (48%) Roofs (36%) Streets (13%)	Streets (76%) Roofs (10%)	Streets (76%) Roofs (11%)	Streets (68%) Roofs (18%)
Large	Paved parking (48%) Roofs (46%)	Paved parking (48%) Roofs (47%)	Park/stor (78%) Roofs (15%)	Roofs (47%) Paved parking (41%)	Paved parking (46%) Streets (25%) Roofs (15%)	Paved parking (51%) Roofs (36%)	Streets (43%) Landscaping (33%) Roofs (17%)	Streets (46%) Landscaping (25%) Roofs (20%)	Streets (37%) Landscaping (28%) Roofs (24%)
Fecal Coliform Bacteria									
Small	Paved parking (70%) Streets (25%)	Paved parking (74%) Streets (23%)	Driveways (68%) Streets (25%)	Paved parking (73%) Driveways (16%)	Paved parking (58%) Driveways (21%) Streets (18%)	Paved parking (83%) Driveways (10%)	Driveways (59%) Streets (41%)	Driveways (61%) Streets (38%)	Driveways (66%) Streets (32%)
Intermediate	Paved parking (69%) Streets (23%)	Paved parking (73%) Streets (22%)	Driveways (65%) Streets (24%)	Paved parking (71%) Driveways (15%)	Paved parking (57%) Driveways (21%) Streets (17%)	Paved parking (82%) Driveways (10%)	Driveways (53%) Streets (37%)	Driveways (56%) Streets (34%)	Driveways (59%) Streets (29%)
Large	Paved parking (70%) Streets (21%)	Paved parking (74%) Streets (19%)	Driveways (58%) Streets (21%)	Paved parking (69%) Driveways (12%)	Paved parking (57%) Driveways (18%) Streets (15%)	Paved parking (80%)	Driveways (41%) Streets (28%) Landscaping (21%)	Driveways (44%) Streets (27%) Landscaping (15%)	Driveways (44%) Streets (21%) Landscaping (19%)
E. Coli Bacteria									
Small	Paved parking (70%) Streets (25%)	Paved parking (75%) Streets (23%)	Driveways (58%) Streets (36%)	Paved parking (73%) Driveways (16%)	Paved parking (58%) Driveways (21%) Streets (18%)	Paved parking (83%) Driveways (10%)	Driveways (58%) Streets (41%)	Driveways (61%) Streets (38%)	Driveways (66%) Streets (32%)
Intermediate	Paved parking (70%) Streets (24%)	Paved parking (74%) Streets (22%)	Driveways (55%) Streets (34%)	Paved parking (71%) Driveways (15%)	Paved parking (57%) Driveways (21%) Streets (17%)	Paved parking (82%) Driveways (10%)	Driveways (53%) Streets (37%)	Driveways (56%) Streets (34%)	Driveways (59%) Streets (29%)
Large	Paved parking (71%) Streets (22%)	Paved parking (75%) Streets (20%)	Driveways (49%) Streets (30%) Park/stor (10%)	Paved parking (70%) Driveways (13%)	Paved parking (57%) Driveways (18%) Streets (15%)	Paved parking (81%)	Driveways (43%) Streets (30%) Landscaping (18%)	Driveways (46%) Streets (29%) Landscaping (13%)	Driveways (47%) Streets (23%) Landscaping (16%)

6.2.3 WinSLAMM Results – BMP Removal Effectiveness

After the model was calibrated for conditions in Antelope Creek, 28 stormwater BMP scenarios were evaluated for the nine land use categories throughout the Antelope Creek watershed (Pitt 7/2011). Two different soil conditions were also modeled based on the most prevalent soil conditions in the watershed: clay loam and sandy loam. The BMP modeling scenarios are listed in Table 6-4. Although other management strategies may also be considered, Table 6-4 provides a basic list of practices that can be used to compare general alternatives and costs to reduce stormwater-related pollutant loads in the watershed. Detailed comparisons of alternative control approaches and associated costs are provided in a series of comparative tables and figures within Pitt (7/2011).

Table 6-4. Stormwater BMP Modeling Scenarios

Scenario	Scenario (cont.)
Rain garden (3% of connected roofs only)	Street cleaning daily
Rain garden (15% of connected roofs only)	Street cleaning monthly
Rain garden (3% of all roofs)	Street cleaning weekly
Rain garden (15% of all roofs)	Street cleaning once in spring and fall
Rain barrels (few)	Catchbasin cleaning
Rain barrels	Grass swale drainage
Rain barrels (many)	Wet pond 0.8%
Rain tanks (small)	Wet pond 1.6%
Rain tanks (medium)	Small wet pond and rain tanks
Rain tanks (large)	Small wet pond and rain gardens (15% of all roofs
Porous pavement on driveways	Small wet pond and swales
Curb-cut biofilters 20%	Small wet pond and curb biofilters 40%
Curb-cut biofilters 40%	Small wet pond, rain garden (15% of all roofs) and curb biofilters 40%
Curb-cut biofilters 80%	--

Source: Pitt 7/2011

For runoff volume controls, each land use group had similar most cost-effective controls in areas having clay loam soils and practices providing at least a 25% reduction in runoff volume. Modeling results for stormwater controls for various source areas are listed below. Controls are listed in the following order: The first control listed has the lowest level of maximum control, but the highest unit cost-effectiveness; and the last control listed has the highest level of maximum control, but the lowest unit cost-effectiveness. Therefore, if low to moderate levels of control are suitable, the first control option may be best. However, if maximum control levels are needed, then the last control option listed would be needed. The resulting summary of stormwater control options by source area includes:

- Strip mall and shopping center areas:
  - Porous pavement (in half of the parking areas)
  - Curb-cut biofilters (along 80% of the curbs) for strip malls or biofilters in parking areas (10%of the source area) for shopping centers
  - Biofilters in parking areas (10% of the source area) and curb-cut biofilters (along 40% of the curbs)
- Light industrial areas:
  - Curb-cut biofilters (along 40% of the curbs)
  - Roofs and parking areas half disconnected from the directly connected impervious areas (DCIA)
  - Roofs and parking areas all disconnected from DCIA
- School, church, and hospital institutional areas:
  - Small rain tank (0.10 $feet^3$ storage per $feet^2$ of roof area) for schools and churches; rain tank (0.25 $feet^3$ storage per $feet^2$ of roof area) for hospitals
  - Roofs and parking areas half disconnected from DCIA

    - Roofs and parking areas all disconnected from DCIA
- Low and medium density residential areas:
    - Curb-cut biofilters (along 20% of the curbs)
    - Curb-cut biofilters (along 40% of the curbs)
    - Curb-cut biofilters (along 80% of the curbs)

For suspended solids, all areas show that wet detention ponds are the most cost-effective control option, irrespective of the conditions. Obviously, other factors may influence the selection of the "best" stormwater control program for an area, beyond least cost for the level of control needed. As an example, wet detention ponds, while being the most cost-effective, are likely very difficult to retrofit into existing areas. However, these analyses indicate that these controls should not be rejected without careful evaluation and searching for potential locations.

Detailed information for all constituents examined (runoff volume, Rv, TSS, TDS, total and filterable phosphorus, nitrates, total and filterable TKN, total and filterable COD, total and filterable copper, total and filterable lead, total and filterable zinc, fecal coliform bacteria, and *E. coli* bacteria) is presented for each land use and soil combination for each set of stormwater controls in the appendices developed by Pitt (7/2011).

6.3. Structural BMPs

The modeling results provided by Pitt (7/2011) can be used to prioritize selection of stormwater BMPs expected to be effective at reducing pollutant loads in Lincoln. Additional factors also influence BMP selection that should be considered early in site development or the retrofitting process. In addition to the BMPs modeled by Pitt (7/2011), other BMP types may also be appropriate. Appendix A provides an overview of several structural BMP types that may be considered for use in the Antelope Creek watershed, including a basic description of site selection factors, general benefits, and limitations. A table is also included for each structural BMP that summarizes their function, typical effectiveness for targeted pollutants, and other considerations. BMPs listed in Appendix A are listed below:

- Grass Buffer
- Grass Swale
- Bioretention (Rain Garden)
- Green Roof
- Extended Detention Basin
- Retention Pond
- Sand Filter Basin
- Constructed Wetland Pond
- Constructed Wetland Channel
- Permeable Pavement Systems
- Underground Practices (when surface BMPs are not feasible)

6.3.1 Selection Criteria

Many different factors should be considered when selecting BMPs for new development or redevelopment projects, based on site-specific conditions. Typically, there is not a single answer to the question of which BMP (or BMPs) should be selected for a site. There are usually multiple solutions, ranging from stand-alone BMPs to treatment trains that combine multiple BMPs, to achieve the stormwater management objectives. When selecting BMPs for a site, selection criteria involve many factors, including:

- Retrofitting and Availability of Land
- Sodium Adsorption Ratio (SAR)
- Clogging of infiltration devices
- Groundwater contamination potential
- Targeted pollutants and BMP processes
- Maintenance and sustainability
- Cost and Performance (discussed further in Section 6.4)

In addition to the criteria listed above, the benefits and limitations listed with each BMP in Appendix A should be deliberated when considering a particular BMP for installation.

Retrofitting and Availability of Land

For the most part, BMPs that are considered in this Basin Plan are those that can be used to retrofit existing developed areas to provide more effective reduction of stormwater pollutant loads. This is one reason that several curb-cut biofilter scenarios were evaluated as part of the WinSLAMM modeling (Pitt 7/2011). For example, curb-cut biofilters can be installed during scheduled repaving and sidewalk repairs that usually occur in many areas every few decades. Rain gardens can be installed by the homeowners with no cost to the City. Street cleaning can be conducted with no change to the land. Redevelopment and new construction periods are the most suitable times for installation for many of these controls in order to have the least interferences with current residents and for the least costs. Table 6.5 outlines the land consumption based on impervious area for a variety of BMPs. Table 6.6 outlines the land requirements and retrofitting potential for an array of BMPs.

Table 6-5. Relative Land Consumption of Stormwater Controls

Stormwater Control Type	Land Consumption (% of Impervious Area of the Watershed)
Retention Basin	2 to 3%
Constructed Wetland	3 to 5%
Infiltration Trench	2 to 3%
Infiltration Basin	2 to 3%
Permeable Pavement	0%
Sand Filters	0 to 3%
Bioretention	5%
Swales	10 to 20%
Grass Buffer	10%

Source: USEPA, 1999

Table 6-6. BMPs Ability to Retrofit and Land Requirements

Controls	Ability to Retrofit	Land Requirements
Roof Runoff Controls		
Rain Gardens	Easy in areas having landscaping	Part of landscaping area
Disconnections	Only suitable if adjacent pervious area is adequate (mild slope and long travel path)	Part of landscaping area
Rain Barrels and Water Tanks	Easy, located close to building, or underground large tanks	Supplements landscaping irrigation, no land requirements
Pavement Controls		
Disconnections	Only suitable if adjacent pervious area is adequate (mild slope and long travel path)	Most large paved areas are not adjacent to suitable large turf areas, except for schools; no additional land requirements, but land is needed.
Biofiltration	Easy if parking lot islands can be rebuilt as bioretention areas; perimeter areas also possible (especially good if existing stormwater drainage system can be used to easily collect overflows)	Part of landscaped islands in parking areas, or along parking area perimeters

Controls	Ability to Retrofit	Land Requirements
Porous Pavement	Very difficult as a retrofit, as it would require complete replacement of pavement system; possible if during re-building effort	Concurrent use of parking area with no reduction in parking spaces
Street Side Drainage Controls		
Grass Swales	Very difficult to retrofit. Suitable if existing swales are to be rebuilt.	Part of street right-of-way
Curb-cut Biofilters	Difficult to retrofit, but much easier than simple swales. Usually built to work with existing drainage system. Can do extensions into parking lanes/shoulders to increase areas.	Part of street right-of-way, but can be major nuisance during construction and may consume street side parking. Can be used to rebuild street edge and improve aesthetics.
Public Works Practices		
Street Cleaning	Very easy, but most effective in areas having smooth streets. If in areas of extensive parking, parking restrictions on days of street cleaning may be needed.	None
Catchbasin Cleaning	Very easy, but requires sumps in catchbasin inlets and hooded outlets for most effective performance. Existing inlets can be replaced with suitable catchbasins	None
Outfall Controls		
Wet Detention Ponds	Usually difficult as land not typically readily available. Can retrofit existing dry detention pond.	Land needed at outfall location, or retrofit existing stormwater control located at outfall location.

Source: Pitt 7/2011

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) can radically degrade the performance of an infiltration device, especially when clays are present in the infiltration layers of a device, and snowmelt containing deicing salts enters the device. Soils with an excess of sodium ions, compared to calcium and magnesium ions, remain in a dispersed condition, and are almost impermeable to rain or applied water. A “dispersed” soil is extremely sticky when wet, tends to crust, and becomes very hard and cloddy when dry. Water infiltration is therefore severely restricted. SAR has been documented causing premature failures of biofiltration devices in northern communities. These failures occur when snowmelt water is allowed to enter a biofilter that has clay in the soil mixture. In order to minimize this failure, do not allow snowmelt water to enter a biofilter unit. As an example, roof runoff likely has little salt and SAR problems seldom occur for roof runoff rain gardens. The largest problem is associated with curb-cut biofilters or parking lot biofilters in areas with snowmelt entering these devices, especially if clay is present in the engineered backfill soil (Pitt 7/ 2011).

The simplest method to minimize degraded performance due to SAR is to not allow snowmelt water to enter a biofilter unit. Another method is to construct a biofilter fill soil without clay. It appears that even a small percentage of clay can present a problem, but little information is currently available on the tolerable clay content of biofilter soils. One helpful improvement to a biofilter unit is the use of an engineered soil mixture of sand and an organic material (such as compost, if nutrient leaching is not an issue or Canadian peat for a more stable material having little nutrient leaching potential) (Pitt 7/2011).

Clogging of Infiltration Devices

The design of infiltration devices must include a review of their clogging potential. As an example, a relatively small and efficient biofilter (in an area having a high native infiltration rate) may capture a large amount of sediment. Having a small surface area, this sediment would accumulate rapidly over the area, possibly reaching a critical

clogging load early in its design lifetime. Infiltration and bioretention devices may show significantly reduced infiltration rates after about 2 to 5 lb/ft^2 (10 to 25 kg/m^2) of particulate solids have been loaded (Pitt 7/2011).

Deeply-rooted vegetation and a healthy soil structure can extend the actual life much longer. However, compaction and excessive siltation can significantly reduce the life of the system. If this critical load accumulates relatively slowly (taking approximately 10 or more years to reach this total load) and if healthy vegetation with deep roots is present, the infiltration rate may not significantly degrade due to the plant's activities in incorporating the imported sediment into the soil column. If this critical load accumulates in just a few years or if healthy vegetation is not present, premature failure due to clogging may occur. Therefore, relatively large surface areas may be necessary in locations having large sediment contents in the runoff, or suitable pre-treatment to reduce the sediment load entering the biofilter or infiltration device would be necessary (Pitt 7/2011).

The calculated annual suspended solids loading from an area can be used to determine the clogging potential for a bioretention device having a specific surface area. Examples of these calculations are located within the WinSLAMM report.

Groundwater Contamination Potential

The potential to contaminate groundwater by infiltrating stormwater is dependent on the concentrations of the contaminants in the infiltrating stormwater and how effective those contaminants may travel through the soils and vadose zone to the groundwater. Stormwater from residential areas is not likely contaminated with compounds having significant groundwater contaminating potential (with the exception of high salinity snowmelt waters). In contrast, commercial and industrial areas are likely to have greater concentrations of contaminants of concern that may affect the groundwater adversely. Therefore, pretreatment of the stormwater before infiltration may be necessary, or specially selected media in the biofilter can be used. If the local groundwater is already contaminated, increases in infiltrating water can speed up the movement of that water, moving contaminants towards other areas needing protection. Table 6.7 lists a variety of pollutants along with their potential for contaminating groundwater post-treatment (Pitt 7/2011).

Pitt recommends in his July 2011 report that the groundwater contamination potential of infiltrating stormwater be reduced by:

1) Careful placement of the infiltrating devices. Most residential stormwater is not highly contaminated with the problematic contaminants, except for chlorides associated with snowmelt.
2) Commercial and industrial area stormwater would likely need pretreatment to reduce the potential of groundwater contamination associated with stormwater. The use of specialized media in the biofilter, or external pre-treatment may be needed in these other areas.

Increased amounts of infiltrating stormwater from some controls located near the creek could increase the flow of naturally occurring groundwater pollutants (such as selenium and chlorides) migrating into nearby water bodies. Although selenium appeared to be below the standard during the project sampling, selenium levels should continue to be monitored within Antelope Creek.

Table 6-7. Groundwater Contamination Potential for Stormwater Pollutants Post-Treatment

Compound Class	Compounds	Surface Infiltration and No Pretreatment*	Surface Infiltration with Sedimentation*	Subsurface Injection with Minimal Pretreatment
Nutrients	Nitrates	Low/moderate	Low/moderate	Low/moderate
Pesticides	2,4-D	Low	Low	Low
	y-BHC (lindane)	Moderate	Low	Moderate
	Atrazine	Low	Low	Low
	Chlordane	Moderate	Low	Moderate
	Diazinon	Low	Low	Low
Other organics	VOCs	Low	Low	Low
	1,3-dichlorobenzene	Low	Low	**High**
	Benzo(a) anthracene	Moderate	Low	Moderate
	Bis (2-ethyl-hexyl) phthalate	Moderate	Low	Moderate
	Fluoranthene	Moderate	Moderate	**High**
	Naphthalene	Low	Low	Low
	Phenanthrene	Moderate	Low	Moderate
	Pyrene	Moderate	Moderate	**High**
Pathogens	Enteroviruses	**High**	**High**	**High**
	Shigella	Low/moderate	Low/moderate	**High**
	P. aeruginosa	Low/moderate	Low/moderate	**High**
	Protozoa	Low	Low	**High**
Heavy metals	Cadmium	Low	Low	Low
	Chromium	Low/moderate	Low	Moderate
	Lead	Low	Low	Moderate
	Zinc	Low	Low	**High**
Salts	Chloride	**High**	**High**	**High**

Note: Overall contamination potential (the combination of the subfactors of mobility, abundance, and filterable fraction) is the critical influencing factor in determining whether to use infiltration at a site. The ranking of these three subfactors in assessing contamination potential depends on the type of treatment planned, if any, prior to infiltration.
* Even for those compounds with low contamination potential from surface infiltration, the depth to the groundwater must be considered if it is shallow (1 m or less in a sandy soil). Infiltration may be appropriate in an area with a shallow groundwater table if maintenance is sufficiently frequent to replace contaminated vadose zone soils. (Modified from Pitt, *et al.* 1994)
Source: Pitt 7/2011

Targeted Pollutants and BMP Processes

In addition to site-specific factors that affect BMP selection, it is important to select a BMP, or BMPs, that provide unit treatment processes expected to be effective at removing the pollutants of interest. BMPs have the ability to remove pollutants from runoff through a variety of physical, chemical, and biological processes. The processes associated with a BMP dictate which pollutants the BMP will be effective at controlling. Primary processes include peak attenuation, sedimentation, filtration, straining, adsorption/absorption, biological uptake and hydrologic processes including infiltration and evapotranspiration. Table 6-8 lists processes that are associated with BMPs in this Basin Plan. For many sites, a primary goal of BMPs is to remove gross solids, suspended sediment, and associated particulate fractions of pollutants from runoff. Processes including straining, sedimentation, and infiltration/filtration are effective for addressing these pollutants. When dissolved pollutants are targeted, other processes, including adsorption/absorption and biological uptake, are necessary. These processes are generally sensitive to media composition and contact time, oxidation/reduction potential, pH, and other factors. In addition to

pollutant removal capabilities, many BMPs offer channel stability benefits in the form of reduced runoff volume and/or reduced peak flow rates for frequently occurring events. Brief descriptions of several key processes generally categorized according to hydrologic and pollutant removal functions are listed below (UDFCD 2011):

Hydrologic Processes

1. Flow Attenuation: BMPs that capture and slowly release the rain event help to reduce peak discharges. In addition to slowing runoff, volume reduction may also be provided to varying extents by BMPs.
2. Infiltration: BMPs that infiltrate runoff reduce both runoff peaks and surface runoff volumes. The extent to which runoff volumes are reduced depends on a variety of factors such as whether the BMP is equipped with an underdrain and the characteristics and long-term condition of the infiltrating media. Examples of infiltrating BMPs include bioretention and permeable pavements. Water quality treatment processes associated with infiltration can include filtration and sorption.
3. Evapotranspiration: Runoff volumes can be reduced through the combined effects of evaporation and transpiration in vegetated BMPs. Plants extract water from soils in the root zone and transpire it to the atmosphere. Evapotranspiration is the hydrologic process provided by vegetated BMPs, whereas biological uptake may help to reduce pollutants in runoff.

Pollutant Removal/Treatment Processes

1. Sedimentation: Gravitational separation of particulates from urban runoff, or sedimentation, is a key treatment process by BMPs that capture and slowly release runoff. Settling velocities are a function of characteristics such as particle size, shape, density, fluid density, and viscosity. Smaller particles under 60 microns in size (fine silts and clays) (Stahre and Urbonas, 1990) can account for approximately 80% of the metals in stormwater attached or adsorbed along with other contaminants, and can require long periods of time to settle out of suspension. Extended detention allows smaller particles to agglomerate into larger ones (Randall et al, 1982), and for some of the dissolved and liquid state pollutants to adsorb to suspended particles, thus removing a larger proportion of them through sedimentation. Sedimentation is the primary pollutant removal mechanism for many treatment BMPs including extended detention basins, retention ponds, and constructed wetland basins.
2. Straining: Straining is physical removal or retention of particulates from runoff as it passes through a BMP. For example, grass swales and grass buffers provide straining of sediment and coarse solids in runoff. Straining can be characterized as coarse filtration.
3. Filtration: Filtration removes particles as water flows through media, such as engineered soils. A wide variety of physical and chemical mechanisms may occur along with filtration, depending on the filter media. Metcalf and Eddy (2003) describe processes associated with filtration as including straining, sedimentation, impaction, interception, adhesion, flocculation, chemical adsorption, physical adsorption, and biological growth. Filtration is a primary treatment process provided by infiltration BMPs. Particulates are removed at the ground surface and upper soil horizon by filtration, while soluble constituents can be absorbed into the soil, at least in part, as the runoff infiltrates into the ground. Site-specific soil characteristics, such as permeability, cation exchange potential, and depth to groundwater or bedrock are important characteristics to consider for filtration (and infiltration) BMPs. Examples of filtering BMPs include bioretention and permeable pavements with a sand filter layer.
4. Adsorption/Absorption: In the context of BMPs, sorption processes describe the interaction of waterborne constituents with surrounding materials (*e.g.,* soil, water). Absorption is the incorporation of a substance in one state into another of a different state (*e.g.,* liquids being absorbed by a solid). Adsorption is the physical adherence or bonding of ions and molecules onto the surface of another molecule. Many factors such as pH, temperature and ionic state affect the chemical equilibrium in BMPs and the extent to which these processes provide pollutant removal. Sorption processes often play primary roles in BMPs such as constructed wetland basins, retention ponds, and bioretention systems. Opportunities may exist to optimize performance of BMPs through the use of engineered media or chemical addition to enhance sorption processes.
5. Biological Uptake: Biological uptake and storage processes include the assimilation of organic and inorganic constituents by plants and microbes. Plants and microbes require soluble and dissolved constituents such as nutrients and minerals for growth. These constituents are ingested or taken up from the water column or growing medium (soil) and concentrated through bacterial action, phytoplankton growth, and other biochemical processes. In some instances, plants can be harvested to remove the constituents permanently.

In addition, certain biological activities can reduce toxicity of some pollutants and/or possible adverse effects on higher aquatic species. Unfortunately, not much is understood yet about how biological uptake or activity interacts with stormwater during the relatively brief periods it is in contact with the biological media in most BMPs, with the possible exception of retention ponds between rainfall events (Hartigan, 1989). Bioretention, constructed wetlands, and retention ponds are all examples of BMPs that provide biological uptake.

It is critical to recognize that for BMPs to function effectively, meet performance expectations, and provide for public safety, BMPs must be:

1. Designed according to City of Lincoln criteria, taking into account site-specific conditions (*e.g.,* high groundwater, expansive clays and long-term availability of water).
2. Constructed as designed. This is important for all BMPs, but appears to be particularly critical for permeable pavements, rain gardens and infiltration-oriented facilities.
3. Properly maintained to function as designed. Although all BMPs require maintenance, infiltration-oriented facilities are particularly susceptible to clogging without proper maintenance. Underground facilities can be vulnerable to maintenance neglect because maintenance needs are not evident from the surface without special tools and procedures for access. Maintenance is not only essential for proper functioning, but also for aesthetic and safety reasons. Inspection of facilities is an important step in identifying and planning for needed maintenance (UDFCD 2010).

Table 6-8. Primary, Secondary, and Incidental Treatment Processes Provided by BMPs

BMP	Hydrologic Processes			Treatment Processes				
	Peak	Volume		Physical			Chemical	Biological
	Flow Attenuation	Infiltration	Evapo-transpiration	Sedimentation	Filtration	Straining	Adsorption/ Absorption	Biological Uptake
Grass Swale	I	S	I	S	S	P	S	S
Grass Buffer	I	S	I	S	S	P	S	S
Constructed Wetland Channel	I	N/A	P	P	S	P	S	P
Green Roof	P	S	P	N/A	P	N/A	I	P
Permeable Pavement Systems	P	P	N/A	S	P	N/A	N/A	N/A
Bioretention	P	P	S	P	P	S	S[1]	P
Extended Detention Basin	P	I	I	P	N/A	S	S	I
Constructed Wetland Pond	P	I	P	P	S	S	P	P
Retention Pond	P	I	P	P	N/A	N/A	P	S
Underground BMPs	Variable	N/A	N/A	Variable	Variable	Variable	Variable	N/A

Notes: P = Primary; S = Secondary, I = Incidental; N/A = Not Applicable
[1] Depending on media
Source: UDFCD, 2010

Maintenance and Sustainability

Maintenance should be considered early in the planning and design phase. Even when BMPs are thoughtfully designed and properly installed, they can become eyesores, cease to function and breed mosquitoes if not properly maintained. BMPs can be more effectively maintained when they are designed to allow easy access for inspection and maintenance. Other factors that increase maintenance ease are property ownership, easements, visibility from easily accessible points, slope, vehicle access, and other factors. For example, fully consider how and with what equipment BMPs will be maintained in the future. If the City is not assuming upkeep responsibilities, clear, legally-binding written agreements assigning maintenance responsibilities should be completed. The City may also require right of access to perform emergency repairs/maintenance should it become necessary (UDFCD 2010).

Sustainability of BMPs is based on a variety of considerations related to how the BMP will perform over time. For example, vegetation choices for BMPs determine the extent of supplemental irrigation required. Choosing native or drought-tolerant plants and seed mixes helps to minimize irrigation requirements following plant establishment. Other sustainability considerations include watershed conditions. For example, in watersheds with ongoing development clogging of infiltration BMPs is a concern. In such cases, a decision must be made regarding either how to protect and maintain infiltration BMPs, or whether to allow use of infiltration practices under these conditions. Various types of porous pavement require frequent maintenance to preserve their function and if clogged, would be difficult to repair (UDFCD 2010). According to WinSLAMM results, many stormwater controls are predicted to have decreased performance when maintenance is not performed or delayed.

Cost and Structural BMP Performance

Costs are a fundamental consideration for BMP selection, but often the evaluation of costs during planning and design phases of a project focuses narrowly on up-front, capital costs. A more holistic evaluation of life-cycle costs including operation, maintenance and rehabilitation is prudent. From a municipal perspective, cost considerations are even broader, involving costs associated with off-site infrastructure, channel stabilization and/or rehabilitation, and protection of community resources from effects of runoff from urban areas. Generally, the components of the whole life cost for a constructed facility include construction, engineering and permitting, contingency, land acquisition, routine operation and maintenance, and major rehabilitation costs minus salvage value. In addition, the cost of administering a stormwater management program could also be included as a long-term cost for BMPs. Whole life costs (also known as life cycle costs) refer to all costs that occur during the economic life of a project. In addition to the cost estimates developed as part of the WinSLAMM modeling effort in Lincoln, several other resources are available that provide costing tools, including the UDFCD BMP-REALCOST tool (www.udfcd.org) and the Water Environmental Research Foundation (WERF) Whole Life Cycle Cost tool (www.werf.org).

6.4. Non-Structural BMPs

Source controls, or non-structural BMPs, reduce the source of the pollutant rather than treating the pollutant through a structural BMP.

Source controls, or non-structural BMPs, reduce the source of the pollutant rather than treating the pollutant through a structural BMP. Source controls are usually low-cost and are typically the responsibility of the resident or property owner to implement (*i.e.,* Low/No-phosphorus fertilizers and picking up pet waste). BMPs that achieve stormwater runoff volume reduction ultimately reduce the volume of surface water reaching Antelope Creek, thus reducing the pollutant load. Infiltration BMPs treat stormwater runoff and capture pollutants prior to reaching Antelope Creek. Recommendations for programmatic changes are discussed separately in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS. Table 6-9 below reinforces the idea that source controls are an effective way for reducing bacteria loading to streams (Pitt, 2007).

Table 6-9. Overview of Bacteria Control Measures and Expected Cost and Effectiveness

Control Measure	Control Effectiveness	Costs
Litter control	Low	Low/Moderate
Bird control on river bridges	Moderate (to 50%)	Low/Moderate
Catchbasin cleaning	Low (<10%)	Moderate/High
Street cleaning	Low/Moderate (to 20%)	Very high
Dog feces control programs	Moderate (to 35%)	Very low
Inappropriate discharge detection and elimination program	High (if present)	Moderate/High
Runoff treatment and disinfection	Can be very high (>99%)	Very high

6.5. Conclusion

Upon review and analysis of all of the data presented in the previous chapters, the following conclusions were made and used to develop the Plan recommendations summarized below and detailed in the following chapters:

1. Based on the cumulative data sets now available, Antelope Creek attains water quality standards for ammonia and copper.

2. Antelope Creek does not attain *E. coli* standards established by NDEQ (126 cfu/100 mL) for the stream during both dry and wet weather conditions. The *E. coli* recreation season geometric mean concentration at AC-9 during the 2004 sampling under the NDEQ rotating basin monitoring program was 3,433 cfu/100 mL. The *E. coli* geometric mean at AC-9 during the 2009 sampling by NDEQ was 620 cfu/100 mL. The *E. coli* geometric mean at AC-9 during the 2010-2011 sampling by EA was 1,511 cfu/100 mL.

Due to the diffuse nature of the sources of E. coli, meeting the standard could be difficult and costly, and will most likely require a long-term, systematic approach.

3. Dry weather sampling of stormwater outfalls to the stream did not show illicit sanitary connections to the storm drainage system; therefore, *E. coli* in the watershed is expected to be associated with diffuse, transient sources such as urban wildlife (*e.g.,* pigeons, raccoons) and potentially domestic pets (background level). Because of the relatively ubiquitous and diffuse nature of such background level pollutants, it is impractical to treat or remove all sources of *E. coli* in the watershed. Nonetheless, from a regulatory perspective, it is important for the City to proactively implement measures that may help to incrementally reduce *E. coli* loads to the stream.
4. Additional investigation into potential sources of *E. coli* in Antelope Creek through MST is not recommended. Although MST could provide additional information on the potential sources of *E. coli* in Antelope Creek, neither the EPA nor the NDEQ currently recognize differentiating between bacteria source organisms (human vs. wildlife for example) in applying Water Quality Standards. Therefore MST would likely not change the existing TMDL nor be considered in the evaluation of attainment of the beneficial use.
5. The level of background bacteria naturally occurring within the watershed is unknown.
6. Due to the diffuse nature of the sources of *E. coli*, meeting the standard could be difficult and costly, and will most likely require a long-term, systematic approach.
7. Antelope Creek does not attain water quality standards for several constituents believed to be associated with naturally occurring conditions in the watershed. Specifically, groundwater inflows to the stream are expected to provide the source of chloride, conductivity and selenium in the lower portion of Antelope Creek. These regulatory issues are best addressed through development of site-specific standards based on naturally occurring conditions and are not addressed as part of this watershed plan.
8. With the exceptions of *E. coli*, conductivity, chloride and selenium, Antelope Creek currently attains all other stream standards assigned to the stream by NDEQ.
9. Nuisance algae are present in various portions of the stream, particularly during warm weather. This is likely due to a combination of physical and chemical factors such as shallow flow depth, low flow velocities and stagnant areas, sunlight (limited tree canopy), and nutrients. Phosphorus, which is often a limiting factor for algal growth, is not particularly elevated in the limited stream samples collected from Antelope Creek to date (compared to typical urban streams); therefore, it is likely that the physical characteristics of the stream and flow regime also play a significant role related to nuisance algae. Hydraulic characteristics of the stream channel above the labyrinth weir create a stagnant area where sediment deposition occurs.
10. The stormwater quality management chapter of the City of Lincoln's Storm Drainage Criteria Manual was last updated in 2004, with significant reliance on 1992 criteria from the Urban Drainage and Flood Control District in Denver.

6.6. Recommendations

Due to the diffuse nature of the pollutant sources within the Antelope Creek watershed and the magnitude of the problem, a plan must be developed and implemented to work towards water quality goals. The Project team recommends;

"Together, the City, Lincoln citizens, and the LPSNRD should work proactively to reduce *E. coli* loads to the stream and implement strategies to reduce overall stormwater pollutant loads to Antelope Creek"

This recommendation was developed with the overall goal of eventually removing Antelope Creek from the 303(d) impaired waters list. To achieve this goal, a variety of control strategies to reduce pollutant loading to Antelope

Creek will need to be implemented. The control strategies can include a combination of structural and non-structural stormwater BMPs encompassing both source controls and water treatment technologies. Below are general Plan recommendations that were used to develop the specific recommended strategies and projects presented in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS and the implementation strategy detailed in SECTION 10 - IMPLEMENTATION.

1. Enforce existing City ordinances to control pollutant sources within the Antelope Creek watershed such as pet waste pickup and sediment control.
2. Consider developing new City ordinances to control sources of the pollutants of concern.
3. Develop and implement wildlife control practices in the Antelope Creek watershed to discourage bird use of areas near the creek, such as on bridges and creek tunnels.
4. Continue and expand preventative maintenance and cleaning activities such as sanitary sewer inspections, street sweeping, and, in-stream sediment removal to minimize future pollutant sources.
5. Continue and expand pollution source control and runoff quantity reduction programs such as public education programs, Low/No-phosphorus fertilizer program, and the rain garden/rain barrel programs.
6. Develop and implement additional pollution source and runoff volume control programs such as downspout disconnection program and yard waste pickup programs.
7. Implement structural stormwater BMPs that treat frequently occurring rainfall events and reduce surface runoff volumes. The BMPs should be designed to target the 90% rainfall event (1.25 inches) or less if possible. Such stormwater BMPs could be implemented on new development projects, with opportunities for retrofits and demonstration projects also pursued by the City, as budgetary constraints allow.
8. Evaluate the feasibility of altering release patterns from Holmes Lake to determine whether more frequent “flushing flows” would be a benefit to water quality in Antelope Creek.
9. Evaluate channel modifications throughout Antelope Creek to minimize sedimentation areas and reduce nuisance algae blooms.
10. Evaluate Lincoln’s Storm Drainage Criteria Manual to ensure consistency with the 2010 version of the Urban Drainage and Flood Control District manual, or another comparable national manual.
11. Consider concentration of resources into a priority sub-basin. A concentration of resources, such as developing several projects in a smaller sub-basin, would allow the City to more closely evaluate BMP performance. Focusing on a sub-basin is a more practical approach for a diffuse pollution source and is typical of EPA approved water quality plans.

The general recommendations listed above were used to develop the specific Plan recommendations detailed in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS. The Antelope Creek Watershed Management Plan Implementation Plan is provided in SECTION 10 - IMPLEMENTATION, along with Plan evaluation criteria and milestones to provide the City and LPSNRD with a road map to achieve the overall goal of removing Antelope Creek from the 303(d) impaired waters list.

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SECTION 7 – BMP SITE INVENTORY

7.1. Introduction

From the conclusions of SECTION 6 - POLLUTION SOURCES AND CONTROL STRATEGIES, both non-structural and structural BMPs are recommended in order to work towards the goal of reducing *E. coli* loading to Antelope Creek. Non-structural controls, detailed in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS, are focused on controlling the pollutant at the source (and are sometimes referred to as source controls). Non-structural controls can be effective for reducing pollutant loads and tend to be less costly than structural practices. Also, the project team has identified several structural BMPs, most of which include a combination of BMPs and are also detailed in Section 8 - Management Practices–Recommended Projects/Programs.

Non-structural controls can be effective for reducing pollutant loads and tend to be less costly than structural practices

These are the initial demonstration projects, with monitoring, modifications may be necessary when applied over wider areas. The efforts, while significant, do not treat all of the stormwater in the watershed to the high level needed, but are targeting the areas that are expected to have the greatest unit area discharges that can be controlled at the least cost. With this experience, more widespread application of stormwater controls can be planned for the whole area (such as long-term implementation at the time of scheduled road reconstruction/repairs).

This section provides the general methodology for water quality structural BMP site selection within the Antelope Creek Basin. These same selection criteria can be applied to other watersheds within the City of Lincoln or throughout the country. Following the general methodology discussion is a detailed description of the site specific process that was used to identify, screen, and select water quality BMP project sites within the Antelope Creek watershed as part of this Basin Plan. This methodology is essential to filtering the potentially hundreds of BMP sites down to a manageable number to be developed into potential projects.

7.2. General Potential BMP Site Selection

The methodology of BMP site selection has four general steps:

1. Field Screening of potential sites for water quality BMPs
2. Desktop review of potential sites for water quality BMPs
3. Development of watershed specific selection criteria
4. Ranking and selecting sites

7.2.1 Field Screening Potential Sites

The first step in the site selection process is to conduct a field screening of the watershed to identify as many potential sites for water quality BMPs as practical; serving as the basis for the potential final site list. This hands-on activity generally involves a map review, understanding watershed characteristics, and ultimately surveying the watershed to observe site conditions. The list is narrowed down throughout the site selection process. It is important to understand that each watershed and its respective water quality goals are different. Field notes detailing the information gathered at each potential site, as-well-as site photographs, should be kept for use in future steps of the site selection process. Public acceptance was an important criteria involved in all aspects of field screening.

7.2.2 Desktop Review of Potential Sites

The second step in the site selection process consists of conducting a desktop review of each of the potential sites for water quality BMPs identified during the field screening. This step in the selection process allows an “apples to apples” comparison of the sites. A one to two page information sheet of each potential site should be developed at this stage. The information sheets should be used to screen potential sites for water quality BMPs for further consideration. As an example, if the site had utilities buried in potential BMP locations, the site may be removed from further consideration due to constructability concerns. Upon completion of the desktop review of potential sites for water quality BMPs, the larger list of potential sites should be narrowed down to the potential sites that have met all of the screening requirements.

7.2.3 Develop Watershed Specific Selection Criteria

The next step in the site selection process is to develop a specific list of selection criteria and rank them in order of importance to achieve the watershed goals. The selection criteria might include any important aspect of the watershed plans, such as public input, regulatory goals, etc.

7.2.4 Rank and Select Potential Project Sites

Using the information gathered from the field screenings and the desktop review, the full list of potential BMP sites identified for potential projects can now be ranked against each other using the criteria list that was developed. Each site should be scored on a scale against each of the selection criteria. The selection criteria can be ranked and weighted to increase the multiplier for the most important selection criteria. For example, if the treatable area was the most important selection criteria out of five choices, a potential site would receive an x5 multiple of the score it received in that category (conversely the least important criteria would receive an x1 multiple). The top scoring sites should be selected and moved onto the next step of the process, conceptual project layouts, described in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS.

7.3. Antelope Creek Potential BMP Site Selection

This section details the site specific methods and criteria used to select potential BMP sites within the Antelope Creek watershed as part of this Basin Plan.

Picture 14: The parking lot at Auld Pavilion was screened as a potential disconnect project

7.3.1 Field Screening

During September and October of 2011 the project team completed a field screening of potential BMP sites within the Antelope Creek watershed. The following list of general field screening criteria was used by EA personnel to develop the preliminary list of potential BMP sites shown in Table 7-1.

Land Ownership/Location – Publically owned property was given a high priority when selecting potential BMP sites. A large amount of land adjacent to Antelope Creek, used for recreation and open space, is owned by the City of Lincoln, and could be available for implementation of structural BMPs. Projects implemented in these public areas also increase opportunities for outreach, public education and information, and placement of interpretive signage. During field surveys, potential sites for water quality BMPs were identified on both private and public properties but were mostly aimed toward publicly owned properties. Projects on private property are recommendations for the land owner to pursue. City or other agencies may be available for partnership or funding assistance.

Land Use – Land use has a direct impact on the quantity and quality of stormwater and is an important factor in the selection of potential BMP sites. As mentioned above, site selection of structural source water controls was prioritized towards public, quasi-public, open space, transportation, and recreational land uses. Commercial and industrial land uses typically have a greater amount of impervious surface, and thus have greater amounts of surface runoff and may be more suitable for BMP siting. However, these land uses make it more difficult for site specific projects due to increased land purchase costs, limited space to implement potential projects, and potential lack of interest from property owners.

Topography – Topography can play a major role in BMP site selection. If a site is hilly and does not have a well-defined stormwater flow path, it can be difficult to design a BMP that is cost effective due to the limited treatable area. More attention was focused on identifying potential sites for water quality BMPs in flat areas with defined stormwater flow paths.

Drainage Patterns – Drainage patterns relate closely with site topography. Two main types of drainage patterns were noted. The first was overland or open channel flow, and the second was closed conduit or storm drain flows. Drainage pattern characteristics were identified, including direction and size of the drainage pattern, make-up of the drainage system, and the condition of the material in the open channel drainage ways (*i.e.,* concrete liner, soil, amount of vegetation, etc.).

Existing Landscaping – The project team took notes and photos of the existing landscaping. The ability to fit water quality BMPs within existing landscaping, or the possibility of designing them to be similar to existing landscaping, can be a major factor in the public acceptance process of BMPs.

Nearby Pollutant Sources – Because a TMDL for *E. coli* was established for Antelope Creek, potential pollutant sources for bacteria were targeted during the field screening. However, since many structural BMPs are effective at removing multiple pollutants from stormwater runoff, the project team recognized other potential pollution sources readily identifiable near the potential site locations. For example, sediment was targeted during site selection in areas such as large parking lots and gravel/sand from roadways.

Maintenance Access – Operation and maintenance costs occur periodically throughout the life of a stormwater control device or practice. Therefore, the project team took into consideration the availability of maintenance staff onsite when siting projects. For example, an institutional land use, such as a school or hospital, could have staff available to ensure vegetation is established and regular maintenance continues. On the other hand, the success of a newly established rain garden in a residential area may be dependent upon local residents desire to provide maintenance.

Spatial Constraints – Due to the highly urbanized nature of the Basin Plan area, land availability was a limiting factor. Most of the control options examined by the project team (and modeled by WinSLAMM) are intended for retrofitting existing structures. Land availability was another reason the project team targeted City owned property or privately owned properties that drained to well defined City owned areas, such as parks and open spaces along Antelope Creek. Privately owned property can present a number of significant challenges including limited accessibility, increased project costs, maintenance issues, and acceptance.

Utilities – Utilities can create major issues during the design, construction, and operation of BMPs. During the field screening, the project team noted visible evidence of utilities, such as gas meters, cable boxes, or electric lines.

7.3.2 Antelope Creek Desktop Review

Upon completion of the field screening activities, the project team completed a desktop review of the identified potential BMP sites. The following details the additional information that was gathered for each potential site. The final screening of the potential sites for water quality BMPs was based upon the gathered information.

Picture 15: Cable box in an area which would have otherwise been suitable for stream enhancement.

Treatable Area – The overall size of each potential site's drainage areas was determined using City drainage maps, and elevation information from available LiDAR, and GIS. Knowing the total drainage area allowed the project team to determine the total area that could be treated by locating BMPs at the potential pollutant sites.

Drainage Area Land Use – After sizing the potential site drainage area, the project team estimated the land use percentages within the drainage areas to determine the major pollutant sources and loading.

Spatial Constraints – Although the potential treatable watershed may be large, the area available to treat the watershed might be small. Sites that fall under this consideration would include large parking lots with only the grassed right-of-way for treatment. These sites could be limited to removing sand and sediment from runoff.

Public Education – Educational opportunities were considered during the desktop review of potential sites for water quality BMPs. Locations in the watershed that are more visible to the public or large groups were targeted for site selection. These areas include the Lincoln Children's Zoo, Union Plaza, parks, schools, trails, and others. In addition, sites located near schools also have the potential to be used for outdoor classrooms.

Utility Conflicts – Although utilities were noted during the field screening, City utility maps were reviewed to identify any additional potential utility conflicts that might not have been noted during the field screening.

Once the project team had gathered the information above for each potential site identified during the field screening effort, the data was used to screen the potential sites for water quality BMPs to develop a final list of potential BMP site locations that present the greatest potential for water quality BMP projects. Table 7-1 provides

general information about the potential sites screened and reasons for dismissal or approval of the potential site. Dismissed sites are shown in red. Figure 7-1 shows the approximate locations of each potential site screened.

Table 7-1. Potential BMP Sites

SITE NUMBER	LAND USE TREATED	LOCATION	APPROVED /DISMISSED	REASON
1	PR/Multi-Family Res	Tributary southeast of 56th and Van Dorn	Approved	Large treatable watershed, high pollutant load, available land for BMP installation
2	PR/Multi-Family Res	Tributary northeast of 56th and Van Dorn	Approved	Large treatable watershed, high pollutant load, available land for BMP installation
3	Residential	60th & South	Approved	Ease of retrofit, high pollutant load, available land for BMP installation
4	Commercial	Piedmont Shopping Mall	Approved	Publicly owned land nearby, high pollutant load, easy access
5	Commercial	Brian LGH East	Dismissed	Little publicly owned land nearby, small treatable watershed
6	Quasi-Public	Seventh-day Adventist Church	Dismissed	Little publicly owned land nearby, small treatable watershed
7	Commercial/ Quasi public	Van Dorn Plaza/Post Office	Approved	Publicly owned land nearby, high pollutant load, easy access
8	Quasi-Public	Morley Elementary School	Dismissed	Low pollutant load, topography, small treatable watershed
9	Transportation	33rd & Sewell near Memorial Park	Dismissed	Small watershed, low pollutant load
10	Residential/ Transportation	Sheridan Area Medians	Dismissed	Little publicly owned land nearby, difficult topography, low pollutant load
11	Multi-Family Res /Commercial	40th and Capital Parkway	Approved	Available land for BMP installation, high pollutant load, easy access
12	Multi-Family Res /Commercial	40th and Capital Parkway	Dismissed	Combined with Site 11
13	Public	Eden Park	Approved	Publicly owned, ease of retrofit, topography
14	Public	Auld Pavilion in Antelope Park	Dismissed	BMPs for this site (pervious pavement) make this project cost prohibitive, minimal impact on *E. coli*
15	Parks and Rec	Lincoln Children's Zoo	Approved	Public education, available land for BMP installation, high pollutant load
16	Public	Gere Library	Approved	Public education, available land for BMP installation, high pollutant load
17	Parks and Rec	East of Orchard Park Retirement Community	Dismissed	Little publicly owned land nearby, maintenance access
18	Parks and Rec/ Residential	Roberts Park	Approved	Publicly owned, available land for BMP installation, large treatable watershed

SITE NUMBER	LAND USE TREATED	LOCATION	APPROVED /DISMISSED	REASON
19	Commercial/ Parks and Rec	44th and D	Approved	Large treatable watershed, available land for BMP installation, high pollutant load
20	Parks and Rec	Woods Park	Approved	Publicly owned, available land for BMP installation, high pollutant load
21	Parks and Rec	Antelope Creek Labyrinth Weir	Approved	Publicly owned, large treatable watershed, high pollutant load
22	Quasi-Public	University of Nebraska–Lincoln	Dismissed	UNL would be better utilized as a program-based partnership for multiple projects.
23	Quasi-Public	Southeast High School	Dismissed	BMPs already in place
24	Quasi-Public	Pius X High School	Approved	High pollutant load, topography, public education
25	Quasi-Public	Sacred Heart School	Dismissed	Little publicly owned land nearby, low pollutant load, small treatable watershed
26	Quasi-Public	Elliott Elementary School	Dismissed	Low pollutant load, small treatable watershed
27	Quasi-Public	Sheridan Elementary School	Dismissed	Low pollutant load, topography, small treatable watershed
28	Quasi-Public	Randolph Elementary School	Dismissed	Little publicly owned land nearby, low pollutant load
29	Quasi-Public	Lincoln High	Approved	Publicly owned, education, high pollutant load
30	Commercial	Hospice of Tabitha	Approved	Topography, drainage patterns, high pollutant load
31	Quasi-Public	Lefler Middle School	Approved	Public owned, education, topography
32	Parks and Rec	Antelope Park	Approved	Public owned, large treatable watershed, high pollutant load, education

Source: EA Field Survey 2011
Note: Sites shown in red were dismissed

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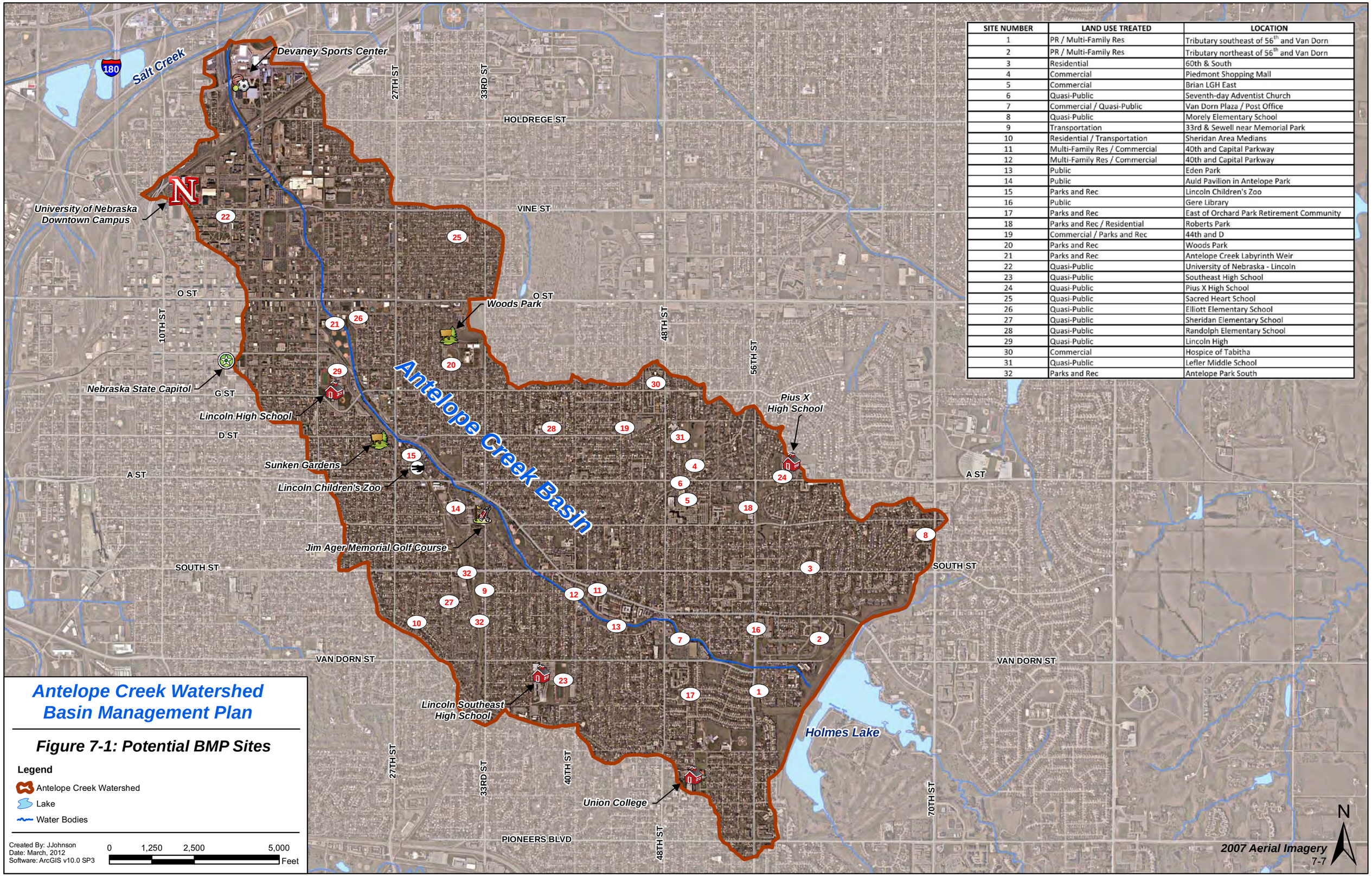

SITE NUMBER	LAND USE TREATED	LOCATION
1	PR / Multi-Family Res	Tributary southeast of 56th and Van Dorn
2	PR / Multi-Family Res	Tributary northeast of 56th and Van Dorn
3	Residential	60th & South
4	Commercial	Piedmont Shopping Mall
5	Commercial	Brian LGH East
6	Quasi-Public	Seventh-day Adventist Church
7	Commercial / Quasi-Public	Van Dorn Plaza / Post Office
8	Quasi-Public	Morely Elementary School
9	Transportation	33rd & Sewell near Memorial Park
10	Residential / Transportation	Sheridan Area Medians
11	Multi-Family Res / Commercial	40th and Capital Parkway
12	Multi-Family Res / Commercial	40th and Capital Parkway
13	Public	Eden Park
14	Public	Auld Pavilion in Antelope Park
15	Parks and Rec	Lincoln Children's Zoo
16	Public	Gere Library
17	Parks and Rec	East of Orchard Park Retirement Community
18	Parks and Rec / Residential	Roberts Park
19	Commercial / Parks and Rec	44th and D
20	Parks and Rec	Woods Park
21	Parks and Rec	Antelope Creek Labyrinth Weir
22	Quasi-Public	University of Nebraska - Lincoln
23	Quasi-Public	Southeast High School
24	Quasi-Public	Pius X High School
25	Quasi-Public	Sacred Heart School
26	Quasi-Public	Elliott Elementary School
27	Quasi-Public	Sheridan Elementary School
28	Quasi-Public	Randolph Elementary School
29	Quasi-Public	Lincoln High
30	Commercial	Hospice of Tabitha
31	Quasi-Public	Lefler Middle School
32	Parks and Rec	Antelope Park South

7.3.3 Antelope Creek Site Selection Key Criteria List

Upon completion of the initial screening process, the project team selected five key criteria from the general field screening and desktop review activities. These five key criteria were ranked as shown below according to importance to achieving the water quality goals of the Basin, and were used as the Selection Criteria for the BMP Site Selection:

1. ***Land Ownership/Location (5x)*** – Publically owned property was a high priority for site selection based upon input from the City and LPSNRD. Additional consideration was given to locations where a series of projects could be located in one sub-basin. Scores were given in the following order from highest to lowest due to ease of installation and maintenance of BMPs; publicly owned land, quasi-public, commercial, residential.
2. ***Public Education (3x)*** – The City and LPSNRD intend to use BMP sites for use as demonstration sites for the public to increase understanding of the purpose of BMPs and the importance of similar practices being implemented City-wide.
3. ***Spatial Constraints (2x)*** – Higher scores were given to sites with adequate open space to construct BMPs that are appropriately sized to meet treatment goals.
4. ***Pollutant Loading (2x)*** – Higher scores were given to sites with the greatest potential for removal of bacteria, TSS, nutrients.
5. ***Treated Area (1x)*** – Higher scores were given to larger sites because they present higher potential for pollutant removal.

7.3.4 Antelope Creek Selected Sites

Using the information gathered from the field screenings and the desktop review, the full list of sites selected for potential projects (19) was ranked against each other using the criteria listed in Section 7.3.3. This was completed using the evaluation matrix shown below in Table 7-2. Each site was scored on the basis of the selection criteria list from a range of 1 to 5, with the highest score showing the ideal site based upon the selection criteria. The top sites were selected and put forth to conceptual design and prioritized as Capital Improvement Program (CIP) projects in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS.

Table 7-2. Potential BMP Site Selection Matrix

Ranking No.	Site Number	Site Location	Site Selection Criteria					Total Score	Total Weighted Score
			Land Ownership/ Location (5x)	Public Education (3x)	Spatial Constraints (2x)	Pollutant Loading (2x)	Treated Area (1x)		
1	32	Antelope Park	5	5	5	5	5	25	65
2	18	Roberts Park	5	4	5	5	5	24	62
3	15	Lincoln Children's Zoo	5	5	3	5	3	21	59
4	20	Woods Park	5	4	4	4	4	21	57
5	16	Gere Library	5	5	3	4	1	18	55
6	13	Eden Park	5	4	5	3	1	18	54
7	21	Antelope Creek Weir	3	4	4	5	5	21	50
8	7	Van Dorn Plaza/Post Office	4	3	3	4	1	15	44
9	11	40th and Capital Parkway	3	3	5	3	1	15	41
10	3	60th & South	3	1	5	5	2	16	40
11	29	Lincoln High	3	5	1	3	1	13	39

Ranking No.	Site Number	Site Location	Site Selection Criteria					Total Score	Total Weighted Score
			Land Ownership/ Location (5x)	Public Education (3x)	Spatial Constraints (2x)	Pollutant Loading (2x)	Treated Area (1x)		
		School							
12	1	Tributary southeast of 56th and Van Dorn	2	1	5	5	5	18	38
13	2	Tributary northeast of 56th and Van Dorn	2	1	5	5	5	18	38
14	31	Lefler Middle School	3	5	1	1	2	12	36
15	19	44th and D	2	2	4	3	3	14	33
16	24	Pius X High School	1	5	1	3	2	12	30
17	4	Piedmont Shopping Mall	1	1	2	3	1	8	19
18	30	Hospice of Tabitha	1	1	1	3	2	8	18

7.4. Non-Structural Sites

Several small scale non-structural stormwater controls, such as roof-top disconnections and bridge retrofits for bird control, were sited throughout the watershed but are too widespread to include as single projects. In some cases, disconnections could be recommended as a component of a larger structural project. Non-structural and program recommendations are discussed in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS.

7.5. Conclusion

The potential project site list developed by the field screening resulted in 32 potential water quality BMP sites. After the desktop review and the selection criteria screening, 18 potential water quality BMP sites remained. These 18 sites were ranked based on the site selection matrix. Although all of the sites were viable, the sites with a score of 40 points or higher were selected and developed as project sites. These sites are shown in Table 7-3 in order of highest potential sites first. Due to the potential for unforeseen opportunities, additional sites may be considered as conditions change in the watershed.

Picture 16: Antelope Park had several high ranking projects after the screening process was completed

Antelope Park ranked as the highest potential site and also has several opportunities for enhancement of existing wetlands and waterways in order to increase water quality benefits. The Antelope Park sub-watershed receives stormwater from mostly residential land uses, is highly visible, and has potential for several structural BMPs.

Table 7-3. Selected BMP Sites

Ranking No.	Site Number	Site Location	Total Weighted Score
1	32	Antelope Park	65
2	18	Roberts Park	62
3	15	Lincoln Children's Zoo	59
4	20	Woods Park	57
5	16	Gere Library	55
6	13	Eden Park	54
7	21	Antelope Creek Weir	50
8	7	Van Dorn Plaza/Post Office	44
9	11	40th and Capital Parkway	41
10	3	60th & South	40

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SECTION 8 – MANAGEMENT PRACTICES – RECOMMENDED PROJECTS/PROGRAMS

8.1. Introduction

During the development of this Basin Plan, Antelope Creek has been studied, monitored, and modeled to determine pollutant sources, quantify source loadings, and evaluate loading reduction strategies for targeted pollutants. One of the goals of the Basin Plan is to identify possible pollution control strategies to help achieve water quality goals for Antelope Creek. Implementation of control strategies can be through both Capital Improvement Program (CIP) Projects (structural projects) and Non-Capital Programs (non-structural programs).

As outlined in SECTION 5 - WATER QUALITY MONITORING, *E. coli* is the primary pollutant of concern for Antelope Creek. Projects and programs that reduce *E. coli* are likely to lower other pollutants of concern. Pollutant sources contributing to bacteria in Antelope Creek do not appear to be point sources, such as illicit discharges, malfunctioning sanitary sewer lines, or runoff directly contributed by a single property. Therefore there is no single repair or structural project at a point source for achieving goals listed in the TMDL for *E. coli.*

Pollutant sources contributing to bacteria in Antelope Creek do not appear to be point sources, such as illicit discharges, malfunctioning sanitary sewer lines, or runoff directly contributing by a single property.

Bacteria in Antelope Creek appear to originate from diffuse sources across the entire watershed. Based upon conclusions drawn in SECTION 6 - POLLUTION SOURCES AND CONTROL STRATEGIES, which were dependent upon WinSLAMM and water quality monitoring results, the use of structural BMPs to reduce *E. coli* loading in Antelope Creek to the regulatory levels for a recreational stream would be extremely costly. In addition, Antelope Creek has little open space available for large scale structural solutions. Retrofitting of existing streets, parking lots, and other infrastructure can also be complicated by utilities in the right-of-way. Due to these circumstances, structural BMPs described in this section are intended to reduce pollutant loading to Antelope Creek, as well as serve as demonstration projects for public outreach and education.

SECTION 7 - BMP SITE INVENTORY, describes the methodology for selecting structural BMP sites throughout the watershed that are most appropriate to limiting pollutant loading across a variety of land uses. Site selection weighed heavily on publicly owned property with a high potential for educational opportunities. This section identifies structural BMP projects for sites recommended in SECTION 7 - BMP SITE INVENTORY. As mentioned within Section 7, projects recommended for private property would only be implemented with willing landowners. The City and LPSNRD may be available for partnering opportunities for water quality projects on private land.

This section also outlines the recommended pollution reduction strategies to improve water quality for Antelope Creek based upon the findings listed in all previous sections. Strategies include both site specific structural projects for incorporation into the CIP, as well as non-structural programmatic actions to be administered throughout the watershed.

- Structural projects – These projects are intended to focus on load reduction goals for specific types of land uses within localized areas.
- Non-structural programs – These programs are basin wide recommendations and encourage property owners to adopt management solutions to reduce non-point pollutant loads.

The implementation strategy described later in SECTION 10 - IMPLEMENTATION includes several of the structural projects and a non-structural program listed in this section and includes a priority sub-basin for project implementation over the first 5-year period. Programs and projects listed in the implementation strategy are actions above and beyond actions listed in the current City's MS4 permit. Implementation strategies provided in this plan are specific to address nonpoint source impairments documented in the 2007 TMDL for Antelope Creek.

An adaptive management approach has been proposed in order to allow the City and LPSNRD an opportunity to evaluate programs and projects as they are implemented. This approach will allow the City and LPSNRD an opportunity to make changes to future projects and programs listed in the Basin Plan during the 5-year plan review. The plan review will include an evaluation of what has been completed thus far, how effective it was, and what the next actions might be to further improve water quality. Evaluation criteria used to determine project and program effectiveness, as well as water quality monitoring criteria, are outlined later in SECTION 10 - IMPLEMENTATION.

8.2. Project and Program Selection Overview

Several non-structural based program recommendations are noted and include the expansion of 11 existing programs or activities, and the addition of nine new programs or activities. These recommendations are listed based upon the potential for removing bacteria and other pollutants. Non-structural recommendations are programmatic and are not ranked through a formalized prioritization process similar to the structural recommendations.

The effectiveness of non-structural BMPs will rely heavily on the capability of the City, LPSNRD and other stakeholders to provide information, education, financial incentives, and cost sharing opportunities to property owners on each non-structural strategy. Non-structural solutions also include recommendations for policy changes, ordinances, and incorporation of water quality features into flood control structures. Table 8-1 below displays both the new and expanded program recommendations, each of which is detailed later in this section.

Table 8-1. Non-structural Recommendations

Non-structural Recommendations	
Expansion of Existing Programs	**New Programs**
Sanitary Sewer Line Inspection Program	Rooftop Disconnection Incentive Program
Dry Weather Storm Drainage Screening Program	Operation and Maintenance Plan for Sediment Removal
Pet Waste Ordinances/Disposal Cans	Paired Watershed Study
Targeted Rain Garden Program for Antelope Creek	Antelope Creek Water Quality Partnership
Targeted Rain Barrel Program for Antelope Creek	Urban Wildlife Management
Long Grass Maintenance Area Expansion	Urban Soil Quality Restoration
Low/No-phosphorus Fertilizers Program	--
Lincoln Children's Zoo Water Quality Management Plan	--
Snow and Ice Management Strategies	--
LPSNRD Cost-share Program	--
Quantitative Microbial Risk Assessment (QMRA)	--

This plan also details 13 demonstration projects for consideration by the City and LPSNRD to implement throughout the upper portion of the Antelope Creek Watershed. Due to the considerable cost associated with structural controls, the number of projects was limited. Projects selected were placed in sites that were screened through the process outlined in SECTION 7 - BMP SITE INVENTORY. Locations include both publicly owned property and private property on varying land uses, and will allow for opportunities to provide education and outreach to Lincoln residents.

Projects listed below in Table 8-2 are further detailed in Section 8.4 including a project number, ownership, project summary, maintenance, monitoring, estimated project cost, and water quality benefits. A map of recommended conceptual improvements is also included for each location. For the purpose of incorporating these BMPs into the City's CIP, each project was prioritized using the Prioritization Methodology Report for Watershed Master Planning Projects established by the City and last revised December 2006. Details on the prioritization process, and a ranking of each project, are provided in Section 8.4.1.

Table 8-2. Proposed Structural Demonstration Projects

Structural Project Recommendations		
Project Number	**Location**	**Description**
P01	Antelope Park: Van Dorn St to Sheridan Blvd	Channel and Wetland Enhancements
P02	Antelope Park: South St to Van Dorn St	Channel Enhancements
P03	Antelope Park: SW of 33rd and South St	Bioretention Areas
P04	Antelope Park: A Street to South Street	Modify parking lot, address erosion in meandering channel

Structural Project Recommendations		
Project Number	**Location**	**Description**
P05	Roberts Park/East of Holmes Elementary School	Offline bioretention areas, inline channel berms
P06	Lincoln Children's Zoo	Green roof, permeable pavement, bioretention
P07	Woods Park	Separators, bioretention areas
P08	Gere Library	Separator and bioretention area
P09	Eden Park	Curb-cut bioretention
P10	Existing Dry Detention Basin near 60th and South	Modify Existing Dry Detention Basin
P11	Labyrinth Weir on Antelope Creek	Water quality improvements at weir
P12	Van Dorn Plaza and US Post Office	Bioretention Areas
P13	SE of 40th and Capital Parkway (N. of Campbell's Nursery)	Separator, bioretention areas in open space north of Antelope Creek

8.3. Non-Structural/Programmatic Recommendations

Non-structural programs are defined as stormwater BMPs that focus on management of pollutants at their source by minimizing exposure to runoff, rather than treating runoff in structural BMPs. For example, using Low/No-phosphorus fertilizer would reduce the potential pollutant source, phosphorus, without requiring any type of structural practice, such as construction of a bioretention area or wet-detention pond. Because bacteria are difficult to reduce once within the water column, reduction at the source becomes more important, and is anticipated to be a more effective removal strategy when compared to structural BMPs. In order for non-structural BMPs to be successful in limiting pollutant loading to Antelope Creek, a strong information and education effort is needed to help in changing current property owner practices in the Antelope Creek watershed.

Because bacteria are difficult to reduce once within the water column, reduction at the source becomes more important, and is anticipated to be a more effective removal strategy when compared to structural BMPs.

Several activities recommended include the installation of small scale structural practices (such as rain gardens), but would be planned and implemented through programs offered to residents and property owners. Therefore, these small scale structural activities would be part of a non-structural program action for the purpose of this Basin Plan.

8.3.1 Expansion of Existing Programs

The following are existing programs available through either the City or LPSNRD that are recommended to be expanded and restructured to target property owners and residences in the Antelope Creek watershed. Recommendations have not been prioritized, but are generally listed in order of importance to meet Basin Plan goals listed in SECTION 1 - INTRODUCTION AND PURPOSE.

Sanitary Sewer Line Inspection Program

The Collection and Sanitary Engineering sections within the City of Lincoln Wastewater System are responsible for cleaning, inspecting, and repairing the City's sanitary sewer system. The City currently has a preventative maintenance program that involves internal inspection of sanitary sewers using a T.V. camera. This camera is mounted on a device similar to a small sled which is pulled by an electric winch through the sanitary sewer and viewed by inspection personnel above ground. Sewer defects are recorded for future reference and repair. The City annually inspects approximately 120 miles of sanitary sewer lines. This type of program is essential to ensuring that point sources for *E. coli* are identified and removed within watersheds.

Recommendation #1: Target programs to inspect sanitary sewer lines in the Antelope Creek Basin Area using the T.V. camera in order to support efforts towards meeting the 2007 TMDL goals, specifically for *E. coli* bacteria. Inspections in this area can provide information on the condition of the sewer lines and changes in observed inflows,

and deposition of materials that could be contributing to water quality degradation. Most defects or identified problems are recommended to be considered a priority repair.

Dry Weather Storm Drainage Screening Program

Dry weather storm drain screening includes locating flows in storm drains during periods in which precipitation has not occurred for a given amount of time. Screening activities may or may not include sampling. During low flow periods, pollutants tend to be more concentrated and are more identifiable. Therefore, sampling dry weather flows can provide valuable information for identifying illicit discharges from illegal connections, leaks in sanitary sewer lines, and domestic water supply lines. Indicators such as color, turbidity, and odor can be simple indicators as to non-stormwater runoff. Tracking the source of the flows can further delineate the origin, and also the potential discharge location. Following established programs and manuals such as the Illicit Discharge Detection and Elimination guidance manual by USEPA can aid in developing a dry weather screening program.

Water quality sampling completed in 2010 and 2011 indicated that dry weather flows from outfalls into Antelope Creek did not appear to be a significant contributor towards increased *E. coli* levels.

Recommendation #2: To monitor changing conditions in the watershed that could potentially contribute to pollutant loadings in Antelope Creek, establish a dry weather screening sampling protocol for the Antelope Creek Basin and develop a work plan to annually monitor Antelope Creek and specified major outfalls or tributaries that discharge to the creek.

Dry weather flows could be sampled for TSS, *E. coli*, phosphorus, nitrogen, and other analytes of interest. The analyte set can be adjusted for the specific watershed to limit sampling to those analytes that are most representative of watershed specific conditions.

Pet Waste Ordinances/Disposal Cans

An inventory of pet waste cans on the trail along Antelope Creek was completed in September 2011. Only one pet waste container was visibly located at Holmes Lake Dam. Several signs encouraging pet waste pickup were located along the trail and other areas of the watershed. Some signs were noted as missing. In addition, several residents and trail users were observed not picking up after their pets.

Recommendation #3: To support efforts towards meeting the 2007 TMDL goals, specifically for *E. coli* bacteria, install and maintain several pet waste containers along parks and recreational areas in the Antelope Creek watershed. Signs explaining the importance of picking up pet waste at each container would likely increase usage of the containers. Assistance from local partners to help with maintenance of pet waste containers, such as neighborhood associations, might be considered.

Recommendation #4: To increase compliance with existing pet waste ordinances notify residents through bill stuffers, letters, news articles, and other means, about the water quality benefits of picking up pet waste and the potential enforcement actions available to the City for those not complying with local pet waste ordinances.

Picture 17: Enforcement of pet waste ordinances is key to reducing *E. coli*

Targeted Rain Garden Program for Antelope Creek

The City of Lincoln's Watershed Management Division launched a 50-50 cost-share program for Lincoln property owners in September 2010 to focus on installation of residential rain gardens. Each qualifying property owner was eligible to be reimbursed up to $1,000 for rain garden expenses. Reimbursement included the cost of soil amendments (compost and sand), plants, drain tile, equipment rentals, and work performed by an approved landscape professional.

Recommendation #5: To motivate residents and property owners in the Basin Plan area to install residential rain gardens, continue the existing city-wide program. Consider raising the city portion of the cost-share incentive in this area, and partner with LPSNRD to use the existing Water Quality BMP Cost-Share program as a contributor of matching funds. Consider recognition of individuals or groups that participate in the program.

Targeted Rain Barrel Program for Antelope Creek Watershed

The City has been proactive in encouraging residents to install rain barrels on their properties to encourage reuse of stormwater. The City offers Build-Your-Own Rain Barrel Classes and workshops, provides instructions for property

owners to construct their own rain barrels, and has sponsored an artistic rain barrel program at the Lincoln Children's Zoo.

Recommendation #6: To encourage stormwater reuse and enhance public education in Antelope Creek, target residents and property owners for an expansion of the existing rain barrel program. Continue to provide opportunities for cost-share. Neighborhood associations and community organizations may be partners for education and outreach opportunities to expand the program. Consider recognition of individuals or groups that participate in the program.

Long Grass Maintenance Area Expansion

The Parks Division of Lincoln Parks and Recreation provides maintenance and upkeep of 128 miles of trails and 125 recreational areas covering 5,200 acres in Lincoln. Since 2007, the Parks Division has been increasing the extent of long grass maintenance areas. In many cases long grass areas include native species which have naturally replaced turf grasses over time. The Parks Division targets lakes, ponds, creeks, streams, and drainage ways to include buffer zones to improve water quality and reduce erosion. The buffer zone is typically 30 feet wide but may vary due to steepness, severity of erosion, and management goals (City Parks and Recreation Department).

Recommendation #7: To increase filtration of pollutants, promote shall sheet flow, and discourage geese gathering, establish native grass species using over seeding or re-seeding in long grass areas in the Antelope Creek watershed. In addition, expand buffer zones to all applicable drainage ways, along Antelope Creek park areas, and throughout Jim Ager Golf Course.

Low/No-phosphorus Fertilizers Program

Most soil in the Lincoln area naturally contains enough phosphorus to support a healthy lawn (Interlinc, 2011). For a small fee, property owners can perform a soil test to see if lawns need additional phosphorus. If not, Low/No-phosphorus fertilizers can be used and are available through most local retailers. The City has encouraged the use of Low/No-phosphorus fertilizers upstream of Holmes Lake as part of the Holmes Lake Watershed Plan implementation in 2004. The City provided property owners information on which vendors supplied Low/No-phosphorus fertilizers, and also conducted a program which made limited amounts of Low/No-phosphorus fertilizer available to residents of the Holmes Lake Watershed.

Most soil in the Lincoln area naturally contains enough phosphorus to support a healthy lawn.

Recommendation #8: To support efforts that limit nutrient loading to Antelope Creek, begin using no-phosphorus fertilizers where applicable on all City property in the Antelope Creek watershed. Establish a Low/No-phosphorus fertilizer program that will encourage residents, property owners, and lawn care providers to use Low/No-phosphorus fertilizers in the Antelope Creek watershed. Provide education and outreach on how nutrients in fertilizer can negatively affect Antelope Creek by contributing to excessive algae growth.

Recommendation #9: Support residents and property owners by making soil testing available for a low cost, or considering offering soil testing for no cost in the Antelope Creek watershed.

Lincoln Children's Zoo

The Lincoln Children's Zoo (Zoo) is a non-profit organization that has been in operation for almost 50 years at a site located within land owned by the City Parks Department. The Zoo has been proactive in water quality management and serves as one of the community's largest environmental education providers. The Zoo currently does not have a water quality management plan, however, water quality BMPs have been installed with the intention of installing more in the future as recommended in this section.

Picture 18: Lincoln Children's Zoo

Recommendation #10: To support existing water quality efforts at the Zoo, encourage and support the Zoo with the establishment of a water quality management plan to outline goals and objectives for water quality management, define and expand existing controls to reduce *E. coli* reaching the creek, display zoo drainage patterns, provide a list of potential water quality projects, and identify potential funding sources for these projects. The water quality plan would list current and future BMPs and insure the excellent maintenance practices at the Zoo continue.

Snow and Ice Management

The City of Lincoln currently has five locations used to stockpile snow, none of which are located in the Antelope Creek watershed.

Recommendation #11: Continue to avoid piling snow in the Antelope Creek Watershed. The City's snow removal management strategies might consider orienting snow dump sites such that snowmelt is directed through an appropriate BMP before entering a waterway. Practice guidelines established within the Urban Drainage and Flood Control District Manual (UDFCD), Volume 3 or comparable manual, would be a great resource for the City.

LPSNRD Cost-share Program

The LPSNRD has created a dedicated Water Quality BMP Cost-Share program to assist landowners with the implementation of BMPs aimed at improving the quality of surface waters within the District. Installing properly sized and designed practices to promote infiltration, such as bioretention areas and pervious pavers, are some of the practices that may be eligible for this program. For selected projects, LPSNRD may fund up to 50% of total project costs, to a maximum of $10,000.

Recommendation #12: To increase opportunities for residents and property owners to install BMPs, use matching funds from the existing LPSNRD cost-share program and higher total maximum cost-share for projects located in the Antelope Creek watershed. Expand eligible practices for new programs listed in this plan, such as the Urban Soil Quality Restoration program.

8.3.2 New Programs

The following are new programs or actions recommended for the City and LPSNRD to consider in order to support efforts to improve water quality in Antelope Creek.

Urban Wildlife Management

As previously documented, bird droppings appear to be a significant source of *E. coli* in Antelope Creek. As a result, EA conducted a bridge survey November 2010. The survey revealed that several of the 29 bridges and overpasses were lacking structure to reduce or discourage bird nesting and perching. Bridges with "I" beam construction, as seen in Figure 8-1, had the most droppings and evidence of bird activity, primarily pigeons.

Reduction of bird activity on Antelope Creek would be an immediate step towards reducing loadings of bacteria to Antelope Creek.

Recommendation #13: To support efforts towards meeting the 2007 TMDL goals, specifically for *E. coli* bacteria, retrofit older bridges and overpasses crossing Antelope Creek to modify habitat to reduce feeding, watering, roosting, and nesting sites for birds. In general, all bridges constructed in association with the Antelope Valley project were built with bird control in mind. Future bridges or overpasses over Antelope Creek should be designed in a manner that reduces habitat suitable for nesting and perching of pigeons and other birds. Other visible perching sites, such as light posts, could be considered for placing mechanisms to discourage perching.

Reduction of bird activity on Antelope Creek would be an immediate step towards reducing loadings of bacteria to Antelope Creek. University of Nebraska–Lincoln's (UNL's) School of Natural Resources nuisance wildlife programs is one local resource that might be able to provide technical assistance such as a study to determine effectiveness of controls on bridges in Antelope Creek.

Recommendation #14: To support efforts towards meeting the 2007 TMDL goals, specifically for *E. coli* bacteria, limit activities of other animals near Antelope Creek. Practices could be coordinated with UNL through the Internet Center for Wildlife Damage Management, as well as UNL's Cooperative Extension Division and/or Wildlife Damage Control staff at the School of Natural Resources. A wildlife assessment study to determine the types of species present in the watershed would provide direction on other activities that would limit habitat of nuisance species that may be contributing to the pollutant load in Antelope Creek.

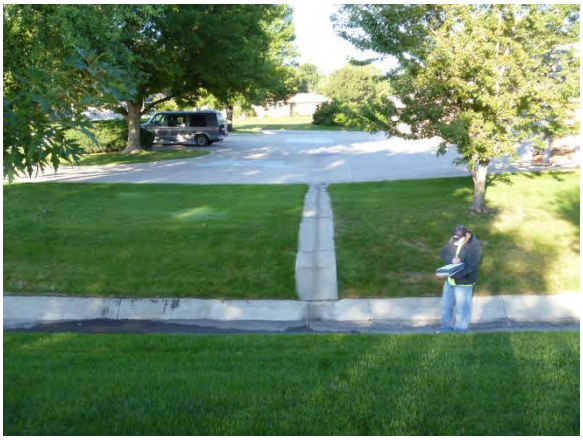
Rooftop and Parking Lot Disconnection Incentive Programs

Throughout the Basin Plan area, several businesses and homes were noted as having downspouts moving water directly from a rooftop to an impervious surface where stormwater runoff travels untreated directly into Antelope Creek. Based upon analysis in WinSLAMM, for clay loam soils which are present through most of Lincoln, disconnecting the roof downspouts in most residential areas is expected to result in annual reductions of roof runoff by about 80%. This would increase to approximately 90% and 95% for areas having silty and sandy soils,

respectively. Parking lots and other impervious areas such as sidewalks can be disconnected by not allowing runoff during frequent events. This can be obtained by pervious pavement systems.

Recommendation #15: To support efforts to limit the quantity of stormwater and pollutant loading, encourage property owners and residents to disconnect runoff from impervious surfaces. Disconnections can be low-cost solutions that if implemented over a large area could have a strong impact on pollutant reduction to Antelope Creek.

Establish an incentive program for property owners in Antelope Creek to disconnect downspouts and roof drains from spilling onto impervious surfaces. Support the program with a considerable educational campaign using bill stuffers, billboards, press releases, social media, news articles, information on the City and LPSNRD's website, and other means. Disconnection of rooftop runoff on properties where adequate vegetative cover is available is important.



Picture 19: Parking lot and down spout disconnections are low cost alternatives for reducing pollutant loads to Antelope Creek

Recommendation #16: To support efforts to limit the quantity of stormwater and limit pollutant loading, identify locations in the Basin Plan area where parking lot drainage to storm drain inlets could be disconnected. Directing flow of stormwater from parking lots onto vegetated surfaces, swales, rain gardens, or other BMPs, could have a considerable positive impact on water quality. Converting impervious areas to pervious areas using pervious pavement systems can have similar effects. Work with property owners to encourage disconnection of parking lots and other large impervious surfaces from the storm drain system.

Operation and Maintenance Plan for Sediment Removal

Sediment has been shown to be a potential source and/or growth media for bacteria in streams. Sediments tend to accumulate nutrients and bacteria from inflows, as well as direct deposition from urban wildlife population. Sediment in Antelope Creek may contribute to elevated levels of bacteria (*E. coli)* in the water column. In addition, sediment accumulation above the labyrinth weir and in the concrete channel in Union Plaza, negatively affect water quality and aesthetics. The City and LPSNRD have mechanically removed sediment from the labyrinth weir and Union Plaza in the past.

Picture 20: Sedimentation upstream of the labyrinth weir

Recommendation #17: Support actions through establishment of an Operation and Maintenance Plan that can regularly remove sediment accumulation from Antelope Creek. Sediment removal from the stream has the potential to lower the overall bacteria loading in the stream, have a positive effect on water quality, and improve aesthetics. Consider both mechanical and hydraulic alternatives for sediment removal, including coordination with the US Army Corps of Engineers to provide occasional flushing flows.

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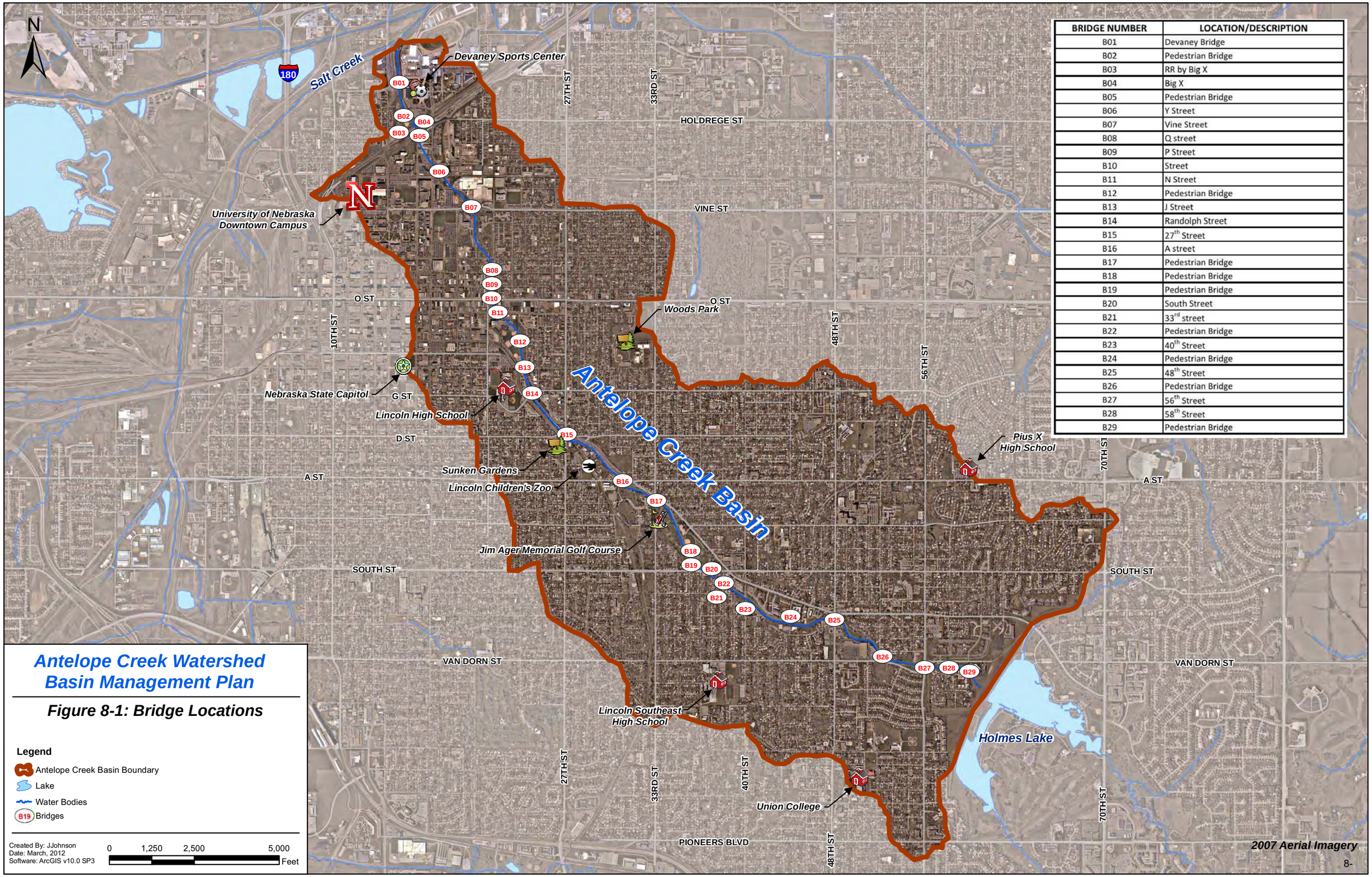


BRIDGE NUMBER	LOCATION/DESCRIPTION
B01	Devaney Bridge
B02	Pedestrian Bridge
B03	RR by Big X
B04	Big X
B05	Pedestrian Bridge
B06	Y Street
B07	Vine Street
B08	Q street
B09	P Street
B10	Street
B11	N Street
B12	Pedestrian Bridge
B13	J Street
B14	Randolph Street
B15	27th Street
B16	A street
B17	Pedestrian Bridge
B18	Pedestrian Bridge
B19	Pedestrian Bridge
B20	South Street
B21	33rd street
B22	Pedestrian Bridge
B23	40th Street
B24	Pedestrian Bridge
B25	48th Street
B26	Pedestrian Bridge
B27	56th Street
B28	58th Street
B29	Pedestrian Bridge

Antelope Creek Watershed Basin Management Plan

Figure 8-1: Bridge Locations

Legend

- Antelope Creek Basin Boundary
- Lake
- Water Bodies
- B19 Bridges

Created By: JJohnson
Date: March, 2012
Software: ArcGIS v10.0 SP3

0 1,250 2,500 5,000 Feet

Paired Watershed Study

A paired watershed study would allow the City and LPSNRD to collect information on the effectiveness of certain BMPs in Lincoln. Information from a paired watershed study could assist in determining the resources necessary to implement non-structural and small scale structural BMPs in a residential setting.

Recommendation #18: To support data collection efforts regarding efficiency of both structural and non-structural BMPs to remove pollutants, establish a paired watershed study. Monitor the effectiveness of small scale structural and non-structural BMPs in a residential land use. This study would allow water quality to be monitored in a controlled area where no structural or non-structural BMPs would be implemented. Water quality would be monitored in an adjacent watershed of similar size, where several small scale structural and non-structural BMPs would be implemented. The following criteria are recommended when selecting paired watersheds:

- Overall similar size
- Comparable topography, land use, and proximity to each other
- Accessible monitoring location
- Defined boundaries
- Utility obstructions avoidance for sampling access
- Controlled sampling location
- Suspected pollutants and their sources

The following non-structural BMPs are recommended for implementation as part of a paired watershed study:

- Rain gardens
- Rain barrels
- Bioretention
- Rooftop disconnections from impervious surfaces
- Use of Low/No-phosphorus fertilizers
- Frequent pet-waste pick-up
- Sweeping of fertilizers from impervious surfaces
- Street sweeping/washing
- Debris/litter removal

Data collected prior to the study would include at a minimum the following:

- Percentage of impervious surface
- Inventory of direct connections
- Identification of pollutant sources (number of pets, wildlife inventory)
- Existing number of structural or non-structural BMPs currently in place
- Area of fertilized turf

Selection of the watershed to receive non-structural controls relies heavily on the willingness of property owners to implement the recommended non-structural BMPs. If landowner willingness to participate is low in a watershed, it would be recommended to use the non-structural controls on the control area and move treatment options to the adjacent watershed. The following protocol is recommended for conducting water quality monitoring for the paired watershed study:

A large amount of sampling events will need to be scheduled in order to provide a high confidence on any findings or conclusions, and could include up to a minimum of 50 samples over 2 years (Pitt, 2012). Each event should produce flow through the sampling location (manhole). If a rain event is intermittent, but provides adequate flows and 6 hours pass between runoff events, a second sampling can be completed as a valid event. Sampling should not occur unless all data requirements and flow conditions are met for both watersheds. Flow should be sampled for TSS, *E. coli*, phosphorus, and nitrogen in all watershed sampling events. Other watershed specific analytes should be added based on known conditions or specific watershed data needs. In addition to chemical and biological parameters, flow estimates should be made as well as precipitation frequency, duration and rainfall amounts, weather conditions

(temperature, wind, cloud cover, etc.), and unusual watershed activity (maintenance and repairs or streets or utilities, street closing, special activities).

Antelope Creek Water Quality Partnership

In addition to the City and LPSNRD, several important stakeholders are located in the Antelope Creek watershed, including the University of Nebraska – Lincoln; which encompasses a majority of the land at the lower end of the watershed. In addition, the newly established Nebraska Innovation Campus (NIC), a public/private research and technology development center, is being constructed north of UNL's City Campus at the site of the former Nebraska State Fairgrounds. Several other businesses have property adjacent to the creek and new opportunities for businesses are available due to completion of the Antelope Valley Project, which greatly reduced the 100-year floodplain of Antelope Creek. Stormwater management decisions made by these stakeholders during new construction and redevelopment activities can impact the water quality of Antelope Creek. Incorporation of water quality BMPs into the planned activities of stakeholders can have tremendous water quality benefits.

Recommendation #20: To have an active stakeholder group available to support decisions with potential to improve water quality in Antelope Creek, the City and NRD are encouraged to establish a formal partnership between the City, LPSNRD, UNL, Nebraska Innovation Campus (NIC) and local businesses to encourage use of BMPs in the Antelope Creek watershed. This partnership would support implementation of projects and programs in this Basin Plan as well as encourage local stakeholders and interested residents, property owners, and developers to utilize stormwater controls as part of any planned development or redevelopment activity.

Urban Soil Quality Restoration[1]

Healthy soils have tremendous capacity for infiltrating and storing water and also have active microbial life that will break down and utilize many pollutants moving in urban non-point source runoff. Directing stormwater flows onto landscapes with good soil quality reduces the volume of runoff that is generated. Soil quality restoration involves several steps including: reducing compaction, increasing pore space, improving organic matter content, and re-establishment of soil dwelling populations (microbes, worms, insects, etc.).

Recommendation #21: To support individual activities by property owners and residents to improve water quality, establish a new Urban Soil Quality Restoration Program. This newly established program would have incentives for residents and property owners in the Antelope Creek area to improve soil quality or work to ensure soil quality is maintained during re-development activities. Through information and education, property owners could learn about the importance of soil quality for treatment of stormwater.

Quantitative Microbial Risk Assessment[2]

Quantitative Microbial Risk Assessment (QMRA) is used to investigate sites that are believed to be predominately impacted by non-human sources of bacteria. While human sources of fecal contamination pose similar health risks regardless of location, the differences in predicted human health risks from recreational water exposure to non-human fecal contamination are dependent on local characteristics that will vary from site-to-site. This assessment can assist in developing equivalent site-specific criteria to account for local scale, non-human sources. QMRA can be initiated for the following reasons:

- To assess the potential for human risk associated with exposure to a known pathogen
- To determine critical points for control, such as watershed protection measures
- To determine specific treatment processes to reduce, remove, or inactivate various pathogens
- To predict the consequences of various management options for reducing risk
- To determine appropriate criteria (regulatory) levels that will protect individuals and/or populations to a specified risk level or range and support changes to the existing TMDL
- To identify and prioritize research needs
- To assist in interpretation of epidemiological investigations

[1] Information summarized from the Iowa Stormwater Management Manual, Version 3; October 2009
[2] http://water.epa.gov – Recreational Water Quality Criteria, December 2011

Recommendation #22: To increase knowledge on the specific types of bacteria present in Antelope Creek, and further understand the risk associated with those types, conduct a QMRA for the Antelope Creek watershed. A QMRA might be considered in the event that bacteria levels do not decline after Phase One implementation.

8.4. Structural Project Recommendations

Projects outlined below include a variety of structural improvements recommended basin-wide to be implemented over time as a starting point for reducing pollutant levels to acceptable levels. At this time, there are no single financially feasible alternatives to reducing levels of *E. coli* in Antelope Creek to acceptable levels. Therefore, several small scale demonstration projects are detailed across varying land uses.

As mentioned above, these projects have been sited mostly on public property where opportunities for public outreach and education of stormwater BMPs can occur. Some sites, such as the Lincoln Children's Zoo and Antelope Park, have several individual projects in one area. Another project, at the labyrinth weir, was included in the recommended project list in order to improve aesthetics along Antelope Creek and improve the quality of water in Union Plaza.

Project benefits will vary depending upon the location but are mostly focused on reduction of *E. coli*, nutrients (phosphorus), and total suspended solids (TSS) to Antelope Creek. Each project description includes the following:

- Project name and general location
- Property owner
- Purpose for site being selected
- Project summary
- Maintenance requirements
- Installation cost
- Water quality benefits/pollutant load reduction summary

8.4.1 Prioritization Methodology

The City of Lincoln has an existing mechanism to prioritize potential capital improvement projects (CIP) listed in master plans (JEO, 2006). This prioritization methodology is intended to provide a flexible tool that can be used as a screening mechanism by City staff when selecting projects to be constructed. The ranking system was specifically developed for CIP projects proposed as part of the on-going watershed master planning efforts. The prioritization methodology can be applied to master plan projects encompassing a wide range of stormwater management goals including: flood control, floodplain management, stream stability, water quality, and public health and safety.

The City of Lincoln's past watershed master planning projects have primarily focused on flood control and drainage improvements, but the criteria are also flexible and represent projects with a primary focus on water quality. Therefore, wholesale changes to the existing prioritization categories were not necessary or desired. The project team used the existing criteria from 2006 to prioritize projects listed in this plan.

From using the site screening process outlined in SECTION 7 - BMP SITE INVENTORY, a total of 32 sites were considered. From these 32 sites, a total of 10 were selected for projects and prioritized using criteria summarized below. Prioritization worksheets are included in Appendix D. Criteria include the following:

Flooding Impacts – This category identifies the impact of floodwater encroachment on structures, public or private property, parking lots, public utilities or other infrastructure. The flooding potential can be identified through hydrologic and hydraulic analysis, study of topographic maps, field investigation, and recorded historical problems.

As previously discussed in SECTION 3 - WATERSHED INVENTORY, the majority of the Basin Plan area has had significant improvements to provide greater flood control throughout the entire watershed. Stormwater BMPs identified in this plan are not intended to provide significant flood benefits. However, potential impacts on flooding resulting from a project, such as infiltration or temporary storage of floodwaters, were considered as part of this prioritization category.

Water Quality – This category identifies the impacts of impaired water quality. The water quality benefits broken down in this category reflect the types of projects developed during watershed master planning efforts. This category is further divided according to the perceived scope of the project benefits, with greater emphasis placed upon projects with broad-based impacts.

Based upon goals as written in the 2007 TMDL, strong considerations were given to BMPs that reduce *E. coli* loading to Antelope Creek. In addition to *E. coli*, BMPs that limited loading of nutrients, sediment, oils and grease were also considered. Consideration was also given for projects that affect overall aesthetics of Antelope Creek.

Stream Stability – This category identifies the impacts of channel erosion and the transport and undermining of soil by stream flow or overland flow. Channel erosion can threaten structures, property, infrastructure, streams, and other natural resources. Channel erosion can also impact water quality through the transportation of sediment. The stream stability and erosion threat may be identified through visual observation, not strictly fluvial geomorphic assessment. This category is further divided according to the nature of the erosion, such as aggressive channel down cutting as compared to gradual channel widening.

The majority of Antelope Creek's stream banks are stabilized. In addition, a significant portion of the stream channel consists of hard armor. Consideration was given to how each proposed BMP may alter the stability of drainage ways and existing controls placed in Antelope Creek, such as removal of existing concrete liners in water ways and replacement with BMPs.

Safety Factor – This category identifies project benefits that decrease the potential threat to public health and safety. The potential for loss of life or bodily injury may include individuals trapped in structures during flooding or vehicles being swept away by floodwater. Erosion near bike paths, sidewalks, and roads can also be a hazard. A safety factor is generally associated with projects addressing structural or non-structural flooding hazard reduction.

Miscellaneous Factors – This category identifies various other miscellaneous factors and additional considerations that have not been addressed in the previous categories. Examples used for Basin Plan prioritization included location, coincident with adjacent properties, and development status. Prioritization scoring of miscellaneous factors included consideration for public property and projects being sited within the city limits.

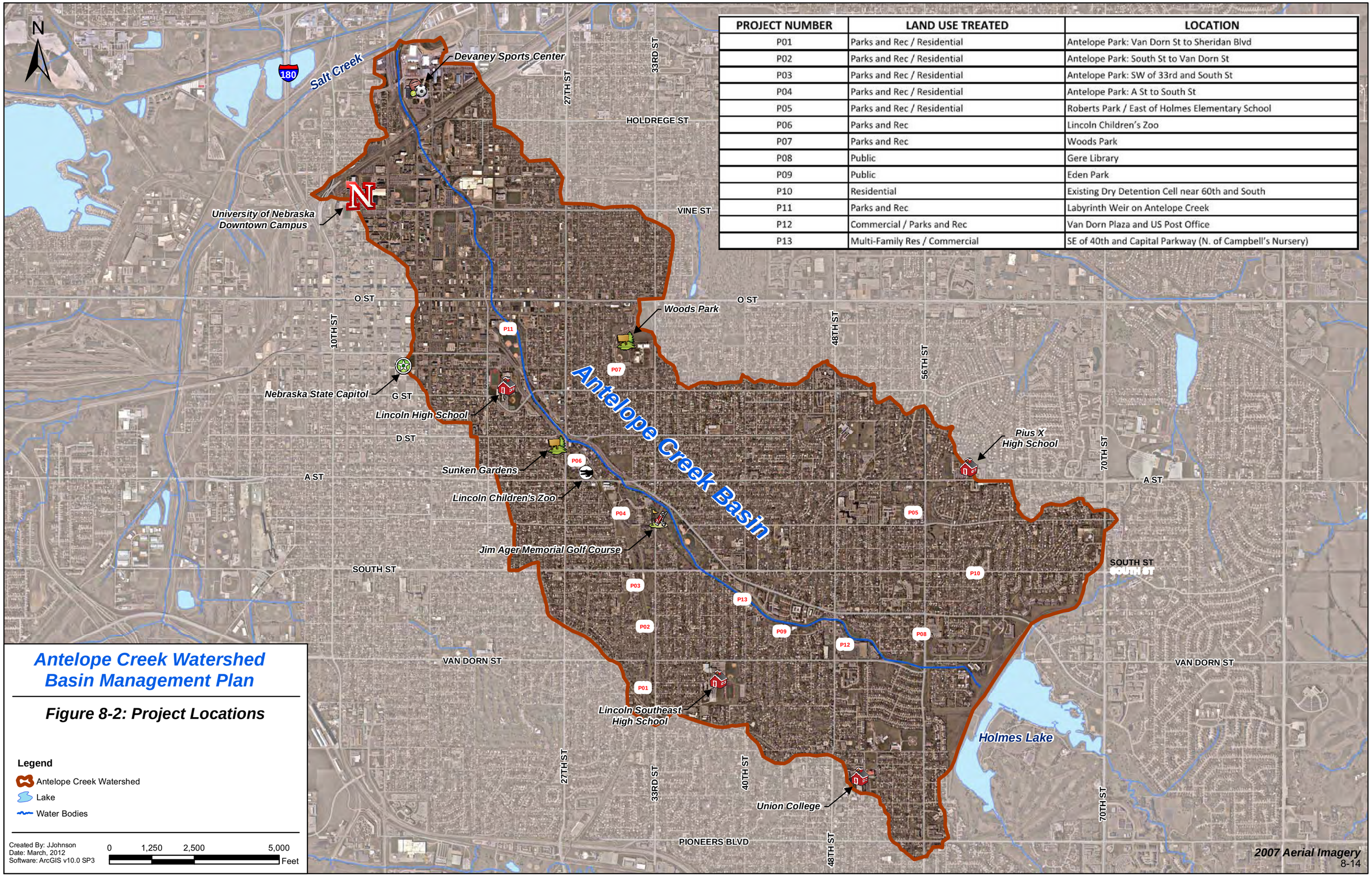
Additional Considerations – The additional considerations category allows issues not covered by the primary categories to be scored. For the purposes of the Basin Plan, how each project addressed the TMDL, along with public education opportunities, was considered.

Table 8-3 below displays the recommended structural BMPs listed by priority, based on the 2006 master plan prioritization analysis, including conceptual design and cost projections. Prioritization ranking worksheets have been completed and are included in Appendix D. Figure 8-2 displays the location of each project in the Basin Plan area.

Table 8-3. Project Prioritization Ranking

Project ID	Location	Ranking Points	Project Cost
P11	Labyrinth Weir on Antelope Creek	370	$625,000
P06	Lincoln Children's Zoo	300	$425,000
P03	Antelope Park: SW of 33rd and South St	260	$125,000
P02	Antelope Park: South St to Van Dorn St	240	$125,000
P01	Antelope Park: Van Dorn St to Sheridan Blvd	200	$125,000
P04	Antelope Park: A Street to South Street	180	$250,000
P05	Roberts Park/East of Holmes Elementary School	180	$375,000
P07	Woods Park	160	$250,000
P09	Eden Park	160	$45,000
P13	SE of 40th and Capital Parkway (N. of Campbell's Nursery)	140	$125,000
P08	Gere Library	130	$95,000
P12	Van Dorn Plaza and US Post Office	130	$65,000
P10	Existing Dry Detention Cell near 60th and South	125	$45,000
	--	**TOTAL**	**$2,675,000**

PROJECT NUMBER	LAND USE TREATED	LOCATION
P01	Parks and Rec / Residential	Antelope Park: Van Dorn St to Sheridan Blvd
P02	Parks and Rec / Residential	Antelope Park: South St to Van Dorn St
P03	Parks and Rec / Residential	Antelope Park: SW of 33rd and South St
P04	Parks and Rec / Residential	Antelope Park: A St to South St
P05	Parks and Rec / Residential	Roberts Park / East of Holmes Elementary School
P06	Parks and Rec	Lincoln Children's Zoo
P07	Parks and Rec	Woods Park
P08	Public	Gere Library
P09	Public	Eden Park
P10	Residential	Existing Dry Detention Cell near 60th and South
P11	Parks and Rec	Labyrinth Weir on Antelope Creek
P12	Commercial / Parks and Rec	Van Dorn Plaza and US Post Office
P13	Multi-Family Res / Commercial	SE of 40th and Capital Parkway (N. of Campbell's Nursery)



Antelope Creek Watershed Basin Management Plan

Figure 8-2: Project Locations

Legend

- Antelope Creek Watershed
- Lake
- Water Bodies

Created By: JJohnson
Date: March, 2012
Software: ArcGIS v10.0 SP3

8.4.2 Project Descriptions

The cost estimates for the proposed projects are based on quantities and costs that have been developed from past projects. Site slopes, location, space, anticipated flows, and many other parameters were included in the conceptual layout of the following projects. General sizes, depths, and other essential characteristics were proposed so that conceptual total project costs could be developed. Project cost estimates do not include maintenance, and are conceptual costs. The designs presented are at the conceptual stage and do not include topographic surveys, geotechnical investigations, flow analysis, digital terrain modeling, wetland delineations, etc. Because of these unknown parameters, these projects are anticipated to change and adapt as they are designed and constructed.

Pollutant load removal estimates have been established based upon available information in WinSLAMM and manufacture's specifications. Load reduction estimates were calculated for each project through desktop review of land uses within each project sub-basin, estimated flow patterns through each BMP, and drainage area. The percent reduction given for each project is the reduction expected at the outfall of each site.

Hydrodynamic separators were not modeled within WinSLAMM. The removal efficiency of these BMPs varies depending on the unit type that is used, level of maintenance performed, and the target sediment particle size. Large underground vaults offer no stormwater quality benefit and no pretreatment if not combined with other BMPs such as bioretention areas. However, these types of BMPs do remove large debris and sand/grit from runoff.

Maintenance costs were not included in the total project costs. Maintenance efforts are generalized as Low, Medium, and High based on existing similar projects within Lincoln. Low maintenance typically refers to projects than require plant removal, minor sediment removal, and mulching. High maintenance typically refers to sites that require regular frequent maintenance for sediment or trash removal, as well as plant removal and mulching.

Project AC-P01: Antelope Park: Channel and Wetland Enhancements from Van Dorn to Sheridan Boulevard

This project is located west of 33rd Street from Sheridan Boulevard to Van Dorn Street as shown in Figure 8-3. The area contains 1,300 feet of the un-named tributary to Antelope Creek, as well as open spaces which capture stormwater runoff from the surrounding residential areas and streets. The sub-watershed for this project is approximately 60 acres in size. Flow within the sub-watershed is generally in a northern direction.

Picture 21: The existing stream channel at AC-P01

Ownership:

All property is owned by the City of Lincoln, which includes Antelope Park.

Site Selection:

This site was selected for the following reasons:

- All property is owned by the City of Lincoln
- Available land for BMP installation
- Large treatable area
- Located in the priority Antelope Park sub-basin

Project Summary:

- Reshape the un-named tributary to provide at least 1 foot of depth, and roughly 4 to 5 feet in width along its entire length. Improvement of a few outlet structures discharging to the tributary is also included to better dissipate energy and improve flow dynamics. Areas adjacent to the tributary should be included in the City's Long Grass program, where possible, with signage.

- Install inline berms perpendicular to the flow approximately every 100 feet as shown in Figure 8-3. The inline berms will produce small bioretention areas within the channel, decreasing flow velocities, promote infiltration into soils, and further stabilizing the stream. Berms are generally 6 inches above the channel flowline, and include an area of roughly 100 square feet upstream of the berm with 2 to 3 feet of engineered soil.
- Improve the existing wetland by enlarging the area, increasing vegetation, or adjusting the site hydraulics.

Picture 22: This existing wetland could be enhanced in Antelope Park

- Install a large bioretention area at one of the outfalls as shown in Figure 8-3. This bioretention area is approximately 2,000 to 3,000 square feet, 0.5 to 1.0 feet deep, and includes 2 to 3 feet of engineered soil along with an overflow that is directed to the tributary.
- Implement pet waste pick-up, and place pet waste containers and signage along the walking trail adjacent to the un-named tributary.

Maintenance:

Post-project maintenance efforts are anticipated to be moderate and may include: cleanout of debris; cleanout of sediment or replacing of soils within wetland; vegetation control; inspections for erosion or standing water problems and maintenance of pet waste containers.

Estimated Total Project Cost: $100,000-$150,000

Water Quality Benefits:

Reshaping the tributary and installing the berms will aid in stabilizing the channel, promote infiltration, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. Allowing the stormwater runoff to flow through a broader channel reduces the volume of runoff by enabling infiltration over a greater area, while also reducing velocities and erosion. Improvements made to outfalls into the tributary are intended to reduce future erosion. Areas along the stream included in the City's Long Grass program will decrease operation and maintenance costs to the City, and the amount of sediment transported off-site. The enhanced wetland, as well as the engineered soil within each berm area and bioretention area, will aid in reducing the volume of runoff by infiltration; further reducing the amount of sediment, nutrients, and *E. coli* being transported off-site. Pet waste pick-up, containers, and signage will have direct impacts on reducing the levels of *E. coli* located within this project's drainage area.

While some of these structural BMPs work to minimize pollutants from being carried off-site or treat pollutants by plant uptake and natural mechanisms, some simply reduce the volume of water by infiltration. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. Table 8-4 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-4. Annual Pollutant Load Reduction Estimates for AC-P01

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	10,990 lbs	2,500-3,000 lbs	23-27%
Phosphorus	25 lbs	0-4 lbs	0-16%
E. coli	2.5×10^{13}	$1\text{-}5 \times 10^{12}$ counts	4-20%

Figure 8-3. Antelope Park Channel and Wetland Enhancements from Van Dorn to Sheridan Boulevard

Project AC-P02: Antelope Park: Channel Enhancements from South Street to Van Dorn Street

This project is located west of 33rd Street from Van Dorn Street to South Street as shown in Figure 8-4. The area contains 2,500 feet of the un-named tributary to Antelope Creek as well as open spaces which capture stormwater runoff from the surrounding residential areas, streets, and a portion of Antelope Park. The sub-watershed for this project is approximately 160 acres in size, including the drainage area from Project 01. Flow within the sub-watershed is generally in a northern direction. The construction of project P01 would create a treatment train including this project. This treatment train would increase the removal efficiency of pollutants, and is encouraged.

Ownership:

All property is owned by the City of Lincoln, which includes Antelope Park.

Picture 23: Existing stream channel in Antelope Park

Site Selection:

This site was selected for the following reasons:

- All property is owned by the City of Lincoln
- Available land for BMP installation
- Large treatable area
- Located in the priority Antelope Park sub-basin

Project Summary:

- Reshape the un-named tributary to provide at least 1 foot of depth, and roughly 4 to 5 feet in width along its entire length. Improvement of a few outlet structures discharging to the tributary is also included to better dissipate energy and improve flow dynamics. Areas adjacent to the tributary should be included in the City's Long Grass program where possible with signage.
- Install inline berms perpendicular to the flow, approximately every 100 feet as shown in Figure 8-4. The inline berms will produce small bioretention areas within the channel, decrease flow velocities, promote infiltration into soils, and further stabilize the stream. Berms are generally 6 inches above the channel flowline, and include an area of roughly 100 square feet upstream of the berm with 2 to 3 feet of engineered soil.
- Install of a bioretention area, as shown on Figure 8-4, to enhance treatment and promote infiltration into soils. This basin is approximately 4,000 to 5,000 square feet in size, 1 to 2 feet deep, and contains 2 to 3 feet of engineered soil.
- Implement pet waste pick-up, and place pet waste containers and signage along the walking trail adjacent to the un-named tributary.

Maintenance:

Post-project maintenance efforts are anticipated to be low and may include: cleanout of debris; cleanout of sediment or replacing of soils within bioretention areas; inspections for erosion or standing water problems and maintenance of pet waste containers.

Estimated Total Project Cost: $100,000-$150,000

Water Quality Benefits:

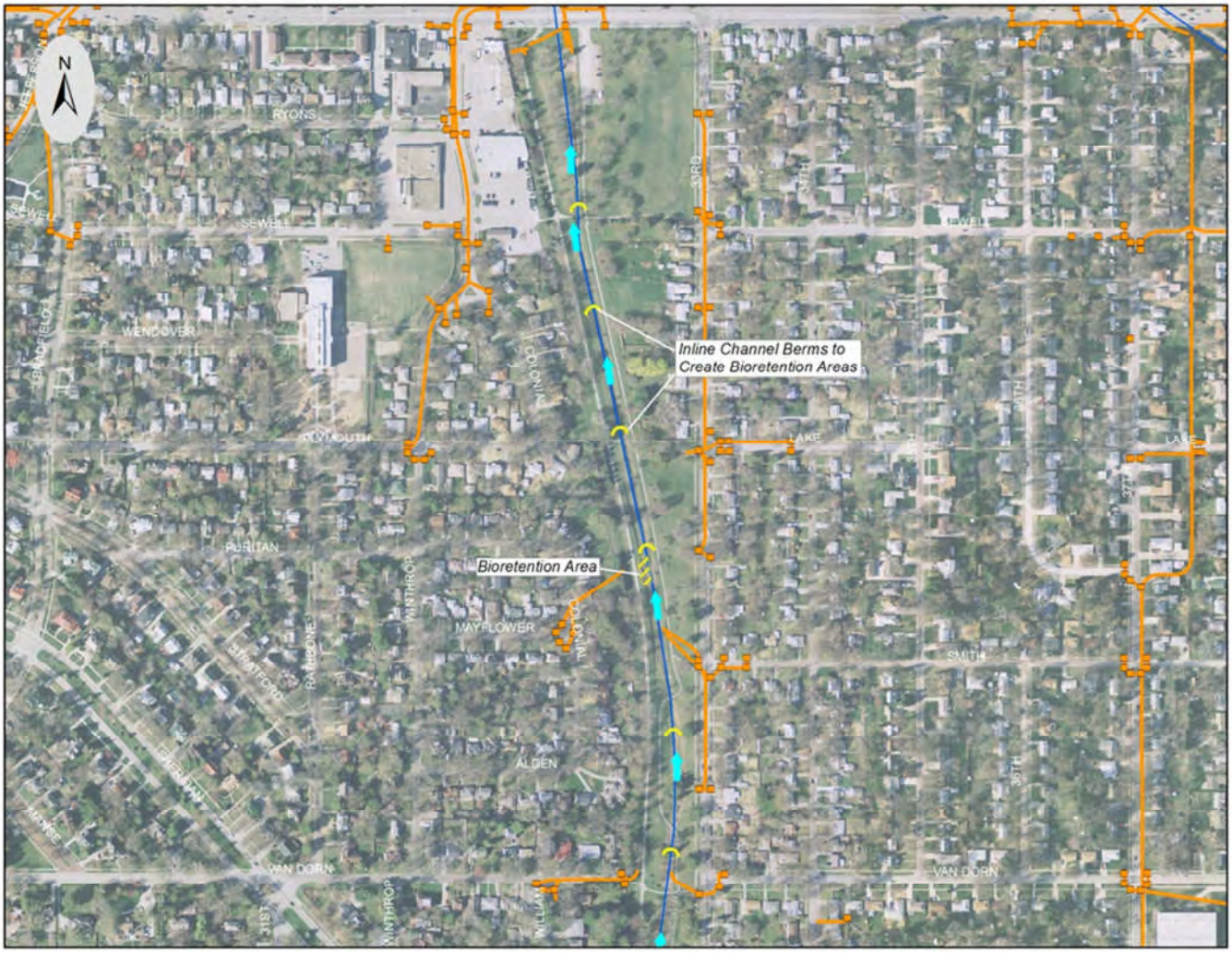
Reshaping the tributary and installing the berms will aid in stabilizing the channel, promote infiltration, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. Allowing the stormwater runoff to flow through a broader channel, reduces the volume of runoff by enabling infiltration over a greater area, while also reducing velocities and erosion. Improvements made to outfalls into the tributary are intended to reduce future erosion. Areas along the stream included in the City's Long Grass program will decrease operation and maintenance costs to the City, and the amount of sediment transported off-site. The enhanced wetland, as well as the engineered soil, will aid in reducing the volume of runoff by infiltration; further reducing the amount of sediment, nutrients, and *E. coli* being transported off-site. Pet waste pick-up containers and signage will have direct impacts on reducing the levels of *E. coli* located within this project's drainage area.

While some of these structural BMPs work to minimize pollutants from being carried off-site, or treat pollutants by plant uptake and natural mechanisms, some simply reduce the volume of water by infiltration. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. Table 8-5 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-5. Annual Pollutant Load Reduction Estimates for AC-P02

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	22,500 lbs	6,000-7,000 lbs	27-31%
Phosphorus	59 lbs	10-15 lbs	17-25%
E. coli	6.6×10^{13} counts	$1\text{-}3 \times 10^{13}$ counts	15-45%

Figure 8-4. Channel Enhancements from South Street to Van Dorn Street



Project AC-P03: Antelope Park: Bioretention Areas SW of 33rd and South St

This project is located southwest of 33rd and South Street as shown in Figure 8-5. The sub-watershed for this project is approximately 185 acres in size, and includes the drainage area from Projects 01 and 02. The land use consists primarily of residential development and a portion of Antelope Park. Flow within the sub-watershed is generally in a northern direction. The construction of projects P01 and P02 would create a treatment train including this project. This treatment train would increase the removal efficiency of pollutants, and is encouraged.

Ownership:

All property is owned by the City of Lincoln; including Antelope Park.

Site Selection:

This site was selected for the following reasons:

- All property is owned by the City of Lincoln
- Available land for BMP installation
- Large treatable area
- Located in the priority Antelope Park sub-basin
- Provides additional treatment to runoff from other BMPs

Picture 24: 33rd and South detention structure

Project Summary:

- Install a bioretention area upstream of the inlet to the main tributary to enhance treatment and promote infiltration into soils. This basin is approximately 5,000 to 6,000 square feet in size, and includes 2 to 3 feet of engineered soil.
- Modifications to the inlet are also included as part of this project, and involve installing a unit that will allow 0.5 to 1.0 feet of water to be impounded, while still allowing the area to fully drain after a predetermined length of time.
- Install a smaller bioretention area to the west of the above mentioned bioretention area. This smaller area is approximately 2,000 to 2,500 square feet, 0.5 to 1.0 feet deep, and contains 2 to 3 feet of engineered soil. An overflow pipe is included, and is intended to direct overflows into the larger bioretention area.
- Modifications to the existing inlet to the west, as shown on Figure 8-5, will allow the stormwater runoff to flow into the small bioretention area. Large runoff events should still be allowed to bypass and flow straight into the existing inlet.

Maintenance:

Post-project maintenance efforts are anticipated to be low and may include: cleanout of debris from the basin outlet; cleanout of sediment from bio-retention area; eventual replacement of soils in bio-retention area; and routine inspections for erosion or standing water problems.

Estimated Total Project Cost: $100,000-$150,000

Water Quality Benefits:

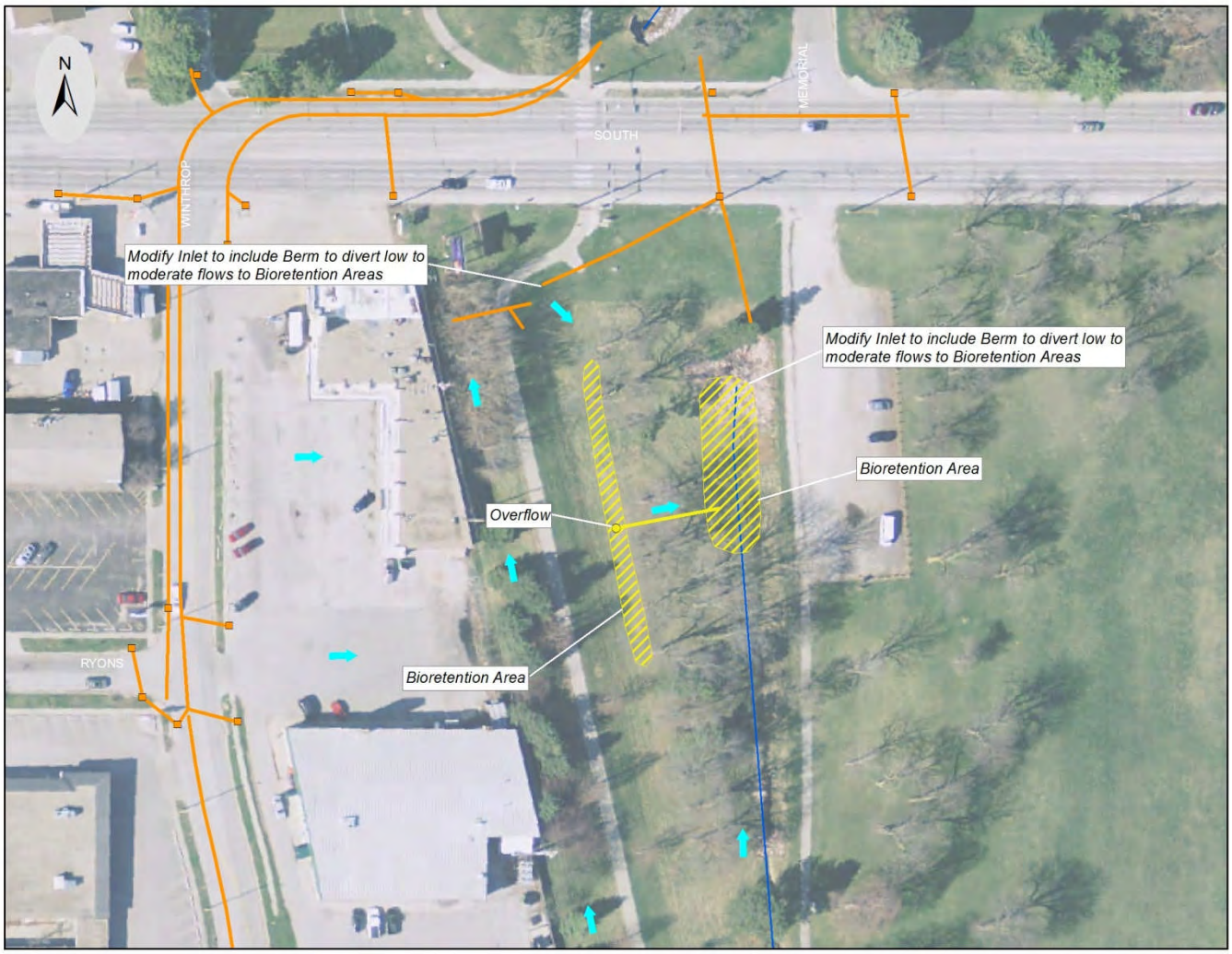
Installing bioretention areas will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. The bioretention areas will also help to slow stormwater runoff, which will aid in the prevention of future erosion downstream. Table 8-6 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. The pollutant load reduction

estimates do not take into account the effectiveness of BMPs upstream of this project. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-6. Annual Pollutant Load Reduction Estimates for AC-P03

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	19,300 lbs	6500-7500lbs	34-39%
Phosphorus	63 lbs	10-15 lbs	16-24%
E. coli	7.9 x 10^{13} counts	1-4 x 10^{13} counts	13-51%

Figure 8-5. Bioretention Areas SW of 33rd and South St



Project AC-P04: Antelope Park: A Street to South Street

This project is located south and southwest of the Auld Pavilion within Antelope Park. Two locations are included within this project, and include the meandering channel to the southwest, and the approximately 2 acre parking lot to the south. The sub-watershed for this project includes a portion of the parking lot, Antelope Park, and 9 acres of residential land use. Flow within the sub-watershed is generally in a western direction.

Ownership:

All property is owned by the City of Lincoln, which includes Antelope Park.

Site Selection:

This site was selected for the following reasons:

- All property is owned by the City of Lincoln
- Available land for BMP installation
- Large treatable area
- Located in the priority Antelope Park sub-basin

Picture 25: The parking lot south of Auld could be disconnected from the storm drain

Project Summary:

- Some locations of the meandering channel are showing signs of erosion. Stream stability improvements along this reach would reduce further channel erosion. In addition, a flow dissipation device installed at the outlet just north of South Street will aid in reducing erosion within the meandering channel
- Installation of a curb cut along the west side of the parking lot will allow runoff to drain into the bioretention area. Plugging the existing storm drain inlet on the west side will allow all runoff to flow through the bioretention area.
- Constructing a bioretention area west of the south parking lot is recommended, as shown in Figure 8-6. This bioretention area is approximately 13,000 to 15,000 square feet, 1 to 2 feet deep, and contains 2 to 3 feet of engineered soil. An overflow pipe is included, and is intended to direct overflows into the tributary.
- Construct a bioretention area east of 29th and Washington as shown in Figure 8-6. This bioretention area is approximately 13,000 to 15,000 square feet, 1 to 2 feet deep, and contains 2 to 3 feet of engineered soil. Small berms approximately 0.05 to 1.0 feet above the flowline are included to allow a small amount of water to be impounded to infiltrate.

Picture 26: Potential area for a bioswale near Auld Pavilion

Maintenance:

Post-project maintenance efforts are anticipated to be low and may include: cleanout of sediment or replacement of soils within bioretention areas; inspections for erosion or standing water problems; and mulch removal and replacement.

Estimated Total Project Cost: $225,000-$275,000

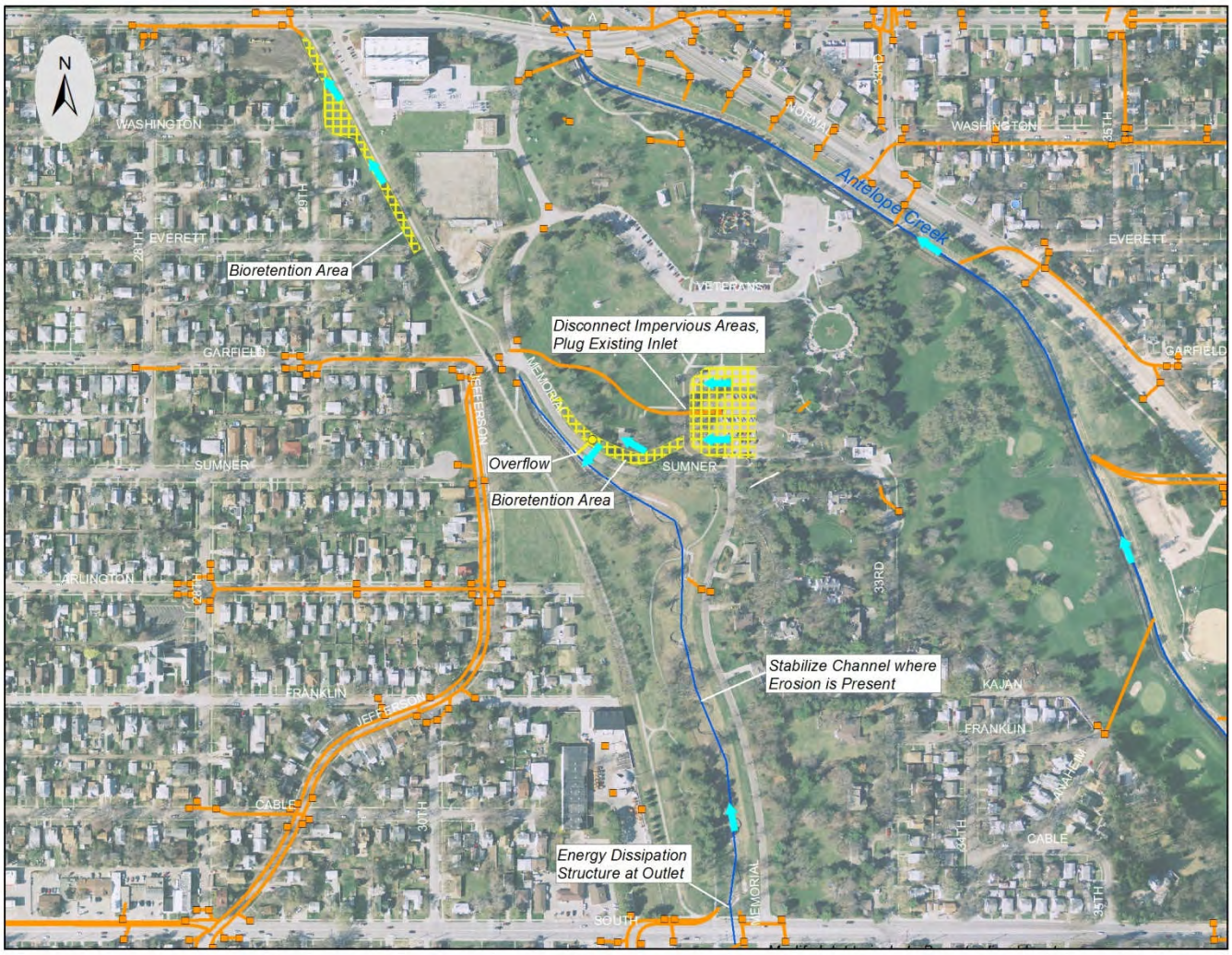
Water Quality Benefits:

The flow dissipation device, as well as the stream stability improvements, will help to stabilize the meandering channel and outfall, and reduce the transport of sediment to Antelope Creek. Re-directing the stormwater runoff from the parking lot to the bioretention area will reduce the volume of stormwater reaching Antelope Creek. Installing bioretention areas will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. The bioretention areas will also help to slow stormwater runoff; aiding in the prevention of future erosion downstream. Table 8-7 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-7. Annual Pollutant Load Reduction Estimates for AC-P04

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	4820 lbs	1000-1100 lbs	21-23%
Phosphorus	8 lbs	0-2 lbs	0-25%
E. coli	5.3 x 10^{12} counts	1-3 x 10^{12} counts	19-57%

Figure 8-6. Antelope Park: A Street to South Street



Project AC-P05: Roberts Park/East of Holmes Elementary School

This project is located southwest of 56th and A Street, illustrated in Figure 8-7. Two channel reaches have been selected for improvements, both in open green space east of Holmes Elementary School at 52nd and Sumner Street. The sub-watershed for this project is approximately 80 acres in size; the land use consists primarily of residential development and a portion of Holmes Elementary School. Flow within the sub-watershed is generally in a southwesterly direction.

Ownership:

All property is owned by the City of Lincoln, which includes Roberts Park and a large green space east of Holmes Elementary School.

Picture 27: Roberts Park

Site Selection:

This site was selected for the following reasons:

- All property is owned by the City of Lincoln
- Available land for BMP installation
- Large treatable area

Project Summary:

- Replace the concrete channel with a grass swale as illustrated in Figure 8-7. Concrete lining at the street crossing shall remain in place to retain the integrity of the structure. Permanent erosion control should be installed in place of concrete channel.
- Install berms perpendicular to the channels as shown in Figure 8-7. Inline berms will produce bioretention areas in the channel; decrease flow velocities and promote infiltration into soils. Berms shall include a pipe at flowline elevation to convey low flows, and concrete weir structures to convey higher flows. Weirs shall generally be 8-12 inches above channel flow line.
- Offline bioretention areas as shown in Figure 8-7 are also included. Total size of the bioretention areas is approximately 16,000 to 18,000 square feet in size. Each bioretention area is approximately 8-12 inches in depth with 2 to 3 feet of engineered soil to promote infiltration.
- Modify the inlet to the downstream 42-inch culvert to aid soil infiltration.

Maintenance:

Post-project maintenance efforts are anticipated to be moderate and may include: cleanout of debris; cleanout of sediment or replacement of soils within bioretention areas; inspections for erosion or standing water problems; and mulch removal and replacement.

Estimated Total Project Cost: $350,000-$400,000

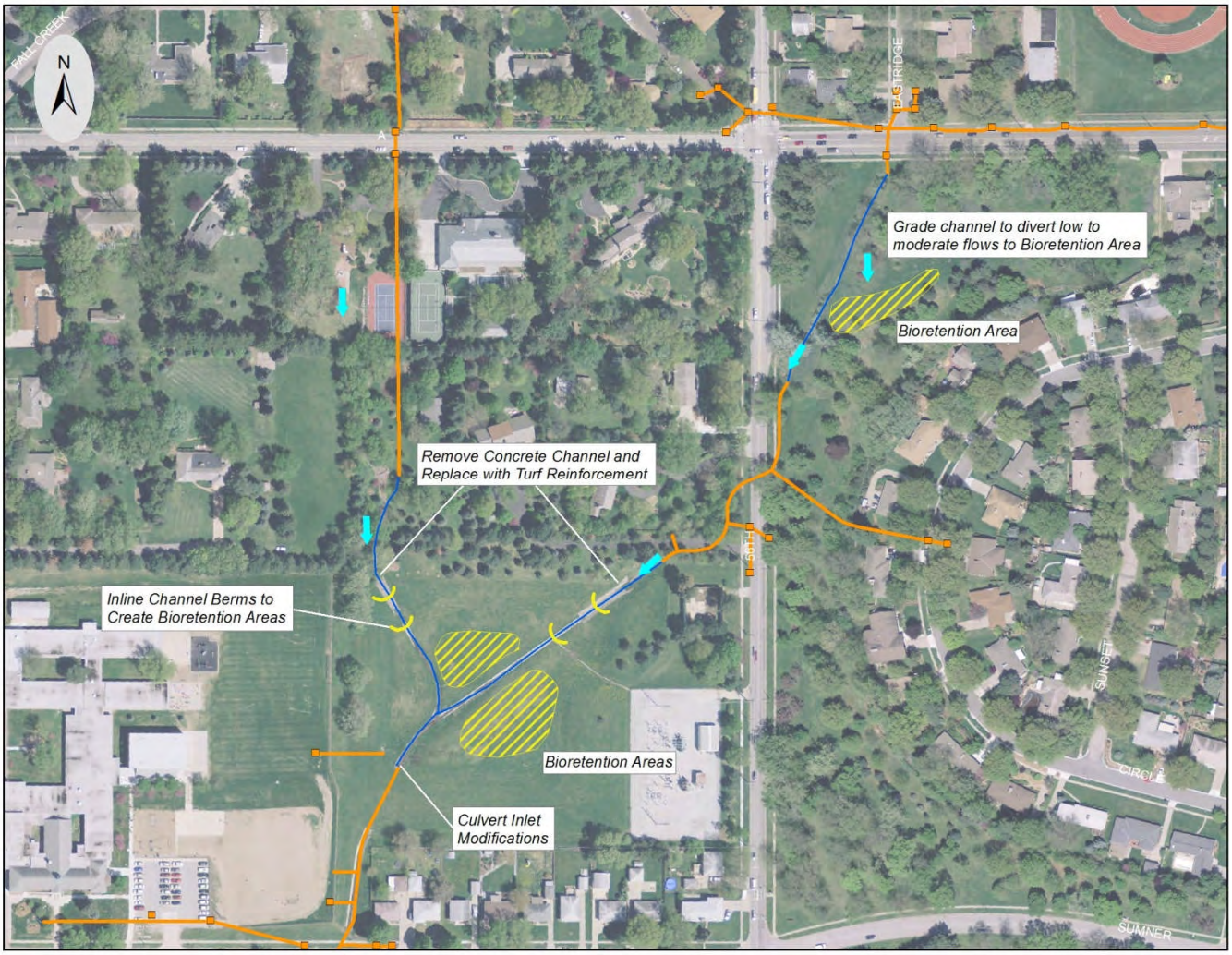
Water Quality Benefits:

Installing the bioretention areas will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. The bioretention areas will also help to slow stormwater runoff, which will aid in the prevention of future erosion downstream. Table 8-8 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-8. Annual Pollutant Load Reduction Estimates for AC-P05

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	20,470 lbs	5000-6000 lbs	24-29%
Phosphorus	39 lbs	5-10 lbs	13-26%
E. coli	3.1×10^{13} counts	$5\text{-}10 \times 10^{12}$ counts	16-32%

Figure 8-7. Roberts Park



Project AC-P06: Lincoln Children's Zoo

This project is located southeast of 27th and Capitol Parkway, illustrated in Figure 8-8. The sub-watershed for this project is approximately 14 acres in size, consisting of park and zoo areas. Flow within the sub-watershed is generally in a northerly direction. The Zoo is a non-profit organization, and leases property from the City Parks and Recreation.

Picture 28: The zoo already has several water quality BMPs including this rain garden

Ownership:

The project lies on two public parcels owned by the City of Lincoln; including Antelope Park.

Site Selection:

This site was selected for the following reasons:

- High public education potential
- Available land for BMP installation
- High pollutant load
- Located in the priority Antelope Park sub-basin

Project Summary:

- Construct bioretention areas as shown in Figure 8-8. Total size of the bioretention areas is approximately 4,500 to 5,000 square feet. Each bioretention area is approximately 1.0 to 1.5 feet deep, with 2 to 3 feet of engineered soil. Overflows within each should have large events directed to nearby storm drain inlets. Curbs should be cut, and downspouts directed where possible to allow runoff from nearby parking areas and rooftops to be captured.
- Installation of a green roof on the building shown in Figure 8-8 is an integral part of this project. Many different components can be included within a green roof. A general cost per square foot of roof was used to estimate the cost. The estimated project cost must be updated based upon the needs of the Zoo.
- Install a permeable paver system in the bike rack area. The system should capture stormwater falling directly on it and infiltrate into the soils below.
- Disconnect as many downspouts as possible throughout the zoo grounds, and direct them onto nearby green spaces. Some downspouts may be directed into a cistern to harvest the rainwater for later use (not included in total project cost).

Maintenance:

Post-project maintenance efforts are anticipated to be moderate and may include: cleanout of debris; cleanout of sediment or replacement of soils within bioretention areas; inspections for erosion or standing water problems; mulch removal and replacement; and occasional cleaning of the permeable paver system.

Estimated Total Project Cost: $400,000-$450,000

Water Quality Benefits:

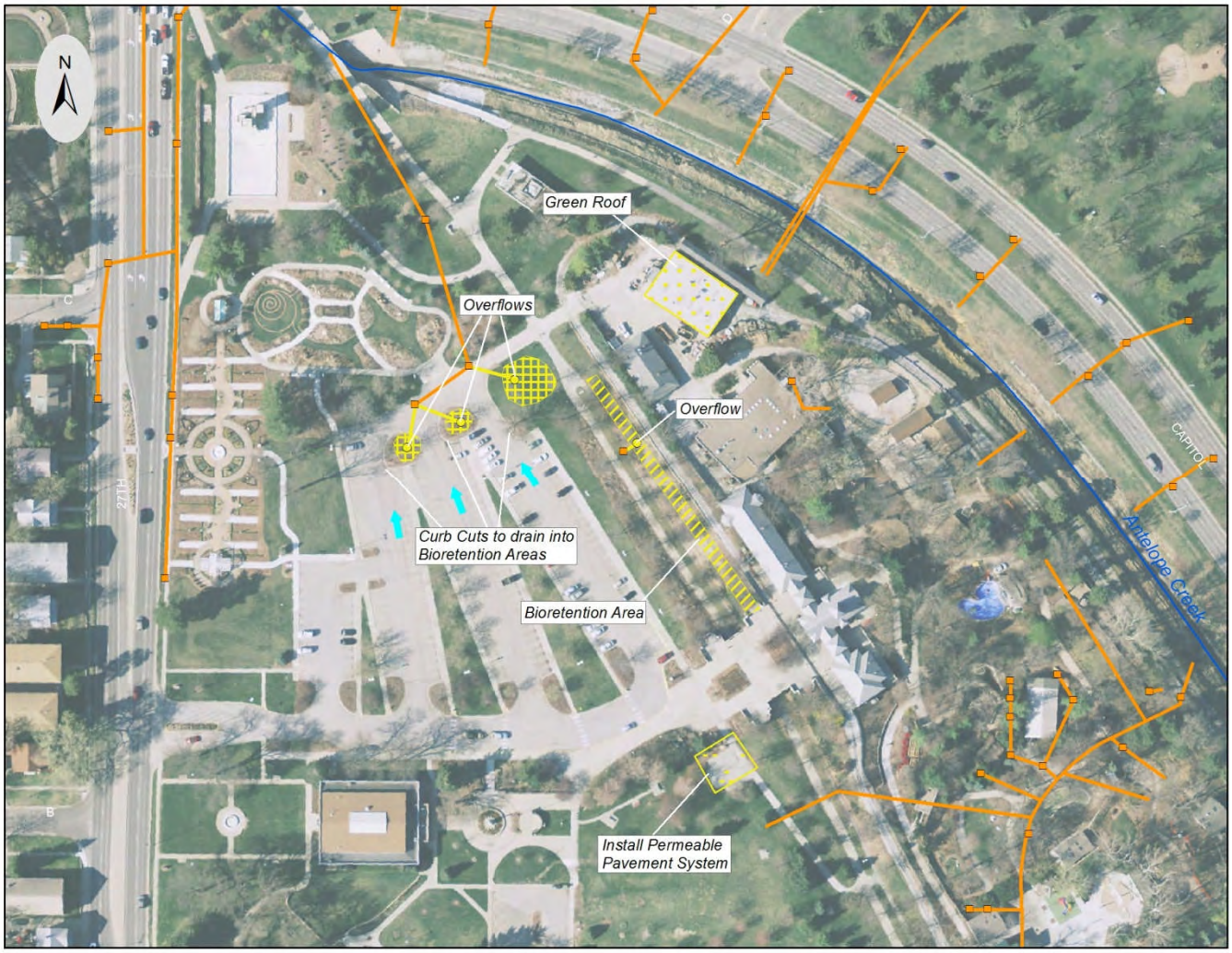
Green roofs reduce runoff rates and volumes, reduce heat island effect, may provide energy savings, and may also extend the lifespan of the roof. Although green roofs provide an aesthetically pleasing space and reduce stormwater runoff, the effects of a single roof on a small number of roofs on overall water quality are minimal. Permeable pavement systems are used to promote volume reduction, provide treatment and slow release of stormwater runoff, and reduce a site's effective imperviousness. Installing the bioretention areas will create large areas that promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. The bioretention areas will also help to slow stormwater runoff; aiding in the prevention of future erosion downstream. Disconnecting downspouts and redirecting them to green areas helps promote infiltration while reducing the volume of stormwater runoff. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. Table 8-9 summarizes the current pollutant load, as well as

the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-9. Annual Pollutant Load Reduction Estimates for AC-P06

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	12,240 lbs	2000-2500 lbs	16-20%
Phosphorus	16 lbs	0-5 lbs	0-31%
E. coli	5.0×10^{12} counts	$3\text{-}7 \times 10^{11}$ counts	6-14%

Figure 8-8. Lincoln Children's Zoo



Project AC-P07: Woods Park

This project is located west of 33rd and J Street at Woods Park, and is illustrated in Figure 8-9. The sub-watershed for this project is approximately 2 acres in size. The land use consists of residential development, park space and recreational facilities. Flow within the sub-watershed is generally in a westerly direction.

Ownership:

All property is owned by the City of Lincoln, which consists of Woods Park.

Site Selection:

This site was selected for the following reasons:

- All property is owned by the City of Lincoln
- Available land for BMP installation
- High pollutant load

Picture 29: Woods Park is another publically owned location with great potential to install BMPs

Project Summary:

- Install hydrodynamic separators near parking areas as shown in Figure 8-9. Flow from the parking areas should be directed into the units. Outflow from units should be either directed back into the storm drainage system or nearby bioretention areas. Grit chambers can be substituted for hydrodynamic separators where only sediment and gravel are of concern.
- Construct bioretention areas as shown in Figure 8-9. Total size of the bioretention areas is approximately 2,000 square feet. Each bioretention area is approximately 1.0 to 1.5 feet deep, with 2 to 3 feet of engineered soil. Overflows within a bioretention cell should carry large rainfall events to nearby storm drains. Curbs should be cut, and inlets modified where possible to allow runoff from nearby parking areas and rooftops to be captured.

Maintenance:

Post-project maintenance efforts are anticipated to be high and may include: cleanout of debris; cleanout of sediment or replacement of soils within bioretention areas; inspections for erosion or standing water problems; mulch removal and replacement; and removal of sediment and debris from hydrodynamic separators.

Estimated Total Project Cost: $225,000-$275,000

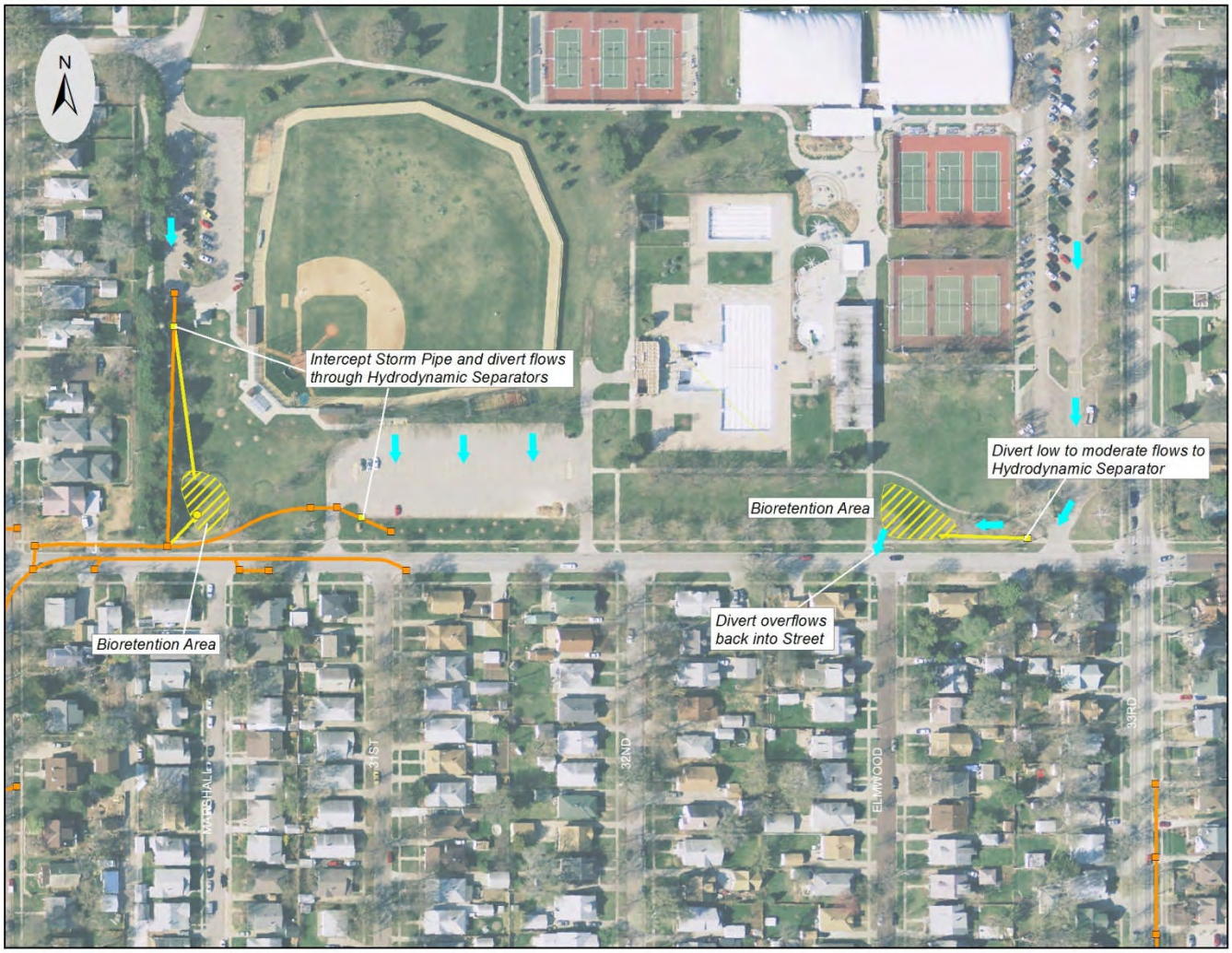
Water Quality Benefits:

Use of hydrodynamic separators can reduce the overall pollutant loading to Antelope Creek by capturing floatable debris, oils, grease, sediment, and gravel. The units should always be located in areas accessible for maintenance. Installing the bioretention areas will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. The bioretention areas will also help to slow stormwater runoff; aiding in the prevention of future erosion downstream. Disconnecting impervious areas and redirecting them to green areas helps promote infiltration while reducing the volume of stormwater runoff. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. Table 8-10 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-10. Annual Pollutant Load Reduction Estimates for AC-P07

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	2,980 lbs	2,000-2,500 lbs	67-84%
Phosphorus	4 lbs	0-0.5 lbs	0-13%
E. coli	7.4×10^{11} counts	$1\text{-}4 \times 10^{11}$ counts	14-54%

Figure 8-9. Woods Park



Project AC-P08: Gere Library

This project is located southeast of 56th and Myrtle Street. The sub-watershed for this project includes the adjacent parking areas to the east; less than 3 acres in size. Flow within the sub-watershed is generally in a westerly direction.

Picture 30: Gere Library already has native vegetation

Ownership:

The project lies on a public parcel owned by the City of Lincoln.

Site Selection:

This site was selected for the following reasons:

- High public education potential
- High pollutant load
- Available land for BMP installation

Project Summary:

- Install a hydrodynamic separator near parking lot as shown in Figure 8-10. Flow from the parking lot should be directed into the unit. Outflow from unit should be directed back into the storm drainage system. A grit chamber can be substituted for the hydrodynamic separator where only sediment and gravel are of concern.
- Construct a bioretention area as shown in Figure 8-10. The bioretention area is approximately 2,000 to 2,500 square feet and approximately 1.0 to 1.5 feet deep with 2 to 3 feet of engineered soil. Overflows should have large events directed to nearby storm drain inlets. Curbs should be cut, or inlets modified where possible to allow runoff from nearby parking areas and rooftops to be captured.

Maintenance:

Post-project maintenance efforts are anticipated to be high and may include: cleanout of sediment or replacement of soils within bioretention areas, inspections for erosion or standing water problems, and removal of sediment and debris from hydrodynamic separators.

Estimated Total Project Cost:

$75,000-$115,000

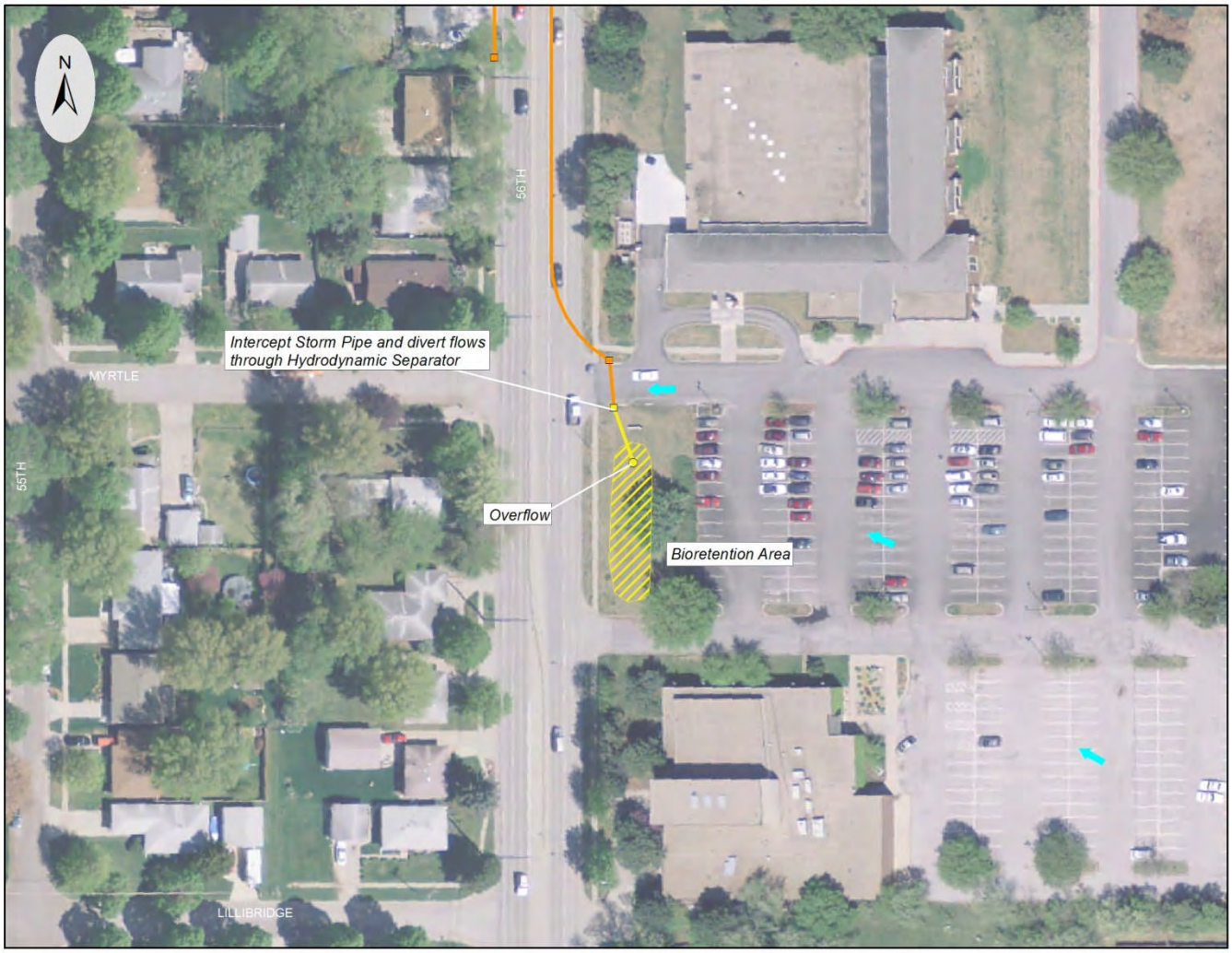
Water Quality Benefits:

Use of hydrodynamic separators can reduce the overall pollutant loading to Antelope Creek by capturing floatable debris, oils, grease, sediment, and gravel. The units should always be located in areas accessible for maintenance. Installing the bioretention areas will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. The bioretention area will also help to slow stormwater runoff, which will aid in the prevention of future erosion downstream. Disconnecting impervious areas and redirecting them to green areas helps promote infiltration while reducing the volume of stormwater runoff. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. Table 8-11 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-11. Annual Pollutant Load Reduction Estimates for AC-P08

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	5,100 lbs	4000-4500 lbs	78-88%
Phosphorus	6 lbs	0-1 lbs	0-17%
E. coli	1.3×10^{12} counts	$1\text{-}5 \times 10^{11}$ counts	8-38%

Figure 8-10. Gere Library



Project AC-P09: Eden Park

This project is located north of 44th and Antelope Creek Road. The sub-watershed for this project is confined to the parking lot and areas immediately adjacent; less than 2 acres in size. The land use consists of parking areas and green space. Flow within the sub-watershed is generally in a northerly direction.

Ownership:

All property is owned by the City of Lincoln, and consists of locations within Eden Park.

Picture 31: A direct impervious connection from Eden Park parking lot to Antelope Creek

Site Selection:

This site was selected for the following reasons:

- All property is owned by the City of Lincoln
- Ease of retrofit
- Topography

Project Summary:

- Installation of curb cuts along the north side of the parking lot to allow runoff to drain into a bioretention area.
- Construct a bioretention area as shown in Figure 8-11. Total size of the bioretention area is approximately 1,000 to 1,200 square feet. The bioretention area is approximately 1.0 to 1.5 feet deep, with 2 to 3 feet of engineered soil. Overflows within a bioretention cell should carry large rainfall events to nearby storm drains.

Maintenance:

Post-project maintenance efforts are anticipated to be low and may include: cleanout of sediment within the bioretention area; inspections for erosion or standing water problems; and mulch removal and replacement.

Estimated Total Project Cost: $40,000-$50,000

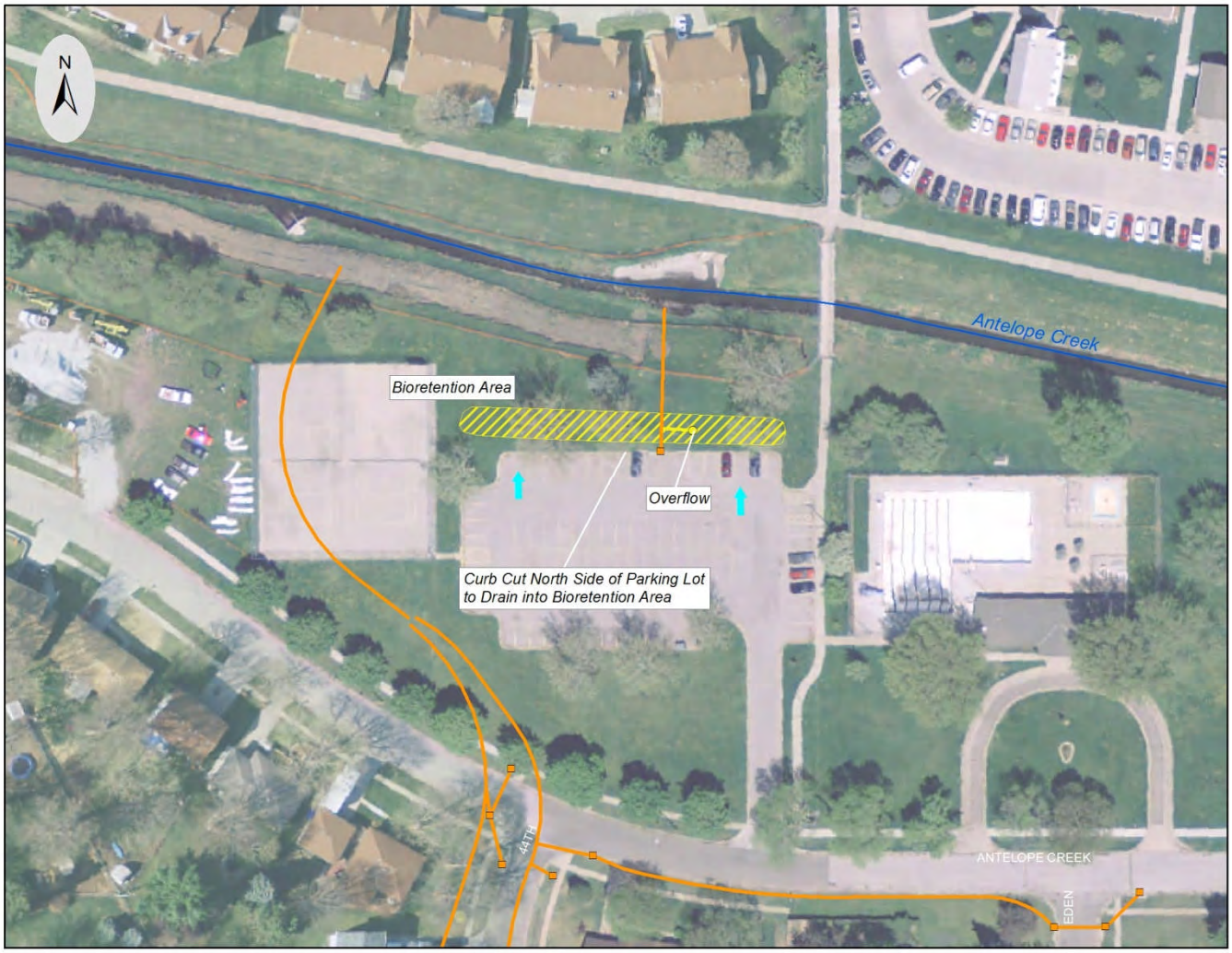
Water Quality Benefits:

Curb cuts allow stormwater from the parking lot to discharge into the bioretention area designed to treat pollutants carried in the water. The bioretention area will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. The bioretention area will also help to slow stormwater runoff, which will aid in the prevention of future erosion downstream. Disconnecting impervious areas and redirecting them to green areas helps promote infiltration while reducing the volume of stormwater runoff. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. Table 8-12 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-12. Annual Pollutant Load Reduction Estimates for AC-P09

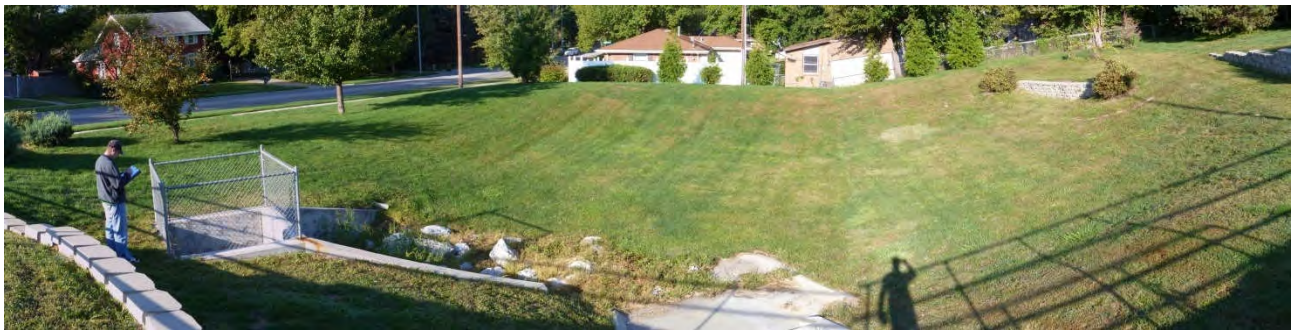
Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	3,400 lbs	600-700 lbs	18-21%
Phosphorus	4 lbs	0-0.5 lbs	0-13%
E. coli	8.5×10^{11} counts	$1\text{-}4 \times 10^{11}$ counts	12-47%

Figure 8-11. Eden Park



Project AC-P10: Extended Detention Cell Near 60th and South

This potential retrofit project is located north of 60th and South Street, illustrated in Figure 8-12. The sub-watershed for this project is approximately 3 acres in size and consists entirely of residential development. Flow within the sub-watershed is generally in a southwesterly direction.



Picture 32: Existing dry detention cell at 60th and South looking north

Ownership:

The project lies on a private parcel owned by a building association.

Site Selection:

This site was selected for the following reasons:

- Ease of retrofit
- High pollutant load
- Available land for BMP installation

Project Summary:

- Modify the lining of the existing extended detention basin to enhance infiltration into soils. This can be accomplished by replacing approximately 1,500 to 2,000 square feet with 2 to 3 feet of engineered soil to promote infiltration, and planting deep rooted vegetation to aid soil aeration.
- Modifications to the basin outlet were also included as part of this project to aid in retaining runoff to infiltration and sediment deposition.

Maintenance:

Post-project maintenance efforts are anticipated to be low and may include: cleanout of sediment or replacement of soils within bioretention areas, and inspections for erosion or standing water problems.

Estimated Total Project Cost: $40,000-$50,000

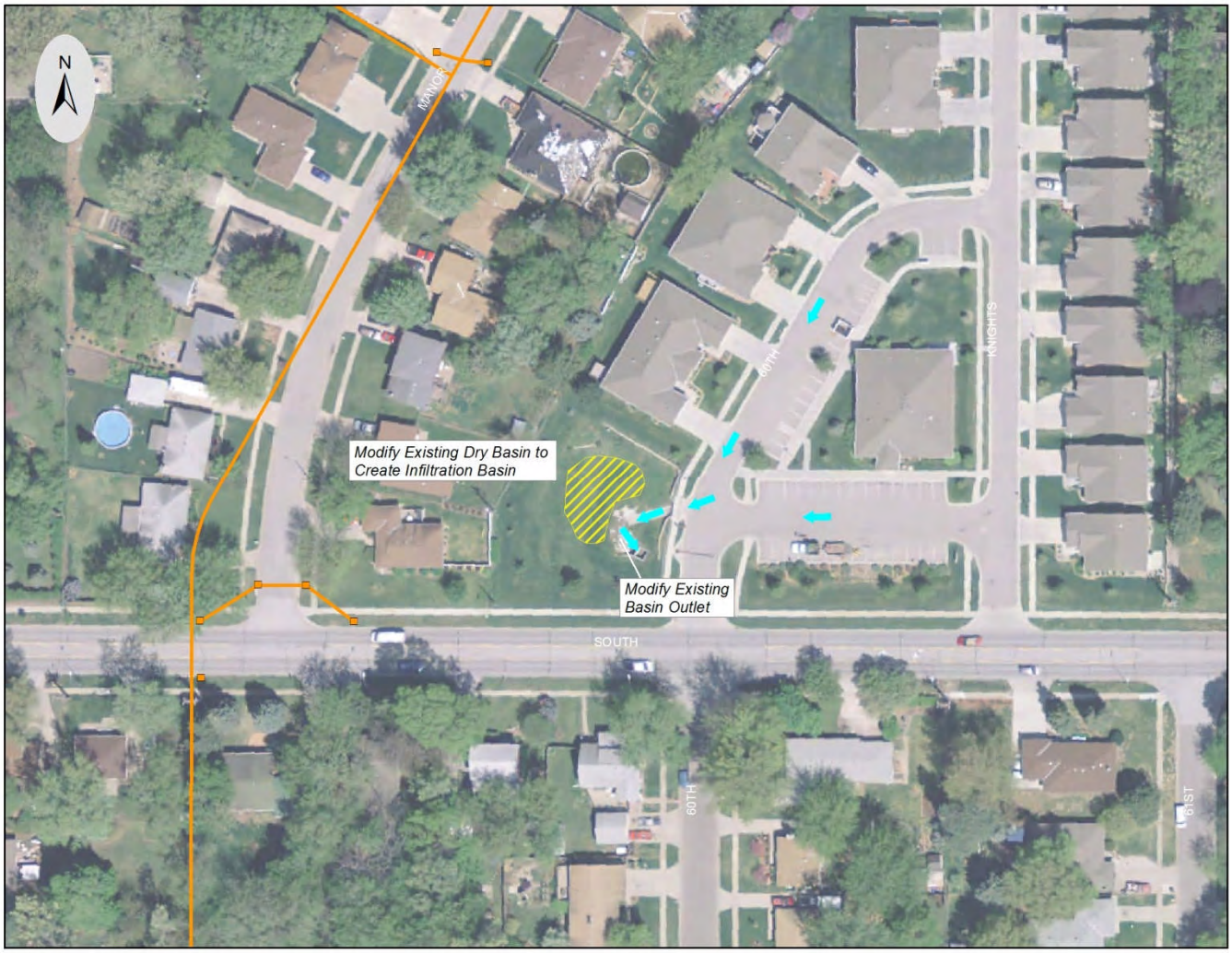
Water Quality Benefits:

Modifying the existing detention basin will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. The detention basin will also help to slow stormwater runoff; aiding in the prevention of future erosion downstream. A reduction in the volume of stormwater runoff directly reduces the loading of sediment, nutrients, and *E. coli to* Antelope Creek. Table 8-13 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-13. Annual Pollutant Load Reduction Estimates for AC-P10

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	370 lbs	100-150 lbs	27-41%
Phosphorus	1 lbs	0-0.1 lbs	0-10%
E. coli	1.5×10^{12} counts	$1\text{-}5 \times 10^{11}$ counts	7-33%

Figure 8-12. Extended Detention Cell near 60th and South



Project AC-P11: Labyrinth Weir on Antelope Creek

This project is located south of N Street, west of 24th Street and is illustrated in Figure 8-13. The watershed (downstream of and not including Holmes Lake) for this project is approximately 3,900 acres in size; the land use is wide ranging, including residential development, commercial development, schools, park space and recreational facilities. Flow within the sub-watershed is generally in a northwest direction.

Ownership:

All property is owned by the City of Lincoln.

Site Selection:

This site was selected for the following reasons:

- All property is owned by the City of Lincoln
- Large treatable area
- High pollutant load

Picture 33: Looking north towards the labyrinth weir

Project Summary:

- Construct an inline concrete weir along Antelope Creek, approximately 250 feet upstream of the labyrinth weir southwest of 24th and N Street. This weir would increase the water surface area, therefore increasing the amount of sunlight exposed to the water and reducing the amount of *E. coli* within Antelope Creek.
- Excavate upstream of the new weir to provide an inline wet pond that is approximately 300 feet long, and 4 to 5 feet deep. The sides of this wet pond should be stabilized with sheet pile, gabion, or concrete. This inline wet pond will create an area for TSS to drop out of the water column and provide an area for easy removal of the captured sediment.
- Remove the existing concrete channel and articulated concrete block lining upstream of the labyrinth weir. Removal would allow the creation of a green space that would provide storage routing capacity during high flows, as well as increase aesthetics.
- Construct a low-flow concrete channel downstream of the new weir. A concrete apron should be placed at the base of the new concrete weir and extended to the outlet of the two stormwater outfalls located just downstream of the new weir. The low flow channel should be constructed to direct base flows toward the sluice gate located in the labyrinth weir. The channel should also be designed with a stub wall so that if the sluice gate is closed or under moderate flows, portions of the flow can be directed to the existing enclosed conduit. During high flows, the green space could potentially fill up and spill over the labyrinth weir.
- Construction of this project will require coordination with the US Army Corps of Engineers.

Maintenance:

Post-project maintenance efforts are anticipated to be moderate and may include: cleanout of sediment within the wet pond upstream of the new weir, and inspections for erosion or standing water problems.

Estimated Total Project Cost: $600,000-$650,000

Water Quality Benefits:

The wet pond is intended to capture large amounts sediment and gravel. A portion of the overall phosphorus load is expected to be bound to the sediment. By placing these types of structures in an area accessible to maintenance crews, the overall phosphorus and sediment load within Antelope Creek can reduced. The new weir would increase the water surface area during base flows, therefore increasing the amount of sunlight exposed to the water and reducing the amount of *E. coli* within Antelope Creek. The new concrete channel and green space will both increase aesthetics and flow through the Labyrinth Weir. Table 8-14 summarizes the current pollutant

load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-14. Annual Pollutant Load Reduction Estimates for AC-P11

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	998,000 lbs	50,000-100,000 lbs	5-10%
Phosphorus	1,900 lbs	500-600 lbs	26-32%
E. coli	1.5×10^{15} counts	$1\text{-}5 \times 10^{14}$ counts	6-33%

Figure 8-13. Labyrinth Weir on Antelope Creek

Project AC-P12: Van Dorn Plaza and US Post Office

This project is located in Van Dorn Plaza, near 48th and Van Dorn Street. The total sub-watershed for this project is approximately 2 acres in size; the land use consists entirely of commercial development. Flow within the sub-watershed is generally in a northeast direction.

Ownership:

The project is within two publicly owned parcels owned by the City of Lincoln and the United States Post Office.

Site Selection:

This site was selected for the following reasons:

- Available publicly owned property nearby
- High pollutant load
- Easy access for operation and maintenance

Picture 34: Existing direct impervious connection area and potential site for a bioswale at Post Office near Van Dorn Plaza

Project Summary:

- Construct bioretention areas as shown in Figure 8-14. Total size of the bioretention areas is approximately 2,000 to 2,500 square feet. The bioretention areas are approximately 1.0 to 1.5 feet deep, with 2 to 3 feet of engineered soil. Overflows within a bioretention area should carry large rainfall events to nearby storm drains. Nearby inlets should be modified to allow runoff from nearby parking areas and rooftops to flow to the bioretention areas.

Maintenance:

Post-project maintenance efforts are anticipated to be low and may include cleanout of sediment within the rain gardens, inspections for erosion or standing water problems, and mulch removal and replacement.

Estimated Total Project Cost: $60,000-$70,000

Water Quality Benefits:

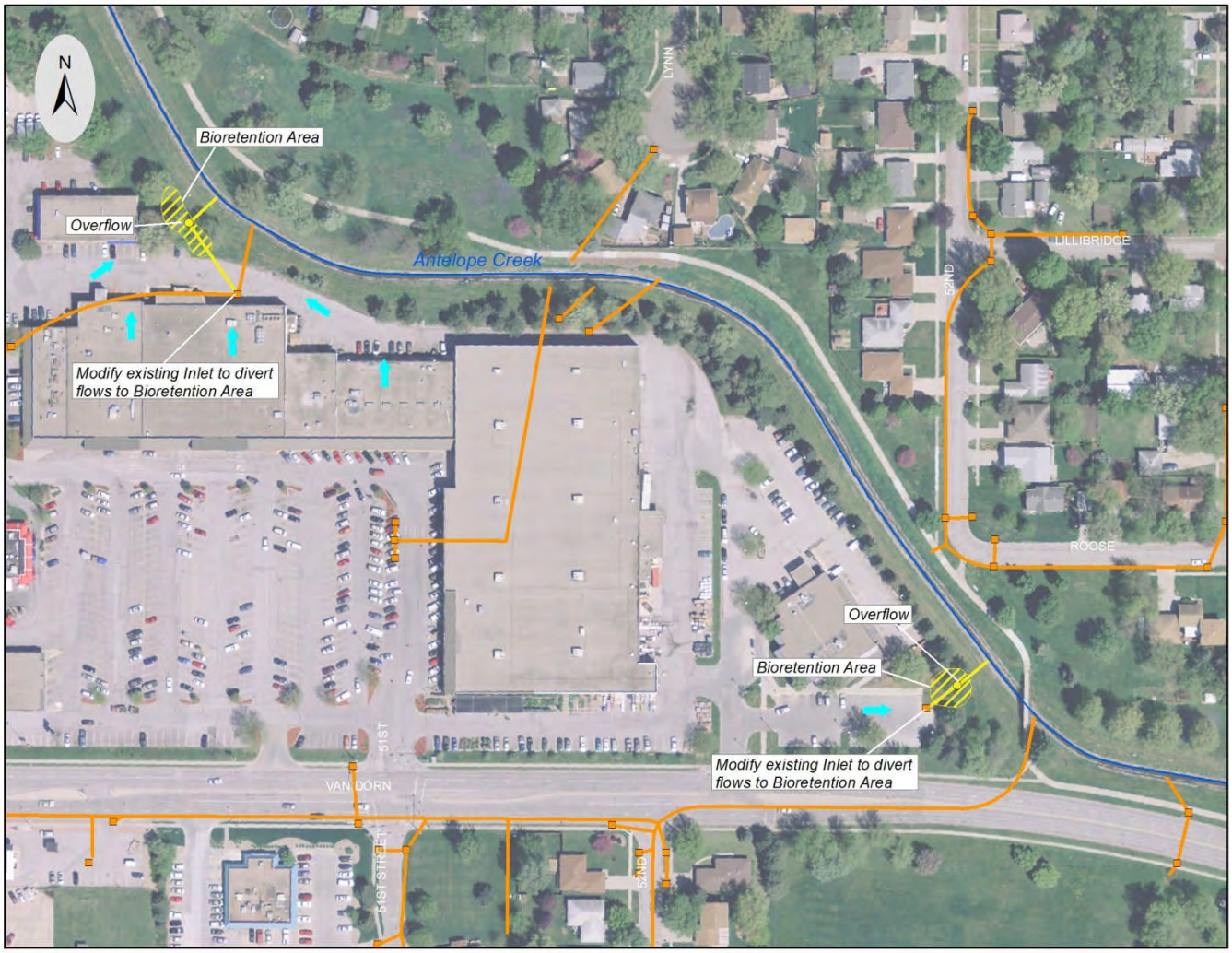
Inlet modifications allow stormwater from the rooftops and parking lots to discharge into the bioretention areas designed to treat pollutants carried in the water. Rooftops and parking lots often pollute stormwater with heavy metals, sediment, gravel and oils and greases. The bioretention areas will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. The bioretention areas will also help to slow stormwater runoff; aiding in the reduction of future erosion downstream. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. Table 8-15 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Picture 35: This parking lot north of the Van Dorn Plaza and adjacent to the creek receives runoff from over 15 downspouts

Table 8-15. Annual Pollutant Load Reduction Estimates for AC-P12

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	3,400 lbs	600-700 lbs	18-21%
Phosphorus	4 lbs	0-1 lbs	0-25%
E. coli	8.5×10^{11} counts	$5\text{-}10 \times 10^{10}$ counts	6-20%

Figure 8-14. Van Dorn Plaza and U.S. Post Office



Project AC-P13: SE of 40th and Capital Parkway (N. of Campbell's Nursery)

This project is located southwest of 40th and Normal Boulevard. The sub-watershed for this project is confined to the parking areas immediately north; less than 3 acres in size. The land use consists of parking areas and residential development. Flow within the sub-watershed is generally in a northwesterly direction.

Ownership:

The project lies on a private parcel owned by a multi-family residential complex. Projects shown on private property are recommendations for the land owner to pursue. City or other agencies may be available for partnership or funding assistance.

Picture 36: This parking lot drains directly into Antelope Creek near 40th Street and south of Capital Parkway

Site Selection:

This site was selected for the following reasons:

- Available publicly owned property nearby
- High pollutant load
- Easy access for operation and maintenance

Project Summary:

- Install a hydrodynamic separator near the parking lot, as shown in Figure 8-15. Flow from the parking lot should be directed into the unit. Outflow from unit should be directed back into the storm drainage system. Grit chambers can be substituted for hydrodynamic separators where only sediment and gravel are of concern.
- Construct bioretention areas as shown in Figure 8-15. Total size of the bioretention areas is approximately 3,000 to 3,500 square feet. The bioretention area is approximately 1.0 to 1.5 feet deep, with 2 to 3 feet of engineered soil. Overflows within a bioretention area should carry large rainfall events to nearby storm drains. Curbs should be cut, or inlets modified where possible to allow runoff from nearby parking areas and rooftops to be captured.

Maintenance:

Post-project maintenance efforts are anticipated to be high and may include: cleanout of debris; cleanout of sediment or replacement of soils within bioretention areas; inspections for erosion or standing water problems; mulch removal and replacement and removal of sediment and debris from hydrodynamic separators.

Estimated Total Project Cost: $100,000-$150,000

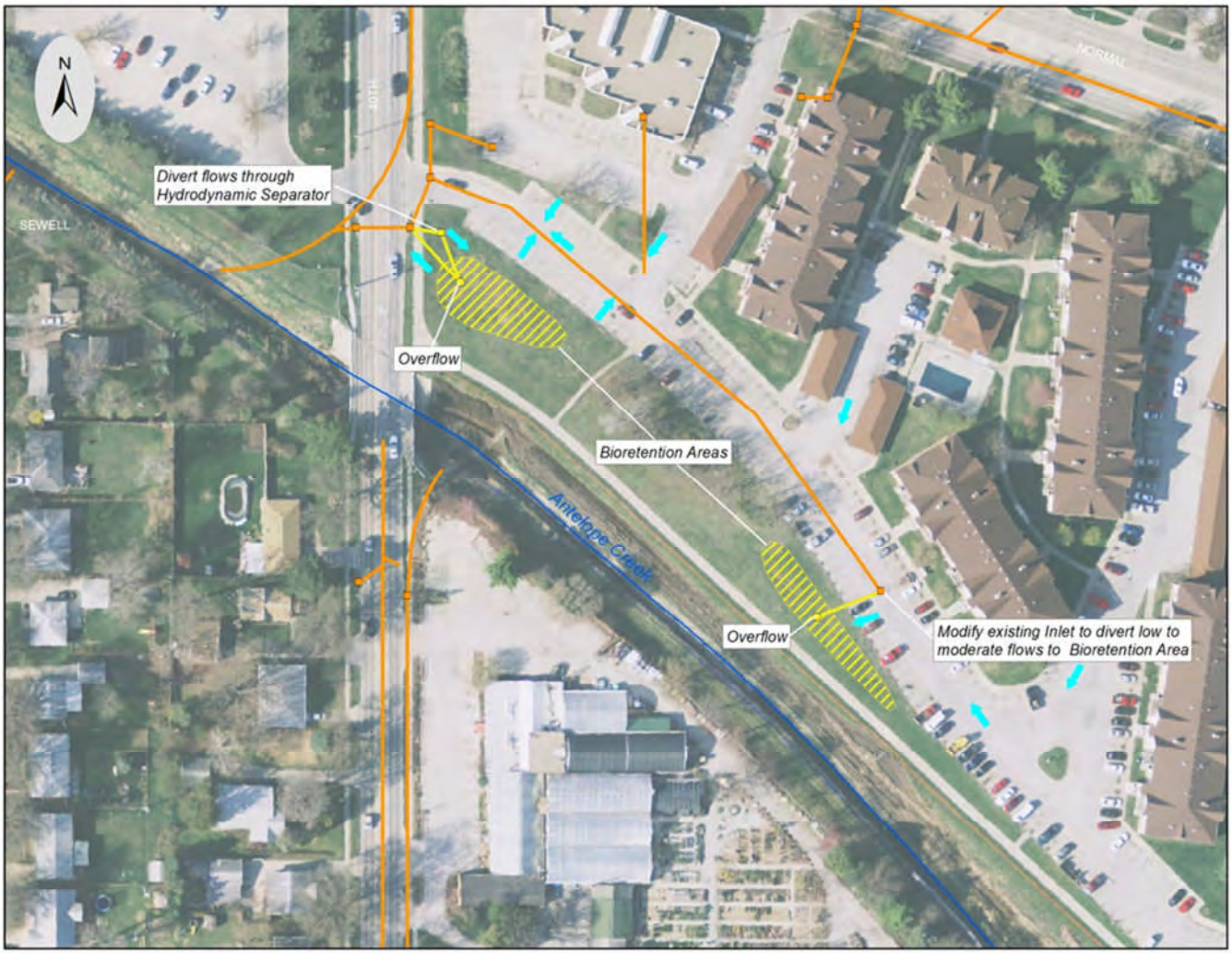
Water Quality Benefits:

Use of hydrodynamic separators can reduce the overall pollutant loading to Antelope Creek by capturing floatable debris, oils, grease, sediment, and gravel. The units should always be located in areas accessible for maintenance. Installing the bioretention areas will promote infiltration, reduce runoff, and reduce the loading of sediment, nutrients, and *E. coli to* Antelope Creek. The bioretention areas will also help to slow stormwater runoff, which will aid in the reduction of future erosion downstream. Disconnecting impervious areas and redirecting them to green areas helps promote infiltration while reducing the volume of stormwater runoff. A reduction in the volume of stormwater runoff directly reduces each pollutant load being carried to Antelope Creek. Table 8-16 summarizes the current pollutant load, as well as the anticipated load reduction based on the structural BMPs to be implemented within this site. These loads are largely based upon WinSLAMM, and were adjusted to account for a variety of site specific measures.

Table 8-16. Annual Pollutant Load Reduction Estimates for AC-P13

Pollutant	Pollutant Load	Anticipated Load Reduction	Percent Reduction
TSS	5,100 lbs	4000-4500 lbs	78-88%
Phosphorus	6 lbs	1-2 lbs	17-33%
E. coli	1.3×10^{12} counts	$1\text{-}5 \times 10^{11}$ counts	8-38%

Figure 8-15. SE of 40th and Capital Parkway



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SECTION 9 – RECOMMENDATIONS CITY-WIDE

9.1. Introduction

Water quality lessons learned and key recommendations from the Basin Plan can be utilized throughout other watersheds in the City, especially those which are already fully developed.

Water quality lessons learned and key recommendations from the Basin Plan can be utilized throughout other watersheds in the City, especially those which are already fully developed. These lessons can also be applied to future growth areas, future comprehensive watershed master plans which focus on flooding, and used to justify policy decisions that can benefit water quality and the environment in Lincoln. Recommendations in this section support the goals and strategies of the Lincoln and Lancaster County Comprehensive Plan, known as LPlan 2040, detailed in the Vision, Environmental Resources, and Energy and Utilities – Watershed Management Section, which support integration of natural resources features into future planning activities. In this case, natural features are recommended to improve water quality, increase community aesthetics, and provide flood control as a secondary benefit.

Once formally adopted by the LPSNRD Board and Lincoln City Council, the Basin Plan will be considered a 'subarea' plan in LPlan 2040. Subarea plans usually focus more on specific issues; in this case water quality in the Antelope Creek watershed. Each of the watershed master plans previously adopted are included in LPlan 2040 as subarea plans.

Recommendations in this Basin Plan should be considered for incorporation into other planning documents, including consideration for post-construction BMPs into private developments and public projects city-wide. In addition, water quality elements of this Basin Plan should be considered by groups such as the Mayor's Clean Water Task Force.

9.2. City-wide Recommendation Overview

In 2010, the City of Lincoln completed an update of the LPlan 2040. This plan serves as the community's future growth. In order to facilitate a sustainable growth pattern, LPlan 2040 has designated Growth Tiers with Priority Areas for the community's growth over the next 50 years. These Growth Tiers represent anticipated areas of development, including new development and in-fill development. The future Growth Tier map can be found in Figure 9-1.

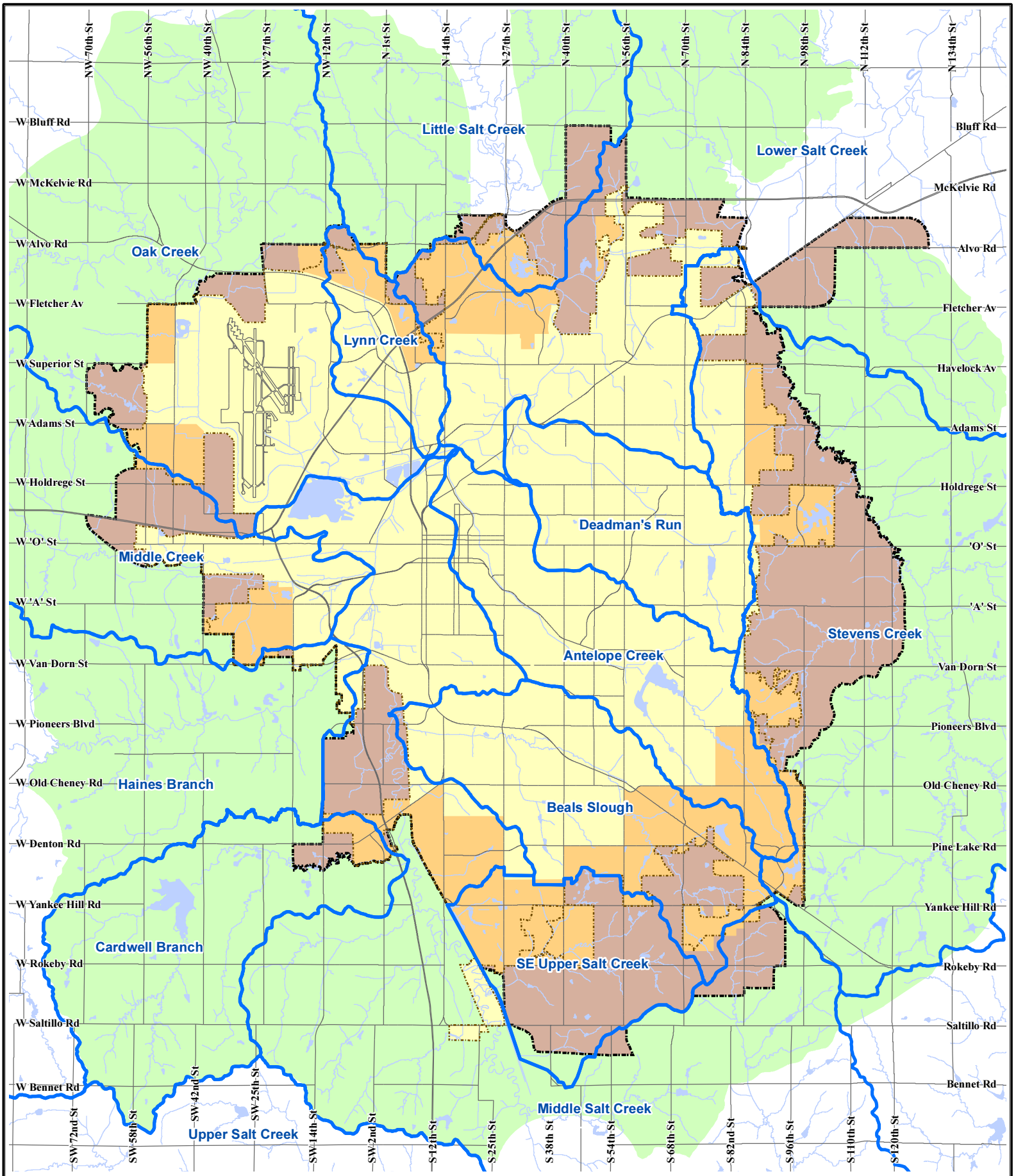
Tier I describes the future service limit, the area anticipated to be served with urban services by the year 2040. Tier I is further broken down into three subareas:

- Tier IA which is either currently within the city limits or has some sort of approved preliminary plan, is considered the "developing" area.
- Tier IB is the area that is anticipated to begin developing by 2025
- Tier IC is the area that is anticipated to begin developing after 2025 but before 2040.

Tier II is the area that is anticipated to begin developing after 2040 but before 2060. Tier III will likely not begin developing until after 2060.

Separate from the comprehensive planning process, Public Works and Utilities has delineated the City into 13 total sub-basins. Each has been grouped into either the developed watershed category, or undeveloped watershed category as part of the ongoing Comprehensive Watershed Master Planning Process as seen in Figure 9-1. As the City and LPSNRD consider water quality improvements, it is important to recognize which projects best fit into areas of the City that are developed, or are being developed for the first time.

The Antelope Creek watershed is nearly 85% urbanized and is located in the heart of the City. The Basin Plan only includes that portion of the basin below Holmes Lake and that portion of the basin is fully (100%) developed. The remainder of the Antelope Creek basin is developing. The portion of the Antelope Creek stream in the Basin Plan area has been significantly improved with hard armor to stabilize the stream banks and widening to improve flood control. Overall, stream bank degradation is no longer a significant concern for Antelope Creek, hence the focus on water quality through development of this Basin Plan. Although no other watershed is identical to Antelope Creek's, several share similar characteristics in land use and pollutant sources. Table 9-1 shows the watersheds broken down by growth tiers as listed above on Figure 9-1. Growth tiers are developed through the comprehensive planning process and Tier I in particular is used as a guideline for directing development of the City over the next 30 years. Table 9-2 shows the same table with breakdowns by percentages.



LINCOLN WATERSHEDS

Figure 9-1: Lincoln Future Growth Tier Map

- Watershed Boundary
- Lincoln Corporate Limits
- Future Service Limit

- Existing City (Not in Tier I)
- Developing (Tier IA)
- Future Development (Tiers IB & IC)
- Beyond 2040 (Tiers II & III)

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Table 9-1. Existing Basin Growth Patterns (acres)

BASIN	TOTAL	(1) URBANIZED	(2) DEVELOPING	(3) FUTURE	(4) BEYOND 2040	OUTSIDE TIER III	INSIDE F.S.L.	INSIDE CITY LIMITS
Antelope Creek	8,623	7,293	1,330	0	0	0	8,623	8,623
Beal Slough	8,835	5,251	2,383	1,182	19	0	8,816	7,546
Cardwell Branch	10,450	0	325	272	9,774	79	597	325
Deadmans Run	6,017	6,017	0	0	0	0	6,017	6,017
Haines Branch	43,745	384	34	21	10,287	33,019	439	417
Little Salt Creek	29,345	0	599	1,193	9,870	17,683	1,792	599
Lower Salt Creek	69,151	6,645	1,741	3,295	12,527	44,943	11,681	8,210
Lynn Creek	2,640	1,778	637	219	6	0	2,634	2,395
Middle Creek	64,153	1,971	888	1,566	8,860	50,868	4,425	2,850
Middle Salt Creek	67,054	6,243	1,416	2,477	14,871	42,047	10,136	7,627
Oak Creek	162,603	6,765	1,021	1,627	15,714	137,476	9,413	7,707
SE Upper Salt Creek	5,751	21	1,929	3,425	376	0	5,375	1,667
Stevens Creek	33,048	1,975	2,154	6,475	22,289	155	10,604	4,146
TOTAL	**511,415**	**44,343**	**14,457**	**21,752**	**104,593**	**326,270**	**80,552**	**58,129**

Source: Provided by the City of Lincoln Planning Department
Notes: (1) Inside city but not in Tier I. (2) Tier 1 A. (3) Tiers 1 B and I C. (4) Tiers II and III. F.S.L = Future Service Limit (Jan. 19, 2012)

Table 9-2. Existing Basin Growth Patterns (percentage)

BASIN	TOTAL (ACRES)	(1) URBANIZED	(2) DEVELOPING	(3) FUTURE	(4) BEYOND 2040	OUTSIDE TIER III	INSIDE F.S.L.	INSIDE CITY LIMITS
Antelope Creek	8,623	84.6	15.4	0.0	0.0	0.0	100	100
Beal Slough	8,835	59.4	27.0	13.4	0.2	0.0	100	85
Cardwell Branch	10,450	0.0	3.1	2.6	93.5	0.8	6	3
Deadmans Run	6,017	100.0	0.0	0.0	0.0	0.0	100	100
Haines Branch	43,745	0.9	0.1	0.0	23.5	75.5	1	1
Little Salt Creek	29,345	0.0	2.0	4.1	33.6	60.3	6	2
Lower Salt Creek	69,151	9.6	2.5	4.8	18.1	65.0	17	12
Lynn Creek	2,640	67.3	24.1	8.3	0.2	0.0	100	91
Middle Creek	64,153	3.1	1.4	2.4	13.8	79.3	7	4
Middle Salt Creek	67,054	9.3	2.1	3.7	22.2	62.7	15	11
Oak Creek	162,603	4.2	0.6	1.0	9.7	84.5	6	5
SE Upper Salt Creek	5,751	0.4	33.5	59.6	6.5	0.0	93	29
Stevens Creek	33,048	6.0	6.5	19.6	67.4	0.5	32	13
TOTAL	**511,415**	**--**	**--**	**--**	**--**	**--**	**--**	**--**

Source: Provided by the City of Lincoln Planning Department
Notes: (1) Inside city but not in Tier I. (2) Tier 1 A. (3) Tiers 1 B and I C. (4) Tiers II and III. F.S.L = Future Service Limit (Jan. 19, 2012)

While land use characteristics within the Antelope Creek watershed are unique, the impairments within the stream are not. Antelope Creek is one of six stream segments in the Lincoln area that are part of a TMDL determination that addresses the Lower Platte River Basin, and of the six, four of them address *E. coli.* TMDL designations for

other Lincoln area water bodies are shown below in Table 9-3. Holmes Lake is also currently listed as impaired, but could be removed from the 303(d) list as water quality improves in the lake following renovation in 2004.

Table 9-3. Water Bodies with TMDL Determinations in Lincoln/Lancaster County

Water Body	Segment ID	Impairment
Salt Creek	LP2-20000	*E. coli*
Oak Creek	LP2-20500	*E. coli*
Deadmans Run	LP2-20400	*E. coli*
Middle Creek	LP2-21000	Atrazine
Salt Creek	LP2-30000	*E. coli*
Holmes Lake	LP2-0040	Sediment and Phosphorous

Source: NDEQ IR, 2010

The Source Loading and Management Model for Windows (WinSLAMM) was developed on the specific layout of the Antelope Creek watershed using lot sizes, age of housing, street size, parking, and estimate of impervious surfaces. Applying results from WinSLAMM for Antelope Creek may not accurately represent differing watersheds City-wide. One similarity is the rainfall estimates used for WinSLAMM; which were based upon actual recorded rainfall in Lincoln. WinSLAMM can be used to give a general idea of what might be expected, but for purposes of stormwater management planning in other watersheds, the model should be developed for that specific area.

In general, newer developments have fewer directly connected downspouts, which can help to reduce the amount of stormwater runoff. The overall lot sizes may also differ in newer developments. For larger lots, Low/No-phosphorus fertilizers may be a more effective source control than disconnections. These differences have not been specifically analyzed as part of this Section.

Non-structural programs focus on management of pollutants at their source by minimizing exposure to runoff, rather than treating runoff in structural BMPs.

Non-structural programs focus on management of pollutants at their source by minimizing exposure to runoff, rather than treating runoff in structural BMPs. Although non-structural programs removal efficiencies vary depending on the pollutant of concern, in general they are a cost effective strategy. According to Table 9-3, it appears that the main constituent of concern in streams in Lincoln is *E. coli*. Due to overall similar stream impairments, and the effectiveness and low-cost of implementing non-structural BMPs, the remainder of this section focuses mostly on how non-structural BMPs can be applied City-wide. While structural BMPs are still a viable solution to treating pollutants in stormwater, details regarding the use or placement of structural alternatives will not be detailed in other basins. The remainder of this section discusses how recommendations for the Antelope Creek watershed can be applied to other watersheds across the city. Recommendations have been divided into three separate categories:

- City-wide recommendations – strategies that can be applied in both urban and developing watersheds
- Developed watershed recommendations – strategies that can be applied to urbanized watersheds
- Undeveloped watershed recommendations – strategies that can be applied to developing watersheds

Generalized structural stormwater BMP recommendations are also included for all watersheds City-wide.

9.3. City-wide Recommendations

City-wide recommendations include structural and non-structural BMPs and considerations such as policy changes or incorporation into planning principles that would encourage activities to limit future pollutant loading to water bodies in the City and future development areas. These actions would be effective regardless of the land use and other characteristics within a specific watershed. The following City-wide strategies are recommended:

- Water quality monitoring
- Overlay districts
- Low/No-phosphorus Fertilizer Ordinance
- Outreach to lawn care providers
- Snow and ice management strategies

- LPSNRD Cost-share Program
- Update Drainage Manual
- Bridge retrofits
- Establishment of native plant species into Capital Improvement Projects
- Regional Water Quality Management Plans
- Incorporation of water quality elements into future Watershed Master Plans
- Water quality partnerships
- Urban wildlife management
- Post Construction Standards
- Pet Waste Ordinances / Disposal Cans
- Long term public education

Picture 37: The City has several existing City-wide actions aimed at improving water quality

Water Quality Monitoring

Sampling at the confluence of each watershed will provide an overall look at the water quality within the watershed as water quality strategies are implemented. This location is the ultimate compliance location for water quality sampling and established TMDL determination. Sampling data from the confluences can be compared to the water quality sampling completed in the past as well as information in relation to an established TMDL determination. Sampling at these locations will not help the City and LPSNRD to understand pollutant load reductions from individual BMPs or load reductions from individual sub-basins. Sampling at the confluences will determine the total percent reduction basin-wide and if goals listed in the TMDL document are being met.

Overlay Districts

The City of Lincoln currently uses several overlay districts – historic districts, capital environs, airport noise and height districts. In these areas, development must meet higher design standards and often has a special review board. The City also uses neighborhood design standards (setbacks, garage placement, pitch of roof, etc.) for neighborhoods that were within the city limits in 1949.

Conservation overlay districts have also been used to address environmentally related land use activities such as restrictions for agricultural producers in a wellhead protection area. These types of overlay districts could be used to regulate land use activities potentially harmful to water quality. Examples might include requirements for disconnection of rooftop runoff to impervious areas, use of Low/No-phosphorus fertilizers, or others.

Low/No-Phosphorus Fertilizer Ordinance

To support efforts of improving water quality city-wide, consider the use of an ordinance to ban or restrict phosphorus fertilizers. Restrictions could apply across the entire city, or be focused in more environmentally sensitive areas such neighborhoods above lakes or within a set distance from waterways.

Outreach to Lawn Care Providers

To support city-wide efforts to increase use of Low/No-phosphorus fertilizer, consider offering education and outreach or incentives to lawn care providers to use or offer Low/No-phosphorus fertilizer and to promote soil testing as an option to customers. Provide flyers and other information to lawn care providers to share with their customers that explain the benefits of Low/No-phosphorus fertilizer on the health of their watershed.

Snow and Ice Management Strategies

The City's snow removal management strategies could implement practices as recommended in Section 8.3.1: Expansion of Existing Programs.

Update Drainage Manual

The City of Lincoln is responsible for providing adequate drainage in urban areas as a necessary component in maintaining the overall health, welfare, and economic wellbeing of the City. The last update of the stormwater chapter in the City's Urban Drainage Criteria Manual was 2004. Stormwater management strategies have evolved substantially since 2004, therefore, it is recommended that the City update the stormwater chapter of the criteria manual.

Bridge Retrofits

Retrofitting bridges to control wildlife was discussed as a recommendation for Antelope Creek in Section 8.3.2: New Programs. Consider expanding activities to control bird activity near waterways City-wide.

Establishment of Native Plant Species into Capital Improvement Projects

Plants are a basic environmental building block, provide habitat and food for animals, as well as aid in sustaining the vegetation that holds the soil and protects water quality. Maintaining a diverse range of plants ultimately supports a healthier environment for all plants and animals. Natural areas provide soil treatment opportunities from enhanced infiltration and other natural processes and should result in decreased bacteria export in stormwater. Long grass vegetation also discourages some waterfowl. To improve stormwater quality City-wide, consider the use of native grass species in areas of existing long-grass, as part of flood control and water quality projects. Prairie plants have the following benefits:

- Control invasive weeds
- Filter carbon dioxide
- Reduce flooding by promoting infiltration
- Feed birds and wildlife
- Reduce maintenance cost
- Are aesthetically pleasing
- Adapted to the local climate

Regional Watershed Management Plans

NDEQ and EPA emphasize watershed management plans that address water quality issues in 303(d) listed waters with a developed TMDL. One option for the development of watershed management plan is to establish a larger-scale plan that encompasses several watersheds. Multi-basin plans are written more generally than a Basin Plan covering one impaired water segment. For example, LPSNRD could cover the entire District with two watershed plans, the Upper Salt Creek Water Quality Management Plan and Lower Salt Creek Water Quality Management Plan. Within each plan several projects would be identified. Once the project sponsor intends to implement a project listed in the regional watershed plan a specific project management plan would then be developed for that individual project.

Water Quality Partnerships

As opportunities arise City-wide the City and LPSNRD could consider working with public/private partnerships to incorporate water quality projects into private development.

Incorporation of Water Quality Elements into Future Watershed Master Plans

To support continued water quality improvements, consider including water quality as either a primary or secondary focus of all future Comprehensive Watershed Master Plans. If an existing plan is updated or amended, consider addressing water quality planning elements.

Urban Wildlife Management

Urban wildlife management is discussed in Section 8.3.2 and could be expanded to other areas of concern across the city.

Post Construction Standards

Incorporate post-construction BMPs for new development and redevelopment projects that aim to address both the increased pollutant loads to local waterway as a result of urbanization as well as the increased quantity of water delivered to a water body during a rainfall event. Take into consideration business, environmental, and neighborhood interest recognizing the need to sustain long-term economic and development opportunities in the City and future growth areas.

Pet Waste Ordinances / Disposal Cans

The use of pet waste ordinances and disposal cans is discussed in Section 8.3.1 and could be expanded to other areas of concern across the city, especially those watersheds with an *E. coli* impairment listed in Table 9-3.

Long Term Public Education

Establish a long term education program. This program will focus on education the public on the benefits of improving water quality, and its effects on the environment.

9.4. Developed Watershed Recommendations

According to the City Planning Department, developed watersheds include those that are fully urbanized, within the City limits, and can only support in-fill development. As the City grows and expands, other watersheds may become fully urbanized, and be considered developed. According to Table 9-2, Deadmans Run is the only 100% urbanized watershed in Lincoln, with Antelope Creek 85% urbanized. Other significantly urbanized watersheds include Lynn Creek (67.3%) and Beal Slough (59.4%).

Non-structural programs focus on management of pollutants at their source by minimizing exposure to runoff, rather than treating runoff in structural BMPs. Although non-structural programs removal efficiencies vary depending on the pollutant of concern, in general they are a cost effective strategy. Due to overall similar stream impairments in Lincoln, and the effectiveness and low-cost of implementing non-structural BMPs, an emphasis on non-structural BMPs across the city is recommended. Non-structural strategies that are specific to developed watersheds are listed below:

- Sanitary Sewer Line Inspection Program
- Dry weather storm drainage screening program
- Pet waste ordinance/enforcement
- Long grass maintenance area expansion
- Flood control structure retrofits
- Rooftop runoff disconnections
- LID strategies
- Urban soil quality restoration

9.4.1 Non-structural Recommendations

Sanitary Sewer Line Inspection Program

A sanitary sewer line inspection program as discussed in Section 8.3.1 should be implemented.

Dry Weather Storm Drainage Screening Program

A sampling program as discussed in Section 8.3.1 is recommended.

Pet Waste Ordinance Enforcement

Pet waste ordinance enforcement as discussed in Section 8.3.1 is recommended.

Long Grass Maintenance Area Expansion

Long grass maintenance area expansion as discussed in Section 8.3.1 is recommended.

Flood Control Structure Retrofits

Retrofitting of existing flood control structures throughout the City to enhance water quality benefits could be a large scale, cost effective treatment option. Currently, many residential neighborhoods and large commercial/industrial

sites have dry detention basins to manage runoff during rainfall events. The dry cells are typically designed to temporarily detain stormwater and allow outflow at a specified rate that will not cause flooding downstream. The cells are usually designed to manage up to a 1% chance rainfall event (100-year).

Existing dry cells can be retrofitted with amended soils and outlet structure modifications to capture and infiltrate the 90% rainfall event (1.25 inches). Retrofit of these cells could have a significant effect on pollutant loads in a watershed, by reducing total runoff volumes and the pollutant load it carries, and trapping sediment from stormwater. Demonstration project AC-P10: Extended Detention Cell Near 60th and South in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS details a potential retrofit of an existing dry cell into an extended detention cell. This project serves as one approach that could be used throughout the City.

Disconnections of Roof Runoff/Parking Lots

As described in Section 8.3.2, disconnections of rooftop runoff and surface water runoff from impervious surfaces such as parking lots can have a considerable benefit to stormwater runoff at a relatively low cost. It is recommended that an incentive program for property owners to disconnect downspouts and roof drains from spilling onto impervious surfaces be established. Support the program with a considerable educational campaign using bill stuffers, billboards, press releases, social media, news articles, information on the City and LPSNRD's website, and other means.

Disconnections of rooftop runoff and surface water runoff from impervious surfaces such as parking lots can have a considerable benefit to stormwater runoff at a relatively low cost.

It is also recommended that locations be identified in the Basin Plan area where parking lot drainage to storm drain inlets could be disconnected. Directing flow of stormwater from parking lots onto vegetated surfaces, swales, rain gardens, or other BMPs, could have a considerable positive impact on water quality and on reducing wet weather peak flows in the streams, with associated BMPs. A process should be established to work with property owners to encourage disconnection of parking lots and other large impervious surfaces from the storm drain system.

Urban Soil Quality Restoration

Urban soil quality restoration is discussed in Section 8.3.2. During re-development activities, City-wide care should be given to ensure soil remains undisturbed during construction activities. This could be accomplished through required fencing of sensitive areas to limit compaction or restore the soil quality after construction.

9.4.2 Structural Recommendations

According to Pitt's April 2011 WinSLAMM report, structural source controls will help reduce pollutant loading and improve water quality, but can be more costly to implement that the non-structural BMPs listed above. As mentioned previously, structural stormwater controls are more efficient when they are stacked, or used in a combination, to provide treatment to one area. Below are a number of effective stormwater controls modeled in WinSLAMM for runoff volume controls for urbanized areas with characteristics similar to those within the Antelope Creek watershed.

- Strip mall and shopping center areas
  - Porous pavement (in half of the parking areas)
  - Curb-cut biofilters (along 80% of the curbs) for strip malls or biofilters in parking areas (10% of the source area) for shopping centers
  - Biofilters in parking areas (10% of the source area) and curb-cut biofilters (along 40% of the curbs)
- Light industrial areas
  - Curb-cut biofilters (along 40% of the curbs)
  - Roofs and parking areas half or all disconnected
- School, church, and hospital institutional areas
  - Small rain tanks (0.10 cubic feet storage/square foot roof area) for schools and churches; rain tanks (0.25 cubic feet storage/square foot roof area) for hospitals
  - Roofs and parking areas half or all disconnected
- Low and medium density residential areas
  - Curb-cut biofilters

9.5. Undeveloped Watershed Recommendations

Undeveloped watersheds include those that are not fully urbanized, have areas that are located outside current City limits, and can support future expansion as shown in Figure 9-1. As the City grows and expands, these watersheds may become fully urbanized and be considered developed. As these watersheds become more developed, the recommendations for each should be updated to reflect their status. The following list includes the currently significantly undeveloped watersheds within the City by percent urbanized (City Planning Department, 2011):

- Cardwell Branch (0.0%)
- Haines Branch (0.9%)
- Little Salt Creek (0.0%)
- Lower Salt Creek (9.6%)
- Middle Creek (3.1%)
- Middle Salt Creek (9.3%)
- Oak Creek (4.2%)
- SE Upper Salt Creek (0.4%)
- Stevens Creek (6.0%)

9.5.1 Non-structural Recommendations

A proactive approach to stormwater management by the City and LPSNRD within developing watersheds would support sustainability regarding water quality. Planning for water quality improvements should begin ahead of new development. Below are two recommendations for non-structural activities ahead of future development in Lincoln's non-developed basins.

Post-Construction Stormwater Management

An effective stormwater quality management approach for developing or redeveloping areas would be Low Impact Development (LID) strategies. LID strategies include the use of structural and non-structural BMPs as part of a planned development to manage stormwater, versus the traditional method which includes moving large amounts of stormwater offsite as quickly as possible. Post-construction BMPs would include those that are used in the layout and construction of new development and redevelopment areas; both public and private. If the natural hydrologic and hydraulic functions of a watershed can be maintained, it will be easier to manage water quality in those areas. Some of the strategies that should be considered are:

- Maintain natural drainage ways and flow patterns
- Maintain as much natural grasslands and existing tree areas during construction as possible
- Consider right-of-way areas along all existing streams and creeks which provide a minimum of 200 foot total buffer width.
- Onsite capture and treatment of stormwater for each parcel to return the volume and peak flow during rainfall events to predevelopment levels
- Use of pervious pavement in residential areas and parking lots
- Using grassed swales and bio-infiltration areas to convey stormwater in lieu of conventional curb and gutter and closed conduit systems.
- Green roofs
- Planter boxes
- Rooftop disconnection requirements for new developments

Disconnection Requirements for New Developments

As described in Section 8.3.2, disconnections of rooftop runoff and surface water runoff from impervious surfaces such as parking lots can have a considerable benefit to stormwater runoff at a relatively low cost. For developing areas, consider requirements that would route rooftop and impervious surface runoff onto pervious surfaces.

9.5.2 Structural Recommendations

Structural BMPs which help reduce pollutant loading and improve water quality are not as economical as the non-structural BMPs listed above. The two most effective water quality BMPs at controlling *E. coli,* TSS, and nutrients are infiltration BMPs and wet ponds. In most of the City it is more feasible to retrofit the infiltration BMPs into project sites. However, in new development areas the City should consider the use of wet ponds to manage stormwater.

SECTION 10 – IMPLEMENTATION

10.1. Introduction

Reducing the pollutant load into Antelope Creek is a complex and challenging effort that will require the City and LPSNRD to acquire outside financial and technical resources. A cost estimate was established in order to quantify potential financial resources necessary to remove Antelope Creek from the impaired waters list and does not reflect any type of commitment of resources by Basin Plan stakeholders. The Source Loading and Management Model for Windows (WinSLAMM), existing structural BMPs, and historical and current non-structural programs were utilized to develop the cost estimate. The many assumptions used to determine the overall cost are detailed later in this section. Mechanical or ultraviolet (UV) treatment of surface water in Antelope Creek is not included in this estimate and was not considered a practical alternative by the City and NRD. Using these assumptions, a projected cost based on average *E. coli* removal efficiency was developed.

An implementation strategy was written using input from the City, LPSNRD, and public, the summary of conclusions drawn during the planning process, and a review of available information regarding Antelope Creek's water quality.

Based on the above statements, approximately $57 million may be necessary to consistently meet existing regulatory criteria for *E. coli* in Antelope Creek. This estimate far exceeds available funding, therefore it is recommended that the City and LPSNRD implement a phased approach, implementing the most cost effective practices in the early years and continuing to evaluate and implement additional practices over a 40-year period. The project team understands that financial expenditures of this magnitude, to consistently meet the EPA criteria in a recreational stream segment within an urbanized watershed, is somewhat impractical as compared to existing financial resources available. As summarized later, 5-year plan reviews could potentially have large effects on the overall cost estimate based upon the effectiveness of the first phase of project and program implementation. It is also important to note that funding assistance from Federal, state, and local sources are anticipated to ease the financial need by the City and LPSNRD.

Although the goal of this Basin Plan is to remove Antelope Creek from the impaired waters list, the structural and non-structural BMPs recommended have multiple benefits. These include, but are not limited to: reduction of a wide range of other pollutants, reduced stormwater runoff volume, reduced landscape maintenance, increased stream stability, reduced infrastructure cost downstream, recharging groundwater levels, aesthetics, and increasing the overall health of Antelope Creek.

An implementation strategy was written using input from the City, LPSNRD, and public, the summary of conclusions drawn during the planning process, and a review of available information regarding Antelope Creek's water quality. The implementation plan was based upon a balance of available resources and the process necessary to achieve the plan's ultimate goal of removing Antelope Creek from the Clean Water Act Section 303(d) list of impaired waters. The implementation plan lays out efforts that will begin the process of lowering the level of *E. coli* in Antelope Creek to acceptable levels over the next 40 years, in addition to reducing other known contaminants such as sediment and nutrients. This implementation section includes combinations of several strategies that have been discussed in previous sections.

Overall, it is recommended that the Antelope Creek watershed be divided into sub-basins following existing stormwater drainage infrastructure. These sub-basins would be more manageable and allow periods of evaluation and resource gathering.

Input from the project team was used to establish the Antelope Park sub-basin as a priority area for concentrating implementation of structural BMPs over the next 5 years. In addition, non-structural BMPs have been recommended basin-wide. To increase public acceptance of stormwater management practices, several demonstration structural BMPs have been recommended to be implemented across the entire Antelope Creek watershed. It is also recommended that a plan update be completed every 5 years.

For purposes of documenting in-stream water quality and establishing the TMDL, Antelope Creek water quality monitoring is completed every 6 years by NDEQ as part of a statewide basin rotation network. Sampling is completed weekly from May through September. Antelope Creek is scheduled to be sampled again in 2015 by NDEQ at the confluence of Salt Creek and Antelope Creek (2010-2011 sampling point AC-9). *E. coli* results from this location are the basis for the TMDL established in 2007, and will remain the location that will determine if progress is being made towards the goal of reducing bacteria in Antelope Creek. Due to the large size of the

watershed, and diffuse pollutant sources, contamination reductions may be difficult to distinguish over the short-term. A monitoring plan has been detailed in this section.

10.2. Implementation Overview

Due to the cost of implementing the entire plan, a phased approach has been established. This allows the City and LPSNRD to concentrate available resources into one priority sub-basin to be implemented over a short-term period of 5 years, and creates flexibility for implementing additional water quality projects elsewhere in the Antelope Creek watershed as priorities shift. In total eight sub-basins have been identified and are shown in Figure 10-1.

Effectiveness of projects and programs implemented in the priority sub-basin and the Antelope Creek watershed as a whole will be measured through monitoring, surveys, and record keeping. A detailed set of milestones and evaluation criteria are documented later in this section.

An implementation strategy has been established that includes a concentration of resources over the first 5 years into a priority sub-basin, referred to as Antelope Park sub-basin. This sub-basin is Phase One of the 40-year implementation plan and is located in the central portion of Antelope Creek watershed, on the west side of Antelope Creek as shown in Figure 10-2. The Antelope Park sub-basin is considered a priority due to the large amount of public land available, ability to enhance existing sites, and the presence of one of the few remaining open channel tributaries to Antelope Creek. This sub-basin also includes the Lincoln Children's Zoo.

Phase One structural recommendations in the Antelope Park sub-basin are a starting point for working towards the goal of reducing pollutant loading to Antelope Creek. In addition, non-structural BMPs are being recommended to be implemented during Phase One throughout the entire Antelope Creek watershed, as well as the Antelope Park sub-basin. For the Antelope Park sub-basin, an emphasis will be placed on area residents and property owners to implement non-structural BMPs through a more intensive information and education process. Water quality milestones have been established that can be used at specific times to evaluate the effectiveness of the water quality implementation plan.

Antelope Creek Baseline Assumptions

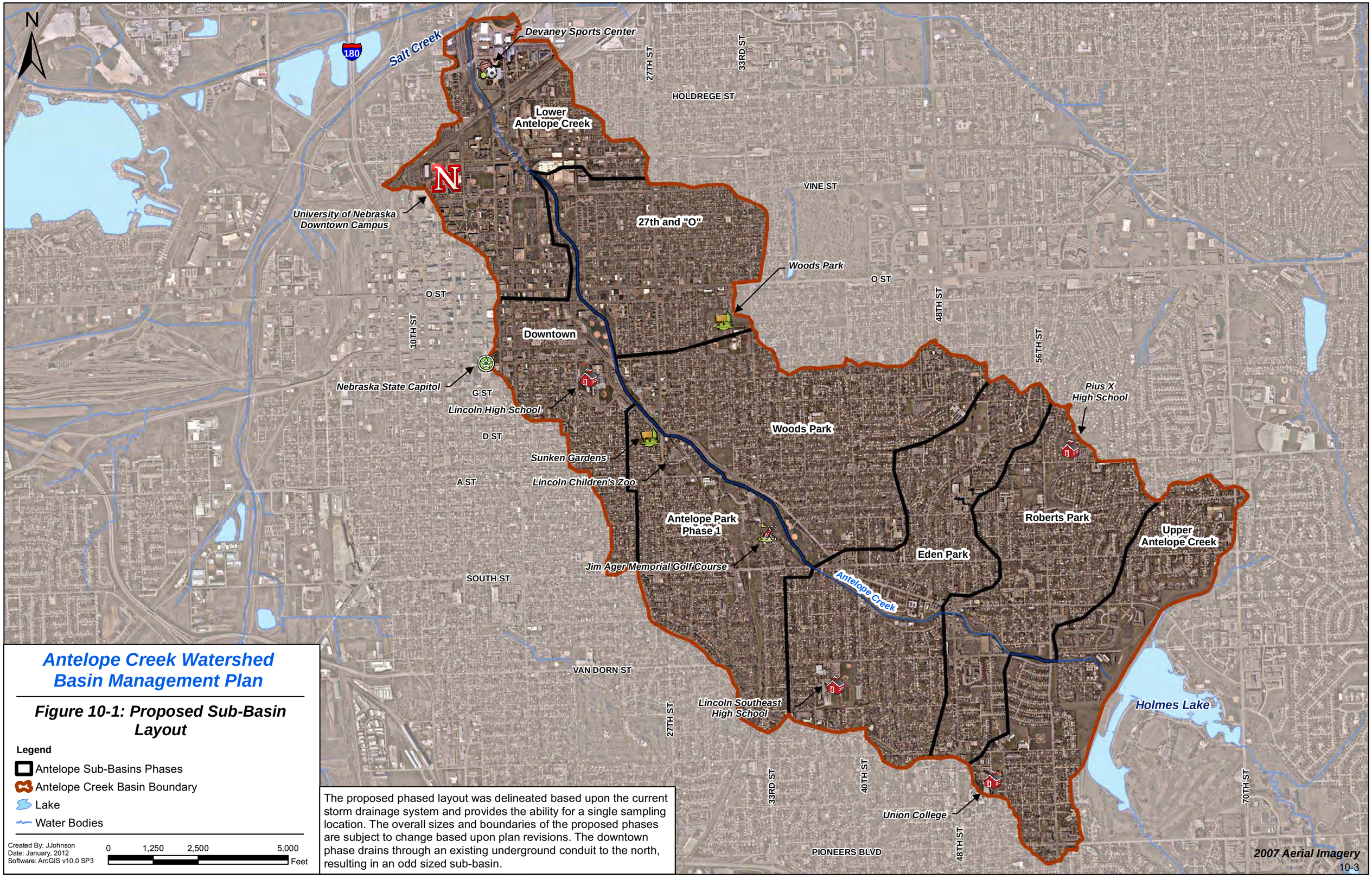
For the purposes of project design and planning, several baseline characteristics of the Antelope Creek watershed have been established and used to create criteria which will be used by the City and LPSNRD as they work towards meeting the goals set in the plan. Information summarized below provides baseline assumptions used to establish the implementation strategy.

- Storm frequencies
- *E. coli* Geometric Mean (May-September 2011)
- Pollutant loading estimates
- Primary pollutants of concern
- Naturally occurring bacteria

Storm Frequency

In order to capture a majority of pollutants and reduce the volume of runoff from frequent rainfall events, structural projects are recommended to be designed up to a 90% rainfall event, which averages 1.25 inches (Lincoln technical Memo, 2012). The City has provided information pertaining to rainfall frequency in Lincoln, as seen in Figure 10-3 below. 90% of rainfall events generally include most of the runoff pollutant discharges by mass which is frequently more than 75% of the annual pollutant discharges. Removing as much of the runoff from this rain event category as practical will most effectively reduce pollutant loading from stormwater runoff into Antelope Creek.

More severe rainfall events are less frequent and produce a greater volume of runoff. However, these storms typically consist of lower concentrations of pollutant discharges than smaller events. Therefore, volume and pollutant load reductions during portions of these large rain events will provide little benefit, and are typically challenging and costly to design and construct. Flows associated with rainfall events greater than the 90% rainfall event are anticipated to contain bacteria concentrations above the TMDL.



Antelope Creek Watershed Basin Management Plan

Figure 10-1: Proposed Sub-Basin Layout

Legend

- Antelope Sub-Basins Phases
- Antelope Creek Basin Boundary
- Lake
- Water Bodies

Created By: JJohnson
Date: January, 2012
Software: ArcGIS v10.0 SP3

0 1,250 2,500 5,000 Feet

The proposed phased layout was delineated based upon the current storm drainage system and provides the ability for a single sampling location. The overall sizes and boundaries of the proposed phases are subject to change based upon plan revisions. The downtown phase drains through an existing underground conduit to the north, resulting in an odd sized sub-basin.

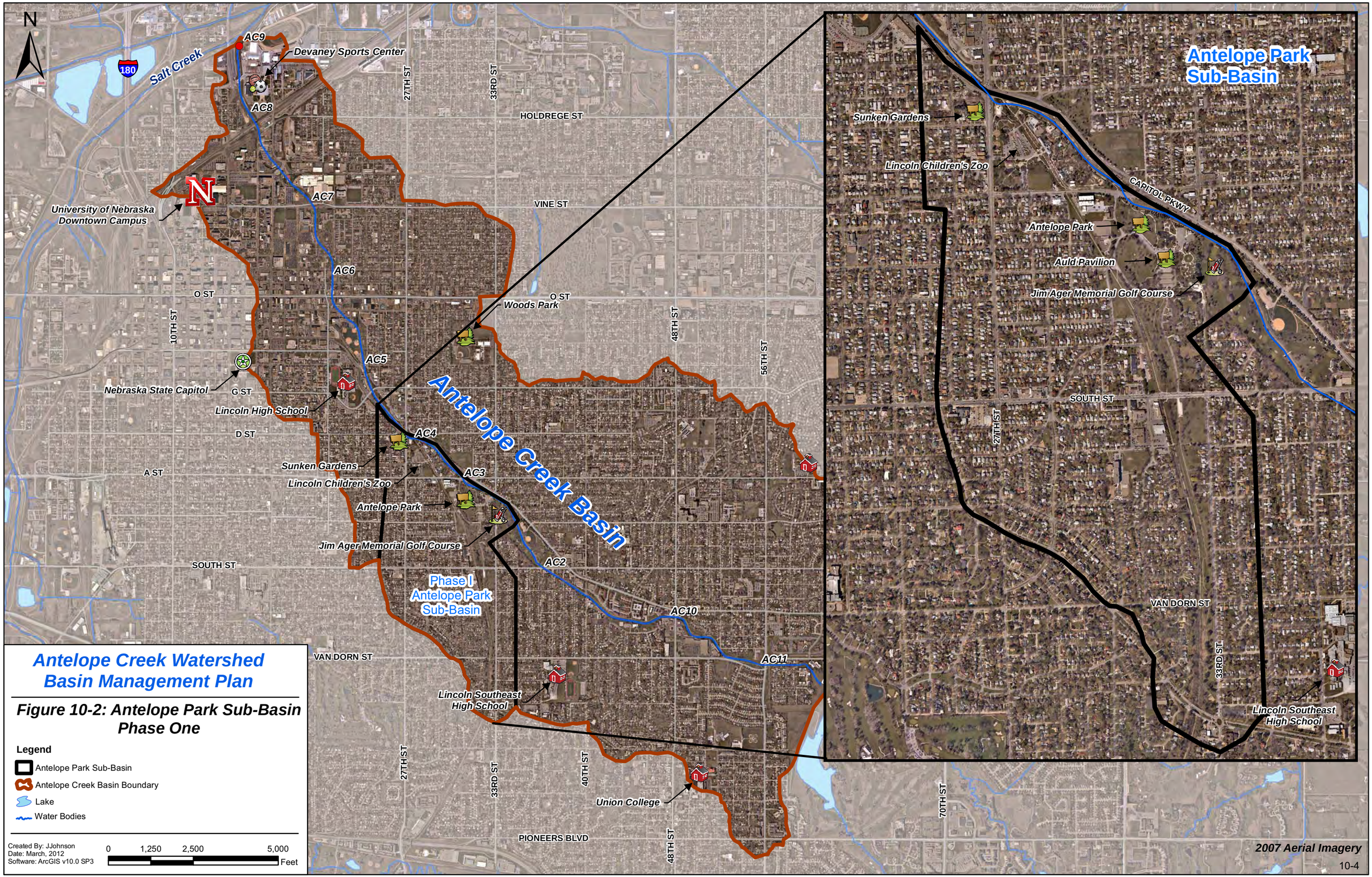
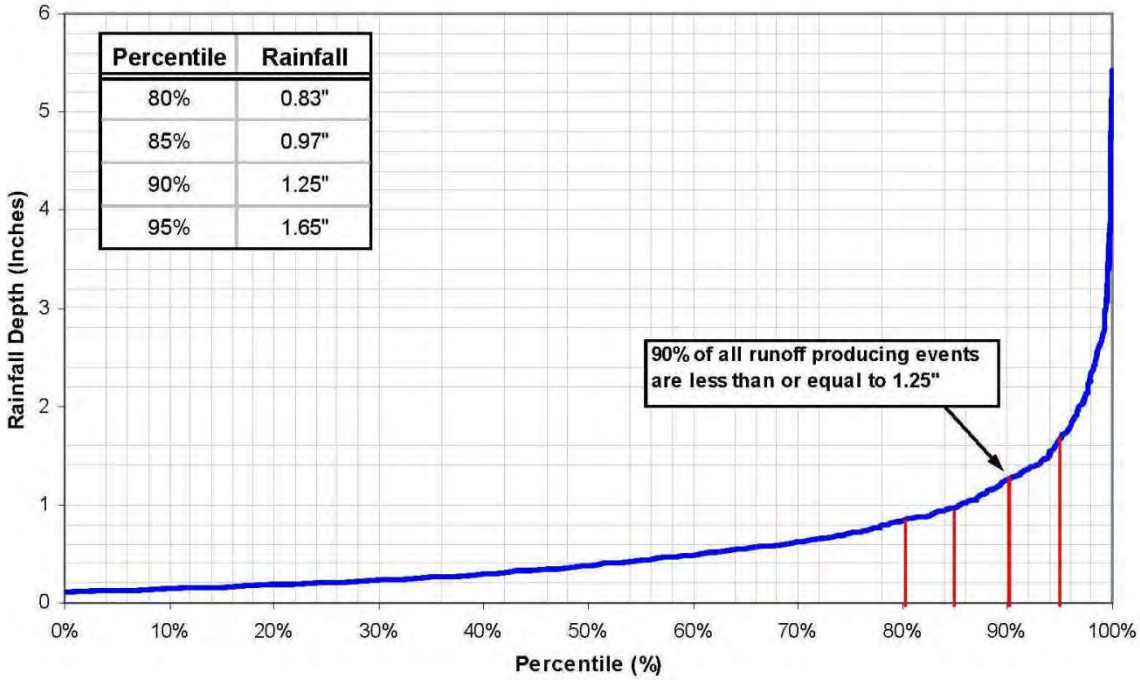

N
Salt Creek
180
AC9
Devaney Sports Center
AC8
27TH ST
33RD ST
HOLDREGE ST
University of Nebraska
Downtown Campus
AC7
VINE ST
AC6
O ST
Woods Park
10TH ST
48TH ST
56TH ST
AC5
Nebraska State Capitol
G ST
Lincoln High School
D ST
AC4
Sunken Gardens
Lincoln Children's Zoo
A ST
AC3
Antelope Park
Jim Ager Memorial Golf Course
Antelope Creek Basin
SOUTH ST
AC2
Phase I
Antelope Park
Sub-Basin
AC10
VAN DORN ST
AC11
Lincoln Southeast
High School
27TH ST
33RD ST
40TH ST
Union College
PIONEERS BLVD
48TH ST
70TH ST
Antelope Park
Sub-Basin
Sunken Gardens
Lincoln Children's Zoo
CAPITOL PKWY
Antelope Park
Auld Pavilion
Jim Ager Memorial Golf Course
SOUTH ST
27TH ST
VAN DORN ST
33RD ST
Lincoln Southeast
High School
Antelope Creek Watershed
Basin Management Plan
Figure 10-2: Antelope Park Sub-Basin
Phase One
Legend
Antelope Park Sub-Basin
Antelope Creek Basin Boundary
Lake
Water Bodies
Created By: JJohnson
Date: March, 2012
Software: ArcGIS v10.0 SP3
0
1,250
2,500
5,000
Feet
2007 Aerial Imagery

Figure 10-3. Rainfall Frequency for Lincoln Municipal Airport



Source: City of Lincoln Technical Memorandum, 2012

E. coli Geometric Mean

Since the NDEQ sampling event in 2004 that determined goals listed in the TMDL, several significant changes have occurred in the Basin Plan area including rehabilitation of Holmes Lake and completion of the Antelope Valley Project. These significant projects address water quality and flooding concerns, respectively. The effects that these significant changes have had on the water quality are unknown. More recently collected data would provide a better representation of existing conditions in the watershed. *E. coli* geometric means as sampled by NDEQ and the project team are shown below in Table 10-1.

Table 10-1. Historic Recreation Season *E. coli* Geometric Means at AC-9

Year	Sampling Entity	Geometric Mean cfu/100 mL
2004	NDEQ	3,433
2009	NDEQ	620
2010 & 2011	EA	1,511

NDEQ's last sampling event for *E. coli* at the confluence with Salt Creek was in 2009 (SLP2ANTLP104). A total of 22 samples were collected weekly between May and September, resulting in a geometric mean of 620 cfu/100 mL.

During sampling conducted in 2010 and 2011 by EA, 18 samples were collected and analyzed at sampling location AC-9 during the recreational season; the same location NDEQ monitored for bacteria in 2009 as part of their 'statewide basin rotation' monitoring network. Samples were collected at this site for confirmation and comparison to the previously collected water quality data and Antelope Creek TMDL criteria. During the 18 sampling events between May and September 2011, the geometric mean was 1,511 cfu/100 mL. Pollutant reduction goals established in the implementation strategy will be based upon the data collected in 2011. Average flows recorded near AC-9 during sampling events were 3.7 cubic feet/second (CFS) or 1,660 gallons/minute, or 2.4 million gallons/day (EA Field Survey, 2012-2011).

Load Reduction Estimates

Pollutant reduction estimates used for the implementation plan are based upon information provided in the two WinSLAMM reports provided by Dr. Pitt. WinSLAMM provides the City and LPSNRD a powerful resource in estimating pollutant reduction levels that could be expected by implementing control strategies for differing land uses

in Lincoln. WinSLAMM can also be used to estimate overall cost of achieving the goal to reduce *E. coli* to the levels listed in the 2007 TMDL.

In order to achieve goals listed in the TMDL results from sampling in 2011, *E. coli* concentration will need to be reduced 93%. The 2007 TMDL is based upon water quality data from 2004 sampling, and calls for a 97% reduction to attain supported status. Due to uncertainty in estimating the nonpoint source load amounts from the Antelope Creek watershed, and the Antelope Park sub-basin, load reduction goals are challenging to quantify. For purposes of planning projects for each sub-basin, it is assumed that a reduction of bacteria concentration by 75-95% per sub-basin will reduce bacteria loading to acceptable levels at AC-9.

Primary Pollutants of Concern

Based upon water quality sampling completed in 2010 and 2011 by EA, *E. coli* was the only constituent of concern identified in the 2007 TMDL that was observed above the applicable water quality standard or TMDL (ammonia was not detected). Based on the 2010 water quality study, the City and LPSNRD have determined that total suspended sediments (TSS) and nutrients should be considered primary pollutants. Therefore, *E. coli,* TSS, and nutrients (phosphorus) will be the focus of pollutant loading reduction estimates and target pollutants for BMPs listed in the implementation strategy.

Naturally Occurring Bacteria

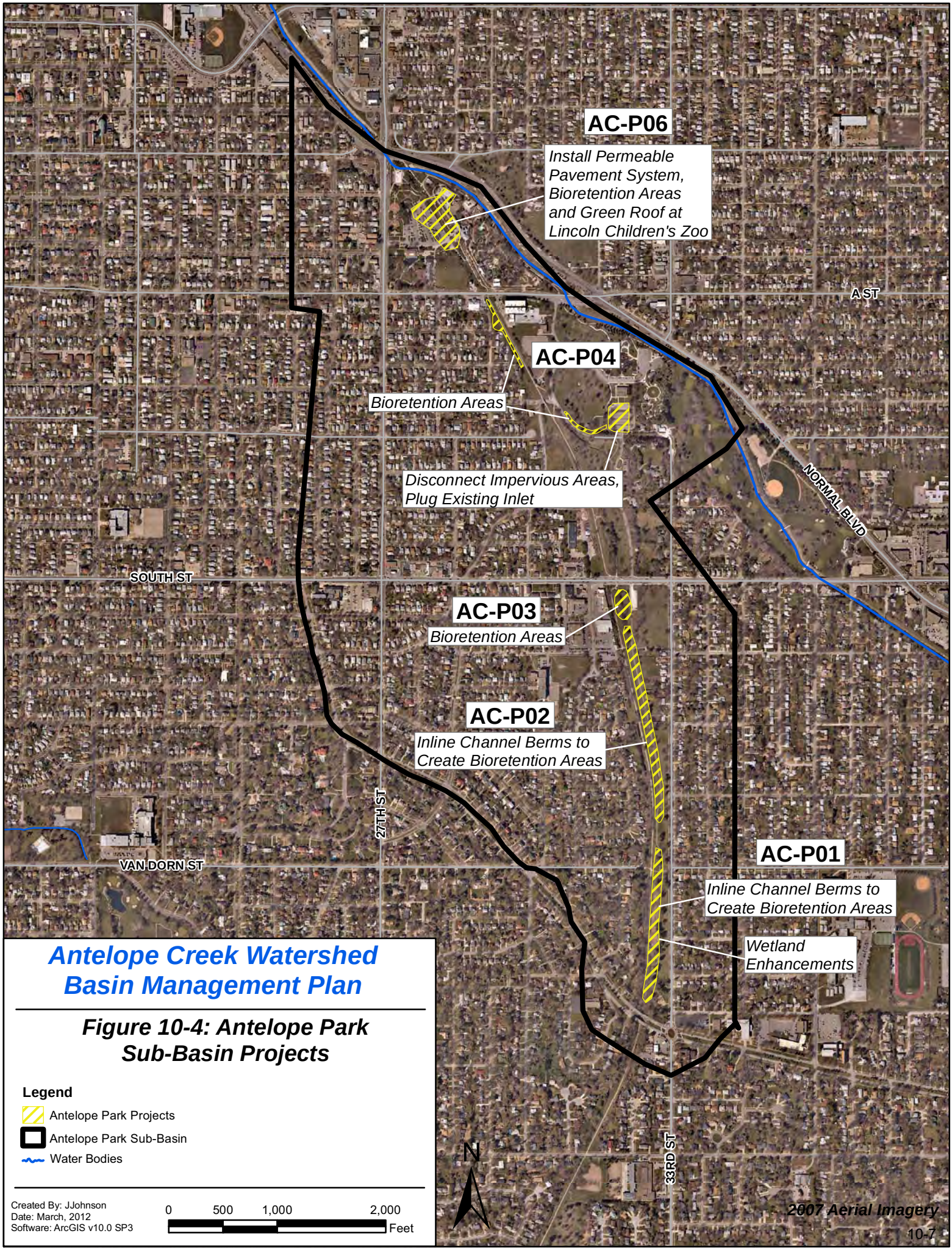
A number of bacteria occur naturally in freshwater streams, and live in the water and sediments. Data currently do not exist to differentiate between anthropogenic (human) and animal sources of *E. coli* bacteria in the Antelope Creek watershed. Therefore, the specific source and quantity of human induced versus naturally occurring bacteria (*e.g.,* wildlife, pets) in the Antelope Creek watershed is unknown. However; sampling in 2010 and 2011 did indicate that concentrations present in Antelope Creek do not represent levels that would indicate an illicit discharge from the sanitary sewer system. Sampling to date indicates a generally ubiquitous distribution of *E. coli* bacteria from below Holmes Lake to the confluence with Salt Creek. No specific drainage inflow or area along Antelope Creek was identified as a primary or major source of the *E. coli* in the watershed. Sampling did not determine the amount of bacteria reaching Antelope Creek from the Antelope Park sub-basin, nor any other sub-basin of Antelope Creek. Although the 2010-2011 sampling did look at low flow *E. coli* contributions from tributaries and at locations throughout the Antelope Creek watershed, the sampling location established for the NDEQ in-stream water quality monitoring network provides the decision point for water quality assessments and TMDL compliance. The historical data from this monitoring point provides *E. coli* levels but no other specific bacteria or specific source tracking information.

10.3. Phased Implementation Strategy

Due to the size of the Antelope Creek watershed, a total of eight sub-basins are anticipated to be used to implement projects and programs over the life of the Basin Plan. A general approach for the additional sub-basins is described later in this section.

A phased approach to implementing a water quality management plan in a watershed of this size can provide a strong chance of success. The proposed approach could allow the City and LPSNRD to meet the EPA's Nine Element requirements for the 319 grant program while allowing for flexibility during the implementation of the Plan to implement projects outside of priority zones. A phased implementation approach also allows for grant applications and funding allocation to follow a methodical stepped approach over a period of years.

A phased implementation strategy will provide the City and LPSNRD a focused approach to begin working towards improved water quality in Antelope Creek. The Antelope Park sub-basin selected by the project team consists of the area around Antelope Park, including Lincoln Children's Zoo. The Antelope Park sub-basin is shown in Figure 10-4.


AC-P06
Install Permeable Pavement System, Bioretention Areas and Green Roof at Lincoln Children's Zoo
A ST
AC-P04
Bioretention Areas
Disconnect Impervious Areas, Plug Existing Inlet
NORMAL BLVD
SOUTH ST
AC-P03
Bioretention Areas
AC-P02
Inline Channel Berms to Create Bioretention Areas
27TH ST
VAN DORN ST
AC-P01
Inline Channel Berms to Create Bioretention Areas
Wetland Enhancements
33RD ST
N
2007 Aerial Imagery
Antelope Creek Watershed Basin Management Plan
Figure 10-4: Antelope Park Sub-Basin Projects
Legend
Antelope Park Projects
Antelope Park Sub-Basin
Water Bodies
Created By: JJohnson
Date: March, 2012
Software: ArcGIS v10.0 SP3
0
500
1,000
2,000
Feet

10.3.1 Phase One

Antelope Park Sub-Basin Description

Antelope Park sub-basin consists of 52.5% residential land use, 16.0% park/recreation/open spaces, and 25.8% 'other'; which includes mostly streets. A land use breakdown is provided in Table 10-2. This sub-basin represents a total of approximately 12.7% of the total 4,932 acre Antelope Creek watershed. Efforts in the sub-basin focus on structural enhancements along a tributary that flows south to north through Antelope Park and reaches Antelope Creek near the Lincoln Children's Zoo.

Table 10-2. Antelope Park Sub-basin Land Use Breakdown

Land Use	Area (ac)	Area (%)
Single Family Residential	283.6	45.1%
Multiple Family Residential	46.2	7.4%
Commercial	11.0	1.8%
Industrial	0.8	0.1%
Public/Quasi-Public	20.1	3.2%
Transportation	4.1	0.7%
Park/Recreation/Open Space	100.7	16.0%
Other (Streets)	161.9	25.8%
Total	628.3	100%

Source: City Planning Department, 2011

Antelope Park Sub-basin Structural Improvements

The City of Lincoln has recently made improvements to portions of the tributary in the sub-basin including bank stabilization, creation of a detention pond, and wetland improvements. Recommended structural improvements outlined below include both new projects and enhancements to existing projects to provide increased water quality benefits. Details for each of these projects are provided in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS. All of the proposed structural improvements are located on publicly owned property, and are listed in Table 10-3 and are graphically displayed in Figure 10-3.

Table 10-3. Antelope Park Sub-basin Water Quality Improvements

Project Number/Name	Description	Cost Estimate	Prioritization Rank
P01: Antelope Park: Van Dorn St to Sheridan Blvd	Channel and Wetland Enhancements	$125,000	200
P02: Antelope Park: South St to Van Dorn St	Channel Enhancements	$125,000	240
P03: Antelope Park: SW of 33rd and South St	Bioretention Areas	$125,000	260
P04: Antelope Park: A Street to South Street	Disconnect parking lot, address erosion in meandering stream	$250,000	180
P06: Lincoln Children's Zoo	Green roof, permeable pavement, bioretention	$425,000	300
	TOTAL	**$1,050,000**	**--**

Non-structural Best Management Practices

In addition to structural improvements in the Antelope Park sub-basin, the implementation of non-structural BMPs will be instituted throughout the entire Antelope Creek watershed. A full list of non-structural BMP recommendations was detailed in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS.

The following five non-structural BMP recommendations would be the responsibility of the City and/or LPSNRD to implement using their resources. These five have been listed based on their efficacy to reduce key pollutants from stormwater in the short-term.

1) Retrofitting older bridges and overpasses crossing Antelope Creek to limit bird activity
2) Sanitary Sewer Line Inspection Program Expansion
3) Dry Weather Storm Drainage Screening
4) Enforcement of existing pet waste ordinances
5) Supplying and maintaining additional pet waste containers

Picture 38: Several bridges over Antelope Creek currently support bird roosting and nesting habitat

Non-structural BMPs listed below would be for residents and property owners to implement through programs offered by the City and/or LPSNRD. These non-structural options have been listed for their efficacy to reduce key contaminants, including *E. coli,* TSS, and nutrients. Each is a new or expanded program and is further detailed in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS.

1) Low/No-phosphorus fertilizer program
2) Rooftop disconnection incentive program
3) Rain garden program
4) Rain barrel program

Basin-wide Information and Education

A significant information and education campaign will be necessary to encourage property owners and residents to begin making changes in everyday routines in order for non-structural BMPs to be successful. The City and LPSNRD can use their websites, news articles, neighborhood association meetings/newsletters, and other traditional mechanisms to inform residents and property owners about the opportunity to improve the health of their watershed. Prior to project implementation, surveys can be used to gather information about existing property management strategies, number of direct connections on properties, number of pets, type of fertilizer used, etc. The City and LPSNRD can then follow-up after implementation to evaluate the effectiveness of each strategy within the Antelope Creek watershed.

Antelope Park Sub-basin Information and Education Emphasis

Emphasis will be placed on notifying property owners and residents within the priority Antelope Park sub-basin. Additional efforts, beyond what is used for the entire watershed, could include letters to homeowners, bill stuffers, presentations to neighborhood associations in the area, or visits by City and LPSNRD staff. Residents and property owners in the Antelope Park sub-basin could be offered additional benefits such as:

- Low/No-phosphorus fertilizer at no or reduced cost
- Additional incentives for installation of rain gardens and rain barrels
- Materials needed to disconnect downspouts at reduced or no cost

Due to the high level of uncertainty in the non-point source reduction estimates and the unknown level of existing *E. coli* bacteria originating from the Antelope Park sub-basin, it is assumed that a combination of structural BMPs and a strong emphasis on non-structural BMPs will have a significant effect in reducing *E. coli* bacteria in Antelope Creek.

Phase One Cost and Load Reduction Estimates

Phase One costs are generally anticipated to include the installation of recommended structural and non-structural BMPs within the Antelope Park sub-basin, as well as basin-wide implementation of non-structural programs, 5-year

review, and monitoring. The estimated cost of each of these components is summarized in Table 10-4. Cost estimates for maintenance is not included. *E. coli* reductions for Phase One are estimated in two ways: reduction within the Antelope Park sub-basin, and reduction at AC-9 sampling location near the confluence with Salt Creek. The estimated *E. coli* reductions for each individual structural BMP were calculated using WinSLAMM.

Due to uncertainty of the existing bacteria contributors in each sub-basin, and uncertainty of the level of implementation, a wide range in reduction estimates exist. For example, if 75% of the bacteria load derives from bird droppings under bridges, and wildlife control measures remove the majority of birds from roosting, the bacteria pollutant load reduction could be upwards of 75%. The *E. coli* reduction estimates for the six structural BMPs are listed below in Table 10-4. If each project is implemented within the Antelope Park sub-basin a total reduction of 6% has been estimated using WinSLAMM. This equates to approximately 1% reduction at AC-9 (see Figure 10-2).

Basin-wide non-structural programs are expected to reduce *E. coli* throughout the Antelope Creek watershed by 15-40%. Assuming a fair contribution of implementation across the entire watershed, the Antelope Park sub-basin would then also experience a similar reduction of 15-40%. Emphasizing the same non-structural programs using a more stringent education and outreach strategy within the Antelope Park sub-basin is expected to achieve an additional 10-50% reduction of *E. coli* in the Antelope Park sub-basin. Combining both the basin-wide and the more stringent Antelope Park sub-basin non-structural programs results in an *E. coli* reduction of 25-90% within the sub-basin. These non-structural programs result in an additional 1-7% reduction at AC-9.

Overall, total reduction estimates for the Antelope Park sub-basin, including structural BMPs, total 31-96%. Combining the estimates for the entire watershed with the reduction estimates from the Antelope Park sub-basin results in a total estimated reduction at AC-9 of 17-46%.

Table 10-4. Cost and Load Reduction Estimates

Basin Plan Watershed	Project Cost	*E. coli* reduction (within Sub-basin)	*E. coli* reduction (at AC-9)
Phase One: Structural BMPs			
P01: Antelope Park: Van Dorn St to Sheridan Blvd	$125,000	2%	<1%
P02: Antelope Park: South St to Van Dorn St	$125,000	3%	<1%
P03: Antelope Park: SW of 33rd and South St	$125,000	1%	<1%
P04: Antelope Park: A Street to South Street	$250,000	<1%	<1%
P06: Lincoln Children's Zoo	$425,000	<1%	<1%
Sub-total	**$1.1 million**	**6%**	**1%**
Phase One: Non-Structural BMPs	**$550,000**	**25-90%**	**16-45%**
Phase One: Review, Monitoring, plan revision	$50,000	NA	NA
Grand Total	**$1.7 million**	**31-96%**	**17-46%**

Non-structural cost estimates were calculated based on experience the City has gained from implementation of several existing programs. Cost estimates include staff time, printing, mailing, etc. The following general assumptions were used:

- Low/no-phosphorus fertilizer $35/bag, purchase 250 bags per year for distribution
- Equipment cost for residential downspout disconnections to re-route runoff to vegetated areas
- Cost to produce newsletters, letters, stamps, billboards, TV ads, press releases, etc.
- Annual clean-out of sediment around bridges and overpasses
- Low-cost bridge retrofits including netting, bird spikes
- Installation of 2,000 square feet of residential rain gardens per year at $10/square foot
- Installation of 20 rain barrels per year at $200 per rain barrel
- Annual dry weather screening of Antelope Creek with limited sampling

10.4. Plan Revisions and Additional Phases

In order to effectively plan for a series of ongoing capital improvements, an adaptive management strategy has been developed that will include plan revisions and review approximately every 5 years. Additional phases and plan revisions will be based upon availability of new technologies and evaluation of performance of BMPs as part of Phase One. This timeline was selected to allow for implementing and evaluating the effectiveness of projects listed in the Antelope Park sub-basin. Projects which were not implemented over the first 5-year period might be considered priorities for the next phase.

The size of each additional sub-basin for future phases of implementation has been determined by the area deemed to be manageable in limiting pollutants over a 5-year period, and the potential high cost and large scope of the problem. Each sub-basin should average 670 acres, but total size may vary depending upon land use and land available for BMPs. Full sub-basin delineation was not completed as part of this plan. Sub-basins will be delineated during the plan update based upon a review of the effectiveness of the strategies listed for Phase One.

10.5. Structural Demonstration Projects (Basin-wide)

Several project opportunities, identified throughout the entire Antelope Creek watershed during site selection and project screening, are listed in further detail in SECTION 8 - MANAGEMENT PRACTICES–RECOMMENDED PROJECTS/PROGRAMS. The intent of locating projects outside of the priority sub-basin is to allow the City and LPSNRD flexibility to implement additional structural projects to serve as demonstration sites. These pilot projects will allow the city to gain valuable experience in how stormwater controls function locally, and allow the City and LPSNRD to more effectively place additional controls in the Antelope Creek watershed based upon lessons learned. These projects may become priority structural projects as additional sub-basins are identified as new priorities during future phase development. In total, 13 projects have been identified basin-wide, including demonstrative projects and the priority-sub basin improvements.

10.6. Other Opportunities

Opportunities for water quality projects during future redevelopment activities (green roof, parking lot redevelopment, etc.) should also be considered by the City and LPSNRD. In many situations, the City and LPSNRD could consider offering cost-share or becoming a grant sponsor to create a partnership with a private entity. Several planned redevelopment activities exist in the watershed, including Innovation Campus and areas recently removed from the floodplain after completion of The Antelope Valley project. The City and LPSNRD should consider identifying other water quality improvements as opportunities are presented.

10.7. Implementation Schedule and Milestones

Project milestones have been established to identify anticipated times in which key components of the Phase One implementation plan are to be started. As the implementation process unfolds, the City and LPSNRD can use these milestones to determine their progress at that time. Milestones have been established for each year of Phase One and include significant actions. The first year of phase two has also been included, as seen in Table 10-5. Milestones for non-structural BMPs are representative of a basin-wide effort for Phase One.

Table 10-5. Phase One Implementation Schedule and Milestones

Milestone	2012	2013	2014	2015	2016	2017	2018
Establishment of priority Non-structural BMP programs		X					
319 Non-point Source Grant Application for Structural and Non-structural BMPs	X	X	X	X	X	X	X
Antelope Park Sub-basin Improvements		X	X	X	X	X	
Begin Update of Basin Plan					X		
Phase Two Implementation Begins							X
NDEQ Statewide Basin Rotation Monitoring Network				X			
Monitoring and Evaluation		X	X	X	X	X	X

10.8. Monitoring Milestones and Schedule

Water quality monitoring will be completed at the confluence with Salt Creek (AC-9) in order to assess in-stream water quality relative to established water quality standards. This location will also serve as the point of compliance for the TMDL. In-stream sampling to support establishment of the TMDL for Antelope Creek, completed in 2007, has been conducted by NDEQ on a rotating statewide basin schedule; the last event occurred in 2009. According to NDEQ, the next scheduled monitoring that includes Antelope Creek will be weekly starting May to September in 2015. This site, referred to as AC-9 in this plan, is the only site directly relevant to potential changes in the TMDL. The City could consider partnering with other local agencies, such as the LPSNRD or University of Nebraska–Lincoln (UNL), to sample Antelope Creek more often. This information could serve multiple purposes, such as research on BMPs or evaluation of the success of BMPs.

In order for water quality data collected by a third-party entity to be used to update the TMDL, approval must first be granted by NDEQ. This could be completed through a quality assurance performance plan approving procedures of the third party entity prior to data collection. Information collected by third party agencies that is not approved by NDEQ could still be utilized for purposes of watershed planning, monitoring, and evaluation by the City and LPSNRD.

10.8.1 Sampling at AC-9 – Confluence with Salt Creek

Sampling at the confluence to Salt Creek will provide an outlook on the *E. coli* reduction progress as projects and programs are implemented. This location is the ultimate compliance location for water quality sampling and the TMDL. This data can be compared to the water quality sampling completed in the past as well as information in relation to the TMDL. AC-9 provides a picture of the whole Antelope Creek watershed with most sub-basin contributions (see Figure 10-2: Antelope Creek Park Sub-Basin Phase One). Sampling at AC-9 will not allow the City and LPSNRD to understand pollutant load reductions from an individual BMP or load reductions from any individual sub-basin. Sampling at the confluence will determine the total percent reduction basin-wide and if the TMDL is being met. Data collection through the recreational season, May to September, will provide comparable data in relation to the TMDL.

Water quality indicators to be sampled in the future should include *E. coli*, TSS, and Total Phosphorus, in addition to general water quality parameters such as conductivity, pH, temperature, and flow. These physical parameters will be helpful in understanding the overall Antelope Creek water quality. The use of analysis of tracer analytes in water samples taken at AC-9 for the purpose of screening illicit discharges is not recommended. Below are recommendations for sampling Antelope Creek at the confluence of Salt Creek:

- Perform weekly sampling for *E. coli* from May 1 to September 30th to calculate the geometric mean, and evaluate whether the TMDL is being met.

- Perform monthly sampling for TSS, Total Phosphorus, conductivity, pH, temperature, and flow during the same time period.
- The City and/or LPSNRD should consider coordination with NDEQ to arrange sampling at AC-9 on an annual basis in order to evaluate progress over the entire watershed.

10.8.2 Sub-basin Sampling

Sampling at the outlet(s) of each sub-basin will not provide information relevant to achieving goals listed in the TMDL due to the key location being at the confluence with Salt Creek. However, monitoring of individual sub-basins or at each individual structural BMP will provide information on percent removals of a given BMP. This information can be used to analyze the design of the BMP and can be compared to the anticipated performance based upon WinSLAMM data to proof the application. Documenting outflow from the sub-basin is critical to determining potential contaminant reductions due to volume reduction of runoff; which should directly reduce the loading of pollutants to Antelope Creek.

Picture 39: EA staff conducts sediment sampling

The following is a recommended water sampling protocol for sampling each sub-basin during its active Phase:

- Sample up to six events that produce measurable runoff from the sub-basin. Selected runoff events should be during rainfall events with less than 1.25 inches of rain.
- Sample between May and September.
- Each event should be sampled for *E. coli,* TSS and phosphorous. Other parameters such as conductivity, pH, temperature, and flow should also be documented.

Establishment of the sampling locations for each sub basin is dependent upon the characteristics of the sub-basin, number of projects being completed, and the number of outlets to Antelope Creek. Specific sampling locations have not been identified and would need to be located prior to monitoring activity. In most sub-basins, several outlets to Antelope Creek exist. Overall, measurement of progress towards meeting goals in the TMDL should be gathered at AC-9.

10.9. Evaluative Criteria

The basis for identifying progress towards program and project success will be measured through several evaluation criteria. Criteria have been split into short term and long term, and include evaluation of structural and non-structural BMPs. The evaluation criteria include data collection through water quality monitoring and record keeping as well as gathering information from property owners and residents.

Short-term information will allow the City and LPSNRD to establish a baseline for existing in-stream conditions in Antelope Creek, and present behaviors of property owners and residents. In-stream monitoring on an annual or bi-annual basis will allow the City and LPSNRD to understand pre-project physical and chemical conditions of the creek.

It is important to gather information from property owners and residents across the entire Antelope Creek watershed, with an emphasis on the Antelope Park sub-basin over the first 5-year period. This could be completed through online and phone surveys, request for information to be submitted to a website, and information gathered at neighborhood association meetings.

Over the long-term, information will be collected on how property owners change their everyday habits to improve the health of their watershed. This information can be collected in a similar fashion. Efforts should again be concentrated into the Antelope Park sub-basin.

To evaluate progress of structural BMPs, the City will keep records of each improvement, the water quality benefits, and other details such as how well native vegetation was established, how well the BMP appeared to be functioning, and pictures of each BMP.

A separate website specific to implementation of the Basin Plan is recommended. Creating an opportunity to view ongoing implementation of projects in the Antelope Creek watershed will allow the public to provide feedback, learn about the benefits of stormwater BMPs, and know what is being planned in the future in the Antelope Creek watershed. This website could also feature locations of known stormwater BMPs in Antelope Creek, how many rain

gardens or rain barrels have been installed, allow residents to post pictures of their projects, and quantify the number of improvements made by residents and property owners (*i.e.,* number of disconnections, rain gardens, rain barrels, etc.).

Water quality monitoring data gathered at AC-9 will be used to evaluate progress towards reducing *E. coli* and other pollutants in Antelope Creek. The Section 303(d) listing for bacteria in Antelope Creek was based on data collection from AC-9. This site will also provide the basis for evaluating progress towards reducing *E. coli* and other pollutants in Antelope Creek. Data collected annually will be assessed bi-annually by NDEQ to evaluate beneficial use support and water quality trends.

10.10. Resource Needs

Cost estimating structural and non-structural BMPs for an urbanized watershed with non-point sources is a highly challenging endeavor, particularly with *E. coli* bacteria as the constituent of concern. Promoting a high level of participation by residents and property owners throughout the watershed through non-structural programs is expected to decrease the cost significantly. Findings of this Basin Plan show that non-structural BMPs will likely have the greatest impact in reducing *E. coli*, TSS, and nutrients throughout the watershed using source controls.

The cost estimates provided in WinSLAMM do not take into account the percentage of reduction anticipated to be achieved over the life of the Plan by less expensive non-structural BMPs. The summary provided in the section below provides a forecast of potential resources necessary to achieve pollution reduction of *E. coli* using a larger balance of structural BMPs then currently listed in the implementation plan.

Evaluation of BMPs implemented as part of Phase One will occur after the first 5 years of the Basin Plan. As part of an adaptive management strategy, these results will determine the next level of effort and resources necessary to continue working towards the plan goal. In the event additional structural BMPs are necessary to reach plan goals, a scenario has been provided that will allow the City and LPSNRD to forecast additional resources that may be necessary. WinSLAMM identifies curb-cut biofilters as the most effective structural BMP of those evaluated in removing *E. coli* from stormwater runoff, therefore curb-cut biofilters are included in this scenario.

The following assumptions have been made to create a scenario to assist with long term planning and resource needs for the life of the Plan:

- Antelope Park priority sub-basin would need an additional 60% reduction in *E. coli* concentration after Phase One.
- Further reduction could not be achieved from non-structural BMPs, such as public education and outreach within the Antelope Park sub-basin.
- Additional reductions needed would be achieved through construction of additional structural BMPs.
- To estimate additional structural costs and project Basin Plan resource needs, 40% curb-cut biofilters were assumed to be constructed within the Antelope Park priority sub-basin as part of future phases.
- Using WinSLAMM, 40% curb-cut biofilters in residential land use areas are estimated to reduce the amount of *E. coli* by approximately 57%.
- Continued basin-wide non-structural programs are expected to reduce *E. coli* throughout the Antelope Creek watershed by 16% beyond Phase One.
- Through the structural BMPs installed in the Antelope Park sub-basin in Phase One (1% *E. coli* reduction), and the additional curb-cut biofilters considered for installation in this sub-basin as part of this scenario (7% *E. coli* reduction), a total additional reduction in *E. coli* of 8% at AC-9 is anticipated.
- With Phase One and additional structural BMPs combined, an estimated reduction of 24% at AC-9 is estimated.

With seven sub-basins remaining, each would need an average 10% reduction to meet the TMDL goal. Since the basin-wide non-structural programs are assumed to be already implemented at this stage, the additional 69% reduction in *E. coli* is assumed to come from other structural BMPs. Multiplying the cost of implementing Phase One and the additional structural practices necessary by seven, excluding the onetime cost of implementing the basin-wide non-structural BMPs, will give an idea of the total cost of implementing this strategy over the next 40 years and reaching the TMDL *E. coli* concentration goal at AC-9. The estimated *E. coli* reductions are summarized in Table 10-6.

Table 10-6. Basin Plan Total Cost Estimates

	Implementation Cost	*E. coli* reduction In Antelope Park sub-basin(s)	*E. coli* reduction At AC09
Phase One (2012-2017)			
Basin wide non-structural	$600,000	25%	16%
Antelope Park sub-basin 1(structural	$1.1 million	6%	1%
Sub-totals	**$1.7 million**	**31%**	**17%**
Phase 2 (2017-2021)	$6.0 million	57%	7%
Phase One and Two Totals	**$7.7 million**	**88%**	**24%**
Phase 3-8			Each will be 10%
Total Estimated Cost of remaining Sub-basins (Sub-basin 1 X (7), excluding basin-wide non-structural)	$49.7 million		65-70%
Estimated Grand Total	**$57 million**	**88%**	**89-94%**

Funding

Funding availability will be a primary driver in the implementation process. This Basin Plan has been written in a manner to be consistent with requirements of EPA's Nonpoint Source Management Program funding provided to NDEQ on an annual basis. Several other potential funding sources are available and are summarized below:

City of Lincoln, Nebraska

1) Public Works and Utilities Department Storm Water Bond Funding – provides funding for design and construction of urban drainage projects, stream rehabilitation and waterway work, comprehensive watershed master plan projects, water quality projects, and basin master planning.

Lower Platte South Natural Resources District

1) Water Quality BMP Cost-Share Program – assist land owners with the implementation of BMPs aimed at improving the quality of surface waters within the District. This program could support programs created through this Basin Plan.
2) Annual Inter-local Agreement with the City – provides cost share to support planned watershed improvement activities as a co-sponsor with the City of Lincoln. Potentially support implementation of demonstration projects and programs to improve water quality in Antelope Creek.

US Environmental Protection Agency (EPA)

1) Section 319 Nonpoint Source Management Program – provides financial assistance for the prevention and abatement of nonpoint source water pollution. Potentially support implementation of projects and programs in the Basin plan including BMPs.
2) Assessment and Watershed Protection Program Grants – provide resources to stakeholders to develop and implement effective, comprehensive programs for watershed protection, restoration, and management.
3) Water Quality Cooperative Agreements – provides grants to state water pollution control agencies including stormwater control.

USDA Natural Resources Conservation Service (NRCS)

1) Landscape Planning – supports watershed rehabilitation, planning, and operations.
2) NRCS Conservation Programs – supports programs that reduce soil erosion and improve water quality.

Nebraska Environmental Trust

1) Environmental Project Fund – provides local governments and organizations funding to conserve, enhance, and restore the natural environment. This funding source possibly will provide assistance to implement BMPs and educational components of water quality projects.

Technical Assistance/Agency Coordination

Implementation of the management strategies and recommendations in the Basin Plan will be a primary responsibility of the City of Lincoln Public Works and Utilities Department, Watershed management. Efforts will be coordinated with the Lower Platte South Natural Resources District, University of Nebraska-Lincoln, NDEQ, and other City Departments including Planning, Parks and Recreation, and Engineering Services. A summary of coordinated responsibilities is listed below:

- **Lower Platte South LPSNRD** – Co-sponsor of projects and programs listed in this plan, providing funding assistance and cost-share for BMPs. Assist in evaluation and monitoring the performance of BMPs.
- **City of Lincoln Planning Department** – Incorporation of water quality elements and city-wide recommendations into the 2040 Comprehensive Plan.
- **City of Lincoln Parks and Recreation Department** – Coordination in implementation of non-structural and structural activities onto parks property. Assistance in public education and outreach through installation of signage and informative panels on park property.
- **City of Lincoln Engineering Services** – Consideration of policy changes, establishment of bio-swales, coordination with activities in the public right-of-way.
- **University of Nebraska-Lincoln** – Incorporation of stormwater source control activities into planned construction and redevelopment activities on UNL's City Campus and Innovation Campus. Provide opportunities for studies on BMP effectiveness, water quality monitoring, wildlife control studies, and other research or educational efforts.
- **NDEQ** – Technical assistance with monitoring, funding assistance, and public information and education activities.

SECTION 11 - GLOSSARY OF TERMS AND REFERENCES

Glossary of Terms

The following terms and acronyms are used throughout the report. This glossary is not intended to provide regulatory or legal definitions of terms. Instead, it is intended to provide users of this Basin Plan with a basic understanding of terms used.

303(d) List— Section 303(d) of the federal Clean Water Act requires states to list those waterbodies that are not attaining water quality standards, including designated uses, and identify relative priorities among the impaired waterbodies. Once a stream is listed on the state 303(d) list, a total Maximum Daily Load (TMDL) is typically required to assign allowable pollutant loads to various sources to enable the waterbody to attain designated uses in the future.

Base Flow— In a perennial stream, the low flow discharge attributable to groundwater flow.

Basin— Basin is used interchangeably with watershed in this Basin Plan

Buffer zone–A designated transitional area around a stream, lake, or wetland left in a natural, usually vegetated state so as to protect the waterbody from runoff pollution. Development is often restricted or prohibited in a buffer zone.

BMP— Best management practice, a structural or non-structural device designed to treat runoff in order to mitigate flooding, reduce pollution, and provide other amenities.

Category 5– Waterbodies where one or more beneficial uses are determined to be impaired by one or more pollutants and all of the TMDLs have not been developed. Category 5 waters constitute the Section 303(d) list subject to EPA approval/disapproval.

cfs— Cubic feet per second, a unit of measurement for labeling flow of water.

CIP— Capital Improvement Program.

Clean Water Act— The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1977. Public law 92-500; 33 U.S.C. 1251 et seq. The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. (www.epa.gov)

Contours— Lines of equal elevation that represent the land surface.

Conveyance system— Natural channels and manmade structures that convey stormwater downstream.

Directly Connected Impervious Area (DCIA) — The impervious portion of a site that drains directly to the storm drainage system.

Dry Weather Flows— Flows from municipal storm drainage systems that are not due to rain or snow-generated urban runoff.

Floodplain—The area of land adjacent to rivers and streams, that is subject to recurring flooding.

ft/sec— Feet per second, a unit of measurement for labeling velocity of water.

ft^2— Square foot or square feet, a unit of measurement for labeling area.

ft^3— Cubic foot or cubic feet, a unit of measurement for labeling volume.

Geomorphic— Geomorphic processes are the primary mechanisms that produce these land forms, including drainage patterns, streams, floodplains, and other watershed features.

Geographical Information System (GIS) — A database of digital information and data on land-use, land cover, ecological characteristics, and other geographic attributes that can be overlaid, statistically analyzed, mathematically manipulated, and graphically displayed using maps, charts, and graphs.

GPS— Global positioning system.

Hydraulic analysis—The study of stormwater flow through the conveyance system that includes underground pipelines, culverts, improved open channels, and natural creeks.

Hydrology analysis—The study of the occurrence, distribution, movement, and properties of waters of the earth and their environmental relations.

Illicit connections—The illegal and/or unauthorized connections that result in untreated wastewater discharges into storm drainage systems and receiving waters.

Illicit discharge— Any discharge to a municipal separate storm drainage system that is not composed entirely of stormwater, except for discharges allowed under a NPDES permit or waters used for certain emergency situations.

Impervious—The characteristic of a material that prevents the infiltration or passage of liquid through it. This may apply to roads, streets, parking lots, rooftops, and sidewalks.

Infiltration— The percolation of water from the land surface into the ground.

lf— Linear foot or linear feet, a unit of measurement for labeling length.

LPSNRD— Lower Platte South Natural Resources District

Municipal Separate Storm Sewer System (MS4)— A publicly owned conveyance or system of conveyances that discharges to water of the U.S. and is designed or used for collecting or conveying stormwater, is not a combined sewer, and is not part of a publicly owned treatment works (POTW).

MS4 Permit— A state or federal stormwater discharge permit to regulate discharges from municipal separate storm sewers (MS4s) for compliance with Clean Water Act regulations.

NDEQ— Nebraska Department of Environmental Quality

NIC— Nebraska Innovation Campus

Non-Point Source Pollution— Pollution that occurs when rainwater, snowmelt, or irrigation transports pollutants from diffuse sources across land surfaces into Waterbodies. Non-point source pollution is contrasted with point source pollution in that it is not discharged from single discharge points such as storm drain systems and wastewater treatment plants.

Non-Structural BMPs— Stormwater BMPs that focus on management of pollutants at their source by minimizing exposure to runoff, rather than treating runoff in constructed facilities. Non-structural BMPs are also referred to as source controls in this Basin Plan.

NPDES—The National Pollutant Discharge Elimination System, established by Section 402 of the Clean Water Act, is a federally mandated program used for regulating point source and stormwater discharges.

Outfall—The point where water flows from a conduit, stream, or drain.

Point Source Pollution— Pollutants from a single, indefinable source such as a factory, refinery, or place of business.

Pollutant Load— The mass of pollutants carried in runoff, calculated based on flow volume multiplied by pollutant concentration. Pollutant loading has units of mass and is calculated over specific timescales such as day, month, or year.

QMRA— Quantitative Microbial Risk Assessment.

RCP— Reinforced concrete pipe.

Retrofit— The creation or modification of a stormwater management practice, usually in a developed area, that improves or combines treatment with existing stormwater infrastructure.

Riparian Vegetation— Woody vegetation that is characteristic of an area bordering a stream or river.

Runoff—The portion of precipitation that is not absorbed by soil but discharged from a drainage area.

RV— Runoff volume coefficient.

SAR— Sodium Adsorption Ratio.

Source Controls— A variety of practices implemented to minimize pollutant transport in runoff by controlling pollutants where they originate and/or accumulate. Representative source controls include good housekeeping measures, landscape management practices, pet waste controls, public education regarding household hazardous waste, covering outdoor storage areas, etc.

Structural BMPs— Engineered structures constructed to provide temporary storage and treatment of stormwater runoff.

Sub-Basin— A division within a basin.

TDS— Total dissolved solids.

Total Maximum Daily Load (TMDL)— A calculation of the total loading (quantity) of a pollutant that a designated waterbody can carry and still meet numeric and narrative water quality standards. Section 303(d) of the federal Clean Water Act requires states to identify waterbodies that do not meet federal water quality standards and establish TMDLs that result in attainment of stream standards.

Treatment Train— BMPs that work together in series to provide stormwater quality treatment.

TSS— Total suspended solids.

UNL— University of Nebraska at Lincoln.

USEPA— United States Environmental Protection Agency.

Watershed— A region of land that drains to a river, creek, or body of water.

Water Quality Control Volume (WQCV) — The quantity of stormwater runoff that is treated. This volume is equivalent to the runoff from a designated storm percentile of the most frequently occurring storms. This volume is encouraged to be fully captured and treated, while larger events are partially treated.

WinSLAMM— Source Loading and Management Model for Windows.

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Appendix A - Best Management Practices

OVERVIEW

This appendix briefly discusses the different BMPs that can be utilized once a site has been selected. These descriptions are not intended as design guidance and are limited to basic descriptions and selection considerations. For additional information on design criteria, design considerations for safety and maintenance, and construction-phase considerations, the appropriate storm drainage design criteria manual should be consulted. Possible sources include the City of Lincoln Drainage Criteria Manual (Revised in May 2004) and the Urban Storm Drainage Criteria Manual, Volume 3 (www.udfcd.org). The Urban Drainage and Flood Control District (UDFCD) has established design criteria, procedures, and details for a number of BMPs providing treatment of post-construction urban runoff. Information contained in this appendix has been adapted from the UDFCD (updated November 2010) prepared by the Urban Drainage and Flood Control District, Denver. Colorado.

BMPs provide treatment through a variety of hydrologic, physical, biological, and chemical processes. The functions provided by BMPs are summarized into three main functions: volume reduction, water quality capture volume (WQCV) capture, and WQCV including flood control. The WQCV represents the runoff volume from frequent storm events. Volume reduction is generally achieved by the slow release of stormwater runoff, encouraging infiltration, plant uptake and evapotranspiration. BMPs can be sized to capture and slowly release the water quality capture volume (WQCV). This size allows the BMP to treat and infiltrate stormwater runoff. Flood control can be incorporated by increasing the size of the BMP to capture more stormwater runoff. Ideally, site designs will include a variety of source control and treatment BMPs combined in a "treatment train" that controls pollutants at their sources, reduces runoff volumes, and treats pollutants in runoff. The BMPs discussed in this appendix are listed below:

- Grass Buffer
- Grass Swale
- Bioretention (Rain Garden)
- Green Roof
- Extended Detention Basin
- Retention Pond
- Sand Filter Basin
- Constructed Wetland Pond
- Constructed Wetland Channel
- Permeable Pavement Systems
- Underground Practices

Each BMP includes a basic description, identifies site selection factors, as well as general benefits and limitations. A table is also included for each that summarizes their function, typical effectiveness for targeted pollutants, and other considerations.

GRASS BUFFER

DESCRIPTION

Grass buffers are densely vegetated strips of grass designed to accept sheet flow from upgradient development. Properly designed grass buffers play a key role by enabling infiltration, slowing runoff, and providing filtration (straining) of sediment. Buffers differ from swales in that they are designed to accommodate overland sheet flow rather than concentrated or channelized flow. Over time, sediment must be removed, and replanting in areas might be needed.

Grass buffer located at 25th and Randolph St.

SITE SELECTION

Grass buffers can be incorporated into a wide range of development settings. Runoff can be directly accepted from a parking lot, roadway, or the roof of a structure, provided the flow is distributed in a uniform manner over the width of the buffer. This can be achieved through the use of flush curbs, slotted curbs, or level spreaders where needed. Grass buffers are often used in conjunction with grass swales. They are well suited for use in riparian zones to assist in stabilizing channel banks adjacent to major drainage ways and receiving waters. These areas can also sometimes serve multiple functions such as recreation. Hydrologic Soil Groups A and B provide the best infiltration capacity for grass buffers. For Type C and D soils, buffers still serve to provide filtration (straining) although infiltration rates are lower.

BENEFITS

- Filters (strains) sediment and trash,
- Reduces directly connected impervious area,
- Can easily be incorporated into a treatment train approach,
- Provides green space available for multiple uses including recreation and snow storage,
- Straightforward maintenance requirements when the buffer is protected from vehicular traffic.

LIMITATIONS

- A thick vegetative cover is needed for grass buffers to be effective,
- Nutrient removal in grass buffers is typically low,
- High loadings of coarse solids, trash, and debris require pretreatment,
- Space for grass buffers may not be available in high intensity urban areas (lot-line-to-lot-line).
- Tend to accumulate sediment if not properly maintained.

Grass Swale	
Functions	
LID/Volume Red.	Yes
WQCV Capture	No
WQCV+Flood Control	No
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Good
Nutrients	Moderate
Total Metals	Good
Bacteria	Poor
Other Considerations	
Life-cycle Costs	Low

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

GRASS SWALE

DESCRIPTION

Grassed swale located south of 60th and Normal Blvd

Grass swales are densely vegetated trapezoidal or triangular channels with low-pitched side slopes designed to convey runoff slowly. Grass swales have low longitudinal slopes and broad cross-sections that convey flow in a slow and shallow manner, thereby facilitating sedimentation and filtering (straining) while limiting erosion. Berms or check dams may be incorporated into grass swales to reduce velocities and encourage settling and infiltration. When using berms, an underdrain system should be provided. Grass swales are an integral part of the LID concept and may be used as an alternative to a curb and gutter system.

SITE SELECTION

Grass swales are well suited for sites with low to moderate slopes. Drop structures or other features designed to provide the same function as a drop structure (e.g., a driveway with a stabilized grade differential at the downstream end) can be integrated into the design to enable use of this BMP at a broader range of site conditions. Grass swales provide conveyance so they can also be used to replace curb and gutter systems making them well suited for roadway projects.

BENEFITS

- Removal of sediment and associated constituents through filtering (straining),
- Reduces length of storm drainage pipes in the upper portions of a watershed,
- Provides a less expensive and more attractive conveyance element than a typical pipe system,
- Reduces directly connected impervious area and can help reduce runoff volumes.

LIMITATIONS

- Requires more area than traditional storm drainage systems,
- Underdrains are recommended for slopes under 2%,
- Erosion problems may occur if not designed and constructed properly.

Grass Swale	
Functions	
LID/Volume Red.	Yes
WQCV Capture	No
WQCV+Flood Control	No
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Good
Nutrients	Moderate
Total Metals	Good
Bacteria	Poor
Other Considerations	
Life-cycle Costs	Low

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

BIORETENTION (RAIN GARDEN)

DESCRIPTION

A BMP that utilizes bioretention is an engineered, depressed landscape area designed to capture and filter or infiltrate the WQCV. In an effort to be consistent with terms most prevalent in the stormwater industry, this document generally refers to the treatment process as *bioretention* and to the BMP as a *rain garden.*

Use of this infiltrating BMP near a structure requires evaluating the suitability of soils, identifying potential impacts, and establishing minimum distances between the BMP and structures.

Rain garden located at 27th and F parking lot

SITE SELECTION

Bioretention can be provided in a variety of areas within new developments, or as a retrofit within an existing site. This BMP allows the WQCV to be treated within areas designated for landscape. In this way, it is an excellent alternative to extended detention basins for small sites. A typical rain garden serves a tributary area of one impervious acre or less, although they can be designed for larger tributary areas. Multiple installations can be used within larger sites. Rain gardens should not be used when a base flow is anticipated. They are typically small and installed in locations such as:

- Parking lot islands,
- Street medians,
- Landscape areas between the road and a detached walk,
- Areas that collect roof drains.

Bioretention requires a stable watershed. Retrofit applications are typically successful for this reason. When the watershed includes phased construction, sparsely vegetated areas, or steep slopes in sandy soils, consider another BMP or provide pretreatment before runoff from these areas reaches the rain garden. The surface of the rain garden should be flat. For this reason, rain gardens can be more difficult to incorporate into steeply sloping terrain; however, terraced applications of these facilities have been successful.

Bioretention (Rain Garden)	
Functions	
LID/Volume Red.	Yes
WQCV Capture	Yes
WQCV+Flood Control	Yes
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good[1]
Nutrients	Moderate
Total Metals	Good
Bacteria	Moderate
Other Considerations	
Life-cycle Costs[4]	Moderate

[1] Not recommended for watersheds with high sediment yields (unless pretreatment is provided).

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

When bioretention (and other BMPs used for infiltration) are located adjacent to buildings or pavement areas, protective measures should be implemented to avoid adverse impacts to these structures. Oversaturated subgrade soil underlying a structure can cause the structure to settle or result in moisture-related problems. Wetting of expansive soils or bedrock can cause swelling, resulting in structural movements. A geotechnical analysis may be needed to evaluate the potential impact of the BMP on adjacent structures based on an evaluation of the subgrade soil, groundwater, and bedrock conditions at the site. Additional minimum requirements include:

- Rain garden should have an underdrain system in locations where subgrade soils do not allow infiltration,
- An underdrain system should be used to divert water away from the structure where infiltration can adversely impact adjacent structures,

- In locations where potentially expansive soils or bedrock exist, placement of a rain garden adjacent to structures and pavement should only be considered if the BMP includes an underdrain designed to divert water away from the structure and is lined with an essentially impermeable geomembrane liner designed to restrict seepage.

BENEFITS

- Bioretention uses multiple treatment processes to remove pollutants, including sedimentation, filtering, adsorption, evapotranspiration, and biological uptake of constituents,
- Volumetric stormwater treatment is provided within portions of a site that are already reserved for landscaping,
- There is a potential reduction of irrigation requirements by taking advantage of site runoff.

LIMITATIONS

- Additional design and construction steps are required for placement of any ponding or infiltration area near or upgradient from a building foundation and/or when expansive (low to high swell) soils exist,
- In developing or otherwise erosive watersheds, high sediment loads can require frequent sediment removal from the rain garden.

GREEN ROOF

DESCRIPTION

Green roofs could be defined as "contained" vegetated living systems on top of buildings.

Green roof owned by the Arbor Day Foundation located above Qdoba's downtown Lincoln

There are two main types of green roofs: extensive and intensive. Extensive green roofs are shallow, usually with 4 inches of substrate, and do not typically support a large diversity of plant species because of root zone limitations. Intensive green roofs are more like rooftop gardens with deep substrate (from 4 inches to several feet) and a wide variety of plants. Most buildings are not designed to withstand the additional weight loading for intensive roofs. For this reason, they are typically limited to new construction. Extensive green roofs are shallower and generally much better suited to the structural capabilities of existing buildings and therefore, are installed more often. Because of this, extensive green roofs are the main focus.

The design of a green roof may involve many disciplines in addition to stormwater engineers, including structural engineers, architects, landscape architects, horticulturists, and others. This description is intended only to provide an overview of green roof information relative to stormwater quality and quantity management.

As LID strategies have been emphasized increasingly throughout the U.S., green roofs have been implemented in some parts of the country, most frequently in areas with humid climates and relatively high annual rainfall. Although there are some green roofs in Lincoln (Pioneers Park Nature Center, Assurity office building, The Arbor Day Foundation on P Street), they have not been widely installed, and research is in progress regarding the best design approach and plant list for Lincoln's climate. Plant selection, growing medium, and supplemental irrigation requirements are generally key considerations when designing a green roof. It should be noted that the U.S. Green Building Council LEED rating system recognizes a second kind of green roof that includes reflective, high albedo roof materials that are not designed for stormwater purposes.

Green Roof [5]	
Functions	
LID/Volume Red.	Yes
WQCV Capture	Yes
WQCV+Flood Control	No
Typical Effectiveness for Targeted Pollutants	
Sediment/Solids	Unknown
Nutrients	Unknown
Total Metals	Unknown
Bacteria	Unknown
Other Considerations	
Life-cycle Costs	Unknown

[5] Water quality data for green roofs are not yet robust enough to provide meaningful conclusions about pollutant removal. By reducing volume, green roofs have the de facto capability to reduce pollutant loads; however, on a concentration basis more data are needed to better define effectiveness.

SITE SELECTION

Green roofs can be installed on commercial or residential buildings as well as on underground structures such as parking garages. Green roofs may be particularly well suited for ultra urban areas where development is typically lot-line-to-lot-line and garden space is at a premium. Green roofs are particularly valuable when their use extends to a place of enjoyment for those that inhabit the building. The Assurity Life building in Lincoln anticipates growing vegetables within their green roof plant selection for the building inhabitants.

For existing buildings, the structural integrity of the building must be verified prior to consideration of retrofitting the building with a green roof. For both existing and new construction, it is essential that the design team be multi-disciplinary. This team may include a structural engineer, stormwater engineer, architect, landscape architect, and horticulturist. It is recommended that all members of the design team be involved early in the process to ensure the building and site conditions are appropriate for green roof installation.

BENEFITS

- Reduces runoff rates and volumes,
- Reduces heat island effect in urban areas,
- May qualify for multiple LEED credits,
- May extend roof lifespan by reducing daily temperature fluctuations and providing shading from ultraviolet light,
- May provide energy savings from additional insulation & evapotranspirative cooling,
- Provides aesthetically pleasing open space in ultra urban areas.

LIMITATIONS

- Limited experience in Lincoln,
- Initial installation costs are greater than conventional roof (although lifecycle costs may be less),
- Supplemental irrigation may be required,
- Maintenance during vegetation establishment (first two years) may be significant.

EXTENDED DETENTION BASIN (EDB)

DESCRIPTION

An extended detention basin (EDB) is a sedimentation basin designed to detain stormwater for many hours after storm runoff ends. This BMP is similar to a detention basin used for flood control, however; the EDB uses a much smaller outlet that extends the emptying time of the more frequently occurring runoff events to facilitate pollutant removal. The EDB's 40-hour drain time for the water quality capture volume (WQCV) is recommended to remove a significant portion of total suspended solids (TSS). Soluble pollutant removal is enhanced by providing a small wetland marsh or "micropool" at the outlet to promote biological uptake. The basins are sometimes called "dry ponds" because they are designed not to have a significant permanent pool of water remaining between storm runoff events.

Extended detention basin photo from UDFCD Manual

An extended detention basin can also be designed to provide Full Spectrum Detention. In this case, the EDB is sized for 100-year peak reduction and the excess urban runoff volume (EURV) is used instead of the WQCV. The EURV is designed with a drain time of approximately 72 hours. Widespread use of Full Spectrum Detention is anticipated to reduce impacts on major drainage ways by reducing post-development peak discharges to better resemble pre-development peaks.

Extended Detention Basin	
Functions	
LID/Volume Red.	Somewhat
WQCV Capture	Yes
WQCV+Flood Control	Yes
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Good
Nutrients	Moderate
Total Metals	Moderate
Bacteria	Poor
Other Considerations	
Life-cycle Costs[4]	Moderate

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

SITE SELECTION

EDBs are well suited for watersheds of 5 to 640 impervious acres. Smaller watersheds can result in an orifice size small enough to increase the potential for clogging. Larger watersheds and watersheds with base flows can complicate the design and reduce the level of treatment provided. EBDs are also well suited where flood detention is incorporated into the same basin. The depth of groundwater should be investigated. Groundwater depth should be 2 or more feet below the bottom of the basin in order to keep this area dry and maintainable.

BENEFITS

- The relatively simple design can make EDBs less expensive to construct than other BMPs, especially for larger basins,
- Maintenance requirements are straightforward,
- The facility can be designed for multiple uses.

LIMITATIONS

- Ponding time and depths may generate safety concerns,
- Best suited for tributary areas of 5 impervious acres or more. EDBs are not recommended for sites less than 2 impervious acres.
- Although ponds do not require more total area compared to other BMPs, they typically require a relatively large continuous area.

SAND FILTER

Source: Platte River Recovery Implementation Program

DESCRIPTION

A sand filter is a filtering or infiltrating BMP that consists of a surcharge zone underlain by a sand bed with an underdrain system (when necessary). During a storm, accumulated runoff collects in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to a nearby channel, swale, or storm drain system. It is similar to a BMP designed for bioretention in that it utilizes filtering, but differs in that it is not specifically designed for vegetative growth. For this reason, it can have a greater depth and be designed for a larger contributing area. A sand filter is also similar to an extended detention basin (EDB) in that it is a dry basin, which can be easily designed to include the flood control volume above the WQCV or EURV. However, a sand filter does not require a forebay or micropool because the solids that would be deposited in these components in an EDB will be retained on the surface of the sand bed in a sand filter. Sand filters can be vegetated with species that will tolerate both wet and dry conditions and occasional inundation. The rain garden growing media is recommended for sand filters where vegetation is desired. Sand filters can also be placed in a vault. Underground sand filters have additional requirements. See underground BMPs description for additional information.

Sand/Media Filter	
Functions	
LID/Volume Red.	Yes
WQCV Capture	Yes
WQCV+Flood Control	Yes
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good[1]
Nutrients	Good
Total Metals	Good
Bacteria	Moderate
Other Considerations	
Life-cycle Costs[4]	Moderate

[1] Not recommended for watersheds with high sediment yields (unless pretreatment is provided).

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

SITE SELECTION

Sand filters require a stable watershed. When the watershed includes phased construction, sparsely vegetated areas, or steep slopes in sandy soils, consider another BMP or provide pretreatment before runoff from these areas reach the sand filter. When sand filters (and other BMPs used for infiltration) are located adjacent to buildings or pavement areas, protective measures should be implemented to avoid adverse impacts to these structures. Oversaturated subgrade soil underlying a structure can cause the structure to settle or result in moisture related problems. Wetting of expansive soils or bedrock can cause swelling, resulting in structural movements. The potential impact of the BMP on adjacent structures should be considered based on an evaluation of the subgrade soil, groundwater, and bedrock conditions at the site. Additional minimum

requirements include:

- An underdrain system should be used in locations where subgrade soils do not allow infiltration,
- An underdrain system should be used in locations where infiltration can adversely impact adjacent structures,

In locations where potentially expansive soils or bedrock exist, placement of a sand filter adjacent to structures and pavement should only be considered if the BMP is lined with an impermeable geomembrane liner designed to restrict seepage and includes an underdrain designed to divert water away from the structure.

BENEFITS

- Provide pollutant removal through settling and filtering,
- Reduces stormwater runoff by providing and area of increased infiltration,
- Recharges groundwater table.

LIMITATIONS

- This BMP may require frequent maintenance if a moderate to high level of silts and clays are allowed to flow into the facility,
- This BMP should not be located within 10 feet of a building foundation without an impermeable membrane. See Bioretention description for additional information,
- The sand filter should not be put into operation while construction or major landscaping activities are taking place in the watershed.

RETENTION POND

Pond within Wyuka Cemetery

DESCRIPTION

A retention pond, sometimes called a "wet pond," has a permanent pool of water with capacity above the permanent pool designed to capture and slowly release the WQCV over 12 hours. The permanent pool is replaced, in part, with stormwater during each runoff event so stormwater runoff mixes with the permanent pool water. This allows for a reduced residence time compared to that of the EDB. The 12- hour drain time helps to both better replicate pre-development flows for frequent events and reduce the potential for short circuiting treatment in smaller ponds. Retention ponds can be very effective in removing suspended solids, organic matter and metals through sedimentation, as well as removing soluble pollutants like dissolved metals and nutrients through biological processes. Retention ponds can also be designed to provide Full Spectrum Detention. Widespread use of full spectrum detention is anticipated to reduce impacts on major drainage ways by reducing post-development peak discharges to better resemble predevelopment peaks.

Retention	
Functions	
LID/Volume Red.	Somewhat
WQCV Capture	Yes
WQCV+Flood Control	Yes
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good
Nutrients	Moderate
Total Metals	Moderate
Bacteria	Moderate
Other Considerations	
Life-cycle Costs[4]	Moderate

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis is based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

SITE SELECTION

Retention ponds require groundwater or a dry-weather base flow if the permanent pool elevation is to be maintained year-round. The designer should consider the overall water budget to ensure that the base flow will exceed evaporation, evapotranspiration, and seepage losses (unless the pond is lined). High exfiltration rates can initially make it difficult to maintain a permanent pool in a new pond, but the bottom can eventually seal with fine sediment and become relatively impermeable over time. However, it is best to seal the bottom and the sides of a permanent pool if the pool is located on permeable soils and to leave the areas above the permanent pool unsealed to promote infiltration of the stormwater detained in the surcharge WQCV.

Studies show that retention ponds can cause an increase in temperature from influent to effluent. Retention ponds are discouraged upstream of receiving waters that are sensitive to

increases in temperature (e.g., fish spawning or hatchery areas).

Use caution when placing this BMP in a basin where development will not be completed for an extended period, or where the potential for a chemical spill is higher than typical. When these conditions exist, it is critical to provide adequate containment and/or pretreatment of flows. In developing watersheds, frequent maintenance of the forebay may be necessary.

BENEFITS

- Creates wildlife and aquatic habitat,
- Provides recreation, aesthetics, and open space opportunities,
- Can increase adjacent property values,
- Cost-effective BMP for larger tributary watersheds.

LIMITATIONS

- Safety concerns associated with open water,
- Requires physical supply of water,
- Sediment, floating litter, and algae blooms can be difficult to remove or control,
- Ponds can attract water fowl which can add to the nutrients and bacteria leaving the pond,
- Ponds increase water temperature.

CONSTRUCTED WETLAND POND

DESCRIPTION

Wetland located SW of 1st and Cornhusker

A constructed wetland pond is a shallow retention pond designed to permit the growth of wetland plants such as rushes, willows, and cattails. Constructed wetlands slow runoff and allow time for sedimentation, filtering, and biological uptake. Constructed wetlands ponds differ from "natural" wetlands, as they are artificial and are built to enhance stormwater quality. Do not use existing or natural wetlands to treat stormwater runoff. Stormwater should be treated prior to entering natural or existing wetlands and other environmentally sensitive areas. Allowing untreated stormwater to flow into existing wetlands will overload and degrade the quality of the wetland. Sometimes, small wetlands that exist along ephemeral drainage ways can be enlarged and incorporated into the constructed wetland system. Such actions, however, require the approval of federal and state regulators.

Regulations intended to protect natural wetlands recognize a separate classification of wetlands, constructed for water quality treatment. Such wetlands generally are not allowed to be used to mitigate the loss of natural wetlands but are allowed to be disturbed by maintenance activities. Therefore, the legal and regulatory status of maintaining a wetland constructed for the primary purpose of water quality enhancement is separate from the disturbance of a natural wetland. Nevertheless, any activity that disturbs a constructed wetland should be cleared through the U.S. Army Corps of Engineers to ensure it is covered by some form of an individual, general, or nationwide 404 permit.

Constructed Wetland Basin	
Functions	
LID/Volume Red.	Somewhat
WQCV Capture	Yes
WQCV+Flood Control	Yes
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good
Nutrients	Moderate
Total Metals	Good
Bacteria	Poor
Other Considerations	
Life-cycle Costs[4]	Moderate

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis is based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

SITE SELECTION

A constructed wetland pond requires a positive net influx of water to maintain vegetation and microorganisms. This can be supplied by groundwater or a perennial stream. An ephemeral stream will not provide adequate water to support this BMP. A constructed wetland pond is best used as a follow-up BMP in a watershed, although it can serve as a stand-alone facility. Algae blooms may be reduced when BMPs that are effective in removing nutrients are placed upstream. Constructed wetland ponds can also be designed for flood control in addition to capture and treatment of the WQCV. Although this BMP can provide an aesthetic onsite amenity, constructed wetland ponds designed to treat stormwater can also become large algae producers. The owner should maintain realistic expectations.

BENEFITS

- Creates wildlife and aquatic habitat,
- Provides open space opportunities,
- Cost effective BMP for larger tributary watersheds.

LIMITATIONS

- Requires physical supply of water to be impounded,
- Ponding depth can pose safety concerns requiring additional considerations for public safety during design and construction,
- Sediment, floating litter, and algae blooms can be difficult to remove or control,
- Ponds can attract water fowl which can add to the nutrients leaving the pond.

CONSTRUCTED WETLAND CHANNEL

DESCRIPTION

Constructed wetland channel

A constructed wetland channel is a conveyance BMP that is built, in part, to enhance stormwater quality. Constructed wetland channels use dense vegetation to slow down runoff and allow time for both biological uptake and settling of sediment. Constructed wetlands differ from natural wetlands, as they are artificial and are built to enhance stormwater quality. Do not use existing or natural wetlands to treat stormwater runoff. Stormwater should be treated prior to entering natural or existing wetlands and other environmentally sensitive areas. Allowing untreated stormwater to flow into existing wetlands will overload and degrade the quality of the wetland. Sometimes, small wetlands that exist along ephemeral drainage ways may be enlarged and incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators. Regulations intended to protect natural wetlands recognize a separate classification of wetlands constructed for water quality treatment. Such wetlands generally are not allowed to be used to mitigate the loss of natural wetlands but are allowed to be disturbed by maintenance activities. Therefore, the legal and regulatory status of maintaining a wetland constructed for the primary purpose of water quality enhancement is separate from the disturbance of a natural wetland. Nevertheless, any activity that disturbs a constructed wetland should be first cleared through the U.S. Army Corps of Engineers to ensure it is covered by some form of an individual, general, or nationwide 404 permit.

SITE SELECTION

Constructed wetland channels provide conveyance of stormwater similar to a grass swale; however, this BMP is appropriate when a base flow can be anticipated. A constructed wetland channel requires a net influx of water to maintain vegetation and microorganisms. This can be supplied by groundwater or a perennial stream. An ephemeral stream may not provide adequate water. In addition to water supply, loamy soils are needed in the wetland bottom to permit plants to take root. Wetland channels also require a near-zero longitudinal slope; drop structures can be used to create and maintain a flat grade.

A constructed wetland channel can be used in the following two ways:

- It can be established in a completely man-made channel providing conveyance and water quality enhancement,
- It can be located in a treatment train configuration, downstream of a stormwater detention facility (water quality and/or flood control) where a large portion of the sediment load has been removed upstream. This allows the wetland channel to benefit from the long duration of outlet flow and reduced maintenance requirements associated with pretreatment.

Constructed Wetland Channel	
Functions	
LID/Volume Red.	Somewhat
WQCV Capture	No
WQCV+Flood Control	No
Typical Effectiveness for Targeted Pollutants	
Sediment/Solids	Unknown
Nutrients	Unknown
Total Metals	Unknown
Bacteria	Moderate
Other Considerations	
Life-cycle Costs[4]	Moderate

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

BENEFITS

- Wetland channels provide natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal,
- Provides effective follow-up treatment to onsite and source control BMPs that rely upon settling of larger sediment particles.

LIMITATIONS

- Requires a continuous base flow,
- Without proper design, salts and other floatables can accumulate and be flushed out during larger storms,
- Safety concerns associated with open water.

PERMEABLE PAVEMENT SYSTEMS

DESCRIPTION

The term Permeable Pavement System, as used in this appendix, is a general term to describe any one of several pavements that allow movement of water into the layers below the pavement surface. Depending on the design, permeable pavements can be used to promote volume reduction, provide treatment and slow release of the WQCV, and reduce effective imperviousness. Use of permeable pavements is a common LID practice and is often used in combination with other BMPs to provide full treatment and slow release of the WQCV. Installations can be designed with an increased depth of aggregate material in order to provide storage for storm events in excess of the water quality (80th percentile) storm event.

Pervious pavement located at 27th and F

SITE SELECTION

This infiltrating BMP may require a geotechnical analysis when proposed near a structure.

Permeable pavement systems provide an alternative to conventional pavement in pedestrian areas and lower-speed vehicle areas. They are not appropriate where sediment-laden runoff could clog the system (e.g., near loose material storage areas).

This BMP is not appropriate when erosive conditions such as steep slopes and/or sparse vegetation drain to the permeable pavement. The sequence of construction is also important to preserve pavement infiltration. Construction of the pavement should take place only after construction in the watershed is complete. For sites where land uses or activities can cause infiltrating stormwater to contaminate groundwater, special design requirements are required to ensure no-infiltration from the pavement section.

Permeable pavements and other BMPs used for infiltration that are located adjacent to buildings, hardscape or conventional pavement areas can adversely impact those structures if protection measures are not provided. Wetting of subgrade soil underlying those structures can cause the structures to settle or result in other moisture-related problems. Wetting of potentially expansive soils or bedrock can cause those materials to swell, resulting in structure movements. In general, the potential impact of the BMP on adjacent structures should be considered based on an evaluation of the subgrade soil, groundwater, and bedrock conditions at the site. In addition, the following minimum requirements should be met:

- Pavement should be underlain by an underdrain system in locations where subgrade soils do not allow infiltration,
- The filter layer should be underlain by an underdrain system designed to divert water away from the structure where infiltration can adversely impact adjacent structures,

Permeable Pavement	
Functions	
LID/Volume Red.	Yes
WQCV	Yes
WQCV+Flood Control	Yes
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good[1]
Nutrients	Good
Total Metals	Good
Bacteria	Unknown
Other Considerations	
Life-cycle Costs[4]	High[2]

[1] Not recommended for watersheds with high sediment yields (unless pretreatment is provided).

[2] Does not consider the life cycle cost of the conventional pavement that it replaces.

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

- In locations where potentially expansive soils or bedrock exist, placement of permeable pavement adjacent to structures and conventional pavement should only be considered if the BMP is lined with an impermeable geomembrane liner designed to restrict seepage and includes an underdrain designed to divert water away from the structure.

BENEFITS

- Permeable pavement systems provide water quality treatment in an area that serves more than one purpose. The depth of the pavement system can also be increased to provide flood control,
- Permeable pavements can be used to reduce effective imperviousness or alleviate nuisance drainage problems,
- Permeable pavements benefit tree health by providing additional air and water to nearby roots,
- Permeable pavements are less likely to form ice on the surface than conventional pavements,
- Some permeable pavements can be used to achieve LEED credits.

LIMITATIONS

- Additional design and construction steps are required for placement of any ponding or infiltration area near or upgradient from a building foundation, particularly when potentially expansive soils exist,
- In developing or otherwise erosive watersheds, high sediment loads can clog the facility.

UNDERGROUND BMPS

DESCRIPTION

Underground stormwater BMPs include proprietary and non-proprietary devices installed below ground that provide stormwater quality treatment via sedimentation, screening, filtration, hydrodynamic separation, and other physical and chemical processes. Conceptually, underground BMPs can be categorized based on their fundamental treatment approach and dominant unit processes. Some underground BMPs combine multiple unit processes to act as a treatment train. While performance data for underground flood-control detention is lacking, this description provides general knowledge of the BMP for determining when the use of underground BMPs may be considered for water quality. When surface BMPs are found to be infeasible, underground BMPs may be the only available strategy for satisfying regulatory water quality requirements, especially in highly built-up urban areas where water quality measures must be implemented as a part of a retrofit to meet regulatory requirements. Underground BMPs should not be considered for standalone treatment when surface-based BMPs are practicable. For most areas of new urban development or significant redevelopment, it is feasible and desirable to provide the required WQCV on the surface. It is incumbent on the design engineer to demonstrate that surface-based BMPs such as permeable pavements, rain gardens, extended detention basins and others have been thoroughly evaluated and found to be infeasible before an underground system is proposed. Surface-based BMPs provide numerous environmental benefits including infiltration, evapotranspiration, groundwater recharge, aquatic habitat, mitigation of "heat island effect", and other benefits associated with vegetation for those that are planted.

Installation of underground BMP (Photo courtesy of Robert Pitt)

Underground BMPs	
Functions	
LID/Volume Red.	Variable
WQCV Capture	Variable
WQCV+Flood Control	Variable
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Variable
Nutrients	Variable
Total Metals	Variable
Bacteria	Variable
Other Considerations	
Life-cycle Costs[4]	Moderate

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

SITE SELECTION

The most common sites for underground BMPs are "ultra urban" environments with significant space constraints. These could include downtown lot-line-to-lot-line development projects, transportation corridors, or small (less than 0.5 acre) redevelopment sites in urban areas. Important site features that must be considered include the following:

- Depth to Groundwater: Due to the potentially large displacement caused by an underground vault, if there is seasonally high groundwater, buoyancy can be a problem. Vaults can be sealed to prevent infiltration of groundwater into the underground system and these systems can be anchored to resist uplift. If seasonally high groundwater is expected near the bottom of an underground system, the engineer should evaluate the potential for infiltration of groundwater and uplift forces and adjust the design accordingly,
- Proximity to Public Spaces: As material accumulates in an underground system, there is potential for anoxic conditions and associated odor problems,
- Gravity versus Pumped Discharge: The ability to drain to the

receiving storm drainage system via gravity is an important consideration. In some cases it may be necessary to pump discharge from an underground system; however, a gravity outfall is always recommended if possible and some communities may not allow pumped systems. If a pumped system must be used, there should be redundancy in pumps, as well as a contingency plan in the event that a power outage disables pumps. Additionally, maintenance of the pump system should be identified as part of the water quality BMP in the maintenance plan. When BMP maintenance records are required by the MS4 permit holder, pump system maintenance records should also be included,

- Access: Equipment must be able to access all portions of the underground BMP, typically at multiple locations, to perform maintenance. As the size of the underground system increases, so must the number of access points,
- Traffic Loading: Due to space constraints, in some situations, underground BMPs may be located in a right-of-way or other location where there may be traffic loadings. Many underground BMPs are or can be constructed for HS-20 traffic loading. Take additional measures when necessary to ensure that the BMP is designed for the anticipated loading,
- Potential for Flooding of Adjacent Structures or Property: For underground BMPs, it is important that the hydraulic grade line be analyzed to evaluate the potential for backwater in the storm drainage system. In addition, some types of underground BMPs, such as catch basin inserts, have the potential to clog and cause flooding if not frequently maintained.

BENEFITS

- Underground BMPs may be designed to provide pre-treatment and/or WQCV in space-constrained situations,
- There are many alternative configurations for proprietary and nonproprietary devices,
- Treatment train applications can be designed using different unit processes in series,
- Some underground BMPs, designed specifically for certain target pollutants, can be used to address a TMDL,
- Many underground devices can be effective for settling of particulates in stormwater runoff and gross solids removal.

LIMITATIONS

- Performance data for underground BMPs in the Lincoln area are limited,
- Maintenance is essential and must be performed frequently,
- Inspection and maintenance can require traffic control, confined space entry, or specialized equipment,
- Devices that do not provide WQCV do not qualify for standalone treatment,
- Gravity outfall may not be feasible in some situations,
- Many do not provide volume reduction benefits,
- Potential for anoxic conditions and odor problems,
- Not recommended when surface alternatives are feasible.

Appendix B - Public Information and Education

OVERVIEW

This appendix contains public participation material for Advisory Council meetings, and Public meetings. The four newsletters are also contained within this appendix. The material is summarized below:

Advisory Council Meetings

- September 14th, 2010
- February 10th, 2011
- November 29th, 2011

Open House Events

- September 30th, 2010
- December 1st, 2011

Newsletters

- Volume One, August 2010
- Volume Two, January 2011
- Volume Three, September 2011
- Volume Four, April 2012

Antelope Creek Watershed Basin Mangement Plan

Advisory Council Meeting #1

Lower Platte South NRD Office - 3125 Portia Street

Tuesday September 14th, 2010 – 5:30 to 7:30PM

1. **Introductions (15 minutes)**
   - Nebraska Open Meetings Act
   - Ed Kouma, PE – Project Manager, City of Lincoln, Public Works and Utilities, Watershed Management, Project Manager
   - Paul Zillig, Assistant Manager, Lower Platte South NRD
   - Dale Schlautman, PE – EA Engineering, Science, Technology
   - Advisory Council Members

2. **Introduction to the Antelope Creek Watershed Basin Management Plan (20 minutes)**
   - Ed Kouma - Continued basin planning efforts
   - Ed Kouma and Paul Zillig – explanation of project
   - Dale Schlautman – explanation of scope/project team

3. **Advisory Council (5 minutes)**
   - Roles and Responsibilities: *Council members will be asked to review elements of the process, ask questions, raise issues, and share information with one another, the public and the project team.*
   - Questions from the group

Break (15 minutes)

4. **Small Group Discussion on Concerns with Water Quality in Antelope Creek (30 minutes)**
   - Discussion in Two groups, 20 minutes
   - One advisory council representative from each group to summarize discussion, 10 minutes

5. **September 30, 2010 Open House Discussion (15 minutes)**
   - Format of meeting
   - Public perception of the project?
   - Discussion

6. **Next Steps/Questions (5 minutes)**
   - Advisory Council communication, Ed Kouma via email
   - Future meeting topics and discussion

7. **Contact Info**
   - Ed Kouma, PE, City of Lincoln, 402-441-7018, ekouma@lincoln.ne.gov
   - Dale Schlautman, PE, EA, 402-476-3766, dschlautman@eaest.com
   - Jonathan Mohr, AICP, JEO, 402-435-3080, jmohr@jeo.com
   - Website – www.lincoln.ne.gov (keyword: watershed), click on Master Plans, then Antelope Creek Watershed

Antelope Creek Watershed Basin Mangement Plan

Advisory Council Meeting #1 - Minutes

Lower Platte South NRD Office - 3125 Portia Street

Tuesday September 14th, 2010 – 5:30 to 7:30PM

Advisory Council:

NAME	TITLE	JURISDICTION
Bob Kuzelka	Retired Professor UNL	Near South Neighborhood
Mike Renken	Executive Director	Neighbor Works
Dale Hardy	Golf Administrator	City of Lincoln
Jennifer Dam, AICP	Assistant Director Campus Planning	UNL
Andrew Campbell	Landscape Department Manager	Campbell's Nursery
Karen Amen	Director	LPS NRD

Other Attendees:

NAME	TITLE	JURISDICTION
Mary Schroer	Non-point Source Pollution Coordinator	NDEQ
Sara Hartzell	Planner	City of Lincoln
Ed Kouma, PE	Engineer	City of Lincoln
Ben Higgins, PE	Senior Engineer	City of Lincoln
Paul Zillig	Assistant Manager	LPS NRD
Jonathan Mohr, AICP	Planner	JEO
Bob Todd	Scientist	EA
Dale Schlautman, PE	Engineer	EA
Jon Trombino, PE	Engineer	EA

When: September 14, 2010
Where: Lower Platte South NRD Office – 3125 Portia Street

MINUTES

The Antelope Creek Watershed Basin Management Plan Advisory Council met for the first time to discuss roles and responsibilities, introduce the project, discuss concerns with Antelope Creek, and provide the Core Work Group with a public perception of the project. Jonathan Mohr facilitated the meeting. Below is a summary of notes, questions, and discussion.

1. Introductions – in addition to the Advisory Council members, members of the Core Work Group were introduced.
2. Roles and responsibilities – Council members will be asked to review elements of the process, ask questions, raise issues, and share information with one another, the public, and the project team.

3. Kouma and Zillig provided an overview of the project in relation to other planning efforts.
4. Schlautman explained the project tasks using a power point presentation.
5. Kuzelka asked if the upper portion of the watershed has been covered by a similar plan. Kouma described that a separate effort was undertaken during rehabilitation of Holmes Lake, but nothing like the detail being address as part of this Basin Plan.
6. Kuzelka asked about the new stream area, how it will be a high public use area and could become an exposure area. The group discussed the importance of ensuring water in the Creek is safe for the expanded recreational opportunities.
7. If Antelope Creek is not meeting Total Maximum Daily Load (TMDL) now, will we be sampling all the areas including tributaries to determine sources? Yes – sampling will be conducted throughout the Basin to more accurately pin point potential contaminate sources.
8. Campbell inquired about existing pipes discharging into the Creek from properties that are 'grandfathered' or allowed under some program in the past that may now not be authorized.
9. Kuzelka recognized industrial sites in the area, are we going to be looking at historical land use data? –e.g. Lincoln poultry may have had industrial discharges and there may be contaminants still flowing or leaving the site from past use. Higgins explained what level of data would be gathered for the Basin Plan, and that they are not getting into soil sampling or similar methods to collect data. Hardy mentioned he has watched this area and has not seen any discharges from the old Lincoln Poultry area.
10. Dam asked about a concern with the Randolph street industrial area, a lot has changed there near the old Coke-Cola Plant.
11. Kuzelka asked about the old Cushman plant. The University has it now but that site could be an area where industrial activities left issues.
12. Schlautman explained about base line sampling, primarily based on evaluation of the TMDL, but will do some additional sampling to track down sources of the E. coli and ammonia as we work our way through the Antelope Creek watershed.
13. Kuzelka asked if the Creek should be posted now to warn the public since it does not meet the TMDL? Todd explained the importance of working to improve water quality and ensure impairments do not worsen. The Creek is 2 to 3 times above the goal listed in the TMDL.
14. Dam discussed the old horse barns at the State Fair Park area may be a source of the E. coli and those will be gone, will sampling be done in that area? EA will be conducting sampling of the Creek in that area.
15. Amen asked about sampling data throughout the Basin? Schlautman explained that the project team has acquired all available data, or is in the process of collecting additional sampling data.
16. Campbell asked about the potential sources of E. coli and ammonia? He considered lawn care and dog/goose waste big possibilities.
17. Renken would like to have more meetings because it will be difficult to keep all the information in mind and to offer productive ideas, the group discussed having the second of potentially three meetings in January.

18. Kuzelka discussed how it might be nice to develop fact sheets or handout that provides information on what a watershed is and other Antelope Creek issues. What are the Councils duties at the public meeting? Will we have specific tasks? Schlautman and Kouma encouraged Advisory Council members to attend the meeting and direct attendees to one of the project team members to have questions answered.
19. Campbell asked about the plan for handout at the public meeting? Need a handout/take away sheet at the meeting. Mohr discussed the game plan to have a project description, FAQs, and other information available, and referenced the City's website.
20. Advisory Council discussed keeping the presentation at open house simple, to start with basic such as 'what is a watershed?', keep the presentation educational and not to technical, and not to use acronyms.
21. Amen explained importance of getting people involved, beyond engineers and scientist, to change habits towards improving water quality.
22. Kuzelka recommended putting neighborhood associations on an overlay of the Antelope Creek Basin map for the meeting. Mohr explained it would be added.
23. Amen asked about having people put sticky notes and comments on the large meeting map or have the Council be available to take comments and notes from the public if the crowd is large and they can't get to the poster areas, or don't want to ask questions in public. Mohr explained that project team staff would be available at the 'large map' and markers will be provided to make notes onto the map.
24. Kuzelka asked if there would be 1-2 follow up public session to provide input after you have come up with alternatives and Best Management Practices.
25. Renken advised that the Mayors Round Table might be a good place to provide public information and get input from neighborhood associations.
26. Campbell suggested using Channel 5 public information adds to get the project information out to the public.
27. Kuzelka asked about the relationship between the City and the NRD. Zillig, Kouma, and Higgins explained that they often alternate being the lead on projects, and commonly split cost and responsibilities.
28. Campbell recommended index cards at the back of the room for people to write comments/questions would be a big help. Mohr explained there would be a box at the sign-in table for feedback.
29. Campbell thought Jan/Feb meeting would be a good time to get back together since a lot of the work will be done and the BMPs may have been evaluated enough to get Council input.
30. Amen asked if the Council could get copies of the descriptions of the actual tasks. The minutes will include copy of actual tasks.
31. Mohr asked the group how do they look at Antelope Creek, as a Creek or a stormwater drain? Overall the group expressed desire to ensure it becomes cleaner and more natural. Work to find a balance between urbanization and the stream.
32. Campbell asked how much groundwater seeped into the Creek.
33. Amen wanted to be sure and recognizes all efforts in the Basin, such as the Assurity Building, Union Park best management practices, etc. We could involve others who have been involved in the project area in the past.

34. Renken mentioned Union Bank and others who have provided funding and other involvement in the planning.
35. The City has put a lot of money into the Antelope Creek Basin and now the public will have access to the area in Union Plaza so we need to consider what the water quality will be and make sure we do not have water quality issues in the area or the public will question why the money was spent.

The Advisory Council is encouraged to direct input or any questions to project manager, Ed Kouma, at 402-441-7018 or ekouma@lincoln.ne.gov. Regular communication will occur with the Advisory Council through email.

Antelope Creek Watershed Basin Management Plan
Advisory Council Meeting #1
Lower Platte South NRD Office – 3125 Portia Street
Tuesday September 14th, 2010 – 5:30 PM
PLEASE PRINT CLEARLY- THANK YOU!

NAME	TITLE	ORGANIZATION Represented	ADDRESS Street Number, Street Name, City, Zip	PHONE	EMAIL
BOB KUZELKA	Retiring ~~UNL Extension~~	UNL	1935 A St 68502	475-0221	rkuzelka1@unl.edu
Mike Renken	Ex Dir	NeighborWorks LINCOLN	2240 Q St	477-7181	mrenken@nwlincoln.org
MARY SCHROER		NDEQ	1200 N Street	471-6988	mary.schroer@nebraska.gov
Jonathan Mohr	Planner	JEO	650 J St. Suite 215 Lincoln NE 68502	435-3080	jmohr@jeo.com
Sara Hartzell	Planner	Lincoln/Lanc. Co	555. S. 10th	441-6371	shartzel@lincoln.ne.gov
Ed Kouma	Engineer	City	555. S. 10th	441-7018	ekouma@lincoln.ne.gov
Ben Higgins	Sr Engr	"	"	441-7589	bhiggins@ "
PAUL ZILLIG	ASST MGR	LPSNRD		476-2729	pzillig@lpsnrd.org
Dale Schlautman	Engineer	EA	221 Sun Valley Blvd Lincoln, NE 68528	476 3766	dschlautman@eacst.com
Jon Trombino	Engineer	EA	" "	" "	jtrombino@eacst.com
Bob Todd	Scientist	EA	" "	" "	rTodd@eacst.com

Antelope Creek Watershed Basin Management Plan

Advisory Council Meeting #1

Lower Platte South NRD Office – 3125 Portia Street

Tuesday September 14th, 2010 – 5:30 PM

PLEASE PRINT CLEARLY- THANK YOU!

NAME	TITLE	ORGANIZATION Represented	ADDRESS Street Number, Street Name, City, Zip	PHONE	EMAIL
DALE HARDY	GOLF ADMINISTRATOR	CITY OF LINCOLN	2740 A STREET 68502	441-3860	DHARDY@LINCOLNNE.GOV
Andrew Campbell	Landscape Dept Mgr	Campbells Nurs.	5625 Pine Lake Rd (16)	484-7788 x101	AJCcampbellsnursery.com
Jennifer Dam	Asst Director IRP Campus planning	UNL	335 Admin UNL 68588	472-2823	jdamshewchuk2@unl.edu
Karen Amen	LPSNRD Board	LPSNRD	3220 Stoughton	499.7930	~~amenkaren@yahoo.com~~ KarenSAmen@gmail.com

Antelope Creek Watershed Basin Mangement Plan

Advisory Council Meeting #2

Lower Platte South NRD Office - 3125 Portia Street
Thursday February 10, 2011 – 7:30 AM to 8:30 AM

1. **Introductions (5 minutes)**
   - Nebraska Open Meetings Act

2. **Advisory Council Roles and Responsibilities -** *"Council members will be asked to review elements of the process, ask questions, raise issues, and share information with one another, the public and the project team."*

3. **Status of the Antelope Creek Watershed Basin Management Plan - Trombino (20 minutes)**
   - Basin inventory summary
   - Sampling efforts
   - Best management practice selection
   - Summary of findings

4. **Public Involvement Discussion - Mohr (20 minutes)**
   - September 30, 2010 open house summary
   - Suggestions for stakeholder meetings (community groups, neighborhood associations, others to present and discuss the Basin Plan)
   - Open House Number 2 of 2 anticipated for July 2011

5. **Questions from Advisory Council (10 minutes)**

6. **Next Steps/Timeline (5 minutes)**
   - Final Advisory Council Meeting likely prior to last Open House
   - Draft plan August 2011, Final Plan September 2011

Core Work Group Contact Info

- Ed Kouma, PE, City of Lincoln, 402-441-7018, ekouma@lincoln.ne.gov
- Paul Zillig, Lower Platte South NRD, 402-476-2779, pzillig@lpsnrd.org
- Jon Trombio, PE, EA, 402-476-3766, jtrombino@eaest.com
- Jonathan Mohr, AICP, EA, 402-476-3766, jmohr@eaest.com
- Website – www.lincoln.ne.gov (keyword: watershed), click on Master Plans, then Antelope Creek Watershed

Antelope Creek Watershed Basin Mangement Plan
Advisory Council Meeting #2 - Minutes

Advisory Council:

NAME	TITLE	JURISDICTION
Bob Kuzelka	Citizen	Near South Neighborhood
Mike Renken	Executive Director	Neighbor Works
Dale Hardy	Golf Administrator	City of Lincoln
Rachael Herpel	Outreach Coordinator	UNL Water Center
Andrew Campbell	Landscape Department Manager	Campbell's Nursery
John Chapo	President	Lincoln Children's Zoo
Scott Wieskamp	Director of Facilities	Lincoln Public Schools
Adam Hornung	City Council	City of Lincoln

Other Attendees:

NAME	TITLE	JURISDICTION
Ed Kouma, PE	Engineer (Project Manger)	City of Lincoln
Paul Zillig	Assistant Manager	LPS NRD
Jonathan Mohr, AICP	Environmental Scientist/Planner	EA
Jon Trombino, PE	Engineer	EA
Jamie Suing	Engineer	EA
Lalit Jha, PE, CFM, D.WRE	Engineer	JEO

When: February 10, 2011, 7:30 to 8:30 AM
Where: Lower Platte South NRD Office – 3125 Portia Street

MINUTES

The Antelope Creek Watershed Basin Management Plan Advisory Council met for the second of three anticipated meetings. The meeting intent was to bring the Council up to speed on project progress, summarize findings of the initial sampling effort and basin inventory, and to discuss possible stakeholder meetings.

1. Introductions (7:35 AM) - Advisory Council members introduced themselves, followed by other members in attendance.
2. Jonathan Mohr began the meeting by thanking Advisory Council members for participating, covering the agenda, reviewing the roles and responsibilities, and turning discussion to Jon Trombino to discuss the task summary.
3. Trombino covered the project team's progress thus far including a summary of the basin inventory and sampling results, work being completed with Wright Water Engineers (WWE) and Dr. Pitt, and the game plan for the next three months.
4. Andrew Campbell asked if there was an expectation or engineering standard to determine the performance of each Best Management Practice (BMP). Trombino explained the advantage of

having WWE's International BMP database, which includes information on BMP performance overtime.

5. Andrew Campbell asked if any other pollutants were present (besides Ammonia and *E.coli*), such as Phosphates. Trombino provided a summary of sampling thus far, *E.coli* remained the most prevalent pollutant, unexpected results haven't occurred.
6. Discussion occurred about the timing of the next Advisory Council meeting. Ed Kouma mentioned the Advisory Council would meet again prior to the draft plan being available for review. Paul Zillig added that the Council would be used to help the project team better understand issues and possible questions the public may have to better prepare the project team when the draft is ready for public review.
7. Mohr began discussion of remaining items on Public Information and Education. Newsletter number two is being mailed this week; there will be two more newsletters. EA and JEO have six stakeholder meetings to facilitate. Mohr asked the Council's input on potential stakeholder groups to meet with, maybe for a one-hour presentation, to increase outreach on the Basin Plan.
8. Bob Kuzelka presented to the Near South Neighborhood Association and provided information on the planning effort. Kuzelka stated that a one-hour presentation to any stakeholder group is probably too much and recommended sending a letter (from the City and NRD) to each Association in the project area to seek interest, or to spread news on the Basin Plan potentially through articles in their newsletters.
9. John Chapo recommended contacting the Downtown Lincoln Association, Local Public Access Channel 5 to include information on how people can receive more information. Chapo also recommended putting a post together about the project. Due to Antelope Creek improvements one area of the Zoo will be closed this summer and Chapo has offered to use that area to post information on the Basin Plan.
10. Andrew Campbell recommended contacting science teachers at Lincoln Southeast and possibly presenting to a group.
11. Councilman Hornung recommended contacting both the Lincoln Independent Business Association and the Homebuilders Association; and possibly the Lincoln Chamber of Commerce.
12. Bob Kuzelka emphasized using the level of knowledge used at the first Open House when discussing the project and recommended booth information at City Earth Day events, Open House at the Zoo, and UNL's Earth Day events.
13. Other discussions included the Earth Wellness Festival.
14. Rachael Herpel asked about using the Basin Plan to discuss at a Fall 2011 Water Seminar Series at UNL.
15. Mike Renken recommended the Mayors Roundtable, Tracey Corr is the primary contact.
16. Next Advisory Council meeting maybe late-July 2011.
17. Scott Wieskamp mentioned that one of the schools could be used for the next Open House.
18. Meeting adjourned at 8:36 AM

The Advisory Council is encouraged to direct input or any questions to project manager, Ed Kouma, at 402-441-7018 or ekouma@lincoln.ne.gov. Regular communication will occur with the Advisory Council through email.

Antelope Creek Watershed Basin Management Plan
Advisory Council Meeting #2
Lower Platte South NRD Office – 3125 Portia Street
Thursday February 10th, 2011 – 7:30 AM
PLEASE PRINT CLEARLY- THANK YOU!

NAME	TITLE	JURISDICTION Represented	ADDRESS Street Number, Street Name, City, Zip	PHONE	EMAIL
John Chapo	President	Lincoln Children's Zoo	1222 So. 27th Linc. 68502	475-6741 ext 125	jchapo@lincolnzoo.org
Lalit Jha	Eng.	JEO		443-8010	ljha@jeo.com
Jon Trombino	Project Manager	EA		476-3766	jtrombino@eaest.com
Jonathan Mohr	Environmentalist	EA		476-3766	jmohr@eaest.com
Jamie Suing	Eng.	EA		476-3766	jsuing@eaest.com
Bob Kuzelka	Citizen	NSNA	1935 A St	475-0221	rkuzelka1@unl.edu
Paul Zillig	Asst. Mgr	LPSNRD		476-2729	pzillig@lpsnrd.org
Rachael Herpel	Outreach Spec.	UNL Wtr Ctr		472-4977	rherpel2@unl.edu

Antelope Creek Watershed Basin Management Plan
Advisory Council Meeting #2
Lower Platte South NRD Office – 3125 Portia Street
Thursday February 10th, 2011 – 7:30 AM
PLEASE PRINT CLEARLY- THANK YOU!

NAME	TITLE	ORGANIZATION Represented	ADDRESS Street Number, Street Name, City, Zip	PHONE	EMAIL
DAN HARDY	CODE ADMINIST-	CITY OF LINCOLN	2740 "A", 68502	441-3860	DHARDY@LINCOLNNE.GOV
Ed Kouma	Engineer	City of Lincoln	555 S. 10TH	441-7018	ekouma@lincolnne.gov
SCOTT WIEGHAMP	DIR OF FAC	LINCOLN PUB SCHOOLS	800 SO. 24th ST	436-1072	SWIEGHA@LPS.ORG
Mike Renken	Executive Director	NeighborWorks LINCOLN	2240 Q St	477-7181	MRenken@nwlincoln.org
Andrew Campbell	manager Land. Dept	Campbells Nursery	5025 Pine Lake Rd	484-7788	AJC@campbellsnursery.com
Adam Hornung		City Council	3025 S. 31st St.	430-0006	ahornung@saddlelaw.com

Antelope Creek Watershed Basin Mangement Plan
Advisory Council Meeting #3
Lower Platte South NRD Office - 3125 Portia Street
Tuesday November 29, 2011 –7:30 AM

1. **Introductions (5 minutes)**
   - Introductions
   - Nebraska Open Meetings Act

2. **Update since February 2011 Meeting (5 minutes)**
   - Extension of timeline and contract
   - WinSLAMM completion July 2011
   - Water Quality Sampling completion September 2011
   - Recommendations and strategies November 2011

3. **Open House #2 Presentation (15 minutes)**

4. **General Discussion of Programs / Projects**
   - Public perception of programs / projects

5. **Next Steps/Questions (5 minutes)**
   - Open House #2, Thursday December 1, 2011 – 5:00 PM to 7:00 PM
   - Review comments, finalize Master Plan
   - January/February 2012 – City Council / NRD approvals

6. **Contact Info**
   - Ed Kouma, PE, City of Lincoln, 402-441-7018, ekouma@lincoln.ne.gov
   - Paul Zillig, LPSNRD, 402-476-2729
   - Jon Trombino, PE, EA, 402-476-3766, jtrombino@eaest.com
   - Jonathan Mohr, AICP, EA, 402-476-3766, jmohr@eaest.com
   - Website – www.lincoln.ne.gov (keyword: watershed), click on Master Plans, then Antelope Creek Watershed

Antelope Creek Watershed Basin Mangement Plan
Advisory Council Meeting #3 - Minutes

Advisory Council:

NAME	TITLE	JURISDICTION
Bob Kuzelka	Citizen	Near South Neighborhood
Mike Renken	Executive Director	NeighborWorks
Jennifer Dam	Campus Planner	UNL
Rachael Herpel	Outreach Coordinator	UNL Water Center
Karen Amen	Director	LPS NRD
John Chapo	President	Lincoln Children's Zoo
Scott Wieskamp	Director of Facilities	Lincoln Public Schools
Adam Hornung	City Council	City of Lincoln

Other Attendees:

NAME	TITLE	JURISDICTION
Ed Kouma, PE	Engineer (Project Manger)	City of Lincoln
Paul Zillig	Assistant Manager	LPS NRD
JB Dixon	Stormwater Specialist	LPS NRD
Jonathan Mohr, AICP	Environmental Scientist/Planner	EA
Jon Trombino, PE	Engineer	EA
Jamie Suing	Engineer	EA
JD Johnson, PE	Engineer	JEO

When: November 29, 2011 7:30 to 8:30 AM
Where: Lower Platte South NRD Office – 3125 Portia Street

MINUTES

The Antelope Creek Watershed Basin Management Plan Advisory Council met for the last of three anticipated meetings. The meeting intent was to go through the Open House presentation to be shown Thursday December 1, 2011 in order to bring the group up to speed on plan recommendations, in addition to allowing the Advisory Council to critique the presentation.

1. Introductions (7:35 AM) - Advisory Council members introduced themselves, followed by other members in attendance.
2. Jonathan Mohr began the meeting by thanking Advisory Council members for participating and summarizing the extended project timeline.
3. Jonathan Mohr began the presentation along with Jon Trombino, which extended through the entire meeting.
4. Several Advisory Council members commented on wording of the presentation and had suggestions to make the presentation better for the public to understand.
5. Paul Zillig suggested having someone available for water quality questions at the open house.

6. Adam Hornung recommended emphasizing what we thought were the pollutant loads (wildlife and pets).
7. The group asked several questions about specifics on what 'impairments' (copper, conductivity, selenium) were versus 'constituents of concern (*E. coli* and ammonia). Trombino provided an explanation.
8. Karen Amen asked about the groundwater influence to the stream. Mohr and Suing explained the areas downstream of the Vine Street where groundwater boils are visible.
9. Kuzelka asked if the Open House was for public input or just to provide further information to the public. Mohr mentioned that there would be public hearings after the plan is developed prior to adoption of the plan by the NRD and City Council.
10. Meeting adjourned at 8:40 AM.

The Advisory Council is encouraged to direct input or any questions to project manager, Ed Kouma, at 402-441-7018 or ekouma@lincoln.ne.gov. Regular communication will occur with the Advisory Council through email.

Antelope Creek Watershed Basin Management Plan
Advisory Council Meeting #3
Lower Platte South NRD Office – 3125 Portia Street
Thursday November 29th, 2011 – 7:30 AM
PLEASE PRINT CLEARLY- THANK YOU!

NAME	TITLE	ORGANIZATION Represented	ADDRESS Street Number, Street Name, City, Zip	PHONE	EMAIL
Jennifer Dam	Campus Planner	UNL	332 Admin 0435	472-2823	jdamshewchuk2@unl.edu
Bob Kuzelka		NSNA	193 A St 68502	475-0221	rkuzelka1@unl.edu
KAREN AMEN	BOARD	LPSNRD	3220 Joy Court	423-3220	amenkarenrae@gmail.com
John Chapo	President	Lincoln Children's Zoo	1222 S. 27th 68502	475-6741 ext-125	jchapo@lincolnzoo.org
SCOTT WIESKAMP	DIR. OF FACILITIES	LINCOLN PUBLIC SCHOOLS	800 S. 24th St. 68510	436-1072 EM. 82010	SWIESKA@LPS.ORG
Rachael Herpel	Ed/Outreach Specialist	UNL Water Center	3310 Holdrege St. Lincoln NE 68583	472-4917	rherpel2@unl.edu
J.D. Johnson	Engineer	JEO Consulting	650 J St. Suite 215	435-3080	jdjohnson@jeo.com
Ed Kouma	Engineer	City of Lincoln			
Paul Zillig	Asst. Manager	LPS NRD			
Jamie Suing	Engineer	EA			
Jon Trimbien	Pj Mngr	EA			
J.B. Dixon	Stormwater Specialist	LPSNRD			

Tmeeting added

Antelope Creek Watershed Basin Management Plan
Advisory Council Meeting #3
Lower Platte South NRD Office – 3125 Portia Street
Thursday November 29th, 2011 – 7:30 AM
PLEASE PRINT CLEARLY- THANK YOU!

NAME	TITLE	JURISDICTION Represented	ADDRESS Street Number, Street Name, City, Zip	PHONE	EMAIL
Adam Hornung	City Council			430-0006	ahornung@scudder-law.com
Mike Renken	NeighborWorks LINCOLN			477-7181	mrenken@nwlincoln.org
Ben Higgins	City of Lincoln			441-7589	bhiggins@lincoln.ne.gov
Jonathan Mohr	EA- Envir. Scientist			476-3766	jmohr@jeo.com

Open House

Charles H. Gere Library
Thursday, September 30, 2010
5 to 7:30 pm

Antelope Creek Watershed Basin Management Plan

Postcard.indd 1 8/30/2010 10:56:58 AM

Open House

You are invited to attend an Open House to learn about the Antelope Creek Watershed Basin Management Plan and provide input to the project team.

Bring your family, invite a friend, and take an active role in improving the health of your watershed!

Charles H. Gere Library

2400 South 56th Street
(56th & Normal)
Thursday, September 30, 2010
5 to 7:30 pm
(20 minute presentations at 5:30 pm and 6:30 pm)

Door Prize
One Rail Barrel
provided by the City of Lincoln

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650 'J' Street, Suite 215
Lincoln, NE 68508

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EA Engineering, Science,
and Technology, Inc.

221 Sun Valley Blvd, Suite D
Lincoln, NE 68528
Telephone: 402.476.3766
Fax: 402.476.7825
www.eaest.com

OPEN HOUSE #1 SUMMARY AND NOTES

Project: Antelope Creek Watershed Basin Management Plan
Date: Thrusday September 30, 2010
Time: 5:30 to 7:30 pm
Location: Charles H. Gere Library, 2400 S. 56th Street
Submitted by: Jonathan Mohr on February 3, 2011

OPEN HOUSE FORMAT

- Three stations with focuses on: water quality, floodplains, and best management practices in corners of the room
- One very large map of the project area with key landmarks over a 2007 aerial photo, markers provided
- Sign in table with: project summary, sign-in sheet, feed back forms, newsletter one
- City of Lincoln Watershed information on rain barrels and rain garden classes
- Seating for 80 with a power point presentation

PRESENTATION FORMAT

Jonathan Mohr, JEO, started the 15-minute presentation by thanking participants for attending and discussing general information such as 'what is a watershed', 'what is stormwater runoff', and what are the pollutants of concern. Jonathan discussed the project purpose and explained the teaming arrangement between the City and NRD. Dale Schlautman, EA, discussed the project scope and explained some stormwater quality best management practices. The presentation was repeated at 6:30, questions were held until the conclusion of the first presentation once the group was welcomed to mingle with the Core Working Group and view the education boards. Questions were accepted immediately after the second presention prior to participants moving about.

QUESTIONS AND DISCUSSION SUMMARY

Due to an article published in local papers just prior to the open house a great majority of questions were concering the public safety risk associated with the body contact with the water in Antelope Creek. Other common themes asked by the nearly 100 particiapnts were:

1) As a homeowner what can I do to help improve the water quality?
2) Will the plan improve flood control?
3) What are the immediate health risks?
4) What types of projects will we see due to the plan?

A rain barrel was presented to a meeting participant by the City of Lincoln Watershed. The next open house is anticipated for July 2011. Nearly the entire core work group was in attendance along with five members of the Advisory Council (see sign-in sheets).

JEO Consulting Group, Inc. EA WWE

CITY OF LINCOLN NEBRASKA

Lower Platte South Natural Resources District

Antelope Creek Watershed Basin Management Plan

OPEN HOUSE

Charles H. Gere Library – 2400 South 56th Street

Thursday September 30th, 2010 – 5:00 to 7:30 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Rachel Ward	☐ Business Owner ☐ Non-Profit ☐ Resident		rjward@unomaha.edu	
Joe Aluine	☐ Business Owner ☐ Non-Profit ☒ Resident		jaluine11888@gmail.com	3080 S. St.
Patrice Engelbrecht	☐ Business Owner ☐ Non-Profit ☒ Resident	4775522		2631 S-41
DANNY WALKER	☐ Business Owner ☐ Non-Profit ☐ Resident	477-7064		427 "E" St.
Janell Evans	☐ Business Owner ☐ Non-Profit ☒ Resident			2521 So 56th St
Pasmore Mudundu	☐ Business Owner ☐ Non-Profit ☒ Resident			
George Elgin	☐ Business Owner ☐ Non-Profit ☒ Resident	488-2580		5345 ROOSE ST.
Dave Larson	☐ Business Owner ☐ Non-Profit ☑ Resident	483 5404	dclarson@windstream.net	6039 CULLEN DR 68506
Mel Burks	☐ Business Owner ☐ Non-Profit ☑ Resident	488-4065 ~~488-8~~		6145 South St
	☐ Business Owner ☐ Non-Profit ☐ Resident			
	☐ Business Owner ☐ Non-Profit ☐ Resident			
	☐ Business Owner ☐ Non-Profit ☐ Resident			
	☐ Business Owner ☐ Non-Profit ☐ Resident			

JEO Consulting Group, Inc. EA WWE

CITY OF LINCOLN NEBRASKA

Lower Platte South Natural Resources District

Antelope Creek Watershed Basin Management Plan
OPEN HOUSE
Charles H. Gere Library – 2400 South 56th Street
Thursday September 30th, 2010 – 5:00 to 7:30 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Marc Rooney	☐ Business Owner ☐ Non-Profit ☐ Resident	489-1859	mrooney@lincolnne.gov	5738 Normal Blvd
Margaret Wood	☐ Business Owner ☐ Non-Profit ☐ Resident	464-4948	margaretwoodd@hotmail.com	864 Elmwood
Dana Barry	☐ Business Owner ☐ Non-Profit ☒ Resident	488-9055	thebarryfamily@earthlink.net	5120 Patmore
Gary Ends	☐ Business Owner ☐ Non-Profit ☒ Resident	430-1157	garyendsgroup.com	2238 S. 48th
Nanci Burchess Smith	☐ Business Owner ☐ Non-Profit ☐ Resident	730-8407	nbs@woodsbros.com	3145 S041
Steve Masters	☐ Business Owner ☐ Non-Profit ☐ Resident	488-1789		7876 Sycamore Dr
Karen Amen	☐ Business Owner ☐ Non-Profit ☐ Resident LPSNRD			
Marco Floreani	☐ Business Owner ☐ Non-Profit ☒ Resident	968-2603	mfloreani@gmail.com	1849 O St Apt 4
Diane Wheeler	☒ Business Owner ☐ Non-Profit ☒ Resident	402-202-0047	dsfall@hotmail.com	6001 S 88th
Mike Renken	☐ Business Owner ☒ Non-Profit ☐ Resident	402.750.0571	mrenken@nwlincoln.org	2240 O St.
Nancy Voff	☐ Business Owner ☐ Non-Profit ☒ Resident	730-5473	ed-nancy@nebrr.com	2739 Andover Dr.
Kaylene Tegtmeier	☐ Business Owner ☐ Non-Profit ☒ Resident	402.617-4826	kaerae11@Gmail	2119 Park Ave 68502
Peggy + Glenn Shorma	☐ Business Owner ☐ Non-Profit ☒ Resident	402-489-5539		4331 Antelope Creek Rd

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CITY OF LINCOLN NEBRASKA

Lower Platte South Natural Resources District

Antelope Creek Watershed Basin Management Plan
OPEN HOUSE
Charles H. Gere Library – 2400 South 56th Street
Thursday September 30th, 2010 – 5:00 to 7:30 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Robert C Anderson	☐ Business Owner ☐ Non-Profit ☐ Resident	483-5455		4941 So. 73 St. Lincoln, Neb 68511
Robert L. Bussmann	☐ Business Owner ☐ Non-Profit ☒ Resident	488 3231		
Billie C. Bussmann	☐ Business Owner ☐ Non-Profit ☒ Resident	488 3231.		
Xun Liu	☐ Business Owner ☐ Non-Profit ☐ Resident	610 5511		535 N 23rd St
Hungtang Kalita	☐ Business Owner ☐ Non-Profit ☐ Resident	402-720-1850		
Nan Zhao	☐ Business Owner ☐ Non-Profit ☐ Resident	402-570-4274		
Trieu Mai	☐ Business Owner ☐ Non-Profit ☐ Resident	402-802-8952		4300 Holdrege St. Apt # A01
JED EAGLE	☐ Business Owner ☐ Non-Profit ☐ Resident	402 550. 8263		
Alison Inguna	☐ Business Owner ☐ Non-Profit ☐ Resident	9083387152		
DAN GAGE	☐ Business Owner ☐ Non-Profit ☐ Resident	402 301 6439		
Eric Schwy	☐ Business Owner ☐ Non-Profit ☐ Resident	402 429 9294		
Lana Schultz	☐ Business Owner ☐ Non-Profit ☐ Resident	2120 So 20		
	☐ Business Owner ☐ Non-Profit ☐ Resident			

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CITY OF LINCOLN NEBRASKA

Lower Platte South Natural Resources District

Antelope Creek Watershed Basin Management Plan

OPEN HOUSE

Charles H. Gere Library – 2400 South 56th Street

Thursday September 30th, 2010 – 5:00 to 7:30 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Andy Szatko	☐ Business Owner ☑ Non-Profit ☐ Resident	402-306-5704	aszatko9@huskers.unl.edu	
Sara Hartzell	☐ Business Owner ☐ Non-Profit ☐ Resident	441-6371	shartzell@lincoln.ne.gov	
Tracy Corr	☐ Business Owner ☐ Non-Profit ☒ Resident	310-7069	tlines24@hotmail.com	1004 S 37
Pat Stear	☐ Business Owner ☐ Non-Profit ☐ Resident	617-8888	lunitatucumana373@msn.com	2812 T St 68503
Wally Martin	☐ Business Owner ☐ Non-Profit ☑ Resident	488-1579	wallymartin@windstream.net	4633 Eden Circle
Sherri Beldin	☐ Business Owner ☐ Non-Profit ☒ Resident	432-5012	sherbel2002@yahoo.com	2725 So. 41st (06)
Peg Johnson	☐ Business Owner ☐ Non-Profit ☒ Resident	570-2196	mjohnson4@unl.edu	
DAVID RUDER	☒ Business Owner ☐ Non-Profit ☒ Resident	475-9375	KATHERINERuder@gmail.com	2400 South 22nd Street
K Ridenour	☐ Business Owner ☐ Non-Profit ☒ Resident		rkbr@gmail.com	
Russell Miller	☐ Business Owner ☐ Non-Profit ☑ Resident	499-2611	NEB31340@windstream.net	
T. Baumbach	☐ Business Owner ☐ Non-Profit ☒ Resident	4889458	N/A	3309 South St
Sandy Marino	☐ Business Owner ☐ Non-Profit ☒ Resident	489-7855	pp31415@windstream.net	1810 S 38th
Ed Rumbaugh	☐ Business Owner ☐ Non-Profit ☐ Resident	730-5413	Ed-NANCY@rr.web.com	2434 Anderson Dr. 68506

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CITY OF LINCOLN NEBRASKA

Lower Platte South Natural Resources District

Antelope Creek Watershed Basin Management Plan
OPEN HOUSE
Charles H. Gere Library – 2400 South 56th Street
Thursday September 30th, 2010 – 5:00 to 7:30 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
ED UBBEN	☐ Business Owner ☐ Non-Profit ☒ Resident	474-0112		2219 "B" ST
Dan Moseman	☐ Business Owner ☐ Non-Profit ☐ Resident Student	795-2511		28221 So 96th Fifth NE
Richard Deaton	☐ Business Owner ☐ Non-Profit ☒ Resident	430 1514		1642 W Mulberry
Wayne Schreur	☐ Business Owner ☐ Non-Profit ☒ Resident	416-8080		4301 Normal #13
Bruce Abernethy	☐ Business Owner ☐ Non-Profit ☒ Resident	817-4763		5901 Franklin ST
Jeff Weber	☐ Business Owner ☐ Non-Profit ☐ Resident Student	890-2249		2853 Jane Lane
Milan Wall	☐ Business Owner ☐ Non-Profit ☒ Resident	435-8908		1530 N. Gate Circle
Ken Fougeron	☒ Business Owner ☐ Non-Profit ☐ Resident	326-0577	kgfougeron@speedwayproperties.com	340 Victory Lane
Jeanette Schroeder	☐ Business Owner ☐ Non-Profit ☒ Resident	489-4561	—	3740 Normal Blvd.
GORDON FITTS	☐ Business Owner ☐ Non-Profit ☒ Resident	489-8469	—	828 S 44TH ST
Michael Hall	☐ Business Owner ☐ Non-Profit ☒ Resident	484 8737		3426 Everett
Crystal Bergman	☐ Business Owner ☐ Non-Profit ☐ Resident			
Doug Samuelson	☐ Business Owner ☐ Non-Profit ☒ Resident			711 Benton St.

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CITY OF LINCOLN NEBRASKA

Lower Platte South Natural Resources District

Antelope Creek Watershed Basin Management Plan
OPEN HOUSE
Charles H. Gere Library – 2400 South 56th Street
Thursday September 30th, 2010 – 5:00 to 7:30 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Lalit Jha	☐ Business Owner ☐ Non-Profit ☐ Resident	402-443-8010	ljha@jeo.com	JEO, Lincoln
Martha Van Sickle	☐ Business Owner ☐ Non-Profit ☑ Resident	402-488-7286	n/a	2640 So. 41st
Zhenghong Tang	☐ Business Owner ☑ Non-Profit ☐ Resident	402-472-9281	ztang2@unl.edu	—
Nate Healey	☐ Business Owner ☐ Non-Profit ☑ Resident	402-310-6942	natehealey@hotmail.com	—
John Linhardt	☐ Business Owner ☐ Non-Profit ☒ Resident	402-486-4290	linhardtjd@windstream.net	9172 Chalk Hill Co
BOB KUZELKA	☐ Business Owner ☐ Non-Profit ☒ Resident	402.475-0221	rkuzelka1@unl.edu	
Calvin Cook	☐ Business Owner ☐ Non-Profit ☑ Resident	402 372 7512	@Packers_4444@hotmail	
Elton Ogorzolka	☐ Business Owner ☐ Non-Profit ☒ Resident	489-5549		2310 So. 56
Andrew Thierolf	☐ Business Owner ☐ Non-Profit ☒ Resident	402 432 4243		Lincoln
SCOTT SAALFELD	☐ Business Owner ☐ Non-Profit ☐ Resident STUDENT	402 871 3372	scottsaalfeld@gmail.com	5012 Burt St, OMAHA 68132
Elaine Bergmeier	☐ Business Owner ☐ Non-Profit ☐ Resident	402-488-0286		1600 S. 44
BRYAN PENAS	☐ Business Owner ☐ Non-Profit ☐ Resident		bpenas@lps.org	
Scott Bulfinch	☐ Business Owner ☐ Non-Profit ☒ Resident	402-742-3053	celticsailor@neb.rr.com	2128 'B' ST, Lincoln 68502

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CITY OF LINCOLN NEBRASKA — Lower Platte South Natural Resources District

Antelope Creek Watershed Basin Management Plan
OPEN HOUSE
Charles H. Gere Library – 2400 South 56th Street
Thursday September 30th, 2010 – 5:00 to 7:30 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Ken Reitan	☐ Business Owner ☐ Non-Profit ☒ Resident	402-423-3540	kareitan@inebraska.com	2310 S. Canterbury Ln
Wallace + Mary Jake	☐ Business Owner ☐ Non-Profit ☒ Resident	402-4585070	mary_gake@net	5522 Aumsen 68506
Jonathan Mohr (JEO)	☐ Business Owner ☐ Non-Profit ☐ Resident	402-435-3080	jmohr@jeo.com	6505 Stroh Suite 219 Lincoln NE 68508
Bonnie Kadary	☐ Business Owner ☐ Non-Profit ☒ Resident	402-489-1521		3633 Everett St. 68506
Rebecca Benthal	☐ Business Owner ☐ Non-Profit ☐ Resident	489-6517		2132 S. 37th 68506
Alva Robinson-Fowler	☐ Business Owner ☐ Non-Profit ☐ Resident	477-0693		2601 Antelope Circle
Jim Buckwalter	☐ Business Owner ☐ Non-Profit ☐ Resident	430-9014		7124 Phoenix Dr Lincoln
Mike Gilligan	☐ Business Owner ☐ Non-Profit ☐ Resident	650-1294	mbgilligan@gmail	262 S. Scott St. Gretna NE
Jason Kubicek	☐ Business Owner ☐ Non-Profit ☐ ~~Resident~~ STUDENT	306-8793	jkubicek10@yahoo.com	404 CHESTNUT DR. #9 GRETNA, NE
Jean Cepek	☐ Business Owner ☐ Non-Profit ☒ Resident	488-0286		1600 S 44 St
Cara Brenner	☐ Business Owner ☐ Non-Profit ☒ Resident	817.729.2666	cbrenner@nlv.org	2435 Winding Way
Margaret Tonoghue	☐ Business Owner ☐ Non-Profit ☒ Resident	486-1910	—	4301 Normal - Unit 214
Ronald D. Svoboda	☐ Business Owner ☐ Non-Profit ☒ Resident	488-8097		6431 Monticello Dr 68510

Antelope Creek Watershed Basin Management Plan

Open House #2

Auld Pavilion

Thursday, December 1, 2011

5:00 to 7:00 pm

more information...

visit lincoln.ne.gov (keyword: watershed)

select “Antelope Creek Watershed Basin Management Plan” under “Featured Sites”

Open House #2

You are invited to attend an Open House
to learn about 1) Results of the Antelope Creek
Watershed Basin Management Plan and
2) Projects and programs being recommended to
improve the water quality in Antelope Creek.

Bring your family, invite a friend, and take an active
role in improving the health of your watershed!

Auld Pavilion

3140 Sumner
(Located in Antelope Park | Note: South Street is closed west of Normal Blvd., access to Antelope Park is recommended from 31st & A Streets)
Thursday, December 1, 2011
5:00 to 7:00 pm
(20 minute presentations at 5:30 pm and 6:30 pm)

Door Prize
One Rain Barrel provided by the City of Lincoln

more information...visit lincoln.ne.gov
(keyword: watershed)
select "Antelope Creek Watershed Basin
Management Plan" under "Featured Sites"
call Ed Kouma Lincoln Public Works and
Utilities Watershed Management
402-441-7018

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EA Engineering, Science,
and Technology, Inc.

221 Sun Valley Blvd, Suite D
Lincoln, NE 68528
Telephone: 402.476.3766
Fax: 402.476.7825
www.eaest.com

OPEN HOUSE #2 SUMMARY AND NOTES

Project: Antelope Creek Watershed Basin Management Plan
Date: Thursday December 1, 2011
Time: 5:00 to 7:00 pm
Location: Auld Pavilion – 3140 Summer, Lincoln, NE
Submitted by: Jonathan Mohr on December 6, 2011

OPEN HOUSE FORMAT

- Three stations with focuses on: structural recommendations, non-structural recommendations, and City/NRD programs
- One very large map of the project area with structural recommendations
- Sign in table with: project summary, sign-in sheet, feed back forms, newsletters 1-3
- City of Lincoln Watershed information on rain barrels and rain garden classes
- Seating for 100 with a presentation

PRESENTATION FORMAT

Open House attendees spent time before and after the presenation asking project team members questions on project recommendations.

A rain barrel was presented to a meeting participant by the City of Lincoln Watershed. Three members of the Advisory Committee were present as well as several of the Core Work Group members.

Antelope Creek Watershed Basin Management Plan
OPEN HOUSE #2
Auld Pavilion – 3140 Sumner
Thursday December 1st, 2011 – 5:00 to 7:00 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Rachael Harpel	☐ Business Owner ☐ Non-Profit ☐ Resident	472-4977	rharpel2@unl.edu	
Becky & Garry Martin	☐ Business Owner ☑ Non-Profit ☑ Resident	402-435-0740	rjmartin2 garrym2@windstream.net	3385 S. 29 Lincoln
John Wragge	☒ Business Owner ☐ Non-Profit ☐ Resident	402 560-9662	JOHNWRAGGE@YAHOO.COM	
Kent Seacrest	☐ Business Owner ☐ Non-Profit ☐ Resident	402 435-6000	kent@sk-law.com	
Lilly Blase	☐ Business Owner ☐ Non-Profit ☒ Resident	402-470-1691	lillyblase@hotmail.com	
Mike Renken	☐ Business Owner ☐ Non-Profit ☐ Resident	402 477-7181	MRenken@nwlincoln.org	
Roger Figard	☐ Business Owner ☐ Non-Profit ☐ Resident	402-525-5620	rfigard@lincoln.ne.gov	
WILLARD BOUWGES	☐ Business Owner ☐ Non-Profit ☒ Resident	402 450-2729	wb90102@windstream.net	3634 SUMNER
Judy Johnson	☐ Business Owner ☐ Non-Profit ☒ Resident	402 435-8946	gunter-judy@inebraska.com	218 S 29TH
Avery Pickering	☐ Business Owner ☐ Non-Profit ☒ Resident	402-423-7818	NEPick1@GMAIL.com	
Boyd Ready	☐ Business Owner ☐ Non-Profit ☒ Resident	308-390-8883	readybt@yahoo.com	2901 A St #109
Ed & Pam Tuchscherer	☐ Business Owner ☐ Non-Profit ☒ Resident	402-483-2062		2300 S. 37th St
	☐ Business Owner ☐ Non-Profit ☐ Resident			

Antelope Creek Watershed Basin Management Plan
OPEN HOUSE #2
Auld Pavilion – 3140 Sumner
Thursday December 1st, 2011 – 5:00 to 7:00 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Adam Rupe	☐ Business Owner ☐ Non-Profit ☐ Resident JEO	402 435.4030	arupe@jeo.com	650 J St. Suite 215 68508
J.D. Johnson	☐ Business Owner ☐ Non-Profit ☐ Resident JEO	"	jdjohnson@jeo.com	"
David Jefferson	☐ Business Owner ☒ Non-Profit ☐ Resident	402-483-4921		Newman Church 23rd R
Jim Christo	☒ Business Owner ☐ Non-Profit ☐ Resident	402-432-0590	jamesrchristo@gmail.com	6945 North 7th Lincoln, NE 68521
Elaine Hansen	☐ Business Owner ☐ Non-Profit ☐ Resident	402 477-0242	you have	5000 N 7
Robert Anderson	☐ Business Owner ☐ Non-Profit ☐ Resident	402-483-5455		4941 South 73 St Lincoln, Nebr 68516
Al Topil	☐ Business Owner ☐ Non-Profit ☒ Resident	402 327 8266	altopil@windstream.net	3619 Garfield Lincoln, NE
Lalit Jha	☐ Business Owner ☐ Non-Profit ☐ Resident	JEO		
Ken Reitan	☐ Business Owner ☐ Non-Profit ☒ Resident	402-423-3540	kareitan@neb.rr.com	2310 S. Canterbury Ln Lincoln 68512
Laurel Van Ham	☐ Business Owner ☐ Non-Profit ☒ Resident	402-474-8467		4150 South Street #06
Gary Stecker	☐ Business Owner ☐ Non-Profit ☐ Resident	402 489-7575		1820 Meadowlark Dr
Ronald Svoboda	☐ Business Owner ☐ Non-Profit ☒ Resident	402-488-809-	rsvoboda@juno.com	6431 Monticello Dr 68510
	☐ Business Owner ☐ Non-Profit ☐ Resident			

JEO EA WWE

Antelope Creek Watershed Basin Management Plan
OPEN HOUSE #2
Auld Pavilion – 3140 Sumner
Thursday December 1st, 2011 – 5:00 to 7:00 PM

NAME	PROJECT INTEREST	PHONE	EMAIL	ADDRESS
Jonathan Mohr	☐ Business Owner ☐ Non-Profit ☐ Resident EA	402-476-3766	jmohr@eaest.com	221 Sun Valley Blvd. Ste D 68528
Jamie Suing	☐ Business Owner ☐ Non-Profit ☐ Resident	402-476-3766	jsuing@eaest.com	221 Sun Valley Blvd Ste D 68528
BASIL CONRY	☐ Business Owner ☐ Non-Profit ☐ Resident	402-475627	—	3320 WASHINGTON
R Berthel	☐ Business Owner ☐ Non-Profit ☒ Resident	402-489-6517		2132 S. 37th St.
DOUG SAMUELSON	☐ Business Owner ☐ Non-Profit ☐ Resident	402-742-7509		711 Benton St. Lincoln 68521
GEO BRAY	☐ Business Owner ☐ Non-Profit ☐ Resident	402 617 5481		3445 Everett St
Lois Hansen	☐ Business Owner ☐ Non-Profit ☒ Resident	402-488-0630		2611 So 46 ST 68506
Dan Schlitt	☐ Business Owner ☐ Non-Profit ☐ Resident			2600 C Street 68502
Tom Pappas	☐ Business Owner ☐ Non-Profit ☒ Resident	402 484 8467	tpappas@windstream.net	4150 South St - 06
Doris Carpenter	☐ Business Owner ☐ Non-Profit ☐ Resident	402 488-1994		3705 D St. 68510
Bob Kuzelka	☐ Business Owner ☐ Non-Profit ☒ Resident	402.417.9424	rkuzelka1@unl.edu	1435 A ST 68502
Dale Sisseks	☐ Business Owner ☐ Non-Profit ☒ Resident	402-30-1540	jsisseks@nsn.com	
	☐ Business Owner ☐ Non-Profit ☐ Resident			

A Publication Sponsored by
City of Lincoln and
Lower Platte South Natural Resources District

August 2010

Watershed News

Antelope Creek Watershed Basin Management Plan

The City of Lincoln and Lower Platte South Natural Resources District (NRD) are working with a project team of scientists and engineers to establish the Antelope Creek Watershed Basin Management Plan (Basin Plan).

What is the concern with Antelope Creek?

The water quality in a stretch of Antelope Creek starting at the outlet of Holmes Lake Dam and extending to Salt Creek (Figure 1, page 2), contains elevated levels of E. Coli bacteria, ammonia, and other contaminants that are considered to cause impairments to everyday uses of the creek. The Nebraska Department of Environmental Quality (NDEQ), as required by the Environmental Protection Agency (EPA), has listed Antelope Creek on the State list, known as the 303(d) list. These contaminants may pose a public health and safety risk.

Levels of E. Coli bacteria and ammonia in Antelope Creek could pose a threat to public health and safety if actions are not taken to improve the water quality.

What is being done to improve the water quality?

The Basin Plan will serve as a road map for actions to improve the water quality in the creek in order to potentially remove it from the NDEQ 303(d) impaired waters listing. Improved water quality in the Antelope Creek will lead to improved public health, safety, and welfare as well as increased aesthetics and other natural benefits to Antelope Creek and adjacent areas.

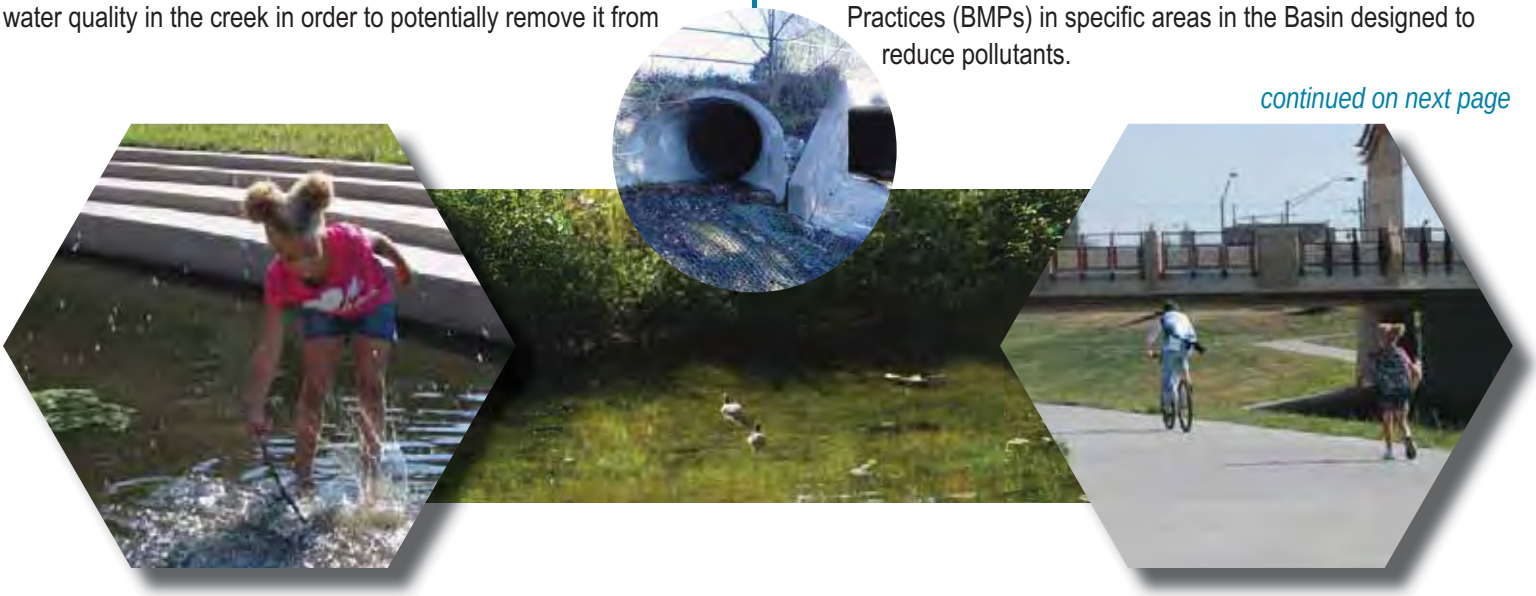
How is the Basin Plan different than the Antelope Valley Project?

The Basin Plan focuses on improvement of water quality in the creek through reduction of pollutants in stormwater runoff. The Antelope Valley Project focused on infrastructure improvements to reduce the threat of flooding in the City, improve transportation, and create recreational and economic development opportunities. Other master plans completed by the City and NRD have focused on drainage, stream bank erosion, and protection of property and infrastructure from flooding, as well as water quality.

What will the Basin Plan do to improve water quality?

The Basin Plan will serve as a tool for the City and NRD staff, as well as other planning and design engineers, to proactively forecast, evaluate, and manage stormwater quality impacts. The plan will identify and manage stormwater quality issues associated with existing and future re-development of the City through identification of structural and non-structural Best Management Practices (BMPs) in specific areas in the Basin designed to reduce pollutants.

continued on next page



Antelope Creek Watershed Basin Management Plan

continued from page 1

Who is paying for the Basin Plan and when will it be complete?

The City of Lincoln and Lower Platte South NRD are splitting the cost of the Basin Plan. The project began in May 2010 and is anticipated to be complete by September 2011. The Basin Plan will help the City and NRD when applying for Federal and State funds to assist with design and construction costs necessary in order to implement solutions identified in the plan.

What are possible ways to improve water quality?

Water quality can be improved through both structural and non-structural solutions. Some examples of structural solutions include:

- bioswales
- rain gardens
- hydrodynamic separators
- wetland areas
- sand filters
- grassed buffers/bio-retention
- channel stability
- pervious pavement
- Silva Cells
- rain barrels
- infiltration basins

Non-structural solutions, many of which are being implemented in Lincoln, may include programs within the basin to encourage activities such as:

- cleaning up after pets
- use of low phosphorus or phosphorus free fertilizers
- use of phosphate-free detergents for washing vehicles
- sweeping excess fertilizers from paved areas
- cleaning up gutters, sidewalks, and driveways
- proper disposal of household hazardous waste
- storm drain stencilling
- street sweeping

Figure 1: Project Area

Project Area Demographics

48,500 full time residents and 8,500 UNL students live and work within the Antelope Creek Basin.

Vegetated Bioswale

Pervious Pavement

Bufferstrip

Bio-Retention

Wetland

Rain Barrel

Rain Garden

Meet the Team

Ed Kouma, PE

Role City of Lincoln Project Manager

Professional Summary B.S. in Civil Engineering from UNL, Engineer with the Watershed Management Division of City of Lincoln Public Works & Utilities

Personal Interest in the Project I feel the most important part of my job is public education about water resources. Each of us has a role to play in protecting the quality of runoff water and managing it in a way that protects our streams and lakes. As the awareness of personal responsibility grows, we will see the results in the improvement of the environment around us. This Basin Management Plan will give us the understanding of water quality issues within this basin and provide tools which may be used to continue the City's on-going efforts of improving the quality of water in our lakes and streams.

Dale Schlautman, PE

Role Consulting Team Project Manager

Professional Summary Civil Engineer, M.S. in Agricultural and Biological Systems Engineering from UNL. Employed by EA Engineering, Science and Technology for 18 years, Dale serves as the Lincoln Branch Manager.

Personal Interest in the Project I believe that the most satisfying projects are those that make a real difference in our community. The Basin Plan is one of those projects. Through this project, the City of Lincoln and the Lower Platte South NRD have the opportunity to improve the environment in which we live and raise our families. Improving water quality in urbanized areas is particularly challenging and the solutions identified will not only help the Antelope Creek Basin, but can be applied to other watersheds throughout the City and the NRD.

*more information...*visit lincoln.ne.gov (keyword: watershed)

The Project Team

This is a joint project led by the City of Lincoln and the Lower Platte South Natural Resources District.

The consulting team is comprised of EA Engineering Science and Technology in association with JEO Consulting Group, Inc. and Wright Water Engineering.

For more information, contact:

Ed Kouma, PE
City of Lincoln
Lincoln Public Works/Utilities Department
402.441.7018 | Phone
402.441.8609 | Fax
ekouma@lincoln.ne.gov
Visit www.lincoln.ne.gov
(keyword: watershed)

Antelope Creek Basin Plan Advisory Council

The Basin Plan is being developed under the guidance of an Advisory Council appointed by Mayor Beutler that will meet periodically throughout the project. The Advisory Council includes both citizens and a core work group of technical representatives. The Council will provide ideas and concerns, review key findings, provide input about problem areas, and review final recommendations. The 12-member council includes representatives from neighborhoods, business owners, and various agencies.

Non-profit Agency ..... Mike Renkin, NeighborWorks
Schools ..... Scott Wieskamp, Lincoln Public Schools
Business Group ..... Andrew Campbell, Campbell's Nursery
Business Group ..... Steve Hill, Assurity
UNL ..... Jennifer Dam, Planner
Golf Course ..... Dale Hardy, Golf Administrator
Lincoln Children's Zoo ..... John Chapo, President
Neighborhood Group ..... Tracy Corr, 40th & A Streets Neighborhood
Neighborhood Group ..... Bob Kuzelka, Near South Neighborhood
UNL Water Center ..... Rachael Herpel
LPSNRD Board ..... Karen Amen
City Council ..... Adam Hornung

Core Work Group
City of Lincoln Planning ..... Sara Hartzell
City of Lincoln Public Works ..... Ben Higgins
Ed Kouma
Miki Esposito
City of Lincoln Parks and Recreation ..... Terry Genrich
LPS NRD ..... Paul Zillig
JB Dixon
NDEQ ..... Mary Schroer

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City of Lincoln and Lower Platte South Natural Resources District

Open House

Antelope Creek Watershed Basin Management Plan

Charles H. Gere Library

2400 South 56th Street (56th & Normal)

Thursday, September 30, 2010 | 5:00 - 7:30 pm

Presentations at 5:30 and 6:30
open discussion and 20 minute presentation (shown twice) with City and NRD staff and the scientist and engineers working on the Basin Plan to improve water quality in Antelope Creek.

You are invited to attend an
Open House to learn about the Basin Plan and
provide input to the project team.

Bring your family, invite a friend, and take an active role in
improving the health of your watershed!

A Publication Sponsored by
City of Lincoln and
Lower Platte South Natural Resources District

January 2011 | *Volume 2of4*

Watershed News

Antelope Creek Watershed Land Uses and Pollutant Loads

Due to the urbanized nature of the Antelope Creek Watershed, the pollution in stormwater runoff (particularly E.Coli bacteria and ammonia) has become a concern to the City of Lincoln and Lower Platte South Natural Resources District (NRD). Stormwater runoff originates from precipitation events such as rainfall or snowmelt. As stormwater drains through the watershed towards the creek as runoff, pollutants, such as fertilizers from lawns and animal waste, travel with the water into the creek. The City of Lincoln and the NRD are working together to improve water quality, by managing the amount of pollutants in stormwater runoff as part of the Antelope Creek Watershed Basin Management Plan (Basin Plan).

The Storm Drain System

Stormwater runoff is collected through a system of curbs and gutters, open channels, and pipes that create the storm drain system. Runoff is discharged into the creek at approximately 221 known locations along the 5.5 miles of Antelope Creek in the Basin Plan project area. The project team has been collecting and testing water samples at approximately 17 of the outfalls during dry-weather. Nine locations along Antelope Creek have also been sampled both during dry weather and after a rain.

Land Uses in Antelope Creek

Land use categories describe how property owners utilize the land, such as residential for homes, commercial for businesses, and industrial for manufacturing. The amount of stormwater runoff can vary greatly depending upon the type of land use. Lower intensity land uses, such as residential lots, allow a greater amount of stormwater runoff to infiltrate into the ground, while higher intensity land uses (commercial or industrial areas) allow runoff to move rapidly across impervious surfaces and travel more rapidly into the creek. Impervious surfaces, such as parking lots and rooftops, convey stormwater runoff quickly compared to more permeable surfaces such as lawns, golf courses, and open spaces. A breakdown of land uses in the Basin Plan project area is found in Table 1.

Table 1: Land Use Type	Total Acres	Percentage of Project Area
Single Family Residential	1,879	38%
Multiple Family Residential	309	6%
Commercial (Shopping Areas)	182	4%
Industrial	94	2%
Public/Quasi-Public (Schools)	639	13%
Transportation (Roads)	1,261	25%
Park/Recreation/Open Space	569	12%
TOTAL	**4,933**	**100%**

Source: City of Lincoln/Lancaster County Planning Department

Stormwater Runoff Potential - Typical Single Family Lot

Over 38% of the project area consists of approximately 10,000 single-family residential lots. The figures below show stormwater runoff amounts from an example residential lot (Figure 1). The same lot is shown in Figure 2 with two rain barrels, a rain garden, and pervious pavement.

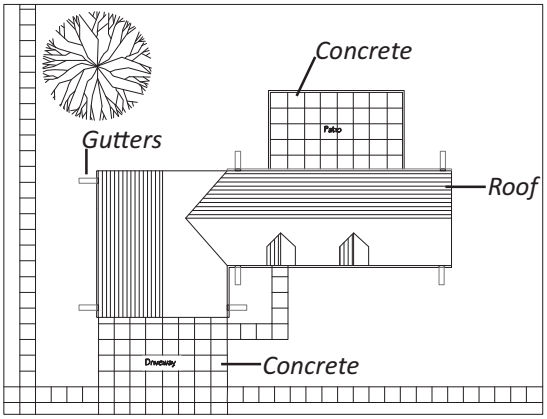

Figure 1 - Typical Lot
Lot Size: 14,520 sq. ft. | Total Coverage: 5,176 sq. ft. (36%)
One Inch Rain Runoff Potential: 3,230 gallons

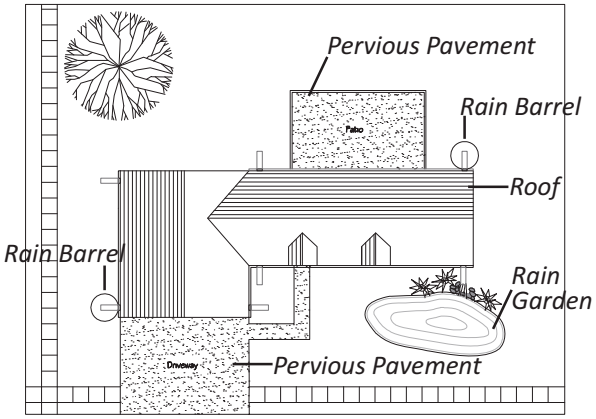

Figure 2 - Typical Lot with Best Management Practices
Lot Size: 14,520 sq. ft. | Total Coverage: 5,176 sq. ft. (36%)
Pervious Pavement: 1,630 sq. ft. (11%)
One Inch Rain Runoff Potential: 1,343 gallons

The roughly 1,900 gallons retained from a one inch rain event might seem small until it is multiplied by the approximately 10,000 lots within the watershed. The water retained on each lot will infiltrate into the ground and replenish groundwater tables and be filtered prior to entering Antelope Creek. Along with reducing the quantity of water flowing rapidly into Antelope Creek, it would also reduce the pollutant loads into Antelope Creek. Residents using rain barrels will also be able to reuse the rainwater during dry weather conditions, reducing their water bill over time.

Open House Summary

A key component to the success of the Basin Plan is public input and education. The project overall will include four newsletters, Advisory Council meetings, stakeholder meetings, a website, and interest group meetings focusing on neighborhood associations and commercial property owners. The first of two open houses was held September 30, 2010, with nearly 100 people in attendance; the final Open House is anticipated for July 2011. Below are a few questions from those attending with corresponding answers from the first Open House meeting:

Q: How can an individual property owner have a positive impact on the watershed?

A: *Individuals can do simple things like using a non-phosphorus fertilizer, sweeping excess fertilizer from sidewalks and driveways, and picking up pet waste. If a lot of property owners each do a little, there will be a positive impact on the basin with improved water quality.*

Q: How will projects identified in the Basin Plan be funded?

A: *City of Lincoln Storm Bonds, Lower Platte South NRD Funds, and grants received from the Nebraska Department of Environmental Quality are key funding sources.*

Q: Will this Basin Plan eliminate flooding issues in the Antelope Creek?

A: *The Basin Plan focuses on improving water quality, not reducing flooding impacts. Numerous other plans completed by the City and NRD have focused on flood control.*

Congratulations!

Eldon Ogorzolka won a rain barrel at the open house, provided by the City of Lincoln.

Meet the Team

Dr. Robert Pitt

Role: Technical Consultant (Wright Water Engineering)
Professional Summary: PhD from the Univerisity of Wisconsin, MSCE from San Jose State University, and B.S. from Humboldt State University
Personal Interest in the Project: Helping to solve environmental problems is a challenge and a very rewarding experience for me, especially when applying research results to actual situations. My interest in this project is helping to develop cost-effective solutions that build on current knowledge by applying newly developed robust technologies.

Paul Zillig

Role: Lower Platte South NRD Project Manager
Professional Summary: B.S. in Natural Resources and Agricultural Economics from UNL, Assistant Manager for the Lower Platte South NRD
Personal Interest in the Project: I live in the Antelope Creek Watershed above Holmes Lake and recreate along Antelope Creek on the Billy Wolff Trail, the Ager Junior Golf Course, and Union Plaza in Antelope Valley. The NRD has improved water quality in Antelope Creek by nearly eliminating streambank erosion. The challenge now is to continue to find ways to reduce non-point source contaminants to acceptable levels.

more information...visit lincoln.ne.gov (keyword: watershed)

The Project Team

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The consulting team is comprised of EA Engineering Science and Technology in association with JEO Consulting Group, Inc. and Wright Water Engineering.

For more information, contact:

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Lincoln Public Works/Utilities Department
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ekouma@lincoln.ne.gov
Visit www.lincoln.ne.gov
(keyword: watershed)

Project Schedule	
2011	**Tasks**
Winter	• Identify Pollutant Sources • Identify Best Management Practices
Spring	• Water Quality Monitoring • Establish Projects to Improve Water Quality
Summer	• Open House #2 • Final Plan
Ongoing	• Informational and Educational Process

Advisory Council

Roles and responsibilities of the Advisory Council are to review elements of the process, ask questions, raise issues, and share information with one another, the public, and the project team.

Non-profit Agency ..... Mike Renkin, NeighborWorks
Schools ..... Scott Wieskamp, Lincoln Public Schools
Business Group..... Andrew Campbell, Campbell's Nursery
Business Group..... Steve Hill, Assurity
UNL ..... Jennifer Dam, Planner
Golf Course ..... Dale Hardy, Golf Administrator
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Neighborhood Group ..... Tracy Corr, 40th & A Streets Neighborhood
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City Council..... Adam Hornung

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Antelope Creek Pollutant Sources

In order to assemble management strategies to improve water quality a 'basin inventory' was completed by the project team during the summer and fall of 2010. Information collected included; water sampling data, field notes, outfall locations, historical records, and a land use breakdown. The information collected is being used to help identify possible sources of pollution in the watershed. Below is a summary of some possible pollutant sources:

Wildlife and Pet Waste – Twenty-nine bridge crossings were found, many of which are older and allow birds to nest and perch, where their droppings may contribute to some contaminants in the creek. Many new bridges nearly eliminate areas for birds to perch. Existing habitat in the watershed provides room for wildlife such as raccoons, squirrels, and feral animals that contribute to pollution sources. Domesticated pets, such as dogs and cats, can also provide a significant source of pollution if waste is not properly disposed.

Fertilizers and Phosphorus in Soils – Excess nutrients in the stream, which may originate from over-fertilizing and soil erosion, contribute to algal blooms in the water. Improper storage and disposal of fertilizers or incidental application to impervious surfaces, such as concrete driveways and sidewalks, can lead to nutrients entering the creek through stormwater runoff.

A Publication Sponsored by City of Lincoln and Lower Platte South Natural Resources District

September 2011 | *Volume 3of4*

Watershed News

Antelope Creek Watershed Basin Management Plan

Over the past year Antelope Creek has been studied, monitored, and modeled to determine sources of potential contamination. Information gathered will be utilized for the Antelope Creek Watershed Basin Management Plan (Basin Plan). The Basin Plan will outline the most effective pollution reduction strategies to improve the water quality of Antelope Creek. The Basin Plan will describe actions the City of Lincoln (City) and Lower Plate South Natural Resources District (NRD) can take to improve water quality over the next several years. Actions will include reducing bacteria in the stream and minimizing loadings of pollutants such as nutrients and sediments. Below is a summary of the lessons learned over the last year and descriptions of potential alternatives that the project team is considering.

What Have We Learned?

Pollutant sources contributing to bacteria in Antelope Creek do not appear to be point sources, such as illegal discharges, malfunctioning sanitary sewer lines, or runoff directly contributed by a single property. Bacteria in Antelope Creek appears to originate from several general sources across the entire watershed. These potential non-point sources include birds and other wildlife, pet waste, and urban stormwater runoff (which collects bacteria from gutters, rooftops, etc.).

Once bacteria enter Antelope Creek, the stream system holds and incubates bacteria through natural functions. Overall, the amount of bacteria that occurs in Antelope Creek is typical of streams in other urban areas across the U.S. The U.S. Environmental Protection Agency's (EPA) nationwide standard for bacteria levels in recreational stream segments, such as Antelope Creek, are stringent and very challenging to meet without going to the large expense of intensive instream treatment alternatives. Therefore, the goals are to work toward a sustainable reduction of pollutant levels. These goals will guide project and program development as part of final plan recommendations.

{Waterfowl Commonly Use the Creek}

{EA Staff Collecting Wet Weather Field Data, Spring 2011, Near Holmes Lake}

What is the Next Step?

As part of the Basin Plan, the consultant team will outline activities for the City and NRD to implement that will focus on reducing bacteria levels and improving the overall health of Antelope Creek. Regulatory agencies, such as EPA and the Nebraska Department of Environmental Quality (NDEQ), monitor activities that communities are taking to improve water quality in impaired streams such as Antelope Creek. Establishment of the Basin Plan is a vital step in working

continued on next page

Antelope Creek Watershed - continued from page 1

towards regulatory goals set up by the EPA and NDEQ. Below is a summary of stormwater controls that are being considered for incorporation in the Basin Plan.

{Wet Weather Flows Near Confluence with Salt Creek}

{Lincoln Children's Zoo Rain Garden}

Potential Structural Stormwater Controls

- Roof runoff: rain gardens, disconnection of downspouts from the storm drain, rain barrels
- Pavement runoff: redirection of gutters that flow onto pavements, bio-filtration, porous pavement, retrofitting parking lots to infiltrate stormwater runoff
- Street side drainage: grass swales and curb-cut bio-filters
- Outfalls: wet detention ponds and retrofitting dry ponds
- Grass areas: buffer strips, tall grass
- Birds: retrofit bridges to limit roosting and nesting

Potential Non-Structural Stormwater Controls

- Pet waste: pick-up after pets programs
- Lawn care: encourage non-phosphorus fertilizers, limiting lawn fertilizing, sweep excess fertilizer
- Operation and maintenance: plan for sediment removal from selected creek areas
- Public Work practices: street sweeping and catch basin cleaning

Where larger spaces are available, a combination of practices, called a treatment train, would be the most efficient method of improving or limiting stormwater runoff. The above listed control practices are currently being evaluated based largely on the land use and availability of space to construct a project.

Plan Recommendations

Previous research and data analysis is being used for the evaluation of several alternatives, including potential residential area demonstration projects (10 to 20 acre areas) in select locations of the Antelope Creek watershed. Also being looked at are watershed based incentive programs, city policy changes, and other programs and projects. Recommendations for specific project locations and sizes are being determined.

Recommended projects and programs will be provided at an upcoming Open House, planned for November 2011.

The Basin Plan is scheduled to be finalized in December 2011, following review and approval by the City and NRD. The next step will be to incorporate projects and programs into capital improvement programs, seek funding for construction and implementation, and continue to inform and educate the public on the numerous environmental benefits effected by the Basin Plan. Lessons learned from the Basin Plan will be incorporated into future planning efforts city-wide.

more information...visit lincoln.ne.gov (keyword: watershed)

Use your smartphone and a QR reader app to view the website.

Meet the Team

Jane Clary

Role: Technical Expert (Water Quality)
Professional Summary: Senior Water Resources Scientist at Wright Water Engineers, Inc. in Denver, Colorado. Jane's background includes an M.S. in Environmental Science from the University of Colorado and a B.S. in Economics from Vanderbilt University. She serves as a Project Manager on the International Stormwater Best Management Practices (BMP) Database project, which she has been involved with for over 15 years.
Personal Interest in the Project: The Antelope Creek project is of significant interest to Jane because it provides an opportunity to work with a community committed to water quality improvement in the challenging context of bacteria pollutants.

Jon Trombino, PE

Role: Project Manager/Engineering Lead
Professional Summary: Engineer, B.S. from the University of Nebraska in Biological Systems Engineering. Project manager and professional engineer with EA Engineering, Science, and Technology in Lincoln, Nebraska for 6 years.
Personal Interest in the Project: "My entire career I have been very interested in low impact design concepts. A big piece of the low impact design strategy is the reduction of stormwater runoff quantity and the improvement of water quality. This project involves work in both of those areas. I have really enjoyed studying the watershed and seeing how the different land uses impact the water quality. As we move into the next phase of the project, I am excited to work with our team to develop best management practices that will improve the water quality in Antelope Creek and make it a wonderful asset to the citizens of Lincoln."

The Project Team

This is a joint project led by the City of Lincoln and the Lower Platte South Natural Resources District.

The consulting team is comprised of EA Engineering Science and Technology in association with JEO Consulting Group, Inc. and Wright Water Engineers.

For more information, contact:

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Advisory Council

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City of Lincoln and Lower Platte South Natural Resources District

Monitoring the Water Quality of Antelope Creek

Water quality monitoring is used as a tool for establishing baseline conditions, evaluating potential sources, and improving the effectiveness of future projects used to improve water quality. Monitoring activities have included sediment and water sampling as well as collection of the streams physical parameters such as flow, pH, conductivity, temperature, and dissolved oxygen. Water sampling for this project has been completed during three different time periods at 11 stream locations and 17 outfalls.

- Dry weather sampling – sampling taken after at least four consecutive days without rain. Dry weather sampling is a representation of flows into the stream other than stormwater runoff (such as springs). Dry weather sampling was completed three times and tested for *E. coli* bacteria, total coliform, ammonia, dissolved organic carbon, and total phosphorus.
- Wet weather sampling – many pollutants, including solids, nutrients, metals, and bacteria, are washed into Antelope Creek during rain events. Sampling is conducted within 24-hours after rainfall stops. Samples were tested for the same parameters as the dry weather sampling.
- Sediment sampling – sediment samples were collected at 11 locations twice during the project. These samples were tested for *E. coli* bacteria, chemical oxygen demand, fecal coliform, phosphorus, and total nitrogen. Sediment sampling data helps describe the overall health of the stream.

‘Watershed News’ Newsletter Volume 4 of 4 is anticipated to be delivered April 2012 during public review of the draft plan.

Appendix C - Site Prioritization Ranking Worksheets

SITE 2

PR 1 1
PR 1 2

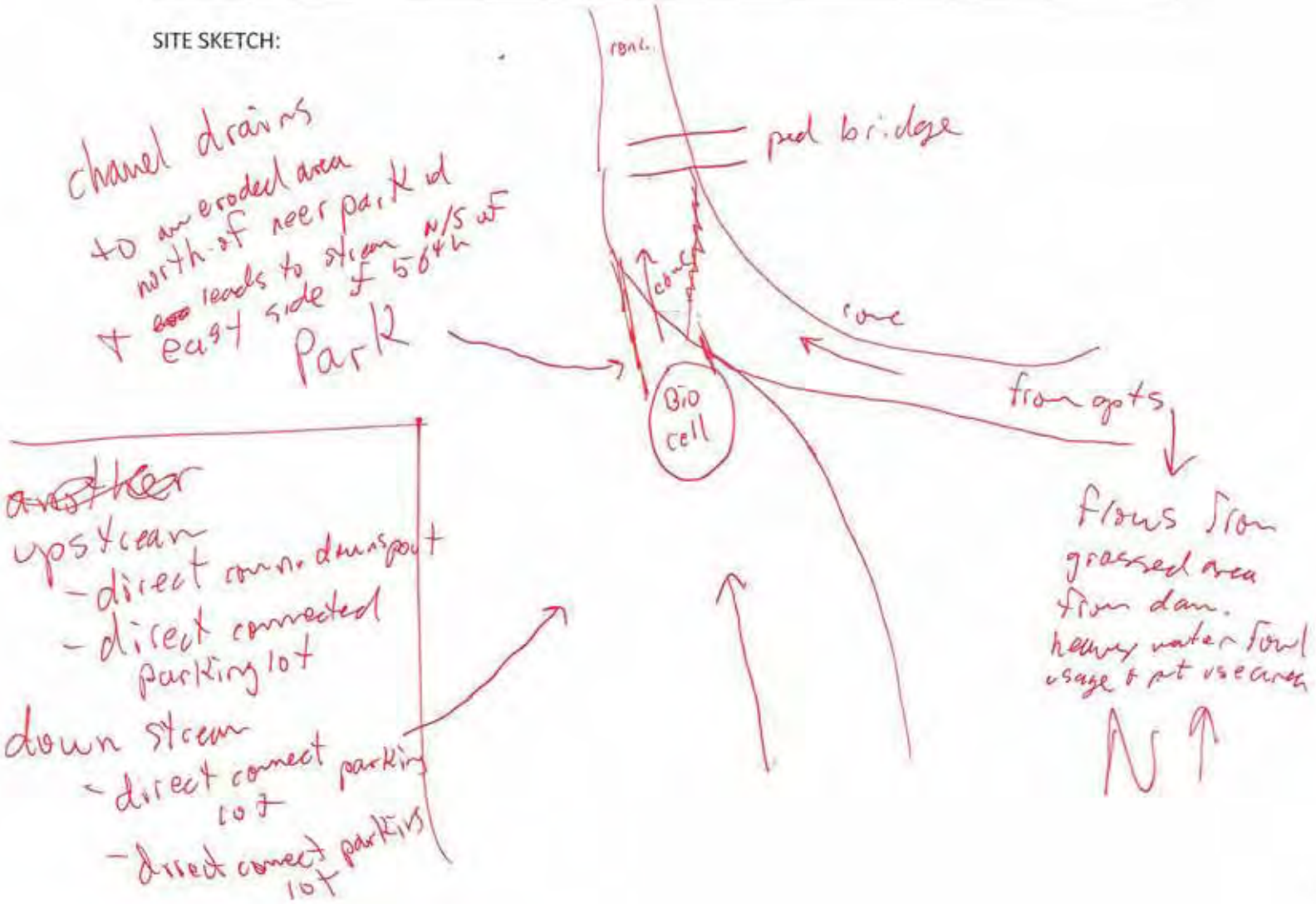
ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 9/22/11
STAFF: Tom T & Jamie S
LOCATION ID #: ~~Park~~ P/R 2
ADDRESS: 56th & north of pioneers
PICTURES AND GPS: (YES) NO #9-~~19~~ pict.
(PUBLIC) or PRIVATE PROERTY #11-19
LAND USE: park
POLLUTANT SOURCES NEARBY: urban wildlife, possible nutrients
TOPOGRAPHY: slopes to concrete channel
MAINTENANCE ACCESS: not ideal, ~~no~~ no streets but up to it, park on street 1 block away
LOCATION DESCRIPTION: park east of 56th concrete channel between houses. Sediment w/in channel but probably can't hydraulically connect

LAND AVAILABLITLY: LOW / MEDIUM / (HIGH)

POTENTIAL PROJECT TYPE: Bio cell, maybe a small hydro sep. but would be impossible to access to remove sediment.

SITE SKETCH:



SITE 2

R1 - 1
R1 - 2

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

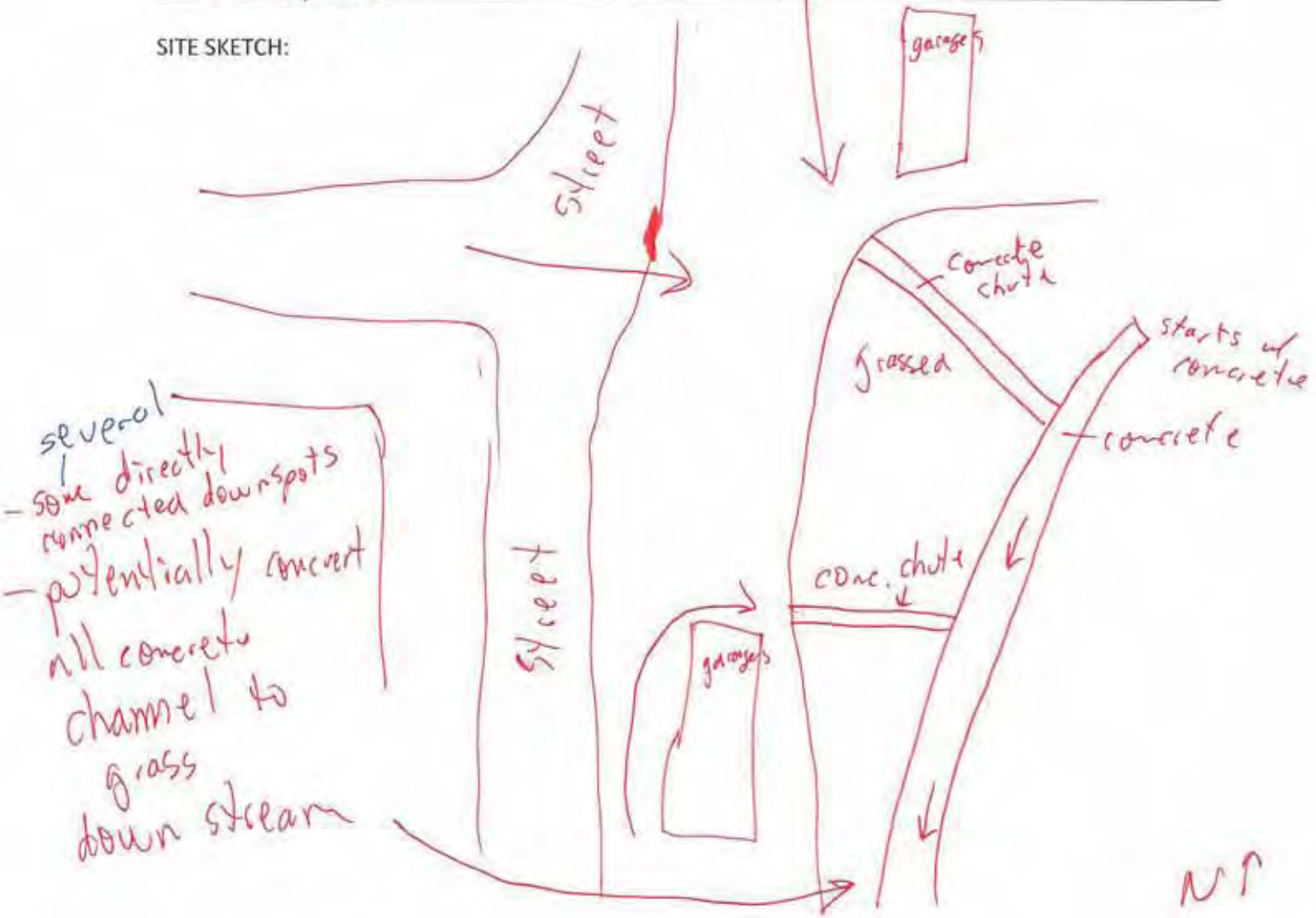
DATE: 9/22/11
STAFF: Jon M & Jamie
LOCATION ID #: R1
ADDRESS: 60th & VanDorn Apts
PICTURES AND GPS: YES NO 20 - 2625
PUBLIC or PRIVATE PROERTY
LAND USE: parking lot for Apts
POLLUTANT SOURCES NEARBY: sediment, nutrients
TOPOGRAPHY: all slopes to 1 area to concrete chute & channel
MAINTENANCE ACCESS: on private property but other than that very ideal

LOCATION DESCRIPTION: parking drains to 2 conc chutes & then to concrete channel which leads to AC.

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Bio-cell or hydro separator. Lot is probably heavily sanded in winter, grass probably fertilized in summer.

SITE SKETCH:



SITE 3

R2_1

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

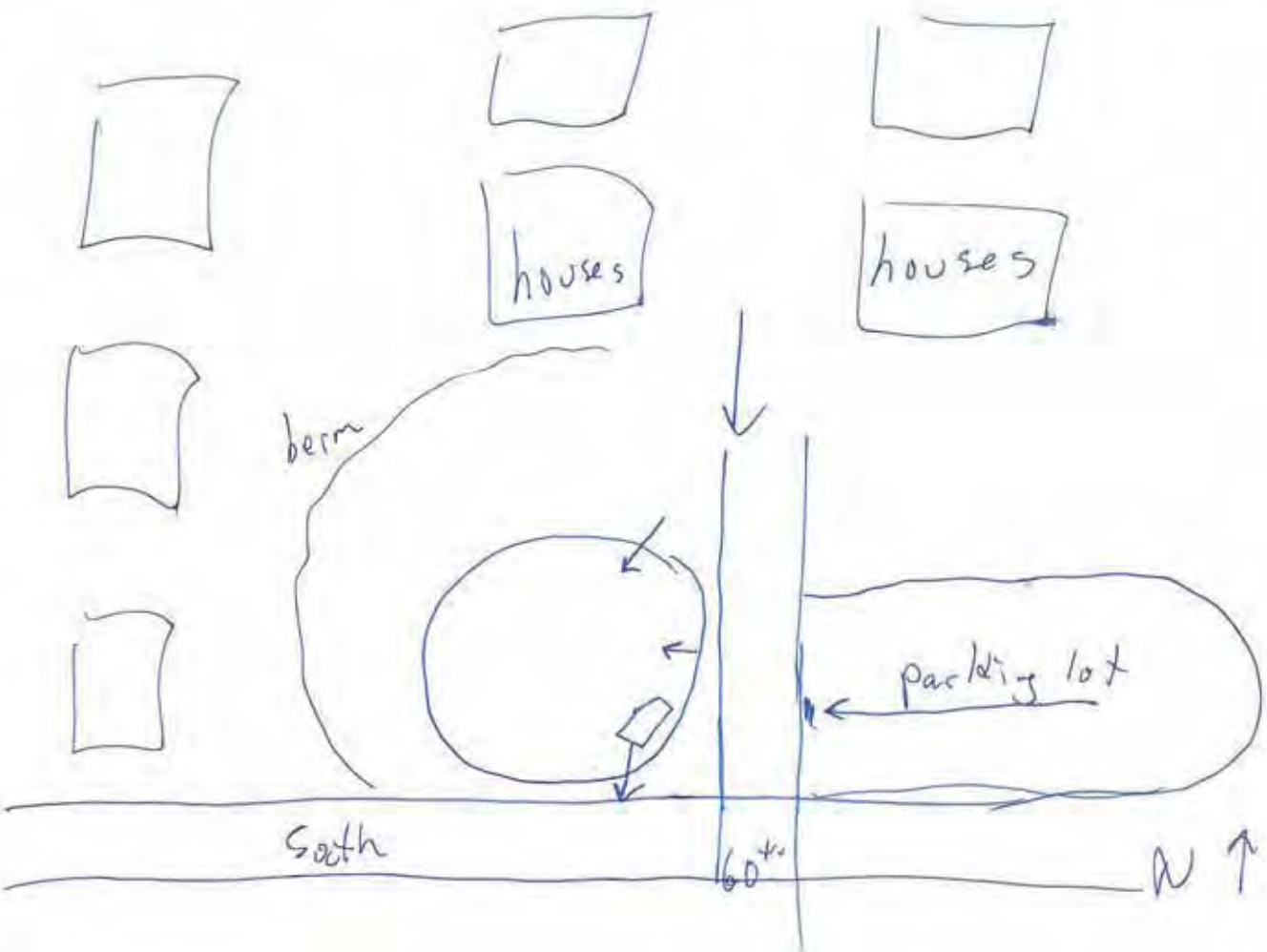
DATE: 9/22/11
STAFF: Jon M.
LOCATION ID #: R2
ADDRESS: 60th & South
PICTURES AND GPS: (YES) NO 26 → 28
PUBLIC or PRIVATE PROERTY – don't know (utility easment)
LAND USE: Parking lot runoff
POLLUTANT SOURCES NEARBY: sediment, nutrients
TOPOGRAPHY: slopes to dry pond
MAINTENANCE ACCESS: ideal

LOCATION DESCRIPTION: dry pond NW of 60th & south
parking lots drain to pond. Pond has inlet/outlet @ same elevation & short cutting most treatment

LAND AVAILABLITLY: (LOW) (MEDIUM) HIGH

POTENTIAL PROJECT TYPE: Make infiltration higher / retrofit

SITE SKETCH:



SITE 4

C1_1

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

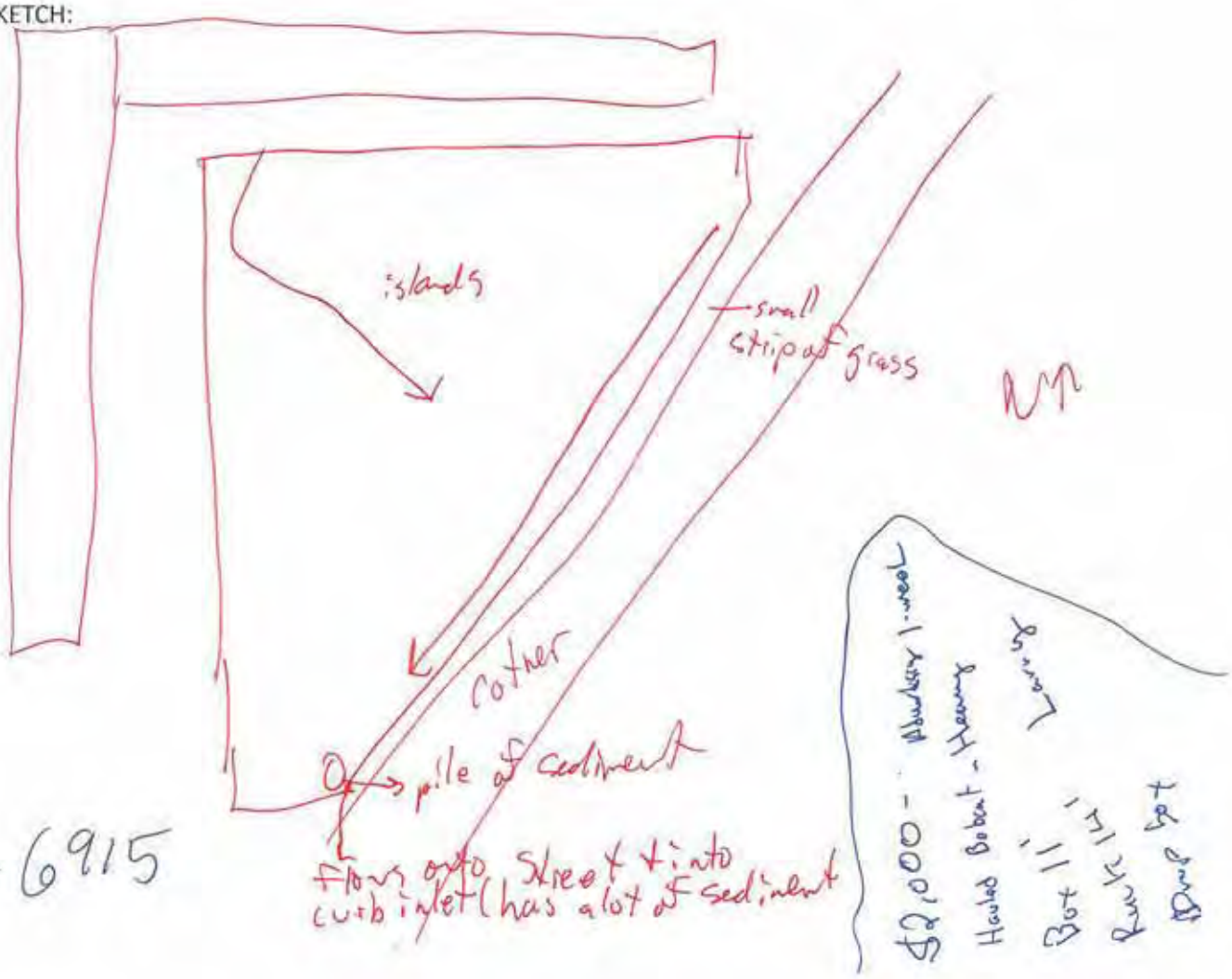
DATE: 9/22/11
STAFF: Jon M. & Jam
LOCATION ID #: C1
ADDRESS: Cotner & Aldrich (Piedmont Shopping area)
PICTURES AND GPS: YES NO 39-4805
PUBLIC or PRIVATE PROERTY
LAND USE: parking lot
POLLUTANT SOURCES NEARBY: lots of sediment, POLs,
TOPOGRAPHY: All slopes to south east
MAINTENANCE ACCESS: ideal

LOCATION DESCRIPTION: Piedmont Mall/Shopping parking lot

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: island bio swales, curb cut bio swales
hydro separator for trash & sediment

SITE SKETCH:



499-6915

SITE 5

I1-1

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

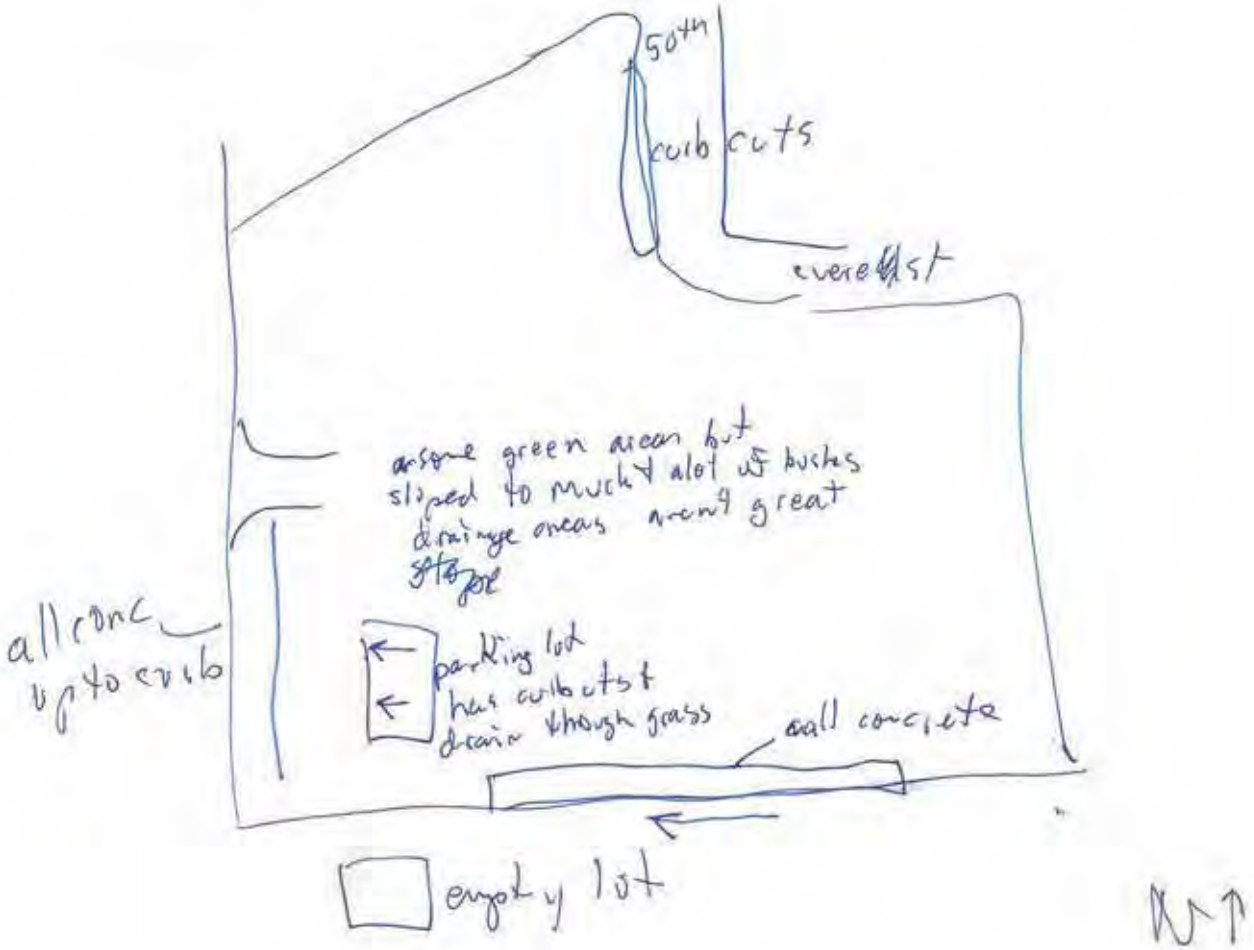
DATE: 9/22/11
STAFF: Jon M. Y
LOCATION ID #: I 1
ADDRESS: Brian LGH East
PICTURES AND GPS: (YES) NO 46447
PUBLIC or (PRIVATE PROERTY)
LAND USE: Institutional
POLLUTANT SOURCES NEARBY: POLS, nutrients, sediment
TOPOGRAPHY: Changes
MAINTENANCE ACCESS: easy

LOCATION DESCRIPTION: Brian LGH

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: curb cuts, inlet traps

SITE SKETCH:



SITE 6

I2_1

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

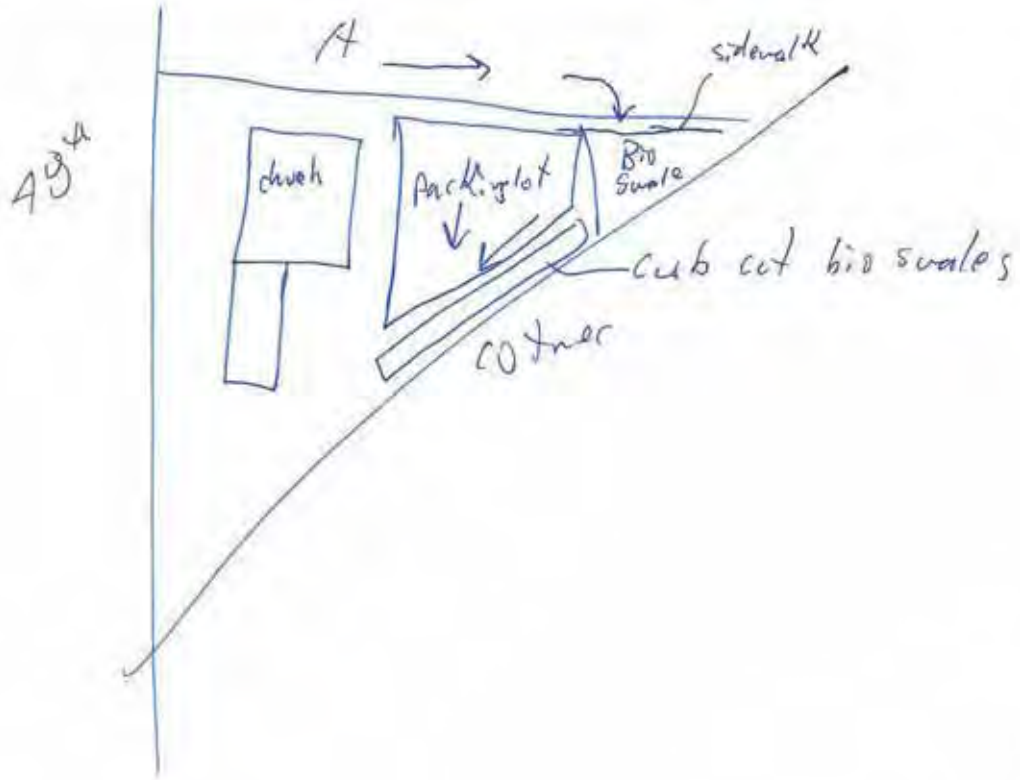
DATE: 9/22/11
STAFF: Jon M Jones
LOCATION ID #: I2
ADDRESS: 50th & A
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY 48 - 53
LAND USE: parking lot & street drainage
POLLUTANT SOURCES NEARBY: sediment piles
TOPOGRAPHY: Slops to inlets on street
MAINTENANCE ACCESS: easy

LOCATION DESCRIPTION: church on ~~50th~~ 48th & A

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: bio swale & curb cuts

SITE SKETCH:



N

SITE 7a

C3_1

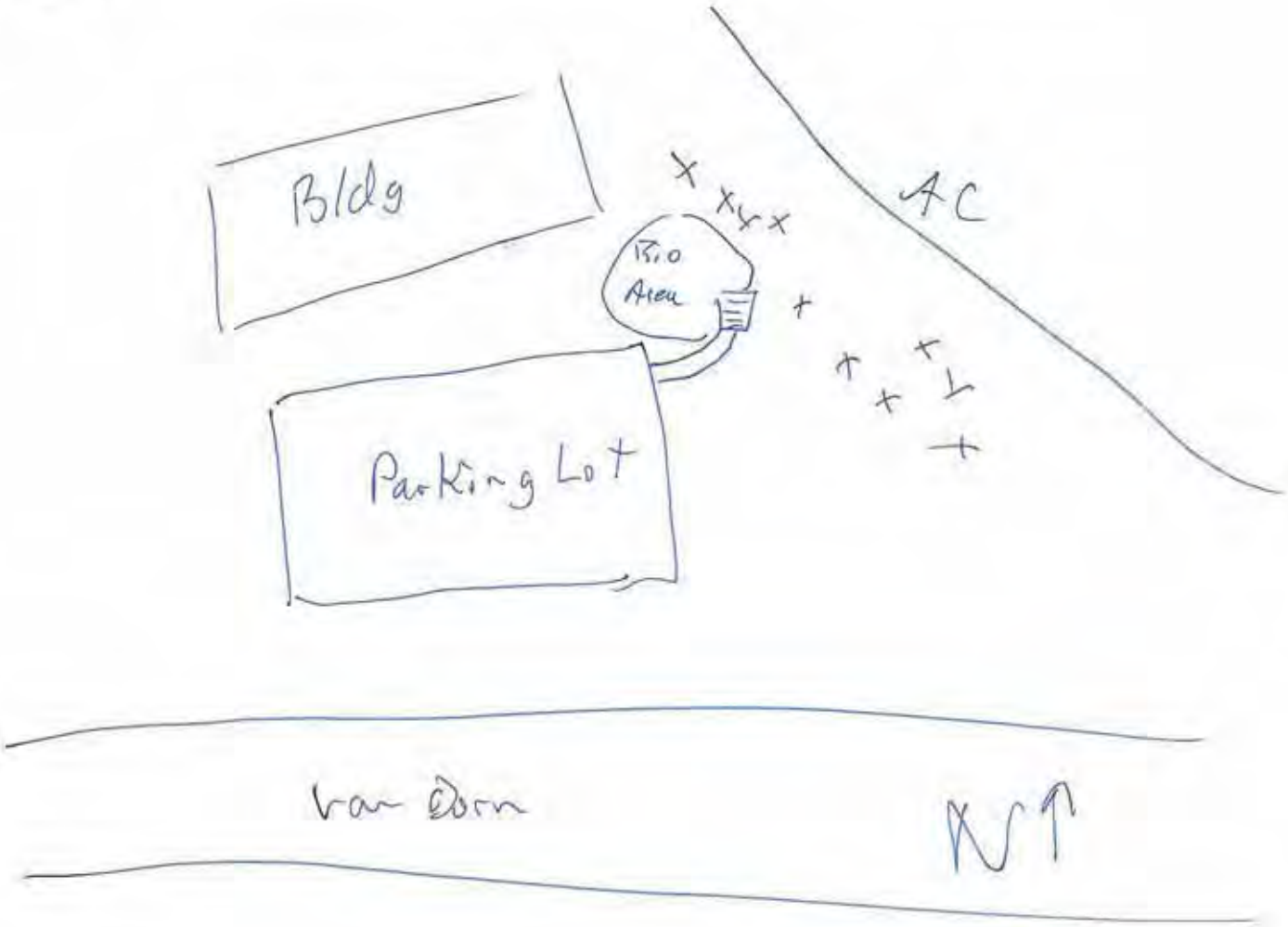
ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 9/22/11
STAFF: Jon M & Jamie
LOCATION ID #: C3
ADDRESS: Post Office on Vandorn
PICTURES AND GPS: YES NO 59-62
PUBLIC or PRIVATE PROERTY – Post offic
LAND USE: Parking lot
POLLUTANT SOURCES NEARBY: Lots of Sediment
TOPOGRAPHY: Parking Lot drains to grate inlet
MAINTENANCE ACCESS: easy
LOCATION DESCRIPTION: Post office on Van Dorn

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Bio swale prior to inlet

SITE SKETCH:



SITE 7b

C2_1

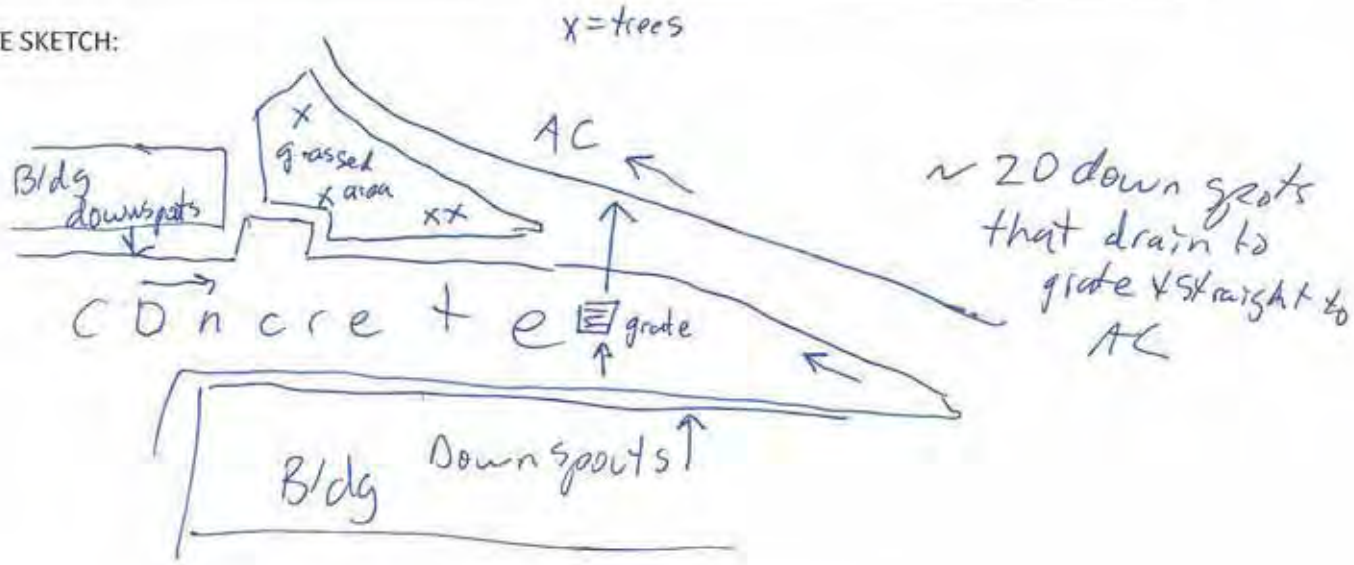
ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

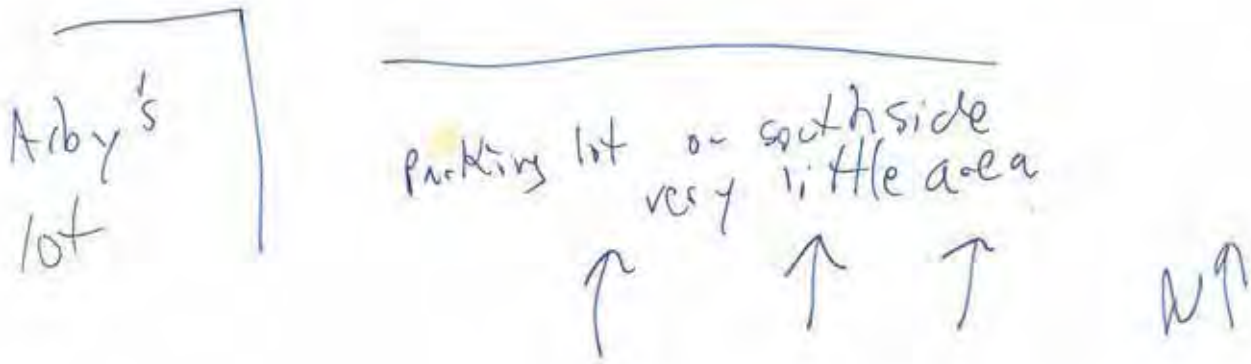
DATE: 9/22/11
STAFF: Jon M. & Jamie S.
LOCATION ID #: C2
ADDRESS:
PICTURES AND GPS: YES / NO 54
PUBLIC or PRIVATE PROERTY
LAND USE: parking lot & roof
POLLUTANT SOURCES NEARBY: metals, sediment, POLs
TOPOGRAPHY: flat & drains to inlet straight to AC
MAINTENANCE ACCESS: easy
LOCATION DESCRIPTION: Northside of Vandorn Plaza

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: bio swale to infiltrate roof on vandorn plaza

SITE SKETCH:





SITE 8

7

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 11/9/11
STAFF: BuCo + JoT
LOCATION ID #:
ADDRESS: 48th & Monterey
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: wildlife low
TOPOGRAPHY: Slopes east to west and west to east school in low spot
MAINTENANCE ACCESS:

bad link out
typo

LOCATION DESCRIPTION: Trees, rooftop, open field east
School parking

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Pervious parking

SITE SKETCH:

SITE 9

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

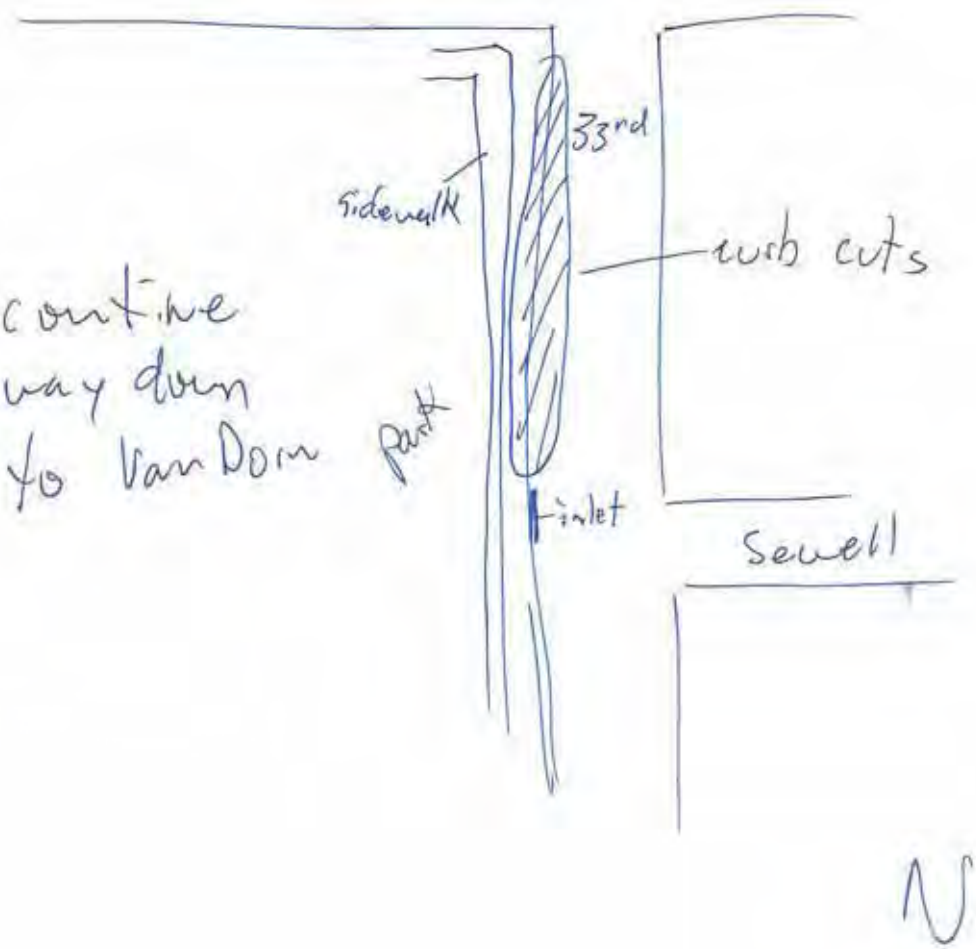
DATE: 9/22/11
STAFF:
LOCATION ID #: P/R 2
ADDRESS: 33 & Sewell
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: ROW
POLLUTANT SOURCES NEARBY: sediment
TOPOGRAPHY: flat
MAINTENANCE ACCESS: easy

LOCATION DESCRIPTION:

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: curb cut bio swale

SITE SKETCH:



can contine all the way down 33rd to Van Dorn part

SITE 10

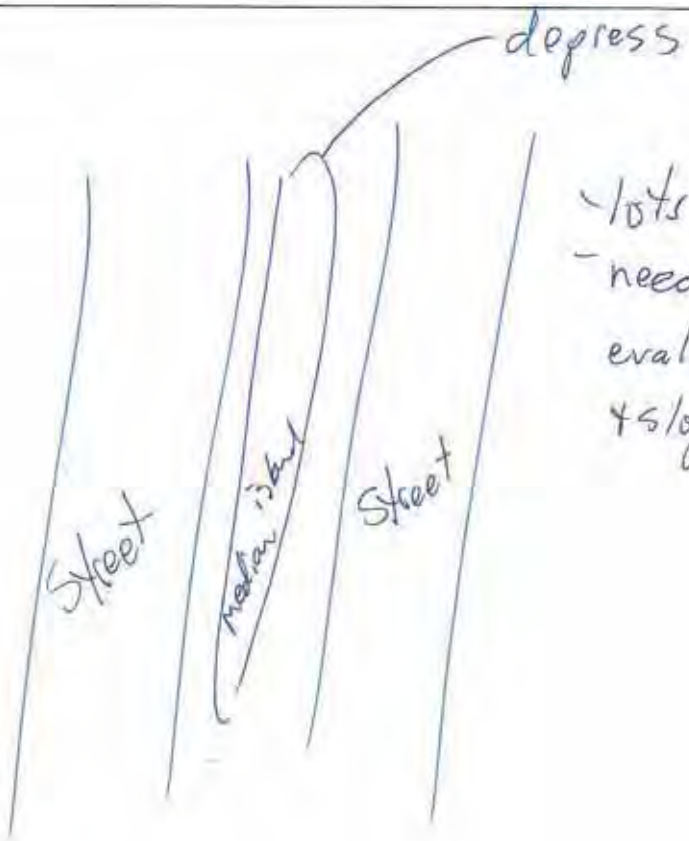
ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 9/22/11
STAFF: Jamie S. Jon M.
LOCATION ID #: ~~Sheridan Street median~~ R3
ADDRESS: ~~Sheridan~~ Bradfield + Stratford
PICTURES AND GPS: YES NO 68-71
PUBLIC or PRIVATE PROERTY
LAND USE: ROW
POLLUTANT SOURCES NEARBY: POC, nutrients, gravel
TOPOGRAPHY: sloped
MAINTENANCE ACCESS: easy
LOCATION DESCRIPTION: median along Bradfield + Sheridan + Stratford Drives

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Bio swales in medians or depressed grass areas w curb cuts

SITE SKETCH:



- lots of area
- needs to be evaluated for flow + slope

SITE 11

RS_1

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

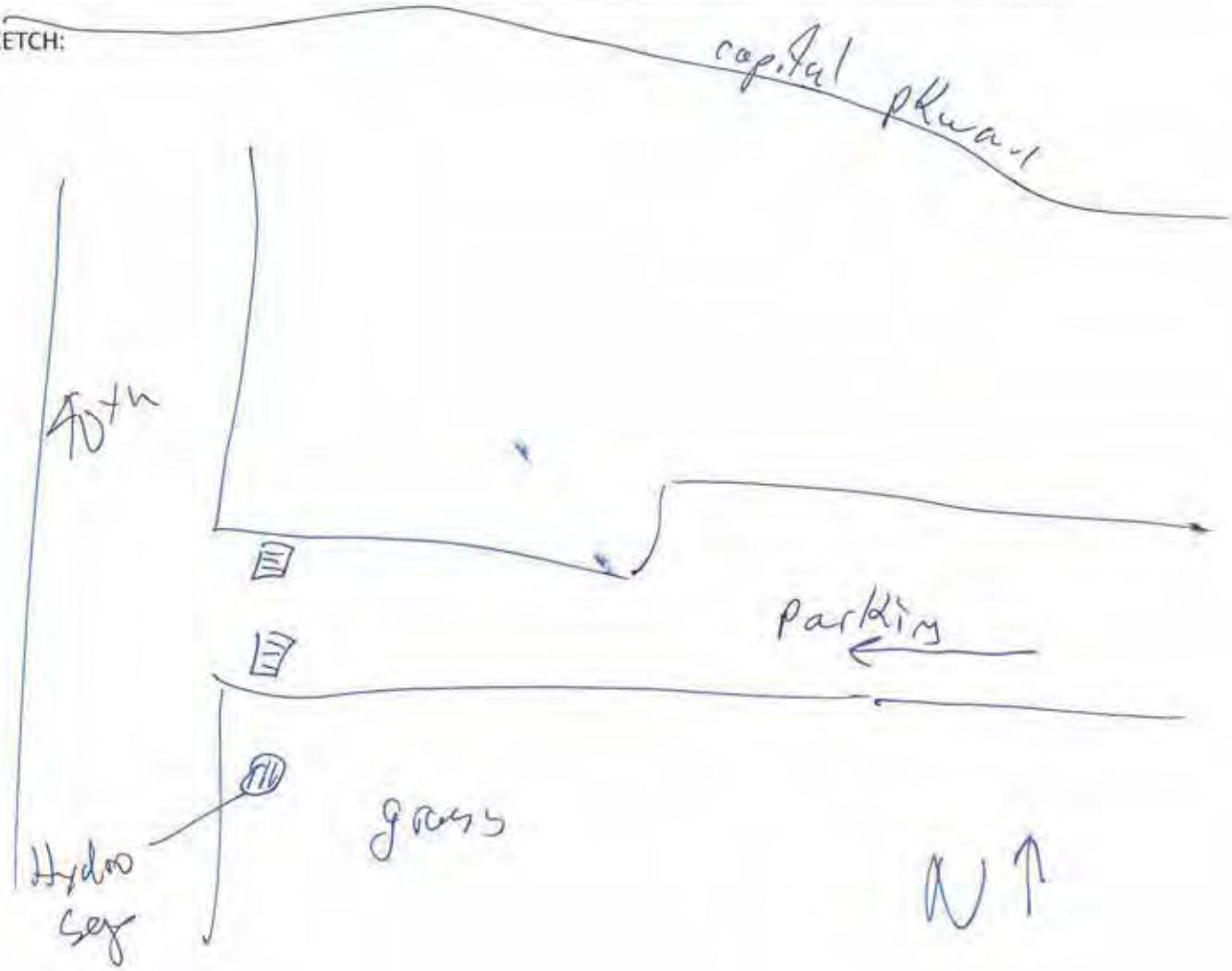
DATE: 7/22/11
STAFF:
LOCATION ID #: R5
ADDRESS: 10th & south capital Pkway
PICTURES AND GPS: YES NO 75-78
PUBLIC or PRIVATE PROERTY
LAND USE: Parking
POLLUTANT SOURCES NEARBY: gravel (lots of gravel)
TOPOGRAPHY: sloped
MAINTENANCE ACCESS:

LOCATION DESCRIPTION: parking lot by apts

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Hydro sep

SITE SKETCH:



SITE 12

R4_1

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

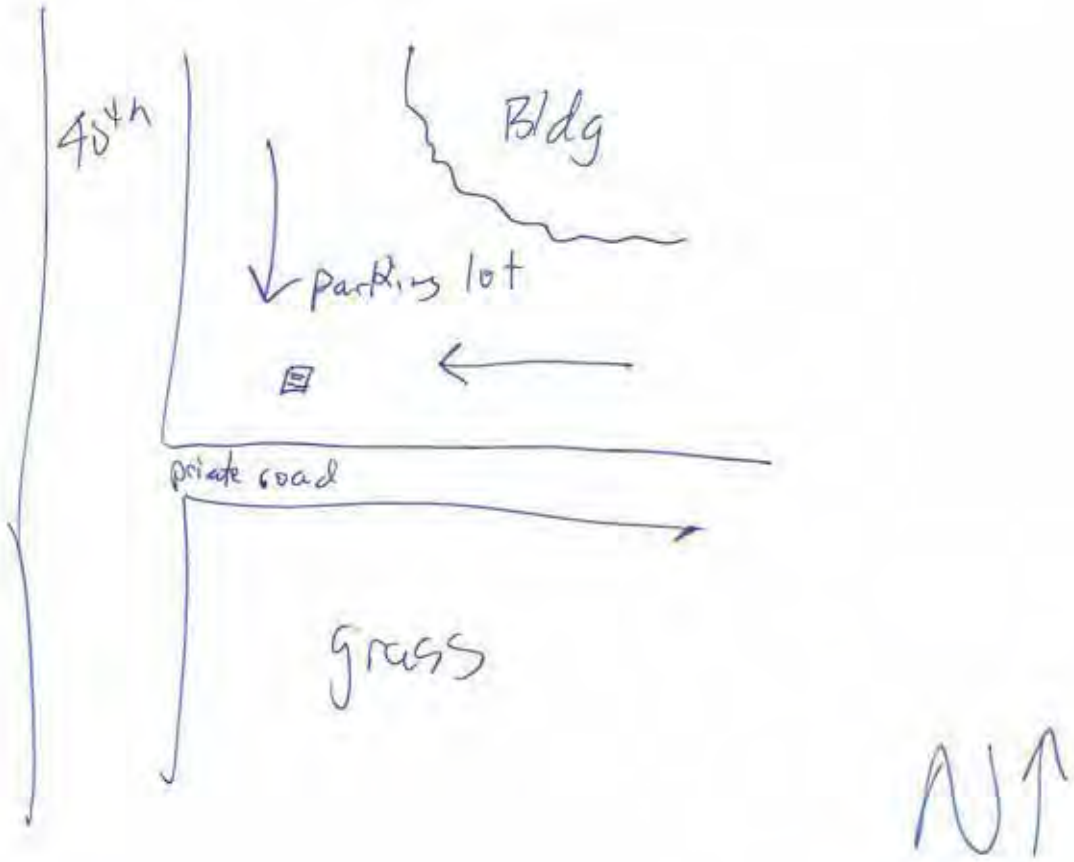
DATE: 9/22/11
STAFF: Jan M. & Janie S.
LOCATION ID #: R4
ADDRESS: 40th & Capital Pkwy
PICTURES AND GPS: YES NO 72-74
PUBLIC or PRIVATE PROERTY both
LAND USE: ROW & private parking lot
POLLUTANT SOURCES NEARBY: sediment & POLS
TOPOGRAPHY: little slope
MAINTENANCE ACCESS: easy

LOCATION DESCRIPTION: parking lot draining to storm grate

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Bio swale

SITE SKETCH:



SITE 13

PR1_83

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

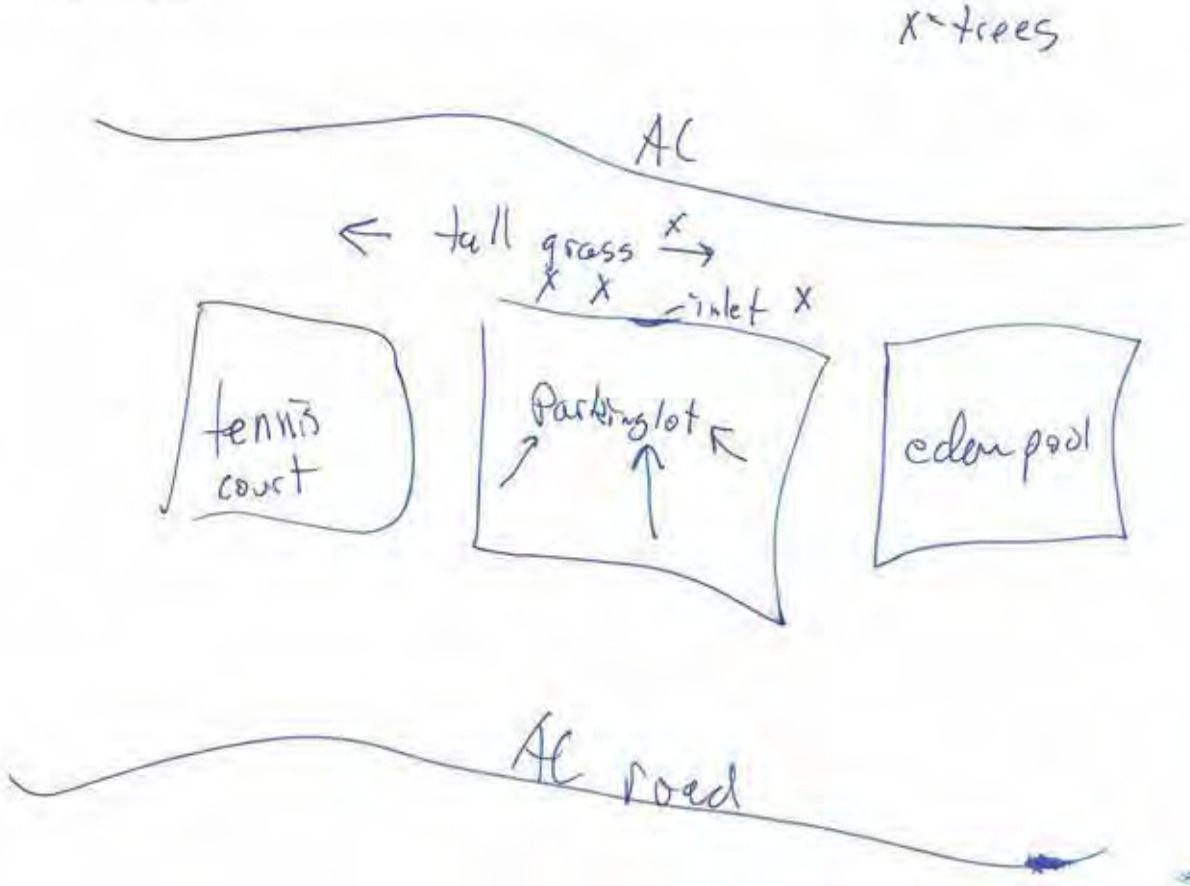
DATE: 9/22/11
STAFF:
LOCATION ID #: P/R 3
ADDRESS: Antelop Creek Rd & west of 18th
PICTURES AND GPS: YES NO -83
PUBLIC or PRIVATE PROERTY
LAND USE: Parking lot
POLLUTANT SOURCES NEARBY: gravel & POLs
TOPOGRAPHY: flat
MAINTENANCE ACCESS: easy

LOCATION DESCRIPTION: Parking lot next to pool

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Bio swale on north side

SITE SKETCH:



SITE 14

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

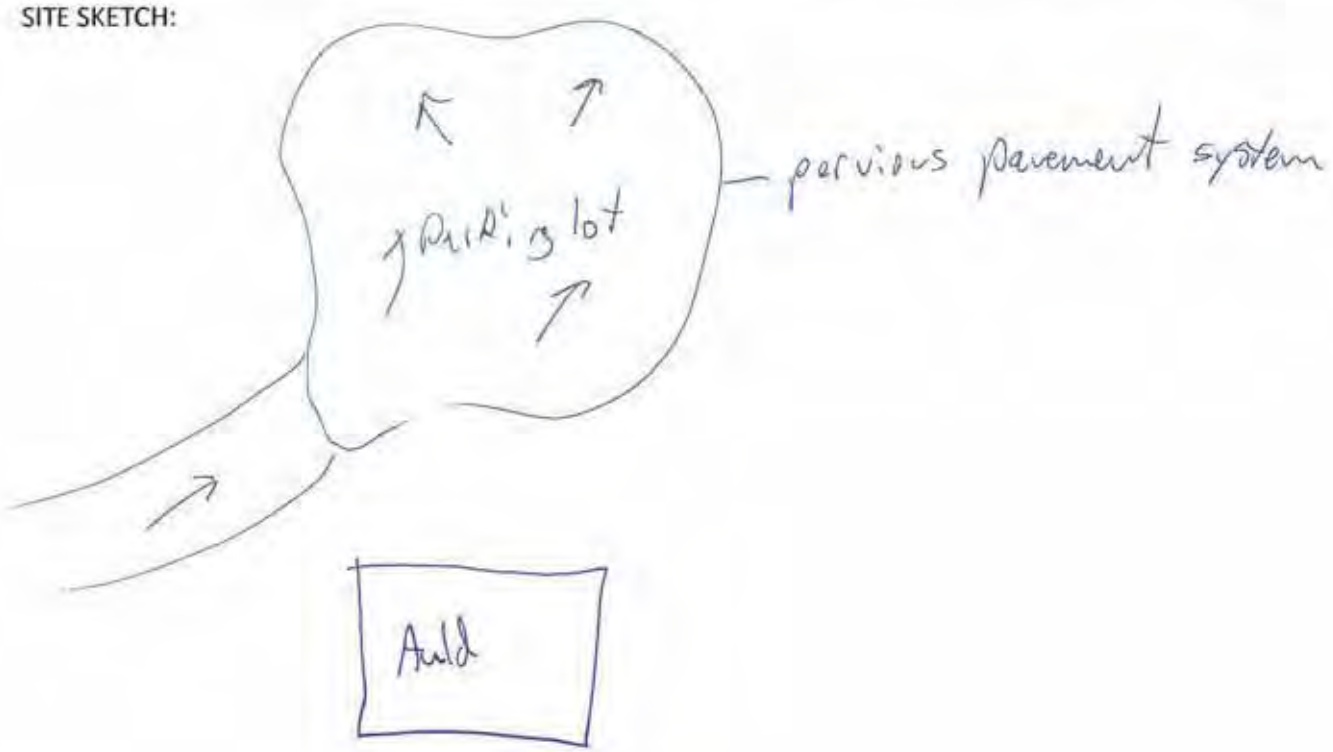
DATE: 9/26/11
STAFF: Jamie S.
LOCATION ID #: Auld Pavilion North
ADDRESS: Antelope Park
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: Parking Lot
POLLUTANT SOURCES NEARBY: gravel, e. coli,
TOPOGRAPHY: gently slope
MAINTENANCE ACCESS: easy

LOCATION DESCRIPTION: large open parking lot N. of Auld Pavilion

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: reduce runoff by impervious pavement system (or draining to nearby greenspace?)

SITE SKETCH:



SITE 15

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 9/22/11
STAFF:
LOCATION ID #: RR 6
ADDRESS:
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: Parking
POLLUTANT SOURCES NEARBY: gravel, PDLs
TOPOGRAPHY: Sloped to storm inlet (curb + gutter)
MAINTENANCE ACCESS: easy

- very public
- very easy to install/design
-

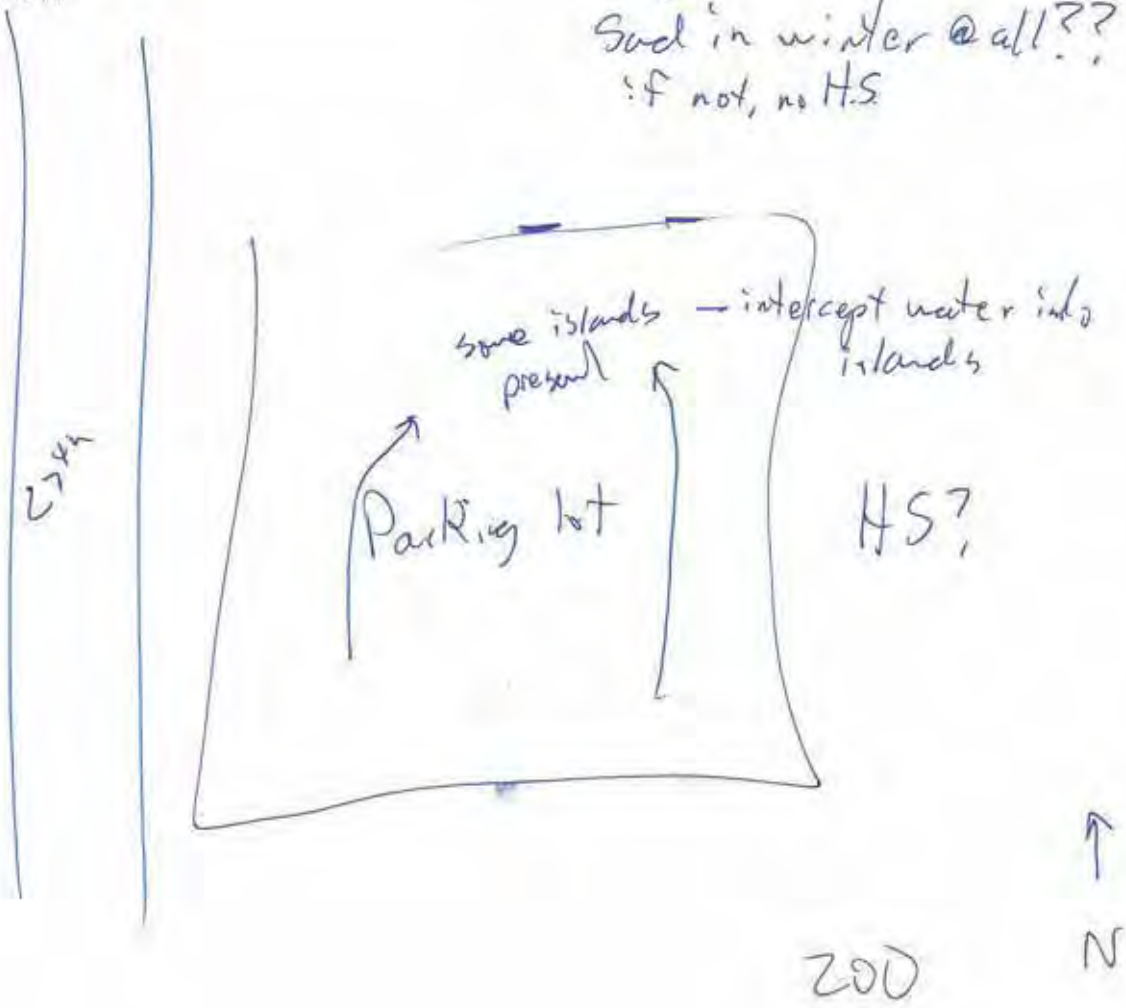
LOCATION DESCRIPTION: Lincoln Children's zoo

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Rain gardens, hydroseparator

Sod in winter @ all??
if not, no HS

SITE SKETCH:



SITE 16

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 9/26/11
STAFF: Jamie S.
LOCATION ID #: C5
ADDRESS: 56th & Normal Blvd
PICTURES AND GPS: (YES) NO
(PUBLIC) or PRIVATE PROERTY
LAND USE: Parking lot
POLLUTANT SOURCES NEARBY: PULs, sediment
TOPOGRAPHY: Flat - drains to storminlets to far NW by 56th
MAINTENANCE ACCESS: easy

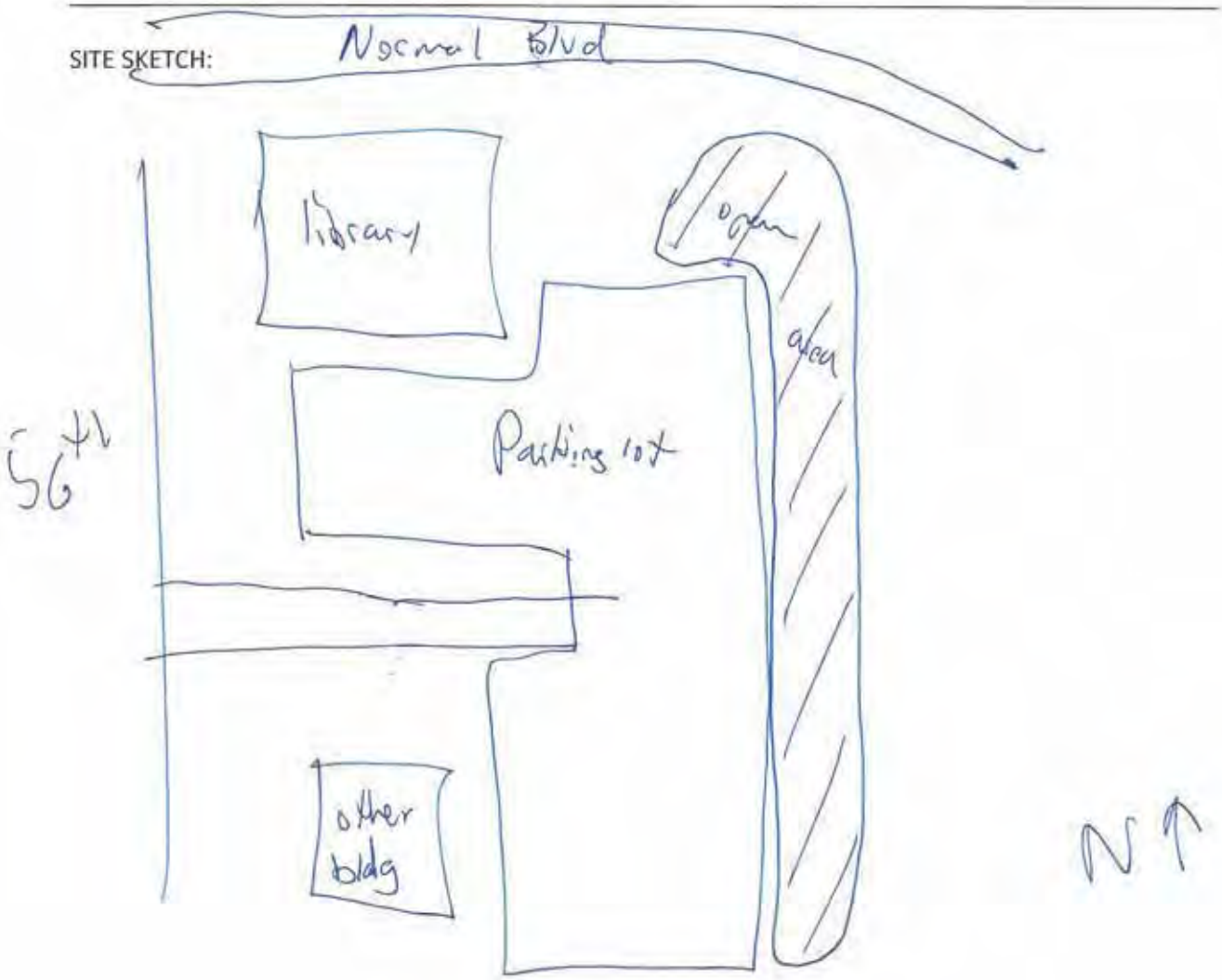
- excellent
- very public
- easy implementation

LOCATION DESCRIPTION: Public Library + other Public Bldg adjacent to 56th street

LAND AVAILABLITLY: LOW / (MEDIUM) / HIGH

POTENTIAL PROJECT TYPE: rain gardens, bio swale, pervious pavement

SITE SKETCH:



SITE 17

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

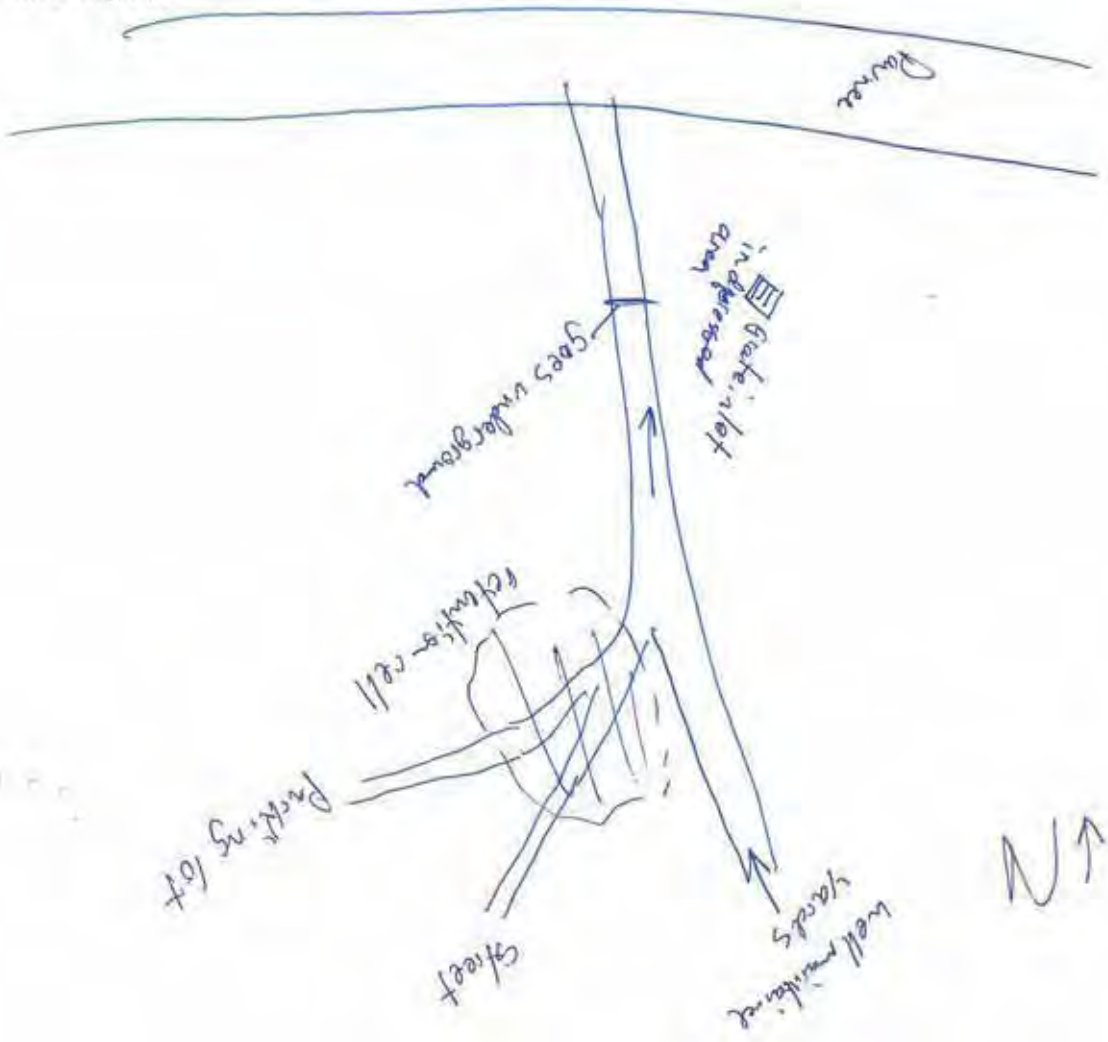
DATE: 9/26/11
STAFF: Jamie
LOCATION ID #: P/R 7
ADDRESS: 52nd & Pawnee
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: Drainage, Park area
POLLUTANT SOURCES NEARBY: POLs, sediment, nutrients
TOPOGRAPHY: gentle slope
MAINTENANCE ACCESS: slightly difficult

LOCATION DESCRIPTION: concrete drainage ditch which captures street & parking lots

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Bioswale, convert concrete channel to grass?

SITE SKETCH:



SITE 18

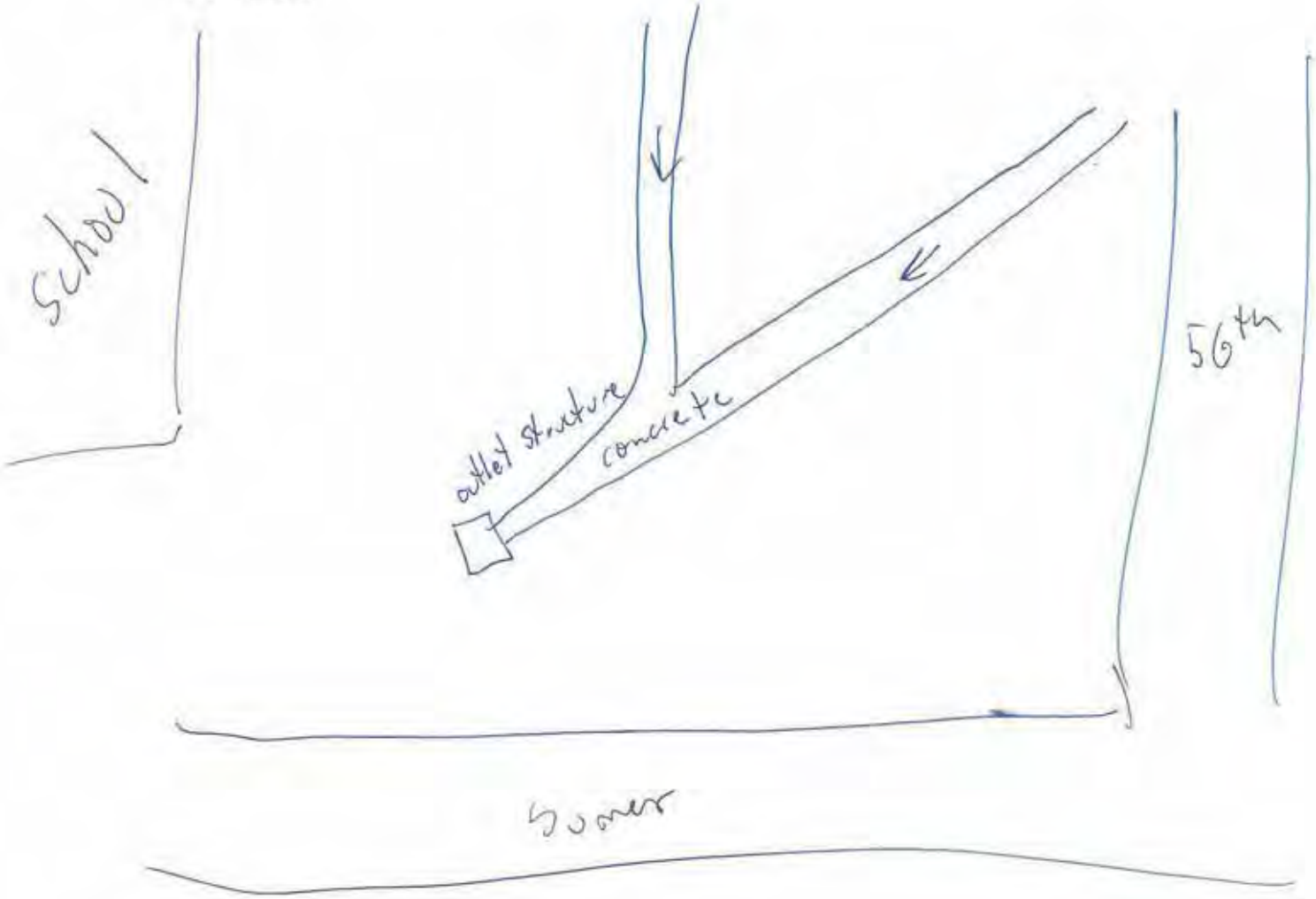
ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 8/26/1
STAFF: Jamie S
LOCATION ID #: PR8
ADDRESS: 56th & North of Sumner
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: park/drainage
POLLUTANT SOURCES NEARBY: nutrients
TOPOGRAPHY: Sloped & berned
MAINTENANCE ACCESS: ~~easy~~ ~~easy~~ park @ substation nearby
LOCATION DESCRIPTION: Park ~~on~~ west of 56th & north of Sumner

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: dry detention basin

SITE SKETCH:



SITE 19

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 9/26/11
STAFF: Jamie S.
LOCATION ID #: PR 9 & I 2
ADDRESS: 14th & D
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: Drainage / Park
POLLUTANT SOURCES NEARBY: PAHs, nutrients, sediment
TOPOGRAPHY: sloped
MAINTENANCE ACCESS: easy

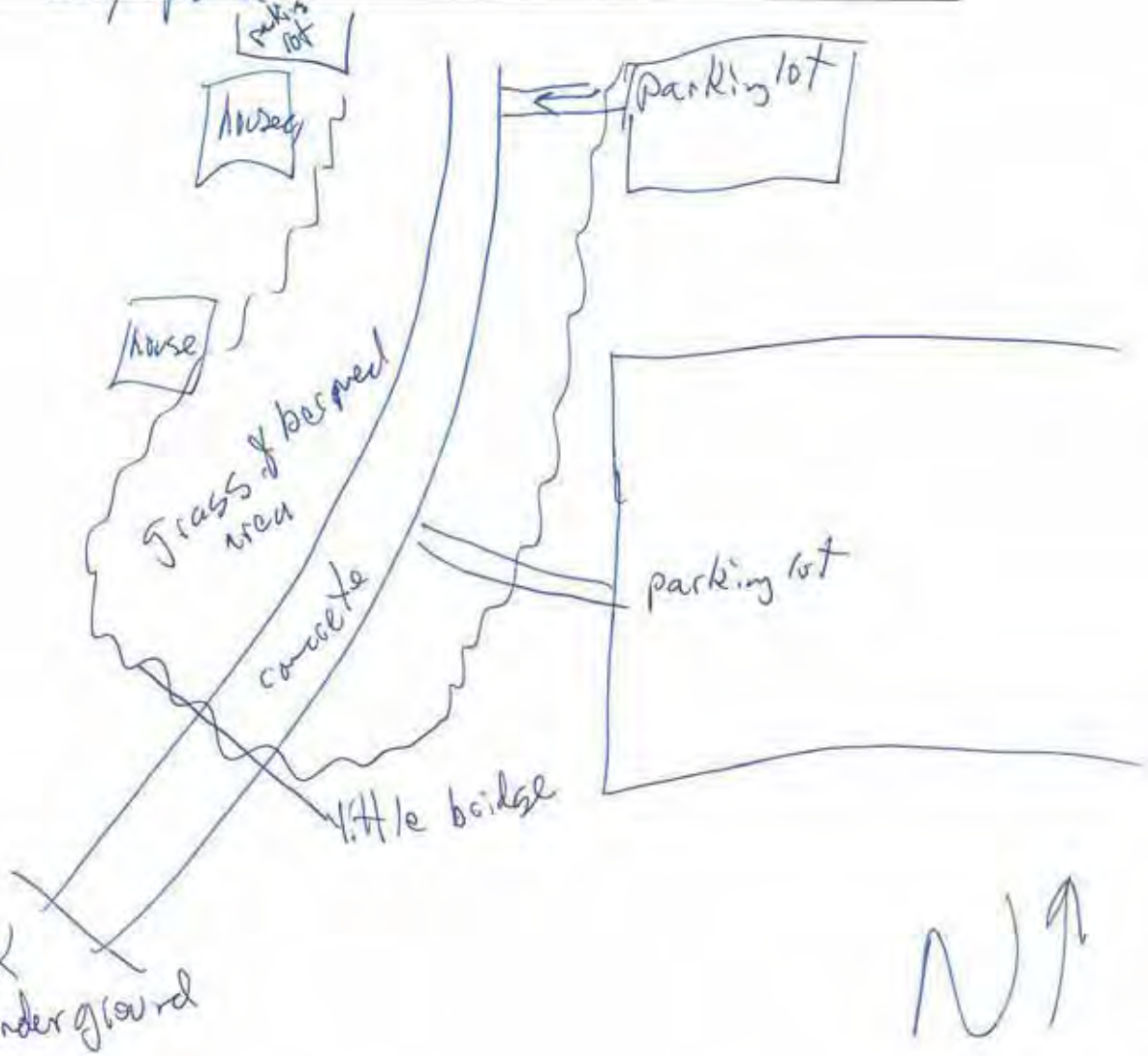
LOCATION DESCRIPTION: drainage channel west of Providence Health career center

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Parking lots to impervious, disconnect directly connected pavement areas
Dry pond?

SITE SKETCH:

- could infiltrate a lot



SITE 20

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

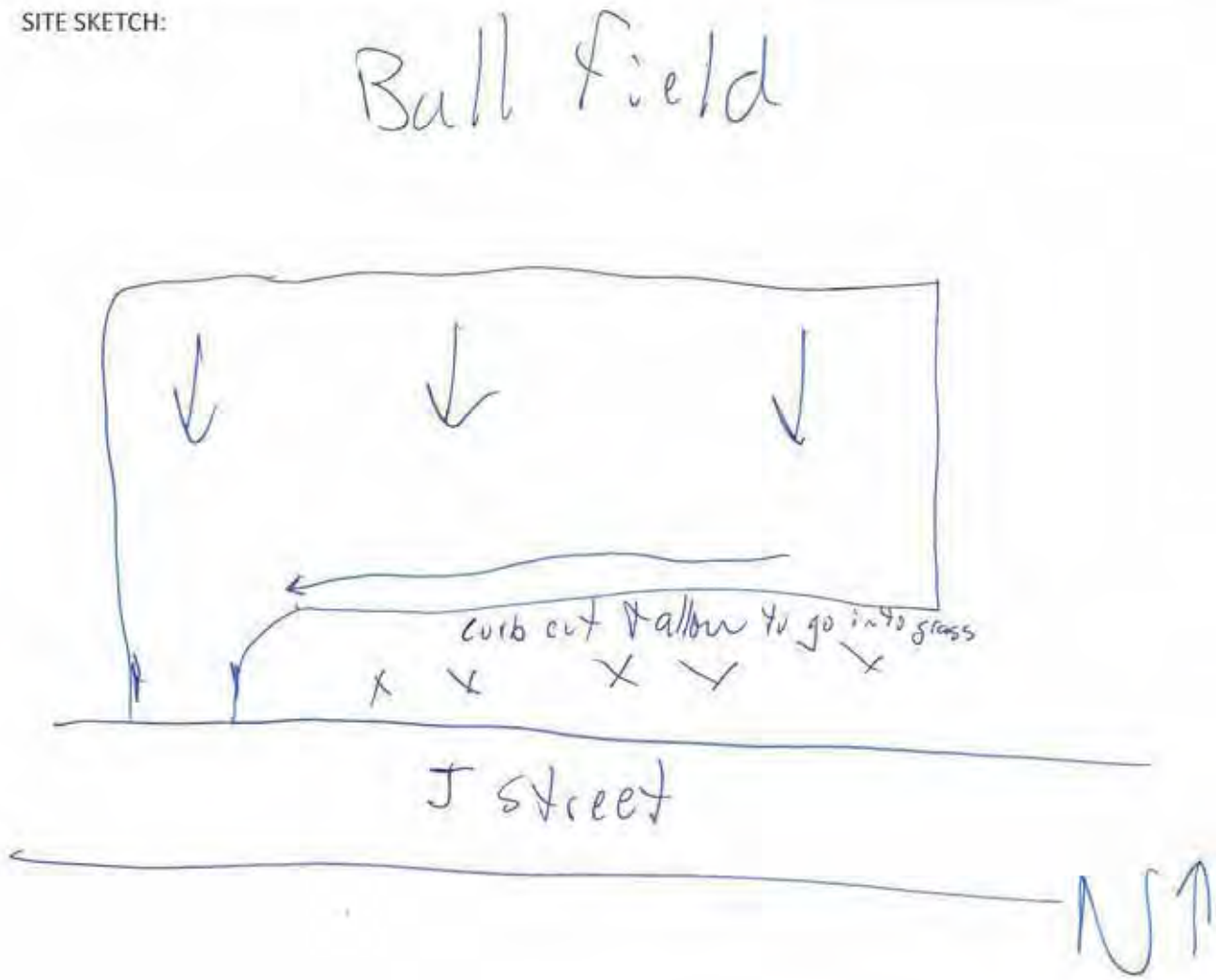
DATE: 8/26/11
STAFF: Jamie S
LOCATION ID #: ~~20~~ 33rd & J P/R ID
ADDRESS:
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: Parking lot
POLLUTANT SOURCES NEARBY: POLs sediment
TOPOGRAPHY: Sloped
MAINTENANCE ACCESS: easy

LOCATION DESCRIPTION: Parking lot next to ball fields

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Bio swals

SITE SKETCH:



SITE 21

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

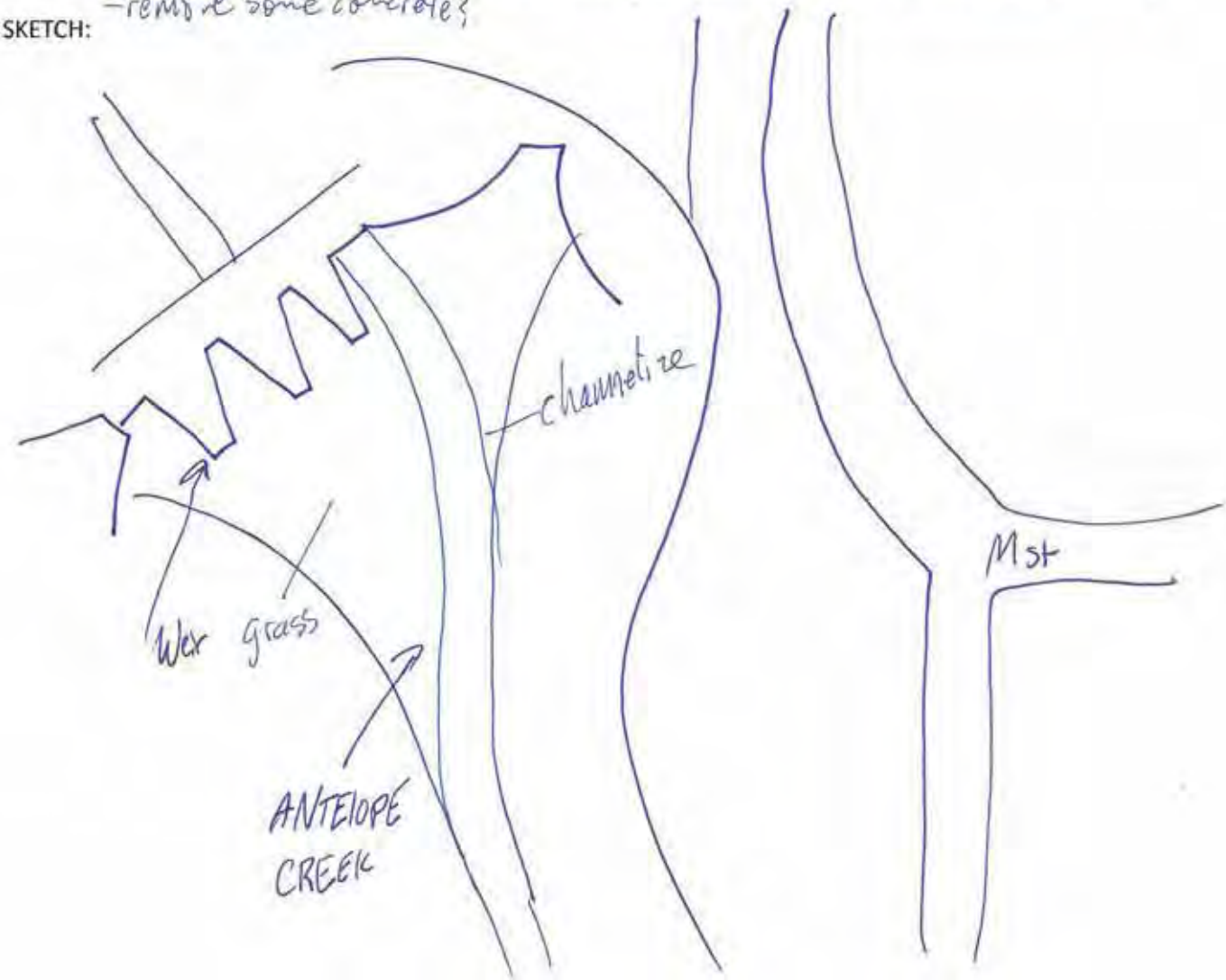
DATE: 9/26/11
STAFF: Jamie S & Jon T.
LOCATION ID #: Antelope Weir
ADDRESS: Labyrinth Weir
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: Public (USACE/Parks)
POLLUTANT SOURCES NEARBY: PCL, Sediments, Nutrients, E. Coli
TOPOGRAPHY: creek bottom
MAINTENANCE ACCESS: Difficult

LOCATION DESCRIPTION: upstream of Labyrinth Weir on AC

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: remove standing water, create area for sedimentation & maintenance
- potential weir to increase sunlight to reduce E. coli concentrations
- remove some concrete?

SITE SKETCH:



SITE 22

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 9/26/11
STAFF: Jamie Suing
LOCATION ID #: Public University
ADDRESS: University of Nebraska
PICTURES AND GPS: YES (NO)
PUBLIC or PRIVATE PROERTY
LAND USE: schooling
POLLUTANT SOURCES NEARBY: Pol's, Sediment, Nutrients, E coli
TOPOGRAPHY: generally flat
MAINTENANCE ACCESS: easy

LOCATION DESCRIPTION:

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE:

SITE SKETCH:

UNL would better AC by using their own research & programs to coordinate w/ the City.

- Very large area
- many different opportunities & pollutants

SITE 23

(B)

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

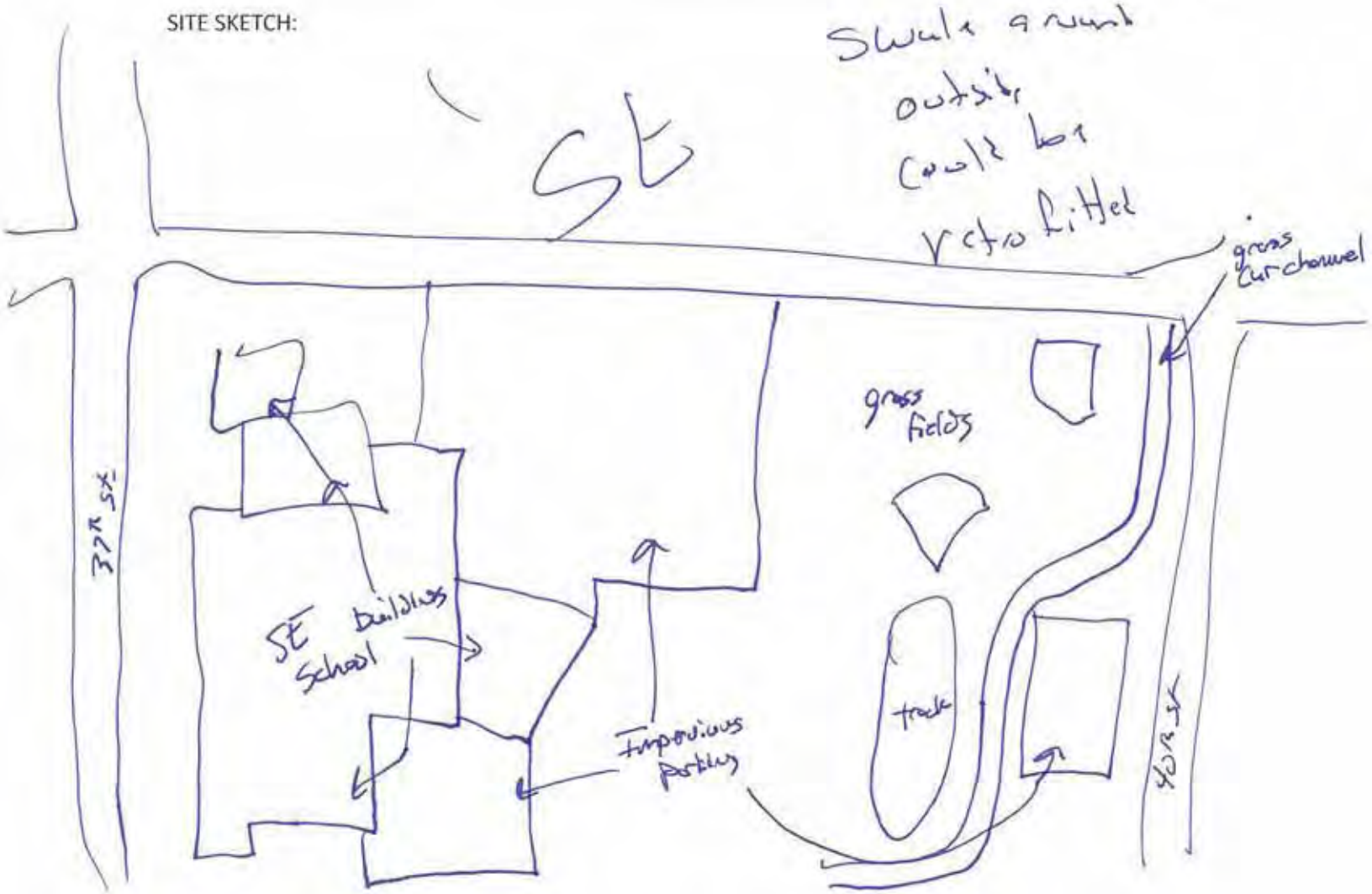
DATE: 11/9/11
STAFF: Jon T & Ben C
LOCATION ID #:
ADDRESS: 37th & Van Dorn
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: ?
TOPOGRAPHY: flat Sloping
MAINTENANCE ACCESS: OK

LOCATION DESCRIPTION: Large lot drain to SS instead of grass swale root low goes underground, low cut out of hillside lot of pervious not much infiltrate

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: bioinf, swale
Swale

SITE SKETCH:



SITE 24

6

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

Pius

DATE: 11/9/11
STAFF: JBoT & BoC
LOCATION ID #:
ADDRESS: 58th & A st
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROPERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: Sediment, POL's, ~~Metals~~ Nutrients
TOPOGRAPHY:
MAINTENANCE ACCESS: OK

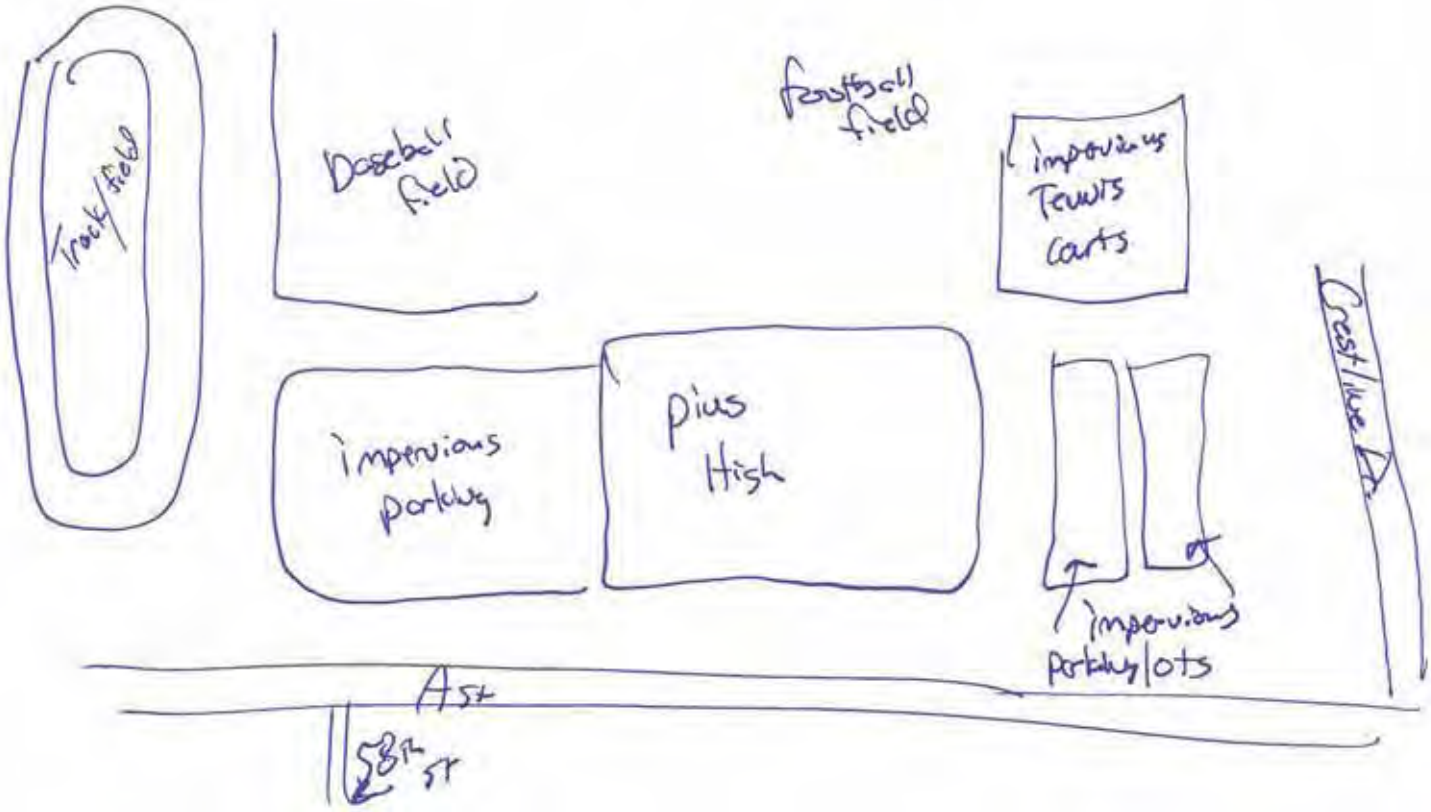
LOCATION DESCRIPTION: Down spout to parking, large parking & bank

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Large Parking lot pervious, swales, hydro sept.

SITE SKETCH:

Pius X



SITE 25

1

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

GPS

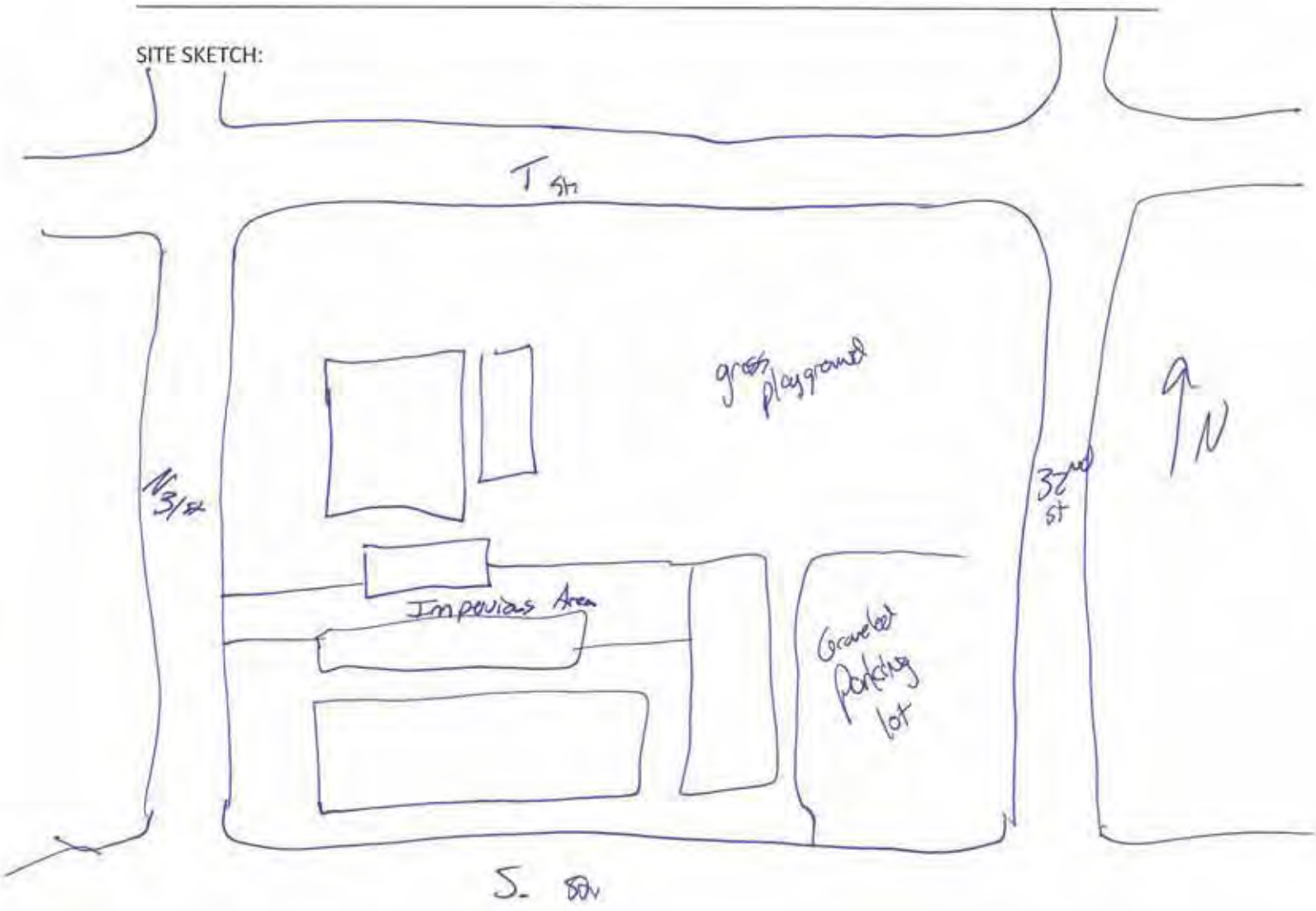
DATE: 11/9/11
STAFF: JT & BL
LOCATION ID #: ~~31st & S~~ Sacred Heart School
ADDRESS: 31st & S st.
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: school
POLLUTANT SOURCES NEARBY: Sediment,
TOPOGRAPHY: flat
MAINTENANCE ACCESS: none

LOCATION DESCRIPTION: Sacred Heart School, One large parking lot, 50% impervious total, down spouts half buried/half over land good grass cover

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: bio swale, permable pave system, downspout disconnect.

SITE SKETCH:



SITE 26

2

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

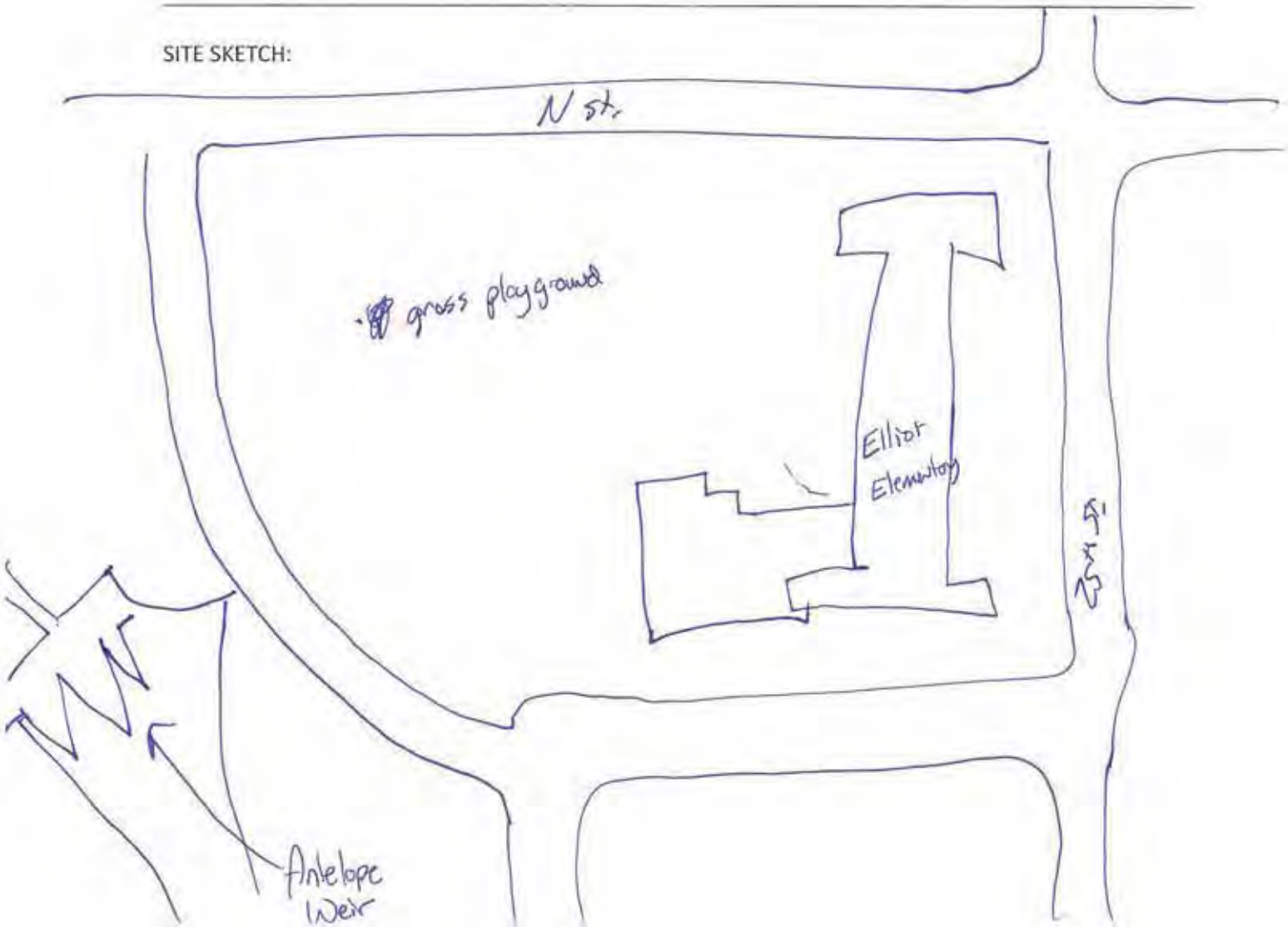
DATE: 11/9/11
STAFF: Jim T. & BC
LOCATION ID #: Elliot Elementary
ADDRESS: 25th & N
~~PICTURES~~ AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: TSS, Nutrients, POC
TOPOGRAPHY: gently sloping
MAINTENANCE ACCESS: none

LOCATION DESCRIPTION: Elliot, grassed area to west, not a lot of impervious area, small parking lot, roof top must drain directly to SS only as downspouts

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: downspout disconnect, permeable paver system

SITE SKETCH:



SITE 27

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

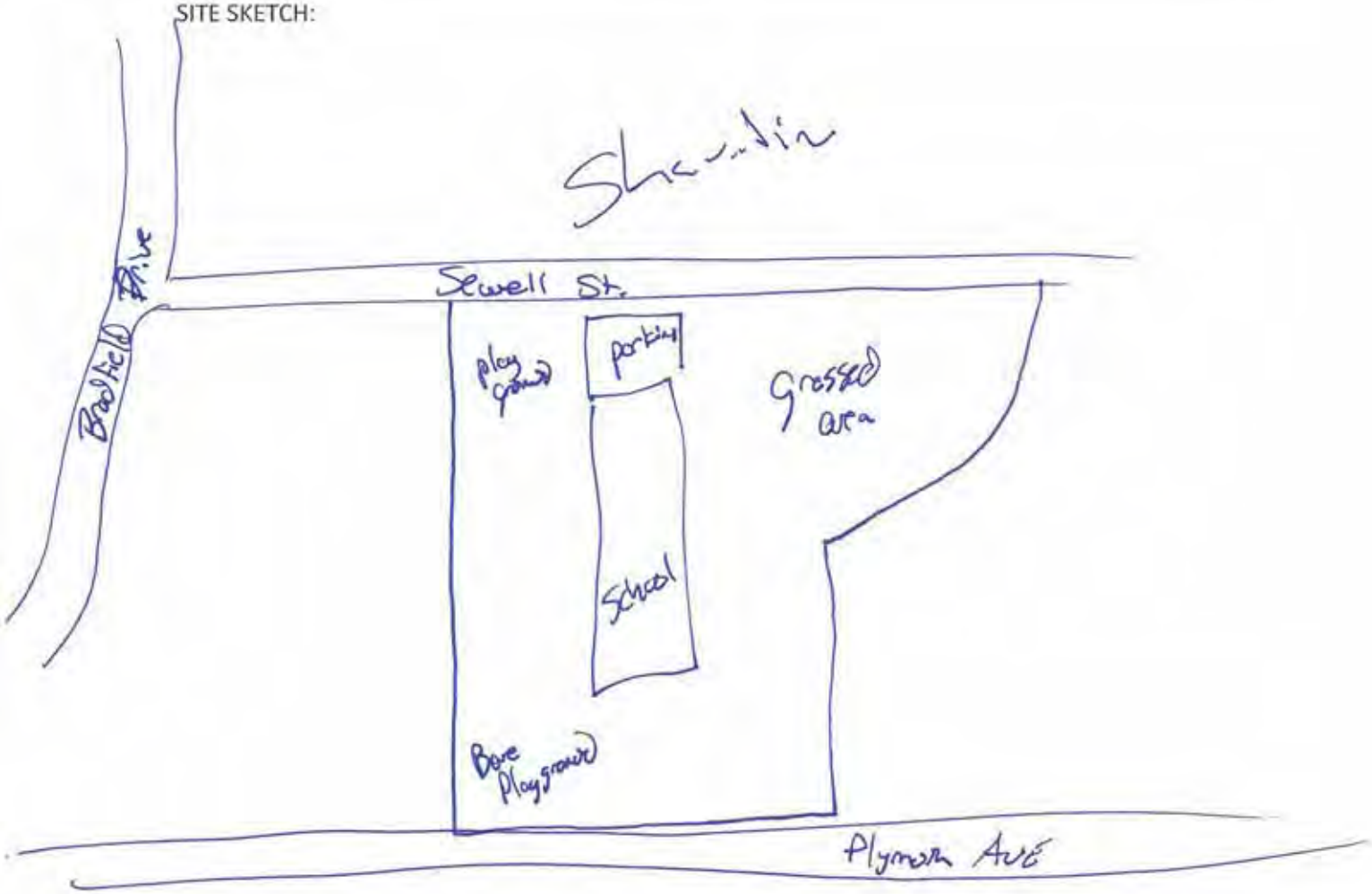
DATE: 11/9/11
STAFF: JOJ & BEN C.
LOCATION ID #:
ADDRESS: Sewell St
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: ?
TOPOGRAPHY: hill steep
MAINTENANCE ACCESS:

LOCATION DESCRIPTION: Rooftops, small parking

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: None

SITE SKETCH:



SITE 28

4

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

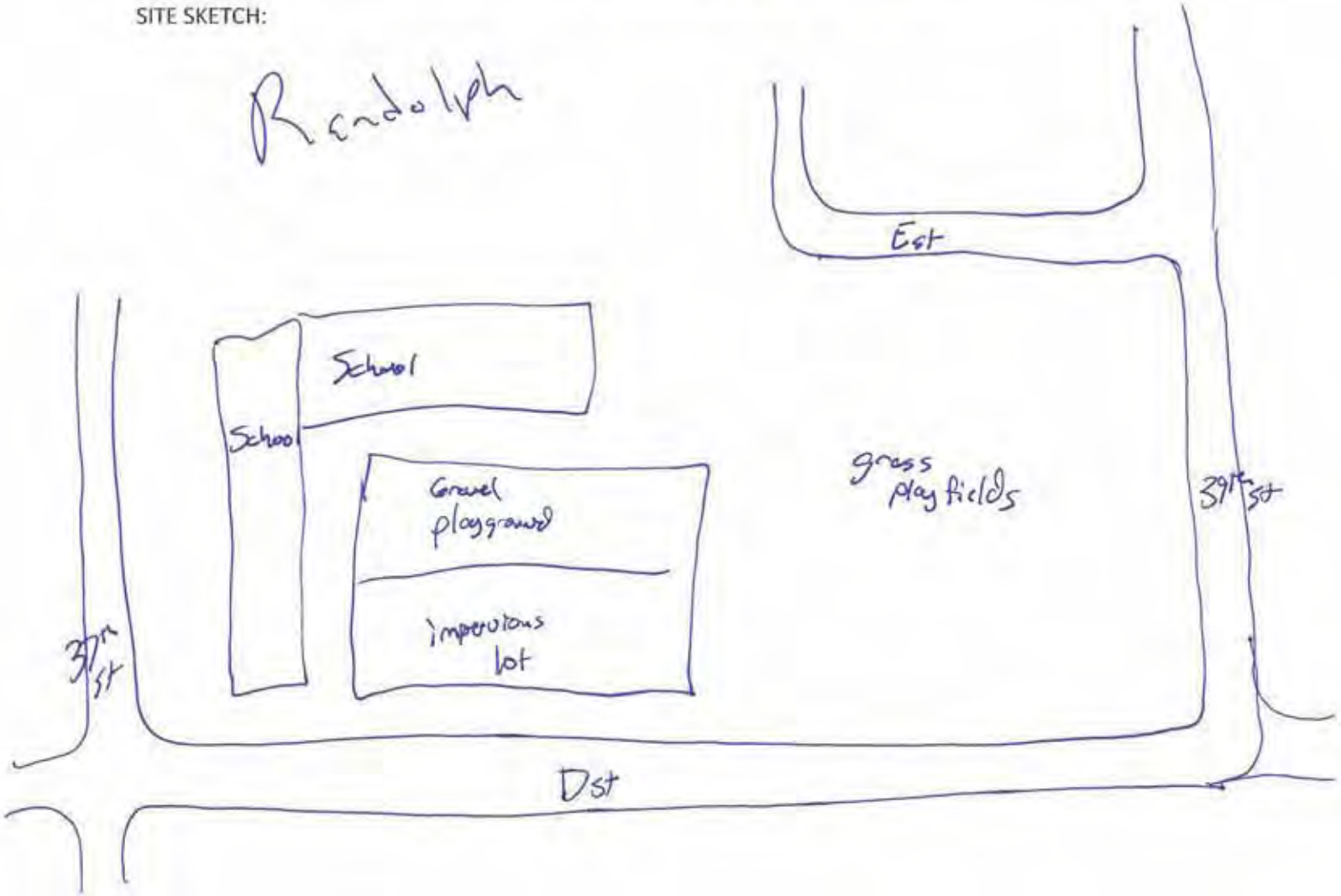
DATE: 11/9/11
STAFF: Joe T + BC
LOCATION ID #:
ADDRESS: 37th D
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: Sediment PCL's Metals
TOPOGRAPHY: L tiv
MAINTENANCE ACCESS: OK

LOCATION DESCRIPTION: Grass fields east, grass in front of large parking lot to the east

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Bad topo & open space
partially pervious

SITE SKETCH:



SITE 29

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

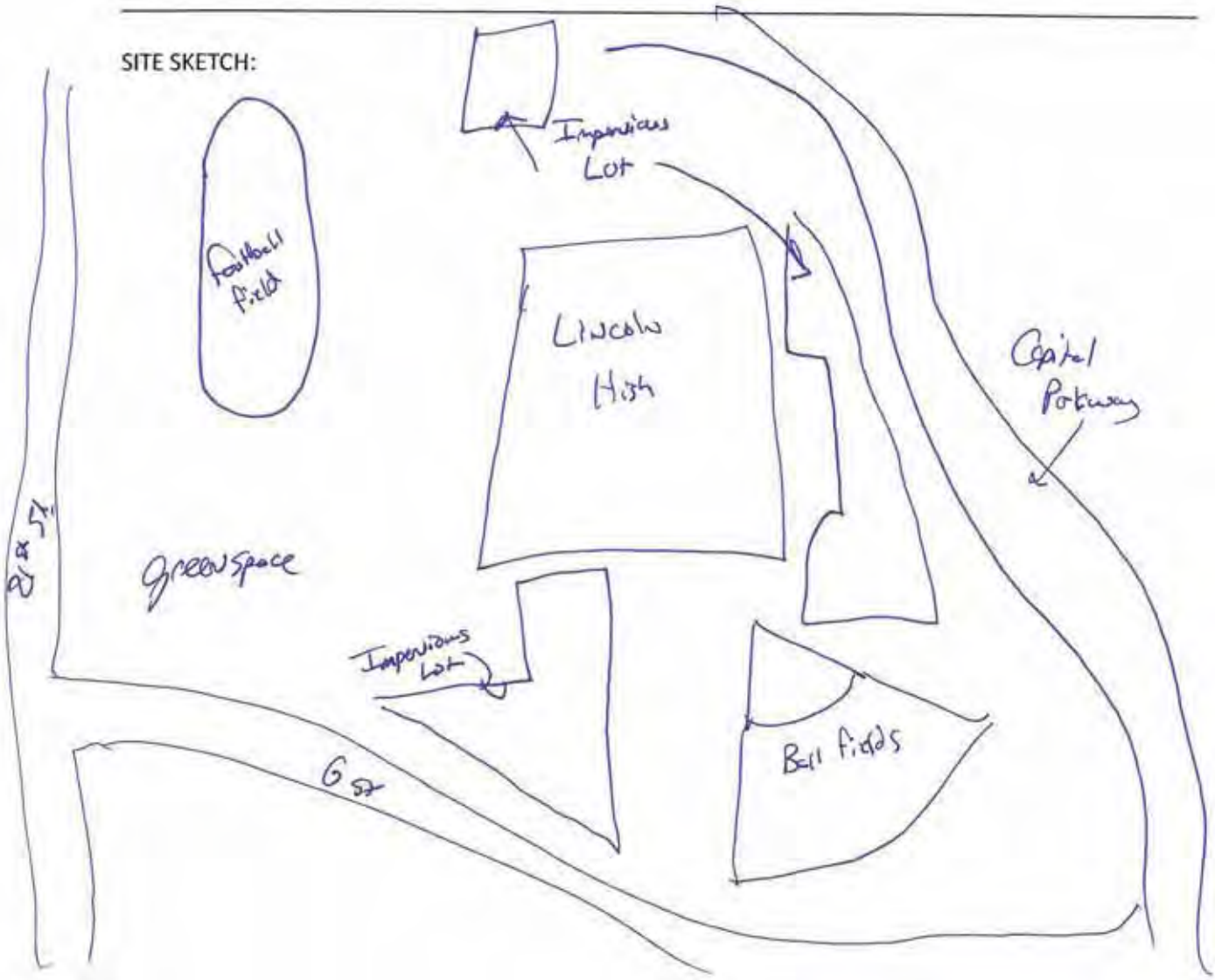
DATE: 9/26/11
STAFF: Jamie S.
LOCATION ID #: Lincoln High
ADDRESS: 21st & G.
PICTURES AND GPS: (YES) NO
(PUBLIC) or PRIVATE PROERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: PCL's Sediment, Nutrients
TOPOGRAPHY: Flat
MAINTENANCE ACCESS: yes

LOCATION DESCRIPTION: Lincoln High. 3 Parking Lots

LAND AVAILABLITLY: (LOW) / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: small bio retention areas

SITE SKETCH:



SITE 30

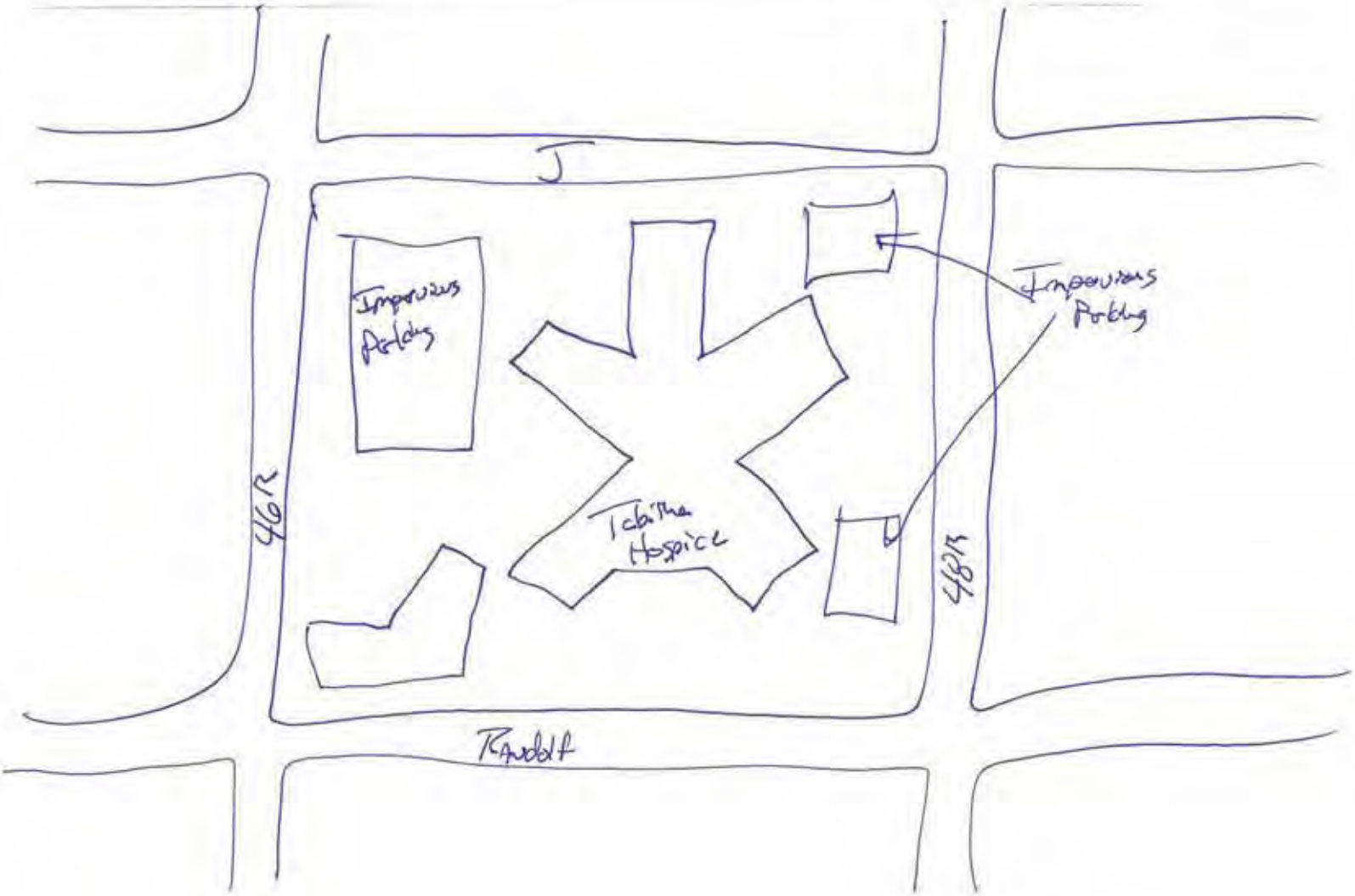
ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 11/9/11
STAFF: Jon T & Ben C
LOCATION ID #: Tabitha
ADDRESS: 48th & Randolf
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: Hospice
POLLUTANT SOURCES NEARBY: Sediment Pol's Nutrients
TOPOGRAPHY: gently sloping
MAINTENANCE ACCESS: none

LOCATION DESCRIPTION: 1 Large + 2 medium parking lots, impervious lots of green space

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: ~~impervious~~ pervious pavement, hydrodynamic separator bio swales, rain gardens



SITE 31

5

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

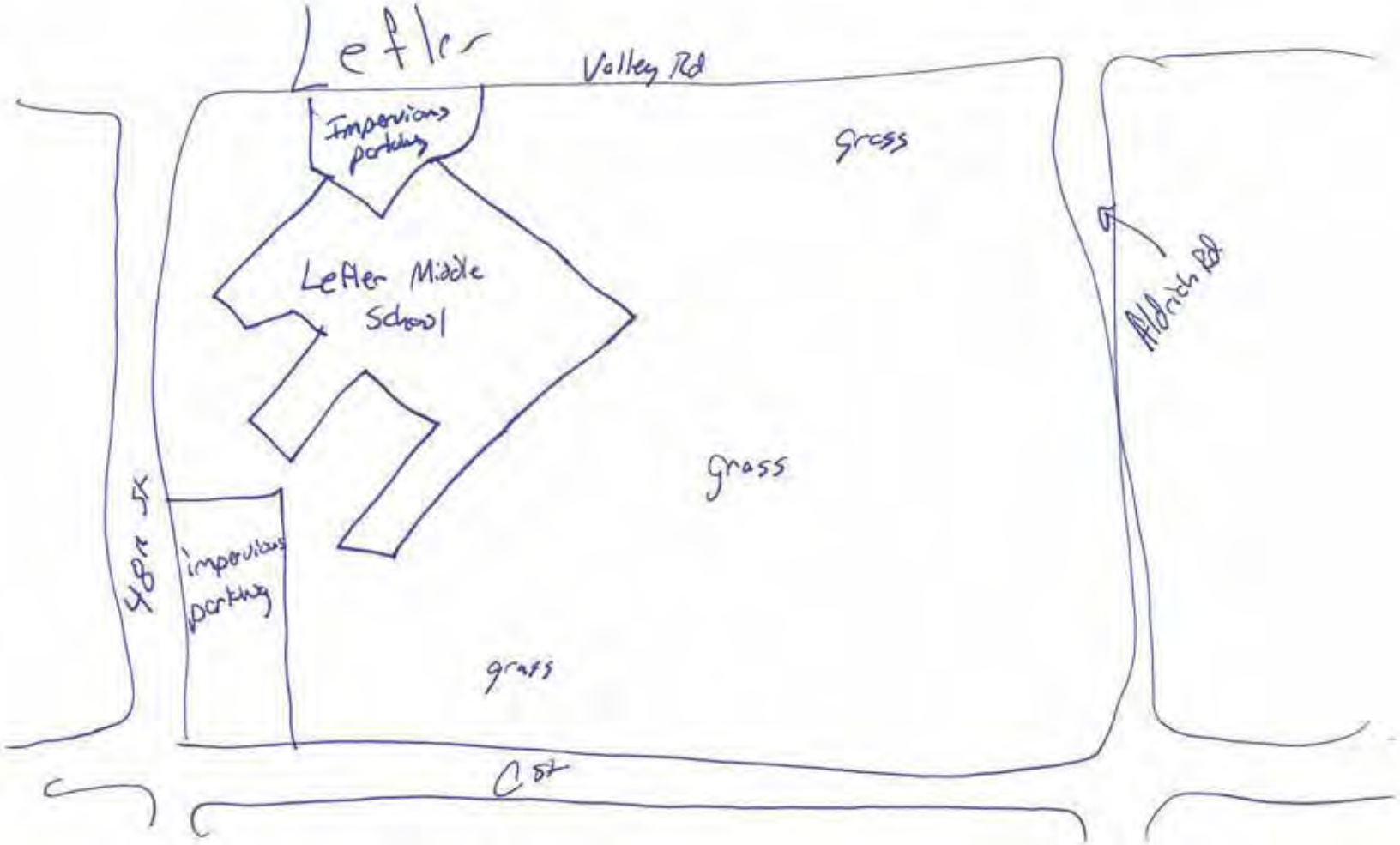
DATE: 11/9/11
STAFF: BENC & JOOT
LOCATION ID #:
ADDRESS: 48th & Valley
PICTURES AND GPS: ~~YES~~ NO
PUBLIC or PRIVATE PROERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: Not many Excepte by cause of lake to it
TOPOGRAPHY: OK
MAINTENANCE ACCESS: OK

LOCATION DESCRIPTION: School ball field, large building
reliable, small parking lot

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: Small parking lot treatment not much.

SITE SKETCH:



Not Considered

3

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

DATE: 11/9/11
STAFF: Jon T & BC
LOCATION ID #:
ADDRESS: 36th & J St.
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: School
POLLUTANT SOURCES NEARBY: Pol, Sediment
TOPOGRAPHY: flat / gently sloping
MAINTENANCE ACCESS: none

LOCATION DESCRIPTION: No land avilable
2 large buildings completly surrounded by impervious pavement.

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: impervious pavement

SITE SKETCH:

SITE 32

ANTELOPE CREEK STRUCTURAL LOCATIONS MAP

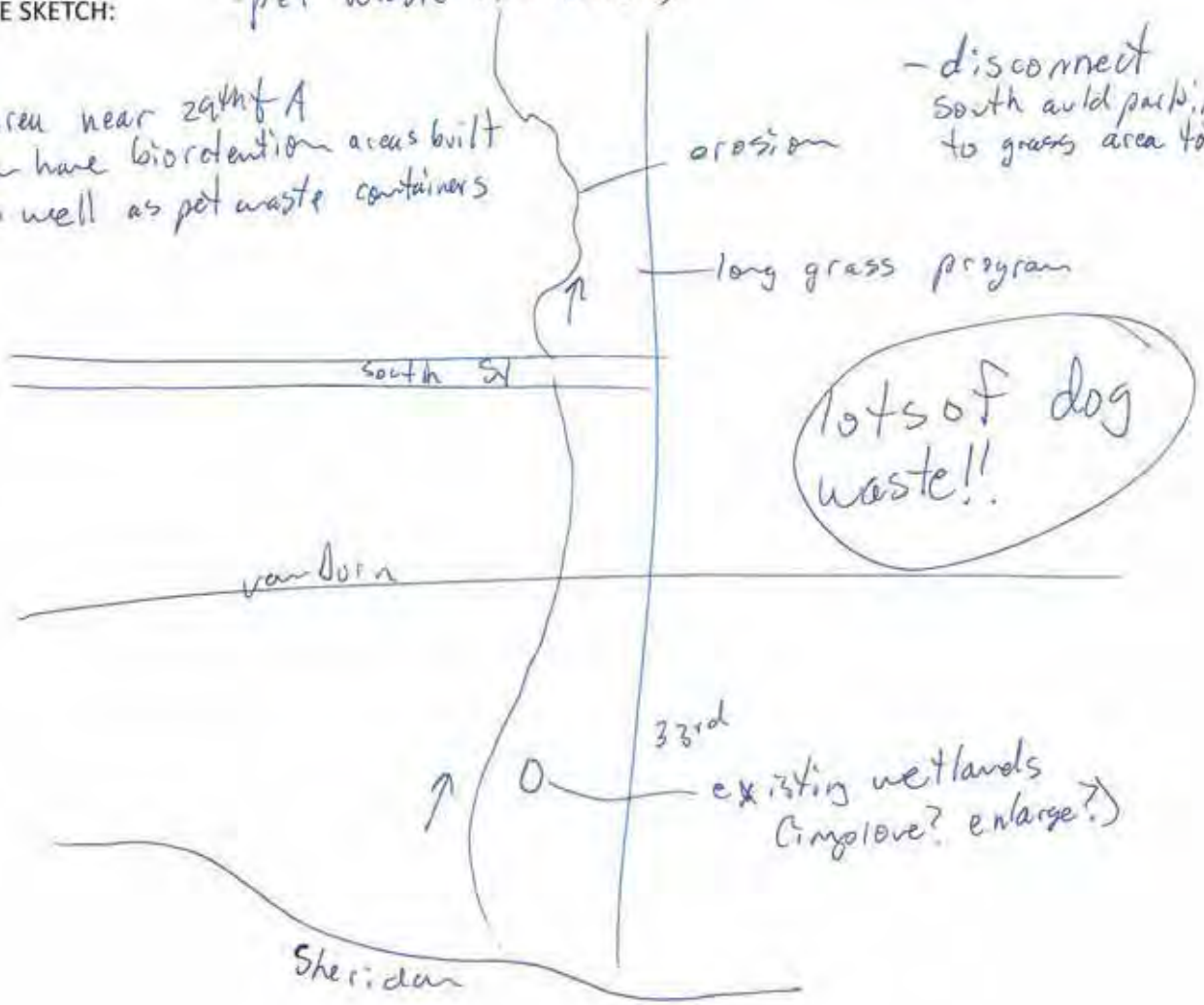
DATE: 1/10/12
STAFF: Jamie S & Jon T.
LOCATION ID #: Antelope Park
ADDRESS:
PICTURES AND GPS: YES NO
PUBLIC or PRIVATE PROERTY
LAND USE: All Park area
POLLUTANT SOURCES NEARBY: Nutrients, POL's, sediment
TOPOGRAPHY: gently sloping
MAINTENANCE ACCESS:

LOCATION DESCRIPTION: Antelope park stretching along 33rd Street between van dorn & A street

LAND AVAILABLITLY: LOW / MEDIUM / HIGH

POTENTIAL PROJECT TYPE: large bioretention areas, disconnect parking lots, address erosion in meandering channel
- improve outfalls & wetland areas
- pet waste containers

SITE SKETCH:



Appendix D - Project Prioritization Ranking Worksheets

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By: JEO Consulting Group, Inc. | Date: 1/10/12

Project ID: P01 | Watershed: Antelope Creek

Project Location: Antelope Park: Van Dorn St to Sheridan Blvd

Project Description: Channel and Wetland Enhancements

Issues Addressed:

Flooding Impacts — Structural and Non-Structural Flooding

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

0

0

A = P_{FD} * C_{FF} 0

Stream Stability — Open Channel and Surface Erosion

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	10

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	2

10

2

B = P_{ET} * C_{EA} 20

Water Quality — Water Quality, Wetlands, Natural Habitat

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

30

3

C = P_{WQ} * C_{WB} 90

Safety Factor — Public Health and Safety

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF} 0

Prioritization Ranking Summary

X = A + B + C + D 110

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items) 30

May Include: Project Location, Coincident Projects, Development Status, etc.

P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points) 60

May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.

TOTAL = ***X*** + P_{MISC} + P_{AC} 200

TOTAL for PROJECT AC-P01 ***200***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides direct public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P01

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P02	Watershed	Antelope Creek
Project Location:	Antelope Park: South St to Van Dorn St		
Project Description:	Channel Enhancements		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	10

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	2

	10
	2
A = P_{FD} * C_{FF}	20

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	35

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	2

	35
	2
B = P_{ET} * C_{EA}	70

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	20

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

	20
	3
C = P_{WQ} * C_{WB}	60

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF}	0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	150
Miscellaneous Factors may be used to adjust scoring:	
P_{MISC} (See attached worksheet for description of miscellaneous items)	30
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	60
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	240
TOTAL for PROJECT AC-P02	***240***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides direct public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P02

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By: JEO Consulting Group, Inc. | Date: 1/10/12

Project ID: P03 | Watershed: Antelope Creek

Project Location: Antelope Park: SW of 33rd and South St

Project Description: Bioretention Areas

Issues Addressed:

Flooding Impacts — Structural and Non-Structural Flooding

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	10

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	2

10

2

A = P_{FD} * C_{FF} 20

Stream Stability — Open Channel and Surface Erosion

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

0

0

B = P_{ET} * C_{EA} 0

Water Quality — Water Quality, Wetlands, Natural Habitat

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	50

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

50

3

C = P_{WQ} * C_{WB} 150

Safety Factor — Public Health and Safety

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF} 0

Prioritization Ranking Summary — Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

X = A + B + C + D 170

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items) 30

May Include: Project Location, Coincident Projects, Development Status, etc.

P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points) 60

May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.

TOTAL = ***X*** + P_{MISC} + P_{AC} 260

TOTAL for PROJECT AC-P03 ***260***

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides direct public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P03

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P04	Watershed	Antelope Creek
Project Location:	Antelope Park: A Street to South Street		
Project Description:	Modify parking lot, address erosion in meandering channel		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

	0
	0
A = P_{FD} * C_{FF}	0

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	10

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	2

	10
	2
B = P_{ET} * C_{EA}	20

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

	30
	3
C = P_{WQ} * C_{WB}	90

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF}	0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	110
Miscellaneous Factors may be used to adjust scoring:	
P_{MISC} (See attached worksheet for description of miscellaneous items)	30
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	40
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	180
TOTAL for PROJECT AC-P04	***180***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides indirect public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P04

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P05	Watershed	Antelope Creek
Project Location:	Roberts Park/East of Holmes Elementary School		
Project Description:	Offline Bioretention Areas, Inline Channel Berms		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	10

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	2

	10
	2
A = P_{FD} * C_{FF}	20

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

	0
	0
B = P_{ET} * C_{EA}	0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

	30
	3
C = P_{WQ} * C_{WB}	90

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF}	0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	110

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items)	30
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	40
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	180
TOTAL for PROJECT AC-P05	***180***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides indirect public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P05

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P06	Watershed	Antelope Creek
Project Location:	Lincoln Children's Zoo		
Project Description:	Green Roof, Permeable Pavement, Bioretention		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	15

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	2

15

2

A = P_{FD} * C_{FF} 30

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

0

0

B = P_{ET} * C_{EA} 0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	60

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

60

3

C = P_{WQ} * C_{WB} 180

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF} 0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D 210

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items) 30

May Include: Project Location, Coincident Projects, Development Status, etc.

P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points) 60

May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.

TOTAL = ***X*** + P_{MISC} + P_{AC} 300

TOTAL for PROJECT AC-P06 ***300***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides direct public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P06

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P07	Watershed	Antelope Creek
Project Location:	Woods Park		
Project Description:	Separators, Bioretention Areas		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

	0
	0
A = P_{FD} * C_{FF}	0

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

	0
	0
B = P_{ET} * C_{EA}	0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

	30
	3
C = P_{WQ} * C_{WB}	90

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF}	0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	90

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items)	30
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	40
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	160
TOTAL for PROJECT AC-P07	***160***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides indirect public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P07

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P08	Watershed	Antelope Creek
Project Location:	Gere Library		
Project Description:	Separator and Bioretention Area		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

	0
	0
A = P_{FD} * C_{FF}	0

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

	0
	0
B = P_{ET} * C_{EA}	0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

	30
	3
C = P_{WQ} * C_{WB}	90

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF}	0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	90

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items)	20
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	20
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	130
TOTAL for PROJECT AC-P08	***130***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P08

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	10
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 20

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P09	Watershed	Antelope Creek
Project Location:	Eden Park		
Project Description:	Curb-Cut Bioretention		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

	0
	0
A = P_{FD} * C_{FF}	0

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

	0
	0
B = P_{ET} * C_{EA}	0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

	30
	3
C = P_{WQ} * C_{WB}	90

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF}	0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	90

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items)	30
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	40
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	160
TOTAL for PROJECT AC-P09	***160***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides indirect public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P09

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P10	Watershed	Antelope Creek
Project Location:	Existing Dry Detention Cell near 60th and South St.		
Project Description:	Modify Existing Extended Detention Basin		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

	0
	0
A = P_{FD} * C_{FF}	0

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

	0
	0
B = P_{ET} * C_{EA}	0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

	30
	3
C = P_{WQ} * C_{WB}	90

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF}	0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	90

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items)	15
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	20
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	125
TOTAL for PROJECT AC-P14	***125***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P10

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	5
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 15

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P11	Watershed	Antelope Creek
Project Location:	Labyrinth Weir on Antelope Creek		
Project Description:	Water quality improvements at weir		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

	0
	0
A = P_{FD} * C_{FF}	0

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

	0
	0
B = P_{ET} * C_{EA}	0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	60

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	4

	60
	4
C = P_{WQ} * C_{WB}	240

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	60

D = P_{SF}	60

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	300
Miscellaneous Factors may be used to adjust scoring:	
P_{MISC} (See attached worksheet for description of miscellaneous items)	30
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	40
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	370
TOTAL for PROJECT AC-P11	***370***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements and provides indirect public education benefits

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P11

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	10
	Existing City Limits	10	
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P12	Watershed	Antelope Creek
Project Location:	Van Dorn Plaza and US Post Office		
Project Description:	Bioretention Areas		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

	0
	0
A = P_{FD} * C_{FF}	0

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

	0
	0
B = P_{ET} * C_{EA}	0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

	30
	3
C = P_{WQ} * C_{WB}	90

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF}	0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D	90

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items)	20
May Include: Project Location, Coincident Projects, Development Status, etc.	
P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points)	20
May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.	
TOTAL = ***X*** + P_{MISC} + P_{AC}	130
TOTAL for PROJECT AC-P12	***130***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P12

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	10
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 20

Prioritization Ranking for Watershed Master Plan Projects

City of Lincoln, Nebraska

Prepared By:	JEO Consulting Group, Inc.	Date:	1/10/12
Project ID:	P13	Watershed	Antelope Creek
Project Location:	Southeast of 40th and Capital Parkway (North of Campbell's Nursery)		
Project Description:	Separator, Bioretention Areas in open space north of Antelope Creek		

Issues Addressed:

Flooding Impacts

Projects primarily intended to address structural or non-structural flooding will usually incorporate a high or low risk safety factor and may, if applicable, incorporate stream stability or water quality benefits.

Flooding Benefits		Points, P_{FD}
Major Structural Flooding Damage		30
Structural Flooding Damage		20
Non-Structural Flooding	Streets / ROW, Other	15
Conservation / Prevention	Easements / Acquisitions	10
None		0
	P_{FD}=	0

Flooding Frequency		Multiplier, C_{FF}
Frequent Flooding	More frequent than 10-year storm	4
Infrequent Flooding	Less frequent than 10-year storm	2
None		0
	C_{FF}=	0

0 → 0 → 0

A = P_{FD} * C_{FF} 0

Structural and Non-Structural Flooding

Stream Stability

Projects primarily intended for stream stability typically will not incorporate flooding impact benefits; though may incorporate water quality benefits.

Stream Stability Benefit	Points, P_{ET}
Channel Erosion Threatening to Structures	50
Channel Erosion Threatening to Public Infrastructure	40
Channel Erosion Threatening to Natural Resources	35
Conservation / Prevention	10
Secondary Stream Stability benefit due to Flood Control or Water Quality Project	10
None	0
P_{ET}=	0

Erosion Activity / Systemic Threat	Multiplier, C_{EA}
Aggressive Channel Erosion	3
Non-Aggressive Channel Erosion	2
None	0
C_{EA}=	0

0 → 0 → 0

B = P_{ET} * C_{EA} 0

Open Channel and Surface Erosion

Water Quality

Projects primarily intended for water quality typically will not incorporate flooding impact benefits; though may incorporate stream stability benefits.

Water Quality Benefits	Points, P_{WQ}
Enhance / Preserve Natural Resource Areas (Lake, Wetlands, etc.)	60
Regulatory Compliance / Stormwater Permit / NPDES	60
Create New Natural Resource Areas (Lakes, Wetlands, etc.)	50
Conservation / Prevention	30
Secondary Water Quality benefit due to Flood Control or Stream Stability Project	20
None	0
P_{WQ}=	30

Project Benefit		Multiplier, C_{WB}
Major Water Quality Benefit	Broad-Based Impacts	4
Water Quality Benefit	Localized Impacts	3
None		0
	C_{WB}=	3

30 → 3

C = P_{WQ} * C_{WB} 90

Water Quality, Wetlands, Natural Habitat

Safety Factor

Public Health and Safety		Points, P_{SF}
High Risk	Potential Loss of Life or Bodily Injury	160
Low Risk	Public Nuisance	60
No Risk		0
	P_{SF}=	0

D = P_{SF} 0

Public Health and Safety

Prioritization Ranking Summary

X = A + B + C + D 90

Miscellaneous Factors may be used to adjust scoring:

P_{MISC} (See attached worksheet for description of miscellaneous items) → 30

May Include: Project Location, Coincident Projects, Development Status, etc.

P_{AC}, Additional Considerations (may be used to add or subtract up to 60 points) → 20

May Include: Legal Issues, Jurisdictional Coordination, Complaints, Outside Funding Sources, Wildlife Benefits, etc.

TOTAL = ***X*** + P_{MISC} + P_{AC} 140

TOTAL for PROJECT AC-P13 ***140***

Project Location, Development Status, Coincident Projects, Condition / Maintenance, Downstream Impacts, Source Reduction, Additional Considerations

Comments or Description of Additional Considerations:

Additional Consideration given as project helps address TMDL requirements

Note: This prioritization methodology is not intended for Urban Drainage Improvement projects.

MISCELLANEOUS FACTORS

P13

		Points Available	Points Assigned
Location	Public Property or willing owner of Private Property	up to 20	20
Coincident with Adjacent Projects	Public Projects (water, sanitary, roads, etc.)	up to 20	
	Private Projects	up to 10	
Development Status	Tier I, Priority A	20	
(Points available are fixed, and are not flexible)	Tier I, Priority B	15	
	Tier I, Priority C	10	
	Existing City Limits	10	10
	Tier II (development 25 - 50 years)	5	
	Tier III (development > 50 years)	0	

Tier I, Priority A - Areas designated for near term development are generally contiguous to existing development and should be provided first with basic infrastructure within six years of the adoption of the Plan. Some of the infrastructure required for development may already be in place. This area includes some land already annexed, with City commitments to fund infrastructure improvements, but the land is still undeveloped and without significant infrastructure in place yet. Some infrastructure improvements may be done in the near term while others, such as road improvements that are generally more costly, may take longer to complete.

Tier I, Priority B - The next areas for development, beyond Priority A, are those which currently lack almost all of the infrastructure required to support development. In areas with this designation, the community will maintain present uses until urban development can commence. Infrastructure improvements to serve this area will not initially be included in the City's CIP, but will be actively planned for in the longer term capital improvement planning of the various city and county departments.

Tier I, Priority C - This is the later phase of development areas and is intended to be served after Priority A and B. Given current growth rates and infrastructure financing, development would not begin in this area until after 2020 or 2025.

Total Miscellaneous Points, P_{MISC} = 30

Appendix E - WinSLAMM Standard Land Use Characteristics and Pollutant Sources Report

R. Pitt
April 22, 2011

Lincoln, Nebraska, Standard Land Use Characteristics and Pollutant Sources

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Standard Land Use Development Characteristics

The Lincoln, NE, project team conducted detailed site surveys for representative land uses within the lower Antelope Creek drainage area. From five to ten homogeneous neighborhoods were surveyed in low density residential, medium density residential <1960, 1960-80, >1980, light industry, strip malls, shopping centers, schools; churches, and hospitals and use areas. The site survey information was organized and presented in both Appendix A and in associated WinSLAMM *.dat files. Table 1 summarizes the breakdown of these categories into directly connected impervious areas (DCIA),

partially connected impervious areas, and pervious areas, plus shows the percentage of the roofs that are directly connected to the drainage system for each of these nine areas.

Table 1. Summary of Major Land Use Characteristics in Lincoln, NE (average and COV)

Land Use Category	Percent of roofs that are directly connected	Total directly connected impervious areas (DCIA)	Total partially connected impervious areas	Total pervious areas
Low density res	12	18	16	66
Med density res <1960	16	22	20	58
Med density res 1960 - 1980	24	18	19	63
Light industry	55	58	27	15
Commercial - strip mall	100	86	0	14
Commercial - shopping center	100	88	0	12
Institutional - school	100	56	0.5	44
Institutional - church	37	44	10	46
Institutional - hospital	80	62	5.4	33

The directly connected impervious percentages are most closely related to the runoff quantities. The partially connected impervious areas contribute runoff at later portions of larger rains, while the pervious areas may only contribute flows after substantial rain has occurred. These nine averaged areas were statistically analyzed and evaluated using WinSLAMM, the Source Loading and Management Model, briefly described below.

WinSLAMM Background Information

WinSLAMM version 9.5 was used to analyze the water quality (stormwater pollution loading) and runoff volume for the land used found in the Antelope Creek study area. WinSLAMM was developed to evaluate stormwater runoff volume and pollutant loadings in urban areas using small storm hydrology. The model determines the runoff based on local rain records and calculates runoff volumes and pollutant loadings from each individual source area within each land use category for each rain. Examples of source areas include: roofs, streets, small landscaped areas, large landscaped areas, sidewalks, and parking lots.

The model can use any length of rainfall record as determined by the user, from single rainfall events to several decades of rains. The rainfall file used in these calculations were developed from hourly data from the EarthInfo CDROMs, using the four years from 1996 through 1999. The model can apply a series of stormwater control practices, such as infiltration/biofiltration (as used in rain gardens and green roofs), water tanks for stormwater beneficial use, street cleaning, wet detention ponds, grass swales, porous pavement, catchbasins, or various proprietary settling devices. The model will evaluate the practices and determine how effectively these practices remove runoff volume and pollutants. Since its beginnings in the 1970's, the program's use has extended across North America and overseas.

WinSLAMM is based largely upon research and studies conducted in the United States and Canada (mostly funded by the US EPA and Environment Canada, plus various state and local agencies and industries), and by studies conducted through the Wisconsin Department of Natural Resources (WDNR) and the United States Geological Survey (USGS). WinSLAMM is licensed by PV & Associates.

WinSLAMM does not use a percent imperviousness or a curve number to general runoff volume or pollutant loadings. The model applies runoff coefficients to each "source area" within a land use category. Each source area has a different runoff coefficient equation based on factors such as: slope, type and condition of surface, soil properties, etc., and calculates the runoff expected for each rain. The runoff coefficients were developed using monitoring data from typical examples of each site type under a broad range of conditions. The runoff coefficients are continuously updated as new research data becomes available.

Each source area also has a unique pollutant concentration (event mean concentrations - EMCs - and a probability distribution) assigned to it. The EMCs for a specific source area vary depending on the rain depth. The source area's EMCs are based on extensive monitoring conducted in North America by the USGS, Wisconsin DNR, University of Alabama, and other groups. These monitoring efforts isolated source areas (roofs, lawns, streets, etc.) for different land uses and examined long term data on the runoff quality. The pollutant concentrations are also continuously updated as new research data become available.

For each rainfall in a data set, WinSLAMM calculates the runoff volume and pollutant load (EMC x runoff volume) for each source area. The model then sums the loads from the source areas to generate a land use or drainage basin subtotal load. The model continues this process for the entire rain series described in the rain file. It is important to note that WinSLAMM does not apply a "unit load" to a land use. Each rainfall produces a unique load from a modeled area based on the specific source areas in that modeled area.

The model also is used to predict stormwater management practice effectiveness (to be examined during the next project activities). The model replicates the physical processes occurring within the practice. For example, for a wet detention pond, the model incorporates the following factors for each rain event:

1. Runoff hydrograph, pollution load, and sediment particle size distribution from the drainage basin to the pond,
2. Pond geometry (depth, area),
3. Hydraulics of the outlet structure,
4. Particle settling time and velocity within the pond based on retention time

Stokes Law and Newton's settling equations are used in conjunction with conventional surface overflow rate calculations and modified Puls-storage indication hydraulic routing methods to determine the sediment amounts and characteristics that are trapped in the pond. Again, it is important to note that the model does not apply "default" percent efficiency values to a practice. Each rainfall is analyzed and the pollutant control effectiveness will vary based on each rainfall and the pond's antecedent condition.

The model's output includes:

1. Runoff volume, pollutant loadings and EMCs for a period of record and/or for each event.
2. The above data pre- and post- for each stormwater management practice.
3. Removal by particle size from stormwater management practices applying particle settling.
4. Other results can be selected related to flow-duration relationships for the study area, impervious cover model expected biological receiving water conditions, and life-cycle costs of the controls.

A full explanation of the model's capabilities, calibration, functions, and applications can be found at www.winslamm.com. For this project, the parameter files were calibrated using the local Lincoln MS4 monitoring data, supplemented by additional information from regional data from the National Stormwater Quality Database (NSQD), available at:
http://www.unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

Observed Stormwater Quality in Lincoln, Nebraska

Local Lincoln, NE, NPDES MS4 monitoring data are available from the master's thesis prepared by M.K. Vegi at the University of Nebraska, February 2008 (*Estimation of Stormwater Pollutant Loads from the City of Lincoln, Nebraska*). Twenty-seven runoff events were monitored at three study areas representing residential, commercial, and industrial areas. These were monitored from April to the end of August, 2008. Table 2 (from the thesis) describes the monitored locations.

Table 2. Wet Weather Monitoring Locations (Higgins, 2007).

Monitoring Point Designation	**Site# 2**	**Site# 5**	**Site# 3**
Name Designation	Tipperary	N Street Storm Drain	W.Commerce Way
Predominant Land Use	Residential	Commercial	Industrial
Location Description	400 ft west of 27th St. & Tipperary Trail	1st & N Sts.	400 ft west of NW 15th & W. Commerce Sts.
Latitude	40° 45' 56.4"	40° 48' 13.9"	40° 50' 52.1"
Longitude	96° 41' 2.27"	96° 43' 13.9"	96° 44' 30.6"
Receiving Stream	Beal Slough	Salt Creek	Oak Creek
Watershed Area	126.6 acres (51 ha)	358.0 acres (145 ha)	48.5 acres (20 ha)
Percent Imperviousness	38 %	85%	72%

Tables 3 through 5 show the monitored concentrations for these events in Lincoln, along with the average concentrations for each land use as calculated using the locally calibrated WinSLAMM model for Lincoln.

Table 3. Lincoln, NE, Residential Area Monitoring Data (Site #2, 27th and Tipperary Trail)

	Rain depth (in)	Average rain intensity (in/hr)	E. coli (#/100 mL)	TSS (mg/L)	TP (mg/L as P)	TKN mg/L as N	Cu (µg/L)	Zn (µg/L)
4/6/2006	0.50	0.17	123,900	135	0.18	3.4	110	50
7/21/2006	0.94	0.13	16,705	38	0.33	1.6	110	800
8/17/2006	0.43	0.07	127,000	15	0.30	1.1	140	50
9/21/2006	0.42	0.04	6,140	43	0.33	1.3	60	<50
4/24/2007	2.08	0.16	3,880	178	0.18	1.2	150	130
7/19/2007	0.92	0.23	128,000	49	0.48		150	130
7/29/2007	0.31	0.06	24,200	41	0.13		200	100
8/8/2007	1.70	0.34	41,000	36	0.27		30	40
8/20/2007	0.63	0.16	242,000	107	0.37	1.3	40	120
Average	0.88	0.15	79,203	71	0.29	1.65	110	178
Standard deviation	0.62	0.09	81,062	55	0.11	0.87	57	254
COV	0.7	0.6	1.0	0.8	0.4	0.5	0.5	1.4
Minimum	0.31	0.04	3,880	15	0.13	1.1	30	40
Maximum	2.08	0.34	242,000	178	0.48	3.4	200	800
Count	9	9	9	9	9	6	9	8
WinSLAMM Average Residential Area Concentrations			78,000	86	0.31	1.67	110	180

Table 4. Lincoln, NE, NPDES Industrial Monitoring Data (Site #3, 15th and W. Commerce)

	Rain depth (in)	Average rain intensity (in/hr)	E. coli (#/100 mL)	TSS (mg/L)	TP (mg/L as P)	TKN (mg/L as N)	Cu (µg/L)	Zn (µg/L)
3/30/2006	0.99	0.17	185	590	0.45	1.4	240	600
7/21/2006	0.97	0.14	52,500	61	0.13	1.2	120	120
8/17/2006	0.63	0.08	1,730	22	0.16	1.5	120	120
9/21/2006	1.43	0.11	3,450	41	0.20	1.1	100	100
4/24/2007	2.60	0.17	880	267	0.42	0.7	160	270
7/29/2007	0.33	0.08	173,000	45	0.02		120	120
8/8/2007	0.97	0.14	2,190	78	0.26		<30	120
8/20/2007	0.24	0.12	700	180	0.36	1.1	60	170
9/10/2007	0.23	0.03	3,200	23	0.11		80	260
Average	0.93	0.11	26,426	145	0.23	1.17	125	209
Standard deviation	0.75	0.04	57,479	186	0.15	0.28	55	160
COV	0.8	0.4	2.2	1.3	0.6	0.2	0.4	0.8
Minimum	0.23	0.03	185	22	0.02	0.7	60	100
Maximum	2.6	0.17	173,000	590	0.45	1.5	240	600
Count	9	9	9	9	9	6	8	9
WinSLAMM Average Industrial Area Concentrations			30,000	91	0.19	1.20	110	150

Table 5. Lincoln, NE, NPDES Commercial Data (Site #5, 1st St. and N. St)

	Rain depth (in)	Average rain intensity (in/hr)	E. coli (#/100 mL)	TSS (mg/L)	TP (mg/L as P)	TKN (mg/L as N)	Cu (µg/L)	Zn (µg/L)
3/30/2006	1.01	0.17	4,495	1,056	1.50	1.6	380	1400
7/21/2006	0.95	0.12	1,160	772	0.72	4.7	520	1000
8/17/2006	0.50	0.07	46,200	88	0.39	2.0	120	190
9/21/2006	0.56	0.04	43,600	113	0.36	0.4	90	70
4/24/2007	2.50	0.18	19,900	675	0.46	1.0	265	660
7/19/2007	0.79	0.20	44,000	347	0.46		265	660
7/29/2007	0.36	0.06	32,600	114	0.36		990	1140
8/8/2007	1.07	0.13	6,375	151	0.36		60	270
8/20/2007	0.73	0.37	8,445	362	0.33	1.3	80	330
Average	0.94	0.15	22,975	409	0.55	1.8	308	636
Standard deviation	0.63	0.10	18,752	348	0.38	1.5	299	463
COV	0.7	0.7	0.8	0.9	0.7	0.8	1.0	0.7
Minimum	0.36	0.04	1,160	88	0.33	0.4	60	70
Maximum	2.50	0.37	46,200	1,056	1.50	4.7	990	1400
Count	9	9	9	9	9	6	9	9
WinSLAMM Average Commercial Area Concentrations			23,000	410	0.51	1.8	310	640

The National Stormwater Quality Database Compared to Lincoln, Nebraska MS4 Data

The characteristics of stormwater discharges vary considerably. Geographical area and land use have been identified as important factors affecting base flow and stormwater runoff quality, for example. Many studies have investigated stormwater quality, with the EPA's Nationwide Urban Runoff Program (NURP) being the best known and earliest effort to collect and summarize these data. Unfortunately, NURP was limited in that it did not represent all areas of the US or all important land uses. More recently, the National Stormwater Quality Database (NSQD) compiled runoff characteristics information from more than 8,000 events from throughout the US. Most of these data were from the EPA's NPDES stormwater permit program for Phase 1 communities. These permits are needed for all large municipal areas having >250,000 in population. The Phase II permit program requires permits from small communities.

As a condition for these permits, municipalities were required to establish a monitoring program to characterize their local stormwater quality for their most important land uses discharging to the municipal separate storm sewer system (MS4). Although only a few samples from a few locations are required each year from these communities, the ten plus years of MS4 data included in the NSQD comprise a suitable number of samples from many locations. Recently, version 3 of the NSQD was completed, and besides expanding to include additional stormwater NPDES MS4 permit holders, most of the older NURP data, and some of the International BMP database information was also added, along

with data from some USGS research projects. A number of land uses are represented in these data, with most data from residential, commercial, and industrial areas, and less data from freeways, institutional and open space areas. These observations were all obtained at outfall locations and do not include snowmelt or construction erosion sources. This version contains the results from about one fourth of the total number of communities that participated in the Phase I NPDES stormwater permit monitoring activities. The database is located at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml.

Figure 1 is a map showing the EPA Rain Zones in the US (not to be confused with EPA administrative regions), along with the locations of the communities containing data in the NSQD, ver 3. Recent revisions to the database have included additional quality control evaluations. In the near future, additional supplemental data from under-represented regions (especially southern California, plus some additional information from recent stormwater research projects) will also be added to the database.

Appendix B summarize the data observations for selected stormwater characteristics (volumetric runoff coefficient, TSS, TDS, COD, TKN, NO_3+NO_2, TP, dissolved P, Cu, Pb, Zn, and fecal coliforms, plus for limited data for E. coli bacteria). These data are separated by the six land uses represented and geographical areas (shown by EPA Rain Zones). Rain Zones 8 and 9 have very few samples, and institutional and open space areas are poorly represented. However, residential, commercial, industrial, and freeway data are plentiful, except for the few EPA Rain Zones noted above. Lincoln, NE, is close to the arbitrary dividing line between Rain Zones 1 and 9, and is also close to Rain Zone 4. The yellow high-lighted cells indicate rain zone-land use combinations having at least 40 events represented, a value expected to result in more reliable concentration estimates than for conditions having very few data observations.

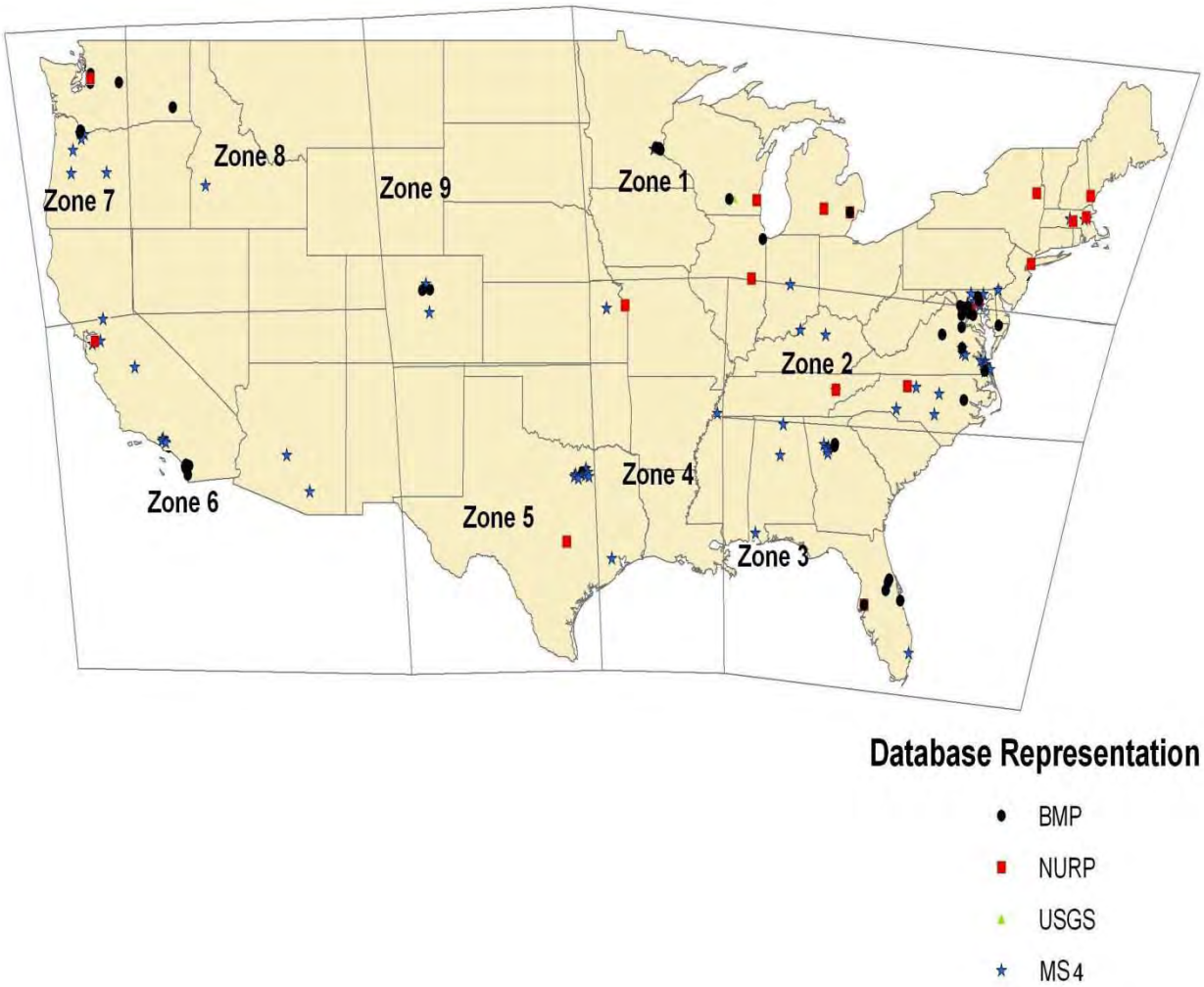


Figure 1. Sampling Locations for Data Contained in the National Stormwater Quality Database, version 3.1.

The values on the tables in Appendix B are the averages, the coefficient of variation, and the number of observations for the observed data (above the detection limits). Besides each land use and rain zone combination, overall land use and overall rain zone values are also shown, along with the overall database values. The average values are shown instead of the median, as the averages better represent long-term mass discharges. Median values artificially reduce the effects of the periodic unusually high concentrations that do occur in stormwater. In most cases, the detection limits are exceeded for more than 90% of the observations. If substitutions were made, then the average values would be slightly smaller, while the medians would likely change very little. Applying substitutions for non-detectable values can cause other artifacts when conducting statistical analyses, especially for paired analyses. No substitutions were therefore made in these analyses for the non-detected values, since the detected percentages were high, and these other statistical artifacts were not desired. Some of the other constituents included in the NSQD (such as filtered forms of metals and organic toxicants) can have much larger fractions of non-detected values, and special procedures are needed when analyzing those data.

Figure 2 is a plot showing the calculated ratios of the average concentrations to the median concentrations for all of the cells represented in the data set summarized in the tables (but including the few E. coli data). The average values are all larger than the median values, with the ratios ranging from 1 up to about 10. This plot shows how this ratio generally increases as the coefficient of variation (COV) values increase. The coefficient of variation is the ratio of the standard deviation to the average value (another reason why the average values are shown on these tables).

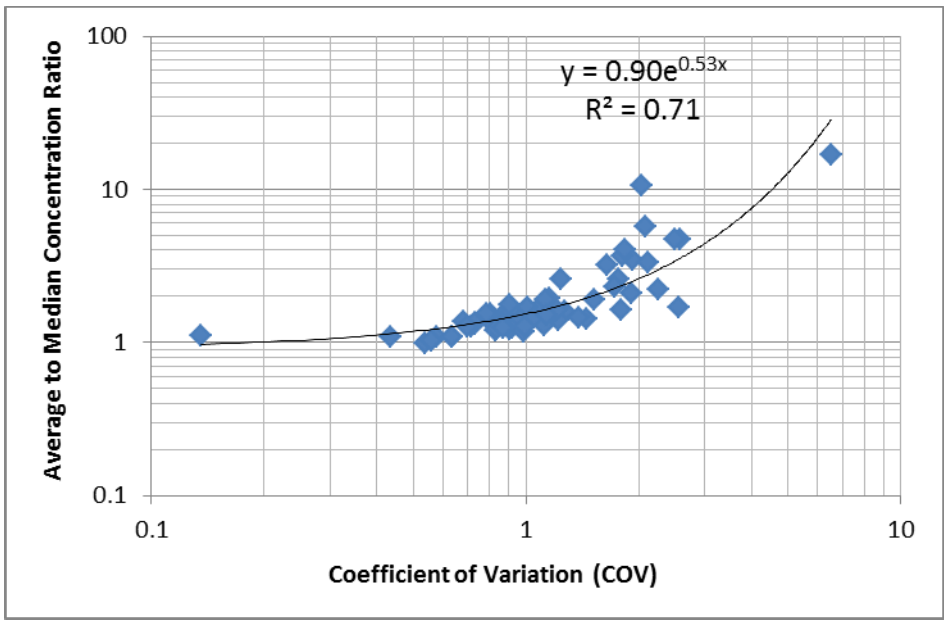


Figure 2. Relationship between the average to median concentration ratios and the COV values.

Stormwater concentrations usually have a log-normal distribution, with a concurrent positive bias, resulting in the average values being larger than the median values. The greater the difference, the greater the positive bias (and the larger the COV). If the COV is less than about 0.5, there is little difference between the median and the average values. However, most of the stormwater concentration COV values are in the range of 0.5 to 2, as indicated on Figure 2, with some much larger. The fecal coliform observations have the largest variations in each sample subgroup, while the Rv, COD, and TKN observations have the smallest variations.

In most cases, the COV values are smaller for the subgroups compared to the overall group values, indicating that the land use and geographical combinations help explain some of the large variability commonly found with stormwater concentrations. Detailed analyses have been conducted using the complete database to statistically identify significant subgroupings. In most cases, the complete matrix of 54 combinations of land use and location is reduced by missing data and by combining similar conditions, resulting in many fewer significant subgroups. The Appendix B tables do not reflect these statistical groupings, as these data are being used to compare the regional NSQD observations with the local Lincoln observations in this report. Actual data for the areas closest in character to the standard land use file locations are desired for these comparisons; therefore, the data in high-lighted cells are compared to the local values. If a cell is not high-lighted, then the land use high-lighted value is used. If

that is not high-lighted, then the overall value is compared. These NSQD data are also used to compare the modeled results when local data are not available.

Statistical Groupings of NSQD Data into Significantly Different Data Subsets

During her Ph.D. research, Bochis (2010) examined all 2-way interactions between the geographical regions and the land use categories for selected constituents in the NSQD. She found that the national data could be combined into a reasonable number of significantly different subsets having similar characteristics. These groups of data have concentrations that are more similar within the group than between the groups. These groupings of the data can be used to assist local stormwater managers in estimating likely stormwater concentrations for similar local conditions. Examining 3-way interactions, by adding seasonal data to the geographical regions and land use information, did not result in many additional category distinctions associated with seasonal effects on stormwater concentrations. Table 6 shows the combined categorical groupings of the national data, with the limited seasonal distinctions identified. At the national level, EPA Rain Zones 1, 3, and 5 were found to have statistically significant differences in land use categories only for total suspended solids. EPA Rain Zones 1 and 2 were found to also have statistically significant differences in land use categories only for total suspended solids. Also, EPA Rain Zones 2 and 5 were not found to have statistically significant differences in land use categories, except for total copper, and EPA Rain Zones 6 and 9 were not found to have statistically significant differences in land use groups, except for metals (total zinc and total copper).

Table 6. Summary of Homogeneous Land Uses and Seasonal Clusters

Stormwater Constituent	All EPA Rain Zones Land Use	Mean (COV)
Total Suspended Solids	1-RE,CO,ID 4-RE,CO,ID 6-RE,CO 9-CO,ID	199 (1.9)
	2-RE 3-RE,CO,ID	76 (1.6)
	2-CO,ID 5- RE,CO,ID 7- RE,CO,ID 9-RE	78 (1.9)
Total Zinc	1-RE	59 (1.9)
	1-CO,ID 2-RE 3-RE,CO,ID 5-RE,CO,ID	92 (1.6)
	2-ID 7-RE,CO,ID 9-RE,CO,ID	163 (2.3)
	2-CO 4-RE,CO,ID 6-RE,CO	261 (1.2)

Table 6. Summary of Homogeneous Land Uses and Seasonal Clusters (cont.)

Total Copper	1-RE,ID 3-RE,CO,ID 5-RE,CO,ID 6-RE,CO	11 (2.3)
	2-RE,ID 7-RE,CO,ID	25 (1.9)
	1-CO 2-CO 9-RE,CO,ID	36 (1.2)
	4-RE,CO,ID	86 (1.9)
Total Phosphorous	1-CO 3-RE,ID 5-CO	0.17 (1.2)
	1-RE,ID 2-RE,CO,ID 3-CO 4-RE,CO,ID 5-RE,ID	0.38 (1.7)
	7-RE,CO,ID	0.3 (1.2)
	6-RE,CO 9-RE,CO,ID	0.52 (0.67)
Total Kjeldahl Nitrogen	1-RE,CO,ID 2-RE,CO,ID 3-CO,ID 4-RE,CO,ID 5-RE,CO,ID 7-(RE,CO) (FA,SU), ID	1.8 (0.99)
	3-RE 7-(RE,CO) (SP,WI)	0.97 (0.90)
	6-RE,CO 9-RE,CO,ID	3.6 (0.73)

Table 6. Summary of Homogeneous Land Uses and Seasonal Clusters (cont.)

Fecal Coliform	1-(RE,CO,ID) (FA,SP,WI) 2-(RE,CO,ID) (SP,WI) 3-(RE,CO,ID) (SP,WI) 4-ID 7-RE,CO,ID 9-(RE,CO,ID) (SP)	29120 (8.2)
	1-(RE,CO,ID) (SU) 2-(RE,CO,ID) (FA,SU) 3-(RE,CO,ID) (FA,SU) 4-RE,CO 5-RE,CO,ID 6-RE 9-(RE,CO,ID) (FA,SU)	40286 (3.0)

Comparison of Local Lincoln MS4 NPDES Data with Regional NSQD Data

Tables 7 through 9 summarize the observed Lincoln MS4 monitored data compared to regional data from the NSQD. The Lincoln data compare well with the regional data from the three adjoining EPA Rain Zones that are close to the city, with the exception of the E. coli bacteria data. There are few E. coli observations available in the NSQD, so those data are not very reliable. Generally, the Lincoln E. Coli values are about 5 to 10 times larger than the reported NSQD observations. Lincoln residential and industrial area TSS concentrations are also substantially smaller (2 to 5 times) than the regional data, while the commercial TSS data are about twice the regional average. The nutrient and zinc observations are quite close, while the Lincoln copper observations are 2 to 5 times larger than the regional averaged copper data. Because of the large variability of stormwater quality data as reflected in the moderate to large COV values, these differences are not unexpected. As an example, Figure 3 shows that with a COV of 1, the ratio of the 90th and 10th percentile concentrations is about 10, while this range ratio is still about 5 for a COV of 0.5. Therefore, these Lincoln observations are not likely statistically dissimilar from the regional data, although further statistical analyses are planned in the future after current NSQD updates are completed.

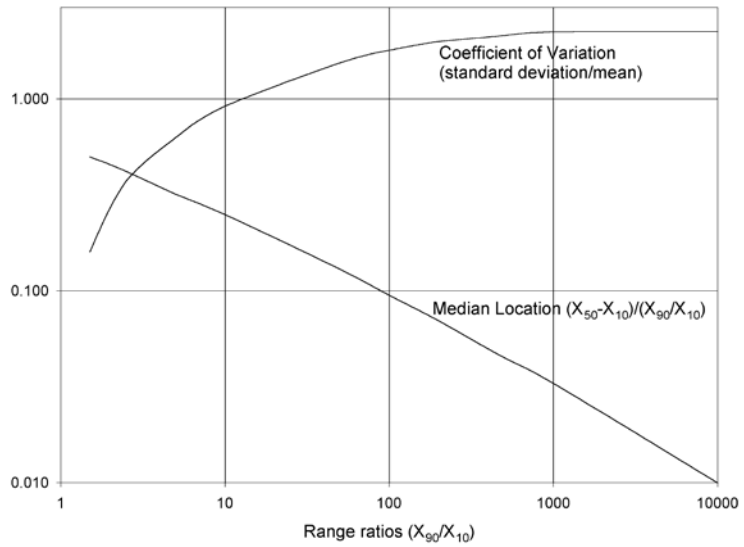


Figure 3. Determination of Coefficient of Variation from Range of Observations (Burton and Pitt, 2001).

Table 7. Residential Area Comparisons

	Lincoln MS4		**NSQD RZ9**		**NSQD RZ4**		**NSQD RZ1**	
	average	COV	average	COV	average	COV	average	COV
E. coli (#/100 mL)	79,203	1.0	6,580	1.9	6,580	1.9	6,580	1.9
TSS (mg/L)	71	0.8	528	2.5	374	1.8	135	1.2
TP (mg/L as P)	0.29	0.4	0.81	1.1	0.7	1.2	0.4	1.1
TKN (mg/L as N)	1.7	0.5	3.8	0.7	2.3	1.5	1.9	0.9
Cu (µg/L)	110	0.5	27	1.8	52	1.8	34	1.8
Zn (µg/L)	178	1.4	139	1.0	264	2.3	132	1.2

Table 8. Commercial Area Comparisons

	Lincoln MS4		**NSQD RZ9**		**NSQD RZ4**		**NSQD RZ1**	
	average	COV	average	COV	average	COV	average	COV
E. coli	22,975	0.8	4,620	2.4	4,620	2.4	4,620	2.4
TSS	409	0.9	133	1.7	232	1.9	201	1.5
TP as P	0.55	0.7	0.37	2.0	0.38	1.6	0.25	2.2
TKN as N	1.8	0.8	1.9	0.9	1.8	0.9	1.5	1.1
Cu	308	1.0	37	2.3	69	1.2	58	0.8
Zn	636	0.7	197	1.4	270	0.9	196	1.4

Table 9. Industrial Area Comparisons

	Lincoln MS4		NSQD RZ9		NSQD RZ4		NSQD RZ1	
	average	COV	average	COV	average	COV	average	COV
E. coli	29,706	2.0	5,240	2.1	5,240	2.1	5,240	2.1
TSS	90	1.0	360	1.9	164	1.4	177	1.4
TP as P	0.21	0.6	0.39	1.5	0.36	1.2	0.33	0.8
TKN as N	1.2	0.2	1.9	1.2	1.6	0.6	1.9	0.9
Cu	109	0.3	46	1.0	99	2.3	25	1.8
Zn	160	0.4	486	0.9	512	2.9	106	1.2

Calibrations of WinSLAMM to Simulate Local Observed Stormwater Conditions

All models need to be calibrated to result in the most effective information. WinSLAMM calibrations for Lincoln were based on a multi-step process. Much source area monitoring data are available from different locations (mainly from California, Alabama, Ontario, and Wisconsin). These data are summarized in a series of peer-reviewed chapters in modeling monographs:

- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 1) – Older monitoring projects." In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 465 – 484 and 507 – 530. 2005.
- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 2) – Recent sheetflow monitoring results." In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 485 – 530. 2005.
- Pitt, R., D. Williamson, and J. Voorhees. "Review of historical street dust and dirt accumulation and washoff data." Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp 203 – 246. 2005.

These data have been used to create calibrated WinSLAMM models in several locations that have since been verified using outfall data. The most extensive data are from the Birmingham, AL area and from the state of Wisconsin. Land use (and stormwater) data from throughout the nation are also available from many research reports. These data were separated into several regional groups. The Lincoln area is included in the Central US area and was originally based on the Wisconsin calibration and verification model sets. The Central model files were then modified based on outfall data from the Central US region as contained in the NSQD. Finally, these Central US files were further modified using the events monitored in Lincoln as part of their MS4 monitoring program.

As noted earlier, the Lincoln rain file was used to calculate long-term stormwater conditions. The four year period from 1996 through 1999 was used. A longer period was not possible due to missing observations. Winter conditions were also defined as being from December 20 to February 10 of each year. During these winter periods, no stormwater calculations were made.

During the Lincoln calibration process, the calculated long-term averaged modeled concentrations were compared to the monitored concentrations for each site. Factors were applied uniformly to each land

use in the Lincoln pollutant and particulate solids parameter files to adjust the long-term modeled concentrations to best match the monitored/observed values. The runoff parameter file was not modified as it has been shown to compare well to observed conditions under a wide range of situations.

Sources of Stormwater Flows and Pollutants and Control Strategy

The locally calibrated WinSLAMM parameter files and averaged land use files were then used to identify the major source areas of each pollutant and flow. This is critical information needed when designing a stormwater management program for an area. Table 10 summarizes the detailed plots presented in Appendix C. Table 10 includes summaries of the major flows and pollutant sources for each of the nine land use categories. The major sources are shown for each flow and constituent, for three different rain event categories: small (<0.5 inches), intermediate (0.5 to 2 inches), and large (>2 inches).

The small category generally includes most of the rain and runoff events by number, but produces a small fraction of the annual runoff mass. This category of events if therefore of greatest interest when the number of events is of concern. If regulatory limits have numeric effluent standards, then the number of runoff events is of the greatest concern, and stormwater control strategies would focus on eliminating as many of the runoff events as possible. Relatively small rains are associated with most of the runoff events, by number (although the total runoff volume from these rains is relatively small). For many locations, typical numeric standards for bacteria and total recoverable heavy metals would be frequently exceeded. Therefore, runoff volume, bacteria, and heavy metals would be of the greatest interest for removal from the small rain category.

The intermediate category generally includes most of the runoff pollutant discharges by mass; frequently more than 75% of the annual pollutant discharges, by mass, occur during these rains. It is therefore greatly desired to remove as much of the runoff from this rain category. However, site soil and development conditions will likely prevent the elimination of all runoff from this category. Therefore, stormwater treatment will be needed for the constituents of concern for runoff that cannot be totally eliminated by site beneficial use or infiltration. Flow, as noted, will always be of interest, but further treatment of stormwater to reduce bacteria, nutrient, and /or heavy metal discharges will also likely be a suitable goal.

The largest rain category includes events that are channel-forming with dramatic effects on habitat conditions. Therefore, volume reductions during some portions of these large rains will provide some benefit, but reductions in runoff energy discharges will also need to be considered. Runoff energy reductions are most effectively associated with flow-duration modifications of the discharge hydrographs. The largest rains in this category (not included in the 4-year rainfall period examined) are associated with drainage design and public safety. Flow sources are therefore of the greatest concern, and like for energy reductions, basin-wide hydraulic analyses would be needed to result in the most effective stormwater management and drainage options. It is unlikely that pollutant discharges would be of great concern during these large events, as they contribute relatively small fractions of the amortized annual flows, and any treatment method that could manage these large flows would be extremely costly and inefficient.

As shown on Table 10, most of the flows originate from the directly connected impervious areas (DCIA), but undeveloped or landscaped areas can contribute large portions of the flows if these areas are very large (such as in the residential areas). For these areas, the landscaped/undeveloped areas can produce significant flows (about 40% of the total flows) during the large rains. The goal of any stormwater

management program should therefore be to reduce/eliminate runoff from the DCIA areas. However, there are many conditions where large-scale infiltration of stormwater may not be desirable (mainly in areas having severely limited soils hindering infiltration, shallow groundwater, or other factors that would not adequately mitigate pollutant movement to the groundwater). In most cases, roof runoff, being the least contaminated DCIA source water, should be preferentially infiltrated or used on site for beneficial uses.

In residential areas, the roof runoff comprises about 15% of the total annual runoff amount, mainly because most of the roofs are disconnected. Streets can comprise the majority of the total flows in residential areas during small to intermediate events. A typical strategy in residential areas would therefore apply rain gardens, or otherwise disconnect the roof drainage, for roof runoff control (for currently directly connected roofs). If possible, soil amendments and other strategies to reduce soil compaction to improve infiltration in the landscaped areas could eliminate much of the runoff from those areas. Street and driveway runoff would remain and are significant flow and pollutant sources. If the area was drained using grass swales, it is likely that most of the total area runoff would be eliminated. If drained by conventional curbs and gutters, curb-cut bioinfiltration areas could be retrofitted to eliminate almost all of the runoff (and associated pollutants). In residential areas having loamy soils that are not compacted and are drained by grass swales, especially if most of the impervious areas are disconnected and drain to pervious areas, no additional stormwater controls may be needed in residential areas. High-density residential areas having larger amounts of impervious areas would obviously require additional effort.

Commercial areas have most of their runoff originating from paved parking areas, streets, and roofs. These are also the main sources for most of the pollutants examined. Few opportunities exist to utilize rain gardens for roof runoff control in most commercial areas, so bioinfiltration areas that collect runoff from mixed sources may be an appropriate approach. In many parking areas, islands or landscaped edges can be retrofitted with infiltration devices for significant runoff volume reductions. Curb-cut biofilters would need to extend out into the street in most cases due to lack of suitable space near the street edge in most commercial areas. Treatment of commercial area stormwater runoff would therefore be needed, as complete infiltration is not likely to be achieved. Critical source area treatments in areas of major automobile activity, plus pollution prevention to reduce the use of galvanized metals are other strategies. Because of the lack of space in most commercial areas, stormwater treatment may need to be situated in adjacent areas, or in underground chambers.

Industrial areas have most of their flows and pollutants originating from paved parking and storage areas. Roofs and streets are lesser, but still important sources. Infiltration in these areas is of greater concern as the runoff from industrial areas is more likely to lead to groundwater contamination. Critical source area controls (such as media filtration and biofilters using specialized media as part of treatment trains) will likely be necessary, along with pollution prevention to reduce the exposure of metals (especially galvanized) and other materials. In some industrial areas, stormwater can be used for dust suppression. If a relatively large site, wet detention ponds could also be located on available land to collect and further treat any remaining surface runoff.

Some institutional areas are predominately landscaped, with less directly connected impervious areas and larger landscaped or undeveloped areas for stormwater management. Designing stormwater management features that take advantage of the topography in these areas can result in significant runoff discharge reductions. Most institutional areas in the Antelope Creek drainage have large parking areas with long-term parking that can benefit from parking lot island or perimeter bioinfiltration areas.

The summaries in Table 10 and Appendix C can be used to illustrate the likely maximum level of control for different stormwater management approaches applied to source areas. If lots of attention were applied to roof rain gardens in residential areas, it is obvious that there will still be significant runoff from other sources, for example. Modeling of the different scenarios can be used to quantify how the different control approaches can (or cannot) meet desired objectives. These summary tables and the figures can however be used to indicate where management strategies should be focused.

Table 10. Summary of Major Sources of Flows and Pollutants, Lincoln, NE Land Uses

	Commercial – Strip Mall	**Commercial – Shopping Center**	**Light Industrial**
Flows			
Small	Paved parking (56%) Streets (23%) Roofs (21%)	Paved parking (58%) Roofs (22%) Streets (20%)	Park/stor (55%) Streets (20%) Driveways (19%)
Intermediate	Paved parking (50%) Roofs (30%) Streets (19%)	Paved parking (51%) Roofs (32%) Streets (17%)	Park/stor (53%) Streets (18%) Driveways (14%)
Large	Paved parking (51%) Roofs (28%) Streets (17%)	Paved parking (52%) Roofs (30%) Streets (15%)	Park/stor (49%) Streets (15%) Driveways (14%)
Total Suspended Solids			
Small	Paved parking (83%) Roofs (12%)	Paved parking (84%) Roofs (12%)	Park/stor (78%) Streets (11%) Driveways (10%)
Intermediate	Paved parking (83%) Roofs (13%)	Paved parking (84%) Roofs (13%)	Park/stor (74%) Driveways (12%)
Large	Paved parking (64%) Roofs (23%)	Paved parking (66%) Roofs (24%)	Park/stor (87%) Driveways (4%)
Chemical Oxygen Demand			
Small	Paved parking (67%) Roofs (28%)	Paved parking (67%) Roofs (29%)	Park/stor (73%) Streets (15%) Driveways (10%)
Intermediate	Paved parking (63%) Roofs (31%)	Paved parking (63%) Roofs (32%)	Park/stor (69%) Streets (13%) Driveways (10%)
Large	Paved parking (44%) Roofs (42%) Streets (11%)	Paved parking (44%) Roofs (44%) Streets (10%)	Park/stor (81%)
Total Phosphorus			
Small	Paved parking (61%) Roofs (31%)	Paved parking (61%) Roofs (33%)	Park/stor (53%) Streets (24%) Driveways (20%)
Intermediate	Paved parking (53%) Roofs (31%)	Paved parking (54%) Roofs (33%)	Park/stor (48%) Streets (22%) Driveways (20%)
Large	Landscaping (39%) Paved parking (36%) Roofs (25%)	Landscaping (34%) Paved parking (31%) Roofs (28%)	Park/stor (59%) Streets (16%) Driveways (10%) Landscaping (12%)

	Commercial – Strip Mall	**Commercial – Shopping Center**	**Light Industrial**
Total Kjeldahl Nitrogen			
Small	Paved parking (64%) Roofs (29%)	Paved parking (64%) Roofs (30%)	Park/stor (64%) Driveways (18%) Streets (13%)
Intermediate	Paved parking (58%) Roofs (33%)	Paved parking (58%) Roofs (34%)	Park/stor (56%) Driveways (18%) Streets (10%)
Large	Roofs (38%) Paved parking (34%) Landscaping (19%)	Roofs (41%) Paved parking (35%) Landscaping (16%)	Park/stor (64%) Landscaping (11%) Roofs (10%)
Nitrites + nitrates			
Small	Paved parking (48%) Roofs (27%) Streets (25%)	Paved parking (49%) Roofs (29%) Streets (22%)	Park/stor (50%) Streets (24%) Driveways (16%)
Intermediate	Paved parking (41%) Roofs (37%) Streets (21%)	Paved parking (42%) Roofs (40%) Streets (18%)	Park/stor (50%) Streets (21%) Driveways (14%)
Large	Paved parking (42%) Roofs (36%) Streets (18%)	Paved parking (43%) Roofs (38%) Streets (16%)	Park/stor (55%) Streets (18%) Driveways (12%)
Total Copper			
Small	Paved parking (79%) Roofs (16%)	Paved parking (80%) Roofs (14%)	Park/stor (63%) Roofs (31%)
Intermediate	Paved parking (77%) Roofs (16%)	Paved parking (78%) Roofs (16%)	Park/stor (52%) Roofs (31%) Streets (10%)
Large	Paved parking (62%) Roofs (25%) Streets (11%)	Paved parking (63%) Roofs (26%) Streets (10%)	Park/stor (58%) Roofs (33%)
Total Lead			
Small	Paved parking (75%) Roofs (22%)	Paved parking (75%) Roofs (23%)	Park/stor (76%) Driveways (16%)
Intermediate	Paved parking (74%) Roofs (24%)	Paved parking (73%) Roofs (25%)	Park/stor (73%) Driveways (16%)
Large	Paved parking (53%) Roofs (40%)	Paved parking (53%) Roofs (42%)	Park/stor (87%)

	Commercial – Strip Mall	**Commercial – Shopping Center**	**Light Industrial**
Total Zinc			
Small	Paved parking (68%) Roofs (27%)	Paved parking (68%) Roofs (28%)	Park/stor (76%) Streets (10%)
Intermediate	Paved parking (67%) Roofs (29%)	Paved parking (66%) Roofs (31%)	Park/stor (70%) Roofs (15%)
Large	Paved parking (48%) Roofs (46%)	Paved parking (48%) Roofs (47%)	Park/stor (78%) Roofs (15%)
Fecal Coliform Bacteria			
Small	Paved parking (70%) Streets (25%)	Paved parking (74%) Streets (23%)	Driveways (68%) Streets (25%)
Intermediate	Paved parking (69%) Streets (23%)	Paved parking (73%) Streets (22%)	Driveways (65%) Streets (24%)
Large	Paved parking (70%) Streets (21%)	Paved parking (74%) Streets (19%)	Driveways (58%) Streets (21%)
E. Coli Bacteria			
Small	Paved parking (70%) Streets (25%)	Paved parking (75%) Streets (23%)	Driveways (58%) Streets (36%)
Intermediate	Paved parking (70%) Streets (24%)	Paved parking (74%) Streets (22%)	Driveways (55%) Streets (34%)
Large	Paved parking (71%) Streets (22%)	Paved parking (75%) Streets (20%)	Driveways (49%) Streets (30%) Park/stor (10%)

Small events: <0.5 inches of rain
Intermediate events: 0.5 to <2.5 inches of rain
Large events: 2.5 and greater inches of rain

Table 10. Summary of Major Sources of Flows and Pollutants, Lincoln, NE Land Uses (cont.)

	Institutional - Schools	**Institutional - Churches**	**Institutional - Hospitals**
Flows			
Small	Paved parking (52%) Roofs (32%) Streets (11%)	Paved parking (46%) Streets (33%) Roofs (15%)	Paved parking (63%) Roofs (24%) Streets (11%)
Intermediate	Roofs (42%) Paved parking (41%)	Paved parking (44%) Streets (31%) Roofs (13%)	Paved parking (53%) Roofs (33%)
Large	Paved parking (39%) Roofs (37%) Landscaping (11%)	Paved parking (40%) Streets (24%) Landscaping (15%) Roofs (10%)	Paved parking (51%) Roofs (30%) Landscaping (10%)
Total Suspended Solids			
Small	Paved parking (48%) Streets (40%)	Streets (78%) Paved parking (18%)	Paved parking (48%) Streets (46%)
Intermediate	Paved parking (53%) Streets (19%) Roofs (14%)	Streets (56%) Paved parking (30%)	Paved parking (59%) Streets (24%)
Large	Paved parking (47%) Landscaping (30%) Roofs (11%)	Paved parking (37%) Streets (26%) Landscaping (25%)	Paved parking (59%) Landscaping (20%) Streets (10%)
Chemical Oxygen Demand			
Small	Roofs (42%) Paved parking (37%) Streets (17%)	Streets (56%) Paved parking (25%) Roofs (14%)	Paved parking (46%) Roofs (30%) Streets (22%)
Intermediate	Roofs (53%) Paved parking (29%)	Streets (37%) Paved parking (32%) Roofs (16%) Landscaping (10%)	Roofs (43%) Paved parking (40%) Streets (10%)
Large	Roofs (44%) Paved parking (26%) Landscaping (24%)	Landscaping (32%) Paved parking (28%) Streets (18%) Roofs (14%)	Roofs (40%) Paved parking (38%) Landscaping (15%)

	Institutional - Schools	Institutional - Churches	Institutional - Hospitals
Total Phosphorus			
Small	Paved parking (43%) Roofs (27%) Streets (16)	Streets (49%) Paved parking (29%) Driveways (12%) Roofs (10%)	Paved parking (54%) Streets (20%) Roofs (20%)
Intermediate	Landscaping (30) Paved parking (25%) Roofs (25%)	Landscaping (39%) Streets (22) Paved parking (22%)	Paved parking (36%) Landscaping (30%) Roofs (22%)
Large	Landscaping (56) Paved parking (12%) Roofs (12%)	Landscaping (74%) Paved parking (11%)	Landscaping (62%) Paved parking (20%) Roofs (12%)
Total Kjeldahl Nitrogen			
Small	Roofs (40%) Paved parking (36%) Streets (19)	Streets (58) Paved parking (35%) Roofs (14%)	Paved parking (44%) Roofs (40%) Streets (24)
Intermediate	Roofs (46%) Paved parking (25%) Streets (14) Landscaping (14%)	Streets (35) Paved parking (25%) Landscaping (18%) Roofs (13%)	Roofs (39%) Paved parking (35%) Landscaping (14%) Streets (11)
Large	Landscaping (36%) Roofs (30%) Paved parking (18%)	Landscaping (46%) Paved parking (18%) Streets (15)	Landscaping (37%) Roofs (28%) Paved parking (27%)
Nitrites + nitrates			
Small	Paved parking (43%) Roofs (41%) Streets (12)	Streets (37) Paved parking (39%) Roofs (19%)	Paved parking (55%) Roofs (31%) Streets (12)
Intermediate	Roofs (52%) Paved parking (33%)	Paved parking (38%) Streets (34) Landscaping (15%) Roofs (14%)	Paved parking (44%) Roofs (42%) Streets (10)
Large	Roofs (46%) Paved parking (31%) Landscaping (11%)	Paved parking (34%) Streets (27) Landscaping (18%) Roofs (14%)	Paved parking (42%) Roofs (38%) Landscaping (10)
Total Copper			
Small	Paved parking (51%) Streets (28%) Roofs (17%)	Streets (68%) Paved parking (25%)	Paved parking (54%) Streets (33%) Roofs (11%)
Intermediate	Paved parking (50%) Roofs (28%) Streets (15%)	Streets (50%) Paved parking (37%)	Paved parking (59%) Roofs (20%) Streets (18%)
Large	Paved parking (52%) Roofs (27%)	Paved parking (45%) Streets (32%) Landscaping (10%)	Paved parking (62%) Roofs (19%) Streets (10%)

	Institutional - Schools	Institutional - Churches	Institutional - Hospitals
Total Lead			
Small	Paved parking (51%) Streets (25%) Roofs (21%)	Streets (66%) Paved parking (26%)	Paved parking (55%) Streets (31%) Roofs (13%)
Intermediate	Paved parking (49%) Roofs (33%) Streets (10%)	Streets (44%) Paved parking (40%)	Paved parking (58%) Roofs (23%) Streets (14%)
Large	Paved parking (48%) Roofs (30%) Landscaping (12%)	Paved parking (47%) Streets (21%) Landscaping (17%)	Paved parking (60%) Roofs (23%) Landscaping (10%)
Total Zinc			
Small	Paved parking (43%) Roofs (33%) Streets (22%)	Streets (64%) Paved parking (25%) Roofs (10%)	Paved parking (49%) Streets (28%) Roofs (22%)
Intermediate	Roofs (49%) Paved parking (39%)	Streets (45%) Paved parking (37%) Roofs (12%)	Paved parking (48%) Roofs (36%) Streets (13%)
Large	Roofs (47%) Paved parking (41%)	Paved parking (46%) Streets (25%) Roofs (15%)	Paved parking (51%) Roofs (36%)
Fecal Coliform Bacteria			
Small	Paved parking (73%) Driveways (16%)	Paved parking (58%) Driveways (21%) Streets (18%)	Paved parking (83%) Driveways (10%)
Intermediate	Paved parking (71%) Driveways (15%)	Paved parking (57%) Driveways (21%) Streets (17%)	Paved parking (82%) Driveways (10%)
Large	Paved parking (69%) Driveways (12%)	Paved parking (57%) Driveways (18%) Streets (15%)	Paved parking (80%)
E. Coli Bacteria			
Small	Paved parking (73%) Driveways (16%)	Paved parking (58%) Driveways (21%) Streets (18%)	Paved parking (83%) Driveways (10%)
Intermediate	Paved parking (71%) Driveways (15%)	Paved parking (57%) Driveways (21%) Streets (17%)	Paved parking (82%) Driveways (10%)
Large	Paved parking (70%) Driveways (13%)	Paved parking (57%) Driveways (18%) Streets (15%)	Paved parking (81%)

Table 10. Summary of Major Sources of Flows and Pollutants, Lincoln, NE Land Uses (cont.)

	Residential – Low Density	**Residential – Medium Density (<1960)**	**Residential – Medium Density (1960 - 1980)**
Flows			
Small	Streets (73%) Driveways (15%) Roofs (12%)	Streets (68%) Driveways (16%) Roofs (16%)	Streets (55%) Roofs (28%) Driveways (16%)
Intermediate	Streets (60%) Landscaping (15%) Driveways (12%) Roofs (11%)	Streets (59%) Driveways (15%) Roofs (14%) Landscaping (11%)	Streets (47%) Roofs (24%) Driveways (15%) Landscaping (14%)
Large	Landscaping (40%) Streets (38%) Roofs (14%)	Streets (40%) Landscaping (32%) Roofs (16%) Driveways (11%)	Landscaping (37%) Streets (29%) Roofs (16%) Driveways (11%)
Total Suspended Solids			
Small	Streets (92%)	Streets (92%)	Streets (90%)
Intermediate	Streets (86%)	Streets (88%)	Streets (86%)
Large	Streets (47%) Landscaping (44%)	Streets (53%) Landscaping (35%)	Streets (48%) Landscaping (40%)
Chemical Oxygen Demand			
Small	Streets (84%) Driveways (11%)	Streets (71%) Driveways (11%)	Streets (77%) Driveways (11%)
Intermediate	Streets (77%) Landscaping (11%)	Streets (79%)	Streets (73%) Landscaping (10%)
Large	Landscaping (45%) Streets (40%)	Streets (45%) Landscaping (36%)	Landscaping (41%) Streets (37%) Roofs (10%)
Total Phosphorus			
Small	Streets (88%) Driveways (10%)	Streets (87%) Driveways (10%)	Streets (85%) Driveways (10%)
Intermediate	Streets (58%) Landscaping (36%)	Streets (64%) Landscaping (29%)	Streets (58%) Landscaping (34%)
Large	Landscaping (81%) Streets (15%)	Landscaping (75%) Streets (20%)	Landscaping (79%) Streets (15%)
Total Kjeldahl Nitrogen			
Small	Streets (79%) Driveways (14%)	Streets (76%) Driveways (14%)	Streets (69%) Driveways (14%)
Intermediate	Streets (52%) Landscaping (37%)	Streets (57%) Landscaping (29%)	Streets (49%) Landscaping (34%)
Large	Landscaping (78%) Streets (14%)	Landscaping (71%) Streets (18%)	Landscaping (75%) Streets (14%)

	Residential – Low Density	**Residential – Medium Density (<1960)**	**Residential – Medium Density (1960 - 1980)**
Nitrites + nitrates			
Small	Streets (73%) Driveways (12%)	Streets (68%) Roofs (17%) Driveways (13%)	Streets (53%) Roofs (34%) Driveways (13%)
Intermediate	Streets (60%) Landscaping (16%) Roofs (14%) Driveways (10%)	Streets (59%) Roofs (17%) Landscaping (12%) Driveways (11%)	Streets (45%) Roofs (28%) Landscaping (14%)
Large	Landscaping (41%) Streets (36%) Roofs (15%)	Streets (38%) Landscaping (33%) Roofs (19%) Driveways (14%)	Landscaping (38%) Streets (28%) Roofs (25%)
Total Copper			
Small	Streets (65%) Driveways (17%)	Streets (74%) Driveways (18%)	Streets (53%) Driveways (18%)
Intermediate	Streets (74%) Driveways (13%)	Streets (74%) Driveways (13%)	Streets (68%) Driveways (15%) Roofs (10%)
Large	Streets (42%) Landscaping (33%) Driveways (13%) Roofs (10%)	Streets (45%) Landscaping (25%) Driveways (14%) Roofs (11%)	Streets (37%) Landscaping (29%) Driveways (14%) Roofs (14%)
Total Lead			
Small	Streets (75%) Driveways (15%) Roofs (10%)	Streets (73%) Driveways (15%) Roofs (12%)	Streets (65%) Roofs (21%) Driveways (14%)
Intermediate	Streets (70%) Landscaping (13%) Driveways (10%)	Streets (71%) Driveways (10%)	Streets (65%) Roofs (14%) Landscaping (11%) Driveways (10%)
Large	Landscaping (49%) Streets (28%) Roofs (12%) Driveways (11%)	Landscaping (40%) Streets (32%) Roofs (15%) Driveways (12%)	Landscaping (42%) Streets (27%) Roofs (18%) Driveways (11%)
Total Zinc			
Small	Streets (80%) Roofs (12%)	Streets (77%) Roofs (14%)	Streets (67%) Roofs (24%)
Intermediate	Streets (76%) Roofs (10%)	Streets (76%) Roofs (11%)	Streets (68%) Roofs (18%)
Large	Streets (43%) Landscaping (33%) Roofs (17%)	Streets (46%) Landscaping (25%) Roofs (20%)	Streets (37%) Landscaping (28%) Roofs (24%)

	Residential – Low Density	**Residential – Medium Density (<1960)**	**Residential – Medium Density (1960 - 1980)**
Fecal Coliform Bacteria			
Small	Driveways (59%) Streets (41%)	Driveways (61%) Streets (38%)	Driveways (66%) Streets (32%)
Intermediate	Driveways (53%) Streets (37%)	Driveways (56%) Streets (34%)	Driveways (59%) Streets (29%)
Large	Driveways (41%) Streets (28%) Landscaping (21%)	Driveways (44%) Streets (27%) Landscaping (15%)	Driveways (44%) Streets (21%) Landscaping (19%)
E. Coli Bacteria			
Small	Driveways (58%) Streets (41%)	Driveways (61%) Streets (38%)	Driveways (66%) Streets (32%)
Intermediate	Driveways (53%) Streets (37%)	Driveways (56%) Streets (34%)	Driveways (59%) Streets (29%)
Large	Driveways (43%) Streets (30%) Landscaping (18%)	Driveways (46%) Streets (29%) Landscaping (13%)	Driveways (47%) Streets (23%) Landscaping (16%)

Appendix A. Lincoln, NE, Land Use Site Descriptions

Land Use	land use	Pitched Roofs to Impervious Areas - connected (%)	Pitched Roofs to Pervious Areas - disconnected (%)	Flat Roofs to Impervious Areas – connected (%)	Flat Roofs to Pervious Areas – disconnected (%)
Low density res	resid	1.8	13.1		
Med density res <1960	resid	2.8	14.7		
Med density res 1960 - 1980	resid	4.4	13.7		
Light industry	indus			5.6	4.6
Commercial - strip mall	commer			25	
Commercial - shopping center	commer			27.1	
Institutional - school	instit			24	
Institutional - church	instit	4.6	2.2	0.7	6.7
Institutional - hospital	instit			19.9	5

Land Use	Parking paved – connected (%)	Parking unpaved – disconnected (%)	Storage paved – connected (%)	Storage unpaved – disconnected (%)	Playground unpaved (%)	Driveways paved – connected (%)
Low density res						2.7
Med density res <1960		1.5				3.5
Med density res 1960 - 1980	0.1	2.1				3.1
Light industry	8.3	5.5	24.8	16.7		9.2
Commercial - strip mall	45.7					0.3
Commercial - shopping center	47.7					0.1
Institutional - school	25.5					1.5
Institutional - church	22.6				0.2	2.3
Institutional - hospital	35.6				0.2	1.1

Land Use	Driveways paved - disconnected (%)	Walkways - connected (%)	Walkways - disconnected (%)	Street Area (%)	Curb Miles (per 100 acres)	Street Width (ft)
Low density res	2.7		0.4	13.2	7.9	28
Med density res <1960	3.5	0.1	0.4	15.1	10	25
Med density res 1960 - 1980	3.1		0.3	10.4	8.4	23
Light industry				10	5.9	28
Commercial - strip mall				15	4.8	54
Commercial - shopping center				13.4	3.8	58
Institutional - school		0.5	0.5	4.5	1.8	42
Institutional - church	0.3	0.4	0.5	13.5	8.5	26
Institutional - hospital			0.2	5.1	2.9	29

Land Use	Large Turf Areas (%)	Small Landscaping Areas (%)	Isolated Areas (%)	Total (%)
Low density res		66.1		100
Med density res <1960		58.4		100
Med density res 1960 - 1980		62.5	0.3	100
Light industry		15.3		100
Commercial - strip mall		14		100
Commercial - shopping center		11.7		100
Institutional - school	34.8	8.7		100
Institutional - church	40	6		100
Institutional - hospital	16.4	16.5		100

Appendix B. NSQD Regional and Land Use Stormwater Characteristics

Volumetric Runoff Coefficients, Rv, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	n/a	0.59 (0.5) 66	0.59 (0.9) 64	0.32 (0.7) 14	0.68 (0.5) 114	0.65 (0.4) 34	n/a	0.48 (0.1) 2	0.59 (0.5) 16	0.62 (0.6) 310	100%
Freeways	n/a	0.31 (0.3) 37	n/a	n/a	0.46 (0.3) 20	0.67 (0.6) 158	n/a	n/a	n/a	0.58 (0.7) 215	100%
Industrial	0.28 (0.6) 9	0.43 (1.0) 54	0.34 (0.7) 50	0.36 (0.2) 7	0.72 (0.2) 110	0.34 (0.9) 69	n/a	n/a	0.30 (0.8) 23	0.48 (0.7) 322	100%
Institutional	n/a	0.04 (1.8) 14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.04 (1.8) 14	100%
Open Space	n/a	0.15 (0.6) 16	n/a	0.16 (1.1) 9	0.33 (0.8) 69	0.06 (0.5) 2	n/a	n/a	0.30 (0.6) 7	0.29 (0.9) 103	100%
Residential	0.30 (2.4) 88	0.28 (1.7) 403	0.18 (1.2) 209	0.34 (0.6) 30	0.33 (0.7) 184	0.20 (0.7) 51	0.23 (1.2) 30	0.55 (1.0) 5	0.24 (1.0) 54	0.27 (1.5) 1054	100%
all land uses	0.30 (2.3) 97	0.32 (1.4) 705	0.28 (1.2) 322	0.31 (0.6) 60	0.50 (0.6) 497	0.51 (0.8) 314	0.28 (1.4) 37	0.50 (1.3) 8	0.31 (0.9) 100	0.39 (1.1) 2115	100%
% detect	100%	100%	100%	100%	100%	100%	100%	100%	100%		

TSS Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	201 (1.5) 310	101 (1.7) 669	56 (2.0) 55	232 (1.9) 67	108 (1.6) 100	132 (1.0) 41	87 (0.9) 61	98 (0.8) 7	247 (1.2) 32	133 (1.7) 1342	98%
Freeways	24 (0.3) 3	80 (1.6) 225	36 (1.4) 13	n/a	144 (1.1) 12	183 (2.8) 105	n/a	n/a	n/a	114 (2.5) 381	100%
Industrial	177 (1.4) 100	97 (1.6) 375	105 (1.2) 105	164 (1.4) 68	155 (1.7) 106	385 (1.2) 95	164 (1.2) 30	n/a	360 (0.9) 39	160 (1.6) 918	97%
Institutional	91 (0.7) 8	86 (1.0) 46	68 (1.4) 15	n/a	n/a	n/a	n/a	n/a	n/a	83 (1.0) 69	99%
Open Space	176 (2.4) 128	98 (1.5) 107	n/a	370 (0.8) 18	202 (1.6) 67	330 (n/a) 1	n/a	n/a	846 (0.4) 7	182 (1.9) 329	98%
Residential	135 (1.2) 507	102 (1.7) 1893	102 (1.6) 207	374 (1.8) 140	129 (0.9) 203	162 (1.0) 75	130 (1.8) 315	140 (0.9) 16	528 (2.5) 116	137 (2.4) 3472	99%
all land uses	156 (1.6) 1132	97 (1.7) 3468	93 (1.6) 395	293 (1.8) 293	141 (1.5) 488	235 (1.7) 318	126 (1.7) 443	140 (1.0) 24	460 (2.3) 194	135 (2.2) 6682	99%
% detect	99%	99%	98%	99%	99%	90%	100%	100%	99%		

TDS Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	388 (2.7) 84	172 (2.9) 404	72 (0.6) 29	159 (1.0) 45	64 (0.6) 99	119 (0.7) 26	226 (2.0) 61	172 (0.5) 5	131 (0.6) 32	178 (2.9) 785	100%
Freeways	210 (0.3) 3	582 (0.5) 20	n/a	n/a	175 (0.4) 12	94 (0.8) 83	85 (1.0) 12	n/a	n/a	178 (1.3) 127	99%
Industrial	510 (2.5) 76	171 (4.0) 290	108 (1.1) 86	175 (1.2) 50	82 (0.6) 106	132 (0.5) 73	69 (0.6) 30	n/a	248 (1.4) 39	182 (3.3) 752	99%
Institutional	138 (0.5) 6	66 (0.7) 18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	84 (0.7) 24	100%
Open Space	n/a	101 (0.6) 101	n/a	199 (0.6) 18	214 (1.3) 67	35 (n/a) 1	n/a	n/a	789 (2.1) 6	171 (2.0) 193	99%
Residential	416 (3.8) 172	100 (1.7) 832	121 (1.3) 126	165 (0.8) 96	100 (1.0) 160	106 (0.6) 50	66 (0.7) 69	203 (0.7) 15	162 (1.3) 45	142 (3.9) 1565	99%
all land uses	423 (3.3) 341	132 (3.0) 1754	111 (1.2) 241	169 (0.9) 209	107 (1.2) 444	111 (0.6) 233	123 (2.2) 183	188 (0.7) 21	212 (2.1) 122	159 (3.3) 3548	99%
% detect	100%	99%	100%	99%	100%	99%	98%	100%	100%		

COD Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	79 (0.8) 249	97 (1.0) 495	69 (1.4) 55	75 (0.8) 98	59 (0.7) 105	232 (0.6) 36	66 (0.9) 61	161 (0.6) 7	197 (0.4) 7	91 (1.0) 1065	99%
Freeways	88 (0.3) 3	68 (0.7) 114	67 (0.8) 14	n/a	82 (1.0) 265	149 (1.0) 56	99 (1.3) 11	n/a	n/a	87 (1.0) 460	100%
Industrial	111 (1.2) 66	65 (0.9) 293	44 (0.9) 112	78 (1.2) 48	50 (0.8) 108	252 (0.7) 60	97 (0.7) 30	n/a	226 (0.4) 14	84 (1.2) 731	99%
Institutional	31 (0.4) 7	75 (0.9) 18	44 (0.7) 15	n/a	n/a	n/a	n/a	n/a	n/a	55 (0.9) 95	95%
Open Space	26 (0.3) 11	37 (1.0) 95	n/a	66 (1.6) 18	41 (0.7) 66	59 (n/a) 1	n/a	n/a	336 (0.7) 7	52 (1.6) 198	92%
Residential	61 (0.9) 277	73 (1.0) 1225	38 (0.9) 202	93 (1.1) 89	69 (0.7) 203	138 (0.6) 71	40 (0.8) 24	216 (0.8) 16	141 (0.7) 54	70 (1.0) 2456	99%
all land uses	72 (1.0) 617	76 (1.0) 2327	45 (1.1) 398	83 (1.1) 205	67 (0.9) 747	186 (0.8) 224	56 (0.9) 445	204 (0.7) 24	177 (0.7) 82	77 (1.1) 5069	99%
% detect	98%	99%	99%	99%	98%	99%	100%	100%	100%		

Total Phosphorus Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	0.25 (2.2) 311	0.37 (1.3) 641	0.39 (1.1) 141	0.38 (1.6) 50	0.64 (3.0) 112	0.57 (0.7) 37	0.35 (1.3) 84	0.57 (0.6) 7	0.34 (0.7) 16	0.37 (2.0) 1399	96%
Freeways	0.43 (0.5) 3	0.95 (1.3) 186	0.16 (0.7) 14	n/a	0.22 (0.7) 245	0.49 (1.6) 135	0.35 (0.6) 24	n/a	n/a	0.50 (1.7) 604	99%
Industrial	0.33 (0.8) 100	0.36 (1.6) 370	0.20 (0.9) 108	0.36 (1.2) 49	0.25 (1.2) 108	1.3 (0.9) 63	0.33 (0.9) 76	n/a	0.46 (0.7) 23	0.39 (1.5) 897	95%
Institutional	0.21 (0.4) 8	0.24 (0.8) 45	0.19 (0.5) 15	n/a	n/a	n/a	n/a	n/a	n/a	0.23 (0.17) 68	99%
Open Space	0.18 (1.7) 139	0.33 (1.1) 106	n/a	0.31 (0.6) 17	0.40 (1.0) 67	0.65 (0.3) 2	n/a	n/a	0.60 (0.5) 7	0.29 (1.2) 338	96%
Residential	0.40 (1.1) 565	0.43 (1.7) 1956	0.20 (1.4) 410	0.70 (1.2) 91	0.47 (0.9) 206	0.54 (1.1) 70	0.30 (1.2) 331	0.85 (0.7) 15	0.81 (1.1) 75	0.71 (1.5) 3719	98%
all land uses	0.32 (0.4) 1203	0.42 (1.7) 3572	0.24 (1.3) 688	0.51 (1.3) 207	0.38 (2.2) 738	0.68 (1.3) 307	0.31 (1.1) 539	0.74 (0.8) 23	0.67 (1.1) 121	0.40 (1.7) 7295	97%
% detect	97%	97%	95%	98%	99%	97%	99%	100%	100%		

Dissolved Phosphorus Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	0.14 (0.5) 81	0.24 (1.9) 386	0.13 (1.7) 43	0.25 (1.2) 30	0.09 (1.0) 103	0.42 (0.8) 26	0.20 (2.3) 13	n/a	0.17 (0.6) 16	0.21 (1.8) 698	77%
Freeways	n/a	0.14 (0.8) 18	0.06 (1.3) 14	n/a	0.04 (0.9) 11	0.78 (2.1) 22	n/a	n/a	n/a	0.34 (3.1) 65	85%
Industrial	0.085 (0.9) 70	0.20 (2.1) 275	0.10 (1.2) 97	0.15 (0.7) 33	0.11 (1.0) 109	0.30 (0.9) 52	0.06 (0.7) 8	n/a	0.24 (0.9) 22	0.17 (1.8) 666	82%
Institutional	0.054 (0.6) 5	0.13 (0.5) 17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.11 (0.6) 22	86%
Open Space	n/a	0.17 (1.1) 100	n/a	0.20 (0.7) 18	0.15 (1.2) 67	0.18 (n/a) 1	n/a	n/a	0.19 (0.5) 6	0.17 (1.1) 192	84%
Residential	0.16 (1.2) 149	0.21 (1.1) 797	0.13 (1.3) 148	0.29 (0.6) 66	0.20 (0.7) 164	0.24 (0.7) 26	0.30 (1.8) 26	n/a	0.26 (0.7) 12	0.21 (1.1) 1388	83%
all land uses	0.14 (1.2) 305	0.21 (1.5) 1675	0.11 (1.4) 302	0.24 (0.8) 147	0.14 (0.9) 454	0.39 (1.9) 127	0.23 (2.0) 47	n/a	0.22 (0.8) 56	0.20 (1.6) 3113	81%
% detect	62%	79%	74%	96%	93%	98%	81%	n/a	100%		

Total Kjeldahl Nitrogen Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	1.5 (1.1) 185	2.0 (0.9) 625	1.2 (0.7) 41	1.8 (0.9) 47	1.1 (0.6) 112	4.3 (0.7) 39	1.6 (1.0) 61	3.7 (0.7) 5	2.6 (0.6) 16	1.9 (0.9) 1131	97%
Freeways	3.6 (0.3) 3	2.4 (1.1) 100	n/a	n/a	2.0 (0.9) 204	3.3 (1.4) 122	1.7 (0.6) 24	n/a	n/a	2.4 (1.2) 450	99%
Industrial	1.9 (0.9) 100	1.8 (1.5) 338	1.5 (0.8) 99	1.6 (0.6) 46	1.2 (0.9) 109	4.2 (0.8) 76	1.9 (0.6) 33	n/a	2.5 (0.6) 23	1.9 (1.2) 824	96%
Institutional	0.79 (0.6) 7	1.6 (0.8) 46	1.4 (0.5) 15	n/a	n/a	n/a	n/a	n/a	n/a	1.5 (0.8) 68	97%
Open Space	0.79 (0.7) 100	1.2 (0.8) 77	n/a	1.9 (0.7) 18	1.7 (0.9) 67	1.8 (0.2) 2	n/a	n/a	3.3 (0.6) 7	1.3 (1.0) 271	91%
Residential	1.9 (0.9) 434	1.8 (1.1) 1783	1.0 (0.9) 335	2.3 (1.5) 74	2.1 (0.9) 183	3.2 (2.7) 74	1.1 (0.9) 318	5.7 (0.8) 15	3.8 (0.7) 64	1.8 (1.1) 3280	98%
all land uses	1.6 (0.9) 834	1.9 (1.1) 3067	1.2 (0.9) 490	2.0 (0.7) 185	1.7 (0.9) 675	3.6 (1.0) 313	1.3 (0.9) 460	5.0 (0.8) 21	3.3 (0.7) 110	1.9 (1.1) 6095	97%
% detect	100%	97%	93%	97%	96%	99%	98%	100%	100%		

Nitrate plus Nitrite Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	0.81 (0.7) 213	0.89 (1.0) 536	0.31 (1.5) 109	0.89 (0.7) 29	0.54 (0.5) 112	1.3 (0.7) 33	0.44 (1.0) 80	1.0 (n/a) 1	1.2 (0.7) 16	0.77 (1.0) 1129	98%
Freeways	0.67 (0.8) 3	2.2 (2.0) 86	n/a	n/a	0.72 (0.7) 11	n/a	0.51 (1.2) 25	n/a	n/a	1.8 (2.2) 122	99%
Industrial	0.67 (0.57) 98	0.79 (0.8) 335	0.71 (1.6) 81	0.82 (0.6) 31	0.67 (0.6) 109	1.8 (0.5) 62	0.37 (0.6) 30	0.26 (n/a(1	1.0 (0.4) 23	0.83 (0.9) 769	97%
Institutional	1.0 (0.5) 7	0.63 (0.7) 46	0.37 (0.5) 14	n/a	n/a	n/a	n/a	n/a	n/a	0.61 (0.7) 67	99%
Open Space	0.41 (0.8) 138	0.81 (0.9) 106	n/a	0.78 (1.0) 17	0.84 (0.7) 67	1.0 (0.6) 2	n/a	n/a	1.2 (0.4) 7	0.66 (0.9) 337	96%
Residential	0.78 (0.6) 434	1.1 (2.5) 1583	0.35 (1.7) 357	0.88 (0.7) 75	0.79 (0.9) 202	1.1 (0.4) 66	0.82 (1.2) 77	1.5 (1.0) 2	1.4 (1.0) 54	0.94 (2.3) 2850	99%
all land uses	0.73 (0.8) 969	1.0 (2.2) 2890	0.39 (1.8) 561	0.86 (0.7) 152	0.72 (0.8) 501	1.4 (0.6) 163	0.59 (1.2) 223	1.1 (0.9) 4	1.2 (0.9) 100	0.88 (2.0) 5506	98%
% detect	98%	99%	97%	100%	99%	100%	90%	100%	100%		

Total Copper Concentrations, µg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	58 (0.8) 141	33 (1.2) 502	7.4 (1.4) 106	69 (1.2) 47	61 (3.5) 109	21 (1.1) 40	29 (1.1) 84	42 (1.2) 7	46 (1.6) 32	37 (2.3) 1068	88%
Freeways	54 (0.1) 3	28 (2.0) 103	1.1 (0.5) 13	n/a	7.4 (1.7) 117	62 (1.4) 101	32 (0.8) 26	n/a	n/a	30 (2.0) 360	98%
Industrial	25 (1.5) 83	22 (1.3) 257	18 (1.0) 106	99 (2.3) 49	17 (0.7) 107	78 (0.9) 93	42 (0.8) 34	n/a	46 (1.0) 39	36 (2.0) 768	86%
Institutional	33 (0.4) 7	25 (0.7) 45	7.3 (0.6) 15	n/a	n/a	n/a	n/a	n/a	n/a	21 (0.8) 67	85%
Open Space	9 (0.1) 6	9 (0.8) 58	n/a	20 (0.8) 12	12 (0.9) 70	119 (1.1) 2	n/a	n/a	28 (0.7) 7	14 (1.5) 155	84%
Residential	34 (1.8) 333	30 (1.6) 1340	10 (2.6) 396	52 (1.8) 111	16 (1.8) 164	36 (1.4) 66	13 (0.7) 24	22 (0.4) 15	28 (0.9) 103	27 (1.8) 2613	88%
all land uses	33 (1.6) 644	29 (1.5) 2339	10 (2.1) 636	65 (2.1) 219	23 (4.3) 567	56 (1.4) 302	26 (1.1) 253	28 (1.0) 23	35 (1.2) 181	30 (2.1) 5087	88%
% detect	78%	89%	79%	89%	98%	99%	93%	90%	83%		

Total Lead Concentrations, mg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	17 (1.3) 101	34 (1.7) 438	9.1 (1.5) 71	63 (1.0) 45	37 (1.2) 111	32 (2.2) 42	44 (1.4) 84	65 (1.2) 7	75 (0.7) 16	34 (1.6) 915	80%
Freeways	n/a	57 (0.8) 100	n/a	n/a	81 (0.8) 138	72 (1.5) 112	55 (1.3) 26	n/a	n/a	71 (1.1) 376	98%
Industrial	15 (0.8) 77	21 (2.3) 327	22 (1.1) 89	113 (2.0) 48	35 (1.4) 108	148 (0.9) 101	45 (0.8) 74	n/a	157 (1.2) 23	55 (1.9) 847	76%
Institutional	22 (0.8) 6	32 (1.5) 46	n/a	n/a	n/a	n/a	n/a	n/a	n/a	30 (1.5) 52	92%
Open Space	n/a	11 (1.2) 107	n/a	140 (n/a) 17	27 (2.4) 70	80 (1.2) 2	n/a	n/a	225 (0.5) 7	30 (2.2) 203	67%
Residential	65 (2.3) 287	19 (2.1) 1052	9.6 (3.5) 317	25 (1.7) 96	25 (1.5) 183	45 (1.0) 56	30 (1.3) 85	22 (0.8) 15	29 (1.2) 51	26 (2.6) 2142	77%
all land uses	45 (2.7) 546	25 (1.9) 2104	11 (2.8) 477	57 (2.3) 206	43 (1.3) 610	89 (1.3) 313	39 (1.3) 293	38 (1.3) 23	81 (1.4) 97	37 (2.0) 4694	78%
% detect	59%	76%	74%	60%	92%	93%	98%	83%	100%		

Total Zinc Concentrations, µg/L, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	196 (1.4) 225	237 (1.2) 513	60 (1.4) 136	270 (0.9) 51	116 (0.8) 111	343 (2.0) 42	138 (1.0) 84	434 (1.1) 7	217 (0.7) 32	197 (1.4) 1201	99%
Freeways	368 (0.1) 3	185 (1.3) 203	7.5 (0.9) 14	n/a	89 (1.2) 267	304 (1.1) 99	211 (0.8) 25	n/a	n/a	159 (1.4) 608	99%
Industrial	106 (1.2) 84	172 (0.9) 326	166 (1.3) 107	512 (2.9) 54	169 (1.1) 107	1720 (2.0) 100	306 (2.9) 81	n/a	486 (0.9) 39	382 (3.5) 898	99%
Institutional	169 (0.2) 7	254 (0.9) 46	90 (0.5) 15	n/a	n/a	n/a	n/a	n/a	n/a	210 (1.0) 68	100%
Open Space	53 (0.8) 10	93 (0.8) 109	n/a	98 (1.0) 17	100 (1.3) 69	225 (1.0) 2	n/a	n/a	439 (0.4) 7	109 (1.1) 214	91%
Residential	134 (1.2) 351	125 (3.6) 1471	61 (1.2) 384	264 (2.3) 120	95 (0.9) 183	260 (1.2) 76	120 (0.8) 328	185 (0.6) 15	139 (1.0) 100	125 (2.8) 3028	97%
all land uses	138 (1.4) 752	162 (2.3) 2711	78 (1.5) 656	310 (2.7) 242	107 (1.1) 737	746 (2.8) 319	152 (2.4) 542	264 (1.1) 22	242 (1.2) 178	178 (3.3) 6036	97%
% detect	98%	97%	95%	98%	100%	97%	100%	100%	94%		

Fecal Coliforms, count/100 mL, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)

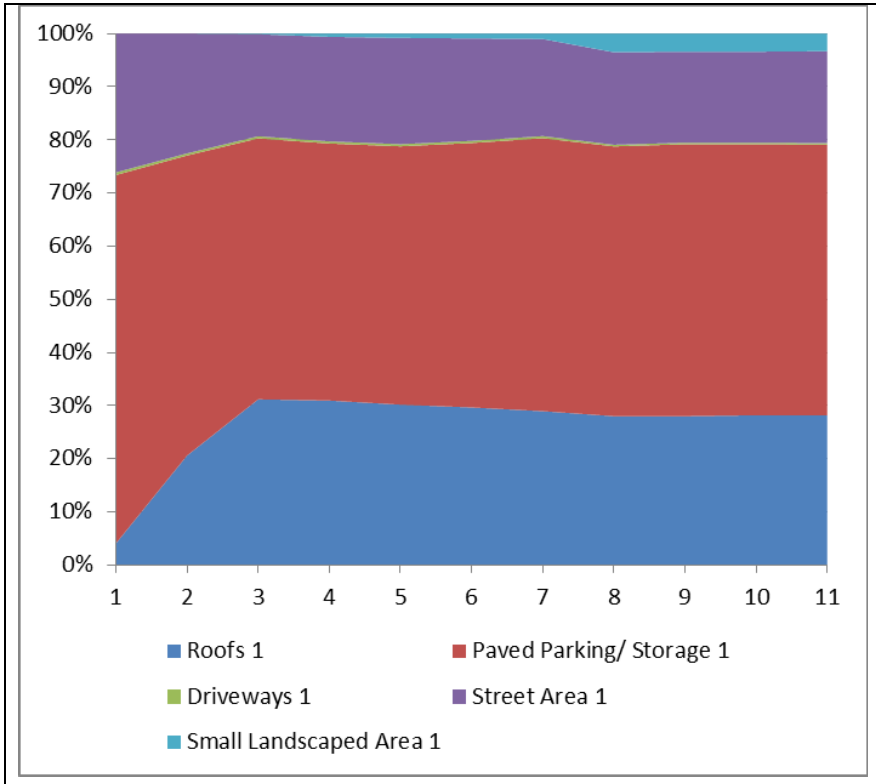
Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	5,160 (2.2) 43	14,200 (2.2) 154	3,220 (1.0) 6	54,500 (1.9) 44	41,000 (2.8) 103	9,500 (1.5) 7	34,000 (4.0) 57	3,500 (1.3) 4	21,600 (1.3) 11	27,400 (3.2) 429	91%
Freeways	<1 (n/a) 3	11,400 (3.3) 18	n/a	n/a	9,000 (2.0) 13	7,900 (2.1) 26	7,060 (1.8) 23	n/a	n/a	8,600 (2.5) 80	100%
Industrial	100,000 (5.7) 44	14,000 (2.5) 150	5,500 (1.8) 65	83,400 (4.2) 46	50,200 (4.9) 109	4,190 (1.0) 22	15,100 (3.5) 34	n/a	24,200 (1.8) 15	35,900 (6.6) 485	90%
Institutional	3,100 (0.4) 3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3,100 (0.4) 3	100%
Open Space	14,300 (1.7) 6	11,100 (3.1) 24	n/a	17,900 (1.0) 16	39,900 (2.1) 67	2,500 (n/a) 1	n/a	n/a	480 (0.6) 2	29,100 (2.4) 116	97%
Residential	210,000 (3.3) 156	33,100 (2.7) 380	20,300 (6.5) 90	41,700 (1.0) 91	88,500 (1.8) 165	5,970 (1.7) 10	25,400 (2.8) 68	17,800 (2.1) 10	25,600 (1.0) 8	69,600 (4.4) 978	91%
all land uses	140,000 (4.2) 301	24,100 (2.9) 731	13,700 (7.2) 161	52,600 (3.4) 197	59,300 (2.8) 457	6,520 (1.9) 66	25,000 (3.6) 191	13,700 (2.3) 14	22,400 (1.5) 36	48,400 (5.0) 2102	91%
% detect	80%	88%	91%	87%	100%	97%	95%	100%	100%		

***E. coli*, count/100 mL, for Different Land Uses and Geographical Areas (EPA Rain Zones) (average, COV, number of observations)**

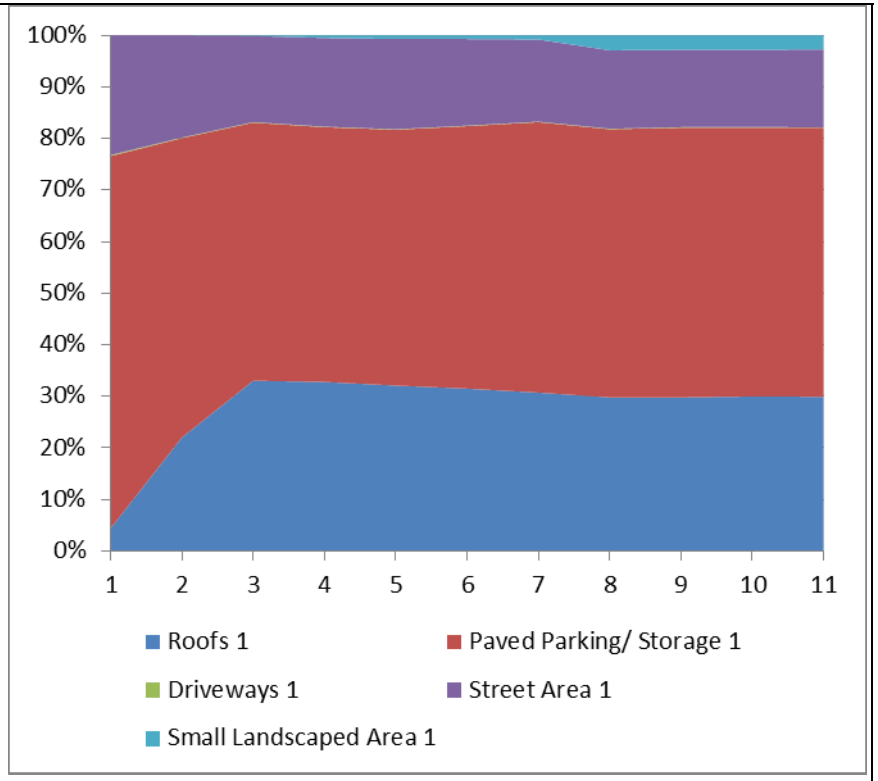
Land Use	**RZ1**	**RZ2**	**RZ3**	**RZ4**	**RZ5**	**RZ6**	**RZ7**	**RZ8**	**RZ9**	**all RZ**	**% detect**
Commercial	3930 (1.8) 32	n/a	n/a	n/a	n/a	n/a	8340 (2.3) 12	1010 (1.1) 6	n/a	4620 (2.4) 50	90%
Freeways	n/a	n/a	n/a	n/a	n/a	n/a	6000 (2.2) 13	n/a	n/a	6000 (2.2) 13	100%
Industrial	3030 (2.1) 20	n/a	n/a	n/a	n/a	n/a	3230 (0.4) 4	n/a	n/a	3060 (1.9) 24	79%
Institutional	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Open Space	1560 (1.2) 5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1560 (1.2) 5	100%
Residential	7300 (1.7) 36	n/a	n/a	n/a	n/a	n/a	4380 (1.5) 12	6560 (2.6) 13	n/a	6580 (1.9) 61	95%
all land uses	4990 (1.9) 93	n/a	n/a	n/a	n/a	n/a	5750 (2.1) 47	4560 (3.0) 20	n/a	5240 (2.1) 155	92%
% detect	89%	n/a	n/a	n/a	n/a	n/a	94%	100%	n/a		

Appendix C. Sources of Stormwater Flows and Pollutants

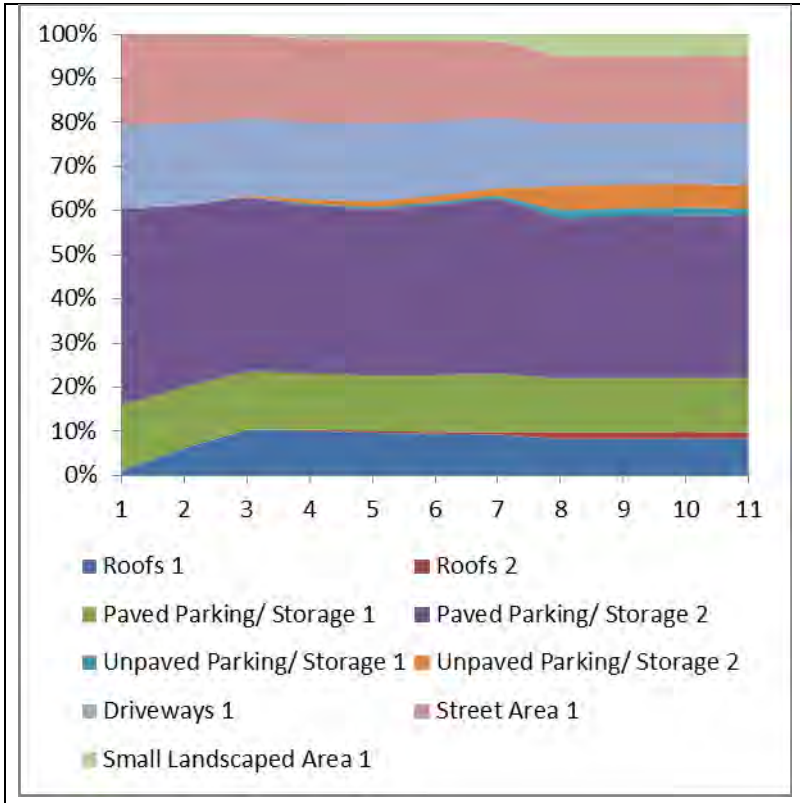
Flow Contributions



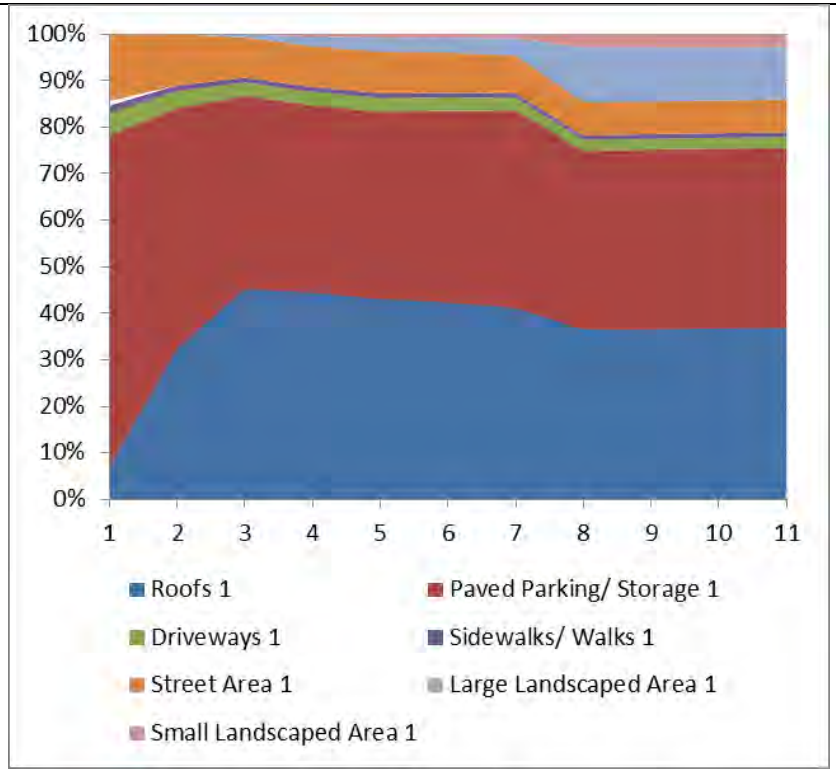
Commercial – Strip Mall Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



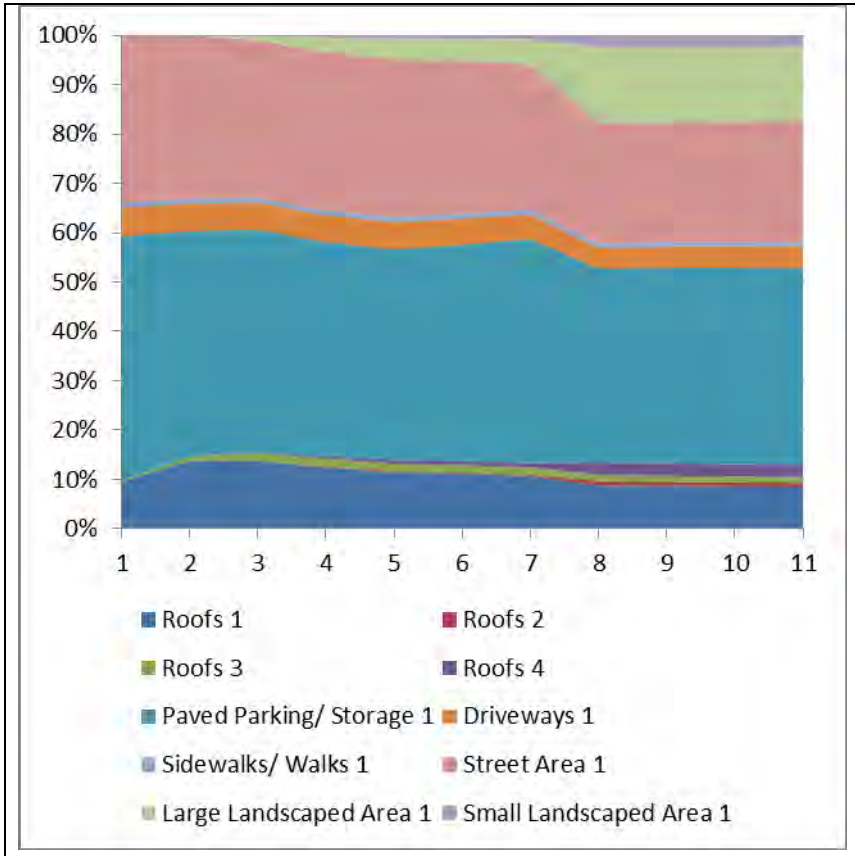
Commercial – Shopping Center Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Light Industrial Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Institutional - School Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Institutional – Church Area Flow Contributions
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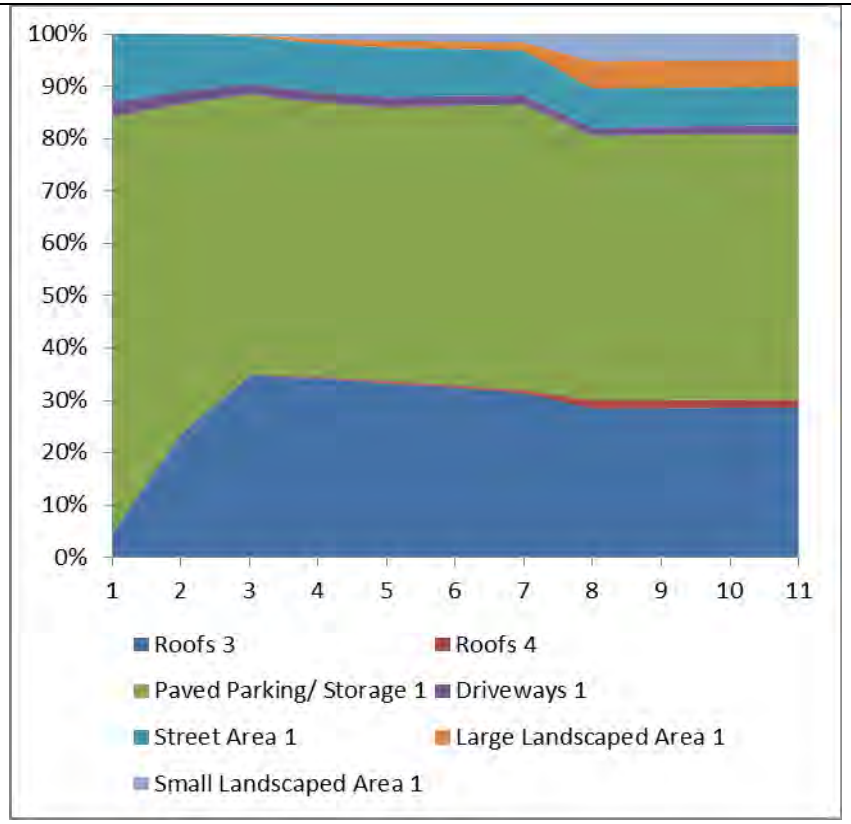
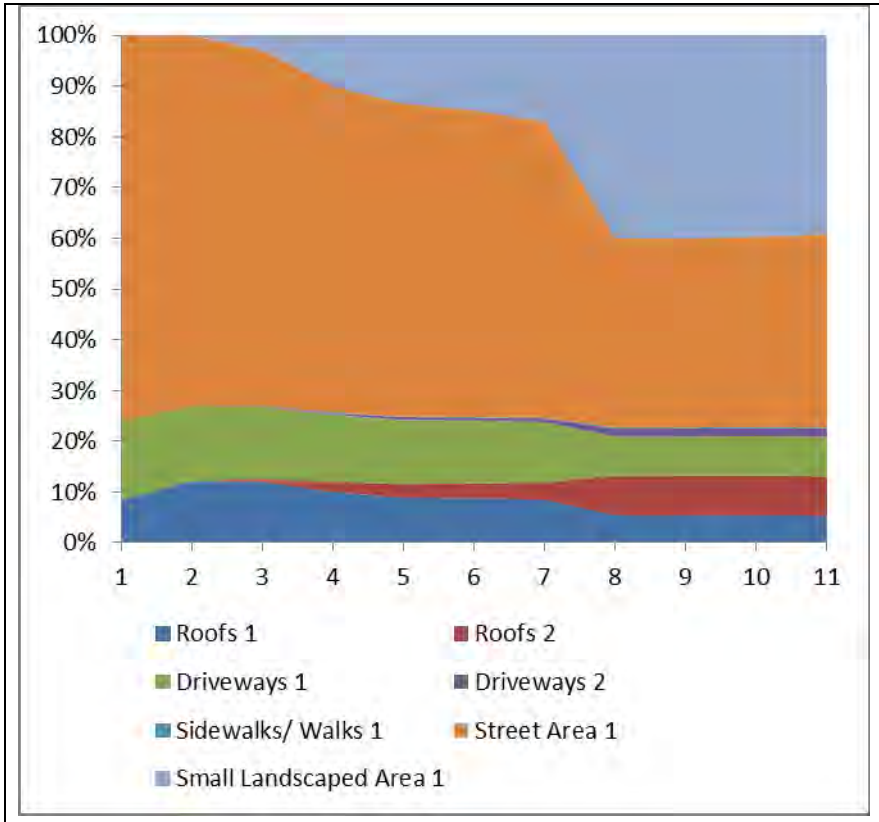
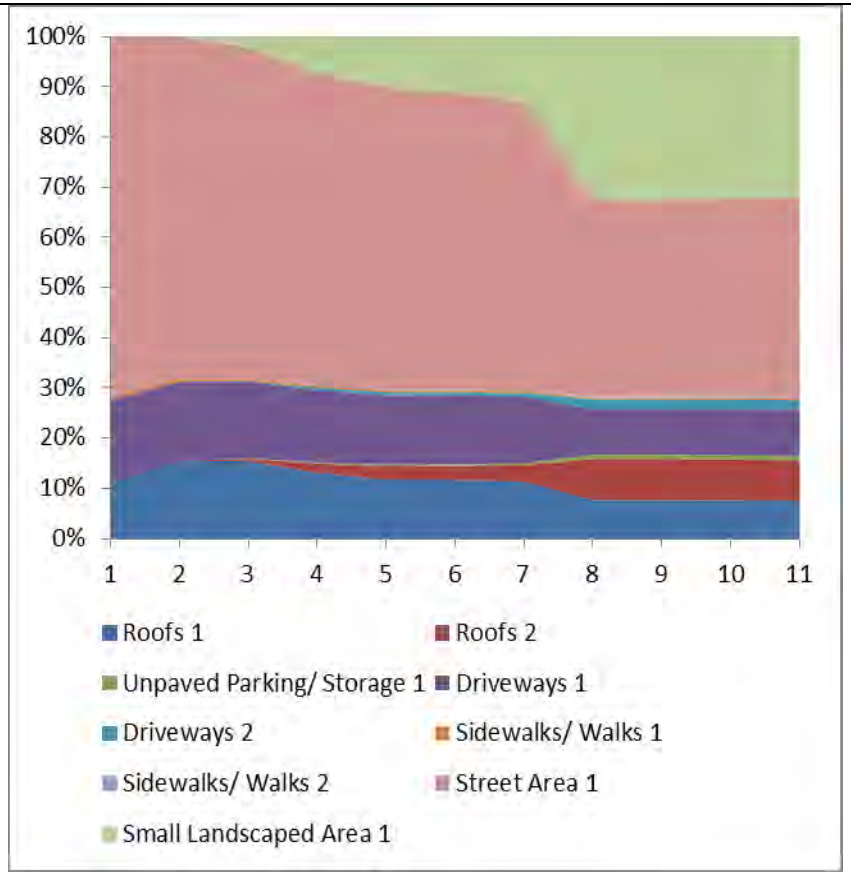


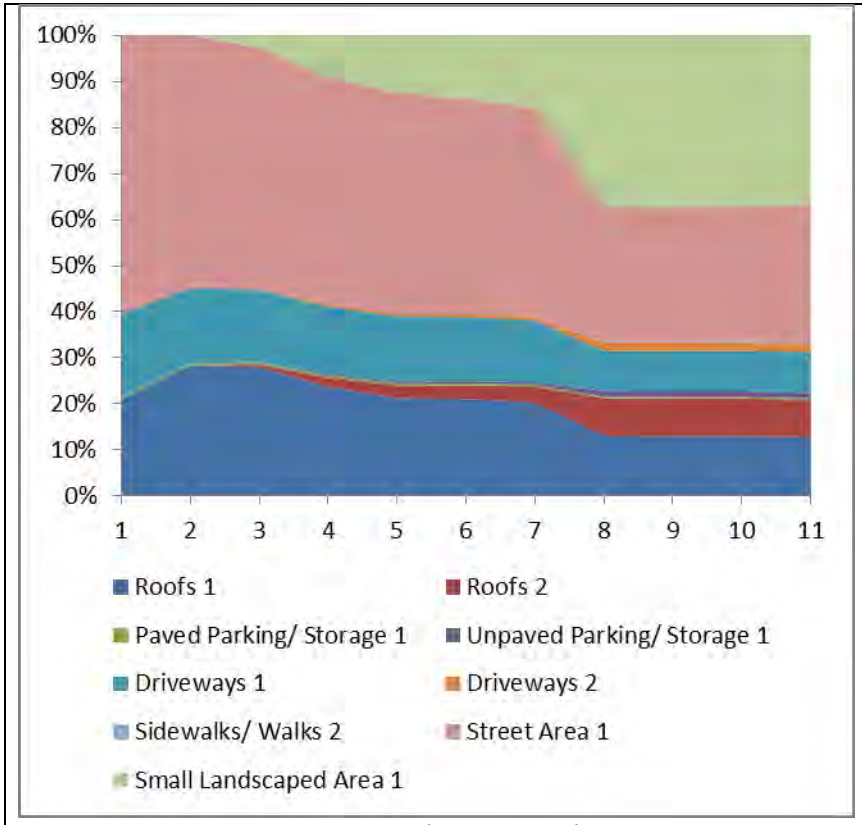
Institutional - Hospital Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

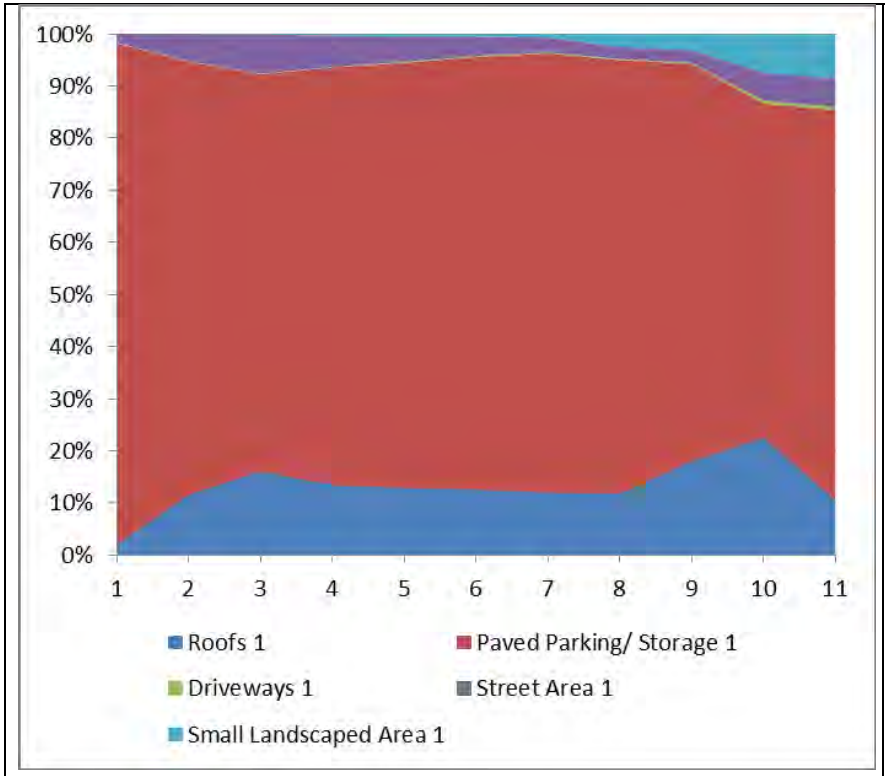


Medium Density Residential Area (<1960) Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

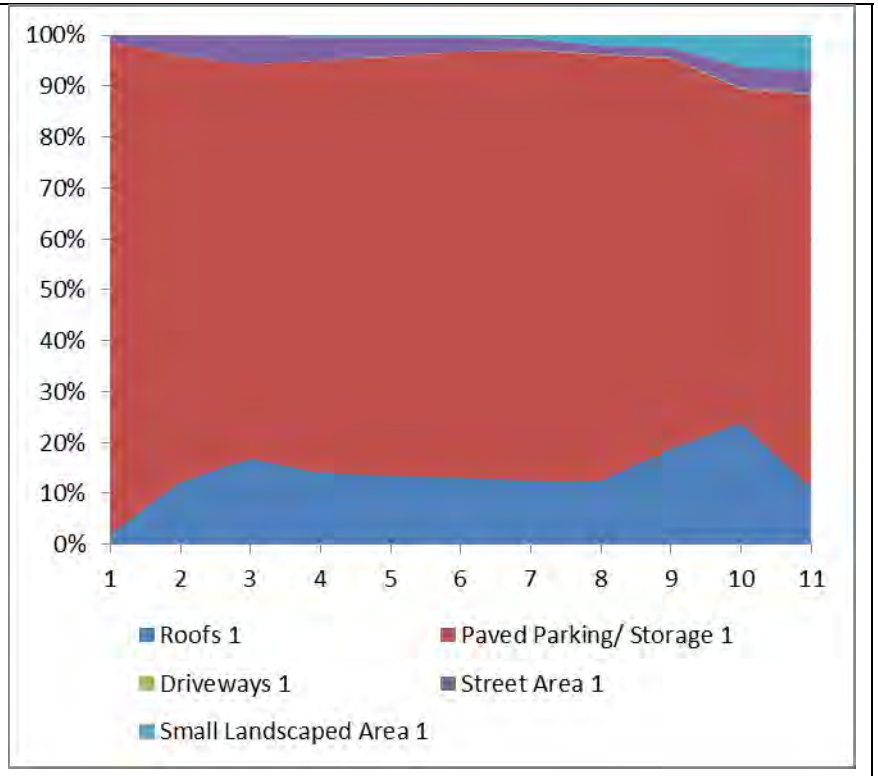


Medium Density Residential Area (1960 - 1980) Flow Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

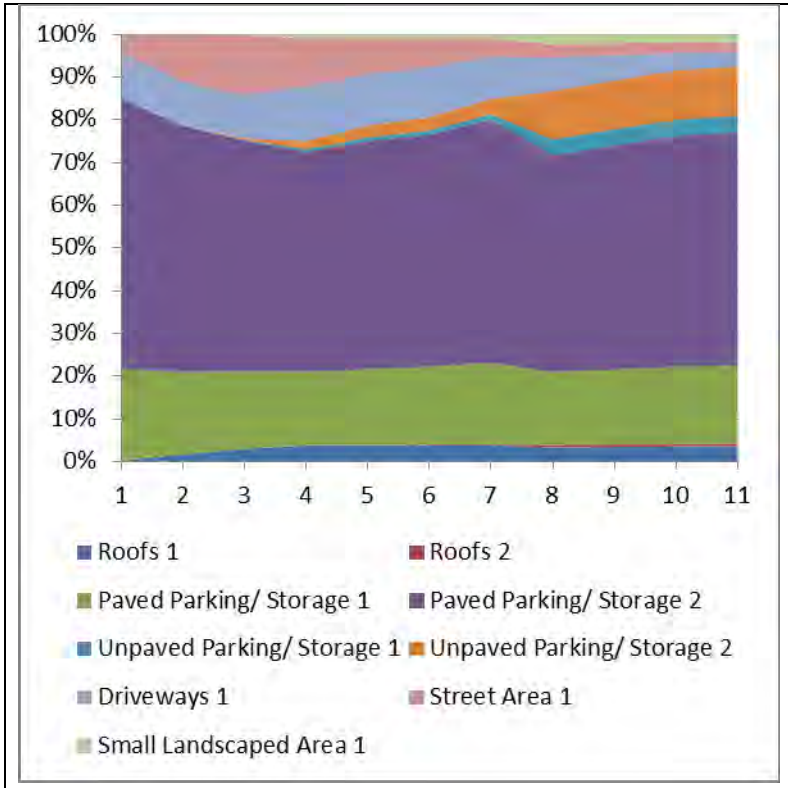
Total Suspended Solids Mass Contributions



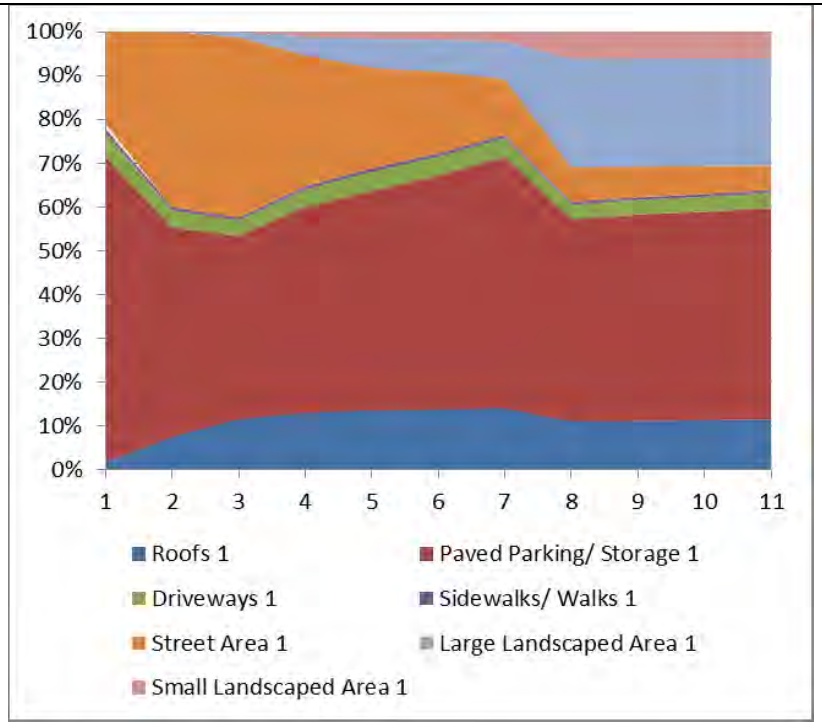
Commercial – Strip Mall Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



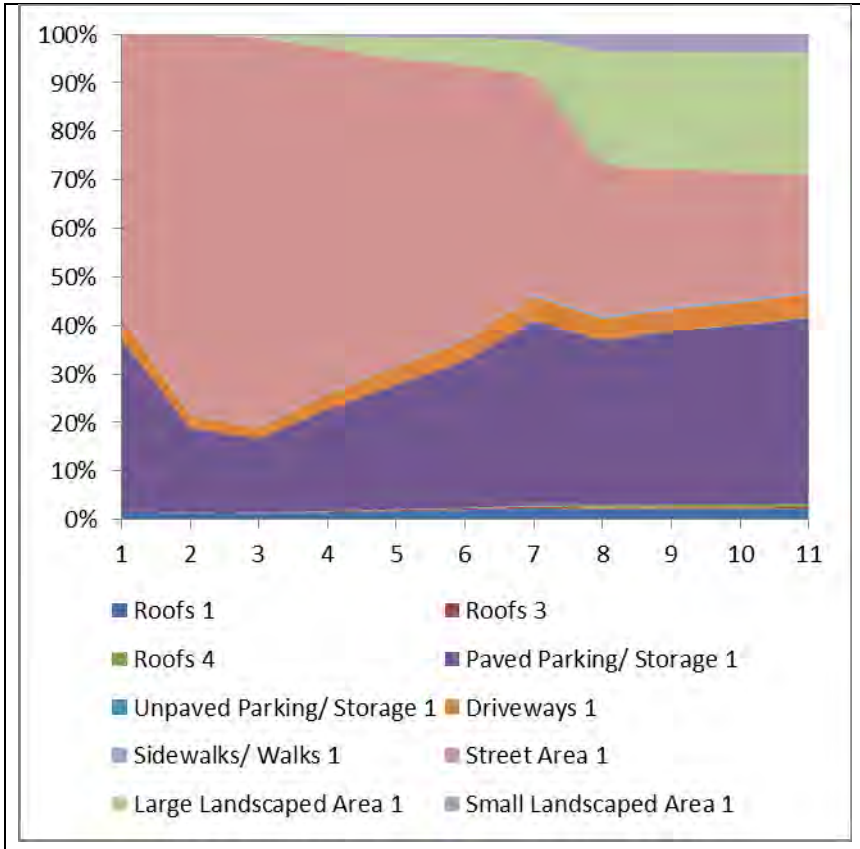
Commercial – Shopping Center Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



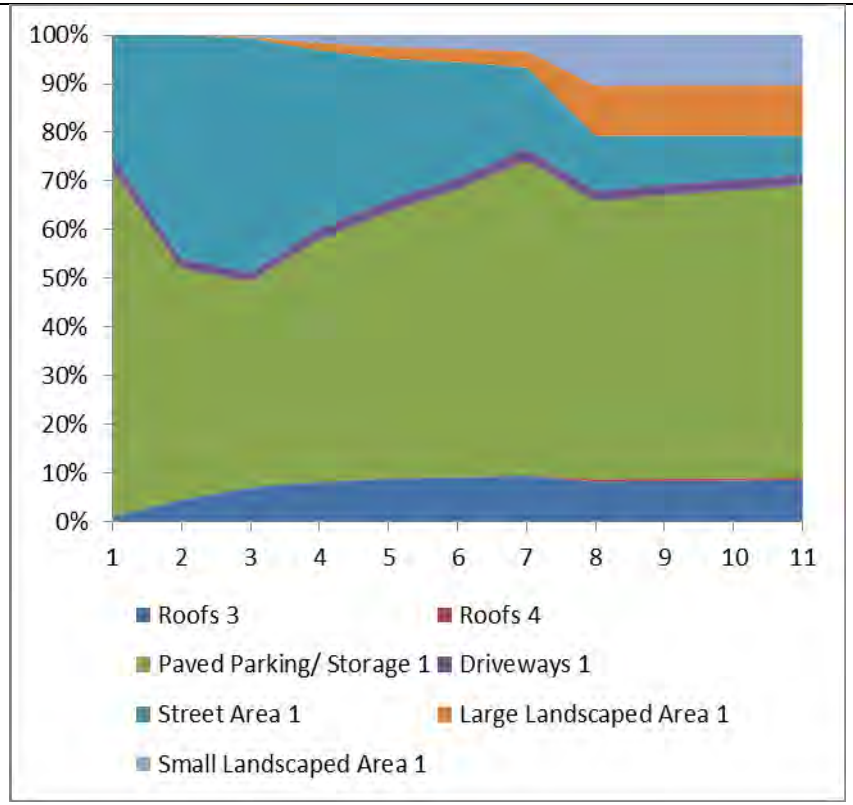
Light Industrial Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



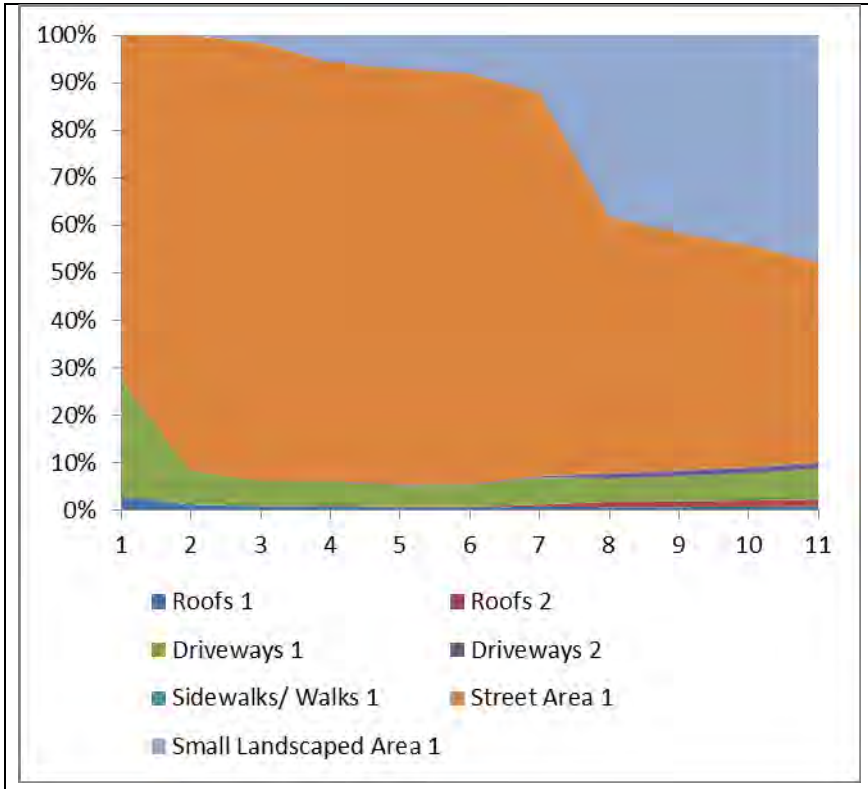
Institutional - School Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



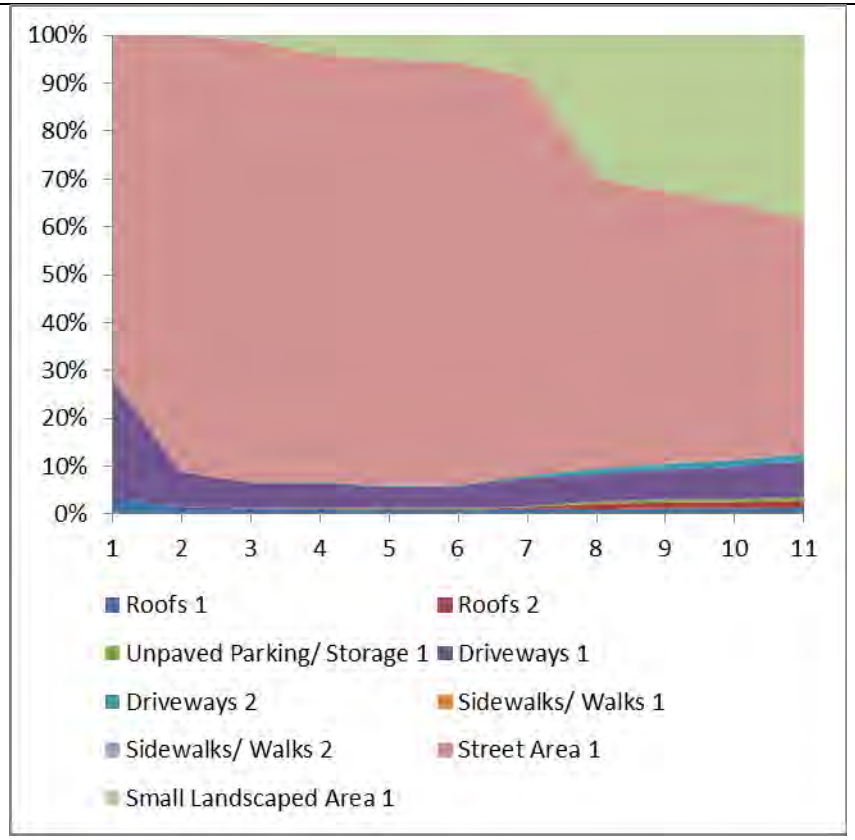
Institutional – Church Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



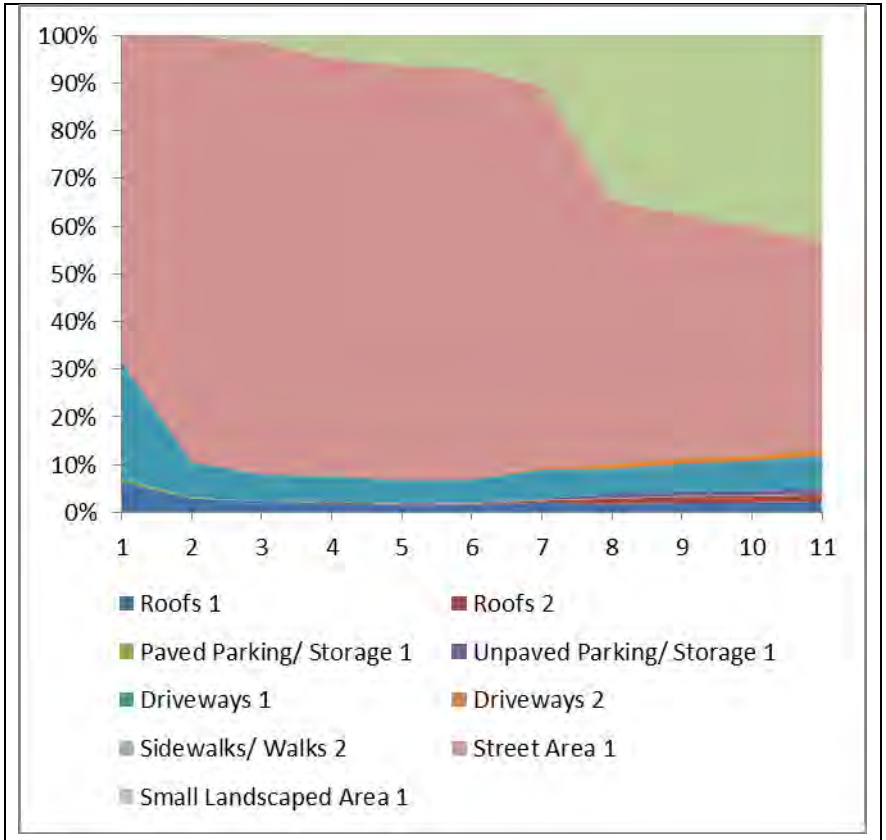
Institutional - Hospital Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

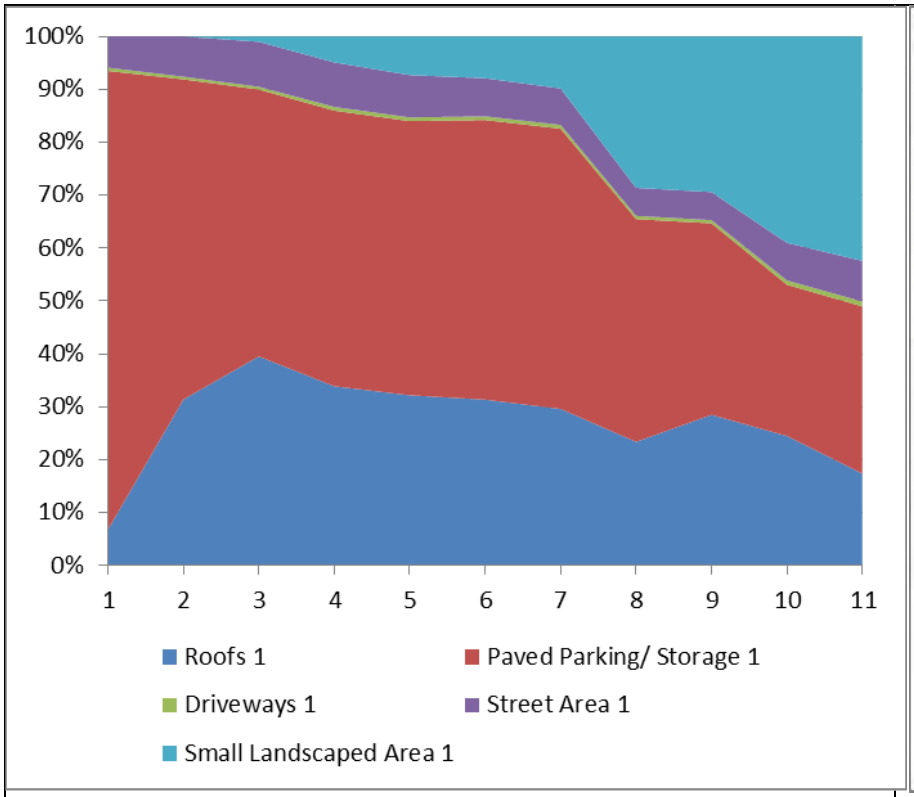


Medium Density Residential Area (<1960) TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

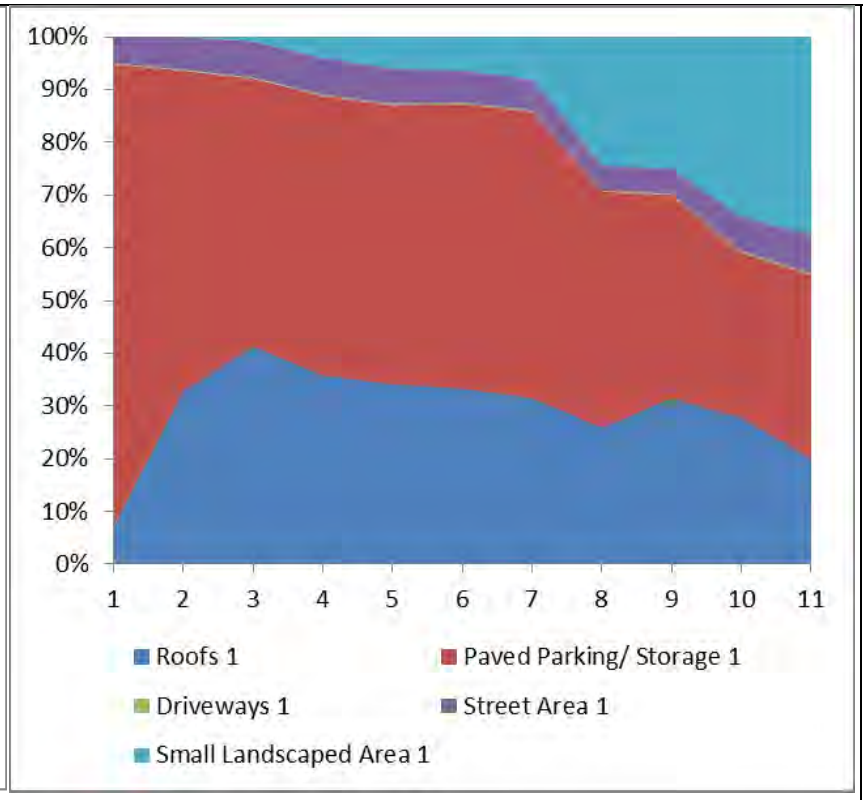


Medium Density Residential Area (1960 - 1980) TSS Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

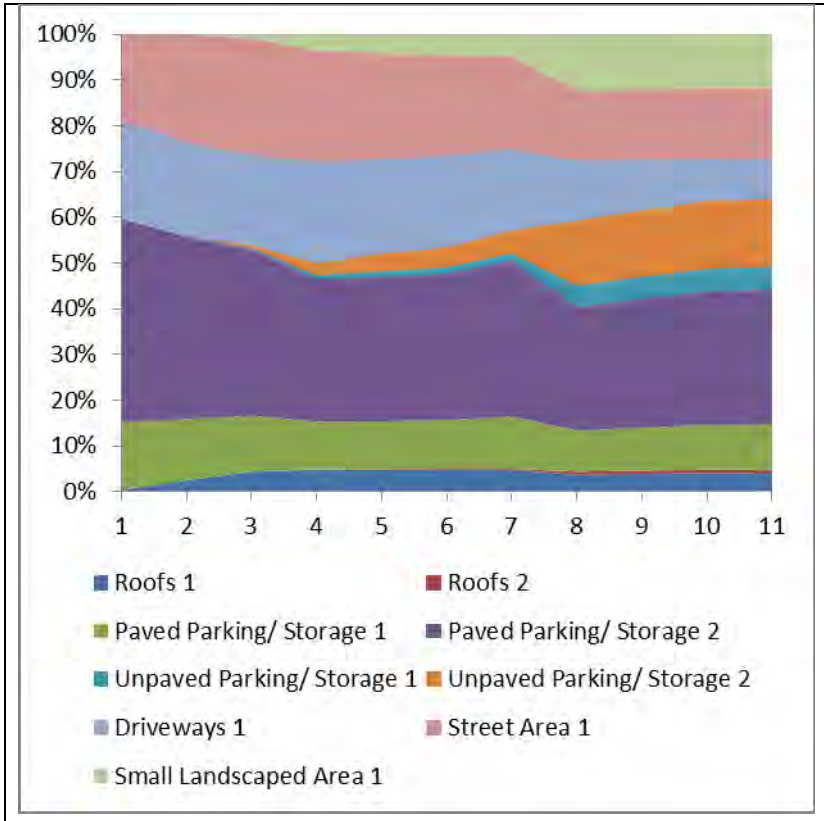
Total Phosphorus Mass Contributions



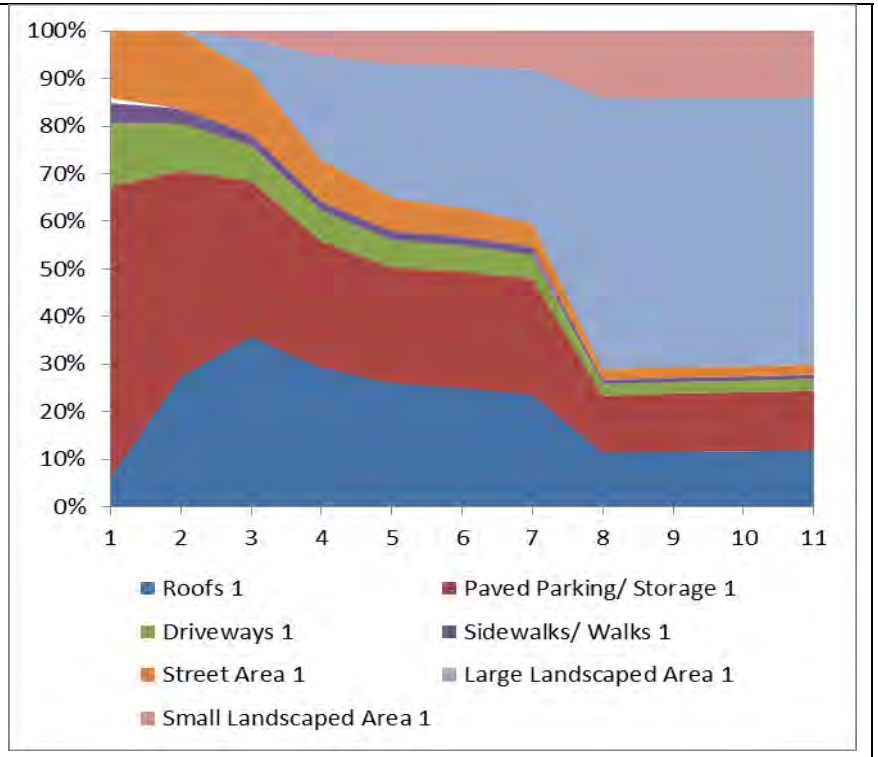
Commercial – Strip Mall Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



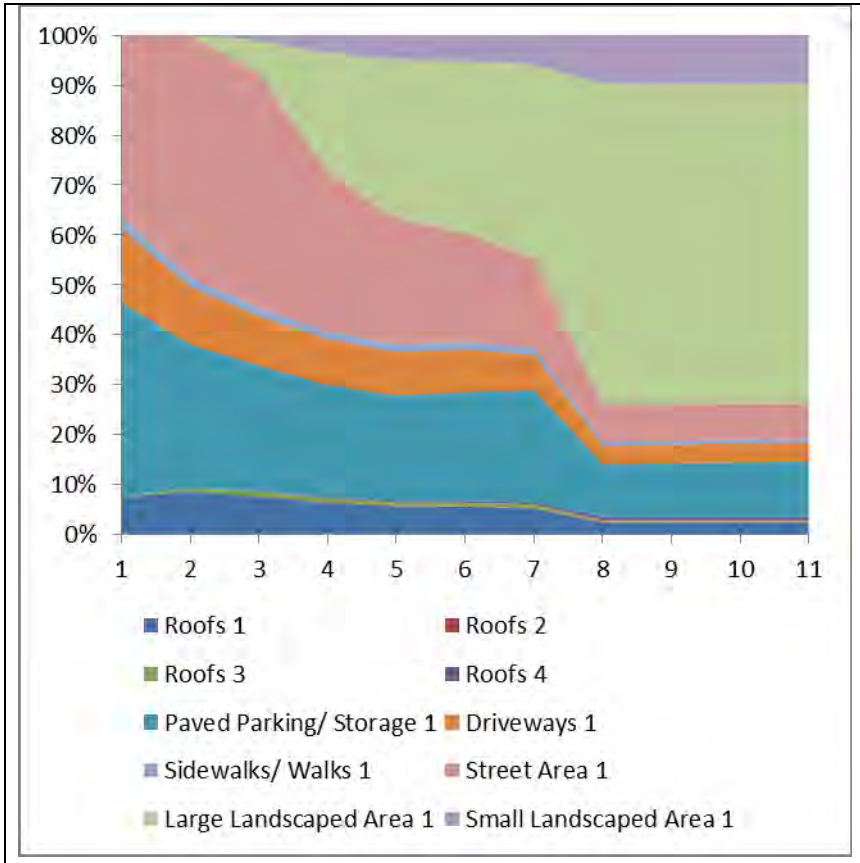
Commercial – Shopping Center Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



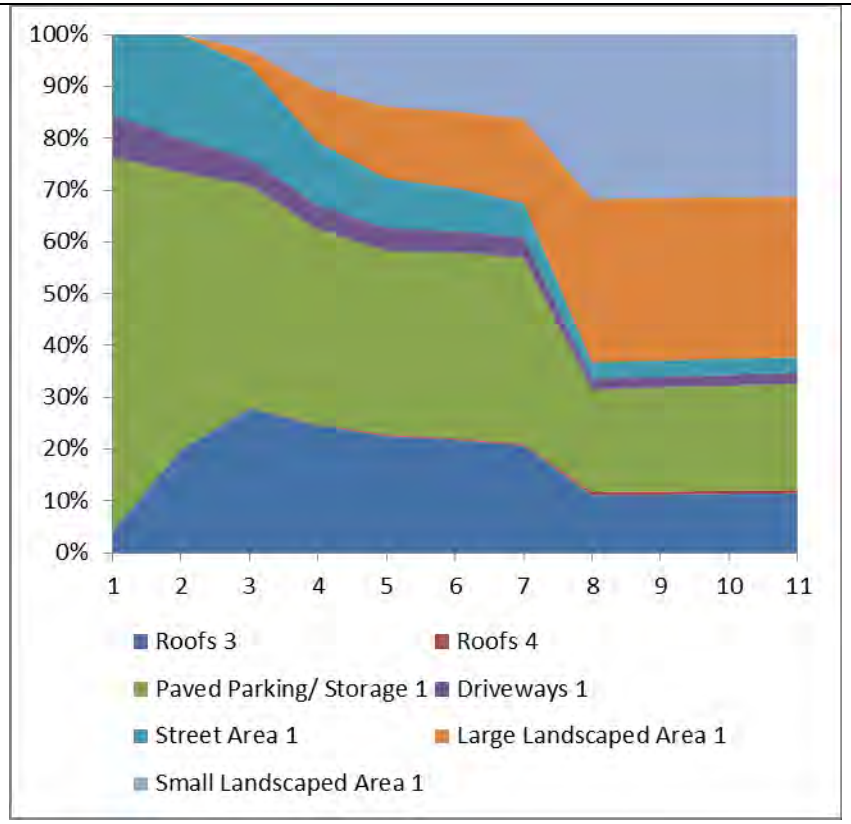
Light Industrial Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



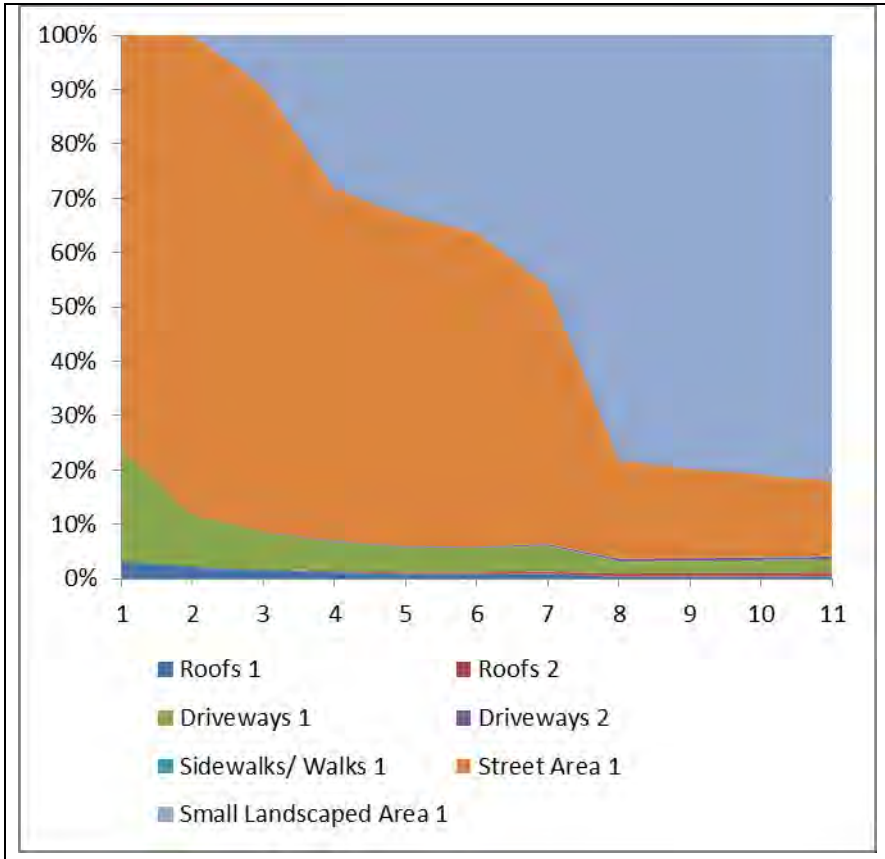
Institutional - School Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



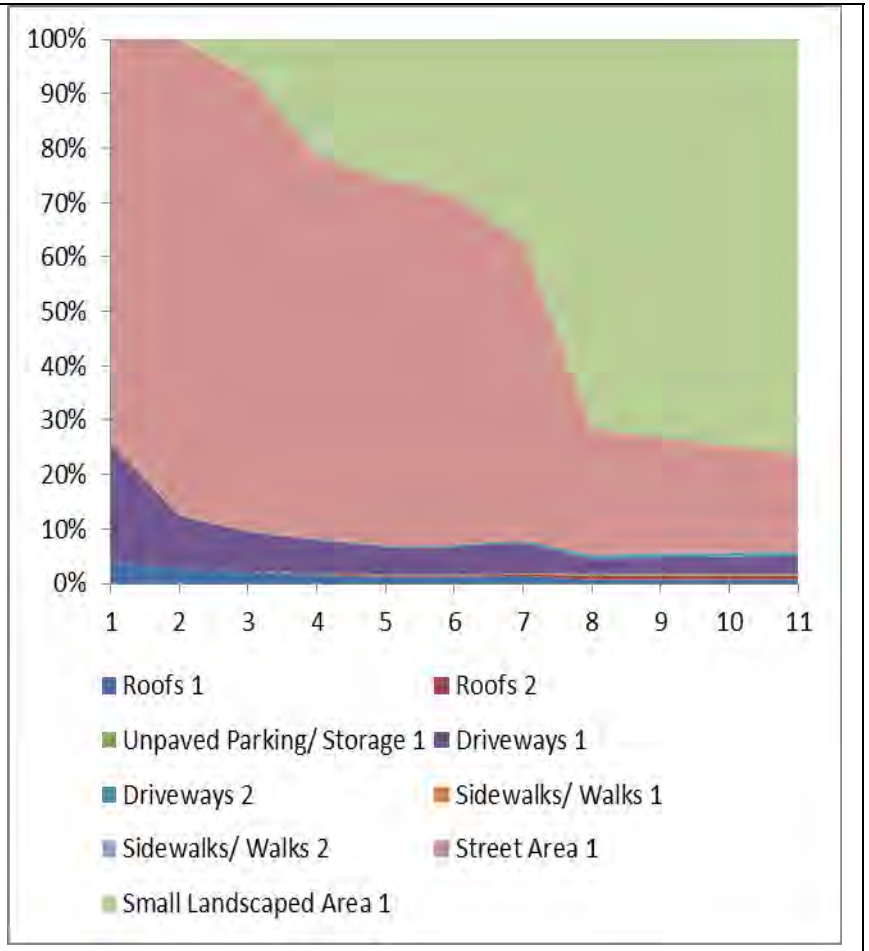
Institutional – Church Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



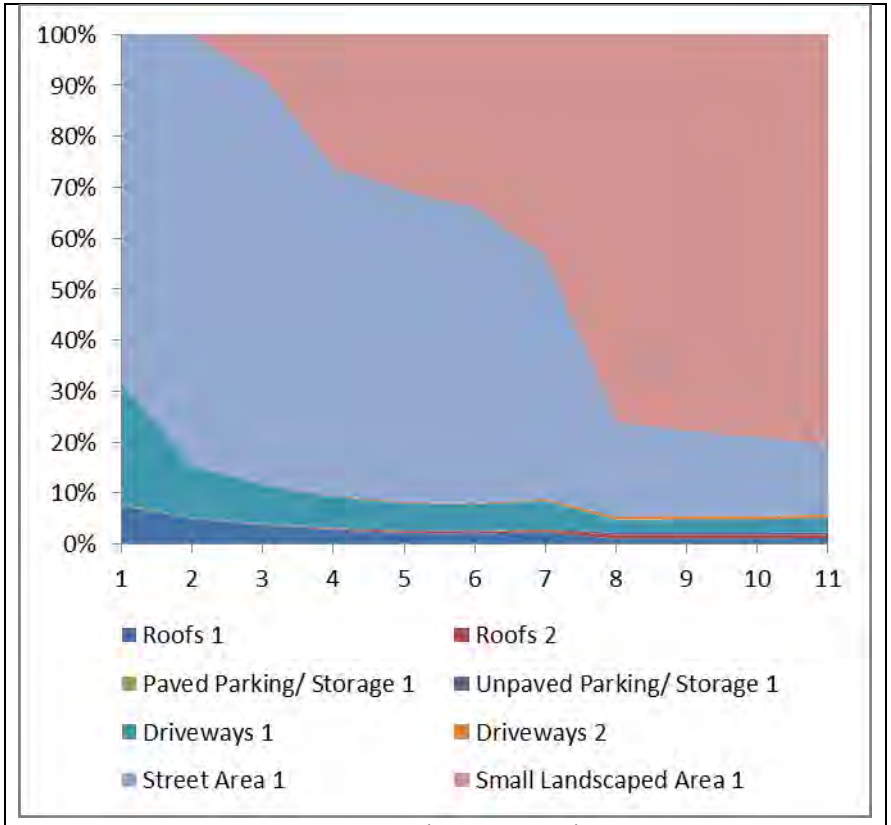
Institutional - Hospital Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

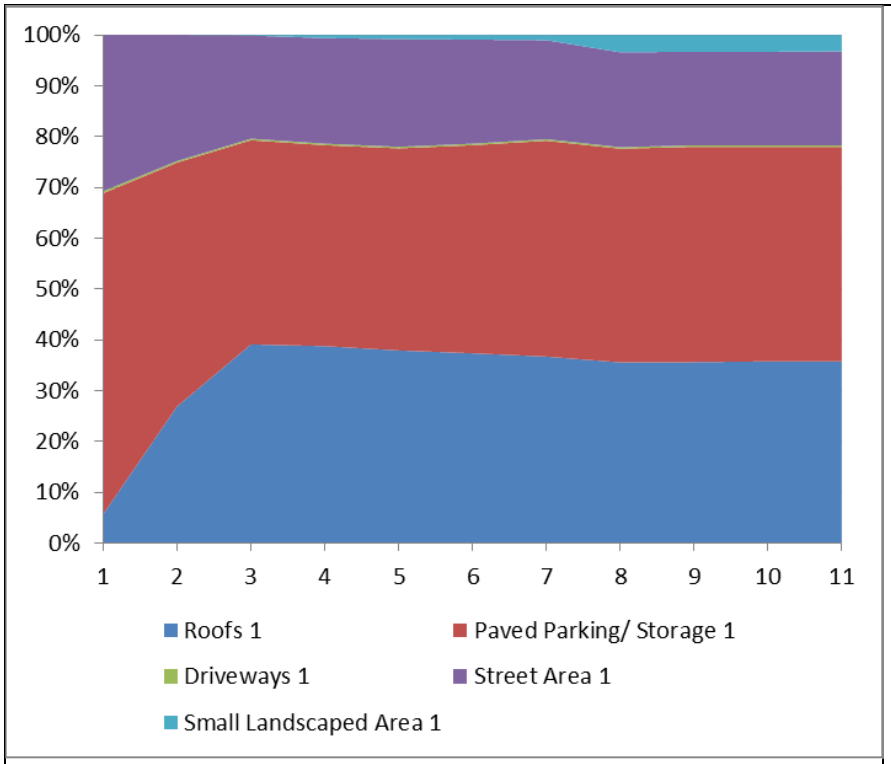


Medium Density Residential Area (<1960) TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

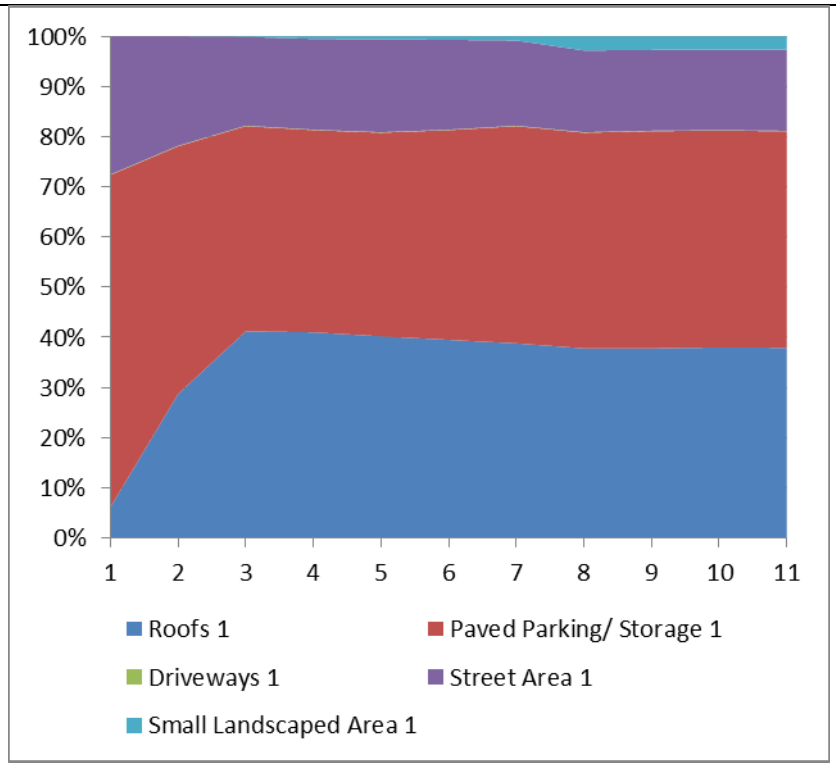


Medium Density Residential Area (1960 - 1980) TP Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

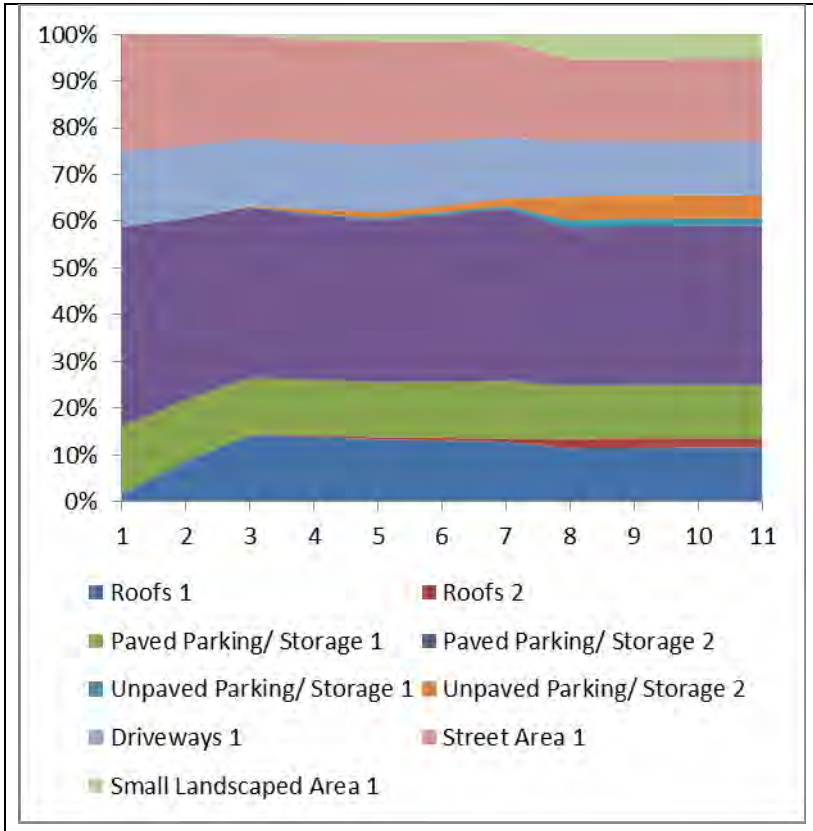
Nitrite plus Nitrate Mass Contributions



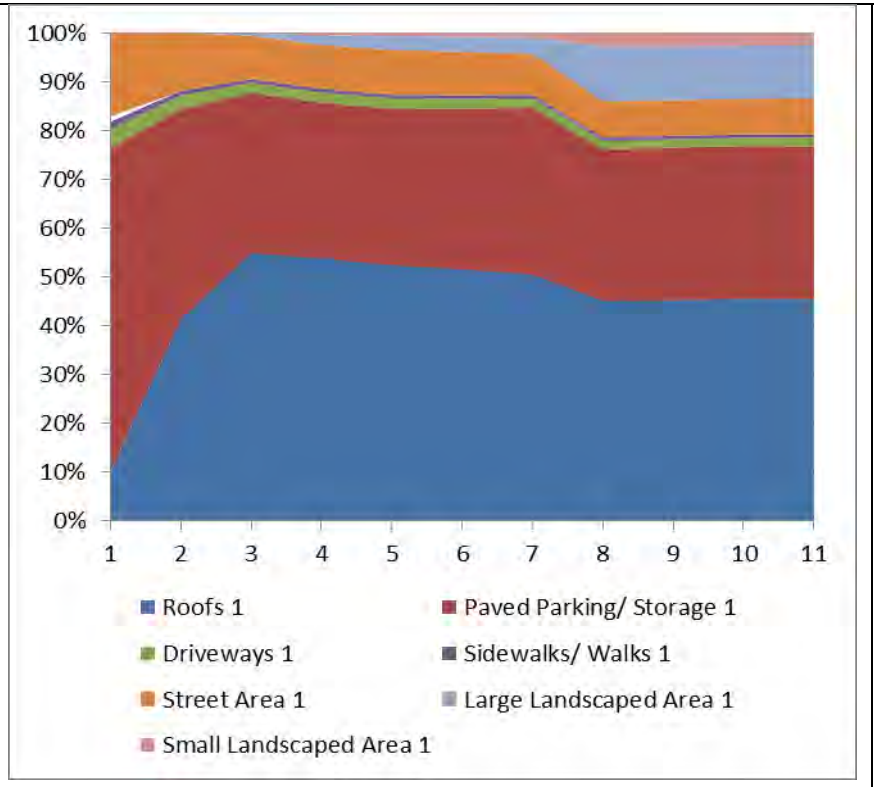
Commercial – Strip Mall Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



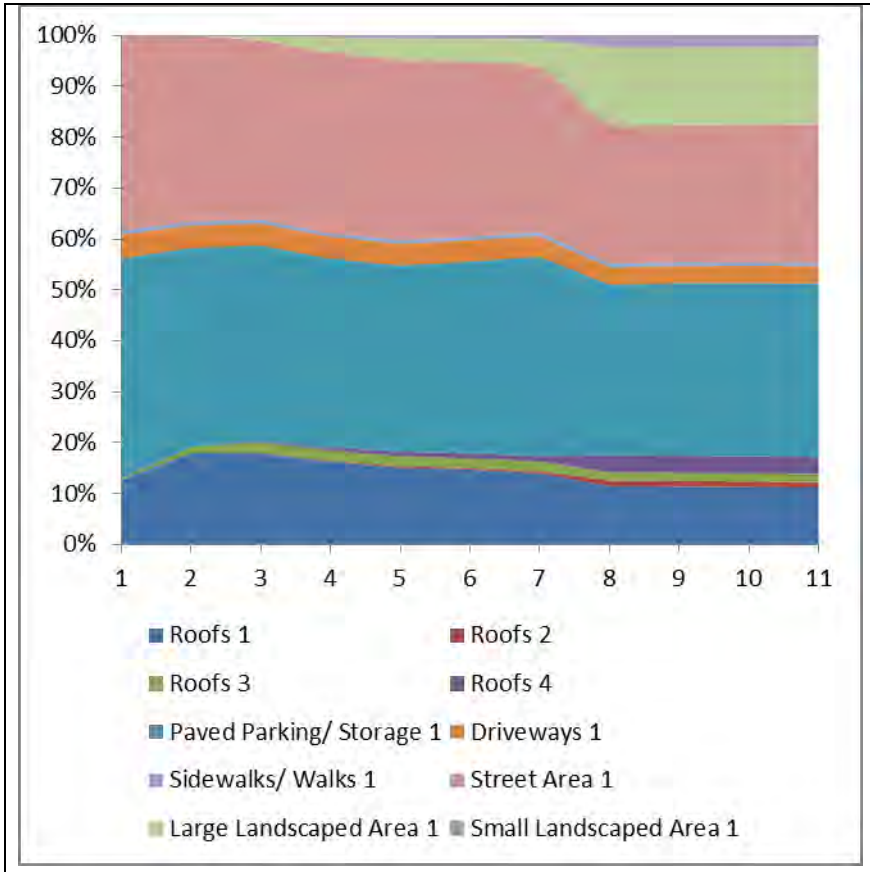
Commercial – Shopping Center Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



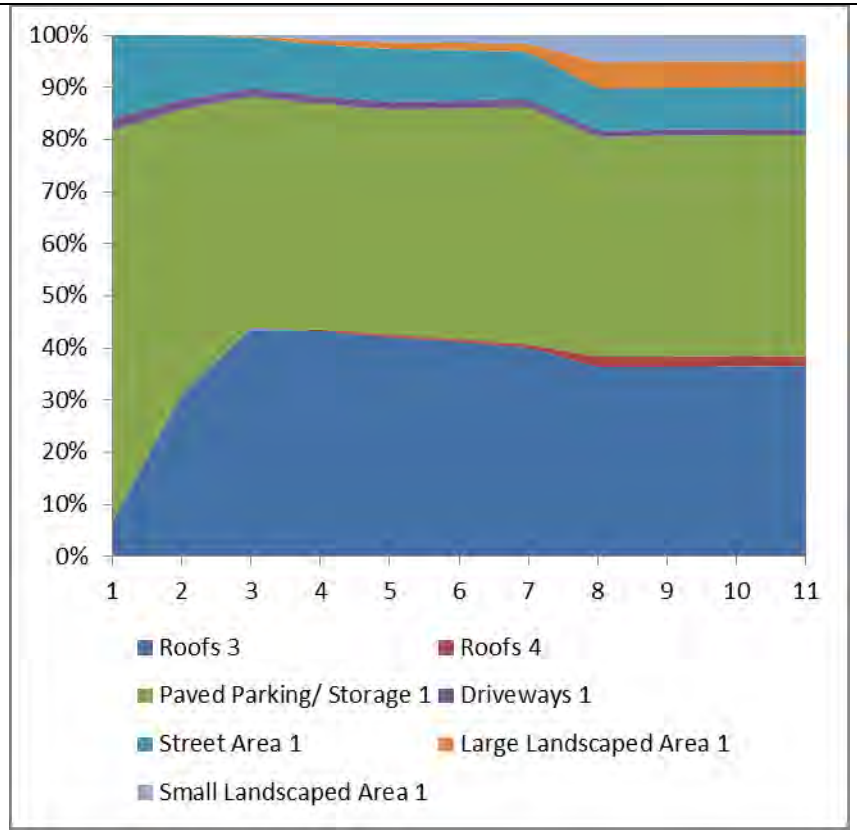
Light Industrial Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



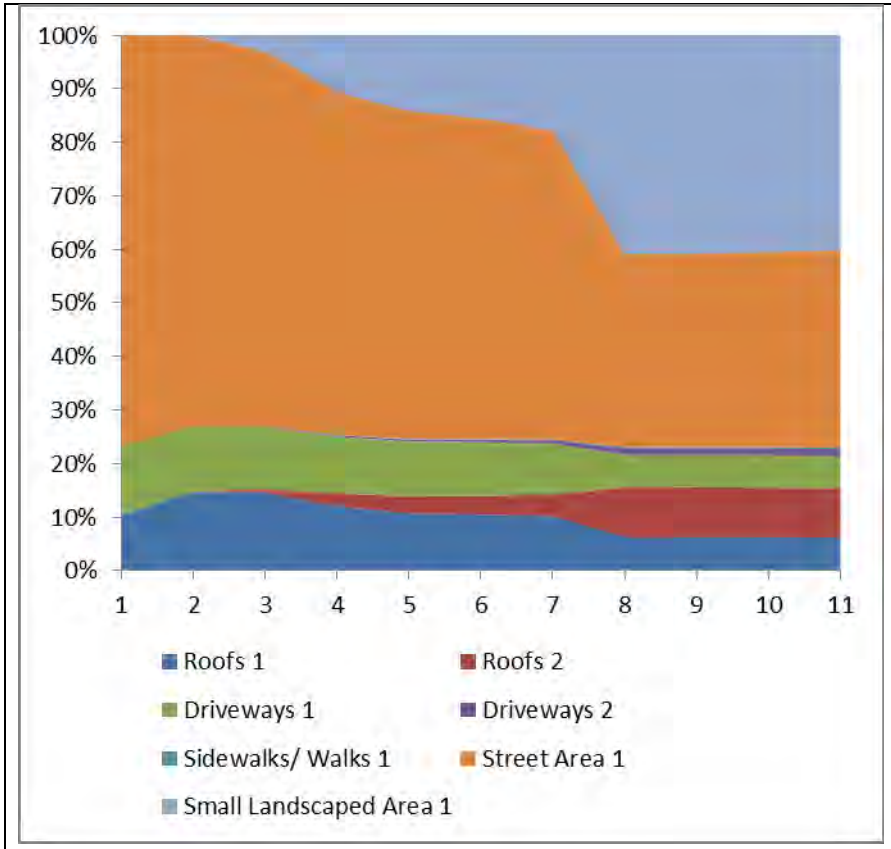
Institutional - School Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



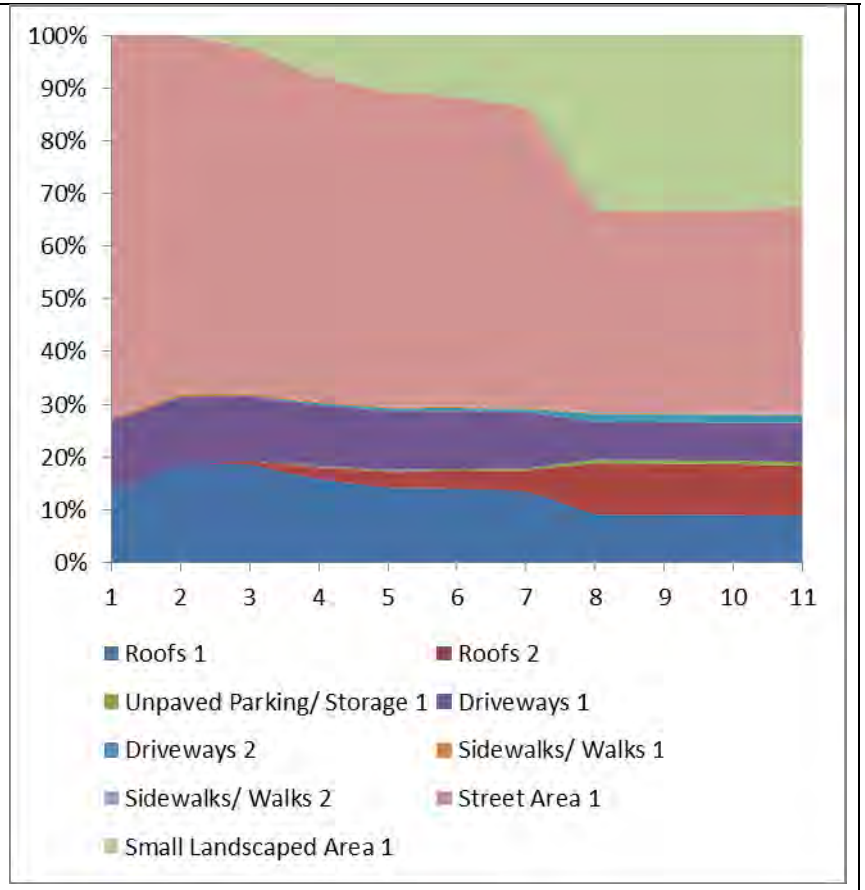
Institutional – Church Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



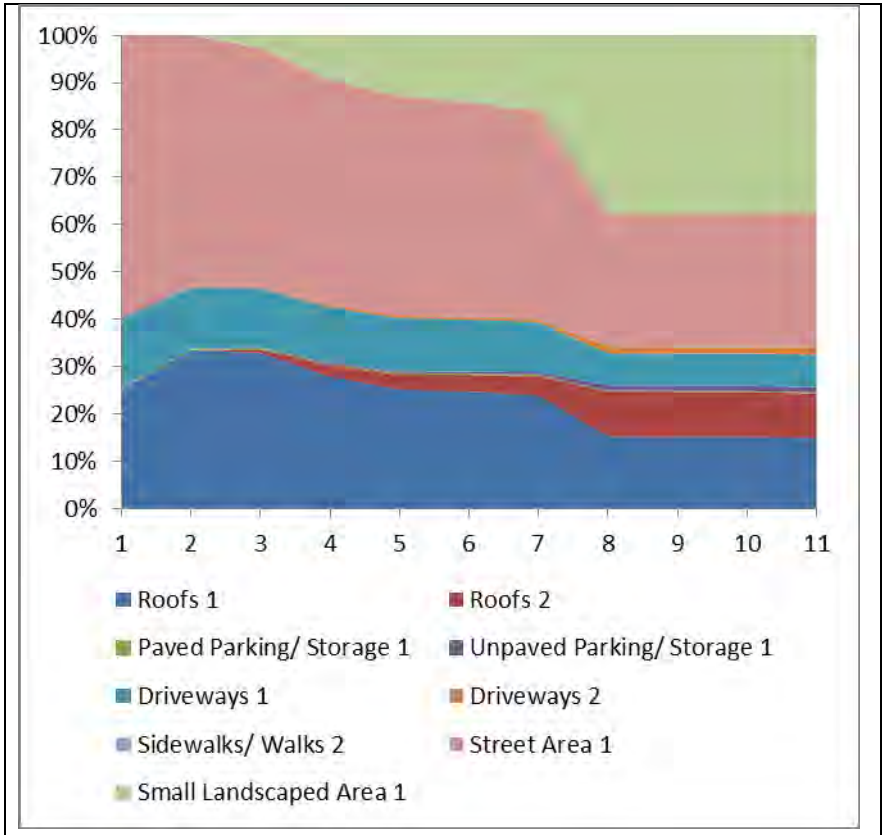
Institutional - Hospital Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



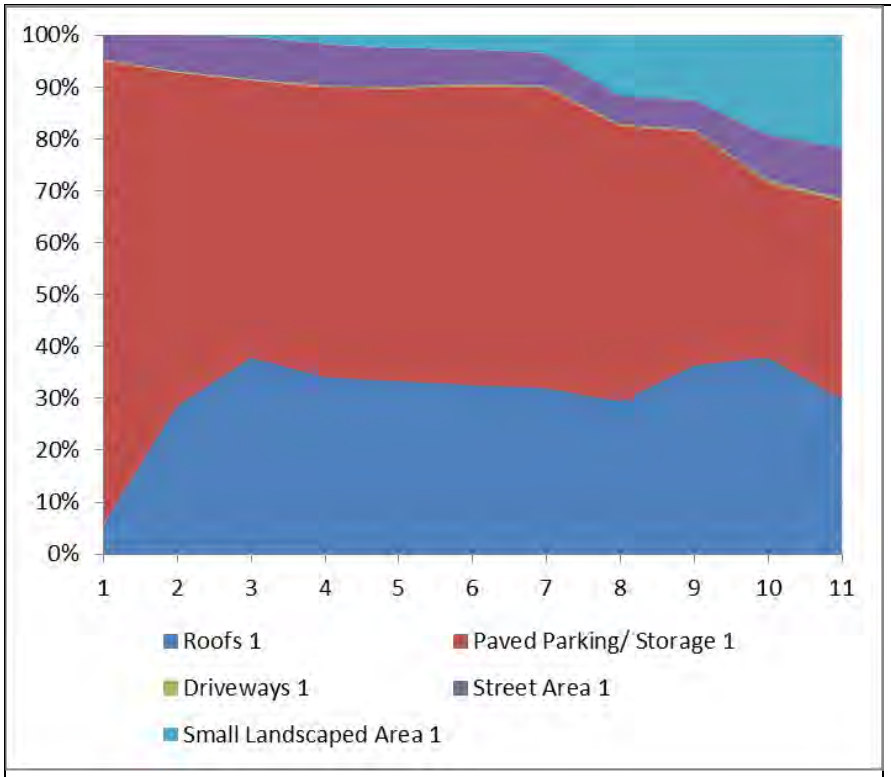
Medium Density Residential Area (<1960) NO_2+NO_3 Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



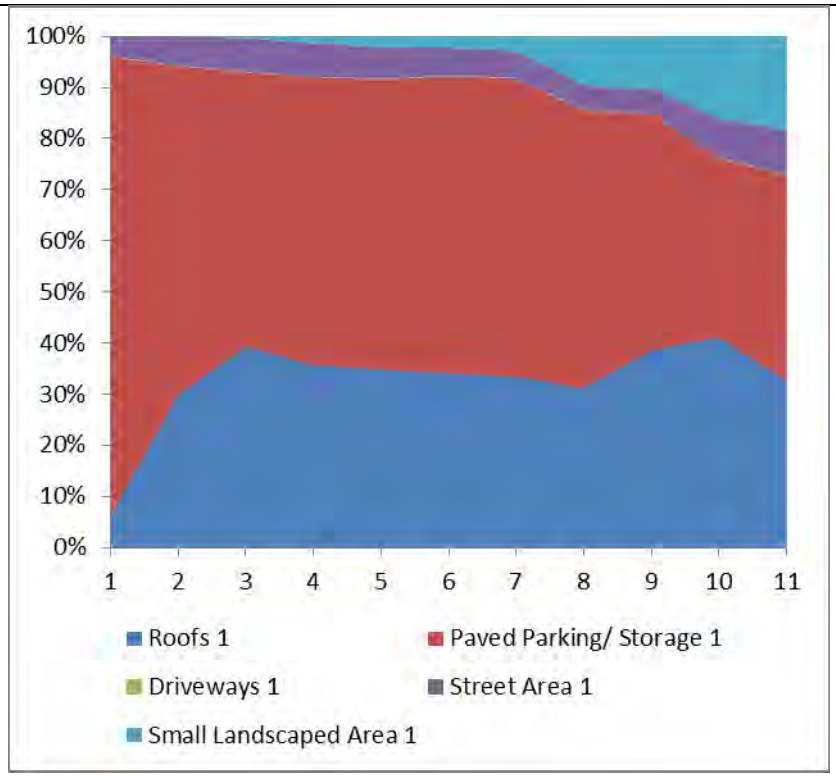
Medium Density Residential Area (1960 - 1980) NO_2+NO_3 Contributions

Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

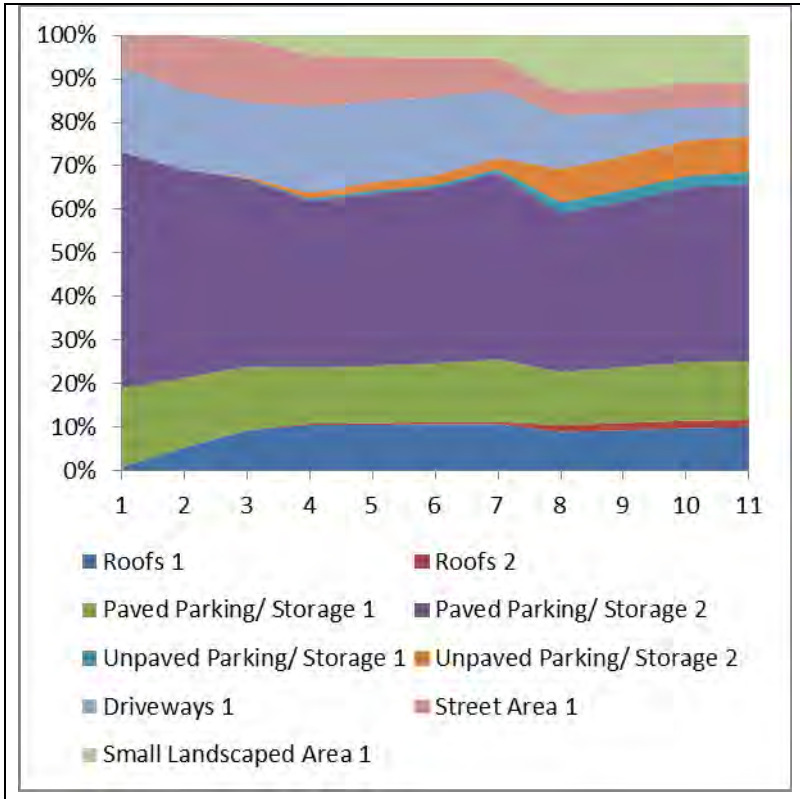
Total Kjeldahl Nitrogen Mass Contributions



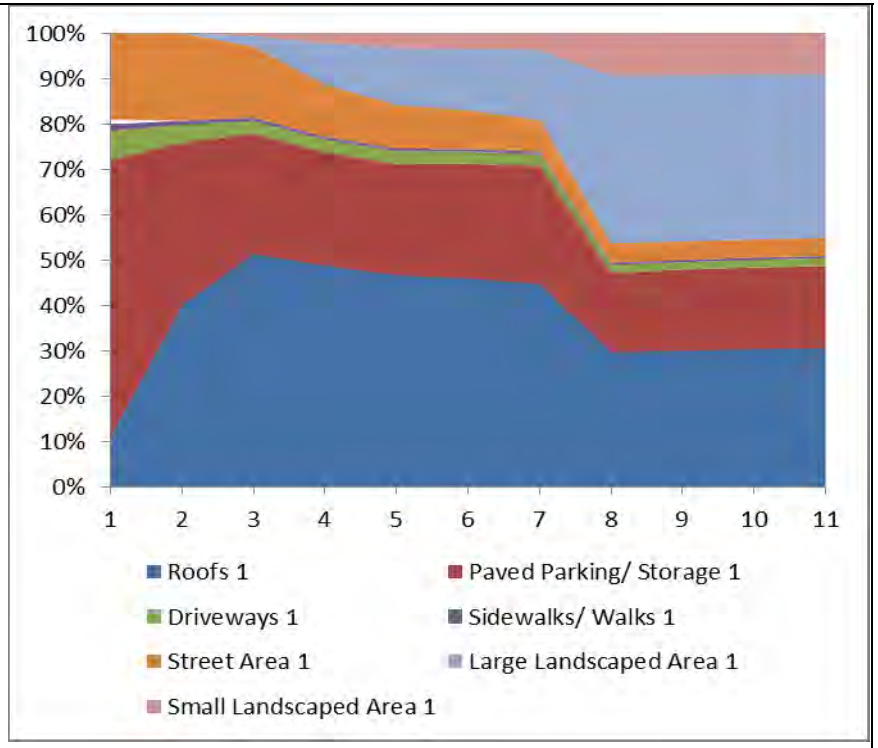
Commercial – Strip Mall Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



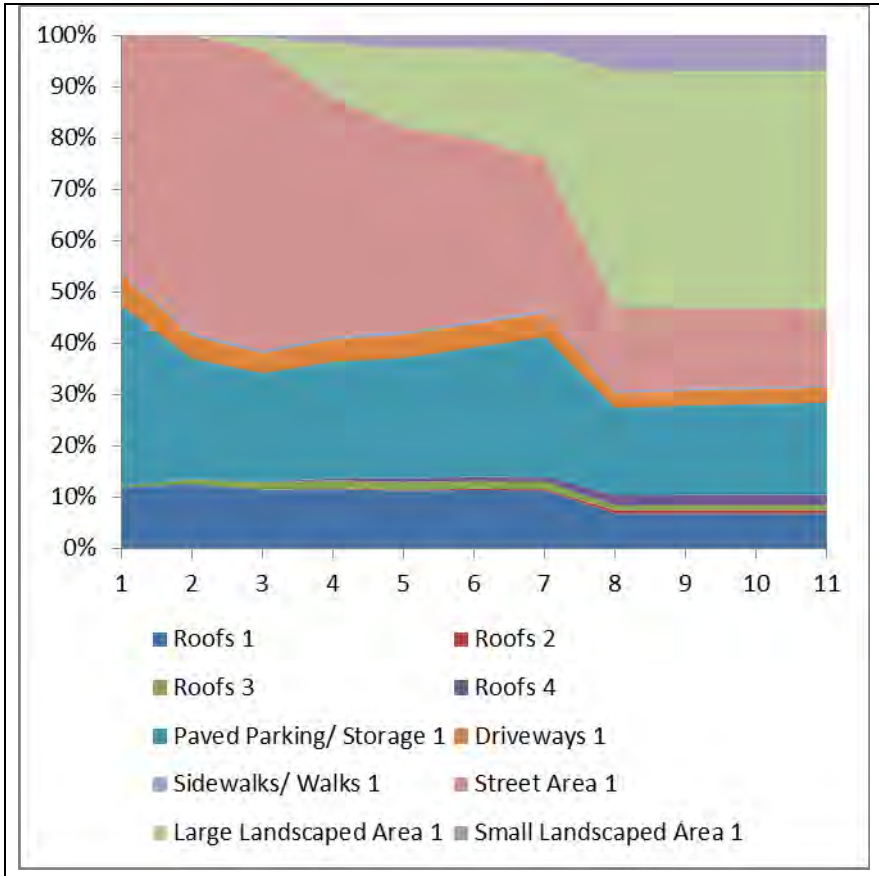
Commercial – Shopping Center Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



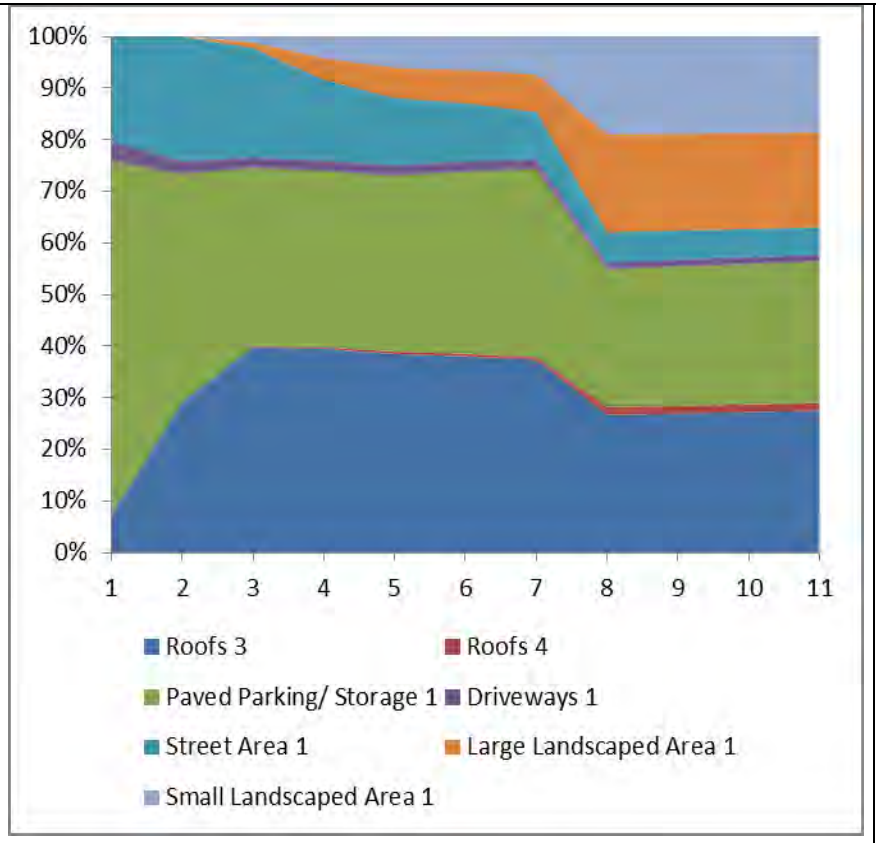
Light Industrial Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



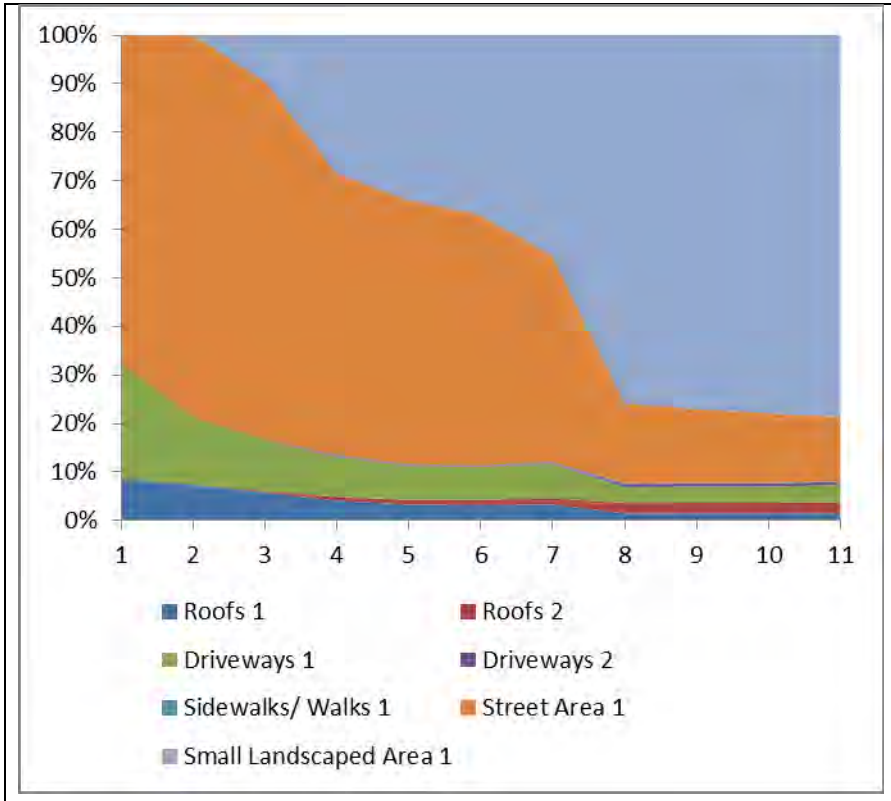
Institutional - School Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



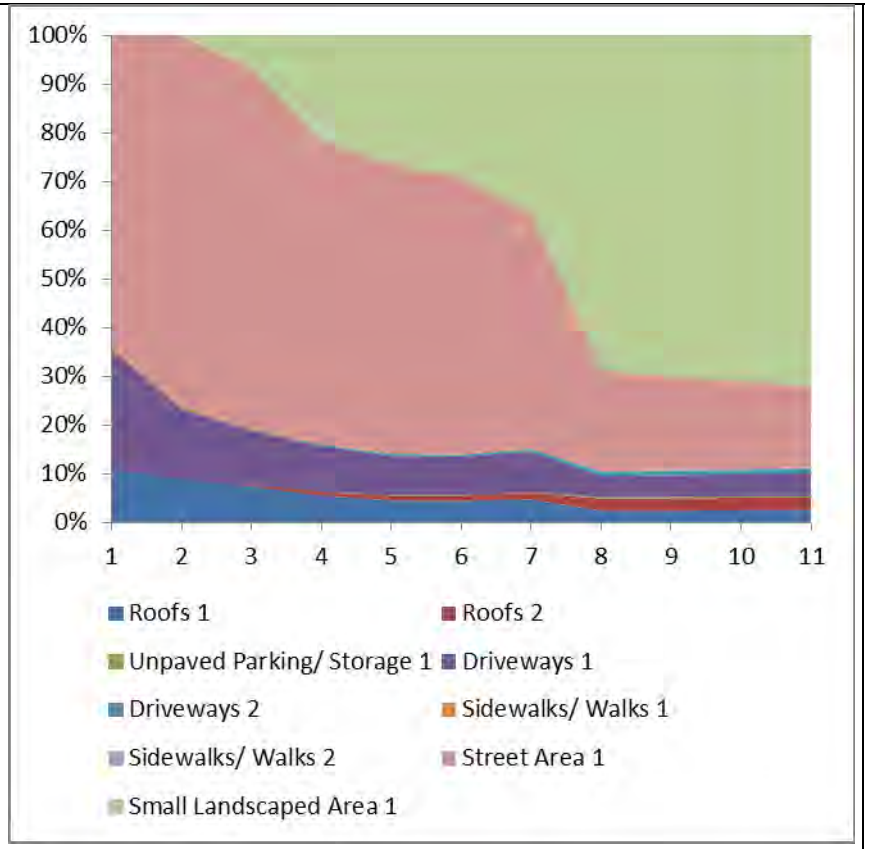
Institutional – Church Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



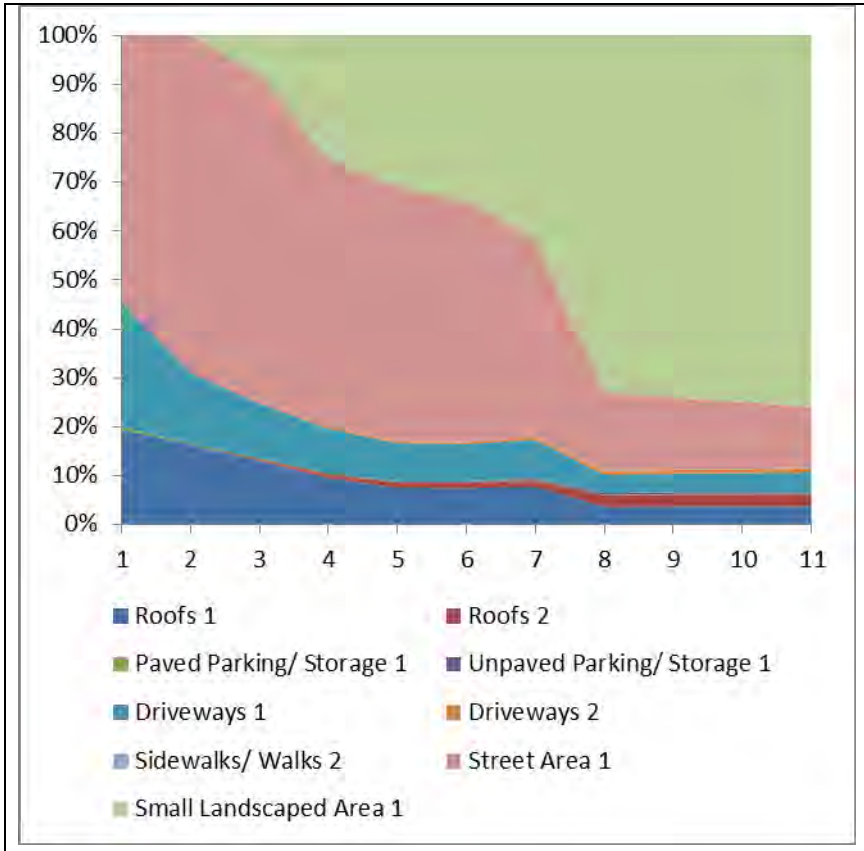
Institutional - Hospital Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

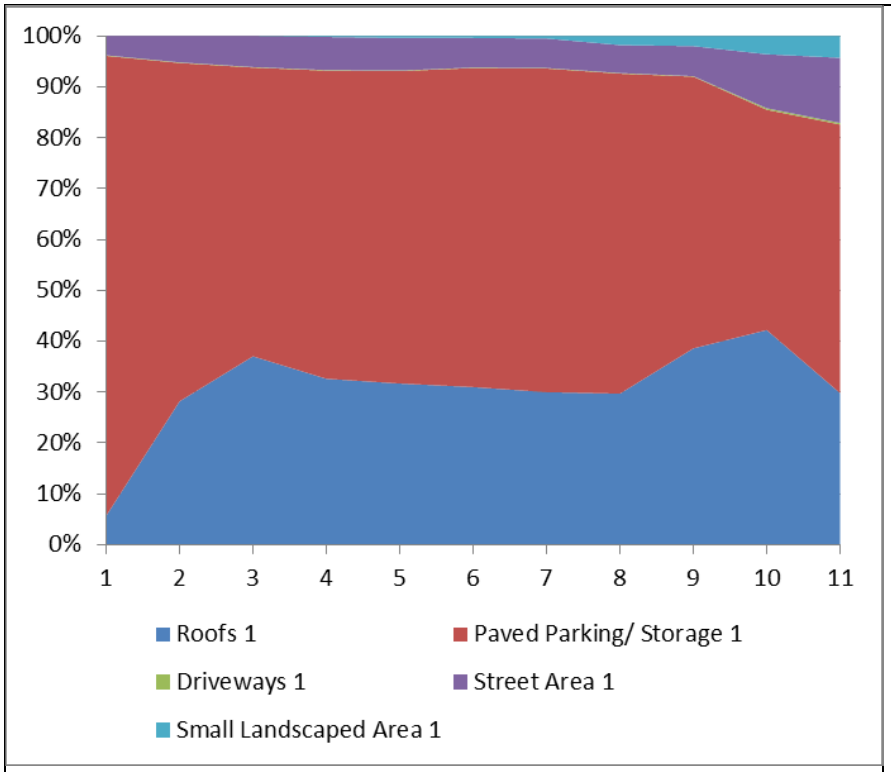


Medium Density Residential Area (<1960) TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

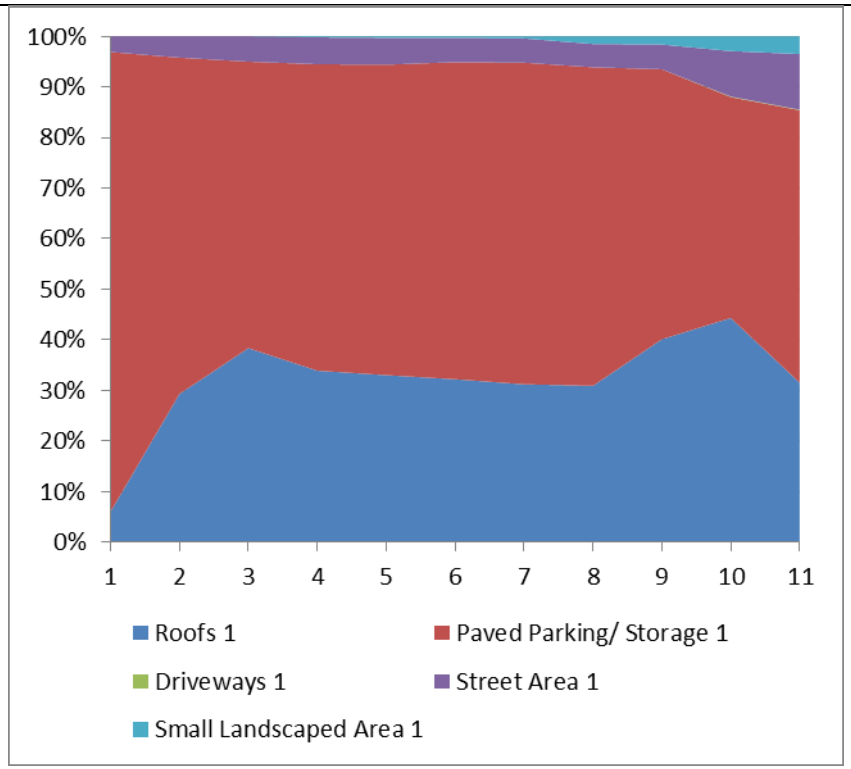


Medium Density Residential Area (1960 - 1980) TKN Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

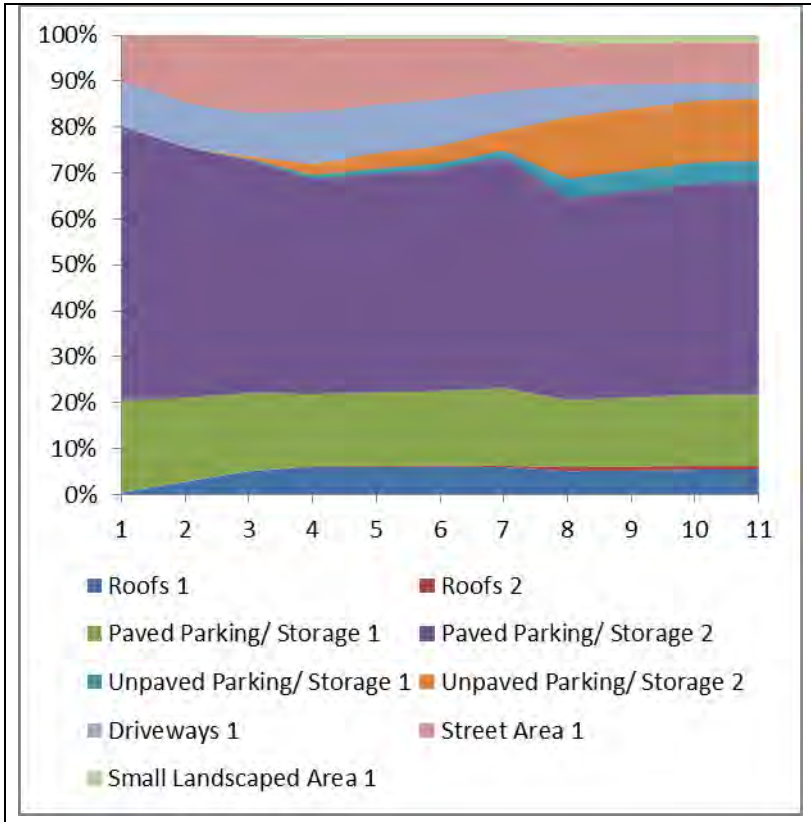
Chemical Oxygen Demand Mass Contributions



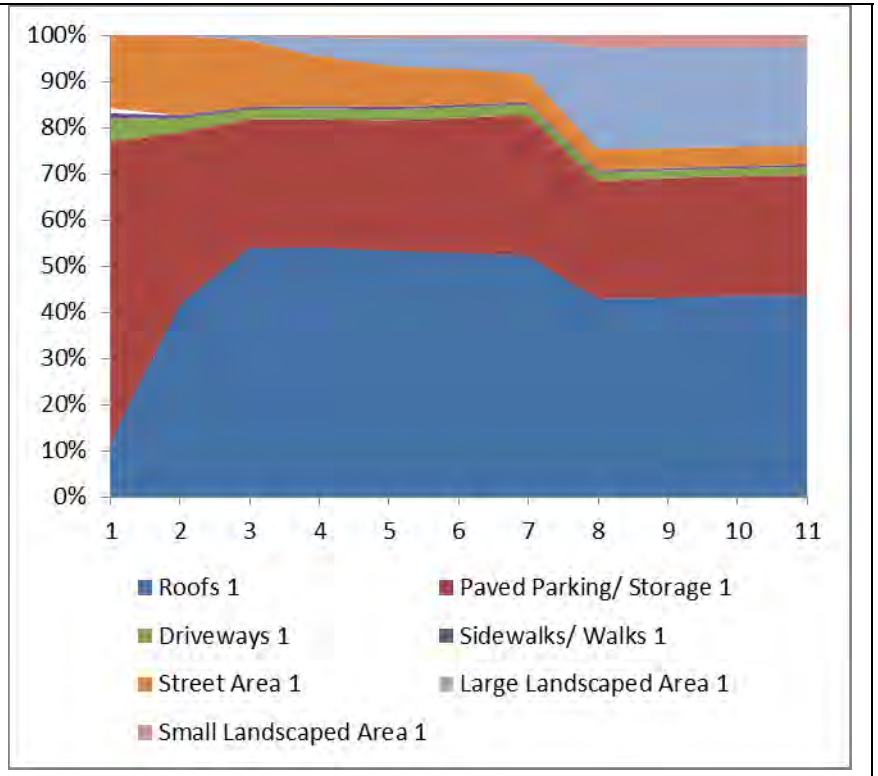
Commercial – Strip Mall Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



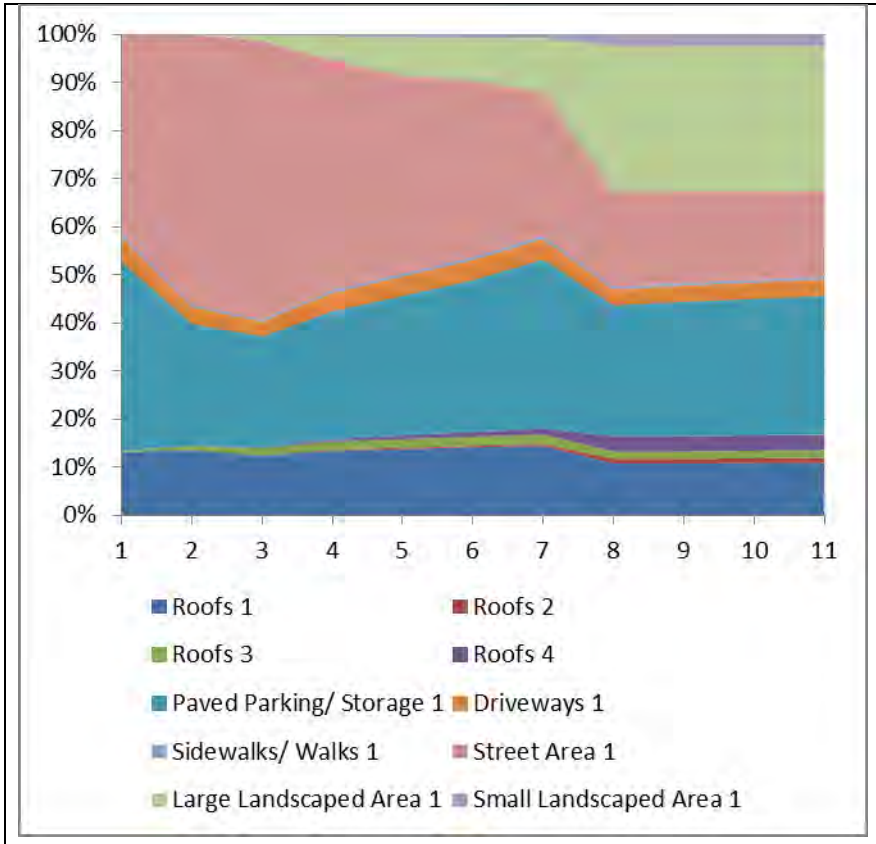
Commercial – Shopping Center Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



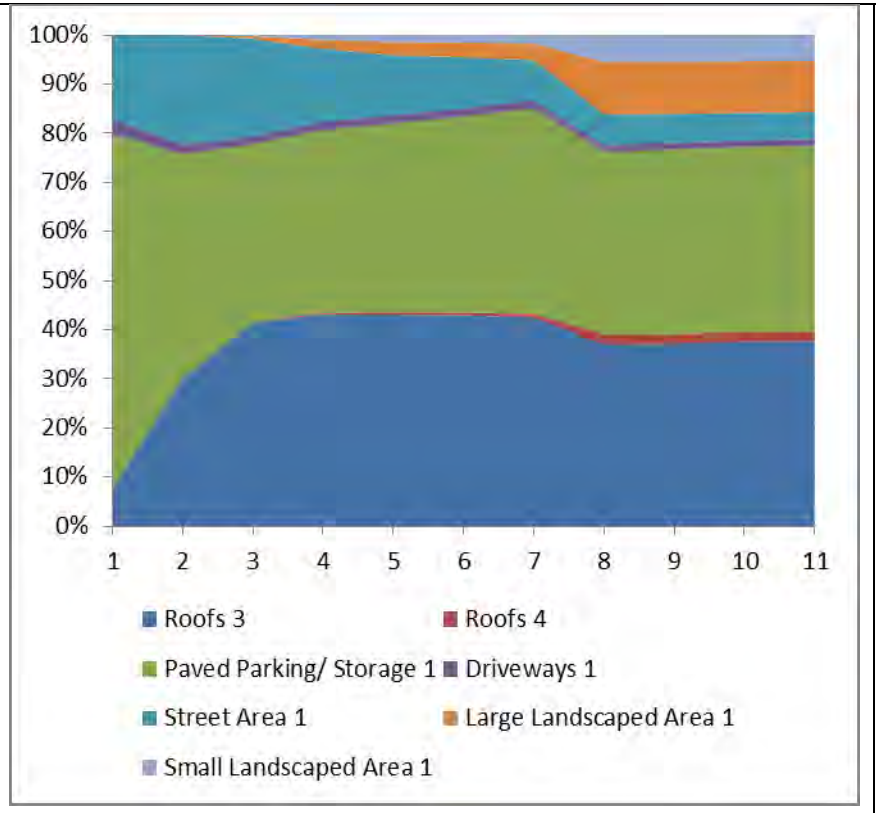
Light Industrial Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



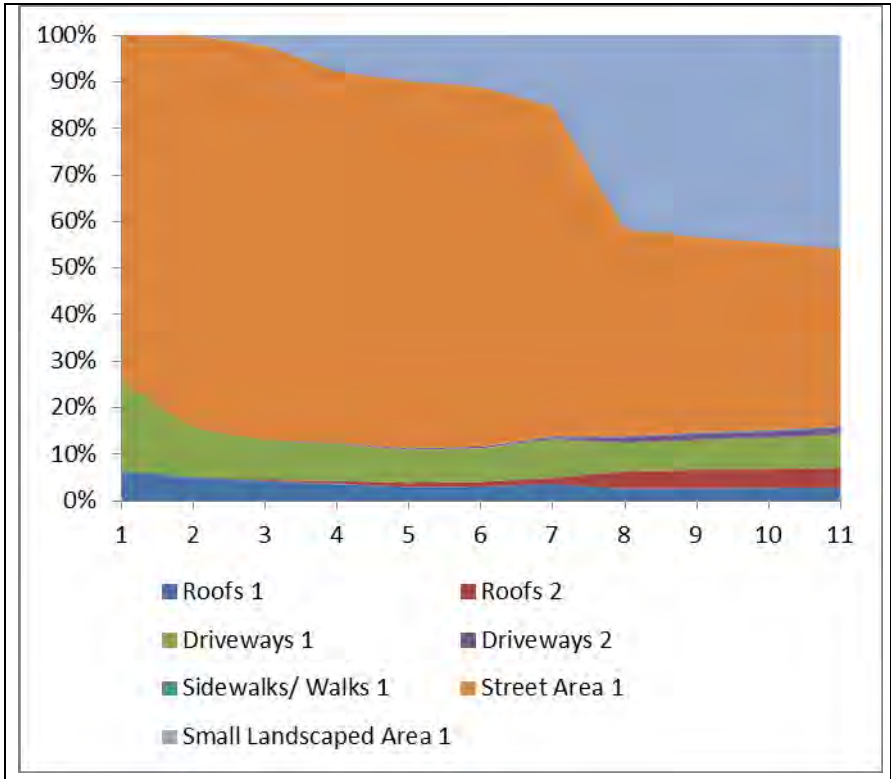
Institutional - School Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



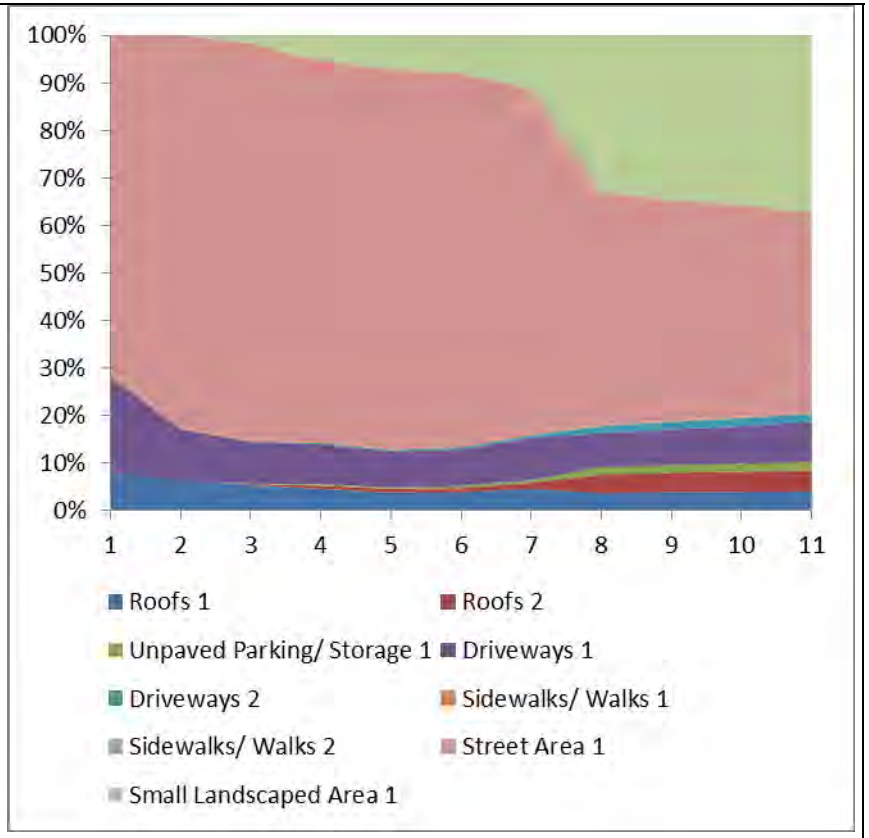
Institutional – Church Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



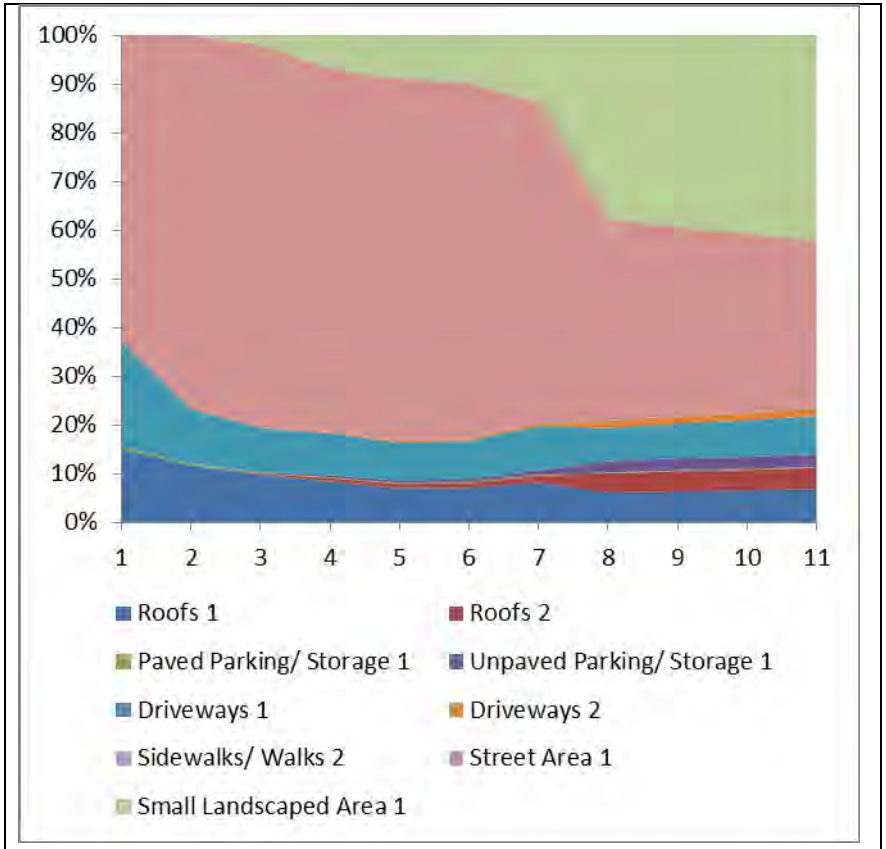
Institutional - Hospital Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”
”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

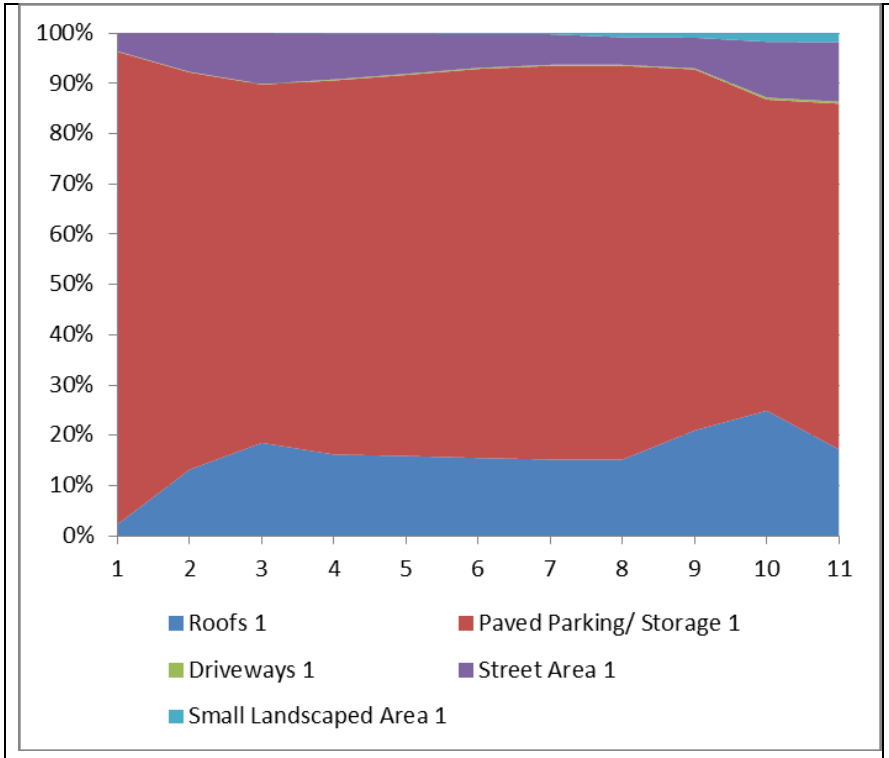


Medium Density Residential Area (<1960) COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

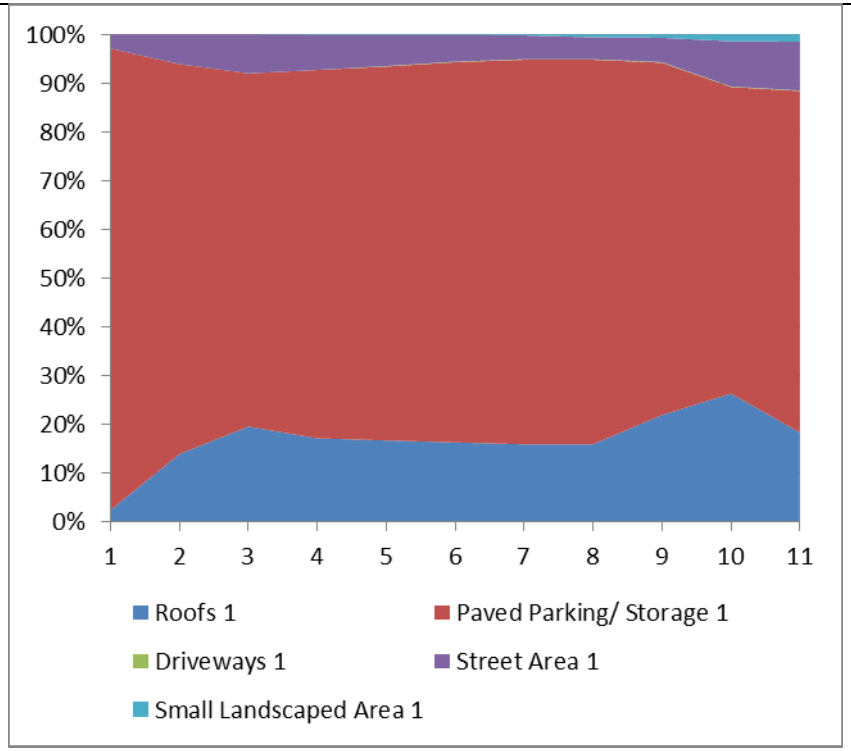


Medium Density Residential Area (1960 - 1980) COD Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

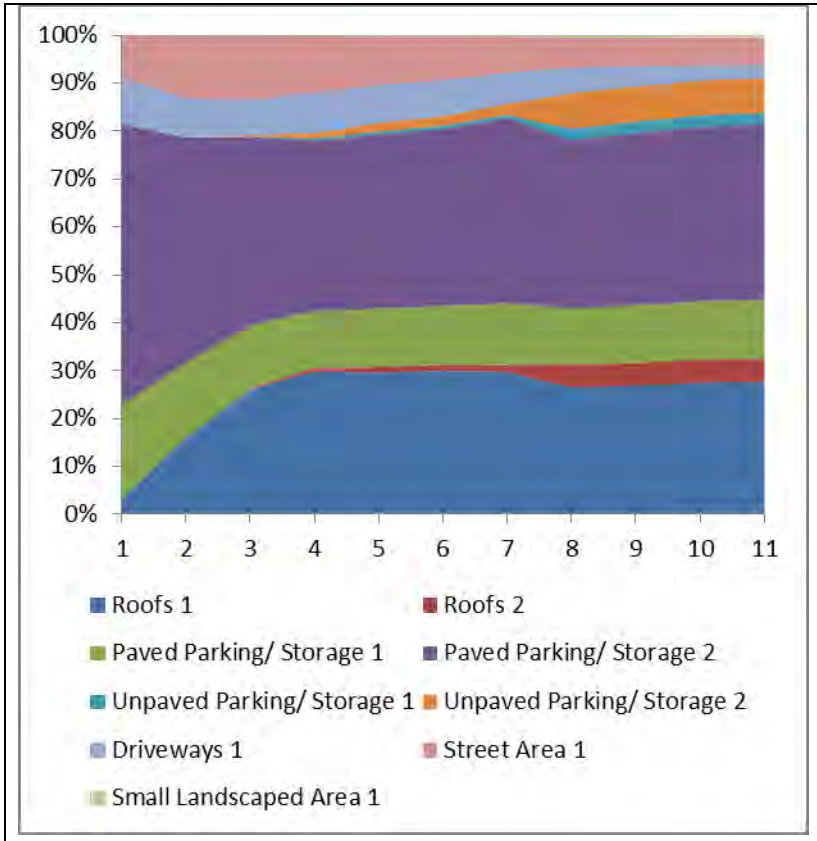
Total Copper Mass Contributions



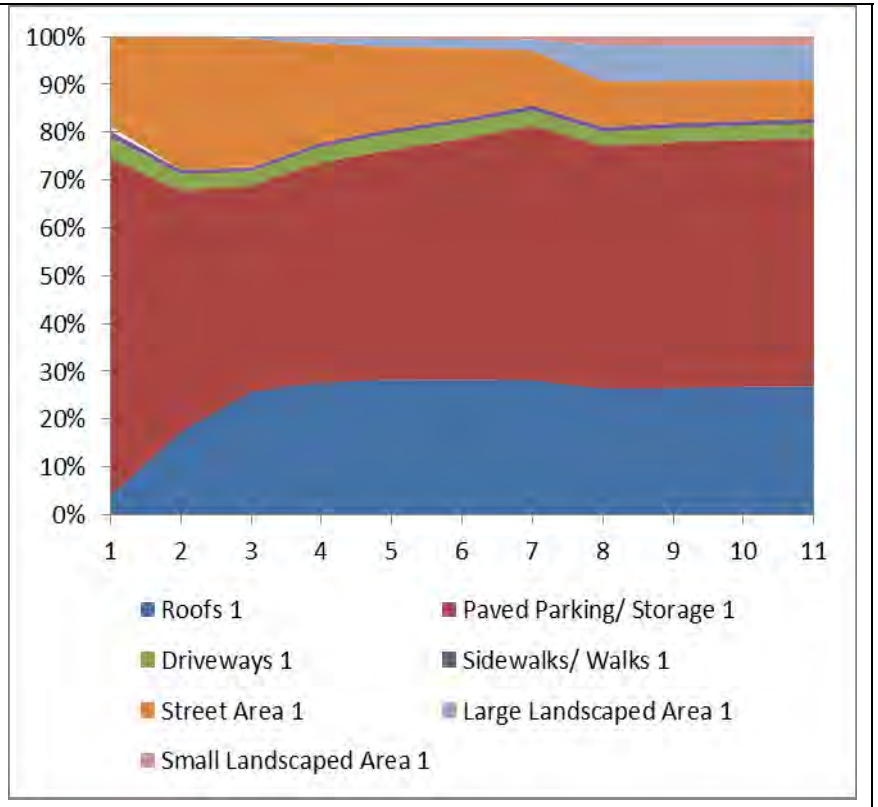
Commercial – Strip Mall Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



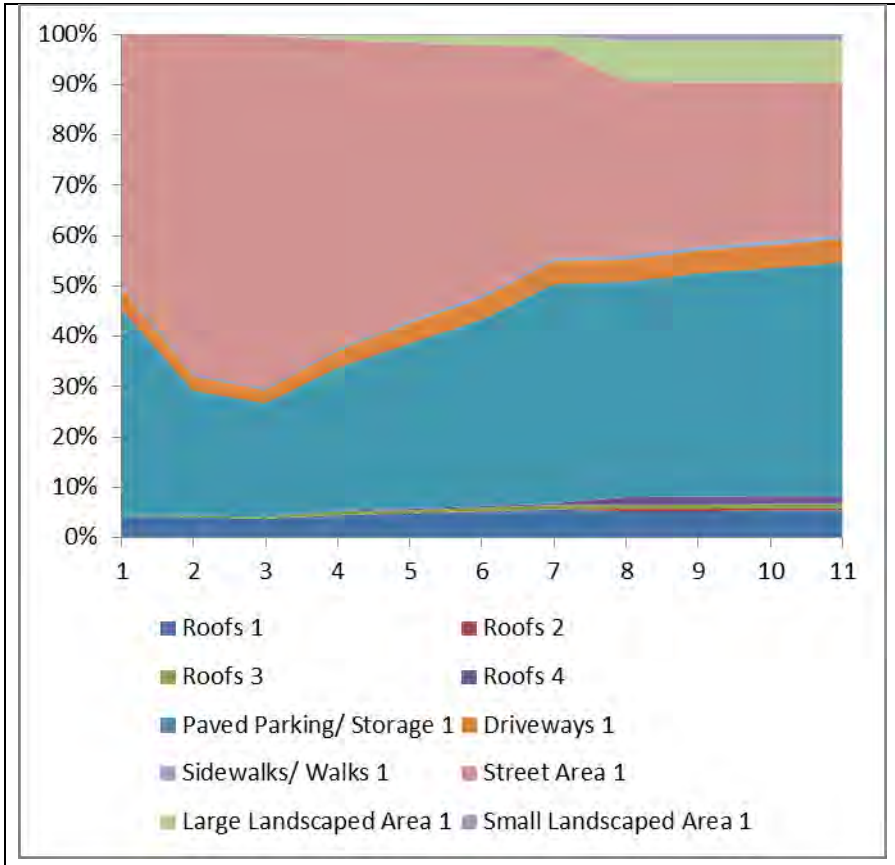
Commercial – Shopping Center Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



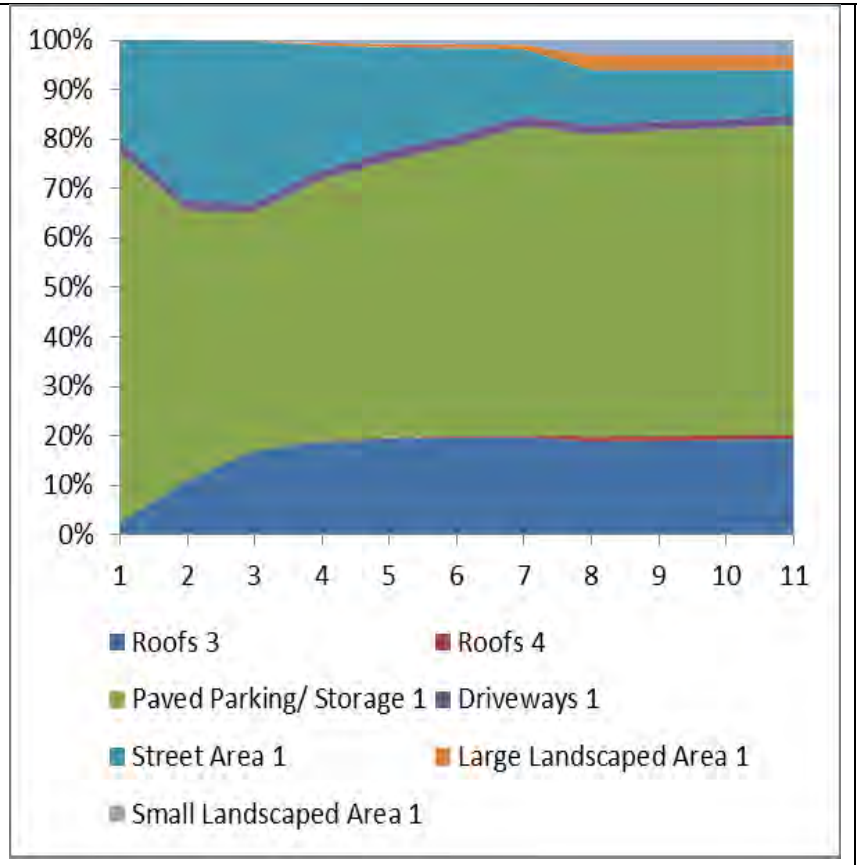
Light Industrial Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



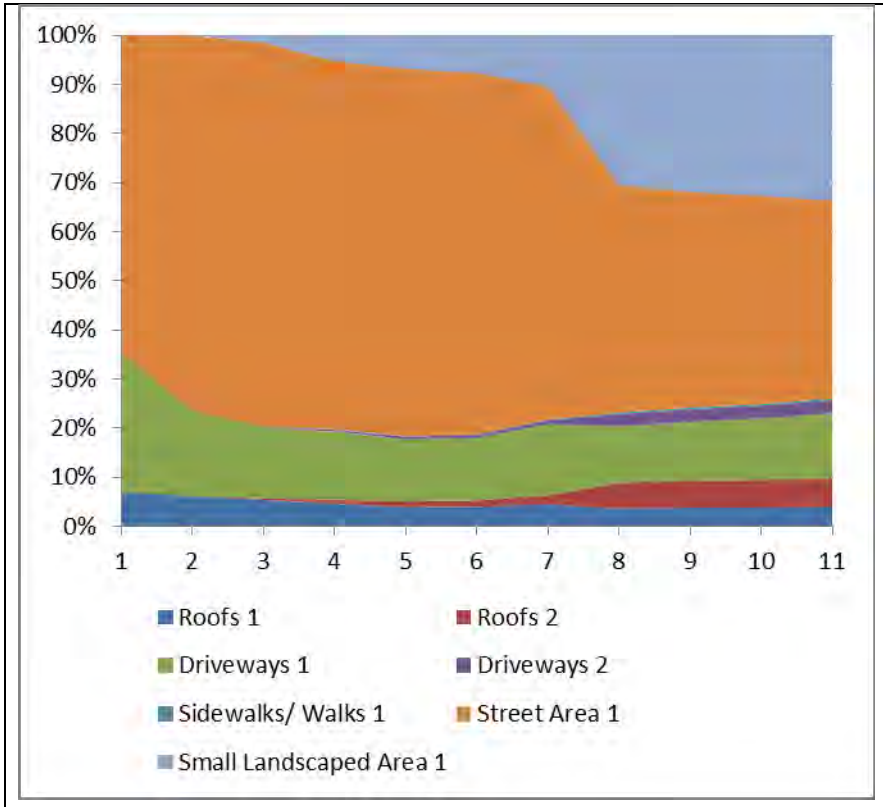
Institutional - School Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



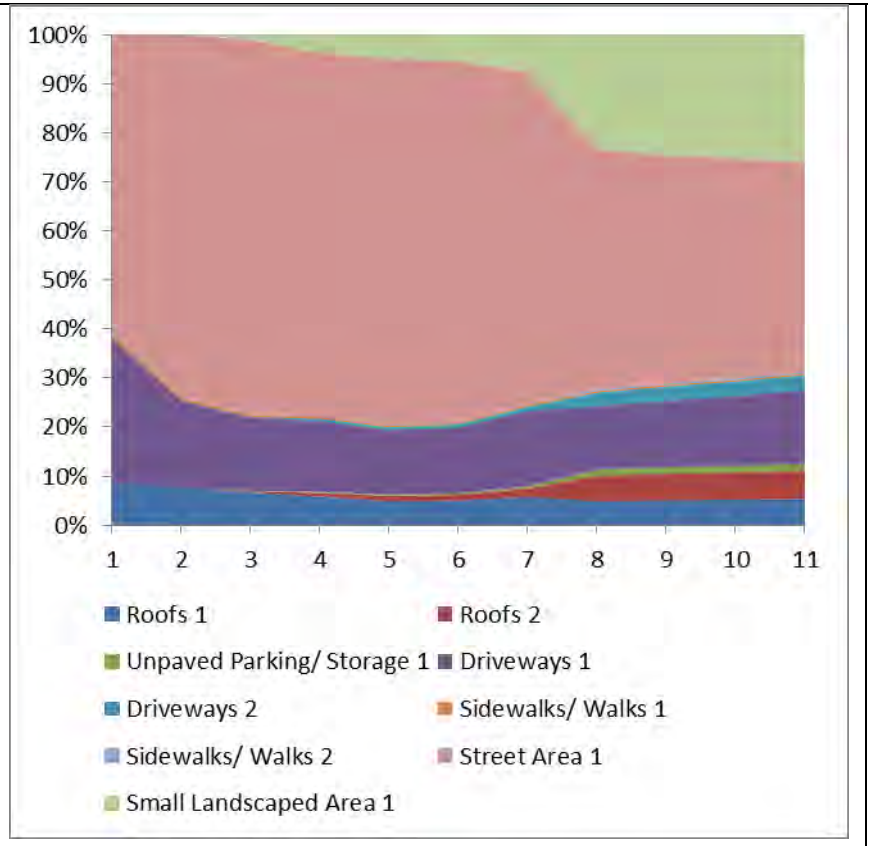
Institutional – Church Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



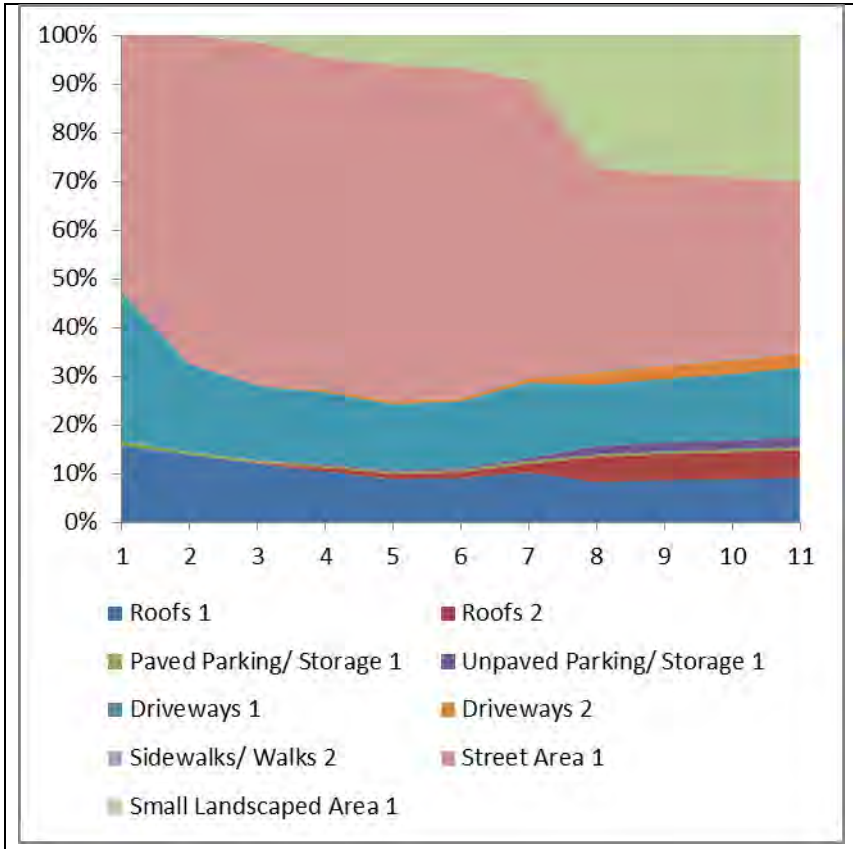
Institutional - Hospital Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

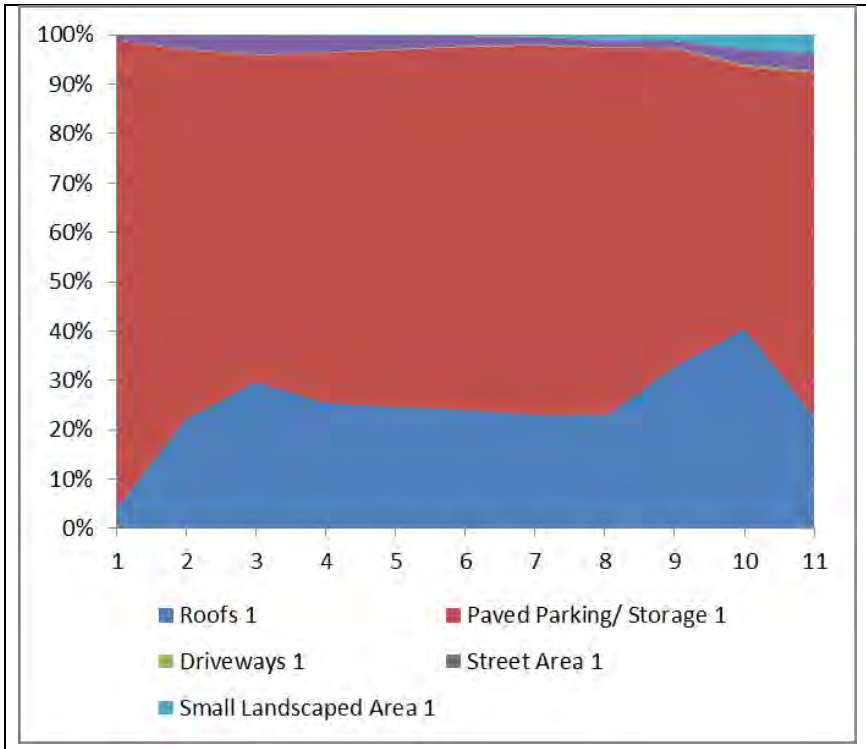


Medium Density Residential Area (<1960) Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

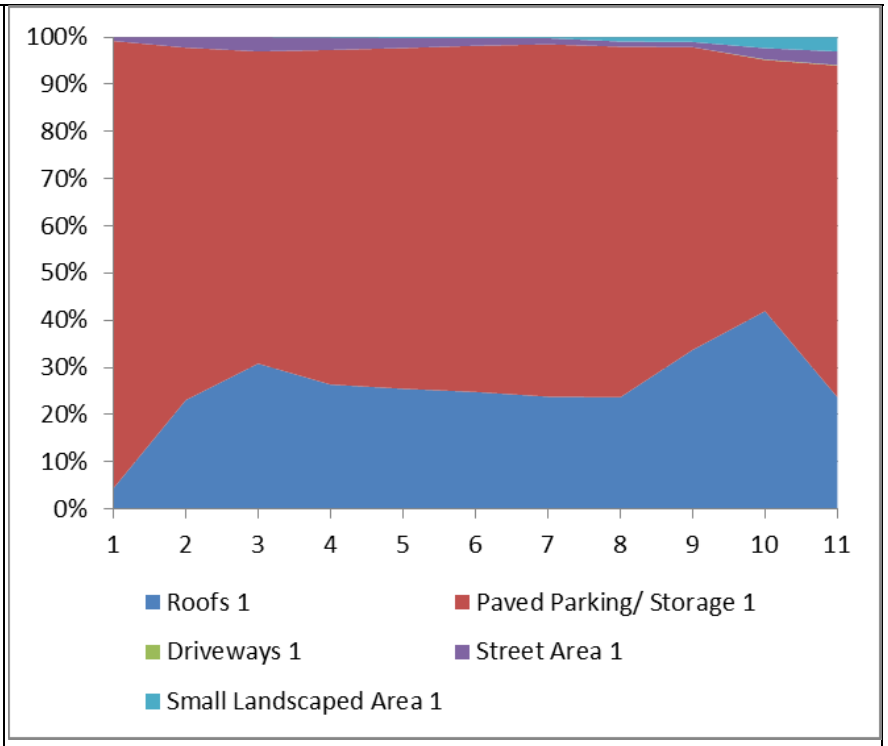


Medium Density Residential Area (1960 - 1980) Cu Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

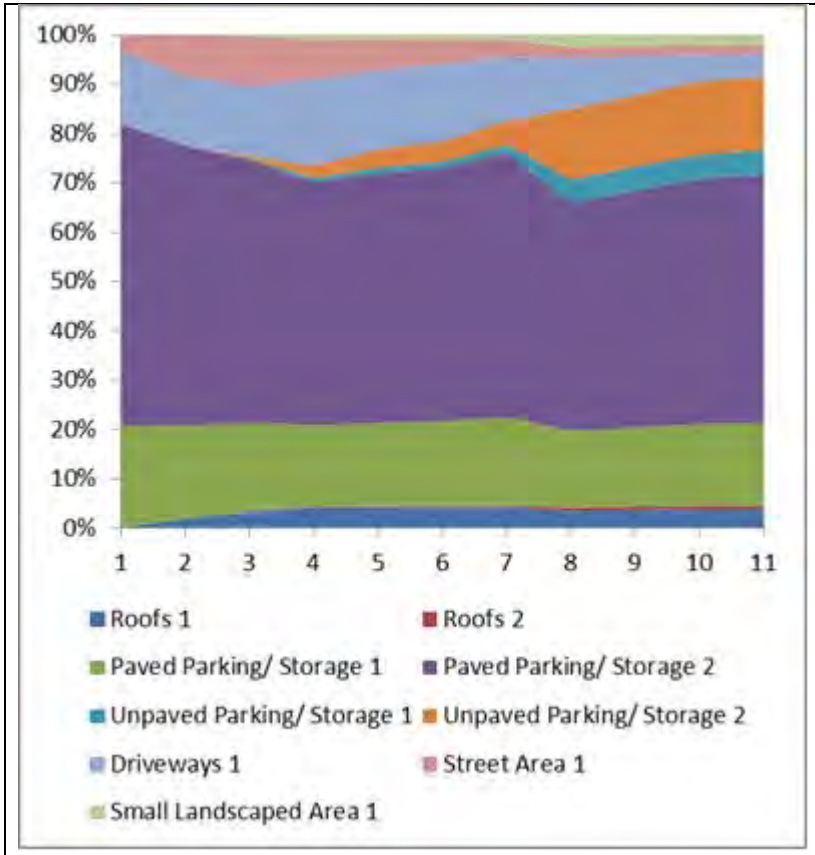
Total Lead Mass Contributions



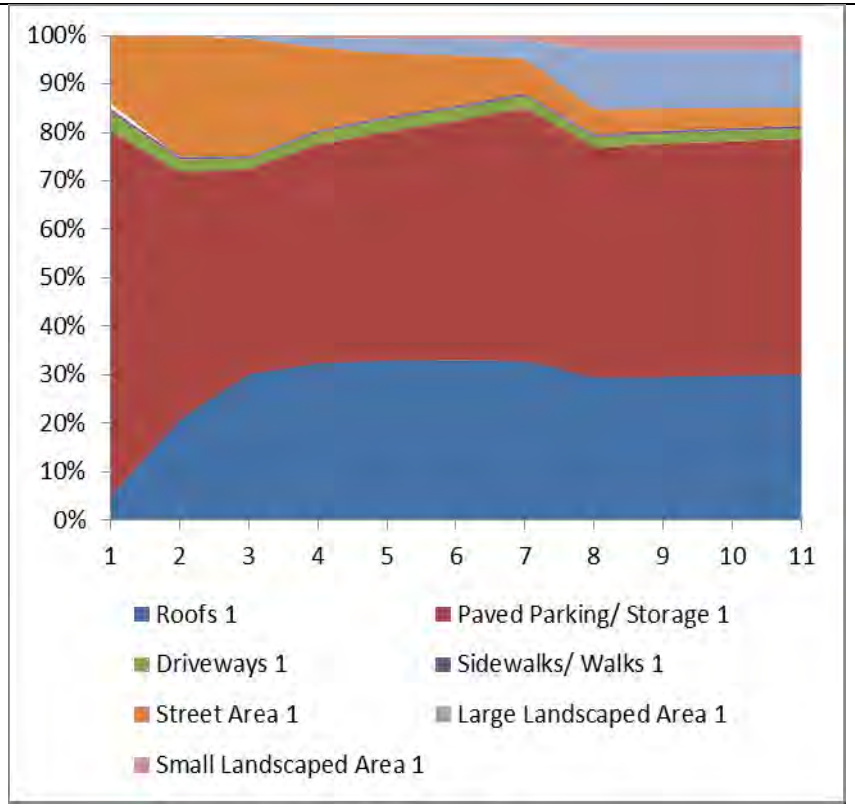
Commercial – Strip Mall Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



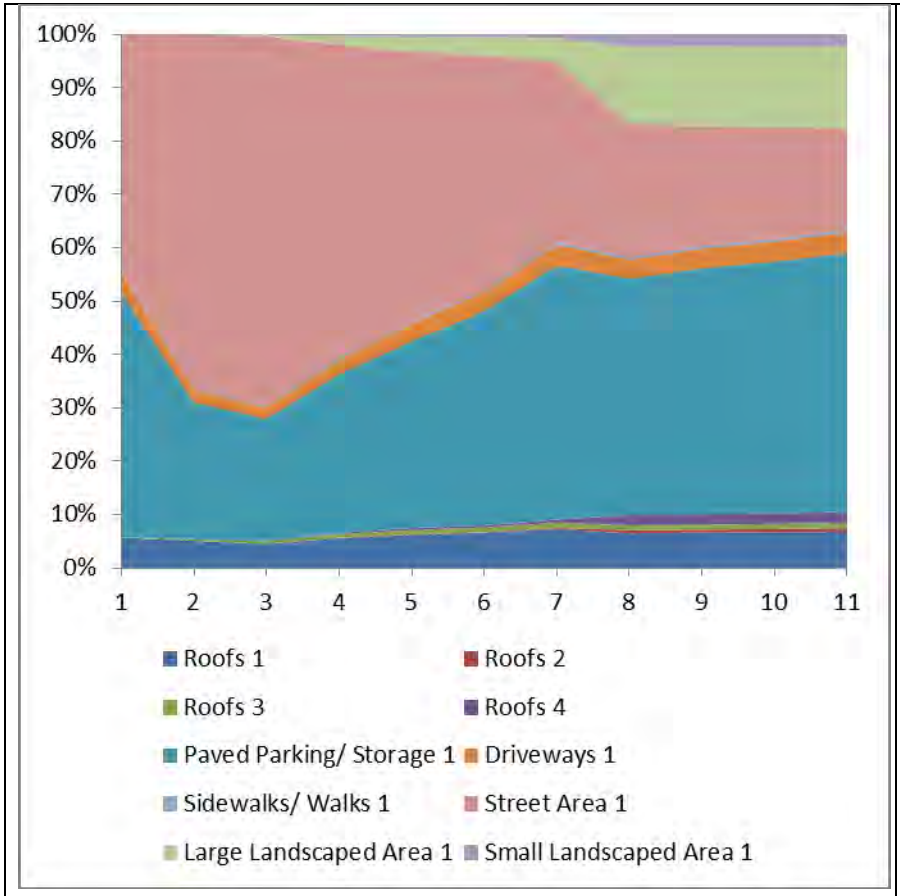
Commercial – Shopping Center Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



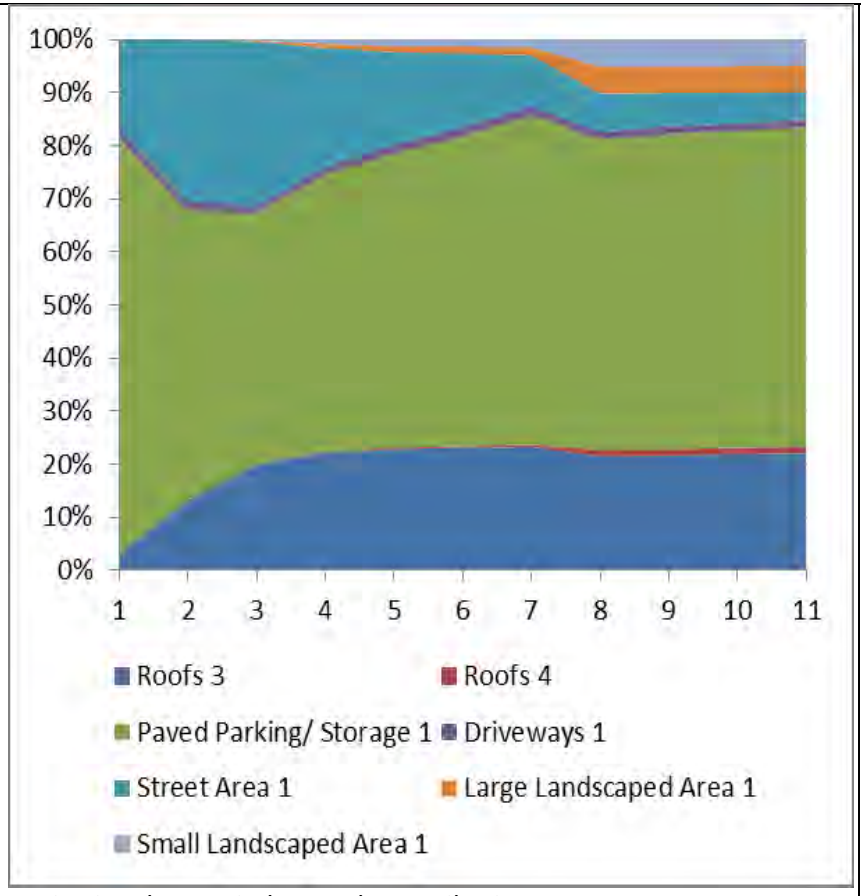
Light Industrial Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



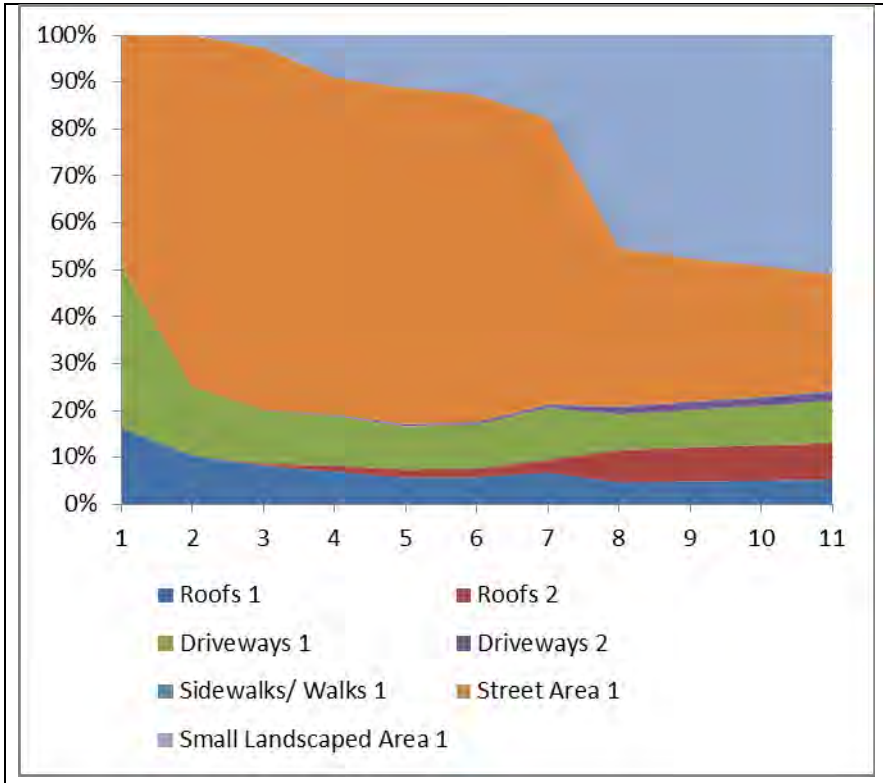
Institutional - School Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



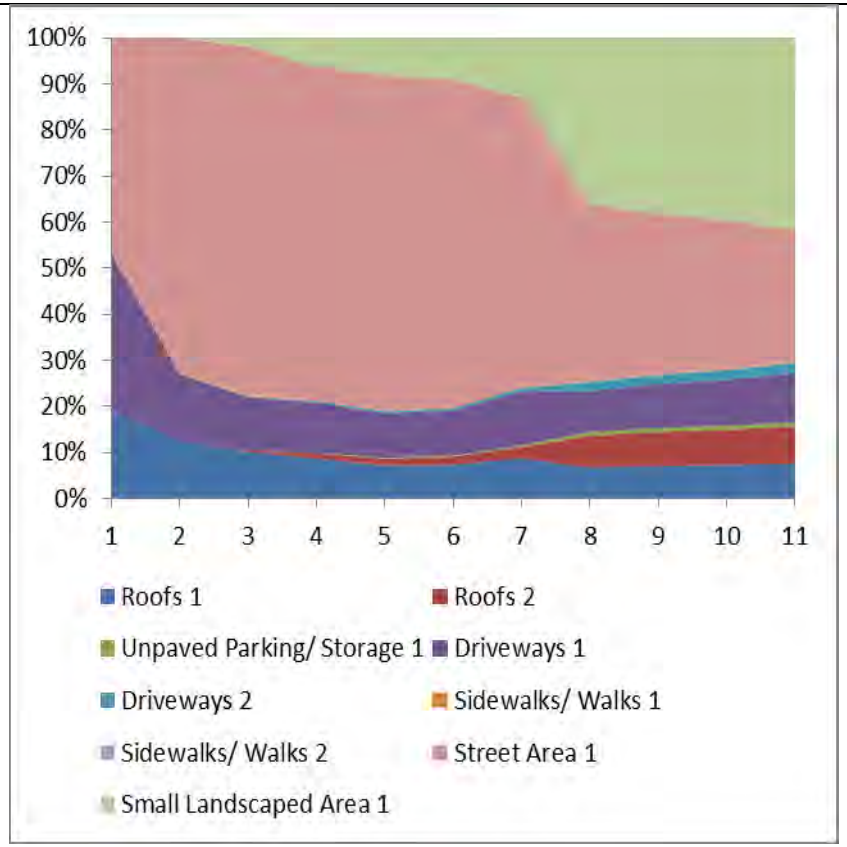
Institutional – Church Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



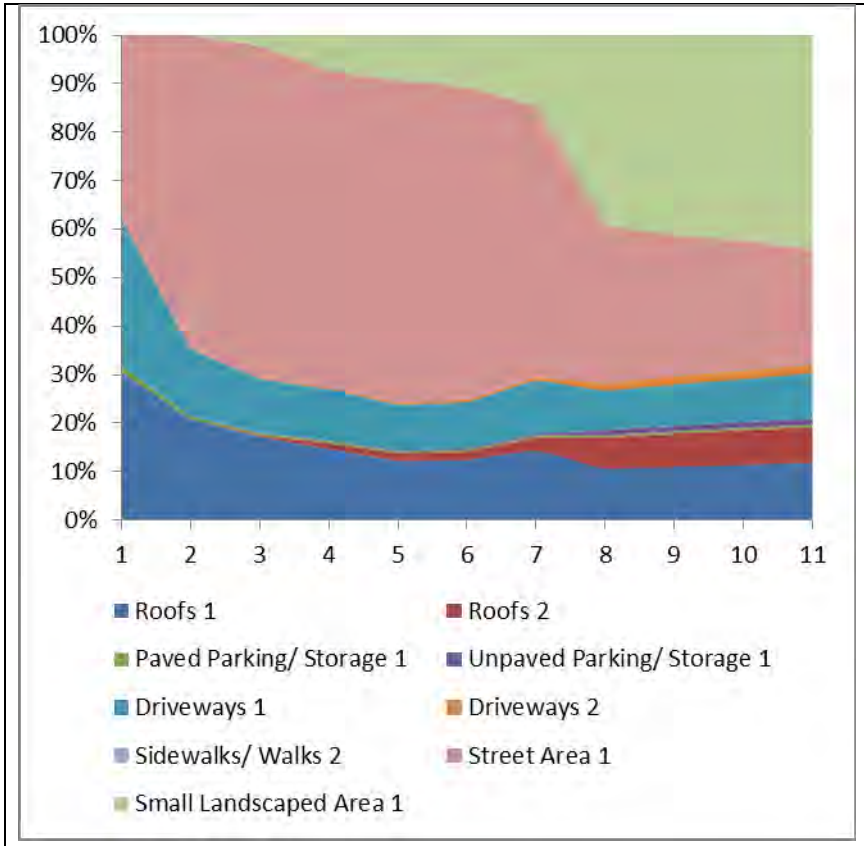
Institutional - Hospital Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

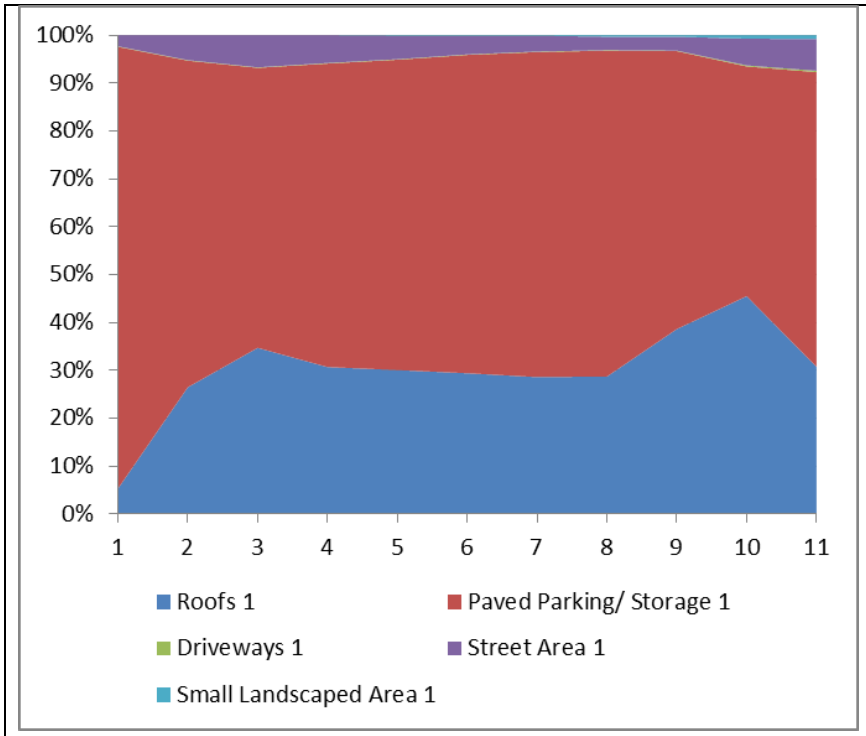


Medium Density Residential Area (<1960) Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

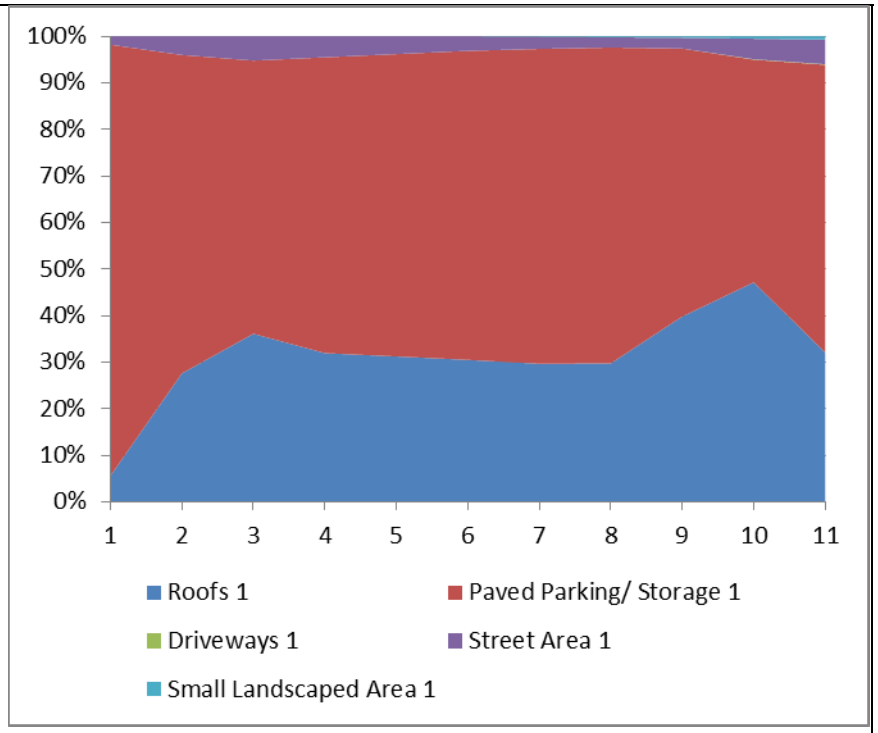


Medium Density Residential Area (1960 - 1980) Pb Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

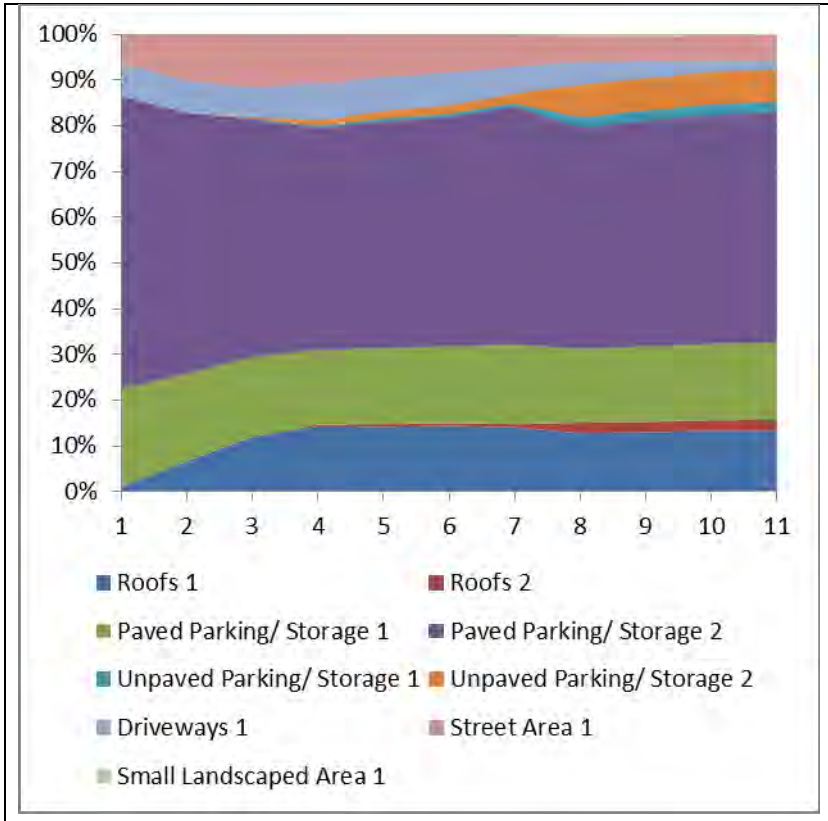
Total Zinc Mass Contributions



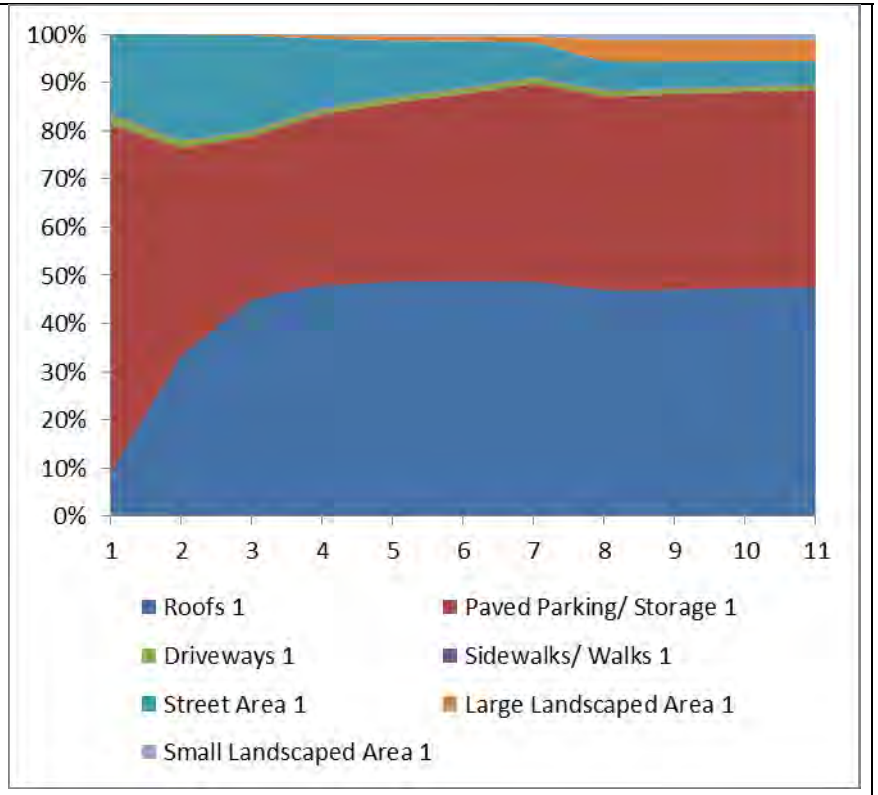
Commercial – Strip Mall Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



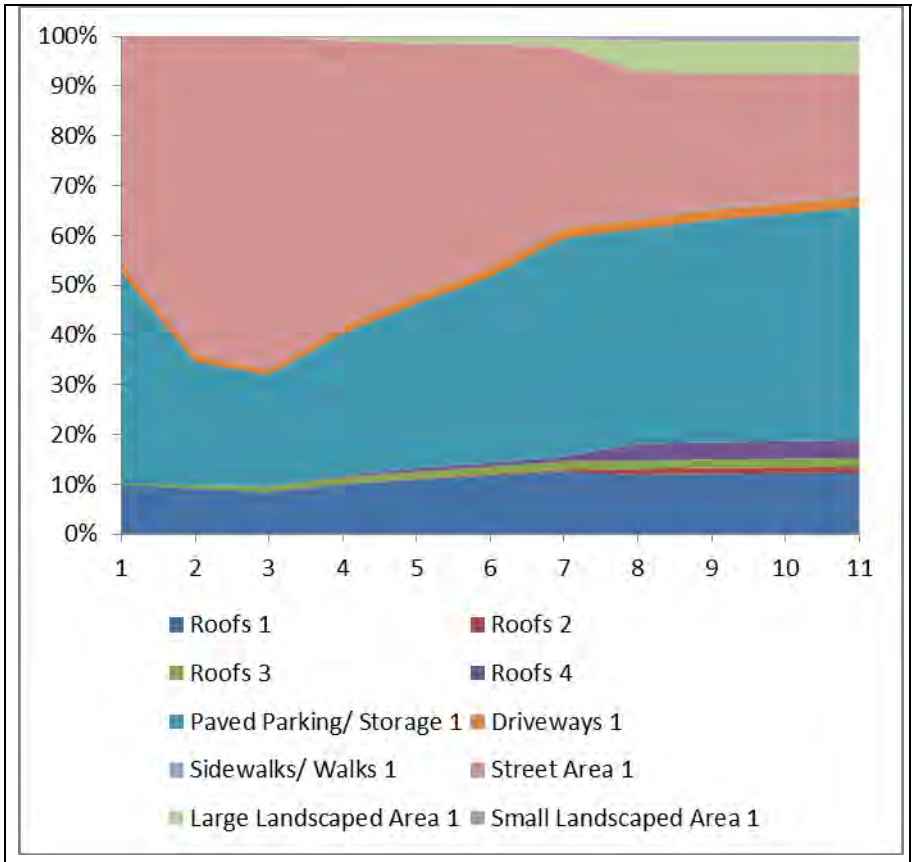
Commercial – Shopping Center Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



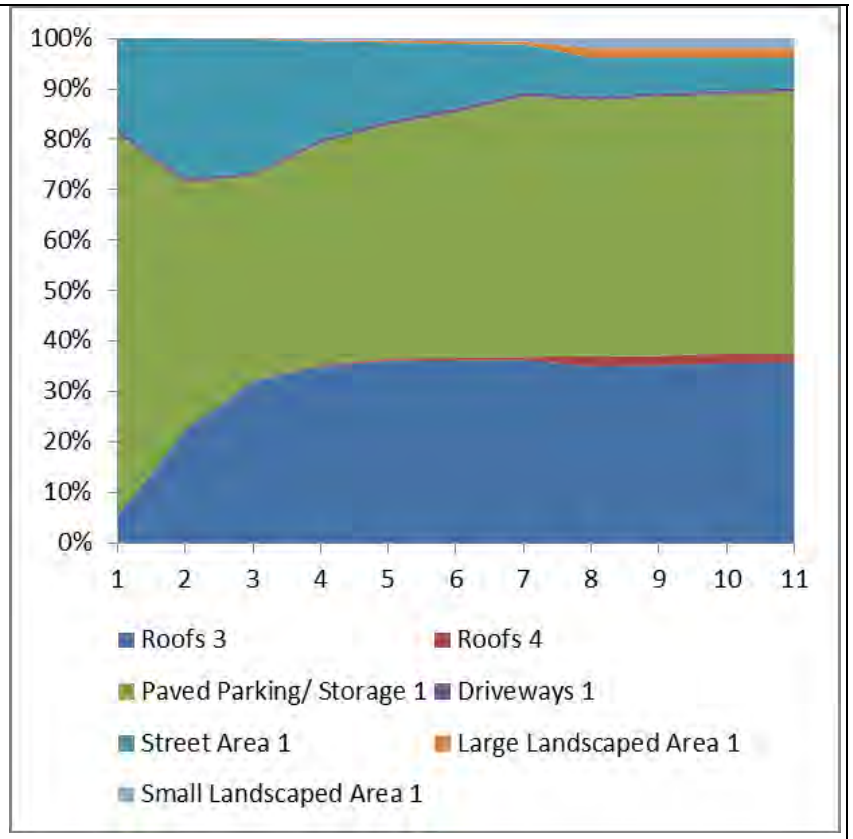
Light Industrial Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



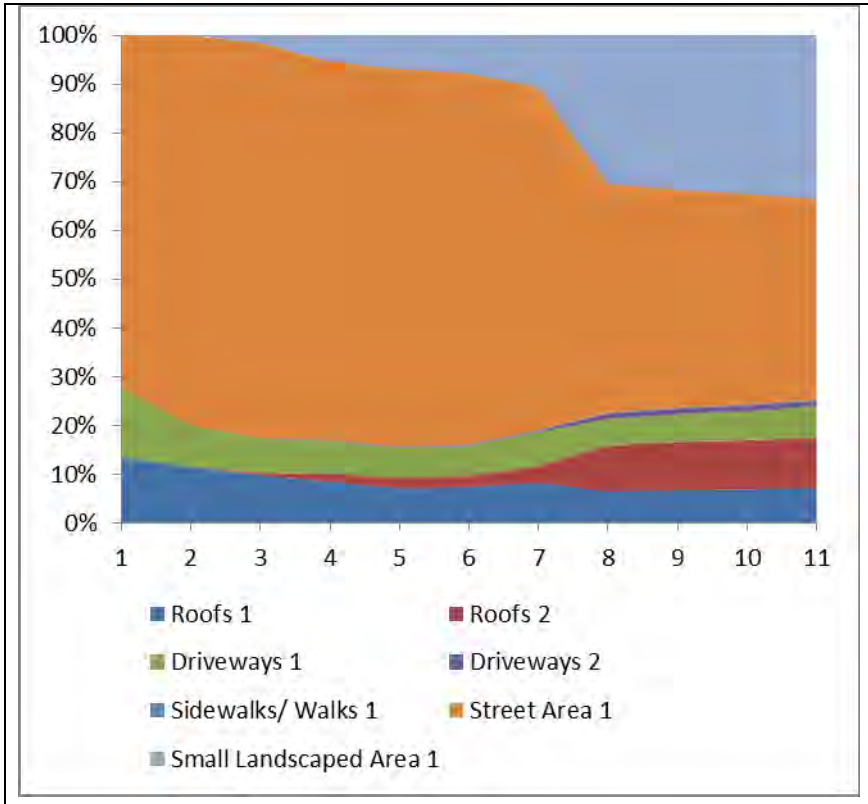
Institutional - School Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



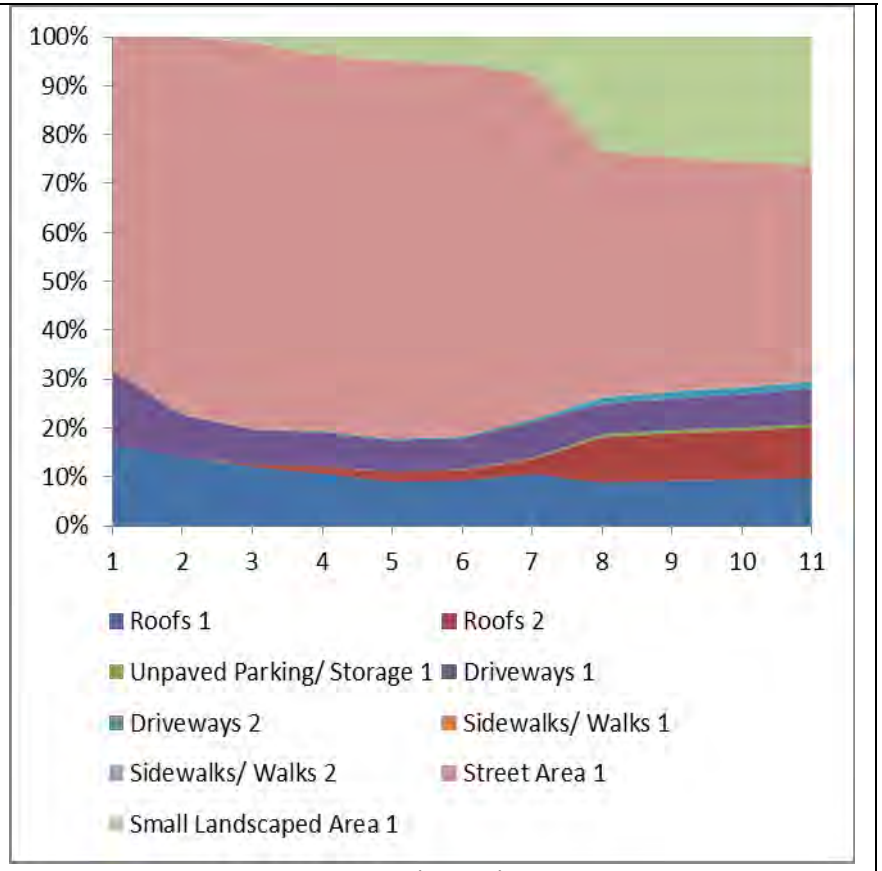
Institutional – Church Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



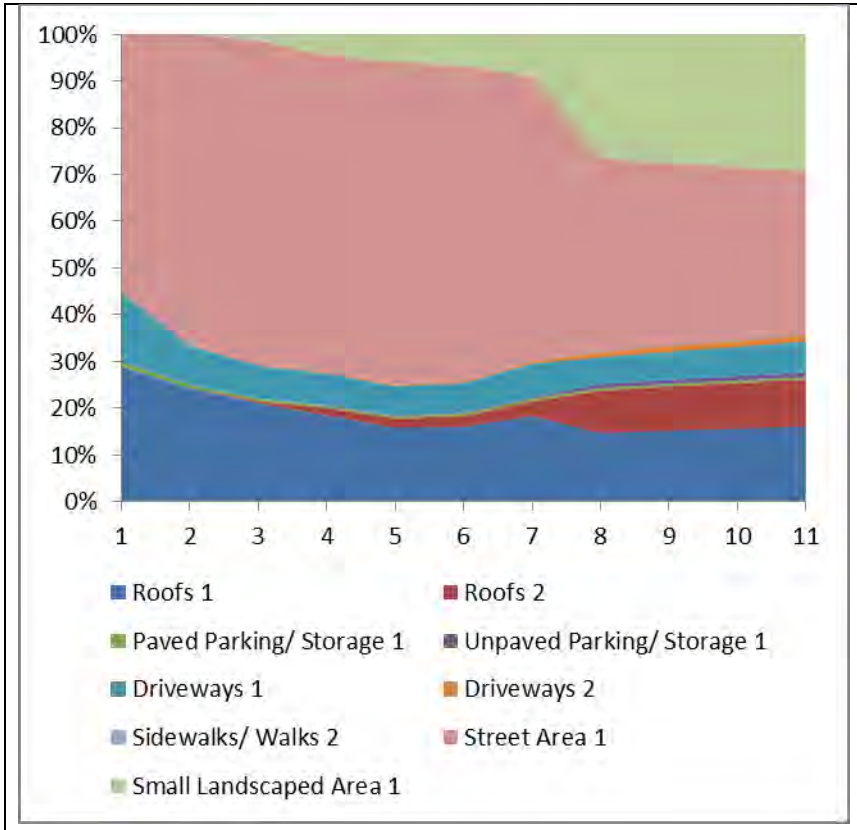
Institutional - Hospital Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

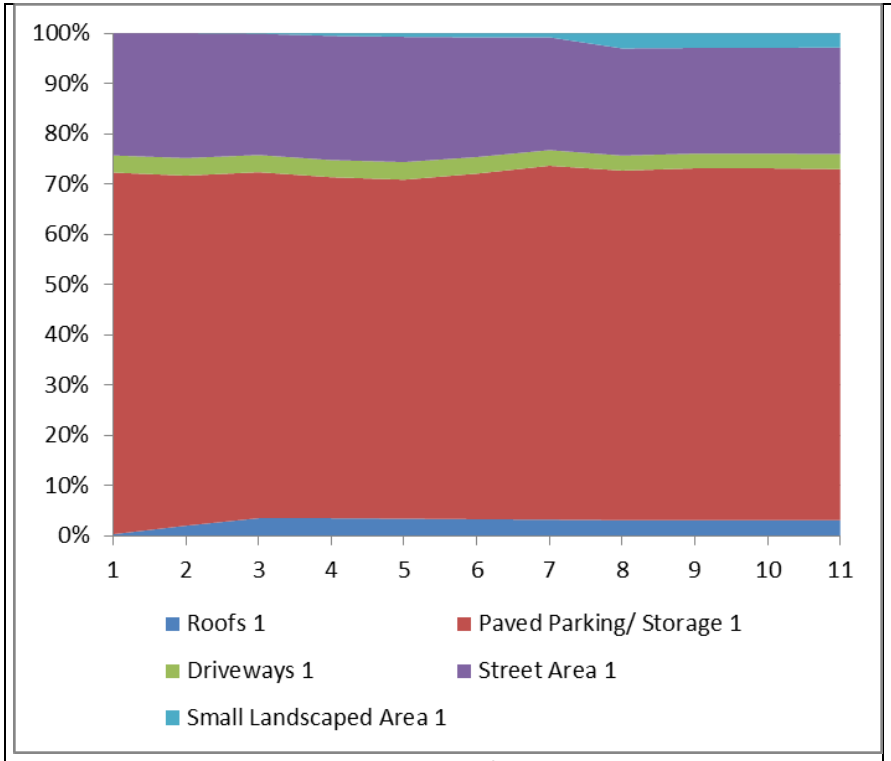


Medium Density Residential Area (<1960) Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Medium Density Residential Area (1960 - 1980) Zn Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

Fecal Coliform Bacteria Contributions



Commercial – Strip Mall Area Fecal Coliform Contributions
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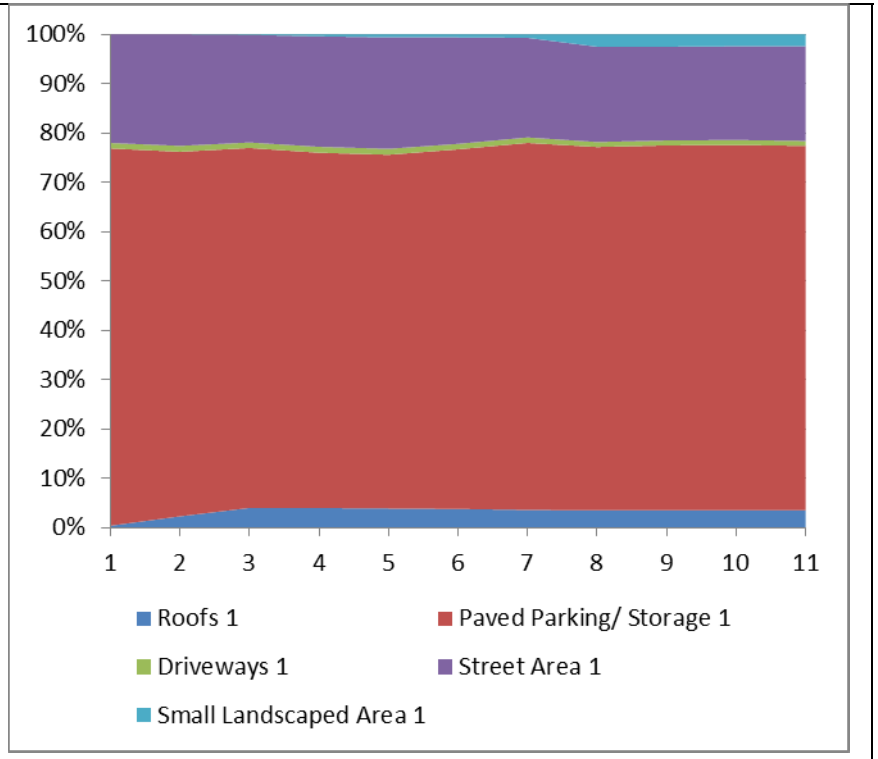

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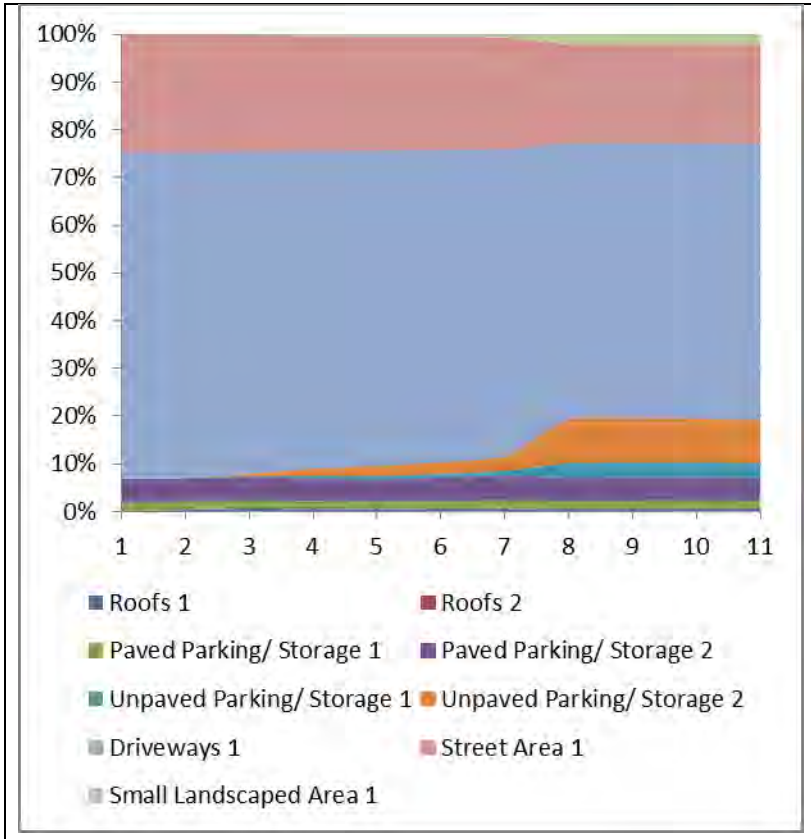

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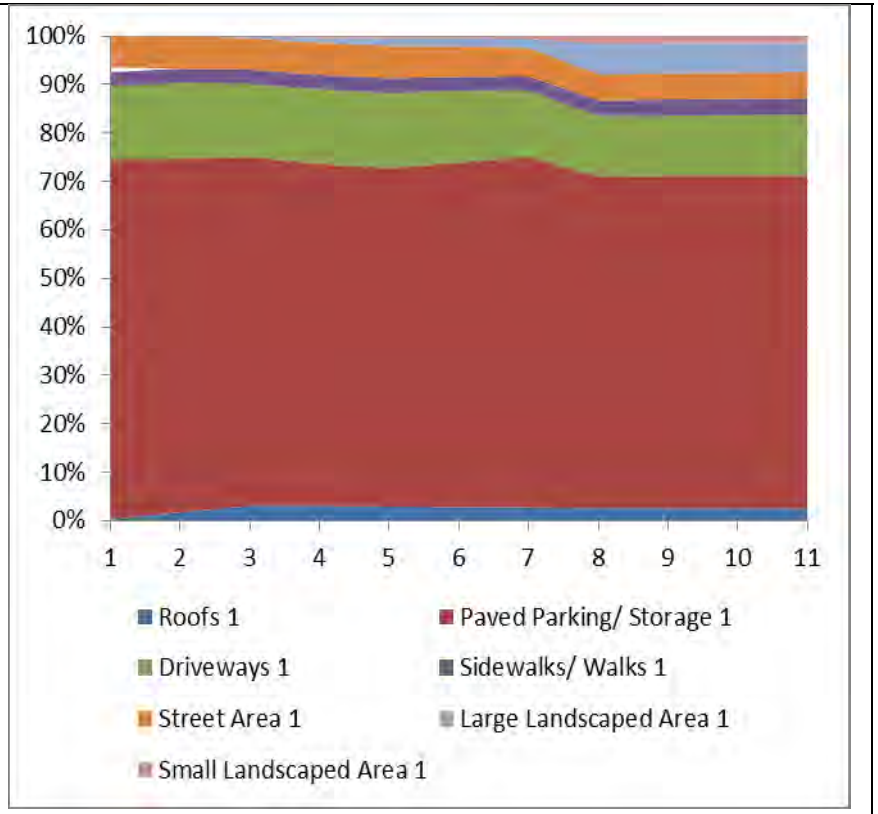

Institutional - School Area Fecal Coliform Contributions
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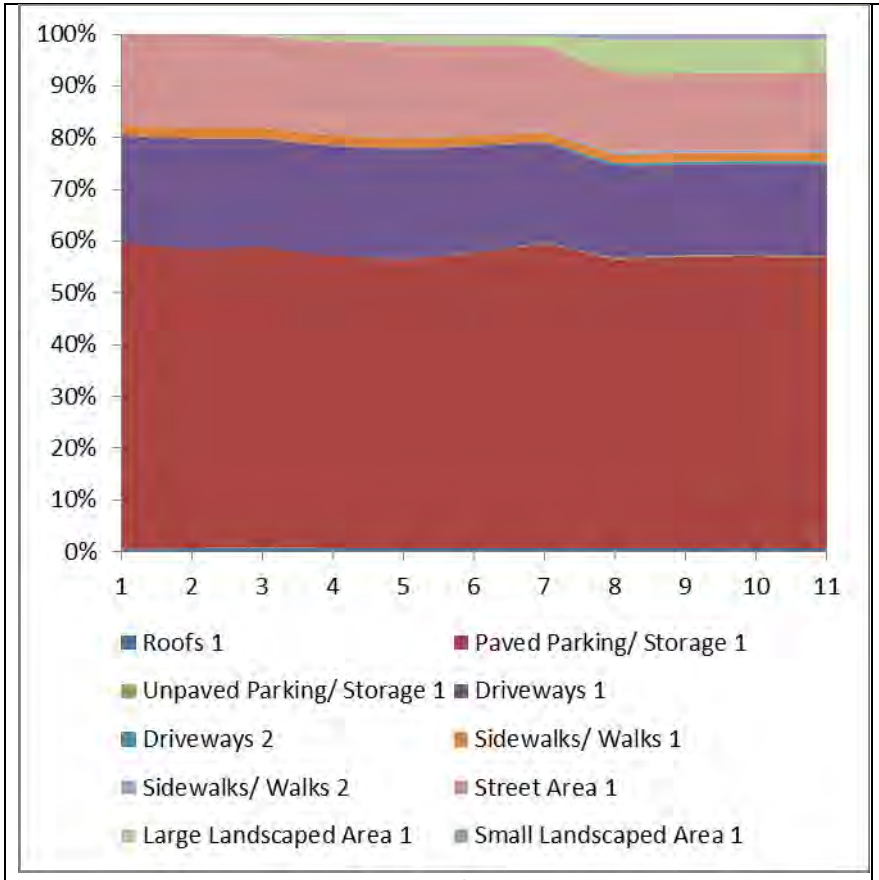

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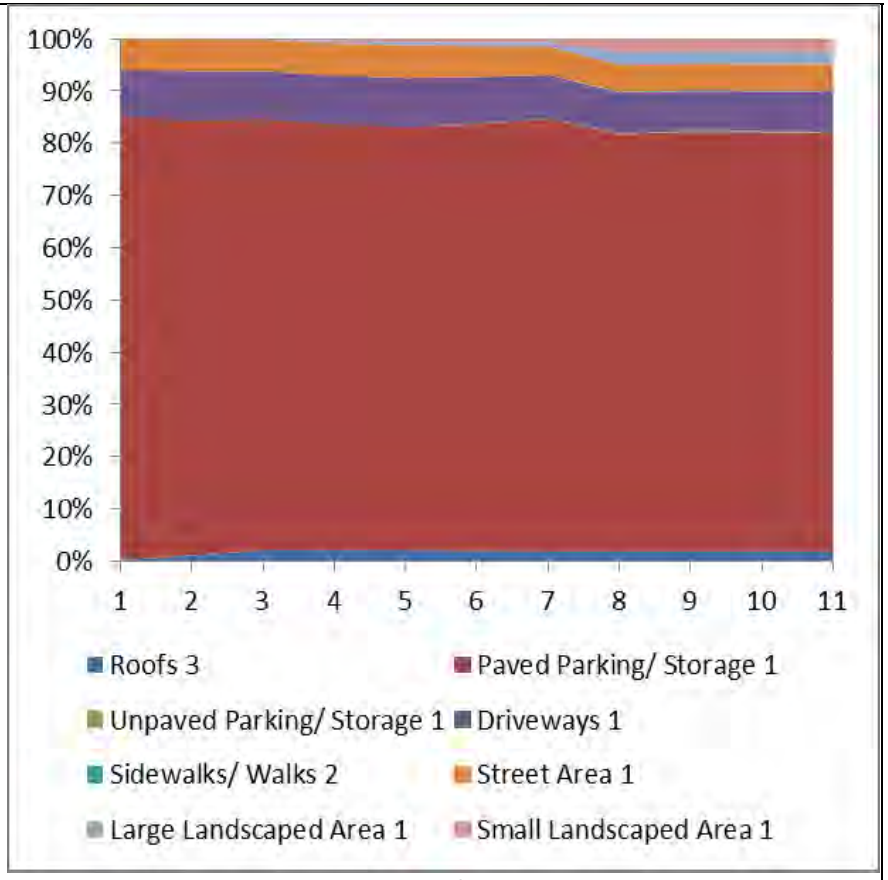

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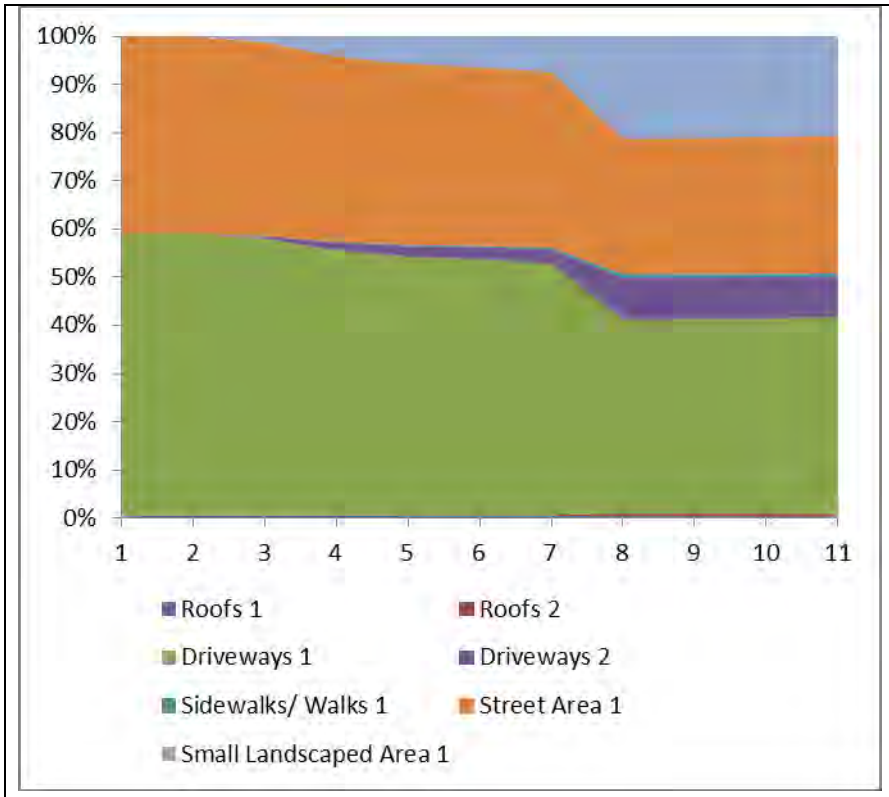

Low Density Residential Area Fecal Coliform Contributions
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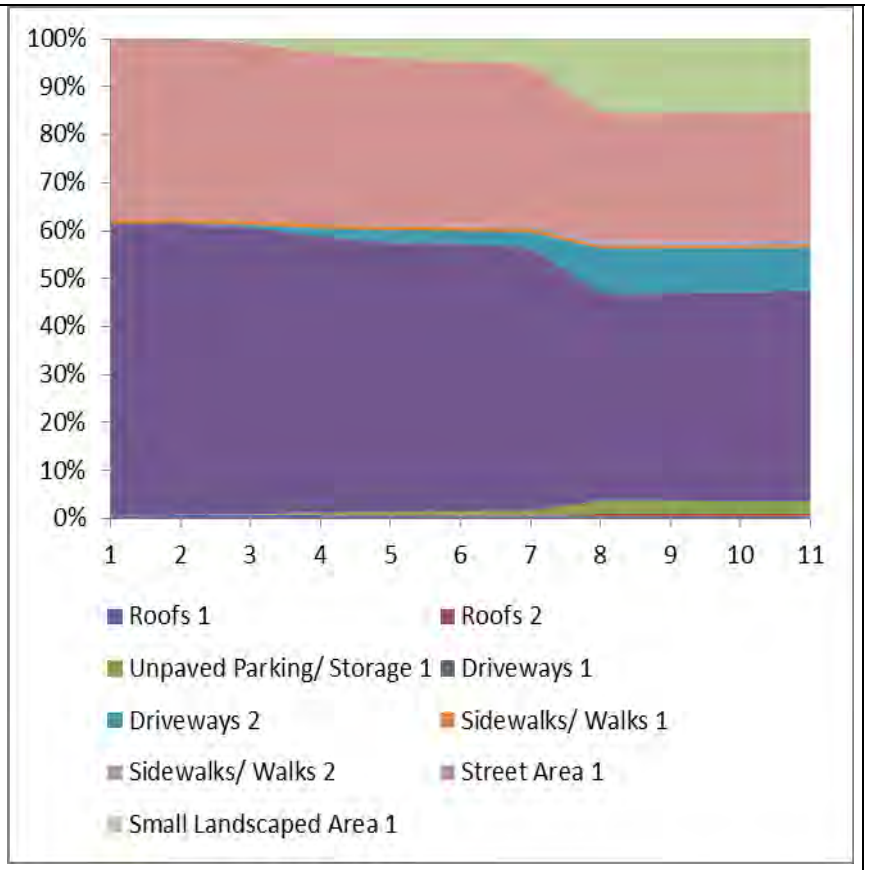

Medium Density Residential Area (<1960) Fecal Coliform Contributions
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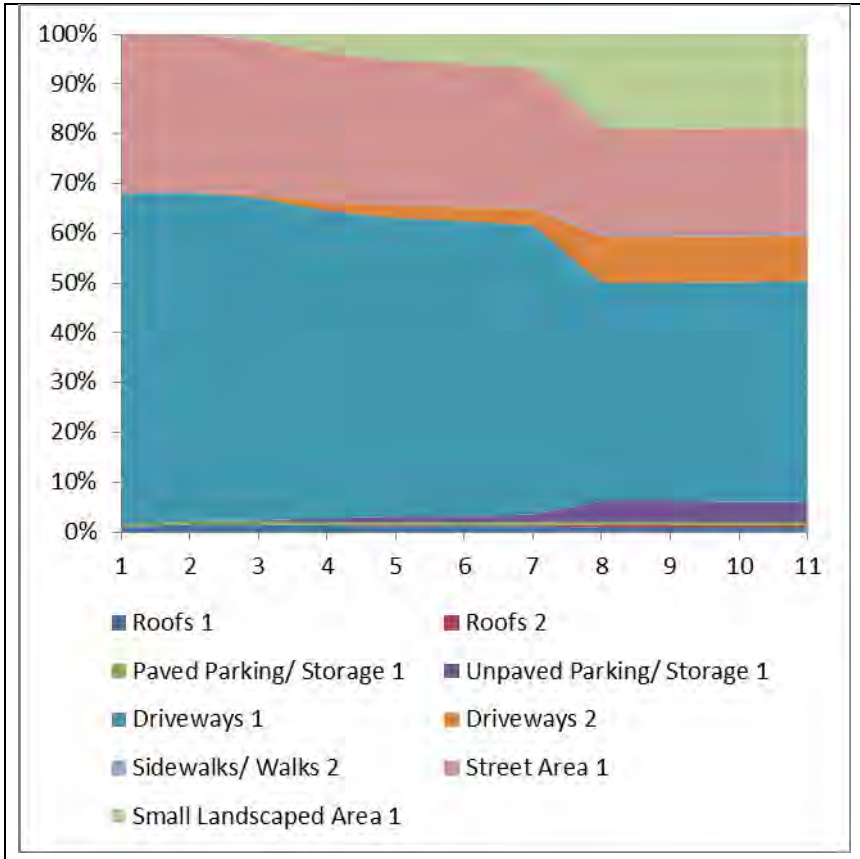
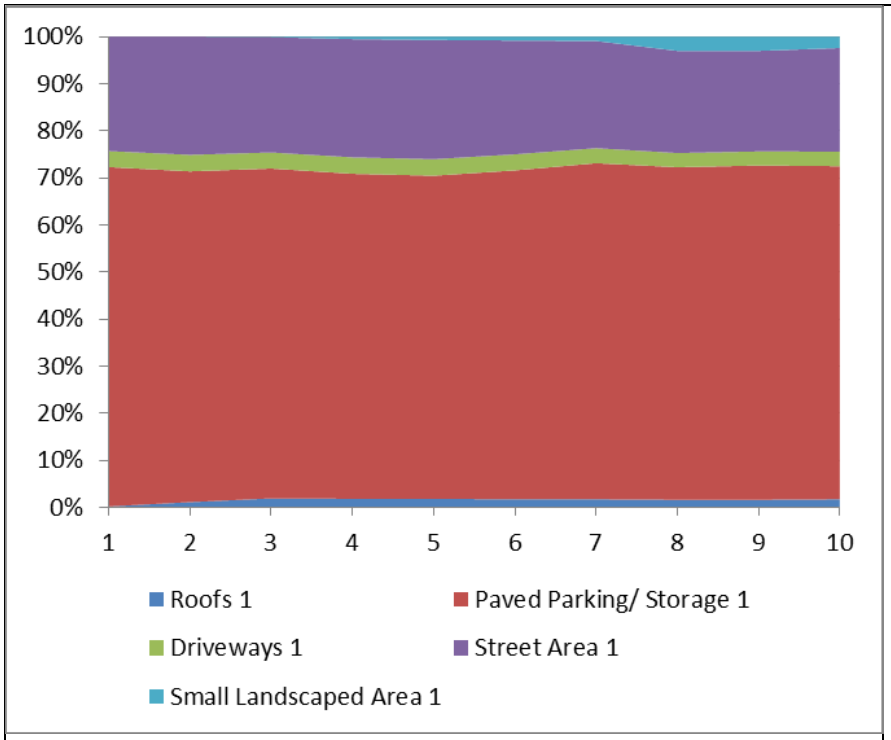


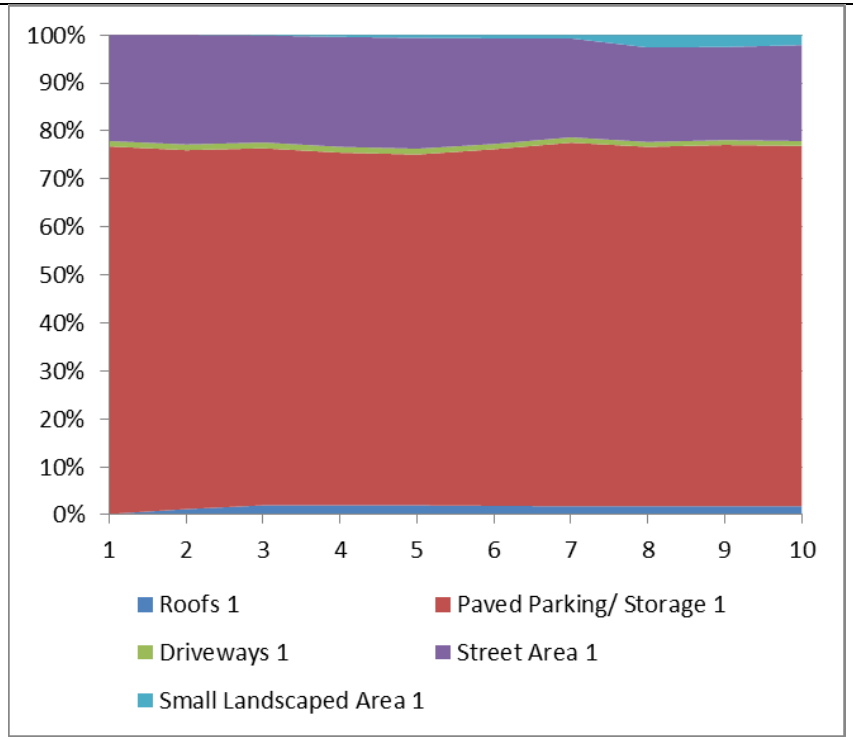
Medium Density Residential Area (1960 - 1980) Fecal Coliform Contributions

Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

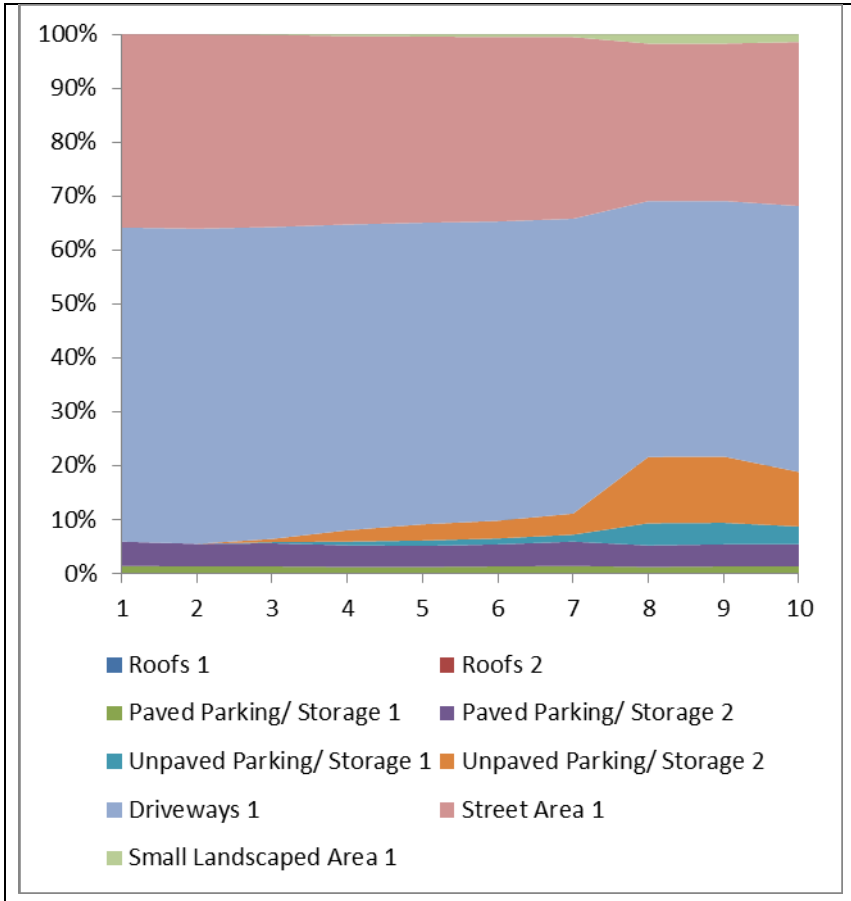
E. Coli Bacteria Contributions



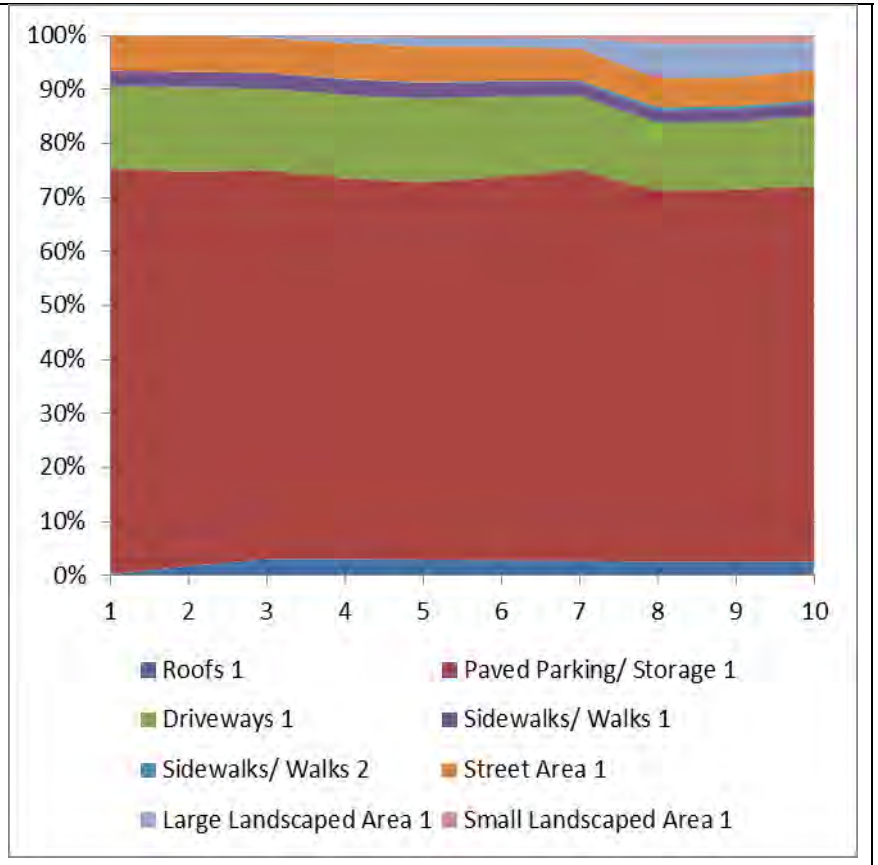
Commercial – Strip Mall Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



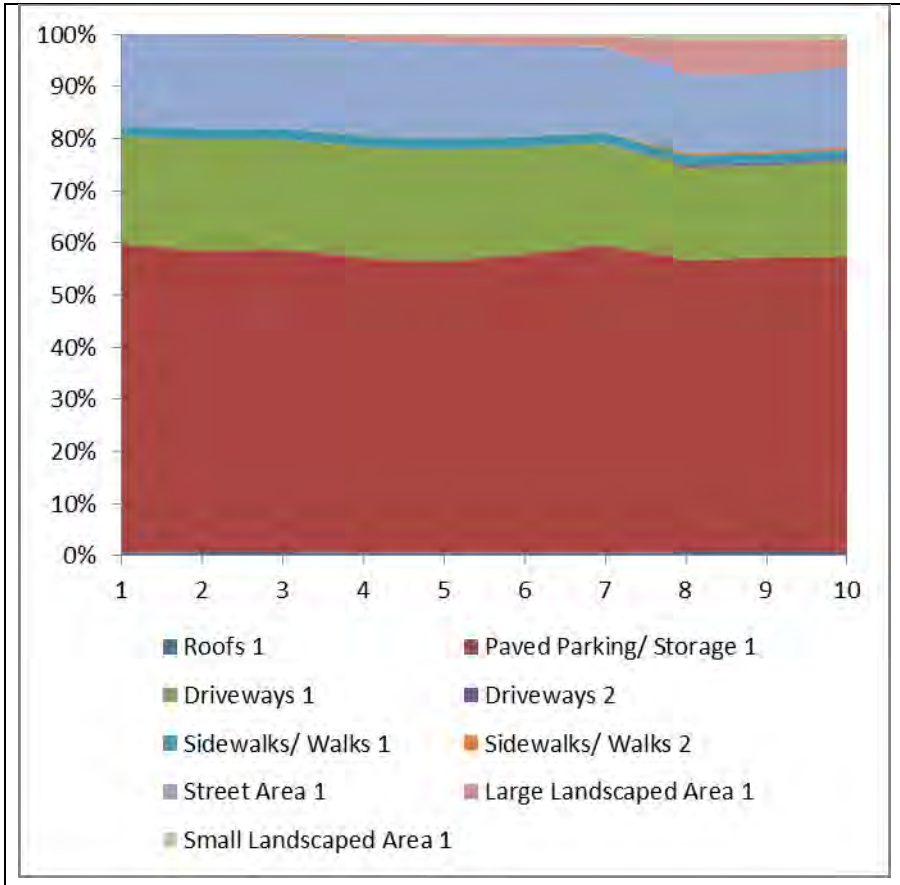
Commercial – Shopping Center Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Light Industrial Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Institutional - School Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Institutional – Church Area E. Coli Contributions
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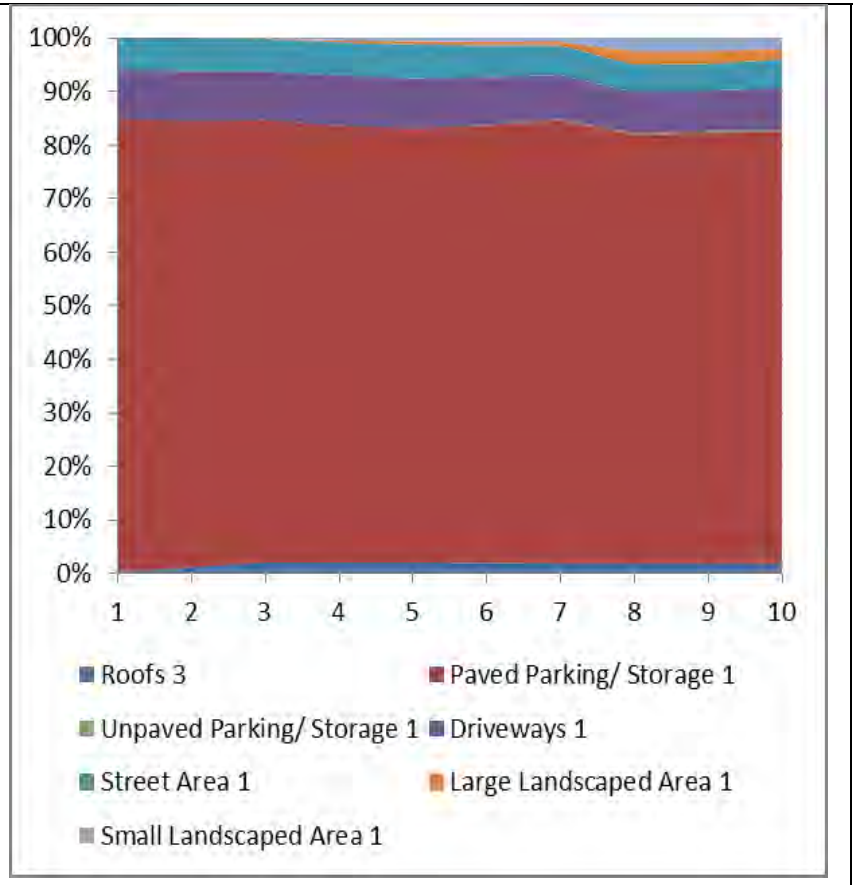
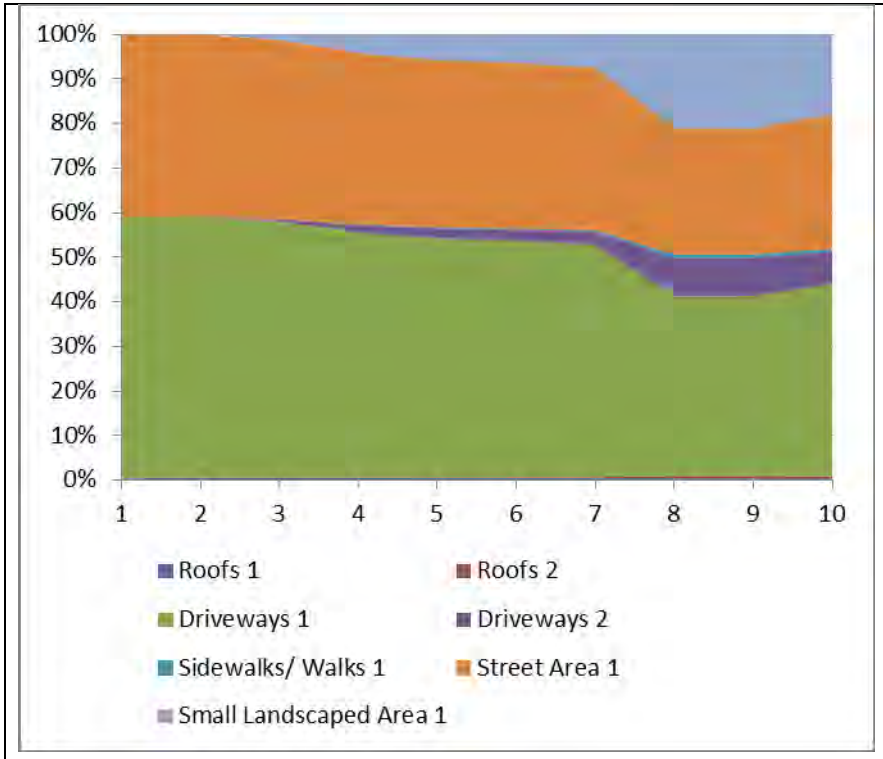
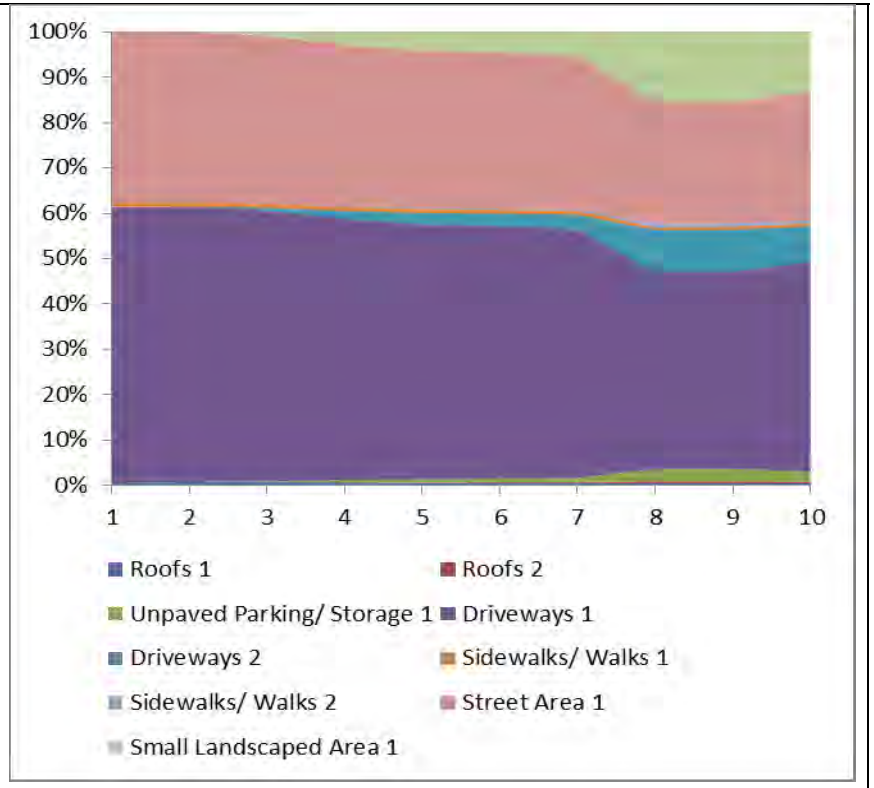


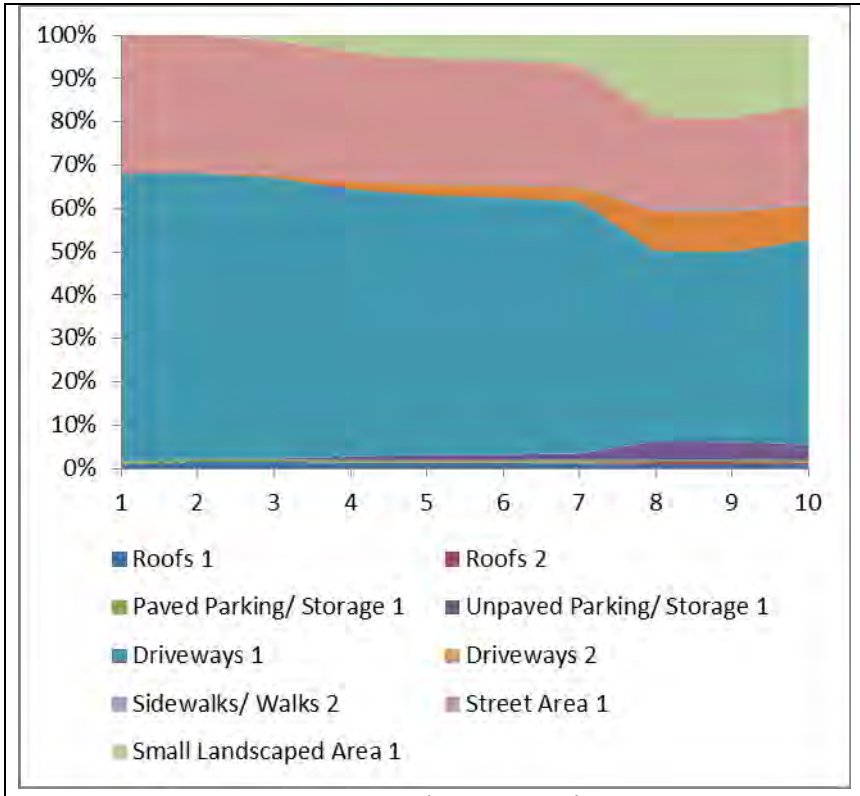
Institutional - Hospital Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Low Density Residential Area E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Medium Density Residential Area (<1960) E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”



Medium Density Residential Area (1960 - 1980) E. Coli Contributions
Rains: 1: 0.05”; 2: 0.1”; 3: 0.25”; 4: 0.5”; 5: 0.75”; 6: 1”; 7: 1.5”; 8: 2”; 9: 2.5”; 10:3”; 11: 4”

Appendix F - WinSLAMM Retrofit Stormwater Management Options Report

R. Pitt
July 29, 2011

Lincoln, Nebraska, Retrofit Stormwater Management Options
- Performance and Relative Costs -

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Introduction

This report describes the expected performance of many alternative stormwater control programs that were evaluated in nine land use categories based on Antelope Creek study area site surveys. The earlier report (R. Pitt. *Lincoln, Nebraska, Standard Land Use Characteristics and Pollutant Sources*, Prepared for Wright Water Engineers, Inc., Denver, CO. April 22, 2011) described these land use areas, the expected stormwater characteristics, and pollutant sources. The discussion of pollutant sources helped to frame the stormwater control program alternatives to examine. This report contains the following main sections that supplement the earlier calibration, characterization, and sources report:

- Introduction
- Descriptions of stormwater control practices (including discussions of factors affecting the use of different controls, combinations of practices, plus variability and uncertainty of predicted outcomes)
- Analysis results (including selecting the most suitable stormwater control program)
- An appendix containing detailed modeling results for all constituents and land uses

Land Uses

This current report is a continuation of the prior report and focusses on stormwater control programs that can be used in the Antelope Creek watershed. The land uses identified in the Antelope Creek study area were examined with more than 25 alternative stormwater control programs in each. Calculated performance attributes are presented and evaluated for each of the following nine land use categories:

Commercial areas:
- Strip malls
- Shopping center

Light Industrial areas

Institutional areas:
- Schools
- Churches
- Hospitals

Residential areas:
- Low density
- Medium density, constructed before 1960
- Medium density, constructed between 1960 and 1980

Stormwater Controls Examined

The stormwater controls examined in the Antelope Creek study area varied somewhat for the different land uses (based on available space and other compatibility issues mostly, plus from the earlier source analyses). The controls examined included the following:

- Roof runoff controls: rain gardens, disconnections, rain barrels and larger water tanks
- Pavement controls: disconnections, biofiltration, and porous pavement
- Street side drainage controls: grass swales and curb-cut biofilters
- Public works practices: street cleaning and catchbasin cleaning
- Outfall controls: wet detention ponds

Some of these controls (especially the roof and pavement controls) are at source areas and their maximum benefits are restricted by the fraction of the constituent of concern originating from those areas. As an example,

consider stormwater beneficial uses using roof runoff for irrigation of landscaped areas. In some of the land uses, roof runoff contributes less than 20% of the total runoff, so the controls are restricted to that somewhat low maximum benefit for the whole area. The drainage system and outfall controls (swales, curb-cut biofilters, and wet detention ponds) can basically treat all of the runoff from the land use and are not restricted by source contributions. If land is available, they can therefore have larger theoretical benefits. The range of difficulties and land requirements varies, mostly depending on available opportunities. In some communities, extensive retro-fitting is occurring including installation of curb-cut biofilters. These can also be installed during scheduled repaving and sidewalk repairs that usually occur in many areas every few decades. Rain gardens are usually installed by the home owners with no cost to the city. The public works practices usually get the most attention, especially street cleaning, as they can be used with no change to the land. Redevelopment and new construction times are the most suitable for installation of many of these controls in order to have the least interferences with current residents and for the least costs and optimal locations.

The designs of the individual control practices are described in this report, along with the WinSLAMM unit process calculation procedures. Calculated runoff, TSS, and *E. coli* conditions for each scenario, and also the estimated costs (capital costs, land costs, maintenance costs, total annual costs, and total present value cost) and the unit removal costs for runoff (dollars per cubic feet removed, compared to the base conditions) and for TSS (dollars per pound removed, compared to the base conditions) are summarized. Scatterplots relating the calculated percent removals of these three stormwater constituents vs. the total annual costs (dollars per 100 acres per year) are also shown. The most suitable stormwater control programs meeting the removal objectives at the least cost can be identified from these figures (also considering other factors affecting the selection process as described earlier, such as groundwater contamination potential, maintenance requirements, suitability for retrofitting, etc.). Detailed information for all constituents examined (runoff volume, Rv, TSS, TDS, total and filterable phosphorus, nitrates, total and filterable TKN, total and filterable COD, total and filterable copper, total and filterable lead, total and filterable zinc, fecal coliform bacteria, and *E. coli* bacteria) is presented for each land use and soil combinations for each set of stormwater controls in the appendix.

Selection of Most Appropriate Stormwater Control Program

For runoff volume controls, each land use group had similar most cost-effective controls, as shown on the following list for the controls having at least 25% levels of runoff volume reduction potential in areas having clay load soils in the infiltration areas. Other control options have similar potential levels of control, but the others are likely more costly. These are listed in order with the first control having the lowest level of maximum control, but the highest unit cost-effectiveness; and the last control listed having the highest level of maximum control, but the lowest unit cost-effectiveness. Therefore, if low to moderate levels of control are suitable, the first control option may be best, but if maximum control levels are needed, then the last control option listed would be needed:

- Strip mall and shopping center areas:
  - Porous pavement (in half of the parking areas)
  - Curb-cut biofilters (along 80% of the curbs) for strip malls or biofilters in parking areas (10 percent of the source area) for shopping centers
  - Biofilters in parking areas (10 percent of the source area) and curb-cut biofilters (along 40% of the curbs)

- Light industrial areas:
  - Curb-cut biofilters (along 40% of the curbs)
  - Roofs and parking areas half disconnected
  - Roofs and parking areas all disconnected

• School, church, and hospital institutional areas:
- Small rain tank (0.10 ft^3 storage per ft^2 of roof area) for schools and churches; rain tank (0.25 ft^3 storage per ft^2 of roof area) for hospitals
- Roofs and parking areas half disconnected
- Roofs and parking areas all disconnected

• Low and medium density residential areas:
- Curb-cut biofilters (along 20% of the curbs)
- Curb-cut biofilters (along 40% of the curbs)
- Curb-cut biofilters (along 80% of the curbs)

For suspended solids, all areas show that wet detention ponds are the most cost-effective control option, irrespective of the conditions. Obviously, other factors may influence the selection of the "best" stormwater control program for an area, beyond least cost for the level of control needed. As an example, wet detention ponds, while being the most cost-effective, are likely very difficult to retrofit into existing areas. However, these analyses indicate that these controls should not be rejected without careful evaluations and searching for potential locations.

There are many attributes and characteristics associated with a stormwater management plan that need to be considered during the selection process. An example decision analysis process is shown for the Lincoln, NE, medium residential area (1960-1980) that represents the largest fraction of the Antelope Creek study area. Some of the characteristics of concern include: *E. coli* discharge reductions, nutrient discharge reductions, costs (initial and maintenance costs, plus total annual costs), land requirements, runoff volume discharge reductions, and TSS discharge reductions. As described in this report, WinSLAMM can calculate these attributes for a broad selection of alternative stormwater programs.

In the simplest case, the selection of the most suitable control can be based on examining the calculated outcomes and filtering them according to set objectives, and then choosing the least costly alternative. As an example, if the runoff reduction objectives were expressed in expected biological conditions of "good" and the required particulate solids (TSS) mass discharge reductions needed were at least 75%, seven of the 29 control programs for this land use would be satisfactory. The least costly alternative involves the use of curb-cut biofilters along at least 20 percent of the total curb length. If this control program meets other objectives (mainly approval of the residents living in the area, and design specifics to overcome possible problems associated with snowmelt and clogging can be developed), this would be a good choice, and is being more frequently used in many US communities.

Formal decision analysis methods can be used when conflicting and complex attributes and objectives make the simpler filtering method described above impractical. Good decision analysis methods are a powerful tool that can be used to compare the rankings of alternative stormwater management programs for different groups of stakeholders. In many cases, final rankings may be similar amongst the interested parties, although their specific reasons vary. This tool also completely documents the decision making process, enabling full disclosure. In this example, the top ranked alternatives are generally similar for each hypothetical stakeholder group, even with very different trade-off values. The municipal governments and local resident's trade-offs are quite similar, but are quite different from the regulatory agency's trade-off values. The overall top ranked alternative is the curb-cut biofilters at 40% of the curb line. This alternative ranked first for the municipal government and local resident stakeholder groups and second for the regulatory agency. The top ranked alternative for the regulatory agency (the curb-cut biofilters at 80% of the curb line) ranked much lower for the other two stakeholder groups

due to its much higher costs. The small wet pond plus the curb-cut biofilters at 40% of the curb line ranked second for the municipal government stakeholders and third for the regulatory agency and the local government stakeholder groups.

Other Considerations Affecting Selection and Use of Stormwater Controls

Certain site conditions may restrict the applicability of some of the controls and need to be considered during the selection process. Some of these examined in the report are summarized below:

• The sodium adsorption ratio (SAR) can radically degrade the performance of an infiltration device, especially when clays are present in the infiltration layers of a device, and snowmelt containing deicing salts enters the device. Soils with an excess of sodium ions, compared to calcium and magnesium ions, remain in a dispersed condition, and are almost impermeable to rain or applied water. A "dispersed" soil is extremely sticky when wet, tends to crust, and becomes very hard and cloddy when dry. Water infiltration is therefore severely restricted. SAR has been documented to be causing premature failures of biofiltration devices in northern communities. These failures occur when snowmelt water is allowed to enter a biofilter that has clay in the soil mixture. In order to minimize this failure, do not allow snowmelt water to enter a biofilter unit. As an example, roof runoff likely has little salt and SAR problems seldom occur for roof runoff rain gardens. The largest problem is associated with curb-cut biofilters or parking lot biofilters in areas with snowmelt entering these devices, especially if clay is present in the engineered backfill soil. The biofilter fill soil should not have any clay. It appears that even a few percent clay can cause a problem, but little information is currently available on the tolerable clay content of biofilter soils. The most robust engineered soil mixtures used in biofilters should be mixtures of sand and an organic material (such as compost if nutrient leaching is not an issue, or Canadian peat for a more stable material having little nutrient leaching potential).

• The designs of infiltration devices need to be checked based on their clogging potential. As an example, a relatively small and efficient biofilter (in an area having a high native infiltrating rate) may capture a large amount of sediment. Having a small surface area, this sediment would accumulate rapidly over the area, possibly reaching a critical clogging load early in its design lifetime. Infiltration and bioretention devices may show significantly reduced infiltration rates after about 2 to 5 lb/ft^2 (10 to 25 kg/m^2) of particulate solids have been loaded.

• The potential for infiltrating stormwaters to contaminate groundwaters is dependent on the concentrations of the contaminants in the infiltrating stormwater and how effective those contaminants may travel thru the soils and vadose zone to the groundwater. Source stormwaters from residential areas are not likely to be contaminated with compounds having significant groundwater contaminating potential (with the exception of high salinity snowmelt waters). In contrast, commercial and industrial areas are likely to have greater concentrations of contaminants of concern that may affect the groundwater adversely. Therefore, pretreatment of the stormwater before infiltration may be necessary, or the use of specially selected media in the biofilter can be used.

• Most of the control options examined in this report are intended for retrofitting in existing urban areas. Therefore, their increased costs and availability of land will be detrimental in developing highly effective control programs. The range of difficulties and land requirements varies, mostly depending on available opportunities. In some communities (especially those with combined sewer overflows), extensive retro-fitting is occurring, including installation of curb-cut biofilters.

Modeling Approach

WinSLAMM version 9.5 was previously used to analyze the water quality (stormwater pollution loading) and runoff volume for the land uses found in the Antelope Creek study area (R. Pitt. *Lincoln, Nebraska, Standard Land Use Characteristics and Pollutant Sources*, Prepared for Wright Water Engineers, Inc., Denver, CO. April 22, 2011). This current report is a continuation of that prior report and focusses on stormwater control programs that can be used in the Antelope Creek watershed. The nine land uses identified in the Antelope Creek study area were examined with more than 25 alternative stormwater control programs in each. Calculated performance attributes are then presented and evaluated for each of the nine land use categories. Relative cost data (focusing on expected total annual costs), along with discharge volume and load reductions are also summarized. The following is a brief discussion of the WinSLAMM model and how it was used in these calculations.

WinSLAMM Background Information

WinSLAMM was developed to evaluate stormwater runoff volume and pollutant loadings in urban areas using small storm hydrology. The model determines the runoff based on local rain records and calculates runoff volumes and pollutant loadings from each individual source area within each land use category for each rain. Examples of source areas include: roofs, streets, small landscaped areas, large landscaped areas, sidewalks, and parking lots.

The model can use any length of rainfall record as determined by the user, from single rainfall events to several decades of rains. The rainfall file used in these calculations for Lincoln, NE, was developed from hourly data obtained from EarthInfo CDROMs, using the four years from 1996 through 1999. The model applied a series of stormwater control practices, including rain barrels and water tanks for stormwater irrigation, pavement and roof disconnections, roof rain gardens, infiltration/biofiltration in parking lots and as curb-cut biofilters, street cleaning, wet detention ponds, grass swales, porous pavement, catchbasins, and selected combinations of these practices. The model evaluates the practices through engineering calculations of the unit processes based on the actual designs and sizes of the controls specified and determines how effectively these practices remove runoff volume and pollutants.

WinSLAMM does not use a percent imperviousness or a curve number to general runoff volume or pollutant loadings. The model applies runoff coefficients to each “source area” within a land use category. Each source area has a different runoff coefficient equation based on factors such as: slope, type and condition of surface, soil properties, etc., and calculates the runoff expected for each rain. The runoff coefficients were developed using monitoring data from typical examples of each site type under a broad range of conditions. The runoff coefficients are continuously updated as new research data becomes available.

Each source area also has a unique pollutant concentration (event mean concentrations - EMCs - and a probability distribution) assigned to it. The EMCs for a specific source area vary depending on the rain depth. The source area’s EMCs are based on extensive monitoring conducted in North America by the USGS, Wisconsin DNR, University of Alabama, and other groups. These monitoring efforts isolated source areas (roofs, lawns, streets, etc.) for different land uses and examined long term data on the runoff quality. The pollutant concentrations are also continuously updated as new research data become available.

For each rainfall in a data set, WinSLAMM calculates the runoff volume and pollutant load (EMC x runoff volume) for each source area. The model then sums the loads from the source areas to generate a land use or drainage basin subtotal load. The model continues this process for the entire rain series described in the rain file. It is important to note that WinSLAMM does not apply a “unit load” to a land use. Each rainfall produces a unique load from a modeled area based on the specific source areas in that modeled area.

The model was used to predict stormwater management practice effectiveness as presented in this project report. The model replicates the physical processes occurring within the practice. For example, for a wet detention pond, the model incorporates the following information for each rain event:

1. Runoff hydrograph, pollution load, and sediment particle size distribution from the drainage basin to the pond,
2. Pond geometry (depth, area),
3. Hydraulics of the outlet structure,
4. Particle settling time and velocity within the pond based on retention time

Stokes Law and Newton's settling equations are used in conjunction with conventional surface overflow rate calculations and modified Puls-storage indication hydraulic routing methods to determine the sediment amounts and characteristics that are trapped in the pond. Again, it is important to note that the model does not apply "default" percent efficiency values to a control practice. Each rainfall is analyzed and the pollutant control effectiveness will vary based on each rainfall and the pond's antecedent condition. This report describes how each stormwater control practice examined in Antelope Creek is evaluated in WinSLAMM.

The model's output is comprehensive and customizable, and typically includes:

1. Runoff volume, pollutant loadings and EMCs for a period of record and/or for each event.
2. The above data pre- and post- for each stormwater management practice.
3. Removal by particle size from stormwater management practices applying particle settling.
4. Other results can be selected related to flow-duration relationships for the study area, impervious cover model expected biological receiving water conditions, and life-cycle costs of the controls.

A full explanation of the model's capabilities, calibration, functions, and applications can be found at www.winslamm.com. For this project, the parameter files were calibrated using the local Lincoln MS4 monitoring data, supplemented by additional information from regional data from the National Stormwater Quality Database (NSQD), available at: http://www.unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

Calibration of WinSLAMM to Simulate Local Observed Stormwater Conditions

All models need to be calibrated to result in the most effective information. WinSLAMM calibrations for Lincoln were based on a multi-step process. Much source area monitoring data are available from different locations (mainly from California, Alabama, Ontario, and Wisconsin). These data are summarized in a series of peer-reviewed chapters in modeling monographs:

- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 1) – Older monitoring projects." In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 465 – 484 and 507 – 530. 2005.
- Pitt, R., R. Bannerman, S. Clark, and D. Williamson. "Sources of pollutants in urban areas (Part 2) – Recent sheetflow monitoring results." In: Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp. 485 – 530. 2005.
- Pitt, R., D. Williamson, and J. Voorhees. "Review of historical street dust and dirt accumulation and washoff data." Effective Modeling of Urban Water Systems, Monograph 13. (edited by W. James, K.N. Irvine, E.A. McBean, and R.E. Pitt). CHI. Guelph, Ontario, pp 203 – 246. 2005.

These data have been used to create calibrated WinSLAMM models in several locations that have since been verified using outfall data. The most extensive data are from the Birmingham, AL area and from the state of Wisconsin. Land use (and stormwater) data from throughout the nation are also available from many research reports. These data were separated into several regional groups. The Lincoln area is included in the Central US area and was originally based on the Wisconsin calibration and verification model sets. The Central model files were then modified based on outfall data from the Central US region as contained in the NSQD. Finally, these Central US files were further modified using the events monitored in Lincoln as part of their MS4 monitoring program, as described in the earlier Antelope Creek stormwater source report.

The Lincoln rain file was used to calculate long-term stormwater conditions. The four year period from 1996 through 1999 was used. A longer period was not possible due to missing observations. Winter conditions were also defined as being from December 20 to February 10 of each year. During these winter periods, no stormwater calculations were made.

During the Lincoln calibration process, the calculated long-term averaged modeled concentrations were compared to the monitored concentrations for each site. Factors were applied uniformly to each land use in the Lincoln pollutant and particulate solids parameter files to adjust the long-term modeled concentrations to best match the monitored/observed values. The runoff parameter file was not modified as it has been shown to compare well to observed conditions under a wide range of situations, and no local runoff quantity data were available for the local monitoring locations.

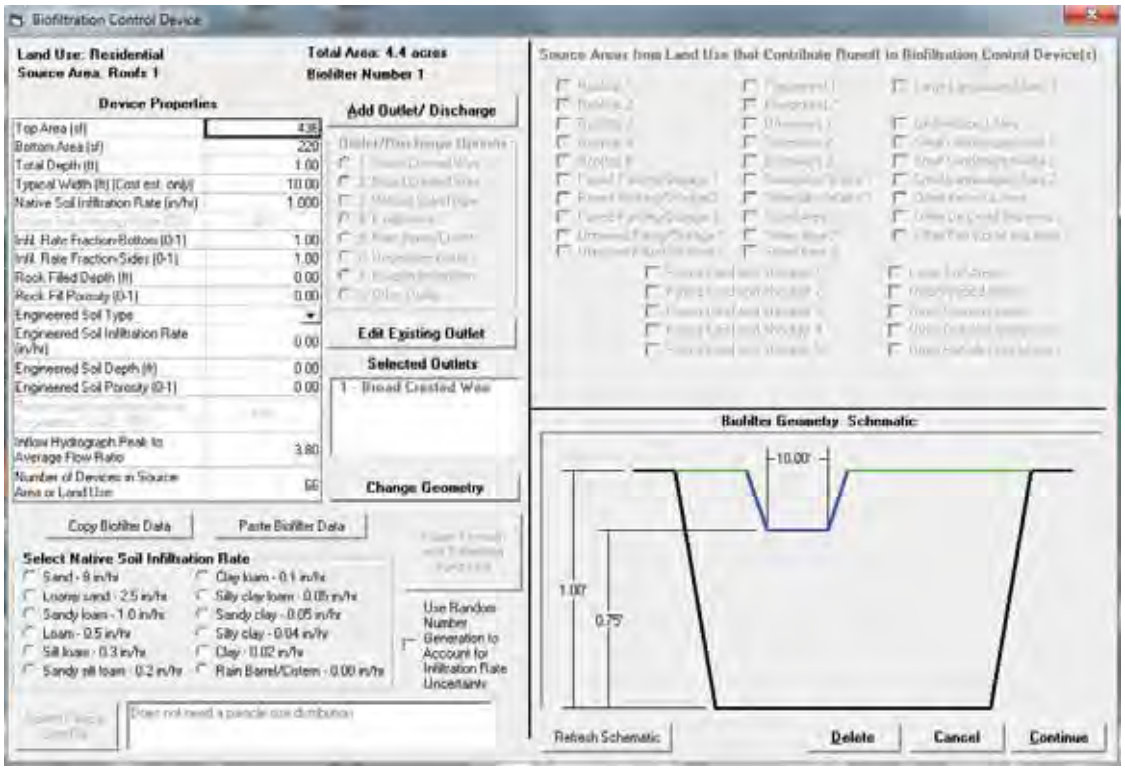
Description of Control Practices

The following subsections describe how WinSLAMM models the performance of the various stormwater control practices considered in this evaluation, plus some individual control production functions. These production functions were used to help determine the range of designs to apply to each land use category to represent the likely best performing sizes and combinations of control practices. As indicated, WinSLAMM calculates the expected performance of the controls based on the unit processes available in the control and the specific designs applied to site specific conditions.

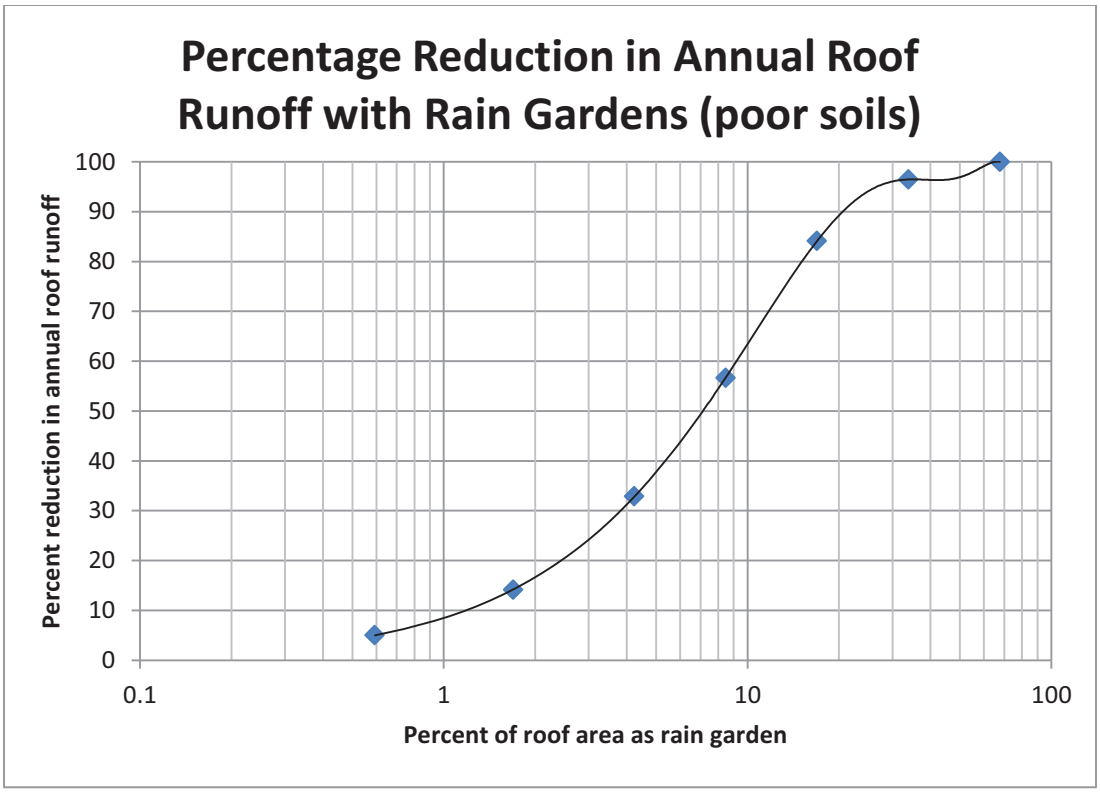
Roof Runoff Controls

Rain Gardens

Rain gardens are simple bioretention devices located adjacent to roofs. The following screen dump from the biofilter information screen in WinSLAMM describes one of the rain gardens used in these analyses. Each rain garden has a top surface area of 436 ft^2, corresponding to 1% of one acre. The number of rain gardens was changed for each scenario corresponding to the size of the rain garden compared to the roof area. In this example, this relatively large rain garden is about 20 by 22 ft in area; however, the performance is directly dependent on the total areas of all the rain gardens being considered in the area. The rain gardens are only excavated to an overall depth of 1 ft, with no fill soil (and no underdrains). In many cases, amendments are tilled into rain garden excavations, usually to improve the tilth and organic content in order to better support the plants and to improve infiltration. The surface 1 ft is left open to provide surface storage 9 inches deep (several inches act as on overflow). Clay loam soils having 0.1 in/hr and sandy loam soils having 1.0 in/hr infiltration rates were examined for each scenario to represent a likely range of urban soil conditions. The only outlet used (besides the natural infiltration) is a surface overflow along one edge of the rain garden that is 3 inches lower than the other edges.



The following figure is a plot of the performance of rain gardens as a percentage of the roof area, based on long-term continuous modeling. This figure was used to select rain gardens having total surface areas of 3 and 15% of the total roof areas in each land use. Even though these are more cost-effective if treating runoff from directly connected roofs, the modeling scenarios examined all roofs in each area (both directly connected roofs draining to the drainage system and roofs already draining to adjacent landscaped areas) in order to maximize the potential control of the roof runoff by rain gardens. The 3% rain gardens are expected to reduce the annual roof runoff volumes by about 25%, while the large rain gardens that are 15% of the roof areas are expected to reduce the annual roof runoff volumes by about 75%.



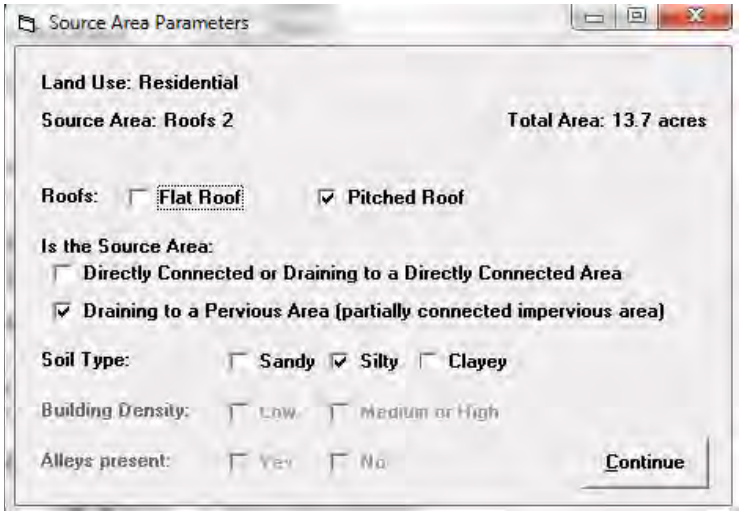
Rain gardens can be very effective in reducing runoff discharges from roofs, but they need to be relatively large, especially in areas having poor soils. Care is also necessary in their construction to prevent compaction and sealing the soils. In many cases, incorporating compost or peat into the top soil layers can enhance their performance. Many references are also available describing plant choices for rain gardens. These are typically constructed and maintained by the individual property owners and are located on private property. Biofilters, described later under pavement controls, are more sophisticated versions of rain gardens.

Disconnections of Roof Downspouts

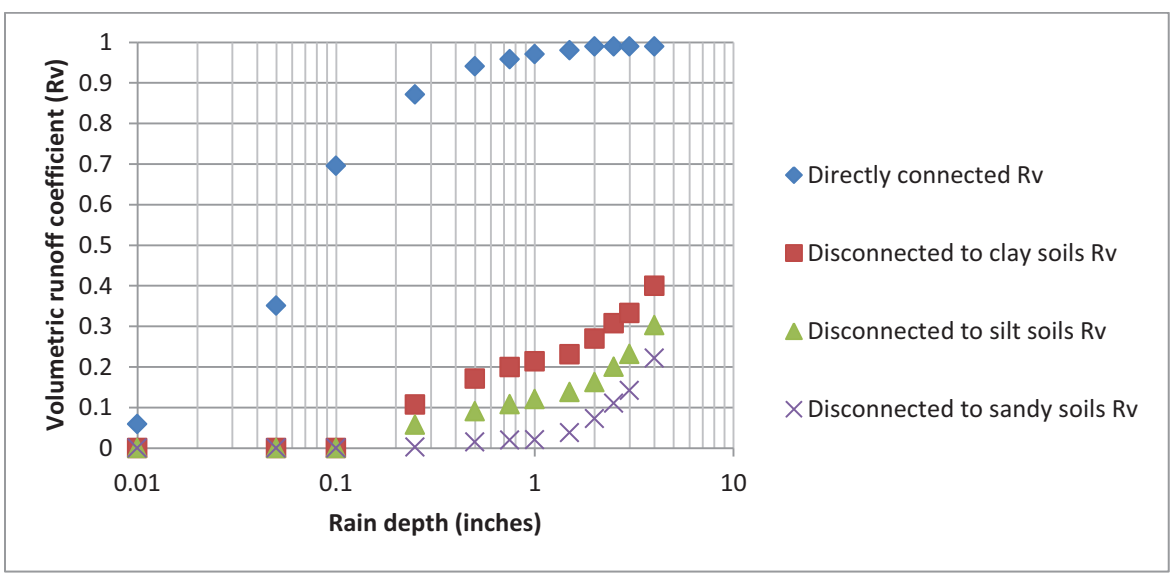
Another option for the control of runoff from directly connected roofs is to disconnect the roof drain downspouts that are currently directed towards pavement that in turn are directly connect to the drainage system. When disconnecting downspouts, the water needs to be redirected over pervious ground, most commonly regular turf grass located adjacent to the downspouts. This is most effective if the water is discharged to relatively flat lawns in good conditions that have flow path lengths of at least 10 feet for small residential roofs. If the soils have poor infiltration characteristics (such as for the clay loam soil conditions), the amount of water that can be infiltrated may be relatively high if the roofs comprise small fractions of the pervious areas. In this case, the available flow paths are also relatively long, increasing the infiltration potential.

WinSLAMM version 9.5 was used to make a preliminary analysis of the benefits of disconnecting the directly connected roofs to allow the runoff to flow across the pervious areas. The new version 10 being completed will be able to more directly calculate these benefits through grass filtering processes. These results can be roughly compared to the benefits associated with rain gardens and rain barrels/tanks, the other roof runoff control options being considered in these analyses. For clay loam soils, disconnecting the roof downspouts in most residential areas (having suitable flow paths) is expected to result in annual reductions of the roof runoff by about 80%. This would increase to about 90% and 95% for areas having silty and sandy soils, respectively.

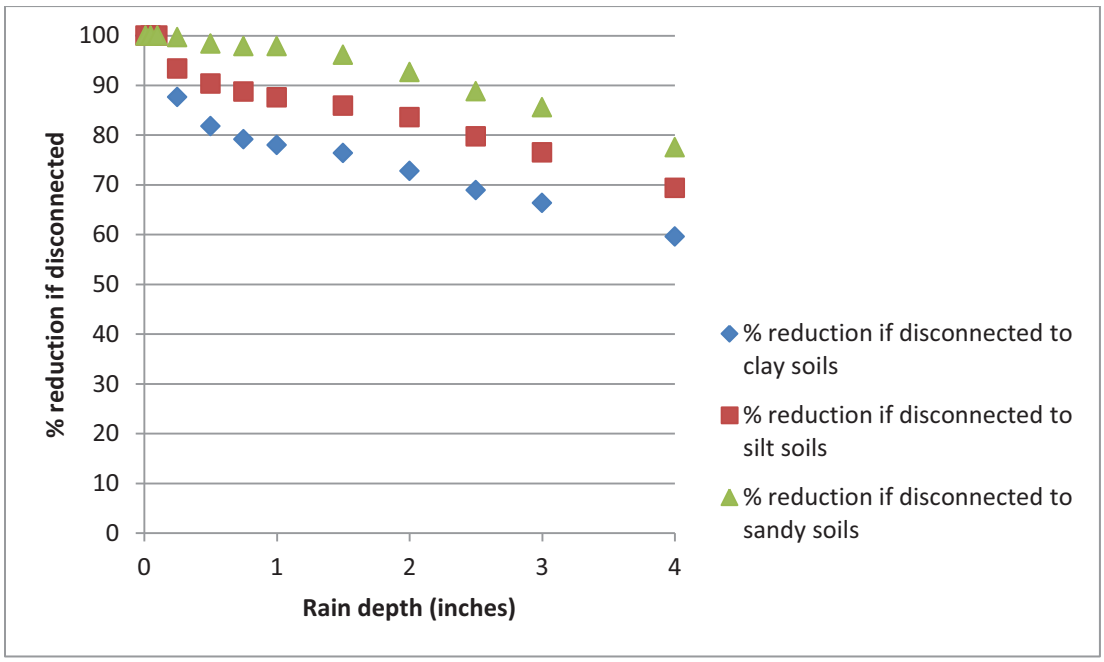
The following is the WinSLAMM entry screen showing how the roof areas are disconnected during a model analysis:



The following plots illustrate the expected benefits of these disconnection practices for different individual rains, up to 4 inches in depth, for residential areas. The volumetric runoff coefficient (Rv), the ratio of runoff volume to rainfall volume falling on an area, is seen to increase with increasing rain depths. For directly connected pitched roofs, the Rv is about 0.7 for 0.1 inch rains, and is quite close to 1.0 for rains larger than about 2 inches in depth. When disconnected to clayey soils, runoff is not expected until the rain depth is greater than about 0.1 inches and the Rv starts to climb steeply with rains larger than several inches in depth. It is expected to be very large for very large and unusual rains that can cause severe flooding, irrespective if they are disconnected or not. However, the benefits for small and intermediate rains are large.



The following graph illustrates the percentage reductions associated with disconnecting the directly connected roofs for the three main soil categories in residential areas. The percentage reduction is about 75% for 1.5 inch rains, being greater for smaller rains. These levels of control can also be achieved using rain gardens in relatively small areas, or by using water tanks and irrigating the landscaped areas with the captured water, if the available landscaped area is relatively large. However, these other controls should only be retrofitted at homes that currently have directly connected roof drains and if disconnecting is not feasible due to poor flow paths or limited space.

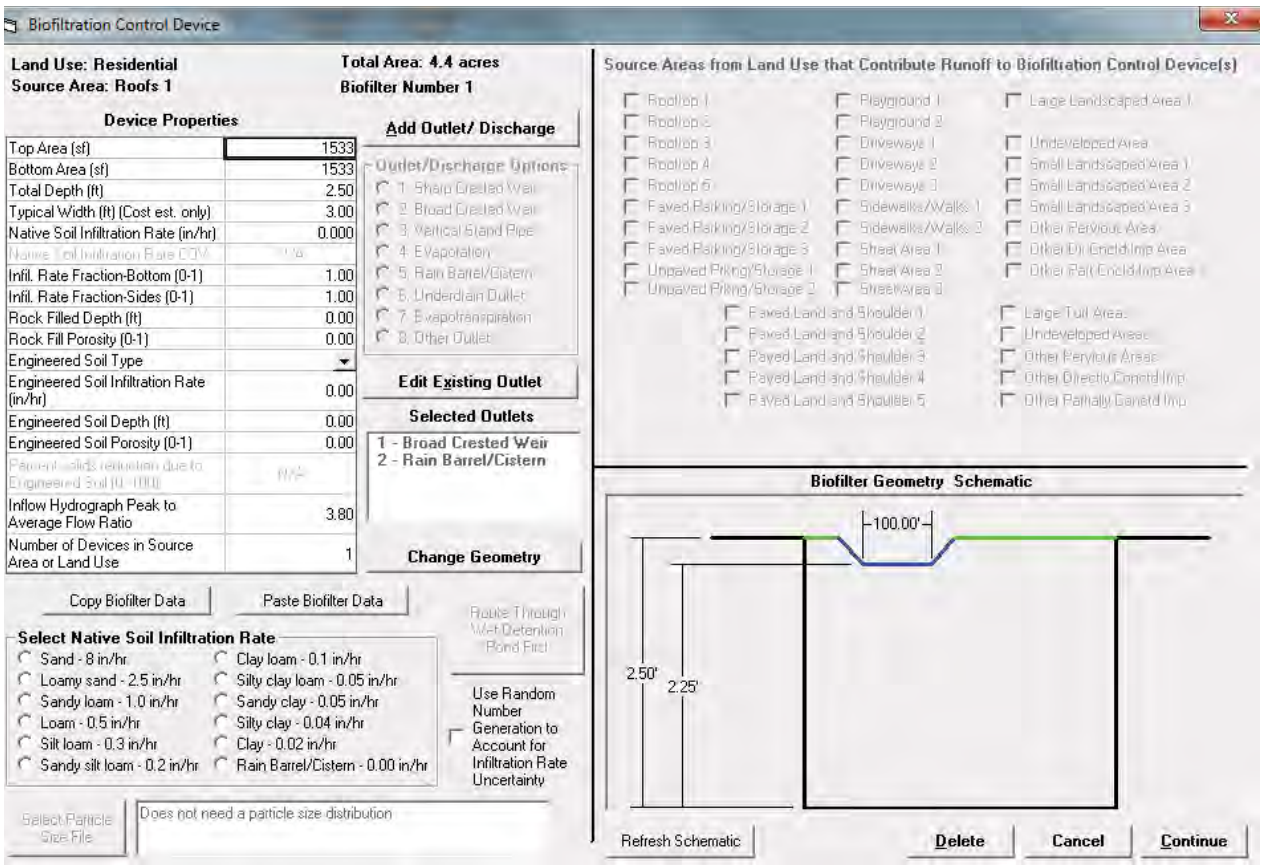


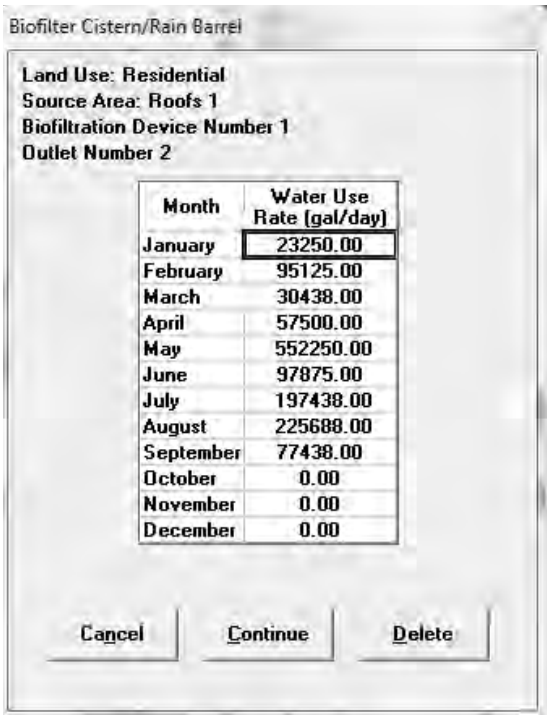
Rain Barrels and Water Tanks for Irrigation using Roof Runoff

Rain barrels are a very simple method for collecting roof runoff for beneficial uses. In these analyses, irrigation of turf grass landscaping around the buildings is the use provided. In some cases, especially for new construction, in-house beneficial uses of stormwater may also be available (such as for toilet flushing). The irrigation opportunity that can be met by the use of stored stormwater is the additional water needed to supplement the long-term monthly average rainfall infiltration in order to match the evapotranspiration requirements for the area. As will be shown in these analyses, small rain barrels provide limited direct benefits, so larger water tanks are also considered in these analyses. Also, in order to be most beneficial, these calculations assume that the irrigation rates are controlled by soil moisture conditions in order to match the ET requirements closely. This level of control is usually most effectively achieved with a single large storage tank connected to an automatic irrigation system. Numerous smaller rain barrels are more difficult to optimally control.

The water harvesting potential for the retrofitted rain barrels and water tanks was calculated based on supplemental irrigation requirements for the basic landscaped areas. The irrigation needs were determined to be the amount of water needed to satisfy the evapotranspiration needs of typical turf grasses, after the normal amounts of infiltration of rainfall added moisture to the soil.

The following is the form used for rain barrel or cistern/water tanks in WinSLAMM version 9.5 (version 10 currently being completed has a more stream-lined water beneficial use/water barrels input screen (but the calculations and data needs are the same). This is the same form used for the biofilters, but conditions relevant to rain barrels and water beneficial use are selected (top and bottom area the same, no native soil infiltration and no fill material needed. The two discharges include the required overflow (just the tank upper rim) and the monthly water use requirements (the irrigation demands to match ET deficits after considering the rain water infiltration).



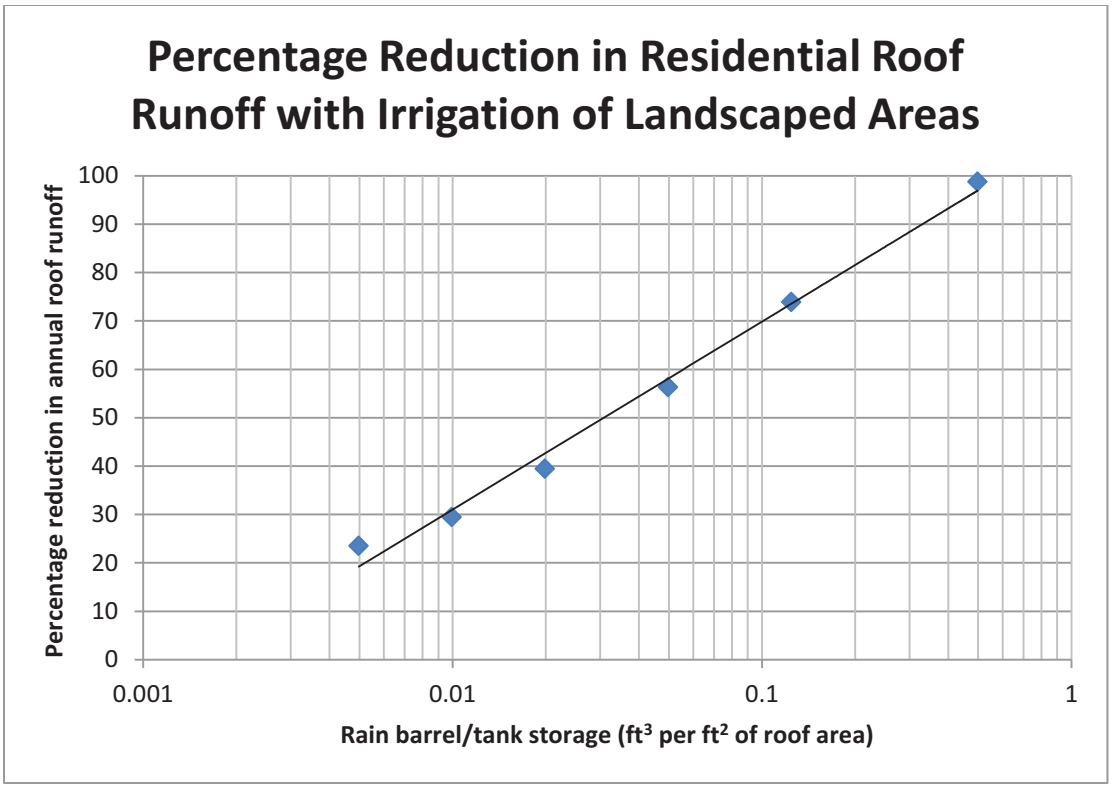


The following tables show the calculations for the maximum water demands, by month, for the nine different land uses examined for these analyses. The water demand was calculated based on long-term modeling of Lincoln, NE, rainfall conditions and calculating the amount of infiltrating rainwater that was available to partially meet the ET requirements for the turf grass landscaped areas. This water demand is the balance of the ET not being met by the rainfall contributions. For each land use, the maximum irrigable land for 100 acres of the land use area was used to calculate the monthly water demand, as shown on the following tables:

month	Water demand to meet local ET for Lincoln, NE (gal/day/acre of landscaped area)	total irrig use (gal/day) for 14 acres of irrigated land per 100 acres of strip malls	total irrig use (gal/day) for 12 acres of irrigated land per 100 acres of shopping centers	total irrig use (gal/day) for 15 acres of irrigated land per 100 acres of light industrial areas	total irrig use (gal/day) for 48 acres of irrigated land per 100 acres of schools
Jan	372	5,208	4,352	5,692	17,670
Feb	1522	21,308	17,807	23,287	72,295
Mar	487	6,818	5,698	7,451	23,133
Apr	920	12,880	10,764	14,076	43,700
May	8836	123,704	103,381	135,191	419,710
Jun	1566	21,924	18,322	23,960	74,385
Jly	3159	44,226	36,960	48,333	150,053
Aug	3611	50,554	42,249	55,248	171,523
Sep	1239	17,346	14,496	18,957	58,853
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0

month	total irrig use (gal/day) for 44 acres of irrigated land per 100 acres of churches	total irrig use (gal/day) for 33 acres of irrigated land per 100 acres of hospitals	total irrig use (gal/day) for 66 acres of irrigated land per 100 acres of low density residential areas	total irrig use (gal/day) for 58 acres of irrigated land per 100 acres of medium density residential areas (before 1960)	total irrig use (gal/day) for 63 acres of irrigated land per 100 acres of medium density residential areas (1960 to 1980)
Jan	16,182	12,239	24,589	21,725	23,250
Feb	66,207	50,074	100,604	88,885	95,125
Mar	21,185	16,022	32,191	28,441	30,438
Apr	40,020	30,268	60,812	53,728	57,500
May	384,366	290,704	584,060	516,022	552,250
Jun	68,121	51,521	103,513	91,454	97,875
Jly	137,417	103,931	208,810	184,486	197,438
Aug	157,079	118,802	238,687	210,882	225,688
Sep	53,897	40,763	81,898	72,358	77,438
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0

The following figure summarizes the calculated benefits of storage and irrigation use of the runoff collected from directly connected residential roofs in the area. As an example, the use of a single rain barrel is expected to provide about a 24% reduction in runoff through irrigation to match ET. However, more than 25 would be needed to reduce the roof's contributions by 90%. In order to match the benefits of disconnection of the connected downspouts (about 78% reductions), about 25 rain barrels would be needed. Twenty-five rain barrels correspond to a total storage quantity about equal to 0.12 ft (1.4 inches). Six different water tankage scenarios were examined for each land use, as the ratio of roof area to landscaped area varied. The resulting storage volumes and numbers of 35 gallon rain barrels and 6 ft tall by 6 ft diameter water tanks that were used in the modeling are shown on these tables for each land use.



The number of rain barrels or water tanks per acre of roof and landscaped area is the same for each land use, but because the roof areas varied by lands use, the number of each storage container varied. The wide range of storage volumes was considered because the irrigation potential varied for each land use.

25 acres of roof area in 100 acres of strip mall area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	931	3	26
rain barrel (at 0.02 ft^3/ft^2)	186	1862	5	51
many rain barrels (at 0.05 ft^3/ft^2)	465	4655	13	128
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	107
rain tank (at 0.25 ft^3/ft^2)			64	267
large rain tank (0.75 ft^3/ft^2)			192	801

27 acres of roof area in 100 acres of shopping center area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	1009	3	28
rain barrel (at 0.02 ft^3/ft^2)	186	2018	5	56
many rain barrels (at 0.05 ft^3/ft^2)	465	5046	13	139
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	116
rain tank (at 0.25 ft^3/ft^2)			64	289
large rain tank (0.75 ft^3/ft^2)			192	868

5.6 acres of roof area in 100 acres of light industrial area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	209	3	6
rain barrel (at 0.02 ft^3/ft^2)	186	417	5	11
many rain barrels (at 0.05 ft^3/ft^2)	465	1043	13	29
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	24
rain tank (at 0.25 ft^3/ft^2)			64	60
large rain tank (0.75 ft^3/ft^2)			192	179

24 acres of roof area in 100 acres of school area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	894	3	25
rain barrel (at 0.02 ft^3/ft^2)	186	1787	5	49
many rain barrels (at 0.05 ft^3/ft^2)	465	4469	13	123
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	102
rain tank (at 0.25 ft^3/ft^2)			64	256
large rain tank (0.75 ft^3/ft^2)			192	769

24 acres of roof area in 100 acres of church area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	894	3	25
rain barrel (at 0.02 ft^3/ft^2)	186	1787	5	49
many rain barrels (at 0.05 ft^3/ft^2)	465	4469	13	123
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	102
rain tank (at 0.25 ft^3/ft^2)			64	256
large rain tank (0.75 ft^3/ft^2)			192	769

20 acres of roof area in 100 acres of hospital area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	741	3	20
rain barrel (at 0.02 ft^3/ft^2)	186	1482	5	41
many rain barrels (at 0.05 ft^3/ft^2)	465	3705	13	102
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	85
rain tank (at 0.25 ft^3/ft^2)			64	212
large rain tank (0.75 ft^3/ft^2)			192	637

1.8 acres of roof area in 100 acres of low density residential area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	67	3	2
rain barrel (at 0.02 ft^3/ft^2)	186	134	5	4
many rain barrels (at 0.05 ft^3/ft^2)	465	335	13	9
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	8
rain tank (at 0.25 ft^3/ft^2)			64	19
large rain tank (0.75 ft^3/ft^2)			192	58

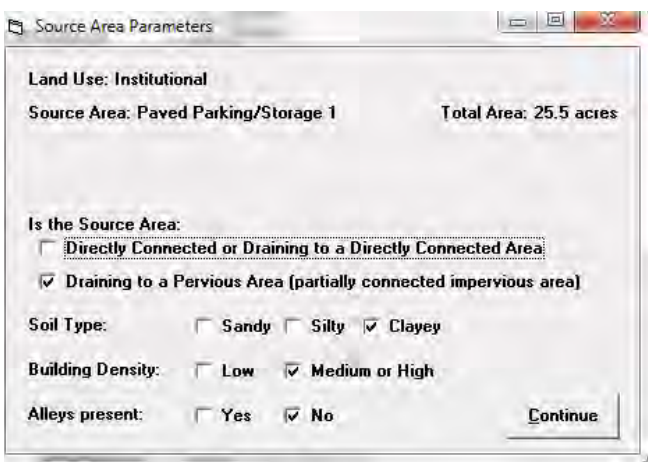
2.8 acres of roof area in 100 acres of pre 1960 medium density residential area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	104	3	3
rain barrel (at 0.02 ft^3/ft^2)	186	209	5	6
many rain barrels (at 0.05 ft^3/ft^2)	465	521	13	14
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	12
rain tank (at 0.25 ft^3/ft^2)			64	30
large rain tank (0.75 ft^3/ft^2)			192	90

4.4 acres of roof area in 100 acres of 1960 to 1980 medium density residential area	number of 35 gal barrels per acre of roof	number of 35 gal barrels per 100 acres of site	number of 6 ft dia 6 ft tall tanks per acre of roof	number of 6 ft dia 6 ft tall tanks per 100 acres of site
2.5 ft tall barrels:				
few rain barrels (at 0.01 ft^3/ft^2)	93	164	3	5
rain barrel (at 0.02 ft^3/ft^2)	186	328	5	9
many rain barrels (at 0.05 ft^3/ft^2)	465	819	13	23
6 ft tall tanks:				
small rain tank (at 0.10 ft^3/ft^2)			26	19
rain tank (at 0.25 ft^3/ft^2)			64	47
large rain tank (0.75 ft^3/ft^2)			192	141

Pavement Controls

Disconnections

Disconnections for roof runoff and for pavements are calculated in similar manners and require similar information in version 9.5. In the upcoming version 10, more direct analyses will be used to calculate the benefits of grass filters. In version 9.5, the results of extensive field monitoring at many locations having varying amounts of disconnected pavement (and roofs) were examined and compared. The model reduces the effective runoff coefficients as a function of land use, the soil type, the building density, and if alleys are present. These factors have all been found to significantly affect the drainage efficiency of an area. The following is the input screen for modifying the pavement connections for an area.



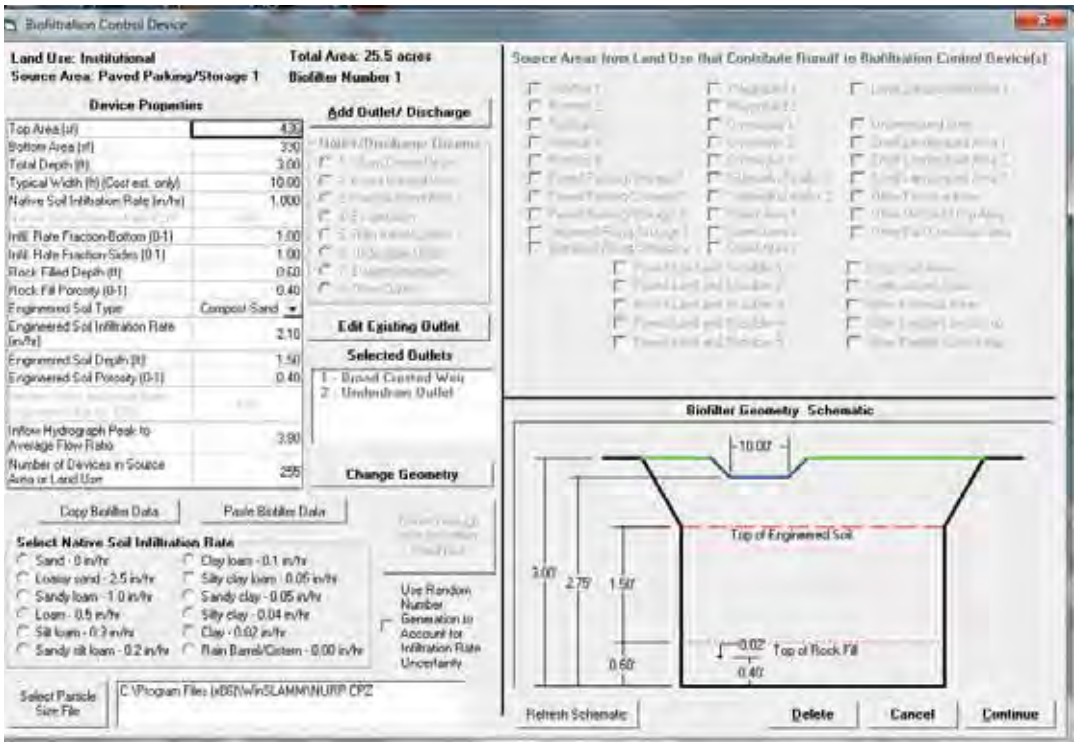
Biofiltration

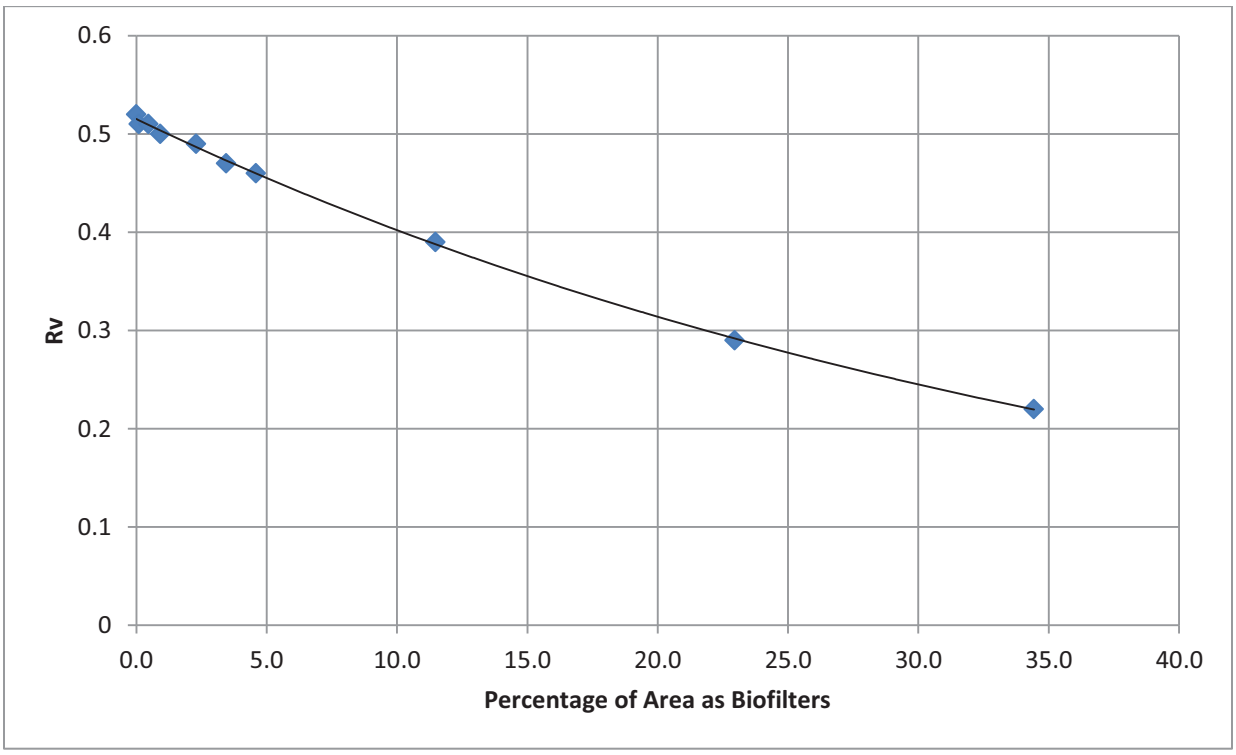
The performance of biofiltration devices is affected by several unit processes that are modeled in WinSLAMM. Modified puls hydraulic routing with surface overflow calculations are the basic processes used in the modeling of these devices. However, several layers in the biofilter are also considered. As runoff enters the device, water infiltrates through the engineered soil or media fill. If the entering rain-runoff cannot all be infiltrated through the surface layer, water will pond. If the ponding becomes deep, it may overflow through a surface outlet. The percolating water moves down through the device until it reaches the bottom and intercepts the native soil. If

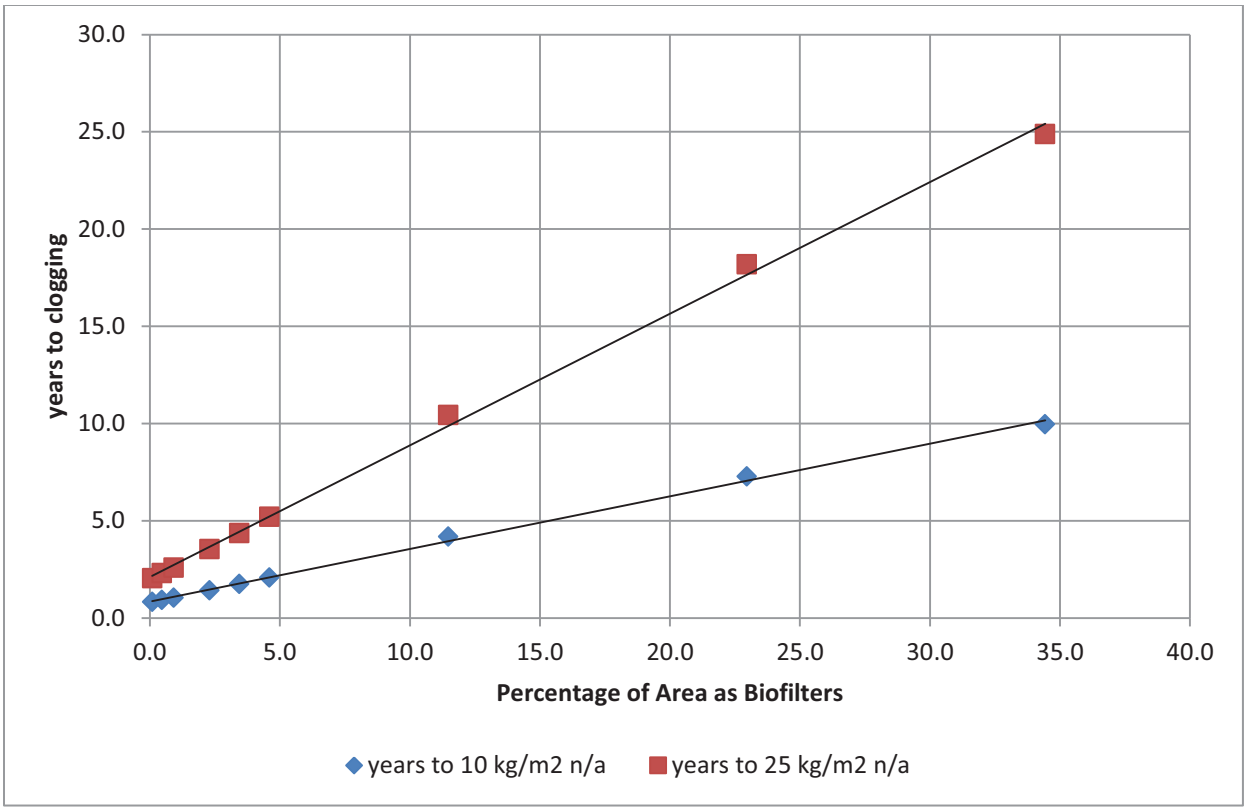
the native soil infiltration rate is less than the percolation water rate, then there is no subsurface ponding; if the native soil infiltration rate is slower than the percolation water rate, ponding will occur. This ponding may buildup to the surface of the device and add to the surface ponding. If an underdrain is present (usually with a subsurface storage layer), the subsurface ponding water will be intercepted by the drain which is then discharged to the surface water, but later in the event and is filtered by the media. With the water percolating through the fill, particulates and particulate-bound pollutants are trapped by the fill through filtering actions. Therefore, the underdrain water usually has a lower particulate solids content than the surface waters entering the device. The calculations are sensitive to the amounts of the different media used as fill and its characteristics (especially its porosity and percolation rate; and if evapotranspiration (ET) is used, the wilting point). The hydraulic routing uses the sum of the void volumes in the device to determine the effluent hydrograph, while the different infiltration/percolation rates affect the internal ponding. The stage-discharge relationships of the outlet devices are all modeled using conventional hydraulic processes. The ET loss calculations are based on the changing water content in the root zone at each time increment, and the ET adjustment factors for the mixture of plants in the device.

Biofilters can be used as control devices in individual source areas, in land uses, as a part of the drainage system or at the outfall. If modeled as an outfall biofilter, the biofiltration control can be used with an upstream wet detention pond for pretreatment. To model biofilters in a source area, as in these examples, the geometry and other characteristics of a typical biofilter are described, then the number of biofilters in the source area is entered. The model divides the total source area runoff flows by the number of biofilters in the source area, creates a complex triangular hydrograph for that representative flow fraction that is then routed through that biofilter, and then multiplies the resulting losses by the number of biofilters for the total source area.

The following is the WinSLAMM input form for the biofilters that were examined. The biofilters described on this form were located in paved parking areas, and contains a SmartDrain. The production functions were prepared by varying the number of these standard sized units. The total area of the devices is the critical measure of application of the biofilters.


Biofiltration Control Device
Land Use: Institutional
Source Area: Paved Parking/Storage 1
Total Area: 25.5 acres
Biofilter Number 1
Device Properties
Add Outlet/ Discharge
Edit Existing Outlet
Selected Outlets
1 - Broad Crested Weir
2 - Underdrain Outlet
Change Geometry
Copy Biofilter Data
Paste Biofilter Data
Select Native Soil Infiltration Rate
Use Random Number Generation to Account for Infiltration Rate Uncertainty
Select Particle Size File
Source Areas from Land Use that Contribute Runoff to Biofiltration Control Device(s)
Biofilter Geometry Schematic
10.00'
Top of Engineered Soil
3.00'
2.75'
1.50'
0.60'
0.02'
0.40'
Top of Rock Fill
Refresh Schematic
Delete
Cancel
Continue


0.6
0.5
0.4
0.3
0.2
0.1
0
Rv
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Percentage of Area as Biofilters

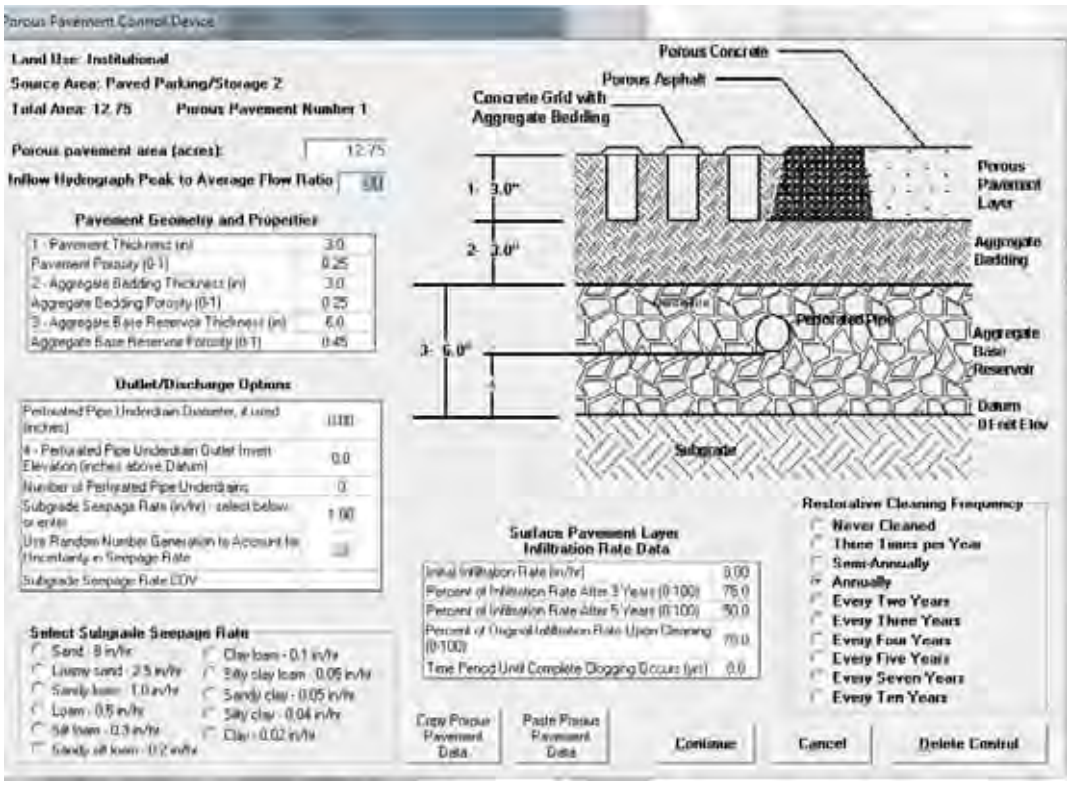


The above production functions were based on typical pavement conditions and relate the area of the paved area dedicated as biofilters to their expected performance. In this example, almost 25% of the paved area would have to be dedicated as biofilters to produce about half the runoff compared to an uncontrolled area, a clearly unworkable option. When examining the clogging potential of biofilters for very dirty paved parking areas, biofilters between about 12 and 34% of the area are needed to prevent clogging loadings (assumed to be between 10 and 25 kg/m^2 within a 10 year period of time). Cleaner sites could have smaller biofilters, while even dirtier sites would need larger biofilters in order to have a ten year service life, assumed to be the goal for these areas. Pretreatment is another option to extend the service life of the biofilters. Pollutant reductions are maximized when the biofilters are about 10% of the area, with no further benefits.

These production functions were used to select the range of biofilters to use for treating paved areas in the different land uses. For clay loam soil conditions, the biofilters examined were 3, 10, and 25% of the paved contributing area, while for sandy soil conditions, the biofilters examined were 3 and 10% of the paved areas.

Porous Pavement

Porous pavement structures can be designed to totally eliminate all runoff from the area covered by the porous pavement. WinSLAMM version 9.5 doesn't allow any run-on to the porous pavement; only rainfall directly onto the porous pavement is considered. Version 10 does allow run-on from adjacent areas. The following screen shows the information entered to analyze porous pavements:



The following is a summary from the porous pavement HELP screens in WinSLAMM: The porous pavement control option uses full routing calculations associated with pond storage in conjunction with other porous pavement features. The "outlet" options for porous pavement include subgrade seepage as well as an optional underdrain, which is modeled as an orifice. The porous pavement control device option also has a surface seepage rate that limits the amount of runoff that can enter the storage system. This surface seepage rate can be reduced to account for clogging over time, and the surface seepage rate can be partially restored with cleaning at a stated cleaning frequency. The porous pavement control device infiltrates water originating from the rainfall hitting the pavement surface area only - it does not accept run-on from other surfaces. The runoff volume reaching the porous pavement surface is therefore equal to the rainfall volume directly falling on the porous pavement. The porous pavement surface area can be any suitable porous pavement material, including paver blocks, porous concrete, porous asphalt, or any other porous surface or just turf reinforcement. Porous pavements are usually installed over a subsurface storage layer that can dramatically increase the infiltration performance of the device.

The porous pavement control option can be used as a control device only in individual source areas. Porous pavements are usually located at paved parking and storage areas, paved playgrounds, paved driveways, or paved walkways. They should be used only in relatively clean areas (walkways or driveways or other surfaces that receive little traffic, for example), to minimize groundwater contamination potential. Porous pavements direct the infiltrating water to subsurface soil layers, usually beneath much or the organic surface soils that tend to sorb many pollutants. Salts used for ice control in northern areas are also problematic when considering infiltrating stormwater. Therefore, only use porous pavements in areas needing minimal salt applications. Consider biofiltration devices to infiltrate water from more contaminated sites, as they can use amended soils to help trap contaminants before infiltration, or use other appropriate pre-treatment before infiltration. No common pretreatment device is suitable for the removal of salts, however, so minimal use is the preferred control option in that case.

Pavement Geometry and Properties:

1. Pavement thickness (inches): Enter the thickness of the surface pavement.

2. Pavement porosity (unit less): Enter the porosity (the ratio of air volume to total volume) of the surface pavement. This ratio can range from zero to one.

3. Aggregate bedding thickness (inches): Enter the thickness of the aggregate bedding layer.

4. Aggregate bedding porosity (unit less): Enter the porosity (the ratio of air volume to total volume) of the aggregate bedding. This ratio can range from zero to one.

5. Aggregate base reservoir thickness (inches): Enter the thickness of the aggregate base reservoir.

6. Aggregate base reservoir thickness porosity (unit less): Enter the porosity (the ratio of air volume to total volume) of the aggregate base reservoir thickness. This ratio can range from zero to one.

Outlet/Discharge Options:

7. Underdrain diameter (inches): Enter the diameter of the underdrain. This is an optional outlet. The model calculates flow through the underdrain as an orifice; it assumes that the discharge flow is not limited by friction through underdrain pipe slots or pipe friction (the water velocity is usually very slow). Any water entering the underdrain is re-directed to surface flows; it is not infiltrated. WinSLAMM adds this runoff volume (and associated pollutants) back to the surface drainage system. An underdrain is usually specified to minimize ponding on the surface of the porous pavement such as when the aggregate grade base reservoir nears capacity.

8. Underdrain outlet invert elevation (inches above datum): Enter the elevation of the invert of the underdrain outlet. The model assumes that all porous pavement surfaces are flat and that the underdrains also have minimal gradient.

9. Number of underdrains. Enter the number of underdrains in the porous pavement control device.

10. Subgrade seepage rate (in/hr): Enter the subgrade seepage rate. Default values for selected soil types are listed in the radio buttons below the data entry table, or you can enter your own values, if known. You can also vary this value stochastically by electing to use the random number generator.

11. Random number generator: Check this box to generate a random subgrade seepage value for each rainfall event. These values are randomly generated based upon a log normal distribution.

12. Subgrade seepage rate COV: Enter the Coefficient of Variation (COV) for the seepage rate you are using if you intend to generate seepage rates stochastically. The COV values are given if you use the radio buttons to select the seepage rate, and are based on numerous field tests. Soil seepage rates can vary greatly over short distances, even for the same soil textures, usually due to compaction, roots, soil animals, etc.

Surface Pavement Layer Infiltration Rate Data:

13. Initial infiltration rate (in/hr): Enter the infiltration rate through the surface layer when the pavement was newly installed. Any rain having intensities greater than this initial infiltration rate will not enter the porous pavement structure, but will run off. The rain intensities are calculated using the complex triangular distribution in WinSLAMM. Initial infiltration rates for porous pavements are usually very large (ranging from 5 to 20, or even more, in/hr, based on the specifications for the material used).

14. Percent of infiltration rate after three years (0-100): Enter the percent of the initial surface infiltration rate you expect the surface to have after three years without cleaning. If you expect it to maintain the initial rate, then enter 100. This, and the next parameter, determines how fast the pavement surface water infiltration rate degrades with time. This value is highly dependent on the type of pavement material Paver blocks may clog more slowly; areas with more traffic clog faster; tracking of mud or other debris also hastens clogging; many site factors affect long-term performance, and this value should be based on regional monitoring for similar conditions and similar porous pavement materials. A suitable value may be about 75%, indicating a 25% reduction over the first three years of porous pavement life.

15. Percent of infiltration rate after five years (0-100): Enter the percent of the initial surface infiltration rate you expect the surface to have after five years without cleaning. If you expect it to maintain the initial rate, then enter 100. This factor is also dependent on site conditions. A suitable factor may be 50% after five years.

16. Percent of original infiltration rate restored upon cleaning (0-100): Enter the percent of the initial surface infiltration rate the surface will have after it is cleaned. If there is more than one cleaning, the surface infiltration rate will return to this percentage of the initial rate after every cleaning. If you expect it to maintain the initial rate, then enter 100. In most cases, typical porous pavement restorative cleaning activities cannot completely restore the initial rate. However, this factor should also be determined locally. A suitable value may be about 85%, but can vary widely.

17. Time period until complete clogging occurs (years): This is the time when complete failure of the surface infiltration rate occurs. It can be regenerated to whatever percent of the initial infiltration rate you entered for the previous variable upon cleaning. This is also dependent on local conditions. With no cleaning, most porous pavements are expected to eventually completely clog. A value of about 10 years may be a suitable value.

18. Restorative cleaning frequency: Enter how often the porous pavement surface will be cleaned. All stormwater controls need maintenance, and porous pavement is no exception. Commercial paved areas may be cleaned quite frequently to remove large debris, but standard pavement cleaning is usually not adequate to maintain an acceptable infiltration rate. Special cleaning operations are needed, but may be much less frequent. Consult the manufacture of the porous pavement for proper cleaning techniques and frequencies. Once a year may be a suitable value, but will depend on local conditions.

The storage provided by the pore space in the pavement (asphalt, concrete, block, or turf reinforcement grids) plus in the bedding and in the storage rock reservoir easily exceeds the depth of rain for even the most severe rains in an area. The reservoir volume than needs to drain through the underlying natural soils before the next rain, or the storage volume is reduced. In these calculations, all porous pavements are 3 inches thick with a 3 inch bedding layer and a 6 inch storage layer. They were used for half of the paved parking areas, in the assumed overflow parking areas that receive little parking. Due to groundwater concerns, porous pavement was

not considered in areas having heavy traffic or parking. These were assumed to be cleaned yearly. The model used a decreasing rate of infiltration as the porous pavement aged, and good recovery was obtained when cleaned. The largest detriments to porous pavements include:

1) high costs, especially when retrofitting in an existing paved area

2) relatively high efficiency of transport of contaminants to the subsurface areas

3) cleaning is needed to maintain high infiltration rates

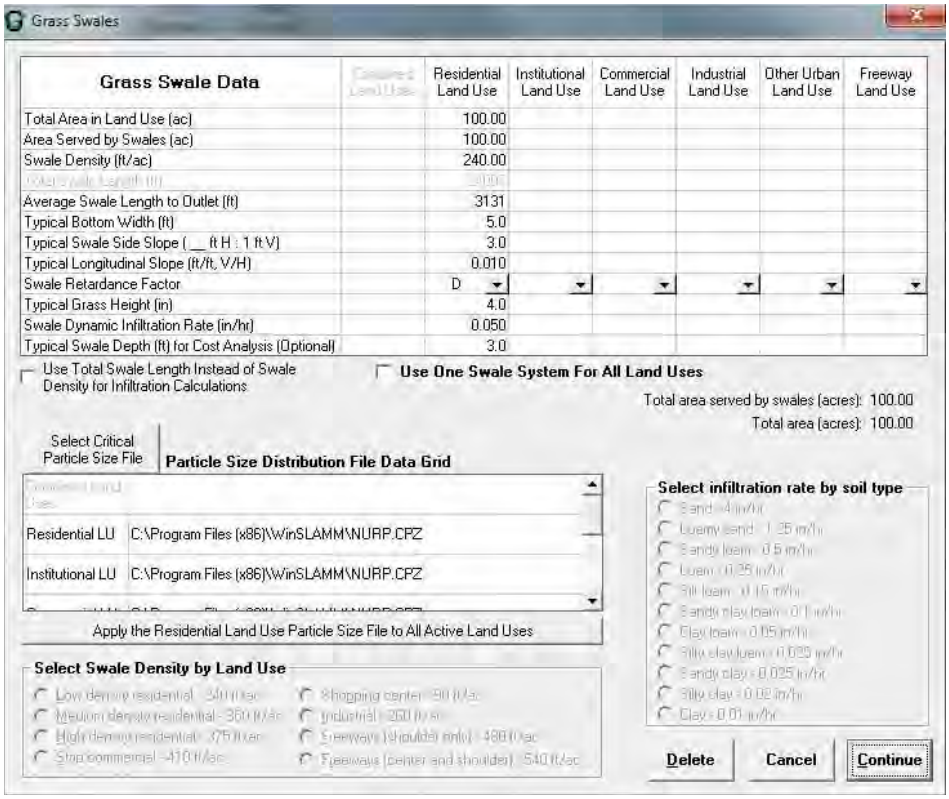
Street Side Drainage Controls

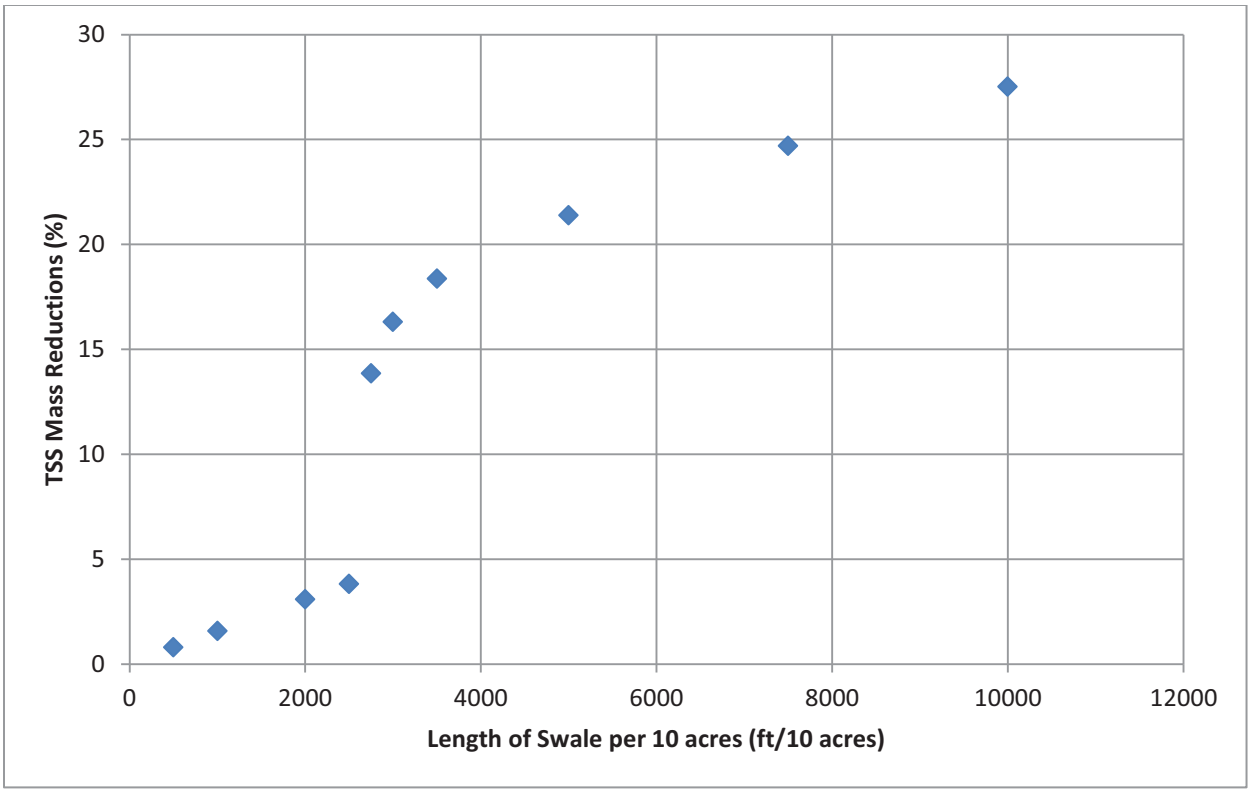
Grass Swales

Grass filters have broad, shallow flows, while grass swales have concentrated flows. Grass filters are modeled as a special case of grass swales in version 9.5 of WinSLAMM. The model calculations are based on extensive pilot-scale and field measurements of grass swales and filters conducted for the Alabama Dept. of Transportation. The algorithms used to determine the Manning's n values used in grass swale hydraulic calculations were developed from the master's thesis work by Jason Kirby (Kirby, J.T., S.R. Durrans, R. Pitt, and P.D. Johnson. "Hydraulic resistance in grass swales designed for small flow conveyance." Journal of Hydraulic Engineering, Vol. 131, No. 1, Jan. 2005.) as part of a WERF-supported research project: Johnson, P.D., R. Pitt, S.R. Durrans, M. Uremia, and S. Clark. Metals Removal Technologies for Urban Stormwater. Water Environment Research Foundation. WERF 97-IRM-2. ISBN: 1-94339-682-3. Alexandria, VA. 701 pgs. Oct. 2003. The particle trapping algorithms were based on the master's thesis research conducted by Yukio Nara (Nara, Y., R. Pitt, S.R. Durrans, and J. Kirby. "Sediment transport in grass swales." In: Stormwater and Urban Water Systems Modeling. Monograph 14. edited by W. James, K.N. Irvine, E.A. McLean, and R.E. Pitt. CHI. Guelph, Ontario, pp. 379 402. 2006.), supported by the University Transportation Center for Alabama: "Alabama Highway Drainage Conservation Design Practices - Particulate Transport in Grass Swales and Grass Filters", by Yukio Nara and Robert Pitt, University Transportation Center for Alabama, University of Alabama, Tuscaloosa, Alabama, November, 2005.

Grass swale performance is determined by routing a complex triangular hydrograph through the swales described in the model by the user. Runoff volume reductions are determined by infiltration losses, and particulate losses are determined through particle trapping. Runoff volume is reduced by the dynamic infiltration rate of the swales for each six minute time step of the hydrograph. The flow and the swale geometry are used to determine the Manning's n to iteratively determine the depth of flow in the swale for each time step, using traditional VR-n curves that were extended by Kirby to cover the smaller flows found in typical drainage swales. Using the calculated depth of flow for each time increment, the model calculates the wetted perimeter (based on the swale cross-sectional shape) which is then multiplied by the total swale length to determine the area used to infiltrate the runoff. The settling frequency and resultant particulate trapping is calculated for each of the thirty-one particle size fractions in the selected particle size distribution file. The resulting particulate concentrations are then combined into one of eight groups of particle sizes, where it is evaluated to determine if it is below the irreducible concentration values for each particle size group. No resulting concentration values are allowed to go below the irreducible concentration values unless the inflow value is already below that level. For grass swales, no particles smaller than 50 µm are trapped due to turbulent resuspensions of the small particles.

The following is the grass swale information screen in WinSLAMM used in these calculations. The swale density (and resulting total swale length) was varied to develop the production function curves that describe swale performance by swale density for the different land uses.

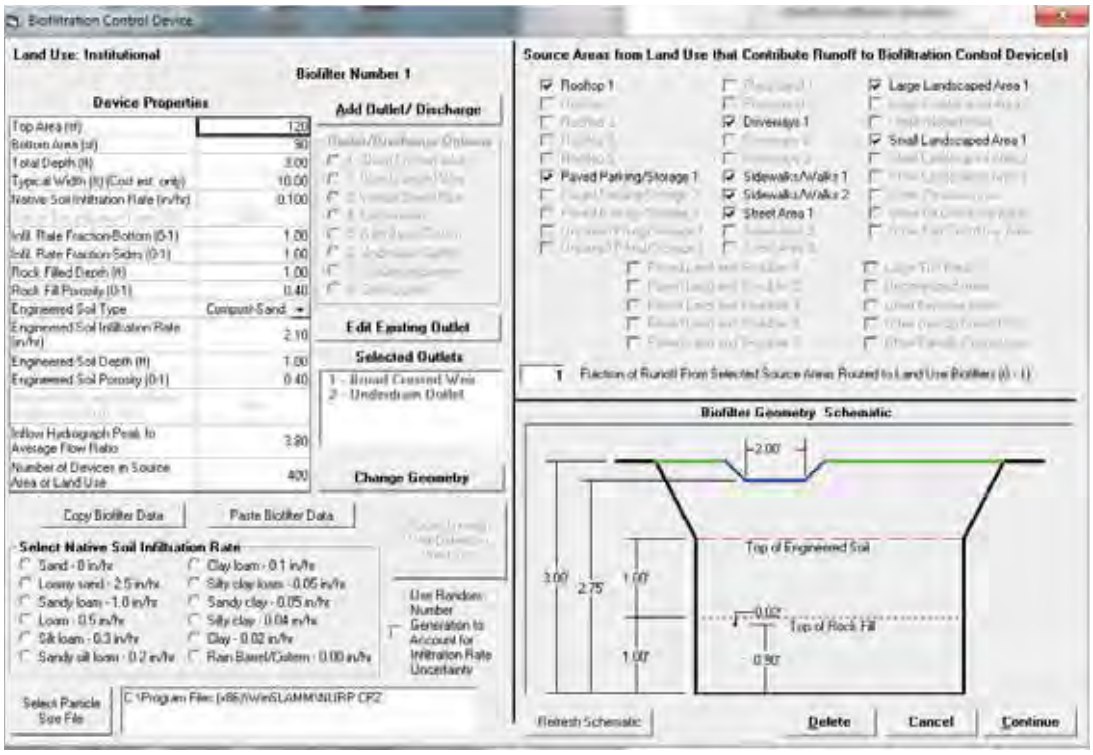




The above production functions show the resulting TSS reductions after treatment in grass swales. The lengths of the swales are shown as length per area (ft per 10 acres). Similar to the biofilters, the benefits of grass swales in reducing runoff volumes is limited because of compacted soils. The plot of TSS mass reductions shows that two mechanisms are responsible for sediment removal. For short swales, the sediment reduction is only associated with the volume reduction of the flowing water. After about 2,800 ft/10 acres, sediment deposition also occurs after sufficient length is available to overcome scour, after about 3,000 ft/10 acres, the sediment reductions change less rapidly.

Curb-cut Biofilters

The mechanisms available for treatment of stormwater in curb-cut biofilters are the same as previously described for parking area biofilters. For these devices, the curb face is cut and the water is allowed to flow into an excavation adjacent to the curb line, usually in an area between the sidewalks and the streets. If this area is too narrow, a curb-extension biofilter may be used. In this case, the excavated area extends out into the street, usually consuming a section of the parking lane. The earlier production functions were examined and sizes of these devices for the Lincoln land uses were determined. Curb-cut biofilters consuming 20, 40, and 80% of the length of the curb length were examined in these calculations, for both clay loam and sandy loam soil conditions in the biofilters, for each land use. The following is the input screen used for these controls:



Public Works Practices

Street Cleaning

The street cleaning control option can be applied to streets and alleys. There are two options for entering in street cleaning dates. 1) Enter Street Cleaning Dates, or 2) Enter a Street Cleaning Frequency. Note that if a street cleaning event occurs on the same day as a rainfall event (such as on April 1 when the 'One Pass Each Spring' option is selected), then the street cleaning event is cancelled for that event.

• Entering a street cleaning frequency. Select the 'Street Cleaning Frequency' check box, and then the desired frequency. This frequency will be applied from the beginning date to the ending date of the model run. The spring pass occurs on the day that the winter season ends during every year in the model run. The fall pass occurs on October 31st of every year of the model run.

· Type of Street Cleaner. Select the type of street cleaner. The program will enter the proper coefficients M and B after you have selected the street cleaner productivity, parking density and parking control option.

· Street cleaning productivity. Select the default productivity by entering the parking density and the parking control status. The parking density options are:

1. None - There is no parking along the street being swept.
2. Light - There is significant spacing between parked cars such that street cleaners can easily get to the curb, between cars, for significant sections of the street.
3. Medium - There is enough spacing between parked cars such that street cleaners can get to the curb for at least some sections of the street.
4. Extensive (short term) - There is not enough space between cars to allow street cleaners to get to the curb for some time during a 24-hour period.

5. Extensive (long term) - There is not enough space between cars to allow street cleaners to get to the curb. This condition persists for most or all of a 24-hour period.

· The parking control status indicates whether parking options such as limited parking hours or alternate side-of-the-street parking have been regulated by the municipality.

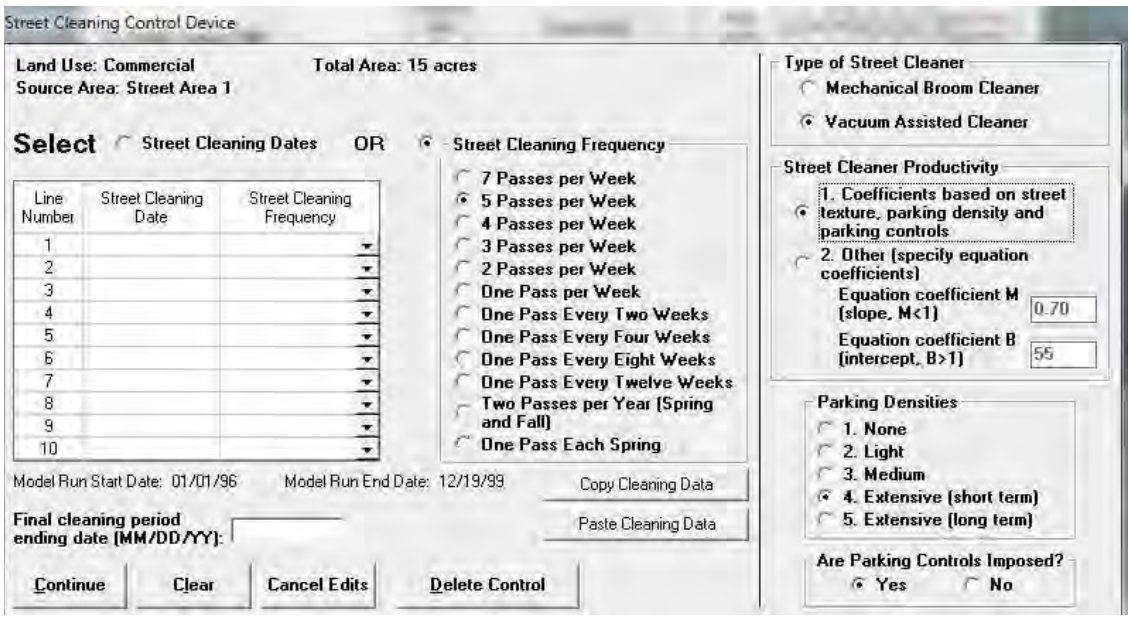
· Street cleaner productivity can also be described by entering the equation coefficients for the linear street cleaning equation, Y = mx + b, where is Y is the residual street dirt loading after street cleaning and x is the before street cleaning load (in lbs/curb-mile). Enter values for:

· m (slope, less than 1)

· b (intercept, greater than or equal to 1)

Where m is the minimum removal fraction, or street cleaning effectiveness, and b is the minimum street dirt loading, after intensive street cleaning.

The following is the street cleaning data entry screen used for these analyses:

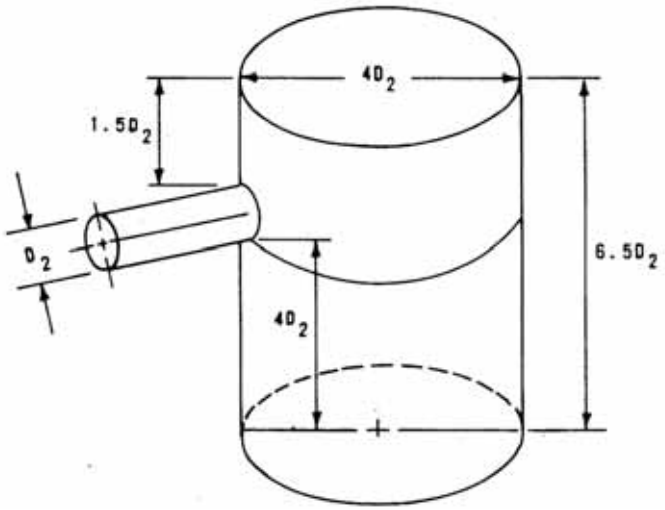


Catchbasin Cleaning

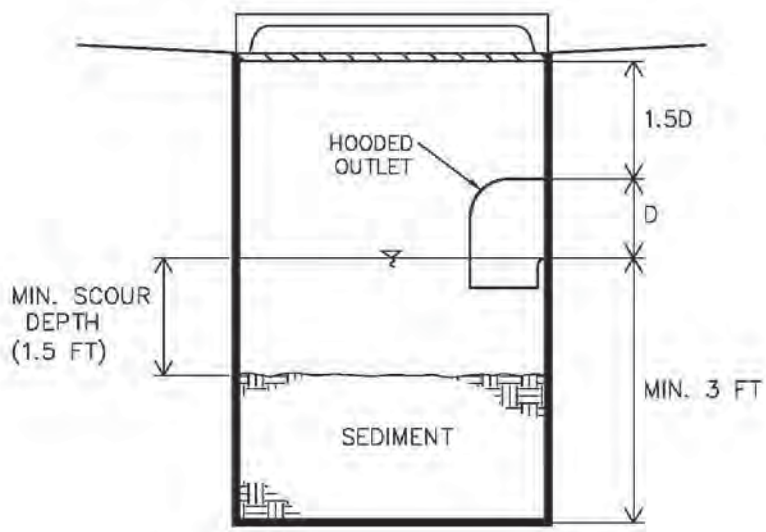
Catchbasins are chambers or sumps installed in a storm sewer, usually at the curb stormwater inlet to the drainage system. Catchbasins have a sump area below the inlet intended to retain captured sediment. By trapping coarse sediment, the catchbasin prevents trapped solids from clogging the sewer or being washed into receiving waters. However, the sumps must be cleaned out periodically to maintain their sediment trapping ability.

Catchbasins with sumps are effective for trapping coarse sediment and large debris and trash. If outfitted with hoods over the outlets, the capture of floatables and other litter can be improved. In addition to reducing sediment loads, catchbasin cleaning may also reduce the load of oxygen demanding substances that reach surface water. However, in the absence of suitable cleaning, they may make water quality worse due to the degradation of captured material.

Catchbasin performance is calculated by assuming flow through a settling area defined by the surface area of the catchbasin. The particulate removal in this settling area is assumed to occur due to ideal settling as described by Stokes Law (for laminar flow), or Newton's law (for turbulent flow). Catchbasin performance has been monitored during many field trials during EPA-sponsored research, and by other international researchers. Metcalf and Eddy (Lager, et al. 1977) developed an idealized catchbasin geometry based on laboratory and field experiments, as shown below:



According to this diagram, if the outlet diameter is 12 inches, the total height of the device should be at least 6.5 feet, the diameter of the manhole would be 48 inches, and the bottom edge of the outlet pipe would be located 48 inches above the device bottom and 18 inches below the top. In almost all full-scale field investigations, this design has been shown to withstand extreme flows with little scouring losses, no significant differences between supernatant water quality and runoff quality, and minimal insect problems. It will trap the bed-load from the stormwater (especially important in areas using sand for traction control) and will trap a low to moderate amount of suspended solids (about 30 to 45% of the annual loadings). The largest size fractions of the sediment in the flowing stormwater will be trapped (typically larger than 50 µm), in preference to the finer material that has greater amounts of associated pollutants. Their hydraulic capacities are designed using conventional procedures (grating and outlet dimensions), while the sump is designed based on the desired cleaning frequency. Pitt and Khambhammettu reviewed the performance of catchbasins from many sources, and recommended a basic catchbasin configuration having an appropriately sized sump with a hooded outlet. The following is the basic recommended configuration showing the hooded outlet for enhanced floatable control:

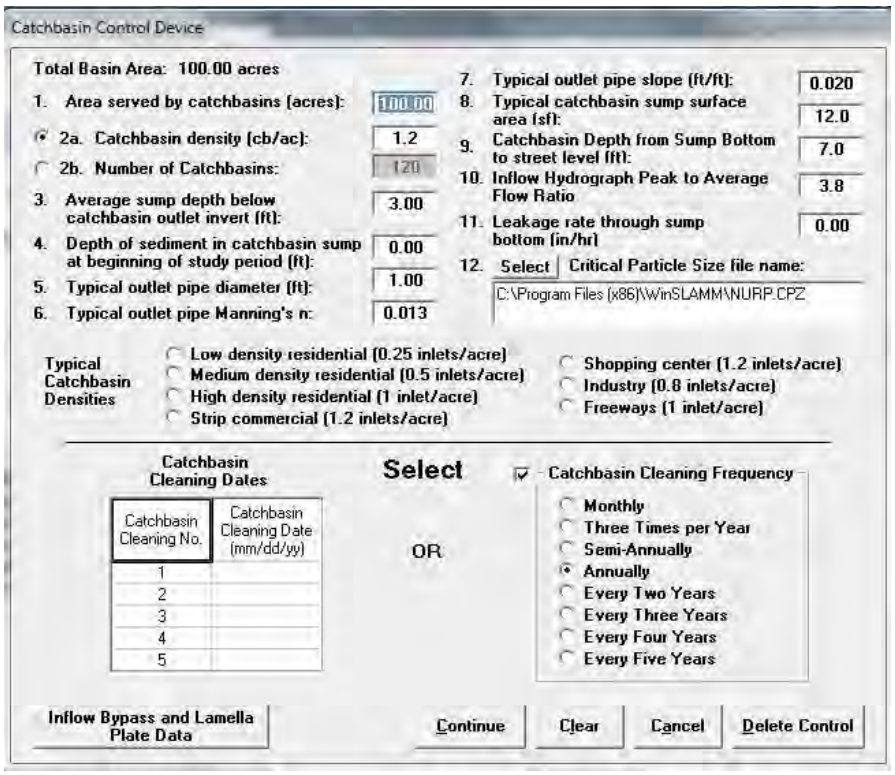


If the water velocity through the catchbasin is slow, slowly falling particles can be retained. If the water velocity is fast, then only the heaviest (fastest falling) particles are likely to be retained. The critical particle settling velocity is equal to the ratio of the discharge water rate to the surface area of the catchbasin. Particles having settling velocities greater than this ratio will be removed. Only increasing the surface area or decreasing the outflow rate will increase settling efficiency. Increasing the catchbasin sump depth does lessen the possibility of bottom scour and increases the estimated time between sump cleanings. Since the settling velocity increases as particle size increases (using Stokes or Newton's law and appropriate shape factors, specific gravity and viscosity values), the catchbasin water quality performance (or percent removal) is determined from the particle size distribution of the solids in the runoff entering the catchbasin. This is done by determining the settling velocity and then calculating the particle size associated with that settling velocity, which is referred to as the critical particle size. The percent of the particles that will settle is then determined from the particle size distribution of the total suspended solids (TSS) concentration of the sediment in the stormwater runoff.

Field test results indicate that the performance of catchbasins is strongly related to the inflowing water rate. The standard surface-overflow-rate (SOR) approach used in water and wastewater treatment facilities, and in sedimentation controls in WinSLAMM, normalizes the inflowing water rate with the surface area of the catchbasin. Detailed scour tests (computational fluid dynamics modeling and full-scale tests) were conducted to verify this approach and to measure critical scour conditions (Avila, H., R. Pitt, and S.E. Clark).

The model assumes that catchbasins with sumps are located at inlets or with minimal flow-through capability. Sumps that are constructed in series would have increasingly larger flow rates in each device, which is not what the program would be modeling. This condition may be evaluated by creating a series of .dat files for the catchbasin series. Each catchbasin would include separate source areas for the upstream drainage areas and the contributing drainage areas. To evaluate flow but not loading in each file, the upstream source areas should have the other control practice activated with 100% control of solids, only. This will allow the program to evaluate each catchbasin with the appropriate flow, from all source areas, while accounting for the loading only from the immediately contributing area.

The following is the data entry form for catchbasins in WinSLAMM:



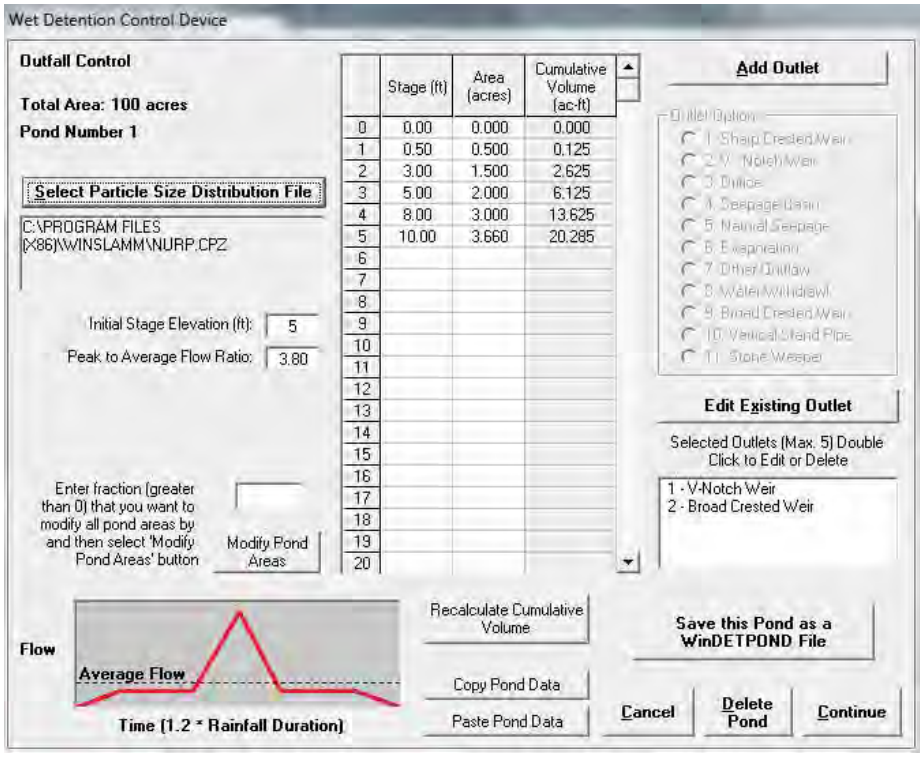
Outfall Controls

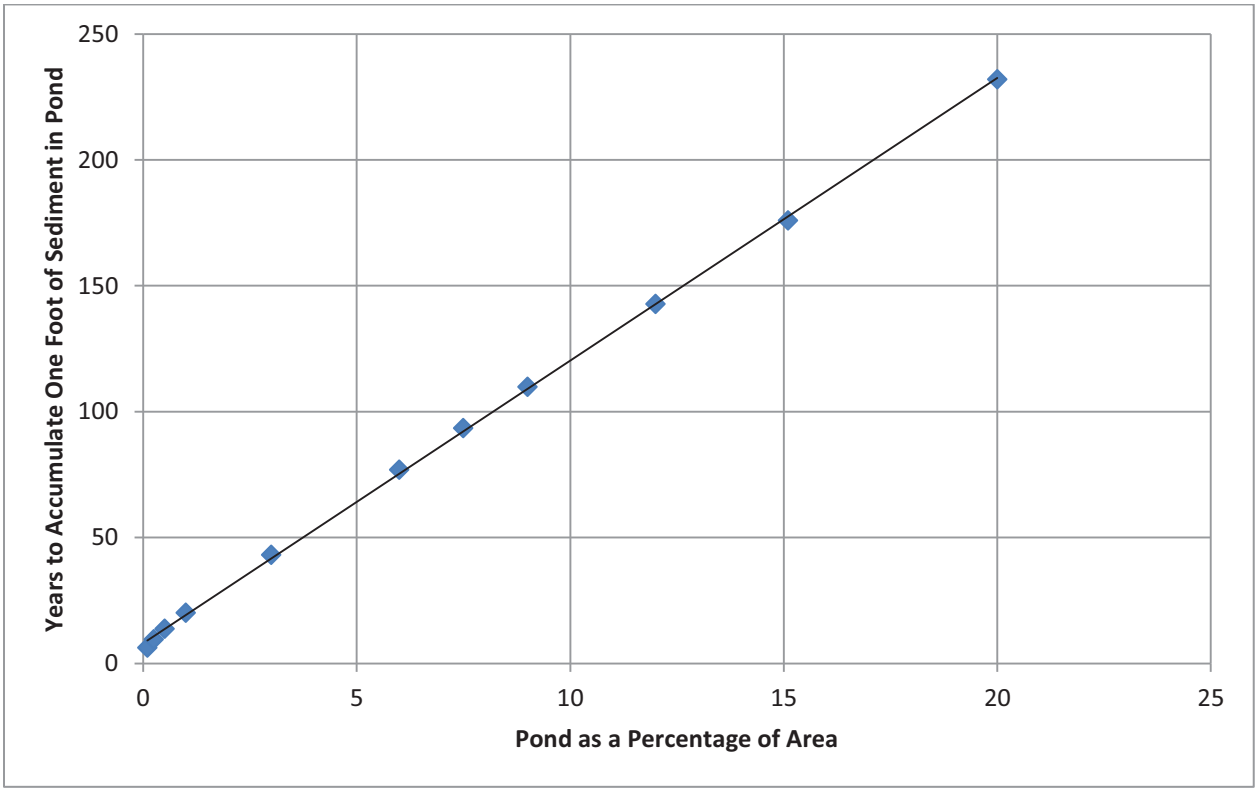
Wet Detention Ponds

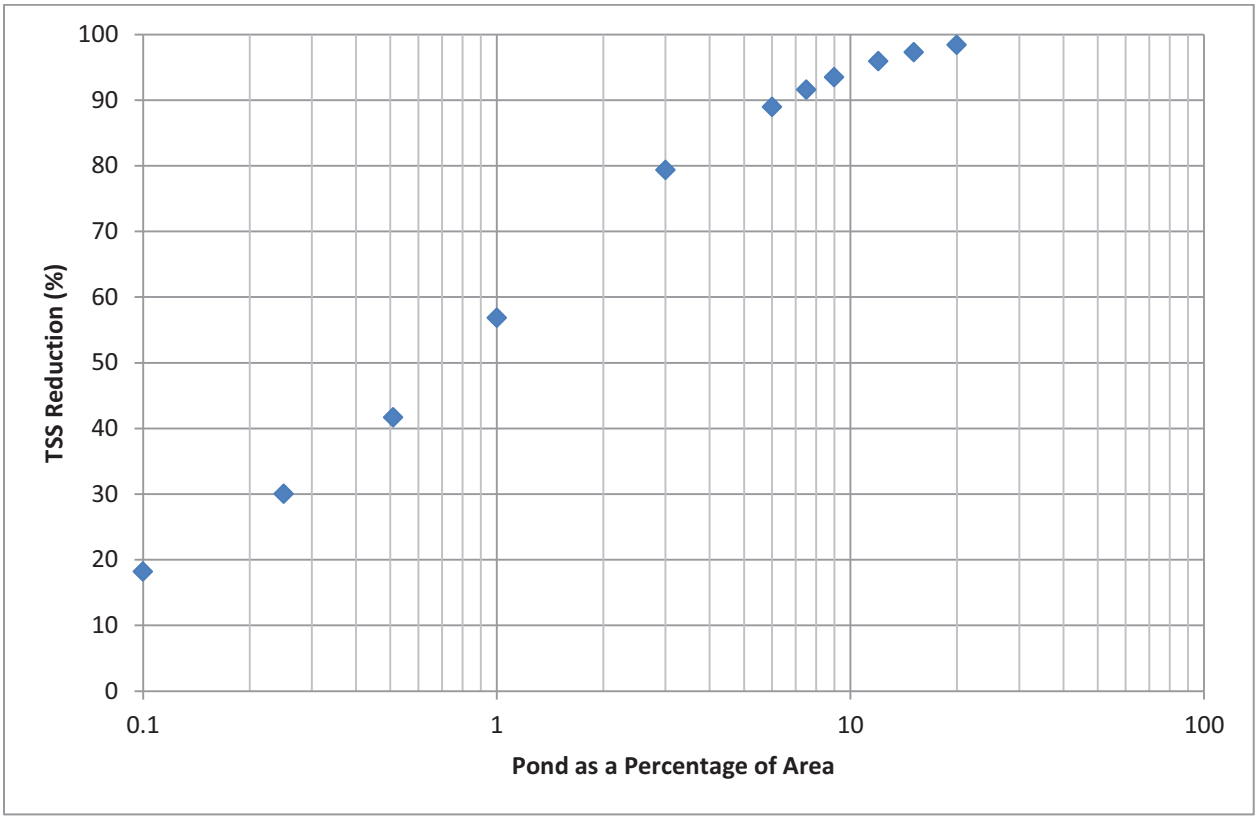
Wet detention ponds are probably the most common management practice for the control of stormwater runoff quality. If properly designed, constructed, and maintained, they can be very effective in controlling a wide range of pollutants and peak runoff flow rates. There is probably more information concerning the design and performance of detention ponds in the literature than for any other stormwater control device. Wet detention ponds are a very robust method for reducing stormwater pollutants. They typically show significant pollutant reductions as long as a few design-related attributes are met. Many details are available to enhance performance, and safety, that should be followed. Many processes are responsible for the pollutant removals observed in wet detention ponds. Physical sedimentation is the most significant removal mechanism.

WinSLAMM uses conventional procedures to calculate hydraulic conditions (pond storage-indication routing) and the behavior of particulates in stormwater as it passes through a detention pond (surface overflow rates described by the Hazen equation and quiescent settling using Stoke's and Newton's laws). WinSLAMM was specifically developed for continuous long-term evaluations using lengthy rain series. Whereas most computer-based pond models require time increment direction from the user and frequently crash due to unstable algorithms, WinSLAMM predicts reasonable calculation increments based on the duration of each rain and interevent period. If the calculation appears to approach unstable conditions, it automatically starts over with a smaller calculation increment. In addition, if the pond design is too small or if the outfall is inadequate, causing catastrophic overflow conditions, the program doesn't crash, but continues using the last known outfall or surface area value, and notes that the pond overflowed. The tabular output of the model can also be easily imported into spreadsheets and graphing programs to produce statistical summaries of the pond performance.

The following screens are used to enter information pertaining to a wet detention pond for analysis with WinSLAMM. The following production functions were prepared by varying the surface area of the pond for different analysis trials.







The wet detention pond is the most effective control for particulate pollutants, as it is usually able to reduce the sediment down to much smaller particle sizes than either biofilters or swales. Wet detention ponds, however, do not provide any volume reductions. It would take about 50 years to accumulate a foot of sediment (average depth) in a pond that is about 3% of the drainage area (a typical size for an industrial area) for typical conditions. With the dirtier sites, the sediment accumulation rate would be much greater. The percentage TSS reductions are much greater for wet detention ponds than for the swales or biofilters. A pond that is 3% of the drainage area would result in about 80% TSS reductions, while about 6.5% of the site would be needed for the pond if the TSS reduction was 90%.

Combinations of Stormwater Control Practices

Combinations of stormwater controls can usually be more effective than individual practices. For biofilters, swales, and wet detention ponds, the increased benefit over the use of ponds alone in minor. However, the other controls can be effective pre-treatment to minimize maintenance in the pond. Again, in this example, the accumulation rate of sediment in the pond is relatively low, so this pre-treatment benefit may not be necessary.

Small wet ponds were used in up to five combinations of stormwater controls:

1) small wet detention ponds and curb-cut biofilters along 40% of the curbs
2) small wet detention ponds and biofilters that are 10% of the paved parking areas (or rain gardens that area 15% of the roof areas in residential areas)
3) small wet detention ponds and medium sized rain tanks to irrigate landscaped areas
4) small wet detention ponds and grass swales

5) small wet detention ponds, curb-cut biofilters along 40% of the curbs, and parking lot biofilters 10% of the paved parking area, or roof gardens that are 15% of the roof areas

As noted, small and moderate-sized controls were examined in combination with each. These are usually the most cost-effective.

Variability and Uncertainty

WinSLAMM contains various Monte Carlo components that enable uncertainly to be evaluated during the model runs. These are available for the infiltration rates for the various infiltration and biofiltration devices, and for the pollutant concentrations. During field investigations, these model parameters have been recognized as having the greatest variabilities that are not explained by the model. The Monte Carlo elements are described by probability distributions, with average and coefficient of variability values (COV) provided, and assumes log-normal distributions of the actual values. If these uncertainty options are selected, the model randomly selects a value of the parameter from this distribution for each rain event. The long-term simulations therefore result in calculated concentrations and loadings of the constituents and the runoff volumes that vary in a similar manner as observed during monitoring. For the calculations in this report, when different options are being compared, the Monte Carlo option was not used as that may affect the average ordering of the different options. However, several different scenarios were repeatedly analyzed and the different concentrations and loads were examined to estimate the likely variability in the model outcomes.

The following table summarizes these results by showing the groups of constituents associated with different ranges of variability and uncertainty. As an example, WinSLAMM is able to predict the runoff volumes and particulate solids loads more accurately than the other constituents. With COV values (the relative standard deviations compared to the average values) of about 5% of the average values, the 95% confidence range of these constituents would be within about 10% of the average (for normal distributions, about 95% of the data is obtained within ± 2 times the standard deviation values). However, for zinc concentrations, the 95% confidence interval is about ± 20 to 30% of the average values. The bacteria data has an even wider range for the confidence interval, as expected (± 60 to 70% for *E. coli* and even wider for fecal coliforms). Therefore, when comparing the ranked sets of control programs that are sorted by expected *E. coli* reductions, control programs that are within about 30% of each other may be difficult to distinguish in practice. In contrast, runoff volume and TSS mass load reduction predictions are expected to be much more precise and it may be possible to distinguish control programs that are much closer.

COV (standard deviation as a percentage of average concentration)	
<5%	runoff volume Rv total and filterable TKN TSS
5 to 10%	total and filterable copper total and filterable lead nitrates
10 to 15%	total and filterable zinc total and filterable COD TDS
30 to 35%	*E. coli* bacteria total and filterable phosphorus
65%	fecal coliform bacteria

Analysis Results

The following subsections contain figures and tables summarizing the performance of the various control programs for each land use and for two soil conditions. The tables are ranked according to the control practice abilities in removing *E. coli*, which has a large coefficient of variability. Runoff volume reductions and TSS reductions are also plotted showing relative unit removal costs. This section shows these plots and summary tables by land use and for clay loam and sandy loam soil conditions at the infiltration devices. The general area soil conditions are all in the silt category, so the only differences based on the sandy loam or clay loam soil are for infiltration or biofiltration devices (not for disconnections, or any of the other practices). The land uses examined were from the land use surveys conducted in the watershed area and were described in the previous stormwater pollutant source report. The land uses include:

- Commercial areas:
  - Strip malls
  - Shopping center
- Light Industrial areas
- Institutional areas:
  - Schools
  - Churches
  - Hospitals
- Residential areas:
  - Low density
  - Medium density, constructed before 1960
  - Medium density, constructed between 1960 and 1980

As noted above, each of these nine land use areas were examined for clay loam (0.1 in/hr) and sandy loam (1 inch/hr) conditions in the infiltration/biofiltration devices. The designs were similar (as described previously), but the infiltration rates were changed to correspond to the soil conditions in the control devices themselves.

The following tables show the calculated runoff, TSS, and *E. coli* conditions for each scenario, and also the estimated costs (capital costs, land costs, maintenance costs, total annual costs, and total present value cost) and the unit removal costs for runoff (dollars per cubic feet removed, compared to the base conditions) and for TSS (dollars per pound removed, compared to the base conditions). The figures are scatterplots relating the calculated percent removals of these three stormwater constituents vs. the total annual costs (dollars per 100 acres per year). The most suitable stormwater control programs meeting the removal objectives at the least cost can be identified from these figures (also considering other factors affecting the selection process as described later such as groundwater contamination potential, maintenance requirements, suitability for retrofitting, etc.). As an example, the volume reduction plot for strip mall commercial areas having clay loam soils at the infiltration/biofiltration control locations indicates that several stormwater control programs are more cost-effective than others at similar levels of volume reductions. If the desired volume reduction was 25%, six of the stormwater control programs could meet this level of control, at least, as summarized in the following table:

Control Program for Commercial Strip Mall Land Use	Volume Reduction (% reduction compared to base conditions for clay loam conditions in the biofilters)	Volume Reduction (% reduction compared to base conditions for sandy loam conditions in the biofilters)	Total Annual Costs ($/100 acres/yr)
Porous pavement (in half of the parking areas)	25%	25%	$180,400
Curb-cut biofilters (along 80% of the curbs)	29	67	$166,500
Biofilters in parking areas (10 percent of the source area)	29	47	$314,000
Small wet pond plus biofilters in parking areas (10 percent of the source area)	29	47	$341,800
Biofilters in parking areas (25 percent of the source area)	40	not analyzed for sandy loam conditions	$785,000
Small wet pond plus biofilters in parking areas (10 percent of the source area) and curb-cut biofilters (along 40% of the curbs)	43	80	$424,600

The least costly option having at least 25% runoff reductions is shown to be the curb-cut biofilters along 80% of the curbs. This option is expected to result in about 29% runoff volume reductions with clay loam soil conditions, so theoretically, the application of this control could be reduced somewhat with some further cost savings (to about 70% of the curbs and $143,500). In this example, the use of porous pavement on half of the parking areas would result in about 25% runoff volume reductions (right at the removal goal), but at about 25% increased costs. This larger cost may be justified if other factors are important. It would be very challenging to install this many curb-cut biofilters, for example; however, the biofilters could be more easily maintained and retrofitted in an existing area and offer some additional protection to the groundwater. The other controls are all likely to be substantially more costly. Using parking lot island biofilters (that are about 10 percent of the paved area in size) would cost almost twice compared to the curb-cut biofilters. Adding a small wet pond adds costs but would not provide any additional runoff volume reductions (but would provide additional sediment reductions). Increasing the size of the parking lot island biofilters to 25% of the paved parking drainage areas (very large) would result in substantially greater runoff volume controls (up to about 40%), but at 2.5 times the cost of the smaller (or fewer) parking lot biofilters. Adding a small wet pond to the fewer parking lot biofilters, plus using some curb-cut biofilters results in the largest runoff volume reductions expected for the alternatives examined. If only runoff volume (and filterable pollutants) were of consideration, but at a higher control level, it would be worthwhile to also examine this last option without the pond (this would provide the same 43% calculated reductions, but the annual costs would be reduced to slightly less than $400,000 per 100 acres per year, or about 2.8 times the least cost option for 25% control, with an associated increase in performance of about 1.7 times. The declining unit cost returns with increasing removals are obvious on the plots. However, if the larger removal rates are needed, the more costly control options would likely be needed.

As noted on the further plots, the same size of controls in a sandy loam area has the same annual costs for the same stormwater control programs as for clay soil conditions, but the performance is substantially greater for programs using infiltration or biofiltration devices. The porous pavement benefits do not change as the clay loam soil is sufficient to remove the same amount of runoff due to the storage volume provided. The large 25%

biofilter areas were not evaluated for sandy soil conditions as they would not likely be used. The runoff volume removal rates for the other control programs are expected to be about double with sandy loam soils compared to clay loam soils for this land use, at the same annual costs.

Detailed information for all constituents examined (runoff volume, Rv, TSS, TDS, total and filterable phosphorus, nitrates, total and filterable TKN, total and filterable COD, total and filterable copper, total and filterable lead, total and filterable zinc, fecal coliform bacteria, and *E. coli* bacteria) is presented for each land use and soil combinations for each set of stormwater controls in the appendix.

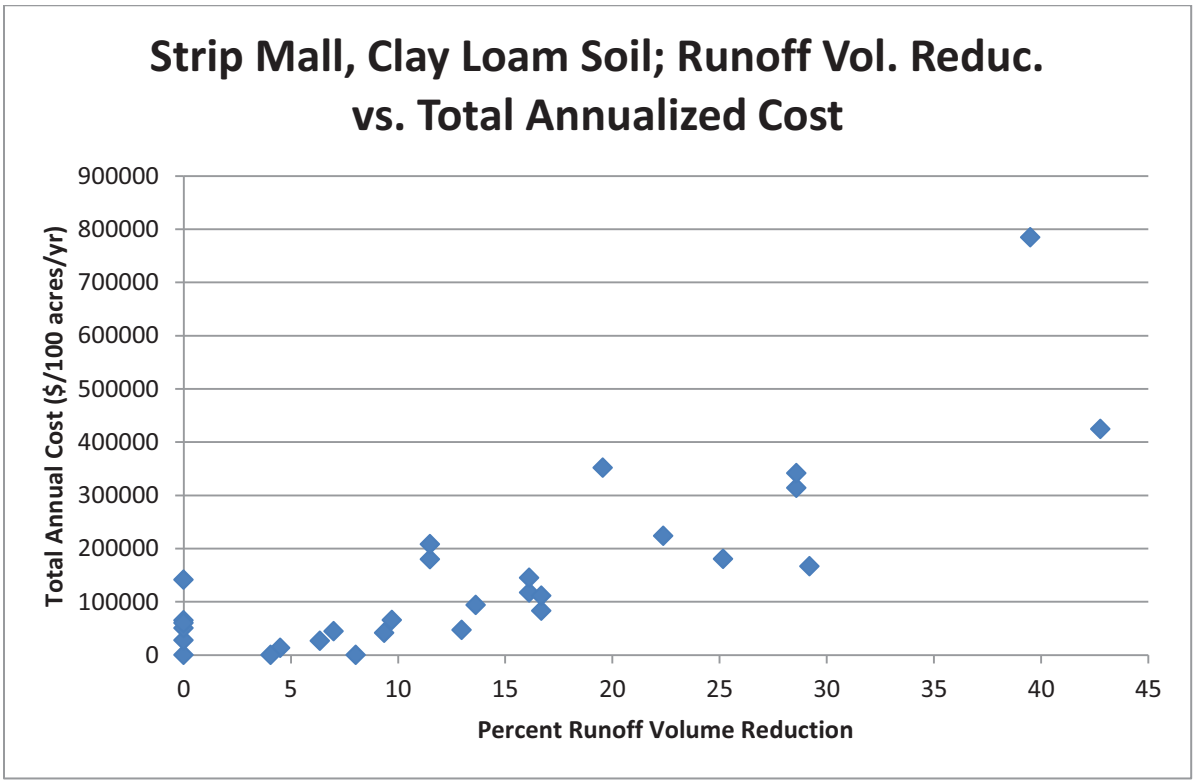
Each appendix table lists the amounts and concentrations expected for a homogeneous 100 acre site for four years of rains. The total amounts therefore represent these conditions. As an example, on the first appendix table, the first line shows the information for the base condition (from the land use land cover survey) for the strip mall commercial areas. The total runoff volume shown is 25,715,040 ft^3 (it was not possible to show many of these total yield values with an appropriate number of significant figures in these tables). The 25.7 million cubic feet of runoff represents the total amount of runoff expected for a 100 acre site exposed to all of the rains occurring in the 4 year test period of rainfall. The sum or yield values therefore need to be reduced by 1/400 to obtain the annual runoff or discharge amounts from one acre for one year. The annual unit acre runoff quantity for this condition is therefore about 64,300 ft^3/acre/year. This is shown to represent about 64% of the total rainfall quantity that fell on this site. The concentration values shown on these appendix tables are not affected by the size of the area or the length of the rain record, but the long records result in more reasonable flow-weighted average values with smaller effects from extreme events that may occur. As an example, the base condition is expected to have a total suspended solids (TSS) concentration of about 410 mg/L, with a total discharge of about 660,000 lbs of TSS for 100 acres over 4 years (or 1,640 lbs/ac/yr). During the 4 year study period, a total of 107.41 inches of rain fell during 340 separate rain events. The largest single rain was 2.63 inches in depth, and the average rain was 0.32 inches.

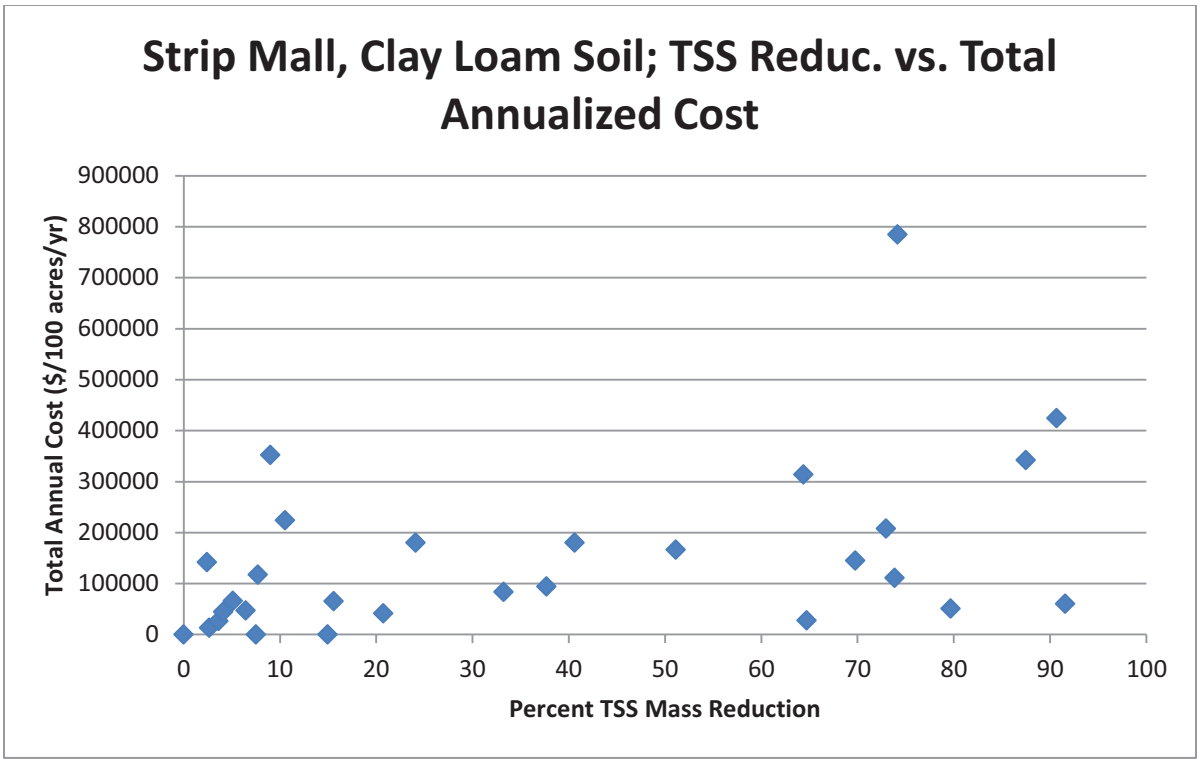
In most cases, total and filterable forms of each pollutant are shown. The control practices were previously described, along with the combinations examined. Also, clay loam and sandy loam soil conditions are examined for each case. The performance of the alternative control programs can be assessed by examining the resulting loadings and concentrations. The filterable forms of the contaminants are reduced through volume reducing infiltration practices (biofilters at parking areas, curb-cut biofilters, disconnected impervious areas, porous pavement, rain gardens, grass swales), plus the beneficial use practices (rain barrels and rain tanks), and combinations of these practices. The particulate-bound pollutants are removed by these same practices, plus the sedimentation practices (wet detention ponds), and the catchbasin and street cleaning public works practices. The removal of the specific pollutants is therefore highly dependent on how the pollutant partitions between the particulate-bound phase and the filterable phase. The bacteria, even though traditionally captured on a small aperture filter, are treated as filterable constituents for these analyses. Some of the bacteria are bound to small particulates and tend to migrate with those materials. Therefore, the calculated bacteria conditions are conservative, with somewhat additional reductions expected.

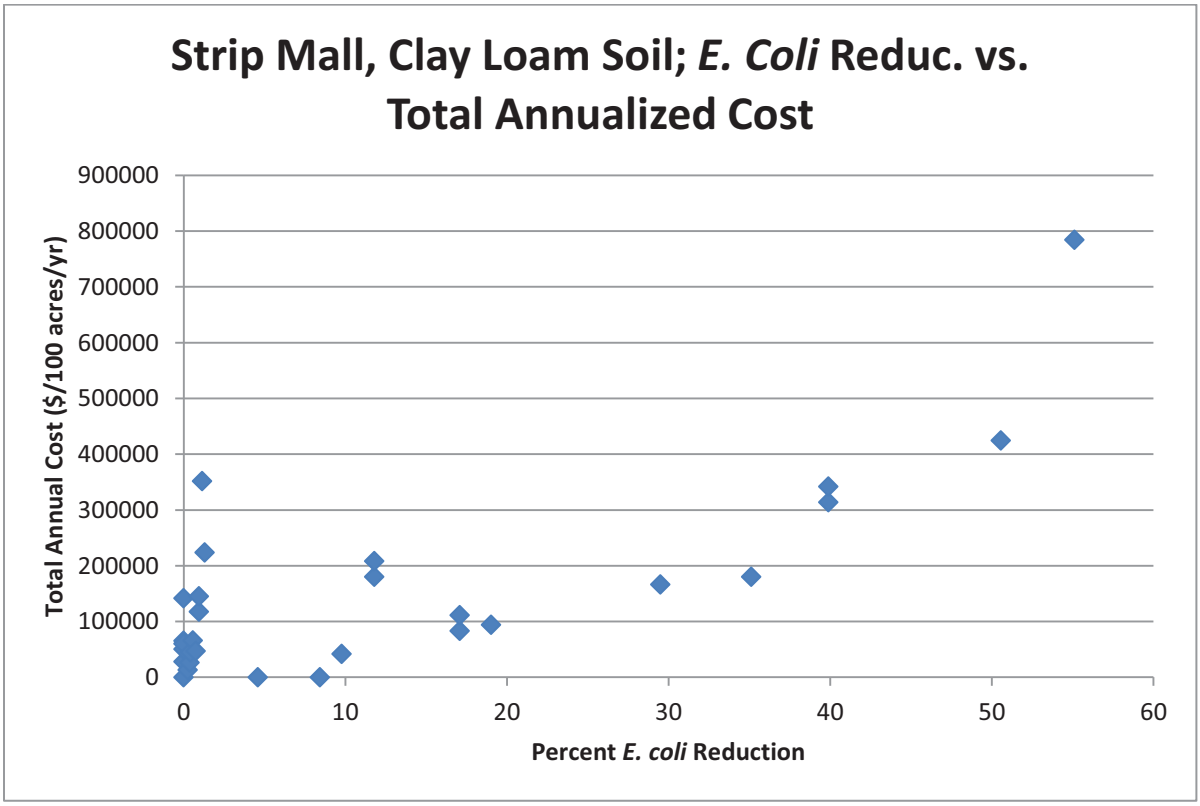
When examining the performance options, it is seen that the mass discharges always decrease, unless a control program option is very inefficient, or for filterable pollutant concentrations for an option that only affect particulate-bound pollutants (such as street cleaning). However, the resulting concentrations after control by some options may actually be seen to increase. An example is for a roof runoff volume reducing control (such as rain gardens) for a pollutant that has low concentrations in roof runoff compared to other source areas. As that cleaner water is infiltrated (always a good idea to minimize groundwater contamination issues), the remaining load of that constituent from all areas is transported with less water, resulting in a higher concentration, even if

the water volume reduction is large. However, the load reduction should still decrease, corresponding to the pollutant content of the infiltrating roof runoff.

Commercial: Strip Mall Land Use
Clay Loam Soil Conditions




Strip Mall, Clay Loam Soil; TSS Reduc. vs. Total Annualized Cost
Total Annual Cost ($/100 acres/yr)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
0
10
20
30
40
50
60
70
80
90
100
Percent TSS Mass Reduction


Strip Mall, Clay Loam Soil; *E. Coli* Reduc. vs. Total Annualized Cost
Total Annual Cost ($/100 acres/yr)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
0
10
20
30
40
50
60
Percent *E. coli* Reduction

Commercial Strip Mall Land Use, Clay Loam Soil, Sorted by *E. coli* Removal (costs are per 100 acres)

File Name	Rv	Biological Condition	Runoff Volume Percent Reduction	Particulate Solids Yield Percent Reduction	*E. coli* Yield Percent Reduction	Particulate Solids Concentration (mg/L)	Capital Cost	Land Cost	Maintenance Cost	Total Annual Cost	Total Present Value Cost	Cost per cubic foot Runoff Volume Reduced ($/cf)	Cost per pound Particulate Solids Reduced ($/lb)
01 strip mall Linc base	0.64	Poor	n/a	n/a	n/a	410	n/a	n/a	n/a	n/a	n/a	n/a	n/a
01 strip mall Linc CB	0.64	Poor	0	16	0	346	566,626	0	19,620	65,088	811,134	-	2.52
01 strip mall Linc pond 085 perct	0.64	Poor	0	65	0	145	251,151	9,938	6,907	27,857	347,165	-	0.26
01 strip mall Linc pond 17 perct	0.64	Poor	0	80	0	83	463,123	19,875	11,783	50,540	629,841	-	0.38
01 strip mall Linc pond 34 perct	0.64	Poor	0	92	0	34	535,234	39,750	14,170	60,308	751,573	-	0.40
01 strip mall Linc street cleaning daily	0.64	Poor	0	2	0	400	26,560	0	139,412	141,543	1,763,935	-	35.42
01 strip mall Linc rain barrels few	0.61	Poor	5	3	0	418	88,474	10,000	5,270	13,172	164,154	0.05	2.99
01 strip mall Linc rain barrels	0.60	Poor	6	4	0	422	176,948	20,000	10,541	26,344	328,308	0.06	4.39
01 strip mall Linc roof rain garden 3 perct clay loam	0.60	Poor	7	4	0	422	266,024	75,069	17,432	44,802	558,331	0.10	6.59
01 strip mall Linc rain barrels many	0.58	Poor	10	5	1	430	442,371	50,000	26,352	65,861	820,770	0.10	7.75
01 strip mall Linc rain tanks small	0.56	Poor	13	6	1	440	294,581	41,667	19,942	46,923	584,766	0.06	4.39
01 strip mall Linc rain tanks	0.54	Poor	16	8	1	451	736,452	104,167	49,854	117,308	1,461,915	0.11	9.18
01 strip mall Linc sml pnd and rain tanks	0.54	Poor	16	70	1	148	987,603	114,104	56,761	145,165	1,809,080	0.14	1.25
01 strip mall Linc rain tanks large	0.52	Poor	20	9	1	463	2,209,356	312,500	149,563	351,924	4,385,745	0.28	23.60
01 strip mall Linc roof rain garden 15 perct clay loam	0.50	Poor	22	11	1	472	1,330,119	375,344	87,159	224,010	2,791,656	0.15	12.82
01 strip mall Linc half disconnected	0.61	Poor	4	8	5	395	0	0	0	0	0	0.00	0.00
01 strip mall Linc disconnected	0.59	Poor	8	15	8	379	0	0	0	0	0	0.00	0.00
01 strip mall Linc curb biofilters 20 clay loam	0.58	Poor	9	21	10	358	283,417	3,444	18,601	41,619	518,670	0.07	1.21
01 strip mall Linc swale clay loam	0.57	Poor	11	24	12	351	1,613,577	0	50,678	180,156	2,245,143	0.24	4.51
01 strip mall Linc sml pond	0.57	Poor	11	73	12	125	1,864,728	9,938	57,586	208,014	2,592,308	0.28	1.72

and swale clay loam													
01 strip mall Linc curb biofilters 40 clay loam	0.53	Poor	17	33	17	328	566,833	6,887	37,202	83,239	1,037,339	0.08	1.51
01 strip mall Linc sml pnd and curb biofilters 40 clay loam	0.53	Poor	17	74	17	129	817,984	16,825	44,109	111,096	1,384,504	0.10	0.91
01 strip mall Linc biofilt parking 3 perct clay loam	0.55	Poor	14	38	19	295	572,422	137,126	37,181	94,117	1,172,910	0.11	1.51
01 strip mall Linc curb biofilters 80 clay loam	0.45	Poor	29	51	30	283	1,133,666	13,774	74,404	166,478	2,074,678	0.09	1.96
01 strip mall Linc porous pvt parking half clay loam	0.48	Poor	25	41	35	325	2,158,148	0	7,223	180,398	2,248,161	0.11	2.68
01 strip mall Linc biofilt parking 10 perct clay loam	0.46	Poor	29	64	40	204	1,909,465	457,420	124,029	313,954	3,912,554	0.17	2.94
01 strip mall Linc sml pnd and biofilt parking 10 perct clay loam	0.46	Poor	29	87	40	72	2,160,616	467,357	130,936	341,811	4,259,720	0.18	2.36
01 strip mall Linc sml pnd and park biofilt 10 perc and curb biofilters 40 clay loam	0.37	Poor	43	91	51	67	2,721,929	474,244	168,138	424,607	5,291,539	0.15	2.82
01 strip mall Linc biofilt parking 25 perct clay loam	0.39	Poor	40	74	55	175	4,771,573	1,143,049	309,936	784,540	9,777,105	0.31	6.38