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Assessment of Total Suspended Solids and Total Phosphorus Removal by Wetlands and Best Management Practices in Lincoln, Nebraska

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Assessment of Total Suspended Solids and Total Phosphorus Removal by Wetlands and Best Management Practices in Lincoln, Nebraska

By:

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Abstract

The availability and quality of local surface and ground water, as well as water in the world's oceans is essential to all. Urbanization brings with it changes in landscape that decreases soils capacity for infiltration of rain, and increase contaminants found in runoff conveyed to surface waters including oceans. Stormwater runoff occurs with small to large size rain events, flowing over a diverse range of impermeable surfaces removing and carrying with it total suspended solids (TSS) and total phosphorus (TP). For these reasons, best management practices (BMPs) were developed, and integrated into existing and future development. The objective is to identify what forms of wetlands and BMPs are used in Lincoln, Nebraska for stormwater management; assessing effectiveness in treatment of stormwater runoff. This assessment will examine the use of BMPs in preventing or reducing runoff by increasing infiltration of rainwater into soil, and investigate the efficiency of wetlands and BMPs in removing TSS and TP. Finally, it will evaluate the influence of flow rate on the effectiveness of wetlands and BMPs water adsorption rate.

Introduction

The City of Lincoln, Nebraska has for the past few decades, worked to improve the quality and quantity of water by implementing a program utilizing existing wetlands, and Best Management Practices (BMPs) for redeveloping established neighborhoods, business areas, and new developments (SDDS, 2015). Stormwater management BMPs are designed to intercept runoff flowing toward surface waters, removing or reducing contaminants transported from impermeable surfaces. This program is intended to comply with a federal law meant to reduce the pollutants found in stormwater runoff from entering receiving waters (SDDS, 2015).

The number of people living in cities is growing, expanding the area covered by impermeable surfaces, and increasing the volume of stormwater runoff flowing into SW (Zhang, et al, 2012, Paul & Meyer, 2001). Stormwater runoff flows off impermeable surfaces such as the roofs of homes and businesses, parking lots, streets, sidewalks, and driveways. Runoff combines as collected surface water when it drains from impermeable surfaces moving through green spaces, down streets, open storm drains, the rainwater management system, and into local surface waters (SW). One might not see the harm in letting the rain water flow over the urban landscape and into SW, but there is a negative aspect to it. Stormwater runoff contains total suspended solids (TSS): metals, pesticides, organic contaminants, nutrients and ions reducing concentration of oxygen in water (Paul & Meyer, 2001). Heated by impervious covers, it results in rising stream temperatures (Paul & Meyer, 2001), increased turbidity, a reduction of aquatic species, and plant growth (Weiss et al., 2005).

Several materials used in construction and maintenance of city green spaces and infrastructure contain chemicals not meant to be released into the environment outside the area of intended use (Krause et al., 2006). These chemicals are dissolved by rain or contained in small particles carried away in runoff. Chemicals found in lawn and garden fertilizer, adsorbed by soil, such as phosphorus (P), undergo desorption when it interacts with rain and runoff (Sharpley, 1985), and is one of the main pollutants carried away by runoff (Paul & Meyer, 2001).

When P enters bodies of surface water, it contributes to the overgrowth of cyanobacteria that produce toxins able to interfere in the growth and development of aquatic species (Ricklefs & Relyea, 2014), and a lethal poison to humans and animals. As bacteria and zooplankton consume the available oxygen necessary for fish and other aquatic species, it creates a dead zone causing significant animal die offs (Ricklefs & Relyea, 2014). A well-known example of this phenomenon on a large scale is the Dead Zone in the Gulf of Mexico. Urban runoff not treated prior to entering the river system of the Mississippi watershed region will eventually flow into the Gulf of Mexico. The size of the dead zone in the gulf fluctuates through the year, increasing in size during the summer at the height of growing season, and decreasing in size through winter months (Ricklefs & Relyea, 2014). To put size into perspective, the dead zone expands to cover 22,000 km^2 roughly the size of New Jersey (Ricklefs & Relyea, 2014). Researchers have studied stormwater runoff for decades to understand its influence on the environment, how to reduce its negative effects, and ways to utilize it as a resource. As more is discovered from each study, new technologies and methods are created and applied in newly developed areas to amend how it is managed.

Historically, the availability of fresh water was believed to be plentiful, a resource that is available as is needed (Golin, et al, 2015). However, fresh water is only a tiny fraction of Earth's total volume of water, and its preservation depends on how people treat it and use it. Saltwater present in Earth's oceans equals 97.5% of the total volume, leaving 2.5% as freshwater (ICA, 2012). Over two-thirds of freshwater is stored as ice in glaciers and permafrost, less than one-third is held in confined and unconfined aquifers, lakes, and rivers while the rest exists in the atmosphere, vegetation, and as soil moisture (ICA, 2012). Of this tiny fraction of freshwater in GW and SW accessible for use the majority of it is used for agriculture, and what remains is utilized for industry, generating power, and domestic use including water for cooking and drinking (ICA, 2012).

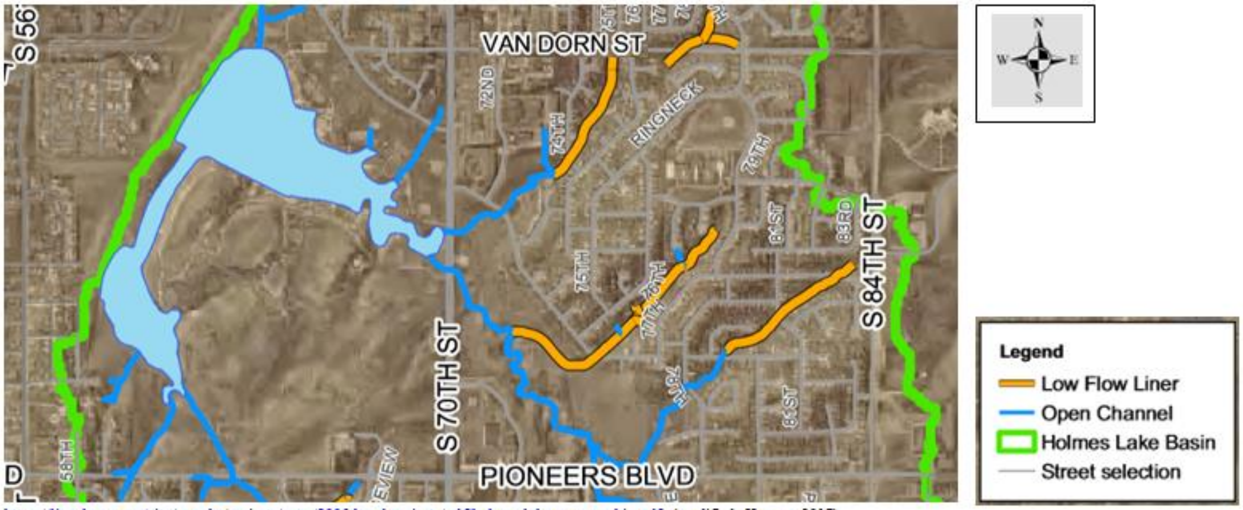
Lincoln's average annual rainfall is 28.94 inches, with the heaviest rainfall occurring between the months of April and September (U.S.C.D., 2018). Most years there is adequate rainfall to sustain vegetation, allow infiltration, and maintain soil water storage. Lincoln has even experienced 17 major floods in the past 118 years (CLWM, 2018). Still droughts do occur. In 2012 Lincoln experienced a flash drought, accumulating 19.14 inches total precipitation (Dewey, 2018). Vertical soil movements occur as a response to soil moisture levels, an increase in moisture causes the soil to swell, and a decrease will cause it to shrink or subside (Corti et al., 2011). This movement can affect the integrity of buildings and infrastructure, reinforcing the necessity for rainwater infiltration to maintain optimal soil moisture content.

In the past, the main priority of stormwater management was to move water away from developed areas, guarding against flooding that would do damage. Stormwater was viewed as an inconvenience, not a valuable resource (CLWM, 2018). Water levels will decline when rainfall, a major source of local water, is not given the time and environmental conditions to recharge aquifers (McGuire, 2014). Over time, the philosophy regarding stormwater changed to adapt to current needs for freshwater, and new technologies are being developed to harvest runoff giving groundwater time to recharge (CLWM, 2018). The challenge is in removing TSS and TP from stormwater runoff prior to entering surface waters in rivers and lakes.

The objective is to identify wetlands and stormwater best management practices (BMPs) used in the 132.0 acres bordered by 70th St., Pioneers Blvd., and Holmes Park Rd. (Figure 3) in Lincoln, and assess their efficiency in removing TSS and TP in runoff. This will be accomplished by: 1) Determining the extent Lincoln utilizes wetlands, and stormwater BMPs to increase the infiltration of rain into the soil to prevent or minimize runoff. 2) Determine the efficiency of wetlands and stormwater BMPs in removing total phosphorus, and total suspended solids from stormwater runoff. 3) Assess the flow rate of stormwater runoffs influence on water adsorption.

Materials and Methods

SITE SELECTION



https://lincoln.ne.gov/city/pworks/projects/wsm/2005-bond-projects/pdf/holmes-lake-geomorphic.pdf (modified, Kouma, 2017)

Figure 1. Holmes Lake Watershed

This study took place inside city limits of Lincoln, NE, Lancaster County, on 132.0 acres of the northwest corner of 70th and Pioneers Blvd., Holmes Park Rd., Cooper Ave., S 76th St., and Lucile Dr. (Fig 1), meeting all research requirements. The first requirement is for urban areas utilizing wetlands, and BMPs to control stormwater runoff, and remove TSS and TP. Next, be in close proximity to contributors of TSS and TP commercial areas with customer parking lots, roads with moderate traffic flow, residential areas, and green spaces (Pitt, 2011, Smith, 2016). Finally, effluent waters from these sites, entering surface waters.

The size of area, and visual perspective of Google Earth, and soil map scale at 1:20,000 (U.S.EPA, 2016, Garrity, 2018, USDA 2018) required use of a drone or an unmanned aircraft system (UAS) to take photographs and video to assist in identifying wetlands and BMPs. At 7.21 miles distance from Lincoln’s airport, measured on Google Earth, this site met the required minimum distance of five miles from the airport to partially fulfill, Part 107 Operating Rules, regulations set by the Federal Aviation Administration (FAA) (U.S.DoT, 2018). Requirements for launch site: accessible by car, public access, walkable terrain, a clear and level launch area, and allows for clear visibility of the drone by the pilot. A launch point was found using Google maps, and previous knowledge of the area. Located near Holmes Park entrance on Cooper Ave, the launch point is northwest from the intersection of the two paths near the entrance. Flight days and times were selected for their absence of precipitation, and wind speeds under 15 mph. The flight altitude was 100 m, and camera angle variable to follow the terrain typically -45^o to -30^o down from the horizontal. Images and video footage were captured with a mini-UAV, a DJI Phantom 4 with 20mm f/2.8 camera (90^{o}FOV), 4000 x 3000 pixel stills, 4K video at 30 fps. Its system links smart phone to UAV allowing the operator to view video and images transmitted in real time with GPS-Enabled Return Home and Position Holding. Flight requirements followed are as stated in Part 107 Operating Rules (U.S. DoT, 2018).

DATA SOURCES

Drone video and images at this site were taken in late winter when tree foliage is at a minimum providing greater visibility to topography of the area, and used to identify wetlands and BMPs in coordination with Google Earth images. Pictures and video were taken by the drone along the length of Antelope Creek, starting at the north end of the site traveling south over Rickmans Run/Holmes Lake Dog Park, and returning to launch point. Other video and images of BMPs were taken by digital camera throughout the site in public spaces.

All measurements for distance and area are sourced from Google Earth, utilizing the ruler, and polygon tool or planimeter. Measurements taken by the polygon tool were converted to area by copying polygon files, transferring it to Earth Point – Tools for Google Earth, using "Polygon Area" under Worldwide Utilities, text box, select coordinates, and calculate result. Large areas were converted into acres, smaller areas into meters squared, totaled, and then converted into acres for greater accuracy. Dimensions for each cover type were tabulated, and total area for each cover recorded (appendix, tables 1-4). The final total area for each cover type was used to find total area for the study site, percent of impervious cover, runoff coefficients, and design storms peak runoff rates in acft as shown below.

% Impervious = Impervious Cover / Area of site
% Pervious = Pervious Area / Area of site
% Gravel, Crushed Rock, Riprap =
Gravel, Crushed Rock, Riprap / Area of site

Some areas, such as parking lots, required features subtracted from them to find more accurate dimensions. For this study, trees in the commercial area, and islands in the parking lots are assumed to be grass, and are part of "business lawns" data. A significant length of Antelope Creek was unobservable by Google Earth, or drone, due to heavy tree canopy, inaccessibility by foot, heavy vegetation, fencing, and other barriers. Because of this, and variability of width of the creek, area for length of the creek was incorporated into the cover type it was surrounded by. The visual perspectives available were used to evaluate sources, and possible directions of stormwater runoff flows throughout the site.

Collected data (see appendix tables 1-4), previous studies, peer reviewed literature, and manuals, will be used to evaluate: TSS and TP contributions, reduction and removal; routes taken from the urban environment through the site; wetlands and BMPs; and soil profile.

The United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS) Web Soil Survey's Area of Interest polygon feature mapped 131.7 acres, a close approximation to the Google Earth measurement 132.0 acres. The soil profile was sourced from USDA NRCS Web Soil Survey's Custom Soil Resource Report. This information was used to find the taxonomic classification of dominate soils for its hydrologic soil group (HSG) and area it covered, peak discharge rate, depth to water table, depth to restrictive feature, and slope to evaluate its effect on stormwater runoff (USDA NRCS, 2018, see appendix figure 4, tables 7-8).

The weighted average of the runoff coefficient (C) for type of cover and soils, and runoff curve (CN) for soils aided in evaluating runoff potential. C is an amalgamation of the properties affecting the volume of stormwater runoff, including infiltration, evaporation, retention, and interception (UDFCD, 2017). Smaller C values indicate an area with high infiltration capability, low runoff volume, minimal sloping, and well vegetated land (SWRCB, 2018). Larger values indicate low infiltration due to a greater area covered by impermeable surfaces, and steep slopes increasing the velocity of runoff (SWRCB, 2018). The Runoff Coefficient (C) gives insight into what percentage of rainfall has potential to infiltrate soil, how much may become runoff carrying with it TSS and TP, and the possibility for flash flooding (SWRCB, 2018). For all CN values the assumption is made that all pervious surfaces are considered to be grass in fair condition (Engineering-Purdue, 2018). The CN accounts for the HSGs ability to infiltrate soil, and possible runoff. Data for C and CN values came from the Denver, CO Urban Storm Drainage Criteria Manual, Lincoln (UDFCD, 2017), NE Alternative Stormwater Best Management Practices (COLNWM-S, 2018), Engineering Purdue (Engineering-Purdue, 2018), and PDH Online Course Estimating Storm Water Runoff (Poullain, 2012).

The Rational Formula (below) (Poullain, 2012) will be used for Design Storm Rainfall Intensities and Peak Runoff Rates to show the relationship between storm intensity and runoffs time spent in BMPs.

Weighted Average of C = Total from all (Area (acres) x C) / Total area of ground cover (acres)
Q = peak discharge in cubic feet per second (*cfs*)
C = Cover - Weighted Average of C (0.50)
i = Rainfall intensity factor (in/hr.)
A = Area (132.0 acres)
Q = C (i) (A)
Q = *cfs*

Results

The area northeast of the corner of 70th and Pioneers Blvd., a part of the Holmes Lake Watershed, has been part of an ongoing project to improve, and protect the quality of water conveyed to Lincoln's popular recreational lake (Kouma, 2017). This site employs a combination of traditional and alternative BMPs arranged to manage the flow of stormwater runoff, and remove total suspended solids (TSS), and total phosphorus (TP).

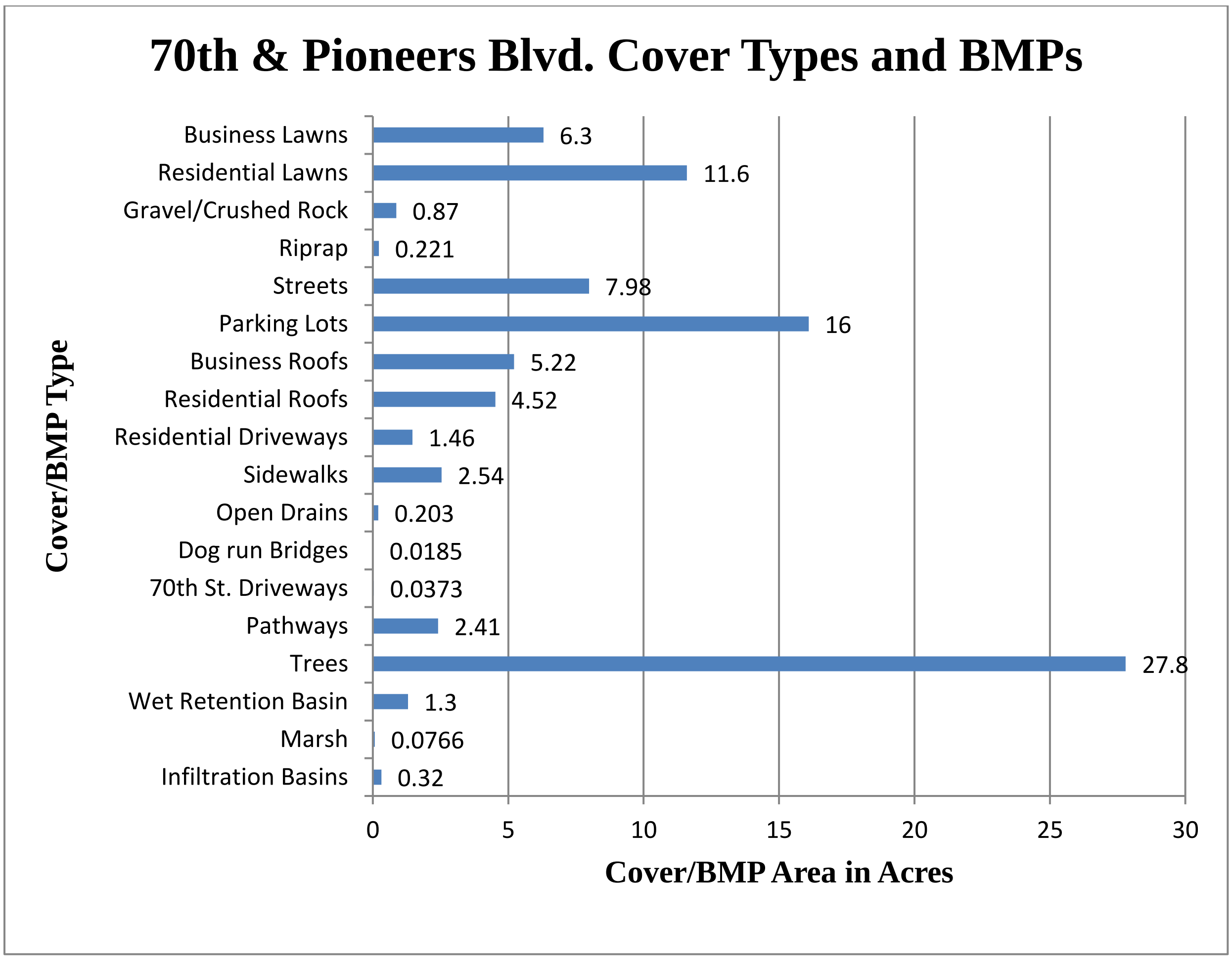


Figure 2. Breakdown of cover types, wetlands, BMPs, and the area they occupy.

- Traditional BMPs found: riprap, and conveyance structures such as open drains/low flow liners.
- Alternative BMPs found: wet retention basins, berm/swale with clover and other natural vegetation (included in total acres of green space), infiltration basin, wet retention marsh, trees, and natural vegetation.
- There is a combination of open areas covered by native grasses/plants with deeper roots providing an opportunity for infiltration of runoff, and turf grass with short root structure (COLNWM-S, 2018) unable to infiltrate rainwater like native grasses/plants, and increasing the amount of runoff (COLNWM-I, 2018).

Table 1: Impervious Cover Acres

Cover Type	**Area (Acres)**
Pathways	2.41
70th St. Driveways	0.0373
Dog run Bridges	0.0185
Open Drains(low flow liners)	0.203
Sidewalks	2.54
Residential Driveways	1.46
Residential Roofs	4.52
Business Roofs	5.22
Parking Lots	16.1
Streets	7.98
Total Acres	**40.5**

Table 2: Pervious Cover Acres

Cover Type	**Area(Acres)**
Lots	0.852
Infiltration Basins	0.32
Swales	0.36
Wet Detention Marsh	0.0766
Wet Retention Basins	1.30
Trees	27.8
Residential Lawns	11.6
Business Lawns	6.30
Total Acres	**48.6**
Riprap	0.22
Gravel/Crushed Rock	0.87
Total Acres	**1.09**

In Tables 1-2, each cover type classified, and acres totaled for Impervious Cover or Pervious Cover. The acres covered by riprap, gravel, and crushed rock are grouped together to make the distinction between what is covered by a solid, constructed, impervious cover, and a collection of impervious units (Figure 3).

Total Acres for 70th & Pioneers Location.....132.0

Total Acres of Impervious Surfaces........(-) 40.5

Total Acres of Gravel/Crushed Rock........(-) 1.09

Total Acres of Green Space....................90.4

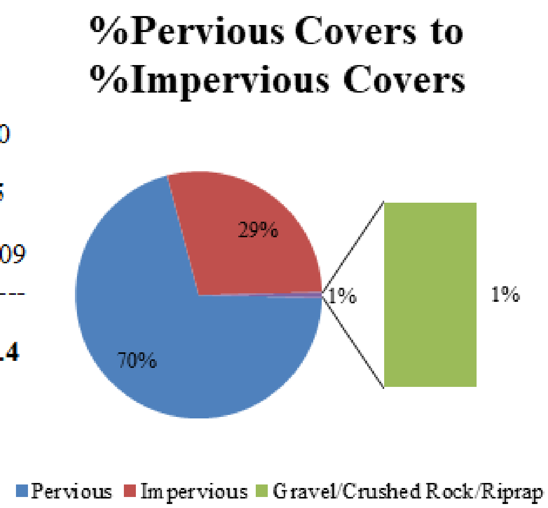


Figure 3.

Local data for TSS and TP from Antelope Creek Watershed Basin Management Plan Section 6 –Pollution Sources and Control Strategies (2018) breaks down sources and contributions of TSS and TP for the sizes of rain events: small (<0.5 inches), medium (0.5-2 inches), large (>2 inches).

1) Total Suspended Solids: % Contributed by rainfall event size for Residential - Medium Density (1960-1980) (COLNWM6, 2018):
    a) Streets - small 90%, intermediate 86%, large 48%
    b) Landscaping - large 40%
2) Total Phosphorus: % Contributed by rainfall event size for Residential - Medium Density (1960-1980) (COLNWM6, 2018):
    a) Streets - small 85%, intermediate 58%, large 15%
    b) Landscaping – intermediate 34%, large 79%
3) Total Suspended Solids: % Contributed by rainfall event size for Commercial shopping center (COLNWM6, 2018):
    a) Paved parking - small 84%, intermediate 84%, large 66%

b) Roofs - small 12%, intermediate 13%, large 24%

4) Total Phosphorus: % Contributed by rainfall event size for Commercial shopping center (COLNWM6, 2018):

a) Paved parking - small 61%, intermediate 54%, large 31%

b) Roofs - small 33%, intermediate 33%, large 28%

c) Landscaping - Large 34%

The traditional and alternative BMPs used are structured with qualities to meet specific needs for this location. Their purpose to slow the velocity of stormwater runoff to extend time spent in BMPs to maximize its ability to remove and reduce the TSS, and TP before conveying runoff to surface waters.

1) Wet Retention Basins capture high volume runoff, holding it for extended periods of time to gravity settle solids, using vegetation and microorganisms to remove nutrients and organics (Weiss et al., 2007). The outlet is positioned higher to maintain a permanent volume of water covering the floor of the basin between runoff events (Weiss et al., 2007).

a) TSS Removal Efficiency – 90%, from drainage area of 12.4-618 acres at <6% slope (Shammaa & Zhu, 2001), 65% with a 67% confidence interval of +/- 32 (Weiss et al., 2005).

b) TP Removal Efficiency – expected typical removal 30% – 65%, median efficiency of dissolved P 34% (Weiss et al., 2005).

Locations:

c) Between Diamond Ct. and Pioneers Blvd.

i) Sources of TSS – drains from adjacent streets, from landscaping in large rain events (COLNWM6, 2018).

ii) Sources of TP – residential lawns along its border, and from neighborhood to the east connected by drain beneath S 76th St., drains from adjacent streets, driveways (COLNWM6, 2018).

iii) The slope for this site is at 0-2%, well within the appropriate range for this structure (USDA/NRCS, 2018). It lies within the moderately well drained hydrologic soil group (HSG) B Nodaway silt loam, depth to the water table is between 36-72 inches, and its depth to restrictive feature is >80 in. (USDA/NRCS, 2018).

d) Between Hamann Meadows Pl., S 76th St., and Crystal Ct.

i) Sources of TSS – drains from adjacent streets, from landscaping in large rain events (COLNWM6, 2018).

ii) Sources of TP – residential lawns along its border, drains from adjacent streets, from landscaping in large rain events (COLNWM6, 2018).

iii) The majority of this site is at 0-1% slope, well within the appropriate range for this structure, but falls in the HSG D, Butler silt loam, is rather poorly drained due in part to the depth of the water table range of 6-18 inches, but its depth to restrictive feature is >80 in. (USDA/NRCS, 2018, Mockus, 2007). HSG C Judson silt loam covers about a fifth of the area, which is reasonably well drained, with a slope range of 2-6%, depth to the water table is >80 inches, and its depth to restrictive feature is >80 in. (USDA/NRCS, 2018, Mockus, 2007). The drain is located in the top half level of the basin, which may compensate for the reduced ability of water to infiltrate soil.

2) Infiltration Basins capture stormwater runoff to reduce flooding, water is then filtered through existing soil and/or filtration media to enter groundwater (Weiss et al., 2005).
   a) TSS Removal Efficiency – 70%, no slope limit (Shammaa & Zhu, 2001).
   b) TP Removal Efficiency – 50-80% (Weiss et al., 2005).

   Location:

   c) West of the homes at the intersection of Holmes Park Rd. and Raven Cir.
      i) Sources of TSS – an open drain with possible connection to Holmes Park Rd., residential landscaping (COLNWM6, 2018).
      ii) Residential landscaping, drains from adjacent streets (COLNWM6, 2018).
      iii) The basins are found to be in HSG C Judson silt loam on a 2-6% slope, and is well drained due to water table depth of >80 inches, and its depth to restrictive feature is >80 in. (USDA/NRCS, 2018, Mockus, 2007).
3) Berm/swale with clover and other natural vegetation (included in total acres of green space) captures and directs sheet flow (NJSBMPM, 2004), and is a filter treatment for other downstream BMPs (Shammaa & Zhu, 2001).
   a) TSS Removal Efficiency – 70%, drainage area <12.36 acres, <5% slope (Shammaa & Zhu, 2001).
   b) TP Removal Efficiency – typical P removal 15-45% (Weiss et al., 2005).

   Location:

c) Along the east side of the main crushed rock dog run path, continuing east on the eastern most section of the path, and is roughly 335 meters in length.

i) Sources of TSS - an open drain with possible connection to Holmes Park Rd., residential landscaping (COLNWM6, 2018), infiltration basin overflow.

ii) Sources of TP - residential landscaping, drains from adjacent streets (COLNWM6, 2018).

iii) A majority of the swale was found to be in HSG C Judson silt loam on a 2-6% slope, is well drained with the water table depth of >80 inches, and its depth to restrictive feature is >80 in. (USDA/NRCS, 2018, Mockus, 2007). The other portion rested on HSG D Butler silt loam, on a slope of 0-1%, is poorly drained at 6-18 inches above the water table, and its depth to restrictive feature is >80 in. (USDA/NRCS, 2018, Mockus, 2007).

4) Wet Detention Marsh (wetlands) a wildlife habitat that maintains a permanent volume of water to support the wetland vegetation, and channels, and effluent moves slower than inflow waters (Weiss et al., 2005, Shammaa & Zhu, 2001).

a) TSS Removal Efficiency – 90%, >12.36 acres, =5% of the watershed area, <6% slope (Shammaa & Zhu, 2001).

b) TP Removal Efficiency - typical TP removal 15-45% (Weiss et al., 2005)

Location:

c) On the North end of the site bordered by 70th St., Holmes Park Rd., and Rickman's Dog Run gravel parking lot.

i) Sources of TSS - Rickman's Dog Run gravel/crushed rock parking lot, adjacent streets (COLNWM6, 2018). The wet retention pond connected by drain under Holmes Park Rd. in the adjacent neighborhood.

ii) Sources of TP – adjacent streets, driveways, residential landscaping (COLNWM6, 2018). The wet retention pond connected by drain under Holmes Park Rd. in the adjacent neighborhood.

iii) The slope for this site is at 0-2%, well within the appropriate range for this structure (USDA/NRCS, 2018). It lies within the moderately well drained hydrologic soil group (HSG) B Nodaway silt loam, its depth to the water table is between 36-72 inches, and its depth to restrictive feature is >80 in. (USDA/NRCS, 2018, Mockus, 2007).

5) The majority of trees here grow in uncompacted soil, with opportunity to reduce total phosphorus concentrations by 72% when compared to trees growing next to buildings and sidewalks, and removal of orthophosphate could be between 70-82% (Page et al., 2015). Forested areas serve as barriers to runoff flows, reduce duration of floods (Paul & Meyer, 2001), and protect the understory of native vegetation (Von Behren et al., 2013). Location:

a) Found throughout the site.

i) Sources of TSS – Paved parking lots, roofs, streets, landscaping (COLNWM6, 2018)

ii) Sources of TP – Paved parking lots, streets, roofs, landscaping, driveways (COLNWM6, 2018)

6) Vegetation, especially native plants with deep roots, leave behind macro-pores as they grow and eventually die and decay creating passages for water to infiltrate (COLNWM-S, 2018), increase sorption of TP onto soil particles, and uptake into plants (Hickey & Doran, 2004). The speed of the stormwater flow is also reduced when vegetation ground cover is dense; increasing the time it has to infiltrate (COLNWM-S, 2018).

   Location:

   a) There is a combination of open areas throughout the site covered by native grasses/plants with deeper roots providing an opportunity for infiltration of runoff, and turf grass with short root structure (COLNWM-S, 2018) unable to infiltrate rainwater like native grasses increasing the amount of runoff (COLNWM-I, 2018).

7) Conveyance structures such as open drains/low flow liners are used to reduce erosion and transport of soil.

   Locations:

   a) At the intersection of Holmes Park Rd. and Cooper Ave. and terminating at the border of the dog run, emptying onto riprap before entering Antelope Creek an estimated 31 meters away.
   b) Originates at the west side of the properties at the intersection of Holmes Park Rd. and Raven Cir., and terminating at the dog run fence line, emptying into the infiltration basins.

8) Riprap was found along the length of Antelope Creek to control erosion, bank stabilization, and reduce speed of stormwater runoff.

The weighted average runoff coefficient for this site from Table 3 is 47%, and used to find the CN value for hydrologic soil groups (HSGs) present. The CN values for three of the four HSGs found to be within the sites borders shown in Table 4. Group B soils are comprised of 10-20% clay, 50-90% sand, it can also contain loamy sand or sandy loam textures, and other components if combined well, when fully wet have relatively low runoff potential (USDA/NRCS, 2018). Group C soils are comprised of 20-40% clay, <50% sand, it can also contain loam, silt loam, sandy clay loam, clay loam, silty clay loam textures and other

Cover Types Weighted Average C and Soils Weighted Average CN

Type of Cover	**Area (Acres)**	**C**	**Area x C**
Paved: streets, sidewalks/pathways, parking lots	19.3	0.95	18.3
Roofs : business, residential	9.74	0.90	8.77
Driveways	1.50	0.90	1.34
Gravel	0.87	0.40	0.35
Woodland : trees	27.8	0.10	2.78
Lawns Business and Residential	17.8	0.15	2.68
Vegetated Areas	55.0	0.5	27.5
Covers - Total Area	**132.0**	**Total**	**61.7**
Type of Soil	**Area (Acres)**	**CN**	**Area x CN**
3713 Butler silt loam D	16.7	90.58	1512.69
7050 Kennebec silt loam C	10.6	87.96	932.376
7206 Aksarben silty clay loam C	6.2	87.96	545.352
7227 Burchard clay loam D	11.9	90.58	1077.9
7231 Judson silt loam C	13.9	87.96	1222.64
7501 Pawnee clay loam D	12.9	90.58	1168.48
7684 Wymore silty clay loam D	16.8	90.58	1521.74
7867 Nodaway silt loam B	42.8	82.66	3537.85
Soils - Total Area	**131.7**	**Total**	**11,519**

(Engineering-Purdue, 2018, Poullain, 2012, SWRCB, 2018, USDA/NRCS, 2018)

Cover - Weighted Average of C
C = 61.7 / 132.0 = 0.47
% Impervious Cover: 47%

Soils - Weighted Average of CN
CN = 11,519 / 131.7 = 87.46
CN = 87.46 - Intermediate runoff potential

Table 4. CN values for Soil

Soil Types at 70th and Pioneers

Watershed	B	C	D
47% Impervious	82.66	87.96	90.58

(modified Engineering-Purdue, 2018)

variations if combined well, and when fully wet had a relatively high runoff potential (USDA/NRCS, 2018). Group D soils have >40% clay, <50% sand with clayey textures, and when fully wet have a high runoff potential (USDA/NRCS, 2018). Group D also has a high shrink-swell potential (USDA/NRCS, 2018). The weighted average CN in Table 3 was found to be 87.34, a roughly average or median value indicating an intermediate volume of runoff.

Slopes for soils range from 0% - 11%, the greater part of the area falls in the 0% - 6% slope. Low slopes slow flow rate increasing the effectiveness of BMPs used by extending the amount of time runoff is in BMPs. Other aspects of this site must also be taken into consideration, the soil profile may have been altered due to construction or natural processes since the soil survey was completed (USDA/NRCS, 2018).

Table 5. There is greater runoff potential with increasing storm size, showing increases in stormwater runoff from the HSGs.

	Storm Return Period C values					
NRCS Hydrologic Soil Group	**2 Year**	**5 Year**	**10 Year**	**25 Year**	**50 Year**	**100 Year**
A (47% Impervious)	0.32	0.33	0.35	0.38	0.43	0.48
B (47% Impervious)	0.31	0.34	0.40	0.51	0.56	0.62

C (47% Impervious)	0.36	0.42	0.48	0.58	0.63	0.68

(Engineering-Purdue, 2018, UDFCD, 2017)

Table 6. Design Storm Rainfall Intensities and Peak Runoff Rates for 70th and Pioneers 132.0 Acres

	Total Rainfall (in)	**1 hr Rainfall Intensity Factor (in/hr)**	**1 hr Q (*cfs*)**	**3 hr Rainfall Intensity Factor (in/hr)**	**3 hr Q (*cfs*)**	**6 hr Rainfall Intensity Factor (in/hr)**	**6 hr Q (*cfs*)**	**12 hr Rainfall Intensity Factor (in/hr)**	**12 hr Q (*cfs*)**	**24 hr Rainfall Intensity Factor (in/hr)**	**24 hr Q (*cfs*)**
1	0.5 [2,3]	0.5	31.02	0.17	10.36	0.08	5.15	0.04	2.61	0.021	1.30
2	1.0 [2,3]	1.0	62.04	0.33	20.66	0.17	10.36	0.08	5.15	0.042	2.61
3	1.5 [2]	1.5	93.06	0.5	31.02	0.25	15.51	0.13	7.76	0.063	3.91
4	2.0 [1,2]	2.0	124.1	0.67	41.38	0.33	20.66	0.17	10.36	0.083	5.15
5	2.5 [1,2]	2.5	155.1	0.83	51.68	0.42	25.87	0.21	12.90	0.104	6.45
6	3.0 [1,2]	3.0	186.1	1.0	62.04	0.5	31.02	0.25	15.51	0.125	7.76
7	3.5 [1,2]	3.5	217.1	1.2	72.4	0.58	36.17	0.29	18.12	0.146	9.06
8	4.0[1,2]	4.0	248.2	1.3	82.7	0.67	41.38	0.33	20.66	0.167	10.4
9	4.5 [1,2]	4.5	279.2	1.5	93.06	0.75	46.53	0.38	23.27	0.188	11.7
10	5.0 [1,2]	5.0	310.2	1.7	103.4	0.83	51.68	0.42	25.87	0.208	12.9

((1)Hershfield, 1963, (2)Pitt, 2011, SDDS, 2015, (3)NCDOACR, 2018)

The majority of the storms that occur are small (<0.5 in), but it is the intermediate (0.5-2 in) that is responsible for more than 75% of pollutant discharges by mass (Pitt, 2011). Meaning, intermediate events are capable of transporting more TSS and TP into SW if not intercepted by BMPs. These first flush events are what the BMPs are structured for (NCDOACR, 2018). Large events producing more runoff than small and intermediate events (Table 5) occur less frequently, structures managing the resulting channel forming flows would require a greater holding capacity, and cost more to treat a few events (COLNWM6, 2018). Table 6 compares the design storms total rainfall, rainfall intensity factors (in/hr), and corresponding cubic feet per second (cfs). Large rainfall events contribute a small fraction in number annually, but falling over a greater period of time the intensity factor and cfs resemble those of the intermediate level storm. It is unknown at this time, but it may be possible storms with an intensity of 3-5 inches per hour occur with less frequency than large storms with low intensity, which would support the decision made by the city to create BMPs capable of mitigating small and intermediate rain event runoff flows, and not large rain event runoff.

An estimation for 800-850 homes was made by using data from residential roofs, lawns, and driveways measured, then applying it to the area bordered by 70^{th}, Van Dorn St., 84^{th}, and Pioneers Blvd. inside the Holmes Lake watershed (Fig.1). It is not possible, in the scope of this research, to account for all impermeable surfaces in residential areas as they are not public property, and are out of control of the developer to know how it was developed after purchase (Krause et al., 2006). Any changes the homeowners have made will affect the imperviousness of the area, but calculations based on data generated do show the possible imperviousness of residential properties.

Based on single family residences the C value ranges between 0.30-0.50 (SWRCB, 2018). The C value results for estimated residential roofs, driveways, and lawns from tables 5-6 (see appendix) is mid-range at 0.41, an intermediate volume of runoff. If all cover types, and soil profile were included the value would increase. This information could be used to evaluate increases or decreases in stormwater runoff by residential pervious covers conveyed into the study site by concrete drains increasing the volume of water to be infiltrated, amount of TSS and TP to be filtered out, and sorbed. Research by Paul & Meyer (2001) supports data demonstrating an increase in imperviousness from urban development, also increases volume of runoff.

Stormwater management BMPs found were a combination of ones traditionally used to prevent erosion, and alternative methods used to reduce or remove total suspended solids (TSS), total phosphorus (TP), and increase infiltration time by holding it for 24-48 hours or use expansive areas to slow the flow of runoff using natural vegetation. The alternative BMP structures are meant to control high volume flow water, and remove high percentages of TSS and TP before reaching surface waters or ground water. Structures are positioned along the east side of Antelope Creek (see appendix figure 2) intercepting point source runoff from drains at Holmes Park Rd. and Raven Cir. emptying into infiltration basins, sheet flow runoff in residential areas flow towards infiltration basins and the berm/swale, and a portion of dog run runoff flows into the infiltration basin and berm/swale. The open concrete drain near the intersection of Holmes Park Rd. and Cooper Ave. ends just inside the fenced in dog run, emptying onto riprap, and into the creek 31 meters from its end.

The west side of the creek treats seven point source flows from the commercial area northeast of 70th and Pioneers Blvd. (see appendix figure 2). Two are open drains connected to the parking lot at the southeast corner of the commercial area spilling onto riprap, and the others convey runoff from parking lots through drains buried underground opening up onto riprap surrounded by forested and densely vegetated areas. The distance between the openings to the creek range from 35 meters to over 100 meters, relying on forested and vegetated areas to slow the speed of runoff, filter out TSS, and adsorb TP. It is unknown at this time, but it is possible for there to be structures in the drains assisting in removing larger solid particulate matter before emptying into the area which would further decrease TSS and TP released into the area.

Discussion

The data, literature, and peer reviewed sources support the City of Lincoln Watershed Managements wetlands and BMP selection utilizing forested areas, natural vegetation, soil profile, and slope of terrain in utilizing alternative BMPs to reduce and remove TSS and TP. This combination appears to be an effective method of removing and reducing the pollutants from stormwater runoff that passes through the BMPs providing they are well maintained. This was an assessment for a single location, not multiple sites throughout the city, but it does demonstrate the movement towards use of alternative BMPs to remove pollutants, and decreased use of traditional methods to convey runoff directly to surface waters.

The runoff coefficient (C) weighted average for cover types is 0.47, and the soil profile weighted average for the runoff curve (CN) is 87.34, both values indicated an intermediate runoff potential (SDDS, 2015, Dewey, 2018). An estimated imperviousness of residential areas not including streets is 41% which would likely increase if streets were included. The C values for HSGs in Table 5 show an increase in runoff as the size of the storms increase along with the possibility of flash flooding (SDDS, 2015), but if intensity of a storm decreases (Table 6), a large storm resembles smaller storms in the amount of runoff in cfs it moves. The majority of rain event sizes occur in the small and intermediate events slowing the flow of runoff, and improving the opportunity for TSS and TP to be removed (NCDOACR, 2018).

Traditional BMPs focused on stabilization of land utilizing concrete open drains/low flow liners to reduce erosion and transport of sediments to surface waters, and riprap a combination of large rock and pieces of concrete for bank stabilization. Alternative BMPs such as wet retention basins, wet retention marsh, and infiltration basins focused on holding large volumes of runoff for 24-48 hours, and have higher rates for infiltration, filtering, and gravity settle TSS and TP (Shammaa et al., 2001, Weiss et al., 2005). The berm/swale, forested areas, open areas covered by natural vegetation slow the movement of runoff increasing time for infiltration, sorption of TP, and filtering particulate matter (COLNWM6, 2018, Page et al., 2015, Hickey et al., 2004). They are most effective when covering larger areas, as they have more than the 9-15 meters need available at this site (Hickey et al., 2004, Page et al., 2015). One exception in vegetation is turf grasses short root structure (COLNWM-S, 2018) is unable to infiltrate rainwater like native grasses with deeper roots increasing the amount of runoff (COLNWM-I, 2018).

All sources agreed that infiltration of stormwater, filtering TSS and TP, depend on the amount of time spent passing through BMPs increases their effectiveness. Time is gained by the acres of land available and a minimum of sloping reducing the flow rate of stormwater runoff.

Still a few concerns remain. Stormwater runoff from adjacent neighborhoods flow into this area connected by concrete drains. It is unknown to what extent structural or non-structural BMPs are used to control TSS and TP throughout the neighborhood before it reaches the study area. Several access points for residential runoff flow into the study area, into one or more alternative BMP where TSS and TP can be removed or reduced before reaching Antelope Creek. With exception of the concrete open drain near the intersection of Holmes Park Rd. and Cooper Ave. It connects to low flow liners in the residential common area that accepts stormwater runoff from streets the primary contributor of TSS and TP, and landscaping contributions during intermediate and large rain events. This water flows onto riprap in the dog run, then to Antelope Creek an estimated 31 meters away bypassing other BMPs. Riprap does slow the flow rate, and used as erosion control, but is not as effective as other BMPs in removing TSS and TP. Current concentrations for TSS and TP in the creek flowing under Pioneers Blvd. into the area were unknown at the time of the study. During one visit to the site in July of 2018, a toxic blue-green algae alert was posted for Antelope Creek. This event shows TP is able to bypass BMPs, and the possibility for TSS being able to bypass them exists as well.

Conclusion

The evidence would suggest that alternative BMPs in place are an effective choice for this site. Covering large areas with low slopes they are able to infiltrate stormwater runoff, filter, and gravity settle TSS and TP from runoff passing through them. Open drains are traditional BMP structures used to prevent erosion not reduce or remove TSS or TP. Additional research would be needed to find a modification to the structure able to do both. Finding sizeable areas to filter all runoff before it enters creeks or lakes in urban areas may prove to be a difficult challenge. Particularly in districts of the city developed before these BMPs were in use. There may not be land available required for such large structures to be successful, leaving surface water at risk for eutrophication. Non-structural options may need to be explored, such as using street sweepers to remove debris from parking lots, and streets as they are a primary source of stormwater runoff, and pollutants (Pitt, 2011, COLNWM6, 2018).

Future work with this project should continue with the use of alternative BMPs, extending into the block grid area within Holmes Lake watershed locating current wetlands and BMPs assessing their effectiveness in filtering TSS and TP from runoff, and infiltration. The site may also need testing for TSS and TP loading to determine longevity of wetlands and BMPs, as well as testing levels of TSS and TP being conveyed to Antelope Creek from the surrounding neighborhood.

The use of wetlands and BMPs is essential to protecting our water supply by keeping surface waters free of pollutants, and recharging groundwater to maintain local aquifers. People depend on freshwater in all aspects of life. Local wildlife depend on freshwater, but does not have a choice where their water comes from using what is available to them. Continued use and improvements of BMPs in urban areas is a necessity for sustaining freshwater quality and quantity for urban locations.

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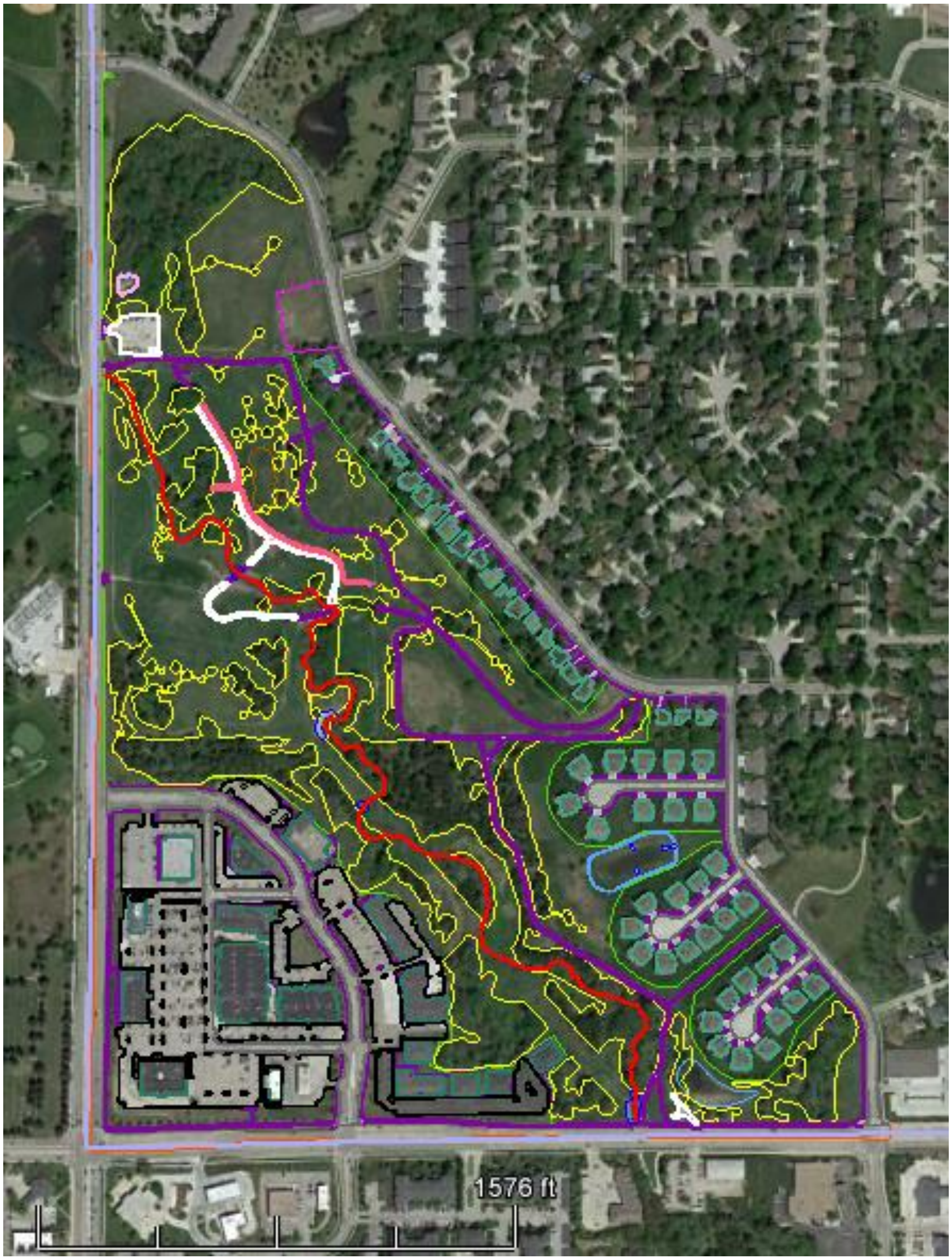
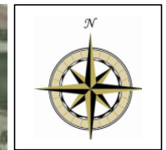
Appendix

70th and Pioneers Blvd. Cover Types and BMPs.

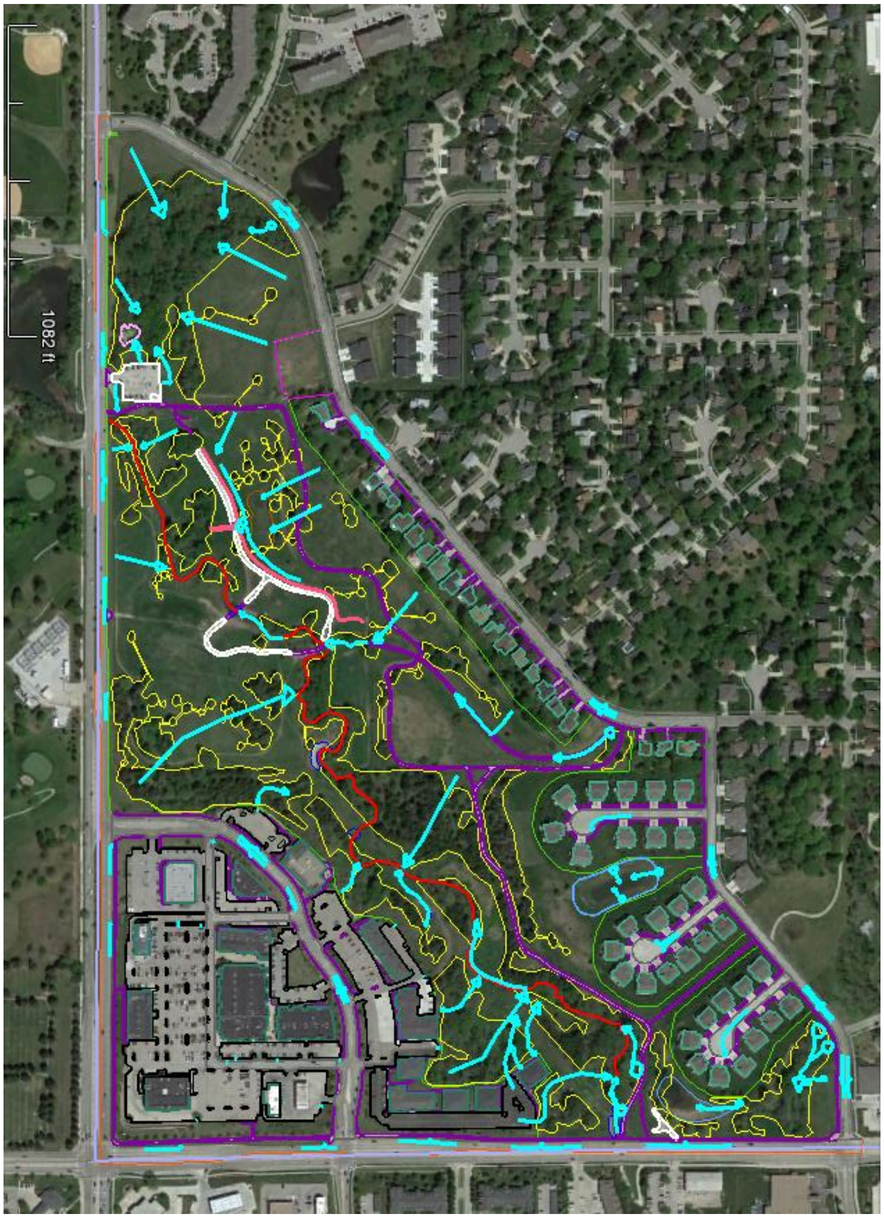




Legend on the following page

Figure 1. Image from Google Earth

70th and Pioneers Blvd. Direction of Stormwater Flow



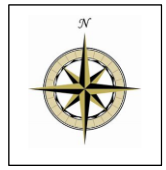


Figure 2. Image from Google Earth

LEGEND

Path of Surface Water

Total area for location

Infiltration Basins

Trees

Driveways/Pathways/Sidewalks/Bridges/Open Drain (concrete)

Business Roofs

Streets

Wet Detention Marsh

Stormwater Flow/Drains

Green Space

70th wet retention basin

Lots

Riprap

Roofs

Parking Lots

Gravel/Crushed rock

Dog Run Swale

Table 1

70th & Pioneers	
70th & Pioneer Total Acres	132
Feature	**Area(Acres)**
Lots	0.852
Infiltration Basins	0.32
Swales	0.36
Wet Detention Marsh	0.0766
Wet Retention Basin	1.30
Trees	27.8
Pathways	2.41
70th St. Driveways	0.0373
Dog run Bridges	0.0185
Open (concrete) Drains	0.203
Sidewalks	2.54
Residential Driveways	1.46
Residential Roofs	4.52
Business Roofs	5.22
Parking Lots	16.1
Streets	7.98
Riprap	0.221
Gravel/Crushed Rock	0.87
Residential Lawns	11.6
Business Lawns	6.30

Table 2

70th & Pioneers	
Feature	**Area (Acres)**
70th & Pioneers green space	75.0
Residential Lawns	11.6
Lots	0.852
70th St. Driveways	0.0373
Sidewalks	2.54
Residential Driveways	1.46
Residential Roofs	4.52
Business Roofs	5.22
Parking Lots	16.1
Streets	7.98
Dog Run parking lot	0.40
Total	**125.7**

Table 3

70th & Pioneers Business Lawns	Area (Acres)
Total area for 70th & Pioneers	132.0
(-) Feature total (above)	125.7
Total Acres Business Lawns	**6.30**

Table 4

70th & Pioneers Residential Lawns	Area (Acres)
Total Residential Area	17.5
(-) Sidewalks 1-45	0.30
(-) Residential Roofs 1-53	4.52
(-) Streets 1-3	1.09
Total Residential Lawns Acres	**11.6**

Table 1. The total acres for 70th and Pioneer location, and each cover type.

Table 2. The sum of these covers is used to determine total acres for business lawns in Table 3.

Table 3. Total acres of business lawns.

Table 4. Impermeable surfaces are subtracted from the total residential area finding acres of residential lawns. This table does not represent all of the changes on the properties made by the home owners, and only takes into account the land they reside on. It is not possible to account for all covers, and assumes these covers are not there.

Holmes Lake Watershed

https://lincoln.ne.gov/city/pworks/projects/wsm/2005-bond-projects/pdf/holmes-lake-geomorphic.pdf (modified (Kouma, 2017)

Figure 3.

Using available data from residential roofs and driveways measured, then applying it to the area bordered by 70th, Van Dorn St., 84th, and Pioneers Blvd. inside the Holmes Lake watershed (figure 3), there are estimated, 800-850 homes in this area. The estimated area covered by roofs, driveways, and lawns.

Estimated number of homes / number of homes measured

800 / 52 = 15.3846 850 / 52 = 16.3462

Total Acres from study site:

Residential Roofs: 4.52 Residential Driveways: 1.46 Residential Lawns: 11.5

Estimated Area of Residential Roofs:

800 Homes: 15.3846 x 4.52 = 69.54 acres

850 Homes: 16.3462 x 4.52 = 73.88 acres

Estimated Area of Residential Driveways:

800 Homes: 15.3846 x 1.46 = 22.46 acres

850 Homes: 16.3462 x 1.46 = 23.87 acres

Estimated Area of Residential Lawns

800 Homes: 15.3846 x 11.55 = 177.69 acres

850 Homes: 16.3462 x 11.55 = 188.80 acres

Table 5. Estimated Area of Residential Cover Types - Weighted C Average

Estimated Area of Residential Cover Types for 800 Homes	**Area (Acres)**	**C**	**Area x C**
Roofs	69.54	0.90	62.59
Driveways	22.46	0.90	20.21
Lawns	177.69	0.15	26.65
Total Area	**269.69**	**Total**	**109.45**

(Engineering-Purdue, 2018, Poullain, 2012, SWRCB, 2018)

Residential Cover Types for 800 Homes - Weighted Average of C

C = 109.45/269.69 = 0.41 % Impervious Cover: 41%

Table 6. Estimated Area of Residential Cover Types - Weighted Average

Estimated Area of Residential Cover Types for 850 Homes	**Area (Acres)**	**C**	**Area x C**
Roofs	73.88	0.90	66.49
Driveways	23.87	0.90	21.48
Lawns	188.80	0.15	28.32
Total Area	**286.55**	**Total**	**116.29**

(Engineering-Purdue, 2018, Poullain, 2012, SWRCB, 2018)

Residential Cover Types for 850 Homes - Weighted Average of C

C = 116.29/286.55 = 0.41 % Impervious Cover: 41%

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
3713	Butler silt loam, terrace, 0 to 1 percent slopes	16.7	12.7%
7050	Kennebec silt loam, occasionally flooded	10.6	8.1%
7206	Aksarben silty clay loam, 2 to 6 percent slopes	6.2	4.7%
7227	Burchard clay loam, 6 to 11 percent slopes	11.9	9.0%
7231	Judson silt loam, 2 to 6 percent slopes	13.9	10.6%
7501	Pawnee clay loam, 4 to 8 percent slopes, eroded	12.9	9.8%
7684	Wymore silty clay loam, 3 to 6 percent slopes, eroded	16.8	12.7%
7867	Nodaway silt loam, channeled, frequently flooded	42.8	32.5%
Totals for Area of Interest		**131.7**	**100.0%**

Table 7. USDA NRCS Custom Soil Resource Report Soil Map (USDA/NRCS, 2018)

Soil	Hydrologic Soil Group	Runoff class
3713—Butler silt loam, terrace, 0 to 1 percent slopes	D	Negligible
7050—Kennebec silt loam, occasionally flooded	C	x
7206—Aksarben silty clay loam, 2 to 6 percent slopes	C	Medium
7207—Aksarben silty clay loam, 6 to 11 percent slopes	C	High
7227—Burchard clay loam, 6 to 11 percent slopes	D	Medium
7231—Judson silt loam, 2 to 6 percent slopes	C	Low
7501—Pawnee clay loam, 4 to 8 percent slopes, eroded	D	High
7684—Wymore silty clay loam, 3 to 6 percent slopes, eroded	D	Medium
7867—Nodaway silt loam, channeled, frequently flooded	B	Negligible

Source: USDA NRCS Custom Soil Resource Report

Table 8. Custom Soil Resource Report - Hydrologic Soil Group & Runoff Class (USDA/NRCS, 2018)

Custom Soil Resource Report
Soil Map

Figure 4. Image Source: USDA NRCS Custom Soil Resource Report (USDA/NRCS, 2018)

Table 9.

CN Values for percent impervious surfaces (pervious surface assumed to be grass in fair condition)

Impervious area	Soil A	Soil B	Soil C	Soil D
0	49.0	69.0	79.0	84.0
5	51.5	70.5	80.0	84.7
10	53.9	71.9	80.9	85.4
15	56.4	73.4	81.9	86.1
20	58.8	74.8	82.8	86.8
25	61.3	76.3	83.8	87.5
30	63.7	77.7	84.7	88.2
35	66.2	79.2	85.7	88.9
40	68.6	80.6	86.6	89.6
45	71.1	82.1	87.6	90.3
50	73.5	83.5	88.5	91.0
55	76.0	85.0	89.5	91.7
60	78.4	86.4	90.4	92.4
65	80.9	87.9	91.4	93.1
70	83.3	89.3	92.3	93.8
75	85.8	90.8	93.3	94.5
80	88.2	92.2	94.2	95.2
85	90.7	93.7	95.2	95.9
90	93.1	95.1	96.1	96.6
95	95.6	96.6	97.1	97.3
100	98.0	98.0	98.0	98.0

(Engineering-Purdue, 2018)

Table 10. CN values for Soil Types at 70^{th} and Pioneers

Watershed	B	C	D
47% Impervious	82.66	87.96	90.58

(modified Engineering-Purdue, 2018)

"…the CN values for percent impervious cover on the four hydrologic soil groups with the pervious cover being grass in fair condition" (Engineering-Purdue, 2018).

Method of Calculation for finding values for 47% imperviousness:

(50B – 45B) / 5 = n 45B+(n x 2) = 47% imperviousness for soil B

Applied this method to C, and D.