UNDERSTANDING WATER QUALITY, VEGETATION ESTABLISHMENT AND STAKEHOLDER SUCCESS FOR THE FARGO PROJECT: A MULTI-STAKEHOLDER LED COMMUNITY-BASED GREEN INFRASTRUCTURE PROJECT

A Dissertation
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Jesse Riley

In Partial Fulfillment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY

Major Department:
Natural Resources Management

November 2022

Fargo, North Dakota

North Dakota State University
Graduate School

Title

UNDERSTANDING WATER QUALITY, VEGETATION ESTABLISHMENT AND STAKEHOLDER SUCCESS FOR THE FARGO PROJECT: A MULTI-STAKEHOLDER LED COMMUNITY-BASED GREEN INFRASTRUCTURE PROJECT

By

Jesse Riley

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

SUPERVISORY COMMITTEE:

Christina Hargiss
Chair

Jack Norland

Matthew Kirkwood

David Crutchfield

Approved:

November 15 2022 — Date

Shawn DeKeyser — Department Chair

ABSTRACT

The Fargo Project is a dry detention basin that holds stormwater drained from urbanized and impervious areas that serves as a component of a greater stormwater infrastructure network. The project goals were to design a multi-use green infrastructure area that would invite neighboring residents into the basin. From its conception, the project has relied on partnerships between stakeholders. A survey was developed and deployed to all stakeholder groups that participated in the community-based project to access stakeholder success. The Fargo Project was viewed as a success by most stakeholders. Project partners felt that the basin’s main goal was to serve a functional purpose as well as contain natural habitat that provided a resource to the community. This new knowledge expands on the traditional top-down governmental approach and allows more input from stakeholders.

One goal of The Fargo Project was to establish native vegetation in the bottom of the basin. A study was established using five different native seed mixes planted in four replicates in the spring of 2016. Four years after planting many of the native species used in the treatments, even though planted at high densities, failed to persist or were at levels below 4% cover. Flooding during the germination and establishment phase negatively affected the long-term persistence of planted native species. This study determined that native plantings within dry detention basins come with challenges atypical to restorations in other natural habitats.

Water quality at different vertical elevations within The Fargo Project basin was investigated. The vertical water quality was sampled after three large precipitation events at different stages within the basin: initial (first flush), at peak elevation, and outfall (as the basin drained). The water quality in two other dry detention basins were sampled for comparison. Most water quality analytes did not differ among the three detention basins except Total Suspended

Solids which declined as the basin drained. The development of a passive vertical water quality sampling system using commonly available materials was effective at sampling vertical water quality in detention basins.

ACKNOWLEDGMENTS

I would like to thank my family that believed in me and supported me in my PhD adventure. To my wife Erin of many years past and more to come. Thank you for supporting me even when the path didn't seem clear. Your understanding of my passions and patience with my persistence in achieving the goals I reach for have made it possible to go further in life than I had expected. Thanks to my kids who only remember me pursuing this dream of higher education. Taelor, Brook, Elle, and Ethan you have been a joy to watch turn into adults and I hope you know you are capable of reaching your dreams as well. Thank you to my mother Bobbie, for showing me the pursuit of education and happiness is time well spent. The Faculty in the Department of Natural Resources Management really helped me to realize the possibility of learning. Dr. Jack Norland, your guidance and tremendous knowledge in this field have helped and guided me through this PhD. Thanks for your tremendous support. Dr. Christina Hargiss recognized my potential to pursue and finish this PhD and for that, I am very grateful. My graduate school cohort played an instrumental role in getting me through the challenges of graduate school. Nikki Ellingson played a key role in my success in this endeavor, her friendship and guidance helped to make sure the “Work got done”. Thank you to The Fargo Project for funding this study. The Fargo Project and its partners should be proud of the venture they took on.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

CHAPTER 1: LITERATURE REVIEW

Introduction

Detention Basins, Ecosystem Services, and Creative Placemaking in Green Infrastructure

Urban stormwater treatment has historically been handled using three distinct methods: sanitary sewer, everything in a sewer, and independent networks (Nascimento et al. 1999). Independent networks for urban stormwater were used for stormwater capture and the attenuation of floodwaters. Conventional construction and design methods have been focused on capturing stormwater runoff volumes for a period of time and then releasing the water in a controlled and metered fashion (Novak et al. 2014). This practice was an attempt to reduce the peak runoff volume, as well as reducing the volume of water reaching downstream areas. The reduction or retention of stormwater pollution was typical of little or no concern (Nascimento et al. 1999). Designers created systems that could limit peak flows and paid little attention to pollution treatment or aesthetic value. During the 1970s, citizens voiced concerns over water pollution in urban areas (Nascimento et al. 1999). It was also discovered that detention basins had the capabilities to reduce the pollutants that were picked up and transported during rainfall events (Valiron 1985; Hall et al. 1993). After this point, detention basins began to address multiple objectives, which currently play an essential part in any stormwater management strategy.

If properly planned, successfully integrated detention basins can benefit the public beyond a single-use design that focuses on hydraulic functions that are necessary to manage stormwater (Urbonas & Stahre 1993). Appropriate development and design for water detention areas can accommodate societal needs for recreation, green space, and natural habitat while mitigating flood potential and removing stormwater contaminants. Distance to green space and other natural amenities seem to benefit property values. Research has found that urban residents prefer to reside close to wetland areas, and the type of wetland has little effect on this preference (Mahan et al. 2000). While the significance of aesthetics is important, the value of pollution, nutrient, and sediment control should be considered during the design and construction phases.

Detention basins may provide ecosystem services that benefit humankind. Ecosystem services are direct or indirect benefits provided by natural systems that improve and sustain human wellbeing (Daily 1997). There are four functions or services that biological systems perform on our behalf; regulating, supporting, provisioning, and cultural (De Groot et al. 2010). A basins design can serve all four services, thus, maximizing its value to a community. A few of the ecosystem services that can be provided at the Fargo Project include a community gathering location, flood attenuation, a recreational space, bioremediation, and improvement in water quality.

Municipalities have the opportunity to develop areas that were historically used primarily for capturing stormwater via creative placemaking. The term creative placemaking was coined by Markusen & Gadwa (2010) using this definition.

"In creative placemaking, partners from public, private, non-profit, and community sectors strategically shape the physical and social character of a neighborhood, town, city, or region around arts and cultural activities. Creative placemaking animates public and private spaces, rejuvenates structures and streetscapes, improves local business viability and public safety, and brings diverse people together to celebrate, inspire, and be inspired" (Markusen & Gadwa 2010).

While urban detention basins and other underutilized spaces provide multi-use opportunities, challenges in programming often arise. Stakeholders involved in creative placemaking sites have various objectives, including increasing employment, reducing crime, attracting or retaining residents, and economic development (Morley & Winkler 2014), and these sometimes conflict with each other.

Stakeholders

Stakeholders play an essential role in the conceptualization and implementation of many community-based natural resources management plans. The term stakeholder was first used in business and public administration journals (Byrd 2007). It refers to a member of a group or individual who can influence outcomes or is impacted by the actions of a group or organization (Freeman & McVea 2001). Involved parties need to have an appropriate and vested interest to be categorized as a stakeholder (Donaldson & Preston 1995). Not all stakeholders need to be involved in every aspect of the decision-making process, but it is important for each stakeholder's interests to be understood (Donaldson & Preston 1995). Stakeholders can advocate for their position in a multitude of ways. Public forums and hearings, advisory committees, surveys, written comments, citizen development boards, and non-profit action groups are various ways stakeholders can participate in community projects (Fiorino 1990; Beierle & Konisky 2000; Nanz & Steffek 2004). Involving stakeholders in the decision process can increase trust (King et al. 1998; Carmin et al. 2003), generate new ideas (Fiorino 1990; Carmin et al. 2003), reduce conflicts that arise (King et al. 1998; Beierle & Konisky 2000; Carmin et al. 2003), and educate the public about local projects (King et al. 1998; Beierle & Konisky 2000). Stakeholder participation allows more participants to have a voice and maybe one key to a successful project.

Project Success

There are several factors that make a stakeholder project successful. While there is no exact template that guarantees success, meeting the project objectives could be a primary measure of success (de Wit 1988). Objectives often vary between stakeholders associated with a project. Factors that can contribute to the success of stakeholder involvement include group culture (Kwan & Ofori 2001; Bryde & Robinson 2005), commitment (Dainty et al. 2001; Fischer et al. 2003), ethics (Wood et al. 2002), and communications (Bryde & Robinson 2005). Multidisciplinary groups that are made of more than a client and contractor can have critical interests in the outcome of a project (de Wit 1988). Due to the various differences amongst groups, the use of an objective hierarchy can assure that all objectives and stakeholders have their needs and interests heard. Groups can even rank and evaluate success (Dyer & Forman 1992). Then, using a project success framework, success criteria or project objectives can be assessed and compared to the category of performance preferred, which would gauge success (Ashley et al. 1987). This can help to ensure a positive outcome when a community-based stakeholder partnership is formed.

Stakeholders and Sustainable Development

The idea of sustainable development is a concept linked to the ecological concept of carrying capacity and the resources (i.e., water, food, and energy) a community can use without replenishment. If the resources used and waste generated does not impede future generations, then development is considered to be sustainable (Rees & Wackernagel 1996). Design professionals and community developers use green building standards to aid in sustainable development. Literature shows that advancements have been achieved regarding green infrastructure and sustainable approaches to stormwater (Wong 2006; Foster et al. 2011). Green infrastructure benefits urban areas by providing ecological and other services such as flood attenuation, habitat diversity, water and air purification, recreational space, and social benefits (Fiksel et al. 2014). Groups of public, private, and government stakeholders can use a participatory form of governance to ensure that stakeholder groups meet their objectives and that the integrity of the environment is ensured. This form of sustainable development in which citizenry participates in sustainable decisions can enhance the partnerships between various stakeholders and help them to seek common ground among groups (Binghan et al. 2005).

Multidisciplinary Urban Stakeholder Projects

Multidisciplinary methodologies address policy, problems, and planning issues from different scientific approaches (Petts et al. 2008). When scientific disciplines collaborate with nonscientific communities, such as government, non-profits, communities, and civic groups, the work becomes transdisciplinary (Attwater et al. 2005). The urban environment is complex and includes social as well as ecological sciences (Whitehead 2003). However, the complexities of stakeholder objectives often find groups having different thoughts on how problems should be addressed. Therefore, if we are to ensure sustainable development and address "real world" problems, multidisciplinary stakeholder groups must work hand in hand on projects and form objectives that can be measured and achieved (Horlick-Jones & Sime 2004). A common motivation to plan and design more sustainable urban environments can begin to reduce some of the complexities in the planning and management of our urban areas.

Two suitable methods for the integration of transdisciplinary partnerships are design thinking and adaptive management. Design thinking embodies the creative strategies used by those in the design profession to describe how they arrived at their solution (Ambrose et al. 2010). This method of designing can be applied to sustainable design planning by using economic, cultural, and natural influences to resolve problems (Johansson-Sköldberg et al. 2013). The other method discussed in the literature, adaptive management, centers around the idea that management is a fluid and continual process; like the environment, it changes with the effects of its surrounding inputs (McLain & Lee 1996). The stakeholders of a project have the ability to change their decision processes based on what new information they have received (Ruckelshaus et al. 2015), but it is up to them to act on this information. Proper planning and management strategies guide stakeholders to reach their desired outcomes more effectively, and both monitoring and feedback are essential to the success of a project.

Designing Stakeholder Surveys

In order to have an effective survey, it is vital to have a representative sample to take the survey. Representative sampling in stakeholder analysis refers to the practice of surveying a small portion of each stakeholder group to make inferences on the entire population (Kruskal & Mosteller 1998). Due to the diverse levels of stakeholder participation, it is essential to include as many groups as possible to identify key objectives and facets involved (Kuntz & Johnson 2004). Designers may benefit from the knowledge obtained from several relevant disciplines corresponding to the scale and size of a project (Silvius & van den Brink 2014). Due to the collaborative nature of multi-stakeholder initiatives, representative sampling is an effective means of gauging the partnership's consensus (Leach et al. 2002).

Stakeholder survey methods must clearly define a concept and construct. These constructs are conjectural levels for characteristics that exist but cannot be directly measured (Abowitz & Toole 2009). Examples of natural resource-based constructs are success, innovation, and equitable access (Frankfort-Nachmias & Nachmias 2007). With clearly defined constructs and carefully defined operational definitions, consistent and reliable results can be obtained (Frankfort-Nachmias & Nachmias 2007). In order to obtain valid data to be used by participating organizations, it is vital to gather measurable data from the stakeholders who are directly affected by the group's decisions (Sinclair & Smith 1999).

To successfully obtain project objectives in a community-based natural resources management project stakeholder collaboration should be participatory. Many projects traditionally have entrenched organizational structures where leading entities typically focused on the direction and scope of the project or actions (Reed et al. 2009). Community-based natural resource projects do not always follow this top-down approach. Information is needed from all stakeholders, including those who are affected by a project, as well as those who will have active roles in the outcome. It is for this reason that both engaged entities should participate in the survey (Grimble & Wellard 1997). Having a broad range of perspectives helps to identify a more significant set of intentions and allows a more robust perspective on the knowledge obtained (Woodhill & Roling 1998; Berkes 1999; Olsson et al. 2004). Through a survey, various stakeholder groups and individuals can be categorized and compared to others in hopes of developing clear goals for a project.

Vegetation

Urban Prairie and Restoration

As Europeans began to arrive and agriculturally develop the United States, native tallgrass prairie stood on at least 68 million hectares of the North American Great Plains (Samson & Knopf 1994; Robertson et al. 1997). Many urban areas are settled over what was once native tallgrass prairie, including the Fargo-Moorhead area. The valuable soils produced by tallgrass prairie proved beneficial for agriculture; for this reason, much of the tallgrass prairie was put into agricultural production (Bryce et al. 1996). The community composition and ecosystem processes were transformed significantly due to the extensive agriculture pressures. The total amount of native tallgrass prairie in Minnesota totals only 1% of the pre-settlement numbers (Samson & Knopf 1994; Robertson et al. 1997). The benefits of prairie ecosystems are increasingly being recognized as performing a myriad of ecosystem services (Green et al. 2015). Urban planners are seeking affordable solutions to install visually and biologically diverse plant communities that can provide ecosystem services in their restorations (Hitchmough & Woudstra 1999). The restoration of prairies offers insight into conservation practices as well as the ecosystem dynamics involved in grassland function and structure that could be used in urban systems (Dobson et al. 1997).

Research has shown that increased urban native vegetation has increased the amount of food and habitat for many pollinators and urban adapted species (Tommasi et al. 2004; Hanson et al. 2005; Vanbergen 2013). Domestic landscapes and planned municipal greenspace make up a substantial proportion of the vegetated networks that fall within the geospatial urban boundaries. These areas can support diverse plant communities beneficial to larger ecosystem matrices (Smith et al. 2006; Owen 2010). With a more significant percentage of the human population now residing within urban areas (United Nations 2011), it will be valuable to determine the significance of the remaining green spaces.

Before an area becomes urban, it undergoes a period of transition. The literature describes this geographical transition zone as peri-urban. Peri-urban areas are locations that are developing and transitioning from rural to urban (McKinney 2002; Nechyba & Walsh 2004). Habitat is altered when land is cleared for urban use. Species that once provided services for the greater system may have been removed from the land (Lambin & Meyfroidt 2011). As this happens across the city and planning changes over time, there is a complex mix of areas with more infrastructure and those with less infrastructure and more green, blue, and open space that is created across the city. Vegetation benefits, in open spaces can be limited by adjacent land use in many urban areas (Kline 1997). The use of urban gradients is promising for studies in urban ecology (Matson 1990; McDonnell & Pickett 1990; McDonnell et al. 1993; Blair 1996; Blair 2001). Urban areas and open spaces vary greatly. The connection between environmental heterogeneity and species abundance can be complicated. The use of urban to rural gradients, ordering land use into categories ranging from natural areas to those of high building density, and human population, can aid in the geospatial categorization of land use (Matson 1990; McDonnell & Pickett 1990; McDonnell et al. 1993).

As urbanization increases, human interactions with nature are increasingly taking place in the cities and towns where residents live (Miller et al. 2002). Urban development often degrades and fragments the existing natural environment (Gaston 2010). In time, attempts are made to restore natural systems that were degraded by urban development. A complete restoration may not be possible due to the alterations that have happened in the ecosystem (Jackson & Hobbs 2009). Vegetation may also fail to be restored due to new microclimates, the heat island effect, and changes in the soil that may affect the growing conditions of the restoration (Grimm et al. 2008).

Greater than 90% of the area once occupied by the floristically diverse tallgrass prairie in North America has been modified for agriculture (Samson & Knopf 1994). Restoration is vital not only for ecological value, but for conservation and cultural value as well (Dobson et al. 1997). The goal of restoring prairie vegetation is to return ecosystem services to areas taken over by agriculture and development (Rowe 2010). The desire for many restorations is a high diversity of grasses and forbs (Rowe 2010). A prairie restoration establishing diversity will attract more wildlife (Ries et al. 2001), improve the soil (Baer et al. 2003), and improve water quality (Meals et al. 2010). Successful prairie restoration can induce functionally diverse systems impacting ecosystem changes at a community and system-level (Camill et al. 2004).

It is becoming more routine to see restored prairies within urban landscapes (Cerver 1994). Currently, urban landscape and conservation planning has benefited from research on species distribution and management implications of urban restorations (Esparrago & Kricsfalusy 2015). The restoration of urban space is desired to achieve one of four "visions of nature"; nature as designed landscape, nature as habitat, nature as recreation, and nature as pre-European settlement landscape (Gobster 2001). This is where the social context of an urban restoration merges with the science of ecologically restoring open spaces. More integrated green network systems are being constructed to protect and enhance natural space while serving as recreation areas and public green commons (Stadtplanung 1996).

Establishing prairies works best when seed mixes are obtained from sources that match the geographical gradient in which the restoration is to occur (Bailey & Martin 2007). While some species can cross gradients, others are limited to areas with similar ecological characteristics (Hitchmough et al. 2004). One potential issue with a native establishment is weed management during the early establishment period (Wise et al. 2009). A process called spike seeding has demonstrated the ability to reduce weed establishment in grassland restorations. Spike seeding is adding forbs to a restoration seed mix (Norland et al. 2013). Forbs are chosen as spike species due to their ability to readily establish and provide diversity within the prairie restoration (McCain et al. 2010). Native seed sources and proper species selection aids in restoration success.

Durability is desired for urban recreational areas, like the World Garden Commons, which experience foot traffic from visitors. The direct physiological effects of trampling, shearing, and crushing of turfgrass are considered wear injury (Shearman et al. 1974; Bonos et al. 2001). Extensive use may increase soil compaction (Carrow 1980; Kowalewski et al. 2010).

Compaction occurs when soil porosity is decreased, and bulk density increases as a result of recurrent interaction from an external force (Lipiec & Simota 1994). This reduction in soil pore space negatively affects vegetation by reducing shoot density and development (Matthieu et al. 2011), hinders root growth, and reduces soil water infiltration (Henderson et al. 2005). To date, most machines used to replicate foot traffic consist of rubber-wheels (Canaway 1976), rollers (Cockerham & Brinkman 1989), and studded drums (Shearman et al. 1974; Vanini et al. 2007). One such method for reproducing foot traffic by applying dynamic force is the Baldree Traffic Simulator (BTS) (Kowalewski et al. 2010). The BTS was designed to be durable while reducing compaction and damage that is similar to tire compaction. Assessment of foot traffic wear injury may help determine durability and establishment potential of vegetation species considered for planting in detention basins.

Vegetation and Stormwater

Little research has been conducted on useful vegetation for stormwater areas. Many studies on stormwater focus on increasing evapotranspiration times and infiltration best management practices (BMPs) (Passeport et al. 2009). There is some literature that discusses vegetation and stormwater runoff as related to vegetated swales and grassy filter strips (Ahiablame et al. 2012). These vegetation channels are typically situated next to roadways or agricultural areas (Barrett et al. 1998). The biofiltration systems improve water quality by intercepting the first pulse of stormwater runoff and filtering the large storm flows they convey to streams and rivers (Shammaa et al. 2002). The water is treated through natural processes such as sedimentation, fine filtration, sorption, and biological uptake.

Plant material may also benefit urban stormwater quality. Individual plant species chosen should be dependent on target pollutant, establishment potential, as well as durability to ensure multifunctional performance (Bratieres et al. 2008). Nitrogen and phosphorous, as well as sediment, heavy metals, and hydrocarbons, are flushed into urban watersheds at heightened levels during rainfall events (Deletic 1998). This runoff inundates the plants and soil, which may prove both favorable and unfavorable to vegetation (Denman et al. 2011). A valuable ecosystem service that vegetation performs is that of nutrient or elemental uptake, and vegetation can act as a biofiltration system in stormwater detention basins (Niemczynowicz 1999). Biofiltration systems (sometimes referred to as biofilters or bioretention systems) are frequently being adopted to reduce pollution from urban waterways by improving stormwater runoff quality (Davis et al. 2001; Kim et al. 2003; Hatt et al. 2007; Henderson et al. 2007). Nitrogen and phosphorus, predominantly the soluble forms that are readily available for uptake, can be detrimental to water quality and lead to eutrophication (Kim et al. 2003; Taylor et al. 2005). Urban stormwater transports heavy metals such as Pb, Zn, Cu, and Cd as well as suspended solids (Davis et al. 2001; Fritioff & Greger 2003; Hatt et al. 2007; Henderson et al. 2007). Biofiltration systems that incorporate vegetation have been shown to improve effluent quality as opposed to non-vegetated soil media (Denman et al. 2011; Henderson et al. 2007).

Biofilters occupied in basins where pulse events occur, such as those at the World Commons Site, have yet to be studied for their effects on pollutant removal. However, research has shown vegetation acting in a filtration capacity is limited by the duration of contact time with water (Scholes et al. 2008). Therefore, species selection is of great consequence, not only for pollutant treatment performance, but the ability to establish and survive in less than optimal growing conditions. Plants proven to withstand the harsh conditions will prove valuable in detention basin design. Decisions regarding plant population and composition may vary when microclimatic conditions regarding site-specific hydrological, topographical, and design conditions are taken into account (Ellis et al. 2003). It is for this reason that proper vegetation should be chosen not only for its treatment performance but also for durability and survivability when subjected to flash flow situations (Bratieres et al. 2008).

Water Quality

Urban Water Quality

In recent decades urbanization and increases in impervious land cover have been proliferating, which has had a direct impact on both the volume and quality of stormwater runoff (Walsh et al. 2005; Line & White 2007). These considerations may vary with levels of anthropogenic disturbance taking place in and near individual basins. The need to treat runoff has generated techniques that capture or reduce the flow of nutrients. One design element discussed above in the vegetation section is the biofilter. The ability to reduce sediment and nutrient loads using a system like this is a critical component for any urban stormwater system.

Urban ecosystems have been shown to exhibit reductions in water quality. Studies from the United States have shown that as urbanization increases, water quality decreases, and this same trend has been documented worldwide (McDonnell & Pickett 1990; Grimm et al. 2000; Brabec et al. 2002; Alberti 2005). Detention basins can be designed to mitigate the adverse effects of a set of general water quality indicators including: total suspended solids; biochemical and chemical oxygen demand; nitrates; phosphates; and fecal coliforms (Wu et al. 1996; Carleton et al. 2000; Scholes et al. 2008; Burns & Meiburg 2012). The performance of individual stormwater BMPs to address these water quality issues may vary from site to site in relation to variables such as design specifications, local hydrologic and climatic conditions, and system age (Ellis et al. 2003). Stormwater detention basins may provide beneficial ecosystem services if retrofitted to replicate services performed in natural systems.

Detention Basins vs. Retention Ponds

Stormwater detention basins fill with runoff from rain events and often carry sediment and pollution (Colford et al. 2012). They differ from retention basins, which are wet ponds that hold water year-round. Retention ponds are usually found in areas where the water table is high (Ficher et al. 2003). Detention basins function by detaining large volumes of water and limiting the outflow to help mitigate downstream impacts such as hydrological disturbance from flash flows (Roy et al. 2008). Detention and retention ponds primary difference is the amount of residency time of impounded water and function. Detention basins are needed to impound runoff generated from impervious surfaces such as rooftops, sidewalks, parking lots, and roads (Paul & Meyer 2001; Konrad & Booth 2005; Ladson et al. 2006).

Detention Basins Water

Most stormwater enters these basins as surface runoff from impervious surfaces (Weiss & Haller 2002; Burns et al. 2005; Chithra et al. 2015). Water then percolates into the ground through pore spaces, especially where sites have a high-water table or sandy soils (Fischer et al. 2003). Water may also enter a detention basin via subsurface infiltration.

Urban runoff is known to contain contaminants such as sediment, *Escherichia coli* (*E. coli*), oil and grease, metals, and nutrients (Reddy et al. 2014). Stormwater detention infrastructure has been shown to be useful at removing pollutants through the settling of sediment (Holler 1989; Stanley 1994; Wu et al. 1996). With proper design, detention basins have been recognized as having the ability to not only detain water, but to improve water quality as well (Wu et al. 1996; Carleton et al. 2000; Burns & Meiburg 2012). Detention basins can serve as a location to retain sediment and other pollutants attached to particulates (Wu & Ahlert 1986; Schueler 1987; Holler 1989; Stanley 1994; Wang et al. 2014). This is important in that it prevents the degradation of streams and rivers by limiting the transfer of sediment and pollutants picked up in the initial runoff of a storm event (Stanley 1994).

Detention Basins Water Quality

Detention basins by nature are designed to capture and hold water so it can be metered out in a slow fashion as not to overwhelm an urban hydrological system (Shuster et al. 2005; Novak et al. 2014). Research has shown the first flush of water after rain or another significant water event is a unique phenomenon that takes place during the runoff cycle (Deledic 1998). During the first flush, the pollutant level is highly concentrated as it removes sediment, pollutants, and heavy metals from impervious surfaces (Goonetillekea et al. 2005). By designing and constructing urban detention basins in key locations, municipalities have the ability to reduce levels of nonpoint source pollutants over a broad range of land (Wu et al. 1996). When basin outlet structures are adequately sized, increasing residency time, basins have shown significant reductions in total suspended solids from stormwater runoff (Middleton & Barrett 2008).

The residence time of water plays a notable role in the process of pollutant removal from detention basins (Whipple & Hunter 1981). Once pollutants are attached to suspended solids and enter a detention basin, there is a chance that it can settle before moving downstream. If water capture and dispersal are delayed, many grain sizes of suspended solids settle out close to 70% of the concentrations that entered during a rain event. This process takes approximately 32 hours (Whipple & Hunter 1981). It is challenging to design a system that is a "one size fits all" because settlement size and particulate size differ across the many pollutants that impact urban and detention basin water quality (Whipple & Hunter 1981; Mangangka et al. 2015). Research regarding the residency time and various fall rates of suspended particulates may aid designers in developing BMPs that could improve the water quality of urban catchment areas.

Literature Cited

Abowitz, D. A., & Toole, T. M. (2010). Mixed method research: Fundamental issues of design, validity, and reliability in construction research. *Journal of construction engineering and management*, *136*(1), 108-116.

Ahiablame, L. M., Engel, B. A., & Chaubey, I. (2012). Effectiveness of low impact development practices: literature review and suggestions for future research. *Water, Air, & Soil Pollution*, *223*(7), 4253-4273.

Alberti, M. (2005). The effects of urban patterns on ecosystem function. *International regional science review*, *28*(2), 168-192.

Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010). How learning works: Seven research-based principles for smart teaching. John Wiley & Sons.

Ashley, D. B., Lurie, C. S., & Jaselskis, E. J. (1987). Determinants of construction project success. Project Management Institute.

Attwater, R., Booth, S., & Guthrie, A. (2005). The role of contestable concepts in transdisciplinary management of water in the landscape. Systems Research and Behavioral Science: *The Official Journal of the International Federation for Systems Research*, 22(3), 185-192.

Baer, S. G., Blair, J. M., Collins, S. L., & Knapp, A. K. (2003). Soil resources regulate productivity and diversity in newly established tallgrass prairie. *Ecology*, *84*(3), 724-735.

Bailey, P., & Martin, C. O. (2007). Regional availability of plants for prairie restoration (No. ERDC-TN-EMRRP-SI-31). Engineer research and development center Vicksburg MS.

Barrett, M. E., Walsh, P. M., Malina Jr, J. F., & Charbeneau, R. J. (1998). Performance of vegetative controls for treating highway runoff. *Journal of environmental engineering*, *124*(11), 1121-1128.

Beierle, T. C., & Konisky, D. M. (2000). Values, conflict, and trust in participatory environmental planning. *Journal of Policy Analysis and Management*, *19*(4), 587-602.

Berkes, F. 1999. Sacred Ecology: Traditional Ecological Knowledge and Resource Management.Philadelphia and London: Taylor & Francis.

Bingham, L. B., Nabatchi, T., & O'Leary, R. (2005). The new governance: Practices and processes for stakeholder and citizen participation in the work of government. *Public administration review*, *65*(5), 547-558.

Blair, R. B. (1996). Land use and avian species diversity along an urban gradient. *Ecological applications*, *6*(2), 506-519.

Blair, R. B. (2001). Birds and butterflies along urban gradients in two ecoregions of the United States: is urbanization creating a homogeneous fauna? In Biotic homogenization (pp. 33-56). Springer, Boston, MA.

Bonos, S.A., E. Watkins, J.A. Honig, M. Sosa, T. Molnar, J.A. Murphy, and W.A. Meyer. (2001). Breeding cool-season turfgrasses for wear tolerance using a wear simulator. *International Turfgrass Soc.*, *9*,137–145.

Brabec, E., Schulte, S., & Richards, P. L. (2002). Impervious surfaces and water quality: a review of current literature and its implications for watershed planning. Journal of planning literature, 16(4), 499-514.

Bratieres, K., Fletcher, T. D., Deletic, A., & Zinger, Y. A. R. O. N. (2008). Nutrient and sediment removal by stormwater biofilters: A large-scale design optimisation study. *Water research*, *42*(14), 3930-3940.

Bryce, S. A., Omernik, J. M., Pater, D. A., Ulmer, M., Schaar, J., Freeouf, J., ... & Azevedo, S. H. (1996). Ecoregions of North Dakota and South Dakota, (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia. US Geological Survey (map scale 1: 1,500,000).(http://www. epa. gov/wed/pages/ecoregions/ndsd_eco. htm).

Burns, D., Vitvar, T., McDonnell, J., Hassett, J., Duncan, J., & Kendall, C. (2005). Effects of suburban development on runoff generation in the Croton River basin, New York, USA. *Journal of Hydrology*, *311*(1-4), 266-281.

Burns, P., & Meiburg, E. (2012). Sediment-laden fresh water above salt water: linear stability analysis. *Journal of fluid mechanics*, *691*, 279.

Byrd, E. T. (2007). Stakeholders in sustainable tourism development and their roles: applying stakeholder theory to sustainable tourism development. *Tourism Review*, *62*(2), 6-13.

Camill, P., McKone, M. J., Sturges, S. T., Severud, W. J., Ellis, E., Limmer, J., ... & Talukder, S. (2004). Community-and ecosystem-level changes in a species-rich tallgrass prairie restoration. *Ecological applications*, *14*(6), 1680-1694.

Canaway, P.M. (1976). A differential-slip wear machine (D.S.1) for the artificial simulation of turfgrass wear. *Journal of Sports Turf Res. Inst*. *52*, 92–99.

Carleton, J. N., Grizzard, T. J., Godrej, A. N., Post, H. E., Lampe, L., & Kenel, P. P. (2000). Performance of a constructed wetlands in treating urban stormwater runoff. *Water Environment Research*, *72*(3), 295-304.

Carmin, J., Darnall, N., & Mil-Homens, J. (2003). Stakeholder involvement in the design of US voluntary environmental programs: does sponsorship matter?. *Policy Studies Journal*, *31*(4), 527-543.

Carrow, R. N. (1980). Influence of Soil Compaction on Three Turfgrass Species 1. *Agronomy Journal*, *72*(6), 1038-1042.

Cerver, F. A., & Martell, J. M. P. (1994). Business and corporation parks. Roof gardens (Vol. 4). Watson-Guptill Pubns.

Cheng, E. W., & Li, H. (2004). Development of a practical model of partnering for construction projects. *Journal of Construction Engineering and Management*, *130*(6), 790-798.

Chithra, S. V., Nair, M. H., Amarnath, A., & Anjana, N. S. (2015). Impacts of impervious surfaces on the environment. *International Journal of Engineering Science Invention*, *4*(5), 2319-6726.

Cockerham, S. T., & Brinkman, D. J. (1989). A simulator for cleated-shoe sports traffic on turfgrass research plots. *California Turfgrass Culture*, *39*(3-4), 9-10.

Colford Jr, J. M., Schiff, K. C., Griffith, J. F., Yau, V., Arnold, B. F., Wright, C. C., ... & McGee, C. (2012). Using rapid indicators for Enterococcus to assess the risk of illness after exposure to urban runoff contaminated marine water. *Water research, 46*(7), 2176-2186.

Daily, G. C. (1997). Nature's services (Vol. 3). Island Press, Washington, DC.

Dainty, A. R., Briscoe, G. H., & Millett, S. J. (2001). Subcontractor perspectives on supply chain alliances. *Construction management and economics*, *19*(8), 841-848.

Davis, A. P., Shokouhian, M., Sharma, H., & Minami, C. (2001). Laboratory study of biological retention for urban stormwater management. *Water Environment Research*, *73*(1), 5-14.

De Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological complexity*, *7*(3), 260-272.

Denman, E. C., May, P. B., & Moore, G. M. (2012). The use of trees in urban stormwater management. Trees, people and the built environment. Forestry commission research report. Forestry Commission, Edinburgh.

De Wit, A. (1988). Measurement of project success. *International journal of project managemen*t, *6*(3), 164-170.

Deletic, A. (1998). The first flush load of urban surface runoff. *Water research*, *32*(8), 2462-2470.

Dobson, A. P., Bradshaw, A. D., & Baker, A. Á. (1997). Hopes for the future: restoration ecology and conservation biology. *Science*, *277*(5325), 515-522.

Donaldson, T., & Preston, L. E. (1995). The stakeholder theory of the corporation: Concepts, evidence, and implications. *Academy of management Review*, *20*(1), 65-91.

Dyer, R. F., & Forman, E. H. (1992). Group decision support with the analytic hierarchy process. *Decision support systems*, *8*(2), 99-124.

Ellis, J. B., Shutes, R. B. E., & Revitt, D. M. (2003). Constructed wetlands and links with sustainable drainage systems. Urban Pollution Research Centre, Environment Agency.

Esparrago, J., & Kricsfalusy, V. (2015). Traditional grassland management and surrounding land use drive the abundance of a prairie plant species in urban areas. *Landscape and Urban Planning*, *142*, 1-6.

Fiksel, J., Bruins, R., Gatchett, A., Gilliland, A., & Ten Brink, M. (2014). The triple value model: a systems approach to sustainable solutions. *Clean Technologies and Environmental Policy*, *16*(4), 691-702.

Fiorino, D. J. (1990). Citizen participation and environmental risk: A survey of institutional mechanisms. *Science, Technology, & Human Values*, *15*(2), 226-243.

Fischer, D., Charles, E. G., & Baehr, A. L. (2003). Effects of stormwater infiltration on quality of groundwater beneath retention and detention basins. *Journal of Environmental Engineering*, *129*(5), 464-471.

Foster, J., Lowe, A., & Winkelman, S. (2011). The value of green infrastructure for urban climate adaptation. *Center for Clean Air Policy*, *750*(1), 1-52.

Frankfort-Nachmias, C., & Nachmias, D. (2007). Study guide for research methods in the social sciences. Macmillan.

Freeman, R. E., & McVea, J. (2001). A stakeholder approach to strategic management. The Blackwell handbook of strategic management, 189-207.

Fritioff, Å., & Greger, M. (2003). Aquatic and terrestrial plant species with potential to remove heavy metals from stormwater. *International Journal of Phytoremediation*, *5*(3), 211-224.

Gaston, K. J., Davies, Z. G., & Edmondson, J. L. (2010). Urban environments and ecosystem functions. *Urban ecology*, 35-52.

Gobster, P. H. (2001). Visions of nature: conflict and compatibility in urban park restoration. *Landscape and urban planning*, *56*(1-2), 35-51.

Goonetilleke, A., Thomas, E., Ginn, S., & Gilbert, D. (2005). Understanding the role of land use in urban stormwater quality management. *Journal of Environmental management*, *74*(1), 31-42.

Green, O. O., Garmestani, A. S., Albro, S., Ban, N. C., Berland, A., Burkman, C. E., ... & Shuster, W. D. (2016). Adaptive governance to promote ecosystem services in urban green spaces. *Urban ecosystems*, *19*(1), 77-93.

Grimble, R., & Wellard, K. (1997). Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities. *Agricultural systems*, *55*(2), 173-193.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. *Science*, *319*(5864), 756-760.

Grimm, N. B., Grove, J. G., Pickett, S. T., & Redman, C. L. (2000). Integrated approaches to long-term studies of urban ecological systems: Urban ecological systems present multiple challenges to ecologists—pervasive human impact and extreme heterogeneity of cities, and the need to integrate social and ecological approaches, concepts, and theory. *BioScience*, *50*(7), 571-584.

Hall, M. J., Hockin, D. L., & Ellis, J. B. (1993). Design of flood storage reservoirs. Butterworth-Heinemann Ltd and CIRIA. Oxford.

Hansen, A. J., Knight, R. L., Marzluff, J. M., Powell, S., Brown, K., Gude, P. H., & Jones, K. (2005). Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological Applications*, *15*(6), 1893-1905.

Hatt, B. E., Deletic, A., & Fletcher, T. D. (2007). Stormwater reuse: designing biofiltration systems for reliable treatment. *Water Science and Technology*, *55*(4), 201-209.

Henderson, J. J., Crum, J. R., Wolff, T. F., & Rogers III, J. N. (2005). Effects of particle size distribution and water content at compaction on saturated hydraulic conductivity and strength of high sand content root zone materials. *Soil science*, *170*(5), 315-324.

Henderson, C., Greenway, M., & Phillips, I. (2007). Removal of dissolved nitrogen, phosphorus and carbon from stormwater by biofiltration mesocosms. *Water Science and Technology*, *55*(4), 183-191.

Hitchmough, J., & Woudstra, J. (1999). The ecology of exotic herbaceous perennials grown in managed, native grassy vegetation in urban landscapes. *Landscape and urban planning*, *45*(2-3), 107-121.

Hitchmough, J., de la Fleur, M., & Findlay, C. (2004). Establishing North American prairie vegetation in urban parks in northern England: Part 1. Effect of sowing season, sowing rate and soil type. *Landscape and Urban Planning*, *66*(2), 75-90.

Holler, J.D. (1989). Water Quality Efficiency of an Urban Commercial Wet Detention Stormwater Management System at the Boynton Beach Mall in South Palm Beach County, Florida. *Florida Scientist*, 48-57.

Horlick-Jones, T., & Sime, J. (2004). Living on the border: knowledge, risk and transdisciplinarity. *Futures*, *36*(4), 441-456.

Jackson, S. T., & Hobbs, R. J. (2009). Ecological restoration in the light of ecological history. *Science*, *325*(5940), 567-569.

Johansson-Sköldberg, U., Woodilla, J., & Çetinkaya, M. (2013). Design thinking: past, present and possible futures. *Creativity and innovation management*, *22*(2), 121-146.

Kim, H., Seagren, E. A., & Davis, A. P. (2003). Engineered bioretention for removal of nitrate from stormwater runoff. *Water Environment Research*, *75*(4), 355-367.

King, C. S., Feltey, K. M., & Susel, B. O. N. (1998). The question of participation: Toward authentic public participation in public administration. *Public administration review*, 317-326.

Kline, V. M. (1997). Orchards of oak and a sea of grass. Tallgrass restoration handbook. Island Press, Washington, DC, USA, 3-21.

Konrad, C. P., & Booth, D. B. (2005, September). Hydrologic changes in urban streams and their ecological significance. In *American Fisheries Society Symposium 47*(157), 17.

Kowalewski, A. R., Rogers, J. N., Crum, J. R., & Dunne, J. C. (2010). Sand topdressing applications improve shear strength and turfgrass density on trafficked athletic fields. *Horttechnology*, *20*(5), 867-872.

Kruskal, W., & Mosteller, F. (1980). Representative sampling, IV: The history of the concept in statistics, 1895-1939. *International Statistical Review/Revue Internationale de Statistique*, 169-195.

Koontz, T. M., & Johnson, E. M. (2004). One size does not fit all: Matching breadth of stakeholder participation to watershed group accomplishments. *Policy Sciences*, *37*(2), 185-204.

Kwan, A. Y., & Ofori, G. (2001). Chinese culture and successful implementation of partnering in Singapore's construction industry. *Construction Management & Economics*, *19*(6), 619-632.

Ladson, A. R., Walsh, C. J., & Fletcher, T. D. (2006). Improving stream health in urban areas by reducing runoff frequency from impervious surfaces. *Australasian Journal of Water Resources*, 10(1), 23-33.

Lambin, E. F., & Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences*, *108*(9), 3465-3472.

Leach, W. D., Pelkey, N. W., & Sabatier, P. A. (2002). Stakeholder partnerships as collaborative policymaking: Evaluation criteria applied to watershed management in California and Washington. Journal of Policy Analysis and Management: *The Journal of the Association for Public Policy Analysis and Management*, *21*(4), 645-670.

Line, D. E., & White, N. M. (2007). Effects of development on runoff and pollutant export. *Water Environment Research*, *79*(2), 185-190.

Lipiec, J., & Simota, C. (1994). Role of soil and climate factors in influencing crop responses to soil compaction in Central and Eastern Europe. In Developments in agricultural engineering (Vol. 11, pp. 365-390). Elsevier.

Mahan, B. L., Polasky, S., & Adams, R. M. (2000). Valuing urban wetlands: a property price approach. *Land economics*, 100-113.

Mangangka, I. R., Liu, A., Egodawatta, P., & Goonetilleke, A. (2015). Performance characterisation of a stormwater treatment bioretention basin. *Journal of environmental management*, *150*, 173-178.

Markusen, A., & Gadwa, A. (2010). Creative placemaking. Washington, DC: National Endowment for the Arts.

Matson, P. (1990). Special feature: the use of urban gradients in ecological studies. *Ecology*, *71*(4), 1231-1231.Matthieu, D. E., Bowman, D. C., Thapa, B. B., Cassel, D. K., & Rufty, T. W. (2011). Turfgrass root response to subsurface soil compaction. *Communications in soil science and plant analysis*, *42*(22), 2813-2823.

McCain, K. N., Baer, S. G., Blair, J. M., & Wilson, G. W. (2010). Dominant grasses suppress local diversity in restored tallgrass prairie. *Restoration Ecology*, *18*, 40-49.

McDonnell, M. J., & Pickett, S. T. (1990). Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. *Ecology*,*71*(4), 1232-1237.

McDonnell, M. J., Pickett, S. T., & Pouyat, R. V. (1993). The application of the ecological gradient paradigm to the study of urban effects. In Humans as components of ecosystems (pp. 175-189). Springer, New York, NY.

McKinney, M. L. (2002). Urbanization, Biodiversity, and Conservation: The impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *Bioscience*, *52*(10), 883-890.

McLain, R. J., & Lee, R. G. (1996). Adaptive management: promises and pitfalls. *Environmental management*, *20*(4), 437-448.

Meals, D. W., Dressing, S. A., & Davenport, T. E. (2010). Lag time in water quality response to best management practices: A review. *Journal of environmental quality*, *39*(1), 85-96.

Middleton, J. R., & Barrett, M. E. (2008). Water Quality Performance of a Batch-Type Stormwater Detention Basin. *Water Environment Research, 80*(2), 172-178.

Morley, E., & Winkler, M. K. (2014). Assessing a set of indicators for creative placemaking: Reflections from the field. *Community Development Investment Review*, *10*(2), 49-55.

Nanz, P., & Steffek, J. (2004). Global governance, participation and the public sphere. *Government and opposition*, *39*(2), 314-335.

Nascimento, N. O., Ellis, J. B., Baptista, M. B., & Deutsch, J. C. (1999). Using detention basins: operational experience and lessons. *Urban water*, *1*(2), 113-124.

Nechyba, T. J., & Walsh, R. P. (2004). Urban sprawl. *Journal of economic perspectives, 18*(4), 177-200.

Niemczynowicz 1999-Department of Water Resources Engineering, University of Lund, Box 118, S-221 00 Lund, Sweden Received 14 January 1999; received in revised form 13 April 1999; accepted 20 July 1999

Norland, J., Fasching, S., Dixon, C., Askerooth, K., Kelsey, K., & Wang, G. (2013). Reduced establishment of Canada thistle (Cirsium arvense) using functionally similar native forbs. *Ecological Restoration*, *31*(2), 144-146.

Novak, C. A., Van Giesen, E., & DeBusk, K. M. (2014). Designing rainwater harvesting systems: integrating rainwater into building systems. John Wiley & Sons.

Olsson, P., Folke, C., & Hahn, T. (2004). Social-ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in southern Sweden. *Ecology and society, 9*(4).

Owen, J. (2010). Wildlife of a garden: a thirty-year study (p. 261). Peterborough: Royal Horticultural Society.

Passeport, E., Hunt, W. F., Line, D. E., Smith, R. A., & Brown, R. A. (2009). Field study of the ability of two grassed bioretention cells to reduce storm-water runoff pollution. *Journal of Irrigation and Drainage Engineering*, *135*(4), 505-510.

Paul, M. J., & Meyer, J. L. (2001). Streams in the urban landscape. *Annual review of Ecology and Systematics*, *32*(1), 333-365.

Petts, J., Owens, S., & Bulkeley, H. (2008). Crossing boundaries: Interdisciplinarity in the context of urban environments. *Geoforum*, *39*(2), 593-601.

Reddy, K. R., Xie, T., & Dastgheibi, S. (2014). Evaluation of biochar as a potential filter media for the removal of mixed contaminants from urban storm water runoff. *Journal of Environmental Engineering*, *140*(12), 04014043.

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., ... & Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of environmental management*, *90*(5), 1933-1949.

Rees, W., & Wackernagel, M. (2008). Urban ecological footprints: why cities cannot be sustainable—and why they are a key to sustainability. In Urban Ecology (pp. 537-555). Springer, Boston, MA.

Ries, L., Debinski, D. M., & Wieland, M. L. (2001). Conservation value of roadside prairie restoration to butterfly communities. *Conservation Biology*, *15*(2), 401-411.

Robertson, K. R., Anderson, R. C., & Schwartz, M. W. (1997). The tallgrass prairie mosaic. In Conservation in highly fragmented landscapes (pp. 55-87). Springer, Boston, MA.

Rowe, H. I. (2010). Tricks of the trade: techniques and opinions from 38 experts in tallgrass prairie restoration. *Restoration Ecology*, *18*, 253-262.

Roy, A. H., Wenger, S. J., Fletcher, T. D., Walsh, C. J., Ladson, A. R., Shuster, W. D., ... & Brown, R. R. (2008). Impediments and solutions to sustainable, watershed-scale urban stormwater management: lessons from Australia and the United States. *Environmental management*, *42*(2), 344-359.

Ruckelshaus, M., McKenzie, E., Tallis, H., Guerry, A., Daily, G., Kareiva, P., ... & Bernhardt, J. (2015). Notes from the field: lessons learned from using ecosystem service approaches to inform real-world decisions. *Ecological Economics*, *115*, 11-21.

Samson, F., & Knopf, F. (1994). Prairie conservation in North America. *BioScience, 44*(6), 418-421.

Scholes, L., Revitt, D. M., & Ellis, J. B. (2008). A systematic approach for the comparative assessment of stormwater pollutant removal potentials. *Journal of environmental management, 88*(3), 467-478.

Schueler, T. R. (1987). Controlling urban runoff: A practical manual for planning and designing urban BMPs. Water Resources Publications.

Shammaa, Y., Zhu, D. Z., Gyürék, L. L., & Labatiuk, C. W. (2002). Effectiveness of dry ponds for stormwater total suspended solids removal. *Canadian Journal of Civil Engineering*, *29*(2), 316-324.

Shearman, R. C., Beard, J. B., Hansen, C. M., & Apaclla, R. (1974). Turfgrass Wear Simulator for Small Plot Investigations 1. *Agronomy journal*, *66*(2), 332-334.

Shuster, W. D., Bonta, J., Thurston, H., Warnemuende, E., & Smith, D. R. (2005). Impacts of impervious surface on watershed hydrology: A review. *Urban Water Journal*, *2*(4), 263-275.

Silvius, A. G., & van den Brink, J. (2014). Taking responsibility: the integration of sustainability and project management. Advances in Project Management: Narrated Journeys in Unchartered Territory, 137.

Sinclair, A. J., & Smith, D. L. (1999). Policy Review The Model Forest Program in Canada: Building Consensus on Sustainable Forest Management?. *Society & natural resources*, *12*(2), 121-138.

Smith, R. M., Thompson, K., Hodgson, J. G., Warren, P. H., & Gaston, K. J. (2006). Urban domestic gardens (IX): composition and richness of the vascular plant flora, and implications for native biodiversity. *Biological conservation*, *129*(3), 312-322.

Stadtplanung Wien, 1996. Vienna, Green Network; the State of the Art. Stadtplanung Wien, Vienna.

Stanley, D. W. (1994). An evaluation of pollutant removal by a demonstration urban stormwater detention pond. NC Department of Environment, Health, and Natural Resources, Albemarle-Pamlico Estuarine Study.

Taylor, G. D., Fletcher, T. D., Wong, T. H., Breen, P. F., & Duncan, H. P. (2005). Nitrogen composition in urban runoff—implications for stormwater management. *Water research*, *39*(10), 1982-1989.

Tommasi, D., Miro, A., Higo, H. A., & Winston, M. L. (2004). Bee diversity and abundance in an urban setting. *Canadian Entomologist*, *136*(6), 851-869.

International Resource Panel, United Nations Environment Programme. Sustainable Consumption, & Production Branch. (2011). Decoupling natural resource use and environmental impacts from economic growth. UNEP/Earthprint.

Urbonas, B., & Stahre, P. (1993). Stormwater: Best management practices and detention for water quality, drainage, and CSO management. Prentice Hall.

Valiron, F. (1985). Gestion des eaux, alimentation en eau, assainissement: cours de l'Ecole nationale des ponts et chaussées. Paris, France, Enpc.

Vanbergen, A. J., & Initiative, T. I. P. (2013). Threats to an ecosystem service: pressures on pollinators. *Frontiers in Ecology and the Environment*, *11*(5), 251-259.

Vanini, J. T., Henderson, J. J., Sorochan, J. C., & Rogers III, J. N. (2007). Evaluating traffic stress by the Brinkman traffic simulator and Cady traffic simulator on a Kentucky bluegrass stand. *Crop science*, *47*(2), 782-784.

Walsh, C. J., Roy, A. H., Feminella, J. W., Cottingham, P. D., Groffman, P. M., & Morgan, R. P. (2005). The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society*, *24*(3), 706-723.

Wang, C. Y., Sample, D. J., & Bell, C. (2014). Vegetation effects on floating treatment wetland nutrient removal and harvesting strategies in urban stormwater ponds. *Science of the Total Environment*, 499, 384-393.

Weiss, G., Brombach, H., & Haller, B. (2002). Infiltration and inflow in combined sewer systems: long-term analysis. *Water Science and technology*, *45*(7), 11-19.

Whipple Jr, W., & Hunter, J. V. (1981). Settleability of urban runoff pollution. *Journal of Water Pollution Control Federation,* 1726-1731.

Whitehead, M. (2003). Analyzing the sustainable city: Nature, urbanization and the regulation of socio-environmental relations in the UK. *Urban Studies*, *40*(7), 1183-1206.

Wise, A. M., Grey, T. L., Prostko, E. P., Vencill, W. K., & Webster, T. M. (2009). Establishing the geographical distribution and level of acetolactate synthase resistance of Palmer amaranth (Amaranthus palmeri) accessions in Georgia. *Weed Technology*, *23*(2), 214-220.

Wong, T. H. (2006). Water sensitive urban design-the journey thus far. *Australasian Journal of Water Resources*, *10*(3), 213-222.

Wood, G., McDermott, P., & Swan, W. (2002). The ethical benefits of trust-based partnering: the example of the construction industry. *Business Ethics: A European Review*, *11*(1), 4-13.

Woodhill, J., & Röling, N. (1998). The second wing of the eagle: the human dimension in learning our way to more sustainable futures. Facilitating sustainable agriculture: *Participatory learning and adaptive management in times of environmental uncertainty*, 46-71.

Wu, J. S., & Ahlert, R. C. (1986). Modeling methodology for dual-function stormwater detention basins. *PB87*, 159711.

Wu, J. S., Holman, R. E., & Dorney, J. R. (1996). Systematic evaluation of pollutant removal by urban wet detention ponds. *Journal of Environmental Engineering*, *122*(11), 983-988,

CHAPTER 2: ASSESSING STAKEHOLDER PERCEPTIONS AND VIEWS OF SUCCESS IN A LARGE URBAN GREEN INFRASTRUCTURE PROJECT

Introduction

Urbanization and anthropogenic impact contribute to habitat loss, watershed degradation, and ecosystem fragmentation worldwide (Foley 2005; Rockstrom 2009). A myriad of challenges affects the governance and management of urban ecosystems including planning uncertainties, strained municipal workloads, and political demand (Kaczorowska et al. 2016). These challenges are complex as they impact many groups, ecosystem scales, and have uncertain outcomes (Reed 2018). Additionally, the ecosystems of urban areas are unique and often have complex issues surrounding zoning, social needs, heterogeneity, and private vs. public ownership (Pickett et al. 2001; Pickett 2011). There is a myriad of ecosystem services and benefits to the urban citizenry that green spaces provide (Nowak & Crane 2002; Davies et al., 2011; Sanesi et al. 2011; Shashua-Bar et al. 2011; Susca et al. 2011; European Commission, 2013; Haase et al. 2014; Petralli et al., 2014; Ugolini et al. 2015). Stakeholder groups, such as municipal residents, commercial groups, and municipal agencies, as well as biotic and abiotic factors, impact the urban environment (Alberti et al. 2003). Urban inhabitants can play a pivotal role in collaborating with municipal entities to develop positive sustainable solutions to urban ecosystem challenges (Ernston et al. 2010; Andersson 2014). Additionally, increased knowledge of these collaborations can improve future projects for all urban inhabitants (Ernston et al. 2010; Andersson 2014). Unfortunately, minimal literature exists on community-based green infrastructure projects and their process, successes, and failures, as most stakeholder processes are not documented or reported.

Most research to date on project success has been literature reviews (Jugdev and Müller, 2005; Turner and Zolin, 2012; Davis 2016). Beyond that, existing stakeholder literature generally focuses on project management (Reed 2018), construction (Rowlinson & Cheung 2008), and workflow (Alladi & Desik 2015). Literature to date for the most part fails to utilize empirical data, but instead focuses on methods and outcomes. It is important that empirical data be used to make sure stakeholder information and perceptions are correctly reflected in the research to improve future projects.

Stakeholder success literature suggests that project participants have different perceptions of how they define project success (Davis 2016) and project performance metrics and success criteria vary amongst projects and stakeholders (Dalcher and Drevin, 2003; Turner et al., 2009). In general, projects that represent stakeholders and the public are more likely to achieve their outcomes, and engagement by these groups is influenced by power dynamics (Reed et al. 2009). Typically, power dynamics exist in a top-down approach (Liu & Jensen 2018). However, this does not need to be the case. It is important to document the successes and challenges of projects that experience a different power dynamic and how this affects the outcome.

Stakeholder groups can enhance environmental sustainability in projects (Molla 2020), and stakeholder participation can produce ecologically minded urban design (Bowler et al. 2010; Demuzere et al. 2014; Liu et al. 2018), foster opportunities for green economy development (Zimmermann & Simpson 2013; Andersson et al. 2014) and develop foundations that strengthen social cohesion (Haase et al. 2014). Additionally, multifunctional green infrastructure components that have been programmed to provide ecosystem services have been shown to create more resilient urban environments (Bowler et al. 2010; Demuzere et al. 2014; Liu et al. 2018; Alves et al. 2018). Previous research has sought to define project success (Jugdev and

Müller, 2005; Turner and Zolin, 2012; Davis 2016); however, urban ecosystem projects are as unique as the areas in which they take place.

Success and failure can be viewed differently by stakeholder groups, therefore assessing stakeholders' perceptions is important. Any successful stakeholder assessment should aim to improve understanding of the project and identify stakeholder expectations (Mathur 2008); as well as, evaluate the opportunity to improve stakeholder outcomes (Markiewicz 2005). Nonprofit and community development groups, surveys and questionnaires, public meetings, and hearings are all ways that allow stakeholders to provide input on a project (Carter et al. 1997; Beierle 2000; Nanz et al. 2004). Research shows that stakeholder groups that provide input and participate in the design phase develop trust and "buy-in", new ideas are produced, and disagreements are diminished (Beierle 2000; Carmin et al. 2003). While some projects are adopting a more equitable decision-making process, many green infrastructure endeavors aimed at water management still utilize a top-down approach (Liu & Jensen 2018). If planners hope to develop broad stakeholder participation and strengthen social inclusion, it is important to determine the public view of success (Galea 2007; Pauleit et al. 2011). Previous environmental stakeholder assessments have focused on issues such as conflict resolution, biodiversity protection, and sustainable resource utilization (Kellert et al. 2000; Berkley 2013; Cebrián-Piqueras et al. 2017). Few, if any, studies with stakeholder involvement have focused on urban ecosystems and stakeholder perception. Assessments of these types of collaborative ventures are often done as an afterthought and with little documentation.

This study sought to garner perceptions of success amongst diverse stakeholder groups on a large urban green infrastructure project. The specific objectives were to: 1) determine organizational ways to assist in managing a project with diverse stakeholders; 2) evaluate the skills and/or tools that different groups contribute; and 3) assess stakeholders' perception of success and how they vary amongst different groups. Information from this project can aid future planners in successfully involving diverse stakeholders in the design and implementation of large green urban projects.

Methods

This project was part of a larger urban green infrastructure project called The Fargo Project (TFP 2021) focused on a large stormwater retention basin (46º 51' 10.10" N 96 º 51' 10.10" W) in Fargo, North Dakota, USA. The founders of the project had hopes of designing a multi-use green infrastructure area that would invite neighboring residents into the basin. They initially invited several participants to program, design, implement, and use a space that would be successful in terms of function, while also providing ecosystem services. Later, this participant group was greatly expanded to include diverse stakeholders from across the city, state, and the region encompassing city leaders, residents, nonprofit groups, different cultures, and different perspectives on design, including artists, engineers, researchers, and landscape architects, just to name a few.

Project leaders used the design goals of: let the water lead; learn from the natural environment; involve the community, and experience nature and ecology to guide the project. The original funding for the project came through the arts, and therefore the project was led by artists who worked with city leaders to choose a site. From there a team of local and national artists reached out to the community to hear what elements they wanted to be incorporated into the retrofitting of a stormwater detention basin. The process of engagement of the community, a large undertaking for this project, brought in as many stakeholder groups as possible and lasted approximately four years. The large stakeholder outreach was conducted to gauge what stakeholders valued in their green infrastructure from diverse perspectives. Information gathered was considered the foundation for designing the project. In accordance with the design principles, involving and learning from stakeholders was a top priority. After involving the community, artists, city leaders, and their partners began to plan the space. The first community input meetings began in 2012 and ended in 2016, followed by design and implementation from 2016 through 2019.

A survey instrument was developed to assess stakeholders' perceptions of the design and implementation process, and their visions of success for the future of the TFP. Stakeholder input on planning, communication, participation, and implementation, while identifying knowledge gaps and overlaps of stakeholder groups were assessed in the survey. Questions were designed utilizing the Likert scale whenever possible. The initial survey contained 99 questions. A focus group consisting of researchers, water resource professionals, city leaders, nonprofit groups, and local citizens were utilized to determine whether the survey made sense and would garner the knowledge sought by researchers. The focus group helped to categorize and clarify questions.

The final survey contained 89 questions (Appendix A) and was approved by the North Dakota State University Institutional Review Board prior to being administered. The first section of the stakeholder participation survey asked the participant to identify with a stakeholder group (ex. engineer, researcher, volunteer) and the area of knowledge they contributed to the project. The next section focused on the individual's vision for success, education about the project, and perceptions of TFP. The remaining questions sought to evaluate the needs and management of TFP based on the stakeholder's perspective. The survey was distributed electronically to 189 stakeholders via email in 2019. The survey was administered electronically using Qualtrics software (Provo, Utah). The survey was conducted anonymously, and no identifying questions were asked. The results of the survey discussed in this paper will not cover all questions, as communication and logistical questions included in the survey were meant to provide organizers project-specific insight and are not likely to be useful to a larger audience.

Results and Discussion

Two subpopulations were identified prior to the survey being sent out: 1) engaged participants, i.e., people who engaged with the project annually or more frequently; and 2) peripheral participants, people who engaged with the project only once. Out of the 189 people invited to complete the survey, there were 44 responses. One of the responses was not completed to a point where results could be assessed. Therefore, 43 responses were analyzed for the study. Of the 43 complete responses, 32 (74% of the total responses) identified themselves as participating annually or more frequently and were considered engaged participants. The other 11 responses (26%) were considered peripheral participants. The one-time peripheral participants were often attendees to the planning and community input events, which were attended by approximately 50 to 75 people. Stakeholders that categorized their involvement as monthly participation were 23% (n=10) of participants, followed by weekly at 16% (n=7). Because 32 of the surveys were from engaged participants, and a total of 50 participants who were sent the survey were estimated to be in the engaged subpopulation, the survey likely resulted in responses from 64% of the engaged participants. According to Baruch and Holtom (2008), a survey response rate for organizational research above 50% of the targeted population is considered representative of the entire population and adequate for scholarly work. Therefore, results can be considered representative of the entire engaged stakeholder population and further statistical analysis and interpretation are not needed. The peripheral participants typically do not make large contributions nor do they often understand the many facets of the project that would constitute the need for a separate analysis of their responses. Therefore, peripheral responses were not interpreted separately and are only included in summarized data.

The survey instrument asked stakeholders to identify their work on the project from a list of 19 categories; 17 of the 19 categories were represented (Figure 2.1). Half of the respondents identified themselves in one of four groups: government officials (30%, n=13), researchers (7%, 7n=3), residents (7%, n=3), and community volunteers (7%, n= 3). Respondents that participated in an advisory role were designers, engineers, artists, researchers, nonprofits, residents, community volunteers, and public or government agencies. This diverse participation level exhibits a wide range of involvement and a transdisciplinary approach to stakeholders. In reference to TFP, the engaged participants met more frequently on the project to design and steer decisions. However, having larger numbers of stakeholders participate less frequently aided project leaders by filling gaps in knowledge and work needs to create a successful project. Increased stakeholder participation has been shown to benefit projects as it allows stakeholders to achieve a greater understanding of the issues that are important and work through conflicts that may arise (Newton & Elliott 2016). Additionally, increased participation by stakeholders can help form unified goals, establish community buy-in, and help create interest across geopolitical boundaries (Platt 2006; Moran et al. 2019).

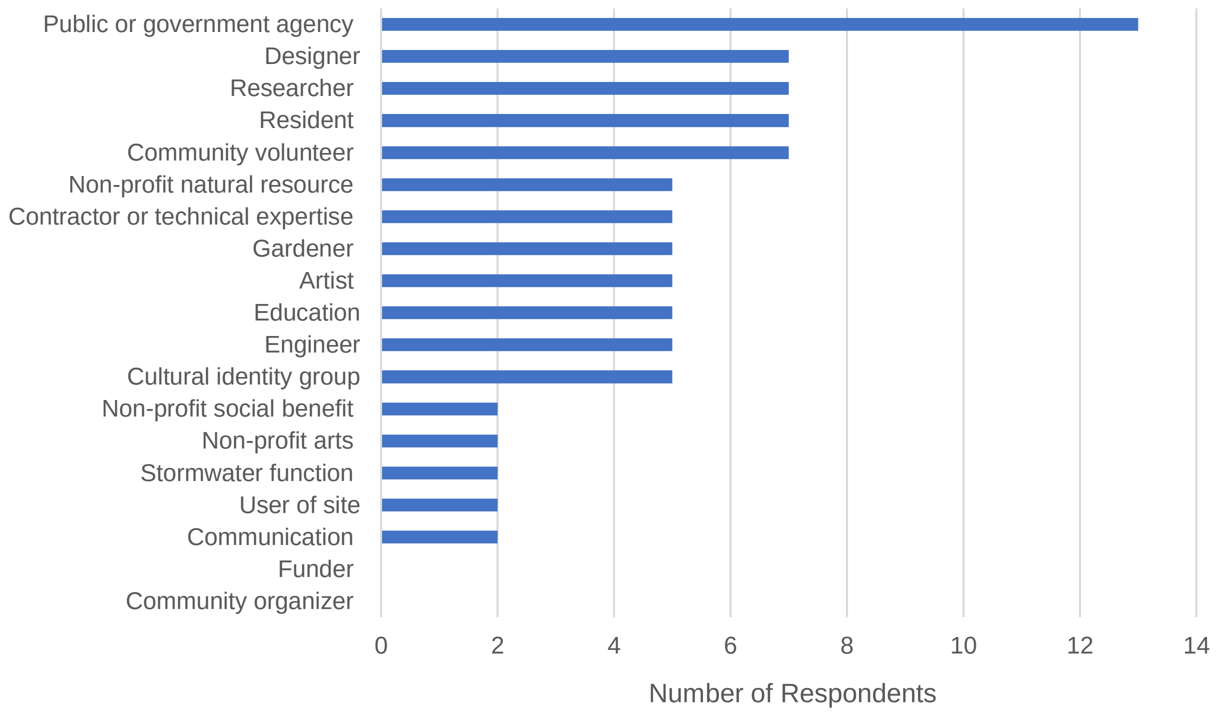

Figure 2.1. Stakeholder groups to which participants identify on The Fargo Project.

Stakeholder Classification and Knowledge

Twenty-two categories were identified as "knowledge" that contributed to the design, development, and management of TFP (Figure 2.2). Stakeholders could be involved in more than one aspect of the project and were asked to mark all categories that applied to their participation. The categories with the most involvement were: planning (9%, n=17); environmental outreach (9%, n=16); project design (9%, n=15); community development (8%, n=14); communications (7%, n=12); native plantings (7%, n=12); and project management (6%, n=10) (Figure 2.2). Fundraising had the lowest participation with only one participant, but funding is a pivotal driver of most green infrastructure projects. The survey revealed that overall, fundraising (1%, n=1), soil specialist (2%, n=3), and permitting personal (2%, n=4) were the most underrepresented knowledge categories. Future projects may want to assess their knowledge needs and specifically target stakeholder groups that showed low participation and are deemed essential to meeting project objectives, such as fundraising and communications. However, for groups representing categories like soil science and permitting, low numbers of participants may be acceptable as only one person with that knowledge might be enough.

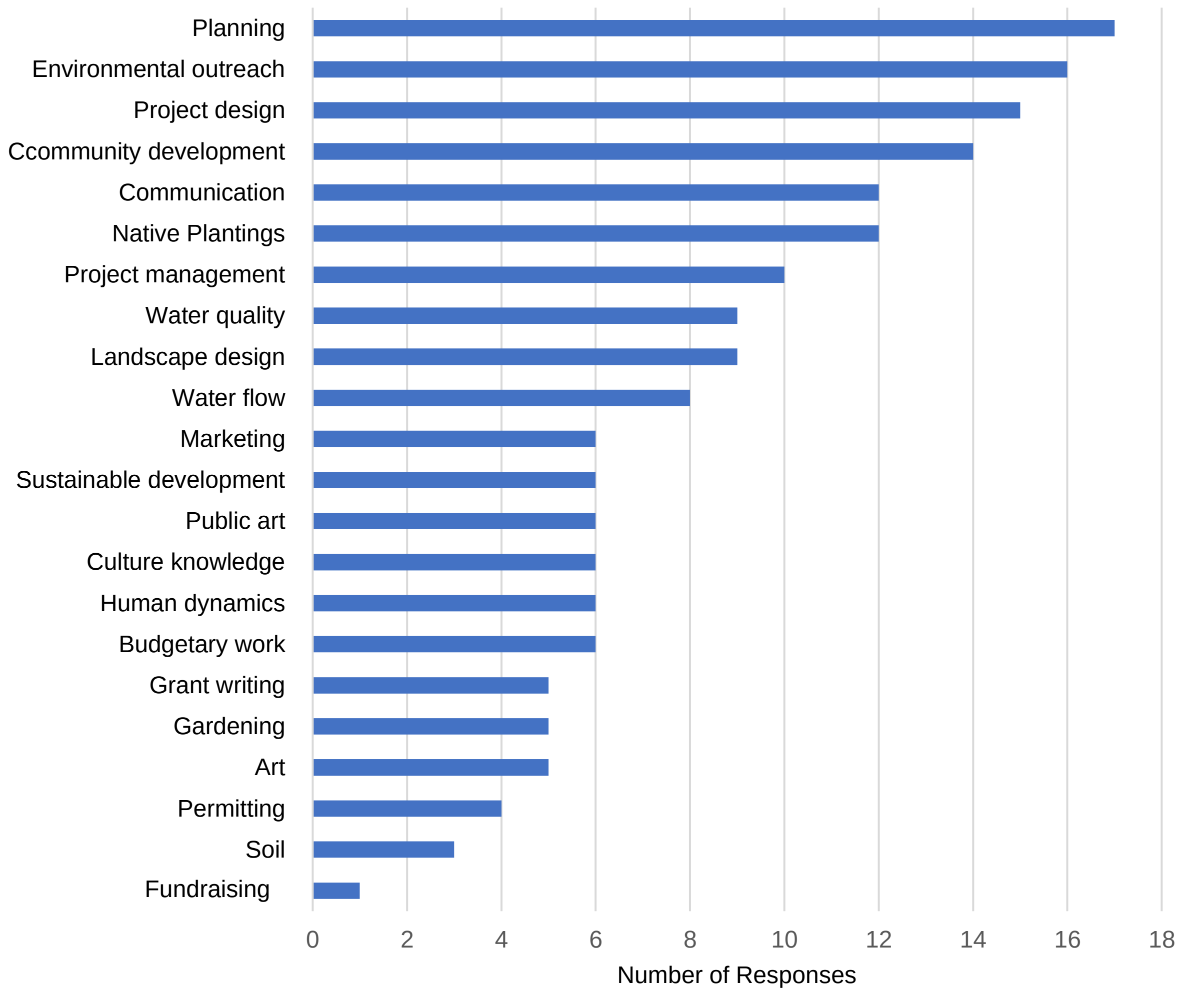

Figure 2.2. Participants knowledge contributions to the Fargo Project.

Projects similar in scope to TFP generally always include engineers and government officials, but not always other stakeholder groups. Including a breadth of stakeholders knowledgeable in topics such as research, art, native plantings, community development, and environmental outreach will likely reach a greater audience amongst area residents (Herslund et al. 2018). Additionally, specifically targeting local stakeholder groups to cover knowledge gaps that may arise in future projects may prove to be beneficial for community-based resource projects (Lederer et al. 2017). Authors feel the diverse stakeholders utilized in TFP helped to meet the goals and ensure the success of the project, as was mentioned being beneficial by Newton and Elliott (2016).

Potential Successes

The design goals of TFP founders were: 1) let the water lead; 2) learn from nature; 3) involve the community; and 4) experience nature. These goals were introduced to stakeholders at the beginning of the project. In the survey, stakeholders were asked to rank many potential successes at the TFP to determine what successes stakeholders valued. Stakeholders were first asked about three major categories of success to see which they valued most: water and nature, successful design, and achieving project goals. Overall, survey respondents viewed water and nature as the most important (55%, n=22), followed by design (24%, n=10), and project goals was a close third at 23% (n=9). Stakeholders' responses reflected what its founders valued when programming and designing the site. Introducing design goals early in a project can aid stakeholders in understanding the human elements of urban ecosystem restorations (Pickett et al. 1997). It may be helpful for project leaders on other projects to define inclusive objectives early in the process and readily communicate them to stakeholders.

Next stakeholders were given the opportunity to rank potential successes at TFP in order of importance, there was a large variety of potential successes, so they were divided into related topics to determine rankings. There were six potential options in each question that respondents could rank 1-6, with one being the most important and six being the least important. The first set of potential successes focused on the purpose of the site, respondents ranked a useful recreation space (29% n=12), more people visiting the space (22%, n=9), and a gathering space (22% n=9) as their top priority (Figure 2.3). The category that ranked the lowest by stakeholders was recognition of project site and name (68% n=28).

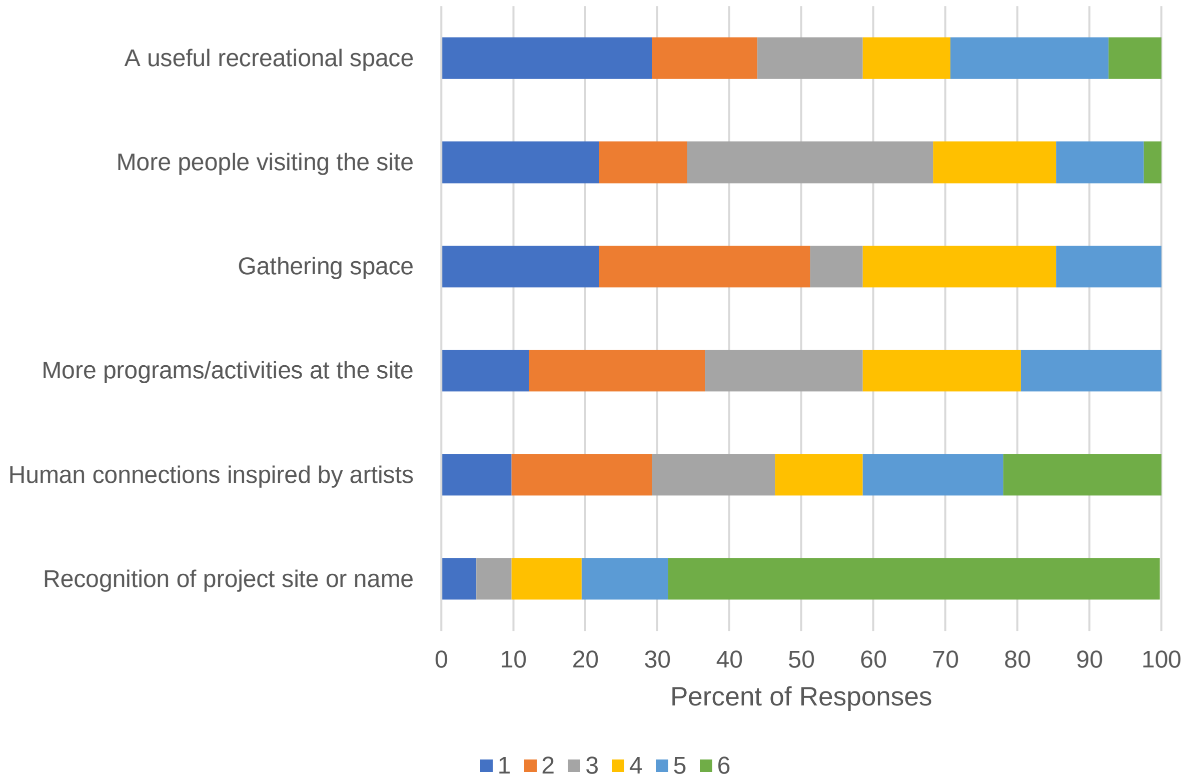

Figure 2.3. Ranking of potential successes in order of importance at the Fargo Project with one being the most important.

When participants were asked to rank potential successes of the natural aspects at TFP, the two highest rankings were having a functional stormwater basin (42%, n=18), followed by a natural space (23%, n=10), and then a place to connect with nature (16%, n=7) (Figure 2.4). Even in a multi-use system, it is important that the primary function, in this case, stormwater detention, is accomplished (Chang et al. 2021). Success at TFP was viewed by stakeholders as multi-faceted, serving purposes greater than just project function. This is similar to the findings of Pickett et al. (2011), who found that a multidisciplinary model would satisfy both natural and social scientists and the success of these models consisted of learning and feedback between urban ecosystems and the humans within them (Pickett et al. 2011).

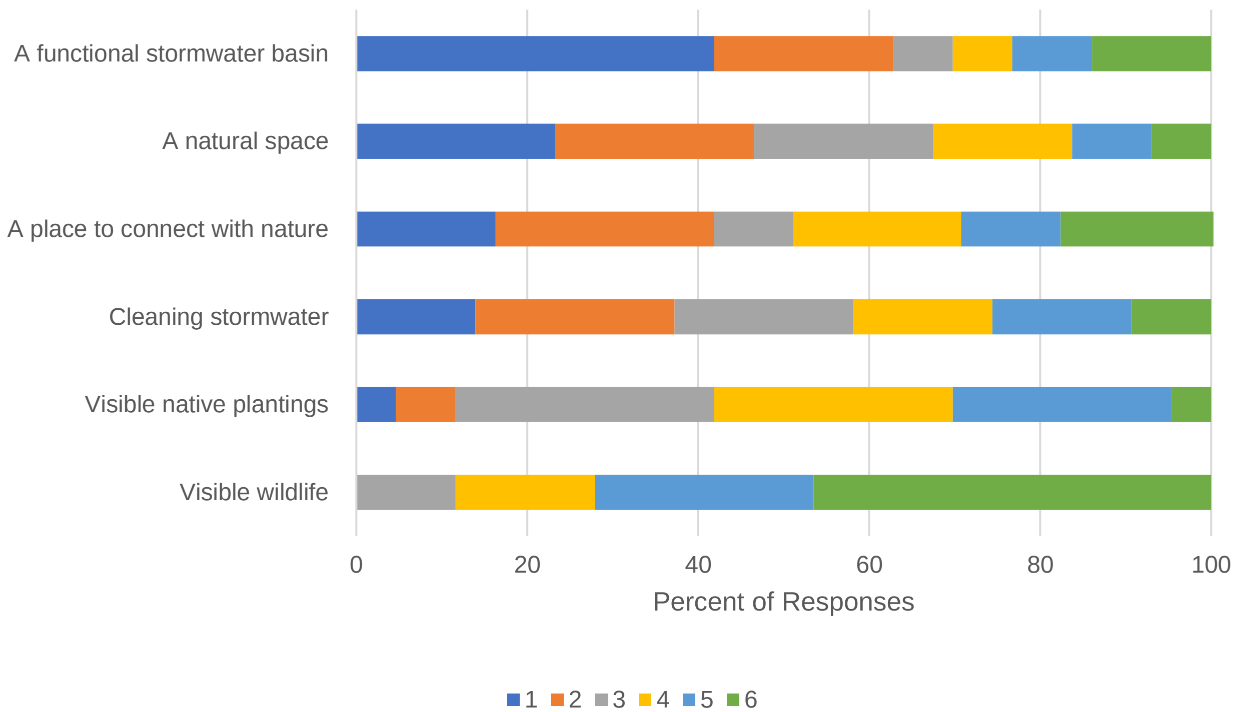

Figure 2.4. Ranking of potential successes at The Fargo Project with one being most important.

Stakeholder success is often viewed as meeting objectives (Newton & Elliott 2016). Respondents in the current study indicated, in regard to project objectives, that they want functional components like stormwater retention, but also feel the site can provide other amenities such as ecosystem services and recreational space. Future projects could benefit from determining objectives early in the planning process with stakeholder input, to ensure the project maintains its objectives throughout (Liu et al. 2018).

Project Communication and Perceptions

Stakeholders were asked how they viewed their experience with TFP (Table 2.1). When asked whether they had a positive or negative response to the statement, "you felt the collaboration methods (meetings, public events, and workshops) were positive", 54% (n=23) agreed, and 32% (n=13) strongly agreed. Often, respondents felt their knowledge was valued and utilized during the project, with 34% (n=14) agreeing and 32% (n=13) strongly agreeing. When asked if "future projects similar in scope to TFP need to include your stakeholder group's knowledge", 49% (n=20) strongly agreed. This high number shows that stakeholders felt that their time and efforts were needed and valued. Not only did stakeholders reiterate their need to be involved in the project, but they expressed a desire to remain active once their stakeholder group had completed its work. The Fargo Project was successful in terms of perception and buy-in as 43% (n=17) of stakeholders agreed with the statement, "you would like to participate in similar projects of this nature," and another 40% (n=16) strongly agreed. Again, when respondents were asked if "you would like to continue to stay involved (communication updates, volunteering) on TFP after your stakeholder group has reached its goals", 43% (n=17) agreed and 34% (n=14) strongly agreed. This demonstrates a “buy-in” and commitment from the stakeholders involved, which is important to perpetuate the success of a project (Hall et al. 2016).

Design goals were established early in TFP to help municipal leaders set the tone. When participants were asked if they think the goals of TFP in terms of “let the water lead” have been achieved, results indicate 48% (n=19) neither agreed nor disagreed it had been achieved, but 68% (n=26) either agreed or strongly agreed that it is achievable. When asked about the goal of “learn from the natural environment”, 65% (n=26) agreed this has already been achieved (Table 2.2). These differences in respondents' answers when asked if they felt the same goal could be or had been achieved show that stakeholders feel the design objectives are achievable, but at the time of the survey, they had not been achieved. It is worth noting that the survey was completed shortly after the construction and implementation of features at the site, but before programming and use of the site was started. Researchers speculate that stakeholder responses reflect the project being new and in the recent implementation state. Continual monitoring and adjustments to the project will be needed to eventually realize its full potential. Holling (1978) defined the term "adaptive management", essentially adapting management of a site based on gained knowledge and lessons learned. The principles of adaptive management are useful in urban green infrastructure projects, as with TFP, to ensure we learn from past management to improve for the future. By continually monitoring and adapting at TFP, the project hopes to meet all of its objectives.

Table 2.1. Percent of responses for questions related to perceptions of the Fargo Project. Number of respondents are in parentheses.

Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
You viewed your experience working on TFP as a positive experience.	0 % (0)	0 % (0)	12 % (5)	51 % (21)	37 % (15)
You felt the collaboration methods (meetings, public events, and workshops) were positive.	0 % (0)	0 % (0)	14% (6)	54 % (22)	32 % (13)
You felt that you were included in the collaboration process.	0 % (0)	7 % (3)	27 % (11)	34 % (14)	32 % (13)
You felt that you were valued in the collaboration process.	0 % (0)	7 % (3)	23 % (9)	40 % (16)	30 % (12)
Future projects similar in scope to TFP need to include your stakeholder group's knowledge.	0 % (0)	0 % (0)	19 % (8)	32 % (13)	49 % (20)
This project could be replicated without your stakeholder groups skill set.	15 % (6)	24 % (10)	32 % (13)	27 % (11)	2 % (1)
You would have liked to participate more in TFP.	0 % (0)	15 % (6)	37 % (15)	29 % (12)	19 % (8)
You would like to participate in similar projects of this nature.	0 % (0)	5 % (2)	12 % (5)	43 % (17)	40 % (16)
You would like to continue working on TFP indefinitely.	0 % (0)	23 % (9)	18 % (7)	30 % (12)	29 % (12)
You would like to continue to stay involved (communication updates, volunteering) on TFP after your stakeholder group has reached its goals.	0 % (0)	10 % (4)	12 % (5)	44 % (17)	34 % (14)

Table 2.2. Percent of responses for questions related goals and attainability. Number of respondents are in parentheses.

Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
As a design goal “Let the water lead” is achievable.	0.0% (0)	5% (2)	28% (11)	46% (18)	21% (8)
As a design goal “Let the water lead” has been achieved.	2% (1)	18% (7)	48% (19)	25.0% (10)	7% (3)
As a design goal “Let the water lead” will be achieved in the near future (next five years).	0.0% (0)	5% (2)	41% (18)	44% (17)	10% (4)
As a design goal “Learn from the natural environment” is achievable.	0.0% (0)	2% (1)	18% (7)	57% (23)	23% (9)
As a design goal “Learn from the natural environment” has been achieved.	0.00% (0)	20.0% (8)	45% (18)	30% (12)	5% (2)
As a design goal “Learn from the natural environment will be achieved in the near future (next five years).	0.00% (0)	1% (1)	18% (7)	56% (23)	25% (10)

This project is unique among traditional urban green infrastructure projects that are often led by city leaders and engineers. From TFP inception, it was led by artists. The local government in charge of the project sought to differ from traditional green infrastructure projects by having "artists, neighbors, engineers, landscape architects, and ecologists work together to develop a solution to transform a neighborhood stormwater basin that fits their unique needs as a community" (TFP 2020). Participants were asked if they understood the overarching goals of TFP, and they agreed they did, with 45% (n=25) agreeing and 25% (n=10) strongly agreeing (Table 2.3). They also agreed 45% (n=25) and strongly agreed 48% (n=19) that TFP is a worthy cause to replicate. A total of 45% (n=25) respondents strongly agreed, and 32.5% (n=13) agreed when asked if they understood TFP was an artist lead and artist funded project. Stakeholders involved in this project, in general, reacted positively to the presence of artists in the list of partners as 35% (n=14) agreed and 50% (n=20) strongly agreed that it is important for future projects similar to TFP to include artists as team members (Table 2.3). The participants also were cognizant of the project having a different character due to the project being led by artists, with 35% (n=14) strongly agreeing and 43% (n=17) agreeing that they noticed a difference in management style for the project.

Overall results for this portion of the survey indicate participants feel it is important to have artists included in urban green infrastructure projects, such as TFP, but they do not feel it is necessary to have the project be led by artists. This difference of opinions and divergence of ideas is not only something seen with TFP, but also worldwide with other urban ecosystem projects involving multiple stakeholders (Gobster 2001; Alberti et al. 2003; Matsuoka & Kaplan 2008). This is valuable information for community governments and project managers responsible for green infrastructure design and urban retrofits, as artists are not always involved as stakeholders of projects, but the community does value their insight and expertise.

Table 2.3. Percent of responses for questions on the goals, mission, and model of TFP. Number of responses are in parentheses.

Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
You understood (before this survey) that TFP is an artist led an artist funded project	0% (0)	7% (3)	15% (6)	33% (13)	45% (18)
You understand the overarching goals of TFP	0.00% (0)	5% (2)	25% (10)	45% (18)	25% (10)
You think TFP is a worthy cause to replicate	0.0% (0)	0.0% (0)	7% (3)	45% (18)	48% (19)
It is important for future projects similar in nature to TFP to include artists as team members	0% (0)	2% (1)	13% (5)	35% (14)	50% (20)
You notice a difference in this project management style due to it being artist LED	0% (0)	2.5% (1)	20% (8)	42.5% (17)	35% (14)

Public projects that hope to develop community buy-in succeed when the public is educated about project goals and objectives through collaboration (Smith 2016). The planners of TFP sought public input from a variety of programs and communication methods. Survey participants agreed that public events 67% (n=28), emails 52% (n=22), and meetings 55% (n=23) were effective methods of educating stakeholders (Table 2.4). These results could aid future planners wishing to effectively involve stakeholders in a project.

Table 2.4. Percent of responses about communication and education about TFP. Number of responses are in parentheses.

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
You found Public Events to be an effective way to educate the public about TFP.	0.00% (0)	2% (1)	17% (7)	67% (28)	14% (6)
You found email to be an effective way to educate the public about TFP.	0.00% (0)	12% (5)	34% (14)	52% (22)	2%(1)
You found meetings to an effective way to educate the public about TFP.	0.00% (0)	9% (4)	31% (13)	55% (23)	5%(2)
You found design events such as the We Design Events to be an effective way to educate the public about TFP.	0.00% (0)	2.% (1)	38% (16)	38% (16)	22% (9)

Respondents were next asked about the management of the TFP. Results signified that most participants did not have strong leanings about management, but many agreed the management of the project was effective (Table 2.5). The most "strongly agree" responses 23% (n=9) were related to design, meaning stakeholders thought the design management part of the project was especially effective. Additionally, 54% (n=21) of TFP participants agreed that the project management in terms of communication/outreach was effective, and 45% (n=18) agreed that education was effective.

Table 2.5. Responses to questions about the management of TFP. Number of responses are in parentheses.

Field	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The project management of TFP in terms of design was effective.	0.0% (0)	2% (1)	33% (13)	43% (17)	23% (9)
The project management of TFP in terms of implementation was effective.	0% (0)	0.0% (0)	48% (19)	42% (17)	10% (4)
The project management of TFP project in terms of project management was effective.	0% (0)	3% (1)	43% (18)	41% (16)	13% (5)
The project management of TFP in terms of communication/outreach was effective.	0% (0)	8% (3)	33% (13)	54% (21)	5% (2)
The project management of TFP in terms of education was effective.	0% (0)	8% (3)	41% (16)	45% (18)	6% (2)

Conclusion

This project was viewed as a success by most stakeholders. There were a variety of different stakeholders involved in TFP: planners; engineers; artists; natural resource professionals; nonprofit groups; researchers; conservation workers; landscape architects; soil scientists; plant and restoration groups; cultural groups; gardeners; and the general public. This diverse group represents a wide range of involvement and a trans-disciplinary approach. All these people came to the table with different ideas of what an urban area is, what stormwater retention should look like, and what would be "success" at TFP. There were many overlaps in the knowledge of stakeholders, but few gaps.

Participants valued the success of the project as maintaining functional purpose and a place that contains natural habitat. Most stakeholders wanted to see a functional stormwater basin, but also a place to recreate passively. In general, participants agreed with the design goals laid out by project founders, and involving stakeholders in those goals and why they were important allowed for good stakeholder buy-in. This is especially interesting as the TFP was artist-led and differed from traditional municipal projects. The Fargo Project's artist leadership demonstrates that similar projects may achieve success even if a non-traditional leader is appointed and/or stakeholder groups are diverse.

Recommendations for future projects are to utilize stakeholder groups with broad and diverse skill sets. This myriad of knowledge expands beyond traditional top-down governmental approaches and allows stakeholders more input. Additionally, identifying objectives early in the process not only provides a road map to success, but creates buy-in with stakeholders. The structure and participation in this project allowed planners to tie their urban environment to the larger landscape, thus creating benefits across geopolitical boundaries not recognized by the natural world. Information gleaned from participants can be applied to other community based green infrastructure projects where success for both municipal leaders and community members is desired.

Literature Cited

Alberti, M., Marzluff, J. M., Shulenberger, E., Bradley, G., Ryan, C., & Zumbrunnen, C. (2003). Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. *BioScience*, 53(12), 1169-1179.

Alberti, M., & Marzluff, J. M. (2004). Ecological resilience in urban ecosystems: linking urban patterns to human and ecological functions. *Urban Ecosystems*, *7*(3), 241-265.

Alladi, A., & Desik, P. H. (2015). Workflow automation process for a reinsurance company using BPM tool: a stakeholder engagement perspective. In *Systemic Flexibility and Business Agility* (pp. 187-202). Springer, New Delhi.

Andersson, E., Barthel, S., Borgström, S., Colding, J., Elmqvist, T., Folke, C., & Gren, Å. (2014). Reconnecting cities to the biosphere: stewardship of green infrastructure and urban ecosystem services. *Ambio, 43*(4), 445-453.

Baruch, Y. & Holtom, B.C. (2008). Survey response rate levels and trends in organizational research. *Human Relations*, *61*(8), 1139-1160.

Beierle, T. C., 2000. Public participation in environmental decisions: an evaluation framework using social goals. Discuss. Pap 99–06, Resource of the Future, Washington. D. C

Berkley, J. (2013). Opportunities for collaborative adaptive management progress: integrating stakeholder assessments into progress measurement. *Ecology and Society*, *18*(4).

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC public health*, *10*(1), 1-10.

Cain, A. (2017). *Water resource management under a changing climate in Angola's coastal settlements*. International Institute for Environment and Development (IIED).

Carmin, J., Darnall, N., & Mil-Homens, J. (2003). Stakeholder involvement in the design of US voluntary environmental programs: does sponsorship matter?. *Policy Studies Journal*, *31*(4), 527-543.

Carter, N. & Darlow, A. (1997). Local Agenda 21 and developers: Are we better equipped to build a consensus in the 1990s? *Planning Practice & Research*, *21*(1), 45-57.

Cebrián-Piqueras, M. A., Karrasch, L., & Kleyer, M. (2017). Coupling stakeholder assessments of ecosystem services with biophysical ecosystem properties reveals importance of social contexts. *Ecosystem Services*, *23*, 108-115.

Collins, J. P., Kinzig, A., Grimm, N. B., Fagan, W. F., Hope, D., Wu, J., & Borer, E. T. (2000). A New Urban Ecology Modeling human communities as integral parts of ecosystems poses special problems for the development and testing of ecological theory. *American Scientist*, *88*(5), 416-425.

Chang, H. S., Man, C. Y., & Su, Q. (2021). Research on the site selection of watershed public facilities as multi-use detention basin: an environmental efficiency perspective. *Environmental Science and Pollution Research*, *28*(29), 38649-38663.

Dalcher, D., & Drevin, L. (2004). Learning from information systems failures by using narrative and ante-narrative methods. *South African Computer Journal*, *2004*(33), 88-97.

Davies, Z.G., Edmondson, J.L., Heinemeyer, A., Leake, J.R., Gaston, K.J., 2011. Mapping an urban ecosystem service: quantifying above-ground carbon storage at a city-wide scale. *J. Appl. Ecol. 48*, 1125–1134.

Davis, K. (2016). A method to measure success dimensions relating to individual stakeholder groups. *International Journal of Project Management*, *34*(3), 480-493.

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., ... & Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of environmental management*, *146*, 107-115.

Ernstson, H., Barthel, S., Andersson, E., & Borgström, S. T. (2010). Scale-crossing brokers and network governance of urban ecosystem services: the case of Stockholm. *Ecology and Society*, *15*(4), 28.

European Commission, 2013. Technical information on Green Infrastructure (GI). SWD(2013) 155 final, Brussels, 6.5.2013. Visited on the 6th September 2014: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX. 52,013SC0155&from=EN

Fiorino, D. J. (1990). Citizen participation and environmental risk: A survey of institutional mechanisms. *Science, Technology, & Human Values*, *15*(2), 226-243.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., ... & Helkowski, J. H. (2005). Global consequences of land use. *Science*, *309*(5734), 570-574.

Galea, S., Ahern, J., Nandi, A., Tracy, M., Beard, J., & Vlahov, D. (2007). Urban neighborhood poverty and the incidence of depression in a population-based cohort study. *Annals of epidemiology*, *17*(3), 171-179.

Glicken, J. (2000). Getting stakeholder participation ‘right’: a discussion of participatory processes and possible pitfalls. *Environmental Science & Policy*, 3(6), 305-310.

Gobster, P. H. (2001). Visions of nature: conflict and compatibility in urban park restoration. *Landscape and Urban Planning*, 56(1-2), 35-51.

Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., Gomez-Baggethun, E., Gren, A., Hamstead, Z., Hansen, R., Kabisch, N., Kremer, P., Langemeyer, J., Rall, E.L., McPhearson, T., Pauleit, S., Qureshi, S., Schwarz, N., Voigt, A., Wurster, D., Elmqvist, T., 2014. A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. *Ambio 43* (4), 413–433

Habitat, U. N. (2008). State of the world's cities 2008/2009: Harmonious cities. Earthscan, London. 264 pp.

Hall, D. M., Gilbertz, S. J., Anderson, M. B., & Ward, L. C. (2016). Beyond "buy-in": designing citizen participation in water planning as research. *Journal of Cleaner Production*, 133, 725-734.

Herslund, L., Backhaus, A., Fryd, O., Jørgensen, G., Jensen, M. B., Limbumba, T. M., ... & Yeshitela, K. (2018). Conditions and opportunities for green infrastructure–Aiming for green, water-resilient cities in Addis Ababa and Dar es Salaam. *Landscape and Urban Planning*, *180*, 319-327.

Holling, C. S. (1978). Adaptive environmental assessment and management, John Wiley and Sons, New York.

Innes, J. E., & Booher, D. E. (2004). Reframing public participation: strategies for the 21st century. *Planning Theory & Practice*, *5*(4), 419-436.

Jugdev, K., & Müller, R. (2005). A retrospective look at our evolving understanding of project success. *Project management journal*, *36*(4), 19-31.

Kaczorowska, A., Kain, J. H., Kronenberg, J., & Haase, D. (2016). Ecosystem services in urban land use planning: Integration challenges in complex urban settings—Case of Stockholm. *Ecosystem Services*, *22*, 204-212.

Kellert, S. R., Mehta, J. N., Ebbin, S. A., & Lichtenfeld, L. L. (2000). Community natural resource management: promise, rhetoric, and reality. *Society & Natural Resources*, *13*(8), 705-715.

La Porte, T. R. (1996). High reliability organizations: Unlikely, demanding and at risk. *Journal of Contingencies and Crisis Management*, *4*(2), 60-71.

Lederer, J., Ogwang, F., & Karungi, J. (2017). Knowledge identification and creation among local stakeholders in CDM waste composting projects: A case study from Uganda. *Resources, Conservation and Recycling*, *122*, 339-352.

Liu, L., & Jensen, M. B. (2018). Green infrastructure for sustainable urban water management: Practices of five forerunner cities. *Cities*, *74*, 126-133.

Markiewicz, A. (2005). 'A balancing act': Resolving multiple stakeholder interests in program evaluation. *Evaluation Journal of Australasia*, *4*(1-2), 13-21.

Mathur, V. N., Price, A. D., & Austin, S. (2008). Conceptualizing stakeholder engagement in the context of sustainability and its assessment. *Construction Management and Economics*, *26*(6), 601-609.

Matsuoka, R. H., & Kaplan, R. (2008). People needs in the urban landscape: analysis of landscape and urban planning contributions. *Landscape and Urban Planning*, *84*(1), 7-19.

Molla, M. B. (2020). The role of stakeholders in improving management practices of urban green infrastructure in Southern Ethiopia. *Planning Practice & Research*, *35*(2), 220-230.

Moore, E. A., & Koontz, T. M. (2003). Research note a typology of collaborative watershed groups: Citizen-based, agency-based, and mixed partnerships. *Society and Natural Resources*, 16(5), 451-460.

Moran, J., & Carlier, J. (2019). Landscape typology and ecological connectivity assessment to inform Greenway design. *Science of the Total Environment*, *651*, 3241-3252.

Morley, E., & Winkler, M. K. (2014). Assessing a set of indicators for creative placemaking: Reflections from the field. *Community Development Investment Review*, *10*(2), 49-55.

Nanz, P. & Steffek, J. (2004). Global governance, participation and the public sphere. *Government and Opposition*, 39 (2), 314-335.

Newton, A., & Elliott, M. (2016). A typology of stakeholders and guidelines for engagement in transdisciplinary, participatory processes. *Frontiers in Marine Science*, 3, 230.

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental pollution*, *116*(3), 381-389.

Olander, S., & Landin, A. (2005). Evaluation of stakeholder influence in the implementation of construction projects. *International Journal of Project Management*, 23(4), 321-328.

Pauleit, S., Liu, L., Ahern, J., & Kazmierczak, A. (2011). Multifunctional green infrastructure planning to promote ecological services in the city. In *Handbook of urban ecology*. Oxford University Press.

Petralli, M., Massetti, L., Brandani, G., Orlandini, S., 2014. Urban planning indicators: useful tools to measure the effect of urbanization and vegetation on summer air temperatures. Int. J. Climatol. 34, 1236–1244, http://dx.doi.org/10. 1002/joc.3760.

Pickett, S. T., Cadenasso, M. L., Grove, J. M., Nilon, C. H., Pouyat, R. V., Zipperer, W. C., & Costanza, R. (2001). Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. *Annual Review of Ecology and Systematics*, 32(1), 127-157.

Pickett, S. T., Cadenasso, M. L., Grove, J. M., Boone, C. G., Groffman, P. M., Irwin, E., ... & Warren, P. (2011). Urban ecological systems: Scientific foundations and a decade of progress. *Journal of environmental management*, *92*(3), 331-362.

Platt, R. H. (2006). Urban watershed management: Sustainability, one stream at a time. *Environment: Science and Policy for Sustainable Development*, *48*(4), 26-42.

Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., ... & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science & Policy*, *77*, 15-24.

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., ... & Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of environmental management*, *90*(5), 1933-1949.

Reed, M. S., Vella, S., Challies, E., de Vente, J., Frewer, L., Hohenwallner-Ries, D., ... & van Delden, H. (2018). A theory of participation: what makes stakeholder and public engagement in environmental management work? *Restoration Ecology*, 26, S7-S17.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., ... & Nykvist, B. (2009). A safe operating space for humanity. *Nature*, 461(7263), 472-475.

Rowlinson, S., & Cheung, Y. K. F. (2008). Stakeholder management through empowerment: modelling project success. *Construction Management and Economics*, *26*(6), 611-623.

Sanesi, G., Gallis, C., Kasperidus, H.D., 2011. Urban forests and their ecosystem services in relation to human health. In: Nilsson, K., Sangster, M., Gallis, C., Hartig, T., de Vries, S., Seeland, K., Schipperijn, J. (Eds.), Forests, Trees and Human Health. Springer, Netherlands, pp. 23–40.

Shashua-Bar, L., Pearlmutter, D., Erell, E., 2011. The influence of trees and grass on outdoor thermal comfort in a hot-arid environment. Int. J. Climatol. 31, 1498–1506

Smith, Z. A. (2015). Perspective from the field: collaborative management in natural resources and environmental administration. *Environmental Practice*, 17(2), 156-159.

Susca, T., Gaffin, S. R., & Dell'Osso, G. R. (2011). Positive effects of vegetation: Urban heat island and green roofs. *Environmental pollution*, *159*(8-9), 2119-2126.

The Fargo Project. (2020). *About – The Fargo project*. The Fargo Project – Prairie For The People. Accessed July 22, 2020 from: https://www.thefargoproject.com/about/.

Turner, J. R., Ledwith, A., & Kelly, J. (2009). Project management in small to medium-sized enterprises: A comparison between firms by size and industry. *International Journal of Managing Projects in Business*.

Turner, R., & Zolin, R. (2012). Forecasting success on large projects: developing reliable scales to predict multiple perspectives by multiple stakeholders over multiple time frames. *Project management journal*, *43*(5), 87-99.

Ugolini, F., Massetti, L., Sanesi, G., & Pearlmutter, D. (2015). Knowledge transfer between stakeholders in the field of urban forestry and green infrastructure: Results of a European survey. *Land use policy*, *49*, 365-381.

Zimmermann, M., & Simpson, R. (2013). Green urban economy: Agenda setting for the urban future. In *The economy of green cities* (pp. 3-10). Springer, Dordrecht.

CHAPTER 3: VEGETATION

Introduction

Green infrastructure is an important element of sustainable urban design (Lafortezza et al. 2013; Mell 2017; Pauleit et al. 2017; Rolf et al. 2019; Hansen et al. 2019). Determining the vegetation that thrives in urban green networks is important to properly design and account for long term viability and success of these areas. It is estimated that between one-third and one-half of the earth's land surface has been transformed by human action (Roberts et al. 2014). As urbanization increases, human interactions with nature are increasingly taking place in the cities and towns where residents live (Miller et al. 2002). It is these human impacts that affect watersheds and water systems within and surrounding urban areas (Wang and Hejazi 2011). To counteract these anthropogenic influences on watersheds municipalities are developing multi-use green infrastructure components to mitigate the impacts of urbanization (Young 2011), for instance utilizing green infrastructure to provide habitat (Zhang et al. 2019; Monberg et al. 2019). Green infrastructure design for stormwater uses vegetation, soils, and natural retrofits in hopes of restoring some of the natural components lost in urban areas (Baldock et al. 2015; Ives et al. 2016; Monberg et al. 2019). The green infrastructure components that form stormwater networks of detention basins, swales, and conveyance elements have yet to be studied in depth (Kazemi et al. 2009; Levin and Mehring 2015; Monberg 2019).

Stormwater that falls in urban areas has little chance to infiltrate into the ground (Chin 2006; Wenger et al. 2009), and storm events coupled with impermeable surfaces make detention basins a necessary component in stormwater systems (Line 2007). Urban detention basins reduce the risk of flooding by retaining water during flash flow events and in some instances help filter water (Arnold and Gibbons 1996; Booth and Jackson 1997). Beyond flood reduction and filtration there is potential for detention basins to include multifunctional elements such as aesthetic features and natural areas (Andrade & Wiesner 2013; Goodspeed et al. 2021). Designs that consider nature can improve habitat and create connections for urban species (Kazemi et al. 2009; Levin and Mehring 2015), and if properly planned, detention basins can benefit the public beyond a single-use that focuses on the management of stormwater (Urbonas and Stahre 1993). Currently, the desire to create effective multiuse infrastructure exists (Young 2011); however, the knowledge needed to understand vegetation plantings, recreational use, and green infrastructure in stormwater systems is largely unexplored (Bonilla-Warford and Zedler 2002; Garbuzov et al. 2015; Southon et al. 2017; Monberg et al. 2019).

Urban programming often requires aesthetically pleasing and recognized plant species in recreation areas (Southon et al. 2017). Additionally, research has shown that using native vegetation can provide habitat for pollinators (Hernandez-Castellano et al. 2020), sequester carbon, and act as a filter for pollutants (Read et al. 2008; Mohanty 2018). However, native prairie vegetation is affected by soil moisture and temporary inundation (Lubin et al. 2021), and the predictability of prairie restorations decreases when the moisture regime is variable (Aronson and Galatowitsch 2008). Until now, stormwater management has primarily focused on flood attenuation (Starzec et al. 2005; Zhu et al. 2020) and pollution control (Davis et al. 2001; Starzec et al. 2005; Zhu et al. 2020). However, within stormwater systems soil moisture is extremely variable and temporary inundation can be common. These conditions and their impacts on vegetation have not been studied in depth (Monberg et al. 2019). While there is a vast knowledge regarding the hydrological dynamics of stormwater systems overall, less is known about vegetation and its ability to establish in retention ponds and detention basins (Monberg et al. 2019).

The goal of this research is to establish which native prairie seed mixtures sown in an existing detention basin would work best for the establishment and persistence of native species. Native seed mixes that are commonly available are compared to those mixes that had added flowering species by spiking them, a technique developed by Norland et al (2013). The spike method is designed to decrease invasive species establishment while increasing pollinator floral resources. By installing vegetation test plots within a detention basin, we hope to determine the best native seed mixtures to plant for future basin retrofits within urban infrastructure systems. By adding native plant material, planners can reduce the amount of introduced and invasive species while adding floral resources. This research will aid future land managers in making informed choices that will benefit their green infrastructure components.

Methods

Study Area

The study area is located within an existing urban stormwater detention basin in the city of Fargo, North Dakota, USA (46º 51’33.28” N, 96º 50’48.18” W) (Figure 3.1). The detention basin was designed to capture water and meter it out slowly, as to not overwhelm the stormwater system. After runoff events the basin is designed to be dry except for the water in two channels, with the east to west having flowing water year-round, and the south to north channel having water only flowing during times of runoff. The basin is 4.34 ha in size and was excavated 4.8 m below grade. The basin was excavated in the dry lakebed of glacial Lake Agassiz. There are three different formations that the excavation went through. Top to bottom, the formations are the Sherack, Poplar River, and Brenna. The bottom Brenna formation is made of thick clays while above that are cross bedded fluvial sands of the Popular River formation, and then the silty clays of the top Sherack formation. The basin has groundwater at or near the surface during much of the year (Anderson 2006). The soils derived from exposing these formation are classified as urban silty clay aquerts that are non-saline to moderately saline (Soil Survey Staff 2022)

This study took place between 2016 and 2019. Funded by a grant from the National Art Foundation, the City of Fargo developed a community partnership that involved engineers, researchers, community organizations, and designers in hopes of restoring ecosystem dynamics in the space. The objectives of this partnership were to: engage area residents in the creation of culturally significant public spaces; provide natural landscape experiences in the area; improve stormwater quality; explore stormwater management practices that incorporate natural components; and restore native prairie in the basin.

The detention basin is named the World Garden Commons and is surrounded by a city park (9.1 ha). The catchment of the basin is 162.5 ha in size and collects stormwater from large adjacent parking lots and streets. The impervious areas within the catchment covers 68.7 ha (42.3% of the total catchment area). The basin has two inlets and one outlet culvert (Figure 3.1). The water is conveyed through earthen channels from the south and east inlets to the outlet in the northwest corner of the basin. Using information from Huggins (2019), who monitored and modeled flooding in the basin in 2018, it was found that precipitation events that exceed 20 mm would flood the study area for more than 18 hours (Figure 3.1). Higher precipitation events could flood the study area for 20 hours or more, with one event of 52 mm flooding the study area for close to 36 hours (Huggins 2019). Therefore, a 20 mm precipitation event was used as the threshold for precipitation events that would flood the study area for more than 18 hours and have an effect on establishment of planted species. Below 20 mm precipitation events may have caused flooding, but only for a short duration, and would not have covered the study area. Within the study area there were six flooding events above the 20 mm level in 2016, four in 2017, six in 2018, and nine in 2019.

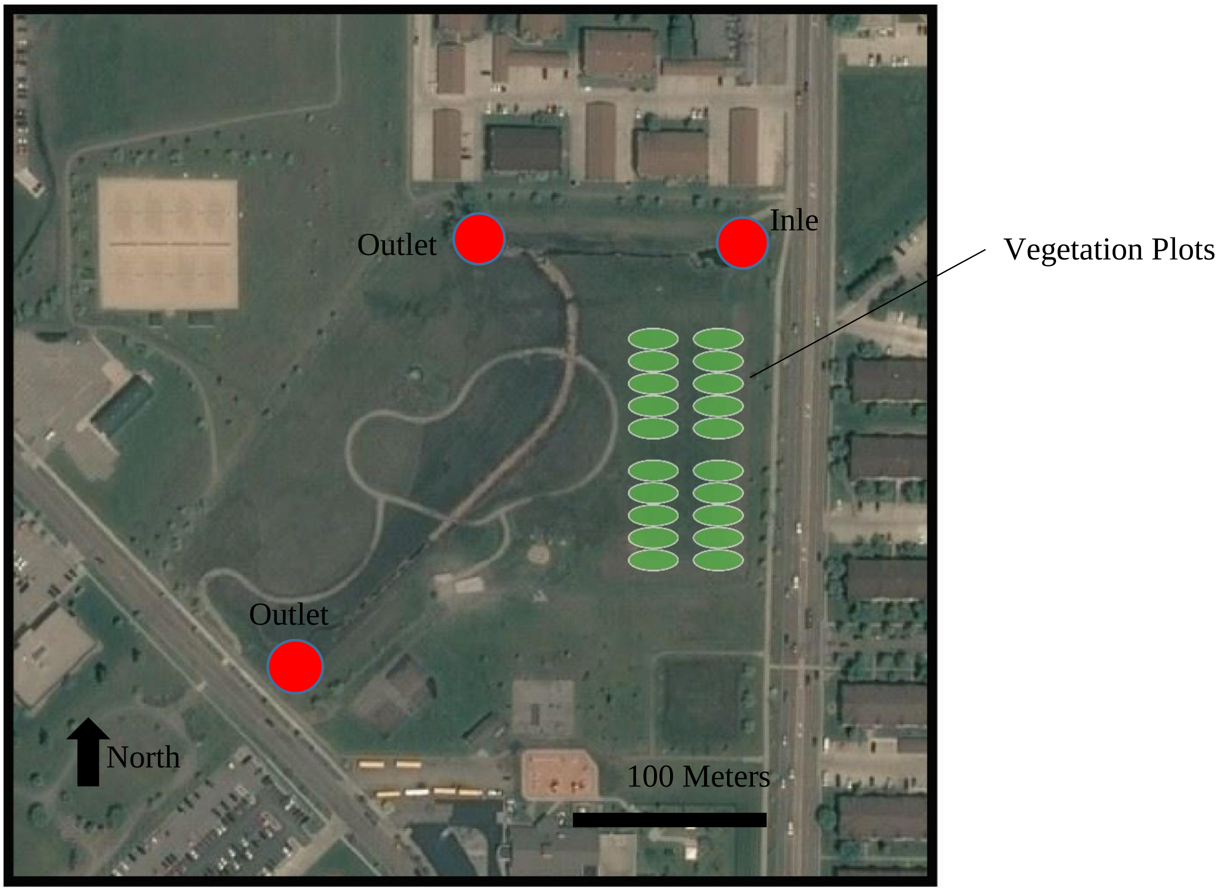

Figure 3.1. Diagram of study area detention basin showing the inlets, outlet, and channels for water as well as the vegetation plot design.

The detention basin has been operational since 1984. The detention basin was enlarged in 2000 and this is where the study area is located. Since 1984 management of the vegetation in the basin was to mow it regularly. The mowing promoted high maintenance species such as Kentucky bluegrass (*Poa pratensis*), but other species such as switchgrass (*Panicum virgatum*), prairie cordgrass (*Spartina pectinata*) and silverweed cinquefoil (*Argentina anserina*), along with other species were present. It is unknown what types of seed mixes were used in the basin after initial construction in 1985 and after enlargement in 2000.

Experimental Design

The study consisted of a randomized block with a split design. Several of the treatments used a spike seeding. The spike seeding adds several native forbs at a high density to the original seed mix. The spike seeding is designed to reduce invasive species establishment while providing an early establishment of floral resources that are aesthetically pleasing and can be used by pollinators (Norland et al 2013). There were five treatments as follows (see Appendix A for species in each treatment):

1. Short/dry mix (SDM). The short dry mix was selected to provide native grasses and habitat for animals. The short/dry mix is ideal for locations where shorter vegetation is desirable.

2. Pollinator mix for dry to mesic soils (PM). The pollinator mix for dry to mesic soils was chosen to provide forbs to promote pollination within the basin. The basin is dry for at least 90% of the growing season, and for this reason researchers chose a mix suitable for dry to mesic soils.

3. Short/dry mix with spike seeding (SDMS). The treatment of short/dry mix with spike seeding was picked with the desire to introduce native grasses and prevent weed encroachment during the establishment phase.

4. Pollinator mix for dry to mesic soils with spike seeding (PMS). The treatment of the pollinator mix for dry to mesic soils with spike seed treatment was chosen to provide forbs to promote pollination within the basin and prevent weed encroachment during the establishment phase.

5. Aesthetic prairie planting mix (APP). The aesthetic mix treatment was chosen to bring attention to the basin and educate urban residents to the value of green infrastructure and native

plant species. Varieties popular with landscape plantings were chosen to add a component of familiarity to the species intended to grow in the basin.

The five treatments were randomly placed within a block and was replicated four times. The split plot consisted of one side of the plot being covered with a seed blanket (Seed Guard manufactured by DeWitt Company Norman, Oklahoma, USA) and the other side with nothing. The seed blanket is designed to increase plant establishment by creating a favorable environment for seed germination. The plots were designed as an oval shape in keeping with design and artistic goals of the site. Each oval was 139 m^2 (19.5 x 8.8 m).

The treatments were seeded during the spring of 2016. The entire oval was planted with a given treatment seed mixture. Prior to seeding the plot was tilled using a rear-tined rototiller mounted on a 40hp tractor two weeks before seeding. The soil was tilled to a depth of 10-15 cm. Tilling was intended to kill existing plants and create a seedbed conducive to seeding. Each plot was broadcast seeded with one of the five treatments listed above. After seeding, the plots were packed with a 121 cm wide cultipacker. After the soil was packed, half of the oval was covered with the seed blanket and the other half was left uncovered (split plot).

Seeds were purchased from Prairie Restoration Inc. (Princeton, MN, USA) who developed the commercially available seed mixes SDM and PM. These two seed mixes are commonly used in regional plantings. The spike species and the APP treatment were chosen from experience and published recommendations. Seed mix SDM was seeded at a rate of 0.57 g/m^2. Seed mix PM was seeded at a rate of 1.14 g/m^2. Seed mix SDMS was seeded at a rate of 0.57 g/m^2 with the spike species seeded at the following rates: *Echinacea purpurea* 55.5 $seeds/m^2$; *Symphyotrichum laeve* 185 $seeds/m^2$; *Achillea millefolium* 299 $seeds/m^2$; *Rudbeckia hirta* 774 $seeds/m^2$; and *Dalea purpurea* 126 $seeds/m^2$. Treatment PMS was seeded at a rate of

1.14 g/m^2 with the spike species seeded at the following rates: *Echinacea purpurea* 55.5 seeds/m^2*; Symphyotrichum laeve* 185 seeds/m^2; *Achillea millefolium* 299 seeds/m^2; *Rudbeckia hirta* 774 seeds/m^2; and *Dalea purpurea* 126 seeds/m^2. Seed mix APP was seeded at the following rate: *Echinacea purpurea* 88.8 seeds/m^2; *Asclepias syriaca* 40.4 seeds/m^2; *Rudbeckia hirta* 1238 seeds/m^2; and *Symphyotrichum laeve* 370 seeds/m^2.

Plant community establishment and encroachment was assessed at the end of the growing season in 2016, 2017, and 2019. The 2016 data were only utilized to determine what species were germinating and were not analyzed for cover and establishment. The plant community was sampled using a 0.5 m^2 quadrat where each individual species was identified within the quadrat and given an ocular estimate of percent aerial cover. A total of six quadrats were randomly placed within each of the 20 oval plots. Three quadrats were placed on the seed blanket side of the oval and three in the no seed blanket side of the oval. The same observer did all the ocular estimates so canopy coverage estimation was consistent over the years.

The species canopy cover data was placed into two categories: 1) Planted cover, which consisted of all the native species included in the seed mixes (planted); and 2) Other cover, which includes all other species either native or introduced (other) (see Appendix B for a list of species in the two categories). The canopy coverage of planted and other was analyzed using the SAS® software, Version 9.4 of the SAS System for Windows (Copyright © 2015 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA) using a mixed model design where the split factor (seed blanket or no blanket) was nested under the treatments and both were treated as fixed factors. Least square mean comparison tests used the Tukey procedure at the $P<0.05$ significance level. The plant community data (species canopy cover) was analyzed as mixed model with treatments as the fixed factor using PERMANOVA (Anderson et al. 2008) as implemented in PRIMER-e™ (Quest Research Limited). The distance measure used was the Bray-Curtis. Paired comparison P values were not adjusted as recommended by Anderson et al. (2008).

A graphical display of the plant community data (species canopy cover) used Nonmetric Multidimensional Scaling (NMS) ordination. The NMS analysis was completed using PC-ORD Version 7 software (Wild Blueberry Media LLC) (Peck 2016). The Bray-Curtis distance measure was used same as in PERMANOVA. Patterns in the data were found by doing 500 iterations of the data in PC-ORD reducing to one axis from six with an instability criterion of 0.0001. The number of axes (dimensions) and model selection was based on: (1) a significant Monte Carlo test ($P<0.05$); (2) a model with a stress <25; (3) an instability <0.0001; and (4) axes selection was discontinued if the next axis did not reduce stress >5. Pearson's Correlation Coefficients $R\geq0.4$ or $R\leq-0.4$ between species cover and axes scores were used to interpret the ordination (Peck 2016).

Results

2017 Sampling

Two growing seasons after planting, the cover of the Planted species among the treatments were significantly different ($P<0.001$). The APP treatment demonstrated significantly higher Planted cover than the other treatments (Figure 3.2). The SDM had the lowest Planted cover. The spike seed mixes (SDMS and PMS) had mixed results, where the spike seed mixes were significantly lower than the APP with only the SDMS higher than the non-spike seed treatments (SDM and PM). Other species cover had treatments that were significantly different

P<0.0001. The APP had significantly lower Other cover, while the non-spike seed treatments had the greatest amount of Other plant cover (Figure 3.3).

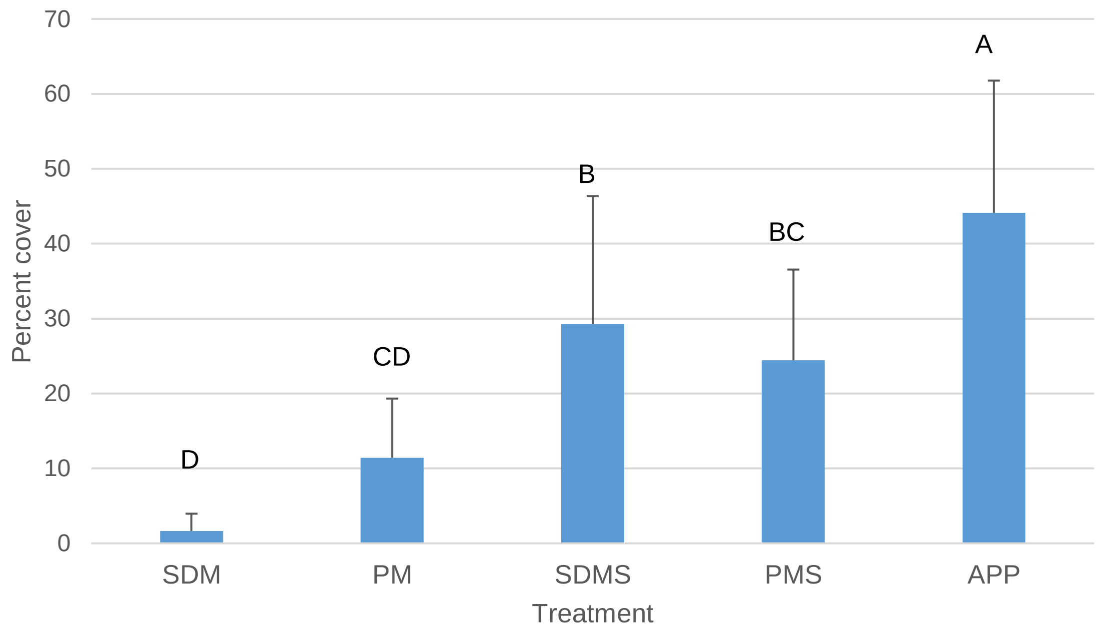

Figure 3.2. Planted species percent cover for the five treatments in 2017. Treatments with different letters are significantly different from the other treatments at P<0.05 level. Error bars represent standard deviation.

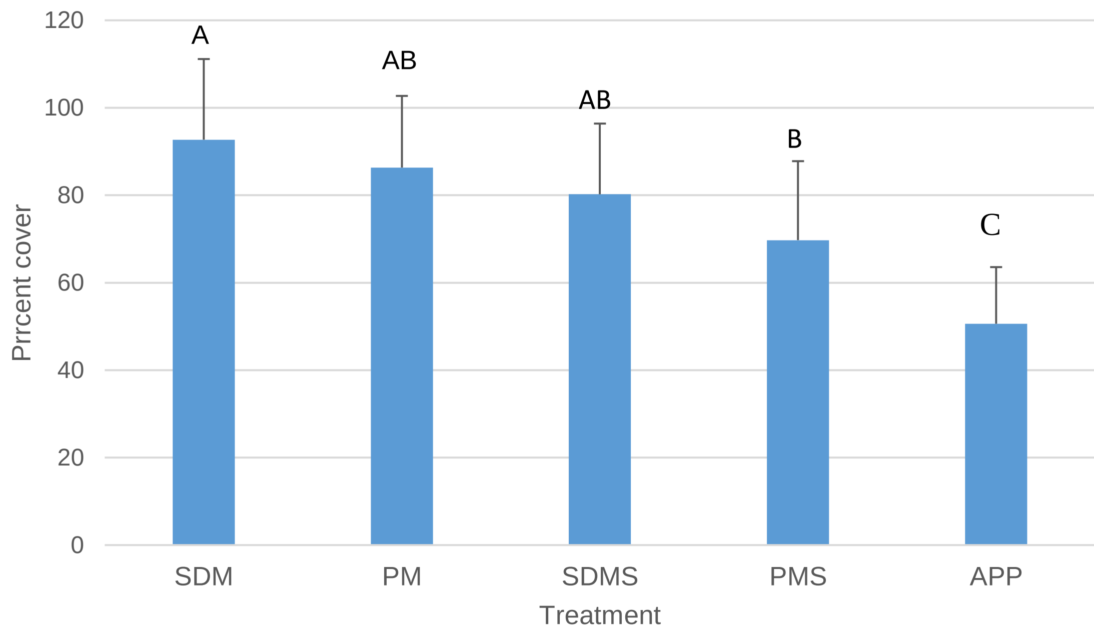

Figure 3.3. Percent cover of other species in each of the five treatments for 2017. Treatments with different letters are significantly different from the other treatments at $P<0.05$ level. Error bars represent standard deviation.

The plant community PERMANOVA analysis for 2017 found there was significant differences between treatments (Pseudo F =3.23, P=0.0002). A pairwise comparisons of the treatments found no significant differences (P>0.05) (Figure 3.4). Species cover that were correlated with NMS axes were a mix of Planted and Other species (Table 3.1). Because all treatments had replications that were found in all four quadrants of the graph, no species are indicative of a treatment effect. The species correlated with the axes were indicative of various other conditions in the basin such as salt affected soils, pre-existing patterns of the Other species, and slight changes in elevation within the basin (see Appendix C for average percent cover of each species found).

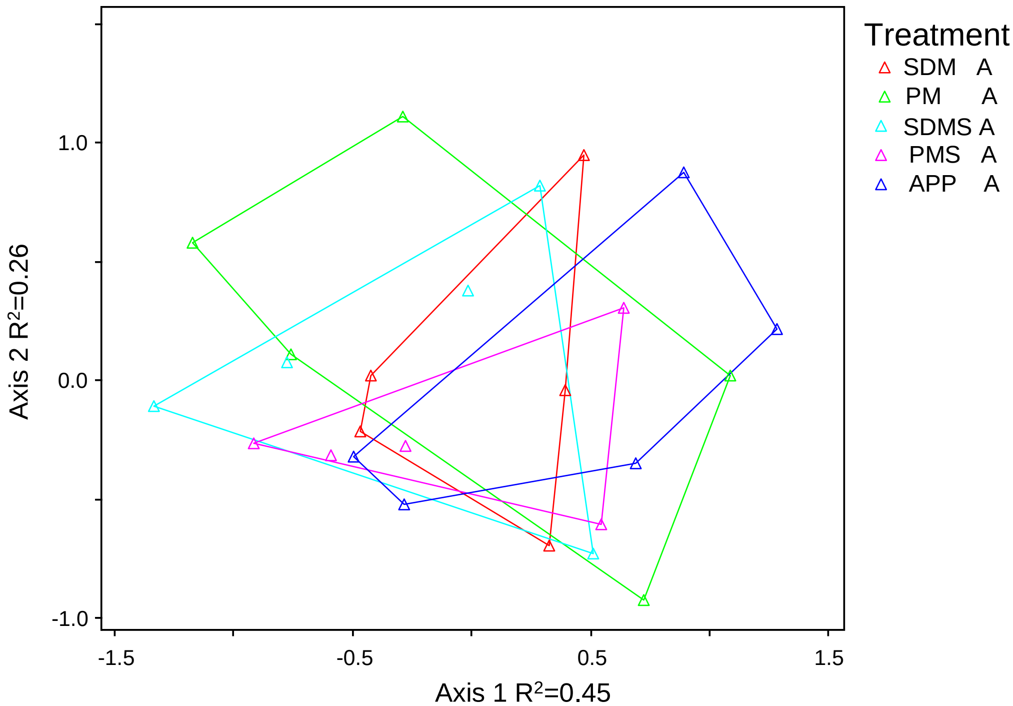

Figure 3.4. Ordination Nonmetric Multidimensional Scaling graph representing the plant community and the five treatments for 2017. Stress was 11.7. Treatment replications are enclosed by a convex hull polygon. Legend items followed by different letters are significantly different at P<0.05. Values after the axis labels show the amount of variability explained by each axis. Axis 3 is not shown, R2=0.13.

Table 3.1. Pearson Correlation Coefficient of species cover values with the 2017 Nonmetric Multidimensional Scaling analysis axes scores that met this criteria, R >0.4 or <-0.4.

Species	Axis 1	Axis 2
Hordeum jubatum	0.5	
Melilotus officinalis	0.55	-0.61
Ratibida columnifera	-0.52	
Rudbeckia hirta	-0.52	-0.53
Lotus corniculatus	-0.88	
Bouteloua curtipendula		0.54
Panicum virgatum		-0.42
Plantago major		0.7

2019 Sampling

Four growing seasons after planting, the Planted species cover was not significantly different among treatments (P=0.18). The SDM treatment had 0% plant cover, with the other treatments having Planted cover at or below 3%, which is a ten-fold drop from the 2017 survey (Figure 3.5). In 2019 the Other cover was also not significantly different among treatments P=0.73. However, the Other cover for all the treatments had come to comprise approximately 80% of the total plant cover. (Figure 3.6).

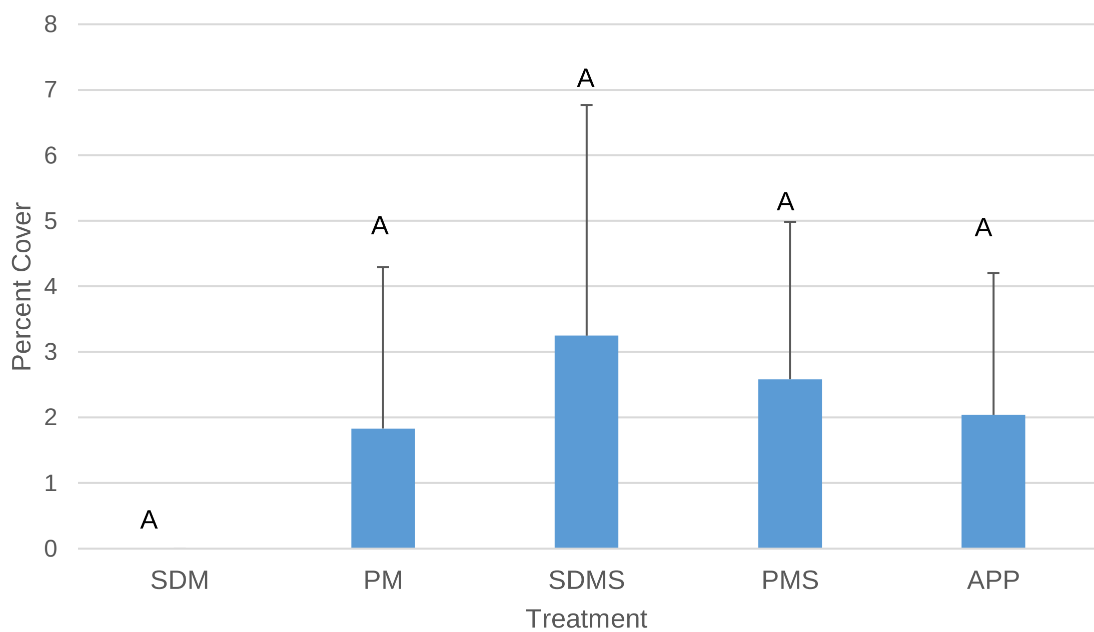

Figure 3.5. Planted species percent cover for the five treatments in 2019. Treatments with different letters are significantly different from the other treatments at P<0.05 level. Error bars represent standard deviation.

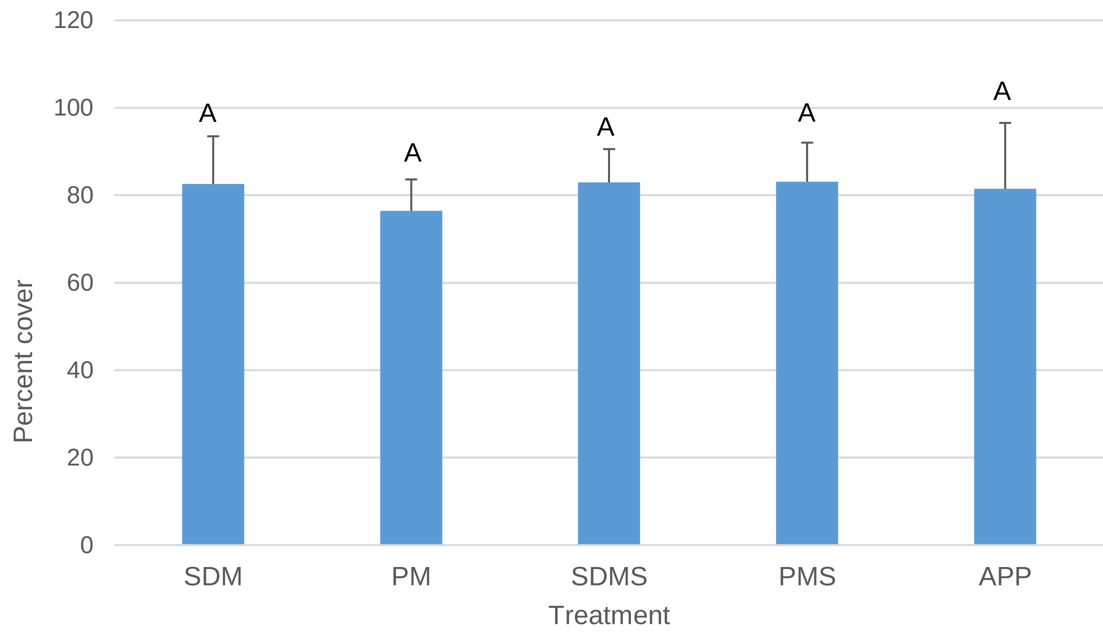

Figure 3.6. Percent cover of Other species in each of the five treatments for 2019. Treatments with different letters are significantly different from the other treatments at P<0.05 level. Error bars represent standard deviation.

The plant community PERMANOVA analysis for 2019 found there were significant differences between treatments (Pseudo F =3.23, P=0.013). A pairwise comparisons of the treatments found no significant differences, similar to the 2017 data (P>0.05) (Figure 3.7). Also, like the 2017 analysis, all treatments had replications that were found in all four quadrants of the graph; therefore, no species were indicative of a treatment effect. As with 2017, the species correlated with the axes (Table 3.2) were indicative of various other conditions in the basin such as salt affected soils, pre-existing patterns of the Other species, and slight changes in elevation within the basin.

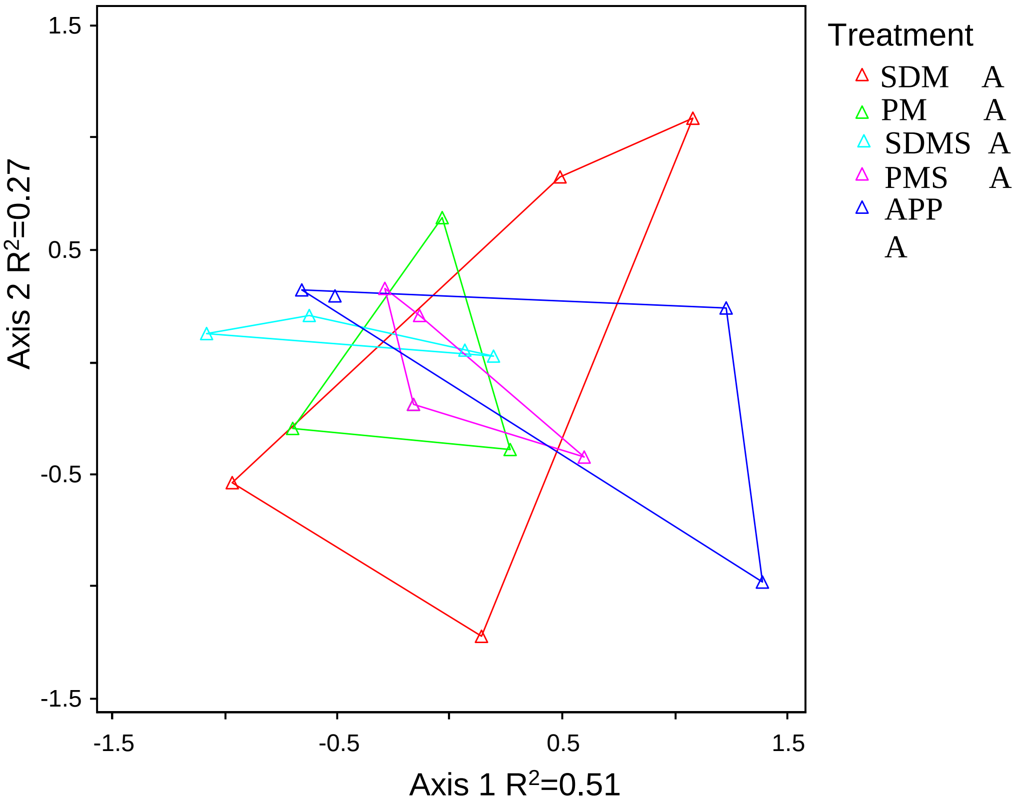

Figure 3.7. Ordination Nonmetric Multidimensional Scaling graph representing the plant community and treatments for 2019. Stress was 9.7. Treatment replications are enclosed by a convex hull polygon. Legend items followed by different letters are significantly different at P<0.05. Values after the axis labels show the amount of variability explained by each axis. Axis 3 is not shown, R2=0.14.

Table 3.2. Pearson Correlation Coefficient of species cover values with the 2019 Nonmetric Multidimensional Scaling analysis axes scores that met this criteria, R >0.4 or <-0.4.

Species	Axis 1	Axis 2
Achillea millefolium	0.41	
Agrostis gigantea	-0.49	
Elymus repens	-0.87	
Lotus corniculatus	0.71	
Monarda fistulosa		0.54
Panicum virgatum		0.71
Plantago major	-0.4	
Poa pratensis		-0.44
Polygonum persicaria	0.41	
Polygonum lapathifolium	0.48	
Rumex crispus	0.5	-0.73
Symphyotrichum laeve		-0.41
Thalictrum venulosum		-0.51

Many of the warm season grasses began to establish in the fall of 2016 after the spring planting season. *Schizachyrium scoparium, Bouteloua curtipendula, and Bouteloua gracilis* were all observed during the 2016 season. However, by the time we surveyed the plots during the fall of 2019, these grasses were absent during our inventory. Pollinator forbs such as *Dalea candida* and *Dalea purpurea* showed signs of germination during the first year of the retrofit, but were greatly reduced in surveys over time. The precipitation events and consequent flooding of the plots may have reduced the chance for the grasses and clovers establishing and thriving in the detention basin microclimate.

Seed Blanket

The 2017 Other vegetative cover for the seed blanket treatment was not significantly different P=0.065 (Figure 3.8). Whereas the Planted cover for the seed blanket treatment had significantly higher Planted cover compared to no seed blanket P=0.006 (Figure 3.9). The effect of the seed blanket was not present in the 2019 plant survey, with neither the Other vegetative cover (P=0.065) or Planted cover (P=0.9) being significantly different (Figures 3.10 and 3.11).

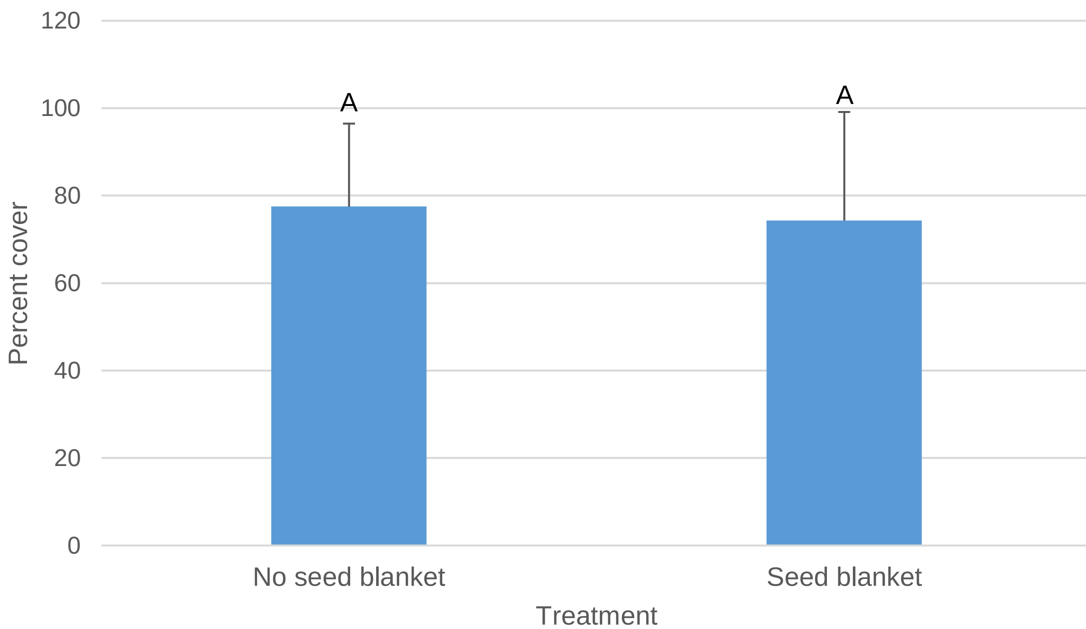

Figure 3.8. Percent cover of Other species with no seed blanket and with a seed blanket in 2017. Different letters over the columns denote significant differences at the P<0.05.

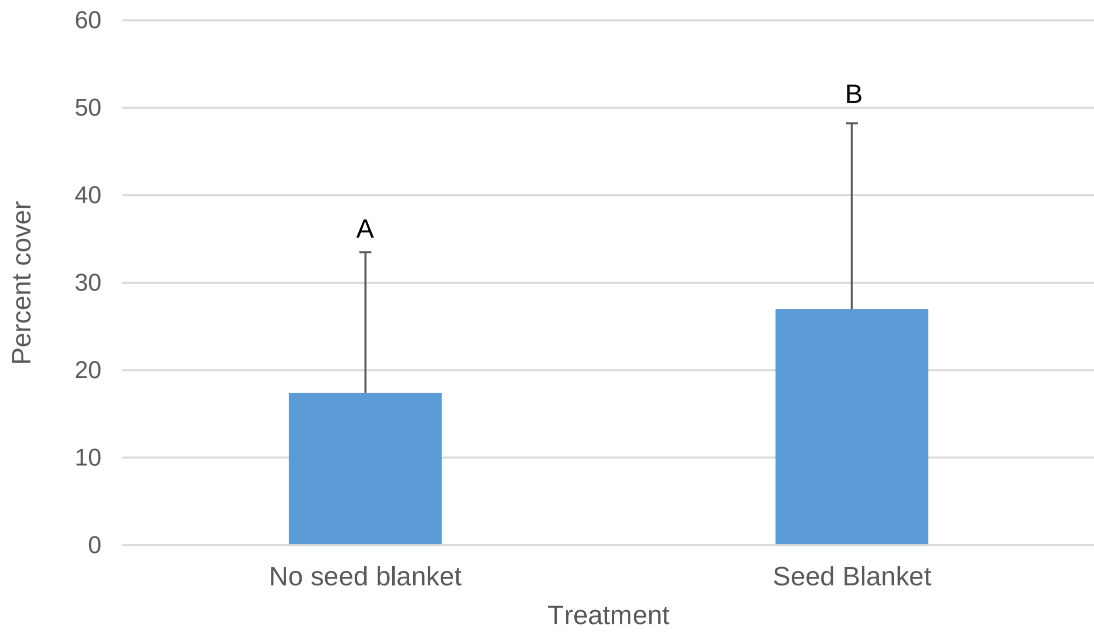

Figure 3.9. Vegetative cover of Planted species with no seed blanket and with a seed blanket in 2017. Different letters over the columns denote significant differences at the P<0.05.

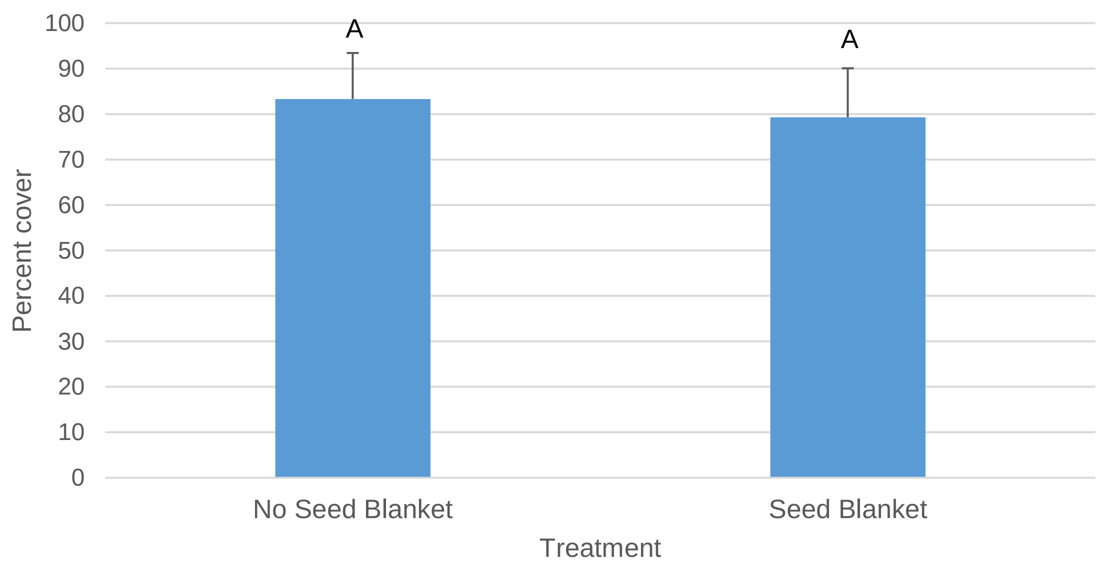

Figure 3.10. Vegetative cover of other species with no seed blanket and with a seed in 2019. Different letters over the columns denote significant differences at the P<0.05.

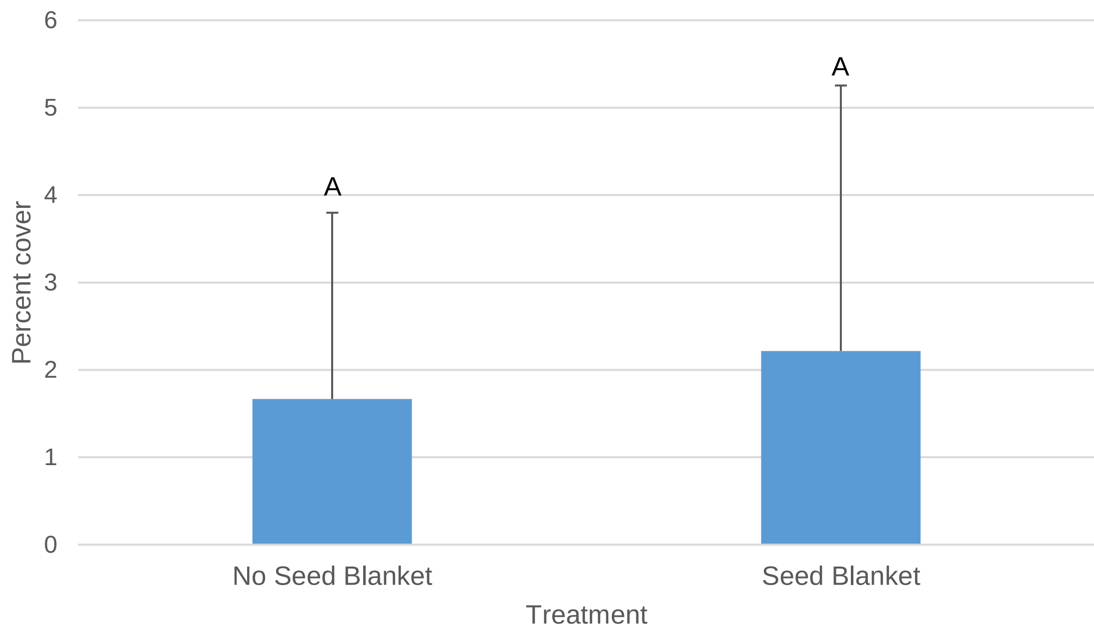

Figure 3.11. Vegetative cover of Planted species with no seed blanket and with a seed blanket in 2019. Different letters over the columns denote significant differences at the P<0.05.

Discussion

Tolerance to Flooding

The introduction of warm season native grasses and aesthetic forb species into a detention basin did not lead to increased forb cover, nor establishment of native grasses, after four growing seasons. The sampling in 2017 was two growing seasons after the treatments were installed and a time where planted species were still attempting to establish. While the 2019 sampling was four growing seasons after the treatments were installed, and this is when there is better predictability on how the planted species would respond long term (Norland et al. 2018). In 2016 the plots were flooded six times, while in 2017 the plots were only flooded four times. In contrast, the flooding events in the later years increased with six in 2018 and nine in 2019. It appears that the low number of flooding events in 2017 was conducive to the native species establishing, while by 2019 the increased flooding events decreased all treatment Planted cover levels to less than 4%, while the other species, which were not planted, increased to 80% of the vegetative cover.

Examining tolerance to flooding and detention basin conditions shows that the treatment with virtually no cover of Planted species by 2019 was the SDM mix where the seed mix was dominated by warm season native grasses. The only species in the mix that may tolerate flooding appears to be *Schizachyrium scoparium,* as it is a facultative wetland upland species occasionally found in wetlands (USDA 2021). All the other grasses were strictly upland plants with little to no tolerance for flooding. The native species used in the other treatments had few species that were facultative wetland, and no species that were obligate wetland species. One native species that is a facultative wetland upland species, *Rudbeckia hirta,* and was seeded at high densities in the SDMS, PMS, and APP treatments, established well in 2017 with an average cover of 13.11% across all treatments, but by 2019 the average cover value had decreased to 0.42%. Even though the flooding events lasted under 24 hours in most instances, this seemed to be enough to reduce the establishment of the native species used in the treatments. This species readily establishes in other native seed plantings in the region; therefore, it was unusual that this species failed to continue its high cover into 2019 (Comeau et al 2020).

Species Cover and Success of Planted Species

The cover of Planted species in any treatment was below 4% cover in 2019, while in 2017 several treatments had cover ranging between 20-40%. It was determined these treatments were not having the desired effect of restoring the basin with native species and floral resources by 2019. Our results in 2017 are similar to what Monburg et al. (2019) found two years post construction, in that there was an increase in species richness. Monburg et al. (2019) also stated that more than two years may be needed to conclude if species will persist. Our results from

2019 lead us to conclude that more than two years are needed for the full expression of detention basin conditions on plantings. It could even be conceivable that with less flooding events within the first several years of planting there could be a period when flooding events will impact plantings similar to how our plantings were affected in 2019. Meaning that it is not time but events that will determine persistence of plantings in a detention basin.

Results from 2019 show that the treatments had reverted to the other species that were originally on the site, and now amounted to 80% of the vegetative cover. The most common of the other species were *Elymus repens, Symphyotrichum lanceolatum*, *Panicum virgatum, Poa pratensis*, *Lotus corniculatus*, *Rumex crispus*, *Taraxacum officinale,* and *Hordeum jubatum*. It is apparent these species are better adapted to the wet and dry periods experienced in this basin and that is why they were the most abundant species before planting. It was observed that the cover of *Lotus corniculatus* varied over the years with higher cover in 2017 and lower cover in 2019. The decreasing cover was attributed to more flooding events and the species being less adaptable to flooding. Thus, the cover of certain pre-planting species may also vary given the number of flooding events during certain time periods. One conclusion that could be made from this is that because the basin had been in existence for 30 plus years, the species that were adaptable to the site had already established there. What was not known prior to this study, is if there were other native species that could establish in the basin, but were not there because there were no seed sources or existing populations in the urban environment. The results from this experiment lead us to conclude that adding more native species to the basin is not that simple given the wet/dry conditions and that after 30 years the original species there are the most adaptable to the conditions of the site. Even though these species were adaptable to this detention basin, it is unknown if they would be species that can be recommended for other dentation basins.

The lack of native species establishment and low cover of planted species points to soil moisture being an important factor that determines the success of native prairie plantings in detention basins. This has also been shown in native prairie plantings in other areas (Lubin et al. 2021). The altered hydrology (wet/dry cycles) of detention basins is also likely a contributing factor in the failure of the restoration, as frequency and basin size are known to affect the species richness of perennial forb establishment in areas subjected to periodic inundation (Mulhouse and Galatowitsch 2007). Additionally, long term restoration success is less predictable when the moisture regime is not constant (Aronson and Galatowitsch 2008). The effect of pollutant loads during first flush events could also have prevented certain species from establishing (Monburg et al. 2019), though it was not assessed in this study. Authors did note that after flooding a thin layer of sediment was visually apparent, and authors speculate this could contribute to poor establishment which has been shown in wetland areas (Ewing 1996; Werner and Zedler 2002). Overall, the complexity of restoration efforts is made more unpredictable by the water dynamics at the site (topsoil erosion, sediment loading, pollutant introduction, moisture regimes, and periodic inundation), as these impacts are typical in detention basin systems (Rasran et al. 2007; Schnoor et al. 2015; Monburg et al. 2019).

There were species that were planted that were no longer present by the time we conducted the 2019 survey. Even species that were seeded at high densities as a spike species and germinated, such as *Dalea purpurea,* failed to establish by the 2019 sampling season. Knowledge of flooding susceptibility, especially when establishing from seed, for many prairie species is not well known compared to characteristics like time of seeding and resistance to weed competition (Lubin et al. 2021; Mulhouse & Galatowitsch 2003). This knowledge of flooding susceptibility for different species would be valuable to increase the success of urban vegetation plantings.

The decision to use native species less tolerant to flooding in this experiment was based on a pilot study where a wet meadow species mix of facultative or obligate wetland species were planted in the basin in 2014 to determine establishment potential. The only establishment by the wet meadow species was in a 10m belt around the channels in the basin. This lack of establishment and knowledge that flooding duration away from the channels was no longer than 24 hours led authors to use less tolerant wetland species in the experiment. In addition, a survey of existing vegetation showed many species at the site were not facultative wetland species but were facultative upland wetland species. The desire with the treatments was also to test if floral resources could be added to the basin for aesthetic and pollinator value, which meant the use of flowering species less tolerant to flooding. In hindsight, it appears that the selection of native species for the treatments were not adaptable enough for the basin conditions. Unfortunately, the basin also is not conducive to wet meadow species establishing away from the channel. Therefore, conditions in the basin are such with wet and dry periods that it is challenging for many plants, both native and introduced, to survive and thrive. There was a small group of species adaptable to the basin, though this study did not screen all possible species, so more species might be adaptable then was found here.

Some planted species were found in adjacent plots from the plotted plantings. Vegetation sampling revealed that some planted species migrated from the area it was planted into different plots. This is believed to be caused by the periodic flooding, where seeds were floated to the other plots as opposed being moved by other factors like wind or animals. Hydrodynamics and inundation are known to create movement of species in restored wetlands (Mulhouse & Galatowitsch 2003).

Panicum virgatum is a perennial grass that is native to the North American tallgrass prairie (Casler et al. 2007). Benefits of *Panicum virgatum* include soil conservation, hay production, grazing, habitat, and biomass production for conversion to energy (Vogel 2004; Caslet et al. 2007; Casler et al 2012). The success of *Panicum virgatum* at the study site might indicate that managers and designers should use tolerant native grass selections in basin restoration seed mixtures. Designers should analyze their local biomes to determine species with the best chances of survivability. With thoughtful preparation urban landscape planners can design systems adapted to their sites that provide a multitude of ecosystem services within their green infrastructure components. They should include local species from their region that are adaptable to periodic inundation and can be used for energy or other provisioning services.

Soil Salinity

The Red River Valley, the larger ecoregion that surrounds the study area, has soil salinity issues which have affected nearly 80,0000 ha of agriculture land (Ulmer er al 2007; Shermer et al 2012). The salinity issues in the region are caused by fluctuating water tables, capillary rise, hydroscopic water pressure, discharge soils, saline seeps, evaporating ponds, and naturally occurring saline rich soils (Anderson et al 2014; Shermer et al 2012; McCauley & Jones 2005; Millar 2003; Tober et al., 2007). High salinity levels impact plant yields and affect plants in all stages of growth (Peel et al. 2004; Shermer et al 2012). The detention basin used in this study has been excavated to 4.8 m below grade, exposing old lake salt bearing sediments that had not experienced weathering (Anderson 2006). Electrical conductivity of soil samples from an unpublished report at the study site found that salinity levels were in the slight to moderately saline categories in the experimental plots. Eleven of the 25 original plots had electrical conductivity readings above 1.9 dS/m with several reaching 3.5-4.5 dS/m. These levels would inhibit growth of salinity sensitive species with only moderately tolerant species being able to grow (Tober et al 2007). Many of the species used in the treatment seed mixes are not tolerant of salinity at those levels. Species like *Achillea millefolium* for example (a species used in the seed mix) is moderately tolerant, but at the limit of tolerance is 4.5 dS/m. Meanwhile *Panicum virgatum* can tolerate much higher levels of salinity (Tober et al. 2007), which likely lead to having higher cover levels in 2019. For detention basins with salinity conditions, there may be a shorter list of species that can tolerate both salinity and flooding. These dynamics remain understudied in detention basins. Thus, when planning plant species to use in detention basin flooding is just one factor to consider and other factors need to be investigated and considered.

Seed Blanket

The plots were covered with a seed blanket to promote environmental conditions conducive for the germination of the treatments and to deter erosion and limit animal disturbance. Erosion mats acting like seed blankets have been known to aid restoration of vegetation in pipeline projects (Hann & Morgan 2006). The seed blankets by the end of the second growing year (2017) did show some increase in Planted cover; however, by the fourth growing season the seed blanket had little effect on the plant community or the planted species. It is apparent the detention basin conditions are the main factor affecting plants and the seed blanket, as least in this instance, made little difference.

Future Considerations

The spike seeding method was included in this project to determine if adding a high density of forb seed would increase the establishment of forbs as found by Comeau et al. (2020).

Unfortunately, due to flooding and salinity, the spike species were not able to establish by 2019. More research is needed to determine the effects of salinity and inundation/moisture tolerance on native plantings in detention basins. While salinity in the soils may be more specific to this study area, other basins may be affected by salinity from salt movement through the soil (Pitt et al. 1999) or brought in by road salts common in climates receiving snow and ice treatments (Marsalek 2003; Copper et at. 2013). Green infrastructure dealing with issues of inundation are common to all detention basins worldwide. The presence of salinity combined with flooding creates a site that has several stressful factors for many native and introduced plants. Further understanding on how each condition impacts native plant species would allow designers worldwide to plan and manage their restoration projects accordingly.

Conclusion

This study determined that native plantings within detention basins come with challenges atypical to traditional restorations. Flooding during the germination and establishment phase negatively affected the long-term persistence of native prairie plantings. Many of the native species used in the treatments, even though planted at high densities, failed to persist or were at levels below 4% cover. The use of a spike seeding to decrease introduced species establishment and increase floral resources did not result in those effects four growing seasons later. The pre-planting vegetation that existed at the site was already adapted to the detention basin flooding and dry periods, and was found to be the species best able to survive and thrive in the basin. These species reclaimed the plots where the native species were planted after four growing seasons. While attempts to restore urban ecosystems may have public support and funding, this study demonstrates that adding new species to detention basins may come with limited success. This research is valuable to urban planners as they will need to carefully determine seed mixtures based on survival of those species in the unique conditions of detention basins, and not rely on previous experiences with native species outside of detention basins.

Literature Cited

Anderson, F.J. (2006). A highlight of environmental and engineering geology in Fargo, North Dakota, USA. *Environmental geology, 49(7)*, 1034-1042.

Anderson M.J., Gorley, R.N. and Clarke, K.R. (2008). PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. PRIMER-E: Plymouth, UK.

Andrade, G. I., Remolina, F., & Wiesner, D. (2013). Assembling the pieces: a framework for the integration of multi-functional ecological main structure in the emerging urban region of Bogotá, Colombia. *Urban ecosystems*, *16*(4), 723-739.

Arnold Jr, C.L., & Gibbons, C.J. (1996). Impervious surface coverage: the emergence of a key environmental indicator. *Journal of the American planning Association*, *62*(2), 243-258.

Aronson, M. F., & Galatowitsch, S. (2008). Long-term vegetation development of restored prairie pothole wetlands. *Wetlands*, *28*(4), 883-895.

Baldock, K. C., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Osgathorpe, L. M. & Memmott, J. (2015). Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1803), 20142849.

Baisakh, N., Subudhi, P. K., & Varadwaj, P. (2008). Primary responses to salt stress in a halophyte, smooth cordgrass (Spartina alterniflora Loisel.). *Functional & Integrative Genomics, 8*(3), 287-300.

Booth, D.B., & Jackson, C.R. (1997). Urbanization of Aquatic Systems: Degradation thresholds, stormwater detection, and the limits of mitigation 1. *JAWRA Journal of the American Water Resources Association*, *33*(5), 1077-1090.

Bonilla-Warford, C.M. and Zedler, J.B. (2002). Potential for using native plant species in stormwater wetlands. *Environmental management*, 29(3), pp.385-394.

Budelsky, R. A., & Galatowitsch, S. M. (2001). Effects of water regime and competition on the establishment of a native sedge in restored wetlands. *Journal of Applied Ecology*, *37*(6), 971-985.

Camill, P., McKone, M. J., Sturges, S. T., Severud, W. J., Ellis, E., Limmer, J. & Talukder, S. (2004). Community-and ecosystem-level changes in a species-rich tallgrass prairie restoration. *Ecological applications*, 14(6), 1680-1694.

Casler, M. D., Stendal, C. A., Kapich, L., & Vogel, K. P. (2007). Genetic diversity, plant adaptation regions, and gene pools for switchgrass. *Crop Science*, *47*(6), 2261-2273.

Casler, M. D. (2012). Switchgrass breeding, genetics, and genomics. In *Switchgrass* (pp. 29-53). Springer, London.

Comeau, P., Norland, J. E., Dixon, C. S., Askerooth, K. L., & Kelsey, K. (2020). Reducing Cirsium arvense (Canada Thistle) Using Spike Seeding: Six Years Later. *Ecological Restoration*, *38*(2), 67-69.

Cooper, C. A., Mayer, P. M., & Faulkner, B. R. (2014). Effects of road salts on groundwater and surface water dynamics of sodium and chloride in an urban restored stream. *Biogeochemistry*, *121*(1), 149-166.

Chin, A. (2006). Urban transformation of river landscapes in a global context. *Geomorphology*, *79*(3-4), 460-487.

DeKeyser, E. S., Kirby, D. R., & Ell, M. J. (2003). An index of plant community integrity: development of the methodology for assessing prairie wetland plant communities. *Ecological Indicators, 3*(2), 119-133.

Ewing, K. (1996) Tolerance of four wetland plant species to flooding and sediment deposition. *Environmental and Experimental Botany,* 36(2), pp.131-146.

Fleishman, E., Ray, C., Sjögren-Gulve, P., Boggs, C. L., & Murphy, D. D. (2002). Assessing the roles of patch quality, area, and isolation in predicting metapopulation dynamics. *Conservation Biology*, *16*(3), 706-716.

Gaston, K.J., Davies, Z.G., & Edmondson, J. L. (2010). Urban environments and ecosystem functions. *Urban ecology*, 35-52.

Gaston, K. J. (2010). Urban ecology. Cambridge University Press.

Goodspeed, R., Liu, R., Gounaridis, D., Lizundia, C., & Newell, J. (2021). A regional spatial planning model for multifunctional green infrastructure. *Environment and Planning B: Urban Analytics and City Science*, 23998083211033610.

Green, O.O., Garmestani, A.S., Albro, S., Ban, N.C., Berland, A., Burkman, C.E., ... & Shuster, W.D. (2016). Adaptive governance to promote ecosystem services in urban green spaces. *Urban ecosystems*, *19*(1), 77-93.

Jackson, S.T., & Hobbs, R.J. (2009). Ecological restoration in the light of ecological history. *Science*, *325*(5940), 567-569.

Hann, M. J., & Morgan, R. P. C. (2006). Evaluating erosion control measures for biorestoration between the time of soil reinstatement and vegetation establishment. *Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group*, *31*(5), 589-597.

Hargiss, C. L., DeKeyser, E. S., Kirby, D. R., & Ell, M. J. (2008). Regional assessment of wetland plant communities using the index of plant community integrity. *Ecological Indicators*, *8*(3), 303-307.

Hernández-Castellano, C., Rodrigo, A., Gómez, J. M., Stefanescu, C., Calleja, J. A., Reverté, S., & Bosch, J. (2020). A new native plant in the neighborhood: effects on plant–pollinator networks, pollination, and plant reproductive success. *Ecology*, *101*(7), e03046.

Huggins, C. P. (2019). Performance of a Retrofit Detention Basin in Fargo, ND (MS thesis, North Dakota State University).

Ives, C. D., Lentini, P. E., Threlfall, C. G., Ikin, K., Shanahan, D. F., Garrard, G. E., ... & Kendal, D. (2016). Cities are hotspots for threatened species. *Global Ecology and Biogeography*, *25*(1), 117-126.

Kazemi, F., Beecham, S., Gibbs, J., & Clay, R. (2009). Factors affecting terrestrial invertebrate diversity in bioretention basins in an Australian urban environment. *Landscape and Urban Planning*, *92*(3-4), 304-313.

Lafortezza, R., Davies, C., Sanesi, G., & Konijnendijk, C. C. (2013). Green infrastructure as a tool to support spatial planning in European urban regions. *IForest*, *6* (1), 102–108.

Levin, L. A., & Mehring, A. S. (2015). Optimization of bioretention systems through application of ecological theory. *Wiley Interdisciplinary Reviews: Water*, *2*(3), 259-270.

Line, D.E., & White, N.M. (2007). Effects of development on runoff and pollutant export. *Water Environment Research*, *79*(2), 185-190.

Lubin, T. K., Alexander, H. M., & Bever, J. D. (2021). Adaptation of plant-mycorrhizal interactions to moisture availability in prairie restoration. *Restoration Ecology*, *29*(1), e13270.

Luke, T.W. (2003). Global cities vs."global cities:" rethinking contemporary urbanism as public ecology. *Studies in Political Economy*, *70*(1), 11-33.

Marsalek, J. (2003). Road salts in urban stormwater: an emerging issue in stormwater management in cold climates. *Water Science and Technology*, *48*(9), 61-70.

McDonnell, M. J., & Pickett, S. T. (1990). Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. *Ecology*,*71*(4), 1232-1237.

Mell, I. C. (2017). Green infrastructure: reflections on past, present and future praxis. *Landscape Research*, *42*(2), 135-145.

Miller, J.R., & Hobbs, R.J. (2002). Conservation where people live and work. *Conservation biology*, *16*(2), 330-337.

Mohanty, S. K., Valenca, R., Berger, A. W., Iris, K. M., Xiong, X., Saunders, T. M., & Tsang, D. C. (2018). Plenty of room for carbon on the ground: Potential applications of biochar for stormwater treatment. *Science of the total environment*, *625*, 1644-1658.

Monberg, R. J., Howe, A. G., Kepfer-Rojas, S., Ravn, H. P., & Jensen, M. B. (2019). Vegetation development in a stormwater management system designed to enhance ecological qualities. *Urban Forestry & Urban Greening*, *46*, 126463.

Mulhouse, J. M., & Galatowitsch, S. M. (2003). Revegetation of prairie pothole wetlands in the mid-continental US: twelve years post-reflooding. *Plant Ecology*, *169*(1), 143-159.

Norland, J., Fasching, S., Dixon, C., Askerooth, K., Kelsey, K. and Wang, G. 2013. Reduced establishment of Canada thistle (*Cirsium arvense*) using functionally similar native forbs. *Ecological Restoration 31*, 144–146.

Norland, J. E., Dixon, C. S., Larson, D. L., Askerooth, K. L., & Geaumont, B. A. (2018). Prairie reconstruction unpredictability and complexity: What is the rate of reconstruction failures? Ecological Restoration, 36(4), 263-266.

Pauleit, S., Hansen, R., Rall, E. L., Zölch, T., Andersson, E., Luz, A. C. & Vierikko, K. (2017). Urban landscapes and green infrastructure. In *Oxford Research Encyclopedia of Environmental Science*.

Read, J., Wevill, T., Fletcher, T., & Deletic, A. (2008). Variation among plant species in pollutant removal from stormwater in biofiltration systems. *Water research*, *42*(4-5), 893-902.

Roberts, B., Atkins, P, & Simmons, I. (2014). People, land and time: an historical introduction to the relations between landscape, culture and environment. Routledge.

Rolf, W., Pauleit, S., & Wiggering, H. (2019). A stakeholder approach, door opener for farmland and multifunctionality in urban green infrastructure. *Urban Forestry & Urban Greening*, *40*, 73-83.

Peck, J.E. 2016. Multivariate analysis for ecologists: Step-by-step, second edition. MJM Software design, Gledneden Beach, OR. 192 pp.

Schmer, M. R., Xue, Q., & Hendrickson, J. R. (2012). Salinity effects on perennial, warm-season (C4) grass germination adapted to the northern Great Plains. *Canadian journal of plant science*, *92*(5), 873-881.

Starzec, P., Lind, B.B., Lanngren, A., Lindgren, A., and Svenson, T. 2005. Technical and environmental functioning of detention ponds for the treatment of highway and road runoff. *Water, Air, and Soil Pollution*, *163*, 153-167.

Tober, D., Duckwitz, W., & Sieler, S. (2007). Plant materials for salt-affected sites in the Northern Great Plains. Natural Resources Conservation Service Technical Note. United States Department of Agriculture, Bismarck, ND, USA. goo. gl/HBNWTm.

USGS. (n.d.). NRCS Soil Survey. Nrcs.Usda.Gov. Retrieved September 16, 2021, from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcseprd1464625

USDA, NRCS. 2021. The PLANTS Database (http://plants.usda.gov, 08/16/2021). National Plant Data Team, Greensboro, NC USA.

Urbonas, B., & Stahre, P. (1993). Stormwater: best management practices and detention for water quality, drainage, and CSO management. Prentice Hall.

Wang, D., & Hejazi, M. (2011). Quantifying the relative contribution of the climate and direct human impacts on mean annual streamflow in the contiguous United States. *Water Resources Research*, *47*(10).

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. 2022. Web Soil Survey. Available online at the following link: http://websoilsurvey.sc.egov.usda.gov/. Accessed [February 15/2022].

Wenger, S.J., Roy, A.H., Jackson, C.R., Bernhardt, E.S., Carter,T.L., Filoso, S., ... & Meyer, J. L. (2009). Twenty-six key research questions in urban stream ecology: an assessment of the state of the science. *Journal of the North American Benthological Society*, *28*(4), 1080-1098.

Werner, K.J. and Zedler, J.B. (2002) How sedge meadow soils, microtopography, and vegetation respond to sedimentation. *Wetlands*, 22(3), pp.451-466.

Young, R. F. (2011). Planting the living city: Best practices in planning green infrastructure—Results from major us cities. *Journal of the American Planning Association*, *77*(4), 368-381.

Zhang, Z., Meerow, S., Newell, J. P., & Lindquist, M. (2019). Enhancing landscape connectivity through multifunctional green infrastructure corridor modeling and design. *Urban Forestry & Urban Greening*, *38*, 305-317.

Zhu, X., Chatain, V., Gautier, M., Blanc-Biscarat, D., Delolme, C., Dumont, N., ... & Kouyi, G. L. (2020). Combination of Lagrangian Discrete Phase Model and sediment physico-chemical characteristics for the prediction of the distribution of trace metal contamination in a stormwater detention basin. *Science of The Total Environment*, *698*, 134263.

Zhu, J. K. (2001). Plant salt tolerance. *Trends in plant science*, *6*(2), 66-71.

CHAPTER 4: VERTICAL WATER QUALITY

Introduction

Urban stormwater detention basins have historically been designed to control large urban stormwater events to reduce flooding and damage to infrastructure (Zubair et al. 2010). A typical basin design provides an impoundment area to store water from rainfall and then meter it out slowly into a receiving body of water (Line & White 2007; Collintine & Futter 2018). Growth in urbanization over time has negatively impacted local aquatic environments by impacting water quality system-wide (Li et al. 2017). Water quality during a rainfall event differs in time as water enters a basin (Macarthy 2009). It is important to assess the water quality as it fills detentions basins in order to determine the best mitigation strategies. Finding a cost-effective means to sample water quality will help to mitigate the anthropogenic impacts of urban development.

The expansion of urban areas notably degrades ecosystems by increasing peak flow rates (Niemczynowicz 1999; Paul & Meyer 2001; Walsh et al. 2005; Strecker et al. 2001; Booth & Konrad 2005), reducing the natural water table through hydraulic change (Walsh et al. 2005), changing water chemistry (Walsh 2016; Miller & Hutchens 2017), increasing sediment levels (Paule-Mercado et al. 2017), and increasing pollutant loads (Walsh et al. 2005; Le et al. 2017). Due to urban water quality concerns, stormwater runoff is increasingly being used for green infrastructure systems (Line & White 2007; Miller & Hutchens 2017; Le et al. 2017) and increasing the effectiveness of detention basins to improve stormwater quality has been explored (Booth & Jackson 1997; Marsalek 2005; Wengne et al. 2009; Gaborit et al. 2013; Kerkez et al. 2016).

Runoff traveling over impervious surfaces picks up sediment, chemicals, solid waste, and metals (Guo et al. 2011). Research shows these are often picked up in stormwater early in a rain event, commonly referred to as the first flush phenomenon (Macarthy 2009). The first flush phenomenon brings in high concentrations of pollutants into detention basins before peak flow is reached (Deletic 1998; Lee et al. 2002; Goonetillekea et al. 2005; Allen et al. 2017).

First flush and stormwater research has demonstrated that detention basins can contain elevated levels of fecal coliforms, heavy metals, total suspended solids and sodium (Taylor et al. 2005; Hettiarchchi et al. 2011; Vitro et al. 2017; Mangani et al. 2005. Olsen et al. (2022) found that the first flush of urban catchments contains elevated levels of organic and inorganic pollutants. While Chow et al. (2011) found that urban catchment areas in Malaysia demonstrated elevated site mean concentrations for Total Suspended Solids (TSS). It has been noted that settling velocity and duration of stormwater detention affect the removal rate of pollutants related to total suspended and dissolved solids (Akan 2009). It has also been documented that to generate removal efficiencies of 60%, detention times need to be at least 24 hours (Shammaa et al. 2002). The increase of particulate or dissolved pollutant material, as it relates to concentration during a precipitation event, may change during basin inundation phases (Bertrand-Krajewski et al. 1998). However, the research that has been conducted on stormwater in urban detention basins has been conducted at only one site (Taylor et al. 2005), during one event (Taylor et al. 2005), only looking at the first flush (Shammaa et al. 2002), or in general at one point and time during a storm event (Shammaa et al. 2002). Knowledge is needed to determine what happens to water quality after the first flush, but while the water is detained in the basin. Water quality studies in regards to first flush dynamics will help water managers inventory the detrimental constituents however more knowledge is needed regarding what is coming into the system during an actual event as the water rises by assessing the analytes within the water column.

This study investigated the dynamics of water quality during storm events at detention basins as they relate to initial filling of the basin (first flush), peak volume (highest level of water in the basin during event), and outfall of stormwater (last water to drain from the basin). More effective methods for water managers are needed to determine the levels of constituents that enter detention basins during inundation events. These methods would be more useful if they could be deployed by municipal workers and water system managers using low-tech devices that could cover more sampling locations. This method differs from current technology in that it tests a simple and cost-effective solution. Automatic samplers have been the standard for urban water quality sampling (Appel & Hudak 2001), however they are expensive and require a power source so cannot be used in all areas. What is new about the system described in this project is that it solves the challenge of testing multiple sites with multiple collectors thus allowing more data to be collected in a catchment area in a low-cost way.

This research aims to determine if detention basins have different water quality concentrations within the vertical water strata at different times during storm events. Specifically, the objectives of this study are to: 1) design and discuss a verified method to assess vertical water quality in detention basins during storm events as water enters, peaks, and leaves the basin; and 2) assess the changes in water quality that flows into and out of the system throughout a storm event and detention of runoff water. Information from this project can provide insight for researchers and water managers on how to sample vertical water quality and the potential of designing basins to improve water quality.

Methods

Study Area

This study was conducted at three stormwater detention basins within Fargo, North Dakota, USA (Figure 4.1), including the: 1) Fisheye Basin (Fisheye) located at 46° 52' 02.16" N 96° 51' 24.40" W; 2) Scheels Basin (Scheels) located at 46° 51' 29.69" N 96° 51' 56.90" W, and 3) The World Common Garden Basin known as The Fargo Project (TFP) located at 46° 51' 10.10" N 96° 51' 10.10" W. The basins were chosen because of their similarities in regard to size, geographic proximity, topography, and surrounding land use, see Table 4.1 for basin attributes. The sampling was designed to be indicative of a typical urban detention basin surrounded by residential land zoning. One key difference between the detention basins was the greening of TFP site while the other basins did not have the same greening. The Fargo Project is a municipally organized endeavor that sought to create green infrastructure within a detention basin that responded to the communities needs for recreation. The greening of TFP stormwater detention basin included removing the concrete channel and having a naturalized channel develop with riparian vegetation, and to stop mowing the basin in conjunction with planting native vegetation. The planners of TFP were also interested in seeing if the greening of the basin can serve dual purposes of capturing water and removing potential pollutants in the stormwater, mitigating downstream water quality impacts, which has been shown in some research (Goonetillekea et al. 2004).

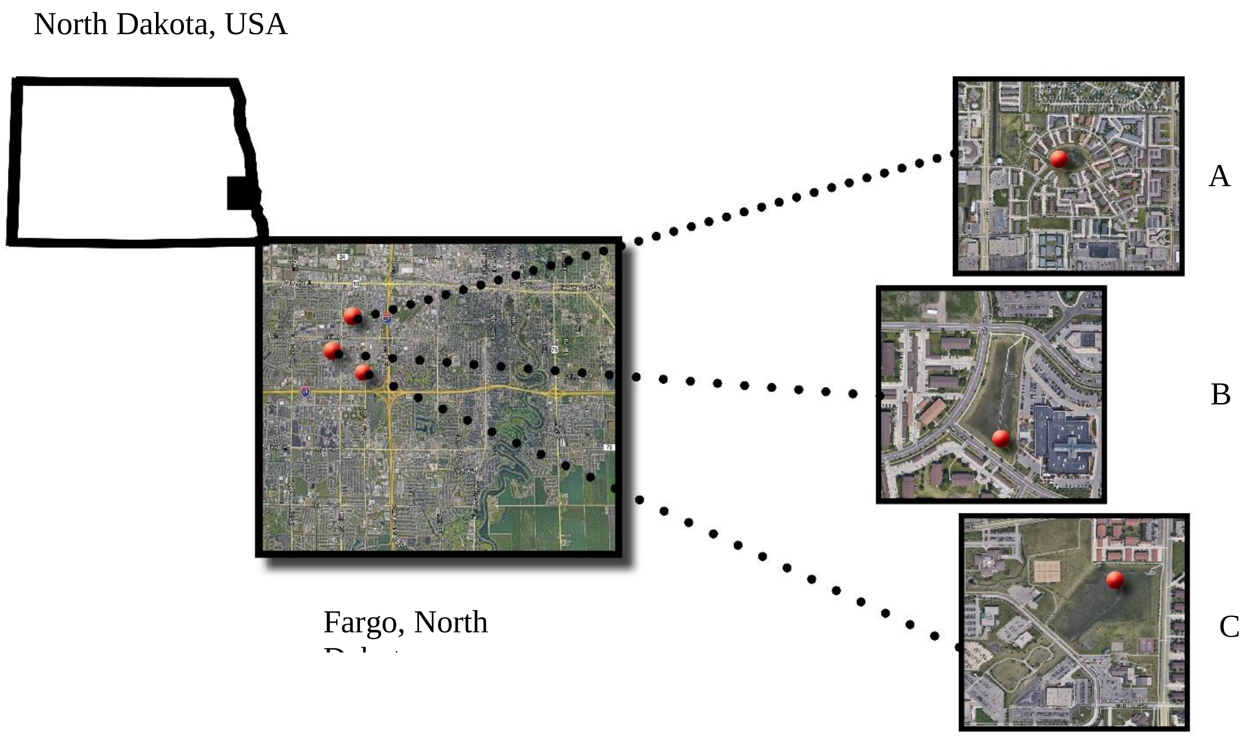

Figure 4.1. Map of North Dakota showing Cass County, where the city of Fargo is located, in the black shaded area. Sample locations are depicted by red dots on aerial photo of Fargo, with expansion to detention basins aerial photos: A) Fisheye; B) Scheels; and C) The Fargo Project.

Within the three basins, stormwater runoff is collected and metered out over a period of 12-36 hours depending on the severity and duration of the storm, as well as stormwater volume. The stormwater from the detention basins, along with all the constituents picked up in the stormwater, is then released into the greater watershed of the Red River of the north. All three catchment areas eventually deposit water into the Red River.

Table 4.1. Detention basin size (surface area), depth (deepest part of the basin from the top of the highest pool level), catchment size, and catchment impervious cover percent.

Basin name	Size m^2	Depth m	Catchment ha	Impervious %
The Fargo Project	40,873.5	2.4	162.5	42.3
Scheels	9,797.1	1.9	16.3	23.1
Fisheye	13,280.3	2.3	138.7	49.2

A unique aspect of the sites is they exist in a region affected by salinity issues in the soils (Ulmer et al 2007; Lobell et al. 2010; Shermer et al 2012). Salinity can be an issue when building detention basins because digging into salt-bearing formations the groundwater can also be saline. Sites in the region have shown impacts from salinity which occurs due to fluctuating water tables, capillary rise, hygroscopic water pressure, discharge soils, saline seeps, evaporating ponds (Shermer et al 2012; McCauley & Jones 2005; Tober et al., 2007; Jacoby et al. 2011). These increased levels of salinity in the region can impact water quality (Peel et al. 2004; Shermer et al 2012; Matthees et al. 2018).

Climate

The study area is located on the eastern edge of North Dakota. This area receives annual precipitation ranging from 35.6 to 55.9 cm (NOAA 2018). The growing season, April to September, accounts for approximately 75% of the total annual precipitation (NOAA 2018). Nominal rainfall takes place during the winter months, and precipitation during this time typically comes as snow. The annual snowfall average for the state ranges from 63.5cm to 114.2 cm (NOAA 2018). There is no dominant rain pattern for the area, in terms of regular type, occurrence, and amount of precipitation. However, the majority of rainfall that does occur, comes in the form of thunderstorms. These events take place statewide 25 to 35 days per year (NOAA 2018).

To determine the long-term hydrologic impact of precipitation on groundwater at the site, the Palmer Drought Severity Index (PDSI) was utilized. The PDSI determines departure from normal in surface water as it relates to long-term climate data. The index ranges from -10 to +10, with negative numbers being indicative of dry regimes, and progressing to positive numbers which indicate increasing moisture (Dai 2011). The local PDSI for the study area exhibited mostly positive numbers showing readings consistent with higher levels of moisture in surface water and groundwater in both sampling seasons (Figure 4.2). The higher PDSI numbers show moisture that is above average level during July and September of 2016 and June of 2017.

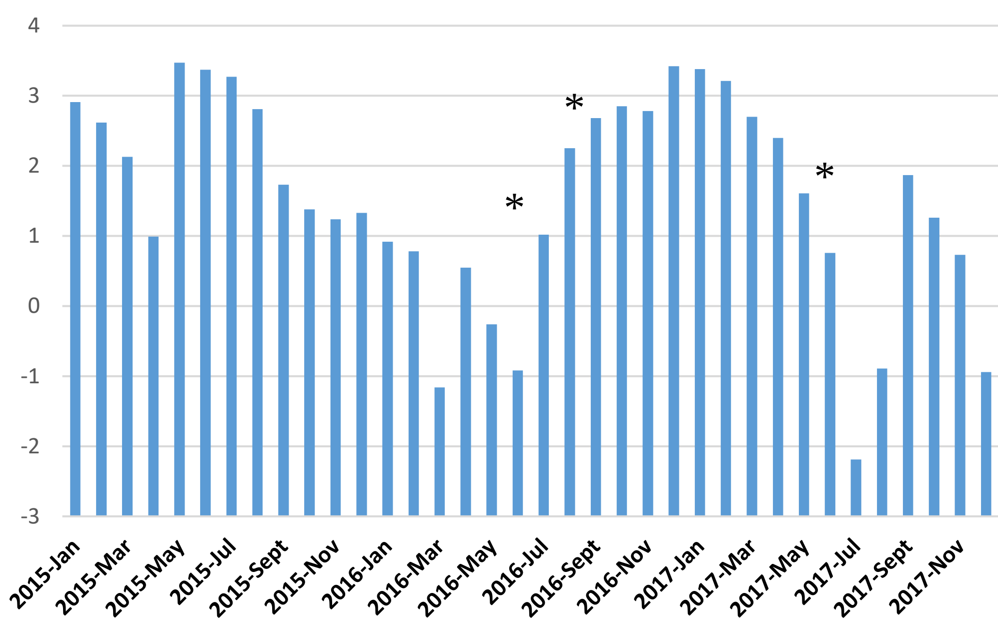

Figure 4.2. Palmer Severity Drought Index January 2015 to December 2017. Periods with asterisks represent the three storm events sampled.

Vertical Water Sampling System

A passive vertical water quality system was designed to sample water as it entered, moved through, and drained from the system during major storm events. Sampling was conducted whenever there was 2.54 cm or more of rain within a one-hour period. This accounted for two events during the summer of 2016 and one event in 2017 (Table 4.2) Water quality samples were taken as the water entered the basin and increased vertically (initial sample), at the maximum point (peak sample), and then as it decreased vertically (outfall sample).

Table 4.2. Dates and amounts of precipitation events that were sampled during the study including the day before and after the event.

Date	Precipitation (CM)
July 8, 2016	0.3
July 9, 2016	36.6
July 10, 2016	1.3
September 6, 2016	0.00
September 7, 2016	44.7
September 8, 2016	0.00
June 12, 2017	0.00
June 13, 2017	34.5
June 14, 2017	0.00

Due to water entering the basins very rapidly, it is difficult to obtain grab samples of all stages needed for sampling. For example, from the time a large rain would slow down or end, it would take approximately one hour before the basins would go from dry to 1.5m of water; while that same water may take up to 24hrs or more to recede from the basin. This quick inundation with water made sampling with automatic samplers not ideal in programming difficulties as well as protecting electronic equipment from inundation. Additionally, having people at the site would be considered dangerous as storms in the area are typically accompanied by thunderstorm warnings, with significant lightening and wind, and occasionally tornado warnings. Therefore, to sample water at different stages entering the basin, researchers developed a passive sampling mechanism to collect water at different heights (Figure 4.3). Large buckets (18.92 liters) were attached to steel t-posts at the deepest part of each basin, but not in the basin channel or edge of the channel. The buckets measured 30.25 cm in diameter on top, 36.83 cm in height, and 26.23 cm in diameter on the bottom. Threaded PVC attached the buckets to the posts. A series of 1.27 cm holes were drilled in a level line just under the lip of the bucket to allow stormwater to infiltrate the bucket once a specific height was reached. The holes of the bucket (on top of the t-post) were set at exactly .61 m, .91 m, 1.21 m, and 1.52 m off the ground. The bucket for .30 m was buried partially into the ground for stability, and to ensure holes were set at the correct height. A tight-fitting bucket lid was then attached and was not removed until after sampling. Buckets were placed at correct heights and locations before storm events. As the water rose within the basins, water would fill into the bucket at the exact height needed for the water sample. Once filled, the water in the bucket would essentially serve as a seal to not allow additional water to enter the bucket or mixing of the water in the bucket. This allowed researchers to sample water at desired heights, and the highest bucket to fill was considered the peak sample. Additionally, as the water receded from the basin it did not mix within the buckets, and researchers could wait until a time and depth that was safe to enter the basin to retrieve the buckets, while allowing the water to remain in an environment that would not cause changes to constituents (beyond dissolved oxygen) and maintain normal biological activity. As the water receded from the basin, grab samples were taken at each of the same heights as the buckets. Because the water in detention basins recedes at a slower rate and dangerous weather has passed, the ability to schedule personnel for grab samples is much easier and there is time to move among the different basins. The draining or outfall samples were collected at the outlet for each basin.

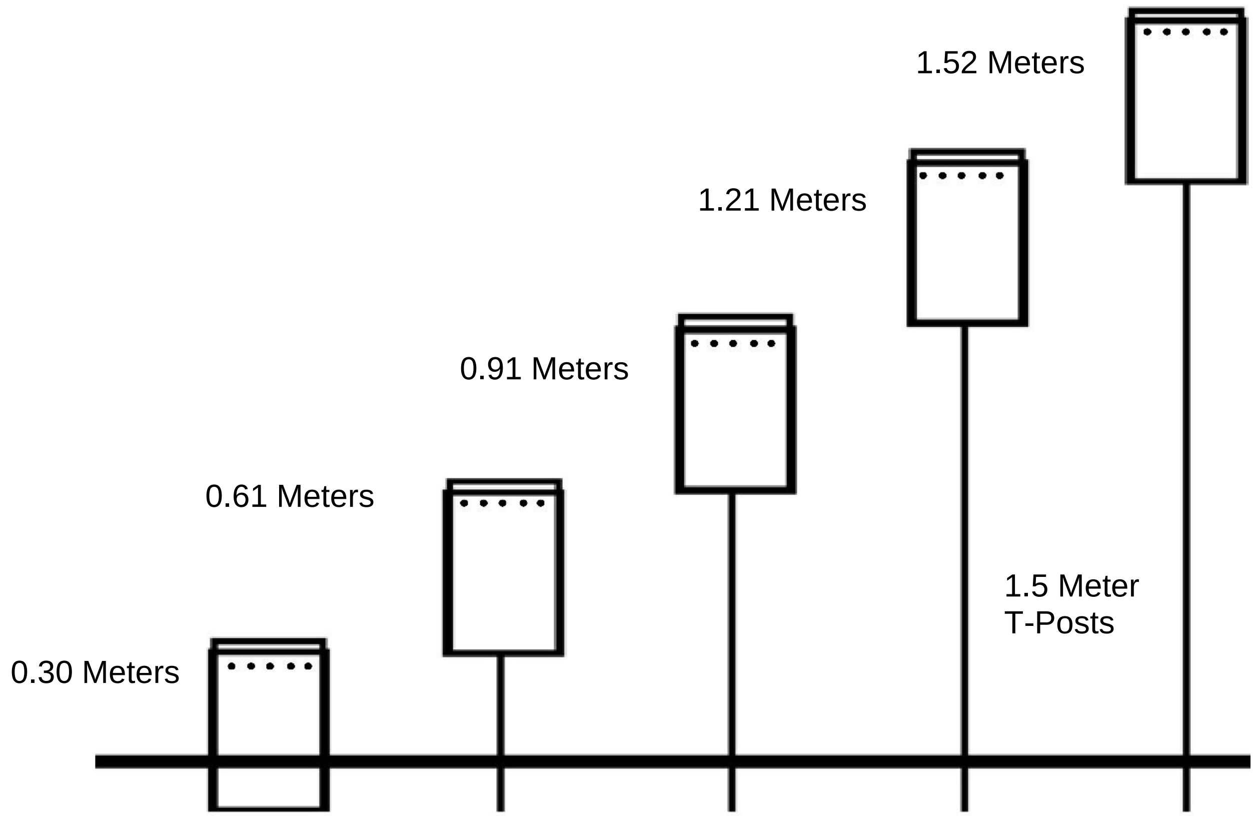

Figure 4.3. Vertical water quality sampling design. Each rectangle represents an 18.29-liter bucket (5 gallons) with a lid on top, with dots representing the fill line height for the bucket.

Sample Analysis

Once removed from the basin, sample buckets were immediately mixed using a SP Bell-Art churn splitter (Bel-Art - SP Scienceware Wayne, NJ, USA) 4 liter to resuspend particulates and take a standard sample of the bucket water. All samples were processed and preserved according to North Dakota Department of Environmental Quality (NDDEQ 2014) and sent to the NDDEQ Lab in Bismarck, North Dakota, USA to analyze for TSS, total dissolved solids (TDS), nutrients complete (Total Kjeldahl Nitrogen (TKN), NO_2, NO_3, NH_3, NH_4, and P), *Escherichia coli* (*E. coli*), 15 general chemistry parameters, eight nutrient analytes, 15 trace elements, oil and grease, and diesel range organics. Not all analytes were chosen to report on as the levels did not exceed levels that would warrant interpretation. Parameters and detection limits can be found in Appendix D. The 15 trace elements were analyzed using aqua regia digestion and inductively coupled plasma-mass spectrometry (ICPMS) or inductively coupled plasma-atomic emission spectrometry depending on laboratory protocol (NDDEQ Laboratory), respectively. Additional samples for diesel range organics (DRO) were taken at one storm event each summer at 0.30 m entering the basin, the maximum height of the water, and 0.30 m receding from the site. The DRO samples are expensive and labor-intensive for the laboratory to process; therefore, only limited samples were taken. Additional onsite measurements were taken with a Yellow Spring Instrument Co. YSI model 650 MDS data logger combined with a model 600 QS Sonde (YSI Incorporated Yellow Springs, OH, USA) to measure temperature, electrical conductivity, pH, and dissolved oxygen, though dissolved oxygen samples were assumed to be incorrect do to mixing with churn splitter. *E Coli* samples were cooled on ice and transported to the NDDEQ's lab. The NDDEQ *E. coli* analysis used the Colilert-18/Quanti-Tray/2000 to quantify *E. coli* (Idexx Laboratories, Inc., Westbrook, Maine). The quantification method is based on the "most probable number" methodology. The results are reported in colony-forming units (CFU)/100 mL. Samples were diluted if the upper detection limit was reached and rerun to determine CFU/100 mL after that if CFU reached the upper limit of 16,000 CFU at which time 16,000 CFU/100 mL was reported, but actual CFU could be much higher.

Statistical Analysis

A general linear model ANOVA was used to determine if there were significant differences in water quality parameters measured. We tested selected analytes for these three factors: 1) events (July 2016, September 2016, and June 2017); 2) stages - initial filling of the basin (Initial), peak for each event (Peak), and outfall (Outfall) or last sample before the basin drained; and 3) site (Fisheye, Scheels, TFP). The analysis design was a complete randomized block design, with the site as the block and events and stage as fixed factors. The analysis used PROC GLM in the SAS® software, Version 9.4 of the SAS System for Windows (Copyright © 2015 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA) and the Tukey adjustment was used for multiple comparisons among the three factors.

Results and Discussion

Passive Vertical Water Quality Sampling System

The passive vertical water quality sampling system performed well as designed. The system was able to provide water samples at different stages. Having a series of buckets at different heights meant that the peak of the water for an event was collected even if the precipitation events varied over time and among basins. This system would benefit agencies that have limited man power or are constrained from purchasing automatic samplers. This water collection system provided a solution to collecting water at different vertical heights as it quickly enters a basin, but there were some drawbacks. Because the samples sat until levels within the basin allowed water retrieval from the buckets the samples were not immediately cooled or chemically stabilized. The cooling and stabilization is important to accurately measure constituents (S·liwka-Kaszyńska et al. 2003). Researchers suggest that the samples be collected as soon as safe to prevent sample degradation. The amount of time that samples sat depended on total precipitation and volume of water that entered the basin. The location of this sampling method proved beneficial in this research in that collection could take place in lowest elevations where inundation takes place first. Having a person taking grab samples from the outer perimeter of a rising basin would be time consuming and not provide accurate reading of various water column depths. For deep basins, the use of watercraft could decrease the time that samples sat rather than waiting until one could access the buckets using waders. Also, if the water receded quickly, it would increase the efficacy of this method. Whether shortening the time will increase the utility of samples requiring cooling and stabilization would need to be considered based on the individual needs of monitoring projects. However, this alternative is a viable solution to spread resources further in hopes of collecting a greater amount of data.

Utilizing a passive system, such as described in this study, with materials easily purchased benefits water managers by mitigating costs and technical expertise associated with automated systems. While automated systems may be necessary to pinpoint analytes for sensitive systems and do have their uses in other water sampling situations, the passive system used here will have distinct advantages. One advantage is this is a low-cost effective method that can be done by almost all organizations. Another advantage is this is a simple method that utilizes the forces within the basin and does not require the training and maintenance often associated with complicated automated systems. With no complicated mechanical devices or power source needed, there is little that can go wrong, which is always beneficial in field sampling. The biggest problem would typically be associated with buckets not being attached to the ground and/or t-posts correctly and the bucket floating rather than staying in place when water fills the basin. The passive vertical water testing system reduced vertical water sampling to a simple water collection and storage system that allows for precise vertical water collection in an uncomplicated and safe manner.

Water quality data were collected for the three stages, initial, peak, and outfall, at each of the three sites to be used in comparative analysis. Water quality at different vertical elevations between the three stages is not reported because the basins differed in the level of water collected at each basin and for each event which resulted in an inconsistent pattern of samples from the different water level heights to be used for comparison. However, the sampling design did prove to be a solid and consistent way to sample water at different heights as it enters the basin.

The data from the detention basins were compared amongst known standards from within the state where the study took place, as well as the United States Environmental Protection Agency (EPA) standards, and federal standards for water quality. Similar to Niemczynowicz (1999), a select group of analytes were focused on due to their prior significance to urban stormwater quality and water quality-related problems downstream.

Chloride and Sodium

Sodium and chloride each had significant differences between storm events ($P \leq 0.05$) (Figures 4.4 and 4.5). However, among the stages, there were no significant difference ($P \geq 0.05$). The basin that exhibited the highest readings of sodium was the TFP (TFP 16.4, Fisheye 13.1, Scheels 9.8 mg/L), and this was significantly higher than the Scheels site ($P \leq 0.01$). Both TFP and Fisheye had significantly higher chloride levels compared to Scheels ($P \leq 0.01$) (TFP 15.9, Fisheye 16, Scheels 4 mg/L). The June 2017 event showed the highest levels of sodium and chloride. This may be due to the extended amount of time between flushes. Soils that readily release salts during leaching produce a salt buildup that can increase sodium concentrations (Shainberg et al. 1991; Warrence et al 2002). There were no rain events before June 2017 of greater than 2.54 cm. Both sodium and chloride were below the standards for waters of the state (NDCC § 33-16-02); 250 mg/L for sodium and 100-250 mg/L (dependent on stream classification) for chloride. As both sodium and chloride levels throughout storm events were below the state standard, it shows that they remain consistent even during the first flush and later waters, and these constituents overall would be of little concern.

However, there were differences between storm events and sampling sites. There are two likely sources of sodium and chloride within the basins, stormwater runoff and the basin soils. Chloride and sodium need precipitation if they are to be transported by conventional urban drainage from basins to receiving waters (Marsalek 2003). With significant runoff volume, the resident sodium and chloride from salts on soil surfaces and winter road maintenance will be flushed with each rain event. If this is true, rain events that occur closer to the change from winter to spring will have higher amounts of sodium and chloride. Additionally, the amount of soil salt will depend on dry periods between precipitation that allow for salts to accumulate on the surface through evaporation of salt-laden soil and water interactions and runoff that does not infiltrate the ground but instead evaporates (Pitt et al. 1999, Hasanuzzaman et al. 2013). Unpublished soil sampling data from TFP found the basin soils have elevated sodium and chloride and would be categorized as salt-affected. Olson (2020) found both sodium and chloride to be present at high levels in groundwater at the TFP and Fisheye compared to other basins in the area. The Scheels basin is the shallowest basin and holds the least amount of water in terms of volume. Therefore, it is likely the Fisheye and TFP would be expected to have more surface salts when compared to the Scheels site, which is what the data showed.

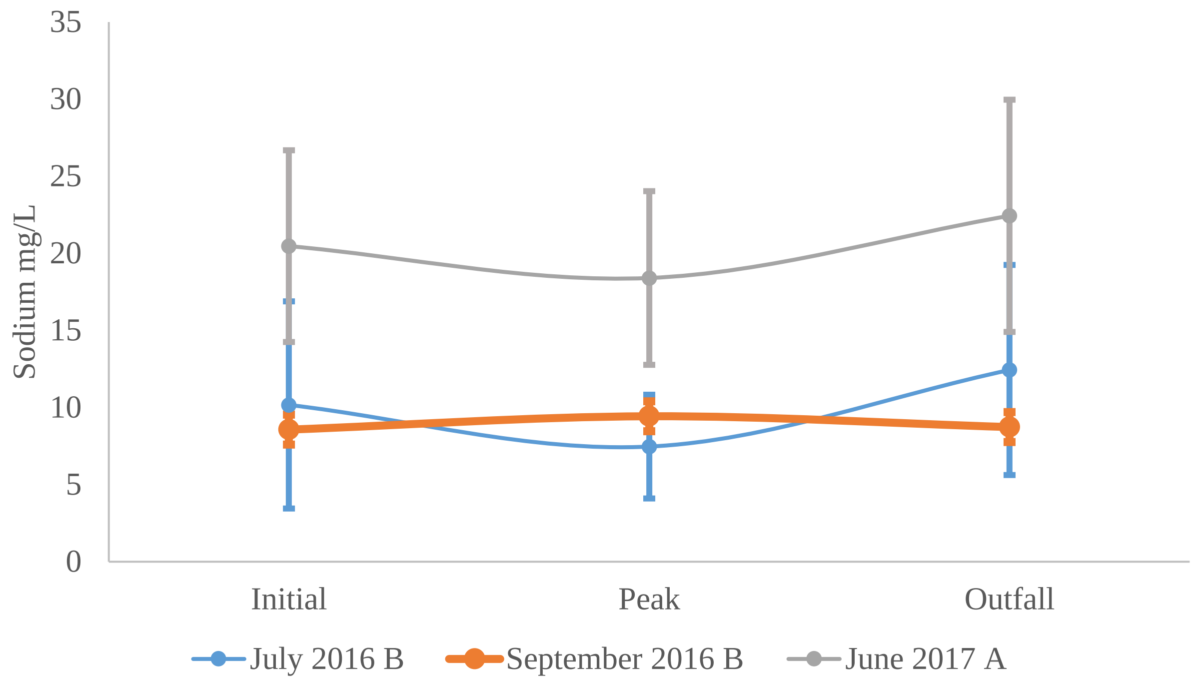

Figure 4.4. Sodium concentrations at initial, peak and outfall stages across storm events. Legend items followed by different letters are significant P≤0.05. Error bars show standard deviation.

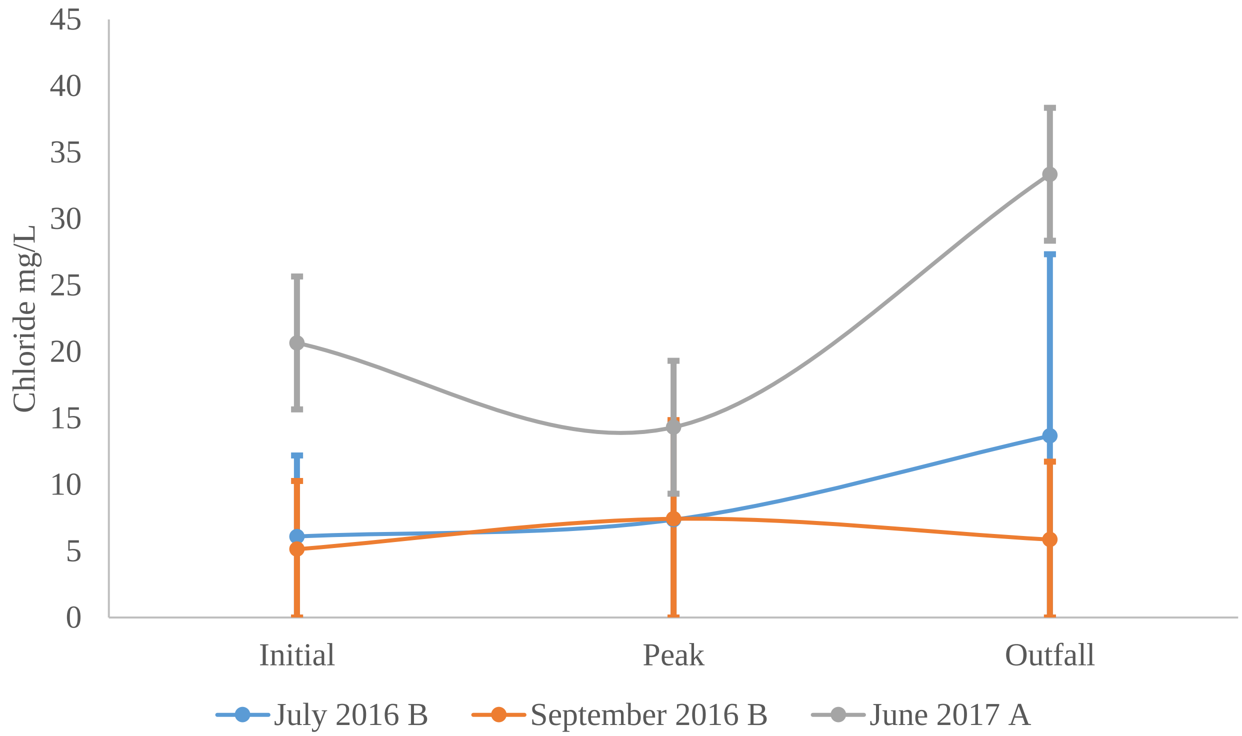

Figure 4.5. Chloride concentrations at initial, peak, and outfall stages across storm events. Legend items followed by different letters are significant P≤0.05. Error bars show standard deviation.

In general, municipalities can reduce sodium and chloride by utilizing best management practices, such as more environmentally friendly de-icers (Marsalek 2003) and planting of salt-tolerant vegetative covers (Szota et al. 2015). However, in this study, since the soils are already salt-affected and salt is moving through groundwater the effectiveness of mitigation like this may be limited. Seasonal inundation of water may have a beneficial effect in the basins by naturally flushing salinity from the basin soils (Smith 2009; Garcia et al. 2010). Research has shown that high levels of salinity affect detention basins by limiting the species growing within them (Peel et al. 2004; Shermer et al 2012; Matthees et al. 2018). Vegetation exposed to increased salt concentrations causes water stress, ion toxicity (Marsalek 2003), and nutrient imbalance (Van Meter et al. 2011). These conditions inhibit the physical growth and nutrient uptake of many native or introduced species that may be grown in a detention basin (Van Meter et al. 2011). The challenge for basins in the northern climates is transporting salt-concentrated storm water away from environmentally sensitive ecosystems to larger waterbodies where dilution can lessen the negative impacts of saline concentrated water (Kim & Jenkins 2006).

Total Dissolved Solids

Results of TDS showed significant differences in both stage and event (Figure 4.6). At TFP TDS was significantly higher than the Fisheye at 124 mg/L and 94 mg/L respectively ($P \leq 0.05$). The peak water reading showed the least amount of TDS. Researchers assume that dilution is responsible for less TDS in the water as the basin fills to its highest volume. The TDS values level off when a certain salinity level is reached, which is similar to results from Dahaan et al (2016). As Marsalek (2003) explains, the physical process of dilution caused by mixing and increased volume of stormwater may cause some analytes to demonstrate reduced concentrations. Dilution and chemistry dynamics are likely factors in results of the current study as well.

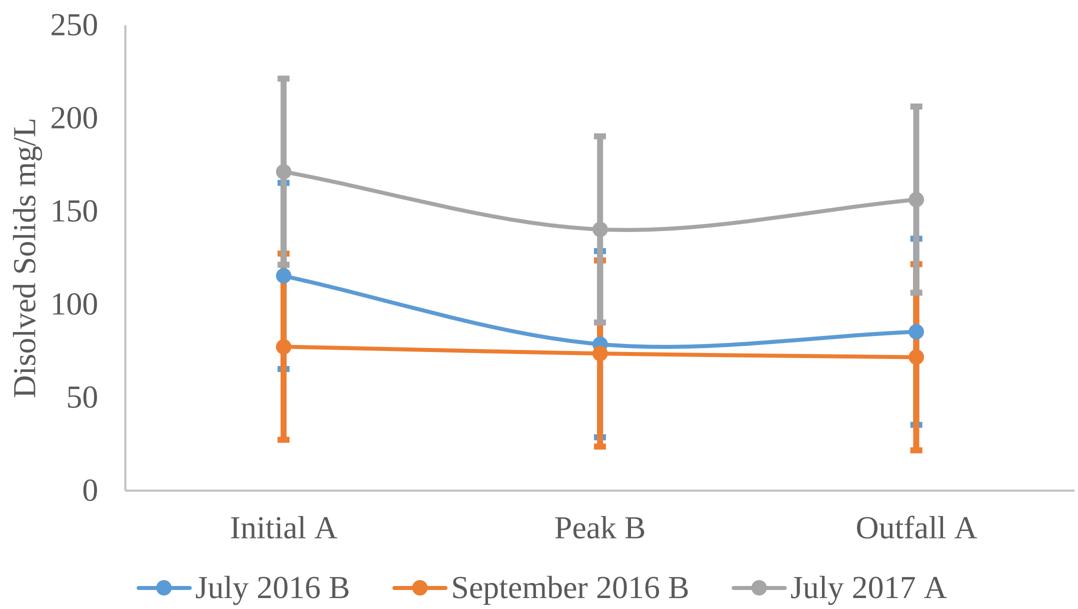

Figure 4.6 Total dissolved solids initial, peak, and outfall stage across storm events averaged over the three sites. Letters on legend represent significant differences at the $P \leq 0.05$. Error bars show standard deviation.

Total Suspended Solids

The TSS analysis showed no significant differences between sites and events ($P \geq 0.05$). However, there were significant differences in stage ($P \leq 0.05$). The TSS readings were highest at the initial stage and then decreased with dilution and residency time (Figure 4.7). There appears to be settling of particles over time as the water remained in the detention basin. This is in line with other research regarding suspended solids, which also shows they can settle with residency time (Lee et al. 2014).

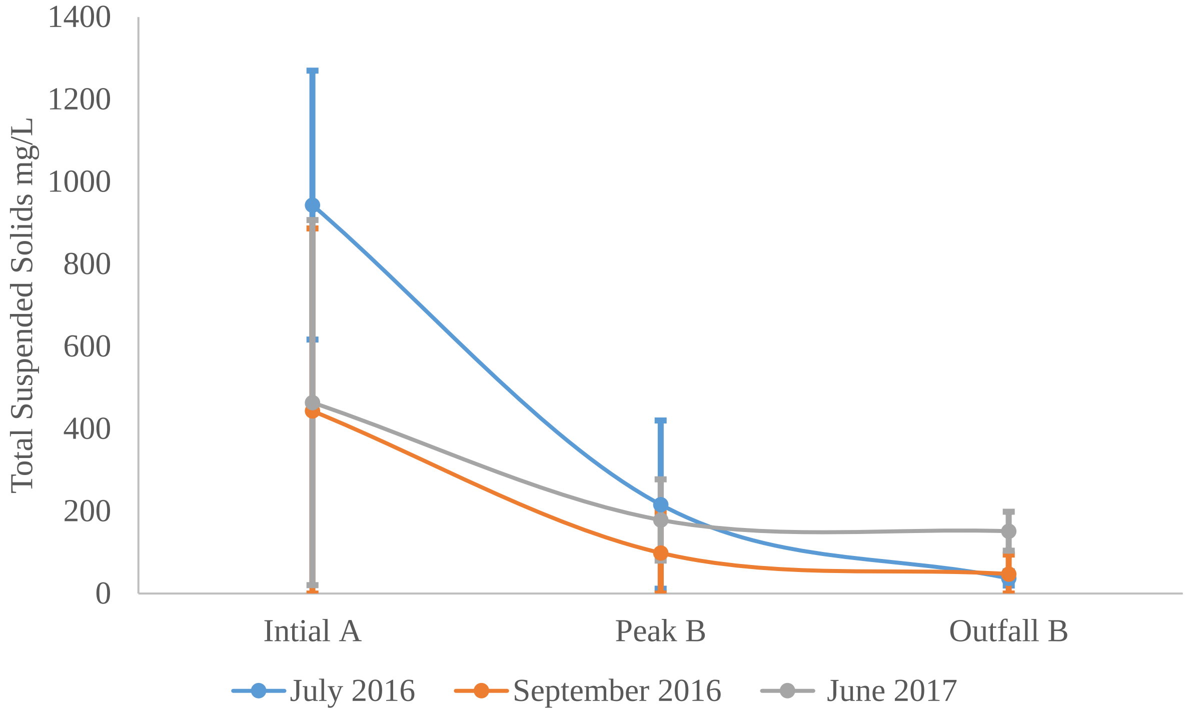

Figure 4.7. Total suspended solids at the initial, peak, and outfall stage showing storm events averaged over the three sites. Different letters represent significant differences at the P≤0.05. Error bars show standard deviation.

Increased levels of sediment have the ability to negatively impact receiving water bodies and harm aquatic ecosystems (Taylor & Owens 2009). Specifically, TSS has been shown to transport harmful pollutants, reduce light in aquatic systems, and build up in waterways (Duncan 1999; Taylor & Owens 2009). Research has also shown that determining factors for TSS include the size of the catchment, surrounding land use, and individual infrastructure components (McCarthy et al. 2012). Another important factor, detention time, can influence the settling of TSS (Shammaa et al. 2002). Previous retrofits have demonstrated substantial pollutant removal efficiency for TSS achieving up to 90% when outlet structures were installed to increase detention times (Carpenter et al 2014). A general detention time of 24 hours is considered enough to generate removal efficiencies of 60% (Shammaa et al. 2002). This is important when considering the TFP has a drawdown time of 18 hours or more. Detention basins receive higher volumes of water during inundation and thus uniquely dilute pollution concentrations with each rain event entering the hydraulic system (Kozak et al. 2019). Monitoring would determine if the added loads rise to a level of concern (Kozak et al. 2019). The fact that the basins in this study showed significant levels of reduction from the first flush to the outfall during storm events is useful in developing solutions to reduce TSS through detention basin design and hydrological planning. Forebays, sluice gates, and outlet design has been shown to reduce sediment flow within basin systems (McNett & Hunt 2010; Pan et al. 2010; Carpenter et al. 2014). Treating the stormwater with a forebay can reduce sediment prior to moving into the basin (Carpenter et al. 2014). The reduction of pollutants using forebays closest to point or non-point source pollution can have positive system impacts such as increased survivability of aquatic habitat (McNett & Hunt 2010), a broader range of vegetation survivability (Karathanasis et al. 2003), and increased soil health (Karathanasis et al. 2003; McNett & Hunt 2010; Carpenter et al. 2014). Municipal leaders and design professionals may want to consider outlet structure retrofits that can reduce draw downtimes to increase sediment removal in the water, as well as to conduct pollutant load monitoring and forebay retrofits to reduce sediment-loaded water before entering the basin.

E. Coli

All *E. coli* samples taken during the study were compared to the state recreational standards (NDCC § 33-16-02). Recreational standard states that surface water quality standards for *E. coli* are not to exceed 126 coliform forming units (CFU)/100 mL and this covers boating, swimming, fishing, and any other water recreational uses. Even though detention basins are not often thought of as recreational spaces, this is an area that has been retrofitted use by humans and therefore the recreation standard was applicable, similar to Olson et al. (2022).

Throughout the study, all *E. coli* samples taken failed to fall below the recreational standard of 126 CFU/100 mL. The September 2016 event had *E. coli* levels that were significantly higher than the other two events ($P \leq 0.05$) (Figure 4.8). Neither the sites nor stages were significantly different ($P \geq 0.05$). During the September 2016 event, all but one sample was at the detention limit of 16,000 CFU/100 mL, the highest value that could be measured. Researchers assume that elevated readings during the September 2016 precipitation event were due to the build-up of surface *E. coli* due to the later seasonal event time and greater amounts of precipitation entering the basin from the first flush (Olson et al. 2022). The September storm event differed in that the PSDI level was +2.75 in September and was near -1 in June, which shows a dry early summer changing to a wet period in September (Figure 4.2). Greater moisture amounts are indicative of the proliferation of bacteria (Hathaway et al. 2010; McCarthy et al 2012). July of 2016 and June of 2017 also had readings that were reported at the maximum level of 16,000 CFU/100 mL, but none of those measurements went below the NDCC recreational standard.

The late-season elevated readings exceeding the ability to detect may be due to sediment and waste build-up, which *E. coli* attaches to, which make their way into the detention basins with the initial stormwater pulse (Taylor et al. 2005; Hettiarchchi et al. 2011; Vitro et al. 2017). While elevated levels of bacteria in the form of fecal coliform have been known to enter detention basins from stormwater (Chen & Chang 2014), research has also found that soils contain naturally existing amounts of *E. coli* (Brennan et al. 2010). Olson et al. (2022) found that *E. coli* was present in both the groundwater and surface water for basins in the area and it was ubiquitous within the groundwater and likely residential.

Data from the present study suggests that elevated levels of *E. coli* persist throughout an event. The lack of declining *E. coli* levels after the first flush contrasts what other researchers have found. Krometis et al. 2007 found declining microbial concentrations at the end of storm events during a study of storm flows in streams in North Carolina, USA. Research has also shown the reduction of microbes is not present in urban area runoff stormwater, prior to entering the water system (MCCarthy, 2009; He et al., 2010; Hathaway & Hunt, 2011).

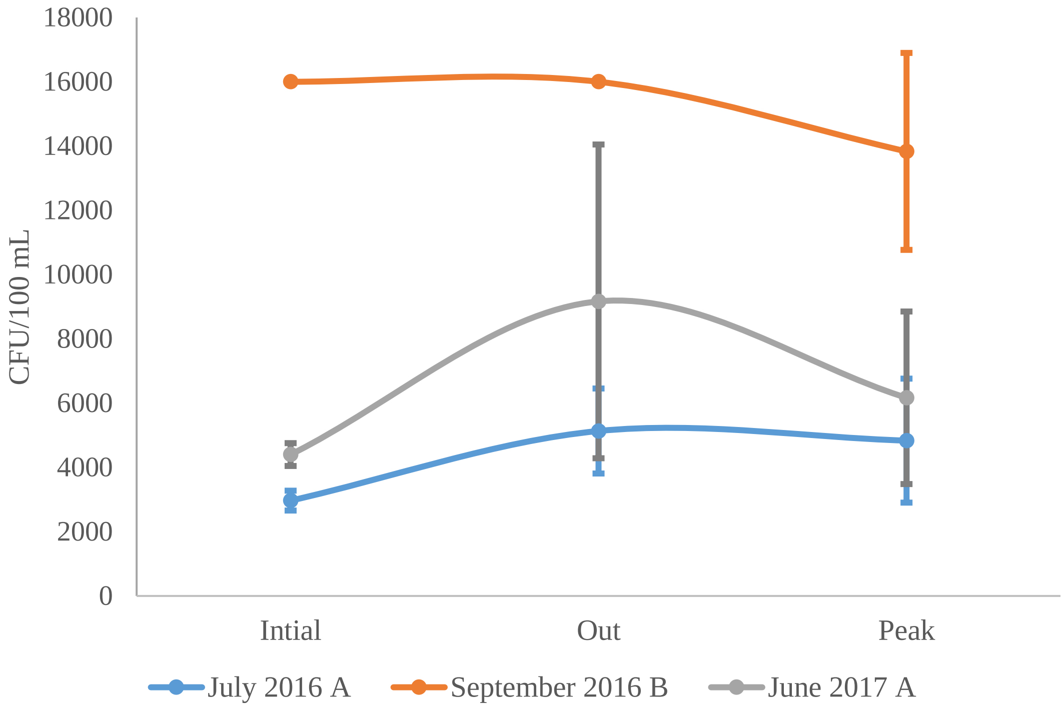

Figure 4.8. *E. coli* levels at the initial, peak, and outfall stage showing storm events averaged over the three sites. Different letters represent significant differences at the $P \leq 0.05$. Error bars show standard deviation.

E. coli is an important factor when determining the safety of a recreational area. The detention basins in this study are being considered for use beyond the function of controlling stormwater runoff. These underutilized lands can serve as a recreational component of larger green networks and thus would have human contact. It is, for this reason, that bacteria levels should be monitored and problems mitigated to ensure safe interactions with municipal residents. Research on Microbial Source Tracking (MST) can provide insight into the biological source of *E. coli* (Jardè et al. 2018, Olson et al. 2022). Genetic source tracking can aid municipalities in mitigating harmful bacteria inputs resulting from human, dog, bird, or bovine sources (Devane et al. 2019).

Total Nitrogen

Total nitrogen (TN) readings of all samples were never recorded above the state standard of 5 mg/L (NDCC 2022), although there were significant differences in the stormwater events ($P \leq 0.05$). September of 2016 had significantly lower N levels than the other two events (Figure 4.9). This could be due to the fact that it was the second major storm event of the year. Typically, N is fixed in terrestrial vegetation during the late summer months. Vegetation and other organisms have tied up available N, therefore there is little to move with stormwater until seasonally available during the decomposition phase (Robertson et al. 1999). Thus, it is possible, surface N had already run off the landscape in the July 2016 storm event. Higher N levels have also been associated with high street tree canopy cover and intensive landscape maintenance (Janke et al. 2017). Neither of these characteristics is prevalent in the catchment areas, so likely not an issue for the current project. Another potential factor dictating the low presence of TN is the lack of agricultural land use in the catchment area, which has been found to be problematic in other areas (Goonetilleke 2004). The N can enter urban water systems by natural means, anthropogenic impact, and biogenic material (Yang & Lusk 2018). With surrounding land use playing such a large factor in N deposition, it is safe to say, in the current project, that the basins were not impacted by large contributing factors. However, it should be mentioned that it does not appear that the basins themselves are removing N from the water, as the N levels throughout events was fairly steady.

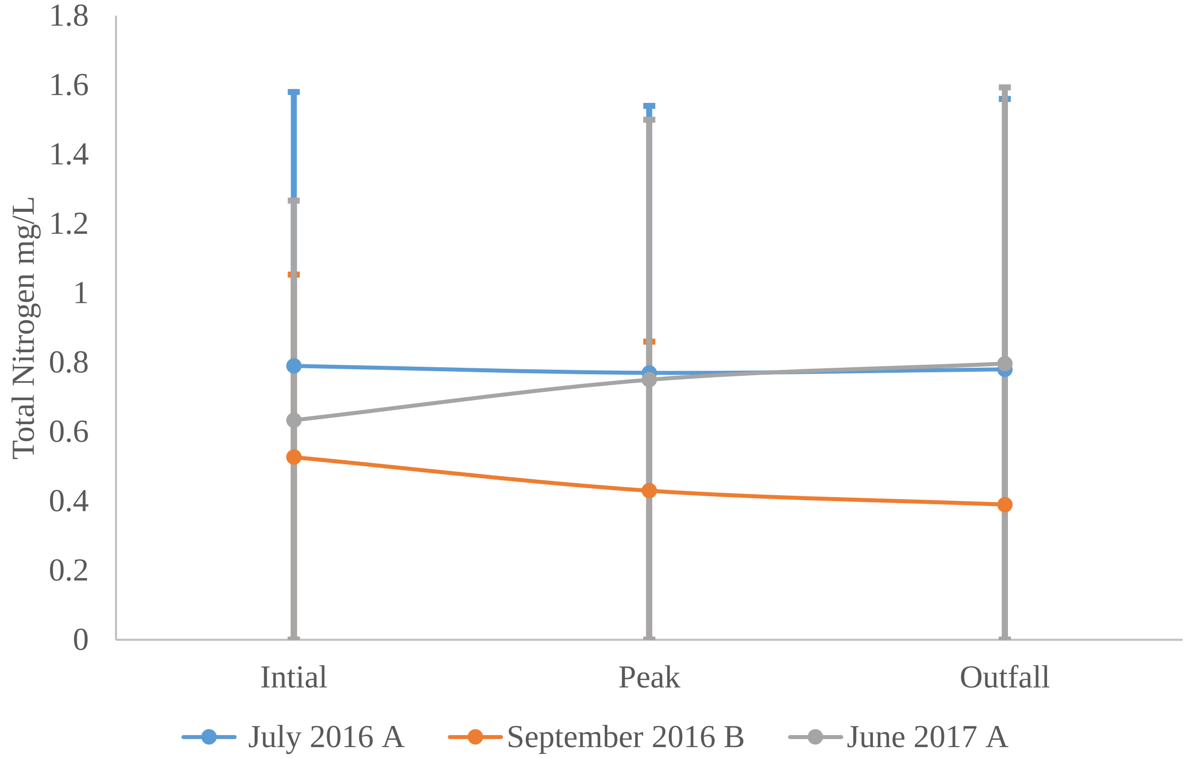

Figure 4.9. Total Nitrogen initial, peak, and outfall stage showing storm events averaged over the three sites. Different letters represent significant differences at the P≤0.05. Error bars show standard deviation.

Phosphorus

Phosphorus (P) readings for the surface samples were never recorded above state standard of 2 mg/L (NDCC 2022) (Figure 4.10). Even though the P readings in stormwater were low, there were significant differences among the stormwater events and stages ($P \leq 0.05$). Measurements of P were greatest during the initial flush of water. Once basins reached their peak, these numbers decreased and remained relatively constant through to the outfall. The P readings for the first event in July 2016 were significantly higher than the second event of 2016 (September). This could be due to soils fixing P throughout the season or decreasing P levels on the landscape. Due to land use within the catchment areas, authors believe P levels will remain low during the season in urban areas with commercial and multi-family use. As vegetation matures and tree canopies drop their leaves, the levels of P may increase due to the larger quantities of biomass leaching and from litterfall (Janke et al. 2017). If needed, landscape maintenance strategies could be considered to limit levels of P entering the watershed (Rodak et al. 2019). With first flush levels having the highest P, it may be advisable to limit P use for landscape maintenance within the catchment area, especially in the fall. Keeping in mind that P in urban areas should be managed from a source perspective, as well as considering natural and anthropogenic sources of P (Yang & Lusk 2018).

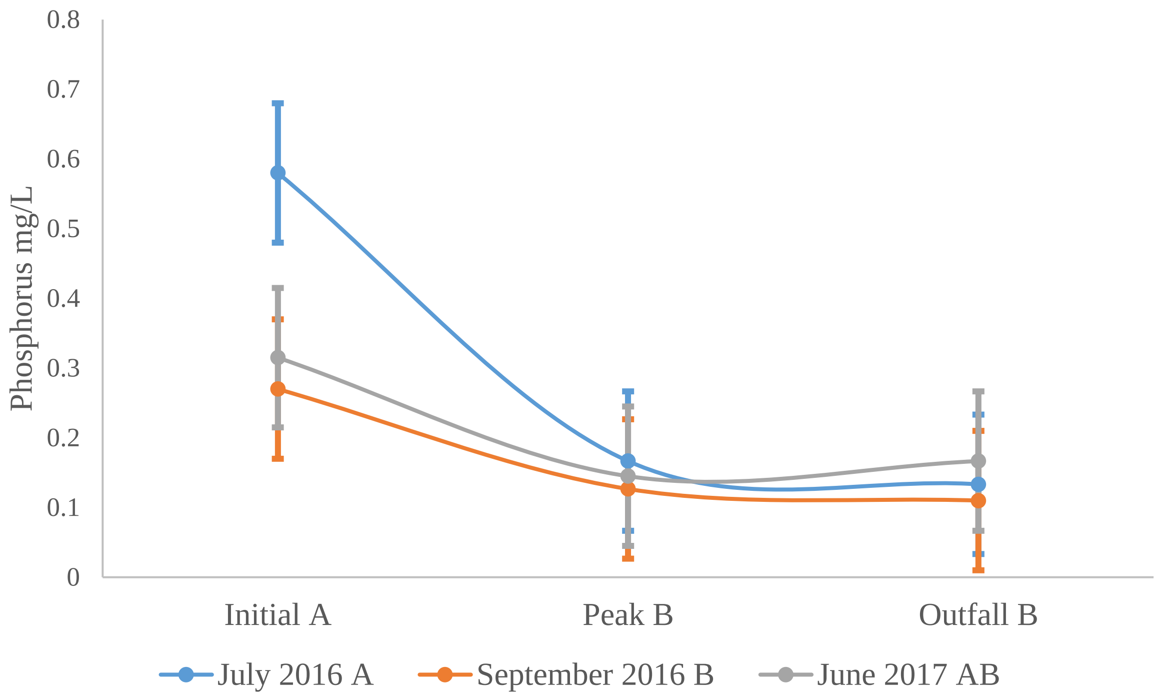

Figure 4.10. Phosphorus initial, peak, and outfall stage showing storm events averaged over the three sites. Different letters represent significant differences at the P≤0.05. Error bars show standard deviation.

Oil and Grease

The oil and grease results showed levels above the state standard (NDDoH 2019) of 15 mg/L for stormwater permits only during the September 2016 stormwater event at two sites, the rest of the readings were all below the standard (Figure 4.11). The other events were significantly lower when compared to the September 2016 event ($P \leq 0.05$). At TFP and Scheel's basins, each recorded level was higher than 15 mg/L during peak and outfall events, while the Fisheye was below for the September 2016 event. Neither sites nor stages were significantly different for oil and grease levels. Oil and grease enter detention basins and the aquatic network primarily through crankcases of automobiles (Stenstrom et al. 1984; Chow & Yusop 2016). Levels of oil and grease from industrial areas and parking lots have been shown to be higher by nearly three times that of residential areas (Stenstrom et al. 1984; Munzie et al. 2002). Highways and commercial areas are also places have been shown to have significantly higher quantities of oil and grease (Chow & Yusop 2016).

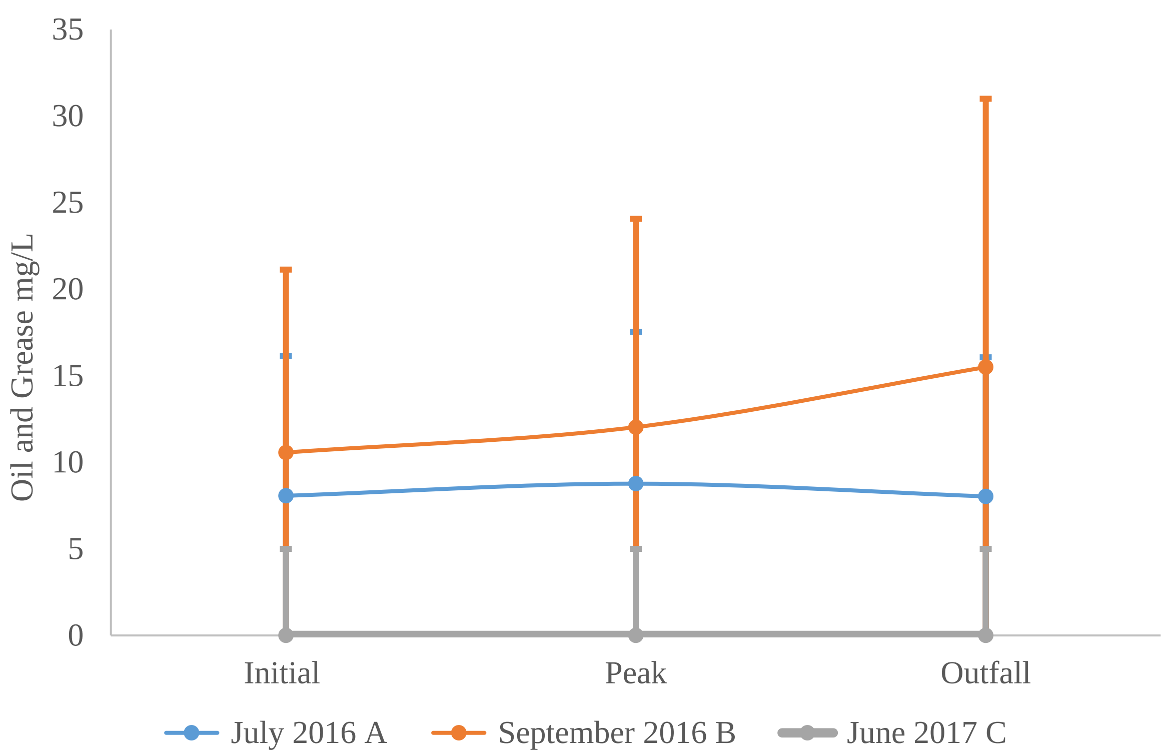

Figure 4.11. Oil and grease initial, peak, and outfall stage showing storm events averaged over the three sites. Different letters represent significant differences at the $P \leq 0.05$. Error bars show standard deviation.

There is little that can be done to limit automobile use in the catchments of the basins studied. However, it has been shown that adding a thin layer of mulch (roughly 3 cm) to a detention basin can effectively remove or decrease levels of oil and grease (Hong et al. 2006). While it may not be feasible to mulch all urban detention basis, there may be opportunities to treat point source inlets with materials to promote sorption and bioremediation (Hong et al. 2006; Muerdter et al. 2018) These practices are worth further investigation for municipal stormwater treatment in sites that exhibit high levels of oil and grease.

Diesel Range Organics

The DRO levels showed no significant differences among sites or stages ($P \geq 0.05$) (Figure 4.12). However, the June 2017 event was significantly higher than the July 2016 event ($P \leq 0.05$). The DRO difference among events is likely a by-product of road and vehicle use in the catchment. Contamination through DRO usually occurs due to: naturally occurring organic compounds; oil activity including drilling muds, flowback, or produced fluids; or general leaking of oil and gas waste, which are all associated with oil activity (Balseiro-Romero et al. 2016). In the current project, there is no oil activity, therefore all DRO would be associated with roads and automobile travel. The build-up of DRO over time likely was a factor for the June 2017 event, as there was no major flush prior to the event. Intense precipitation events cause the flushing of water from catchment areas aiding the flushing of DRO and isolated hydrocarbon supplies (Bach et al. 2010). These events may remove contaminants from the land surfaces and transport contaminated runoff to downstream water bodies (Bach et al. 2010). Further testing of stormwater during an increased duration of time, without precipitation, would help to determine if levels can increase high enough to warrant mitigation.

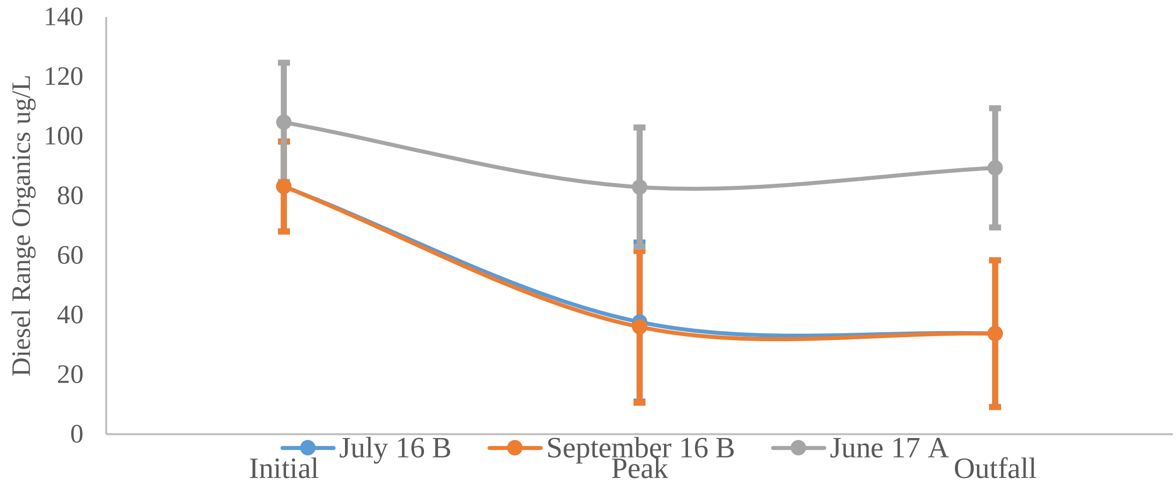

Figure 4.12. Diesel Range Organics initial, peak, and outfall stage showing storm events averaged over the three sites. Different letters represent significant differences at the P≤0.05

First Flush Dynamics

The increase of particulate or dissolved pollutant material as it relates to concentration during a precipitation event is typically referred to as the first flush (Bertrand-Krajewski et al. 1998). Mangani et al. (2005) found that the first flush of urban catchments contained elevated levels of organic and inorganic pollutants. Chow et al. (2011) found that urban catchment areas in Malaysia demonstrated elevated site mean concentrations for TSS, Biological oxygen demand, oil and grease, TP, chemical oxygen demand, nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen during a precipitation event first flush. Catchment areas in Isfahan, Iran were affected primarily by solids and organic pollutants (Taebi & Droste 2004), while areas in south Florida registered elevated levels of heavy metal and chemical oxygen demand (Miller & Mattraw 2007). In general, research has shown that regional site characteristics and non-point source pollution are factors in pollutant loads (Zhu et al. 2015). In the current study, only three constituents reduced during the filling and receding of the water, while the others did not change.

Therefore, in this research the first flush may not be a reliable mechanism to judge water quality coming from detention basins.

Did the Greening of the TFP Basin Make a Difference in Water Quality?

There was hope that removing the concrete channel at TFP basin and completing a native vegetation retrofit would improve water quality as it flows within the basin. Data shows that this was not the case. The constituents measured showed some significant differences when comparing stages and events but did not exhibit significant differences when comparing the site with the native vegetation retrofit compared to the existing detention basins. While there are some aesthetically beneficial impacts to removing an existing concrete channel and restoring vegetation, the practice should not be considered one for water quality improvement. Researchers believe that impoundment times and settlement durations caused much of the differences in water quality, while vegetation had little impact on the runoff of the impounded water. If phytoremediation was a goal of a detention basin, then detention times would need to be metered by outlet design.

Conclusions

This study analyzed the vertical water column of detention basins as water entered, peaked, and exited the basins. Many pollutant constituents' authors hypothesized would be high before the study, including N, DRO, P, oil, and grease did not present at high levels during storm events. This was unexpected, as many other urban water quality studies and first flush research have shown high levels of these constituents. Readings of TSS, which is a major contributor to the conveyance of pollutants, exhibited significant levels of reduction from the first flush to the outfall during storm events. This shows that detaining water from urban catchments for longer periods of time has the ability to reduce sediment, nutrients, and other pollutants before they enter downstream ecosystems. This research has expanded what is known about early concentrated runoff by demonstrating that impounding of stormwater in urban areas has an inverse relationship with TSS, meaning the longer time water is impounded, TSS in the water is decreased. Further studies are needed to determine the ideal residency time for settling based on the size of the basin and constituent removal needs.

E. coli was high in all samples during all phases of the storm events and at all sites. All sample levels for *E. coli* taken during the study exceeded recreational standards. These levels of *E. coli* are concerning as the detention basins are part of a multi-use green infrastructure network. If water managers hope to use detention basins while dry for urban recreational areas more research is needed to determine safety and potential mitigation. These high levels of bacteria should be studied further to determine its source and most effective means of mitigation.

Using the vertical water quality collection system utilized in this study, researchers and water managers can perform simple and inexpensive water sampling. Researchers in the current study chose to utilize five different heights for water sampling. However, future research could add more sampling heights or less depending on research needs. The vertical water quality sampling system is simple and versatile and could be utilized in most areas in the world with commonly found items.

The results of the current study varied from other first flush studies of detention basins as many constituents remained fairly steady through inflow of water, peak, and receding of storm water. Therefore, within given systems and across storm events it is important to recognize that the first flush may carry the highest level of bacteria, pollutants, and nutrients; however, in other systems this may not apply. Depending on project needs and use within the basin, it will be important for researchers and managers to assess over entire storm events to meet project goals.

As the urban populations continue to grow worldwide, it will only become more important to address water quality issues in urban catchment areas to ensure healthy ecosystems and safe use for humans.

Literature Cited

Akan, A.O. (2009). Design aid for water quality detention basins. *Journal of Hydrologic Engineering*, *15*(1), 39-48.

Al Dahaan, S., Al-Ansari, N., & Knutsson, S. (2016). Influence of groundwater hypothetical salts on electrical conductivity total dissolved solids. *Engineering*, *8*(11), 823-830.

Allen, D., Arthur, S., Haynes, H., & Olive, V. (2017). Multiple rainfall event pollution transport by sustainable drainage systems: the fate of fine sediment pollution. *International Journal of Environmental Science and Technology*, *14*(3), 639-652.

Anderson, B.C., Watt, W.E., & Marsalek, J. (2002). Critical issues for stormwater ponds: learning from a decade of research. *Water Science and Technology*, *45*(9), 277-283.

Appel, P. L., & Hudak, P. F. (2001). Automated sampling of stormwater runoff in an urban watershed, north-central Texas. *Journal of Environmental Science and Health, Part A*, *36*(6), 897-907.

Bach, P. M., McCarthy, D. T., & Deletic, A. (2010). Redefining the stormwater first flush phenomenon. *Water Research*, *44*(8), 2487-2498.

Balseiro-Romero, M., Macías, F., & Monterroso, C. (2016). Characterization and fingerprinting of soil and groundwater contamination sources around a fuel distribution station in Galicia (NW Spain). *Environmental Monitoring and Assessment, 188*(5), 292.

Booth, D.B, & Konrad, C.P. (2005). Hydrologic changes in urban streams and their ecological significance. *American Fisheries Society Symposium, 47*, 157-177.

Booth, D. B., & Jackson, C. R. (1997). Urbanization of aquatic systems: degradation thresholds, stormwater detection, and the limits of mitigation. *JAWRA Journal of the American Water Resources Association*, *33*(5), 1077-1090.

Carpenter, J. F., Vallet, B., Pelletier, G., Lessard, P., & Vanrolleghem, P. A. (2014). Pollutant removal efficiency of a retrofitted stormwater detention pond. *Water Quality Research Journal of Canada*, *49*(2), 124-134.

Chow, M. F., Yusop, Z., & Mohamed, M. (2011). Quality and first flush analysis of stormwater runoff from a tropical commercial catchment. *Water Science and Technology*, *63*(6), 1211-1216.

Chow, M. F., & Yusop, Z. (2017). Quantifying the quality and sampling time of oil and grease in urban stormwater runoff. *KSCE Journal of Civil Engineering*, *21*(4), 1087-1095.

Collentine, D., & Futter, M. N. (2018). Realising the potential of natural water retention measures in catchment flood management: Trade-offs and matching interests. *Journal of Flood Risk Management*, *11*(1), 76-84.

Deletic, A. (1998). The first flush load of urban surface runoff. *Water Research*, *32*(8), 2462-2470.

Devane, M. L., Moriarty, E. M., Robson, B., Lin, S., Wood, D., Webster-Brown, J., & Gilpin, B. J. (2019). Relationships between chemical and microbial fecal source tracking markers in urban river water and sediments during and post-discharge of human sewage. *Science of the Total Environment*, 651, 1588-1604.

Duncan, H. P. (1999). Urban stormwater quality: a statistical overview. Cooperative Research Centre for Catchment Hydrology.

Gaborit, E., Muschalla, D., Vallet, B., Vanrolleghem, P. A., & Anctil, F. (2013). Improving the performance of stormwater detention basins by real-time control using rainfall forecasts. *Urban Water Journal*, *10*(4), 230-246.

Garcia, J., Rousseau, D. P., Morato, J., Lesage, E. L. S., Matamoros, V., & Bayona, J. M. (2010). Contaminant removal processes in subsurface-flow constructed wetlands: a review. *Critical Reviews in Environmental Science and Technology*, *40*(7), 561-661.

Guo, J.C., Shih, H.M.M., & MacKenzie, K.A. (2012). Storm-Water Quality Control Basin with Micropool. *Journal of Irrigation and Drainage Engineering*, *138*(5), 470-475.

Goonetilleke, A., Thomas, E., Ginn, S., & Gilbert, D. (2004). Understanding the role of land use in urban stormwater quality management. *Journal of Environmental Management*, *74*(1), 31-42.

Hasanuzzaman, M., Nahar, K., Fujita, M., Ahmad, P., Chandna, R., Prasad, M. N. V., & Ozturk, M. (2013). Enhancing plant productivity under salt stress: relevance of poly-omics. *Salt Stress in Plants*, 113-156.

Hathaway, J. M., Hunt, W. F., & Simmons III, O. D. (2010). Statistical evaluation of factors affecting indicator bacteria in urban storm-water runoff. *Journal of Environmental Engineering*, *136*(12), 1360-1368.

Heitz, L.F., Khosrowpanah, S., & Nelson, J. (2000). Sizing of surface water runoff detention ponds for water quality improvement. *JAWRA Journal of the American Water Resources Association*, *36*(3), 541-548.

Hettiarchchi, M., Anurangi, J., and De Alwis, A. 2011. Characteristics and description of surface water quality in the threatened urban wetlands around the city of Colombo. *Journal of Wetlands Ecology*. *5*:10-19.

Hong, E., Seagren, E.A., & Davis, A.P. (2006). Sustainable oil and grease removal from synthetic stormwater runoff using bench-scale bioretention studies. *Water Environment Research*, *78*(2), 141-155.

Janke, B. D., Finlay, J. C., & Hobbie, S. E. (2017). Trees and streets as drivers of urban stormwater nutrient pollution. *Environmental Science & Technology*, *51*(17), 9569-9579.

Jardè, E., Jeanneau, L., Harrult, L., Quenot, E., Solecki, O., Petitjean, P., Lozach, S., Chevè, J., and Gourmelon, M. 2018. Application of microbial source tracking based on bacterial and chemical markers in headwater and coastal catchments. *Science of the Total Environment. 610-611*, 55-63.

Karathanasis, A. D., Potter, C. L., & Coyne, M. S. (2003). Vegetation effects on fecal bacteria, BOD, and suspended solid removal in constructed wetlands treating domestic wastewater. *Ecological engineering*, *20*(2), 157-169.

Kerkez, B., Gruden, C., Lewis, M., Montestruque, L., Quigley, M., Wong, B., ... & Poresky, A. (2016). Smarter stormwater systems. *Environmental Science and Technology*, 7267-7273.

Kim, D. H., & Jenkins, B. M. (2008). Rates of drainage-water evaporite salt dissolution in water. *Desalination*, *227*(1-3), 306-313.

Kozak, C., Fernandes, C. V. S., Braga, S. M., do Prado, L. L., Froehner, S., & Hilgert, S. (2019). Water quality dynamic during rainfall episodes: integrated approach to assess diffuse pollution using automatic sampling. *Environmental monitoring and assessment*, *191*(6), 1-13.

Krometis, L. A. H., Characklis, G. W., Simmons III, O. D., Dilts, M. J., Likirdopulos, C. A., & Sobsey, M. D. (2007). Intra-storm variability in microbial partitioning and microbial loading rates. *Water Research*, *41*(2), 506-516.

Li, C., Fletcher, T. D., Duncan, H. P., & Burns, M. J. (2017). Can stormwater control measures restore altered urban flow regimes at the catchment scale?. *Journal of Hydrology*, *549*, 631-653.

Lee, J. H., Bang, K. W., Ketchum Jr, L. H., Choe, J. S., & Yu, M. J. (2002). First flush analysis of urban storm runoff. *Science of the Total Environment*, *293*(1-3), 163-175.

Lee, S., Maniquiz-Redillas, M. C., & Kim, L. H. (2014). Settling basin design in a constructed wetland using TSS removal efficiency and hydraulic retention time. *Journal of Environmental Sciences*, *26*(9), 1791-1796.

Line, D.E., & White, N.M. (2007). Effects of development on runoff and pollutant export. *Water Environment Research*, *79*(2), 185-190.

Lobell, D. B., Lesch, S. M., Corwin, D. L., Ulmer, M. G., Anderson, K. A., Potts, D. J., ... & Baltes, M. J. (2010). Regional-scale assessment of soil salinity in the Red River Valley using multi-year MODIS EVI and NDVI. *Journal of environmental quality*, *39*(1), 35-41.

Manchanda, G., & Garg, N. (2008). Salinity and its effects on the functional biology of legumes. *Acta Physiologiae Plantarum*, *30*(5), 595-618.

Mangani, G., Berloni, A., Bellucci, F., Tatàno, F., & Maione, M. (2005). Evaluation of the pollutant content in road runoff first flush waters. *Water, Air, and Soil Pollution*, *160*(1), 213-228.

Marsalek, J. (2003). Road salts in urban stormwater: an emerging issue in stormwater management in cold climates. *Water Science and Technology*, *48*(9), 61-70.

Marsalek, J. (2005). Evolution of urban drainage: from cloaca maxima to environmental sustainability (pp. 28-30). Burlington, ON: National Water Research Institute.

Matthees, H. L., Thom, M. D., Gesch, R. W., & Forcella, F. (2018). Salinity tolerance of germinating alternative oilseeds. *Industrial Crops and Products*, *113*, 358-367.

McCarthy, D.T., Hathaway, J.M., Hunt, W.F., & Deletic, A. (2012). Intra-event variability of Escherichia coli and total suspended solids in urban stormwater runoff. *Water Research*, *46*(20), 6661-6670.

McCarthy, D. T. (2009). A traditional first flush assessment of E. coli in urban stormwater runoff. *Water Science and Technology*, *60*(11), 2749-2757

McCauley, A., & Jones, C. (2005). Water and solute transport in soils. *Soil & Water Management, Module*, 4, 1.

McNett, J. K., & Hunt, W. F. (2010). An evaluation of the toxicity of accumulated sediments in forebays of stormwater wetlands and wetponds. In *2010 Pittsburgh, Pennsylvania, June 20-June 23, 2010* (p. 1). American Society of Agricultural and Biological Engineers.

Miller, J. D., & Hutchins, M. (2017). The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom. *Journal of Hydrology: Regional Studies*, *12*, 345-362.

Miller, R. A., & Mattraw Jr, H. C. (1982). Storm water runoff quality from three land-use areas in south Florida. *JAWRA Journal of the American Water Resources Association*, *18*(3), 513-519.

Muerdter, C. P., Wong, C. K., & LeFevre, G. H. (2018). Emerging investigator series: The role of vegetation in bioretention for stormwater treatment in the built environment: Pollutant removal, hydrologic function, and ancillary benefits. *Environmental Science: Water Research & Technology*, *4*(5), 592-612.

Niemczynowicz, J. (1999). Urban hydrology and water management – present and future challenges. *Urban Water*, *1*(1), 1-14.

National Oceanic and Atmospheric Administration (NOAA). (2018). Climate of North Dakota. Accessed November 27, 2017 from the National Oceanic and Atmospheric Administration website:https://search.usa.gov/search?utf8=%E2%9C%93&affiliate-=noaa.gov&query=north+dakota+average+temparture.

North Dakota Department of Health (2019) Standard operating procedures for field samplers. January 2019 (revised). Bismarck: North Dakota Department of Health, Division of Water Quality.

Olson, E. L. (2020). Understanding Escherichia coli and Water Quality in Stormwater Retention Ponds and Detention Basins in Fargo as Part of the Red River Watershed (Doctoral dissertation, North Dakota State University).

Olson, E., Hargiss, C. L., & Norland, J. (2022). Escherichia coli levels and microbial source tracking in stormwater retention ponds and detention basins. *Water Environment Research*, *94*(1), e1675.

Pan, X., Jones, K., Wang, S., Guerrero, J., & Garza, A. (2010). Design and implementation of a forebay-pond-wetland system for urban stormwater treatment in South Texas. Canadian Society for Bioengineering, CIGR XVIIth World Congress.

Paul, M.J., & Meyer, J.L. (2001). Streams in the urban landscape. *Annual Review of Ecology and Systematics*, *32*(1), 333-365.

Paule-Mercado, M. A., Lee, B. Y., Memon, S. A., Umer, S. R., Salim, I., & Lee, C. H. (2017). Influence of land development on stormwater runoff from a mixed land use and land cover catchment. *Science of the Total Environment*, *599*, 2142-2155

Papa, F., Adams, B.J., & Guo, Y. (1999). Detention time selection for stormwater quality control ponds. *Canadian Journal of Civil Engineering*, *26*(1), 72-82.

Peel, M. D., Waldron, B. L., Jensen, K. B., Chatterton, N. J., Horton, W. H. and Dudley, L. M. 2004. Screening for salinity tolerance in alfalfa: a repeatable method. *Crop Sci. 44*, 2049-2053.

Pitt, R., Clark, S., & Field, R. (1999). Groundwater contamination potential from stormwater infiltration practices. *Urban water*, *1*(3), 217-236.

Robertson, G. P., Wedin, D., Groffmann, P. M., Blair, J. M., Holland, E. A., Nadelhoffer, K. J., & Harris, D. (1999). Soil carbon and nitrogen availability: nitrogen mineralization, nitrification, and soil respiration potentials. In Standard soil methods for long-term ecological research (pp. 258-271). Oxford University Press.

Rodak, C. M., Moore, T. L., David, R., Jayakaran, A. D., & Vogel, J. R. (2019). Urban stormwater characterization, control, and treatment. *Water Environment Research*, *91*(10), 1034-1060

S·liwka-Kaszyńska, M., Kot-Wasik, A., & Namieśnik, J. (2003). Preservation and storage of water samples. *Critical Reviews in Environmental Science and Technology 33*(1),31-44.

Schmer, M. R., Xue, Q., & Hendrickson, J. R. (2012). Salinity effects on perennial, warm-season (C4) grass germination adapted to the northern Great Plains. *Canadian journal of plant science*, *92*(5), 873-881.

Shammaa, Y., Zhu, D. Z., Gyürék, L. L., & Labatiuk, C. W. (2002). Effectiveness of dry ponds for stormwater total suspended solids removal. *Canadian Journal of Civil Engineering*, 29(2), 316-324.

Stenstrom, M.K., Silverman, G.S., & Bursztynsky, T.A. (1984). Oil and grease in urban stormwaters. *Journal of Environmental Engineering*, *110*(1), 58-72.

Strecker, E.W., Quigley, M.M., Urbonas, B.R., Jones, J.E., & Clary, J.K. (2001). Determining urban storm water BMP effectiveness. *Journal of Water Resources Planning and Management, 127*(3), 144-149.

Taylor, G.D., Fletcher, T.D., Wong, T.H.F., Breen, P.F., and Duncan, H.P. 2005. Nitrogen composition in urban runoff—implications for stormwater management. *Water Research, 39*, 1982–1989.

Taylor, K.G., & Owens, P.N. (2009). Sediments in urban river basins: a review of sediment–contaminant dynamics in an environmental system conditioned by human activities. *Journal of Soils and Sediments*, *9*(4), 281-303.

Taebi, A., & Droste, R. L. (2004). First flush pollution load of urban stormwater runoff. *Journal of Environmental Engineering and Science*, *3*(4), 301-309.

Van Meter, R. J., Swan, C. M., & Snodgrass, J. W. (2011). Salinization alters ecosystem structure in urban stormwater detention ponds. *Urban Ecosystems, 14*(4), 723-736.

Tober, D., Duckwitz, W., & Sieler, S. (2007). Plant materials for salt-affected sites in the Northern Great Plains. Natural Resources Conservation Service Technical Note. United States Department of Agriculture, Bismarck, ND, USA. goo. gl/HBNWTm.

Ulmer, M., Benedict, P., Corwin, D. L., Potts, D., Doolittle, J., & Anderson, K. (2007, November). Saline soils in the Red River Valley. In American Society of Agronomy Abstracts (No. 1321).

Vitro, K.A., BenDor, T.K., Jordanova, T.V., and Miles, B. 2017. A geospatial analysis of land use and stormwater management on fecal coliform contamination in North Carolina streams. *Science of the Total Environment. 603-604,* 709-727

Wenger, S. J., Roy, A. H., Jackson, C. R., Bernhardt, E. S., Carter, T. L., Filoso, S., ... & Meyer, J. L. (2009). Twenty-six key research questions in urban stream ecology: an assessment of the state of the science. *Journal of the North American Benthological Society*, *28*(4), 1080-1098.

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., & Morgan, R.P. (2005). The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society, 24*(3), 706-723.

Walsh, C. J., Booth, D. B., Burns, M. J., Fletcher, T. D., Hale, R. L., Hoang, L. N., ... & Wallace, A. (2016). Principles for urban stormwater management to protect stream ecosystems. *Freshwater Science*, *35*(1), 398-411.

Warrence, N. J., Bauder, J. W., & Pearson, K. E. (2002). Basics of salinity and sodicity effects on soil physical properties. Departement of Land Resources and Environmental Sciences, Montana State University-Bozeman, MT, 129, 1-29.

Weiss, J. D., Hondzo, M., & Semmens, M. (2006). Storm water detention ponds: modeling heavy metal removal by plant species and sediments. *Journal of Environmental Engineering*, *132*(9), 1034-1042.

Yang, Y. Y., & Lusk, M. G. (2018). Nutrients in urban stormwater runoff: Current state of the science and potential mitigation options. *Current Pollution Reports*, *4*(2), 112-127.

Zhu, Q. D., Sun, J. H., Hua, G. F., Wang, J. H., & Wang, H. (2015). Runoff characteristics and non-point source pollution analysis in the Taihu Lake Basin: a case study of the town of Xueyan, China. *Environmental Science and Pollution Research*, *22*(19), 15029-15036

Zubair, A., Hussain, A., Farooq, M. A., & Abbasi, H. N. (2010). Impact of storm water on groundwater quality below retention/detention basins. *Environmental monitoring and assessment*, *162*(1), 427-437.

APPENDIX A: STAKEHOLDER PARTICIPATION SURVEY

1. Identify the stakeholder group or category that you most strongly identify yourself with as most involved in The Fargo Project (TFP) (Identify only one). If you take part in TFP for work please identify primarily with that group.

______Designer

______Engineer

______ Communication

______Artist

______Researcher

______Non-profit social benefits

______Cultural identity group

______Public or government agency

______Gardener

______ Non-profit arts

______Education

______User of site

______Stormwater function

______Community organizer

______Non-profit- natural resource

______Resident

______Community volunteer

______Contractor or technical expertise

______Funder

2. On average how often have you worked on TFP (identify only one).

______One time

______Monthly

______Annually

______Weekly

3. What areas of knowledge have you contributed to the project? (Mark as many as apply)

______Communication

______Native plantings

______Soil

______Gardening

______Water flow

______Water Quality

_____ Art

_____ Landscape Design

_____ Fundraising

_____ Community Development

_____ Grant Writing

_____ Budgetary work

______Human Dynamics

______Cultural Knowledge

______Project Design

______Project Management

______Planning

_____ Environmental outreach

_____ Public Art

_____ Sustainable Development

_____ Permitting

_____ Marketing

4. What areas of knowledge could you have contributed the project? (Mark as many as apply; same as last question but asking what additional knowledge you could provide)

______Communication

______Native plantings

______Soil

______Gardening

______Water flow

______Water Quality

______Human Dynamics

______Cultural Knowledge

______Project Design

______Project Management

______Planning

_____ Art

_____ Landscape Design

_____ Fundraising

_____ Community Development

_____ Grant Writing

_____ Budgetary work

_____ Environmental outreach

_____ Public Art

_____ Sustainable Development

_____ Permitting

_____ Marketing

5. Please rank these potential successes at TFP in order of importance. (Rank 1-6; 1 being most important).

Water and Nature

_____ Cleaning storm water

_____A functional stormwater basin

_____ Visible wildlife

_____Visible native plantings

_____ A natural space

_____ A place to connect with nature

6. Please rank these potential successes at TFP in order of importance. (Rank 1-6; 1 being most important).

Successful Design

_____ More people visiting the site

_____ More programs/activities at the site

_____ A useful recreational space

_____ Recognition of project site or name

_____ Gathering space

_____Human connections inspired by artists

7. Please rank these potential successes at TFP in order of importance. (Rank 1-6; 1 being most important).

Project Goals

_____ Space for gardening

_____ A site that reflects cultural values

_____ A site that contains art

_____A natural space to passively recreate (walking, enjoying scenery)

_____A safe outdoor space to spend time

_____A place to learn about North Dakota ecology

8. Please rank these overall categories in order of importance (based on question categories above). (Rank 1-3; 1 being most important).

______Project Goals

______Successful Design

______Water and Nature

Questions 9-14: Knowledge applied to the project.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

______9. Your knowledge aided in the overall design of the project.

______10. Your knowledge aided in the overall implementation of the project.

______11. Your stakeholder group was able to bring knowledge to the table.

______12. There were knowledge gaps among groups involved in the project.

______13. There were knowledge overlaps between groups involved in the project.

______14. I am not aware how my knowledge was applied to the project.

Questions 15-20: Stakeholder group participation. Please use stakeholder group you self-identified in #1.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

______15. Your identified stakeholder group is important to projects similar in nature or type to TFP

______16. Your stakeholder group has completed its work.

______17. Your stakeholder group would like to continue to work on TFP in the future.

______18. You think your stakeholder group is important to TFP.

______19. Your stakeholder group is continuing to work on the TFP.

______20. The project could be completed without your stakeholder group.

Questions 21-31: Communication

1 Strongly Disagree	2 Disagree	3 Neither Agree nor Disagree	4 Agree	5 Strongly Agree

______21. You would have liked to have more information on the project as a whole.

______22. You have a clear understanding of the vision of TFP.

______23. You have a clear understanding of your role on TFP.

______24. You have a clear understanding of how your knowledge was used on TFP.

______25. You found public events to be an effective form of communication.

______26. You found email to be an effective form of communication.

______27. You found partner/stakeholder meetings to be an effective form of communication.

______28. You found word of mouth to be an effective form of communication.

______29. You found the Sunday series (Summer of 2017) at the World Commons Garden to be an effective form of communication

______30. You found the website (thefargoproject.com) to be an effective form of communication.

______31. You found the World Common Gardens Facebook page to be an effective form of communication.

Questions 32 – 40 Education about the project

1 Strongly Disagree	2 Disagree	3 Neither Agree nor Disagree	4 Agree	5 Strongly Agree

_____32. You found Public Events to be an effective way to educate the public about TFP.

______33. You found email to be an effective way to educate the public about TFP.

______34. You found meetings to an effective way to educate the public about TFP.

______35. You found design events such as the We Design Events to be an effective way to educate the public about TFP.

______36. You found word of mouth to be an effective way to educate the public about TFP.

______37. You found the Sunday series (Summer of 2017) at the World Commons Garden to be an effective way to educate the public about TFP

______38. You found signage at the site to be an effective way to educate the public about TFP.

______39. You found the website (thefargoproject.com) to be an effective way to educate the public about TFP.

______40. You found the World Common Gardens Facebook page to be an effective way to educate the public about TFP.

Questions 41 - 51: Perceptions of TFP

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

_____41. You viewed your experience working on TFP as a positive experience.

_____42. You felt the collaboration methods (meetings, public events, and workshops) were positive.

_____43. You felt that you were included in the collaboration process.

_____44. You felt that you were valued in the collaboration process.

_____45. Future projects similar in scope to TFP need to include your stakeholder groups knowledge.

_____46. This project could be replicated without your stakeholder groups skill set.

_____47. You would have liked to participate more in TFP.

_____48. Your suggestions and ideas were reflected in the projects design.

_____49. You would like to participate in similar projects of this nature.

_____50. You would like to continue working on TFP indefinitely.

_____51. You would like to continue to stay involved (communication updates, volunteering) on TFP after your stakeholder group has reached its goals.

Questions 52-60: Team or Partners (appropriate means from your perspective the necessary groups were included and no pertinent groups were left out)

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

_____52. The appropriate cultural disciplines were brought into the project.

_____53. The appropriate social science disciplines were brought into the project.

_____54. The appropriate arts disciplines were brought into the project.

_____55. The appropriate engineering disciplines were brought into the project.

_____56. The appropriate design disciplines were brought into the project.

_____57. The appropriate scientific disciplines/principles were brought into TFP.

_____58. The appropriate communications disciplines were brought into the project.

_____59. The appropriate management disciplines were brought into the project.

_____60. The appropriate marketing disciplines were brought into the project.

Questions 61 - 72: Design Goals and attainability

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

_____61. As a design goal “Let the water lead” is achievable.

_____62 As a design goal “Let the water lead” has been achieved.

_____63. As a design goal “Let the water lead” will be achieved in the near future (next five years).

_____64. As a design goal “Learn from the natural environment” is achievable.

_____65. As a design goal “Learn from the natural environment” has been achieved.

_____66. As a design goal “Learn from the natural environment” will be achieved in the near future (next five years).

_____67. As a design goal “Involve community-Belonging” is achievable.

_____68. As a design goal “Involve community-Belonging” has been achieved.

_____69. As a design goal “Involve community-Belonging” will be achieved in the near future (next five years).

_____70. As a design goal “Experience Nature and Ecology” is achievable.

_____71. As a design goal “Experience Nature and Ecology” has been achieved.

_____72. As a design goal “Experience Nature and Ecology” will be achieved in the near future (next five years).

73. Please rank design principals in order of importance. (Rank 1-4; one being most important)

_____ Let the water lead

_____ Learn from the natural environment

_____ Involve Community-Belonging

_____ Experience Nature and Ecology

Questions 74 - 80: Goal, Mission, Model of the TFP

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

_____74. You understand the overarching goals of TFP.

_____75. You think TFP is a worthy cause to replicate.

_____76. You understood (before this survey) that TFP is an artist lead and artist funded project.

_____77. It is important for TFP to be artist led and include artists as team members.

_____78. It is important for future projects similar in nature to TFP to be artist led.

_____79. It is important for future projects similar in nature to TFP to include artists as team members.

_____80. You noticed a difference in this project management style due to it being artist led.

Questions 81 - 87: Management of TFP

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

_____81. The project management of TFP in terms of design was effective.

_____82. The project management of TFP in terms of implementation was effective.

_____83. The project management of TFP project in terms of project management was effective.

_____84. The project management of TFP in terms of communication/outreach was effective.

_____85. The project management of TFP in terms of education was effective.

_____86. The project management of TFP in terms of funding was effective.

_____87. The project management of TFP in terms of allocation of funding was effective.

88. Please rank correspondence in order of importance. (Rank 1-4; one being most preferred)

______You would like to receive updates on TFP daily.

______You would like to receive updates on TFP weekly.

______You would like to receive updates on TFP monthly.

______You would like to receive updates on TFP yearly.

89. Please rank how you would like to receive updates. Rank (1-5; one being most preferred)

______E-mail

______ Text

______An update on website

______Facebook

______ A meeting

APPENDIX B: COMPOSITION OF TREATMENT SEED MIXES

Short/dry Mix (SDM) – Grasses: 40% Schizachyrium scoparium, 35% Bouteloua curtipendula, 13% Bouteloua gracilis, 4% Danthonia spicata, 4% Koeleria macrantha, 2% Sporobolus cryptandrus, and 2% Sporobolus heterolepis

Pollinator mix for dry to mesic soils (PM) – Grasses: 5% Sporobolus heterolepis, 4% Schizachyrium scoparium, 3.5% Bouteloua curtipendula, 3.5% Koeleria macrantha, 2% Bouteloua gracilis, 2% Elymus canadensis; Forbs: 6% Amorpha canescens, 6% Asclepias tuberosa, 6% Asclepias syriaca , 6% Penstemon spectabilis, 6% Verbena stricta, 5% Heliopsis helianthoides, 4% Dalea candida 4% Dalea purpurea, 3% Liatris pycnostachya, 3% Monarda fistulosa, 3% Rudbeckia hirta, 3% Symphyotrichum laeve, 3% Tradescantia occidentalis 3% Zizia aurea, 2% Asclepias syriaca, 2% Coreopsis palmata, 2% Liatris punctata, 2% Potentilla pensylvanica, 2% Rosa arkansana, 2% Solidago nemoralis 2% Solidago ptarmicoides, 1% Astragalus canadensis, 1% Galium boreale.

Short/dry mix with spike seeding treatment (SDMS) – See above for SDM seed composition; Spike species with equal percentage: Echinacea purpuera, Symphyotrichum laeve, Achillea millefolium, Rudbeckia hirta, and Dalea purpurea.

Pollinator mix for dry to mesic soils with spike treatment (PMS) – See above for PM seed composition; Spike species with equal percentage: Echinacea purpuera, Symphyotrichum laeve, Achillea millefolium, Rudbeckia hirta, and Dalea purpurea.

Aesthetic prairie plantings mix (APP) – Forbs with equal percentages: Echinacea purpuera, Asclepias syriaca, Rudbeckia hirta, and Symphyotrichum laeve.

APPENDIX C: AVERAGE PERCENT COVER FOR ALL SPECIES

Table C1. Average percent cover for all species from the 2017 and 2019 surveys. Species are designated as Planted or Other.

Species	2017 average percent cover	2019 average percent cover	Planted (P) or Other (O)
Achillea millefolium	9.61	4.38	P
Agrostis gigantea	0.00	0.42	O
Ambrosia artemisiifolia	5.09	0.00	O
Argentina anserina	0.00	0.17	O
Asclepias syriaca	0.00	1.38	P
Bouteloua curtipendula	0.58	0.00	P
Bromus inermis	0.00	0.83	O
Cirsium arvense	0.83	0.60	O
Dalea purpurea	0.00	0.33	P
Echinacea purpurea	0.60	1.17	P
Echinochloa crus-galli	0.17	0.00	O
Elymus canadensis	0.00	0.60	P
Elymus repens	3.17	27.42	O
Helianthus annuus	3.60	0.00	O
Helianthus helianthoides	1.83	1.06	P
Hordeum jubatum	6.22	2.50	O
Lotus corniculatus	14.95	9.78	O
Melilotus officinalis	12.25	0.00	O
Monarda fistulosa	2.22	0.47	P
Panicum virgatum	12.26	11.59	O

Species	2017 average percent cover	2019 average percent cover	Planted (P) or Other (O)
Pascopyrum smithii	3.19	1.44	O
Phalaris arundinacea	0.00	0.50	O
Phleum pratense	0.00	1.43	O
Plantago major	1.97	1.00	O
Poa pratensis	2.31	9.69	O
Polygonum pensylvanicum	0.00	2.17	O
Polygonum spp.	1.46	3.04	O
Ratibida columnifera	4.05	0.61	O
Rudbeckia hirta	13.11	0.42	P
Rumex crispus	2.11	6.22	O
Schizachyrium scoparium	2.50	0.00	P
Solidago canadensis	0.00	0.33	O
Symphyotrichum laeve	0.23	1.04	P
Symphyotrichum lanceolatum	1.17	11.09	O
Taraxacum officinale	3.19	1.74	O
Thalictrum dasycarpum	0.00	1.00	O
Trifolium pratense	0.00	0.50	O
Trifolium repens	1.94	0.00	O
Tripleurospermum inodorum	2.14	1.39	O
Viola nephrophylla	0.00	0.39	O
Zizaia aurea	0.00	0.58	P

APPENDIX D: WATER QUALITY PARAMETERS AND DETECTION LIMITS

Table D1.Water Quality Standards

Field Measurements	General Chemistry	Detection Limits	Nutrients	Detection Limits	Biological	Detection Limits	Hydro-carbons	Detection Limits
pH	Alkalinity	3.30 mg/L	Ammonia	0.030 mg/L	*E. coli*	10 #/100 mL	Oil & Grease	15mg/L
Temperature	Anion Sum	NL[2]	Nitrate-nitrite	0.030 mg/L				
Dissolved Oxygen	Bicarbonate	1 mg/L	Total Kjeldahl Nitrogen	0.061 mg/L				
Specific Conductance	Calcium	2.00 mg/L	Total Nitrogen	0.015 mg/L				
	Carbonate	1 mg/L	Total Phosphorus	0.004 mg/L				
	Cation Sum	NL[2]	Sodium Adsorption Ratio	NL[2]				
	Chloride	0.300 mg/L						
	Fluoride	4.00 mg/L						
	Hardness	NL[2]						
	Hydroxide	1 mg/L						
	Iron	0.050 mg/L						
	Magnesium	1.00 mg/L						
	Manganese	0.010 mg/L						
	Potassium	1.00 mg/L						
	Silica	2.00 mg/L						
	Sodium	3.00 mg/L						
	Sulfate	0.300 mg/L						
	Total Dissolved Solids	NL[2]						
	Total Suspended Solids	5 mg/L						