Assessing Impermeable Surface Area Impacts on Modeling: Implications for the Combined Sewer Overflow Long Term Control Plan in Omaha, Nebraska

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Assessing Impermeable Surface Area Impacts on Modeling: Implications for the Combined Sewer Overflow Long Term Control Plan in Omaha, Nebraska

By:
Andrew D. Szatko

A Professional Project Report

For the Degree:
Master of Community and Regional Planning
Community and Regional Planning Program
University of Nebraska

Project Advisory Committee:
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Prof. Steven Rodie, Co-Chair
Prof. Gordon P. Scholz
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Client: City of Omaha, Department of Public Works
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Jim Thieler, P.E., CSO Program Manager

May 2012
Acknowledgements

I am extremely fortunate to find myself where I am at today, and the journey here has been nothing short of amazing. When looking back at everything that has come together in order for me to complete my master’s degree in Community and Regional Planning, the best movie screen writer couldn’t have written a better story.

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Sincerely,
Andy Szatko
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>2</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>4</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>7</td>
</tr>
<tr>
<td>STORMWATER &amp; CSO BACKGROUND INFORMATION</td>
<td>8</td>
</tr>
<tr>
<td>INFOWORKS MODELING BACKGROUND</td>
<td>19</td>
</tr>
<tr>
<td>PROJECT DESCRIPTION</td>
<td>22</td>
</tr>
<tr>
<td>PROJECT GOAL AND OBJECTIVES</td>
<td>23</td>
</tr>
<tr>
<td>PROJECT LOCATION</td>
<td>23</td>
</tr>
<tr>
<td>TASKS</td>
<td>24</td>
</tr>
<tr>
<td>METHODOLOGY</td>
<td>25</td>
</tr>
<tr>
<td>RESULTS (BY OBJECTIVE)</td>
<td>28</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>38</td>
</tr>
<tr>
<td>PROJECT LIMITATIONS</td>
<td>44</td>
</tr>
<tr>
<td>CONCLUSION</td>
<td>44</td>
</tr>
<tr>
<td>DEFINING ISA REDUCTION</td>
<td>46</td>
</tr>
<tr>
<td>DEVELOPING AN INTEGRATED SYSTEM</td>
<td>47</td>
</tr>
<tr>
<td>IN SUMMARY</td>
<td>48</td>
</tr>
<tr>
<td>APPENDIX A - DEFINITIONS</td>
<td>51</td>
</tr>
<tr>
<td>APPENDIX B – DOUGLAS &amp; SARPY COUNTIES ISA ESTIMATES BY ZONING DISTRICT</td>
<td>57</td>
</tr>
<tr>
<td>APPENDIX C: MAPS</td>
<td>59</td>
</tr>
<tr>
<td>APPENDIX D – SUBCATCHMENT 202 ZONING DISTRICT DESCRIPTIONS FROM THE OMAHA ZONING CODE</td>
<td>76</td>
</tr>
</tbody>
</table>
List of Figures & Tables

FIGURE 1 - PAPILLION CREEK WATERSHED & CSS AREA) ................................................................. 14
FIGURE 2 – MAP OF THE OMAHA CSO STUDY BASINS ................................................................. 22
FIGURE 3 - CLOSE-UP OF SUBCATCHMENT 202 AND STREETS ......................................................... 23
FIGURE 4 - ZONING DISTRICT MAP FOR SUBCATCHMENT 202 ......................................................... 28
FIGURE 5 – ASSUMED & ACTUAL ISA PERCENT COVERAGE COMPARISON ....................................... 30
FIGURE 6 – SUBCATCHMENT 202 ZONING DISTRICT MAP WITH DELINEATED ISA ............................ 32
FIGURE 7 – ISA PERCENT REDUCTION ON PEAK FLOW ...................................................................... 33
FIGURE 8 - ISA PERCENT REDUCTION ON VOLUME .......................................................................... 34
FIGURE 9 - HYDROGRAPHS OF SUBCATCHMENT 202 INFOWORKS MODEL RUNS .............................. 35
FIGURE 10 - SEWER INFRASTRUCTURE DETAIL ADDED FOR SUBCATCHMENT 202 ...................... 35
FIGURE 11 - DELINEATION OF SUBCATCHMENT 202 INTO MULTIPLE SUBCATCHMENTS ................... 36

TABLE 1 - AREAL COVER OF ZONING DISTRICTS IN SUBCATCHMENT 202 ........................................... 28
TABLE 2 - SUBCATCHMENT 202 ISA BY ZONING DISTRICT ................................................................ 29
TABLE 3 - SUBCATCHMENT 202 ISA BY TYPE .................................................................................... 30
TABLE 4 - SUBCATCHMENT 202 ISA BY ZONING DISTRICT & TYPE ..................................................... 31
TABLE 5 - SUBCATCHMENT 202 ISA BY MODELED CATEGORY ............................................................. 31
TABLE 6 - ZONING DISTRICT & PAVEMENT COVER FOR OMAHA CSO STUDY BASINS .................. 37
TABLE 7 - OMAHA CSO STUDY BASIN ZONING DISTRICT BREAKDOWN ........................................... 37
Introduction

The Federal CSO Control Policy requires communities with combined sewer systems (CSSs) to limit the number of overflows to four per year or capture of 85% by volume of the combined sewage collected in the CSS on an annual basis. Each community must develop a long term control plan (LTCP) that describes the exact strategies employed to meet either one of those goals. The City of Omaha is in the early stages of a $1.7 billion sewer project to limit the number of combined sewer overflows (CSOs) from the combined sewer system (CSS) that discharge untreated sewage and stormwater into the Missouri River and Papillion Creek. Currently, Omaha’s LTCP relies wholly on gray infrastructure, including but not limited to: separating of combined sewers, increasing capacity of the wastewater treatment facility, and the constructing a large storage tunnel to store stormwater and sewage until it can be treated. The city also utilizes green infrastructure (i.e. strategies to manage stormwater runoff near where it lands) as a margin-of-error in improving the performance of the LTCP.

Currently the City of Omaha relies on zoning districts to estimate ISA percent cover. The goal of this project is to determine the impact impermeable surface areas (ISAs) have on the CSS area of Omaha, Nebraska and its LTCP and the benefits associated with the direct mitigation of them. To achieve this, three objectives were established to assess: 1) the accuracy of using zoning districts to estimate ISAs, 2) the modeled peak flow and volume benefits associated with ISA reduction, and 3) how model output with increased levels of detail about ISAs, existing sewers, and subcatchment slope and width are inputted into the modeling program.

In performing this study, the intent is to gauge the accuracy of estimating ISAs by zoning district, establish if further detailing of subcatchments in the CSS is warranted, and determine whether ISA reduction provides enough benefits to be considered in Omaha’s CSO LTCP.
Described next is a general background on stormwater issues, Omaha’s situation as it relates to those issues, and the InfoWorks modeling software currently used by Omaha’s CSO program.

**Stormwater & CSO Background Information**

The City of Omaha, along with 772 other communities across the country, must improve water quality by limiting the amount of overflow that comes from their CSS. During the mid to late 1800s as cities across the United States grew in population, density, and physical size, the lack of an efficient management strategy to dispose of sanitary waste led to numerous disease outbreaks and unsanitary living conditions. One solution that quickly became the standard was the development of a sanitary sewer system; underground pipes that carry sanitary wastes by gravity from homes and businesses to a discharge point or a wastewater treatment facility. The first such systems were in Chicago, Illinois and Brooklyn, New York in the 1850’s and the first treatment facility was in Worcester, MA in 1890 (Leonard, 1914). These sewer systems were often designed also to carry stormwater runoff away and to create a self-cleaning system, thus creating the CSS. These systems work well when no precipitation occurs, but problems arise during rainfall or snowmelt. The large volume of stormwater flowing in the sewer system during rain events or snow-melting can overwhelm the piping system and its water treatment facility. In Omaha, rain events that exceed one tenth of an inch are enough to exceed the capacity of the wastewater treatment facility, as stated by City of Omaha officials. The excess flow then bypasses the facility and discharges, untreated, into the Papillion Creek or the Missouri River, creating a Combined Sewer Overflow (CSO). In a 2004 EPA Report to Congress on the Impacts and Controls of CSOs and SSOs (Sanitary Sewer Overflows), the annual volume of CSOs was estimated at 850 billion gallons (EPA, 2004). Prior to approval of the Federal CSO Control Policy, it is estimated that over one trillion gallons of overflow discharged annually (EPA, 2004).
In Omaha, an average of 58 to 78 overflow events occur annually, generating approximately 8 billion gallons of raw sewage admixed with stormwater entering the Papillion Creek and the Missouri River.

The nexus of the CSO issues facing Omaha and the other 772 communities arises from stormwater runoff exacerbated by ISAs. Stormwater runoff generated from rain and snowmelt events flows over land or impervious surfaces, not percolating into the ground (EPA, 2010). This runoff also picks up sediment, animal wastes, tire residue, air pollution fallout, deicing compounds, fertilizers, pesticides, vegetation, trash, heavy metals, and many more pollutants as it flows over surfaces leading to the stormwater collection system.

To the average citizen, the current paradigm of managing stormwater runoff appears to work fine, because unless a street, home or business floods or some other type of impact occur, no one notices. This is changing however, banks near waterways are beginning to erode and community costs are increasing to maintain and repair existing infrastructure. Likewise, when a new neighborhood experiences poor drainage resulting from compacted soils and improper lot grading, citizens begin to understand something is not working. These issues are the culmination of multiple triggering factors. Collectively, these include a development’s cost/return ratio, amount of available open land, population increases, poor land use management, poor design, undervaluing water, assuming nature will take care of itself, and emphasizing short-term goals over long-term community and environmental sustainability. These all lead to a decision point for stormwater management; do we stay the course with our current stormwater management paradigm of only narrowly focusing on the site-specific goal of getting water away as quickly as possible? Or do we establish a new paradigm, one that is modeled after natural systems and manage stormwater as close to where it lands as possible?

Andy Szatko
Generally, stormwater management encompasses many components, from structured systems to detailed maintenance plans. Communities must define their approach and strategies for stormwater in a comprehensive plan so that citizens, businesses, industries, and regulators know what to do and demonstrate if they are meeting current regulations. The scope of a LTCP or other stormwater management plan can vary significantly in scale, from focusing within city or county boundaries to addressing an entire watershed that may cross numerous political boundaries. Addressing and planning for stormwater issues within the confines of political boundaries appears efficient from an organizational perspective, but it becomes difficult because water flows across all land, ignoring political boundaries. Efficient planning for stormwater within a common watershed yields higher quality benefits. A plan can focus on one issue, such as addressing the CSO (Combined Sewer Overflow) Control Policy, or it can address multiple issues such as flooding, construction, and post-construction stormwater management.

Successful LTCP’s and stormwater management plans must address both quantity and quality of stormwater. Quantitative control is applied through a system of vegetative or structural measures, or both, that control the increased volume and rate of stormwater runoff caused by human-made changes to the land. Qualitative control is established through a system of vegetative, structural, or other measures that reduce or eliminate the physical, chemical or thermal degradation of runoff caused by human-made changes to the land. (South Carolina, 2007). Prior to human influence on the land, a natural hydrologic balance existed where most runoff soaked into the soil. Before development, a certain level of ‘pollution’ occurred, including sediments, plant debris, and animal wastes. After human influence, i.e. agriculture, homes, commercial developments, etc…., the natural hydrology of a given piece of land becomes altered and the preexisting hydrologic balance degrades. Today, the addition of heavy metals, oils,
fertilizers and increased water temperatures, volume, and rates of flow require bringing the qualitative and quantitative system back into a balanced hydrological state. This is the primary goal of stormwater management.

Stormwater management approaches fall into one of three categories: gray infrastructure, green infrastructure, or a combination of the two. Gray infrastructure usually prevails as the paradigm/strategy of choice today; it collects and transports stormwater off of the site as quickly as possible, failing to reproduce nature’s natural drainage system. Reinforced by standard practices tending to focus on site-specific problem solutions, this strategy ignores consideration of downstream impacts. Gray infrastructure quickly moves stormwater away from a site through the use of concrete swales, curbs, gutters, tunnels, and pipes and then discharges it into the nearest sewer, treatment facility, waterway, or water body.

Historically, municipalities with CSOs attempted to reduce sewer overflow by focusing their efforts and expenses on separating combined sewers, upgrading decaying pipes, and expanding treatment capacity and sewer system storage. However, these solutions solely rely on gray infrastructure and can take a long periods and heavy funding. Even when a sewer system is upgraded and the storage capacity is expanded, the function and performance of the all-gray infrastructure solution does not comprehensively and effectively address both stormwater quality and quantity. Furthermore, long-term maintenance of gray infrastructure systems is costly, may be undersized relative to handle the volume from a fully built-out watershed, and returns minimal ancillary benefits beyond rapid conveyance of wastewater.

Stormwater management plans relying only on gray infrastructure merely capture, convey, and focus the relatively small runoff issues generated by ISAs on a site into a much more significant problem downstream. This stormwater runoff from nonpoint source pollution
leads to the collapse of healthy freshwater ecosystems in the United States. The percentage of ISA cover in a watershed directly affects its overall water quality and habitat stability. U.S cities continually expand their built environment, including roofs, roadways, and parking lots. This progress ultimately leads to a higher percentage of imperviousness and environmental degradation. With as little as 10% of a watershed covered in ISAs, visible degradation begins to occur.

In order to address the consequences of gray infrastructure and the issues associated with current land uses, emphasis needs to be placed on strategies that manage rain and snow melt where they land and mimic as close as possible predevelopment hydrology. This relatively new approach is often referred to as Low Impact Development (LID), green infrastructure (GI), or sustainable landscaping. For the purpose of this project, green infrastructure (GI) will be the term used in reference to this stormwater management strategy. The concept of GI itself is broken down into three different scales; site, neighborhood, and watershed (EPA, 2010). On the site level, GI strategies include bioretention and rain gardens, rain harvesting, permeable pavements, and green roofs, just to name a few. As is the case in each level of GI, utilization of plants and the natural environment play key roles; hence, the name green infrastructure. These specific strategies aim to capture, slow, infiltrate, evaporate, and transpire excessive precipitation. Secondary benefits accrue to include improved biodiversity, reduced water and energy bills, and urban heat island mitigation.

On the neighborhood level, GI focuses more on planning strategies and the management of those strategies. One strategy that falls into this category includes the conservation, development and management of the urban forest as a stormwater management feature. Although this infrastructure component can easily be overlooked, numerous research papers and
data have been compiled that document the significant impact that trees have on managing stormwater (Bartens, et al. 2008).

On the watershed level, GI encompasses the broader context of protecting, conserving, designing and interconnecting new and existing open green spaces and the natural conveyance system. This includes developing the policies and strategies to both establish and maintain these spaces, all of which support a stronger, healthier environment. A watershed, technically, is an area surrounded by a divide separating one drainage area from another (Chow, 1964). Within a watershed, large, open, green areas are often referred to as hubs. Smaller green areas (green roofs, rain gardens) are referred to as sites. The physical connections between these areas are referred to as links. The links can also be considered as the natural conveyance system as well, preserving and mimicking the natural waterways. Fragmented environments composed of relatively small, isolated areas, poorly resists stresses resulting from impermeable surfaces, such as pollutant loading. Linking these fragmented environments allows for movement of water and wildlife, therefore increasing adaptation, resiliency, and health. At this scale, common strategies focus on building partnerships between multiple municipalities and organizations within a watershed. This approach can be very effective and equitable with potential benefits, costs, and responsibilities spread across an entire watershed and shared by its residents.
Omaha CSO Program’s Background

Omaha has two types of sewer systems, the CSS and the municipal separate storm sewer system (MS4), where sanitary waste and stormwater runoff are in separate pipes. Omaha lies within the Papillion Creek Watershed, a 275 square mile area running from Washington County in the north down through Douglas County into Sarpy County. The watershed’s wastewater system is managed through two regional treatment plants, the Missouri River Plant and the Papillion Plant. A smaller plant on the western side of Douglas County treats the Elkhorn community. The CSS is located on the eastern edge of Omaha, approximately between Interstate 680 on the north, the Douglas-Sarpy County line on the south, the Missouri River on the east, and 72nd Street on the west side (see the yellow shaded area in Figure 1). Altogether, it covers 43 square miles of the city and includes a total of 29 CSO outfalls, points where the untreated overflow from the system discharges. Ten of the outfalls discharge to the Papillion Creek and the other 19 into the Missouri River. The CSS area was broken into ten separate study basins for the LTCP, their names and sizes are depicted in Figure 2.

The Omaha CSO Program’s deadline for completion of the long term control plan (LTCP) is set for 2024. While currently a number of projects have begun, its cornerstone, the storage tunnel, will not begin construction until approximately 2015. The tunnel is currently

Andy Szatko
designed to be located approximately 180 feet below ground along the Missouri River, expands to 17 feet in diameter, extend for 5.2 miles, ending at the Missouri River Wastewater Treatment Facility near the Veteran’s Bridge in south Omaha. The LTCP’s elements and goals are summarized below.

The 393-page Omaha LTCP for CSOs includes a 1032-page Appendix volume, addressing the requirements of the EPA’s National CSO Control Policy of 1994 and the Administrative Consent Order with the Nebraska Department of Environmental Quality (NDEQ). The CSO Control Policy requires a municipality to control 85% of the total overflow volume or limit the number of annual overflow events to four or less.

An assessment was performed to determine which pollutants originating from CSO discharges resulted in the non-compliant receiving waterway. E-coli, which generally correlates to the presence of sanitary or animal waste in stormwater runoff, was determined to be the only pollutant of concern associated with CSOs. The LTCP does not directly address flooding and comprehensive, watershed-level water quality issues, although benefits in both of those areas would be possible with its implementation. To guide the project as a whole, three project goals were set:

- **Regulatory compliance** as set forth by the EPA and the Nebraska Department of Environmental Quality (NDEQ) and completed within an identified schedule
- **Economic affordability** by minimizing costs and completing the project within or under budget
- **Community acceptance** through continuous dialogue, providing information, and pursuing opportunities for multiple benefits in the CSO LTCP
The LTCP primarily utilizes gray infrastructure to meet the CSO Control Policy Act’s regulatory requirements, but GI has been incorporated into it as well. Basic assumptions made by the City of Omaha regarding GI (their term is Green Solutions in the plan), are listed below. This list does not include all assumptions, but rather describes the initial ones made at the onset of plan development that constricted its potential development:

- Information presented at the 2010 International Erosion Control Association Great Plains Chapter annual conference, discusses green solutions during plan development
  - Green Solutions must be built on public property to qualify as a potential CSO Control
  - Green Solutions are not a CSO control alternative
  - Green Solutions will not be relied upon to achieve compliance with the EPA CSO Control Policy, but may provide a ‘margin of safety’

- Omaha CSO LTCP
  - Volume II, Appendix P, p.2: “E. coli is the pollutant of concern addressed in the LTCP”
  - Volume I, section 4.2.1: “It is presumed that if the CSO controls meet one of the criteria listed in the EPA CSO Control Policy under “Presumption Approach,” then water quality standards are met.” Presumption Approach criteria are:
    - No more than 4 CSO events during an average year
    - 85% by volume, capture and treatment of volume entering CSS during wet weather
Volume II, Appendix O, p.3: “The incorporation of Green Solution projects into the LTCP is not anticipated to have a significant impact on the structural CSO controls proposed since these are designed to address large events.”

Volume I, section 2.5.4: “While it is not practical to control the CSOs by only implementation of Green Solutions, in some instances they can provide some reduction in the sizing of the larger CSO controls (that dictate the sizing of controls).”

Technical Memorandum, Green Solutions Guidance for the City of Omaha CSO Long Term Control Plan: In reference to green roofs, rain harvesting, and disconnection of impermeable surfaces, “This technology cannot be implemented on its own, but needs to be connected to a conveyance, detention, or infiltration BMP.”

Listed below are the eight non-monetary benefits used to help determine the most economical and best solutions for the LTCP. These benefits were developed by the Community Basin Panel (CBP), a group comprised of individuals from various utilities, community organizations, the Chamber of Commerce, and at-large members:

- Water quality improvement
- Reduction of combined sewer backups into basements, as well as foul odors
- Reduction of street flooding
- Minimizing community disruption
- Simplicity of solutions
- Opportunities for infrastructure/utility improvements
- Compatibility with community
- Opportunities for community enhancements

These categories were scored and weighted by consultants to reflect their level of importance in each of the 11 study basins in Omaha. These weighted scores were then incorporated into the evaluation of various alternate controls being considered for each of the basins.

The City of Omaha recognized that GI could provide benefits above that of mitigating stormwater. Following is a listing of recognized benefits, as stated in the Omaha LTCP:

- Provide a factor of safety for the CSO Long Term Control Plan
- Mitigate hard infrastructure facilities and/or reduce hard infrastructure facility costs
- Improve water quality
- Limit the amount of stormwater runoff entering the CSS
- Reduce peak storm flow into the CSS
- Create neighborhood amenities
- Enhance wildlife habitat
- Serve to improve public awareness and learning opportunities of CSO control technologies

To determine what extent Green Solutions could be incorporated into the LTCP, Omaha performed a GIS analysis of its land area and developed criteria to determine where the utilization of GI could be implemented, in conjunction with its engineered controls. Criteria for GI require that the GI strategies being proposed must be ‘cost neutral’, meaning that the total cost of the project cannot exceed current cost estimates and provide the same level of service. The land use analysis was performed using GIS and identified public and semi-public land use
areas throughout Douglas County for potential sites where GI could be used (schools, boulevards, parks, golf courses and cemeteries). Those locations were ranked on a 3-tier system for their potential GI utilization (aspects included soil type, slope, and current land use). It was determined there was insufficient land to implement GI on a large enough scale to meet the EPA’s CSO Control Policy. Currently, after GI projects and strategies are conceptualized and preliminary cost-neutral estimates are developed, they are presented to the project leads and engineers for consideration into the LTCP.

In addition to the regulatory requirements for the CSO permit, the City of Omaha also has regulatory requirements for their MS4 permit. One component of the permit is to address post-construction stormwater discharges. In response to that requirement, Omaha enacted a post-construction stormwater ordinance in 2008 requiring new or redevelopment projects that disturb over 5,000 square feet of land and cover one acre in size or greater, must capture and treat the first 0.5” of runoff from across the site. Meeting this ordinance requires the use of BMPs, such as bioretention gardens, soil conditioning, or permeable pavements. As part of the ordinance, a maintenance agreement is attached to the title of the property, ensuring that the BMPs will be maintained and exist into perpetuity. Tracking implemented BMPs also required. All of this is part of regulatory compliance with the Omaha’s MS4 permit, allowing it to discharge stormwater runoff into the waters of the United States.

**InfoWorks Modeling Background**

The Omaha CSO Program uses hydraulic modeling software, called InfoWorks CS v11.5.6, to support the development of ‘the best solution’ to reduce annual CSO events to only four per year. Critical elements of the combined and sanitary sewer systems put into the model include existing sewers (24” pipes and larger) and their slopes, estimated impermeable surface

Andy Szatko
cover, and delineated subcatchments (watersheds) with their average width and slope. Once the model is loaded with the existing sewer system characteristics, a select number of design solutions and strategies are modeled to determine the most efficient and effective means to achieve regulatory compliance in a cost-effective way. The various solutions and scenarios analyzed are called CSO control alternatives, presenting the means by which the EPA ensures municipalities properly vet the chosen solution for regulatory compliance with the CSO Control Policy. The model utilizes hourly weather data from Eppley Airfield’s weather station during 1969. The chosen representative year chosen, 1969, had typical weather patterns common for our climate; large downpours, hot dry summers, cold and windy winters, etc...

The InfoWorks model, like any model, is only as good as its input information. The purpose by which the model is used is a key consideration for how to interpret its results. Utilized primarily as a planning-level model, where it guides the development of the LTCP and not in the design of specific elements. By using it as a planning-level tool, certain assumptions and estimates had to be made that may not be consistent for all variables applied to in order to get a broad assessment of the CSO area and guide plan development. The critical elements listed above are described in terms of their breadth and scope below.

- **Existing sewers**: Only pipes 24” or larger and their slopes are put into the model. Elevations and locations for them had to be verified. Incorporation of pipes to just 18” would essentially double the number of pipes and was not possible with resources available. An individual study adding pipes down to 18” was performed in the Saddle Creek basin to test the accuracy of only modeling 24” pipes. Adding the smaller pipes requires breaking the area down into smaller subcatchments to accurately model water entering the sewers. The
results did not vary from the modeling of only 24” pipes, according to CSO Program officials.

- **ISA and pervious areas**: These are organized into three categories: road impermeable, non-road impermeable, and pervious. In a given subcatchment, the distribution of ISA and pervious areas are not taken into account; rather, the model looks at it as a pie chart, with certain amounts of area designated as road impermeable, non-road impermeable, and permeable. The distinction between road and non-road impermeable relates to the assumption that roads are directly connected with the sewer system, where some non-road impermeable surfaces (sidewalks, driveways, etc...) may not. Determining the actual ISA for the CSS was not possible with the resources available. In order to get as accurate an estimate as possible, zoning districts were used for estimating ISA. Zoning districts limit the types of uses for a piece of land, and in the case of Omaha, the zoning districts stipulate the maximum amount of ISA coverage on a property. These percentages were adapted to the CSO Program and reflected actual representative percentages for given zoning districts. The assumed values for ISA are included in Appendix B.

- **Subcatchment delineation**: Topography is not taken into account in the model; however, the width and generalized slope of the contributing area is taken into account. The width is the average width across the subcatchment, perpendicular to the flow across it. The average slope comes from finding the percent slope from the high point of the main conveyance channel to the low point.

Numerous variables, in addition to what has been previously described, play a part in how a sewer system works and ultimately determines how many times a CSO event occurs. The Omaha CSO Program has and continues to incorporate as many relevant variables into the model.
as possible to increase reliability of its output. Unfortunately, it is not possible to include all variables and related data because of limited resources and funds. However, elements of InfoWorks provide flexibility in how variables can be modeled which touch on water quality. For example, increased infiltration in a subcatchment can be included to account for water lost through increased infiltration capacities. GI structural or non-structural elements can be incorporated as can physical removal of ISAs. It is also capable of considering if ISAs are directly connected to the sewer system (no infiltration possible before entering the sewer system) or if it is disconnected (flows through permeable areas prior to entering sewer system using a cascading planes concept). This flexibility, once properly utilized, can help realize the multiple benefits, including improved water quality associated with reduced ISAs and GI.

**Project Description**

Initial discussions about this project with persons involved with the Omaha CSO Program centered around developing a better understanding of the extent of ISAs volume impacts on the CSS area. Understanding this relationship, through the processes of the InfoWorks model, would be highly valuable and could lead to better solutions in meeting regulatory requirements. This project’s focus on ISAs will establish grounds to further investigate and utilize ISA reduction as a strategy in the LTCP. If ISA reduction is found to
provide significant benefits, then future work will need to be done to define ISA reduction and apply it on a basin by basin basis. Below is the framework that guided the project forward.

Project Goal and Objectives

Goal

- Assess the accuracy of ISA assumption by using zoning districts, its impact on the modeling of the LTCP, and identify areas of potential improvement.

Objectives

1. Assess the accuracy of estimating ISA coverage by zoning district in the CSS by digitizing all impervious surfaces within a subcatchment and comparing the results with the assumed percent coverages.
2. Model various percent reductions in ISA within the study subcatchment to assess changes to peak flow and volume.
3. Perform a sensitivity analysis to the increased level of detail of factors in the current modeling software to assess the changes in peak flow and volume between model runs.

Project Location

Subcatchment 202 in the Cole Creek study basin covers approximately 101 acres near the intersection of 72nd and Maple Street (see
figure 3). This subcatchment encompasses multiple zoning districts and is scheduled to have its combined sewer converted into a separate storm sewer system (MS4) starting in 2014. Currently, the subcatchment overflows during rain events into Cole Creek at CSO outfall number 202. The dominant zoning district R4(35), medium density, single-family housing makes up 74% of the subcatchment area. Road pavement is the second largest type of land use at 13.6%, while commercial land uses, zoning district CC and GC, comprise a little more than 8% of the subcatchment.

**Definitions**

To ensure clarity for terms used in this report, Appendix A includes definitions as adapted by the University of Nebraska - Lincoln Extension. Also included is the list of acronyms commonly used in the Omaha CSO Program, found in the Sewer Separation Protocol Rev.001 document of the Omaha CSO Program.

**Tasks**

1. Gather information on all ISAs from subcatchment area 202, utilizing a Geographic Information System (GIS), and classify into the following planimetric layers:
   a. Buildings
   b. Road pavement
   c. Driveways
   d. Sidewalks
   e. Parking lots
   f. Parking structures
   g. Recreational facilities (basketball, tennis courts, tracks)
   h. Patios and decks

Andy Szatko
i. Swimming pools, including the immediate deck materials surrounding them

2. Gather information on zoning districts in subcatchment area 202, including maximum allowable ISA, areal coverage, and the assumed ISA percent coverage used for the Omaha CSO program modeling.

3. Associate digitized ISAs with each zoning district to determine actual percent coverage by zoning district.

4. Compare estimated and actual ISA percent coverages to assess accuracy.

5. Separate subcatchment 202 into 18 smaller subcatchments and calculate slope and width of each one. Associate digitized ISAs to each of the smaller subcatchments, incorporate all existing sewer lines into the model, and run the model. Compare results of increased detail level with the original model with only one subcatchment.

6. Model ISA percent reductions for subcatchment area 202 to assess the associated peak flow and volume benefits. Perform the same analysis with subcatchment 202 divided into 18 smaller subcatchments to compare results with the model run with only the one larger subcatchment 202.

Methodology

1. ArcGIS was utilized to manually digitize planimetric layers at a scale of 1:200 or less using the City of Omaha’s most recent aerial photos (April 2011) and its oblique imagery as a reference during digitizing. Assumptions for defining ISA feature classes included:
   a. Buildings are defined as the area inside the perimeter of a continuous structure for human occupancy or use.
b. Road pavement with curbs is measured from back of curb to back of curb. Road pavement without curbs, is measured from edge of pavement to edge of pavement. For gravel roads, the outer edge of discernible gravel will be the defined extent.

c. Driveways are defined as the area inside the perimeter of the ISA used for moving vehicles onto a property, including the approach (the portion directly connected to the road pavement). Those driveways with no direct connection to road pavement are defined as not having an approach.

d. North to south oriented sidewalks terminate at the south or north edge of the east to west oriented sidewalks at intersections. Sidewalks are defined as the area inside the perimeter of ISAs where the dominant method of transportation is pedestrian or bicycle. All sidewalks, public and private, are accounted for in this classification.

e. Parking lots are defined as the area inside the perimeter of ISAs where vehicles park, including their direct connection to road pavement or other pavement feature and their associated drive lanes for vehicular movement to, through, and within the parking lot.

f. Recreational facilities are defined as the area inside the perimeter of ISAs used for athletic or recreational uses.

g. Patios are defined as the area inside the perimeter of ISAs used by people, not vehicles, for social or private events and can be either private (residential or commercial) or public use.

h. Swimming pools are defined as the area inside the perimeter of ISAs surrounding the body of water, including the associated pool deck.

2. ArcGIS and the City of Omaha’s existing zoning district and pavement maps were utilized to
measure areal coverage of zoning districts in subcatchment 202 and across all of the CSO study basins. The zoning district polygons only extend to right-of-ways, leaving a gap between the zoning district boundary and pavement polygons. To account for all area within subcatchment 202, zoning polygons were extended to share edges with the pavement polygons and with the boundary of the subcatchment itself. For determining areal coverage for the CSO study basins, the total of each zoning district and the pavement was calculated together. The total areal coverage of the CSO study basins was then calculated and the total for zoning district and pavement coverage was subtracted from this amount. This remaining area was proportioned among the zoning districts based upon their percent coverage of the total zoning areal coverage.

3. Digitizing of ISAs and computation of their percent land covers and the geodatabase file was shared with the Omaha CSO Program and inputted into the InfoWorks model. The initial model run for subcatchment 202 established the current modeling results used by the Omaha CSO Program. Subsequent model runs included using the actual ISA coverage, and the ISA percent reductions of 10, 20, and 30% from the actual ISA coverage respectively. These reduction levels were chosen to understand results over a large range, allowing for interpolation to occur between modeled percentages. For each model run, hydrographs were generated and provided the data on peak flow, timing, and volume.
Results (by objective)

1. Compare the results of assumed zoning district ISA coverage to actual ISA coverage.

- **R1**, Single-family, large-lot, low-density residential occurs along the west side of 72nd Street, encompassing the adjacent sidewalk. There was not enough coverage of this zoning district in subcatchment 202 to accurately assess output changes. As a result, the results for R1 will not be indicative of the true ISA percent cover for it.

- **R4(35)**, Single-family, medium-density residential – this is the dominant zoning district for this subcatchment, with approximately 74 percent coverage of subcatchment 202. The total percentage of ISA cover was relatively close to the Omaha CSO Program’s estimation, 5 percent lower than the estimated value.
• **R7**, Multi-family, medium-density residential – 3.7 percent of subcatchment 202 was zoned R7. The actual ISA percent cover was nearly 10 percent higher than estimated.

• **CC**, Community Commercial – this zoning district applies to commercial areas near intersections of civic importance. Besides R1, this zoning district comprises the second smallest area of the subcatchment. The difference between the assumed and actual ISA percent covers was small, within 2.5 percent.

• **GC**, General Commercial – this zoning district, covering 5.3 percent of the subcatchment, had the greatest difference between the assumed and actual ISA percent coverages, 9.4 percent higher than estimated.

• **Pavement** (roads) – this constitutes the second highest land use in the subcatchment, with 13.6 percent of the area covered by pavement. Pavement is not associated with zoning districts and has been separated out from zoning districts. It is reflected in

• **Overall** – There was a net difference of 17.7 percent between the assumed and actual ISA percent cover in this subcatchment. When taking into account pavement, the difference drops to 12.9 percent.

<table>
<thead>
<tr>
<th>Zoning District</th>
<th>Areal Cover (acre)</th>
<th>% Cover of Basin</th>
<th>Assumed ISA % Cover</th>
<th>Areal ISA Cover (acre)</th>
<th>Actual ISA % Cover</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>0.2</td>
<td>0.2%</td>
<td>22.50%</td>
<td>0.03</td>
<td>12.6%</td>
<td>-9.9%</td>
</tr>
<tr>
<td>R4(35)</td>
<td>74.9</td>
<td>74.1%</td>
<td>37.50%</td>
<td>24.40</td>
<td>32.6%</td>
<td>-4.9%</td>
</tr>
<tr>
<td>R7</td>
<td>3.7</td>
<td>3.7%</td>
<td>52.50%</td>
<td>2.29</td>
<td>61.9%</td>
<td>9.4%</td>
</tr>
<tr>
<td>CC</td>
<td>3.2</td>
<td>3.2%</td>
<td>63.75%</td>
<td>2.12</td>
<td>66.2%</td>
<td>2.5%</td>
</tr>
<tr>
<td>GC</td>
<td>5.3</td>
<td>5.3%</td>
<td>67.50%</td>
<td>4.71</td>
<td>88.2%</td>
<td>20.7%</td>
</tr>
<tr>
<td>Subtotal</td>
<td>87.3</td>
<td>86.5%</td>
<td>33.55</td>
<td></td>
<td>17.7%</td>
<td></td>
</tr>
<tr>
<td>Pavement</td>
<td>13.8</td>
<td>13.6%</td>
<td>18.4%</td>
<td>13.8</td>
<td>13.6%</td>
<td>-4.7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>101.13</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>47.0</strong></td>
<td><strong>47.0</strong></td>
<td><strong>12.9%</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Table 2 - Subcatchment 202 ISA by Zoning District*
ISA in subcatchment 202 was distributed among eight ISA types; the distribution of ISA by these types is listed in Table 3. Buildings were the dominant type of ISA, covering 14.7 percent of the subcatchment. Close behind was roads impervious at 13.6 percent; driveways were third with 7.2 percent.
The types of ISA in each zoning district are shown in Table 4. This breakdown will be useful for later analysis of potential ISA reduction strategies.

<table>
<thead>
<tr>
<th>Subcatchment 202 ISA by Zoning District &amp; Type (in acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoning District</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>R1</td>
</tr>
<tr>
<td>R4(35)</td>
</tr>
<tr>
<td>R7</td>
</tr>
<tr>
<td>CC</td>
</tr>
<tr>
<td>GC</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Total Zoned ISA</td>
</tr>
<tr>
<td>Roads Impervious</td>
</tr>
<tr>
<td>Total ISA</td>
</tr>
</tbody>
</table>

Table 4 - Subcatchment 202 ISA by Zoning District & Type

Table 5 summarizes the estimated and actual ISA percentages for subcatchment 202 into the three categories the InfoWorks model uses during the modeling process. The estimated and actual ISA and pervious percent cover numbers are within 3.6 percent of each other, with the actual pervious area greater than what was estimated.

<table>
<thead>
<tr>
<th>Subcatchment 202 ISA Breakdown for InfoWorks Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>InfoWorks Category</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Roads Impervious</td>
</tr>
<tr>
<td>Non-road Impervious</td>
</tr>
<tr>
<td>Pervious</td>
</tr>
</tbody>
</table>

Table 5 - Subcatchment 202 ISA by Modeled Category
Figure 6, shows the digitized ISAs with the zoning districts overlaid. Of note within each zoning district is the pattern of development, each having a distinct pattern associated with it.

2. **Model various percent reductions of ISA within the subcatchment 202 to assess peak flow and volume benefits.**

Figure graphs the peak flow results from model runs using the actual ISA percent cover, 10, 20, and 30 percent reductions in the total amount of ISA within subcatchment 202. The
results show a linear relationship between ISA percent cover and the associated peak flow reduction. When the subcatchment was modeled with the actual ISA cover, there was a 2.6 percent reduction in the modeled peak flow. At 10 percent ISA reduction from the actual ISA cover, there is a 22.8 percent modeled reduction. This pattern continues for both the 20 percent and 30 percent reductions, approximately a 1:2 ISA reduction to peak flow reduction ratio. The 1-year, 24-hour storm event was chosen because it would indicate the relationship between ISA and peak flows and volume that could be applied to other events. Given the lack of variability in modeling factors (i.e. only three categories of land surface type), the relationship of peak flow and volume reduction to ISA reduction will be similar for other storm events.

![Graph](image)

**Figure 7 – ISA Percent Reduction on Peak Flow**

Figure graphs the volume reductions from model runs using the actual ISA percent cover, 10, 20, and 30 percent reductions of ISA within subcatchment 202. The results show a linear relationship between ISA percent cover and the associated reduction in volume. When the actual ISA cover was modeled, there was a 7.1 percent reduction in the modeled

Andy Szatko
volume. At 10 percent ISA reduction from the actual ISA cover, there was a 24.7 percent reduction in the modeled volume. This pattern continues for both the 20% and 30% reduction models; with almost a 1:2 ISA reduction to volume reduction ratio.

![Influence of ISA % Reduction on Volume Reduction](image)

3. **Evaluate whether an increased level of detail in modeling will modify modeling results from the current modeling method.**

Figure 9 shows the hydrographs for each of the model runs performed for this study. The greatest amount of peak flow occurs with the CSO Program’s estimated percent pervious model run, approximately 41 cubic feet per second (cfs). With subcatchment 202 divided into 18 subcatchments and all of the known existing sewers put into the model, the modeled flow was approximately 40 cfs, only 1 cfs lower than the current model, or 2.5 percent under the estimated value. In the detailed model, the flow from the subcatchment reaches the sewer pipes slightly faster, by approximately 5 minutes. The ISA reduction model runs have similar hydrographs with consistent decreases in flow as the ISA percent reduction is increased. Figure 10 shows the
screenshots of the InfoWorks model and the increase in the number of sewer pipes modeled between the current and the detailed model. Figure 1 shows the delineation of subcatchment 202 into the 18 smaller subcatchments, labeled 108A to 108R.

Figure 9 - Hydrographs of Subcatchment 202 InfoWorks Model Runs

Figure 10 - Sewer Infrastructure before (left) and after (right) Detail Added for Subcatchment 202
4. **Inventory the coverage of zoning districts and pavement in the CSS area**

There are 28 different zoning districts within Omaha’s CSO study basins. I utilized the City of Omaha’s current GIS map and attribute table to develop this inventory of zoning districts for the CSO Study Basins. The breakdowns of those districts are detailed in Table 7 below. R4(35) encompasses the largest area with approximately 7,100 acres, or 24 percent of the CSO study basin area. Zoning districts R7, CC, and GC comprise approximately 1,700, 600, and 675 acres or 5.7 percent, 2.0 percent, and 2.3 percent respectively. Based on the CSO Program’s assumed ISA percent cover, the total area in ISA was calculated in acres.
### Zoning District & Pavement Coverage of all CSO Study Basins

<table>
<thead>
<tr>
<th>Area</th>
<th>sf cover</th>
<th>Acres</th>
<th>Sq. Miles</th>
<th>% Cover of CSO Study Basins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total CSO Study Basin Area</td>
<td>1,511,835,577</td>
<td>34,707</td>
<td>54.2</td>
<td></td>
</tr>
<tr>
<td>Zoning District Coverage Area</td>
<td>1,352,336,222</td>
<td>31,045</td>
<td>48.5</td>
<td>89.4%</td>
</tr>
<tr>
<td>Total Pavement Area</td>
<td>159,499,355</td>
<td>3,662</td>
<td>5.7</td>
<td>10.6%</td>
</tr>
</tbody>
</table>

Table 6 - Zoning District & Pavement Cover for Omaha CSO Study Basins

### Detailed Zoning District Coverage of all CSO Study Basins

<table>
<thead>
<tr>
<th>Zoning District</th>
<th>Area in acres</th>
<th>Percent Cover of CSO Area</th>
<th>Percent Cover of Zoning District Cover</th>
<th>Assumed ISA Percent Cover</th>
<th>Assumed Area of ISA (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0.37</td>
<td>0.00%</td>
<td>&lt;0.01%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AV</td>
<td>3.08</td>
<td>0.01%</td>
<td>0.01%</td>
<td>50.00%</td>
<td>1.54</td>
</tr>
<tr>
<td>LC</td>
<td>22.10</td>
<td>0.07%</td>
<td>0.08%</td>
<td>56.25%</td>
<td>12.43</td>
</tr>
<tr>
<td>AG</td>
<td>23.70</td>
<td>0.08%</td>
<td>0.09%</td>
<td>7.50%</td>
<td>1.78</td>
</tr>
<tr>
<td>LI</td>
<td>25.20</td>
<td>0.08%</td>
<td>0.10%</td>
<td>60.00%</td>
<td>15.12</td>
</tr>
<tr>
<td>LO</td>
<td>26.52</td>
<td>0.09%</td>
<td>0.10%</td>
<td>75.00%</td>
<td>19.89</td>
</tr>
<tr>
<td>MH</td>
<td>45.11</td>
<td>0.15%</td>
<td>0.17%</td>
<td>37.50%</td>
<td>16.92</td>
</tr>
<tr>
<td>NBD</td>
<td>79.77</td>
<td>0.27%</td>
<td>0.30%</td>
<td>67.50%</td>
<td>53.85</td>
</tr>
<tr>
<td>R8</td>
<td>187.88</td>
<td>0.63%</td>
<td>0.71%</td>
<td>60.00%</td>
<td>112.73</td>
</tr>
<tr>
<td>R6</td>
<td>247.83</td>
<td>0.83%</td>
<td>0.93%</td>
<td>45.00%</td>
<td>111.52</td>
</tr>
<tr>
<td>MU</td>
<td>254.03</td>
<td>0.85%</td>
<td>0.95%</td>
<td>63.75%</td>
<td>161.95</td>
</tr>
<tr>
<td>GO</td>
<td>279.56</td>
<td>0.94%</td>
<td>1.05%</td>
<td>60.00%</td>
<td>167.74</td>
</tr>
<tr>
<td>DS</td>
<td>325.69</td>
<td>1.09%</td>
<td>1.22%</td>
<td>75.00%</td>
<td>244.27</td>
</tr>
<tr>
<td>R1</td>
<td>374.28</td>
<td>1.26%</td>
<td>1.41%</td>
<td>22.50%</td>
<td>84.21</td>
</tr>
<tr>
<td>CBD</td>
<td>428.05</td>
<td>1.44%</td>
<td>1.61%</td>
<td>75.00%</td>
<td>321.04</td>
</tr>
<tr>
<td>CC</td>
<td>597.17</td>
<td>2.01%</td>
<td>2.23%</td>
<td>63.75%</td>
<td>380.69</td>
</tr>
<tr>
<td>RR</td>
<td>599.33</td>
<td>2.01%</td>
<td>2.24%</td>
<td>18.75%</td>
<td>112.37</td>
</tr>
<tr>
<td>GC</td>
<td>675.14</td>
<td>2.27%</td>
<td>2.54%</td>
<td>67.50%</td>
<td>455.72</td>
</tr>
<tr>
<td>R5</td>
<td>932.97</td>
<td>3.14%</td>
<td>3.51%</td>
<td>41.25%</td>
<td>384.85</td>
</tr>
<tr>
<td>R5(35)</td>
<td>1,029.96</td>
<td>3.46%</td>
<td>3.87%</td>
<td>41.25%</td>
<td>424.86</td>
</tr>
<tr>
<td>HI</td>
<td>1,117.24</td>
<td>3.76%</td>
<td>4.20%</td>
<td>75.00%</td>
<td>837.93</td>
</tr>
<tr>
<td>R2</td>
<td>1,379.19</td>
<td>4.64%</td>
<td>5.19%</td>
<td>30.00%</td>
<td>413.76</td>
</tr>
<tr>
<td>R4</td>
<td>1,610.00</td>
<td>5.41%</td>
<td>6.05%</td>
<td>37.50%</td>
<td>603.75</td>
</tr>
<tr>
<td>R7</td>
<td>1,708.60</td>
<td>5.74%</td>
<td>6.42%</td>
<td>52.50%</td>
<td>897.01</td>
</tr>
<tr>
<td>GI</td>
<td>1,856.47</td>
<td>6.24%</td>
<td>6.98%</td>
<td>67.50%</td>
<td>1,253.12</td>
</tr>
<tr>
<td>R3</td>
<td>1,999.08</td>
<td>6.72%</td>
<td>7.51%</td>
<td>33.75%</td>
<td>674.69</td>
</tr>
<tr>
<td>DR</td>
<td>3,678.56</td>
<td>12.37%</td>
<td>13.83%</td>
<td>18.75%</td>
<td>689.73</td>
</tr>
<tr>
<td>R4(35)</td>
<td>7,101.22</td>
<td>23.87%</td>
<td>26.69%</td>
<td>37.50%</td>
<td>2,662.96</td>
</tr>
<tr>
<td>Total</td>
<td>26,608.10</td>
<td>89.45%</td>
<td>100.00%</td>
<td>11,116.44</td>
<td>41.78%</td>
</tr>
</tbody>
</table>

Table 7 - Omaha CSO Study Basin Zoning District Breakdown
Discussion

1. Assess the accuracy of estimating ISA coverage by zoning district

The accuracy of ISA percent cover is dependent on how the results are viewed. Strictly looking at the breakdown of ISA by zoning district to the assumed value compared to actual ISA, accuracy is poor. The net difference (actual minus assumed) between them is +17.7 percent and +12.9 percent when pavement is included. If we take away zoning district R1 because it does not cover a significant area of the subcatchment to be an accurate representation, the net difference increases to 27.6 percent and 22.9 percent with pavement included.

Specifically looking at the R4(35) zoning district, which makes up the majority of the subcatchment, the accuracy of the assumed ISA is relatively good, within 5 percent of the actual ISA. Throughout this zoning district, there were some properties that were dominated by ISA cover while others were minimal, sometimes even without driveways. When looked as a whole though, the properties balanced out and a range either side of the assumed ISA value used by the Omaha CSO Program. This is to be expected due to variations in property owners distributing ISA across their properties. The scope of this project did not look at parcel level ISA percent cover. This analysis would be worth performing, by zoning district, to get an accurate sampling of the ISA percent cover range of each zoning district.

The General Commercial (GC) zoning district had the greatest discrepancy, approximately 20 percent higher than the estimated value, with ISA totaling approximately 89 percent of the land area. This designation allows for numerous permitted uses and has a high limit for ISAs, 70 percent for the building itself and 90 percent for the entire site. By nature, the GC zoning district allows and generates a high spread in total ISA percent cover, making the use of it as an ISA estimation tool unreliable. However, one of the reasons this is the case in
subcatchment 202 likely is the result of its location within the city. As land within a city becomes developed and its value begins to increase with development, it becomes more intensely developed to reach its maximum potential, resulting in increased utilization of the parcel and increasing ISA cover. It would be worth studying this trend within different parts of the city, specifically within areas of varied density levels to see the ISA percent cover spread within zoning districts with the highest allowable ISA cover.

The breakdown of ISA types can help to characterize a watershed’s potential in terms of peak flow, runoff volume, and pollutant loading. It also allows better understanding of what types of pollutants may be more prevalent, i.e. if there are parking lots, one can expect higher levels of hydrocarbons and heavy metals that are associated with automobiles. This can help planning efforts to address specific pollutants of concern and choosing the most appropriate best management practices (BMPs) to manage them. In subcatchment 202, the dominant type of ISA was buildings, covering approximately 15 percent of the total area and pavement (not considered part of the zoning districts) was approximately 14 percent. Those numbers are double the next ISA type, driveways, which covers approximately 7 percent of the total area.

Distinct characteristics appear in each zoning district in regard to ISA type distribution. Both CC and GC parking lot cover percentages were double that of the buildings. It would be expected with this type of distribution that pollution originating from automobiles would be the dominant pollutant type, and the ISAs would likely be directly connected to the sewer system. In contrast, for R4(35) the building cover percentage was approximately 70 percent greater than driveways. Runoff from homes can be wide ranging, from being discharged directly onto a driveway to running into a turf area that flows through backyards for a great distance. The pollutant types coming from these surfaces are likely some petrochemicals from roofing
materials and driveways, organic wastes (plant debris and animal droppings), and household chemicals.

Table 4 details the distribution of ISA by type in each zoning district of subcatchment 202, helping to characterize the distribution of ISA within the subcatchment. If ISA reduction is a stated strategy of a municipality in meeting regulatory requirements, this data allows a planning level assessment of whether it is attainable in a given subcatchment. For example, in commercial zones, parking lots could be targeted for reduction or downspouts directly connected to the sewer system could be disconnected and routed through permeable surfaces instead. In residential zones, an incentive program can be implemented to encourage the adoption of GI strategies that will partially offset the costs associated with upgrading infrastructure. In both cases, an education program could be used to educate land owners of simple solutions they could implement themselves to help reduce stormwater runoff, including discharging downspouts into the yard rather than onto the driveway.

Table 5 most directly relates to the accuracy of ISA cover by zoning district. The InfoWorks model simply interprets ISA cover in this manner, regardless of type or distribution. The difference between the assumed and actual values was approximately 3.5%, indicating that in the case of subcatchment 202 this method of ISA estimation is relatively accurate. This result, however, does not guarantee that the same result will be demonstrated in other subcatchments. In subcatchment 202, the dominant zoning district is R4(35), in which the maximum permitted ISA is a fairly accurate predictor of actual ISA cover. This close relationship helped keep the overall subcatchment’s ISA cover close to the assumed value. In a subcatchment where GC, the zoning district with the greatest difference between assumed and actual, is the dominant zoning district, the accuracy of predicting ISA cover could be low.
2. Model various percent reductions in ISA and assess peak flow and volume benefits.

In understanding how the InfoWorks model operates, it is not surprising to find the relationship between ISA cover, peak flows, and volume to be a linear relationship. The model recognizes ISA cover simply as a percentage of the subcatchment, with a slight variation between roads impervious and non-roads impervious. This variation was created to acknowledge the direct connection most roads have with the sewer system and the uncertainty that remaining ISAs are directly connected or not. Because ISA is viewed as a single factor with three distinguishing characteristics, its relationship with peak flow and volume is direct and straightforward. The model is inherently conservative in how runoff from ISA interacts with the sewer system. Currently, only verified 24” sewer pipes and associated inlets are modeled for conveying flows, and runoff from ISA ‘stacks’ on top of the inlet until it is able to pass through. Since surface type is not taken into account in the model, the volume and peak flows from each of the three types of surfaces are consistent, resulting in ISA cover having a linear relationship with peak flow and volume reduction. InfoWorks is capable of having multiple types of pervious and impervious land covers that more closely relate the actual land cover, and if utilized, could lead to more accurate modeling and representation of various GI projects and strategies. InfoWorks is also able to model various levels of infiltration within a subcatchment, an additional opportunity to refine the model. That said, this is currently a planning level model, and the Omaha CSO Program has protocols and standards for project teams requiring more detailed information to be taken into account when moving into the design phase of projects.

The benefits associated with ISA reduction shown in Figure 7 and Figure 8 is significant. The relationship between peak flow and volume to ISA cover is nearly a 2 to 1 relationship, meaning that for every percent of ISA reduction, you can estimate approximately a two percent
reduction in both modeled peak flow and volume. In terms of peak flow, this is significant because when designing a sewer system, the pipe going in the ground needs capacity to handle the amount of flow during a design storm event; for the CSO Program, this is the 10-year, 24-hour storm event. Broadly speaking, this potential reduction in peak flow could reduce sewer pipe sizes and associated costs. In the case of a CSO event, lower volumes entering the sewer system means that the total volume of untreated stormwater and sewage entering the Papillion Creek and Missouri River would be reduced. The degree of benefit would vary from subcatchment to subcatchment, but this level of demonstrable benefit warrants further investigating as a viable tool in meeting regulatory requirements associated with CSOs and stormwater. Areas of future focus should be on the definition of ISA reduction, both by physical removal and disconnection from the sewer system.

3. **Perform a sensitivity analysis of increased levels of detail in modeling to current modeling results.**

   The measure to determine whether increased levels of detail changed the results of modeling was the hydrograph from modeling the 1-year, 24-hour storm event. The hydrograph of each model run (Figure 9) were graphed together to get a visual indication of how each scenario changed the results from the current modeling scenario. The inclusion of all existing sewer pipes and delineating subcatchment 202 into 18 detailed subcatchments only resulted in approximately one cfs (2.5 percent) reduction in peak flow and approximately reaching the pipe five minutes sooner than the current model. The volume remained similar between the model runs as well. This indicates minimal benefit in increased levels of detail of sewer infrastructure or refining a subcatchment into smaller, more detailed ones, in the current InfoWorks model. A previous evaluation conducted by the Omaha CSO Program looked at the Saddle Creek basin of
the CSS area. Sewer pipes down to 18” diameter were put into the model, a doubling of the total number of sewer pipes, and many new subcatchments were delineated. The modeling with the increased level of data took a substantial amount of time and generated similar results to that of modeling at a less detailed level.

The InfoWorks model, as mentioned earlier, is setup and designed for the Omaha CSO Program to be a planning-level model and is not calibrated to be utilized at a project design-level, which it has the capability to be. This means that the model has been optimized for modeling smaller storm events and intensities (1 and 2-year, 24-hour events), it does not consider any type of constraint on water entering the sewer, and is primarily focused on the outflow from the entire watershed at the end of the pipe. The lack of change in modeling outputs for subcatchment 202 does not conclusively determine that similar results will be seen in other subcatchments. The broad-natured (i.e. three types of surfaces) view of the core components in the current model (ISA, existing sewer system, and topography) precludes the model from generating simple results to depict a complex and dynamic system. InfoWorks, however, has the capacity and flexibility to be calibrated to a greater level of detail. For example, the EPA Stormwater Management Model (SWMM) can be added into the model and perform continuous simulations, different levels of pervious areas can be defined and applied (similar to the currently used two categories of ISA), and infiltration parameters within a subcatchment can be adjusted to reflect varying degrees of permeability of the pervious areas. Each of these areas of increased detail would likely improve the modeling results above what was demonstrated with this project and provide more confidence in its results. No matter what level of detail is utilized for modeling software, it is only as good as the data used. The quality of data and information should be thoroughly vetted prior to modeling.
Project Limitations

This project’s goals were focused on assessing the current planning-level ISA estimation and modeling of Omaha’s CSO Project as it relates to ISAs; as a result, understanding the limitations of this study are important. Listed below are the main limitations of this project:

1. The study area comprises only approximately 101 acres of the 26,600 total acres within the CSO study basins.
2. Aerial photographs from April 2010 were utilized during the digitalization process and would not encompass current changes within subcatchment 202.
3. The 1-year, 24-hour storm event was used as a representative event to establish peak flow and volume rates, instead of the 10-year, 24-hour storm event that is currently the storm event used for design in the Omaha CSO Program.

Conclusion

Utilizing zoning districts as a means to estimate ISA cover provides varying results. Accuracy is dependent on the scale of area studied at and the distribution of zoning districts within that area. In the case of Omaha’s subcatchment 202, the dominant zoning district is R4(35), medium-density single-family housing, covering approximately 74 percent of the subcatchment. The estimated ISA cover for this zoning district is 37.5%, and the actual ISA cover for subcatchment 202 was 32.6%, for a difference of -4.9%. This is a relatively accurate estimation of ISA cover, and because of it, the Omaha CSO Program’s overall ISA estimate for this subcatchment was good, +3.6% above actual ISA cover. Zoning districts, which often dictate the extent by which a given parcel can be covered in ISAs, in absence of other techniques or technology, can be a relatively reliable means to estimate ISA cover. As determined by the

Andy Szatko
Omaha CSO Program, utilizing the zoning districts maximum allowable ISA cover may be an excessive estimate for some zoning districts. Using the maximum percentage instills a level of confidence that estimates will likely not be understated. However, this can also result in inaccurate estimates, modeling, and excessively sized infrastructure, given the actual characteristics of the subcatchment. If requirements of zoning codes are to be used in estimating ISA cover, attention should be paid to the distribution of zoning districts in a subcatchment or a larger watershed. If the area is dominated by commercial zoning districts, where there is likely more variability in ISA cover between properties, a greater degree of detail in ISA cover may be needed to determine accurate estimates of ISA percent cover. Zoning codes are used in virtually all cities across the US and help determine how land is used. Thus, utilizing zoning districts in a comprehensive watershed management plan may be a viable option in addressing ISA cover and the associated runoff from it.

Another tool that is valuable and necessary when addressing infrastructure projects is modeling software. InfoWorks is the modeling software that the City of Omaha has used to plan and develop their long term control plan (LTCP) in meeting the EPA’s CSO Control Policy. The same model, within a 101 acre subcatchment of the CSS area, has demonstrated that ISA reduction can have a significant impact on reducing peak flows and volumes; for every one percent reduction in ISA there is approximately a two percent reduction in peak flow and volume. This linear relationship highlights the significance that ISAs have on the health and hydrology within a watershed and for those downstream. ISA reduction, while not structural in nature, is a strong component within the context of green infrastructure (GI) and achieving its goals. Required reduction of ISA would provide opportunities to connect fragmented green spaces, decrease stress on the sewer system, and provide a wide array of benefits to the Omaha’s
residents, above and beyond just addressing regulatory requirements. GI is being increasingly promoted by the EPA for utilization in meeting regulatory requirements, such as the CSO Control Policy.

With demonstrated substantial benefits associated with ISA reduction, going forward there should be an effort and focus in two principal areas to build upon from this project, 1) defining ISA reduction, and 2) developing a dynamic, integrated system that can track and monitor ISA reduction, GI strategies, and their associated benefits to achieve community and regulatory goals.

**Defining ISA Reduction**

Defining ISA reduction practices and methods is needed in order to establish minimum criteria for designers, engineers, and city officials to follow and ensure that the desired benefit is realized. ISA reduction can be achieved in two ways: physical removal and disconnection.

Physical removal is the permanent removal of ISAs and the rehabilitation of the impacted land area under and directly adjacent to it, restoring its historic permeability once again. The last part of that definition is important because of the likelihood of excessively compacted soils associated with former ISAs.

Disconnection of ISAs can be defined as allowing ISA to remain, but creating a diversion to intercept the normally unimpeded flow of runoff to the sewer system. Disconnection criteria could include a minimum flow distance through a permeable surface for ISA runoff to flow through, minimum characteristics for those permeable areas, and/or defining a storm event that needs to be managed on-site before flow can continue towards the sewer system. Establishing minimum criteria is necessary to avoid scenarios such as a downspout being routed through a four foot wide turf area with compacted soils and discharging directly onto the street. This could
be perceived as disconnected, but actually, it yields little if any discernible runoff reduction and therefore should not be recognized as a disconnection. Establishing these definitions in detail is beyond the scope of this project, but this should be one of the next steps.

**Developing an Integrated System**

As stated above, GI is increasingly being utilized as a cost-effective, multi-benefit, and effective strategy to mitigate stormwater runoff and CSOs by municipalities across the country and promoted by the EPA in addressing regulatory requirements. However, GI is often not utilized by municipalities because of preconceived perceptions and attitudes, an excessive amount of maintenance, and requiring that it needs to be located on public property to account for its benefits. One of the more common reasons given as to why GI is not utilized is its inability to address large storm events. It is true that GI is most effective when designed to handle small storm events, but in addressing those small events, it is able to address the vast majority of rainfall events for Omaha’s climate. Based on over 50 years of weather data from the Eppley Airfield weather station, 90% of all rain events (excluding events of 0.10 inch or less) are equal to or below 1.18 inches.

Each of these issues can be addressed through the development of an integrated monitoring and modeling system. InfoWorks has the capability to model BMPs and GI practices and strategies. Connecting that capability of InfoWorks with the tracking of GI and other BMPs being implemented as a result of Omaha’s post-construction stormwater ordinance, which are legally obligated to be maintained into perpetuity, then private property GI and BMPs benefits can be realized through an integrated system between the CSO and Stormwater Programs. Certainly one bioretention garden or green roof does not have a significant effect on the overall hydrology of an urban watershed, but 100 within a subcatchment could. And if one is removed,
the same can be said; it is only one and it will not have a significant impact in a watershed with 99 more. The current post-construction stormwater ordinance for Omaha is firmly in place and with land development constantly occurring, more GI and BMPs will be implemented. In developing this system, research should be conducted to establish the methodology of modeling GI and developing criteria for evaluating GI’s feasibility in a given subcatchment.

Having the ability to account for BMP benefits establishes a link between the Omaha CSO Program and the City of Omaha’s Stormwater Program. The implemented BMP practices, both on public and private property, and their benefits, can be recognized in a dynamic tracking system created through integration of these programs. With a dynamic tracking system, private property BMP applications can be inventoried, monitored, modified, and scheduled for maintenance if necessary. For example, if new property owners remove a BMP and the benefit for the sewer system is lost, it can be accounted for in the tracking system and proper action can be taken to restore its benefit to the system. BMPs will constantly be coming online as a result of Omaha’s half-inch ordinance. It is acknowledged that one rain or bioretention garden may be removed at any given time, but the net loss on the system will be minimal. The City is also in the midst of developing a new online portal to allow professionals to do all of their required documentation of projects (such as permits) online. This has and will allow for quick harvesting of data related to post-construction stormwater BMP performance. There are many variables that would need to be addressed and overcome if a dynamic tracking system were to be implemented, but the dots are there just waiting to be connected.

**In Summary**

Stormwater, at a minimum, is a $1.7 billion issue for the City of Omaha. Mayor Jim Suttle has traveled many times to Washington, DC, to speak on behalf of the U.S. Conference of
Mayors, where he serves as an active member on the Mayors Water Council and has been part of the discussions that led to EPA’s Integrated Planning Memorandum (a document indicating a move toward flexibility in meeting the CSO Control Policy Act and emphasizing utilization of green infrastructure practices). In order to address Omaha’s water and stormwater issues comprehensively and efficiently, an integrated approach to environmental and regulatory requirements is needed. Currently, regulations and management of water-related issues are addressed through independent programs; i.e. the CSO Control Policy Act is addressed through the Omaha CSO Program, and its LTCP and the MS4 permit is addressed through the Stormwater Program. The City would be well-served to better integrate these programs to address similar regulatory requirements together, share resources, and create more benefits for the citizens of Omaha.

Planning at a watershed scale or city scale brings together diverse stakeholders such as planners, landscape architects, engineers, politicians, horticulturalists, hydrologists, and citizens is vital in achieving a community’s stormwater goals. For example, this is partially being done currently through the Papillion Creek Partnership, with varied results and participation levels. This project highlights an important role for a planning-level effort in not only Omaha’s situation concerning stormwater and CSOs, but for other cities across the country that are trying to mitigate stormwater impacts from ISAs on the natural environment and meet regulatory requirements.

Strong efforts should be made to utilize current simulation models to incorporate ISA reduction and GI elements into them and increase the quality of the parameters inputted into them. Doing this will help find solutions outside of traditional gray infrastructure and provide
the best possible approach that incorporates many more benefits to the environment and the citizens, not only in Omaha, but also to communities across the country.
Appendix A - Definitions

Adapted from the University of Nebraska – Lincoln Extension publication, *Stormwater Management: Terminology*. EC701. 2010.

**Best Management Practice (BMP)** – A stormwater Best Management Practice (BMP) is a practice that is suitable for treating pollutants in stormwater runoff and/or reducing the volume of runoff. BMPs may include changing a cultural practice, such as reducing the amount of fertilizer used; or a structural practice, such as bioretention garden to collect, convey, and utilize water that would have otherwise run off the area. Stormwater BMPs are sometimes referred to as Stormwater Control Measures (SCMs).

**Bioretention** – The process of collecting stormwater in a treatment area consisting of soil and plant materials to facilitate infiltration and remove sediment and other contaminants through physical, chemical, and biological processes.

**Bioretention Garden** – A shallow depression in the landscape that is designed to capture and infiltrate stormwater runoff in a short period of time (usually 24-48 hours). The garden consists of engineered soils covering a portion of the bottom of the garden, an underdrain, and deep-rooted native/adapted plants.

**Clean Water Act (CWA)** – The CWA (1974), adapted from the Federal Water Pollution Control Act (1948), is federal legislation that provides the legal basis for the National Pollution Discharge Elimination System (NPDES). It established goals of eliminating releases of high amounts of toxic substances to receiving waters, eliminating additional water pollution sources, and ensuring that surface waters will meet the water quality standards for their intended uses.
Combined Sewer Overflow (CSO) – In a combined sewer system, during wet-weather events, the volume of runoff entering the sewer system can exceed the capacity of the waste water treatment facility, resulting in the excess volume to bypass the facility and discharge untreated into receiving waters.

Combined Sewer System (CSS) – Conveys domestic, commercial, and industrial wastewater as well as stormwater through a single pipe system to a publicly owned treatment facility.

Detention – The process of capturing and holding stormwater runoff for a period of time and then slowly releasing it to a receiving water or storm sewer system.

Disconnection – The disconnecting of stormwater runoff from direct entry into the storm drain system via roof downspouts, gutters, or paved surfaces.

Environmental Protection Agency (EPA) – A federal agency with the directive to protect human health and the environment. When congress passes an environmental law, the EPA implements the law by writing and enforcing regulations.

Evapotranspiration (ET) – The transport of water into the atmosphere from surface evaporation (soil, wet plant surfaces, etc.) and through plant processes (transpiration).

First Flush – The concept that runoff water from the first ½ to 1 inch of rainfall in a storm event is the most contaminated with pollutants. This is especially true when rainfall has not occurred for a long period of time.

Green – Is used to describe a process, structure, or idea that integrates environmental considerations, i.e. green buildings, green cities, green roofs, green industry, green collar jobs. Energy efficiency and environmental sustainability are key characteristics of being “green”.

Andy Szatko
**Hydrograph** – A graphical representation of water flow rate as a function of time. Hydrographs are used to describe water flow in streams, rivers, pipes, or other means of conveyance.

**Hydrologic Cycle** – The continuous movement of water through its liquid, solid, and gaseous phases above, on, and below the surface of the earth. This includes the processes of transpiration, evaporation, precipitation, condensation, and others.

**Impervious Surface Area (ISA)** – A surface or ground cover that has very limited or no capacity to absorb and/or infiltrate water. For this project, ISAs are defined as pavement, driveways, sidewalks, buildings, patios, pools, and recreational facilities. Compacted soils or other natural features that have no or limited infiltration were not included into the classified ISAs.

**Gray Infrastructure** – All components in traditional systems used to collect and convey stormwater runoff, such as curbs and gutters, storm drains, culverts, sewer pipes, and storage structures. The name is derived from the use of concrete to manufacture many of these components.

**Green Infrastructure** – The use of soil, plants, and other natural features to mimic natural processes to manage precipitation as close to where it falls as possible through reuse, infiltration, evaporation, and plant use. It varies in scale from site level (i.e. rain gardens, permeable pavement), community level (i.e. urban forests, conservation subdivision), and the watershed level (i.e. preservation, restoration, and connection of natural environments).

**Infiltration** – The process of water moving into the soil from the soil surface. Although sometimes used interchangeably with percolation, they describe different processes (see percolation).
**Invert** – The lowest elevation of a pipe, pond, or drainage facility where water is designed to flow out.

**Long Term Control Plan (LTCP)** – Provides guidance on the development and implementation of a long-term control plan and includes these essential components: 1) characterization, monitoring, and modeling of the combined sewer system, 2) public participation, 3) consideration of sensitive areas, 4) evaluation of alternatives to meet CWA requirements using either the "presumption approach" or the "demonstration approach", 5) cost/performance considerations, 6) operational plan, 7) maximizing treatment at the existing POTW treatment plant, 8) implementation schedule, and 9) post-construction compliance monitoring program.

**Low Impact Development (LID)** – A land development approach, utilized at the site or community level of green infrastructure that emphasizes site design and planning techniques that mimic the natural infiltration-based hydrology of the historic landscape. LID techniques generally manage stormwater by retaining it and infiltrating it on-site.

**Municipal Separate Storm Sewer System (MS4)** – A system of conveyances that is owned by a state, city, town, village, or other public entity that discharges to waters of the United States. The system (including storm drains, pipes, ditches, curbs, gutters, etc.) collects and conveys stormwater but is not part of a sewage treatment system.

**National Pollutant Discharge Elimination System (NPDES)** – A part of the Clean Water Act that requires point source dischargers of pollution to apply for and be granted a permit, often referred to as a General Permit. The EPA or state regulatory agencies set specific limits on the type and amount of pollutants that an entity can discharge into a waterbody based on the intended use of that waterbody.

Andy Szatko
Nebraska Department of Environmental Quality (NDEQ) – A state agency that enforces environmental regulations, administers environmental programs, and provides other assistance to protect the quality of Nebraska’s air, land, and water resources.

Nonpoint Source Pollution – Pollution (sediment, nutrients, pesticides, bacteria, heavy metals, etc.) that cannot be easily traced to one source or one property. Rather, small amounts accumulate from many sources and many properties, eventually reaching concentrations that may impair water resources. Nonpoint source pollution is one of the leading causes of water quality impairment.

Outfall – The point where runoff water exits a drainage system and discharges into a receiving waterbody.

Peak Flow Rate – The maximum flow of water during a storm event, usually expressed in cubic feet per second (cfs).

ISA Percent – Refers to the percentage of a given area that will not allow water to infiltrate. The greater the ISA percent cover, the more runoff that will occur.

Percolation – The flow of water within the soil profile once it has moved through the soil surface (see Infiltration)

Point Source Pollution – Pollution that enters the environment from a single point such as a factory, an oil or chemical spill, a municipal wastewater treatment plant, or a stormwater discharge pipe.

Rain Garden – A shallow landscape depression designed to capture and treat stormwater runoff. The plants and soil in a rain garden facilitate infiltration and pollutant removal. They are
designed to hold water for a short period of time (24-48 hours). Water collected in the garden will infiltrate, evaporate, transpire, or overflow as surface runoff. Rain gardens are similar to bioretention gardens, but do not have an underdrain.

**Receiving Waters** – Bodies of water or surface water systems that receive water from upstream sources.

**Retention** – The process of collecting and holding stormwater runoff.

**Runoff** – Runoff is excess rainfall, snowmelt, or irrigation water that flows over the surface of the land. It will eventually infiltrate into the ground, evaporate, or flow into a storm drain system, stream, river, lake, or other waterbody.

**Sanitary Sewer** – Conveyances that collect and transport wastewater (e.g. water from toilets, sinks, showers, etc.) from building plumbing systems to a wastewater treatment facility.

**Storm Sewer** – The inlets and conveyances that collect and transport stormwater runoff to a discharge point such as a stream, river, lake, or other waterbody. Most storm drainage is not treated before it is discharged.

**Stormwater** – Water from rainfall or snowmelt that does not immediately infiltrate into the soil.

**Subcatchment** - Subdivision of a drainage area that drains to a particular point, often applied to an inlet of a sewer system.

**Watershed** – The land area from which water drains to a particular waterbody such as a stream, river, or lake. Watersheds can range in size from less than an acre to several thousand square miles.
### Appendix B – Douglas & Sarpy Counties ISA Estimates by Zoning District

<table>
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<th>Zoning Code</th>
<th>District Name</th>
<th>PERCENT IMPERVIOUS (%)</th>
<th>Zoning Code</th>
<th>District Name</th>
<th>PERCENT IMPERVIOUS (%)</th>
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<td>RG-50 - Single Family - 5,000 Sq. Feet</td>
<td>41.25</td>
</tr>
<tr>
<td>RS-60</td>
<td>RS-60 - Single Family Residence - 6,000 Sq. Feet</td>
<td>41.25</td>
<td>RS-60</td>
<td>RS-60 - Single Family Residence - 6,000 Sq. Feet</td>
<td>41.25</td>
</tr>
<tr>
<td>RD-60</td>
<td>RD-60 - Single Family - 6,000 Sq. Feet</td>
<td>41.25</td>
<td>RD-60</td>
<td>RD-60 - Single Family - 6,000 Sq. Feet</td>
<td>41.25</td>
</tr>
<tr>
<td>R50</td>
<td>R50 - Two Family Residential District</td>
<td>41.25</td>
<td>R50</td>
<td>R50 - Two Family Residential District</td>
<td>41.25</td>
</tr>
<tr>
<td>RD-50</td>
<td>RD-50 - Two-Family Residential District</td>
<td>41.25</td>
<td>RD-50</td>
<td>RD-50 - Two-Family Residential District</td>
<td>41.25</td>
</tr>
<tr>
<td>RG-20</td>
<td>RG-20 - Single Family - 2,000 Sq. Feet</td>
<td>52.5</td>
<td>RG-20</td>
<td>RG-20 - Single Family - 2,000 Sq. Feet</td>
<td>52.5</td>
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<tr>
<td>RG-28</td>
<td>RG-28 - Single Family - 2,800 Sq. Feet</td>
<td>52.5</td>
<td>RG-28</td>
<td>RG-28 - Single Family - 2,800 Sq. Feet</td>
<td>52.5</td>
</tr>
<tr>
<td>RG-25</td>
<td>RG-25 - General Residential District (&gt;) 25k sq ft/living area</td>
<td>52.5</td>
<td>RG-25</td>
<td>RG-25 - General Residential District (&gt;) 25k sq ft/living area</td>
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<tr>
<td>RG-25-PD</td>
<td>General Residential District (&gt;) 25k sq ft/living area - Planned Development District</td>
<td>52.5</td>
<td>RG-25-PD</td>
<td>General Residential District (&gt;) 25k sq ft/living area - Planned Development District</td>
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<td>R8</td>
<td>High-Density Multiple-Family Residential District</td>
<td>R-4</td>
<td>R-4 - Multiple-Family Residential District</td>
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<td></td>
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<tr>
<td>MH</td>
<td>Mobile Home Residential District</td>
<td>37.5</td>
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<tr>
<td>LO</td>
<td>Limited Office District</td>
<td>75BN</td>
<td>BN - Neighborhood Business Zone</td>
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<tr>
<td>GO</td>
<td>General Office District</td>
<td>60O</td>
<td>O - Office District</td>
<td>60</td>
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</tr>
<tr>
<td>BG</td>
<td>General Business District - Floodplain District</td>
<td>67.5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>BGC</td>
<td>BGC - Planned General Business Center</td>
<td>67.5</td>
<td></td>
<td></td>
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<tr>
<td>BH</td>
<td>BH - Highway Business District</td>
<td>67.5</td>
<td></td>
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<tr>
<td>BHS</td>
<td>BHS - Highway Service Business District</td>
<td>67.5</td>
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<tr>
<td>BGM</td>
<td>BGM - Metropolitan General Business Zone</td>
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<tr>
<td>BNH</td>
<td>BNH - Heavy Neighborhood Business Zone</td>
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<tr>
<td>LC</td>
<td>Limited Commercial District</td>
<td>56.25</td>
<td>LC - Limited Commercial District</td>
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<td>CC</td>
<td>Community Commercial District</td>
<td>63.75</td>
<td>CC - Community Commercial District</td>
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<td>NBD</td>
<td>Neighborhood Business District</td>
<td>67.5C-3</td>
<td>C-3 - Highway Commercial/Office Park District</td>
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<td>GC</td>
<td>General Commercial District</td>
<td>67.5C-2</td>
<td>C-2 - General Commercial</td>
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<td>CH</td>
<td>Highway Commercial Services District</td>
<td>67.5HSB</td>
<td>HSB - Highway Service Business Zone</td>
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<td>CBD</td>
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<td>DS</td>
<td>Downtown Service District</td>
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<td>C-1 - Shopping Center District</td>
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<td>LI</td>
<td>Limited Industrial District</td>
<td>60-1</td>
<td>I-1 - Light Industrial</td>
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<td>SI</td>
<td>General Industrial District</td>
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<td>SI - General Industrial</td>
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<td>HI</td>
<td>Heavy Industrial District</td>
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<td>I-2 - Heavy Industrial</td>
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<td>AV</td>
<td>Aviation District</td>
<td>50OAFB</td>
<td>OAFB - Offut Air Force Base</td>
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<td>RR</td>
<td>Railroad</td>
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<td>PUD</td>
<td>Planned Unit Development District</td>
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<td>NC</td>
<td>Neighborhood Conservation District</td>
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<td>MD</td>
<td>Major Development District</td>
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<td>ED</td>
<td>Environmental Resources District</td>
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<td>FP/FW</td>
<td>Floodplain/Floodway Districts</td>
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<td>F - Floodway Zone or Selected Floodway</td>
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<td>PK</td>
<td>Parking District</td>
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<td>QUESTION</td>
<td>50</td>
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</tr>
</tbody>
</table>
Appendix C: Maps

Omaha CSO Subcatchment Area 202
Study Area

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Omaha CSO Subcatchment Area 202
Zoning Code Map with ISAs

Legend
- Community Commercial
- General Commercial
- Residential: Single Family 1
- Residential: Single Family 4(35)
- Residential: Multi-Family 7

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Omaha CSO Subcatchment Area 202
All Impermeable Surface Areas (ISAs)

Legend
- Road Pavement
- Buildings
- Driveways
- Sidewalks
- Patios
- Pools
- Parking Lots
- Recreational Facilities

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Omaha CSO Subcatchment Area 202
Buildings

Legend
- Buildings

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Omaha CSO Subcatchment Area 202
Pavement

Legend
- Road Pavement

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Omaha CSO Subcatchment Area 202
Sidewalks

Legend
- Sidewalks

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Omaha CSO Subcatchment Area 202
Patios, Pools, & Recreational Facilities

Legend
- Patios
- Pools
- Recreational Facilities

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Omaha CSO Subcatchment Area 202
2010 Infrared Aerial

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Omaha CSO Subcatchment Area 202
Zoning Code R4 ISA

Legend
- Parking Lots
- R4(35)
- Driveways
- Sidewalks
- Patios
- Buildings

Cold Creek

0 200 400 800 Feet
Omaha CSO Subcatchment Area 202
Zoning Code GC ISA

Legend
- Buildings
- GC
- Driveways
- Sidewalks
- Patios
- Parking lots

Legend
- Buildings
- GC
- Driveways
- Sidewalks
- Patios
- Parking lots

Legend
- Buildings
- GC
- Driveways
- Sidewalks
- Patios
- Parking lots

Legend
- Buildings
- GC
- Driveways
- Sidewalks
- Patios
- Parking lots

Legend
- Buildings
- GC
- Driveways
- Sidewalks
- Patios
- Parking lots
Appendix D – Subcatchment 202 Zoning District Descriptions from the Omaha Zoning Code

Omaha Zoning Code for Districts R1, R4, and R7

Sec. 55-121. - R1 single-family residential district (large lot).

Sec. 55-122. - Purpose.

The R1 single-family residential district is intended to provide for low-density residential neighborhoods, characterized generally by single-family dwellings on large lots with supporting community facilities. The R1 district provides for conditional approval of community facilities which generate larger quantities of traffic than residential uses. It is appropriate for established parts of the city, where it serves to preserve existing low-density environments; for newly developing, low-density neighborhoods; and for areas in which environmental considerations preclude the platting of smaller lots.

(Code 1980, § 55-122)

Sec. 55-123. - Permitted uses.

The following use types are permitted:

(a) Residential uses.
    Single-family (detached)
    Small group living (disabled)
    Day care (limited)
    Local utility services
    Park and recreation services
    Primary educational facilities

(b) Civic uses.

(Code 1980, § 55-123; Ord. No. 38198, § 6, 7-29-08)

Sec. 55-124. - Conditional uses.

The following use types are allowed, subject to approval of a conditional use permit, as provided by approval of a conditional use permit, as provided by section 55-883:

section 55-883:

(a) Civic uses.
    Administrative services
    Community recreation
    Cultural services
    Religious assembly

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Safety services  Secondary educational facilities
facilities

(Code 1980, § 55-124)

**Sec. 55-125. - Special permit uses.**

The following use types are allowed, subject to issuance of a special use permit by the city council, as issuance of a special use permit by the city council, as provided by section 55-884: provided by section 55-884:

(a) *Residential uses.*

Large group living

Small group living (nondisabled)

Single-family residential (attached)

(b) *Civic uses.*

Cemetery

Assisted living

(c) *Miscellaneous uses.*

Day care services (general)

Social clubs

Recreational clubs

Emergency residential care care

Broadcasting tower

Wind energy conservation system conservation system

(Code 1980, § 55-125; Ord. No. 34178, § 3, 5-6-97; Ord. No. 38198, § 6, 7-29-08)

**Sec. 55-126. - Site development regulations.**

Each site in the R1 single-family residential district shall be subject to the following site development regulations:

<table>
<thead>
<tr>
<th>Regulator</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot area</td>
<td>20,000 square feet minimum</td>
</tr>
<tr>
<td>Lot width</td>
<td>100 feet minimum</td>
</tr>
<tr>
<td>Site area/unit</td>
<td>20,000 square feet</td>
</tr>
<tr>
<td>Floor area ratio</td>
<td>No restriction</td>
</tr>
<tr>
<td>Height</td>
<td>35 feet</td>
</tr>
<tr>
<td>Building coverage</td>
<td>25 percent maximum</td>
</tr>
<tr>
<td>Impervious coverage</td>
<td>30 percent maximum</td>
</tr>
</tbody>
</table>

(Code 1980, § 55-126)
Sec. 55-127. - Additional regulations.

(a) Use of zero lot line in single-family detached dwellings. (See drawing following this section.) Within a common development, one interior side yard may be equal to zero for single-family detached residential use, subject to the following additional regulations:

1. The side yard opposite to the zero yard must equal at least 50 feet.

2. The normal side yard setback requirements must be maintained adjacent to any lot with an existing structure not within the common development, or not otherwise designated for zero lot line use.

3. An easement providing for maintenance of the zero lot line facade shall be filed with the county register of deeds and the permits and inspections division of the planning department at the time of application for a building permit.

(b) Lot clustering. Certain site development regulations may be modified in accordance with section 53-11 of the city's subdivision regulations and section 55-784 of this chapter, providing for cluster subdivisions.

(c) Single-family attached dwellings. Single-family attached residential is allowed by special permit subject to the following additional regulations:

1. The units must be located in a cluster subdivision, approved by the planning board and city council.

2. The side yard opposite to the common wall must equal at least 25 feet.

(Code 1980, § 55-127)

FIGURE 55-127(a). ZERO LOT LINE IN R1 DISTRICT

IMAGE NOT FOUND:\file1.municode.com09455-127.01.jpg

———

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Sec. 55-181. - R4 single-family residential district (high density).

Sec. 55-182. - Purpose.

The R4 single-family residential district is intended to provide for medium-density residential neighborhoods, characterized generally by single-family dwellings on small lots and including supporting community facilities. The R4 district allows for several development options, adaptable to both infill construction in established neighborhoods and to developing areas. It provides for conditional approval of community facilities with greater traffic generating characteristics than the permitted residential use. The R4 district is appropriate for established neighborhoods in the city, particularly those exhibiting relatively small lots, and in newly developing areas.

(Code 1980, § 55-182)

Sec. 55-183. - Permitted uses.

The following use types are permitted:

(a) Residential uses.  Day care (limited)  
   Single-family (detached)  Local utility services  
   Small group living (disabled)  Park and recreation services  
(b) Civic uses.  Primary educational facilities  
   Community recreation facilities  

(Code 1980, § 55-183; Ord. No. 38198, § 9, 7-29-08)

Sec. 55-184. - Conditional uses.

The following use types are allowed, subject to approval of a conditional use permit, as provided by approval of a conditional use permit, as provided by section 55-883:

section 55-883:

(a) Residential uses.  College and university facilities  
   Single-family (attached)  Cultural services  
(b) Civic uses.  Religious assembly  
   Administrative services  Safety services  

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Secondary educational facilities

(Code 1980, § 55-184)

**Sec. 55-185. - Special permit uses.**

The following use types are allowed, subject to approval of a special use permit by the city council, as approval of a special use permit by the city council, as provided by section 55-884:

provided by section 55-884:

(a) **Residential uses.**

Large group living

Small group living (nondisabled)

Townhouse residential, only within planned unit developments

(b) **Civic uses.**

Cemetery

(b) **Civic uses.**

Cemetery

(c) **Miscellaneous uses.**

Day care (general)

Emergency residential care

Recreational clubs

Social clubs

Assisted living

Wind energy conservation system

(Cause 1980, § 55-185; Ord. No. 34178, § 6, 5-6-97; Ord. No. 38198, § 9, 7-29-08; Ord. No. 38723, § 1, 5-11-10)

**Sec. 55-186. - Site development regulations.**

Each site in the R4 single-family residential district shall be subject to the following site development regulations:

<table>
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<tr>
<th>Regulator</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot area</td>
<td>5,000 square feet minimum</td>
</tr>
<tr>
<td>Lot width</td>
<td>50 feet minimum</td>
</tr>
<tr>
<td>Site area/unit</td>
<td>5,000 square feet</td>
</tr>
<tr>
<td>Floor area ratio</td>
<td>No restriction</td>
</tr>
<tr>
<td>Height</td>
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<tr>
<td>Building coverage</td>
<td>40 percent maximum</td>
</tr>
<tr>
<td>Impervious coverage</td>
<td>50 percent maximum</td>
</tr>
</tbody>
</table>

(Code 1980, § 55-186)

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Sec. 55-187. - Additional regulations.

(a) Use of zero lot line in single-family detached dwellings. (See drawing on page following this section.) Within a common development, one interior side yard may be equal to zero for single-family detached residential use, subject to the following additional regulations:

1. The side yard opposite to the zero yard must equal at least ten feet.

2. The normal side yard setback requirement must be maintained adjacent to any lot with an existing structure not within the common development, or not otherwise designated for zero lot line use.

3. An easement providing for maintenance of the zero lot line facade shall be filed with the county register of deeds and the permits and inspections division of the planning department at the time of application for a building permit.

(b) Lot clustering. Certain site development regulations may be modified in accordance with section 53-11 of the city’s subdivision regulations and section 55-784 of this chapter, providing for cluster subdivisions.

(c) Single-family attached dwellings. (See drawing on page following this section.) Single-family attached residential is allowed by conditional use permit, provided that the side yard opposite to the common wall must equal at least ten feet.

(d) Townhouse residential uses. Townhouse residential is allowed by special permit within a planned unit development, subject to the following additional regulations:

1. A maximum of four townhouse units may be attached in any one townhouse structure.

2. The site area per unit for any common townhouse development must equal at least 5,000 square feet.

3. The minimum size for any townhouse lot sold individually shall be 3,000 square feet.

4. The minimum width for any townhouse lot sold individually shall be 20 feet, except as provided in an approved cluster subdivision.
(5) The building and impervious coverage percentages are computed for the site of the entire development.

(e) **Front yard setback adjustment.** All new construction within areas zoned and developed with a 35-foot minimum front yard setback, prior to the effective date of this chapter [March 4, 1987], shall maintain that setback. These areas will be designated as R4(35) on the official zoning map of the city.

(Code 1980, § 55-187)

FIGURE 55-187(a). ZERO LOT LINE IN R4 DISTRICT

IMAGE NOT FOUND:

FIGURE 55-187(c). SINGLE-FAMILY ATTACHED IN R4 DISTRICT

IMAGE NOT FOUND:

**Sec. 55-241. - R7 medium-density multiple-family residential district.**

**Sec. 55-242. - Purpose.**

The R7 medium-density multiple-family residential district is intended to provide locations for medium-density multiple-family housing, in the approximate range of 40 dwelling units per acre. It provides for the integration of multiple-family housing with lower density housing types. In addition, the R7 district provides for the inclusion of limited office and commercial uses by special permit within principally residential developments, subject to specific standards governing land use intensity and compatibility. This allows for a mixture of compatible uses within appropriate neighborhoods.

The R7 district applies to established neighborhoods where moderately high densities are appropriate, transitional areas between lower intensity and higher intensity uses, mixed use neighborhoods, and developing multiple-family areas.

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Sec. 55-243. - Permitted uses.

The following use types are permitted:

(a) Residential uses.  Secondary educational facilities

Single-family residential (detached)

Single-family residential (attached)

Duplex residential

Two-family residential

Townhouse residential

Multiple-family residential

Assisted living

Small group living (disabled)

Small group living (nondisabled)

(b) Civic uses.

College and university facilities

Community recreation

Day care (limited)

Day care (general)

Emergency residential care

Local utility services

Park and recreation services

Primary educational facilities

Religious assembly
Sec. 55-244. - Conditional uses.

The following use types are allowed, subject to approval of a conditional use permit, as provided by section 55-883:

(a) Civic uses.

Administrative services
Convalescent services
Cultural services
Safety services
Social clubs

Sec. 55-245. - Special permit uses.

The following use types are allowed, subject to approval of a special use permit by the city council, as provided by section 55-884:

(a) Residential uses.

Large group living

(b) Civic uses.

Recreational clubs
Transitional living

(c) Office uses.

General offices

(d) Commercial uses.

Bed and breakfast inns

(e) Miscellaneous uses.

Consumer convenience services
General retail sales
Personal services
Restaurant (limited)
Broadcasting tower
Wind energy conservation system

(Code 1980, § 55-243; Ord. No. 34178, § 9, 5-6-97; Ord. No. 38198, § 13, 7-29-08)

(Code 1980, § 55-244; Ord. No. 38198, § 13, 7-29-08)

(Code 1980, § 55-245; Ord. No. 37095, § 2, 7-26-05; Ord. No. 38198, § 13, 7-29-08)
*See additional regulations, section 55-247(c)(2)

All uses:

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<td>75 feet maximum</td>
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<td>Building coverage</td>
<td>60 percent maximum</td>
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<td>Impervious coverage</td>
<td>70 percent maximum</td>
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</table>

(Code 1980, § 55-246; Ord. No. 38198, § 13, 7-29-08)

Sec. 55-247. - Additional regulations.

(a) Use of zero lot line in single-family detached dwelling. Within a common development, one interior side yard may be equal to zero for single-family detached residential use, subject to the following additional regulations:

   (1) The side yard opposite to the zero yard must equal at least seven feet.

   (2) The normal side yard setback requirement must be maintained adjacent to any lot with an existing structure not within the common development, or not otherwise designated for zero lot line use.

   (3) An easement providing for the maintenance of the zero lot line facade shall be filed with the county register of deeds and the permits and inspections division of the planning department at the time of application for a building permit.

(b) Two-family residential uses. Two-family residential use is allowed, subject to the following additional regulations:

   (1) The second dwelling unit shall be located to the rear of the site and shall be separated from the front dwelling unit by a minimum of 20 feet.

   (2) The second dwelling unit shall be served by a paved driveway at least ten feet in width.

(c) Townhouse residential uses. Townhouse residential is allowed, subject to the following additional regulations:

   (1) Building and impervious coverage percentages are computed for the site of the entire

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are computed for the site of the entire townhouse development.

(2) The minimum width of any townhouse lot sold individually shall be 20 feet, except as provided in an approved cluster subdivision.

(d) Lot clustering. Certain site development regulations may be modified in accordance with section 53-11 of the city’s subdivision regulations and section 55-784 of this chapter, providing for cluster subdivisions.

(e) Office and commercial uses. Certain office and commercial uses are allowed as special permit uses within predominantly residential developments in the R7 district, subject to the following additional regulations. Additional conditions may be required as part of approval of a special use permit.

(1) Office and commercial uses may be located within the same building as residential use or within separate buildings incorporated into a mixed use common development.

(2) Office and commercial uses combined shall not comprise more than 25 percent of the gross floor area within any single mixed use common development.

(3) Each 200 square feet of office or commercial use shall be counted as one dwelling unit for the purpose of computing permitted density on the site.

(4) Each development incorporating office or commercial uses shall provide a landscaped bufferyard of no less than 20 feet adjacent to any lot within a zoning district of lower intensity. Landscaping shall be subject to the provisions of sections 55-718 through 55-722 of this chapter.

FIGURE 55-247(e). OFFICE AND COMMERCIAL USES IN R7 DISTRICT

Example: A property owner owns a one-acre parcel and is interested in developing the land with a mixture of residential and office uses. The owner wants to compute the possible uses for the site.

Answer: In the R7 district, each site must provide a minimum of 1,000 square feet per housing unit. This means that the permitted residential density on the
means that the permitted residential density on the owner's site is 43.5 units.

Each 200 square feet of office or commercial space counts as one housing unit. The chart below describes the possible mixtures that the owner can place on the site:

<table>
<thead>
<tr>
<th>Office or Commercial Area* (square feet)</th>
<th>Allowed Residential Units</th>
</tr>
</thead>
<tbody>
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<td>0</td>
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</tr>
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<td>1,000</td>
<td>38.5</td>
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<td>2,000</td>
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<td>3,000</td>
<td>28.5</td>
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<td>4,000</td>
<td>23.5</td>
</tr>
<tr>
<td>5,000</td>
<td>18.5</td>
</tr>
<tr>
<td>6,000</td>
<td>13.5</td>
</tr>
</tbody>
</table>

*Area used for office or commercial purposes cannot exceed 25 percent of the total building area on the site.

(Code 1980, § 55-247; Ord. No. 38198, § 13, 7-29-08)
Omaha Zoning Code for Districts CC and GC

Sec. 55-342. - General purpose.

The commercial districts are included in this chapter to achieve the following objectives:

(a) To reserve appropriately located area for a broad range of commercial services in the Omaha metropolitan area.

(b) To recognize the environmental characteristics of different types of commercial development and to establish appropriate land use regulations for each type.

(c) To ensure adequate access, off-street parking and loading, and other service features for commercial development.

(d) To promote flexibility in the design and development of commercial services, while maintaining high standards of design and ensuring neighborhood compatibility.

(e) To facilitate planning for urban services appropriate to anticipated traffic, service requirements, and commercial needs generated by the city and its neighborhoods.

(Code 1980, § 55-342)

Sec. 55-361. - CC community commercial district.

Sec. 55-362. - Purpose.

The CC community commercial district is intended for commercial facilities which serve the needs of several neighborhoods. Allowed commercial and office uses are generally compatible with nearby residential areas. However, uses allowed in the CC district may generate more traffic and have more effect on residential neighborhoods than those allowed in the less intense LC district. Site development regulations are designed to minimize these effects. CC districts usually to minimize these effects. CC districts usually require access from major streets, primarily minor and major arterials. CC districts are most appropriate at major street intersections, at the edge of residential areas, or at the junction of several neighborhoods, and in the junction of several neighborhoods, and in other areas appropriate for well-developed commercial areas appropriate for well-developed commercial facilities. The CC district, combined with the MD major development overlay district, provides further facilities. The CC district, combined with the MD major development overlay district, provides further...
major development overlay district, provides further thorough review of commercial projects that may be regional in scope. A conditional review process for large projects further assures high development standards for planned commercial facilities.

(Code 1980, § 55-362)
Sec. 55-363. - Permitted uses.

The following use types are permitted:

(a) Office uses.
   - Financial services
   - General offices
   - Medical offices

(b) Commercial uses.
   - Automotive washing
   - Bed and breakfast inns
   - Building maintenance services
   - Business support services
   - Business or trade school
   - Cocktail lounge
   - Communications services
   - Consumer convenience services
   - Consumer repair services
   - Food sales (limited)
   - Food sales (general)
   - Food sales (convenience)
   - Funeral services
   - General retail sales
   - Hotel/motel
   - Indoor entertainment
   - Liquor sales
   - Pawnshop services

   Personal improvement services
   - Personal services
   - Pet services
   - Restaurant (drive-in)
   - Restaurant (limited)
   - Restaurant (general)
   - Service station
   - Veterinary services

(c) Civic uses.
   - Administrative services
   - College and university facilities
   - Cultural services
   - Day care (limited)
   - Day care (general)
   - Emergency residential care
   - Guidance services
   - Hospital services (limited)
   - Hospital services (general)
   - Local utility services
   - Park and recreation services
   - Postal facilities
Recreational clubs
Religious assembly
Secondary educational facilities
facilities
Social clubs

(Code 1980, § 55-363; Ord. No. 33545, § 10, 5-2-95; Ord. No. 37095, § 2, 7-26-05)
Ord. No. 37095, § 2, 7-26-05)

Sec. 55-364. - Conditional uses.

The following use types are allowed, subject to approval of a conditional use permit, as provided by approval of a conditional use permit, as provided by section 55-883:

(a) Residential uses.

Duplex residential
Multiple-family residential
Single-family (attached)
Single-family (detached)
Townhouse residential
Two-family residential
Small group living (disabled)
Small group living (nondisabled)

(b) Civic uses.

Primary educational facilities
Public assembly

(c) Commercial uses.

Safety services
Agricultural sales and service service
Auto repair services
Indoor sports and recreation
Laundry services
Research services

(d) Parking.

Paking structure
Surface parking

(e) Industrial uses.

Warehousing and distribution (limited).
Warehousing and distribution (limited).

(Code 1980, § 55-364; Ord. No. 33545, § 11, 5-2-95; Ord. No. 38198, § 19, 7-29-08)

Sec. 55-365. - Special permit uses.

The following use types are allowed, subject to approval of a special use permit by the city council, as approval of a special use permit by the city council, as provided by section 55-884:

Andy Szatko
provided by section 55-884:

(a) Residential uses.
   Large group living

(b) Civic uses.
   Transitional living

(c) Commercial uses.
   Automotive rentals
   Automotive sales
   Construction sales and service
   Convenience storage
   Exterminating services

(d) Transportation uses.
   Transportation terminal

(e) Industrial uses.
   Custom manufacturing

(f) Miscellaneous uses.
   Broadcasting tower
   Wind energy conservation system

(Code 1980, § 55-365; Ord. No. 38198, § 19, 7-29-08)

Sec. 55-366. - Site development regulations.

Each site in the CC community commercial district shall be subject to the following site development regulations:

<table>
<thead>
<tr>
<th>Regulator</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot area</td>
<td>5,000 square feet minimum</td>
</tr>
<tr>
<td>Lot width</td>
<td>50 feet minimum</td>
</tr>
<tr>
<td>Floor area ratio</td>
<td>1.0 maximum</td>
</tr>
<tr>
<td>Front yard</td>
<td>25 feet minimum</td>
</tr>
<tr>
<td>Street side yard</td>
<td>15 feet minimum</td>
</tr>
<tr>
<td>Interior side yard</td>
<td>No requirement</td>
</tr>
<tr>
<td>Rear yard</td>
<td>15 feet</td>
</tr>
<tr>
<td>Height</td>
<td>60 feet maximum; 45 feet maximum where building is within 100 feet of property classified as R6 or lower intensity district</td>
</tr>
<tr>
<td>Building coverage</td>
<td>60 percent maximum</td>
</tr>
<tr>
<td>Impervious coverage</td>
<td>85 percent maximum</td>
</tr>
</tbody>
</table>
Sec. 55-367. - Additional regulations.

(a) Residential uses. Residential uses are allowed in the CC district as a special or conditional use subject to the site development regulations for residential uses in the R7 medium-density multiple-family district. Other conditions may be required as part of approval of a special or conditional use permit.

(b) Large projects.

(1) Projects proposed in the CC district for sites of four acres and over or including a building floor area of 40,000 square feet and over are subject to site plan approval, as set forth in section 55-882. Site plan approval is further required for projects involving phasing or expansion when the total project meets or exceeds these limits.

(2) Any project encompassing an area of ten acres or over within the CC district shall require a special permit as set forth in section 55-884. A special permit is further required for projects involving phasing or expansion when the total project is equal to or greater than ten acres.
Sec. 55-403. - Permitted uses.

The following use types are permitted:

(a) Office uses.
   Financial services
   General offices
   Medical offices
(b) Commercial uses.
   Agricultural sales and service
   Automotive washing
   Auto rental
   Auto repair services
   Bed and breakfast inns
   Building maintenance services
   Business support services
   Business or trade school
   Cocktail lounge
   Communications services
   Construction sales and services
   Consumer convenience services
   Consumer repair services
   Equipment rental and sales
   Equipment repair services
   Exterminating services
   Food sales (limited)
   Food sales (general)
   Food sales (convenience)
   Funeral services
   General retail sales
   Hotel/motel
   Indoor entertainment
   Indoor sports and recreation
   Laundry services
   Liquor sales
   Pawnshop services
   Personal improvement services
   Personal services
   Pet services
   Research services
   Restaurant (drive-in)
   Restaurant (limited)
   Restaurant (general)
   Service station
   Veterinary services
(c) Transportation uses.
   Transportation terminal
(d) Industrial uses.
| Custom manufacturing                                      | (e)  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(limited)</td>
<td></td>
</tr>
<tr>
<td>Civic uses.</td>
<td></td>
</tr>
<tr>
<td>Administrative services</td>
<td></td>
</tr>
<tr>
<td>Hospital services (general)</td>
<td></td>
</tr>
<tr>
<td>(general)</td>
<td></td>
</tr>
<tr>
<td>Local utility services</td>
<td></td>
</tr>
<tr>
<td>Cultural services</td>
<td></td>
</tr>
<tr>
<td>Park and recreation services</td>
<td></td>
</tr>
<tr>
<td>services</td>
<td></td>
</tr>
<tr>
<td>Day care (limited)</td>
<td></td>
</tr>
<tr>
<td>Postal facilities</td>
<td></td>
</tr>
<tr>
<td>Day care (general)</td>
<td></td>
</tr>
<tr>
<td>Public assembly</td>
<td></td>
</tr>
<tr>
<td>Emergency residential care</td>
<td></td>
</tr>
<tr>
<td>Recreational clubs</td>
<td></td>
</tr>
<tr>
<td>Guidance services</td>
<td></td>
</tr>
<tr>
<td>Religious assembly</td>
<td></td>
</tr>
<tr>
<td>Hospital services (limited)</td>
<td></td>
</tr>
<tr>
<td>Social clubs</td>
<td></td>
</tr>
</tbody>
</table>

(Code 1980, § 55-403; Ord. No. 33545, § 14, 5-2-95; Ord. No. 36246, § 2, 4-29-03; Ord. No. 37095, § 2, 7-26-05)

Sec. 55-404. - Conditional uses.

The following use types are allowed, subject to approval of a conditional use permit, as provided by approval of a conditional use permit, as provided by section 55-883:

section 55-883:
(a) *Residential uses.*

Single-family (detached)

Single-family (attached)

Duplex residential

Two-family residential

Townhouse residential

Multiple-family residential

Large group living

Small group living (disabled)

Small group living (nondisabled)

(b) *Civic uses.*

College and university facilities

Maintenance and service facilities

(c) *Commercial uses.*

Kennels

Outdoor sports and recreation

Surplus sales

(d) *Parking uses.*

Parking structure

Surface parking

(e) *Industrial uses.*

Warehousing and distribution (limited)

(Code 1980, § 55-404; Ord. No. 33545, § 15, 5-2-95; Ord. No. 38198, § 21, 7-29-08)

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**Sec. 55-405. - Special permit uses.**

The following use types are allowed, subject to approval of a special use permit by the city council, as provided by section 55-884:

(a) *Civic uses.*

Transitional living

Vehicle storage

Maintenance and service facilities

(b) *Commercial uses.*

Auto sales

Body and fender repair services

(c) *Miscellaneous uses.*

Convenience storage

Broadcasting tower

Wind energy conservation system

(Code 1980, § 55-884; Ord. No. 33545, § 15, 5-2-95; Ord. No. 38198, § 21, 7-29-08)
Sec. 55-406. - Site development regulations.

Each site in the GC general commercial district shall be subject to the following site development regulations:

<table>
<thead>
<tr>
<th>Regulator</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot area</td>
<td>5,000 square feet minimum</td>
</tr>
<tr>
<td>Lot width</td>
<td>50 feet minimum</td>
</tr>
<tr>
<td>Floor area ratio</td>
<td>2.0 maximum</td>
</tr>
<tr>
<td>Front yard</td>
<td>The greater of 15 feet or 50 feet from the center line of the fronting street</td>
</tr>
<tr>
<td>Street side yard</td>
<td>The greater of 15 feet or 50 feet from the center line of the fronting street</td>
</tr>
<tr>
<td>Interior side yard</td>
<td>No requirement</td>
</tr>
<tr>
<td>Rear yard</td>
<td>15 feet</td>
</tr>
<tr>
<td>Height</td>
<td>75 feet maximum; 45 feet maximum where building is within 100 feet of property classified as R6 or a lower intensity district</td>
</tr>
<tr>
<td>Building coverage</td>
<td>70 percent maximum</td>
</tr>
<tr>
<td>Impervious coverage</td>
<td>90 percent maximum</td>
</tr>
</tbody>
</table>

Sec. 55-407. - Additional regulations.

(a) Residential uses. Residential uses are allowed as a conditional use in the GC district, subject to the site development regulations for residential uses in the R8 high-density multiple-family residential district. Other conditions may be required as part of approval of a conditional use permit.

(b) Large projects.

(1) Projects proposed in the GC district for sites of four acres and over or including a building floor area of 40,000 square feet and over are subject to site plan approval, as set forth in section 55-882. Site plan approval is further required for projects involving phasing or expansion when the total project meets or exceeds these limits.
(2) Any project encompassing an area of ten acres or over within a GC district shall require a special permit as set forth in section 55-884. A special permit is further required for projects involving phasing or expansion when the total project is equal to or greater than ten acres.

(Code 1980, § 55-407)
Bibliography


