Floyd River Drainage Mitigation

FOR THE LEEDS NEIGHBORHOOD IN SIOUX CITY, IOWA

REPORT PREPARED FOR THE CITY OF SIOUX CITY.

SWAG & K Associates

THE UNIVERSITY OF IOWA | SENIOR DESIGN APRIL 31, 2015

BENJAMIN ADEY, JACLYN GUTMAN, BRIAN KRUSE, ISAAC SCHROCK, AND ARYN WEBSTER

The University of Iowa
IOWA INITIATIVE
FOR SUSTAINABLE COMMUNITIES

Executive Summary

The enclosed design report provided by SWAG & K Associates addresses the Floyd River Drainage Mitigation Project. Project boundaries include the drainage basins immediately west of the Floyd River between 28th and 41st Street. To alleviate devastating floods from the Floyd River, control measures including channelization, levees and floodgates were authorized and installed by the US Army Corps of Engineers. The drainage outlet gates must be closed during flood stages, which causes ponding in the Leeds neighborhood during severe rainfall events.

The design proposed by SWAG & K Associates is comprised of detention basins, pump stations and green alternative stormwater management practices that remove the classification of Sioux City residents from FEMA-mandated areas requiring flood insurance. SWAG & K Associates designed a mitigation strategy to accommodate a 100-year 2-hour design storm, a total of 4.06 inches of precipitation over the entire 2,230 acre watershed.

Fourteen detention basins were designed to maximize storage capacity while minimizing downstream risk, berm height and berm width. Detention basins will temporarily store 29.34 million gallons of stormwater in order to extend the hydrograph. The detention basins were located at optimal in-channel locations in the agricultural region that were hydraulically above the Leeds neighborhood. Dry detention basins were chosen for design to maximize potential storage volumes and minimize inundated properties.

The total projected runoff volume for the design storm was less than the storage and ponding capacity of the detention basin system. Pump stations, although not necessary to prevent immediate Leeds neighborhood ponding, will still be required in order to design for projected scenarios. At minimum, the pump station must accommodate the expected orifice flow from the bottom drain in the lower three detention basins; a total of 4,215 gallons per minute (gpm). The designed pump station consists of a 5,000 gpm pump and will take approximately 14 days to fully empty the runoff from the temporary ponding area. Because the pump stations will be adjacent to the existing Floyd River levee, SWAG & K recommends a design similar to other pump stations designs developed for the USACE.

The total projected construction costs are estimated at approximately $1.6 million dollars, and the annual operations and maintenance costs are predicted to be approximately $70,000 dollars annually for all components of this design.

The final design proposes the addition of rain gardens along roadway easements for a number of reasons. Rain gardens in the right-of-way will control the roadway runoff for minor rainstorms, naturally filter the contaminants, improve groundwater recharge and increase property values by improving the neighborhood aesthetics. The Leeds neighborhood will need a minimum of 25 rain gardens (100-300 sq. ft.) to handle the runoff generated from a 2-year, 2-hour rainstorm event.

SWAG & K Associates believes this design will meet the overall goal of the project with a minimal negative impact on the surrounding area. However, before a final design plan set is published, SWAG & K Associates recommends comprehensive flow modeling to be applied to this design solution to accurately determine flow rates, hydraulic connectivity between basins, hydrographs, real-time ponding fluctuations with pump rates and subsequent design storms. While this type of software was not available, SWAG & K Associates is confident these design methods will reduce or eliminate flood insurance rates for property owners within the Leeds neighborhood by controlling the extent of ponding when the Floyd River floodgates are closed.

1. Introduction

Located at the confluence of the Missouri and Floyd rivers, the area now occupied by Sioux City has experienced centuries of flooding and since the establishment of Sioux City in 1854, major floods have devastated the community time and time again. The Northside Leeds neighborhood is no exception to the historic and seasonal concern of flooding, and experienced occasional flooding until the Floyd River was channelized and the current levee system was installed. The levees have been successful in protecting the Leeds neighborhood from high water on the Floyd River since their construction, but a recent levee recertification process led to major financial changes for the residents of the Leeds neighborhood.

The levee recertification process included a FEMA-approved reassessment of the extent of the floodplain under 100-year design storm conditions. The methodology included new assessment techniques and approaches. Specifically, the possibility of localized rainfall and subsequent ponding behind the levee during a floodgate closure on the Floyd River was considered. This consideration extended the overall area of the floodplain into the Leeds neighborhood. Extension of the floodplain caused many more businesses and homeowners to fall within the 100-year FEMA floodplain insurance maps, requiring every affected property owner to pay high flood insurance rates.

The city of Sioux City desires to alleviate the economic burden of required flood insurance by improving and modifying the civil infrastructure in and around the Leeds neighborhood. SWAG & K Associates was hired to develop alternative infrastructure plans that address the overall goal of removing the Leeds neighborhood from the FEMA floodplain insurance maps. The final design detailed herein uniquely and economically addresses these issues with a balance of engineering design and constructability in mind.

2. Problem Statement

This final report details SWAG & K Associates' official solutions in response to RFP#05-spr2015, originally solicited by the Instructors of Project Design and Management on behalf of the city of Sioux City. The accepted proposal between the Instructors and SWAG & K Associates included engineering design and evaluation services including dynamic modeling of flood protection measures, design of culverts and open channels, modifications to the existing storm network and investigation of piping and overflows of the berms and project cost estimates as deemed necessary and justified by SWAG & K Associates. These services were provided with the mutually-agreed intent of mitigating floodplain ponding concerns and floodplain insurance rates for the Leeds neighborhood of Sioux City.

SWAG & K Associates focused on this core issue and developed unique and cost-effective solutions that will enable residences within the Leeds neighborhood to be removed from the high flood insurance risk zone on FEMA floodplain maps. The unique solutions detailed herein provide distinct alternatives to the plans prepared by HR Green for the City of Sioux City, rather than enhancing or more deeply investigating HR Green's plans. Unique solutions were developed apart from HR Green's plans for two distinct reasons. Primarily, enhancing HR Green's engineering design was determined to be professionally inappropriate, unethical and unsafe without a complete review of HR Green's design. And secondly, SWAG & K believed there to be excellent alternative solutions that were not addressed in HR Green's recommendation. This report addresses the options presented within SWAG & K's original proposal, provides comparisons and a final recommendation.

2.1 Design Objectives

The Leeds neighborhood within the city of Sioux City, IA has experienced many significant flood events, due to its' proximity to the Floyd River. To alleviate the possibility of flooding, the US Army Corps of Engineers channelized the Floyd River and installed levees and floodgates to protect the neighborhood. However, recent improvements to the FEMA floodplain maps have classified many properties in the Leeds neighborhood as a high-risk flood area, even though they are protected by the levee. These levee-protected properties are classified as high-risk because ponding behind the levee can occur during local rainfall events that coincide with flood conditions on the Floyd River. During high discharges or flooding conditions, the levees and floodgates protect the neighborhood, but don't allow stormwater to enter the channel, causing ponding scenarios during local rainfall events. Design solutions must be developed to mitigate the threat of ponding behind the levee and reduce flood insurance rates for the Leeds neighborhood.

2.2 Approaches

SWAG & K Associates unique design options and final design were borne from different starting perspectives. Two options address the root causes (i.e. land use) of the ponding on watershed scale, while the third option focuses only the symptom (i.e. ponding). The final design encompasses both these approaches by adjusting land-use practices in the rural portion of the watershed, implementing alternative stormwater infiltration structures in the urban portion of the watershed and removing excess ponded water. The multi-faceted approach requires a broad array of design guides, similar case-study projects and appropriate permits to address and inform each aspect of the design.

A number of design guides and technical resources were utilized in the process; Iowa DNR Stormwater Management Manual, Iowa DNR Technical Bulletin Number 16: Design Criteria and Guidance for Iowa Dams, NRCS Design Storm and SCS Curve Runoff Number Method (insert other design manuals or guides here). Additionally, a number of projects with similar goals were studied to inform and guide the design process. These projects included the Flood Risk Management Project Feasibility Study for the Cedar River in Cedar Rapids, Iowa, and the Operations and Maintenance Manual for the Big Sioux River and Floyd River Mitigation Projects in Sioux City, Iowa.

Before construction may begin, the final design must be vetted by a number of regulatory agencies through the permitting process. The agencies that will require a permit to complete this project are the City of Sioux City, the Iowa DNR and the US Army Corps of Engineers. All of the agencies require that a permit application include the finalized design plan set, permit application, and application fee. A number of the permits must be completed and approved before others may be applied for; these permits are denoted in the list below. Please see Section 5, Final Design Details and the permitting appendix for more information and links to online permit applications.

List of Required Permits for Final Project Design

- Sioux City Grading Permit (The City of Sioux City, contingent on approved Iowa DNR NPDES General Permit)
- NPDES General Permit (Iowa DNR)
- Protecting Iowa Waters - Joint Permit Section 401 (Iowa DNR, USACE - Omaha District, National Flood Insurance Program)
- Section 404 Permit (USACE, contingent on application for Joint Permit Section 401)
- Section 408 Permit (USACE, contingent on application for Joint Permit Section 401)

2.3 Constraints

Three common constraints to flood management projects include cost, space and available time. The budget for this project must not be exceeded, which limits the different types of design alternatives that can be implemented. Another constraint that must be considered includes the amount of space allotted for this project. The Leeds neighborhood is well-developed and the agricultural sections located in the upper portion of the watershed are not ideal for dry detention basins. Proposed alternatives must be adapted to fit within the Leeds neighborhood and agriculture section in order to coordinate with the specific characteristics of the area. In addition, there are two existing railroad lines that run parallel to the levee that must also be considered. Existing railroads must be considered for all proposed designs as they cannot be moved, and modifications near or underneath railroads are difficult to approve and very expensive to construct. SWAG & K’s proposed design avoided all modifications to the railroad as it would add a significant and unnecessary burden to the project design, significantly increase capital outlay costs and prove very difficult to construct. Time is a standard constraint, and this project is no exception. The City of Sioux City client desires this project to be completed on a reasonable timescale.

Specific constraints identified for this project include aesthetics, environmental considerations, trail usage, and business concerns. Since this project is within the limits of Sioux City, and especially the Leeds neighborhood, aesthetics are a very important aspect for this project.

Proposed construction within this area must be accepted by the community. Environmental concerns for this project also represent an important constraint. As the project is located within the Floyd River floodplain, this project also includes several existing stormwater drains that lead directly to the river. Because the project will occur within a floodplain and affect the natural environment specific permits from various agencies will be required for the design and construction of this project. On the project site near the levee, an existing trail must be taken into account when considering the project design. Additionally, the existing trail will be modified in conjunction with this this project, and the two designs should not impact the other. The final constraint represents the existing businesses along Floyd Boulevard and proposed business properties along the railroad corridor. These businesses will require specific considerations during the construction phase and maintenance of proposed designs.

2.4 Challenges

The project location along the Floyd River represents a major challenge for this project. During seasonal flood periods the levee's floodgates are closed, creating a ponding problem within the Leeds neighborhood. The proposed project must be able to control the ponding from 10-year and 100-year rainfall events while the floodgates that drain the local stormwater runoff are closed. Another challenge of this project includes the potential environmental impacts. Since the stormwater drainage of the neighborhood leads to the river, the final stormwater ponding will occur adjacent to the levee system. Therefore, the alternatives considered for the project must be environmentally sound as they will be in contact of the river system and could affect the existing levee system. The final and most important challenge is to reduce the ponding to a specific level that will be recognized by FEMA. Current ponding of the 100-year local rainfall event causes ponding behind the levee and requires some areas of the neighborhood to purchase expensive flood insurance. The project alternatives need to remove or reduce the flooding in a manner approved by FEMA in order to remove the boundaries of the flood stage map from the neighborhood. The final design must modify the floodplain boundaries in order to eliminate the FEMA-mandated flood insurance requirements for homeowners and property owners within the Leeds neighborhood.

2.5 Societal Impacts

Implementing the design outlined in this report will provide distinct and beneficial economic, environmental and societal impacts across the Leeds neighborhood, city of Sioux City and state of Iowa. The final multi-faceted design solution will address the ponding and insurance issue, as well as improve stormwater management for small scale rainstorms. The dual nature of the final design yields a diverse array of societal benefits, which can be separated according by design component. For example, implementing neighborhood-wide rain gardens will provide different benefits than constructing detention basins and large volume pump stations. To fully address unique benefits and impacts derived from both components, the societal impacts will be detailed separately for both portions of the design.

Construction of the detention basins and pump stations will yield numerous positive impacts, with minimal negative or neutral effects. Fundamentally, this system will meet requirements set forth by the Federal Emergency Management Agency (FEMA) and National Floodplain Insurance Program (NFIP) and remove personal property and businesses from the floodplain. Removal from the floodplain insurance maps will eliminate expensive and compulsory flood insurance for homeowners and businesses within the Leeds neighborhood. The comprehensive flood protection and elimination of mandatory flood insurance will boost property values currently in the FEMA floodplain and permit the city of Sioux City to continue developing the commercial property in the neighborhood. Specifically, the final design ponding elevation of 1107 will easily facilitate commercial development of key properties along Floyd Boulevard and near the intersection with Outer Drive, because little to no will be required to elevate new businesses above the maximum pond level. From a construction perspective, a local construction project of this magnitude will provide an excellent one-time economic stimulus to the region through detention basin and pump station construction.

In a social context, this construction project will improve the neighborhood and allow residents to return to normality. After the change in FEMA flood map procedures in 2013/2014, long-term residents suddenly found themselves in a high-flood-insurance region, mandated by the federal government. Implementing these civil infrastructure projects will improve their property values without modifying their property and improve livability within the Leeds neighborhood. The final design presented herein facilitates this transition, without affecting homeowners within the Leeds neighborhood. However, some farmland will be required to construct and maintain the upstream detention basins. The farmland may be purchased for a fair value, but will still require cooperation and flexibility on the part of local farmers. Farmers with a detention basin on their property may not farm the basin or berm area, because permanent vegetation is necessary to avoid erosion. Regardless, the number of farmers impacted by the final design is significantly less than the number of beneficiaries in the Leeds neighborhood.

On the local and global scale, the project will create numerous beneficial environmental impacts. The basins will improve both water quantity and quality concerns in the region. Dry detention basins, like those included in the final design, not only shift the hydrograph, but facilitate infiltration and reduce nutrient and suspended solids loading to the Floyd River. Although dry detention basins are common, the total capacity for this project sets them apart from many other designs. Successful implementation of multiple, upstream, detention basins in this project will provide a positive example for other stormwater managers, and city engineers to consider as they address localized ponding/flooding concerns. The unique design and positive experience will turn the Leeds neighborhood in Sioux City into a case study for other municipalities and supply first hand evidence for the positive economic, environmental and social impacts that can be realized through a similar design.

Numerous positive societal impacts will be recognized through the addition of rain gardens to the Leeds neighborhood as detailed in the final design. Consider the large-scale process of developing the plains regions for intensive agriculture and urbanization. The landscape has changed drastically over the past 300 years. Increases in area covered by infrastructure and farming have drastically impacted natural hydrology. Without intense agriculture and urbanization, the hydrological cycle was infiltration-based and groundwater-driven. Today, the hydrological system has changed to a runoff-driven system, where infiltration is restricted by tile-drainage in agricultural regions and structures in urban regions.

The landscape of pre-settlement Iowa was dominated by prairie and surface water was mostly fed by groundwater seepage rather than runoff. However, human-made drainage structures and impervious surfaces have increased the quantity of runoff significantly. Additionally, the increased soil compaction decreases the mobility of the water and does not allow it to properly percolate into the groundwater. The installation of rain gardens will help to restore the hydrological functionality of the landscape and partially restore the water cycle by improving infiltration and enabling shallow groundwater aquifer recharge.

The addition of rain gardens in the Leeds Neighborhood will not only benefit the environment, but it will also benefit the homeowners. Rain gardens help to deal with stormwater runoff, but they are also aesthetically pleasing and attract wildlife, such as birds. By installing a rain gardens, residents and city officials can create landscapes that add beauty, increase wildlife habitat and improve sustainability. A successful rain garden will hold and infiltrate the water rather than cause water quality problems and flooding due to excess runoff. Other cities throughout Iowa have implemented rain gardens as a solution to stormwater runoff from impervious surfaces for minor rainstorms with great success. To further enable the beautification and stormwater management, some cities in Iowa have provided tax incentives to the homeowners if they wish to install a rain garden on their private property. Rain gardens will improve the aesthetic of the Leeds neighborhood and represent the type of municipal investments that increase property values and the local tax base.

3. Preliminary Development of Alternative Solutions

3.1 Design Alternative #1: Detention Basins

The first design alternative that was proposed was using dry detention basins to retain the excess rainfall that is falling within the rural section of the watershed. The Leeds neighborhood watershed can be broken down into three sub-basins. The northern section flows to floodgates 3 and 4. The center section flows to floodgate 17 and the southern section flows to the three floodgates immediately South of Outer Drive. When the floodgates are closed, the runoff from each watershed forms a single ponded area that is adjacent to the levee along the Floyd River.

The first step to the design was to identify the expected extent of ponding. Using the software program ArcGIS and the files provided by the City of Sioux City, the 100 year flood elevation was identified to be at approximately 1116 ft. in elevation. Flooding at this elevation places half of the Leeds neighborhood within the 100 year floodplain. In order to remove the whole neighborhood from the floodplain, the ponding extent would need to be reduced. Upon further investigation, the acceptable extent of ponding would have to be limited to an elevation of 1107 ft.

Using this elevation, the maximum volume of water that could be ponded to an elevation of 1107 ft. was calculated. The maximum volume of water that can be ponded without flooding is 113.16 MG (million gallons). This volume was found by creating a surface at 1107 ft. in ArcGIS and calculating the volume between this surface and a TIN surface created with the contours that were provided by the City of Sioux City.

Next, the design storm was modeled. A 100 year, 2 hour design storm was used to calculate the total runoff in the Leeds neighborhood along with the rural regions in the upper extents of the watershed. The design storm was 4.06 inches over a 2 hour period for the 100 year storm in Woodbury County (Section 4). This information was found in the Iowa Stormwater Management Manual. The effective rainfall, taking infiltration into account, was reduced to 2.13 inches of rainfall averaged over the entire watershed. The total area of the Leeds neighborhood watershed is 2,230 acres. A rainfall runoff total of 2.13 inches over this area gives 128.98 MG of non-infiltrating water. The runoff exceeds the storage volume at an elevation of 1107 ft. by 15.82 MG.

The installation of dry detention basins within the rural section of the watershed would detain a portion of this excess water. There are fourteen suitable locations for detention basins within the rural section of the watershed. Four of the proposed detention basins are located within the northern section of the watershed. Eight of the detention basins are located within the center section of the watershed. And two are located in the southern section of the watershed. The detention basins vary in berm height from 5 to 15 feet in height depending on the topography of the area where the detention basin is located.

The 14 dry detention basins would retain approximately 29.34 MG of runoff from the agricultural portion of the watershed. The temporary storage of this amount of water would decrease the total runoff over the entire watershed to 99.64 MG. Thus, with the detention basins and the temporary ponding volume, the total storage volume is greater than the expected 100-year runoff by 13.52 MG. This provides a small factor of safety against a larger volume of runoff, and successfully retains the total expected runoff for the 100-year design storm.

The drawback of this design is that the detention basins need to be kept dry to have the maximum amount of storage available at the beginning of the 100 year storm event. Each detention basin will have a drain outflow that will allow a maximum orifice outflow of 1,405 gpm (gallons per minute), in addition to a concrete weir over the berm. The orifice outflow will occur for the lowest detention basin from the beginning of the storm until the detention basin is emptied. All detention basins are in series and parallel, and the maximum orifice outflow will be the sum of the three lowest detention basins in each parallel basin, for a total orifice outflow of approximately 4,215 gpm. This will increase the amount of water in the ponded section slowly over time. If the floodgates are not opened immediately after the 100 year storm, the outflow of the detention basins would raise the elevation of the ponded area above the 1107 ft. elevation mark, thus placing part of the neighborhood in the floodplain.

3.2 Design Alternative #2: Pumping Stations

A second flood mitigation option was analyzed that implemented the functionality of pump stations. Information regarding pumping was referenced from the 2011 Chief's Report of the Flood Risk Management Project and Feasibility Study Report with Integrated Environmental Assessment for the Cedar River in Cedar Rapids, Iowa, that was obtained from the US Army Corps of Engineers (USACE). Per client's request, the flood mitigation project in Cedar Rapids was designed similarly as with the Lock and Dam No. 11 pumping project in Dubuque, Iowa. Using the two similar projects as references, the pump station types and required capacities were evaluated.

Since the implemented pump stations serve stormwater runoff, the stations will consist of concrete structures located atop of a storm line. As used in Cedar Rapids and Dubuque, the concrete structure would consist of two chambers separated by a sluice gate. During conditions where flooding is not present, the sluice gate remains open that allows for gravity flow. When flooding occurs, two chambers that act as a wet well and discharge chamber are formed by closing the sluice gate. Motors located atop of the chamber use vertical shaft pumps in the wet well-side pump the water through a pipe which outlets on the discharge side. A stop-log closure is also provided on the outlet side of the discharge chamber. For the Cedar Rapids flood management project, Crisafulli pumps were used whose size was estimated upon on the necessary capacity and total required head.

For the evaluation of the second flood mitigation option, no detention ponds would be used. Rather, the installed pump stations would be solely responsible for removing all stormwater runoff. Since the urban and rural areas within the watershed boundaries do not provide natural storage for stormwater runoff, the flow from the 100-year design storm was determined to have an immense magnitude. According to the analysis of the 100-year rainstorm event, constructed pump stations must be capable of pumping a required capacity of 16 million gallons per minute (GPM) of stormwater runoff in order to eradicate flooding within the urban areas located within the project boundaries.

Consistent with the City of Cedar Rapids Flood Risk Management Project, the USACE evaluated pump station capacities ranging from 500 to 24,000 gallons per minute (GPM). In order to pump the required 16 million GPM of stormwater over the levee system into the Floyd River to prevent the urban area of Sioux City from flooding, an astounding 667 pump stations with the largest available pumping capacity of 24,000 GPM would need to be constructed along the levee from 28th St to 41st St. Based upon the economic and spatial constraints associated with this necessary solution, implementing pumping stations as the sole means of flood mitigation from a 100-year rainfall event within the project boundaries does not provide a feasible flood management strategy.

3.3 Design Alternative #3: Green Alternatives

Rain Garden

Initial investigations of the total runoff quantities for the 10- and 100-year rainfall events confirmed SWAG & K's initial projections that green alternative stormwater management practices would absolutely not accommodate such a volume of stormwater outflows. With this conclusion in mind, rain gardens, bioretention cells and bioswales were investigated for their possible impact within a broader stormwater management plan, and that alternative is detailed herein.

Capturing water from rooftops, driveways, yards and streets, a rain garden is a depression or a shallow bowl made in the landscape that is level from side to side and end to end. The runoff that travels to a rain garden is temporarily ponded, the water then infiltrates through the soil or the excess water is carried out through a piping system and discharged to the storm-water collection system. By installing a rain gardens, residents and city officials can create landscapes that add beauty, increase wildlife habitat and improve sustainability. A successful rain garden will hold and infiltrate the water rather than cause water quality problems and flooding due to excess runoff.

Figure 3.3.1: *Potential schematic of a roadside rain garden*

The average rainfall in ranges from 28 – 36 inches annually. Finding solutions to deal with the runoff from the impervious surfaces throughout Iowa, has led to many cities implementing green solutions. Urban properties generate stormwater runoff which contributes to the water quality degradation. The runoff from impervious surfaces contains pollutants than can find their way into receiving waters without treatment. Implementing rain gardens along the impervious surfaces in the Leeds neighborhood will help to control the storm water runoff and allow for the contaminated runoff to natural filter through the landscape before being discharged into the water collection system.

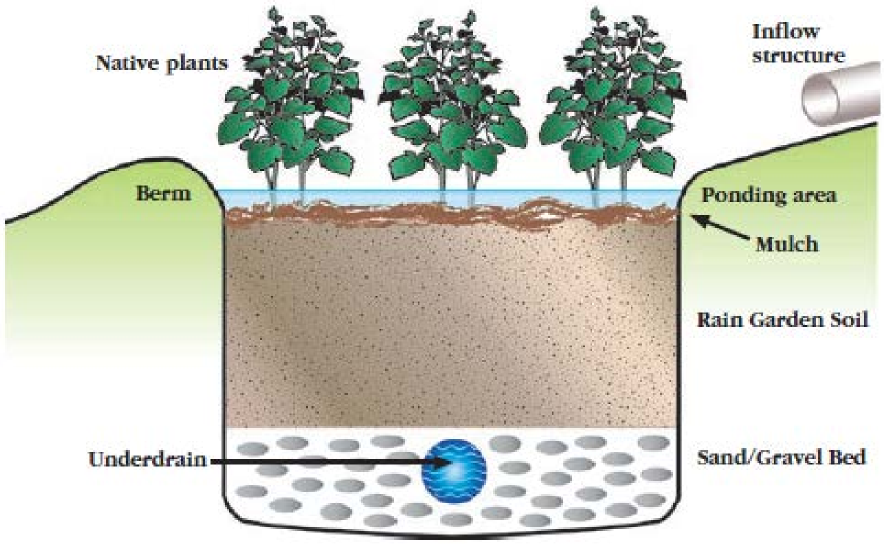


Figure 3.3.2: *Cross-sectional view of a rain garden indicating specific parts to ensure success.*

Determining the proper location for installing a rain garden is an important component when determining its success rate. Ideally, one should examine the site area of potential rain gardens during a rainfall event and monitor how the undisturbed land holds storm-water. Locating a rain garden along the natural flow of the runoff is ideal and will ultimately reduce costs during construction. Determine how the proposed rain garden site deals with the runoff and its retention time. If ponding occurs for an extended period of time (more than 24 hours), the soil is not percolating well and the rain garden site should be reconsidered.

There are several restrictions as to where rain gardens can be installed. Sites should not be constructed upslope from residential homes, within 10 feet from a foundation, or under trees. Areas with high water tables or shallow soils over bedrock are also not ideal. The maximum slope of a rain garden is 15%, if the slope is greater than this, then the soil may become unstable when saturated rendering the rain garden useless to infiltration processes. If the slope of the proposed rain garden is near the maximum slope, the use of retaining walls in recommended. Implementing retaining walls will require more labor and excavation, increasing the cost.

Determining the type of soil located at the site is pertinent to the success of the rain garden. By conducting a soil investigation, the percolation of the soil can be determined. If there is poor percolation rates, then the site either needs to be relocated or the installation of a bioretention cell could be considered. The soil found in majority of Sioux City is impacted by the Loess Hills, with a significant portion of the land falling in the floodplain. The composition of the soil is mostly silt with some clay and sand. This combination of soil indicates either a type C or type D soil classification.

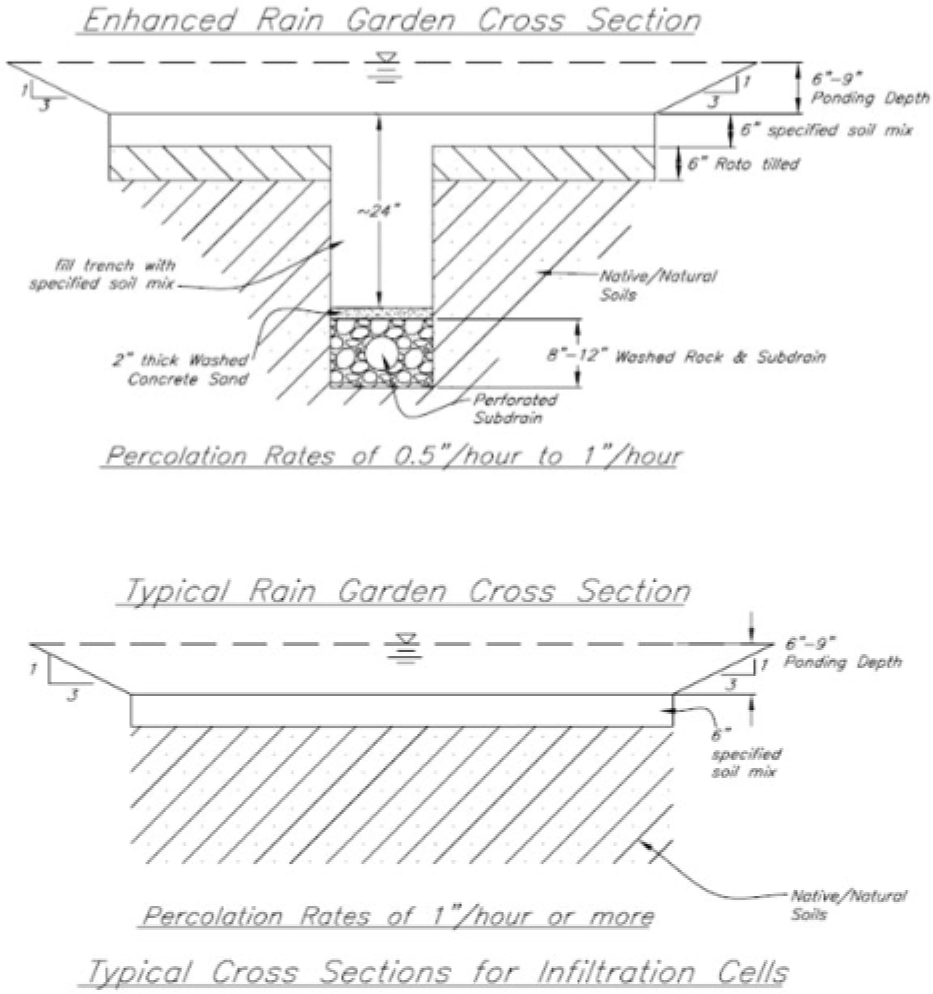


Figure 3.3.3: *Cross-sectional design of a rain garden with appropriate slopes and ponding depth.*

The Iowa Stormwater Management Manual provides design standards that ensure that infiltration-based stormwater management practices will infiltrate 90% of rainfall events. Based on the Iowa DNR, rain gardens have been designed to handle the runoff from the 1.25 inches of rain. Ideally residential homes have enough space to construct a rain garden big enough to handle the runoff for this storm. Rain gardens that effectively manage the water quality volume specifications will be eligible for financial assistance programs.

When determining which plants to select for the rain garden, consulting a specified list is important. Not all plant species are ideal for handling large amounts of water. When choosing the types of plants to install, it is recommended to use native plants. Native plants have the ability to develop deep root systems that will help to build and maintain high organic matter content and porosity. Native plants do not require the use of fertilizer, in fact species will overgrow and flow over if they encounter rich conditions. Studies have shown that native plants are well accepted if they appear to be orderly and well kept.

Table 3.3.1: *Hydrological soil table. Sioux City soil consists of mostly silt with some sand and clay, indicating a soil group of either C or D.*

Hydrologic soil properties classified by soil texture

Soil Texture Class	Hydrologic Soil Group	Effective Water Capacity (C_w) (in/in)	Minimum Percolation Rate (in/hr)	Effective Porosity (in^3/in^3)
Sand	A	0.35	8.27	0.025 (0.022-0.029)
Loamy sand	A	0.31	2.41	0.024 (0.020-0.029)
Sandy loam	B	0.25	1.02	0.025 (0.017-0.033)
Medium Loam	B	0.19	0.52	0.026 (0.020-0.033)
Silt loam	C	0.17	0.27	0.300 (0.024-0.035)
Sandy clay loam	C	0.14	0.17	0.020 (0.014-0.026)
Clay loam	D	0.14	0.09	0.019 (0.017-0.031)
Silty clay loam	D	0.11	0.06	(0.026 (0.021-0.032)
Sandy clay	D	0.09	0.05	0.200 (0.013-0.027)
Silty clay	D	0.09	0.04	0.026 (0.020-0.031)
Clay	D	0.08	0.02	0.023 (0.016-0.031)
Note: Minimum rate: soils with lower rates should not be considered for infiltration BMPs				

Source: Rawls et al., 1982

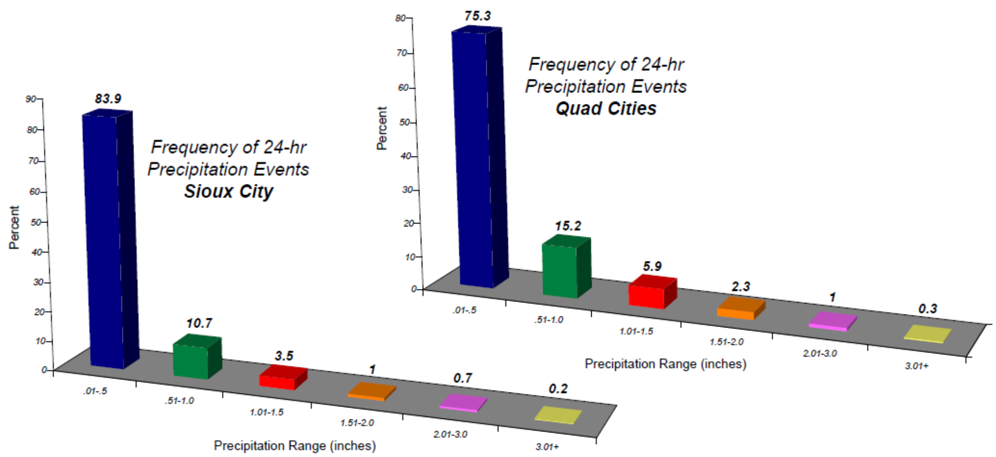


Figure 3.3.4: *3-D graph depicting the 1"/24 hour infiltration, which is necessary for a successful rain garden.*

The plant design of the rain garden should follow a specific placing. Using a monoculture border will give the rain garden a defining edge and a well-kept appearance. The floor of the rain garden should consist of a variety of species that will bloom throughout the growing season. Clumps of species should be planted 1 to 1.5 feet apart from each other and have a maximum height growth of 4 feet. It is important to minimize foot traffic before, during and after construction. If foot traffic cannot be avoid, consider adding a rock strip or a small bridge over the rain garden so that the garden bed is not destroyed. Mulching a rain garden is recommended to provide a weed barrier and to conserve moisture for young plants during the first year. A recommended mulching layer of 2 – 3 inches is ideal.

An established rain garden does not require much maintenance if proper measures are taken during the beginning phases. During the first year, rain gardens may need to be watered weekly if timely rainfall does not occur. The first year is crucial to the success of the rain garden. It may require extra water depending on the hydrological cycle and it will require maintenance in terms of weeding and mending to the plants. If constant weeding is maintained during the beginning phases eventually minimal weeding will occur due to the establishment of native plants.

Maintenance teams should keep an eye out for sediment build-up or organic matter at the inlet of the rain garden. Sediment entering the rain garden will create a crusted surface that will limit infiltration. Maintenance teams should also keep an eye out for standing water lasting more than 24 hours, vegetation that has died and needs replacing, visible erosion of the berm and developing low spots due to a settling berm.

Installations of rain gardens have limiting factors if certain criteria is not met. The compaction of the soil determines the percolation rate of the water and will ultimately determine whether a rain garden will be functional in the proposed area or not. High water tables do not yield productive rain gardens, however an alternative would be to invest in soil quality restoration to help the landscape better absorb rainfall.

Bioretention Cells

A bioretention cell (bio-cell) captures and infiltrates stormwater runoff from impervious surfaces to reduce water pollution and stabilize stream flows. It is designed with a specific square footage of surface area and specified depth, similar to a rain garden. However a bioretention cell has an engineered sub-grade that extends to the frost line, roughly 42 – 48 inches below the surface. The sub-grades composition is an 8 – 12 inch gravel bed with an embedded perforated drain tile. A bio-cell also contains 24 – 30 inches of an “engineered” soil mixture (60% sand, 25% compost and 15% topsoil). A bio-cell typically has a ponding depth similar to a rain garden and is mainly used when impounded water is not able to infiltrate into the surrounding soil. The ponded water is released via the drain tile is a similar manor as groundwater infiltrating down a gradient of natural soils. A limiting factor for placement of a bioretention cell may be the lack of an outlet for the sub-drain. An outlet is necessary to ensure proper drainage.

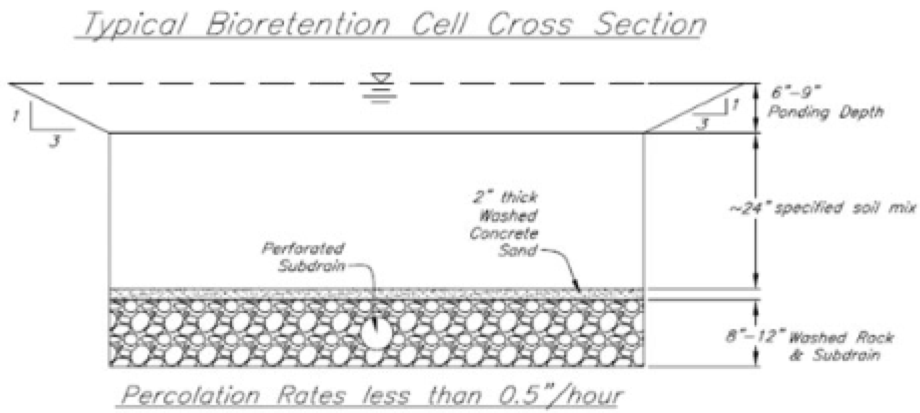


Figure 3.3.5: *Cross-sectional design of a bioretention cell with appropriate slopes and ponding depth.*

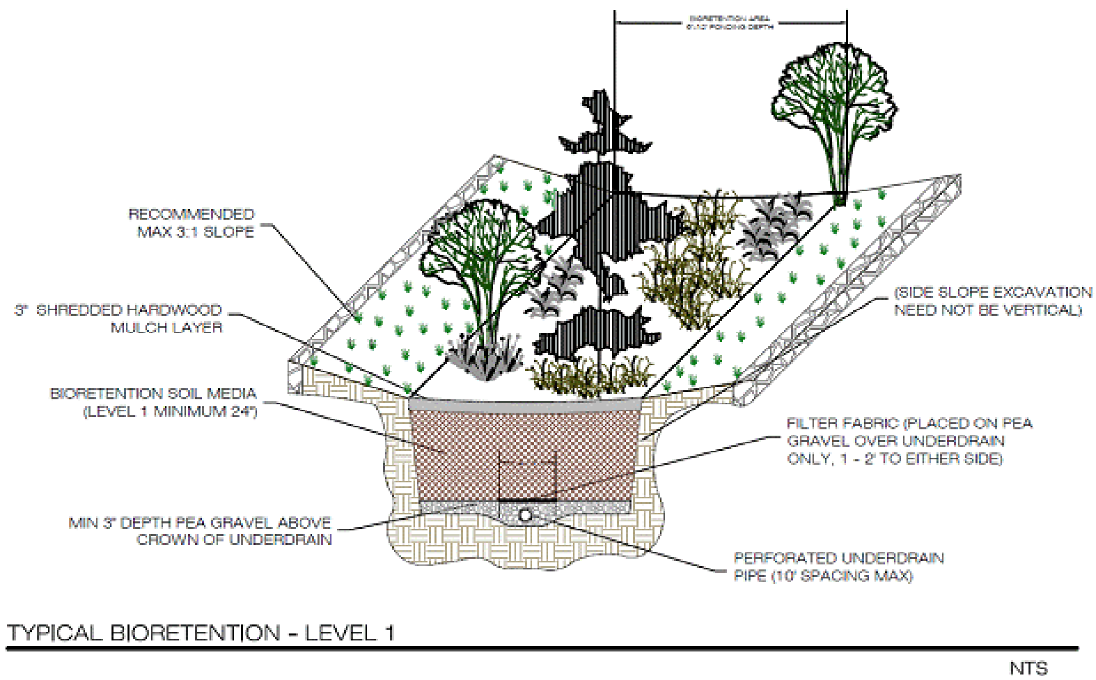


Figure 3.3.6: *Cross-sectional view of a bioretention cell indicating specific parts to ensure success.*

Bioswales

Bio-swales are landscape elements designed to remove silt and pollution from surface runoff water. They consist of a swale drainage course with gently sloped sides and filled with vegetation, compost and/or riprap. Usually installed as an alternative to underground storm sewers. A bioswale is engineered so runoff from frequent, small rains infiltrate into the soil below. In the case of a larger storm, a bioswale will slow the flow of runoff while utilizing the vegetation to filter and clean the stormwater runoff before it is discharged into the local stream aquifer.

4. Selection Process

To compile a final design solution, both qualitative and quantitative assessments were utilized. Specifically, a decision matrix was applied to the three previously-described design alternatives to assess each alternative in five different categories; effectiveness, capital cost, operations and maintenance, urban space considerations and aesthetics. In addition to the point-by-point decision matrix, SWAG & K Associates considered the broader picture of stormwater management issues for the Leeds neighborhood and the northeast portion of Sioux City.

The decision matrix is set-up to accurately compare each design alternative. Each design alternative is graded one through three (with three being the best) across a set of six categories that SWAG & K Associates deemed important. Each category was then assigned a weight based on the importance of that specific category (a weight of six is the most important category and a weight of one is the least important category). The total number of points for each alternative was computed. The highest score should correspond to the best design alternative.

Table 4.1.1 *Decision Matrix.*

	Effectiveness (6 pts)	Capital Cost (5 pts)	Operations & Maintenance (4 pts)	Urban Space (3 pts)	Environmental Impacts (2 pts)	Aesthetics (1 pt)	Total Score
Pumping	3	1	1	3	2	2	42
Detention Basins	2	2	3	2	1	1	43
Green Alternatives	1	3	2	1	3	3	41

Each category was given a weight based off the importance. The most important category was the effectiveness of the design alternative to alleviate the ponding issue behind the levee. Capital cost and operations and maintenance (O&M) were deemed to be the second and third most important respectively. The urban space requirements were determined to be fourth most important and environmental impacts were chosen to be fifth due to the proximity to the Floyd River. The aesthetics is the least important category because function is more important than form.

Clearly, none of these options addresses the major goals of the project significantly better than the other options. In light of the results, long-term and neighborhood-wide stormwater management implications were considered and weighed as the details of the final design were assembled. Although SWAG & K Associates was charged with the design an engineering solution that removed the Leeds neighborhood properties from the high-flood insurance risk area, these other considerations factored into the final solution. Clearly, moving homeowners, purchasing properties or elevating houses on stilts would negatively affect the historic and quaint Leeds neighborhood. Other options presented by HR Green involved increasing flooding/ponding risk for other properties to benefit the Leeds neighborhood and expensive/challenging construction across a railroad and a major highway. SWAG & K Associates selected design alternatives that did not increase ponding or flooding risk for other neighborhoods, and minimized challenging construction projects, like installing culverts across roadways. Unfortunately, these design alternatives cannot independently accommodate the project requirements economically or effectively.

However, combining the three options yields a unique, effective, and intelligent design that will achieve the flood insurance reduction goals while minimizing complex permitting and construction projects. Although the green alternatives do not factor into calculations about ponding extents or flood insurance, they provide significant benefits beyond floodplain ponding management. Green alternatives will enhance stormwater management for small scale rain events and in conjunction with trails, sidewalks and other projects, improve the aesthetic and value of the Leeds neighborhood in Sioux City. For these reasons, green alternatives are included as an integral portion of SWAG & K Associates final design.

Both pump stations and detention basins provide unique characteristics that work together in combination to address the issue of floodplain ponding. Providing pump stations at the flood gates to remove all ponded water would be tremendously expensive. Similarly, detention basins cannot reasonably or economically accommodate back-to-back 100-year design storms. Together, detention basins can retain sufficient quantities of stormwater from the agricultural portion of the watershed and effectively shift the hydrograph for a moderate amount of runoff. The changed hydrograph and partially-controlled outflow allows reasonably-sized pumps to move flashy urban runoff over the levee immediately, and pump some of the agricultural runoff up to 24 hours after the storm event. In conjunction with an acceptable level of ponding at 1107 feet (which does not affect the Leeds neighborhood), the pump stations and detention basins provide an effective solution to protect the neighborhood and reduce or eliminate flood insurance costs.

5. Final Design Details

The final design is comprised of detention basins and pump stations as well as green alternative stormwater management practices. Detention basins and pump station design details will be addressed jointly, and the green alternative stormwater management gardens will be detailed subsequently. Permitting details are included at the end of the section. Further calculations and details of the design are included in the subsequent pages and the appendix.

A number of simplifying assumptions guide the structure of the final design. SWAG & K Associates assumed that the solution should be designed to accommodate a 100-year 2-hour design storm, a total of 4.06 inches of precipitation over the entire 2,230 acre watershed. Infiltration was assumed to occur, and the NRCS curve number runoff method was applied to determine the total volume of runoff, approximately 128.98 million gallons (MG). These are reasonable assumptions and are the same assumptions that HR Green made in their designs.

Within GIS, a surface was utilized to determine the extent of ponding at different elevations. It was determined that ponding at the 1107 feet elevation would not affect the Leeds neighborhood, and only slightly impact future businesses along Floyd Boulevard. It was assumed that before future businesses are constructed, the site could be filled with soil to place the new building well above the 1107 foot elevation – a negligible effect on the ponding volume.

SWAG & K Associates assumed that temporary ponding at the 1107 foot elevation level was an acceptable method to store excess runoff until it could be pumped over the levees into the Floyd River or released through the floodgates. Contributions to the Floyd River from the pump station were determined to be negligible when compared to the overall flood stage discharge on the Floyd River. From this elevation of 1107 feet, the total expected temporary ponding storage volume was calculated to be 113.16 MG, assuming no infiltration beyond the initial precipitation incident on the ponding area. The extents of ponding at the 1107 foot elevation are presented on the following pages.

Fourteen detention basins were designed to maximize storage capacity, but minimize downstream risk, berm height and berm width. The detention basins will store approximately 29.34 MG of water temporarily, shifting the hydrograph forward in time. The detention basins were located in optimal in-channel locations in the agricultural region hydraulically above the Leeds neighborhood. All of the detention basins were located on private property, and the expected costs of property acquisition were included in the cost estimates. All detention basins must be dry detention basins to maximize the potential storage volume. Typical dimensions, materials, sizing, weir structure and outlet structure are included in design sheets in the subsequent pages. The detention basin outlet structure orifice flow drains are sized to drain the average basin volume in approximately 24 hours, but this will vary depending on the basin size. Typical detention basin materials, sizes and design plans are included in the appendix.

A simplified water balance was utilized to accurately size the pump stations. A total of 113.16 MG of runoff will be ponded up to the 1107 foot elevation, and 29.34 MG of runoff can be stored in the dry detention basins. The total projected runoff for the design storm is 99.63 MG, because the volume of water stored in the temporary detention basins will not runoff immediately. This means that the detention basins and ponding volume can accommodate more water than is predicted to runoff during the 100-year storm event.

However, pump stations will still be required to design for projected scenarios. At minimum, the pump station must be sized to accommodate the expected orifice flow from the bottom drain in the lower three detention basins, a total of approximately 4,215 gallons per minute (gpm). The minimum pump station capacity would be a 5,000 gpm pump, however, this design will only accommodate a single 100-year design storm during a given floodgate closure, and will take 14 days to fully empty the ponding area of runoff. This scenario would leave the area exposed to flooding above the 1107 level if another major rainstorm (10- or 25-year, etc.) would occur before the ponding area was emptied.

While the 5,000 gpm pump station capacity is adequate to accommodate the flow from the 100-year 2-hour rainfall event, redundant pumping capacity was not provided. While draining the series of detention basins in the 14-day period provides the most economic solution, it may not be adequate to prepare for a second major rainstorm while the Floyd River floodgates are closed. Since the first and O&M costs associated with pump stations are large, the City of Sioux City should conduct a feasibility study in order to assess the probabilities of sequential rainfall events that have the capability of overloading the designed system. Additional pumping structures will decrease the current drainage window of 14 days while adding costs that may or may not be within the City of Sioux City's allowable budget. The final design should also meet specifications set by the United States Army of Corps of Engineers.

Although the joint combination of dry detention basins and pump stations is unique to SWAG & K Associates, the US Army Corps of Engineers has completed similar projects. Specifically, the USACE has installed similar pump stations Waterloo, IA and has done extensive planning for a similar project in Cedar Rapids, IA. Because the pump stations will be adjacent to the existing Floyd River levee, SWAG & K recommends a pump station design amenable the USACE and similar to pump station designs for these similar projects. The specific location of the pump station is presented on the subsequent pages.

SWAG & K Associates believes this design will meet the overall goal of the project with a minimal negative impact on the surrounding area. However, before a final design plan set is published, SWAG & K Associates recommends that comprehensive flow modeling be applied to this design solution to accurately determine flow rates, hydraulic connectivity between basins, hydrographs, real-time ponding fluctuations with pump rates and subsequent design storms. The extensive hydraulic and hydrologic modeling required was beyond the capabilities of the software available to SWAG & K Associates. The commercial software package, XPSWMM provides simultaneous modeling capacity for open-channel, sheet and stormwater network flow, as well as the ability to model surface impoundments, such as dry detention basins. While this type of software was not available, SWAG & K Associates is confident that this design approach will meet the fundamental goals of the project by reducing the extent of ponding during closed floodgates and simultaneous heavy local rainfall events.

Implementing rain gardens along the impervious surfaces in the Leeds Neighborhood will provide numerous benefits to the area. Rain Gardens will help control the storm water runoff for the 2-year, 2-hour storm and serve as a natural filter for contaminants before discharging the water to the groundwater or municipal stormwater collection system. The impervious pavement of the Leeds Neighborhood generates approximately 127,400 cubic feet of runoff from the 17.0 miles of roadway.

The final design proposes the addition of rain gardens along the roadway easements to help deal with the roadway runoff. The average rainfall in Sioux City in ranges from 28 to 36 inches annually. SWAG & K recommends the typical installed rain gardens to be between 100 square feet and 300 square feet. SWAG & K recommends designing and spacing the rain gardens to accommodate a 2-year, 2-hour rainstorm. A total of 25 rain gardens spread at ideal locations across the Leeds neighborhood will easily accommodate the runoff generated from small storm events.

A map of the Leeds Neighborhood on the following page specifies four major areas that would be ideal for rain garden installation. The specified areas were then zoomed in to show the individual house and the general landscape of the area. On the zoomed in areas, there are several lines indicating potential sites where rain gardens could be installed. The specified areas range from public property to sections of easement between sidewalks and the roadway. The final indication on the feasibility and success rate of the rain garden will be provided after a thorough on-site soil test to determine percolation rates and official home owner's consent.

Before construction may begin on the pump stations and detention basins, five individual permits must be applied for and approved to ensure the final design meets all regulatory requirements. Specifically, five major permit applications must be completed, although initial application status or successful application approval is required for three of the permits to be filed (Sioux City Grading Permit, USACE Section 404 and Section 408 permits). The Iowa NPDES General Permit (Iowa DNR) and Protecting Iowa Waters - Joint Permit Section 401 (Iowa DNR, USACE and NFIP) must be filed first, before the other three permits may be filed. The list of required permits for the final design is below.

List of Required Permits for Final Project Design

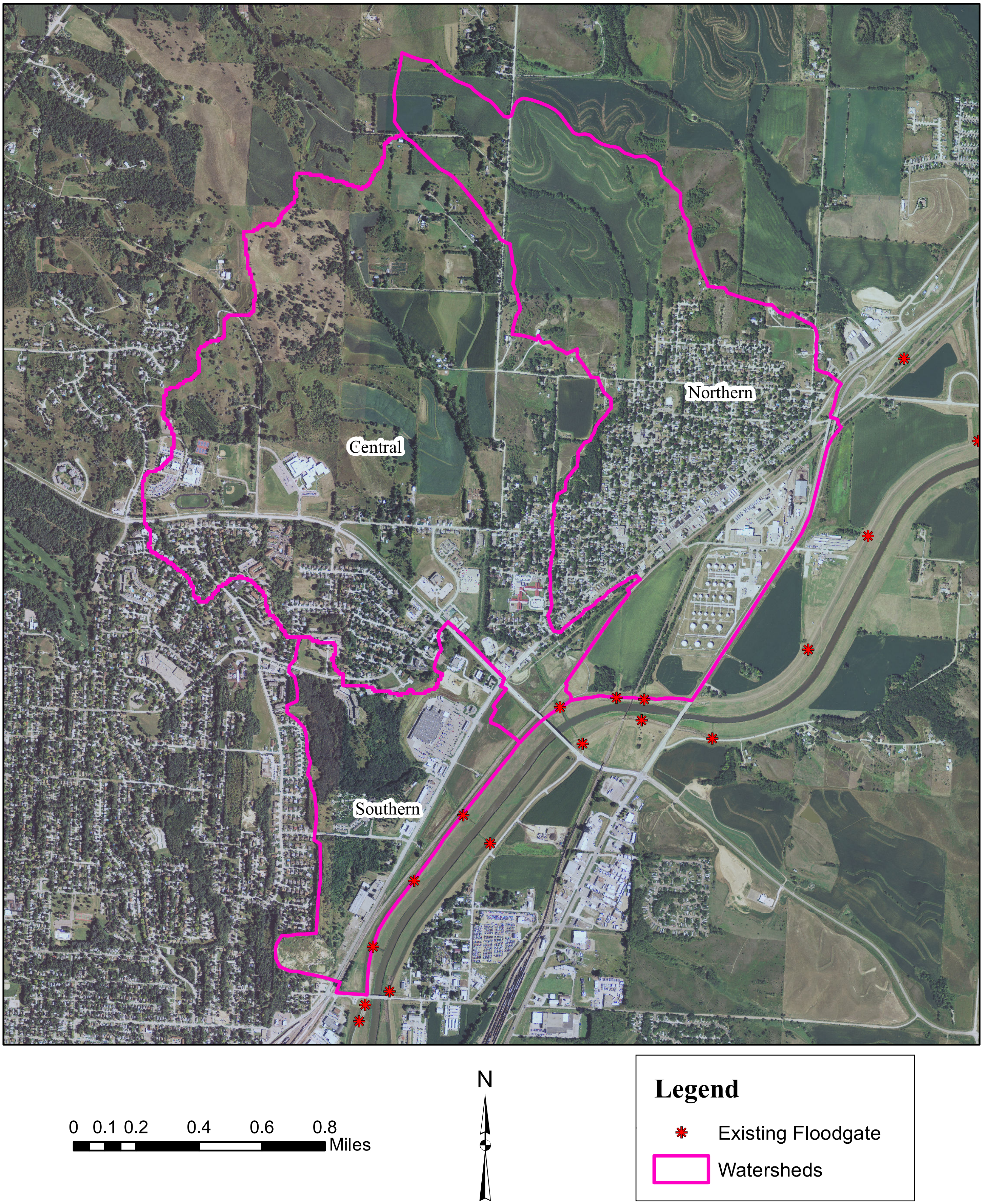
- Sioux City Grading Permit (The City of Sioux City, contingent on approved Iowa DNR NPDES General Permit)
- NPDES General Permit (Iowa DNR)
- Protecting Iowa Waters - Joint Permit Section 401 (Iowa DNR, USACE - Omaha District, National Flood Insurance Program)
- Section 404 Permit (USACE, contingent on application for Joint Permit Section 401)
- Section 408 Permit (USACE, contingent on application for Joint Permit Section 401)

The City of Sioux City Grading Permit is issued by the City of Sioux and will be necessary to construct both the pump stations and detention basins. The application must include a final set of plans and a Stormwater Pollution Prevention Plan (SWPPP) with a valid National Pollutant Discharge Elimination System (NPDES) General Permit. The Iowa DNR administers the General Permit, which must be approved before the Grading Permit may be issued.

The Protecting Iowa Waters - Joint Permit Section 401 is administered jointly by the Iowa DNR, USACE and National Flood Insurance Program (NFIP). The application must include a final set of plans for the pump stations and detention basins, and the Earth Embankment Dam addendum must also be included in the permit application to cover construction of the upstream detention structures. Joint Permit Section 401 is a pre-requisite permit to the USACE Section 404 and Section 408 permits. The USACE - Omaha District will oversee the Section 404 and 408 permit applications, which address projects that affect waters of the United States and projects that affect existing federal levee system.

It should be noted that modifying the conveyance mechanism for stormwater via a detention basin or pump station will likely not require an additional permit application. The city of Sioux City already has a Municipal Stormwater Permit #4 (MS4), and after conversation with the Iowa DNR, modification to the stormwater path should not require any additional work. The Iowa DNR's review of the plan set through the Joint Permit application will provide sufficient opportunity to confirm this assertion made by the Iowa DNR MS4 permit office.

Leeds Neighborhood Overview

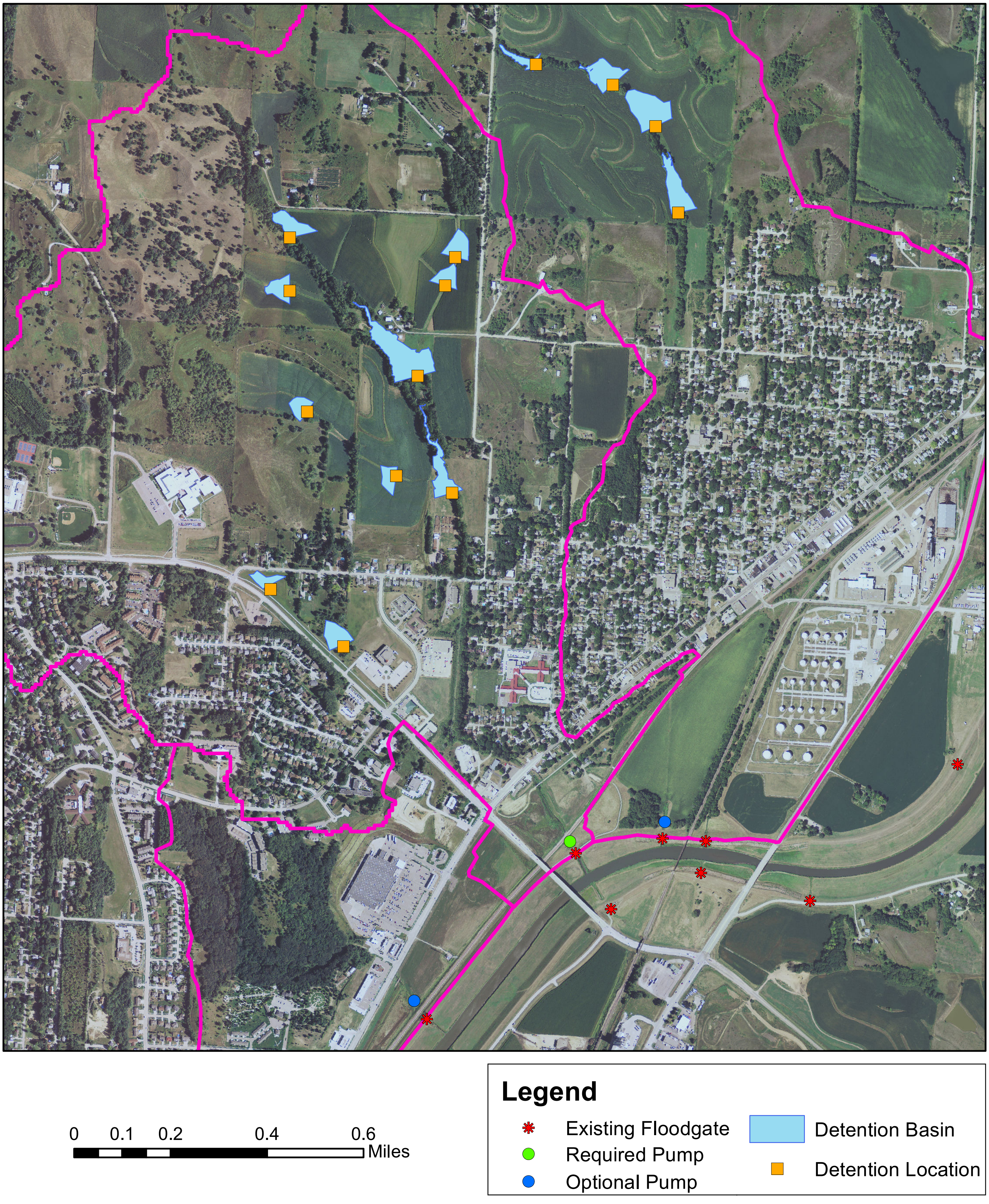


Extent of Ponding (Elev. 1107 ft.)

Legend

Ponding Extent

Recommended Detention Basin and Pump Location



Optimal Areas for Rain Garden Installation

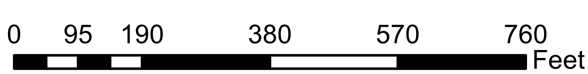
0 220 440 880 1,320 1,760 Feet

Optimal Areas for Rain Garden Installation

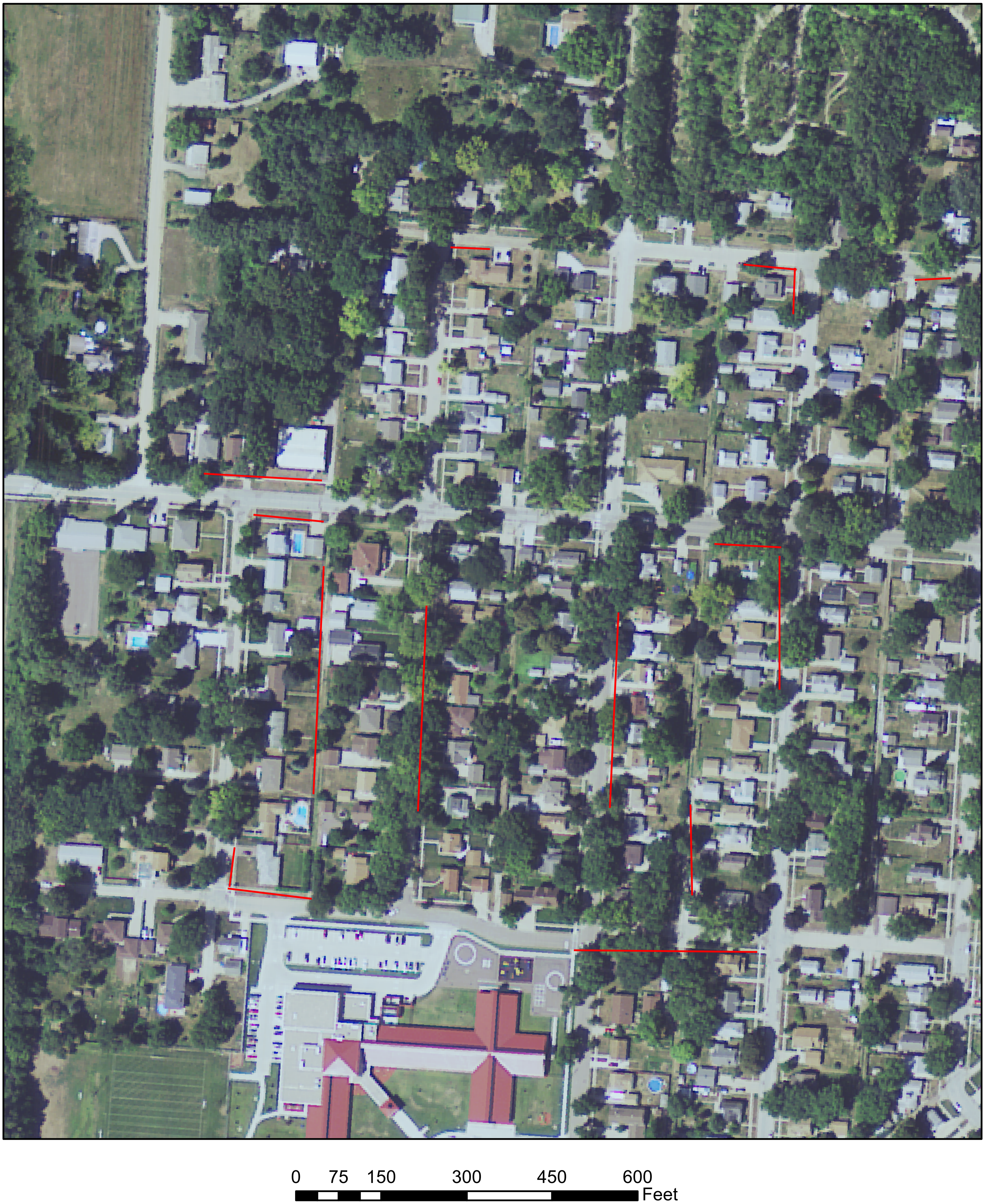
Optimal Areas for Rain Garden Installation

0 95 190 380 570 760
Feet

Optimal Areas for Rain Garden Installation



Optimal Areas for Rain Garden Installation



6. Cost and Construction Estimates

In addition to the preliminary expected construction schedule, detailed upfront construction and operations & maintenance (O&M) cost estimates were completed for each component of the project; pump stations, detention basins and green alternatives. Construction cost estimates for each component were prepared separately to improve accuracy and allow more flexibility in the bidding process. With separate construction cost estimates for each component of the final design, the components may easily be bid on together in one bid package or separately as three independent bid packages. This method provides the most flexibility for the City of Sioux City, and will ensure the lowest-cost and most effective combination is available. Operations and maintenance costs are presented together in one figure below, because Sioux City will own these structures.

Detention Basin Cost

The total projected cost for construction (labor, materials, excluding land purchase) of the detention basins in presented below. SWAG & K Associates' estimate is presented along with three other empirical estimates. The empirical estimates were developed by technical committees and municipal agencies and provide confirmation of SWAG & K's final construction cost estimate. Please see the appendix for more information regarding the methodology and background of these other cost estimates, as well as a detailed breakdown of SWAG & K Associates' construction cost estimates for the detention basins. Note that land value was not included in the cost comparison, because the empirical cost estimates do not include land values, a spatially and temporally variable cost.

Table 6.1: *Comparison of Detention Basin costs.*

DETENTION BASIN UPFRONT COST ESTIMATE VALIDATION	
Cost Estimate Source	**Overall Cost**
	(excluding land purchase)
SWAG & K Associates Estimate	$ 1,221,000.00
Metropolitan Washington Council of Governments	$ 2,716,000.00
Weigand, et al.	$ 1,041,000.00
Young, et al.	$ 1,475,000.00

Overall, SWAG & K Associates' cost estimate falls within the range of construction costs estimated by the other three empirical methodologies. SWAG & K believes this cost estimate to be reasonable and valid for the location and typical construction costs for the Siouxland region. The total construction cost estimate (including land purchase cost) is $1.45 million dollars and is presented below, along with projected O&M costs. Typical O&M annual cost estimates for detention basins fall in the range of 3-5% of the total construction cost, according to the US Environmental Protection Agency. With this estimate, typical O&M annual costs for the detention basins should range between $60,900 and $89,900. This is included in the final design O&M cost estimate.

Pump Cost

As stated within the US Army Corps of Engineer's report, Section 3 of the Flood Control Act of 1936 and Section 103 of the Water Resource Development Act of 1986 (WRDA 1986) requires that a non-Federal sponsor, e.g. City of Sioux City, pay 100 percent of the costs for OMRR&R of structural flood damage reduction projects. According to the Army Corps of Engineers, operation includes all activities required for the safe and efficient functioning of the project to achieve its intended benefits. Maintenance is the performance of activities needed for proper care and efficient project operation. Repair includes activities that are of a routine nature and will maintain the project's condition in a well-kept manner. Replacement covers the activities necessary to replace worn-out project elements. Rehabilitation refers to the activities required to bring a deteriorated project back to its original condition.

Typical operation requirements include maintenance and emergency operation of pump stations, maintenance and emergency operation of gate-wells and shut-off valves, maintenance and emergency erection of all closure structures and removable walls, continual updating of the OMRR&R Manual and emergency response plans that accounts for modifications made to the system and updating all emergency contacts and suppliers.

The City of Sioux City would be responsible for coordinating all project modifications subsequent to completion of the construction project. Modifications to the system include any plans that impact the function or physical footprint of the project. Modifications also include any work not coordinated before its placement. Impacts include physical changes to the system, encroachments, drainage system disruption. The City of Sioux City would also be responsible for funding and carrying out annual operation and maintenance of the system.

The attached cost estimate represents the estimates of the total annual costs of pumps for a 5,000 GPM pumping facility. Pump costs were obtained from a similar proposed pumping station that was designed in Cedar Rapids, Iowa. A design pump in Cedar Rapids had a capacity of 5,000 GPM, therefore, the pump, construction, annual O&M and annual replacement costs from the Cedar Rapids Flood Management Project were assumed to be approximately the same for the Floyd River project in Sioux City. As assumed by the USACE, annual operation and maintenance was estimated at $4,500 for the pump. Additionally, the City of Cedar Rapids implemented pump stations located on concrete pads exposed to nature and vandalism since the pumps would be infrequently used. An expected replacement life of 25 years was estimated for concrete pads compared to the pump life expectancy of 35 years for pumps operated within pump houses. Costs within US Army Corps of Engineer's report included the cost of the pump with motor, the cost of the concrete pad, and the cost of the all piping.

Table 6.3a: *Capital and annual cost estimate for 5,000 gpm pump.*

5,000 GPM PUMPING STATION AND CONSTRUCTION FIRST COST ESTIMATE						
Number	**Item**	**Units**	**Number**	**Cost/Unit**	**Total Cost**	
1.1	5,000 GPM Crisafulli Pump Cost			LS	$	60,040.00
1.2	Other Costs (Construction)			LS	$	30,000.00
				Total Projected First Cost	**$**	**90,040.00**

Table 6.3b: *Capital and annual cost estimate for 5,000 gpm pump.*

5,000 GPM PUMPING STATION ANNUAL COSTS					
Number	**Item**	**Units**	**Number**	**Cost/Unit**	**Total Cost**
2.1	Annualized First Cost			LS	$ 4,460.00
2.2	Annual O&M			LS	$ 4,500.00
2.3	Annual Replacement			LS	$ 1,500.00
				Total Projected First Cost	**$ 10,460.00**

Table 6.4: *References for pump cost estimates.*

5,000 GPM PUMPING STATION AND CONSTRUCTION FIRST COST ESTIMATE-REFERENCES		
5,000 GPM Crisafulli Pump Cost	1.1	USACE, Flood Risk Management Project, Feasibility Study Report, Table A-47
Other Costs (Construction)	1.2	USACE, Flood Risk Management Project, Feasibility Study Report, Table A-47
Annualized First Cost	2.1	USACE, Flood Risk Management Project, Feasibility Study Report, Table A-47
Annual O&M	2.2	USACE, Flood Risk Management Project, Feasibility Study Report, Table A-47
Annual Replacement	2.3	USACE, Flood Risk Management Project, Feasibility Study Report, Table A-47

Green Alternative Cost

Many components go into the determination of the total cost estimate for a rain garden. Determining the overall cost depends on what plants the client would like to use for a rain garden, the amount of rain gardens that is requested by the client and the materials needed to create the garden. There are essentially three phases for a rain garden construction: Pre-building, building and maintenance.

The pre-building phase consists of monitoring the site area and determining the extent of ponding. This allows for the contractor to determine the quantity of the materials needed to build the necessary rain gardens. The cost associated with this phase would be the cost to pay the landscaper and surveyor for one working day.

The building phase includes the cost of a one-time purchase of building materials, the necessary amounts of topsoil, mulch and plants to fill the desired number of rain gardens. Depending on the slope of the land, a rain garden might utilize a retaining wall to help with stabilization. If a retaining wall is necessary there will be an added cost to purchase the materials needed to build the retaining wall. Materials used to properly line the rain garden, like Rip Rap limestone will have to be purchased from a company that specializes in selling this product. Depending on the size and number of rain gardens desired for the client, there may be an additional cost for transporting the materials from the company site to the location of the rain gardens. Most 300 square foot rain gardens can be completed in one working day, therefore the additional cost of labor would be the equivalent to one working day pay.

The maintenance phase is quite extensive in the beginning, but if done properly, the required work for the rain gardens will greatly decrease. During the first year, rain gardens must be constantly monitored and maintained. The total cost of maintenance will greatly decrease following the first year of installation.

Table 6.2: *Cost Breakdown of Green Alternatives.*

Total Materials	$ 106.40
Total Base Design	$ 308.90
Total Plants **	$ 243.61
Total Retaining Wall	$ 259.39
Total Labor	$ 1,023.84
Total Transportation	Varies on Distance
Maintenance	$ 4,576.00
Sub Total *	$ 1,942.14
Grand Total	$ 45,999.90

The overall cost to build one rain garden, including labor, is **$1,942.** Given the calculated area of impervious pavement and the total amount of runoff, the Leeds neighborhood would require 20 to 25 rain gardens to adequately handle the runoff from the impervious pavement. Therefore to install the maximum number of rain gardens in the Leeds neighborhood, the cost estimation for this phase of the project would be **$45,999.90**.

Summary Cost Table

The Floyd River Drainage Mitigation Final Cost Estimate summarizes the overall project costs for each component of the final design; pump station, detention basins and rain gardens. The project costs are broken down into upfront construction costs and operation and maintenance costs, and the total project construction costs are included as well.

Table 6.5: *Total Cost of Implementing Design.*

FLOYD RIVER DRAINAGE MITIGATION FINAL COST ESTIMATE			
No.	Description	Capital Costs	Annual O&M
1	Detention Basin	$ 1,450,000.00	$ 61,000.00
2	Pump Stations	$ 90,040.00	$ 4,500.00
3	Green Alternatives*	$ 46,000.00	$ 4,600.00
	Total Cost	$ 1,586,040.00	$ 70,100.00
*Green Alternative O&M costs only associated with first year			

7. Conclusion

The City of Sioux City desires to alleviate the high flood insurance rates experienced by many property owners within the Leeds neighborhood since the FEMA floodplain maps were updated over the past few years. FEMA extended the floodplain to address the possibility of localized ponding behind the levee during floodgate closures along the Floyd River levees. A number of alternatives were proposed, but the City of Sioux City solicited official request for proposals to further investigate design alternatives to mitigate the flooding potential in the Leeds neighborhood.

SWAG & K Associates was selected as the design engineering firm to investigate the hydraulics and hydrology of the location and develop a cost-effective and non-invasive solution. The final solution developed addresses the potential flooding issue and consequently will lower or eliminate flood insurance rates for property owners within the Leeds neighborhood.

The final design presented in this report presents the engineering design work completed by SWAG & K Associates to address this issue. The final design proposes a two-fold solution to address the ponding issue and broader stormwater management issues in the Leeds neighborhood. To address the ponding issues, SWAG & K investigated the capacity of the existing land surface to pond water without flooding the property owners. It was determined that water can be ponded to an elevation of 1107 feet adjacent to the levee using the existing land surface. Additional temporary water storage capacity is provided by a series of 14 dry detention basins that will be installed in-channel across portions of the agricultural section of the watershed. A pump station must be installed to evacuate the excess runoff over the levee into the Floyd River and empty the ponded area before further rainstorms flood the area.

When combined, the pump stations and detention basins will meet or exceed the requirements laid out by the City of Sioux City. Before final construction plans are complied, SWAG & K recommends that a complete hydraulic model for the proposed solution be developed to validate the final design. Modeling software capable of simultaneously modeling pipe, channel and sheet flow, as well as detention basin flow and existing stormwater structures was not available, because of the complex hydraulic features of the final design.

In the broader context of stormwater management, SWAG & K Associates recommends installing rain gardens in the right-of-way in the Leeds neighborhood. The rain gardens will accommodate moderate flow amounts of runoff from small rainstorms (2-year, 2-hour), increase shallow groundwater recharge, filter contaminants within the runoff and increase property values by improving aesthetics within the neighborhood.

SWAG & K Associates is honored to have been selected to offer alternative engineering solutions to address the Floyd River Floodplain Mitigation project. We are confident in the concepts behind our design and believe that with proper hydraulic modeling, final details may be developed to deliver economical and easily-constructed final plans to exceed the City of Sioux City's goals for the project.

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Appendices

Appendix A - Permits

The City of Sioux City

Sioux City Grading Permit - Issued by the City of Sioux, this permit will be necessary for any construction project within the city of Sioux City that involves excavation. The permit will need to cover pump station construction, channelization and grading between the basins and retention basin construction west of the Leeds neighborhood. Scale drawings and grading/erosion control plans must be included. Sioux City's stormwater permit must also include a Stormwater Pollution Prevention Plan (SWPPP) with a valid National Pollutant Discharge Elimination System (NPDES) General permit to cover stormwater discharges during construction. The SWPPP and NPDES permits must be approved before the Sioux City Grading Permit may be approved. Please see Iowa DNR NPDES General permit for more information. Please see subsequent pages for copy of Sioux City Grading Permit.

Contact Information:
The City of Sioux City
Engineering Department
712-279-6324
https://www.sioux-city.org/attachments/article/67/GRADING%20PERMIT%20APPLICATION%20WITH%20SWPPP%20PACKET%20FORM.pdf

The Iowa Department of Natural Resources
Iowa DNR NPDES General Permit - Administered by the Iowa DNR, the permit will be necessary because the total disturbed area for the project will be greater than 1 acre. The permit must cover the entire project area, including pump station construction, channelization and grading between the basins and retention basin construction west of the Leeds neighborhood. Through the SWPPP the permit will require that adequate erosion protection mechanisms are installed and will ensure downstream waters are minimally affected by excavated construction sites. Permit application may be completed online at link provided below.

Joint Permit, Protecting Iowa Waters, Section 401 - Administered jointly by the Iowa DNR and USACE, the Section 401 permit provides regulatory oversight for construction projects within wetlands, streams, lakes and/or floodplains. The application must be submitted prior to the USACE issuing a 404 permit. This project incorporates detention basins that will likely be subject to the Iowa DNR Dam Safety program, according to the Iowa Administrative Code (567-71(d)). The Earth Embankment Dam application addendum will be required, along with a hydraulic analysis. Because the project is located within the USACE - Omaha District, that agency and the Iowa DNR will jointly issue the permit. Pump station construction, grading and culvert installation adjacent to the existing levees will require a section 401 permit because these activities will take place within the Floyd River floodplain. Additionally, this permit will cover construction activity within the floodplain as regulated by the National Flood Insurance Program. This portion of the permit will be monitored and enforced on the local level and will include reassessment of the floodplain due to ponding events after project completion. Permit application may be completed online at link provided below.

National Flood Insurance Program permit - see Joint Permit, Protecting Iowa Waters, Section 401 for more information. Permit application may be completed online at link provided below.

Note: Modifying the conveyance mechanism for stormwater (i.e. including a pump station near the Floyd River levee system and upstream retention basins), should be included in the City of Sioux City's existing Municipal Stormwater Permit #4 (MS4). The Iowa DNR confirmed this practice for typical stormwater conveyance mechanisms, but this fact should be confirmed with the Iowa DNR after the final plan set has been completed.

Contact Information
The Iowa Department of Natural Resources
Regulatory - Water
515-725-8415 or 515-724-8417
http://www.iowadnr.gov/InsideDNR/RegulatoryWater/NPDESStormWater/WhoMustApply.aspx
http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WetlandsPermitting.aspx
http://www.iowadnr.gov/InsideDNR/RegulatoryLand/FloodPlainManagement/NationalFloodInsProgram.aspx

United States Army Corps of Engineers
Joint Permit, Protecting Iowa Waters, Section 401 - see IDNR section for more information.

USACE Section 404 permits - This permitting process was established by the Clean Water Act of 1972, and Section 404 provides a regulatory mechanism for construction projects that could impact the waters of the United States. The USACE Omaha district will administer and oversee this permit application. The permit is necessary because the Floyd River is protected under the Clean Water Act, and the construction required on the retention basins and stormwater pump stations adjacent to the levees could impact the Floyd River. Permit application will be available after successful completion of Section 401 permit application.

USACE Section 408 permits - This permitting process provides a regulatory mechanism for construction projects that might impact portions of the federal levee protection system. The Floyd River levees currently protecting Sioux City are USACE designed and certified, and any modification or nearby construction must obtain either a major or minor Section 408 permit. Construction of the culvert underneath the railroad, pump station construction and grading activities near the levee structure must be included in this permit application. The permit will be administered and overseen by the USACE Omaha District. Permit application will be available after successful completion of Section 401 permit application.

Contact Information
USACE - Omaha District
1616 Capitol Ave., Ste. 9000
Omaha, NE 68102
Phone: (888) 835-5971 or
(402) 995-2229
http://www.nwo.usace.army.mil/Missions/RegulatoryProgram/PermittingProgram.aspx

Appendix B – Design Storm

Table B.1: *Design Storm for Sioux City, Iowa. The rainfall for the 10 and 100 year were adjusted to account for infiltration.*

NRCS Type II Design Storm			
100 year - 2 hour storm			
Climatic Sectional Code for Iowa - 04 - West Central			
Section	Duration	10 - year	100 - year
4	2 - hr	0.87	2.13

NRCS 24-Hour Rainfall Distributions			
Time	**Incremental Rainfall**	**10 - year (in)**	**100 - year (in)**
11.00	0.021	0.03	0.08
11.25	0.026	0.04	0.10
11.50	0.104	0.16	0.40
11.75	0.276	0.43	1.06
12.00	0.044	0.07	0.17
12.25	0.028	0.04	0.11
12.50	0.023	0.04	0.09
12.75	0.018	0.03	0.07
13.00	0.015	0.02	0.06

Cumulative Rainfall			
Time	**Incremental Rainfall**	**10 - year (in)**	**100 - year (in)**
0.00	0.021	0.03	0.08
0.25	0.026	0.07	0.18
0.50	0.104	0.24	0.58
0.75	0.276	0.67	1.64
1.00	0.044	0.74	1.81
1.25	0.028	0.78	1.92
1.50	0.023	0.82	2.00
1.75	0.018	0.85	2.07
2.00	0.015	0.87	2.13

Appendix C – Detention Basin

Table C.1: *Overall watershed area and runoff for the Leeds neighborhood.*

Total Area				**Runoff**	
Watershed	**NAME**	**AREA (ft^2)**	**Area (acres)**	**10 - year (ft^3)**	**100 - year (ft^3)**
Northern	Gates 3&4	36,341,884.63	834.29	2,634,786.64	6,450,684.52
Central	Gate 17	48,071,525.77	1,103.57	3,485,185.62	8,532,695.82
Southern		12,728,847.38	292.21	922,841.43	2,259,370.41
	Total	**97,142,257.78**	**2,230.08**	**7,042,813.69**	**17,242,750.76**

Table C.2: *Rural Land area and runoff within the Leeds neighborhood watershed.*

Rural Area				**Runoff**	
OBJECTID	**LandUse**	**AREA (ft^2)**	**Area (acres)**	**10 - year**	**100 - year (ft^3)**
1	Row Crops	7,313,666.80	167.90	530,240.84	1,298,175.86
2	Row Crops	3,147,747.02	72.26	228,211.66	558,725.10
3	Row Crops	3,418,004.22	78.47	247,805.31	606,695.75
4	Row Crops	524,597.82	12.04	38,033.34	93,116.11
5	Row Crops	2,156,029.51	49.50	156,312.14	382,695.24
6	Grassland	136,814.06	3.14	9,919.02	24,284.50
7	Grassland	215,185.89	4.94	15,600.98	38,195.50
8	Grassland	205,830.63	4.73	14,922.72	36,534.94
9	Grassland	11,098,031.30	254.78	804,607.27	1,969,900.56
14	Row Crops	496,053.87	11.39	35,963.91	88,049.56
15	Row Crops	1,354,744.29	31.10	98,218.96	240,467.11
16	Grassland	1,074,601.18	24.67	77,908.59	190,741.71
17	Grassland	839,070.40	19.26	60,832.60	148,935.00
18	Grassland	60,956.25	1.40	4,419.33	10,819.73
19	Grassland	87,093.91	2.00	6,314.31	15,459.17
27	ROW	2,128,116.10	48.85	154,288.42	377,740.61
	Total	**34,256,543.27**	**786.42**	**2,483,599.39**	**6,080,536.43**

Table C.3: Urban Land area and runoff within the Leeds neighborhood watershed.

Urban Area				Runoff	
OBJECTID	LandUse	AREA (ft^2)	Area (acres)	10 - year	100 - year (ft^3)
10	Commercial	708,084.16	16.26	51,336.10	125,684.94
11	Commercial	83,136.00	1.91	6,027.36	14,756.64
12	Industrial	1,303,516.08	29.92	94,504.92	231,374.10
13	Industrial	2,086,208.32	47.89	151,250.10	370,301.98
20	Residential	11,978,155.59	274.98	868,416.28	2,126,122.62
21	Undeveloped Residential	2,345,413.11	53.84	170,042.45	416,310.83
22	Undeveloped Residential	4,323,600.12	99.26	313,461.01	767,439.02
23	Undeveloped Residential	4,008,664.49	92.03	290,628.18	711,537.95
24	Residential	2,846,930.58	65.36	206,402.47	505,330.18
25	Undeveloped Residential	45,404.47	1.04	3,291.82	8,059.29
26	Undeveloped Residential	130,977.57	3.01	9,495.87	23,248.52
28	Commercial	2,721,656.11	62.48	197,320.07	483,093.96
	Other*	30,303,967.91	695.68	2,197,037.67	5,378,954.30
	Total	**62,885,714.51**	**1,443.65**	**4,559,214.30**	**11,162,214.33**

* Assumed areas that were not classified as rural were considered urban

Table C.4: Detention basin information. Watershed 0 is the Northern section, Watershed 1 is the Central section and Watershed 4 is the Southern section.

Watershed	Pour Point FID	Watershed Area (ft^2)	Pour Point Elevation (ft.)*	Channel Bank Elevation	Channel Depth (ft.)	Detention Basin Elevation (ft.)!	Detention Height (ft.)	Detention Length (ft.)
0	0	9,727,367.99	1173	1180	7	1186	13	283.82
	1		1193	1193	0	1203	10	376.05
	2		1219	1227	8	1234	15	391.25
	3		1206	1214	8	1214	8	212.80
							Total	
1	0	18,517,623.17	1160	1164	4	1170	10	320.26
	1		1192	1192	0	1200	8	464.25
	2		1216	1216	0	1224	8	319.84
	3		1226	1226	0	1234	8	309.86
	4		1239	1239	0	1249	10	358.26
	5		1229	1229	0	1239	10	328.24
	6		1180	1180	0	1188	8	321.35
	7		1228	1228	0	1236	8	260.29
							Total	
4	0	7,766,647.05	1166	1166	0	1172	6	291.03
	1		1187	1187	0	1192	5	289.03
							Total	

*Pour Point Elevation is at the bottom of channel

! Detention Basin Height is from top of retention basin to bottom of the channel

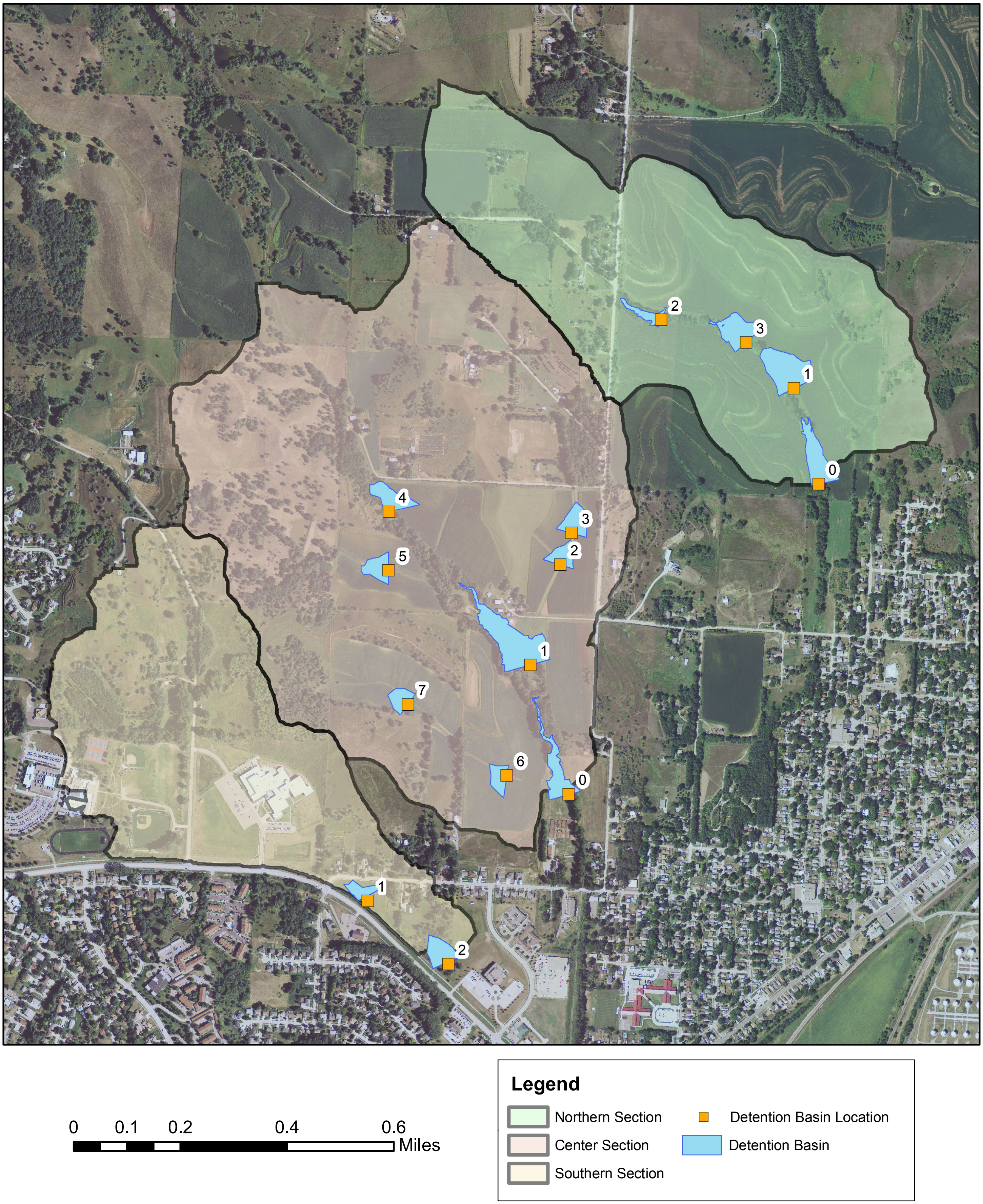
Table C.5: *Detention basin area and detention capacity for each section.*

Watershed	Pour Point FID	Watershed Area (ft^2)	Surface Area (ft^2)	Detention Volume (ft^3)	10 yr. flow	100 yr. flow	Percent of 10 yr. flow	Percent of 100 yr. flow
0	0	9,727,367.99	106,964.71	335,978.33	705,234.18	1,726,607.82	47.64%	19.46%
	1		145,383.44	554,340.58			78.60%	32.11%
	2		35,491.05	175,609.50			24.90%	10.17%
	3		92,414.88	255,210.88			36.19%	14.78%
		Total	**380,254.08**	**1,321,139.29**			**187.33%**	**76.52%**
1	0	18,517,623.17	92,472.02	254,744.68	1,342,527.68	3,286,878.11	18.98%	7.75%
	1		219,473.10	1,080,606.23			80.49%	32.88%
	2		45,939.13	133,392.07			9.94%	4.06%
	3		61,062.79	169,213.75			12.60%	5.15%
	4		70,578.79	278,610.49			20.75%	8.48%
	5		52,428.19	206,596.78			15.39%	6.29%
	6		40,854.38	116,415.07			8.67%	3.54%
	7		42,182.06	136,066.55			10.14%	4.14%
		Total	**624,990.46**	**2,375,645.62**			**166.82%**	**68.14%**
4	0	7,766,647.05	61,920.66	170,618.71	563,081.91	1,378,579.85	30.30%	12.38%
	1		32,911.30	55,345.78			9.83%	4.01%
		Total	**94,831.96**	**225,964.49**			**40.13%**	**16.39%**

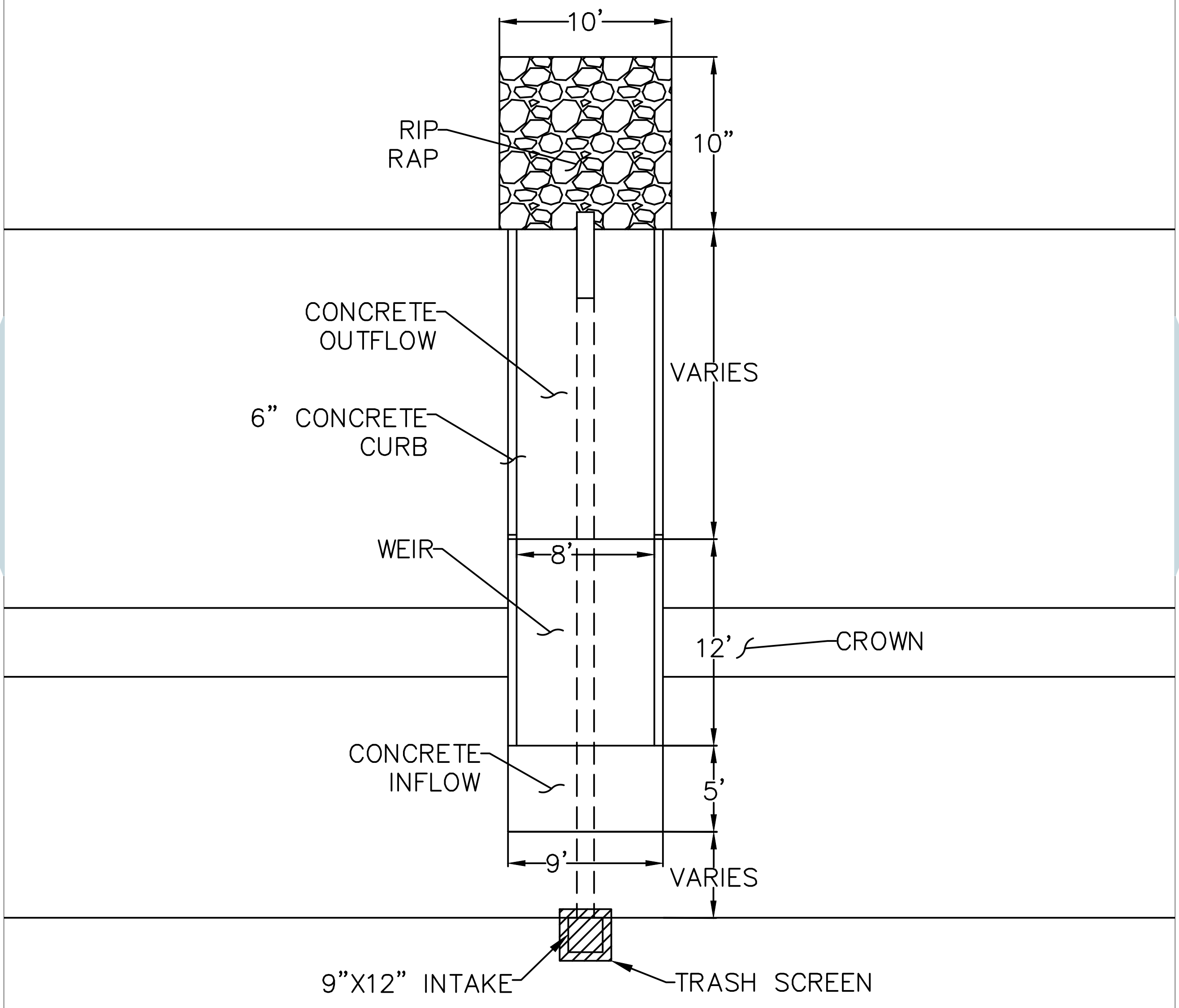
*Pour Point Elevation is at the bottom of channel

! Detention Basin Height is from top of retention basin to bottom of the channel

Proposed Detention Basin Locations



PLAN VIEW (TYP.)

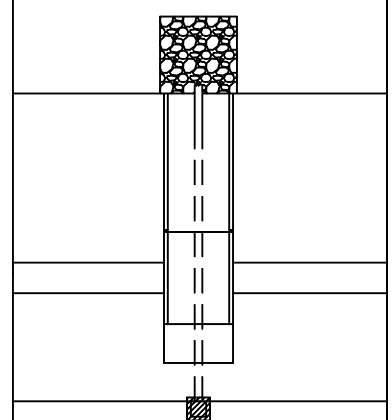


SWAG & K Associates

TYPICAL DETENTION BASIN DESIGN

LEGEND

KEY MAP

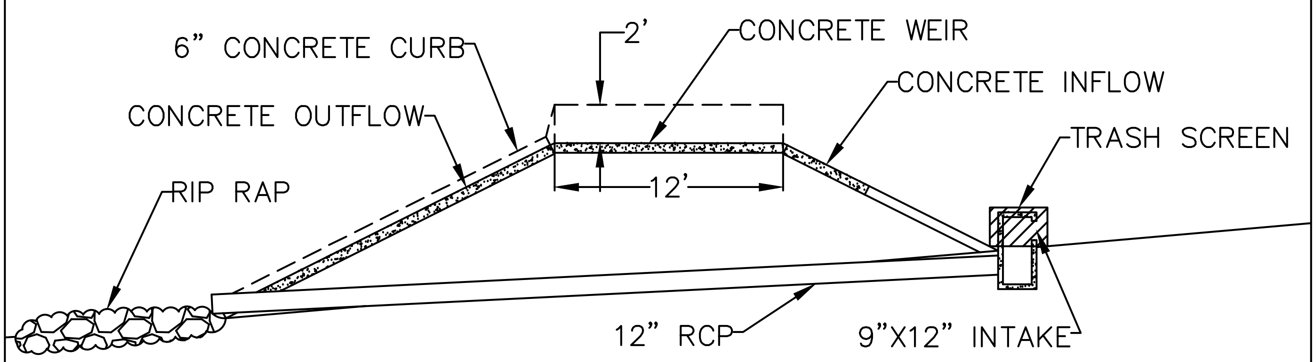


SCALE	SHEET NUMBER
1"=10'	101
PLOT DATE	
04/30/15	

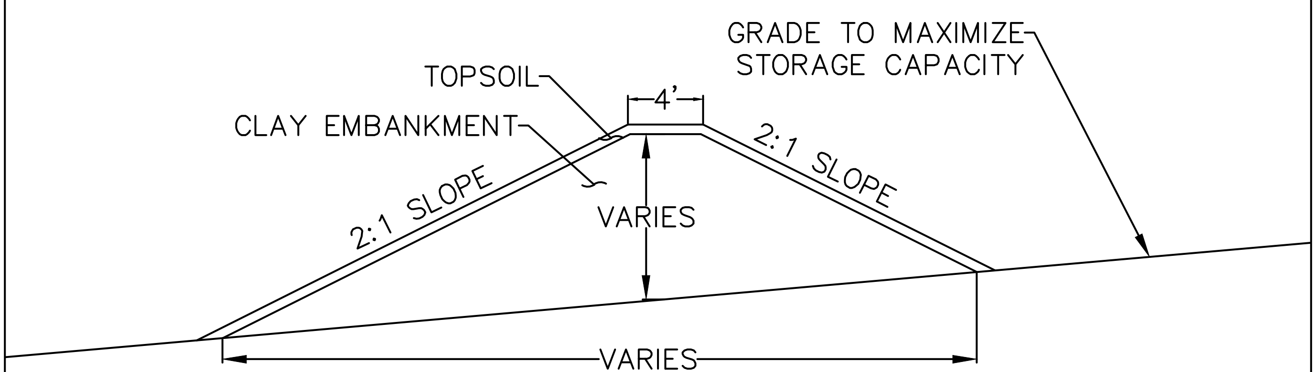
PROJECT NAME

FLOYD RIVER PROJECT

CROSS-SECTION A–A (TYP.)



CROSS-SECTION B–B (TYP.)

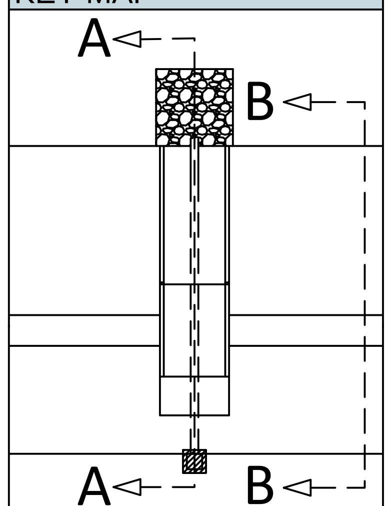


SWAG & K Associates

TYPICAL DETENTION BASIN DESIGN

LEGEND

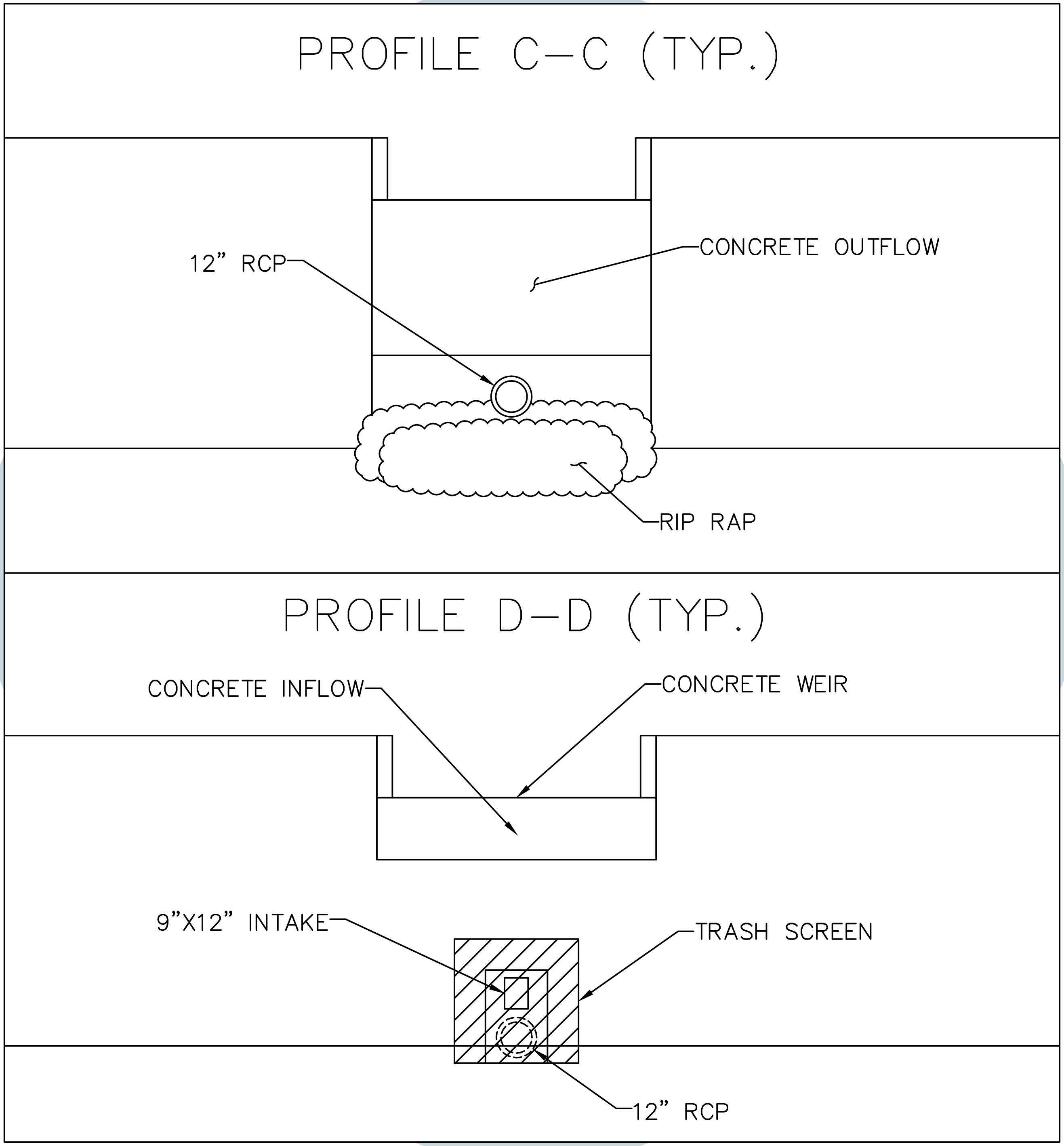
KEY MAP



SCALE	SHEET NUMBER
1"=10'	102
PLOT DATE	
04/30/15	

PROJECT NAME

FLOYD RIVER PROJECT

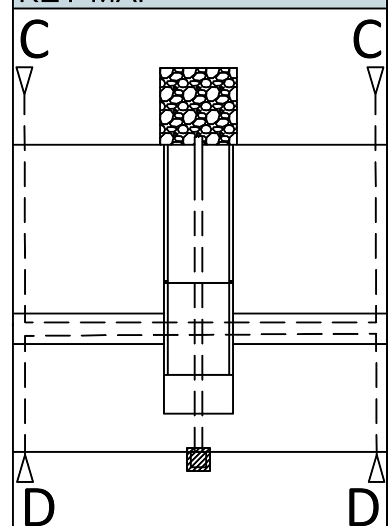


SWAG & K Associates

TYPICAL DETENTION
BASIN DESIGN

LEGEND

KEY MAP



SCALE	SHEET NUMBER
1"=5'	103
PLOT DATE	
04/30/15	

PROJECT NAME

FLOYD RIVER PROJECT

Appendix D – Pumping Calculations

Table D.1: *Ponding volumes with required pumping volume*

With Detention Basins*		
Total Inflow	Storage Available	Required Pumping Volume
13,320,001.36	15,127,775.70	(1,807,774.34)
Without Detention Basins*		
Total Inflow	Storage Available	Required Pumping Volume
17,242,750.76	15,127,775.70	2,114,975.06
* All units are in cubic feet		

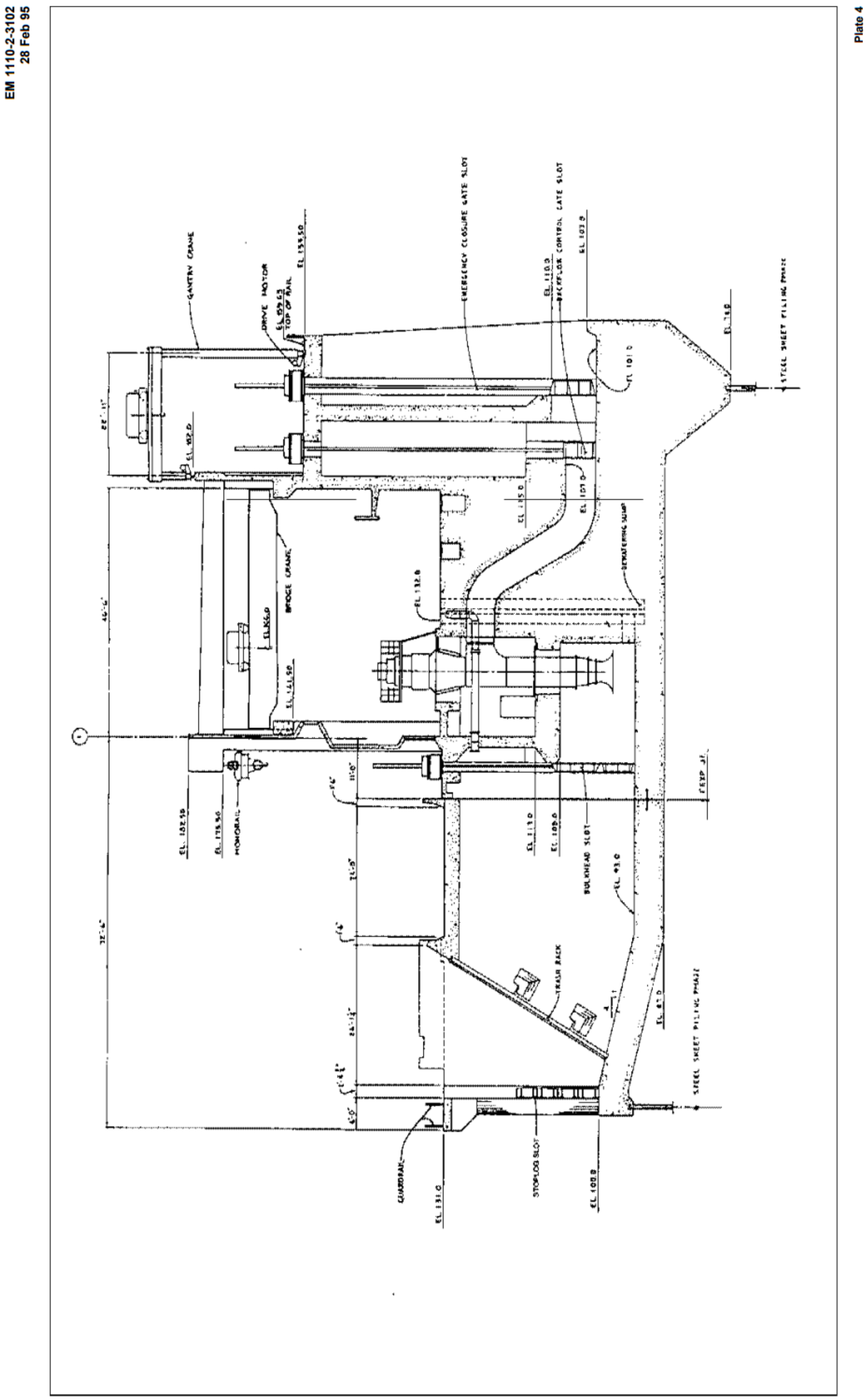


Figure D.1: *Typical Pump Station Design*

Appendix E - Detention basin costs

As described in the Cost Estimates section of the report, construction costs were separated out between the three major components of the final design; detention basins, pump stations and green alternatives. This portion of the appendix details the construction cost calculations for the detention basins only.

SWAG & K Associates' approached the cost estimation process of the detention basins from two perspectives. First, a detailed line-item cost estimate tabulation was developed, with each item delineated and estimated. Second, empirical models developed by researchers and engineers were applied to the detention basin design. These models provided validation of SWAG & K Associates' line-item cost estimates and final total projected cost. The line-item construction cost estimate tabulation and associated references may be found on the subsequent pages of the appendix. Empirical models presented in the report are detailed subsequently.

The three empirically-developed numerical equations to estimate construction costs of dry detention basins were developed by Young, et. al. (Young), Weigand, et. al. (Weigand), and the Metropolitan Washington Council of Governments (MWCG). The estimated construction costs (excluding land purchase cost) to build the detention basins outlined in this project are presented below.

Table E.1: *Detention basin cost comparison*

DETENTION BASIN UPFRONT COST ESTIMATE VALIDATION	
Cost Estimate Source	**Overall Cost**
	(excluding land purchase)
SWAG & K Associates Estimate	$ 1,221,000.00
Metropolitan Washington Council of Governments	$ 2,716,000.00
Weigand, et al.	$ 1,041,000.00
Young, et al.	$ 1,475,000.00

All models function similarly, having been developed with a series of projects of a given size with a known final construction cost. All three models are exponential in nature, and require a known volume to estimate the costs. The expected full volume storage capacity of all 10 detention basins specified in the final design were applied to the equations and summed to yield a final cost estimate. Although the equations yield a difference in final cost estimation of approximately $1.7 million dollars (largest to smallest), they provide agreement for the final design construction costs of the 10 detention basins in the low millions, and bookend the line-item cost estimate presented subsequently. Each equation utilized in the calculations is presented below. Note that the MWCG's equation was calculated in 1985 dollars, and so a conversion of 2.2 was applied to translate the costs into 2015 dollars. The other two equations final estimates account for inflation.

$$Young's\ Equation\quad C\ (dollars) = 55{,}000 \times V\ (MGal)^{0.69}$$

$$Weigand's\ \ Equation\quad C\ (dollars) = 10.71 \times V\ (cu\ ft)^{0.694}$$

$$MWCG's\ Equation\quad C\ (1985\ dollars) = 6.1 \times \left(\frac{V\ (in\ m^3)}{0.02832}\right)^{0.75}$$

Table E.2: *Detention Basin Cost Breakdown*

DETENTION BASIN LAND ACQUISITION AND CONSTRUCTION COST ESTIMATE					
Number	Item	Units	Number	Cost/Unit	Total Cost
1	Mobilization (5-10% of total)				$ 95,586.20
2	ready mix concrete, 4500psi, including local aggregate and sand (Type II mixture)	CY	110	$ 121.00	$ 13,310.00
3	placing slab on grade concrete, including labor/equipment to place, level and consolodate,	CY	110	$ 26.50	$ 2,915.00
4	rip rap, placed, 6-18", 1' deep	SY	120	$ 103.00	$ 12,360.00
5	gravel, 1-1/2" stone base, 8" deep, underneath concrete, pipe and rip rap, placed	SY	550	$ 11.95	$ 6,572.50
6	trash rack/screen	EACH	10	$ 3,000.00	$ 30,000.00
7	Precast, custom-design, concrete inlet structure	EACH	10	$ 1,200.00	$ 12,000.00
8	12" Reinforced Concrete Pipe, gasketed, class 3	FT	600	$ 25.50	$ 15,300.00
9	erosion control - place and remove haybales	TON	2	$ 825.00	$ 1,650.00
10	erosion control - filter sock	LF	20000	$ 3.00	$ 60,000.00
11	erosion control - revegetation mat	SY	50000	$ 5.85	$ 292,500.00
12	clearing/grubbing, cut and chip medium, trees to 12" diameter, grub stumps and remove	ACRES	10	$ 6,850.00	$ 68,500.00
13	Topsoil, strip and stockpile on site (beneath levee area)	CY	2500	$ 2.00	$ 5,000.00
14	Rough Grading, 3000 acres (avg)/site, 10 sites	SITES	10	$ 5,250.00	$ 52,500.00
15	native seeding, including 2nd year partial re-seed, Economy Grass Mix - Statewide Mesic 40	ACRES	45	$ 110.00	$ 4,950.00
16	Labor and Materials required for seeding	LS	1	$ 6,000.00	$ 6,000.00
17	Medium Cost Clay Levee 10' high on average, 3:1 slopes (actual 2:1), clay and placement costs	MILES	0.95	$ 345,000.00	$ 326,704.55
18	Clay delivery cost, BCY to LCY, assume swell factor of 1.3	LCY	3200	$ 14.25	$ 45,600.00
19	Labor, 2 months of work, 5 days/week, crew of 4, 8 hours/day	HOURS	1280	$ 35.33	$ 45,225.52
20	Contingency - 20%	-	-	-	$ 219,334.75
					$ -
					$ 1,220,422.32
-	Sioux Falls or Council Bluffs weighted average, approximately 100%				$ 1,220,422.32
					$ -
21	Land Acquisition	ACRES	30	7600	$ 228,000.00
					$ -
	Total Projected Construction and Land Acquisition Costs				**$ 1,448,423.00**

Table E.3: *References for Detention Basin Cost Breakdown*

DETENTION BASIN LAND ACQUISITION AND CONSTRUCTION COST ESTIMATE - REFERENCES		
Component	**Number**	**References**
Detention basins	2	RSMeans Heavy Construction pg 75
Detention basins	3	RSMeans Heavy Construction pg 76
Detention basins	4	RSMeans Heavy Construction
Detention basins	5	RSMeans Landscaping pg 362
Detention basins	6	http://www.stormwatercenter.net/Manual_Builder/Maintenance_Manual/7-%20Maintenance%20Frequency%20Table-NA/cost_frequency.pdf
Detention basins	7	estimation from previous knowledge acquired during internship
Detention basins	8	RSMeans Heavy Construction pg 361
Detention basins	9	RSMeans Heavy Construction pg 261
Detention basins	10	http://water.epa.gov/polwaste/npdes/swbmp/Compost-Filter-Socks.cfm
Detention basins	11	RSMeans Heavy Construction pg 261
Detention basins	12	RSMeans Heavy Construction pg 217
Detention basins	13	RSMeans Heavy Construction pg 219
Detention basins	14	RSMeans Heavy Construction pg 219
Detention basins	15	Quote from Allendan Seed Company, April 23, 2015
Detention basins	16	estimation from previous knowledge acquired during internship
Detention basins	17	RSMeans Heavy Construction
Detention basins	18	RSMeans Heavy Construction
Detention basins	19	http://enr.construction.com/economics/ & RSMeans Heavy Construction
Detention basins	20	Contingency
Total (except land)		RSMeans Heavy Construction
Detention basins	21	ISU Center for Agricultural and Rural Devleopment, 2014 Iowa Land Value Survey
Total (including land)		$ 1,448,423.00

Detention Basin Maximum Outflow

Weir Flow Equation

$q = 3.33(b - 0.2h)(h^{\frac{3}{2}})$

q- flow in cubic feet per second (ft^3/s)

b- length of weir (ft)

h- head over weir (ft)

- Head must be less than 2 feet

Calculation

b = 8 ft, q = 20 ft/s

$20 = 3.33(8 - 0.2h)(h^{\frac{3}{2}})$

$20 = (26.64 - 0.666h)(h^{\frac{3}{2}})$

$20 = 26.64h^{3/2} - 0.666h^{5/2}$

$0 = -20 + 26.64h^{\frac{3}{2}} - 0.666h^{5/2}$

h = 0.45 ft < 2 ft

Final Weir Design

b = 8 ft

h = 0.45 ft

q = 20 ft/s = 8976 gallons/min

Orifice Flow Equation

$Q = C_d A_o (2gh^{0.5})$

Q = flow in cubic feet per second (ft^3/s)

C_d = drag coefficient over weir

- Standard value of 0.6 used

A_o = area of orifice in square feet (L * h) (ft^2)

g = gravity constant (ft/s^2)

h = head of water in orifice in feet (ft) – assumed at maximum level

Calculation

$Q = 0.6(1 * 0.75)(2 * 32.2 * 0.75)^{0.5}$

Q = 0.6(0.75)(6.94)

Q = 0.45(6.94)

Q = 3.13 ft^3/s = 1405 gallons/min

Final Orifice Design

L = 1 ft

h = 0.75 ft

Q = 3.13 ft^3/s = 1405 gallons/min

Total Outflow of Detention Basin

$Q_T = Q + q$

$Q_T = 1405 + 8976$

Q_T = 10,381 gallons/min

Appendix F - Rain Gardens

Rational Method Equation

Q = CiA

Q = runoff volume in cubic feet (ft^3)

C = runoff coefficient for specified surface

- value used of 0.825 for asphalt and concrete

i = rainfall for design storm in inches (in)

A = area of surface(s) being considered in square feet (ft^2)

- area of roads in neighborhood

Calculation

$$Q = 0.825(0.86)(\frac{1}{12})(2155507.5)$$

$$Q = 127{,}444.36\ ft^3$$

Table F.1: *Unit cost breakdown for Green Alternatives*

Items	Quanity	Cost per unit	Total Cost
Materials			
Shovel	1	$ 21.97	$ 21.97
Rake	1	$ 15.97	$ 15.97
Rope	1	$ 7.77	$ 7.77
Wooden Stakes	1	$ 4.57	$ 4.57
Flags	1	$ 3.88	$ 3.88
String	1	$ 2.29	$ 2.29
Tape Measure	1	$ 15.97	$ 15.97
Wheel Barrow	1	$ 33.98	$ 33.98
Base Design			
Top Soil	100	$ 2.09	$ 209.00
Mulch	30	$ 3.33	$ 99.90
Plants			

Blue Grama	1		$ 54.95	$ 54.95
Butterfly milkweed	1		$ 24.95	$ 24.95
Columbine	1		$ 24.95	$ 24.95
Fox sedge	1		$ 23.96	$ 23.96
Mountain Mint	1		$ 59.90	$ 59.90
Prairie blazing star	1		$ 24.95	$ 24.95
silky aster	1		$ 29.95	$ 29.95
Retaining Wall				
Stone	100		$ 1.36	$ 136.00
Mortar	1		$ 14.47	$ 14.47
Gravel	8		$ 7.99	$ 63.92
Rip Rap Limestone	1		$ 41.00	$ 41.00
PVC pipe	1		$ 4.00	$ 4.00
Labor	**# of workers**	**Hours**		
Landscaper	1	8	$ 11.00	$ 88.00
Architect	1	8	$ 31.11	$ 248.88
Surveyer	1	8	$ 20.00	$ 160.00
Engineer	1	8	$ 24.04	$ 192.32
Engineer, P.E.	1	8	$ 41.83	$ 334.64
Transportation				
Delivery (< 10 mi)	1		$ 60.00	$ 60.00
Delivery (> 10 mi)	1		Varies	Varies on distance

Appendix G – Project Schedule

Table G.1: *Project Schedule*

Task Name	Duration	Start	Finish	Predecessors
Floyd River Drainage Mitigation	**140 days**	**Wed 4/29/15**	**Thu 11/12/15**	
Bid Acceptance	1 day	Wed 4/29/15	Wed 4/29/15	
Permitting	**139 days**	**Thu 4/30/15**	**Thu 11/12/15**	
City of Sioux City	16 days	Thu 6/11/15	Thu 7/2/15	5
Iowa DNR	30 days	Thu 4/30/15	Wed 6/10/15	2
Army Corps of Engineers	60 days	Thu 4/30/15	Thu 7/23/15	2
Green Alternatives	**79 days**	**Fri 7/24/15**	**Thu 11/12/15**	
Rain Gardens	30 days	Fri 7/24/15	Thu 9/3/15	6
Bio-Swales	10 days	Fri 7/24/15	Thu 8/6/15	6
Bioretention Ponds	14 days	Fri 7/24/15	Wed 8/12/15	6
Pump Stations	**79 days**	**Fri 7/24/15**	**Thu 11/12/15**	
Levee Inspection	10 days	Fri 7/24/15	Thu 8/6/15	6
Pump Installation	30 days	Fri 8/7/15	Fri 9/18/15	12
Detention Basins	**79 days**	**Fri 7/24/15**	**Thu 11/12/15**	
Land Acquisition	30 days	Fri 7/24/15	Thu 9/3/15	6
Site Survey	5 days	Fri 9/4/15	Fri 9/11/15	15
Construction	30 days	Mon 9/14/15	Fri 10/23/15	16
Final Checks	**14 days**	**Mon 10/26/15**	**Thu 11/12/15**	
Review Construction	8 days	Mon 10/26/15	Wed 11/4/15	17
Make Necessary Adjustments	5 days	Thu 11/5/15	Wed 11/11/15	19
Complete Contract	1 day	Thu 11/12/15	Thu 11/12/15	20

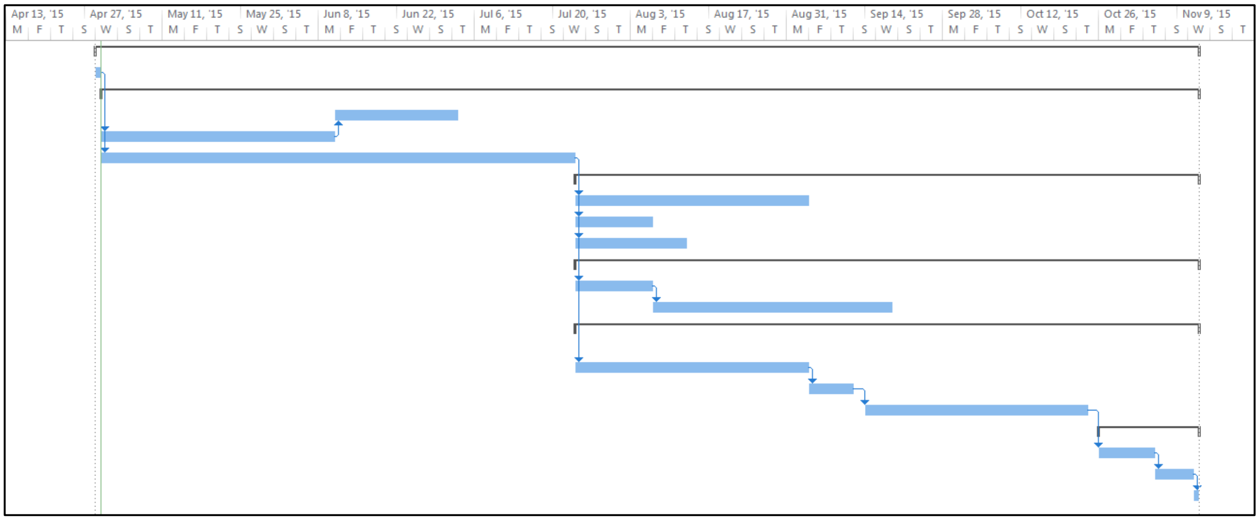


Figure G.1: *Gantt Chart showing project schedule*

Appendix H - HR Green Reports

The HR Green reports that have been referenced in other portions of this report are included here for reference on the subsequent pages.

TECHNICAL MEMORANDUM

To:	Jade Dundas – Public Works Director, City of Sioux City, IA Brittany Anderson – Civil Engineer, City of Sioux City, IA
From:	Chris Harrington, P.E. - HR Green, Inc. Mike Ryan, P.E. - HR Green, Inc. Jonathon Kusa, P.E. - HR Green, Inc.
Subject:	Floyd River Flood Reduction Concept Design Recommendation
Date:	August 7, 2013

Goal and Background

The goal of this study is to provide a recommendation for reducing the extent of the flood zone and accommodating a proposed recreational trail in the Leeds area of the City of Sioux City, Iowa.

For the flooding aspects of this project the levee certification documentation was the source of the most relevant information. HR Green assisted the City of Sioux City (the City) with the process of levee certification for the Floyd River flood protection levees in 2012. FEMA approved the City of Sioux City Floyd River Levee Certification Report in August of 2012. For the levee certification HR Green generated maps of the extent of ponding on the protected side of the levee expected under high river levels with coincident local rain storms. The combination of local rain fall and high river level that produces the most local flooding is referred to as the worst case ponding event, and that mapping is used by FEMA to determine the flood zone. The mapping of the worst case ponding event in the Leeds area of the City resulted in numerous businesses and homes being located within the flood zone (Figure 1). The most densely developed area located within the flood zone consists of an approximately 10 block zone centered along Floyd Boulevard between Van Buren and Grant Streets.

For the trail aspects of this project the Floyd River Valley Trail Study was the source of the most relevant information. In April 2012, the Siouxland Regional Transportation Planning Association (SRTPA) formed a Regional Bike Group to evaluate the feasibility of a trail between the communities of Sioux City and La Mars, Iowa. Subsequently the SRTPA has published the Floyd River Valley Trail Study in June of 2013, which is referred to in this memo.

Under existing conditions there are three distinct ponding basins, or watersheds (Figure 2). Each watershed has a different worst case ponding elevation. Providing a hydraulic connection between watersheds 1, 2 and 3 would allow the ponding to level out between the three watersheds. Combining the watersheds would alleviate some of the ponding in the intensely developed area along Floyd Blvd, though it would worsen the ponding in other less developed areas. HR Green calculates that if the three basins are combined the ponding elevation in watershed 1 can be reduced from 1109 to 1108 ft (Figures 1 & 2). Simultaneously, the ponding elevations in watersheds 2 and 3 will rise to 1108, from 1106 and 1104, respectively (Figures 1 & 2).

Recommended Concept Design- Combining Increased Recreational Opportunities with Flood Reduction in the Leeds Area

HR Green recommends using 12' wide by 10' tall trail box culverts suitable for below grade railroad and highway crossings to provide a hydraulic connection between watersheds 1 and 3 (Figure 4). These culverts will serve as hydraulic connections as well as linear trail connections following the trail path proposed in the Floyd River Valley Trail Study. For connecting watersheds 2 and 3 an 8' wide by 4' tall box culvert is recommended to augment the hydraulic connection of those two watersheds (Figure 5).

Ponding volume calculations under proposed conditions followed generally the same methodology that was followed for the levee certification project. These calculations assumed no loss of ponding due to infiltration, and the same flow rates through the open gates as were used in the levee certification. Prior to final design new flow calculations through the open Floyd gates need to be performed at the water levels seen under proposed conditions. For levee certification calculations the volume of storage within the Magellan Pipe Line Company storage tank berms was counted as storage volume. For the final design a walk-through of the facility is recommended and a decision needs to be made as to whether or not to include these berm volumes as storage. For the calculations of culvert capacity in this memo the Magellan berm storage was not included.

For the purposes of ponding calculations the east and west sides of the BNSF railroad are united within watershed 1 by storm sewer pipe parallel to Floyd Blvd (Figures 1, 2, and 3). Despite already being hydraulically connected, the trail box culvert beneath the BNSF railroad (Figure 4) is recommended in order to enhance the hydraulic connection between the east and west side of the railroad, as well as to provide a safe railroad crossing for the recreational trail. The difficulties pointed out in the Floyd River Valley Trail Study can be overcome by creating a safe trail crossing beneath the tracks. Additionally, it is not recommended to rely on the storm sewer parallel to Floyd Blvd to serve as the only hydraulic connection across the BNSF tracks unless modeling is done to confirm that its capacity would be adequate to carry sufficient water to the highway 75 trail box culvert.

The highway 75 trail box culvert will serve to hydraulically connect watersheds 1 and 3 (Figure 4). In order to reduce ponding to elevation 1108 in watershed 1 from elevation 1109 a total of 7,606,000 gallons of water need to pass beneath Highway 75. A 12' wide by 10' tall box culvert will allow the flow required to pass within 4.4 hours with a headwater elevation of 1104 and a tailwater elevation of 1103. A headwater elevation of 1104 was chosen since the full ponding depth of 1108 is only reached at the peak of flooding. Dynamic modeling is recommended to confirm the actual ponding elevations throughout the course of a rain event under the worst case coincident scenario.

41st street is distinct from the crossings of the BNSF railroad and highway 75 in that the recommended hydraulic connection and recommended trail crossing are not in the same location (Figure 5). An existing vegetated open channel runs north from gate 13 to 41st street (Figure 1). Due to the proximity of another existing vegetated open channel on the north side of 41st Street, located in the SW corner of watershed 2 (Figure 1), HR Green recommends an 8' wide by 4' tall box culvert be placed to connect the two open channels (Figure 5). An 8' wide by 4' tall box culvert will allow the flow required to pass within 3.5 hours. Following the same logic as for the highway 75 culvert capacity a headwater elevation of 1104 and a tailwater elevation of 1103 were used for that calculation. To prevent a flow bottleneck on the north side of 41st street an open channel excavation is recommended (Figure 5).

HR Green recommends that the trail continue along the top of the Floyd River levee to 41st Street following the proposed route in the Floyd River Valley Trail Study (Figure 5).

<u>Private Property Impacts of Recommended Concept Design</u>

The crossing of the BNSF railroad tracks will require a permit from the railroad. Since the City of Sioux City owns the property on both sides of the tracks, other than what is required by the railroad, additional easements will not be required for that crossing (Figure 4).

The private property of Magellan Pipe Line Company LP on the west side of highway 75 and Babe James and Norman Claude Paterson on the east side of the highway will be impacted by the recommended design (Figure 4). The existing berm partially on Magellan property and partially on City of Sioux City property will need to be relocated further to the north to provided adequate space for an excavated open channel flow path. The open channel excavation is recommended due to the relatively high grade elevation (from 1106 to 1108) in the area which would delay the distribution of flood water from watershed 1 to watershed 3.

The private property of Babe James and Norman Claude Paterson is also recommended to be regraded (Figure 4) in order to avoid a bottleneck for distributing water from watershed 1 to watershed 3. The excavation could be placed as close as possible to the Floyd levee but private property impacts will likely be required to provide an adequately sized open channel.

The private properties owned by Ribob Company and Avery Brothers LLC are also recommended to be regraded. This regrading will enhance the rate of equalization of water levels between watersheds 1, 2 and 3, via the culvert beneath 41st St.

Property owned by Babe James, Norman Claude Paterson, Ribob Company, and Avery Brothers LLC, discussed above will also be impacted by increased flooding on their properties as a result of the recommended project. In addition Janice L Durig and Eve M Ivener Trustee #15245 will also be impacted by increased flooding on their properties.

Schematic Opinion of Probable Construction Cost of Recommended Concept Design

Presented below are the overall project costs at the planning level for the recommended alternative. The costs presented are expected to be the upper limit of cost for the project. The tunnels beneath the railroad and the highway are the greatest contributor to overall project cost. Based on preliminary conversations with tunneling contractors 12' diameter circular tunnels beneath the railroad and highway are likely to be less expensive than the recommended box culvert tunnels; however, using circular tunnels would reduce the trail width and bike handlebar clearance. The method of tunneling used would also be subject to approval by the Department of Transportation and BNSF.

$2,280,000	Schematic Opinion of Probable Construction Cost
$460,000	20% Contingency
$2,740,000	Total (not including engineering or easement acquisition)

List of Potential Regulatory Permitting Requirements of Recommended Concept Design

- City Permits
  - Floodplain
  - Stormwater Construction Permit
- Corps of Engineers Section 408 Levee Permit (Trail Construction and work on levee areas)
- National Environmental Policy Act (NEPA)
  - Required if receiving federal funding
  - Categorical exclusion may be possible for small projects as determined by FEMA
- FEMA
  - Ponding Analysis Reviews and associated Re-Mapping
- Joint Application Form – Protecting Iowa Waters
  - US Army Corps of Engineers (USACE)
    - Wetland and channel impacts
  - Iowa Department of Natural Resources (DNR)
    - Section 401 Water Quality
  - State Historic Preservation Office (SHPO)

- Iowa Department of Transportation Permit for Crossing Hwy 75
- Permit for shut down of 41st Street
- BNSF Railway Company
    - Crossing Permit

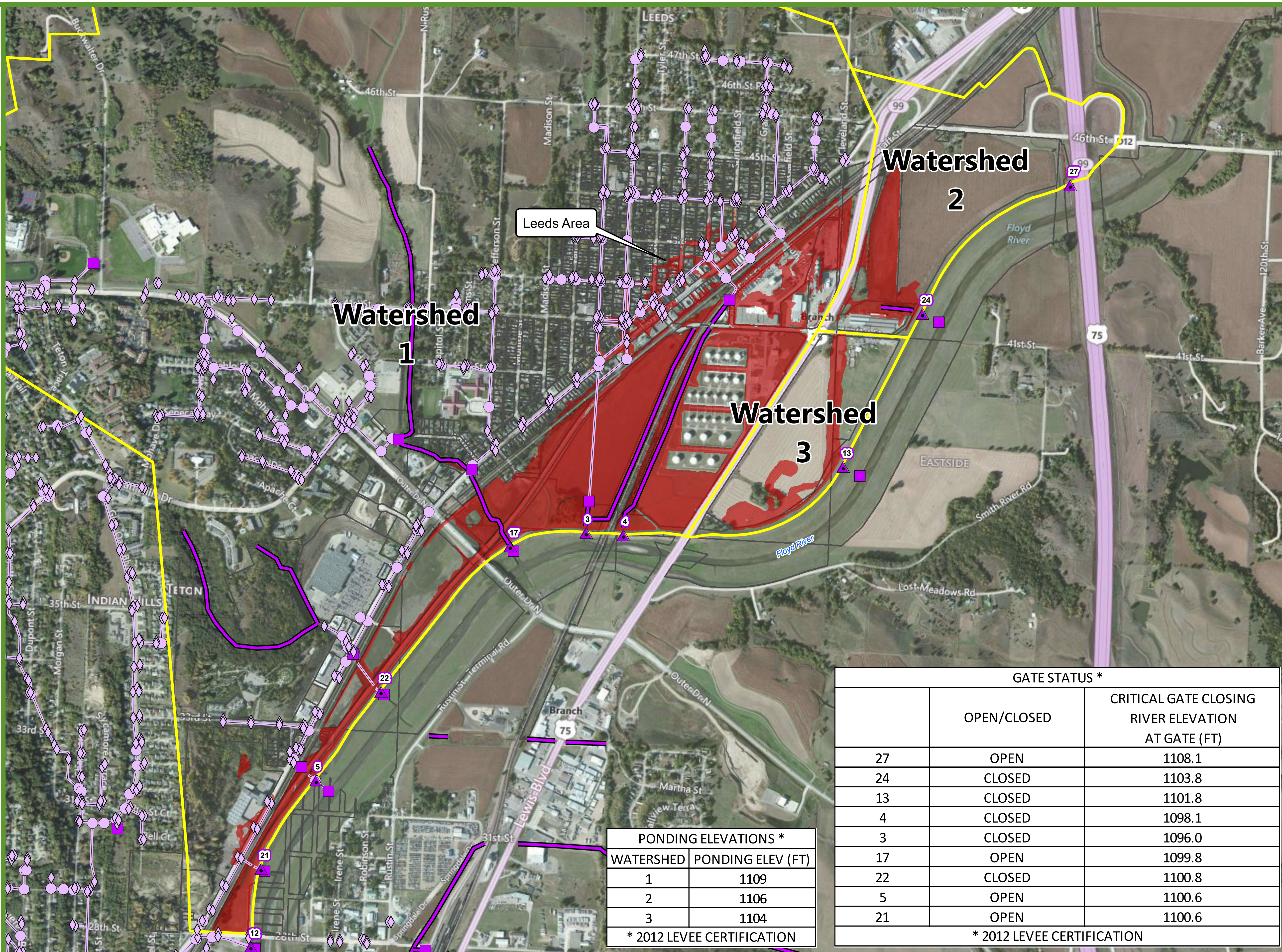
Conclusion

The recommended concept design would reduce the total number of property owners located within the flood zone, and enhance the recreational trail along the Floyd River. Prior to final design, dynamic modeling of the flows through the proposed culverts, open channels, and existing storm network is recommended along with an investigation of the piping and overflows of the tank berms on the Magellan Pipe Line Company property.

FIGURE 1 - WORST CASE PONDING EXTENTS UNDER EXISTING CONDITIONS

FLOYD RIVER FLOOD REDUCTION

SIOUX CITY, IA



Legend

- Floyd Floodgates
- Inlets
- Outlets
- Storm Manhole
- Open Drain
- Storm Pipe
- Watershed Boundaries
- Worst Case Ponding Extents
- Parcels

Data Source: ESRI; Iowa DNR; USGS; HR Green
Project Coordinate System:
NAD 1983 StatePlane Iowa North FIPS 1401 Feet
Projection: Lambert_Conformal_Conic
Vertical Datum: NAVD 88

1 inch = 1,200 feet

0 600 1,200 2,400 Feet

N E S W

SIOUX CITY SUCCESSFUL SURPRISING SIOUX CITY

HRGreen

Date: 8/6/2013

PONDING ELEVATIONS *	
WATERSHED	PONDING ELEV (FT)
1	1109
2	1106
3	1104

* 2012 LEVEE CERTIFICATION

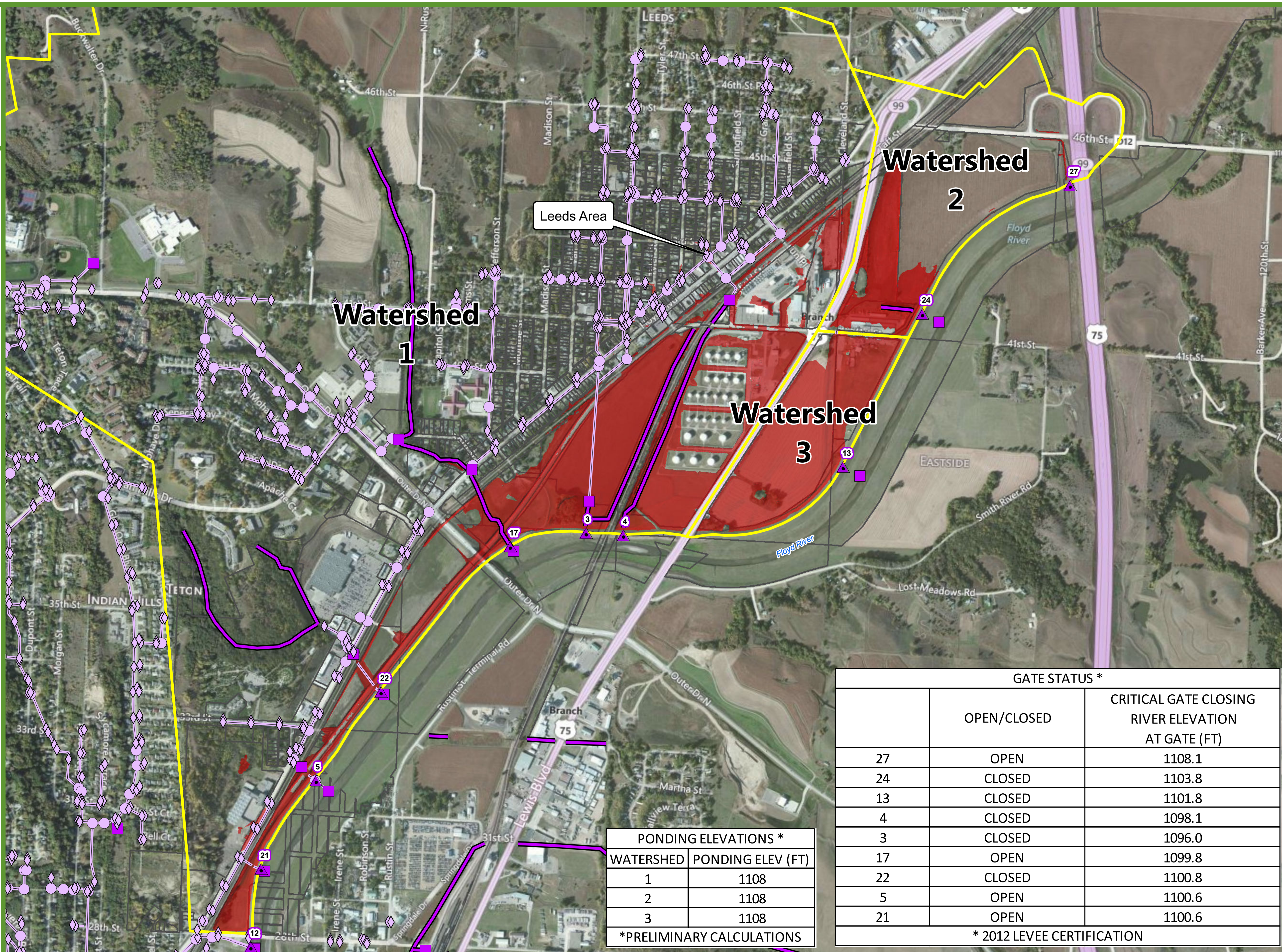
GATE STATUS *		
	OPEN/CLOSED	CRITICAL GATE CLOSING RIVER ELEVATION AT GATE (FT)
27	OPEN	1108.1
24	CLOSED	1103.8
13	CLOSED	1101.8
4	CLOSED	1098.1
3	CLOSED	1096.0
17	OPEN	1099.8
22	CLOSED	1100.8
5	OPEN	1100.6
21	OPEN	1100.6

* 2012 LEVEE CERTIFICATION

FIGURE 2 - WORST CASE PONDING EXTENTS UNDER PROPOSED CONDITIONS

FLOYD RIVER FLOOD REDUCTION

SIOUX CITY, IA



GATE STATUS *		
	OPEN/CLOSED	CRITICAL GATE CLOSING RIVER ELEVATION AT GATE (FT)
27	OPEN	1108.1
24	CLOSED	1103.8
13	CLOSED	1101.8
4	CLOSED	1098.1
3	CLOSED	1096.0
17	OPEN	1099.8
22	CLOSED	1100.8
5	OPEN	1100.6
21	OPEN	1100.6

* 2012 LEVEE CERTIFICATION

PONDING ELEVATIONS *	
WATERSHED	PONDING ELEV (FT)
1	1108
2	1108
3	1108

*PRELIMINARY CALCULATIONS

Legend

- Floyd Floodgates
- Inlets
- Outlets
- Storm Manhole
- Open Drain
- Storm Pipe
- Watershed Boundaries
- Worst Case Ponding Extents
- Parcels

Data Source: ESRI; Iowa DNR; USGS; HR Green
Project Coordinate System:
NAD 1983 StatePlane Iowa North FIPS 1401 Feet
Projection: Lambert_Conformal_Conic
Vertical Datum: NAVD 88

1 inch = 1,200 feet

0 600 1,200 2,400 Feet

N E S W

SIOUX CITY SUCCESSFUL SURPRISING SIOUX CITY

HRGreen

Date: 8/6/2013

FIGURE 3 - TRAIL AND CULVERT IMPROVEMENTS OVERVIEW

FLOYD RIVER FLOOD REDUCTION

SIOUX CITY, IA

Legend of Existing Elements

- Floyd Floodgates
- Inlets
- Outlets
- Storm Manhole
- Open Channel
- Storm Pipe
- Top of Flood Berm
- Existing Trail
- Parcels

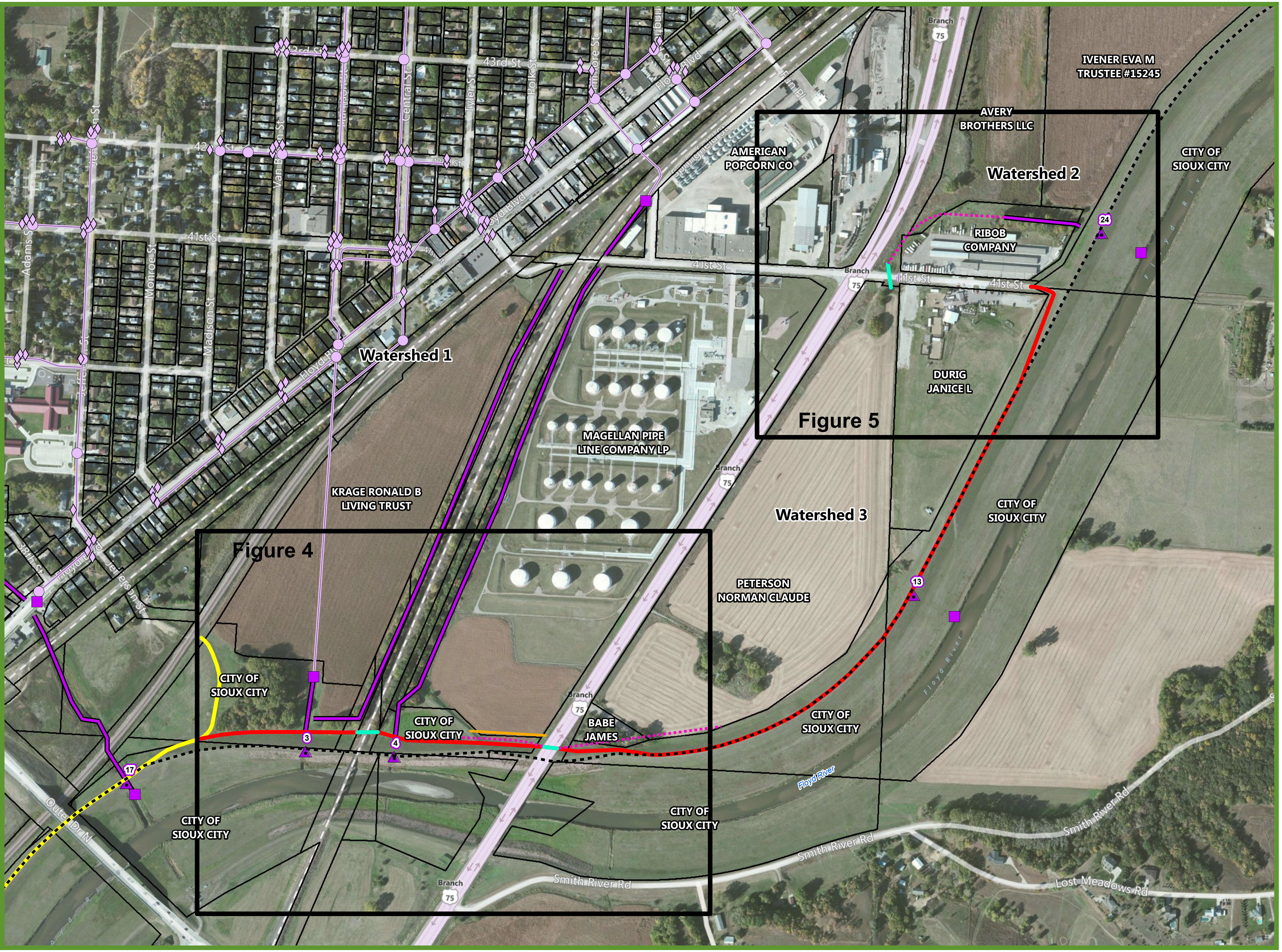
Legend of Proposed Elements

- Proposed Open Channels
- Proposed Berm
- Proposed Culverts
- Proposed Trail

Data Source: ESRI; Iowa DNR; USGS; HR Green
Project Coordinate System:
NAD 1983 StatePlane Iowa North FIPS 1401 Feet
Projection: Lambert_Conformal_Conic
Vertical Datum: NAVD 88

1 inch = 500 feet

0 250 500 1,000 Feet



SIOUX CITY
SUCCESSFUL SURPRISING SIOUX CITY

HRGreen

Date: 8/6/2013

FIGURE 4 - BNSF AND HIGHWAY 75 AREA IMPROVEMENTS

FLOYD RIVER FLOOD REDUCTION

SIOUX CITY, IA

Legend of Existing Elements

- Floyd Floodgates
- Inlets
- Outlets
- Storm Manhole
- Open Channel
- Storm Pipe
- Top of Flood Berm
- Existing Trail
- Parcels

Legend of Proposed Elements

- Proposed Open Channels
- Proposed Berm
- Proposed Culverts
- Proposed Trail

Data Source: ESRI; Iowa DNR; USGS; HR Green
Project Coordinate System:
NAD 1983 StatePlane Iowa North FIPS 1401 Feet
Projection: Lambert_Conformal_Conic
Vertical Datum: NAVD 88

1 inch = 200 feet

0 100 200 400 Feet

N E S W

SIOUX CITY SUCCESSFUL SURPRISING SIOUX CITY

HRGreen

Date: 8/6/2013

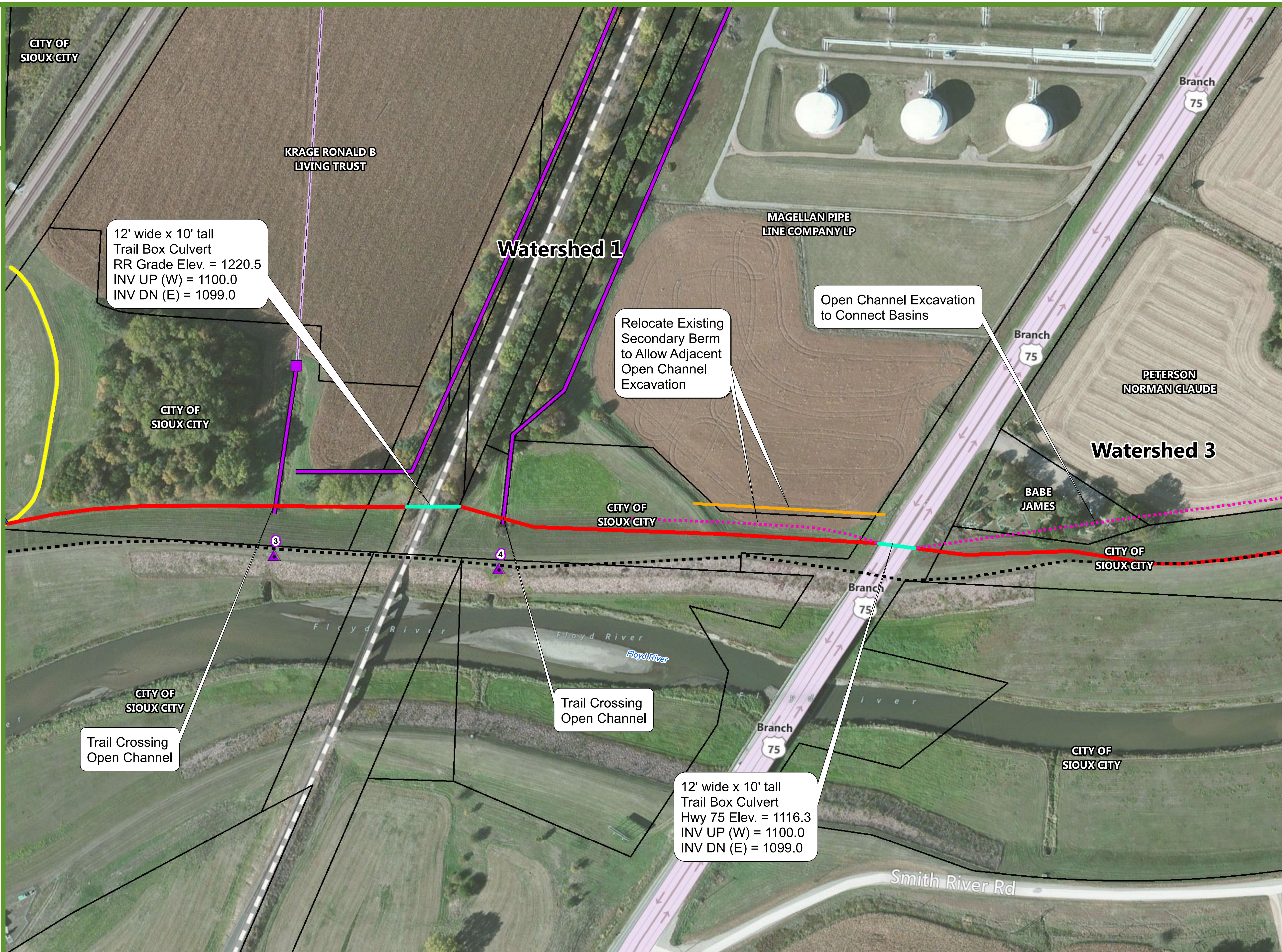


FIGURE 5 - 41st ST
AREA IMPROVEMENTS

FLOYD RIVER
FLOOD REDUCTION

SIOUX CITY, IA

Legend of Existing Elements

- Floyd Floodgates
- Inlets
- Outlets
- Storm Manhole
- Open Channel
- Storm Pipe
- Top of Flood Berm
- Existing Trail

Legend of Proposed Elements

- Proposed Open Channels
- Proposed Berm
- Proposed Culverts
- Proposed Trail

Data Source: ESRI; Iowa DNR; USGS; HR Green
Project Coordinate System:
NAD 1983 StatePlane Iowa North FIPS 1401 Feet
Projection: Lambert_Conformal_Conic
Vertical Datum: NAVD 88

1 inch = 150 feet

0 75 150 300 Feet

N W E S

SIOUX CITY
SUCCESSFUL SURPRISING SIOUX CITY

HRGreen

Date: 8/6/2013

MEMO

To:	City of Sioux City
From:	HR Green
Subject:	Leeds Area Watershed Interior Drainage Analysis – Interim Report
Project No.	10130158
Date:	October 22, 2014

The Leeds area is located in the general vicinity north and northeast of the Floyd Blvd. and Outer Drive intersection. The area includes residential, commercial, light industrial and public land-use. As part of the Floyd River Levee Certification project, watershed areas draining to the Floyd River through the existing levee alignments were mapped for potential ponding during gatewell closures. Calculations were completed to determine the amount of ponding that would occur when high floodwater levels in the Floyd River required gate closures on the existing pipes and culverts extending through the levee. For the Leeds area and in several adjacent watershed areas, the ponding limits covered extensive areas. When FEMA completed review and provided concurrence with the Levee Certification Report, it also began an initiative to map areas of potential flood risk on the communities Flood Insurance Rate Maps. This mapping initiative included mapping portions of the Leeds area to identify the potential flood risk from the ponding conditions.

This work and report identifies in greater detail the existing conveyance network and ponding scenarios associated with a number of storm events. This project will build upon the data collected for, and the results of the previous project (see Floyd River Flood Reduction Concept Design Recommendation Memo dated August 7, 2013). Figure 1 outlines the ponding area (red) for the Leeds Area and areas east and southwest of the lower watershed area of the Leeds Watershed. It identifies the various existing gatewell structures along the Floyd River in this reach of the levee system and this gatewell numbering system will factor in discussions of modeling results. Principally, what we refer to as the Leeds Area drains to the conveyance systems draining to Gatewell 4 (east of the Burlington Northern Railroad tracks) and Gatewell 3.

From the August 7, 2013 study, and represented in Figure 1, interior drainage areas labeled as Watershed 1 that drain through Gatewells No. 3 and No. 4 in the Floyd River Levee are the focus of the study. However, as we will detail later in this document, Gatewell 17, located southwest of Gatewell 3 has influence on ponding conditions for Gatewell 3 including the ponding extents extending up to Floyd Blvd. and Leeds area.

Data Collection
For this project, additional information about the storm sewer network in the watershed area was collected from City GIS and other data sources. Future land-use conditions and zoning designations was reviewed and incorporated in the runoff data base. This information will be used to develop existing and future hydrological impacts in the basin using the detailed XPSWMM Model.

Hydrology and Hydraulics Analysis

<u>Watershed Analysis</u>

Leeds Area hydrology (area flowing to levee gates 3 & 4) was modeled using XPSWMM. Watersheds were delineated to inlets along Floyd Blvd and to the major trunklines of each storm sewer network

(Figure 2). SCS curve numbers (CNs) were determined based on existing and future land use, and Atlas 14 rainfall data was used to determine peak runoff flows. Building on the Floyd River Flood Reduction Memo, a Huff rainfall distribution was created for a 2-, 5-, 10-, and 100-year 2-hour SCS Type II design storm events.

Flow values from the model were compared to the runoff characteristics developed during the Floyd River Levee Certification project. The certification report used a 4.06-inch 100-yr rainfall value and did not include infiltration to forecast a conservative, worst case ponding condition. The current Leeds Area study used a 4.2-inch 100-year rainfall event and allowed infiltration. The certification report work provided a runoff volume of 27,147,360 cubic-feet included all watershed areas flowing to gates 21, 5, 22, 17, 3, and 4. These locations are shown in Figure 1. Since the Leeds area flows to Gatewells 3 and 4, a flow/area ratio was used to estimate the expected flow volume to Gatewells 3 and 4 alone using the previous rainfall and no infiltration. Total Watershed 1 area was 3.44 square-miles, and the total watershed area flowing to Gatewells 3 and 4 is 1.30 square-miles. The expected flow volume comparison value to Gatewells 3 and 4 is approximately 10,286,550 cubic-feet. After running the XPSWMM model with the Leeds Area information, the total 100-year ponding volume is expected to be 7,526,400 cubic-feet.

For significant storm events, considering closures are occurring for area Gatewells 17, 3 and 4 plus the gatewells southwest of Gatewell 17 (Gatewells 5, 21 and 22), the runoff contribution from the Gatewell 17 drainage area can overflow to the Gatewell 3 area. This occurrence from the Gatewell 17 watershed adds significant ponding volume to the Leeds Area Gatewell 3 and Gatewell 4 ponding elevations.

In the Levee Certification Report, it was shown that the 100-year ponding of the Watershed 1 runoff volume inundated areas north of the levee, including the Leeds area, to elevation 1109. The watershed of Gatewell 17 is hydraulically connected to the watershed area of Gatewell 3 at Elevation 1103.

A comparison was then reviewed where we “blocked” the Gatewell 17 contribution from flowing to the Gatewell 3 and 4 watersheds. When placing the resulting volume from the XPSWMM model for the runoff from Gatewell 3 and 4 areas, the ponding is limited to elevation 1105. Figure 3 provides ponding limits for the condition of Gatewells 3 and 4 ponding without influence of Gatewell 17.

To reduce ponding volume in the Leeds area, additional review for Gatewell Watershed 17 should be completed to fully evaluate hydraulic ponding conditions if we could physically isolate the Gatewell 17 area from Gatewells 3 and 4 areas. In other words, where would that runoff volume end up since it cannot pond in the 3 and 4 areas? Part of that review would include the investigation of a hard closure in the nature of a small earthen levee or potentially reviewing having pumping capabilities at Gatewell 17 that serves the Gatewells 17, 3 and 4 in total.

FIGURE 1 - WORST CASE PONDING EXTENTS UNDER EXISTING CONDITIONS

FLOYD RIVER FLOOD REDUCTION

SIOUX CITY, IA

Legend

- Floyd Floodgates
- Inlets
- Outlets
- Storm Manhole
- Open Drain
- Storm Pipe
- Watershed Boundaries
- Worst Case Ponding Extents
- Parcels

Data Source: ESRI; Iowa DNR; USGS; HR Green
Project Coordinate System:
NAD 1983 StatePlane Iowa North FIPS 1401 Feet
Projection: Lambert_Conformal_Conic
Vertical Datum: NAVD 88

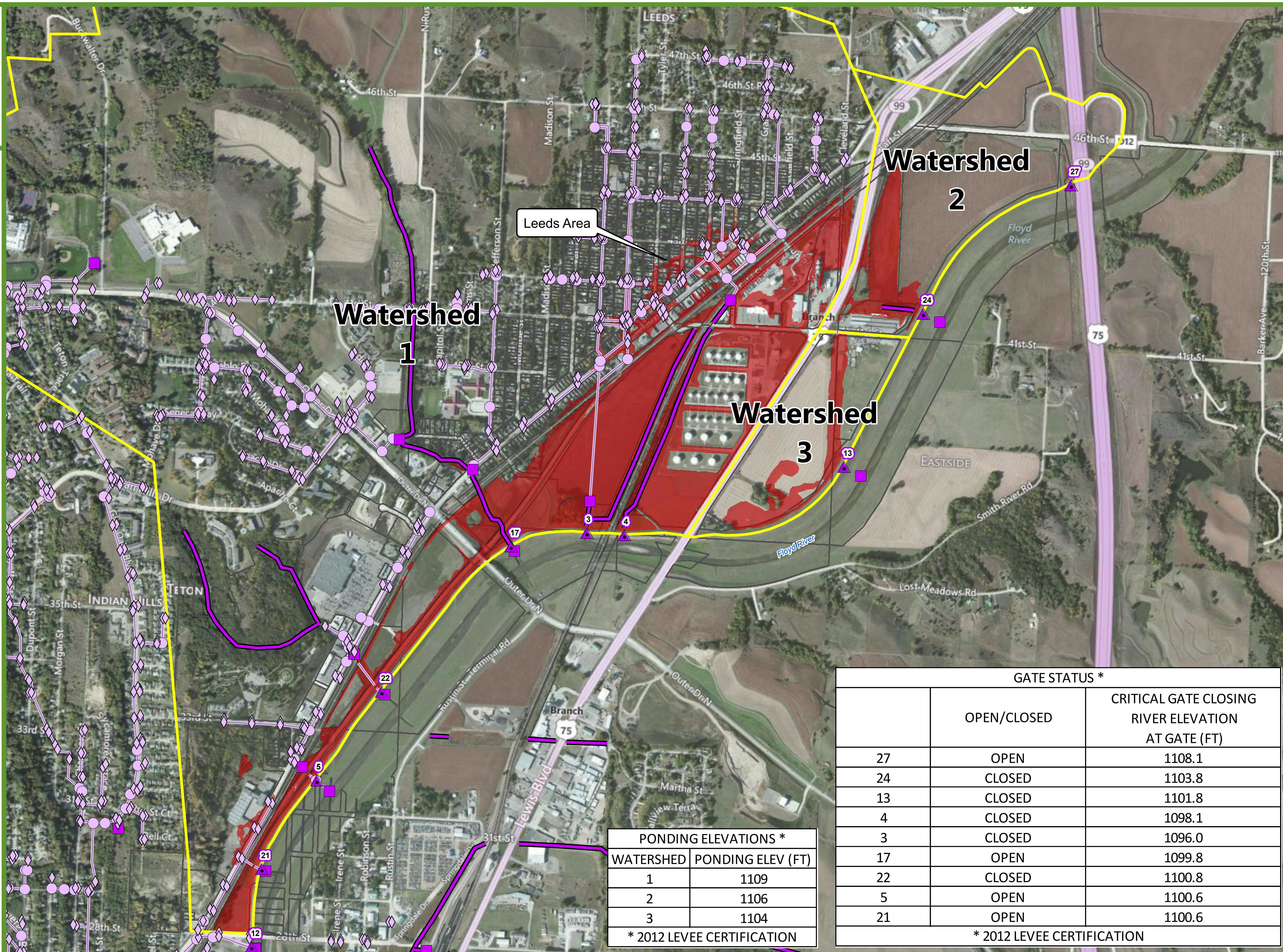
1 inch = 1,200 feet

0 600 1,200 2,400 Feet

SIOUX CITY
SUCCESSFUL SURPRISING SIOUX CITY

HRGreen

Date: 8/6/2013



PONDING ELEVATIONS *	
WATERSHED	PONDING ELEV (FT)
1	1109
2	1106
3	1104

* 2012 LEVEE CERTIFICATION

GATE STATUS *		
	OPEN/CLOSED	CRITICAL GATE CLOSING RIVER ELEVATION AT GATE (FT)
27	OPEN	1108.1
24	CLOSED	1103.8
13	CLOSED	1101.8
4	CLOSED	1098.1
3	CLOSED	1096.0
17	OPEN	1099.8
22	CLOSED	1100.8
5	OPEN	1100.6
21	OPEN	1100.6

* 2012 LEVEE CERTIFICATION

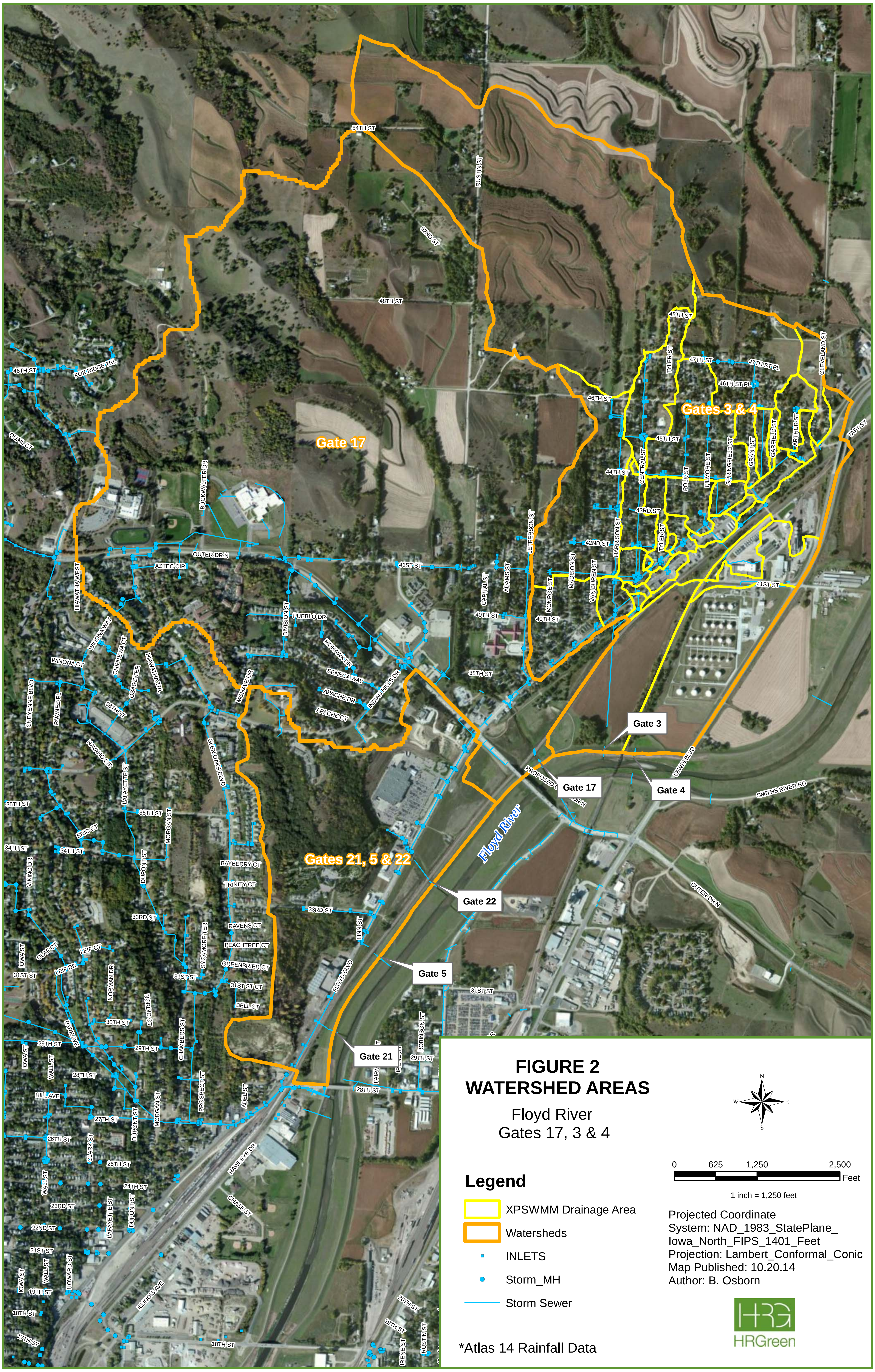


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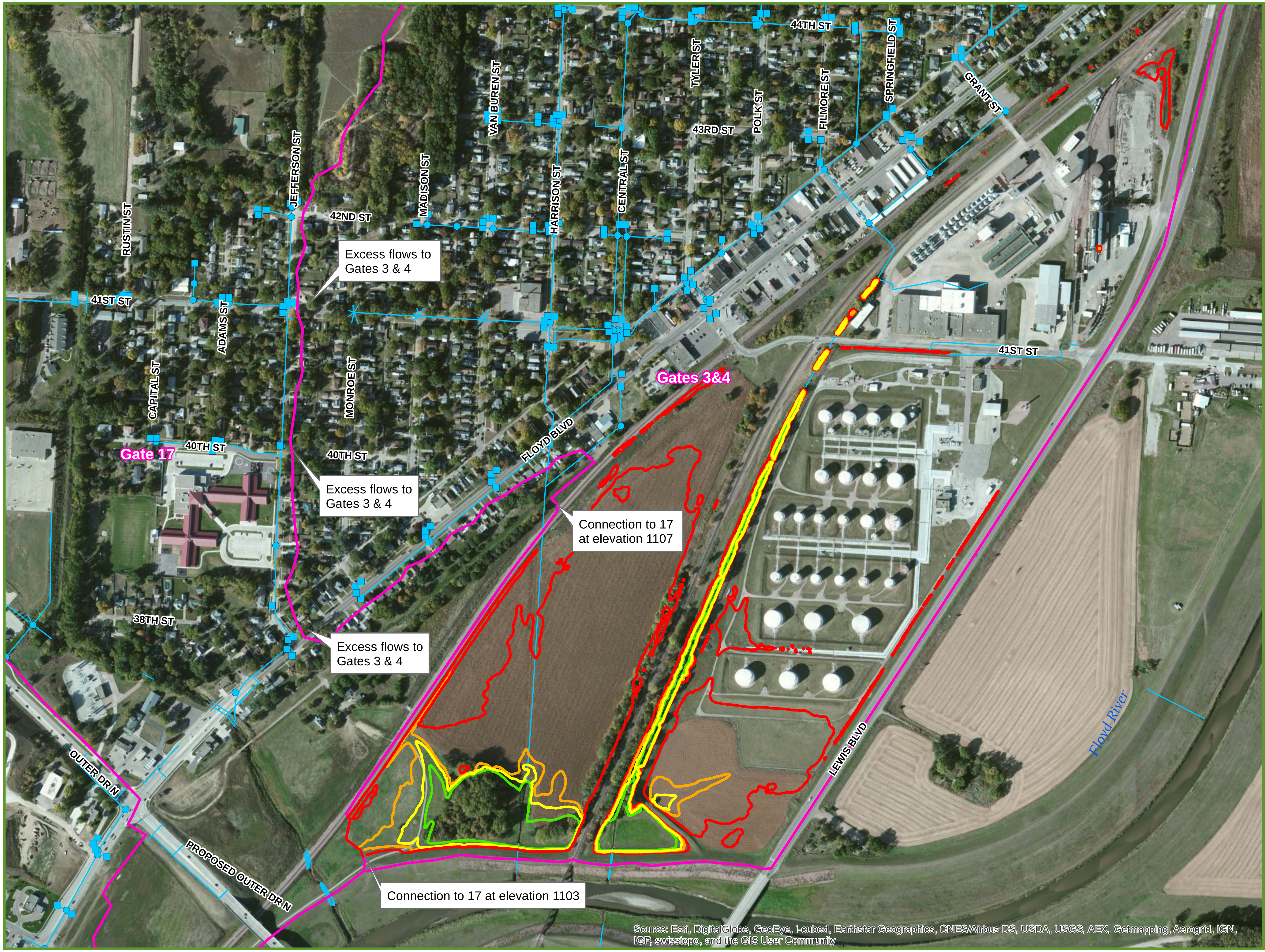
FIGURE 3

Floyd River Gates 3 & 4

INTERIOR FLOODING

Isolated From 17



Legend

Elevation

- 1100: 2yr - 2hr
- 1102: 5yr - 2hr
- 1103: 10yr - 2hr
- 1105: 100yr - 2hr
- Watersheds
- INLETS
- Storm_MH
- Storm Sewer

*Atlas 14 Rainfall Data

N E S W

0 225 450 900 Feet

1 inch = 450 feet

Projected Coordinate System: NAD_1983_StatePlane_Iowa_North_FIPS_1401_Feet
Projection: Lambert_Conformal_Conic
Map Published: 8.28.14
Author: B. Osborn

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PLOT: 9:01:13 AM 8/29/2014 FILE: \\hrgcrnas\data\10130158\GIS\MXD\BaseMap-7.2.14.mxd