City of Minot
Storm Water Management Plan

Volume 1: Introduction & Systems

V1




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Appendices

Executive Summary

The City of Minot is experiencing unprecedented growth, not seen since its founding. This growth has prompted the need for the City to be proactive in determining the infrastructure needs of the future. The challenge is determining the most cost-effective means to provide expanded City services, while at the same time correcting existing system deficiencies and maintaining the integrity of the systems that are currently serving the residents of Minot.

In an effort to meet this challenge, the City of Minot contracted with Ackerman-Estvold to prepare a Stormwater Management Plan that will guide the expansion of and improvements to the existing stormwater system for the City of Minot and surrounding areas in Ward County. This Plan will be made available as a resource for area residents, developers, policy makers, and City and County staff.

In addition to the recommended improvements summarized in this document, the Storm Water Management Ordinance was updated for the first time since 2004 and revisions were made to the 2002 Storm Water Design Standards Manual.

4 parts to the plan

VOLUME 1:
Analyzed Key Drainage Systems

VOLUME 2:
Updated City of Minot Storm Water Management Ordinance

VOLUME 3:
Revised Storm Water Design Standards Manual

APPENDICES:
Contain all the technical details

City of Minot

ACKERMAN ESTVOLD

Puppy Dog, First Larson, and Second Larson Coulees Recommended Improvements

First Larson Coulee at US Hwy 83

- Earthen Embankment
- 84" Culvert Primary Spillway
- 60' Grassed Emergency Spillway
- 111.1 Acres Inundated

Construction Cost: $2,308,915.44

First Larson Coulee 1/2 Mile West of 16th ST SW

- Earthen Embankment
- 72" Culvert Primary Spillway
- 60' Grassed Emergency Spillway
- Modifications to 62nd St SW
- 14.4 Acres Inundated

Construction Cost: $3,209,918.40

Puppy Dog Coulee at 13th ST SE

- Substantial Raise of Existing Earthen Embankment
- Modifications to Existing 78" Culvert Primary Spillway
- 24' High Flow Spillway
- 60' Concrete Emergency Spillway
- 48.0 Acres Inundated

Construction Cost: $17,389,347.69

Puppy Dog Coulee 1/2 Mile West of 30th ST SW

- Earthen Embankment
- 24" Culvert Primary Spillway
- 22' High Flow Spillway
- 8' Diameter Overflow Riser
- Divert Discharge to First Larson Bypass
- Acquisition of Platted Residential Lots
- 82.6 Acres Inundated

Construction Cost: $872,639.95

Four Regional Detention Areas

Three Storm Sewer Trunks

Puppy Dog Coulee to First Larson Coulee Bypass Trunk System

3,050 LF of 84" Storm Sewer

Construction Cost: $4,770,119.15

37th Avenue SW Storm Sewer Trunk System

7,550 LF of 21" to 72" Storm Sewer

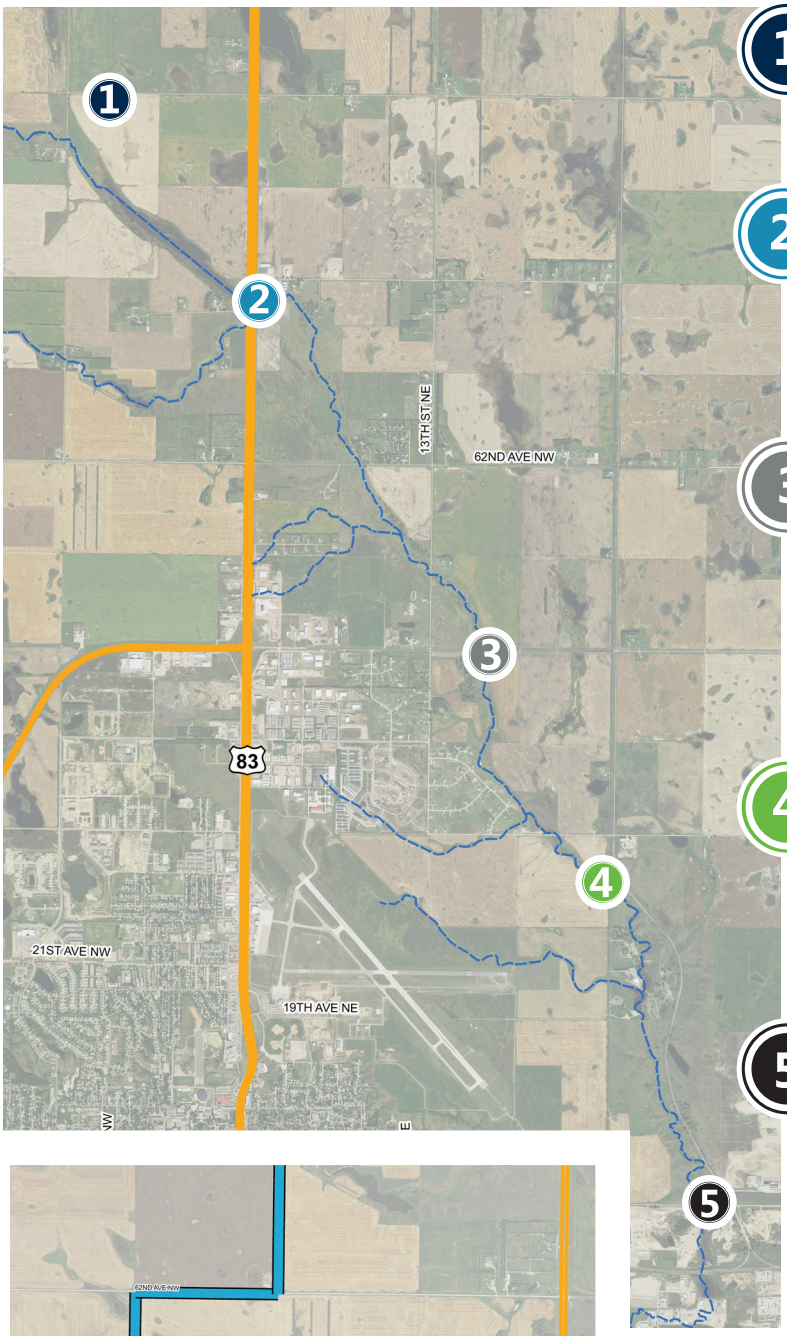
Construction Cost: $7,894,653.00

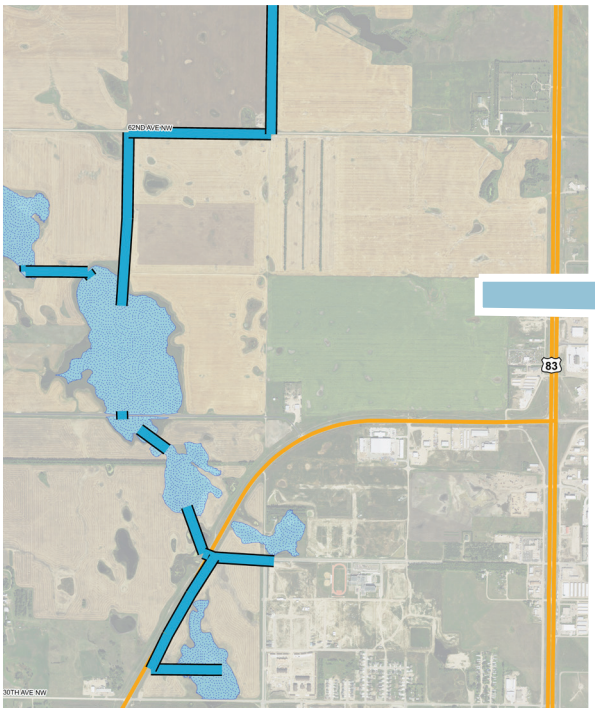
43rd Avenue SW Storm Sewer Trunk System

5,720 LF of 30" to 72" Storm Sewer

Construction Cost: $5,977,865.60

Livingston Coulee and Livingston Lakes Recommended Improvements





Overflow – Livingston Coulee to Egg Creek

- Prohibit Future Building in Innundation Area
- Existing Natural Land Formation at Elevation 1628'

Regional Detention – Livingston Coulee East of US Hwy 83

- Prohibit Future Building in Innundation Area
- Existing 114" by 77" CMPA
- Existing Roadway Elevation 1632.2'
- 145.6 Acres Inundated

Regional Detention – Livingston Coulee upstream of 46th Ave NE

- Prohibit Future Building in Innundation Area
- Replace Existing Road Crossing with 30" Culvert
- Raise Road 6 feet to 1624'
- 205.2 Acres Inundated
- Construction Cost: $1,040,291.85

Regional Detention – Livingston Coulee upstream of County Road 19

- Prohibit Future Building in Innundation Area
- Existing Twin 72" RCP
- Existing Roadway Elevation 1610'
- 73.3 Acres Inundated

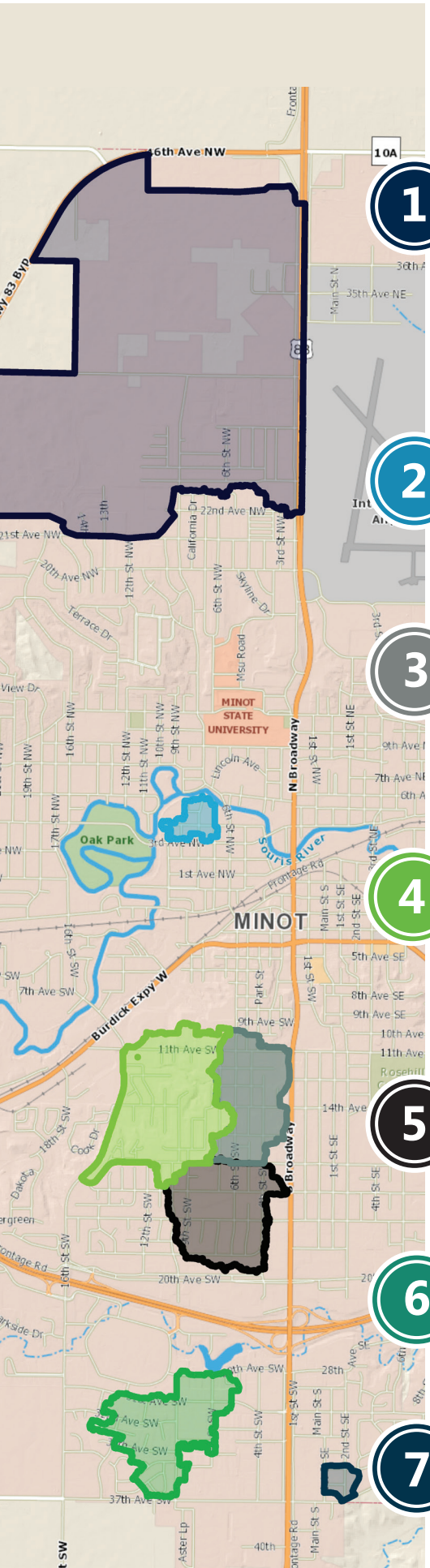
Regional Detention – Livingston Coulee upstream of County Road 12

- Prohibit Future Building in Innundation Area
- Existing Twin 72" RCP
- Raise Road 5 Feet to 1594'
- 84.1 Acres Inundated
- Construction Cost: $2,558,645.44

Livingston Lakes Storm Sewer Trunk System

- Over 16,000 Feet of Storm Sewer Trunk Line
- Pipe Sizes Range from 30" to 84" with an Average Slope of 0.2%
- Minimum Peak Flow Rate – 13 cfs
- Maximum Peak Flow Rate – 500 cfs
- 193.3 Acres Inundated
- Construction Cost: $8,504,548.44

Minor Systems Recommended Improvements



Polaris Park

Problem: flooding along the North Broadway Frontage Road and along the west side of US Highway 83

- Replace the existing culvert under US Highway 83 with a larger diameter pipe or supplement the existing 24" RCP with an additional culvert under the highway
- Replace the existing 36" RCP inlet on airport property with a large diameter inlet/pipe connection to the existing 48" RCP
- Increase pipe diameter at downstream channel crossings at farm access point
- Increase pipe diameter at downstream channel crossings at 30th Ave NE
- Install curb inlets at the intersection of 30th Ave NW and the frontage road when 30th Ave NW is upgraded to an urban section
- Construction Cost: $784,266.99

4th Avenue Northwest

Problem: flooding along the corridor, infrastructure was originally built in the 1930's

- Completely new stormwater sewer system
- Proposed inlets at existing inlet locations
- Add two additional inlets north along 8th St NW
- Increase pipe diameter throughout
- Construction Cost: $1,262,598.16

11th Avenue Southwest

Problem: flooding along 11th Avenue SW

- Additional inlets throughout the area
- Construction Cost: $2,764,418.96

16th Street SW & Southwest Knolls

Problem: flooding in the area of 16th St SW and Southwest Knolls, physically separate yet interconnected existing storm sewer systems

- Additional inlets
- Increase capacity of the inlets at the intersection of 13th St SW and 12th Ave SW
- physically connect the four existing systems
- Expand the existing pond located at the southwest corner of the intersection of 16th St SW and 11th Ave SW
- Construct a new outfall into the expanded pond is proposed
- Construction Cost: $2,897,471.36

18th Avenue Southwest

Problem: flooding along 18th Ave SW between Edison Elementary and the intersection of 18th Ave SW and S Broadway

- Additional inlets
- Replace existing 10" lateral pipes with 18" RCP lateral pipes
- Construction Cost: $2,037,275.31

10th Street Southwest

Problem: flooding along 10th St SW, frequent damaged along 10th St SW due to high water table

- Additional inlets
- Add under-pavement drainage tile system
- Construction Cost: $3,685,878.56

37th Avenue South

Problems: flooding along 37th Ave near Main Street

- Construct a new stormwater system
- Construction Cost: $263,110.12

2 Introduction

The City of Minot – Stormwater Management Plan is intended to be a resource for area residents, developers, policy makers, and City and County staff. The Plan will guide the expansion of and improvements to the existing stormwater system for the City of Minot and surrounding areas in Ward County.

2.1 Location and History

The City of Minot is located in Ward County in north central North Dakota. Minot was founded in 1886 and has since been known as the Magic City because if it's rapid overnight growth.

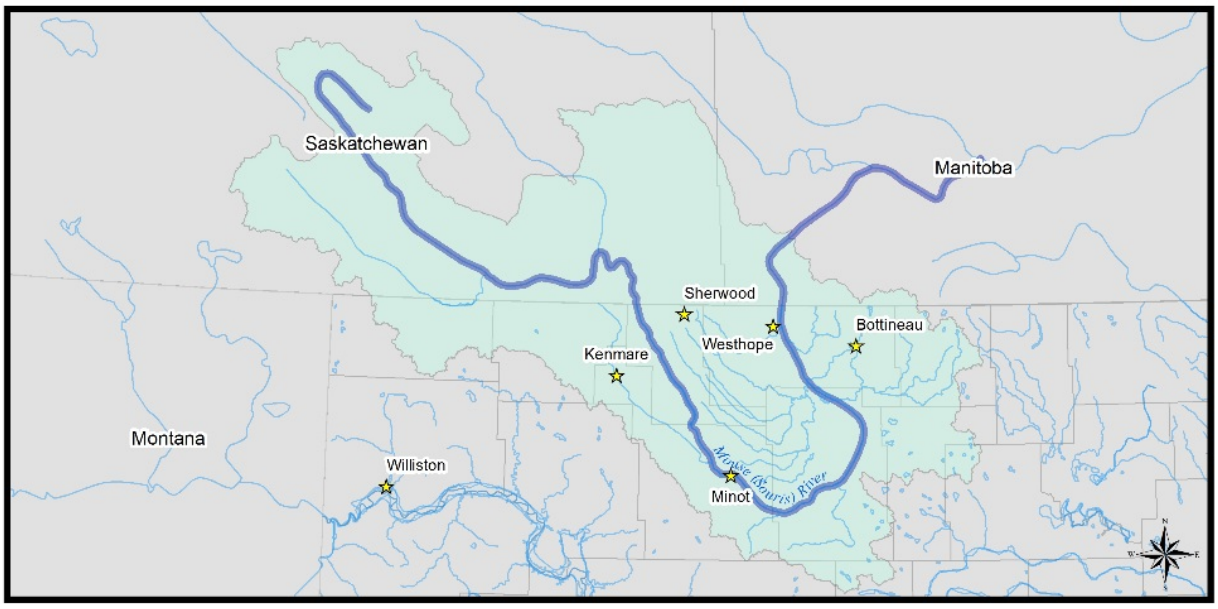


Figure 2-1: Souris River Drainage Basin

Minot is part of the Souris (Mouse) River drainage basin. The Souris River flows south entering North Dakota from Canada near Sherwood. The river loops through Minot before heading north back into Canada near Westhope. Eventually the Souris River joins the Assiniboine River.

There are five major watersheds which flow through the City of Minot; First Larson Coulee, Second Larson Coulee, and Puppy Dog Coulee from the south and Livingston Coulee and Upper Livingston Lakes from the north. In addition to these major systems, there are dozens of minor systems within the City.

The City of Minot's previous Storm Water Design Standards Manual was published in 2002 and the Storm Water Management Ordinance in 2004.

2.2 Need for the Plan

The City of Minot is again experiencing unprecedented growth, not seen since its founding. This growth has prompted the need for the City to be proactive in determining the infrastructure needs of the future. What once took decades to come to fruition in the City of Minot is seemingly being accomplished in months. The challenge is determining the most cost-effective means to provide services to expand the City, while at the same time correcting existing system deficiencies and maintaining the integrity of the systems that are currently serving the residents of Minot.

Increasing Population		
Year	Minot	Ward County
2013	46,321	67,990
2010	40,888	61,675
2000	36,567	58,797
1990	34,544	57,923
1980	32,843	58,394
1970	32,290	58,562
1960	30,987	47,074
1950	22,032	34,784

Table 2-1: Population Data from US Census

2.3 Purpose & Scope

The purpose of this plan is to identify system deficiencies, the potential for system upgrades, address the need for expansion of storm sewer service in Minot's growth areas, and identify recommended policy revisions to be considered by the Minot City Council. This will be accomplished by reviewing the currently policies in place by the City of Minot and Ward County and the requirements of other regulatory agencies, analyzing the five major systems and identifying the potential for regional detention, analyzing eight existing minor systems with known deficiencies and recommending improvements, proposing revisions to the City of Minot Storm Water Management Ordinance and Storm Water Design Standards Manual, and finally discussing the implementation of these pieces.

2.4 Plan Organization

The City of Minot Stormwater Management Plan will be issued in four volumes; Volume I will include the analysis of the major and minor systems, Volume II is the Storm Water Management Ordinance, Volume III is Storm Water Design Standards Manual, and the Appendix will include the complete technical memorandums for the major and minor systems.

3 Regulatory Environment

This section provides details of the City of Minot's programs and regulations that affect water resources management within the city. It also provides a general overview of the programs and regulations of other government entities affecting Minot and the watersheds surrounding the city.

The plans, ordinances, and programs referenced in this section are intended as a resource for City staff, residents, and people doing business in Minot. They also serve as a guide to the City of Minot's water resources program for developers, project reviewers, and others.

The details presented here represent the programs as they exist at the date of this Plan. Some of the programs will certainly change. Users of this section should check the City's web site at http://www.minotnd.org/ to locate any revisions to the following programs that may have occurred since publication of this Plan. When discrepancies arise between this Plan and City codes or ordinances, information presented in the City codes of ordinances should be considered the most accurate.

3.1 City of Minot Regulatory Framework

The City of Minot manages storm water to protect life, property, and environmental resources within and downstream of the city. To that end, the City implements the following regulatory and guidance documents:

- City of Minot Storm Water Ordinance (2014),
- City of Minot Storm Water Design Standards Manual (2014) ,
- City of Minot 2012 Comprehensive Plan,
- Long Term Recovery Framework with an Emphasis on Hazard Mitigation (2012), and
- This Minot Storm Water Management Plan

These documents are described in greater detail in the following sections.

3.1.1 Storm Water Ordinance (2004)

City of Minot Code of Ordinances Chapter 28.1 (Chapter 28.1) is the City's primary regulation for storm water discharge and provides standards and guidance for storm water system analyses and design within the city and for the extraterritorial jurisdiction areas adjacent to it. Chapter 28.1 was updated in conjunction with the development of this Plan. Requirements for storm water and erosion control are specified for construction activities and post-construction site design.

Storm Water Management Plans

Prior to any proposed activity altering the storm water system, a developer must submit a storm water management plan that must be approved by the City; exceptions include 1 or 2 family units, utility work, and "non-building" sites, where the proposed disturbance is less than 1 acre. The Minot Storm Water Ordinance, 2014 (Chapter 28.1) specifies the required elements of the storm water plan. The storm water management plan must comply with federal, state and county requirements.

The plan must be prepared and signed by a Professional Engineer registered in the State of North Dakota. Under current practice, developers submit a single site plan application (including the storm water management plan) to the City. Proposed activities within the 2-mile Extra-Territorial Area are required to submit a site plan application to the City of Minot and a storm water management plan to the City of Minot and Ward County Water Resource District for approval. A checklist of storm water management plan submittal requirements is available from the City; the completed checklist must be included with the storm water plan.

Specific elements required in each storm water management plan are included in Chapter 28.1 and the storm water management plan checklist, but may be simplified into the following major elements:

1. A map of existing conditions at the site and at immediately adjacent areas,
2. A construction site plan identifying proposed construction activities,
3. A final site plan (at the same scale as the map of existing conditions), and
4. A narrative analysis describing the following elements:
    a) Pre- and post-development hydrologic and hydraulic analysis
    b) Erosion and sediment control used prior to, during, and after construction
    c) Protective measures for proposed and existing structures, and water quality concerns
    d) Feasibility of on-site infiltration to reduce runoff volume and address water quality concerns
    e) Planned maintenance activities and intervals, inspection intervals, and access considerations for all permanent storm water management features
    f) A letter of acknowledgement or maintenance agreement signed by the developer or agent who will perform the planned maintenance activities
    g) Discussion of how the storm water management plan applies or observes the principles of Subdivision B of the City of Minot Ordinance Ch. 28.1
    h) Certification statement by Professional Engineer registered in the State of North Dakota

As well as requiring that plans meet the standards and guidelines set forth in the Minot Design Guidelines, Chapter 28.1 (Subdivision B) sets additional standards and guidelines for storm water management plans. Section D.7 of each storm water management plan must describe how the project addresses the following issues:

- Planning preferences for storm water management
- Capacity considerations
- Floodplain considerations
- Water Quality considerations, and
- Operation, maintenance, and inspections.

Planning preferences include:

- If suitable soil and geological conditions are available using the natural infiltration of precipitation and runoff on-site, preserving as much natural or vegetated area on the site as possible, while minimizing impervious surfaces, and directing runoff to vegetated areas rather than onto adjoining streets, storm sewers and ditches.
- The use of natural topography and land cover such as wetlands, ponds, natural swales and depressions as they exist before development to the degree that they can accommodate the additional water flow without compromising the integrity or quality of these natural features.
- The use of storm water detention facilities.
- The use of storm water retention facilities.

Capacity considerations include:

- The hydraulic capacities of downstream natural channels, reaches, storm sewer systems, and streets, must be reviewed in order to determine whether they have sufficient conveyance capacity to receive and accommodate post-development runoff discharges and volumes without causing:
    - channel erosion;
    - increased property damage; or
    - any increase in the established base flood plain elevation.
- Review of the adequacy of any outlet used as a discharge point.

- Meet the requirement that there is no increase in peak rates from existing conditions for the critical duration 2-, 5-, 10-, and 100-year, 24-hour storm events, and the 100-year, 10-day snow melt event, except where the City has provided sufficient downstream flood detention facilities for the development or redevelopment area's proposed land use and area of imperviousness (as determined by the City Engineer).
- Consider the feasibility of infiltrating or otherwise retaining 1 inch of runoff from the impervious area of the project in situations where downstream volume capacity issues exist (as determined by the City Engineer).

Floodplain considerations include meeting the following requirements for lowest floor minimum building elevations:

- Those listed in the City's Zoning Ordinance for areas shown on City FIRMs and Federal Emergency Management Agency (FEMA) FIRMs
- At least one foot above the County Floodplain Management Area flood elevation or three feet above the base flood elevation (BFE), whichever is greater, for all new plats located outside the FIRM.
- At least 1 foot clearance between a structure's lowest floor and the 100-year flood elevation of all adjacent storm water management features, including:
    - Ponds
    - Wetlands
    - Streams
    - Sloughs
    - Overland conveyances

Water quality considerations are described in the Storm Water Design Manual, and include:

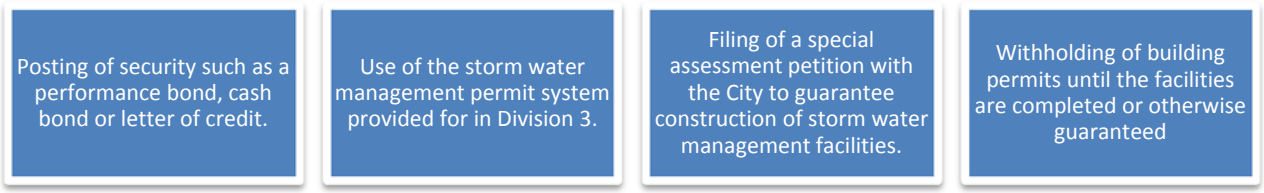
- Pretreatment of all temporary off-site discharges during construction.
- Implementation of applicable erosion and sediment control devices and practices as specified in Chapter 11 of the Design Manual.
- Treatment of the first 1 inch of runoff from impervious area of the project for new development. The City encourages the use of the following methods to achieve water quality goals, in order of decreasing preference:
    - Infiltration or other abstraction
    - Filtration
    - Extended detention

Operations, maintenance, and inspection considerations include:

- The desirability of a design which minimizes the need for maintenance.
- The right of the City Engineer to inspect such improvements from time to time and, to that end, the need of a legal right of access to them, such as by easements or other property interests.

Storm Water Management Plan Approval Process

The City Engineer may allow a storm water management plan to be submitted and approved in phases, with such interim storm water alteration activities being performed in the interim between phases as allowed or required in the plan itself. The City Engineer may also require enforcement mechanisms specific to a particular storm water management plan, which may include the following:



The City Engineer, subject to the approval of the City Council, may approve a storm water management plan which provides for the payment of a specified in lieu fee instead of the provision for, and performance of, certain work which otherwise would form part of such plan. Typically, the in lieu fee would be applied to the cost of a regional storm water management plan or project to which a sub-watershed drains. Notwithstanding the employment of such a fee, the plan may still provide for and require the dedication or retention of easements or other interest in land as may be necessary in the future for the full implementation of the plan.

Chapter 28.1 requires that post-construction "as-built" drawings be prepared and presented by a developer once the storm water management plan has been implemented and establishes the City's right to inspect the work performed under the plan.

The City of Minot may require that a permit be issued as part of the approved storm water management plan. The permit can be used as an enforcement mechanism in those cases where ongoing, detailed, precise, and intensive control over activities affecting the discharge of storm water is desired.

Erosion and Sediment Control Plans

When the construction of improvements called for in a storm water management plan are of sufficient magnitude and consequence, the City Engineer may require that the plan include an erosion and sedimentation management plan, including details of silt fences, storm drain inlet protection, erosion control facilities and other Best Management Practices (BMPs) as well as construction specifications describing erosion, sedimentation, and water control requirements to be utilized during and after construction, and defining the entities responsible for the installation and maintenance of the BMPs.

Construction Site Regulations

During construction builders and developers are prohibited from discharging in a manner that causes erosion, sedimentation or downstream flooding. Water pumped from a construction site must be treated before discharge to the City system or receiving waters. Chapter 28.1 calls for housekeeping BMPs such as proper disposal of waste materials, spill control, proper application of fertilizers, and vegetative waste. Construction sites must include parking/staging areas and construction entrances. Adjacent streets must be cleaned within 24 hours of deposition of sediments on them.

Chapter 28.1 calls for construction site BMPs to follow the requirements and guidelines contained in the City of Minot Design Manual (see Volume 3).

Article IV (Excavations and Water Runoff Control) of Chapter 9 (Buildings and Housing) of the City of Minot Code of Ordinances requires excavators receive permission from the City to impact utilities and prohibits excavation and other activities from causing damage to adjacent properties or causing sediments or debris to be carried by runoff to adjacent properties.

3.1.2 Storm Water Design Manual (2002)

The City of Minot Storm Water Design Standards Manual (Design Manual) is adopted by reference in the Minot Code of Ordinances Chapter 28.1 (Chapter 28.1). The Design Manual contains standards and design criteria for developing an effective and acceptable storm water management plan. Chapter 28.1 was updated in conjunction with the development of this Plan.

The Design Manual describes in detail the City's expectations regarding the contents of storm water management plans, criteria for hydrologic evaluations, the design of storm water management system facility components, water quality protection standards, instructions for the development of erosion and sedimentation control plans, and requirements for easements and right-of-way. It also includes a discussion of operation and maintenance requirements, standard forms to be used, and standard construction details adopted by the City.

The Design Manual also gives an overview of the City's policies, objectives, and general requirements relating to storm water management.

Policies

The Design Manual describes the policies that are the basis for the City's Storm Water Management Ordinance and Design Manual outlined as follows:

1. The City considers storm water to be an integral part of the overall urban system, and shall require storm water management planning for all developments or land disturbing activities to include the allocation of space for storm water management facility construction and maintenance, which may entail the dedication of right-of-way and/or easements.
2. The City promotes unified storm water drainage efforts through an integrated storm water management plan.
3. The City encourages the development of local storm water master plans for local flood control facilities which are compatible with regional master plans. These local storm water master plans shall also set forth site requirements for new development and identify required public improvements.
4. The City recognizes that runoff volumes will increase with further development of contributing watersheds. However, the City will require that peak runoff rates not exceed existing conditions and/or not exceed the capacity of downstream conveyance facilities. Runoff rates shall be controlled by the use of a regional or on-site detention facility.
5. Subwatershed discharge rates and flood storage volumes shall be consistent with an approved storm water management plan, or a regional storm water management plan adopted by the City of Minot.
6. Storm water management improvements shall be designed based on the critical storm event for the drainage area.
7. Storm water conveyance systems shall be designed to insure flood protection for the improved area and for all receiving water resources downstream.
8. The City requires the optimal use of lakes, ponds, and wetlands throughout the City for storing storm water runoff and improving water quality and other amenities.
9. Storm water discharges may be routed to water treatment ponds, or other acceptable facilities before discharging to lakes, streams, or wetlands.
10. The City requires the submission and implementation of an erosion and sediment control plan to prevent erosion or sedimentation from land disturbance activities.
11. The City requires the design of storm water management facilities for new development to incorporate water quality treatment.
12. The City promotes the infiltration (or other abstraction) of storm water runoff, where feasible and appropriate, to reduce runoff rates and promote water quality.
13. The City requires that property owners or developers be responsible for the maintenance of all privately-owned, on-site drainage facilities including, but not limited to, inlets, pipes, channels, and detention basins, unless modified by separate agreement. Should the property owner or developer fail to adequately maintain said facilities, the City shall have the right to enter said property, upon notice, for the purposes of maintenance. All such maintenance costs shall be assessed against the owner.
14. The City will provide for the revision of its storm water ordinance and encourage changes to the Storm Water Design Standards Manual as new technology is developed and experience gained in the use of these standards.

15. The City shall require all new development or land disturbing activities to provide for the planning, design, and construction of storm water management facilities for both the minor and major storm events, and include emergency flow paths for flows exceeding the major storm event. The minor storm event shall have a recurrence interval of 2 to 10 years, depending on the degree of protection required. The major storm event shall have a recurrence interval of 100 years.
16. The City shall require all storm water management plans, studies, and construction plans/specifications to be reviewed and approved by the City Engineer.
17. The City encourages the flood proofing of existing structures located within a designed floodplain area which are not built in conformance with the adopted floodplain regulations.
18. The City encourages measures in the design of storm water management systems which will not only prevent introduction of additional pollutants, but will improve overall water quality, and to maintain water quality downstream from any land disturbing activities.
19. It is also the policy of the City of Minot to be in conformance with other ordinances and regulations that apply in Minot and for the vicinity of Minot. Agencies with existing ordinances and regulations for local, state, and federal jurisdictions include: the City of Minot, Ward County, Ward County Water Resource District, the North Dakota State Water Commission, the North Dakota Department of Health, the North Dakota Department of Transportation, the State Historical Society, the US Environmental Protection Agency, and the US Army Corps of Engineers.

Goals and Objectives

The goals and the objectives of Chapter 28.1 and the Design Manual are intended to provide a reasonable, manageable, and enforceable approach to controlling undesirable impacts from urban storm water runoff in an environmentally responsible manner. These impacts include, but are not limited to, increased runoff volumes, flood peaks, and flow duration, increased soil erosion, sedimentation, and water quality degradation.

The Design Manual outlines methods by which persons submitting a storm water management plan or applying for a permit can comply with the goals and objectives outlined in the following:

Water Quantity Goal: Storm water design considerations should focus on the prevention of damage to the development site, streams, watercourses, streets, and public and private property.

Water Quantity Objectives:

1. Emphasis should be placed on infiltration at regional ponding facilities where soil conditions allow; in situations where infiltration is not feasible, extended detention or filtration should be performed.
2. Prevent the increase in the existing peak runoff rate for the 2-, 5-, 10-, and 100-year, 24-hour storm events using the Atlas 14 storm distribution (to be selected by the City) and the 100-year 10-day snowmelt event, except where the city has provided sufficient downstream flood detention facilities for the development or redevelopment area's proposed land use and area of imperviousness (as determined by the City Engineer).
3. Require local detention for developments when the downstream conveyance capacities are not capable of handling the increased, undetained peak flow rate from the development.
4. The capacity of downstream conveyance systems shall be analyzed and their adequacy determined based on runoff from the development as fully improved.
5. Local detention will be required when designated in a Regional Storm Water Master Plan to reduce the peak runoff rate in regional facilities.
6. The use of streets for storm water drainage is allowable within specific limitations, as called for in the Design Manual.
7. Retain the 100-year flood flows within dedicated streets, storm sewer easements, streams, and within public properties, with the exception of a natural river and streams with designated floodplains and floodways.

8. Developers shall evaluate the feasibility of infiltrating, or otherwise retaining, 1 inch of runoff from the impervious area of the project, in situations where downstream volume capacity issues exist (as determined by the City Engineer). Developers must demonstrate the infeasibility of infiltration using soil testing or soil site index data.
9. The City discourages the use of wet ponds.

Water Quality Goal: Storm water management planning and design should protect and/or enhance the quality of storm water runoff.

Water Quality Objectives:

1. Design storm water management facilities to enhance the quality of storm water runoff.
2. Promote the utilization of infiltration systems for the management of both water quantity and water quality.
3. Encourage the utilization of grassed or other buffer areas for runoff quality management.

Erosion and Sedimentation Goal: Erosion and sediment control plans should reduce or eliminate the potential for soil erosion and sedimentation through proper storm water management planning and design.

Erosion and Sedimentation Objectives:

1. Require flows to be discharged to downstream properties at non-erosive velocities and depths of flow.
2. Maintain the flow of storm water runoff within its natural drainage path where ever possible.
3. Require construction operations to utilize techniques such as silt fences, on-site sediment detention ponds, or other Best Management Practices (BMPs) to prevent erosion of recently disturbed areas.
4. Insure the establishment of vegetation and/or other land cover as quickly as possible after completion of any land disturbing activity.
5. Reduce or eliminate sedimentation in storm water discharge outlets during and after development.

Operation and Maintenance Goal: Storm water management facilities should be designed for operational reliability, minimum maintenance, and the ability to function as intended.

Operation and Maintenance Objectives:

1. Require all storm water management facilities to be designed to minimize facility maintenance as well as to provide ease of maintenance.
2. Require that all storm water management facilities be provided with reasonable access for maintenance.
3. A minimum 30-foot wide storm water easement shall be provided for all publicly maintained drainage facilities.

Minor and Major Drainage Systems

Every developed area in Minot is simultaneously a part of two separate levels of drainage system classification: the Minor Drainage System and the Major Drainage System. Multiple Minor Drainage Systems form each Major Drainage System.

The Major Drainage System is designed to convey runoff from the 100-year recurrence interval flood to minimize health and life hazards, damage to structures, and interruption to traffic and services. In the City of Minot and its extraterritorial jurisdiction, a major drainage system is defined as any watershed with a named river or stream, natural or manmade, as its primary conveyance feature.

The Minor Drainage System is designed to transport the runoff from a 2 to a 10-year recurrence interval flood, depending upon land use, with minimal disruption to the urban environment. The design of the Minor Drainage System shall also account for the conveyance of the 100-year recurrence interval flood event. Minor storm water drainage can be conveyed in the curb and gutter area of the street or roadside ditch, by storm sewer

piping, channel, or other conveyance facilities. A Minor Drainage System within the City of Minot and its extraterritorial jurisdiction is considered to be any subwatershed located within a Major Drainage System having as its primary conveyance feature a tributary to the named river or stream and/or a constructed storm sewer system and associated surface flow corridor.

A typical drainage system within a subdivision would consist of allowable flow in the gutters, inlets, and storm sewer pipes, which in combination to carry the flows from the minor storm without effects of detention. These flows would be discharged to a larger sewer system or an open channel, having capacity adequate for larger floods. As the storm intensity increases, storm water detention should be used to reduce the developed flood peaks to pre-development levels. During the calculation of the major storm runoff, the benefits of upstream on-site detention can be accounted for during the routing of flood peaks through the development.

General Requirements

The following general requirements are specified in the Design Manual for storm water management plans:

1. Design data provided by the design engineer should demonstrate that storm water management investigations include:
   a) The function of the streets as part of the storm water conveyance system.
   b) Assurance that gutters and intakes are adequate to prevent excessive flooding of streets and parking areas.
   c) Assurance that culverts and storm sewer pipes are designed to sufficient size and hydraulic capacity.
   d) Assurance that adequate overland relief is present for storm events larger than the design storm, or that an adequate storage volume and a release system are provided to accommodate a 100-year flood with a minimum of 3 feet of freeboard.
   e) Assurance that street grades are coordinated with lot drainage and that lot drainage slopes will not be less than 0.5%.
2. An evaluation should be made of storm water management alternatives to manage the runoff resulting in the selection of the optimum design which strikes a balance between initial capital costs, operation and maintenance costs, public convenience and safety, and environmental protection.
3. Runoff analysis should be based upon the proposed or projected land use, and should take into consideration all contributing runoff from areas outside of the immediate project area.
4. All undeveloped land lying outside of the study area should be considered as fully developed based upon the Storm Water Master Plan for the area, if one exists. The probable future flow pattern in undeveloped areas should be based on existing natural topographic features (existing slopes, watercourses, etc.). Average land slopes in both developed and undeveloped areas may be used in computing runoff, however, for areas in which drainage patterns and slopes are established, these should be utilized.
5. Flows and velocities which may occur at a design point when the upstream area is fully developed should be considered. Drainage facilities should be so designed that such increased flows, velocities and durations will not cause erosion and/or sedimentation damage.
6. Streets should not be used as floodways for the initial storm runoff. The primary use of streets should be for the conveyance of traffic. The computed amount of runoff in streets should not exceed the requirements set forth in the Design Manual.
7. The use of on-site detention and natural watercourses is recommended and encouraged whenever possible. The relocation of a natural watercourses or a substantive change in a watershed boundary will not be approved unless such change is shown to be without unreasonable hazard and liability, substantiated by a thorough analysis and investigation.
8. Restrictive covenants (agreements or contracts), surface flow easements and impoundment easements may be required to be executed and recorded to provide for the protection and

maintenance of drainage swales and drainage detention areas within built-up areas. In the use of natural channels, the design engineer may be required to show that the project will have minimum disruption of the existing environment, and covenants may be required by the City Engineer to be executed and recorded to provide this protection.

9. In the design of storm water management systems, consideration should be given to both surface and subsurface water sources. Subsurface drainage systems should be designed where required and should not allow flow over sidewalks or onto streets after completion of the project.
10. Land grading of the project site should be performed to take advantage of existing contours and minimize soil disturbance. Steep slopes should be avoided. If steep slopes are necessary, an attempt should be made to save natural grasses, shrubs, and trees on these slopes and reestablish ground cover and permanent erosion control measures as soon as possible.
11. During construction grading phases, temporary diversions, contour furrows, terraces and other remedial conservation practices should be used to reduce erosion and excessive water drainage to downstream adjacent properties. Sediment traps and basins should be used at the lower end or along watercourses and provisions should be made for their maintenance.
12. The planning and design of drainage systems should be such that problems are not transferred from one location to another. Under no circumstance shall significant drainage be diverted and/or released overland to a downstream property at points not receiving such drainage prior to the proposed development. Also, flows shall not be concentrated onto downstream properties where sheet flow previously existed, unless it is determined these properties can accommodate these flows without adverse impacts.
13. Where a proposed development or land disturbing activity discharges into an existing storm drain, the developer shall provide to the City the hydraulic capacity of that drain and computations for that capacity.
14. In the event that storm water runoff from a development drains into an existing flood drainage area and/or erosion problem area, as determined by the City Engineer, the peak discharge from this site shall not be greater than the peak leaving this site prior to development.
15. In the event that runoff from a proposed land disturbing activity has in the past discharged directly into a relatively large body of water, such as a river, or has or could discharge to such bodies of water via a ditch or pipeline sized to accommodate anticipated increased runoff in the proposed land development, then it shall be the sole decision of the City Engineer to permit or not permit such increased runoff to said bodies of water from the proposed land disturbing activity.
16. Floodplain information (floodway, base flood elevation, and floodway fringe) will be required on all preliminary and final drainage plans when known, and should include the area inundated by the major storm runoff. Lands that lie within "flood hazard zones" as shown on the appropriate maps prepared by the Federal Emergency Management Agency (FEMA), shall comply with the regulations of the National Flood Insurance Program (NFIP). The City of Minot may designate floodplains in areas not shown on the Flood Insurance mapping, using approximate or detailed methods of study.
17. Where a Storm Water Master Plan is available, the flow routing for both the minor storm and the major storm runoff events should conform to that plan. Drainage easements conforming to the master plan will be required and shall be designated on all drainage drawings and subdivision plats.
18. Any proposed building or construction of any type of structure including retaining walls, fences, etc., or the placement of any type of fill material which will encroach on any utility or drainage easement, requires written approval of the City Engineer. The function of the drainage easement (conveyance, ponding, etc.) shall not be impaired, nor shall drainage from adjacent areas be impeded.
19. All storm water management systems, including collection, conveyance and restrictions (i.e., detention/retention), not located on city property, shall be so located in a dedicated public right-of-

way or easements approved by the City. All drainage right-of-way or easements shall be shown on construction plans and on the final subdivision plat.

20. The design for storm water management facilities should be in conformance with the following guidelines:
    a) Requirements and standards of the North Dakota State Water Commission.
    b) Requirements and standards of the North Dakota Department of Health.
    c) Design standards and construction specifications of the City of Minot.
    d) The most current plumbing code.
    e) The requirements and standards of the North Dakota Department of Transportation, where applicable.
    f) In case of conflict between the above design standards, the most restrictive requirement should apply.
21. No polluted water or water from a polluted source shall be discharged into any storm water management system. This includes wash water and interior building drainage water. Snow disposal sites or runoff from irrigation systems may be included under special circumstances.
22. The North Dakota Department of Health administers the National Pollutant Discharge Elimination System (NPDES) permit program and issues permit requirements for storm water discharges within the State of North Dakota. The design of storm water management facilities shall comply with the requirements and standards of the North Dakota Department of Health for storm water discharge permits.

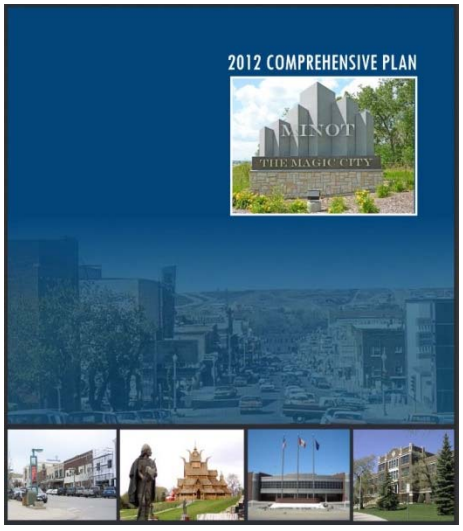
Chapters 2-13 of the Design Manual present detailed design criteria and methods, including example calculations for each storm water topic. These detailed methods are aimed at meeting the above policies, objectives, and general requirements of the City of Minot.

3.1.3 2003 Storm Water Management Plan

Chapter 20 of the City of Minot Zoning Ordinance addresses flood protection requirements. The requirements included in this ordinance are limited to floodplain areas delineated on flood insurance rate maps (FIRMs) developed by the City and the Federal Emergency Management Agency (FEMA). Chapter 20 specifies minimum building elevations for structures located within floodplain areas mapped on City and FEMA FIRMs.

Chapter 20 specifies that new or substantial improvements of residential structures must have a lowest flood at least equal to or greater than the base flood elevation, which is defined as athe water level corresponding to the 100-year event. New or substantial improvements to non-residential structures must have a lowest floor at, or be flood-proofed to, an elevation equal to or greater than the base flood elevation.

Note that minimum building elevations adjacent to storm water system features are specified in Chapter 28.1 and the Design Manual, and require minimum building elevations that are more restrictive than Chapter 20. The City will likely revise Chapter 20 of the Zoning Ordinance in response to the results of the ongoing Mouse (Souris) River study.



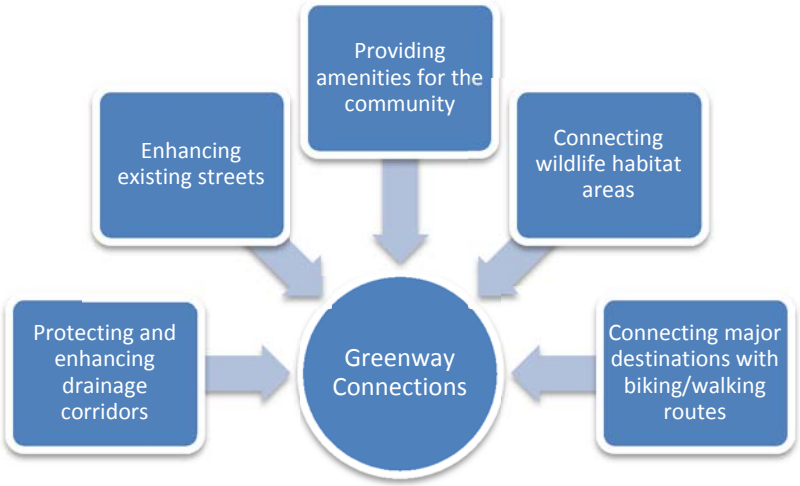
3.1.4 Comprehensive Plan (2012)

The City of Minot 2012 Comprehensive Plan (Comp Plan) was approved on June 4, 2012. It documents city-wide planning efforts undertaken in 2010-2012 and sets future goals and directions for development in the city. The Comp Plan identifies five key planning elements:

1. Revitalized Downtown
2. Greenway Connections
3. Compact Development
4. Housing Opportunities
5. Transportation

All of these Key Elements have implications for storm water management. The Key Element 2, Greenway Connections, explicitly discusses water resource implications within the element goals and directions.

The Comp Plan calls for green corridors to be an important part of new development and re-development. Green corridors would provide multiple functions including drainage and storm water management. The Comp Plan recognizes that it is desirable to provide areas for collecting and infiltrating water as close to the source as possible. It encourages the City to identify and preserve as many key drainage corridors as possible so that storm water management can begin close to the source of runoff and provide the benefits associated with greenways.



The Comp Plan suggests that: “there are many innovations for new storm water treatment that provide design amenities. Many of these include improved ponds or rain gardens. These can be used in multiple locations and types of developments.”

The Comp Plan, Land Use Chapter includes the following goal and water resource related policies:

> Goal 2: Ensure that zoning and subdivision ordinances and official master plan documents are consistent with the intent and specific direction provided within the Comprehensive Plan.
>
> Rationale: Sound land-use plans and the official controls that implement them are essential tools that enable the community to attract those specific uses intended for the land and ensure the quality community Minot citizen’s value.
>
> Policies:
>
> 1. Provide clearly defined zoning ordinances to achieve public values including, but not limited to:
>   a) Preserving open space and park and recreational needs through park dedication.
>   b) Managing storm water using natural filtration and other ecologically based approaches to avoid down-stream flooding.
>   c) Providing housing that meets all stages in the life cycle and affordability ranges.
>   d) Expand/diversify the tax base to lessen the tax burden on residential properties.
>   e) Providing infrastructure that benefits community beyond the project site.
> 2. Ensure developments meet the standards specified within the land-use plan and official controls, including zoning and subdivision ordinances and official maps.
> 3. Ensure compatibility of adjacent land uses in new developments and work to improve compatibility in existing redevelopment areas.

3.1.5 Long Term Recovery Framework (2012)

The Long Term Recovery Framework with an Emphasis on Hazard Mitigation sets strategies for recovery after the catastrophic Mouse (Souris) River 2011 flood event. The document includes goals, strategies, projects, processes, and land use strategies to set Minot back on a positive course after the flood.

Along with a large scale project to protect the "core valley" of Minot to the level of the 2011 flood (27,400 cfs), the following goals are established:

- Reduce the risk of flood damage
- Minimize the flood control infrastructure footprint
- Minimize increases in flood level, rates and duration
- Establish key transportation corridors that can remain open during flood
- Minimize environmental impacts to facilitate permitting
- Design a project that is consistent with long range community objectives

The City of Minot Long Term Recovery Framework prioritizes a set of projects toward these goals including (priority ranking):

- 6th Street SW Underpass Pump Station, storm drain improvements, and home acquisitions. (1-2)
- Water Treatment Plant protection including flood walls, intake relocation, 16th Street storm drain improvements, and levee tie-backs. (3-7)
- Generators for storm pumping stations. (8)
- Utility relocations. (9-11)
- 3rd Street NE and 3rd Street SW storm drain improvements. (12-13)
- Reconstruct water line crossings. (14)
- 4th Avenue NE floodwalls. (15)
- 27th Street SE diversion. (16)
- Maple diversion. (17)
- Levees Hwy 83 bypass to 2nd Ave. (18)
- Levees and floodwalls Broadway to Hwy 2. (19)
- Home acquisition 8th St NE and 2nd St NE. (20)
- Communications upgrades and program. (22)
- Various home and business acquisitions. (21, 23, 24)
- Emergency generators for sanitary lift stations. (25)

It is expected that as recovery efforts progresses and funding becomes available, the priority rankings may change.

3.2 Regulatory Programs Affecting the City

There are several programs at the state and federal level which govern the management of water resources within and around the City of Minot. Key programs affecting the city are described in this section of the Plan, and include:

- National Pollution Discharge Elimination System (NPDES) Program / North Dakota Department of Health
- US Army Corps of Engineers Section 404 Permitting
- Federal Emergency Management Agency (FEMA) Flood Insurance Program
- Ward County Water Resources District

3.2.1 National Pollution Discharge Elimination System (NPDES)

The City of Minot is included in a group of communities with populations greater than 10,000 that are federally required to obtain a Municipal Separate Storm Sewer System (MS4) permit for managing non-point source

storm water. The Phase II National Pollution Discharge Elimination System (NPDES) permit program requires cities such as Minot to file a Phase II NPDES MS4 permit with the North Dakota Department of Health (NDDOH), which administers the NPDES program in the state of North Dakota. The City's MS4 permit addresses how the city will regulate and improve storm water discharges. The permit must include a Storm Water Pollution Prevention Program (SWPPP) addressing all of the requirements of the permit.

The NPDES program also includes the NPDES General Storm Water Permit for Construction Activity (Permit NDR10-0000) and the NPDES General Industrial Storm Water Permit program (Permit NDR05-0000). Project owners must also develop a storm water pollution prevention plan (SWPPP) and receive coverage from the North Dakota Department of Health under the North Dakota Pollutant Discharge Elimination System General Permit (NPDES) for construction sites that:

- Propose land disturbance (clearing, grading or excavating) that is greater than or equal to one acre, or
- Propose land disturbance that is less than one acre and the site is part of a larger common plan of development or sale with the total land area disturbed equal to or greater than one acre, or
- Create potential for contribution to a violation of a water quality standard or potential for significant contribution of pollutants to waters of the state.

Minot submitted its most recent permit application in 2014. The City's SWPPP is described in this Section. The NDDOH is in the process of reissuing the Phase II NPDES MS4 Permit. It is anticipated that the timing of the permit update and implementation will not affect the next renewal of the City of Minot MS4 Permit, expected in 2015.

City of Minot SWPPP

The current Phase II NPDES MS4 permit must include a SWPPP addressing all of the requirements of the permit. Minot's NPDES Phase II MS4 SWPPP addresses six minimum control measures (MCMs) outlined in the permit requirements. The City of Minot has already developed and put in place many of the best management practices (BMPs) required in the NPDES permit. The MCMs required by the permit are:

1. Public Outreach and Education
2. Public Participation/Involvement
3. Illicit Discharge Detection and Elimination
4. Construction Site Runoff Control
5. Post Construction Runoff Control
6. Pollution Prevention/Good Housekeeping

The SWPPP is designed to address these issues, thereby minimizing the discharge of pollutants into the city's storm water system, protecting and enhancing water quality, and satisfying the appropriate requirements of the Clean Water Act of 1984 (as amended).

During a conversation with the NDDOH, the following process improvements for the City of Minot's MS4 program were recommended:

1. Public Outreach and Education
    a) Water bill insert – quarterly reminder about the storm sewer system
    b) Work with the Minot Association of Builders to include information in their newsletters
    c) Use news outlets to get information out (PSAs)
    d) Creation of door hangers
2. Public Participation/Involvement
    a) See if local schools can help out with Storm Drain Stenciling or talking about the storm sewer system

   b) Adopt a Storm Inlet (similar to the Adopt a Road or Hydrant) Program
3. Illicit Discharge Detection and Elimination
   a) Promote public involvement by providing a method to report issues
   b) Institute a hotline (voicemail) or a dedicated #/person and reporting times
4. Construction Site Runoff Control
   a) Improve Training Program for local contractor and inspectors (use visuals – video)
   b) Recommended MNDOT training videos
   c) Provide a written reminder about inlet protection being pulled before the first hard freeze
5. Post Construction Runoff Control
   a) Recommended a clear chain of custody on plans and in stormwater management plan (i.e. who will own the facility, who will maintain the facility, etc.)
6. Pollution Prevention/Good Housekeeping
   a) Improve Training Program – Good Housekeeping for all municipal employees

Several items are not currently required as part the MS4 program, however, the NDDOH recommends these actions take place and a record of the action be noted within the MS4 annual report. These items include maintaining As-Builts and chain of custody documents in one location and an inventory of these documents be updated regularly.

3.2.2 US Army Corps of Engineers (COE) Programs

The COE administers the Section 10 of the Rivers and Harbors Act permit program, and the Section 404 permit program. More information is available at the COE website: www.usace.army.mil

Section 404 - Authorizations

The Federal Clean Water Act requires that anyone who wants to discharge dredged or fill material into US waters including wetlands must first obtain a Section 404 permit from the COE. Examples of activities that require a Section 404 permit include: construction of boat ramps, placement of riprap for erosion protection, placing fill in a wetland, building a wetland, construction of dams or dikes, stream channelization, and stream diversion.

When Section 404 permit applications are submitted to the COE, the applications are typically posted for the US Fish and Wildlife Service, the US Forest Service, the US EPA, and other federal agencies to review and provide comments on the application. The COE evaluates permit requests for the potential impact to various functions and values of the wetland.

Section 401 - Water Quality Certifications

Section 401 Certification is required to obtain a federal permit for any activity that will result in a discharge to navigable waters of the US. The program is primarily administered by the COE along with the NDDOH. A Section 401 water quality certification may be granted if the applicant demonstrates that the proposed activity will not violate North Dakota's water quality standards or result in adverse long-term or short-term impacts on water quality.

3.2.3 Federal Emergency Management Agency – National Flood Insurance Program

The City of Minot administers a floodplain ordinance to govern development within the City. The floodplain ordinance references Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs), allowing the City of Minot to participate in the National Flood Insurance Program (NFIP).

Homeowners within FEMA-designated floodplains are required to purchase flood insurance if their community participates in the NFIP. NFIP provides subsidized flood insurance rates to many participants. The Biggert Waters Flood Insurance Reform Act of 2012 was intended to increase financial solvency of NFIP by reducing subsidies to many participants, although the implementation of the legislation has been delayed.

Homeowners within FEMA-designated floodplains are required to purchase flood insurance if their community participates in the NFIP. NFIP provides subsidized flood insurance rates to many participants. The Biggert Waters Flood Insurance Reform Act of 2012 was intended to increase financial solvency of NFIP by reducing subsidies to many participants, although the implementation of that legislation has been delayed.

In some cases, homes within FEMA-designated floodplains on the FEMA floodplain maps may actually not be in the floodplain. In order to waive the mandatory flood insurance requirements for their homes, residents must remove their homes from the FEMA-designated floodplain by obtaining Letters of Map Amendment (LOMA).

3.2.4 Ward County Water Resource Board

The Ward County Water Resource District provides oversight and review of stormwater management plans at the request of the City for projects near City limits or in sensitive areas. Also, proposed projects within the 2-mile Extra-Territorial Area submit stormwater management plans to the City, which forwards these documents to the Ward County Water Resource District for review and approval prior to City approval.

4 Stormwater System Analysis

4.1 Introduction

The following sections will describe the major and minor drainage systems within the scope of this study. The major systems will include discussion of existing conditions, future conditions due to changes in land use, modeling methods, and proposed improvements. The minor systems will include discussion of existing conditions, existing deficiencies, modeling methods, and proposed improvements. Also included is a summary of the opinion of probable costs for the proposed improvements associated with both the major and minor systems.

4.2 Major Systems Analysis

The following summarizes each of the major system's existing conditions, future conditions due to changes in land use, modeling methods, and proposed improvements. Technical memorandums for each system with detailed calculations and larger figures can be found in the Appendix.

4.2.1 First Larson, Second Larson, and Puppy Dog Coulees

INTRODUCTION

Three major coulees drain the south and southwest sections of the City of Minot, as well as large undeveloped agricultural areas located to the west outside of the corporate boundary as shown in Figure 4.2-1. The three coulees are First Larson Coulee, Second Larson, and Puppy Dog Coulees (the Coulees). Existing development, as well as planned development, have changed, and will continue to change the stormwater runoff rate and volume within the respective watersheds of these coulees. As part of the current stormwater management plan update, these major systems are being analyzed such that planned development can be incorporated without negatively impacting the existing coulees and exacerbating existing problems.

The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) was used to simulate the hydrology of the Coulees. The HEC-HMS model was developed to quantify the stormwater runoff volume and discharge rate at various locations within the respective watersheds under existing land use and future land use conditions, and to size and evaluate the effectiveness of regional detention facilities. Details regarding modeling methods and results are discussed in the following sections.

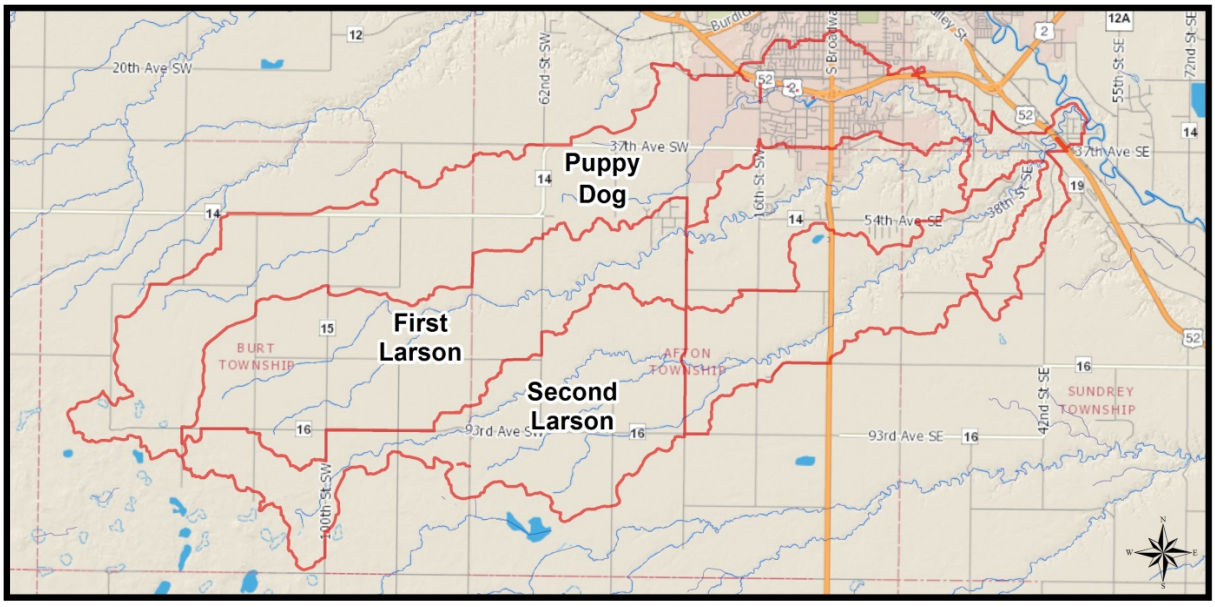


Figure 4.2-1: Puppy Dog, First Larson, and Second Larson Watersheds

MODELING METHODS

HEC-HMS models for the Coulees based on subbasin delineations were refined using the 2010 Ward County LiDAR data. The headwaters of the Coulees originate approximately 11 miles southwest of the City of Minot. The Coulees drain long narrow watersheds while flowing from west to east. The confluences of First Larson Coulee and Second Larson Coulee with Puppy Dog Coulee are located at the eastern end of the watershed near the confluence of Puppy Dog Coulee with the Mouse River. The overall watershed data for each of these coulees includes:

Watershed	Area (sq mi)
First Larson Coulee	16.57
Puppy Dog Coulee (Above First Larson)	17.39
Puppy Dog Coulee (Above Second Larson including First Larson)	34.71
Second Larson Coulee	16.23
Puppy Dog Coulee at Confluence with Mouse River.	52.21

Table 4.2-1: Watersheds

Rainfall and Snowmelt Events

Twenty-four (24)-hour rainfall and 10-day snow melt events were analyzed for this study. Return frequencies considered included the 2-year, 10-year, 25-year, 50-year and 100-year events. The rainfall distribution utilized for this study is the 24-hour Soil Conservation Service (SCS) Type II synthetic event. The precipitation totals for the design storms were taken from the NOAA Atlas 14 Point Precipitation Frequency Estimates for the Minot, ND area. The snowmelt event was modeled using the 10-day Principal Spillway Hydrograph published in the North Dakota Hydrology Manual.

Existing and Future Land Use

In the headwaters of all three coulees, the existing land use is predominantly agricultural. As the city boundary is approached, small rural development is more prevalent. Within the city boundary, the land use is mostly residential and commercial/business developments. Existing land use data within the growth area limits were obtained from the 2012 City of Minot Comprehensive Plan (2012 Comp Plan); existing land use data outside of the corporate limits was obtained from the 2006 National Land Cover Data (NLCD) from the Multi-Resolution Land Characteristics (MRLC) Consortium. The existing land use category percentages for the Coulees are shown in Table 4.2-2 and graphically in Figure 4.2-2.

The city has delineated a growth area boundary that expands outside of the city boundary. Under future land use conditions, the areas outside of the growth area boundary have the same designated land use as the existing condition. The areas within the growth area boundary, but outside of the city boundary, change from agricultural and meadow to residential and commercial/business developments under future land use conditions. The future land use data within the growth area limits were obtained from the 2012 Comp Plan and the land use for areas outside of the corporate limits were based on the 2006 NLCD. The future land use category percentages for the Coulees are shown in Table 4.2-3 and graphically in Figure 4.2-3.

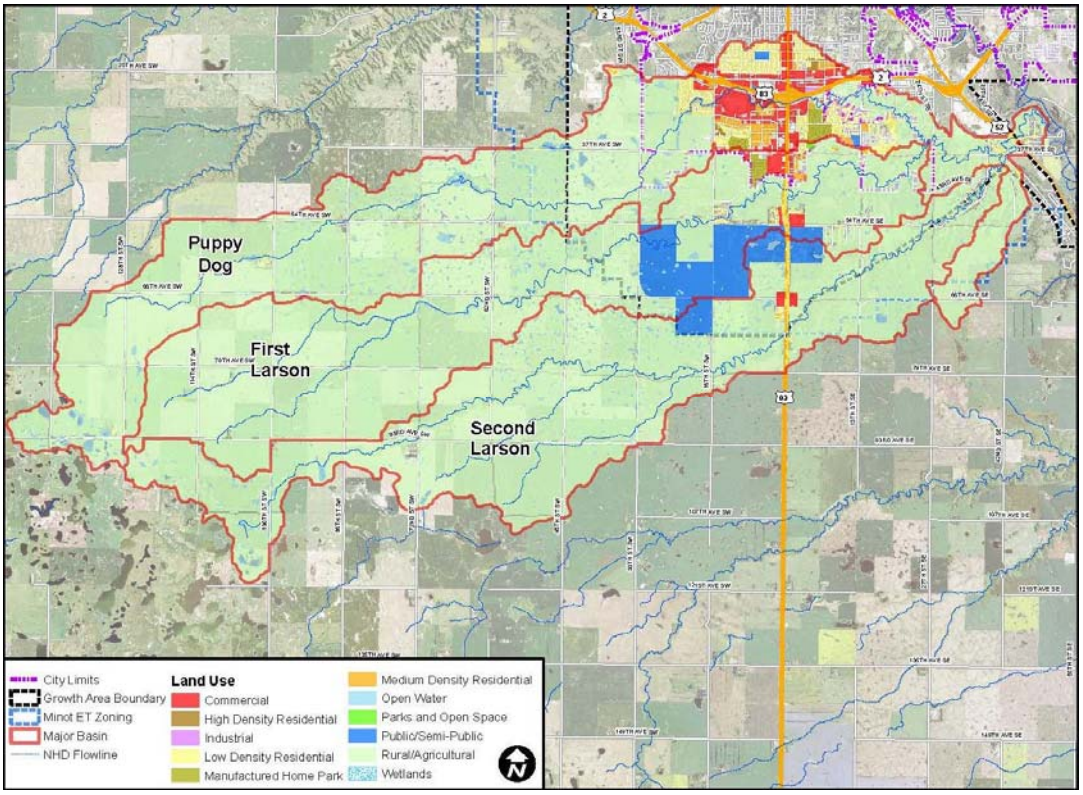


Figure 4.2-2: Coulees with Existing Land Use

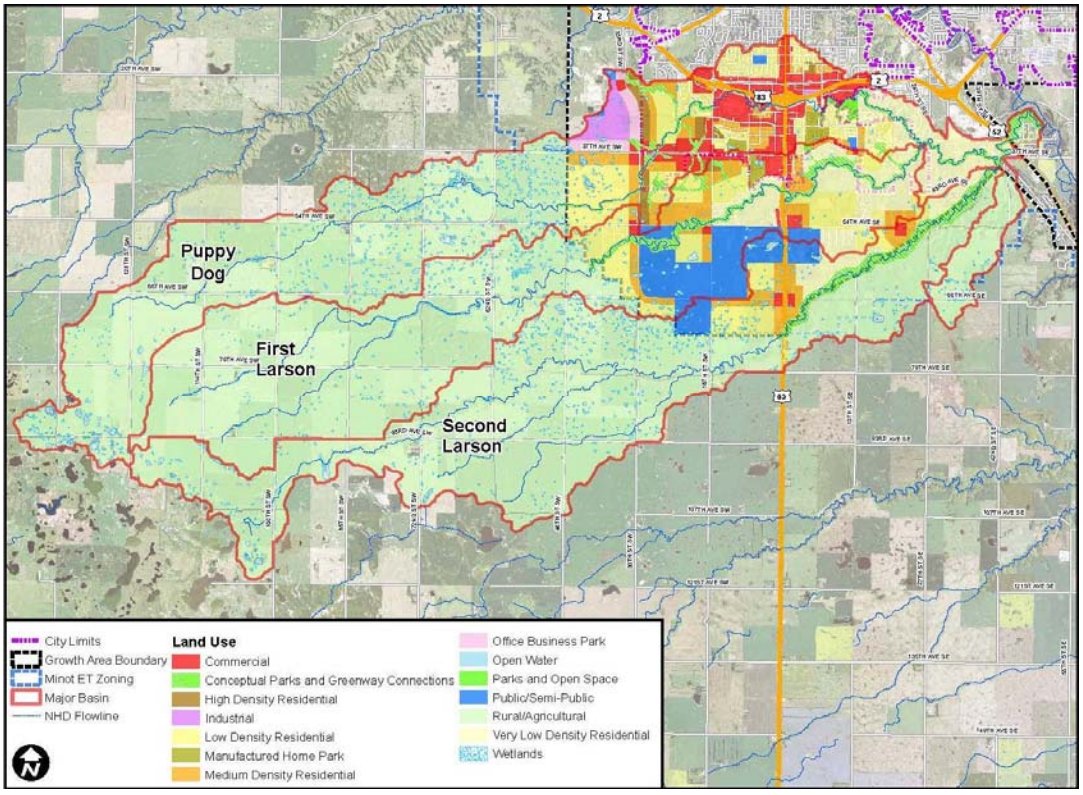


Figure 4.2-3: Coulees with Future Land Use

Table 4.2-2: Existing Land Use for the Puppy Dog, First Larson, and Second Larson Coulees

Minot Land Use Category	Land Use Category	Puppy Dog Coulee	First Larson Coulee	Second Larson Coulee
Rural/Agricultural/Public/ Semi Public	Agricultural	59.3%	69.5%	69.8%
Rural / Agricultural	Pasture	3.2%	0.4%	1.0%
Rural / Agricultural	Meadow	9.9%	19.5%	19.2%
Rural / Agricultural	Woods	0.8%	1.1%	1.2%
Water / Wetland	Water	3.7%	2.4%	3.4%
ROW	Road ROW	9.1%	4.9%	4.7%
Commercial	Commercial/Business	5.0%	0.5%	0.0%
Industrial	Industrial	0.0%	0.0%	0.0%
High Density Residential	High Density Residential	0.2%	0.0%	0.0%
Medium Density Residential	Medium Density Residential	2.5%	0.7%	0.1%
Low Density Residential	Low Density Residential	5.9%	0.9%	0.7%
	Very Low Density Residential	0.0%	0.0%	0.0%
Vacant/ Unknown	New Developing	0.1%	0.0%	0.0%
Parks / Open Space	Open Space	0.0%	0.1%	0.0%
	Barren	0.3%	0.0%	0.0%
Public / Semi Public	Airport	0.0%	0.0%	0.0%

Table 4.2-3: Future Land Use for the Puppy Dog, First Larson, and Second Larson Coulees

Minot Land Use Category	Land Use Category	Puppy Dog Coulee	First Larson Coulee	Second Larson Coulee
Rural/Agricultural/Public/ Semi Public	Agricultural	43.3%	54.4%	60.5%
Rural / Agricultural	Pasture	1.9%	0.4%	0.7%
Rural / Agricultural	Meadow	3.8%	7.3%	14.6%
Rural / Agricultural	Woods	0.4%	0.4%	1.1%
Water / Wetland	Water	3.3%	2.2%	3.1%
ROW	Road ROW	8.6%	3.3%	4.2%
Commercial	Commercial/Business	9.9%	8.1%	4.9%
Industrial	Industrial	1.8%	0.0%	0.0%
High Density Residential	High Density Residential	1.7%	0.1%	0.0%
Medium Density Residential	Medium Density Residential	5.8%	5.0%	2.7%
Low Density Residential	Low Density Residential	12.0%	8.5%	3.8%
	Very Low Density Residential	7.2%	10.2%	4.4%
Vacant/ Unknown	New Developing	0.0%	0.0%	0.0%
Parks / Open Space	Open Space	0.6%	0.1%	0.0%
	Barren	0.0%	0.0%	0.0%
Public / Semi Public	Airport	0.0%	0.0%	0.0%

MODEL SCENARIOS

Existing Conditions

The existing conditions HEC-HMS model for the Coulees generates runoff from the sub-basins in each coulee and routes the flow along the coulees to where the flows combine and then discharge into the Mouse River. Hydrograph attenuation due to storage behind the following existing structures was considered:

- First Larson Coulee at 62nd Street
- First Larson Coulee at 30th Street
- First Larson Coulee at Highway 83
- Second Larson Coulee at 62nd Street
- Second Larson Coulee at 30th Street
- Second Larson Coulee at Ward County Road 14A

No storage was included within the Puppy Dog Coulee reach.

Future Conditions

The future land use conditions model scenario accounts for the future growth and development as identified in the 2012 Comp Plan. The updated Future Land Use Plan includes large areas of residential, commercial, and business developments to accommodate future growth, but also identifies locations for new parks and greenways. These areas are outside of the current city boundary, but are within the identified growth area boundary. Most of these areas are currently undeveloped or open agricultural land.

MODEL CONSTRUCTION

First Larson Coulee Watershed

First Larson Coulee drains approximately 16.57 square miles of area. The headwaters of the First Larson Coulee originate approximately 11 miles southwest of the City of Minot. The land use in the upstream watersheds is generally agricultural with some larger meadow areas. The downstream portion of the watershed is largely meadow with several scattered low-density residential developments. A small portion of the First Larson Coulee is within the City of Minot city boundary and has been developed as residential and commercial/business. Future land use changes will generally involve the conversion of agricultural and meadow to residential and commercial/business developments as shown in Figure 4.2-3. The changes in curve number from existing to future conditions for several of the subbasins reflect this land use shift. The curve numbers for existing land use and future land use conditions are shown in Table 4.2-5.

Table 4.2-4: First Larson Coulee Subbasin Areas

Subbasin	Area (square miles)
FL-1	8.699
FL-2	1.949
FL2-S	0.385
FL3-DS	2.483
FL-3US	0.197
FL-3USS	0.475
FL-4	2.384

Table 4.2-5: First Larson Coulee Subbasin Curve Numbers

Existing Conditions Model		Future Conditions Model	
Subbasin	CN	Subbasin	CN
FL-1	76.1	FL-1	76.1
FL-2	70.2	FL-2	72.2
FL2-S	77.9	FL2-S	78.2
FL3-DS	74.9	FL3-DS	83.4
FL-3US	69.2	FL-3US	90.8
FL-3USS	78.3	FL-3USS	88.4
FL-4	66.7	FL-4	75.0

Second Larson Coulee Watershed

Second Larson Coulee drains approximately 16.23 square miles of area. The headwaters of the coulee originate approximately 11 miles southwest of the City of Minot. The land use in the upstream watersheds is generally agricultural. The downstream portion of the watershed is largely meadow with several scattered low-density residential developments. No portion of the Second Larson Coulee is within the current City of Minot city boundary. A small portion of the coulee is within the growth area boundary. Under future land use conditions, the land use within the growth area boundary changes from generally agricultural and meadow to residential and commercial/business developments as shown in Figure 4.2-3. The changes in curve number from existing to future conditions for several of the subbasins reflect this land use shift. The curve numbers for existing land use and future land use conditions are shown in Table 4.2-7.

Table 4.2-6: Second Larson Coulee Subbasin Areas

Subbasin	Area (square miles)
SL-1	3.862
SL-2	0.835
SL-3	3.287
SL-4	1.736
SL-5	3.026
SL-6	2.603
SL-7	0.876

Table 4.2-7: Second Larson Coulee Subbasin Curve Numbers

Existing Conditions Model		Future Conditions Model	
Subbasin	CN	Subbasin	CN
SL-1	76.3	SL-1	76.3
SL-2	76.7	SL-2	76.7
SL-3	74.7	SL-3	74.7
SL-4	76.6	SL-4	76.6
SL-5	75.6	SL-5	78.1
SL-6	68.6	SL-6	72.3
SL-7	66.5	SL-7	69.1

Puppy Dog Coulee Watershed

Puppy Dog Coulee drains approximately 17.39 square miles of area at its confluence with First Larson Coulee and approximately 52.21 square miles at its confluence with the Mouse River. The basin delineation is shown in Figure 4.2-1 and the subbasin areas are listed in Table 4.2-8.

Table 4.2-8: Puppy Dog Coulee Subbasin Areas

Subbasin	Area (square miles)
PD-1	5.027
PD-2	4.363
PD-3DS	0.849
PD-3US	1.272
PD-4DS	0.431
PD-4DSS	0.121
PD-4US	0.570
PD-4USS	1.265
PD-5	0.304
PD-6	0.584
PD-7DS	1.552
PD-7US	0.241
PD-USS	0.046
PD-8	0.759
PD-9	0.692
PD-10	1.333

Table 4.2-9: Puppy Dog Coulee Subbasin Curve Numbers

Existing Conditions Model		Future Conditions Model	
Subbasin	CN	Subbasin	CN
PD-1	77.2	PD-1	77.2
PD-2	77.8	PD-2	77.8
PD-3DS	77.0	PD-3DS	82.9
PD-3US	74.8	PD-3US	74.4
PD-4DS	77.7	PD-4DS	83.1
PD-4DSS	77.5	PD-4DSS	89.7
PD-4US	74.2	PD-4US	85.9
PD-4USS	78.0	PD-4USS	84.4
PD-5	84.9	PD-5	84.9
PD-6	88.2	PD-6	88.1
PD-7DS	82.2	PD-7DS	84.3
PD-7US	89.3	PD-7US	89.3
PD-7USS	87.3	PD-7USS	87.3
PD-8	68.3	PD-8	72.7
PD-9	62.7	PD-9	69.2
PD-10	73.3	PD-10	73.7

The headwaters of the coulee originate approximately nine miles southwest of the City of Minot. The land use in the upstream watersheds is generally agricultural. The downstream watersheds within the City of Minot corporate boundary are developed with land use classified as residential and commercial/business. The downstream watersheds, near the confluences with First Larson and Second Larson Coulees, are outside of city limits and are primarily natural open spaces (meadow and pasture) and low density residential developments. Under future land use conditions, the land use within the growth area boundary but outside of the corporate boundary, changes from generally agricultural to residential, commercial/business, and industrial developments as shown in Figure 4.2-3. The changes in curve number from existing to future conditions for several of the subbasins reflect this land use shift. The curve numbers for existing land use and future land use conditions are shown in Table 4.2-9.

RESULTS

First Larson Coulee

Existing and future conditions were modeled for First Larson Coulee considering the land use changes discussed above. The results above the confluence with Puppy Dog Coulee have been summarized in Table 4.2-10 for the 2-, 10-, 25-, 50- and 100-year rainfall and 10-day snowmelt events. Changes in the future land use within the lower watershed will cause the 100-year peak discharge to increase as much as 34% at confluence of First Larson Coulee with Puppy Dog Coulee. In addition, the rainfall events produce higher discharges than the snow melt events and will therefore be used for the sizing of mitigation options. Computed future peak runoff from the snow melt events are slightly smaller than those computed for existing conditions due to hydrograph timing. For this 10-day event, the improved drainage in future conditions will allow runoff from the local watershed to pass downstream before the drainage from the upstream basin arrives at a given location. Complete results have been summarized for various locations along First Larson Coulee within the Appendix.

Table 4.2-10: First Larson Coulee Peak Flow Summary

First Larson Coulee (Above the Confluence with Puppy Dog Coulee) Peak Flows Contributory Area = 16.57 sq mi				
Frequency	24-Hr SCS Type II Rainfall Event		10-Day Snowmelt Event	
	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	Existing Peak Flow (cfs)	Future Peak Flow (cfs)
2-Year	319	396	229	225
10-Year	658	812	539	532
25-Year	800	1096	683	674
50-Year	898	1317	789	776
100-Year	1148	1539	932	911

Second Larson Coulee

Existing and future conditions were modeled for Second Larson Coulee considering the land use changes discussed above. The results have been summarized in Table 4.2-11 for the 2-, 10-, 25-, 50- and 100-year rainfall and 10-day snowmelt events at the confluence with Puppy Dog Coulee. Minimal changes in the future land use within the watershed will result in minimal discharge increases in the future. As with First Larson Coulee, the rainfall events produce higher discharges than the snow melt events and will therefore be used for sizing of mitigation options.

Table 4.2-11: Second Larson Coulee Peak Flow Summary

Second Larson Coulee (Above the Confluence with Puppy Dog Coulee) Peak Flows Contributory Area = 16.32 sq mi				
Frequency	24-Hr SCS Type II Rainfall Event		10-Day Snowmelt Event	
	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	Existing Peak Flow (cfs)	Future Peak Flow (cfs)
2-Year	345	356	271	269
10-Year	820	835	655	648
25-Year	1173	1186	883	872
50-Year	1442	1452	1079	1066
100-Year	1706	1711	1265	1250

Puppy Dog Coulee

Existing and future conditions were modeled for Puppy Dog Coulee considering the land use changes discussed above. The results have been summarized in Table 4.2-12 for the 2-, 10-, 25-, 50- and 100-year rainfall and 10-day snowmelt events above the confluence with the Mouse River. Changes in the future land use within the lower watershed will cause the 100-year peak discharge to increase as much as 11% at the confluence with First Larson Coulee, as much as 29% at the confluence the Second Larson Coulee, and as much as 17% at the confluence the Mouse River. In addition, the results indicate that the rainfall events produce higher discharges than the snow melt events and will therefore be used for the sizing of mitigation options. Results have been summarized for various locations along Puppy Dog Coulee within the Appendix.

Table 4.2-12: Puppy Dog Coulee Peak Flow Summary

Puppy Dog Coulee (Above the Confluence with Mouse River) Peak Flows Contributory Area = 52.21 sq mi				
Frequency	24-Hr SCS Type II Rainfall Event		10-Day Snowmelt Event	
	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	Existing Peak Flow (cfs)	Future Peak Flow (cfs)
2-Year	770	1093	654	646
10-Year	1802	2295	1603	1585
25-Year	2590	3153	2177	2155
50-Year	3211	3824	2668	2646
100-Year	3845	4508	3147	3124

REGIONAL DETENTION AND DIVERSION

The results indicate that the peak discharge will increase as the urban development occurs. The City of Minot has in the past, required that each development site maintain pre-development peak discharge conditions. This resulted in many small detention basins constructed on each site. Ownership and maintenance of these small on-site basins has become an issue. No overall planning, interaction, and discharge timing is taken into account as part of the pre-project vs post project analysis. Regional detention areas were therefore examined as part of this study.

The future land use conditions with regional detention scenario accounts for the future growth as described above, but also considers regional stormwater detention facilities and diversion at the several locations within Puppy Dog and First Larson Coulees. Regional detention was considered at the following locations:

- First Larson Coulee at US Highway 83 (South Broadway)
- First Larson Coulee approximately one-half mile west of 16th Street SW, in area currently owned by the State of North Dakota
- Puppy Dog Coulee upstream of 13th Street SE
- Puppy Dog Coulee approximately one-half mile west of 30th Street SW, in area identified as a community park

In addition, the effectiveness of a 400 cfs diversion between Puppy Dog Coulee and First Larson Coulee was examined.

Figure 4.2-4 shows the Puppy Dog, First Larson, and Second Larson Coulees and the proposed regional stormwater detention and diversion locations considered for this study. The purpose of the regional stormwater detention facilities at the above-referenced locations is to reduce peak flow rates during runoff events, considering future development conditions.

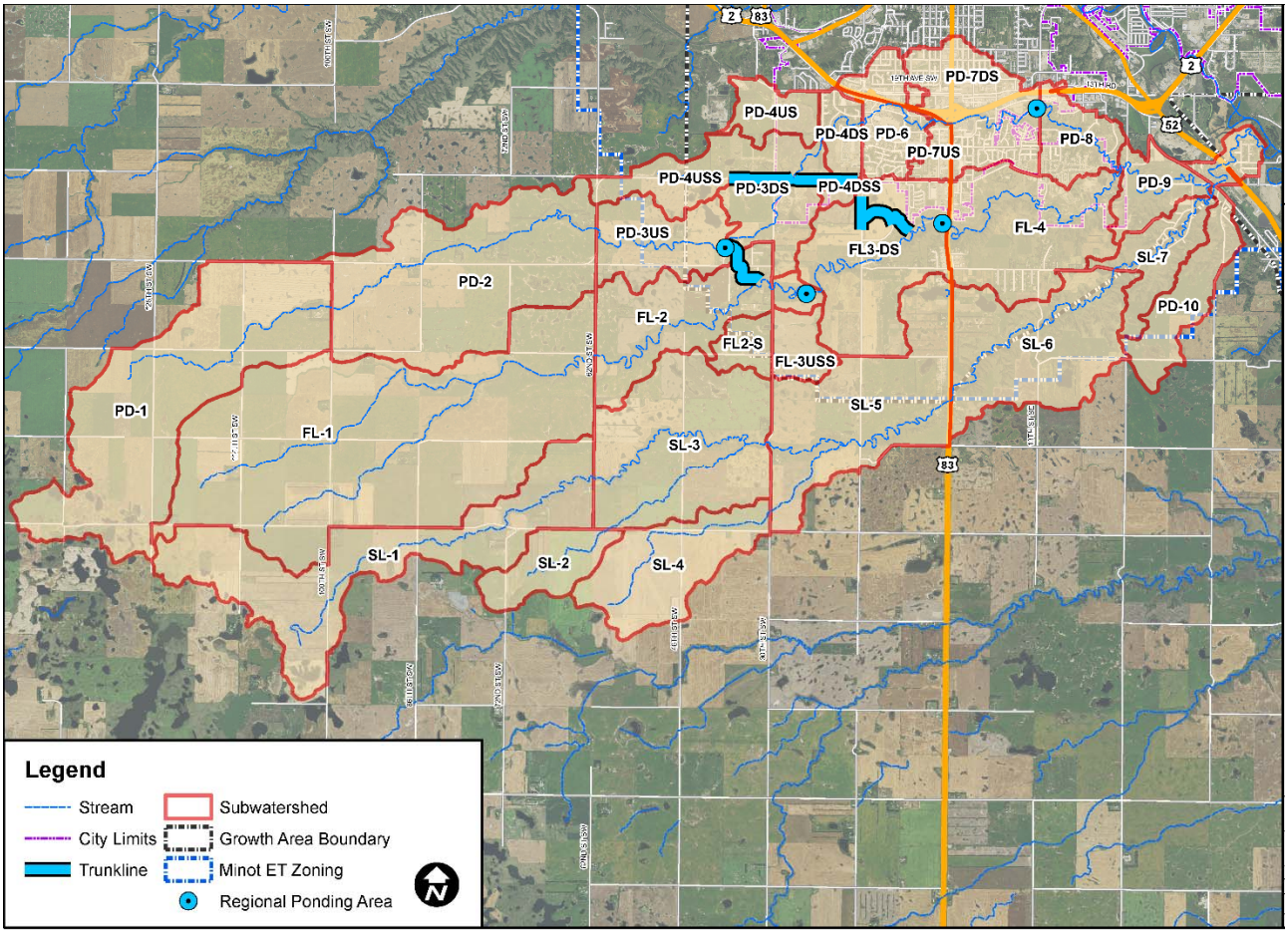


Figure 4.2-4: Proposed Regional Stormwater Detention and Diversion Locations

The effect of the proposed detention / diversion facilities was modeled individually and in various combinations to determine the overall effectiveness of each facility. These combinations are listed in the Table 4.2-13. A more detailed analysis can be found in Appendix 1.

Table 4.2-13: Regional Detention Locations and Effects

Test	Detention Location	Primary Effect
1	First Larson at US Highway 83	Reduces discharge of First Larson downstream of US Highway 83
2	First Larson upstream of 16th Street SW	Reduces discharge on First Larson downstream of 16th Street SW
3	Puppy Dog Coulee upstream of 13th Street SE	Reduces discharge downstream to Souris River.
4	Puppy Dog Coulee ½ Mile upstream of 30th Street SW	Reduces discharge on Puppy Dog Coulee upstream of 37th Avenue SE
5	Puppy Dog Coulee ½ Mile upstream of 30th Street SW; Trunk Line upstream of 30th Street SW from Puppy Dog Coulee to First Larson Coulee.	Reduces discharge on Puppy Dog Coulee upstream of 37th Avenue SE Increases discharge on First Larson Coulee
6	Puppy Dog Coulee ½ Mile upstream of 30th Street SW; Trunk Line upstream of 30th Street SW from Puppy Dog Coulee to First Larson Coulee; First Larson upstream of 16th Street SW	Reduces discharge on Puppy Dog Coulee upstream of 37th Avenue SE; Reduces discharge on First Larson downstream of 16th Street SW
8	Puppy Dog Coulee upstream of 13th Street SE; Puppy Dog Coulee ½ Mile upstream of 30th Street SW; Trunk Line upstream of 30th Street SW from Puppy Dog Coulee to First Larson Coulee; First Larson upstream of 16th Street SW; First Larson at US Highway 83	Reduces discharge on Puppy Dog Coulee upstream of 37th Avenue SE; Reduces discharge on First Larson downstream of 16th Street SW; Reduces discharge on Puppy Dog Coulee from 13th Street SE downstream to Souris River.

If all four detention basins and the bypass trunk line between Puppy Dog Coulee and First Larson Coulee are constructed, the following system changes will occur:

- Discharge on Puppy Dog Coulee between ½ mile upstream of 30th Street SW and 37th Avenue SW will be reduced to at or below existing peak discharge values.
- There will be no reduction of discharge on Puppy Dog Coulee through the Green Acres subdivision or through the Dakota Square Mall area. This peak discharge is a result of local runoff from projected future development. Parcel development north of 37th Street SW will therefore require on-site detention to meet pre-development conditions.
- Discharge on Puppy Dog Coulee from 13th Street SE to the confluence with First Larson Coulee will be reduced to existing conditions for all events except the 2-year storm. The duration of flood events will increase.
- Discharge on Puppy Dog Coulee from the confluence with First Larson Coulee to Second Larson Coulee will be reduced to at or below existing conditions for all events except the 2-year and 10-year storms. The duration of flood events will increase.
- Discharge on Puppy Dog Coulee from the confluence of Second Larson Coulee to the Mouse River will be reduced to existing conditions for the 50-year and 100-year events. The duration of flood events will increase.

- Discharge on First Larson Coulee from 16th Street SW to US Highway 83 will be reduced to existing conditions for all events except the 2-year and 10-year events. The duration of flood events will increase.
- Discharge on First Larson Coulee from US Highway 83 to its confluence with Puppy Dog Coulee will be reduced to existing conditions for all events except the 2-year event. The duration of flood events will increase.

REGIONAL DETENTION DESIGN AND INUNDATION

In order to be effective, the regional detention areas must be quite large. The required embankments will likely be considered dams of medium or high hazard categories. The regional detention facilities will therefore need to be designed in accordance with the North Dakota Dam Design Handbook including meeting the principal spillway criteria (pass the 50-year event) and emergency spillway criteria (pass the 0.5 probable maximum precipitation event). Geotechnical and structural requirements must also be met. In addition, proper operations and maintenance, as well as emergency action requirements, will need to be implemented by the City of Minot.

STORM SEWER TRUNKS

Trunk lines were sized to convey storm water runoff to either regional detention facilities or to major drainageways. As part of the southern major systems study, three trunk lines were sized including:

- Puppy Dog Coulee to First Larson Coulee Bypass Trunk System
- 37th Avenue SW Storm Sewer Trunk System
- 43rd Avenue SW Storm Sewer Trunk System

Puppy Dog Coulee to First Larson Coulee Bypass Trunk

This storm sewer trunk system is intended to convey 400 cfs of discharge from Puppy Dog Coulee to First Larson Coulee to provide flood relief to the urbanized portions of Puppy Dog Coulee. The storm sewer trunk line will consist of 3050 feet of 84-inch storm sewer at approximately 0.5% with a maximum bury depth of 33 feet.

37th Avenue SW Storm Sewer Trunk System

The 37th Avenue SW Storm Sewer is intended to capture discharge for the parcels adjacent to 37th Avenue SW from 16th Street SW to ½ mile west of 30th Street SW and discharge the captured stormwater into Puppy Dog Coulee north of 37th Avenue SW. The trunk line sizes vary from 21-inch to 72-inches in diameter, with bury depths up to 17 feet deep.

43rd Avenue SW Storm Sewer Trunk System

The 43rd Avenue SW Storm Sewer is intended to capture discharge for the parcels adjacent to 16th Street SW south of 37th Avenue SW and parcels adjacent to 43rd Avenue SW and discharge the collected storm water into First Larson Coulee. The intent of this storm sewer is to route as much storm water away from Puppy Dog Coulee as possible to First Larson Coulee, where regional detention is planned. Trunk line size varies from 30-inch to 72-inch, with bury depths as much as 15 feet.

CONCLUSIONS & RECOMMEDATIONS

Puppy Dog Coulee, First Larson Coulee, and Second Larson Coulees, were analyzed to determine the effect of future city expansion. If development occurs without storm water detention, the discharge in each of these coulees will increase, exacerbating existing downstream flooding problems. The Coulees were analyzed with regard to the use of regional detention and installation of storm sewer trunks.

Four regional detention basins were considered including:

- On Puppy Dog Coulee, ½ mile west of 30th Street SW
- On Puppy Dog Coulee, upstream of 13th Street SE
- On First Larson Coulee, west of 16th Street SW
- On First Larson Coulee, west of US Highway 83

To be effective, these regional detention basins are quite large and could be considered medium to high hazard dams by the NDSWC.

In addition, an 84-inch bypass trunk line was analyzed which would convey storm water from Puppy Dog Coulee to First Larson Coulee. This bypass would reduce downstream flooding that would result from the portions of the watershed. The bypass would result in additional flow passing through First Larson Coulee. Mitigation of the additional flood risk on First Larson Coulee resulting from this bypass would be accomplished by regional detention of First Larson west of 16th Street SW.

Examination of the flow hydrographs show that for the 100-year event, indicates that the regional detention upstream of 30th Street SW is not effective in reducing the peak discharge on Puppy Dog Coulee through the Green Acres subdivision or through the Dakota Mall storm sewer system. The peak discharge is a result of local runoff. The current on-site detention policies should remain in force for development located north of 37th Avenue SW.

The regional detention on Puppy Dog Coulee upstream of 13th Street SE is the most effective means of reducing the downstream discharge in Puppy Dog Coulee. This detention basin captures runoff from highly urbanized areas. Raising and rebuilding the 13th Street SE may not be acceptable, since this roadway has recently been rebuilt and the geotechnical stability of the embankment is unknown. This structure would require a substantial emergency spillway which may be difficult to locate due to the existing development. Acceptable alternative sites downstream of 13th Street SE were not located as part of this study but may be preferable.

Regional detention on First Larson Coulee at the locations studied would be simpler due to the substantial valley and less existing development. At these locations, a “dry” detention dam with a primary spillway consisting of a culvert and a grassed emergency spillway could be constructed. Flood discharges up to the 2-year flood could be passed without ponding upstream of the embankments.

4.2.2 Livingston Coulee and Livingston Lakes

INTRODUCTION

Livingston Coulee drains the north and northeast sections of the City of Minot, as well as large undeveloped agricultural areas located to the north and west of the corporate boundary, as shown in Figure 4.2-5. A large portion of the area north and northwest of Minot within the Minot growth area, known as Livingston Lakes, is landlocked and does not currently contribute runoff to Livingston Coulee. Existing development, as well as planned development, has changed, and will continue to change the stormwater runoff rate and volume within the Livingston Coulee and Livingston Lakes watersheds. As part of the current stormwater management plan update, these major systems are being analyzed such that planned development can be incorporated without negatively impacting the existing coulee or landlocked area and exacerbating existing problems.

The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) was used to simulate the hydrology of watersheds contributory to Livingston Coulee. The HEC-HMS model was developed to quantify the stormwater runoff volume and discharge rate at various locations within the respective watersheds under existing land use and future land use conditions, and to size and evaluate the effectiveness of regional detention facilities. The existing conditions for the Livingston Lakes area was modeled using GIS methods to determine non-contributing areas within the land locked watershed.

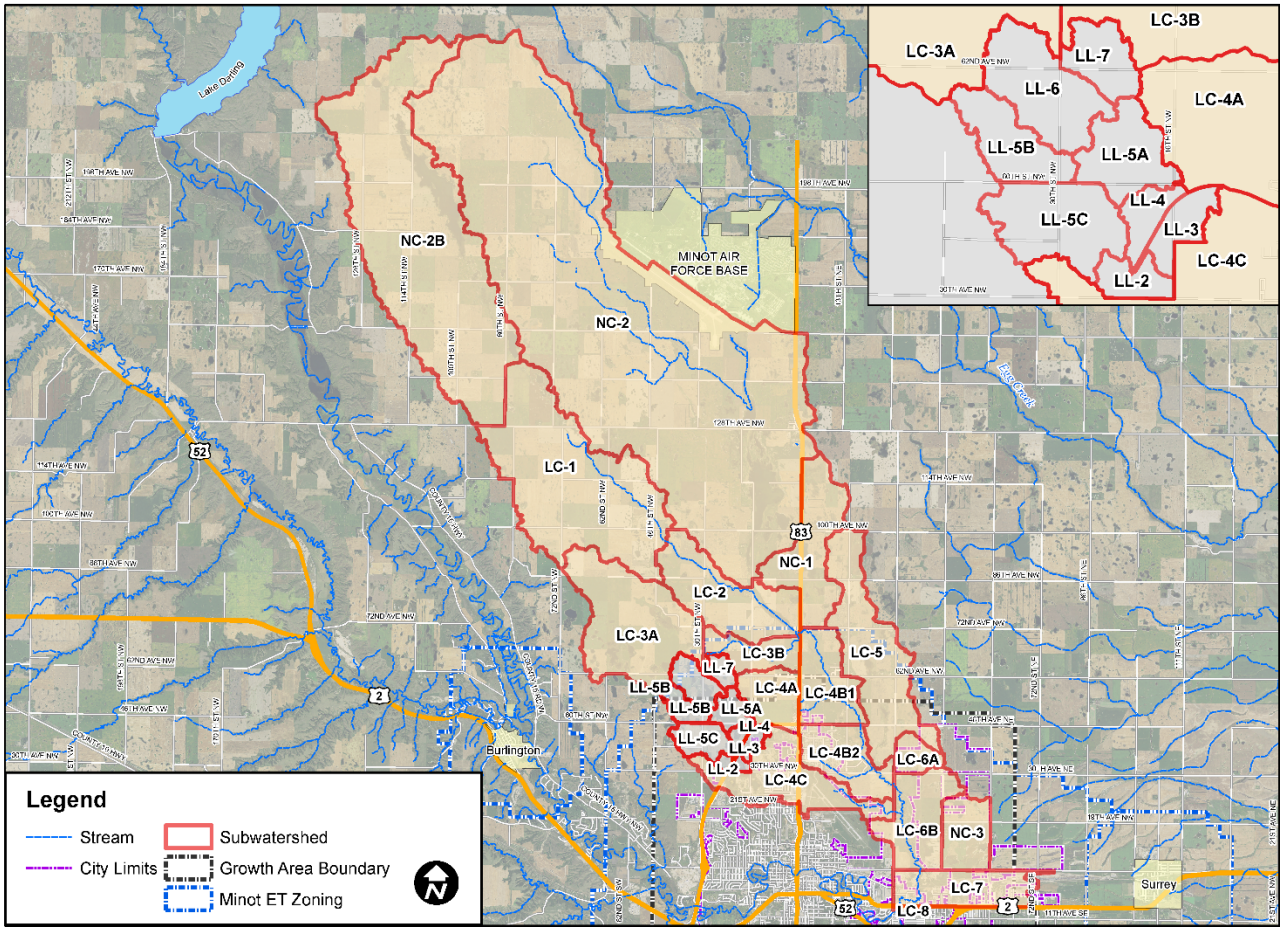


Figure 4.2-5: Livingston Coulee and Livingston Lakes Sub-watersheds

MODELING METHODS

Hydrologic (HEC-HMS) models for Livingston Coulee, based on subbasin delineations (Figure 1), were refined using the 2010 Ward County LiDAR data. Subbasins designated as LC-# contribute directly to Livingston Coulee, subbasins designated as LL-# contribute to the Livingston Lakes area, and subbasins designated as NC-# refer are considered non-contributing / partially contributing. The overall watershed data is shown in Table 4.2-14.

Table 4.2-14: Regional Detention Locations and Effects

Watershed	Area (sq mi)
Livingston Coulee	39.8[a]
Livingston Lakes	3.1
Non-Contributing to Livingston Coulee	58.3
[a] Includes NC-3 which flows both to Livingston Coulee and to Egg Creek	

Examination of the LiDAR and the HUC designations indicates that the non-contributing watersheds NC-2, NC-2B and NC-1 are likely part of the Egg Creek watershed and drain to the north and east. It should be noted, as Livingston Coulee flood waters backup and pond west of US Highway 83, the Livingston Coulee will break out and flow north into SubBasin NC-2 before US Highway 83 is overtopped.

Rainfall and Snowmelt Events

Twenty-four (24)-hour rainfall and 10-day snow melt events were analyzed for this study. Return frequencies considered include the 2-year, 10-year, 25-year, 50-year and 100-year events. The rainfall distribution utilized for this study is the Soil Conservation Service (SCS) Type II over a 24-hour duration. The precipitation totals for the design storms were taken from the NOAA Atlas 14 Point Precipitation Frequency Estimates for the Minot, ND area. The snowmelt event was modeled using the 10-day Principal Spillway Hydrograph published in the North Dakota Hydrology Manual.

Existing and Future Land Use

The headwaters of Livingston Coulee is predominantly agricultural with large portions considered “non-contributing” due to the large areas of wetland storage within the watersheds. As the city boundary is approached, small rural development is more prevalent. Within the city boundary, the land use is mostly residential and commercial/business developments. Existing land use data within the growth area limits were obtained from Stantec, Inc. as part of the 2012 City of Minot Comprehensive Plan (Comp Plan) updates; existing land use data outside of the corporate limits was obtained from the 2006 National Land Cover Data (NLCD) from the Multi- Resolution Land Characteristics (MRLC) Consortium.

The city has delineated a growth area boundary that expands outside of the city boundary. Under future land use conditions, the areas outside of the growth area boundary have the same designated land use as the existing condition. The areas within the growth area boundary, but outside of the city boundary, change from agricultural and meadow to residential and commercial/business developments under future land use conditions. The future land use data within the growth area limits were obtained from the Comp Plan and the land use for areas outside of the corporate limits were based on the 2006 NLCD. The land use category and the existing and future percentages of each land use for Livingston Coulee and the Livingston Lakes area are in Table 4.2-15.

Table 4.2-15: Existing and Future Use for the Livingston Coulee and Livingston Lakes Watersheds

Minot Land Use Category	Common General Land Use Category	Existing Land Use	Future Land Use
Rural / Agricultural	Agricultural	77.64%	65.62%
Rural / Agricultural	Pasture	1.22%	1.22%
Rural / Agricultural	Meadow	4.21%	4.21%
Rural / Agricultural	Woods	0.02%	0.02%
Water / Wetland	Water	6.58%	6.27%
ROW	Road ROW	5.29%	4.49%
Commercial	Commercial/Business	0.26%	1.25%
Industrial	Industrial	0.65%	7.51%
High Density Residential	High Density Residential	0.13%	0.21%
Medium Density Residential	Medium Density Residential	0.44%	2.38%
Low Density Residential	Low Density Residential	1.19%	3.30%
	Very Low Density Residential	-	0.37%
Vacant / Unknown	New Developing	1.40%	2.18%
Parks / Open space	Open Space	0.05%	0.05%
	Barren	0.00%	0.00%
Public / Semi Public	Airport	0.92%	0.92%

MODEL SCENARIOS

Existing Conditions

The existing conditions HEC-HMS model for the Livingston Coulee generate runoff from the sub-basins in each coulee and routes the flow along the coulees to where the flows combine and then discharge into the Mouse River. Hydrograph attenuation due to storage behind the following existing structures was considered:

- 16th Street NW (on un-named tributary)
- 70th Avenue NW (on un-named tributary)
- US Highway 83
- 46th Avenue NE
- Ward County Road 19
- Ward County Road 12
- BNSF Railroad

Future Land Use Conditions

The future land use conditions model scenario accounts for the future growth and development as identified in the City of Minot Comp Plan. The updated Future Land Use Plan includes large areas of residential, commercial, and business developments to accommodate future growth, but also identifies locations for new parks and greenways. These areas are outside of the current city boundary, but are within the identified growth area boundary. Most of these areas are currently undeveloped or open agricultural land.

To represent the future land use conditions, a composite CN for each subbasin was recomputed using the future land use data. In addition, the lag time was recomputed using the updated curve number. Subbasin boundaries were not modified when considering future conditions.

MODEL CONSTRUCTION – EXISTING CONDITIONS

Livingston Lakes Watershed - Existing Conditions

The Livingston Lakes watershed is located to the northwest of the City of Minot. The Livingston Lakes area is land locked and is considered non-contributing to Livingston Coulee and the Mouse River. Only a portion of the Livingston Lakes watershed (subwatershed LL-7) contributes runoff to Livingston Coulee under existing watershed conditions. The area of the Livingston Lakes subbasins are included in Table 4.2-16.

Table 4.2-16: Livingston Lakes Subbasin Areas

Subbasin	Area (square miles)
LL-2	0.205
LL-3	0.241
LL-4	0.200
LL-5A	0.508
LL-5B	0.481
LL-5C	0.754
LL-6	0.743
LL-7	0.340

A noncontributing drainage area analysis for the remaining subwatersheds was conducted to calculate the peak water surface elevations within each wetland for the 100-year 10-day runoff event. Due to infiltration considerations, the 100-year 10-day snowmelt event (3.9 inches) was used for the analysis because this event will generate larger runoff depths than the 100-year 24-hour rainfall (4.6 inches) event. It is assumed that negligible infiltration losses will occur during the snow melt event (frozen ground) while infiltration will occur during the rainfall events.

The seven Livingston Lakes subbasins were subdivided using automated methods based on areas contributory to local depressions. These minor subbasins are shown on Figure 4.2-5.

Runoff volume for each minor subbasin was computed based on the subbasin area and the runoff depth. The depression storage volume below the overflow elevation for each minor subbasin was computed based on the 2010 LiDAR data using GIS methods. If the runoff volume is less than the depression storage volume, the minor subbasin is considered non-contributing. If the runoff volume is greater than the depression storage volume, the excess runoff volume is spilled to the next downstream minor subbasin. This fill and spill process was conducted progressively downstream through successive subbasins. Since the Livingston Lakes watershed is land locked and non-contributing, the maximum water surface elevation for existing conditions were determined for the major storage areas located in Subbasins LL-2, LL-4, LL-5A, and LL-6.

It should be noted that this noncontributing drainage analysis is highly dependent on the initial (starting) water surface elevation. For this study, the initial water surface elevations were based on the 2010 LiDAR data.

Livingston Coulee Watershed – Existing Conditions

Livingston Coulee drains approximately 39.8 square miles of area. The headwaters of Livingston Coulee originate approximately 8 miles north and northwest of the City of Minot. The subbasin delineation areas are shown in Figure 4.2-5.

An additional 58.3 square miles of headwater area that is considered non-contributing was examined to determine if these areas could potentially contribute runoff during prolonged wet periods. The portion of NC-1 east of Highway 83 could potentially be brought into the Livingston Coulee watershed area as development occurs and associated fill and drainage structures are constructed. Subbasins NC-2 and NC-2B have the potential to drain either north and east to Egg Creek or south and east to Livingston Coulee. Examination of the 2010 LiDAR data indicate that during extreme wet periods, Subbasins NC-2 and NC-2B will likely drain north through the Minot Air Force Base and would not breakout to Livingston Coulee.

As a result of the US Highway 83 roadway embankment, floodwater will pond west of US Highway 83. Due to the height of this embankment, the floodwaters will breakout from Livingston Coulee and flow north into the wetlands contained in the non-contributing Subbasin NC-2 before the US Highway 83 embankment is overtopped. This breakout flow will add potential floodwater that could drain north through the Minot Air Force Base.

The 3.1 square mile Livingston Lakes area is currently land locked and non-contributing but will potentially be drained to Livingston Coulee as development occurs. The 1.5 square miles east of 42nd Street and north of County Road 12 (NC-3) contributes little flow to Livingston Coulee since it contains large prairie pothole areas capable of storing runoff. In addition, drainage from this subbasin can flow to both Livingston Coulee and Egg Creek.

The subbasin areas are listed in Table 4.2-17 and Table 4.2-18.

Table 4.2-17: Livingston Coulee Subbasin Areas

Subbasin	Area (square miles)
LC-1	9.273
LC-2	3.556
LC-3A	5.092
LC-3B	1.262
LC-4A	1.376
LC-4B1	2.145
LC-4B2	2.061
LC-4C	3.113
LC-5	4.714
LC-6A	0.631
LC-6B	2.469
LC-7	2.174
LC-8	0.074
LL-7	0.340
NC-3[a]	1.510
[a] Includes NC-3 which flows both to Livingston Coulee and to Egg Creek	

Table 4.2-18: Livingston Coulee Non-Contributing Subbasin Areas

Subbasin	Area (square miles)
LL-2	0.205
LL-3	0.241
LL-4	0.200
LL-5A	0.508
LL-5B	0.481
LL-5C	0.754
LL-6	0.743
NC-1	3.143
NC-2	39.450
NC-2B	15.720

MODEL CONSTRUCTION – FUTURE CONDITIONS

Livingston Coulee – Livingston Lakes – Future Conditions

For existing conditions, as Shown in Figure 4.2-6, Livingston Coulee drains approximately 39.8 square miles of contributing watershed area at its confluence the Mouse River. It should be noted that within the watershed, there is approximately 62.9 square miles of non-contributing / partially contributing area including the headwaters areas to the north and west, the Livingston Lakes area, and portions of the North Dakota Port Services development. For the purpose of this study, it is assumed that in the future, 3.1 square mile Livingston Lakes area will contribute to Livingston Coulee by means of a storm sewer trunk. The 1.5 square mile North Dakota Port Services area north of Ward County Road 12 and east of 42nd Street will likely contribute to Livingston Coulee in the future, but the runoff is expected to be controlled as to not increase downstream peak discharges. The 58.3 square mile headwaters area are assumed to remain non-contributing in the future.

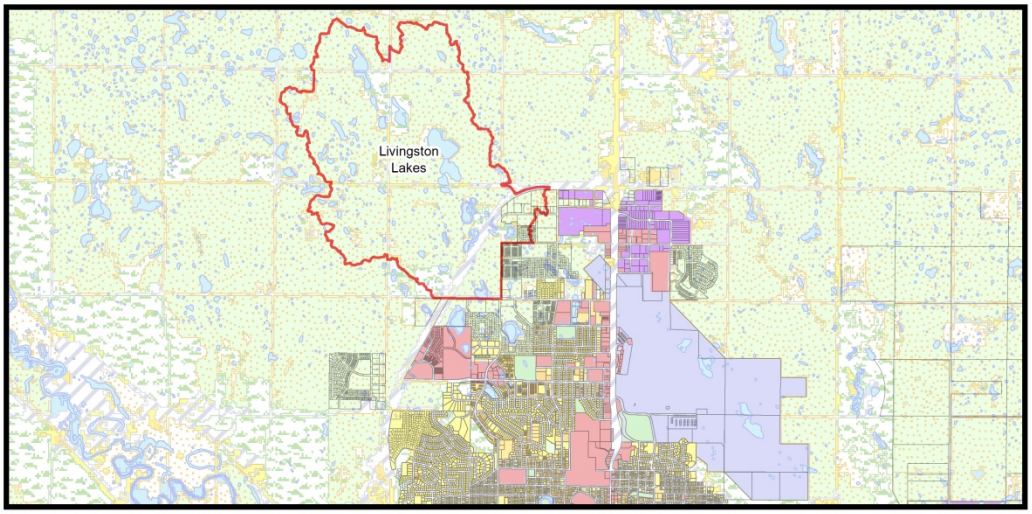


Figure 4.2-6: Livingston Lakes Existing Land Use

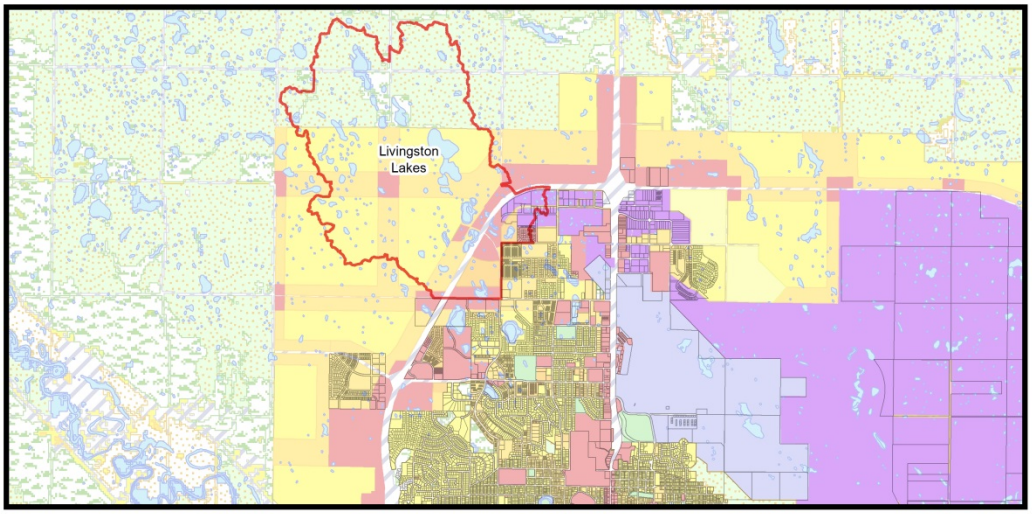


Figure 4.2-7: Livingston Lakes Future Land Use

Under future land use conditions, as Shown in Figure 4.2-7, the land use within the growth area boundary changes from generally agricultural to residential, commercial/business, and industrial developments. The changes in curve number from existing to future conditions for several of the subbasins reflect this land use shift. The curve numbers for existing land use and future land use conditions are shown in Table 4.2-19.

Table 4.2-19: Livingston Coulee / Livingston Lakes Curve Numbers

Existing Conditions Model		**Future Conditions Model**	
Subbasin	CN	Subbasin	CN
LC-1	76.9	LC-1	76.9
LC-2	75.8	LC-2	75.8
LC-3A	78.0	LC-3A	78.0
LC-3B	74.3	LC-3B	74.3
LC-4A	77.5	LC-4A	82.7
LC-4B1	72.6	LC-4B1	77.8
LC-4B2	78.3	LC-4B2	81.9
LC-4C	77.1	LC-4C	80.6
LC-5	77.8	LC-5	79.2
LC-6A	77.9	LC-6A	89.0
LC-6B	71.3	LC-6B	87.6
LC-7	79.8	LC-7	87.9
LC-8	87.7	LC-8	87.6
-	-	LL-2	87.9
-	-	LL-3	89.7
-	-	LL-4	88.5
-	-	LL-5A	81.8
-	-	LL-5B	79.8
-	-	LL-5C	79.0
-	-	LL-6	77.4
LL-7	78.0	LL-7	78.1
NC-1	78.8	NC-1	78.8
NC-2	77.9	NC-2	77.9
NC-2B	78.4	NC-2B	78.4
NC-3	78.4	NC-3	89.1

STORM SEWER TRUNKS

Trunk lines were sized to convey storm water runoff to either regional detention facilities or to major drainage-ways. As the Livingston Lakes area develops, the changes in land use will decrease infiltration and therefore increase runoff during rainfall events. In addition, depressions will likely be filled or graded and drained, thus increasing flood elevations of the major ponding areas shown on Figure 4.2-9. In order to maintain the current flood level, storm sewer trunks will be installed to drain the Livingston Lakes area to Livingston Coulee. Four storm sewer trunks and several additional drainage structures were sized including:

- Storm sewer trunk system from the existing wetland / lake area north of Ward County Road 10 to Livingston Coulee (located in Subbasin LL-5A).

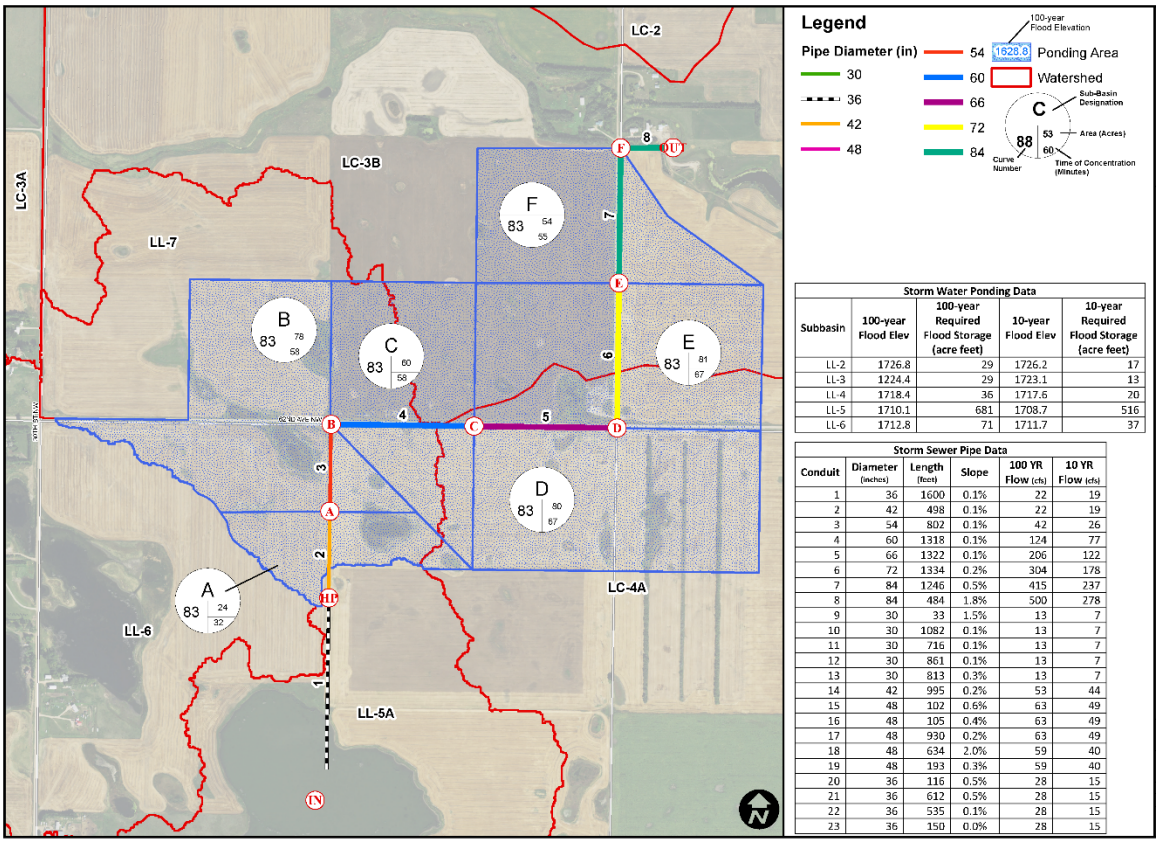
- 30-inch storm sewer trunk outlet from the regional detention adjacent in the northwest quadrant of the intersection of 30th Avenue NW and 16th Street NW (located in Subbasin LL-2).
- 42-inch storm sewer trunk from the existing trunk line the intersection of 36th Avenue NW and 16th Street NW west along the 36th Avenue NW alignment to the US 83 Bypass (located in Subbasin LL-3).
- 36-inch storm sewer trunk outlet from wetland areas southeast of the 62nd Avenue NW and 30th Street NW intersection to the existing wetland / lake area north of Ward County Road 10 (located in Subbasin LL-6).

Additional drainage structures include:

- Upgrade conveyance from east to west through the US highway 83 Bypass (assume 48-inch RCP).
- Control conveyance from between wetlands/detention areas between the US Highway 83 Bypass and Ward County Road 10 (assume 48-inch RCP).
- Upgrade conveyance through Ward County Road 10 (assume 48-inch RCP).

Storm Sewer Trunk Connecting Livingston Lake to Livingston Coulee

For the Livingston Lakes area to develop consistently, the potential flood elevation fluctuations within the Livingston Lakes area must be controlled. The ponding elevations within the Livingston Lakes area have increased within the past few years resulting in the Ward County Highway Department raising roads in the area, including a 12 foot raise of Ward County Road 10. The current overflow elevation is nearly 15 feet above the water surface elevation shown by the 2010 LiDAR, indicating the potential for additional increases in the lake elevations.



Storm Water Ponding Data

Subbasin	100-year Flood Elev	100-year Required Flood Storage (acre feet)	10-year Flood Elev	10-year Required Flood Storage (acre feet)
LL-2	1726.8	29	1726.2	17
LL-3	1224.4	29	1723.1	13
LL-4	1718.4	36	1717.6	20
LL-5	1710.1	681	1708.7	516
LL-6	1712.8	71	1711.7	37

Storm Sewer Pipe Data

Conduit	Diameter (inches)	Length (feet)	Slope	100 YR Flow (cfs)	10 YR Flow (cfs)
1	36	1600	0.1%	22	19
2	42	498	0.1%	22	19
3	54	802	0.1%	42	26
4	60	1318	0.1%	124	77
5	66	1322	0.1%	206	122
6	72	1334	0.2%	304	178
7	84	1246	0.5%	415	237
8	84	484	1.8%	500	278
9	30	33	1.5%	13	7
10	30	1082	0.1%	13	7
11	30	716	0.1%	13	7
12	30	861	0.1%	13	7
13	30	813	0.3%	13	7
14	42	995	0.2%	53	44
15	48	102	0.6%	63	49
16	48	105	0.4%	63	49
17	48	930	0.2%	63	49
18	48	634	2.0%	59	40
19	48	193	0.3%	59	40
20	36	116	0.5%	28	15
21	36	612	0.5%	28	15
22	36	535	0.1%	28	15
23	36	150	0.0%	28	15

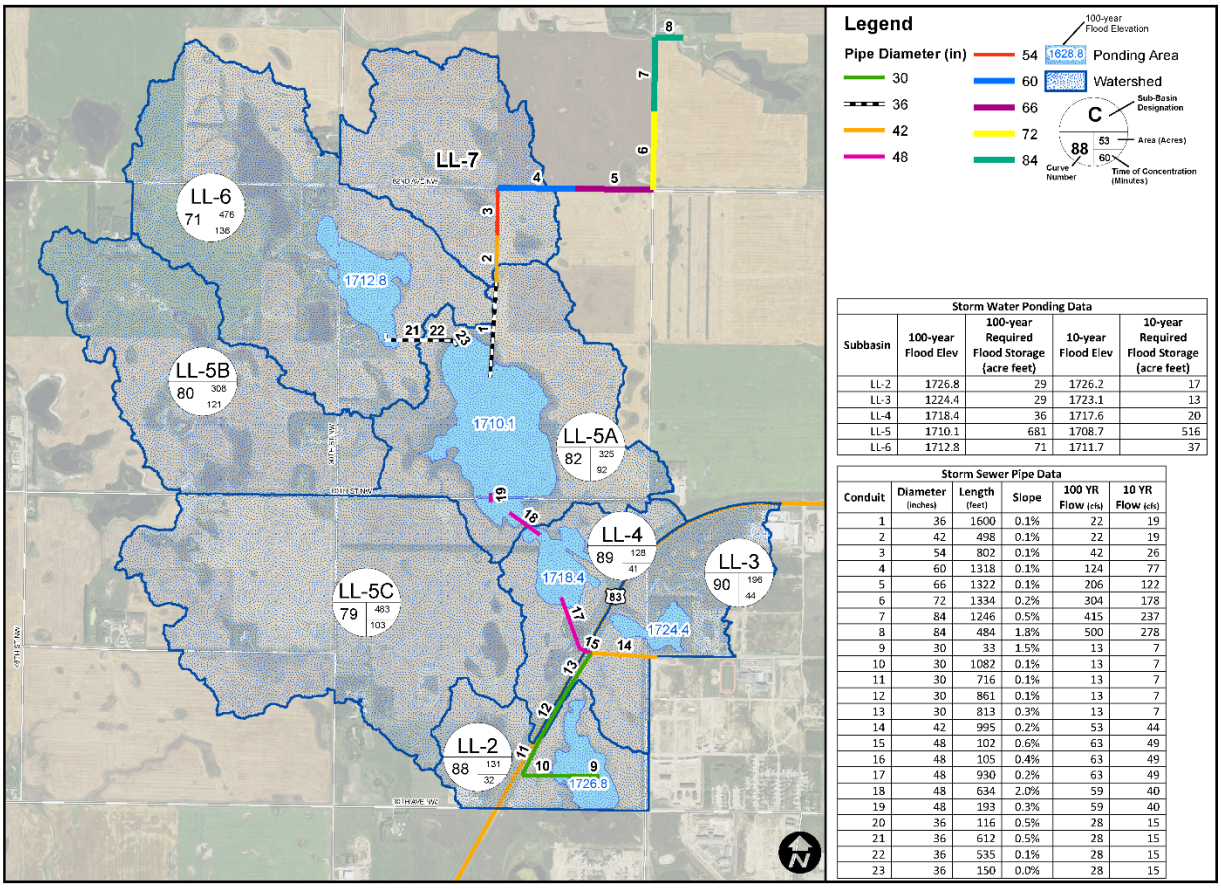
Figure 4.2-8: Livingston Lakes to Livingston Coulee Trunk Line

A storm sewer trunk was sized to mitigate these fluctuations and route excess stormwater to Livingston Coulee. City staff requested this storm sewer trunk be sized as a gravity storm sewer rather than a pumped force main. In addition, City staff requested that this storm sewer trunk be sized to account for future development within subbasin LL-7. Figure 4.2-8 shows the storm sewer trunk layout as well as the assumed additional contributing area. To accommodate the additional flow entering the storm sewer trunk from future development with in subbasin LL-7, the size of the trunk line will vary from 36-inch to 84-inch. To accommodate drainage from the land locked Livingston Lakes area alone, only a 36-inch to 42-inch trunk would be required.

For gravity drainage to be feasible, the bury depth of this of this storm sewer trunk will need to be as much as 30 feet. The feasibility of a pump and force main system was briefly examined. Such a system would require two 5600 gpm pumps and a 1 ½ mile long, 36-inch force main. Per direction from the City, this alternative was not developed further.

Storm Sewer Trunks within the Livingston Lakes System

Figure 4.2-9 shows the layout of all of the Livingston Lakes storm sewers trunks and drainage structures proposed as part of this storm water management plan. In addition, ponding areas within the Livingston Lakes area are shown with the computed peak flood elevation that would occur during the 100-year flood event. The objective of the storm sewer system and ponding areas is to convey storm water to the lowest detention area in the Livingston Lakes area (LL-5A) where it will be discharged to Livingston Coulee via the storm sewer trunk described above.



Storm Water Ponding Data

Subbasin	100-year Flood Elev	100-year Required Flood Storage (acre feet)	10-year Flood Elev	10-year Required Flood Storage (acre feet)
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LL-4	1718.4	36	1717.6	20
LL-5	1710.1	681	1708.7	516
LL-6	1712.8	71	1711.7	37

Storm Sewer Pipe Data

Conduit	Diameter (inches)	Length (feet)	Slope	100 YR Flow (cfs)	10 YR Flow (cfs)
1	36	1600	0.1%	22	19
2	42	498	0.1%	22	19
3	54	802	0.1%	42	26
4	60	1318	0.1%	124	77
5	66	1322	0.1%	206	122
6	72	1334	0.2%	304	178
7	84	1246	0.5%	415	237
8	84	484	1.8%	500	278
9	30	33	1.5%	13	7
10	30	1082	0.1%	13	7
11	30	716	0.1%	13	7
12	30	861	0.1%	13	7
13	30	813	0.3%	13	7
14	42	995	0.2%	53	44
15	48	102	0.6%	63	49
16	48	105	0.4%	63	49
17	48	930	0.2%	63	49
18	48	634	2.0%	59	40
19	48	193	0.3%	59	40
20	36	116	0.5%	28	15
21	36	612	0.5%	28	15
22	36	535	0.1%	28	15
23	36	150	0.0%	28	15

Figure 4.2-9: Trunk Lines within Livingston Lakes

A 30-inch storm sewer trunk would be required to maintain the flood elevation in the ponding area within subbasin LL-2, northwest of the intersection of 30th Avenue NW and 16th Street NW. Also, a 42-inch storm sewer is needed to convey storm water along the 36th Avenue NW alignment, to tie into the potential regional pond and existing storm sewer system. These two systems would flow into a single 48-inch storm sewer pipe under the US 83 Bypass. In addition, a 36-inch storm sewer trunk is necessary to convey storm water from the ponding area within subbasin LL-6 to subbasin LL-5A. This trunk line could be replaced with drainage ditches as part of a final design of the system. Additional drainage features necessary are a 48-inch storm sewer which drains the ponding area within LL-4 and an upgrade of the culvert under Ward County Road 10 to a 48-inch equivalent. The 48-inch storm sewer which drains LL-4 could also be replaced by a drainage ditch and drop structure as part of the final design and site planning of the area.

RESULTS

Livingston Coulee

Existing and future conditions were modeled for Livingston Coulee considering the land use changes discussed above. Other changes that are assumed for future conditions is that the Livingston Lakes storm sewer trunk system and regional detention is in place which will allow controlled discharge from this land locked basin to discharge to Livingston Coulee. The results have been summarized in Table 4.2-20 for the 2-, 10-, 25-, 50- and 100-year rainfall and 10-day snowmelt events on Livingston Coulee upstream of the confluence of the Mouse River. Changes in the future land use within the lower watershed will cause the 100-year peak discharge to increase by as much as 22% at confluence of Livingston Coulee at the Mouse River. In addition, the rainfall events produce higher discharges than the snow melt events and will therefore be used for the sizing of mitigation options. Computed future peak runoff from the snow melt events are slightly smaller than those computed for existing conditions due to hydrograph timing. For this 10-day event, the improved drainage in future conditions will allow runoff from the local watershed to pass downstream before the drainage from the upstream basin arrives at a given location.

Results have been summarized for various locations along Livingston Coulee within the Appendix.

Table 4.2-20: Livingston Coulee Peak Flow Summary

Livingston Coulee (Upstream of Confluence with Mouse River) Peak Flows Existing Contributory Area = 38.34 sq mi Future Contributory Area = 41.47 sq mi				
Frequency	24-Hr SCS Type II Rainfall Event		10-Day Snowmelt Event	
	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	Existing Peak Flow (cfs)	Future Peak Flow (cfs)
2-Year	230	377	230	229
10-Year	579	719	577	574
25-Year	745	925	726	722
50-Year	859	1216	831	823
100-Year	1132	1532	1075	1062

REGIONAL PONDING

The results indicate that the peak discharge will increase as the urban development occurs. The City of Minot has, in the past, required that each development site maintain pre-development peak discharge conditions. This

resulted many small detention basins constructed on each parcel. Ownership and maintenance of these small on-site basins has become an issue. No overall planning or interaction and discharge timing is taken into account as part of the pre-project vs post project analysis. Regional detention areas were therefore examined as part of this study.

The future land use conditions with regional ponding scenario, accounts for the future growth as described above, but also considers regional stormwater detention facilities and diversion at several locations within the Livingston Lakes and Livingston Coulee watershed areas. Regional detention areas are intended to use existing wetland and pothole areas or existing detention upstream of roadway embankments. Regional detention was considered in the Livingston Lakes area as part of the "future conditions" modeling. These regional detention locations are shown in Figure 4.2-9 and listed below:

- Northwest quadrant of 30th Avenue NW and 16th Street NW
- Northwest quadrant of 36th Avenue NW and 16th Street NW
- East of the US Highway 83 Bypass
- North of Ward County Road 10
- Southeast quadrant of 62nd Avenue NW and 30th Street NW

The regional detention on Livingston Coulee will consist of raising roads to eliminate any flow over the roadways and to force discharge up to and including the 100-year event through the existing or proposed culverts. Regional detention is also considered on Livingston Coulee at:

- Upstream of 46th Avenue NE. Regional detention will be obtained by blocking/removing the existing 48-inch and 54x88-inch culverts and installing a 30-inch culvert as the detention basin outlet. In addition, the roadway will be raised an additional 6 feet to elevation 1624 to prevent overflow of the embankment.
- Upstream of County Road 12 (4th Street NE). Regional detention will be obtained by raising the roadway an additional 5 feet to elevation 1594. Existing twin 72-inch culverts will remain in place.

The regional detention will reduce the 100-year discharge immediately downstream of the detention basins to the current rates, but not to the discharge rates reported in the 2002 *City of Minot FIS, Flood Insurance Study Report.*

Table 4.2-21: Regional Detention Locations and Effects

Test	Detention Location	Primary Effect
1	Northwest quadrant of 30th Avenue NW and 16th Street NW	Reduces size of required storm sewer trunk
2	Northwest quadrant of 36th Avenue NW and 16th Street NW	Reduces size of required storm sewer trunk
3	East of Highway 83 Bypass	Reduces size of required storm sewer trunk
4	North of County Road 10	Reduces size of required storm sewer trunk
5	Southeast quadrant of 62nd Avenue NW and 30th Street NW	Reduces size of required storm sewer trunk
6	Upstream of 46th Avenue NE	Reduces effect of upstream land use changes
7	Upstream of County Road 12	Reduces effect of upstream land use changes

REGIONAL DETENTION DESIGN AND INUNDATION

In order to be effective, the regional detention areas must be quite large. The required embankments that will be constructed at 46th Avenue NE and at County Road 12 may be considered dams of medium or high hazard categories. The regional detention facilities would therefore need to be designed in accordance with the *North Dakota Dam Design Handbook,* including meeting the principal and emergency spillway criteria. Geotechnical and structural requirements must also be met. In addition, proper operations and maintenance, as well as emergency action requirements, will need to be implemented by the City of Minot.

Inundation mapping and 100-year flood elevations along Livingston Coulee are included in the Appendix. The mapping shows inundation resulting from storm water ponding upstream of the road crossings at County Road 12, County Road 19, 46th Street NE, and US Highway 83.

In addition, Figure 4.2-13 mapping shows regional detention in the Livingston Lakes area. These regional detention areas incorporate existing depressions and wetlands. The storm sewer trunk lines are required to control the peak flood elevation to those elevations shown Figure 4.2-13.

RESULTS AND DISCUSSION

In order to compare the effectiveness of regional detention, the HEC-HMS model was modified to take into account regional detention. Results at the confluence with the Mouse River are shown in Table 4.2-22. Results at several additional locations are shown in the Appendix. Since the regional detention basins consist of road raises that leave the existing low flow structures in place, the detention basins are more effective attenuating the large, less frequent flood events.

It should be noted, that the discharges listed in the tables are downstream of roadways that act as controls. The peak discharge value upstream of these roadways is larger.

Table 4.2-22: Livingston Coulee Peak Flows

Livingston Coulee (At Confluence with Mouse River) Peak Flows					
Frequency	24-Hr SCS Type II Rainfall Event				
	Existing Peak Flow (cfs)	Future Peak Flow (cfs)	Future Peak Flow (All Detention) (cfs)	Future Peak Flow (46th Avenue NE Detention) (cfs)	Future peak (Ward CR 12 Detention) (cfs)
2-Year	230	377	377	377	377
10-Year	579	719	706	706	719
25-Year	745	925	925	925	925
50-Year	859	1216	1097	1119	1097
100-Year	1132	1532	1272	1464	1272

If the two regional detention basins, as well as the storm sewer trunks and additional drainage features are installed, the following system changes will occur:

- Peak 100-year ponding elevations in the Livingston Lakes area will be controlled to the elevations shown on Figure 4.2-9.
- Peak discharge in Livingston Coulee will increase from US Highway 83 to 46th Avenue NE.
- Peak discharge downstream of 46th Avenue NE will decrease to below existing conditions.

- Peak discharge downstream of County Road 19 will decrease for all return frequencies tested except the 2-year event.
- Peak discharge downstream of County Road 12 will decrease for the 50-year and 100-year event by not allowing overflow of the highway.
- Peak discharge upstream of the confluence with the Mouse River will increase (approximately 11%) due to land use changes between the regional detention at County Road 12 and the confluence with the Mouse River.

CONCLUSIONS & RECOMMENDATIONS

Existing and future conditions for the Livingston Coulee and the Livingston Lakes area were studied. The effects of storm sewer trunks and regional detention were considered.

The proposed storm sewer trunks and regional detention within the Livingston Lakes area will effectively control the flood elevations within this land locked basin to predictable levels. There will be a substantial volume of storm water that may be discharged into Livingston Coulee if the proposed storm sewer trunk is constructed. The peak discharge from the Livingston Lakes area is controlled with a peak discharge of approximately 30 cfs. This may act as a "base flow" within Livingston Coulee and the Livingston Coulee tributary after storm events.

The regional detention basins on Livingston Coulee could be constructed by road raises while generally leaving the existing culverts in place. The culverts at 46th Street, however, would be replaced or modified to limit the discharge. The regional detention is less effective in controlling the peak discharges within Livingston Coulee. The regional detention will effectively reduce the peak discharge immediately downstream of the detention basins during rare, large events (100-year, 50-year). The peak discharge will then increase downstream of the detention areas due to the changes in land use. The detention basins will have little effect with regard to reducing the peak discharge from frequent events (2-year event).

In addition, breakout flow from Livingston Coulee will occur approximately 1 mile east of US Highway 83. This breakout flow will discharge to large wetland areas (in excess of 1000 acres) to the north. For ordinary events, this area is considered non-contributing. During periods of high rainfall, it is possible that the storage capacity of these wetlands may be filled resulting in breakout flow onto the Minot Air Force Base. As a result of the land use and Livingston Lakes to Livingston Coulee storm sewer trunk, an additional 5 acre-feet of storm water (less than 0.1% of total) may be discharged to the north during the 100-year event. Due to the large volume of storage available, the peak flood elevation should not increase when comparing proposed conditions to existing conditons.

It is recommended that the City of Minot construct storm sewer trunks and preserve natural regional detention capacity within the Livingston Lakes area. It is further recommended that the City construct regional detention by implementing road raises along Livingston Coulee at 46th Avenue NE and County Road 12. The outlet culverts would be modified at 46th Avenue NE while the existing drainage structures at County Road 12 would remain in place. Since these regional detention basins do not fully mitigate the effects of future land use changes, it is recommended that the City implement restrictive floodplain management within areas that will be inundated by the 100-year event, such as requiring compensatory storage and adequate conveyance capacity.

4.3 Minor Systems Analysis

The City of Minot identified eight (8) problem areas that Ackerman-Estvold evaluated. These areas include both highly developed residential areas within the heart of the city and rural areas at the edge of the city that are poised to be developed within the next few years (See Location of Minor Systems Watershed). Each problem area is considered a "minor system" within the City of Minot Storm Water Design Standards Manual (SWDSM).

Below is a list of the minor systems that were evaluated.

1. Polaris Park
2. 4th Avenue Northwest at 8th Street
3. 11th Avenue Southwest, from 6th Street to Broadway
4. 16th Street Southwest, from 11th Avenue to 16th Avenue*
5. Southwest Knolls, Phase II Subdivision*
6. 18th Avenue Southwest, from 10th Street to Broadway
7. 10th Street Southwest, from 31st Avenue to 37th Avenue
8. 37th Avenue South at Main Street

* Due to proximity and hydrologic/hydraulic connectivity of the systems, the 16th Street SW and Southwest Knolls systems were analyzed as a single system.

A hydrologic and hydraulic model of the existing conditions was created for each area. In conjunction with conversations with City of Minot staff, these stormwater models were used to understand the source of the problem. Potential solutions were then identified and the models were used as the basis for analyzing potential solutions. Alternative solutions were considered for each problem area and presented to City staff through regular project meetings in 2013. During these conversations, alternatives were discarded due to a variety of reasons (e.g. maintenance access issues, constructability issues, public palatability issues, etc.) The proposed improvements provided within this report are the preferred solutions identified by the City during these project meetings.

The following summarizes each of the minor system's existing conditions, existing deficiencies, modeling methods, and proposed improvements. The full memorandums for each system with detailed calculations and larger figures can be found in the Appendix.

4.3.1 Polaris Park

Introduction

This memorandum documents the findings of an analysis of the watershed known as the Polaris Park drainage basin. The analysis was directed by the City of Minot as part of the Minot Stormwater Management Plan Project. The Polaris Park drainage basin was identified as a known problem area within the scope of work. Business owners have complained about frequent roadway flooding along the North Broadway Frontage Road (Frontage Road), along the west side of US Highway 83 (the Highway) between 24th Ave NW and 30th Ave NW. The extent and depth of flooding severely limits vehicular traffic use of the Frontage Road and frequently threatens the southbound lanes of the Highway.

At the request of the City of Minot, the proposed pipe design, open channel conveyance capacity improvements, and cost estimate have incorporated the design of a temporary measure to alleviate the most severe instances of flooding along the Frontage Road.

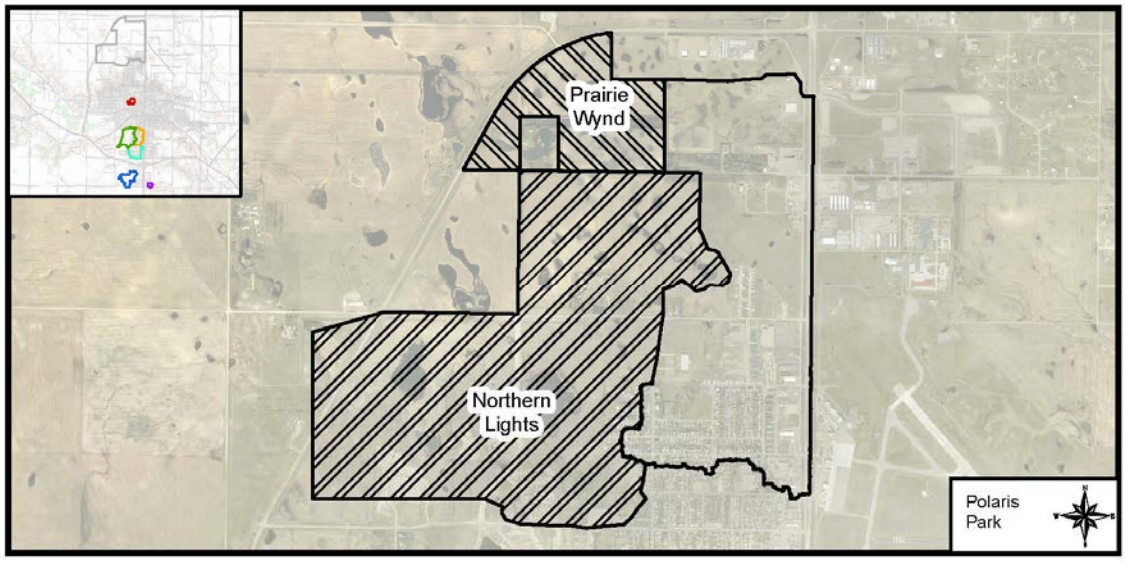

Figure 4.3-2: Polaris Park Drainage Basin

General Location and Description

The overall watershed which drains to the problem area extends from 24th Ave NW to 42nd Ave NW and from 8th St NW to the northbound lanes of the Highway (See Figure 4.3-2). The total watershed area encompasses approximately 425 acres of residential, business, and public use properties. Within the total watershed, a series of sub-watersheds have been delineated by the various development projects currently underway. These projects include the Prairie Wynd and Northern Lights Developments. Stormwater runoff within each of these developments is captured within natural and man-made drainage facilities (swales, ditches, inlets, pipe networks, and ponding areas) which attenuate the developed peak flow rate to existing levels. Excluding the Prairie Wynd and Northern Lights developments, the contributing drainage basin is 153 acres. All drainage within the watershed is transmitted via overland flow over public and private property, within the street right-of-way, and partially through a disjointed pipe conveyance system eastwards to the Highway roadside ditch between the Frontage Road and the southbound lanes of the Highway. Drainage within the Highway roadside ditch is transmitted via culverts and open channel conveyance to an existing 24" Reinforced Concrete Pipe (RCP) culvert under the Highway to the Minot International Airport property. Within the airport property, a series of culverts and open channels transmits the concentrated stormwater flows eastwards to a natural drainage channel along 30th Ave NE, which ultimately discharges into Livingston Coulee, approximately 800 feet upstream

of the 30th Ave NE and Livingston Coulee crossing. The existing infrastructure was installed by a combination of various projects, including the North Dakota Department of Transportation (NDDOT) upgrade of the Highway from 2 lanes to 4 lanes, the City of Minot project to install the 48″ RCP along 30th Ave on airport property, and various individual commercial/residential site improvements.

The land use within the watershed is 1/4-acre residential lots, high density residential and commercial along the south portion of the watershed and along the Highway corridor. The remainder of the watershed is currently open space used for pasture or meadow. A large section of land within the north portion of the watershed will remain undeveloped due to the restrictions on the property by the Minot International Airport.

Existing Conditions

During rain events within the southern developed portion of the basin, the majority of runoff enters street right-of-way via overland flow through lawns, driveways, and parking lots. In the street right-of-way, the stormwater is then conveyed by the curb and gutter system to one of two locations. Existing inlets capture stormwater runoff and transmit it to an existing detention pond/wetland area south of 30th Ave NW. An 18" outfall from this pond zigzags between existing apartment buildings towards the east, ultimately discharging into the Highway roadside ditch. The stormwater runoff not conveyed to the existing inlets is transmitted by the curb and gutter system directly into the Highway roadside ditch.

During rain events within the northern, undeveloped portion of the basin, the majority of runoff enters the Highway roadside swale via overland flow through ill-defined drainage ways and pocket wetlands. Based upon discussions with the City, it was assumed that the stormwater infrastructure upstream of the problem areas was correctly sized and does not require analysis, therefore only the drainage system downstream of the problem was modeled as part of this effort.

Once within the Highway roadside ditch, drainage from the northern, undeveloped areas and southern, developed areas travel within the roadside ditch to the lowest point. The roadside ditch acts as a detention pond before discharging into a 24" RCP under the southbound lanes of the Highway. Based upon conversations with the NDDOT and As-Builts, the 24" RCP culvert daylights briefly between the north and southbound lanes of the Highway, before continuing under the northbound lanes of the Highway to the eastern roadside ditch. After the runoff is discharged under the Highway, an open channel conveys stormwater onto Minot International Airport property. Once on airport property, the stormwater is conveyed under a chain-link fence and an access road culvert. This culvert is estimated to be an 18" CMP based upon field reconnaissance. Upon exiting the access road culvert, the stormwater is conveyed by a 700 foot long open channel before entering a 36" RCP before crossing airport property (specifically the runway emergency extension).

Photo **4.3-1: Highway 83 Roadside Ditch**

This 36″ RCP wyes into an east/west 48" RCP along the 30th Ave corridor within airport property. The 48″ RCP then daylights into an open channel. This channel runs along the south side of 30th Ave NE for approximately 1,000 feet before entering a natural drainage way. This natural drainage way is flowing south/southeast across a field before turning to the north/northeast towards Livingston Coulee.

As a complication to the Polaris Park drainage conveyed through the existing east/west 48" RCP along the 30th Ave corridor, the Northern Lights Development Drainage utilizes this pipe for its ultimate drainage outfall from the large pond located on Block 7. The Northern Lights Development Drainage discharges stormwater through a closed pipe system running along 27th Ave NW, the Frontage Road, and under the Highway to the existing 48" RCP on airport property. This closed system bypasses the Polaris Park drainage facilities located west of the Highway.

A single watershed was delineated for the problem area. Once the watershed boundary was refined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model. Calculations regarding these input variables are available in the Appendix. Table 4.3-2 below lists the XP-SWMM resultant peak flows for the problem area.

Polaris Park XP-SWMM Model Results at the 24" RCP (cfs)					
2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
18.0	57.8	94.5	135.4	188.5	235.1

Table 4.3-2: XP-SWMM Modeled Peak Flow

Since the Highway is a state-owned, the culverts within the Highway right-of-way must meet the 25-year Stream Crossing Standards as noted within Article 89-14 of the ND Administrative Code. The maximum allowable headwater over a 24" pipe is 48" above the upstream pipe invert. The existing headwater elevation of the 25-year event was determined to be nearly 8 feet above the upstream pipe invert. This model indicates that during the 24-year event the road will be overtopped by approximately 2-inches of water. An additional culvert will be required to provide additional conveyance capacity under the Highway to meet the 25-year Stream Crossing Standards. The improvements associated with this additional culvert will be discussed further in the Proposed Conditions section.

Upon entering airport property, the 18" CMP under the airport access road further restricts the flow capacity of the drainage system. The headwater elevation above the access road culvert was determined to be approximately 4 feet above the upstream pipe invert. During the 25-year event, the access road will be overtopped by approximately 3 inches of water. This road is on private property, and therefore is not required to meet a minimum design standard.

The open channel between the Highway right-or-way and the 36" RCP inlet on airport property was determined to have a full flow capacity of 489 cfs. With the existing 24" pipe restricting flows under the Highway and the existing 18" pipe further restricting flows under the airport access drive, the open channel between the access drive and the 36" RCP inlet on airport property adequately conveys the 25 year event. This area is on private property, and therefore is not required to meet a minimum design standard. However, if the culvert capacity under the Highway is increased to meet the minimum 25-year Stream Crossing Standards, the existing open channel has the capacity to adequately convey the increased flows.

The 36" RCP inlet on airport property was analyzed to determine if the existing infrastructure was adequately sized to handle the peak discharge rate from the Polaris Park drainage basin. Review of the LiDAR information indicated that ponding in excess of 3 feet above the pipe invert will be diverted into the airport's internal drainage system to the south. It was found that during the 25-year event, the flow will be almost evenly split between the 36-inch RCP and the overflow to the south. This area is private property, and therefore is not required to meet a minimum design standard. In order to prevent this breakout flow from entering the airport's internal drainage system, this inlet will need to be increased. The improvements associated with increasing this private inlet will be discussed further in the Proposed Conditions section.

The open channels downstream of the existing 48" RCP were reviewed to verify that the expected flow from the Northern Lights Project and the Polaris Park Drainage Basin are adequately conveyed through the existing natural drainage way. This natural drainage way ultimately discharges into Livingston Coulee. Calculations show that the drainage way is capable of carrying almost twice the discharge rate as what is currently leaving the Northern Lights Project and the Polaris Park Drainage Basin.

Finally, two downstream channel crossings (24" CMP and 36" RCP) were noted as undersized based upon field reconnaissance and the upstream pipe sizes. The improvements associated with increasing these channel crossings will be discussed further in the Proposed Conditions section.

Proposed Conditions

A series of upgrades to the existing stormwater conveyance system are being proposed for this project (See Figure 4.3-3). There are four proposed improvements to the drainage system known as the Polaris Park Project. First, the existing crossing under the Highway does not meet the 25-year Stream Crossing Standard which will require a capacity increase either by replacing the existing culvert with a larger diameter pipe or supplementing the existing 24" RCP with an additional culvert under the Highway. Second, the existing 36" RCP inlet on airport property limits the functionality of the downstream pipe system and therefore needs to be increased. To prevent this overflow the inlet needs to be replaced with a large diameter inlet/pipe connection to the existing 48" RCP. Finally, two downstream channel crossings (a farm access point and 30th Ave NE) need to be replaced with larger pipes to meet the 25-year Stream Crossing Standards.

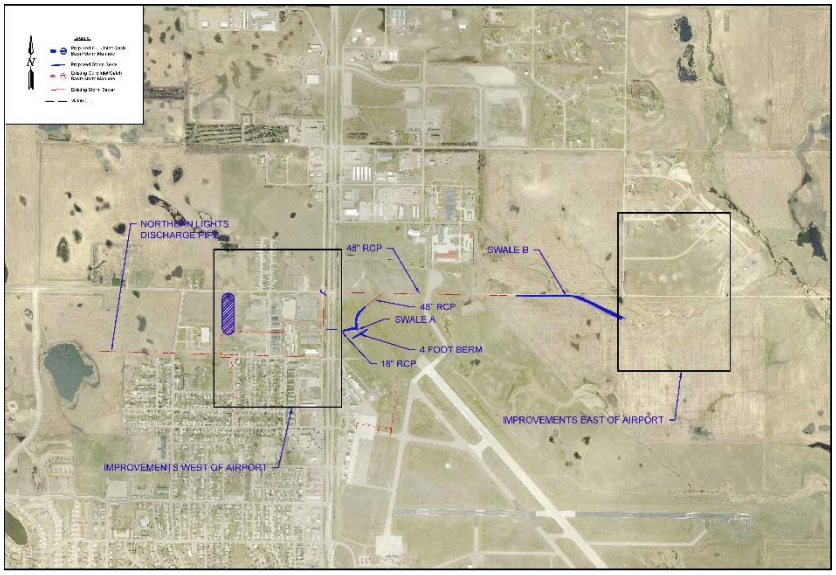

Figure **4.3-3: Polaris Drainage Proposed Improvements**

In addition, per discussions with the City, the stretch of roadway along 30th Ave NW west of the Highway is expected to be improved in the near future. The scope of this project was expanded to include a planning level design of curb inlets at the intersection of 30th Ave NW and the Frontage Road with the sole purpose of providing a stormwater collection point for the future upgrade of 30th Ave NW to an urban section.

Replacing the existing 24" RCP culvert under the Highway was deemed unfeasible due to the required traffic interruption during construction. It was determined during conversations with the City that placing an additional culvert parallel to the existing via jack and bore methods was preferred. Even though the northern portion of the watershed is currently rural in nature, it was also decided that the design of the proposed conditions improvements would not take into account future land development improvements to the drainage basin. These future land development improvements will be required to incorporate detention on-site that will attenuate the developed peak flow rate to existing levels. With an added 42" RCP under the Highway, the water ponds up within the roadside ditch between the Frontage Road and the southbound lanes of the Highway to a height of 4.9 feet above the invert. It should be noted that with the additional 42" RCP in place, the roadway will be overtopped by one (1) inch of water during the 100-year storm. The roadside ditch between the Frontage Road and the southbound lanes of the Highway act as a detention pond and the modeling effort associated with this project reflected this function.

If in the future, the Highway is urbanized, this detention functionality will be eliminated. It is recommended that off-line detention is incorporated into an expansion of the existing pond located approximately 700 feet west of the intersection of 5th St NW and 30th Ave NW. It is further recommended that the volume of off-line detention created is equal to or greater than the volume of detention eliminated during the urbanization of the Highway.

Figure **4.3-4: Polaris Drainage Proposed Improvements**

The existing 36" RCP inlet within airport property was shown to be undersized in the existing conditions analysis. Replacing this with a 48" RCP inlet and was shown to adequately capture the stormwater runoff if the breakout is prevented to an elevation approximately 5 feet above the invert of the pipe. This would require the construction of a 2-foot high berm across the break out point. It should be noted that during the 100-year event, water is expected to exceed 8.7 feet above the pipe invert and a 6 foot berm would be necessary to completely prevent the breakout to the airport's internal drainage system to the south.

The farm access road culvert and the 30th Ave NE culvert sizes downstream of the airport were determined using the 25-year Stream Crossing Standards. These proposed culverts are 48" and 54" RCP respectively.

Recommendations and Conclusion

As indicated in the Proposed Improvements section of this memorandum, by installing a new storm system with correctly sized connection pipes the surface runoff is collected and transmitted easterly under US Highway 83 (North Broadway), where it makes its way to Livingston Coulee. The recommended additions have been shown to meet the current City of Minot Design Criteria for residential streets. The proposed improvements meet or exceed the requirements set forth in the Minot Storm Water Design Standards Manual.

4.3.2 4th Avenue NW and 8th Street

Introduction

The 4th Ave NW, between 7th St NW to 10th St NW drainage basin, as shown in Figure 4.3-5 was identified as a known problem area within the scope of work. Residents have complained about frequent roadway flooding along the 4th Ave corridor. The extent and depth of flooding severely limits vehicular traffic use of 4th St NW and frequently floods the homes immediately north of the 4th Ave NW and 8th St NW intersection.

General Location and Description

The overall watershed drains to 4th Ave NW, with the portion of the basin north of 4th Ave NW sloping south to 4th Ave NW and the portion of the basin south of 4th Ave NW sloping north to 4th Ave NW. In addition, the overall watershed is relatively flat with the entire road and all inlets approximately level with each other. The existing infrastructure was originally built in the 1930's and is made up of vitrified clay pipe and brick inlets.

Figure 4.3-5: 4th Avenue NW Drainage Basin

The watershed draining to the subject area encompasses approximately 19 acres of residential and public use properties. The watershed extends from 6th Ave NW on the north to 3rd Ave NW on the south and from 10th St NW on the west to 7th St NW on the east.

Existing Conditions

During rain events, the majority of runoff enters street right-of-way via overland flow through residential lawns. In the street right-of-way, the stormwater is then conveyed by the street curb and gutter system to existing inlets. Per the As-Builts provided by the City of Minot and field verification, each inlet is connected to an outfall into the Mouse River immediately west of the intersection of 10th St NW and 4th Ave NW. The connecting pipes are vitrified clay with sizes ranging from 8" to 12" in diameter.

One watershed was delineated for each existing curb inlet using LiDAR information provided by the City and accounts for road crowns, existing storm sewer infrastructure, field verification, and engineering judgment. Once these watersheds were defined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model. The peak flow rates from the XP-SWMM model at each inlet was found to be well below the inlet capacity for each inlet. It was determined that the connecting vitrified clay pipes were undersized for the peak flow rates and volume of water needed to be transported to the Mouse River.

Proposed Conditions

A completely new stormwater sewer system has been proposed for this project, as shown in Figure 4.3-6. The existing inlet locations have been used as the locations for the proposed inlets. At the request of the City of Minot, two additional inlets have been placed immediately north of the northernmost existing inlets along 8th St NW.

Figure 4.3-6: Proposed Improvements

Recommendations and Conclusion

As indicated in the Proposed Improvements section, by replacing the existing storm system with correctly sized connection pipes the surface runoff will be captured and transmitted to the Mouse River before it becomes a nuisance. The recommended additions have been shown to meet the current City of Minot Design Criteria for residential streets. The propose improvements meet or exceed the requirements set forth in the Minot Storm Water Design Standards Manual.

4.3.3 11th Avenue SW, 6th Street to Broadway

Introduction

The 11th Ave SW drainage basin, as shown in Figure 4.3-7 was identified as a known problem area within the scope of work. Residents have complained about frequent roadway flooding along 11th Ave SW between the intersection of 6th Street SW and 11th Ave SW and immediately west of the intersection of S Broadway St and 11th Ave SW. The extent and depth of flooding severely limits vehicular traffic use of 11th Ave SW between the two intersections. Up to one (1) foot of standing water is not uncommon to see at low points within the intersection of 6th Street SW and 11th Ave SW and immediately west of the intersection of S Broadway St and 11th Ave SW.

General Location and Description

The overall watershed drains to 11th Ave SW, with the portion of the basin north of 11th Ave SW sloping south to 11th Ave SW and the portion of the basin south of 11th Ave SW sloping north to 11th Ave SE. In addition, the overall watershed slopes easterly to S Broadway St, with the highest point of the watershed along southwestern border and the lowest point of the watershed at six curb inlets located west of the S Broadway St and 11th Ave SW intersection.

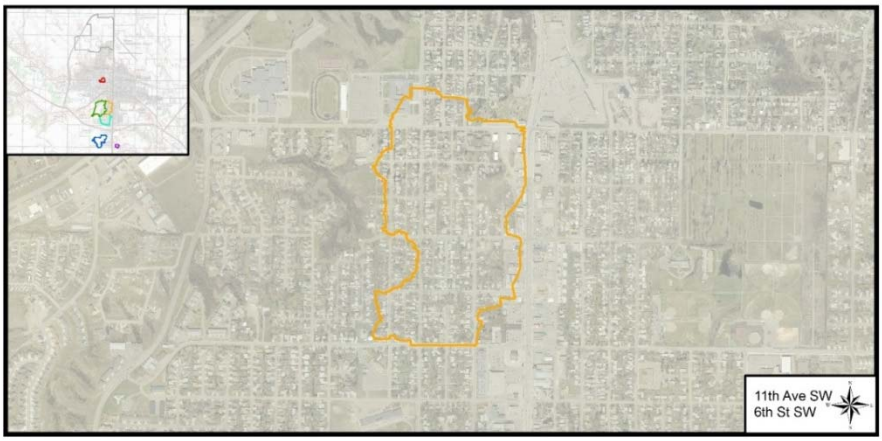

Figure **4.3-7: 11th Avenue SW Drainage Basin**

The watershed draining to the subject area encompasses approximately 98 acres of residential, commercial/industrial and public use properties. The watershed extends from 10th Ave SW on the north to 16th Ave SW on the south and from 7th St SW on the west to S Broadway commercial district on the east.

Existing Conditions

During rain events, the majority of runoff enters street right-of-way via overland flow through lawns, driveways, and parking lots. In the street right-of-way, the stormwater is then conveyed by the curb and gutter system to the eight (8) existing inlets within the 11th Ave SW right-of-way. Each of the inlets was identified on As-Builts provided by the City of Minot and field verified for type and sizing information.

Also per the As-Builts provided by the City of Minot and field verification, each inlet is connected to the storm sewer system located within S Broadway which conveys stormwater north through downtown Minot, with an ultimate outfall into the Mouse (Souris) River. Based upon discussions with the City and a few quick calculations, it was assumed that the stormwater infrastructure along S Broadway is adequately sized to convey runoff to the Mouse (Souris) River and therefore was not fully modeled as part of this effort.

One watershed was delineated for each existing curb inlet. Once these watersheds were refined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model. Calculations regarding these input variables and the XP-SWMM resultant peak flows for each curb inlet are available in the Technical Memorandums in the Appendix.

Utilizing the peak flow rates from the XP-SWMM model, FlowMaster was used to determine the depth of flow at the street gutter and crown as well as the extent of gutter spread. FlowMaster Analysis Reports are available in the Technical Memorandums in the Appendix.

Proposed Conditions

Additional inlets located upstream of the intersection of S Broadway and 11th Ave SW have been proposed to remove stormwater runoff from the street gutter system and convey the peak flows to the existing S Broadway sewer system via an underground storm sewer system. Additional inlets are proposed at the intersections of 11th Ave SW and 5th St SW, 11th Ave SW and 6th St SW, 12th Ave SW and 5th St SW, 13th Ave SW and 4th St SW, 13th Ave SW and 5th St SW, 13th Ave SW and 6th St SW, 14th Ave SW and 4th Ave SW, and 14th Ave SW and 6th St SW as well as mid-block along 6th St SW between 13th Ave SW and 14th Ave SW and 12th Ave SW between 3rd St SW platted Right-of-Way and 4th St SW (See Figure 4.3-8).

Each intersection and mid-block location is designed to contain at least two (2) inlets, one on each side of the street. The drainage basin contributing to each proposed inlet was first delineated using ArcHydro and then refined in a similar manner as the existing drainage basins noted above. The existing inlets located east of the S Broadway and 11th Ave SW intersection are to remain in place and will capture a smaller portion of their existing watersheds. The limits of the watersheds were used to determine the necessary input variables used in an XP-SWMM hydrological model.

Figure **4.3-8: Proposed Improvements**

Calculations regarding the proposed conditions input variables, the XP-SWMM resultant peak flows for each proposed curb inlet and the four existing curb inlets, the gutter spread and depth of flow at the street gutter and crown for the proposed improvements, determined by FlowMaster, and the calculated gutter spread and water depth at the gutter and the street crown are available in the Technical Memorandums in the Appendix. At the request of the City of Minot, four additional inlets have been placed between the intersections of 6th St SW and 13th Ave SW and 6th St SW and 14th Ave SE. These inlets are not necessary to be installed to meet the current City of Minot Design Criteria, therefore the individual drainage basin calculations and the gutter spread and depth of flow at the street gutter and crown have not been provided for these inlets.

Recommendations and Conclusion

As indicated in the Proposed Improvements section of this memorandum, by placing additional inlets upstream of the existing inlets along 11th Ave SW, the existing storm system captures the surface runoff before it becomes a nuisance. The recommended additions have been shown to meet the current City of Minot Design Criteria for residential streets. The propose improvements meet or exceed the requirements set forth in the Minot Storm Water Design Standards Manual.

4.3.4 16th Street SW, 11th Avenue to 16th Avenue & Southwest Knolls, Phase II

Introduction

This memorandum documents the findings of an analysis of the watershed southeast of 16th St SW and 11th Ave SW intersection (16th St and SW Knolls). The analysis was directed by the City of Minot as part of the Minot Stormwater Management Plan Project. The 16th St and SW Knolls drainage basin was identified as a known problem area within the scope of work. Residents have complained about frequent roadway flooding along all of the road corridors within the drainage basin. The extent and depth of flooding severely limits vehicular traffic use of 10th St SW, 12th St SW, 13th St SW, 12th Ave SW and 11 ½ Ave SW.

In the original scope of work, the City of Minot identified two separate minor systems (16th St SW between 11th Ave to 16th Ave and Southwest Knolls, Phase II). Due to the interconnected nature of the existing storm sewer infrastructure draining these systems, the City of Minot approved the combination of these two minor systems into one summary report, stormwater model, improvement district and opinion of probable cost.

General Location and Description

The overall watershed drains to the intersection of 11th Ave SW and 16th St SW, with the majority of the basin sloping north towards an unnamed natural drainage way located approximately 500 feet south of 11th Ave SW. At various points throughout the watershed, storm sewer infrastructure has been placed to capture and manage runoff from the impervious surfaces.

The watershed draining to the subject area encompasses approximately 175 acres of residential (townhomes and ¼ acre lots), commercial, open space, and public use properties. The watershed extends from 11th Ave SW on the north to 16th Ave SW on the south and from 16th St SW on the west to 7th St SW on the east.

The land use within the watershed is considered 1/4-acre residential lots, high density residential (townhomes), commercial, and open space at various locations throughout the entire watershed. The area along 11th Ave SW is commercial, while the townhomes are located near the intersection of 16th St SW and 16th Ave SW.

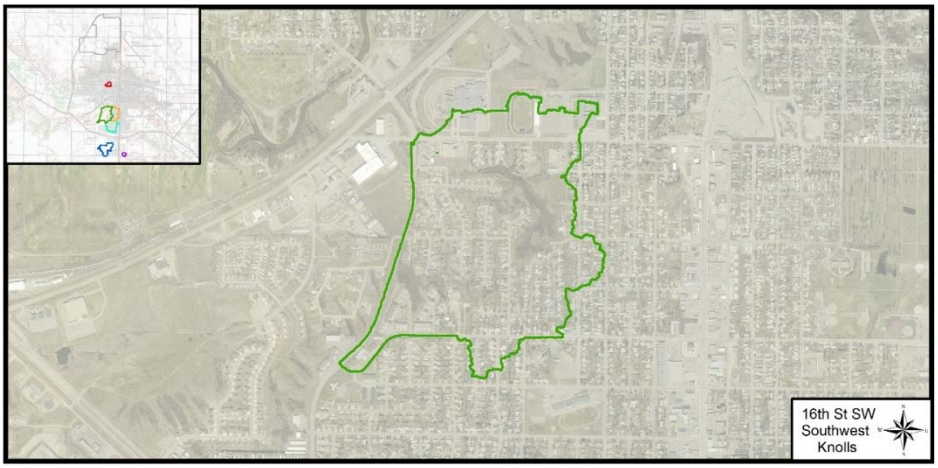

Figure **4.3-9: 16th Street SW/SW Knolls Drainage Basin**

Existing Conditions

During rain events, the majority of runoff enters street right-of-way via overland flow through residential lawns, driveways, and parking lots. In the street right-of-way, the stormwater is then conveyed by the curb and gutter system to several (30) existing inlets. There are four (4) individual systems of inlets within the watershed.

First, at the intersection of 16th St SW and 11th Ave SW, a series of inlets capture street runoff and direct the discharge into an existing stormwater pond located immediately southwest of the intersection of 16th St SW and 11th Ave SW and a storm sewer system along 11th Ave SW transferring runoff towards the Mouse (Souris) River.

Second, at the intersection of 14th Ave SW and 10th St SW, a series of six (6) inlets capture runoff and direct the discharge to a half-pipe flume immediately east of the intersection. This flume empties stormwater into the natural drainage way that ultimately enters the previously noted storm system.

Third, a series of five (5) inlets, located at the intersection of 16th St SW and 14th Ave SW, capture roadway drainage and discharge runoff to a conveyance channel running along undeveloped property west of 16th St SW. This conveyance channel directs stormwater into the existing stormwater pond located immediately southwest of the intersection of 16th St SW and 11th Ave SW.

Finally, near the intersection of 16th St SW and 16th Ave SW, six (6) inlets capture roadway drainage and an end section that captures drainage collected within a natural drainage way. The discharge point of this system has been modified from the original design by the City of Minot to a 12" pipe discharging runoff into a natural drainage way that exits the overall 16th St SW and SW Knolls drainage system.

All four existing storm sewer infrastructure systems are interconnected by the street layout/slopes and the effects of bypass flows transferring between the four systems. Stormwater flows that exceed the inlet capacities are accounted for as bypass flows entering the drainage basin of the inlet immediately downstream (regardless of which storm sewer system the bypassed inlet is located). These bypass flows were modeled as part of this effort to understand the impacts to downstream inlets on insufficient infrastructure upstream.

One watershed was delineated for each existing curb inlet. Once these watersheds were refined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model. Calculations regarding these input variables and the XP-SWMM resultant peak flows for each curb inlet can be found in the Appendix.

Utilizing the peak flow rates from the XP-SWMM model, FlowMaster was used to determine the depth of flow at the street gutter and crown as well as the extent of gutter spread. This gutter spread doesn't account for the bypass flows passing by the existing infrastructure upstream. FlowMaster Analysis Reports and calculated gutter spread and water depth at the gutter and the street crown for existing conditions are available in the Appendix.

Proposed Conditions

Additional inlets located south and southeast of the intersection of 16th St SW and 11th Ave SW have been proposed to remove stormwater runoff from the street gutter system and convey the peak flows to the existing systems via an underground storm sewer system. In addition, the configuration of the proposed storm sewer system will physically connect the four existing systems. The proposed inlet locations were chosen based upon the upstream corners of the existing road intersections, areas within the watershed that do not currently meet the City of Minot's Stormwater Design Standards Manual (SWDSM), and at the direction of the City of Minot Staff. Additional inlets are proposed at the intersections of 12th St SW and 11 ½ Ave SW, 12th St SW and 14th Ave SW, 11th St SW and 14th Ave SW, 12th St SW and 12th Ave SW, as well as mid-block along 16th St SW, 12th St SW, and 14th Ave SW. Expansion of the existing pond located at the Southwest corner of the intersection of 16th St SW and 11th Ave SW will provide a space for the peak flows from the 16th St SW and SW Knolls drainage basins to attenuate, eliminating the need to increase the size of the storm sewer system downstream to the Mouse (Souris) River outfall. Also, to reduce the impact to the existing infrastructure along 16th St SW, immediately south of the intersection of 16th St SW and 11th Ave SW, a new outfall into the expanded pond is proposed. Finally, to increase the capture efficient of the existing inlets, it is recommended that the inlets at the intersection of 13th St SW and 12th Ave SW are replaced with larger structures.

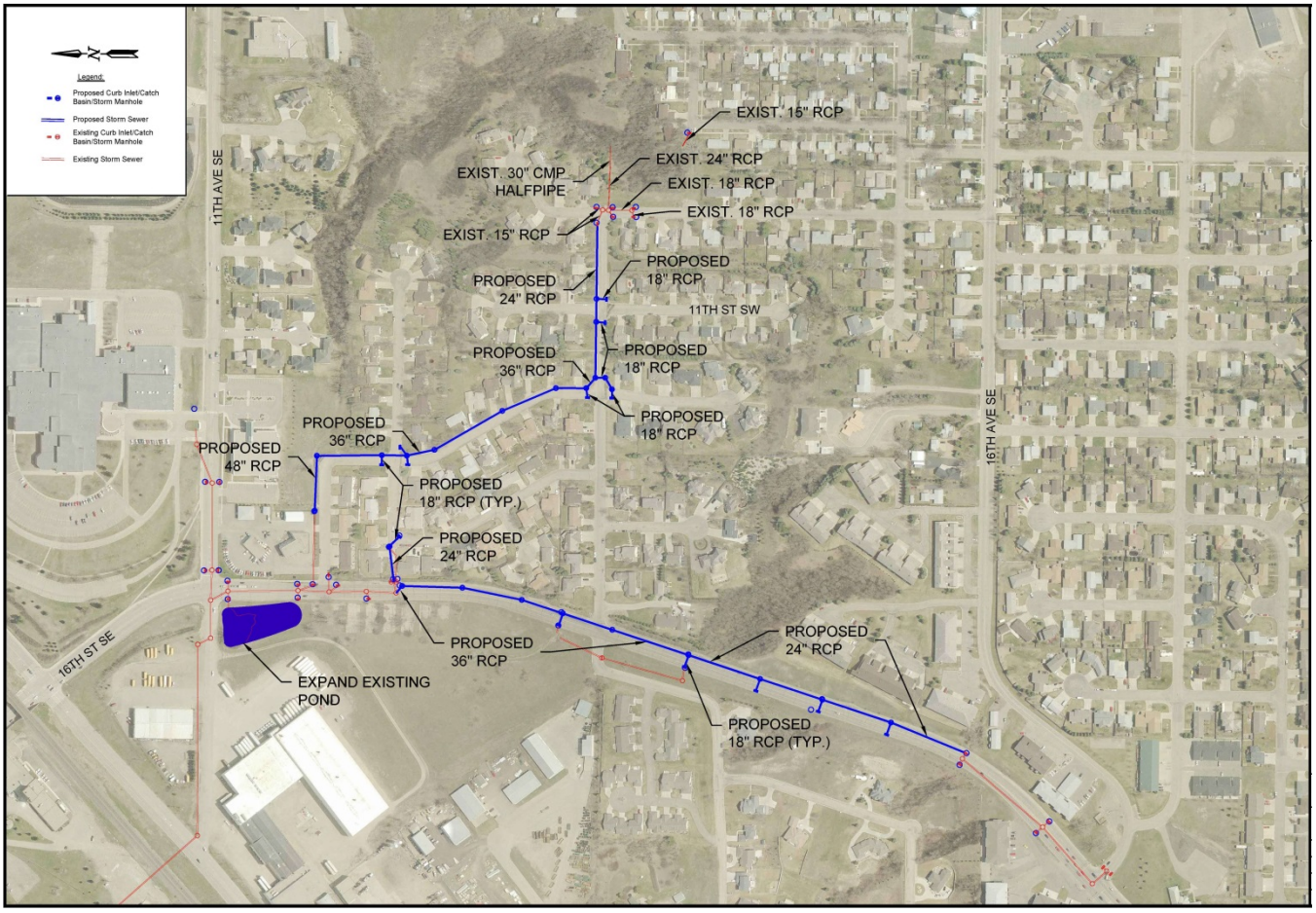

Figure **4.3-10: Proposed Improvements**

The drainage basin contributing to each proposed intersection was first delineated using ArcHydro. The GIS-generated watersheds were imported into AutoCAD and refined to account for road crowns, existing storm sewer infrastructure, field verification, and engineering judgment. Once these watersheds were refined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model. Calculations regarding the proposed conditions input variables and the XP-SWMM resultant peak flows for each curb inlet are available in the Appendix.

Utilizing the peak flow rates from the XP-SWMM model, FlowMaster was used to determine the depth of flow at the street gutter and crown as well as the extent of gutter spread. FlowMaster Analysis Reports and calculated gutter spread and water depth at the gutter and the street crown are available in the Appendix.

Recommendations and Conclusion

As indicated in the Proposed Improvements section of this memorandum, by placing additional inlets to connect the existing four (4) separate storm systems and improving the conveyance capabilities of the existing facilities, the surface runoff will be captured before it becomes a nuisance. The recommended additions have been shown to meet the current City of Minot Design Criteria for residential streets. The proposed improvements meet or exceed the requirements set forth in the Minot Storm Water Design Standards Manual.

4.3.5 18th Avenue Southwest, from 10th Street to Broadway

Introduction

The 18th Ave SW, between 10th St SW and S Broadway St drainage basin was identified as a known problem area within the scope of work. Residents and business owners have complained about frequent roadway flooding along 18th Ave SW between Edison Elementary and the intersection of 18th Ave SW and S Broadway St. The extent and depth of flooding severely limits vehicular traffic use of 18th Ave SW and 4th St SW. Up to two (2) feet of standing water is not uncommon to see along 18th Ave SW at the intersection.

General Location and Description

The overall watershed drains to 18th Ave SW, with the portion of the basin north of 18th Ave SW sloping south to 18th Ave SW and the portion of the basin south of 18th Ave SW sloping north to 18th Ave SW. In addition, the overall watershed slopes easterly, with the highest point of the watershed along the western border and the lowest point of the watershed at four curb inlets located east of the 18th Ave SW and 4th St SW intersection (See Figure A). Properties of note within the watershed include Our Lady of Grace Catholic Church at 707 16th Ave SW and Edison Elementary School at 701 17th Ave SW.

Figure **4.3-11: 18th Ave SW Drainage Basin**

The watershed draining to the subject area encompasses approximately 138 acres of residential, commercial/industrial and public use properties. The watershed extends from 16th Ave SW on the north to the commercial district along 20th Ave SW on the south and from 10th St SW on the west to the S Broadway St commercial district on the east.

Existing Conditions

During rain events, the majority of runoff enters street right-of-way via overland flow through residential lawns. In the street right-of-way, the stormwater is then conveyed by the street curb and gutter system to four existing curb inlets. Two of the existing curb inlets are located approximately 160 feet east of the 18th Ave SW and 4th St SW intersection. Per the As-Builts provided by the City of Minot and field verification, each curb inlet is a double catch basin consisting of two Type-2 Double inlets (NDDOT Standard D-722-2). The two other curb inlets are located approximately 180 feet west of the 18th Ave SW and S Broadway St intersection. Per the As-Builts provided by the City of Minot and field verification, each curb inlet is a triple catch basin consisting of two Type-2 Double inlets (NDDOT Standard D-722-2). Each inlet is connected to a storm manhole in the eastern driving lane of 18th Ave SW with 10" leads. These inlets are located in the uppermost reaches of Storm Sewer District No. 95. The ultimate outfall of this storm sewer system into Puppy Dog Coulee is located south of the US Highway 2& 52 Bypass and immediately east of 6th St SE. Based upon discussions with the City, it was assumed that the stormwater infrastructure within Storm Sewer District No. 95 is adequately sized to convey runoff to Puppy Dog Coulee and therefore was not fully modeled as part of this effort.

One watershed was delineated for each existing curb inlet. Once these watersheds were refined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model.

Calculations regarding these input variables are available in the Appendix. The below table lists the XP-SWMM resultant peak flows for each curb inlet.

XP-SWMM Modeled Peak Flow Rates Existing Conditions (cfs)				
Rain Event	Basin Name			
	Ex-18thAveNorthA	Ex-18thAveSouthA	Ex-18thAveNorthB	Ex-18thAveSouthB
2-yr 24hr	4.6	2.8	4.2	4.2
5-yr 24hr	14.4	9.8	6.9	7.0
10-yr 24hr	23.2	16.0	8.8	9.0
50-yr 24hr	45.0	32.0	13.2	13.5
100-yr 24hr	55.8	39.9	15.1	15.5

Table 4.3-3: XP-SWMM Modeled Peak Flow Rates – Existing Conditions

The streets within this watershed are considered Local Streets in the City of Minot Comprehensive Plan. Based upon this classification, these streets must contain the minor storm events contained within the street, with no curb overtopping and the flow can spread to the crown of the street. During a 100-year storm event, the inundation area cannot exceed the street right-of-way and the depth of the water above the street crown cannot exceed 6 inches, whichever is less. At locations where gutter flow crosses the street at intersections or at a point mid-block, the design storm runoff cannot exceed 6-inches of depth at the crown or in the cross pan and the 100-year design storm runoff cannot exceed 9-inches of depth at the crown or in the cross pan.

Utilizing the peak flow rates from the XP-SWMM model, FlowMaster was used to determine the depth of flow at the street gutter and crown as well as the extent of gutter spread. FlowMaster Analysis Reports are available in the Appendix.

Proposed Conditions

Additional inlets located upstream of the intersection of 18th Ave SW and 4th St SW have been proposed to remove stormwater runoff from the street gutter system and convey the peak flows to the existing Storm Sewer District No. 95 system via an underground storm sewer system. Additional inlets are proposed at the intersections of 18th Ave SW and 5th St SW, 18th Ave SW and 6th St SW, 18th Ave SW and 7th St SW, 18th Ave SW and 8th St SW, 17th Ave SW and 4th St SW, and 17th Ave SW and 6th St SW (See Figure 4.3-12).

Each intersection is designed to contain two (2) inlets, one on each side of the street. The drainage basin contributing to each proposed inlet was first delineated using ArcHydro and then refined in a similar manner as the existing drainage basins noted above. The existing inlets located east of the 18th Ave SW and 4th St SW intersection are to remain in place and will capture a smaller portion of their existing watersheds. The limits of the watersheds were used to determine the necessary input variables used in an XP-SWMM hydrological model. Calculations regarding the proposed conditions input variables are available in the Appendix. The XP-SWMM resultant peak flows for each proposed curb inlet and the four existing curb inlets is also available in the Appendix.

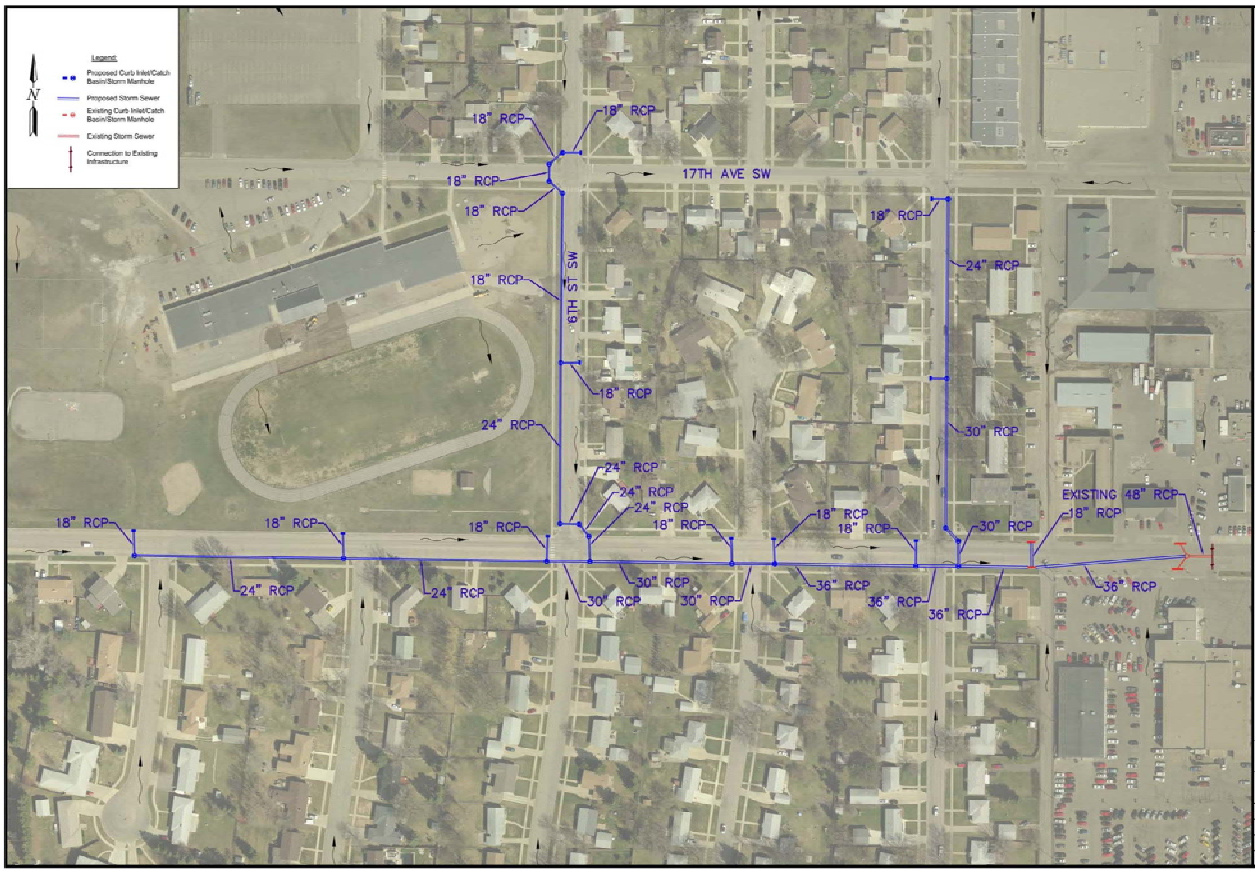

Figure 4.3-12: Proposed Improvements

The gutter spread and depth of flow at the street gutter and crown for the proposed improvements was determined by FlowMaster and is available in the Appendix. The calculated gutter spread and water depth at the gutter and the street crown is available in the Appendix.

In addition to the installation of the additional inlets and manhole/storm sewer connections, it is also recommended that the existing 10" lateral pipes from the existing inlets approximately 160 feet east of the intersection of at 18th Ave SW and 4th St SW be replaced with 18" RCP lateral pipes. The replacement of these lateral pipes includes the replacement of the existing storm manhole connecting these laterals to the storm sewer system.

Recommendations and Conclusion

As indicated in the Proposed Improvements section of this memorandum, by placing additional inlets upstream of the existing inlets at 18th Ave SW and 4th St SW, the existing storm system captures the surface runoff before it becomes a nuisance. The recommended additions have been shown to meet the current City of Minot Design Criteria for residential streets. The propose improvements meet or exceed the requirements set forth in the Minot Storm Water Design Standards Manual.

4.3.6 10th Street SW, 31st Avenue to 37th Avenue

Introduction

The 10th St SW drainage basin was identified as a known problem area within the scope of work. Residents have complained about frequent roadway flooding along 10th St SW south of the intersection of 31st Ave SW and 10th St SW, as well as within the 31st Ave SW and 10th St SW and the 31st Ave SW and 7th St SW intersections. The extent and depth of flooding severely limits vehicular traffic use of 10th St SW south of the 31st Ave SW and 10th St SW intersection to 35th Ave SW, 31st Ave SW between 10th St SW and 7th St SW and the intersections of 31st Ave SW and 10th St SW and 31st Ave SW and 7th St SW.

At the request of the City of Minot, the proposed pipe design and cost estimate has incorporated the improvement of the 10th St SW road corridor immediately south of the 31st Ave SW and 10th St SW intersection to include a standard curb and gutter system as well as a drain tile system where none is currently present.

General Location and Description

The overall watershed, as shown in Figure 4.3-12, drains northwards to Thompson Lake along Puppy Dog Coulee immediately north of the intersection of 28th Ave SW and 7th St SW. Drainage south of 31st Ave SW within the subject watershed is transmitted via overland flow over public and private property and within the street right-of-way northwards to the extensive stormwater inlet system along 31st Ave SW. The stormwater runoff west of 10th St SW drains easterly to the 10th St SW right-of-way. The stormwater runoff east of 10th St SW is split evenly between west, north, and easterly directions. Drainage flows via overland flow westerly to the 10th St SW right-of-way, northerly to the 31st Ave SW right-of-way, and easterly to the 7th St SW right-of-way. The drainage system within 31st Ave SW captures stormwater runoff and transmits it via an underground pipe system from the intersection of 31st Ave SW and 14th St SW westerly along 31st Ave SW to the intersection of 31st Ave SW and 7th St SW. The pipe system then turns north along 7th St SW to Thompson Lake. The existing infrastructure was originally built in the early 1990's when the NDDOT upgraded the 31st Ave SW corridor (NDDOT Project Number: SU-4-989(020)020) and is made up of standard Type I and Type II inlets, manholes, 44" x 27" reinforced concrete arch and 18" to 36" reinforced concrete pipe.

Figure 4.3-12: 10th Street SW Drainage Basin

The watershed draining to the subject area encompasses approximately 115 acres of residential, business, and public use properties. The watershed extends from 28th Ave SW on the north to 37th Ave SW on the south and from 14th St SW on the west to 6th St SW on the east.

Existing Conditions

During rain events, the majority of runoff enters street right-of-way via overland flow through lawns, driveways, and parking lots. In the street right-of-way, the stormwater is then conveyed by the curb and gutter system to the existing inlets within the 31st Ave SW right-of-way. Per the As-Builts provided by the City of Minot and field verification, each inlet is connected to an outfall to Thompson Lake along Puppy Dog Coulee approximately 200

feet north of the intersection of 28th Ave SW and 7th St SW. Based upon discussions with the City, it was assumed that the stormwater infrastructure downstream of the problem areas was undersized and required analysis, therefore the entire drainage system utilizing this outfall was modeled as part of this effort.

In addition, during discussions with the City, the stretch of roadway along 10th St SW between 31st Ave SW and 33rd Ave SW is frequently damaged due to high water table conditions. The scope was further expanded to include a planning level design of an under-pavement drainage tile system with the sole purpose to lengthen the life of the pavement along 10th St SW between these two intersections.

One watershed was delineated for each existing curb inlet using ArcHydro. The GIS-generated watersheds were imported into AutoCAD and refined to account for road crowns, existing storm sewer infrastructure, field verification, and engineering judgment. Once these watersheds were refined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model. Calculations regarding these input variables are available in Attachment 1. The below table lists the XP-SWMM resultant peak flows for each curb inlet.

Proposed Conditions

An upgrade to the existing stormwater sewer system has been proposed for this project (Figure 4.3-13). The proposed inlet locations were chosen based upon the upstream corners of the existing road intersections , areas within the watershed that do not currently meet the City of Minot's Stormwater Design Standards Manual, and at the direction of the City of Minot Staff.

The drainage basin contributing to each proposed intersection was first delineated using ArcHydro. The GIS-generated watersheds were imported into AutoCAD and refined to account for road crowns, existing storm sewer infrastructure, field verification, and engineering judgment. Once these watersheds were refined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model. Calculations regarding the proposed conditions input variables are available in the Appendix. The attached tables list the XP-SWMM resultant peak flows for each proposed curb inlet.

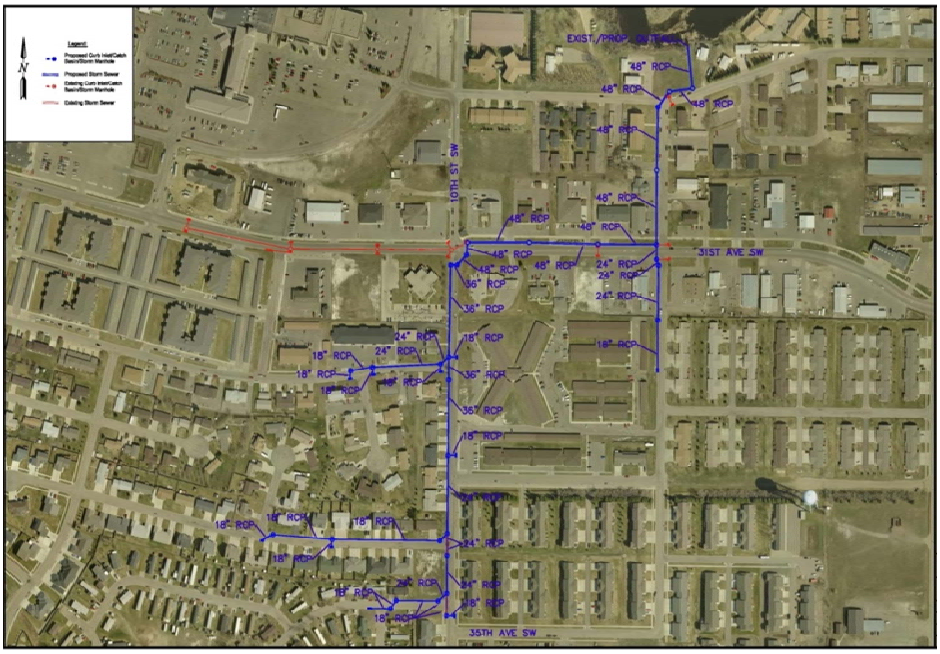

Figure 4.3-13: Proposed Improvements

Utilizing the peak flow rates from the XP-SWMM model, FlowMaster was used to determine the depth of flow at the street gutter and crown as well as the extent of gutter spread. FlowMaster Analysis Reports are available in the Appendix.

The proposed conditions for the 10th St SW roadway corridor between 31st Ave SW and 33rd Ave SW includes the installation of an under-pavement drainage tile system. This drainage tile system has been located to remove excess moisture from approximately 700 linear feet of 10th St SW between 32nd Ave SW and 31st Ave SW. The depth and size of the drainage tile has been assumed to minimally meet the current City of Minot Design Criteria.

Recommendations and Conclusion

As indicated in the Proposed Improvements section of this memorandum, by placing additional inlets upstream of the existing inlets along 31st Ave SW, the existing storm system captures the surface runoff before it becomes a nuisance. Also, by installing a drainage tile system under 10th St SW, excess moisture will be captured and improve the lifespan of road courses. The recommended additions have been shown to meet the current City of Minot Design Criteria for residential and minor arterial streets. The propose improvements meet or exceed the requirements set forth in the Minot Storm Water Design Standards Manual.

4.3.7 37th Avenue S and Main Street

Introduction

The 37th Ave S, between 1st St SE and 2nd St SE drainage basin was identified as a known problem area within the scope of work. Residents have complained about frequent roadway flooding along all of the road corridors within the drainage basin. The extent and depth of flooding severely limits vehicular traffic use of 36th Ave SE and 35th Ave SE as well as 1st St SE and 2nd St SE.

Additional coordination is required for this drainage basin to provide connection information for the Broadway Center and 37th Ave Upgrade Projects. These two projects are expected to be constructed within the next 18 months and will include the construction of the necessary connections to accommodate the proposed drainage improvements identified within this memorandum. The Broadway Center Project has been designed by Houston Engineering and will include the construction of upgrading the 1st St SE corridor to an urban section. The 37th Ave S drainage basin documentation will provide proposed pipe sizes, inverts, and locations to connect with the Broadway Center project at the intersections of 1st St SE and 36th Ave SE and 1st St SE and 35th Ave SE. The 37th Ave Upgrade Project is being designed by KLJ and includes the construction of subsurface utility improvements as well as upgrading the road corridor to an urban section. The 37th Ave S drainage basin documentation will provide proposed pipe sizes, inverts, and locations to connect with the 37th Ave Upgrade Project at the intersection of 2nd St SE and 37th Ave SE.

Finally, at the request of the City of Minot, the proposed pipe design and cost estimate has incorporated the upgrade of the roadway sections along 35th Ave SE, 36th Ave SE, and 2nd St SE within the drainage basin bounds.

General Location and Description

The overall watershed drains to the intersection of 37th Ave SE and 2nd St SE. Roadside swales along 1st St SE and 2nd St SE slope to the south to 37th Ave SE. Drainage within the roadside swales along 36th Ave SE and 35th Ave SE are split at midblock with the stormwater flowing west along the western half of the street and flowing east along the eastern half of the street. The drainage within the northern roadside swale along 37th Ave SE drains to the intersection of 37th Ave SE and 2nd St SE. The stormwater then flows through a culvert under 37th Ave SE to agricultural land adjacent to 1st Larson Coulee. Areas draining to the Broadway Center Project and the stormwater runoff from developed areas south of the 37th Ave road corridor were not analyzed.

In addition, the overall watershed, as shown in Figure 4.3-14, is relatively flat with the entire road and all roadside swales approximately level through their individual lengths. The existing limited infrastructure was originally built in the 1940's when the subdivision was first laid out and is made up of small diameter corrugated metal and reinforced concrete pipes.

The watershed draining to the subject area encompasses approximately 12 acres of residential and public use properties. The watershed extends from 35th Ave SE on the north to 37th Ave SE on the south and from 1st St SE on the west to 2nd St SE on the east.

Figure 4.3-14: 37th Ave Drainage Basin

Existing Conditions

During rain events, the majority of runoff enters street right-of-way via overland flow through residential lawns. In the street right-of-way, the stormwater is then conveyed by the roadside swale system, under driveways via a variety of culvert size and types. Per the As-Builts provided by the City of Minot and field verification, each swale is connected to a culvert under 37th Ave SE immediately west of the intersection of 37th Ave SE and 2nd St SE. Stormwater exiting the roadway culvert travels via overland flow on private land to 1st Larson Coulee approximately 1,400 feet southeast.

Due to the two adjacent projects and the expanded scope to include the road upgrades to urban sections, no existing conditions model was created for this drainage basin.

Proposed Conditions

A completely new stormwater sewer system has been proposed for this project, as shown in Figure 4.3-15. The proposed inlet locations were chosen based upon the upstream corners of the existing road intersections and the locations for the proposed connections to the Broadway Central Project and the 37th Ave Upgrade Project.

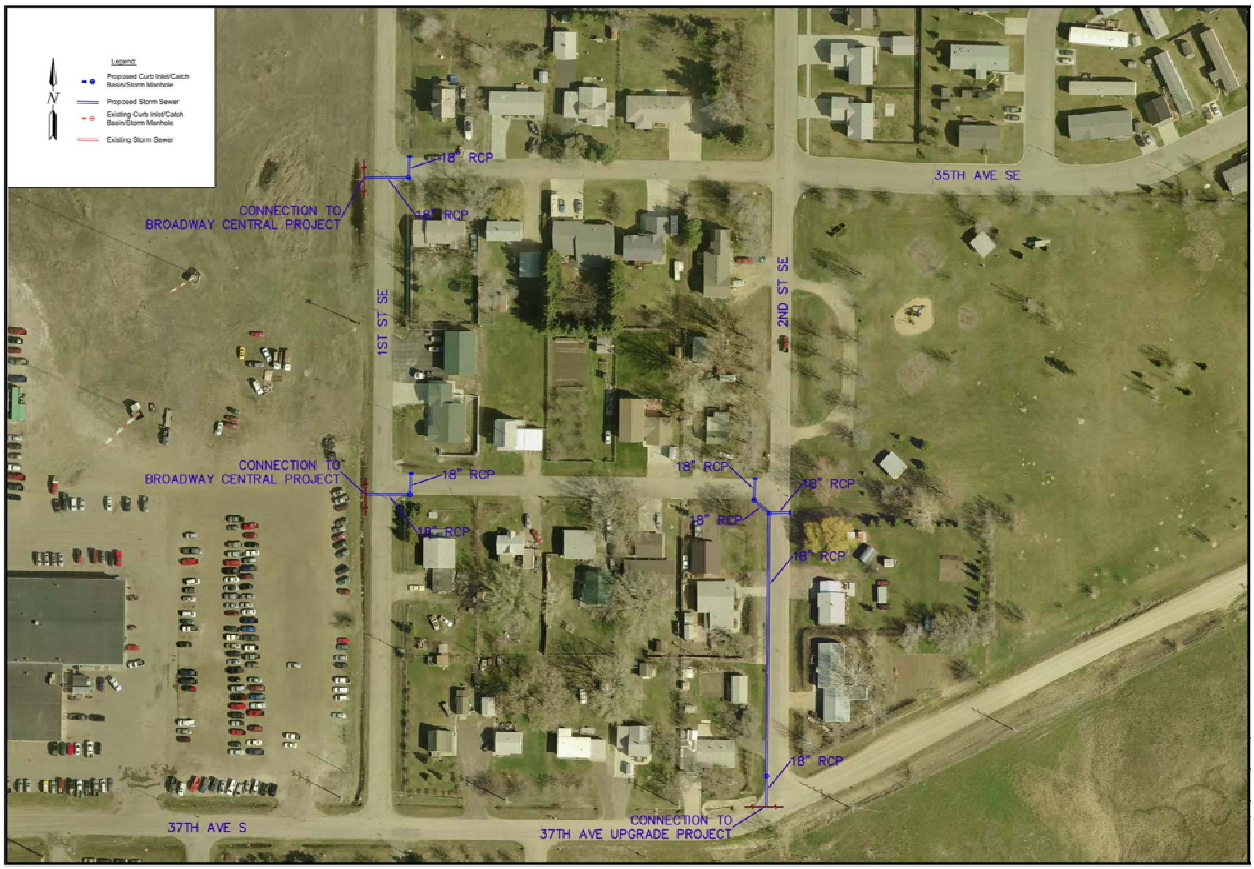

Figure 4.3-15: Proposed Improvements

Each intersection is designed to contain at least two (2) inlets, one on each side of the street. The drainage basin contributing to each proposed inlet was first delineated using ArcHydro. The GIS-generated watersheds were imported into AutoCAD and refined to account for road crowns, existing storm sewer infrastructure, field verification, and engineering judgment. Once these watersheds were refined, the limits of the watershed were used to determine the necessary input variables used in an XP-SWMM hydrological model. Calculations regarding the proposed conditions input variables are available in the Appendix

Recommendations and Conclusion

As indicated in the Proposed Improvements section, by installing a new storm system with correctly sized connection pipes, the surface runoff is collected and transmit it to the South Broadway and 37th Ave Upgrade Projects before it becomes a nuisance. The recommended additions have been shown to meet the current City of Minot Design Criteria for residential streets. The proposed improvements meet or exceed the requirements set forth in the Minot Storm Water Design Standards Manual.

4.4 Proposed Improvement Costs

The following sections summarize the opinion of probable costs for each proposed improvement within the major and minor systems. A more detailed breakdown of these costs can be found in the Appendix.

4.4.1 Major Systems Opinion of Probable Costs

Major Systems	
Project	**Total Cost**
Hwy 83 South Regional Detention	$2,308,915.44
16th Street Regional Detention	$3,209,918.40
13th Street Southeast Regional Detention	$17,389,347.69
Puppy Dog Coulee Regional Detention	$872,639.95
Puppy Dog Bypass	$4,770,119.15
37th Avenue Trunk Line	$7,894,653.00
43rd Avenue Southwest Trunk line	$5,977,865.60
Livingston Lakes Trunk Line	$4,723,079.11
Livingston Lakes Ponding	$3,781,469.33
46th Avenue Northeast Grade Raise	$1,040,291.85
County Road 12 Grade Raise	$2,558,645.44

4.4.2 Minor Systems Opinion of Probable Costs

Minor Systems	
Project	**Total Cost**
Polaris Park	$784,266.99
4th Avenue Northwest	$1,262,598.16
11th Avenue Southwest	$2,764,418.96
16th Street & Southwest Knolls	$2,897,471.36
18th Avenue	$2,037,275.31
10th Street Southwest	$3,685,878.56
37th Avenue South	$263,110.12