Final

October 2011

City of Gillette Stormwater Strategic Plan

Phase II Project

Stormwater Master Plan

URS

City of Gillette
Energy Capital of the Nation
Gillette, Wyoming

FINAL

CITY OF GILLETTE

STORMWATER MASTER PLAN

DEPARTMENT OF ENGINEERING

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PREPARED BY URS CORPORATION

October 2011

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LIST OF ACRONYMS AND ABBREVIATIONS

ac-ft	acre–feet
BNSF	Burlington Northern Santa Fe Railroad
CBC	concrete box culvert
WYDOT	Wyoming Department of Transportation
cfs	cubic feet per second
CMP	corrugated metal pipe
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
ft	feet
ft/ft	feet per foot
ft/sec	feet per second
GIS	geographic information systems
HEC-HMS	Hydrologic Engineering Centers Hydraulic Modeling System
HEC-RAS	Hydrologic Engineering Centers River Analysis System
hr	hours
I-90	Interstate 90
ID	identification number
min	minutes
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic & Atmospheric Administration
NRCS	Natural Resources Conservation Service
PMP	Probable Maximum Precipitation
RCP	reinforced concrete pipe
SCS	Soil Conservation Service
SEO	State Engineer's Office (Wyoming)
sq. mi.	square miles
t_c	time of concentration
UPRR	Union Pacific Railroad
URS	URS Corporation
USGS	U.S. Geologic Survey

EXECUTIVE SUMMARY

PURPOSE AND OBJECTIVE

This Stormwater Master Plan is part of a stormwater planning study authorized by the City of Gillette (City), Wyoming, in an agreement regarding the Stormwater Strategic Plan, dated August 3, 2009 (Project No. 09EN38). The sponsoring agency is the City of Gillette. Stakeholders and community members include Campbell County, the Campbell County Conservation District, business owners, developers, and citizens.

The City's current Stormwater Master Plan was completed in 1978 and has not been re-evaluated on a comprehensive level since that time. During the past 30 years, the City has grown considerably. Currently, new development is required to address local site drainage by controlling increases in stormwater runoff with the use of detention "cells," which are small areas into which stormwater is collected and detained. There are numerous cells scattered throughout the City, which require periodic maintenance, such as mowing and trash collection/removal, and is performed by the City's Public Works and Parks Departments. Many of the cells are in areas that are difficult to access, and they provide no other amenities to the neighborhoods in which they are located. There are also know areas of potential flooding, poor surface drainage, limited access, maintenance problems and water quality concerns within the study area.

To address poor drainage and flooding issues, provide maintenance more efficiently and at the same time provide more appealing and useful open space areas, the City initiated this stormwater master planning project to investigate the feasibility of creating regional detention ponds, which would serve larger drainage areas, and abandon the small pocket detention cells that serve individual developments. There is also the potential of designing regional detention ponds that are contained within regional parks, creating multi-use facilities.

The objectives of this project are to:

- Update the stormwater infrastructure inventory performed in 2005.
- Develop a comprehensive Stormwater Master Plan with a focus on regional detention and major drainage conveyance improvements.
- Integrate drainageways into parks and open spaces to create public amenities.
- Develop a GIS based computer model of the stormwater system for the City's "stormwater district" service area.
- Develop capital improvement projects and a capital plan to reduce or eliminate drainage and/or flooding problems with available resources.

This report presents the conceptual design, estimated costs and projected benefits of detention, conveyance and storm sewer improvements as agreed upon by the City in the Selected Plan.

STUDY AREA DESCRIPTION

The main study area consists of the area within the current City limits and outward 1-1/2 miles to the ultimate planning boundary. The two primary streams within Gillette are Stonepile Creek and Donkey Creek, which originate in the upland plains of central Campbell County. Stonepile

Creek flows easterly through central Gillette to its confluence with Donkey Creek at the southeastern city limits. Donkey Creek flows northeasterly through the southern half of Gillette to Fishing Lake, and then to its confluence with the Belle Fourche River, which is in southwestern Crook County near the Town of Moorcroft. The project area also includes the headwaters of Little Rawhide Creek and Dry Fork Little Powder River, which flow northwesterly toward the Gillette Campbell County Airport. The topography of the area also includes “playas,” which are closed depressions that have no natural outlet. Examples of these are Burlington Lake and the unnamed lake at Spruce Drive and Kluver Avenue.

PLANNING PROCESS

This Stormwater Master Plan project began with interviews with City staff, site visits, and a review of past studies and identification of the direction for this study. The City provided pertinent studies and reports relating to the project area drainage basins. Most reports were used to cross-check drainage basin data and flow rates, prepare data for hydraulic calculations, cross-check as-built data, or compare sub-basin boundaries. Bridges, culverts, and other drainage structures were surveyed by the City in the project area for the hydraulic analysis. Site visits were also conducted by URS and the City at select locations throughout the study area, and photographs were taken documenting the key drainage features.

New hydrologic modeling was prepared and hydraulic models were developed for each major basin using InfoSWMM. InfoSWMM is highly developed, well supported hydrologic/hydraulic modeling software that is fully GIS integrated. The study area was divided into 12 major drainage basins ranging in area from 1.9 to 22.2 square miles. Sub-basins were delineated at tributaries, major road crossings, changes in slope, and major drainage features such as ponds and storm sewers. Topographic mapping used in the analysis consists of aerial topographic mapping compiled in October 2010 by Fugro, Inc. for Donkey Creek, aerial mapping compiled in 2003 for the remainder of the City, and USGS mapping in outlying areas. The results of the hydrologic modeling were compared to the 1978 Master Plan and other study results for reasonableness.

The regulatory HEC-RAS model cross-sections were revised at the some locations utilizing the project mapping, as-built information and/or field observations. All other parameters were kept the same except where new topographic features were encountered, such as new bridges or culverts. New HEC-RAS models were developed for certain study reaches that had not been studied previously. The hydraulic modeling conducted as part of this study was specifically not to redefine the regulatory floodplain, but to determine potential for flood damages and to allow modeling of alternative improvements.

A series of monthly progress meetings, 21 in all, were held at the City of Gillette offices and were attended by Engineering and Planning Department personnel. In these meetings, URS engineers presented findings of the interim analyses and discussed concepts and issues with the City. The City provided direction for each new stage of analysis ensuring that the City’s ideas, concerns and goals were being addressed. As the project moved toward the draft report stage of the alternatives analysis, a City Council workshop was held on March 28, 2011, to discuss the master planning effort and solicit input.

The alternatives analysis and URS' recommendations were reviewed with the City in a meeting on June 30, 2011, and a Selected Plan was developed. This Stormwater Master Plan advances the Selected Plan to the conceptual design level and presents in more detail recommended detention and conveyance facilities, costs and actions on a "project" basis for the entire study area.

ALTERNATIVE ANALYSIS

The current conveyance systems within the City generally have a 10-year capacity and were constructed under a varying set of design criteria. During problem identification and damage analysis, it was found that the primary flooding issues occur on the main stem channels of Donkey Creek and Stonepile Creek, North Donkey Creek and Antelope Butte Creek within the City limits. There are numerous other locations where local roadway crossing structures and storm sewer systems have inadequate capacity (based on the City's Storm Drainage Design Manual criteria).

Existing condition 100-year flow rates on Donkey Creek range from about 3,700 cfs at Highway 50 to about 8,000 cfs at the downstream study limit. There are six local and six arterial or collector roadway crossings on Donkey Creek, of which only the bridge at Garner Lake Road has adequate capacity according to the evaluation criteria.

It is important to note that the floodplain in the reach of Donkey Creek from Highway 59 to Butler Spaeth Road, which passes through Fishing Lake and Dalby Park, has not been mapped by FEMA, although both the upstream and downstream reaches have been mapped. According to this analysis, Fishing Lake Dam acts as a weir and creates shallow flooding (1 to 2 feet deep) to the north across Edwards Street, which would extend onto residences between Lakeway Road and Edwards Street. Upstream from here, there are a number of structures along Carlisle Street that are in the floodplain, and there are structures in the floodplain upstream of Donkey Creek Drive, near Jayhawker Street and along Hidden Drive.

The 100-year flow rates on Stonepile Creek range from about 2,500 cfs at the upstream study limit near I-90 to about 5,400 cfs at the confluence with Donkey Creek. Stonepile Creek has 6 local, 1 collector, and 10 arterial crossings within the study area, none of which are adequate for the 100-year flow. Split flows would occur at many of these crossings in a major event, creating separate flow paths and causing flooding issues in areas away from the main channels.

The reaches of Stonepile Creek from Donkey Creek to I-90 on the east and from Highway 14/16 to the upstream limit on the west have been mapped by FEMA using detailed methods, but between I-90 and Highway 14/16 in the central part of Gillette the main stem of Stonepile Creek has been mapped using approximate methods. There are many structures in the currently effective FEMA floodplain upstream of Highway 14/16 on Stonepile Creek, but the 100-year future conditions floodplain delineated in this analysis is much larger than the current "approximate" FEMA Zone AE in central Gillette, and would include many more structures in this area.

In other areas of the City, there are at least 30 structures identified from the 2009 aerial photographs in the Antelope Butte Creek floodplain, and there are many locations with flat grades that were reported as problem areas due to poor runoff conveyance.

Alternative plans were formulated to confine the future, fully developed conditions100-year flood within a conveyance system and remove all structures from the 100-year floodplain. A minimum of two alternative plans to mitigate the flood hazards and improve water quality aspects within each basin were developed, and include regional detention, channel improvements, selected structural improvements, and floodplain management.

The objectives of the alternatives evaluation are to identify cost effective measures to control developed runoff from the watersheds such that:

1) Developed runoff rates can be conveyed safely within existing and proposed infrastructure as much as possible,
2) Potential for damages to conveyances and structures within the watershed from the design flood is reduced, and
3) Flood control measures can be implemented effectively as development occurs.

Opportunities for expanding green space and trail connectivity in concert with the development of drainage alternatives were also considered. Generally, the criteria and methods used to develop detention and conveyance requirements follow the Gillette SDDM. Each alternative was developed to reduce impacts to private property, especially property that is highly developed. The alternatives address flood impacts, and consider stream stability, cost effectiveness, implementation, and opportunities for multiple uses.

In the detention alternative, regional ponds were sized and evaluated using the InfoSWMM model. All proposed channels and culverts were sized for the future conditions 100-year peak flow rates with detention. Conveyance improvements are proposed only where needed or where existing conveyance elements are undersized for existing conditions.

For the conveyance alternative, all channels and structures in the study reaches need to have capacity for the full 100-year developed conditions flow. No new on-site or regional detention is proposed. Only existing City detention ponds were included in this model, and all “inadvertent” roadway detention was removed from the model. Channels and structures required to convey future conditions and 100-year peak flows were sized according to current City criteria.

Local structure improvements were considered for inadequate roadway crossings that are isolated and located in sparsely developed areas without detention.

Floodplain management is an administrative approach to manage development such that existing drainageways are preserved and protected, and is applicable to all study reaches.

The detention and conveyance, and local structure improvements alternatives were evaluated by assembling necessary design requirements using the current criteria and estimating the capital cost of each set of improvements. Based on the evaluation of flood impacts, stream stability, and cost effectiveness, the detention alternative was recommended for implementation on the main stems of Stonepile and Donkey Creeks, as well as in Basins 6, 7, 8 and 9. In the other Basins and certain study reaches, channel improvements, storm sewer improvements and selected local structural improvements were recommended.

MASTER PLAN

The results of the Alternatives Analysis were reviewed with the City, and the City chose elements in each basin as a basis for the preparation of conceptual design. Regional detention is the most cost effective way to meet all the criteria of the Stormwater Master Planning Study. The plan allows development in the Donkey Creek, Stonepile Creek and Antelope Butte Creek basins without the requirement for onsite detention. Master plan projects are illustrated in Figure ES.1.

To control flood potential on Donkey Creek, two large regional detention facilities are proposed, one in Milne Valley, Milne Valley –mid, and one in Hidden Valley. These large detention facilities are needed to reduce 100-year peak flows to a rate that allows use of most of the existing downstream channel sections and crossing structures on the main stem. These detention facilities will be large enough to require a permit from Wyoming's Office of the State Engineer in order to construct them.

The proposed improvements on Donkey Creek also include a new outlet structure and spillway for Fishing Lake, and channel improvements downstream to Butler Speath Road. These are needed to alleviate shallow flooding potential to the north at this location. Channel improvements are also recommended on Donkey Creek is upstream of Douglas Highway to approximately Carlisle Blvd.

On the main stem of Antelope Butte Creek (Basin 6), a large regional detention facility is proposed, Antelope Butte Creek Detention, which over-detains enough flow so that the structure at Lee Avenue can convey the 100-year peak discharge. With this detention pond in place, the existing natural channel downstream to Donkey Creek is adequate to convey the 100-year future conditions peak discharge and the only structure improvement necessary is at Douglas Highway. The intent is to provide a combination of over-detention and floodplain management, with developed conditions 100-year conveyance facilities in all new development. The plan then allows development in the Antelope Butte Creek basin without the requirement for onsite detention.

In the Donkey Creek Tributary South watershed (Basin 7), the City Land Pond is proposed for major regional detention, and new detention facilities are proposed for the Saunders Tributary, the Hitt Estates Tributary, and the Sunburst Tributary. Each new pond detains developed flows such that the existing downstream conveyance facilities have capacity to meet 100-year criteria for these systems without modification. The proposed Hitt Estates Pond is an existing produced water pond that would be formalized as permanent stormwater detention when development of the surrounding land occurs. The proposed Saunders and Sunburst ponds are necessary for existing development and runoff conditions.

The selected plan for North Donkey Creek (Basin 8) proposes expanding existing detention ponds at Sage Valley Park R1 and Sunflower Park R5, formalizing the inadvertent detention that occurs north of I-90, and adding one new pond south of the new Boxelder Road extension, labeled Upper Sage Valley. Even with the increased detention, the conveyance structures at Birch, Maple and Emerson need to be replaced, and channel improvement is recommended for the lower reach from E-Z Street to Butler Speath Road.

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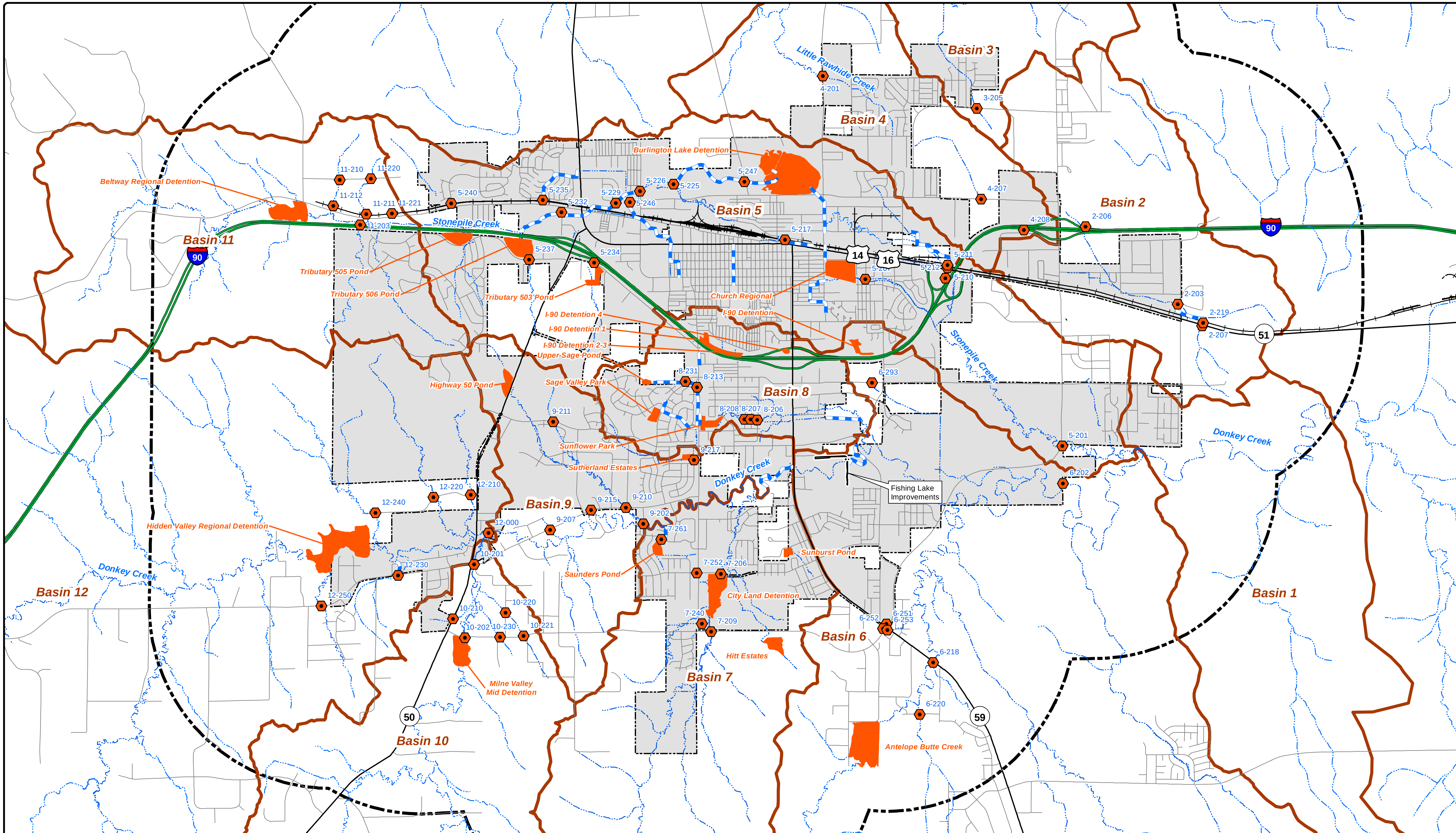

Open Channel
Interstate
State or US Highway
Streets
Railroad
Basin 8 Major Basin
City Limits
Study Area
Proposed Structure
Proposed Channel or Storm Drain Improvements
Proposed Detentions

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Stormwater Master Plan

Gillette Stormwater Master Plan

ES.1

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Two detention facilities are proposed in Basin 9. The first requires formalization of the inadvertent detention upstream of Highway 50, which would not require any grading, but probably would require a drainage easement for the ponding area adjacent to the highway. The second detention improvement is to increase the volume in the existing Sutherland Estates detention facility to reduce the potential for flooding in 4-J Road during major storm events. A new outlet structure and storm sewer in 4-J Road is also proposed.

The selected plan for the main stem of Stonepile Creek (Basins 5 and 11) proposes six new regional and sub-regional detention facilities totaling more than 900 acre-feet of capacity. This will reduce future conditions peak 100-year flows to be within the capacity of most existing channel reaches and crossing structures on Stonepile Creek in the established areas of the City of Gillette.

The plan includes using Burlington Lake for regional detention by breaching the existing embankment to allow flooding of the area on the northwest side of the dam. To direct more stormwater to Burlington Lake, a new diversion structure in Stonepile Creek is proposed, consisting of a new diversion weir in the Stonepile Creek channel and un-gated opening to an enlarged Burlington Ditch diversion channel. The enlarged channel follows the alignment of the existing ditch, and includes a new, larger crossing structure under Hannum Road. Since the lake currently has no outlet, a new outlet from Burlington Lake to Stonepile Creek is proposed. A 72-inch storm sewer with an invert set at the elevation of the existing water surface in Burlington Lake would extend to the southeast and down Gurley Avenue to discharge into Stonepile Creek at 4th Street.

Even with these new detention facilities, conveyance improvements are required in certain reaches on Stonepile Creek consisting of new open channel sections and new roadway crossing structures. Channel reaches needing improvements to increase conveyance are upstream of Burma Avenue to the confluence with Tributary 506. New structures are needed at Garner Lake Road, Church Avenue, Burma Avenue, Commercial Drive, Newton Road and a private drive.

Proposed improvements on the Stonepile Creek Tributaries consist of selected storm sewer, structure and channel improvements.

On the East Fork Little Rawhide Creek (Basin 4) and Dry Fork Little Powder River (Basin 3), roadway drainage structure improvements are proposed at I-90, Warlow Road, and Little Powder River Road, and Kluver Road.

In the closed basin (Basin 2), a new roadway crossing is proposed at Potter Ave. The plan for improving this crossing includes new channel improvements downstream.

The total estimated construction costs for the Master Plan are summarized in Table ES.1.

Table ES.1
Summary of Construction Costs by Basin

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)
Donkey Creek Watershed						
Donkey Creek Main Stem	$ 9,894,330	$ 2,968,299	$ 12,862,630	$ 1,929,394	$ 1,421,554	$ 16,214
Antelope Butte Creek Main Stem (Basin 6)						
Antelope Butte Creek Main Stem (Basin 6)	$ 2,634,231	$ 790,269	$ 3,424,500	$ 513,675	$ 83,590	$ 4,022
Antelope Butte Creek Tributaries (Basin 6)						
Antelope Butte Creek Tributaries (Basin 6)	$ 705,470	$ 211,641	$ 917,111	$ 137,567	$ -	$ 1,055
Donkey Creek Tributary South (Basin 7)						
Donkey Creek Tributary South (Basin 7)	$ 4,408,337	$ 1,322,501	$ 5,730,838	$ 859,626	$ 269,701	$ 6,860
North Donkey Creek Tributary (Basin 8)						
North Donkey Creek Tributary (Basin 8)	$ 3,221,216	$ 966,365	$ 4,187,581	$ 628,137	$ 47	$ 4,816
Donkey Creek Tributary (Basin 9)						
Donkey Creek Tributary (Basin 9)	$ 1,244,185	$ 373,256	$ 1,617,441	$ 242,616	$ 90,675	$ 1,951
Basin 10 Milne Valley						
Donkey Creek Tributary (Basin 10)	$ 1,164,088	$ 349,226	$ 1,513,314	$ 226,997	$ -	$ 1,740
Basin 12 Donkey Creek Direct Flow Areas						
Donkey Creek Tributary (Basin 12)	$ 327,218	$ 98,165	$ 425,383	$ 63,808	$ -	$ 489
Donkey Creek Watershed - Total Cost	**$ 23,599,075**	**$ 7,079,722**	**$ 30,678,797**	**$ 4,601,820**	**$ 1,865,566**	**$ 37,146**
Stonepile Creek Watershed						
Stonepile Creek Main Stem	$ 15,755,870	$ 4,726,761	$ 20,482,631	$ 3,072,395	$ 769,740	$ 20,647
Stonepile Creek Tributaries	$ 5,791,900	$ 1,737,570	$ 7,529,470	$ 1,129,421	$ -	$ 8,659
Stonepile Creek Watershed - Total Cost	**$ 21,547,771**	**$ 6,464,331**	**$ 28,012,102**	**$ 4,201,815**	**$ 769,740**	**$ 29,305**
Little Rawhide Creek - Basin 4						
Little Rawhide Creek - Basin 4	$ 583,665	$ 244,800	$ 828,465	$ 124,270	$ -	$ 1,220
Dry Fork Powder River - Basin 3						
Dry Fork Powder River - Basin 3	$ 20,152	$ 6,046	$ 26,198	$ 3,930	$ -	$ 30
Closed Depression Playas - Basin 2						
Closed Depression Playas - Basin 2-Tributary 201	$563,513	$169,054	$732,567	$ 109,885	$ -	$842
Basins 2, 3 and 4 - Total Cost	**$ 1,167,331**	**$ 419,900**	**$ 1,587,231**	**$ 238,085**	**$ -**	**$ 2,092**

This report covers the plan in detail, culminating with conceptual design plan and profile sheets in Appendix G. The plan described on these sheets is presented at a "conceptual" design level. The final design of the Master Plan allows great flexibility to incorporate alternative concepts as long as they maintain the hydraulic function described in this report. Aesthetic enhancements, landscaping alterations, recreational features and other improvements to the plan are encouraged during final design. Where improvements occur on public lands coordination with local governing agencies, such as Parks, should be undertaken to ensure compliance with the goals of the participating entity.

STORMWATER QUALITY

Certain elements of this plan are permanent water quality "Best Management Practices" (BMPs) as described in Chapter 12 of the SDDM, and can help improve stormwater quality on these and other City drainageways.

- Generally, closed depressions are "retention ponds". The playas in Basins 2, 3, 4 and 6 should be considered flood control and water quality facilities.
- Certain open water bodies, such as Fishing Lake and Burlington Lake, act as retention ponds and provide a water quality benefit for the downstream reaches.
- By constructing the low level outlet from Burlington Lake back to Stonepile Creek, low flows in Stonepile Creek downstream of Gurley Avenue will increase, which in turn would improve dilution and consequently general water quality of Stonepile Creek downstream of the sewage treatment plant.
- Constructed wetlands could be used downstream of the sewage treatment plant to improve overall water quality in Stonepile Creek before it flows into Donkey Creek.
- The proposed detention facilities in Basins 7, 8 and 9 and on Tributaries 503, 505 and 506 of Stonepile Creek could provide water quality benefits if planned as part of the projects.
- Certain existing detention cells that are to be retained, such as those in Basin 6, could be retrofitted to provide Extended Dry Detention BMPs for subareas of the City.
- In addition, any proposed channel improvements and drop structures and would result in decreased flow velocities through the drainageways. Decreasing discharge rates and flow velocities will result in less erosion and sediment transport, thereby enhancing water quality.

At some point, the City will require all new developments and redevelopments to prepare Stormwater Pollution Prevention Plans (SWPPPs) associated with construction activities. Controlling erosion and sediment discharged from construction sites will go a long way toward helping the City meet stormwater quality goals.

GENERAL RECOMMENDATIONS

Also part of this stormwater master plan, it is recommended that the City and Campbell County:

- Take steps to stabilize all major drainageways as the watersheds urbanize and aggressively control erosion and sediment transport during construction activities. Preserve existing natural drainageways as much as possible.
- Initiate a new detailed study of Stonepile Creek from its confluence with Donkey Creek to the western limit of the current detailed study, and a detailed study of the reach of Donkey Creek between Butler Speath Road and Douglas Highway.
- Continue to enforce floodplain management regulations, including regulation of the 100-year floodplain and floodway, and continue to participate in FEMA's flood insurance Community Rating System and public education programs.
- Monitor land use changes and whenever the land-use changes result in imperviousness ratios that exceed the projections identified in this study, steps should be taken to further limit increases in stormwater runoff.
- Require all new development, redevelopment, and publicly funded projects provide stormwater quality BMPs as recommended in Sections 11 and 12 of the Gillette SDDM.

SECTION ONE
INTRODUCTION

1.1 AUTHORIZATION

This Stormwater Master Plan is part of a stormwater planning study authorized by the City of Gillette (City), Wyoming, in an agreement regarding the Stormwater Strategic Plan, dated August 3, 2009 (Project No. 09EN38). The main study area, shown in Figure 1.1, consists of the area within the City limits; however, the ultimate planning boundary extends 1-1/2 miles outside the current City limits. The sponsoring agency is the City of Gillette. Its stakeholders and community members include Campbell County, the Campbell County Conservation District, business owners, developers, and citizens.

1.2 BACKGROUND

The City of Gillette was incorporated in January 1892, and encompassed 360 acres. Today, the population of Gillette is approximately 32,000 and the area within the current City limits is 18.2 square miles. Additional annexations into the City are pending. (Source: Developing Gillette, Reference 7).

The City's current Stormwater Master Plan (1978 Plan) (Reference 11) was completed in 1978 and has not been re-evaluated on a comprehensive level since that time. During the past 30 years, the City has grown considerably. From 1970 to 2005, the annual number of new plats has been 75 to 80. During the past 5 years, new plats increased to 110 to 120 per year. In 2008, the City added 11% to housing.

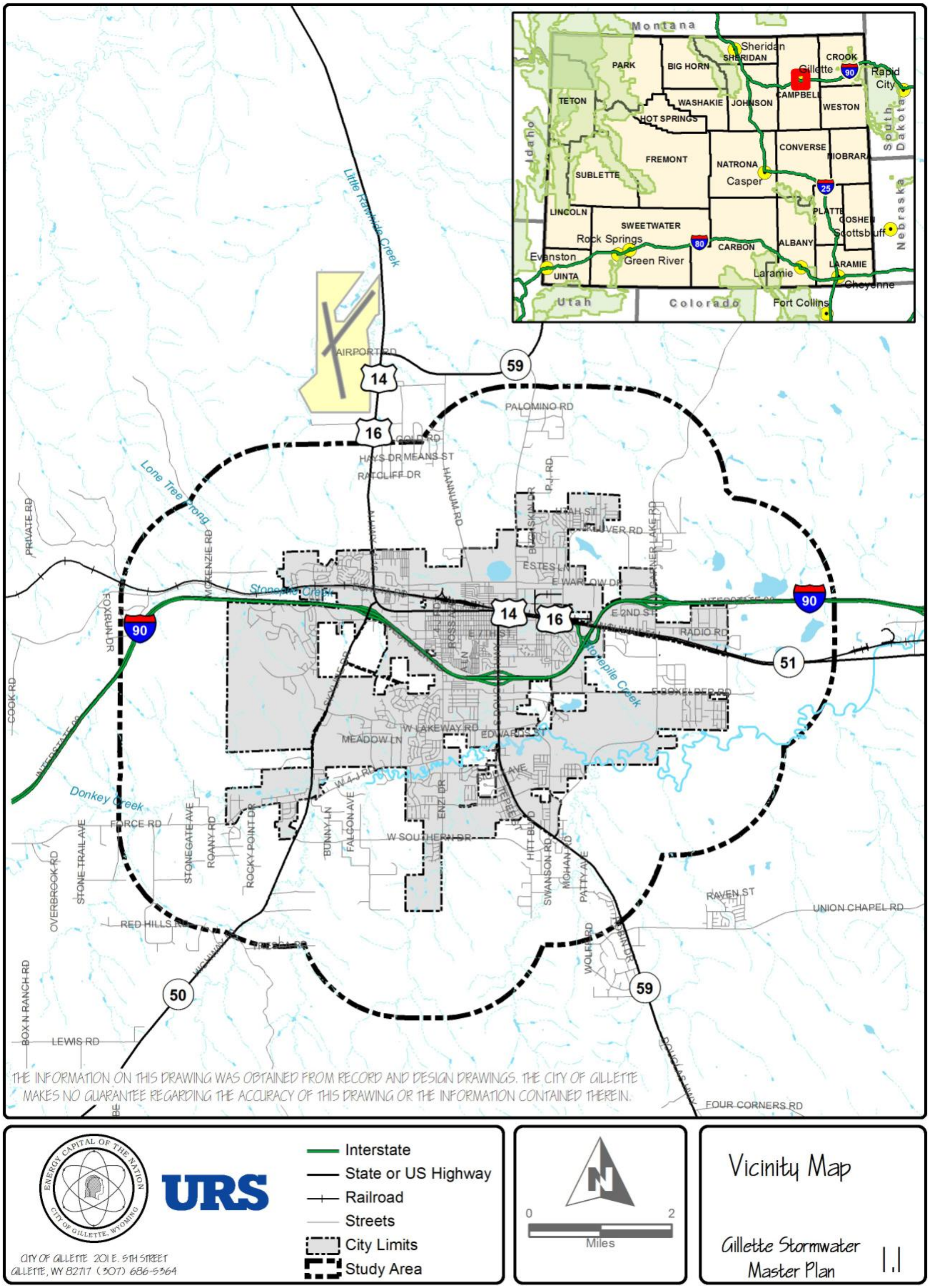
Currently, new development is required to address local site drainage by controlling increases in stormwater runoff with the use of detention "cells," which are small areas into which stormwater is collected and detained. There are numerous cells scattered throughout the City. These detention cells require periodic maintenance, such as mowing and trash collection/removal. Maintenance of the cells is performed by the City's Public Works and Parks Departments. Many of the cells are in areas that are difficult to access and they provide no other amenities to the neighborhoods in which they are located.

To provide maintenance more efficiently and at the same time provide more appealing and useful open space areas, the City initiated the stormwater master planning project to investigate the feasibility of creating regional detention ponds, which would serve larger drainage areas, and abandon the small pocket detention cells that serve individual developments. There is also the potential of designing regional detention ponds that are contained within regional parks, creating multi-use facilities.

1.3 PURPOSE AND SCOPE

The purpose of this project is to prepare a comprehensive Stormwater Master Plan that will:

- Update the stormwater infrastructure inventory performed in 2005.
- Develop a stormwater master plan with a focus on regional detention and improvements.
- Integrate drainageways into parks and open spaces to create public amenities.


Montana
Sheridan
SHERIDAN
CROOK
Gillette
Rapid City
PARK
BIG HORN
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WESTON
HOT SPRINGS
Idaho
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FREMONT
NATRONA
CONVERSE
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LINCOLN
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PLATTE
GOSHEN
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Rock Springs
CARBON
ALBANY
Evanston
Green River
LARAMIE
UINTA
Laramie
Cheyenne
Utah
Colorado
Fort Collins
Little Rawhide Creek
AIRPORT RD
PALOMINO RD
Lone Tree Prong
PRIVATE RD
Stonepile Creek
FOXRUN DR
COOK RD
Donkey Creek
FORCE RD
STONEGATE AVE
ROANY RD
ROCKY POINT DR
BUNNY LN
FALCON AVE
W SOUTHERN DR
MEADOW LN
W LAKEWAY RD
RADIO RD
E BOXELDER RD
RAVEN ST
UNION CHAPEL RD
OVERBROOK RD
STONE TRAIL AVE
RED HILLS RD
BOX N RANCH RD
LEWIS RD
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State or US Highway
Railroad
Streets
City Limits
Study Area
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Miles
Vicinity Map
Gillette Stormwater Master Plan
1.1

- Develop a GIS based computer model of the stormwater system for the City's "stormwater district" service area.
- Develop capital improvement projects and a capital plan to reduce or eliminate drainage and/or flooding problems with available resources.

In addition, the City desires to develop a proactive stormwater program that will enable the City to address the stormwater infrastructure needs for existing and future development.

This Stormwater Master Plan begins with evaluating stormwater infrastructure conveyance and retention/detention systems, including local and regional facilities. Based on this comprehensive system evaluation, a capital improvement program (CIP) addresses areas where the stormwater system is unable to meet performance criteria that are also established as part of this project. An important tool in using this Master Plan will be the City's GIS mapping within the city limits, which includes topographic and land use information. Specifically, this Stormwater Master Plan scope includes the following tasks:

- Develop hydrologic and hydraulic stormwater runoff models for the major drainage basins.
- Evaluate the existing stormwater conveyance infrastructure within the City limits and planning area.
- Develop alternatives for mitigating flooding/system constraints.
- Evaluate the engineering, financial, and legal feasibility of each significant stormwater conveyance and retention/detention system alternative.
- Prepare separate visual and written explanations of the size/capacity/effects/benefits for each selected stormwater conveyance and retention/detention system alternative.
- Identify the structures that would be impacted and/or benefited by each alternative.
- Provide additional information concerning stormwater quality enhancement that might be expected.

1.4 PROJECT COORDINATION

Throughout the course of this Stormwater Master Planning project, meetings were held with representatives of the City, and Campbell County, as well as engineers, developers, and citizens with an interest in stormwater planning. The primary reason for the coordination effort was to obtain technical information and to identify concerns with regard to the development of design criteria, stormwater management alternatives and existing and proposed facilities within the City.

1.5 ACKNOWLEDGEMENTS

URS wishes to acknowledge the individuals who assisted in the development of this Stormwater Master Plan.

Dustin Hamilton, PE	Director, Engineering and Building
Terry Wolterstorff, PE	Gillette City Engineer, Regulatory
Kurt Siebenaler, PE	Gillette City Engineer, Capital Projects

Doug Ninas	Gillette GIS Manager
Levi Jensen	Gillette Civil Engineer
Rick Staskiewicz	Gillette City Public Works Director
Charlie Anderson	Gillette City Attorney

The following URS personnel were responsible for development and completion of this Master Plan:

- Principal-In-Charge: Tim Volz, PE
- Project Manager: John Griffith, PE
- Hydraulic/Civil Engineer: Joel Jones, PE
- Hydraulic/Civil Engineer: Max Shih, PhD, PE
- Hydraulic/Civil Engineer: Betsy Young, EI
- Hydraulic/Civil Engineer: Joey Machala, EI

1.6 SUMMARY OF DATA OBTAINED

The City has a comprehensive stormwater system inventory and conditional assessment of the stormwater infrastructure that was last updated in June 2005. Infrastructure installed after June 2005, is available on subdivision and capital construction record drawings and is being incorporated into the City's GIS database. The City also provided drainage reports and studies it has on file, and current GIS information. The GIS data is not considered legal survey data.

Relevant data were collected as part of this project to construct and complete the required hydrologic and hydraulic models. Data collection included topography, soils, land use, aerial photography, rainfall, and field survey data, along with previous drainage and floodplain studies. A majority of the data was collected and utilized in GIS format. The City and government agencies provided the necessary data. Table 1.1 lists the major data collected along with the sources.

URS performed several site visits to photograph and document existing drainage structures, vegetative cover, development status, and other physical features. URS also obtained pertinent information from the City to establish a database of financial information. Stormwater regulations were obtained from the City and the State of Wyoming.

In addition to the listed data, reports such as the 1996 Donkey Creek Floodway Study (Reference 16) and the County FIS (References 18, 20) were utilized. A number of drainage reports, sketch plans, preliminary and final design drawings, development plans, and existing drainage facility maps were collected from the City. A complete list of reports cited is in Section 7.

Table 1.1
Major Data Sources and Data Obtained

Data Source	Data Obtained
City of Gillette	Existing land use, future land use, and Major Transportation Corridors Plan. Flood Insurance Studies (FIS), Letters of Map Revision (LOMRs). Digital Terrain Model (DTM) with 2-ft contour intervals, and aerial photographs.
National Oceanic and Atmospheric Administration (NOAA)	Rainfall data
Natural Resources Conservation Service (NRCS)	Soil Survey Geographic (SSURGO) data

1.7 MAPPING AND SURVEYING

Mapping used in the analysis for the City of Gillette consists of aerial topographic mapping compiled in October 2010 by Fugro, Inc. for Donkey Creek, aerial mapping compiled in 2003 for the remainder of the City, and USGS mapping in outlying areas for use in the hydrologic analysis. The aerial topographic mapping includes 2-ft contours and was used in the hydraulic structures assessment (see Section 4), hydrologic and hydraulic analyses, and in the alternative planning phases of this project. The vertical datum used is North American Datum 83 (NAVD 83).

Bridges, culverts, and other drainage structures were surveyed by the City in the project area for the hydraulic analysis. Site visits were also conducted by URS and the City at select locations throughout the basin, and photographs were taken documenting the key drainage features.

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SECTION TWO
PROJECT AREA

2.1 OVERVIEW

The City of Gillette is located in the Northwestern Great Plains, which is a semiarid rolling plain of shale and sandstone punctuated by occasional buttes. Agriculture is restricted by the erratic precipitation and limited opportunities for irrigation. Native grasslands cover rangeland areas on broken topography, while level ground supports crops of spring wheat and alfalfa, and ranching. The region also supports significant coal-bed methane and coal mining industries.

The study area is mostly in the Upper Belle Fourche River watershed. There are two major basins in the Powder River watershed, and one basin made up of closed depressions, or "playas."

The two primary streams within Gillette are Stonepile Creek and Donkey Creek. Donkey Creek is a tributary of the Belle Fourche River, originating in the upland plains of central Campbell County. Stonepile Creek flows easterly through central Gillette to its confluence with Donkey Creek at the southeastern city limits. Donkey Creek flows northeasterly through the southern half of Gillette to Fishing Lake, and then to its confluence with the Belle Fourche River, which is in southwestern Crook County near the Town of Moorcroft. The project area also includes the headwaters of Little Rawhide Creek and Dry Fork Little Powder River, which flow northwesterly toward the Gillette Campbell County Airport.

The topography of the area also includes "playas," which are closed depressions that have no natural outlet. Examples of these are Burlington Lake and the unnamed lake at Spruce Drive and Kluver Avenue.

2.2 CLIMATE

The Northwestern Great Plains are arid; the City of Gillette gets 16 inches of rain per year compared to the U.S. average of 37 inches. Average snowfall is 57 inches, and the average number of days with measurable precipitation is 81. A comparison of the average climate statistics for Gillette and the United States is provided in Table 2.1.

Table 2.1
Gillette Climate

Climate	Gillette, WY	United States
Rainfall (in.)	15.6	36.5
Snowfall (in.)	56.5	25
Precipitation Days	81	100
Sunny Days	209	205
Avg. July High	86	86.5
Avg. Jan. Low	11.1	20.5
Elevation ft.	4,852	1,060

Source: http://www.bestplaces.net

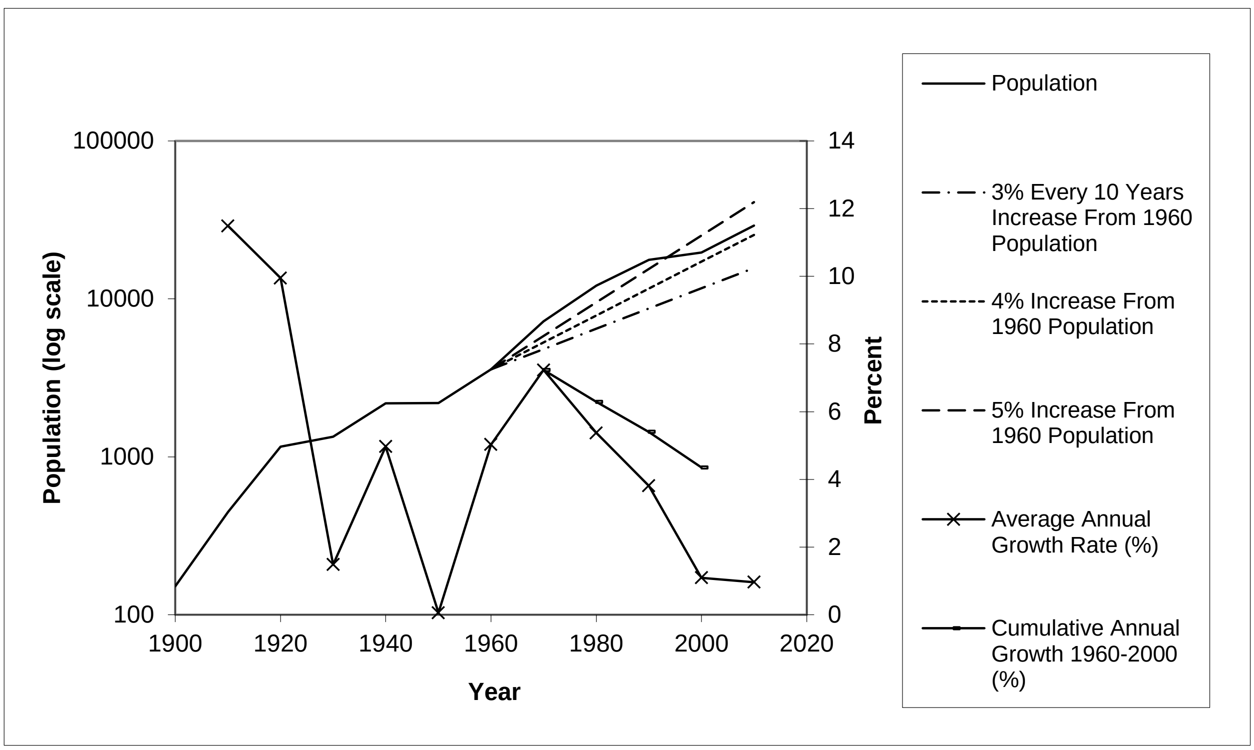
2.3 CURRENT AND PROJECTED POPULATION

During the period from 1975 to the mid-1980s the City's population was increasing at average annual rate exceeding 4 percent. The decline of population that occurred in the mid-1980s was attributed to the US economy and reduction in the nation's energy business.

The U.S. Census bureau reported City of Gillette 1990, 2000, and 2010 populations of 17,635, 19,646, and 29,087, respectively. According to the City's planning department, "During the period from 1975 to the mid-1980s the City's population was increasing at average annual rate exceeding 4 percent."

The population data from the 2006 Gillette Comprehensive Plan (Reference 9) are summarized in Figure 2.1. Lines depicting population growth at 3, 4 and 5 percent since 1960 have been added to the comprehensive plan data. From this chart, a 3% growth rate for Gillette is not an unreasonable assumption. Assuming a future 3% growth rate, the population will double in 25 years, and the corresponding impervious area surrounding Stonepile and Donkey Creeks, while perhaps not doubling, will increase significantly.

Figure 2.1
Gillette Population



Source: "Developing Gillette" (2009) (Reference 7)

2.4 WATER QUALITY

Donkey Creek from the Belle Fourche River upstream through the City has been listed by the Wyoming Department of Environmental Quality (WYDEQ) as impaired for human contact recreation due to contamination with fecal bacteria. Stonepile Creek within the City is also listed as impaired and unable to support contact recreational uses. The WYDEQ states that development of TMDLs for all listed pollutants on the Belle Fourche River, Donkey Creek and Stonepile Creek will be completed in 2011.

The Gillette Fishing Lake was assessed in a study conducted by the Campbell CCD and was determined to be impaired due to high amounts of sediment and phosphate coming from stormwater runoff. Gillette Fishing Lake is also listed on the 303(d) List. The Campbell CCD, in cooperation with the City, developed a watershed plan to address the water quality in Fishing Lake. The City installed stormceptors, and has proposed to construct a wetland upstream of Fishing Lake to trap sediment and phosphorus from stormwater runoff before it reaches the lake. Additionally, the City plans to dredge Fishing Lake to remove sediment, and install bank stabilization to control erosion.

Because of the impairments to the City's major surface water bodies, stormwater quality is becoming an increasing concern with the City and Campbell County. Eventually, Gillette could be required to apply for coverage under a Phase II WYPDES (MS4) Permit. The requirements of the permit are to develop and implement a Stormwater Program to reduce transport and contribution of stormwater pollution to the City's waterways to the "maximum extent practicable." A typical Permit application includes a series of specific, measurable goals focused on meeting the intent of six Minimum Control Measures (MCMs): 1) Public Education and Outreach, 2) Public Involvement and Information, 3) Illicit Discharge Detection and Elimination, 4) Construction Site Runoff Control, 5) New Development/Redevelopment/Post-Construction, and 6) Pollution Prevention/Good Housekeeping.

By implementing this project to develop the Stormwater Master Plan, the City is pro-actively beginning to address the six MCMs that would be required under an MS4 Permit.

2.5 SOILS AND LAND USE

The geology of the Donkey Creek watershed is composed predominantly of the Wasatch Formation and secondarily of quaternary rocks and unconsolidated deposits within and directly adjacent to the creek (USGS, 1985). The Wasatch Formation is composed of highly erosive variegated red to gray, brown, and gray mudstone and sandstone lenses (USGS, 1985). Soils in the watershed are considered highly erosive.

NRCS classifies soils into hydrologic soil groups (HSGs) for hydrologic modeling. HSG is a parameter assigned to each soil series by the NRCS to reflect the relative rate of infiltration of water into the soil profile. NRCS *Technical Release 55* (*TR-55*) (1986) (Reference 138) defines HSG into A, B, C, and D as follows:

HSG A - soils have low runoff potential and high infiltration rates, even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission.

HSG B - soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

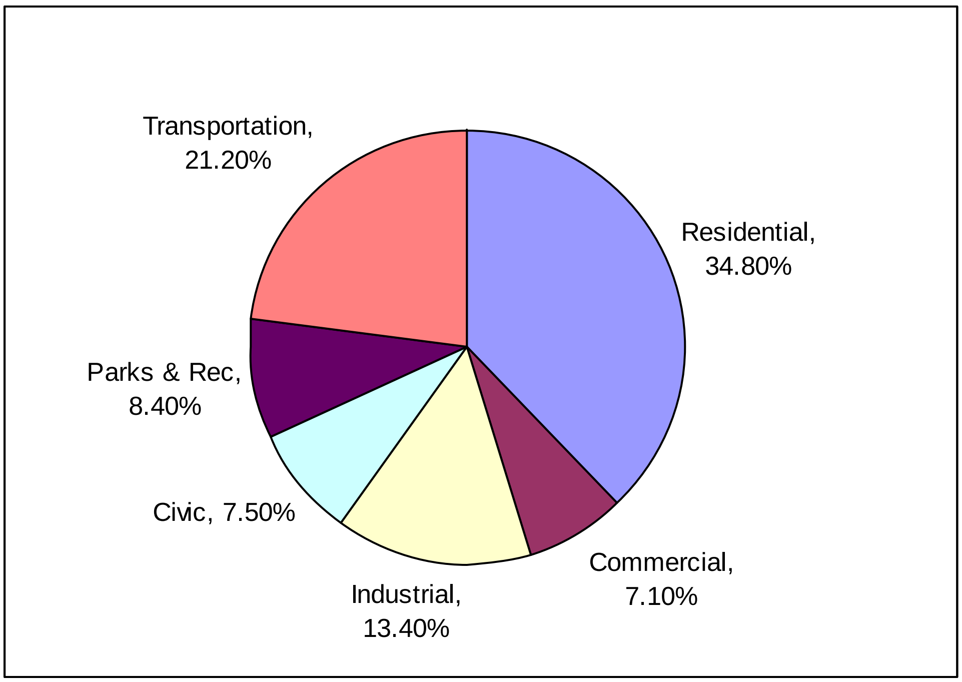
HSG C - soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission.

HSG D - soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

The soils data are digital versions of the soil survey from the NRCS, and each soil type identified was associated with a hydrologic soil group designation.

In all of the major basins the undeveloped land cover is semi-arid rangeland, which is either predominantly sagebrush with a grass understory or an herbaceous mixture of grass, weeds and low growing brush. The existing developed land use is well described in Table 3.2 of the Gillette Comprehensive Plan (RDG 2006) (Reference 9), reproduced in pie chart form in Figure 2.2.

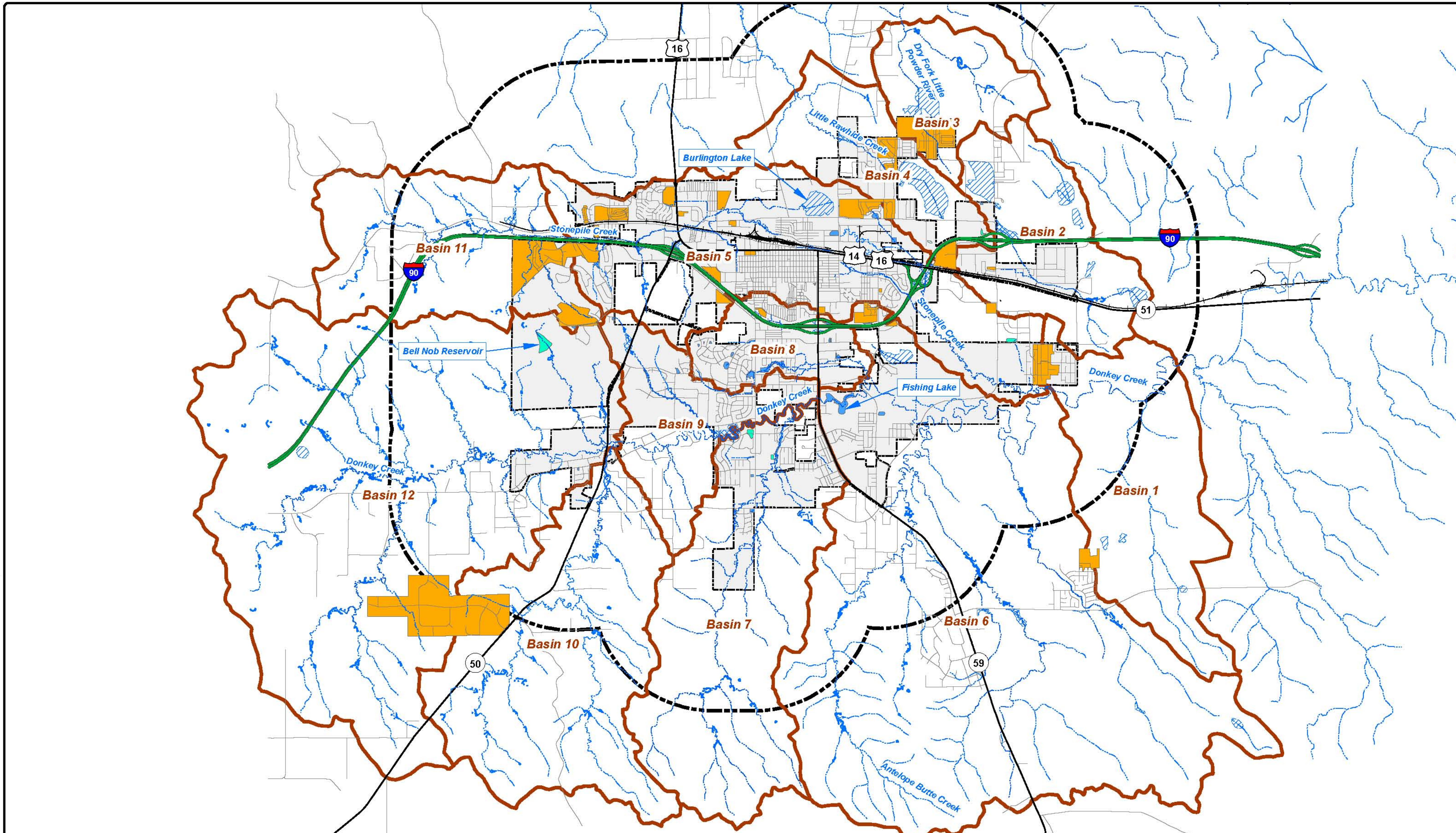
Figure 2.2
Gillette Developed Land Use 2004 Distribution



2.6 MAJOR DRAINAGE BASINS

2.6.1 Basin Delineations

The study area was divided into 12 major drainage basins, shown on Figure 2.3, ranging from 1.9 to 22.2 square miles in area. Basin data is summarized in Table 2.2. Sub-basins were delineated at tributaries, major road crossings, changes in slope, and major drainage features such as ponds and storm sewers. For the NRCS Runoff and Loss Method, the sub-basins should be larger than 0.156 sq. mi. (100 ac), if possible. For some areas, the sub-basins are smaller to accurately represent road crossings or detention. Each major drainage basin within the study area is described in the following paragraphs.



Open Channel
Interstate
State or US Highway
Streets
Railroad

Basin 8 Major Basin
City Limits
Study Area
Disturbed Since 2003

Detention Type
City
County
Private
Stock Pond
Road Inadvertent
Depression Playa

THE INFORMATION ON THIS DRAWING WAS OBTAINED FROM RECORD AND DESIGN DRAWINGS. THE CITY OF GILLETTE MAKES NO GUARANTEE REGARDING THE ACCURACY OF THIS DRAWING OR THE INFORMATION CONTAINED THEREIN.

URS

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

0 6,000
Feet

Major Drainage Basins

Gillette Stormwater Master Plan

2.3

F:\Projects\22241173_Gillette_Stormwater\Sub_00\7.0_CAD_GIS\7.01_GIS_Maps\Figures 201108\Fig2-03 Major Drainage Basins.mxd 8/19/2011

Table 2.2
Summary of Drainage Basin Delineations

Major Basin	Total Area (sq. mi.)	Number of Sub-basins	Max. Sub-basin Size (ac)	Min. Sub-basin Size (ac)	Max. Sub-basin Size (sq. mi.)	Min. Sub-basin Size (sq. mi.)	Lowest Basin Elevation (ft)	Max. Basin Elevation Gain (ft)
1	5.7	8	896	177	1.400	0.276	4420	450
2	4.0	17	579	18	0.905	0.028	4412	180
3	2.5	7	513	55	0.802	0.085	4385	213
4	3.2	14	489	8	0.765	0.013	4404	291
5	8.8	63	311	5	0.486	0.008	4450	335
6	22.2	38	2890	11	4.516	0.017	4450	540
7	8.3	20	3325	11	5.195	0.017	4521	469
8	1.9	29	136	1	0.212	0.001	4503	255
9	3.2	22	223	10	0.348	0.016	4521	313
10	8.6	9	3887	4	6.073	0.006	4572	408
11	5.5	12	1303	16	2.037	0.025	4616	312
12	19.9	17	3583	6	5.599	0.009	4572	408

Notes:
ac = acre
ft = feet
sq. mi. = square mile

2.6.2 Ponds and Detention

Within the study area, there are 147 ponds, which were identified from the 2009 aerial photo provided by the City and the 2009 NAIP. These ponds include stock ponds and produced water ponds, most of which are outside the city limits. Their total area is approximately 265 acres. If the ponds detain 1 foot of water, then this storage represents 265 ac-ft of storage for all minor events. A large portion of this storage is in the upper watersheds of Donkey Creek and Stonepile Creek, and contributes to the infrequency of flood flows in these creeks.

These private ponds are known to attenuate serious flooding (GNR 2001b) (Reference 133). They also intercept minor event flows that might otherwise flow to the creek, so the downstream drainageways (Donkey Creek or Stonepile Creek) only flow when there is a significant event. This creates public complacency about flooding. Reducing low flows also lessens the dilution of flows from the City's wastewater treatment plant.

From a broader perspective, properly maintained ponds *may* provide protection for storms ranging from minor events to a 10- or 25-year event. For major storms, these ponds may actually *increase* the risk of flooding, because of the potential to wash out or otherwise fail and increase the downstream flood flows.

For the purposes of this study, the presence of these structures and their storage volume has been ignored for the following reasons.

- The ponds are privately owned and maintained, and therefore their presence and maintenance into the future cannot be ensured.
- The design criteria for the ponds are unknown.
- The outlet structures are unknown.

- Their operation and maintenance characteristics are unknown. It may be assumed that stock ponds are maintained as full as is practical, so that the owners may ensure water for their stock, and a full pond has little storage.

2.6.3 Donkey Creek and Tributaries

2.6.3.1 Fox Park (Basin 1)

The Fox Park basin includes the most downstream reach of Donkey Creek, which is the only reach downstream of the confluence with Stonepile Creek in the study area. It is included in this plan to provide peak flow rates and a baseline floodplain assessment for future development. Most of this basin is outside the study area. There are no controls on Donkey Creek or the other main drainageways within Basin 1, and all of the channels are natural. Three depression playas were identified in Basin 1. There are no reported areas with drainage problems within this basin.

The only development is in the far northwest corner of this basin, the Fox Park and Arley Acres subdivisions. The soils are dominated by HSG B, with only a small fraction of HSG D and the remainder HSG C.

2.6.3.2 Antelope Butte Creek (Basin 6)

Antelope Butte Creek basin is the largest tributary to Donkey Creek in the study area. Major features in this basin include the confluence of Donkey Creek and Stonepile Creek, Highway 59, South Garner Lake Road, and Butler Spaeth Road.

Fishing Lake, the most notable of the lakes within Gillette, is on Donkey Creek within the study area of Basin 6. Fishing Lake is located in Dalby Park and is a publicly-owned lake. It is created by the Fishing Lake Dam, one of the three jurisdictional (state regulated) dams within the study area. The state reports the dam is a low hazard class, 15-ft high earthen dam, with 94 ac-ft of storage available for fishing. The 2009 Draft TMDL (HDR 2009) (Reference 145) reports that ice cover is present on Gillette Fishing Lake typically from the end of November to mid-April. General information for Fishing Lake is listed in Table 2.3.

Because the lake is kept full for recreation, only about 8 ac-ft of storm storage is available for flood control. Including Fishing Lake, there are 5 detention ponds that were modeled in Basin 6, 3 depression playas, and at least 18 stock ponds. The small City detention pond in the Providence Crossing subdivision was not modeled due to insufficient information. The available mapping indicates that its area and depth are less than half of Pond P6-4, which is about 300 feet downstream. The major drainageways in Basin 6 are all natural channels.

Drainage problems have been identified in the flat area immediately south of Gillette Fishing Lake. The Healthy Styles Market, South of Dalby Park reported 2 feet of water in the 2001 flood. At the intersection of Highway 59 and Southern Drive/South Garner Lake Road, flooding 2 feet deep was reported on May 28, 2001 (GNR, 2001a) (Reference 135).

Highway 59 runs through Basin 6 north and south, and there are large pre-annexation areas including the Sleepy Hollow and Antelope Valley subdivisions in the upper watershed. This is an indication that the basin is under high development pressure.

The soils are dominated by HSG B, with only a small fraction of HSG D and the remainder HSG C.

Table 2.3
General Information – Gillette Fishing Lake

Hydrologic Unit Code	101202010601
303(d) Waterbody ID	WYBF101202010601_01
Year Established	1949
Latitude (near center of lake)	44° 15' 53.147"N
Longitude (near center of lake)	105° 29' 16.453"W
Pool Elevation	4519 feet
WDEQ/WQD Waterbody	2AB
Tributaries	Donkey Creek
Receiving Water	Donkey Creek
Lake Surface Area	25 acres
Maximum Depth	10.4 feet
Mean Depth	5.3
Original Lake Volume	133 acre-feet
Current Lake	94 acre-feet
Watershed Area	25,770 acres
Watershed/Lake Area Ratio	1,000:1
Estimated Annual Inflow to Lake	525 acre-feet/year
Estimated Annual Outflow to Lake	670 acre-feet/year

Source: HDR 2009

2.6.3.3 Donkey Creek Tributary South (Basin 7)

Basin 7, Donkey Creek Tributary South (DCTS) is also under heavy development pressure. A recently completed CLOMR on DCTS has been submitted by the City to FEMA. The Sinclair St., Shoshone Avenue, and Southern Drive Crossings of Donkey Creek Tributary South are all in Basin 7. There are 6 City-owned detention ponds, 2 county-owned detention ponds and 10 stock ponds.

The northernmost 20% of Basin 7 is fully developed, and development pressure is on adjacent lands to the south side of this. The county has recently completed a state-of-the-art recreation center and a new campus of Gillette High School in Basin 7.

Problems with drainage have been noted as icing in the Remington Subdivision, DCTS flooding of Sinclair St. and Southern Drive, flooding and an inadequate channel in the Saunders tributary, and shallow flooding in the Sunburst Subdivision. There are 10 structures visible in the latest aerial photograph (2009) that lie within FEMA Zones A or AE for Donkey Creek, all clustered at the end of Carlisle St.

The soils in Basin 7 are dominated by HSG C, with only a small fraction of HSG D and the remainder HSG B.

2.6.3.4 North Donkey Creek (Basin 8)

Basin 8 is nearly fully developed with residential, commercial and industrial land uses. North Donkey Creek (NDC) has been heavily controlled and channelized through its upper and middle reaches with extensive grass-lined and concrete channels. There are 8 roadway crossings, including Highway 59 and South 4-J Road, 14 City-owned detention ponds and 5 significant inadvertent detention areas along the north side of Interstate-90 (I-90).

Drainage problems noted include 2 flat areas subject to icing in the winter, flooding in the middle reach of NDC (GNR 2007a, GNR 2007b) (References 136, 134), and erosion and sediment problems in the northwest corner along 4-J Road A lower reach of NDC that is not in the City has not been mapped into the FIRM.

Development pressures exist in the remaining 10% of undeveloped land in the basin. Soils in Basin 8 are dominated by HSG D, with only a small fraction of HSG B and a moderate amount of HSG C.

2.6.3.5 Basin 9

Basin 9 contains smaller direct flow areas to Donkey Creek. Basin 9 is about 60% developed into primarily residential subdivisions. There are a number of parcels along West 4-J Road that are listed as pre-annex, so development pressures are viewed as high here. Donkey Creek flows from west to east through Basin 9, and there are crossings at Enzi Drive, Saunders Blvd., Brorby Blvd., Donkey Creek Drive, West 4-J Road, and one private drive crossing. There are 2 City-owned detention ponds and 2 stock ponds in the basin. The soils are dominated by HSG C, with equal fractions of HSG B and HSG D.

There are 8 structures (3 of them appear to be substantial homes) visible in the 2009 aerial photograph that lie within FEMA Zones A or AE for Donkey Creek, and these constitute the major drainage problem noted for the basin. There is also reported flooding in Harder Drive (GNR 2007a) (Reference 136). Aside from road crossings and stock and detention ponds, the major drainageways in Basin 9 are uncontrolled grass-lined channels.

2.6.3.6 Milne Valley (Basin 10)

Milne Valley is a large tributary of Donkey Creek, and about 1/3 of Milne Valley has been developed with very large lot residential developments. Almost all of Basin 10 is outside the city limits, with about 10% of the land in the City or under pre-annexation. There are major crossings of the tributary at Southern Drive and Force Road. There are 25 stock ponds in the basin. The soils are mostly HSG C, with some HSG B in the drainageways, and scattered patches HSG D.

Four structures (2 of them appear to be homes) lie within FEMA Zone A for the tributary and these are the major drainage problems noted for the basin. These structures are visible in the 2009 aerial photograph. Aside from road crossings and stock ponds, the major drainageways are all grass-lined channels.

2.6.3.7 Upper Donkey Creek (Basin 12)

Basin 12 is the largest major basin for Donkey Creek, and its character is similar to Basin 10, with about 1/3 developed into very large lot residential developments. Here again, almost the entire basin is outside the city limits, with about 10% of the land in the City or under pre-annexation. The only major crossing of Donkey Creek is at Highway 50. The soils are mostly HSG C, with some HSG B in the drainageways, and scattered patches HSG D.

There are 2 City-owned detention ponds, 1 depression playa, and at least 67 stock ponds in the basin. There is also the Bell Nob No. 2 dam and reservoir, one of the 3 jurisdictional (state regulated) dams in the study area. This is a low hazard class, well-fed reservoir used primarily for irrigation of the Bell Nob Golf Course. The earthen dam and plastic-lined reservoir intercepts a 0.138 sq. mi. drainage area. The following data was obtained from the Wyoming State Engineers Office permit application map (Permit No. 13163R):

Table 2.4
Selected General Information for Bell Nob No. 2 Reservoir

Year Enlarged	2008
Latitude (near center of lake)	44° 16’ 35.10”N
Longitude (near center of lake)	105° 33’ 44.78”W
Pool Elevation	4695 feet
Tributaries	Unnamed
Receiving Water	Wells
Lake Surface Area	14 acres
Maximum Depth	27 feet
Crest Elevation	4709.5
Storm Storage Volume	30 acre-feet
Current Lake	164 acre-feet
Watershed Area	0.14 sq. mi.

As described later in Section 3, this dam and reservoir is expected to intercept all of the 100-year flows and contain them, even when operating full.

The most pressing drainage problem noted in this basin is the 6 homes and numerous smaller structures that lie within FEMA Zones A or AE for Donkey Creek or its tributaries. Most of these lie along the north side of Force Road in the Donkey Creek Zone AE. These structures are visible in the 2009 aerial photograph. Aside from road crossings and stock ponds, the major drainageways are all grass-lined channels.

2.6.4 Stonepile Creek

Stonepile Creek is a north bank tributary to Donkey Creek, and has been broken up into two major basins for this study: Basin 11 - Upper Stonepile and Basin 5 - Lower Stonepile. The City began as a settlement on Stonepile Creek, so the history of the Creek and the City are closely tied.

2.6.4.1 Upper Stonepile Creek (Basin 11)

Basin 11 is the upper Stonepile Creek watershed, and its character is similar to Basin 12, with about 1/3 developed into large lot residential developments. The entire basin is outside the City limits, with about 10% of the land under pre-annexation. The only major crossing of Stonepile Creek is at Echeta Road, more than half way up the basin. The BNSF railroad tracks that parallel Echeta Road cause a barrier to drainage flows into Stonepile Creek from the north. The soils are mostly HSG C, with some HSG B in the drainageways, and two patches of HSG D.

There are 12 City-owned detention ponds and 15 stock ponds in the basin. Drainage problems noted in the basin include a home and numerous other structures visible in the 2009 aerial photograph, which lie within FEMA Zones A or AE for Stonepile Creek along the south side of Echeta Road. Stonepile Creek has been channelized in the area between I-90 and Echeta Road for about 3,600 feet, where the detailed FEMA Zone AE analysis stops and the approximate methods in Zone A begin. All of the channels are grass lined.

2.6.4.2 Lower Stonepile Creek (Basin 5)

This basin is the most complex and highly developed basin in the study area. It is approximately 90% developed, with all types of land uses. About 80% of the basin is within the city limits. Approximately 5 miles or 70% of Stonepile Creek is channelized within the basin, and many of the tributaries are heavily controlled or completely developed, with little provision for major drainage conveyance and little detention.

The current FEMA floodplains have no building structures in them from the confluence with Donkey Creek up to the Highway 14/16 crossing. Just upstream of the Highway 14/16 crossing there are many small building structures in the Zones A or AE. Known flooding problems exist in several areas:

- The Foothills subdivision contains a major tributary that is diverted by the BNSF and causes flow through the streets, a source of recent flooding (GNR 2007b) (Reference 134).
- There are known flooding issues along 1st and 2nd Streets downtown in central Gillette.
- There are flooding issues at Gurley and 9th St.
- There have been flooding accounts in the Energy Park Subdivision along the BNSF railroad tracks.

There are 2 stock ponds, 10 City-owned detention ponds, 2 County-owned detention ponds, and one relatively small depression playa in Basin 5. One of the City ponds is a large depression playa named Burlington Lake, which is described in the following section.

The soils in Basin 5 are mostly HSG D, with some HSG B on the north edge and southern end, with the remainder HSG C. These clay soils have contributed to the frequent flooding issues.

2.6.4.3 Burlington Lake (Basin 5)

Burlington Lake is in a large depression playa divided by Gillette Dam, one of the 3 jurisdictional (state regulated dam permit No. 1046R) dams in the study area. This is a low hazard class reservoir/playa that was used as a water supply for the railroad and for the City. A diversion structure on Stonepile Creek diverts low flows to the reservoir for flood control. The WYSEO lists the Gillette Dam as 10 feet high and the capacity as 2080 ac-ft. The full playa intercepts a 0.48 sq. mi. catchment without the Stonepile Creek diversion. This catchment is a closed basin within Basin 5, Lower Stonepile Creek. The City has plans to improve McManamen Park, which surrounds Burlington Lake, and provide some stabilization for the inlet channel that conveys flows from Stonepile Creek to the lake.

2.6.5 Little Rawhide Creek (Basin 4)

This basin contains the headwaters of Little Rawhide Creek Watershed and includes a depression playa that overflows to the northwest through the Anderson and Prairie Blossom subdivisions and into the Little Rawhide Creek. This basin slopes to the northwest into the Little Rawhide Creek basin outside the study area. The approximately 128-acre playa and the Little Rawhide Creek channel downstream of the playa were recently studied for a LOMR for the City (Bruce 2008) (Reference 37).

The basin is approximately 25% developed with primarily residential development. About 50% of the basin is within the city limits. Approximately 4000 feet of Little Rawhide Creek is channelized in a grass- and concrete-lined section northwest through the Anderson, Heritage Village and Prairie Blossom subdivisions. This is the reach that has been studied in the LOMR by Bruce Engineering. Little Rawhide Creek has major crossings at Little Powder River Road, Buckskin Drive, Constitution Drive, American Lane, Orchid Lane and Kluver Road. Little Powder River Road has no culvert or low level crossing, and all flows either pond behind or overtop the roadway. There is one crossing of I-90 that conveys upland flows to the depression playa.

Flooding problems have been noted along Spruce and Phoenix Avenues, and along Kluver Road from Orchid Court to Spruce Avenue. This is reflected in the existing FEMA Zone A delineation shown on the 2008 FIRM, and Zone A includes 50 structures in its limits. The LOMR shows floodplain limits mostly within the constructed channels, with some flood waters in Constitution Drive and in American Lane.

Aside from the one large depression playa, there are 2 City-owned and 1 County-owned detention ponds, 1 stock pond, and 2 private detention ponds in the basin. HSG B and C soils predominate in the uplands, while the soils around the creek and under the playa are HSG D.

2.6.6 Dry Fork Little Powder River (Basin 3)

This basin slopes to the northwest into the Little Powder River basin outside the study area. About 10 percent of the basin is in the City and about 60 percent is owned by the Fort Union Coal Mine. This will limit development in this basin. Basin 3 is generally divided into two areas, the southwest area, which drains first to the depression playa and then to the north into the Dry Fork of the Little Power River; and the northeast area, which drains to the northwest into the Dry Fork of the Little Power River.

This basin has about 10-15% of its area developed. There are 6 stock ponds and 1 large depression playa on the north end of the developed area. This depression playa was graded to drain to an open channel to the north by the developer of the Bittercreek Estates subdivision upon an agreement with the mine, which wanted the area drained for their own purposes. The outfall from the developed area is to the depression playa. Other than the channelization of this tributary in the Bittercreek Estates subdivision, the main drainageways in basin 3 are all grass-lined channels. There are no reported areas with drainage problems in this basin. HSG C soils dominate in the uplands, while the soils under the playa are HSG D.

2.6.7 Basin 2

Basin 2 is an area of closed depression playas that lie on the northeast corner of the City. Major drainage crossings exist at I-90 and the BNSF railroad, but there are not many other major drainage structures because of the lack of well-defined flowpaths. There are 5 large depression playas, most of which have no outfall and are more than 5 feet deep. There are also 1 City-owned pond, 1 County-owned pond and 1 stock pond. HSG B and C soils are equally prevalent in the uplands, while the soils under the playas are HSG D.

There is scattered development amounting to about 30% of the basin, and about 10% of the basin is in the City or in pre-annexation. Most of the channels are grass-lined and undeveloped. A short reach of channel in the Collins Heights Subdivision has been controlled with a grass-lined, constructed channel section. This channel has 6 crossings, including one at Potter Avenue. Flooding was reported in low lying areas of this channel on May 9, 2007 (GNR 2007), in Industrial Park. To address the flooding issues in Industrial Park, the City has recently completed a drainage improvement project consisting of selected structure and channel improvements.

2.7 PREVIOUS REPORTS

The City provided pertinent studies and reports relating to the project area drainage basins. The following sections describe the most significant reports and their relevance to this document. All reports received are listed in Section 7, References, but not all of the reports are referenced in the text. Most reports were used to cross-check drainage basin data and flow rates, prepare data for hydraulic calculations, cross-check as-built data, or compare sub-basin boundaries.

2.7.1 City-wide Reports

The US Department of Housing and Urban Development (HUD) Federal Insurance Administration developed a Flood Hazard Boundary Map for the City in May 1976 using approximate methods. HUD subsequently developed a Flood Insurance Study (FIS) in 1977 and a Flood Insurance Rate Map (FIRM) dated May 1978.

The City contracted with Wright McLaughlin Engineers to develop the Master Drainage Plan for the City of Gillette Drainage District (1978 Plan) (Reference 11). The 1978 Plan developed hydrology for Stonepile Creek for its entire length and Donkey Creek from its confluence with Stonepile Creek to upstream of Highway 50. Hydraulic models were developed for Donkey Creek from Highway 59 to Jayhawker Street.

In 1988, the Federal Emergency Management Agency (FEMA) completed a Flood Insurance Study (Reference 18) that covered Stonepile Creek, Donkey Creek, and North Donkey Creek (referred to as Donkey Creek Tributary in the FIS).

In 2008, a new FEMA FIS (Reference 20) was developed for Campbell County, which combined floodplains and profiles from Campbell County and incorporated areas in Gillette. This 2008

FIS did not change the hydrology or peak flow rates from the 1988 FIS, but it did incorporate the 1996 Donkey Creek Floodway Study (Reference 16) described in Section 2.7.2.

The Wyoming Water Quality Assessment and Impaired Waters List (2010 Integrated 305(b) and 303(d) Report) (Reference 29) from WYDEQ describes water quality in Stonepile Creek, Donkey Creek and Fishing Lake:

"Gillette is the fourth largest community in Wyoming and lies at the headwaters of the Donkey Creek drainage. Monitoring by WDEQ (2000) and Campbell County Conservation District (CCCD) indicate that Donkey Creek, from the Belle Fourche River upstream to an undetermined distance above Antelope Butte Creek is impaired for contact recreation due to exceeding the fecal bacteria criterion. Stonepile Creek, a tributary to Donkey Creek, is also on the 303(d) List for not supporting its contact recreation uses, and data from the Little Powder River and Belle Fourche Drainages Watershed Implementation Section 319 Project (CCCD, 2008) show that this impairment extends to an undetermined distance above the junction of highways 14/16 and 59. A watershed plan and implementation to address this listing focuses on septic system improvements. TMDLs for all listings on the Belle Fourche River, Donkey Creek and Stonepile Creek are expected to be completed in 2011.

Gillette Fishing Lake is currently on the 303(d) List for sediment and phosphate impairments. The source of these pollutants was investigated by CCCD using Section 205j funding, and data suggested that stormwater from the City of Gillette was the primary source. CCCD, in cooperation with the City of Gillette, has developed a watershed plan to address these two impairments. Corrective actions by City of Gillette have included the installation of stormceptors and plans to build a wetland, both of which are expected to remove sediment and phosphorus from stormwater. There are also plans to dredge the lake to remove sediment, and to install bank stabilization structures in 2012. The City of Gillette is currently pursuing a grant from the Wyoming Wildlife and Natural Resource Trust to help offset the costs of upgrading Gillette Fishing Lake. The City is also in the process of preparing a TMDL for Gillette Fishing Lake."

A draft TMDL was prepared for Gillette Fishing Lake, and after review it was decided to prepare a use attainment analysis that would change the use classification. Its current class is 2AB, which supports game fish and drinking water. The water quality status of Gillette Fishing Lake as of the writing of this report is that the Lake will be dredged and the shores stabilized as a project for 2011. A floating vegetative island was established in 2010 in an effort to absorb nutrients and improve water quality. Donkey and Stonepile Creeks are both classed as 3B, or "Tributary waters including wetlands not supporting fish or drinking water."

2.7.2 Reports for Donkey Creek and Tributaries

In 1996, Consolidated Engineers, Inc. developed a Floodway Study of Donkey Creek for the City (Reference 16) under project No. 95EN42. This study concluded that the basin curve numbers had not changed significantly since the 1978 Plan was developed, so no new hydrology was developed. HEC-2 was used to estimate flood depths for the 10-, 50-, 100-, and 500-year events.

For North Donkey Creek, *The Homestead Trickle Channel Hydraulic Analysis* by WWC Engineering in 2007 (WWC 2007) (Reference 30) for WYDOT documents the drainage study for an area mostly upstream of Highway 59 (Douglas Highway), the storm sewer design along the highway, and the design of the Highway 59 crossing of North Donkey Creek.

The Phase II Final Drainage And Erosion Control Report for RC Ranch Phase I (August 2006) (Reference 93) in Donkey Creek Tributary South (Basin 7) cites and reproduces a 1982 report that accounts for "storage" *above* the 100-year floodplain as defined in the 1978 Plan. While there are good reasons *not* to detain flood flows from properties directly adjacent to a major drainageway, storage above the flood levels in the main channel is generally considered a rise in the base flood elevation and not allowed. This "existing detention" was not modeled as part of this study.

Similarly, the Drainage Report for College Park II Subdivision (March 2007) (Reference 66) documents use of the Donkey Creek Tributary South floodplain for detention.

A regional study completed for the Sunburst West outfall to Donkey Creek is documented in *Storm Drainage Study for The Sunburst West Addition* by Worthington, Lenhart & Carpenter, Inc. in September, 2003 (Reference 111). The hydrology in this report used the Colorado Urban Hydrograph Procedure and provided recommendations for two options for storm improvements. Eventually, about 3,600 linear feet of box culvert was installed along Bird Street based on this study.

2.7.3 Stonepile Creek

Two studies were completed on tributaries to Stonepile Creek that go through the center of town. Hoskins-Western-Sonderegger, Inc. completed the Preliminary Report on 1st Street and Richards Avenue Stormwater Flooding in 1982 (Reference 77). The Rational Method was used to estimate flows on the south side of the BNSF railroad and between Burma Avenue and Gillette Avenue. This report provided flow rates at design points in this area, evaluations of the systems existing at the time, and recommendations for changes. It recognizes the surcharges at 2nd St. and Stocktrail (overflows at Rohan), and cites a storm in the summer of 1982 where the highway was overtopped.

PCA completed the Second Street Drainage Study in July 1986 (Reference 105). The Rational Method was used to estimate flows in an area South of 2nd St. and between Brooks Avenue and Richards Avenue. The report provided peak flows to the main storm sewer in Second St., but it did not provide an evaluation of the main line.

Although plans and specifications were provided for improvements to Burlington Lake and McManamen Park, no hydrologic or hydraulic information was included.

2.7.4 Little Rawhide Creek (Basin 4)

The LOMR report on Little Rawhide Creek by Bruce Engineering reports flow rates and provided the HEC-RAS model used for this floodplain delineation. The Rational Method was used to calculate flow rates.

For analyzing the playa, it was assumed that the water surface elevation in the playa was equal to the invert of the 30-inch diameter pipe outfall. The 100-year event was routed through the 733-acre playa subcatchment using CUHP hydrology, and the calculations show that the 100-year storm would cause a 3-inch increase in the lake level. The 3-inch increase results in a 5 cfs flow rate through the 30-inch outlet pipe, which is the documented upstream flow for the Rawhide Creek LOMR.

SECTION THREE
HYDROLOGIC ANALYSIS

3.1 METHODOLOGY AND DATA

New hydrologic and hydraulic models were developed for each major basin using InfoSWMM (Reference 137). InfoSWMM is highly developed, well supported hydrologic/hydraulic modeling software that is fully GIS integrated. Within InfoSWMM, the National Resources Conservation Service (NRCS) Unit Hydrograph (UH) method was used for estimating rain storm distributions and watershed runoff conditions. The NRCS-UH method is deterministic and uses the NRCS curve number method to determine losses due to soil infiltration, evaporation, and loss due to ground cover. This method is described in Technical Release 55 (TR-55) (NRCS 1986) (Reference 138). Model components and selected methodology are listed in Table 3.1. All hydrologic models prepared for this study are based on the proposed City of Gillette Storm Drainage Design Criteria, which have been developed concurrently with this Master Planning effort, and modeling guidelines developed separately for the City as part of this project.

Table 3.1
Model Components

Model Component	Selected Methodology
Infiltration Loss	NRCS Runoff Curve Number Method
Runoff Transformation	NRCS Unit Hydrograph Method
Channel Routing	Kinematic Wave

Notes:
NRCS = Natural Resources Conservation Service (formerly named SCS)

3.1.1 Design Rainfall

The design rainfall for this study is based on current rainfall data used in Gillette, which is from the National Oceanic & Atmospheric Administration (NOAA) Atlas 2, Volume II-Wyoming Isopluvial maps (NOAA 1973) (Reference 122). The 24-hour rainfall depths used in the hydrologic modeling are listed in Table 3.2. Rows in **bold** font were used in the hydrologic modeling.

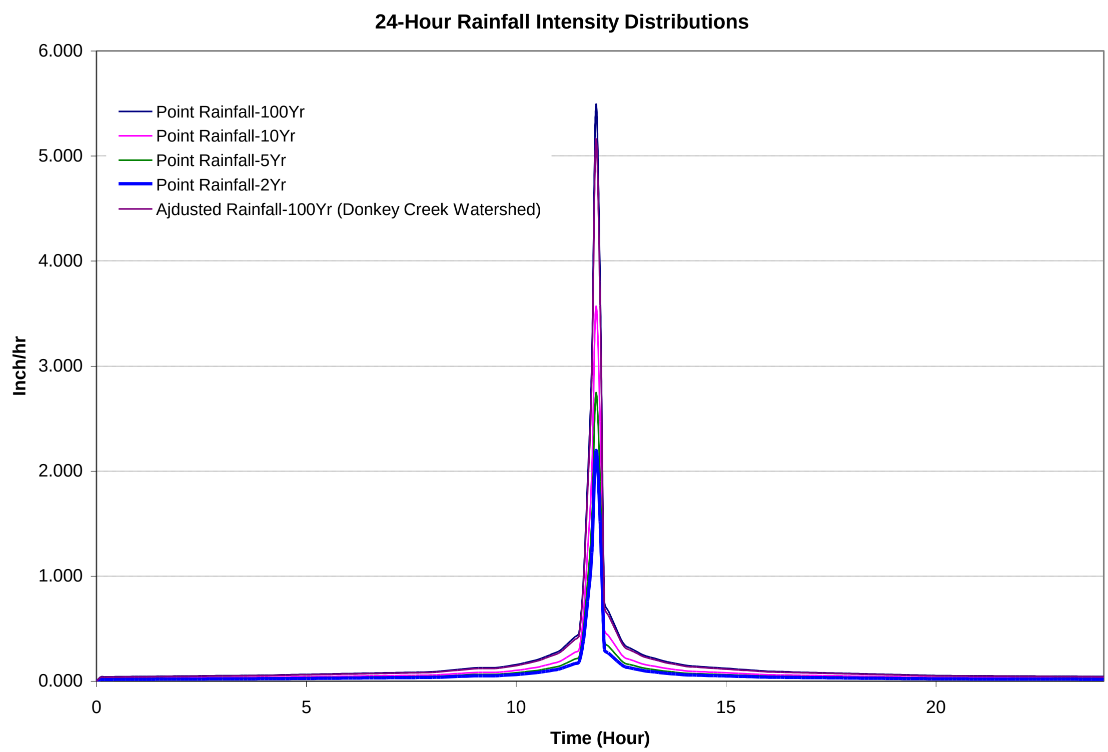
Table 3.2
Design Rainfall

Return Period (years)	24-hour Rainfall (inches)
2	**1.6**
5	**2.00**
10	**2.60**
25	3.20
50	3.60
100	**4.00**

The rainfall intensity distribution of the 24-hour frequency storm is the NRCS Type II rainfall distribution. The 24-hour rainfall intensity distributions of 2-year, 5-year, 10-year, and 100-year storms were generated, based on NRCS Type II rainfall distribution and shown in Figure 3.1. The distributions were entered into the hydrologic model as a time series for each storm event.

For watersheds over 10 square miles in area, it is appropriate to reduce the amount of point rainfall over the entire watershed. For example, according to Figure 14 in NOAA ATLAS 2, Volume II (Reference 122), a 24-hour depth-area reduction factor of 0.94 was defined for Donkey Creek watershed, which has a total area of 84.2 sq. mi. The 100-year, 24-hour point rainfall depth was multiplied by the reduction factor, then the adjusted rainfall total was applied to the 100-year, 24-hour storm distribution for Donkey Creek watershed.

Figure 3.1
24-hour NRCS Type II Rainfall Distribution of Frequency Storms in City of Gillette, Wyoming



3.1.2 Sub-basin Delineations

Sub-basins for the InfoSWMM model were delineated in ArcGIS from drainage divides shown on the 2-foot contour topography (2003) provided by the City, and U.S. Geologic Survey (USGS) 7.5-minute quadrangles for the upper areas of the major basins. Sub-basins were further delineated based on the expected control of runoff by ponds, structures, and roadway fills and cuts. Basin delineation and stream network definition were completed in an ArcMap® GIS environment. The sub-basin boundaries and stream network were refined using 2-ft contours, aerial photography, field survey, and site visit data.

The study area was divided into a total of 257 sub-basins with areas ranging from 0.001 sq. mi. up to 6.1 sq. mi. Basin maps are provided in Figure 3.2.

Existing condition parameters including area (measured in GIS), curve number (CN), and time of concentration (t_c) for each sub-basin were estimated for use in the InfoSWMM model, described as follows.

Soils and Geology

The HSG was determined for each of the soil mapping units from the NRCS SSURGO data for Campbell County, shown in Figure 3.3. Three HSGs are found within the Gillette study area. Group C soils, with low infiltration rates, dominate the study area at 52% coverage. Almost all of the soils in the Gillette study area are in HSGs C and D, with low and very low infiltration and high runoff characteristics. In undeveloped areas, the predominance of HSG C and D soils give these basins a higher runoff per unit area, as compared to basins with soils dominated by HSG B. Table 3.3 provides statistics for the HSGs within each major drainage basin.

Table 3.3
HSGs within the Gillette Study Area Drainage Basin

HSG	Basin Coverage (%)	Major Drainage Basin									
		Donkey Creek and Tributaries				Stonepile Creek			East Fork Little Rawhide Creek Basin 4	Dry Fork Little Powder River Basin 3	Closed Basins Basin 2
		Basin 6	Basin 7	Basin 8	Basins 9, 10, 12	Basin 5	Basin 11	Burlington Lake			
A	0	0	0	0	0	0	0	0	0	0	0
B	36	58	27	1	25	33	25	40	47	10	51
C	52	29	67	41	67	31	73	4	15	87	44
D	12	13	6	58	8	36	2	56	38	3	5

Notes:
HSG = Hydrologic Soil Group
% = percent

Land Use

Existing land use data was not directly applied in developing hydrologic parameters, but the parameters developed were checked for reasonableness against the existing land use map, included in Appendix A from the Gillette Comprehensive Plan (Reference 9). Development of the existing hydrologic parameters is based on soil type and measured impervious areas, as explained below. Future land use projections from the Gillette Comprehensive Plan were used to develop hydrologic parameters. This map is also in Appendix A.

Runoff Curve Number (CN) Development

Runoff CN is a parameter developed by the NRCS to quantify the relationship between rainfall, infiltration, and runoff. It represents the combination of an HSG and a land use class and condition (McCuen 1998). Runoff CNs are estimated as functions of land use or imperviousness, HSG, and antecedent moisture condition (AMC).

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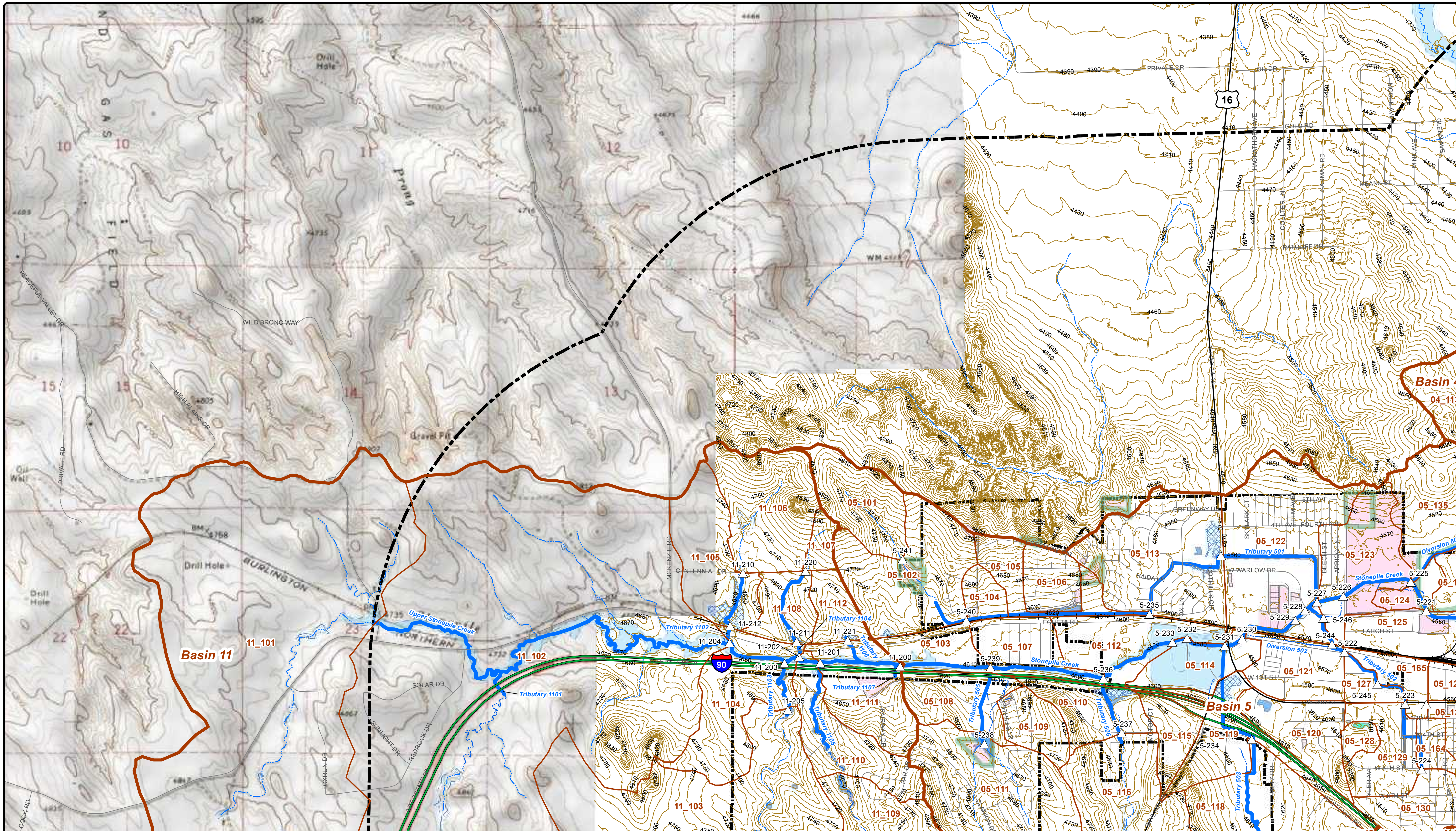

8-210

Legend	
Design Points	Topographic Contour (ft)
Study Reaches	Interstate
Open Channel	State or US Highway
Basin 8 Major Basin	Streets
08_101 Subbasin	Railroad
Floodplain	
City Limits	
Study Area	
City Property	
Existing Parks	

Detention Type

- City
- County
- Private
- Stock Pond
- Road Inadvertent
- Depression Playa

URS

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

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Drainage Basin Map
Page 1 of 6

Gillette Stormwater Master Plan

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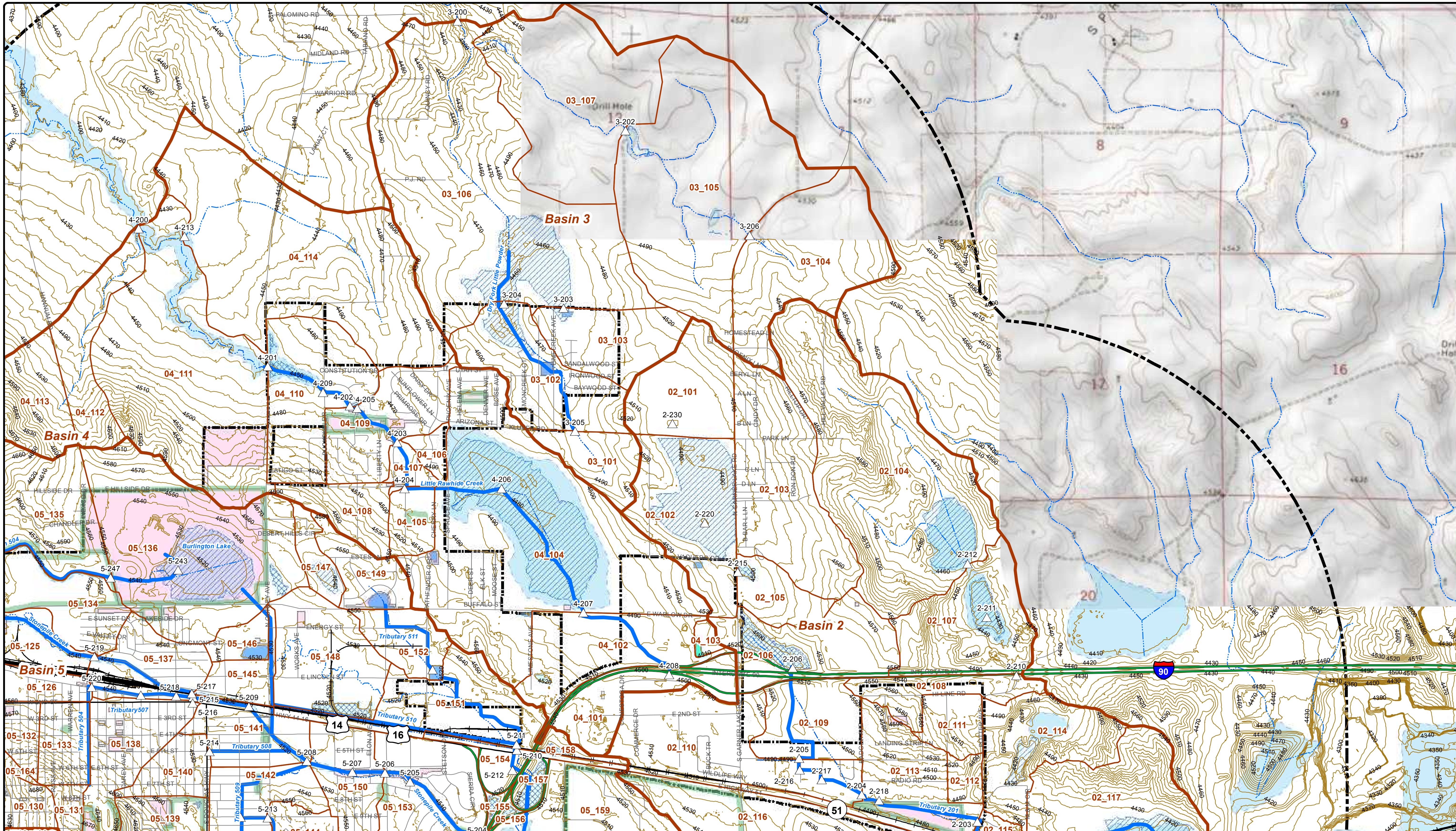

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8-210 Design Points	Floodplain	Topographic Contour (ft)	**Detention Type**
Study Reaches	City Limits	Interstate	City
Open Channel	Study Area	State or US Highway	County
Basin 8 Major Basin	City Property	Streets	Private
08_101 Subbasin	Existing Parks	Railroad	Stock Pond
			Road Inadvertent
			Depression Playa

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Drainage Basin Map
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Gillette Stormwater Master Plan

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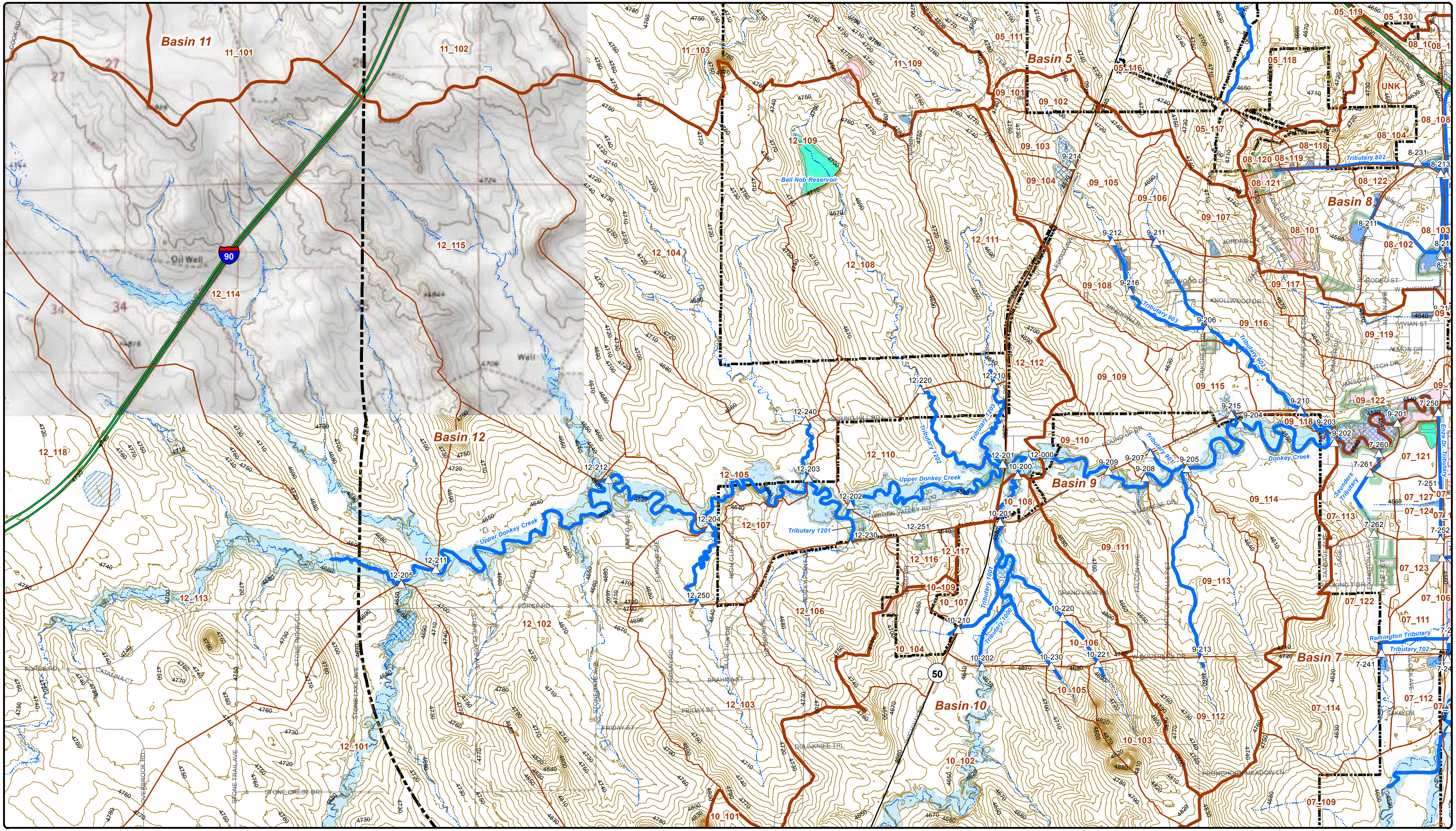

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- 8-210 Design Points
- Study Reaches
- Open Channel
- Basin 8 Major Basin
- 08_101 Subbasin
- Floodplain
- City Limits
- Study Area
- City Property
- Existing Parks
- Topographic Contour (ft)
- Interstate
- State or US Highway
- Streets
- Railroad

Detention Type

- City
- County
- Private
- Stock Pond
- Road Inadvertent
- Depression Playa

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Drainage Basin Map
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Gillette Stormwater Master Plan

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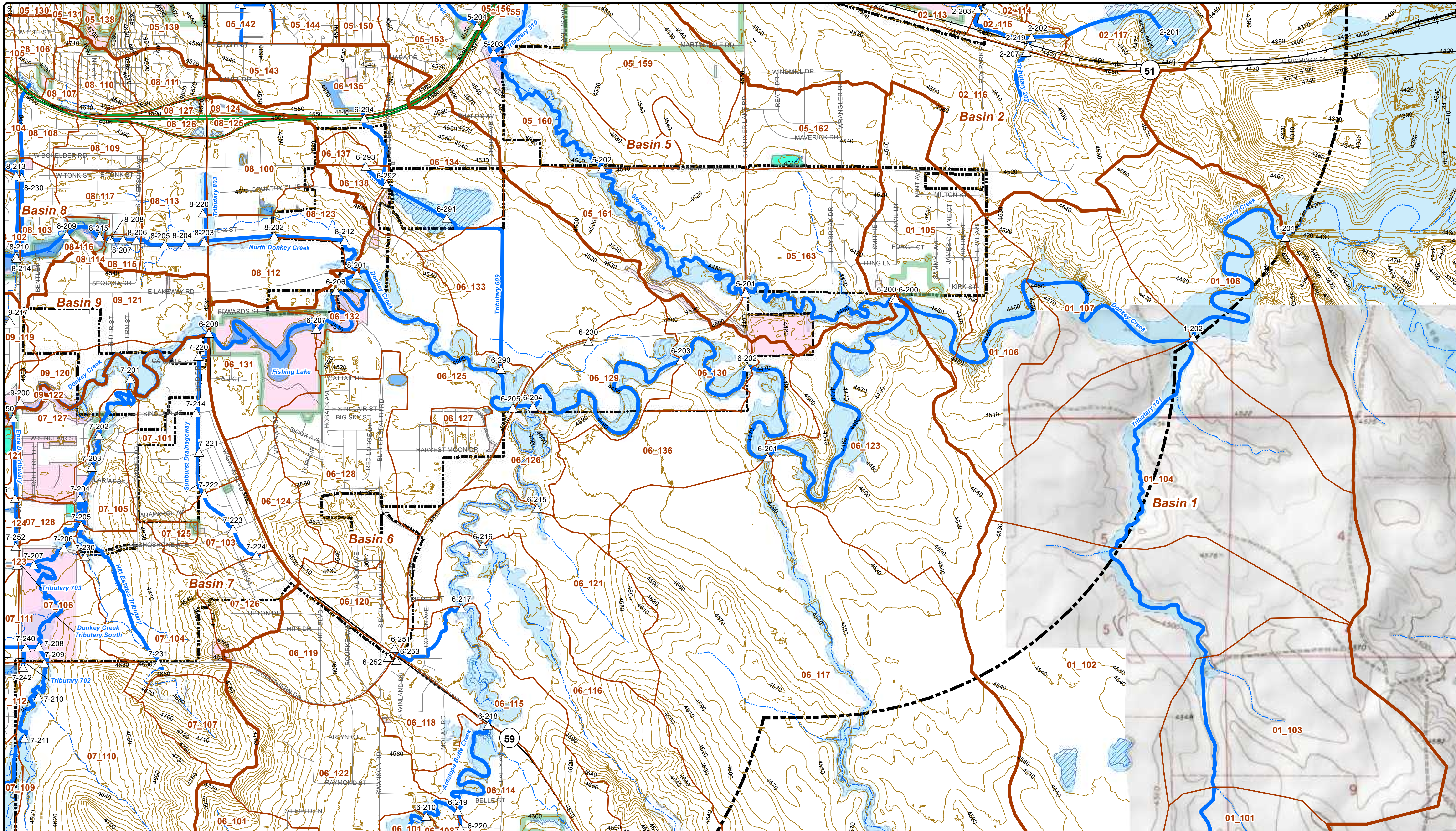

8-210 Design Points
Study Reaches
Open Channel
Basin 8 Major Basin
08_101 Subbasin
Floodplain
City Limits
Study Area
City Property
Existing Parks
Topographic Contour (ft)
Interstate
State or US Highway
Streets
Railroad

Detention Type
City
County
Private
Stock Pond
Road Inadvertent
Depression Playa

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Drainage Basin Map
Page 4 of 6

Gillette Stormwater Master Plan

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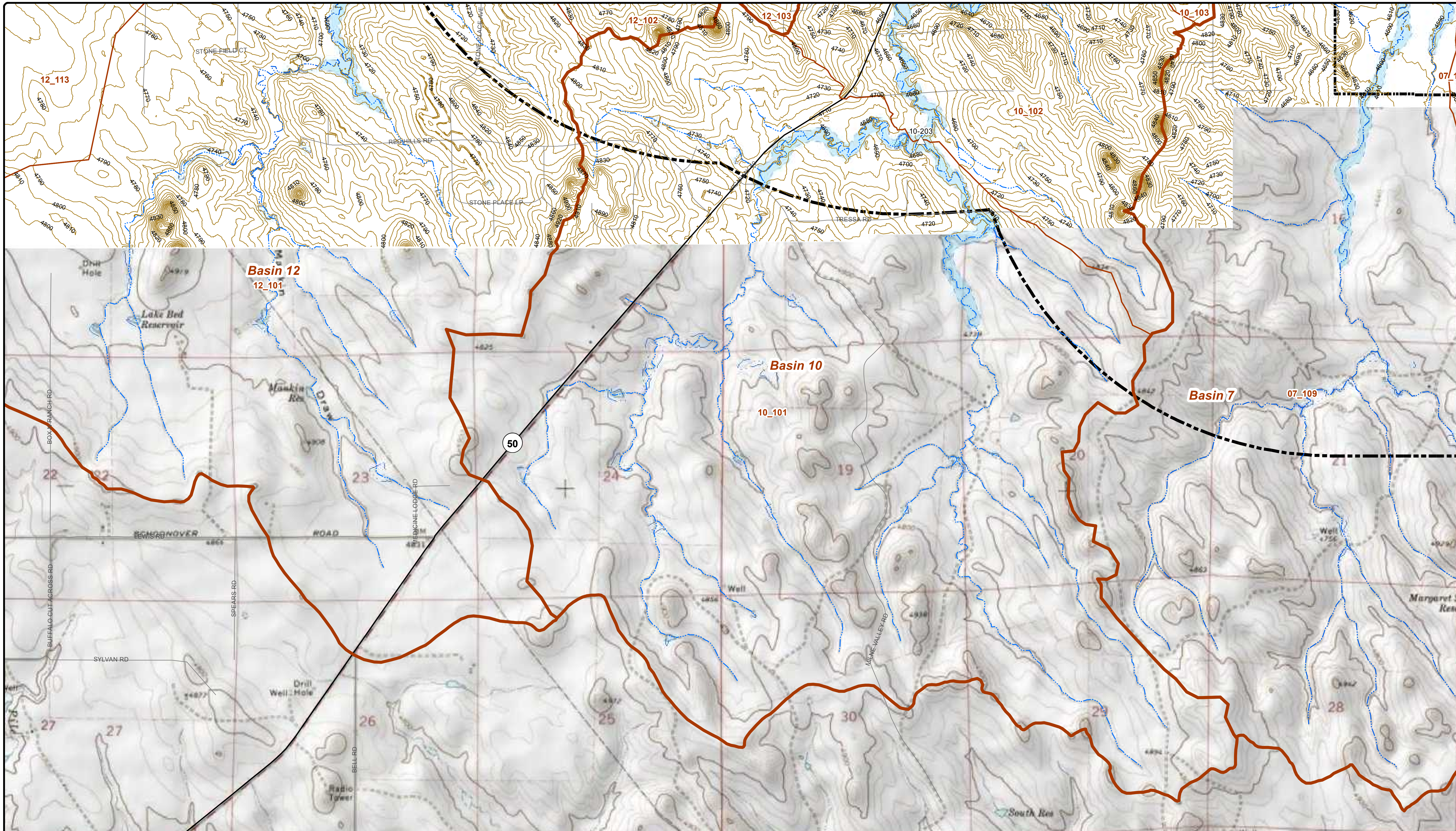

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8-210 Design Points
Study Reaches
Open Channel
Basin 8 Major Basin
08_101 Subbasin

Floodplain
City Limits
Study Area
City Property
Existing Parks

Topographic Contour (ft)
Interstate
State or US Highway
Streets
Railroad

Detention Type
City
County
Private
Stock Pond
Road Inadvertent
Depression Playa

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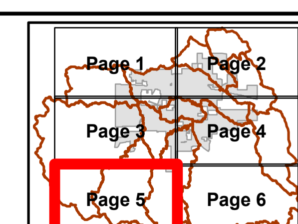

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Drainage Basin Map
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Gillette Stormwater Master Plan

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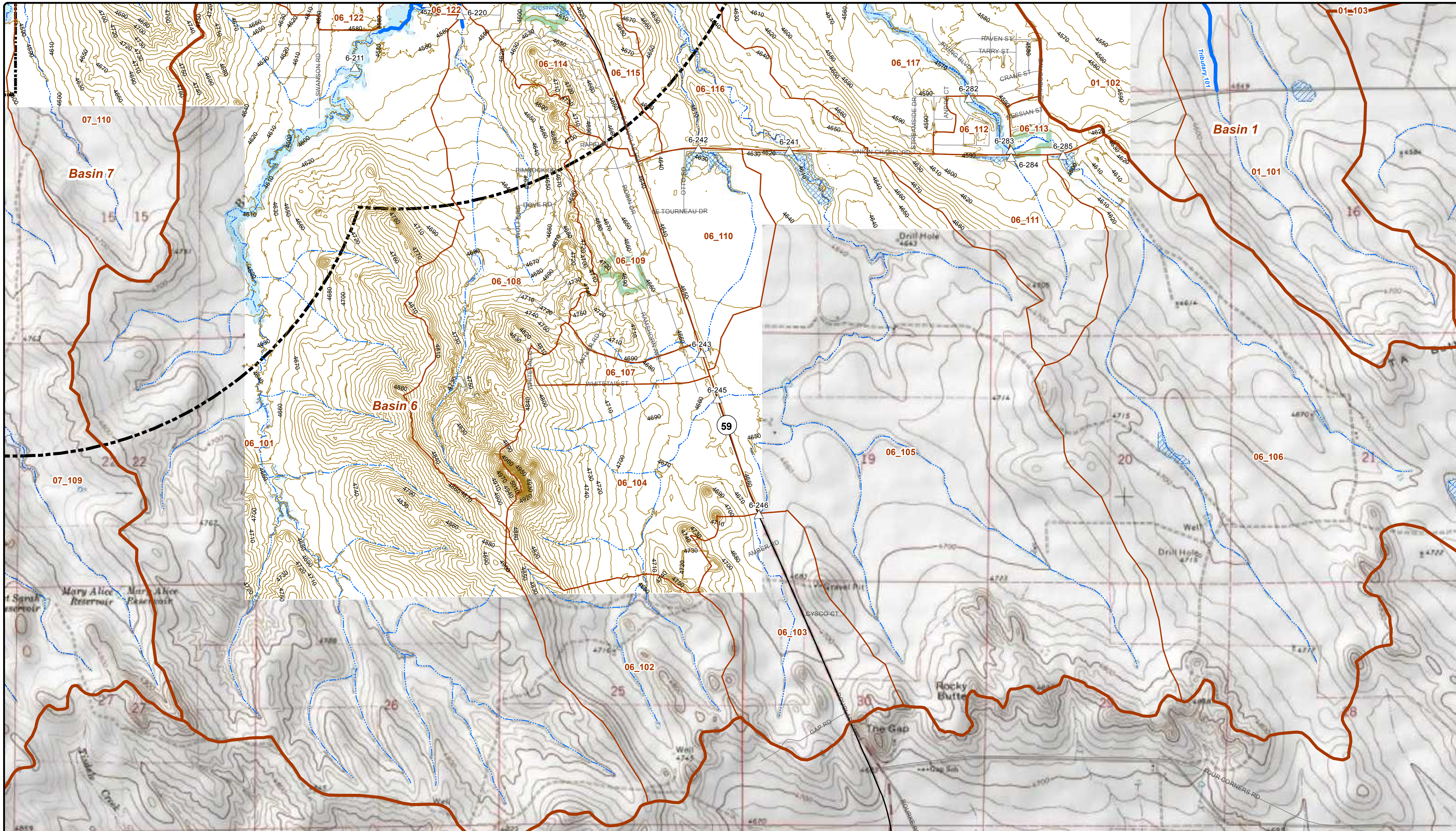

8-210 Design Points
Study Reaches
Open Channel
Basin 8 Major Basin
08_101 Subbasin
Floodplain
City Limits
Study Area
City Property
Existing Parks
Topographic Contour (ft)
Interstate
State or US Highway
Streets
Railroad

Detention Type
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County
Private
Stock Pond
Road Inadvertent
Depression Playa

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Drainage Basin Map
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Gillette Stormwater Master Plan

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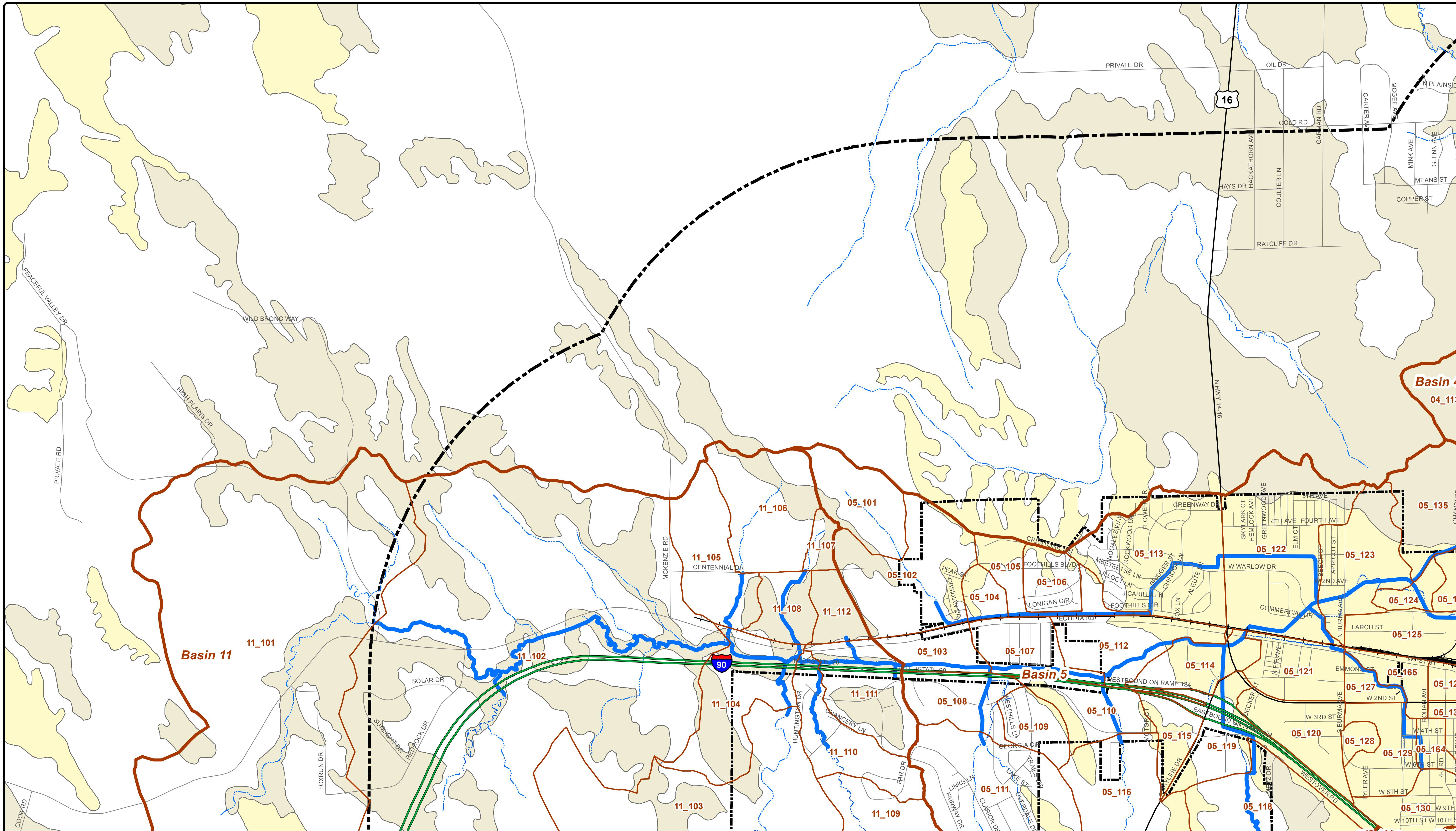

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Study Reaches	Interstate
Open Channel	State or US Highway
Basin 8 Major Basin	Streets
08_101 Subbasin	Railroad
City Limits	
Study Area	

Hydrologic Soil Group B
Hydrologic Soil Group C
Hydrologic Soil Group D
Water

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Hydrologic Soil Groups
Page 1 of 6

Gillette Stormwater Master Plan

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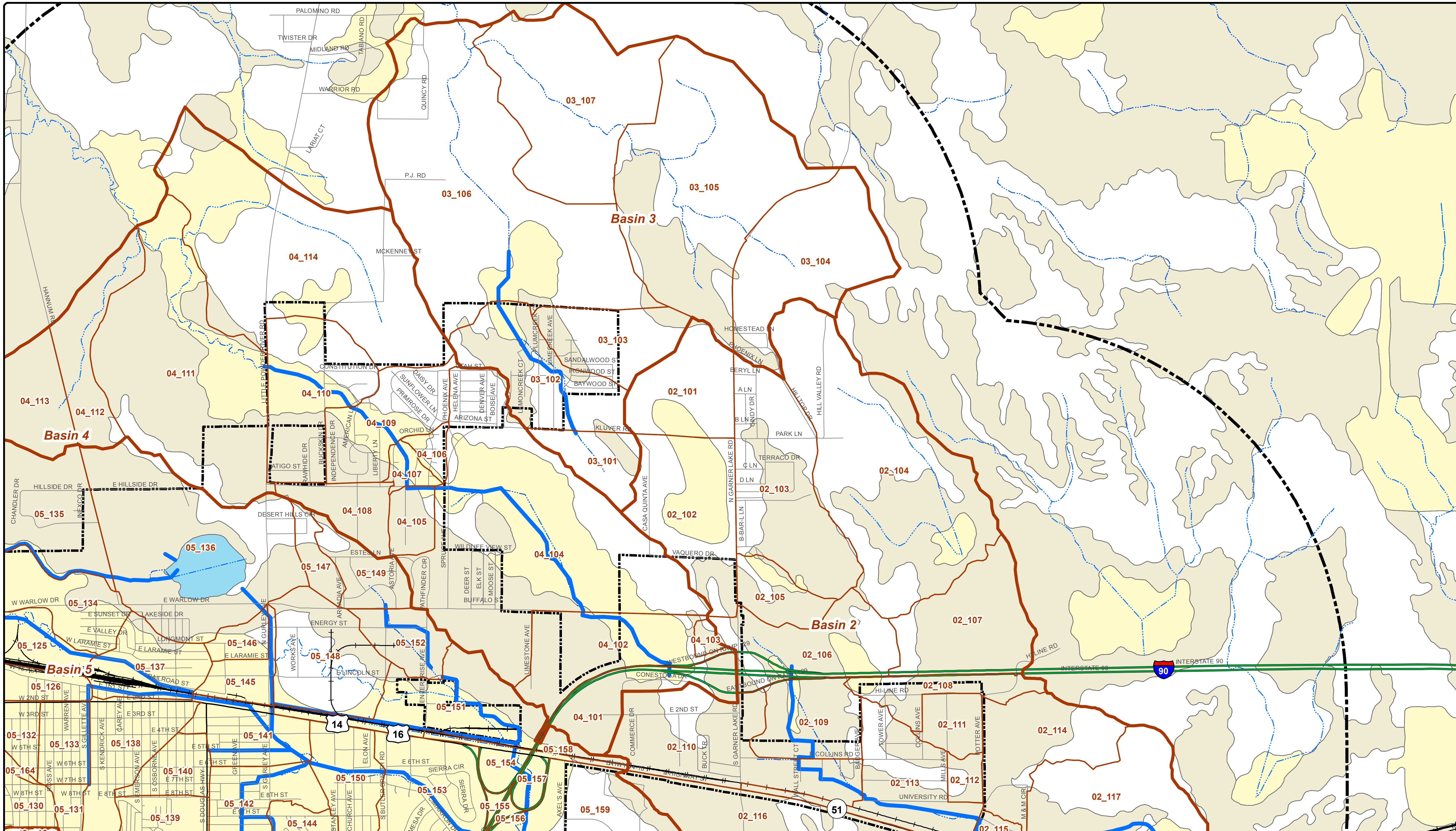

Study Reaches	Interstate
Open Channel	State or US Highway
Basin 8 Major Basin	Streets
08_101 Subbasin	Railroad
City Limits	
Study Area	

Hydrologic Soil Group B
Hydrologic Soil Group C
Hydrologic Soil Group D
Water

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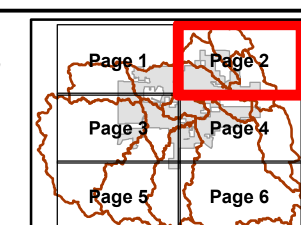

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Hydrologic Soil Groups
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Gillette Stormwater Master Plan

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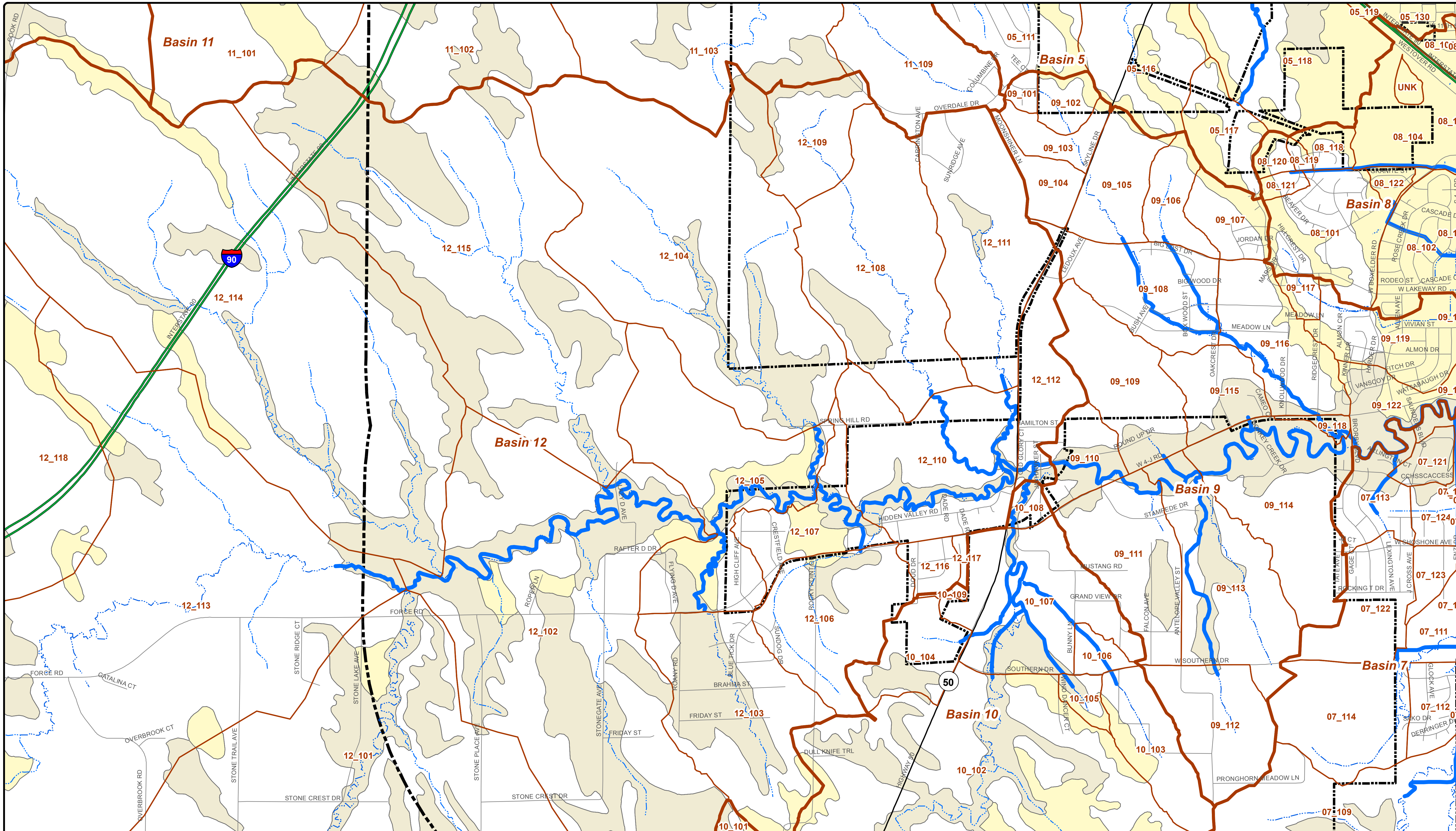

Study Reaches	Interstate
Open Channel	State or US Highway
Basin 8 Major Basin	Streets
08_101 Subbasin	Railroad
City Limits	
Study Area	

Hydrologic Soil Group B
Hydrologic Soil Group C
Hydrologic Soil Group D
Water

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Gillette Stormwater Master Plan

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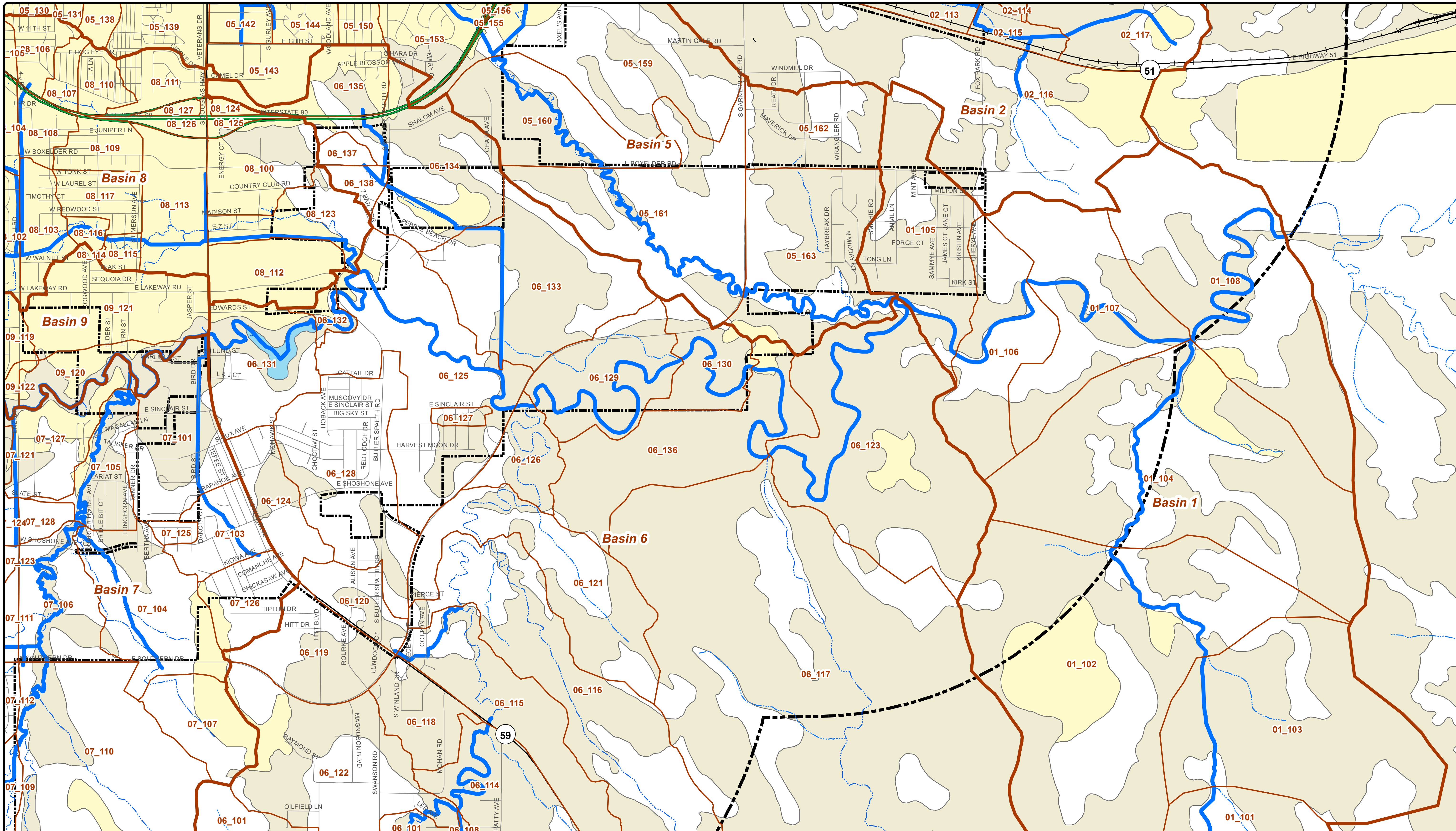

ENERGY CAPITAL OF THE NATION · CITY OF GILLETTE, WYOMING
CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

URS

Legend	
Study Reaches	Interstate
Open Channel	State or US Highway
Basin 8 Major Basin	Streets
08_101 Subbasin	Railroad
City Limits	Hydrologic Soil Group B
Study Area	Hydrologic Soil Group C
	Hydrologic Soil Group D
	Water

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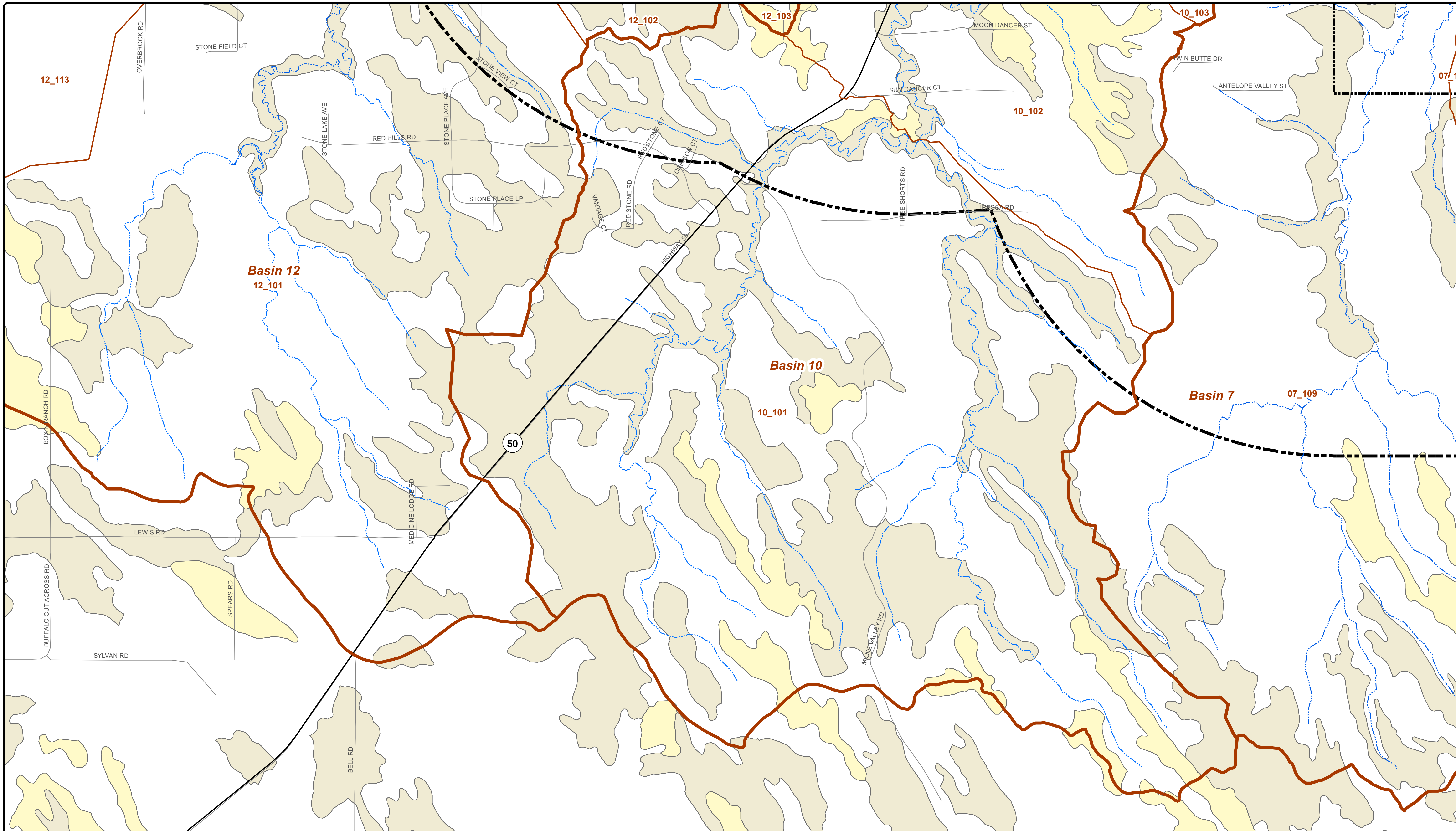
Feet

Hydrologic Soil Groups
Page 4 of 6

Gillette Stormwater Master Plan

3.3



Study Reaches
Open Channel
Basin 8 Major Basin
08_101 Subbasin
City Limits
Study Area

Interstate
State or US Highway
Streets
Railroad

Hydrologic Soil Group B
Hydrologic Soil Group C
Hydrologic Soil Group D
Water

ENERGY CAPITAL OF THE NATION · CITY OF GILLETTE, WYOMING

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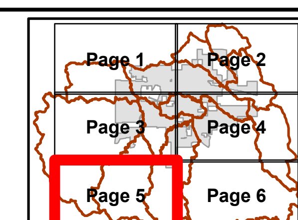

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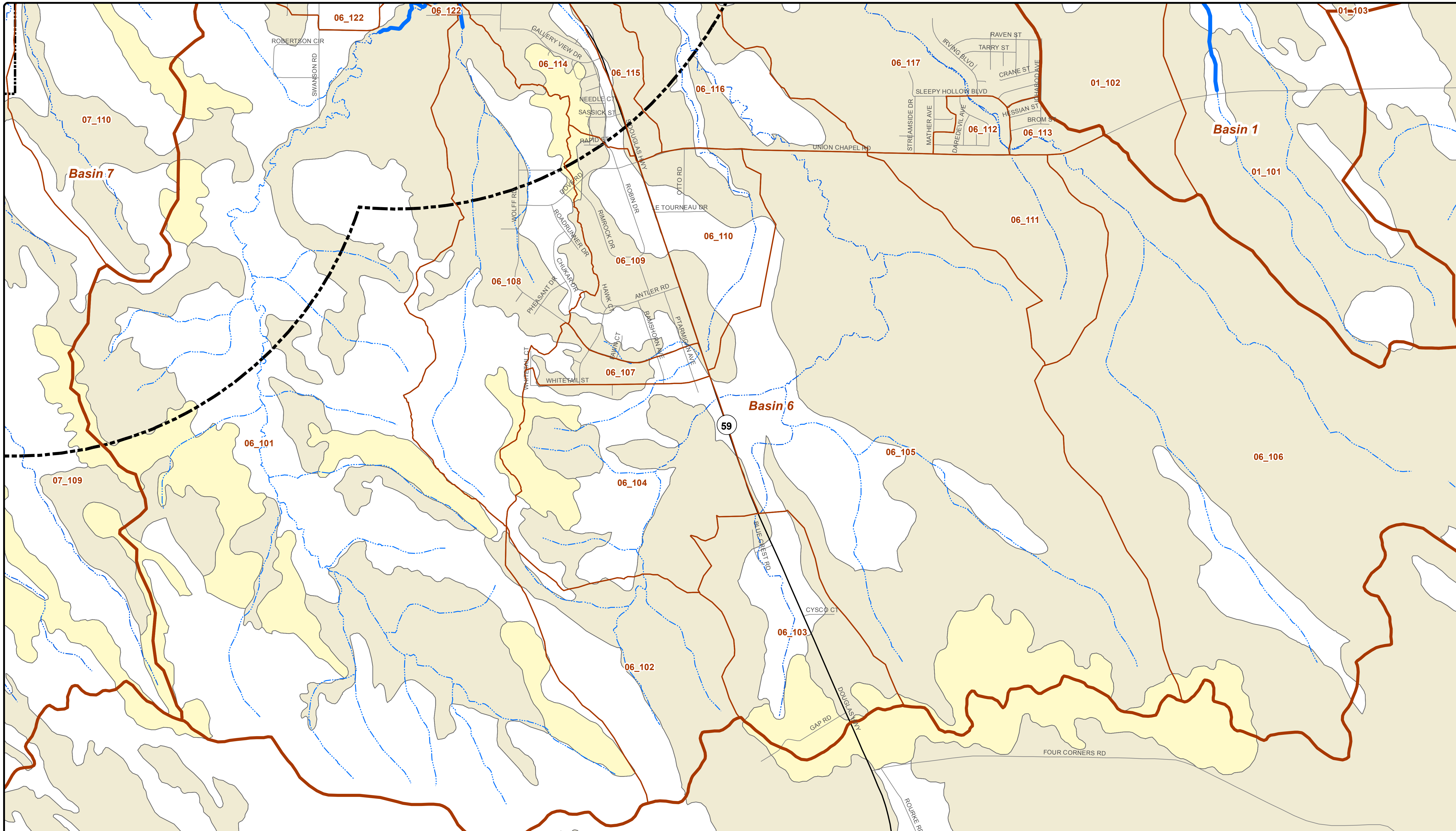
Hydrologic Soil Groups
Page 5 of 6

Gillette Stormwater Master Plan

3.3



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URS

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

- Study Reaches
- Open Channel
- Basin 8 Major Basin
- 08_101 Subbasin
- City Limits
- Study Area
- Interstate
- State or US Highway
- Streets
- Railroad
- Hydrologic Soil Group B
- Hydrologic Soil Group C
- Hydrologic Soil Group D
- Water

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Hydrologic Soil Groups
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Gillette Stormwater
Master Plan

3.3

For each sub-basin in the study area, infiltration and runoff volumes were calculated using the NRCS Runoff Curve Number (runoff CN) Loss Method. A composite runoff CN was calculated for each sub-basin and imported into InfoSWMM. For modeling purposes, initial infiltration loss rates were calculated as functions of composite runoff CNs and entered into the model as "Depression Loss."

The sub-basin parameter CNs were estimated first for Basins 7 and 8. A curve number for the basin was estimated that would be applied if there were no impervious land cover in the basin. This was done noting soil types and pervious land cover in each sub-basin, and equating these with the tables of curve numbers in TR-55 (Reference 138). This CN was then modified by estimating the percent of impervious land in the basin, and calculating an area weighted average of the impervious CN (98) and pervious CN.

Impervious areas in each sub-basin in Basins 7 and 8 were estimated using the extensive GIS data available from the City. Impervious area due to buildings was estimated directly from the Buildings GIS polygons. Impervious areas resulting from roadway pavements were estimated using an assumed offset distance from the City of Gillette street centerline database. Impervious areas outside the buildings for single family residences (SFRs) were estimated by counting the number of SFRs per sub-catchment and multiplying with an average additional impervious area for each SFR. This average was obtained by sampling random SFRs throughout the City and measuring the added impervious area, then calculating the average area. Non-SFR impervious areas were estimated using a factor of 2.2 on the total building area for each sub-catchment. The non-SFR impervious areas and the SFR impervious areas were combined and divided by the total sub-catchment area to obtain the percent impervious for each sub-catchment.

The resulting calculated percent of impervious land was compared to an estimate made by comparing it to the aerial image data for reasonableness. The resulting CN was also compared to the aerial photographs for reasonableness. CN values for the sub-basins in the other major basins were estimated by comparing them to sub-basins in 7 and 8 visually, using the aerial photograph and soils data.

Future conditions CNs were estimated by overlaying the sub-basins with the future land use maps from the Gillette Comprehensive Plan. Each sub-basin was then evaluated for change from the existing condition, and each sub-basin that changed was assigned a future CN that corresponded to the future land use. Sub-basins that did not change were assigned a CN equal to the existing condition CN.

Average runoff CNs for the study area are summarized in Table 3.4. CNs for the study area are shown in Figures 3.4 and 3.5 for existing and future basin conditions, respectively. Detailed sub-basin data is summarized in Table B.1 in Appendix B. CN calculations and percent imperviousness calculations are also in Appendix B.

Table 3.4
Runoff Curve Number Summary

	Existing Runoff CN	Future Runoff CN
Minimum	60	61
Maximum	96	97
Area Weighted Average	72	72

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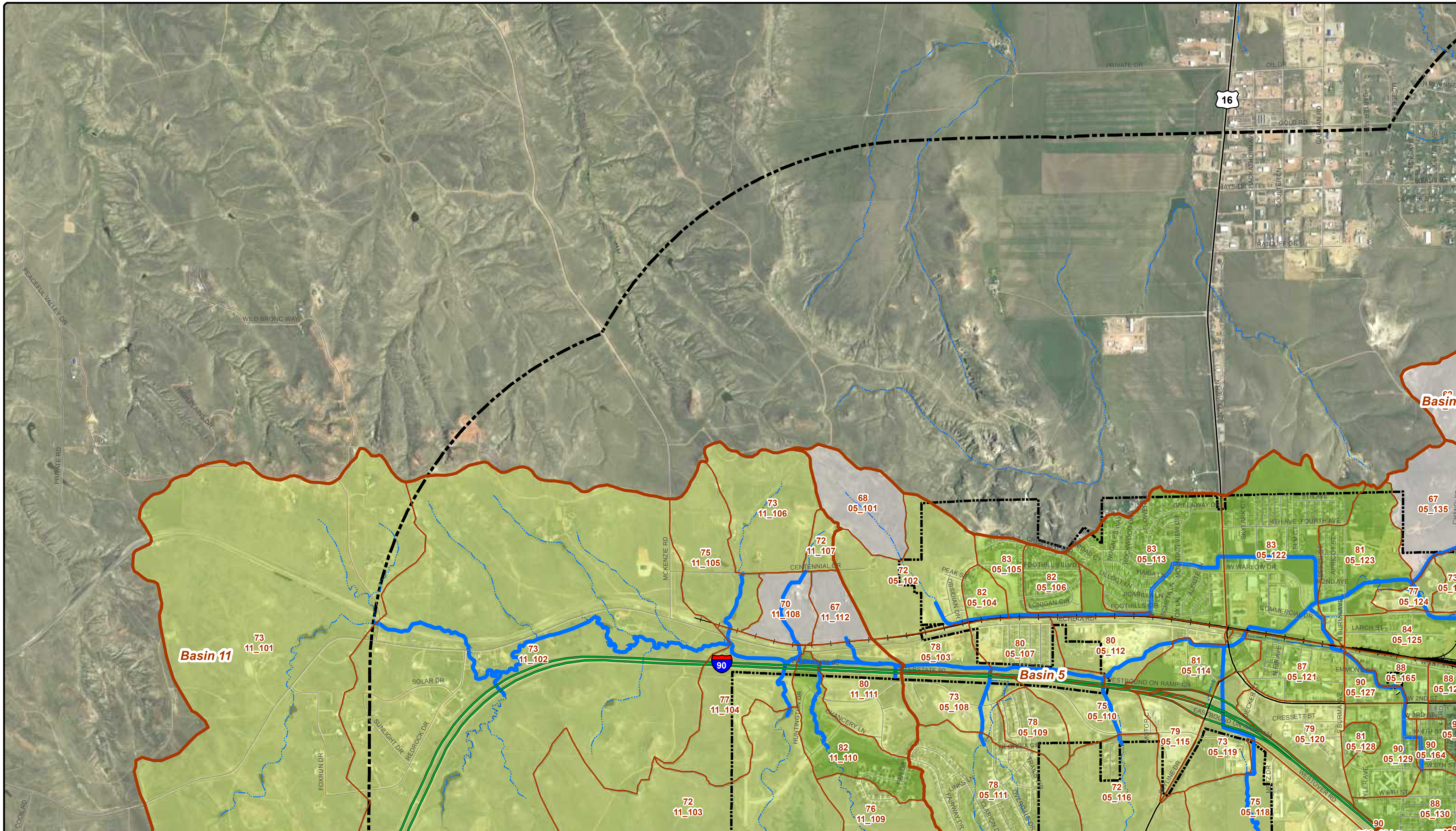

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

URS

- Study Reaches
- Open Channel
- Basin 8 — Major Basin
- 08_101 — Subbasin
- City Limits
- Study Area
- Interstate
- State or US Highway
- Streets
- Railroad

Curve Numbers

- 60 - 70
- 71 - 80
- 81 - 90
- 91 - 100

69 — Sub-basin Curve Number
07_107 — Sub-basin ID

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Existing Condition Curve Numbers
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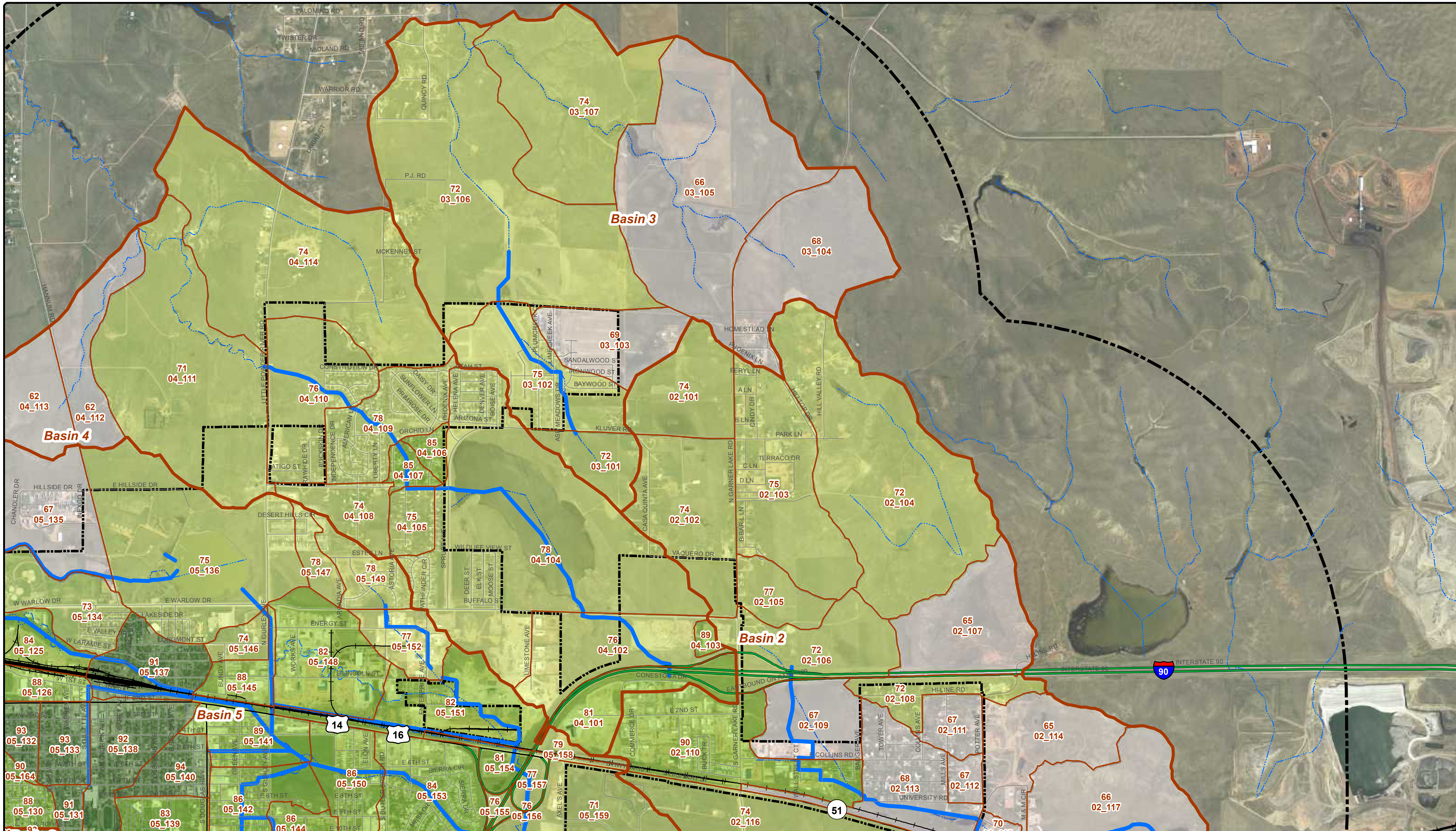
Gillette Stormwater Master Plan

3.4



Study Reaches
Open Channel
Basin 8 Major Basin
08_101 Subbasin
City Limits
Study Area

Interstate
State or US Highway
Streets
Railroad

Curve Numbers
60 - 70
71 - 80
81 - 90
91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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Existing Condition Curve Numbers
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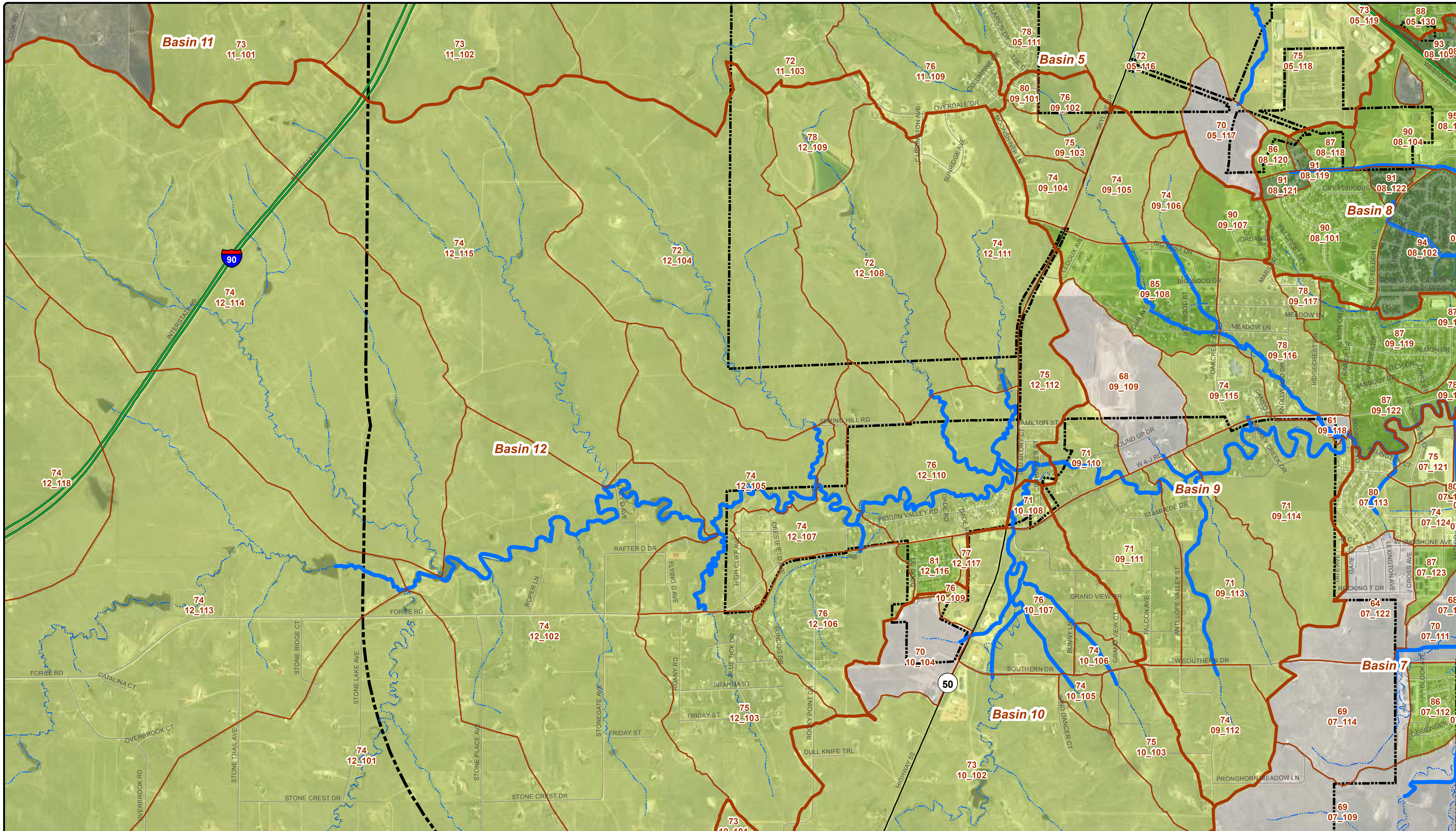
Gillette Stormwater Master Plan

3.4



Study Reaches
Open Channel
Basin 8 Major Basin
08_101 Subbasin
City Limits
Study Area

Interstate
State or US Highway
Streets
Railroad

Curve Numbers
60 - 70
71 - 80
81 - 90
91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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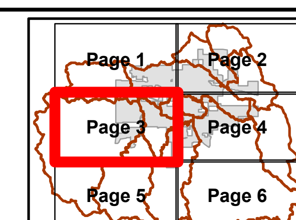

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Existing Condition Curve Numbers
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Gillette Stormwater Master Plan

3.4

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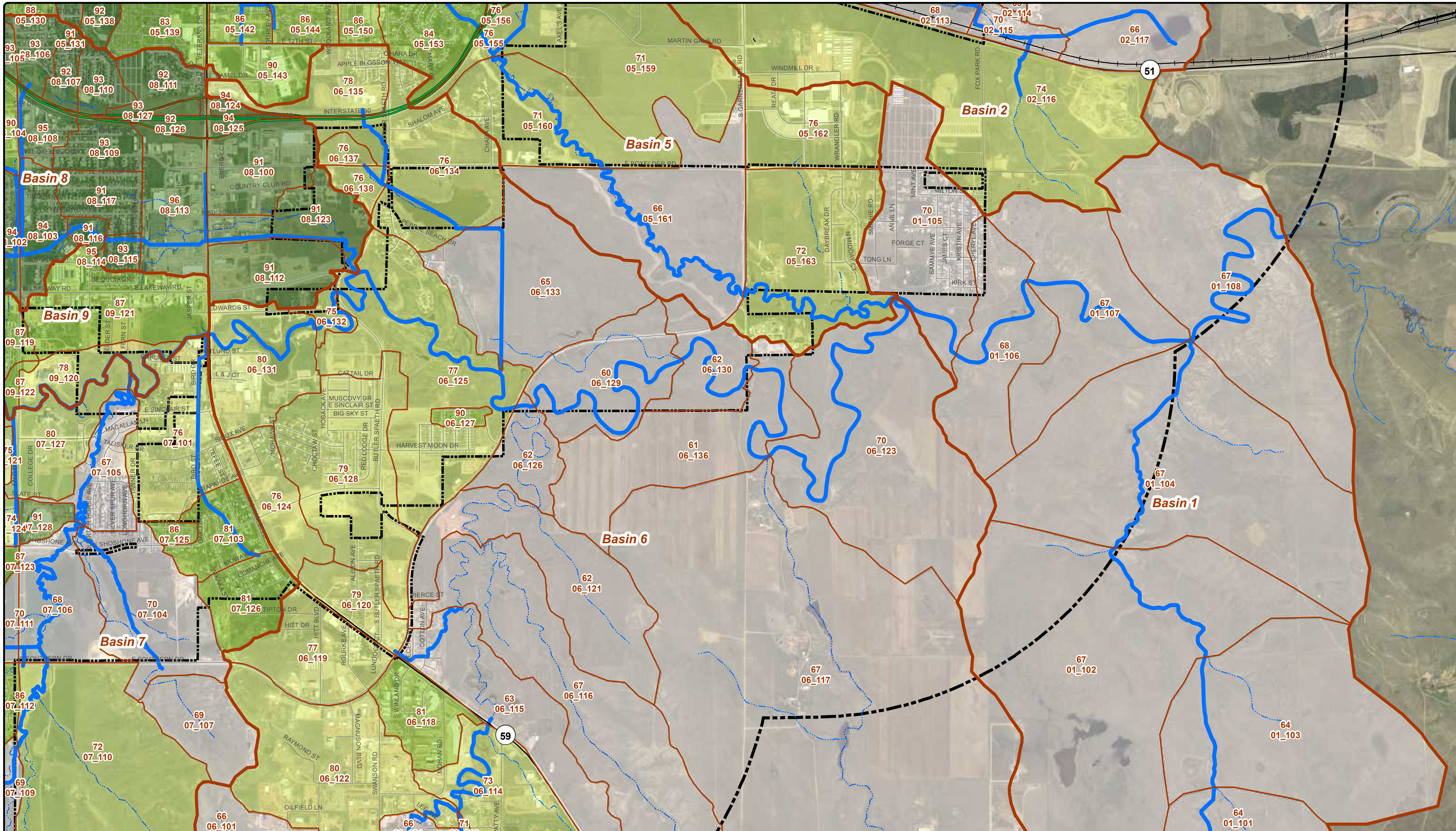
URS



- Study Reaches
- Open Channel
- Basin 8 Major Basin
- 08_101 Subbasin
- City Limits
- Study Area
- Interstate
- State or US Highway
- Streets
- Railroad

Curve Numbers

- 60 - 70
- 71 - 80
- 81 - 90
- 91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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URS
CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

Existing Condition Curve Numbers
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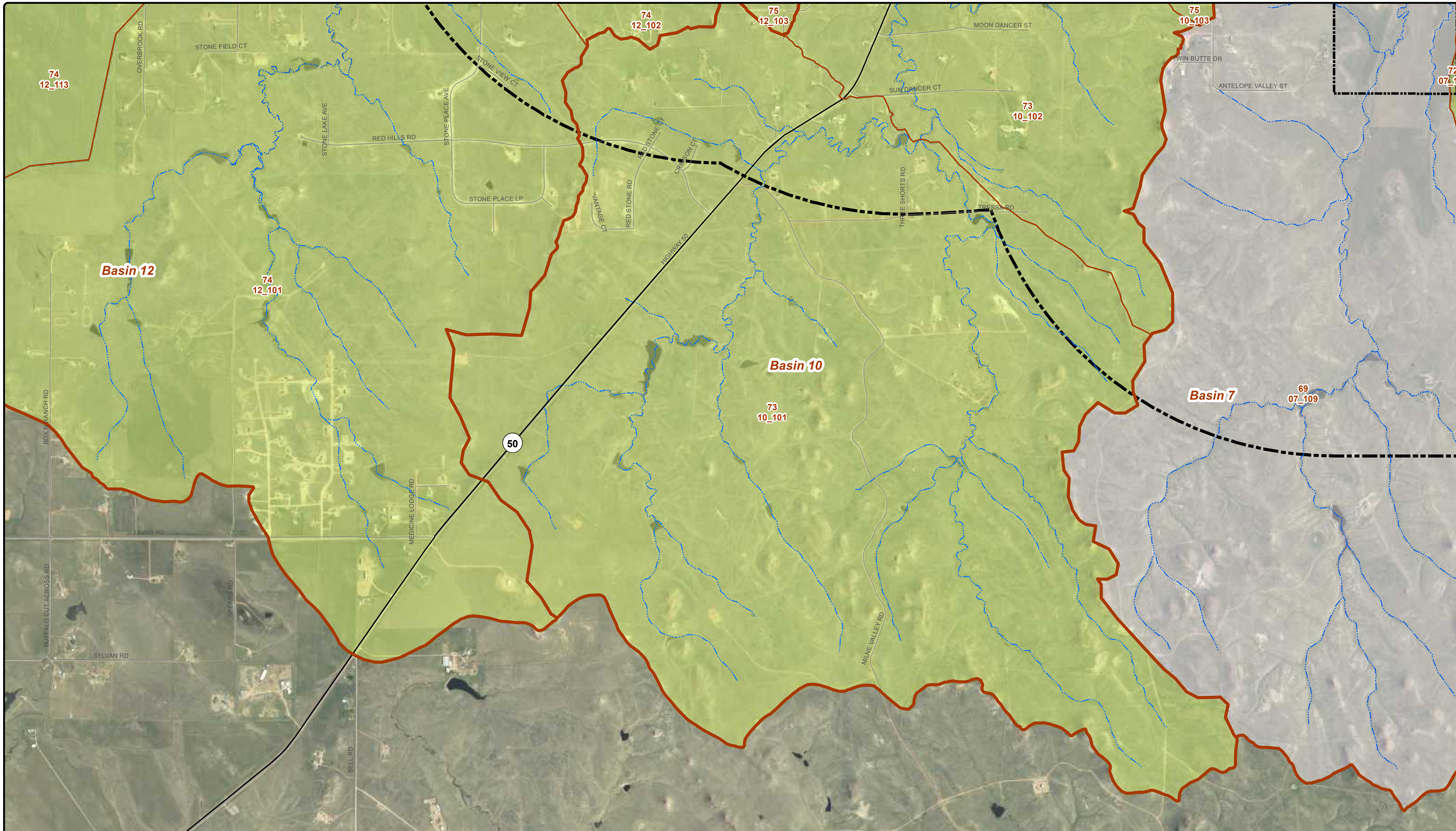
Gillette Stormwater Master Plan

3.4



CITY OF GILLETTE 201 E. 5TH STREET
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URS

- Study Reaches
- Open Channel
- Basin 8 Major Basin
- 08_101 Subbasin
- City Limits
- Study Area
- Interstate
- State or US Highway
- Streets
- Railroad

Curve Numbers

- 60 - 70
- 71 - 80
- 81 - 90
- 91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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Existing Condition Curve Numbers
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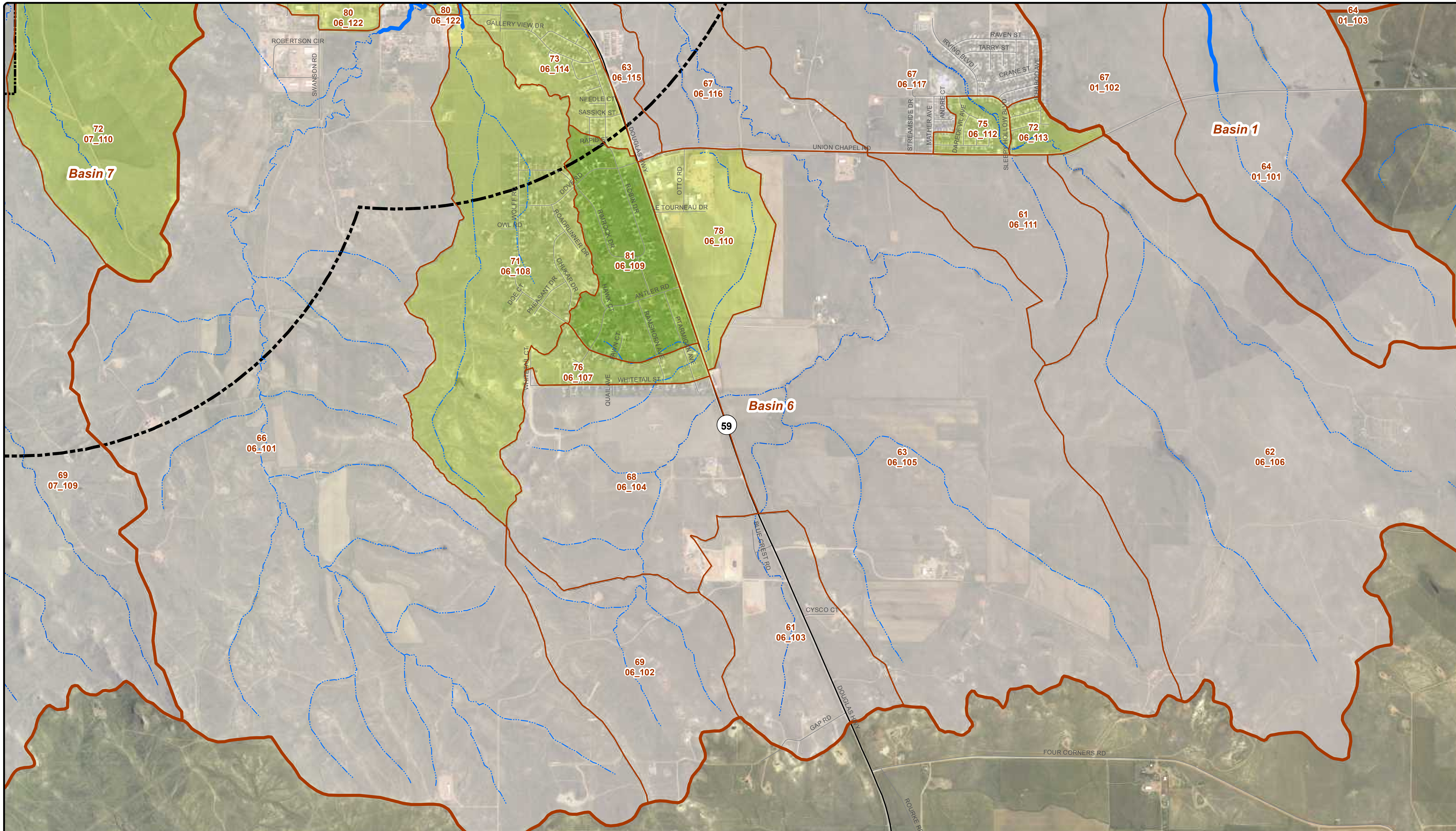
Gillette Stormwater Master Plan

3.4



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CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

URS

Study Reaches	Interstate	**Curve Numbers**	69 Sub-basin Curve Number
Open Channel	State or US Highway	60 - 70	07_107 Sub-basin ID
Basin 8 Major Basin	Streets	71 - 80	
08_101 Subbasin	Railroad	81 - 90	
City Limits		91 - 100	
Study Area			

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Existing Condition Curve Numbers

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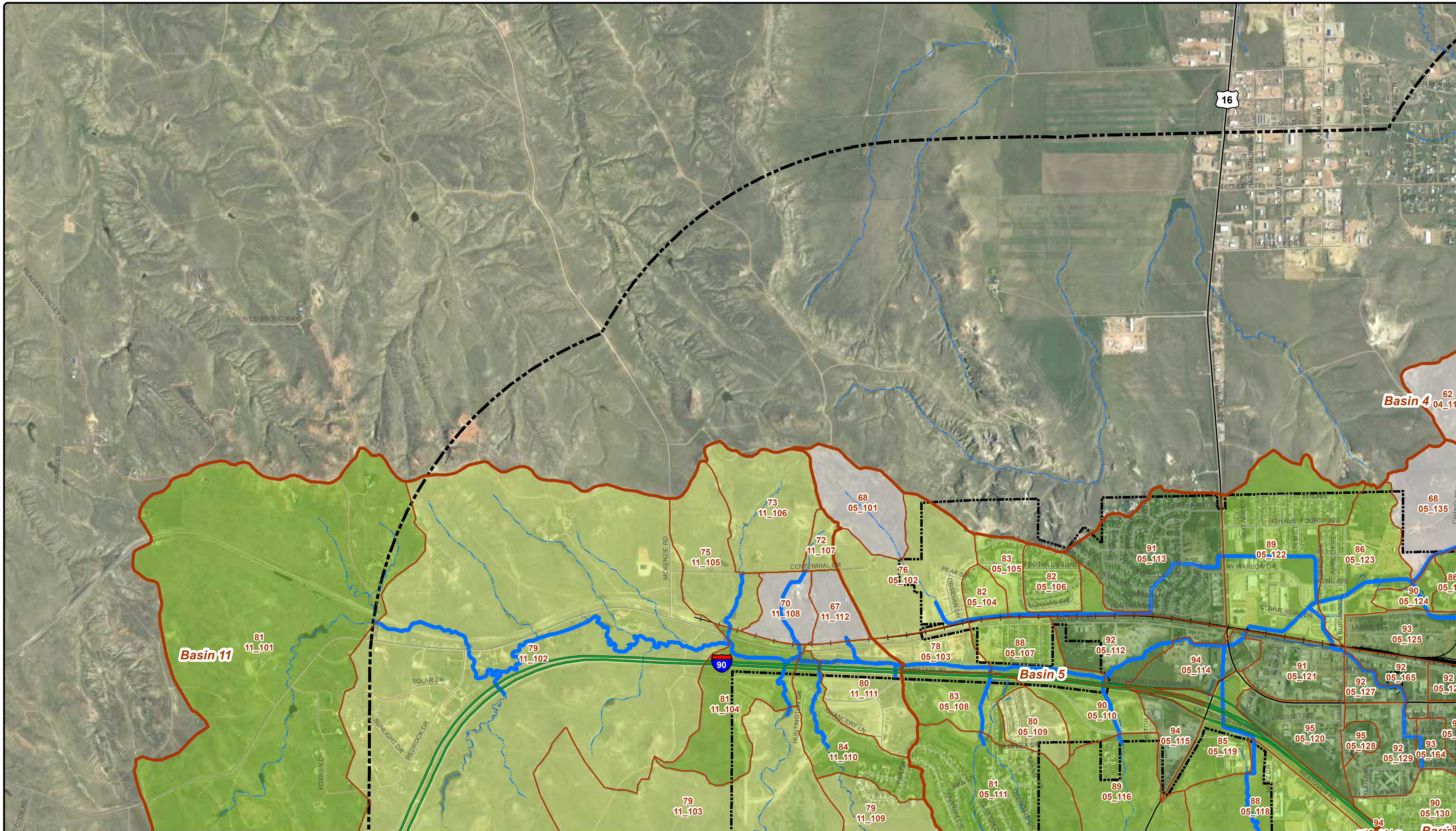
Gillette Stormwater Master Plan

3.4



Study Reaches	Interstate
Open Channel	State or US Highway
Basin 8 Major Basin	Streets
08_101 Subbasin	Railroad
City Limits	
Study Area	

Curve Numbers

- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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URS

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GILLETTE, WY 82717 (307) 686-5364

Future Condition Curve Numbers

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Gillette Stormwater Master Plan

3.5

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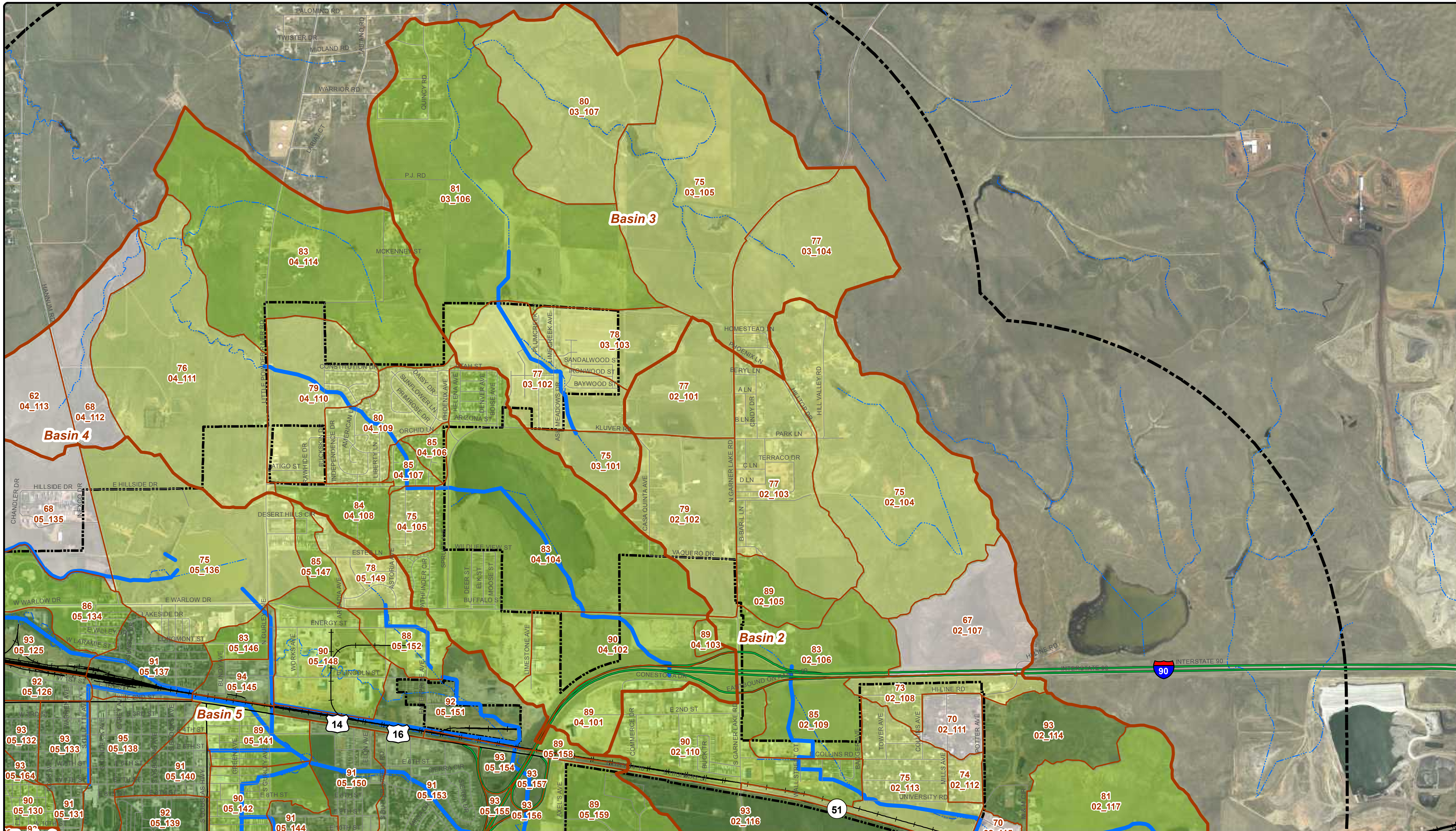

- Study Reaches
- Open Channel
- Major Basin (Basin 8)
- Subbasin (08_101)
- City Limits
- Study Area
- Interstate
- State or US Highway
- Streets
- Railroad

Curve Numbers

- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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Future Condition Curve Numbers

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Gillette Stormwater Master Plan

3.5

URS

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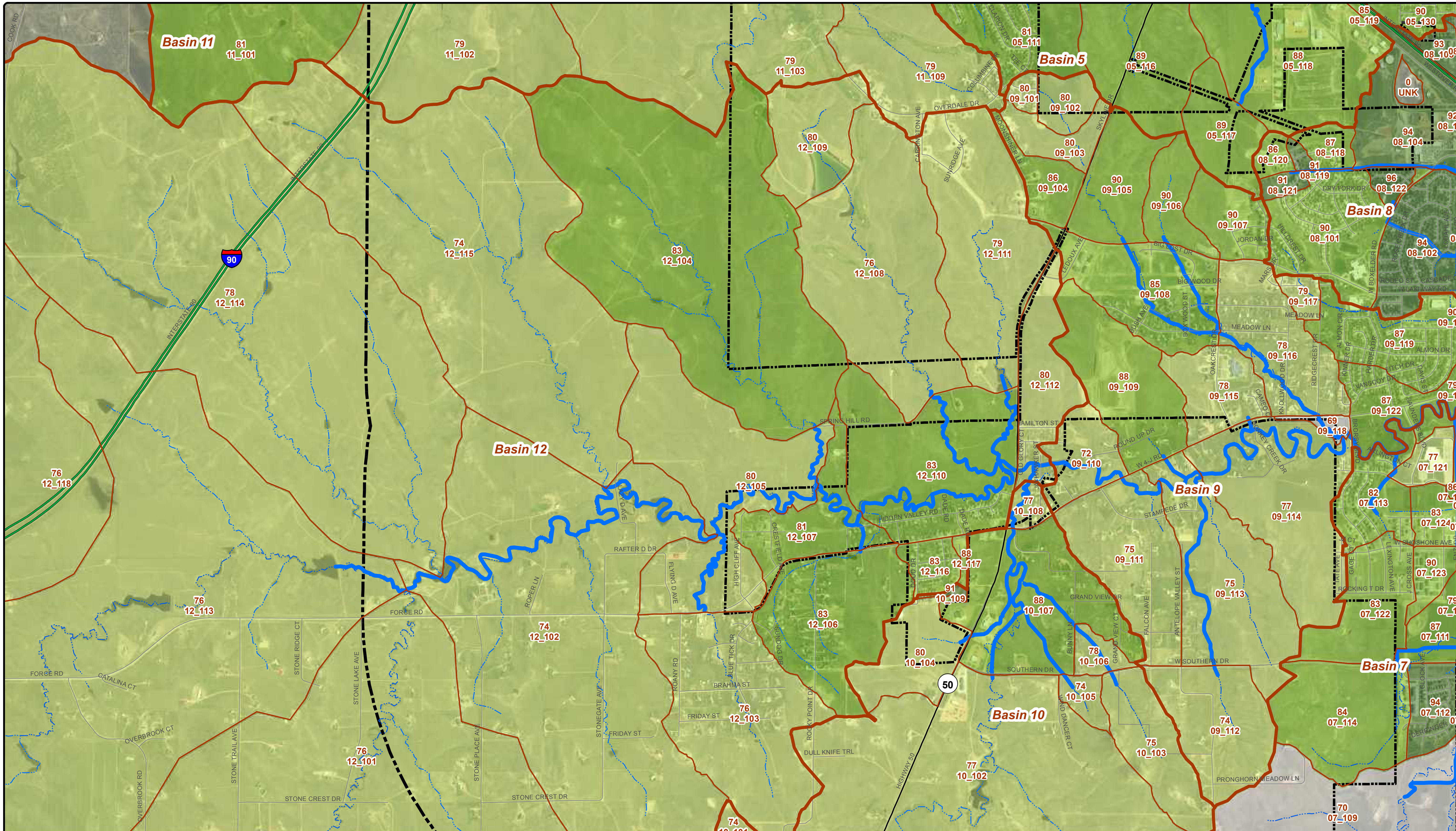

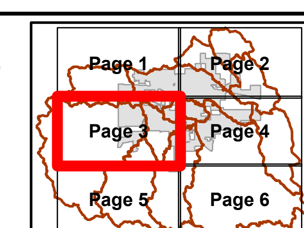

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

URS

Legend	
Study Reaches	Interstate
Open Channel	State or US Highway
Basin 8 — Major Basin	Streets
08_101 — Subbasin	Railroad
City Limits	
Study Area	

Curve Numbers

- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100

69 — Sub-basin Curve Number
07_107 — Sub-basin ID

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Future Condition Curve Numbers
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Gillette Stormwater Master Plan

3.5

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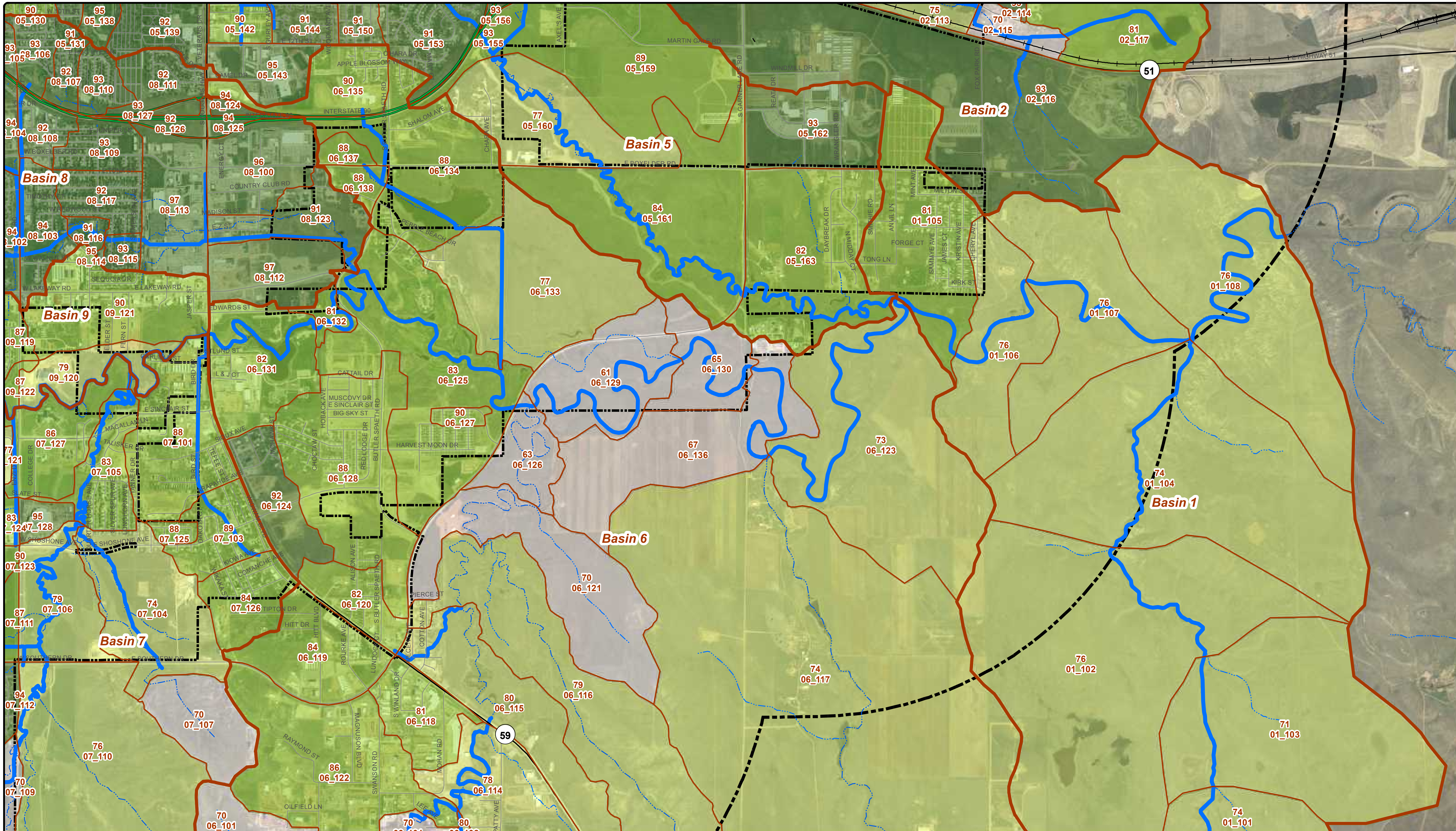

Study Reaches
Open Channel
Basin 8 Major Basin
08_101 Subbasin
City Limits
Study Area

Interstate
State or US Highway
Streets
Railroad

Curve Numbers

61 - 70
71 - 80
81 - 90
91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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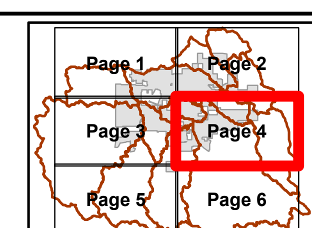

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URS

Future Condition Curve Numbers
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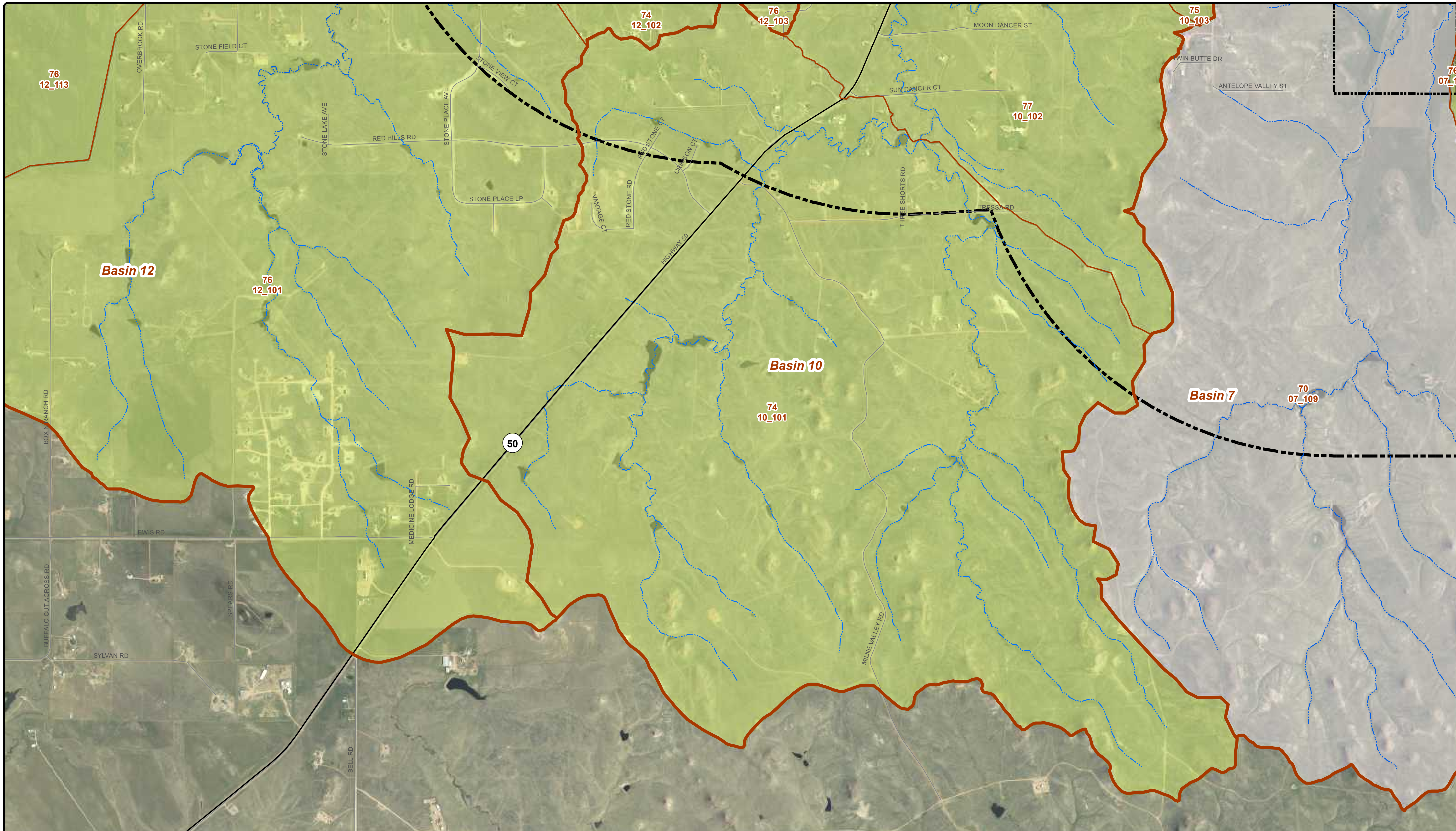
Gillette Stormwater Master Plan

3.5



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URS

Study Reaches
Open Channel
Basin 8 Major Basin
08_101 Subbasin
City Limits
Study Area
Interstate
State or US Highway
Streets
Railroad

Curve Numbers
61 - 70
71 - 80
81 - 90
91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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Future Condition Curve Numbers
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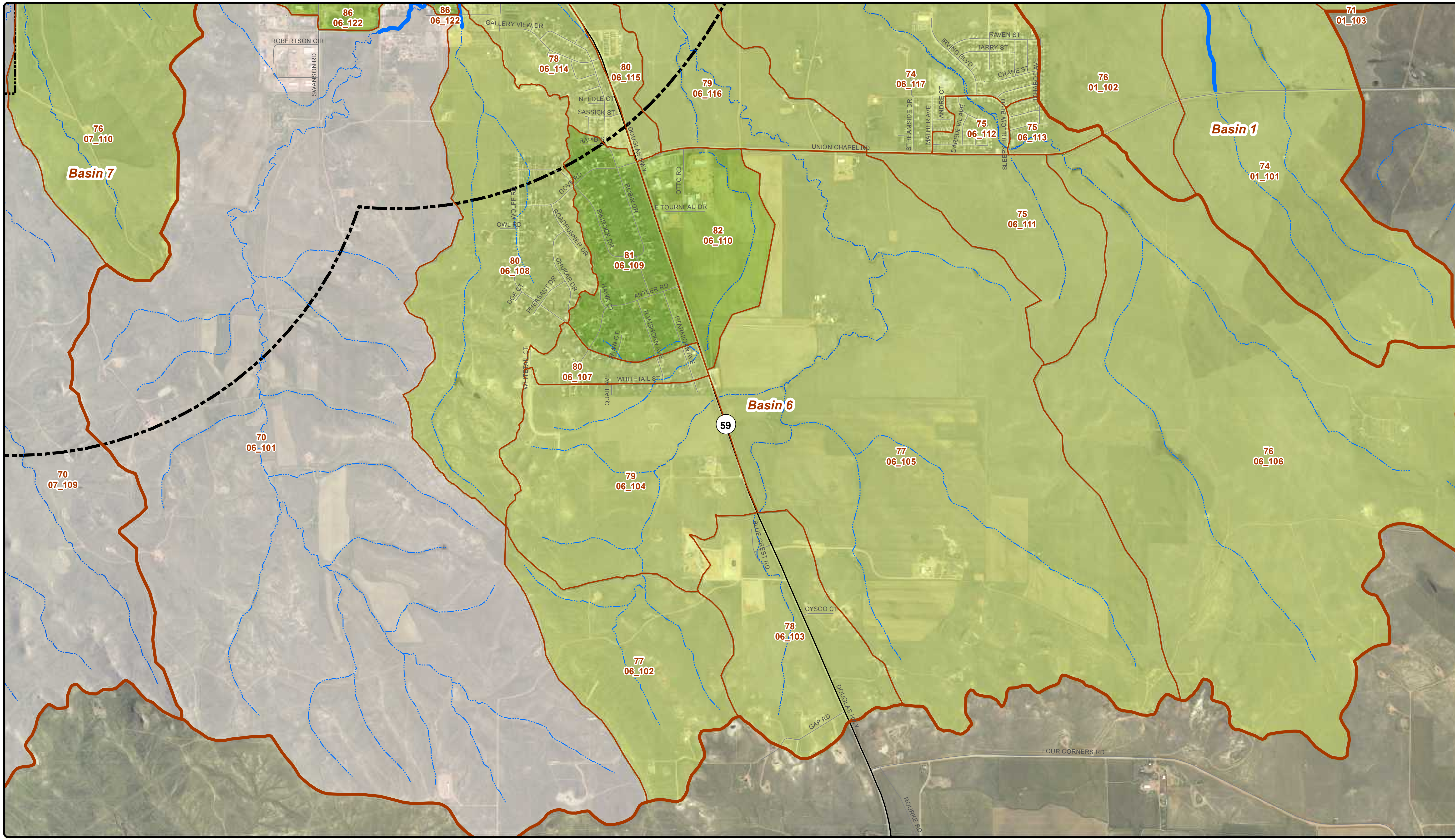
Gillette Stormwater Master Plan

3.5



CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

URS

Study Reaches	Interstate
Open Channel	State or US Highway
Basin 8 Major Basin	Streets
08_101 Subbasin	Railroad
City Limits	
Study Area	

Curve Numbers
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100

69 Sub-basin Curve Number
07_107 Sub-basin ID

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N
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Feet

Future Condition Curve Numbers
Page 6 of 6

Gillette Stormwater Master Plan

3.5

Time of Concentration (T_c)

Times of concentration were estimate using the traditional method described in detail in TR-55. This method uses an upland flow time added to a shallow concentrated flow time, which is then added to a channel flow time. Times of concentration were calculated for each sub-basin from topographic data provided by the City. Sub-basin slopes range from 0.6% to 1.8% in the study area.

Detailed t_c calculations are also contained in Appendix B and are listed in the input and output files of the InfoSWMM model.

3.2 HYDROGRAPH ROUTING

Within InfoSWMM, the sub-basins are connected to nodes and then to channels and conduits for hydrograph routing. Geometric information for each of the conveyance elements, i.e., length, slope, Manning's roughness coefficient, and physical dimensions of each link, were entered into the InfoSWMM model using GIS methods. Routing schematics of the connectivity of the sub-basins, junctions, and reaches are provided in Figures B.1 through B.14 in Appendix B.

Detentions were modeled as reservoirs, including numerous "inadvertent" detention areas at certain road crossings. Stage-versus-storage relationships were also developed for existing detention ponds and storage reservoirs in the watersheds, and are contained in Appendix B.

3.3 CHANNEL ROUTING

The Kinematic Wave Method was selected to develop the channel routing component of the InfoSWMM model. This method was chosen to represent the travel time in the channel because it is recommended by the USACE over other methods for channels with geometry similar to the channels in Gillette (USACE 2009). Typical cross-sectional dimensions for each channel reach were developed within the model using InfoSWMM's Transect Extractor tool. This tool automatically takes a cross-section of a channel based on the topography supplied.

The Manning's roughness coefficient (n value) for each channel reach was selected by inspection of the 2009 aerial photo, land use, and field visits. A shallow, natural grass lined channel is dominant in the majority of the study area, and a Manning's "n" value of 0.035 was assigned to the majority of open channel reaches. Some portions of the study area have been channelized in developments or along roads. Conveyance types and "n" values for the study area are listed in Table 3.5.

Table 3.5
Typical Conveyance Characteristics

Conveyance	Type	Manning's Roughness Coefficients
Natural Channel	Grass-lined	0.035
Constructed Channel	Concrete	0.016
Constructed Channel	Grass-lined	0.03
Roadside Ditch	Grass-lined	0.03
Culvert	Concrete	0.013
Culvert	Metal	0.024

3.4 STORAGE ROUTING AND GROUNDWATER

In the Gillette study area, some detention storage may occur in storage occurs in stock ponds, low areas (playas), and retention ponds, and high groundwater or reservoir usage can affect storage capacity, e.g. Fishing Lake. Ponds that do not have an outlet structure or routine maintenance have been ignored in this analysis. Some temporary storage also occurs behind road and railroad embankments where the culvert provided is not adequate to pass the storm event without ponding. In most cases, this storage has been conservatively ignored. Reliance on this storage for flood control is usually not advisable, since the road could wash out during a large storm or the culvert may be replaced with an adequate structure. Inadvertent detention has been quantified for this analysis where the ponding has a very significant volume and where the embankment is at a railroad, major arterial or a state or federal highway.

Characteristics of existing detention ponds in the study are summarized in Table 3.6. The following sections discuss the different types of detention and the hydrologic methods and assumptions used for evaluation in the InfoSWMM model.

3.4.1 City and County Detention Cells

All of the City- and County-owned ponds were incorporated into the InfoSWMM model with the exception of a few very small volume ponds. The stage- elevation curve for these ponds was developed from as-built data where it was available; otherwise the existing contour data was used to directly calculate volume. City and County owned detention cells are assumed to receive routine maintenance and therefore the outlet is assumed to be in good condition, i.e. un-silted and free of obstructions. Discharge from the ponds was calculated within the InfoSWMM model, typically through an orifice, and overflow through a weir. Typical values for orifice and weir coefficient were used and are listed in the Table 3.7.

3.4.2 Depression Playas

Depression playas are natural low areas that are common in and around the Gillette area. They do not have outlets and are typically shallow, unmaintained, and are generally on private land.

Table 3.6
Existing Detention Pond Summary

Basin 2

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P2-1	I-90 Inadvertent Detention	115.6	N/A	Modeled with InfoSWMM	Does not overtop – max volume detained 12.4 AF

Basin 3

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P3-1	Ash Meadows	1.5	100-year	Modeled with InfoSWMM	Overtops in 100 YR event by 93 cfs. DR used different methods, rain.

Basin 4

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P4-1	County Pond	3.9	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 0.5 AF

Basin 5

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P5-1	South Stocktrail Elem	21.3		Modeled with InfoSWMM	Does not overtop - max volume detained 8.9 AF
P5-2	Westover Hills	8.4	25 yr.	Modeled with InfoSWMM	Overtops in 100 YR event by 216 cfs. Drainage report prepared for offline pond. As-builts show as online to trib 506.
P5-3	Iron Horse Sub	3	100-year	Modeled with InfoSWMM	Overtops in 100 YR event by 41 cfs. Drainage Rpt did not consider Offsite flows
P5-4	Camplex Pond	10.6	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 1.9 AF
P5-5	West Valley Sub	5.8	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 13 cfs
P5-6	Campbell Cty Mem Hospital	4.7	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 1.6 AF
P5-7	Lasting Legacy Park	0.5	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 182 cfs
P5-8	District 42	2.6	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 64 cfs
P5-9	Energy Park	10.1	25 yr.	Modeled with InfoSWMM	Does not overtop - max volume detained 4.2 AF
P5-10	Lakeland Hills Sub	10.8	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 10.1 AF
N/A	Burlington Pond	N/A	N/A	Modeled as an outfall	N/A

Table 3.6
Existing Detention Pond Summary

Basin 6

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P6-1	Moon Shadow Regional	7.9	25 yr.	Modeled with InfoSWMM	Does not overtop - max volume detained 3.7 AF
P6-2	Moon Meadow Estates	1.9	25 yr.	Modeled with InfoSWMM	Does not overtop - max volume detained 0.64 AF
P6-3	Fishing Lake	6.4	N/A	Modeled with InfoSWMM	Overtops in 100 YR event by 5823 cfs
P6-5	Depression Playa 1	139	N/A	Modeled with InfoSWMM	Overtops in 10YR event by 20 cfs; 55 in 100YR event
P6-4	I-90 Inadvertent Detention/Hillcrest Elementary School	20.8	N/A	Modeled with InfoSWMM	Does not overtop - max volume detained 12.8 AF

Basin 7

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P7-1	Willamette Park Pond	0.76	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 0.36 AF
P7-2	Remington Pond D1	3.21	25-year	Modeled with InfoSWMM	Overtops in 100 YR event by 26.6 cfs
P7-3	Remington Pond D2	4.59	25-year	Modeled with InfoSWMM	Does not overtop - max volume detained 3.8 AF
N/A	Hitt Estates Pond (Stock or produced water pond)	27.59	N/A	Not Modeled - Private	N/A
N/A	Hitt Estates Inadvertent behind Southern Drive	6.55	N/A	Not Modeled - too small	N/A
P7-4	GHS South Campus Pond	21.99	25-year	Modeled with InfoSWMM	Does not overtop - max volume detained 1.54 AF
P7-5	Campbell County Recreation Center Pond	10.6	100-year and 5-year	Modeled with InfoSWMM	Does not overtop - max volume detained 1.53 AF
P7-6	RC Ranch NE (Business Park)	3.15	100-year	Modeled with InfoSWMM	Does not overtop - max volume detained 1.42 AF
P7-7	RC Ranch Detention E	1.26	100-year	Modeled with InfoSWMM	Overtops in 100 YR event by 17.3 cfs
N/A	College Park Detention	N/A	100-year	Not Modeled - Channel Storage	N/A
N/A	Lariat St. Detention	N/A	25year	Not Modeled - Channel Storage	N/A
N/A	College Park Detention (In Floodplain)	N/A	100-year	Not Modeled - Channel Storage	N/A

Table 3.6
Existing Detention Pond Summary

Basin 8

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P8-1	Upper Sage Valley Pond A	1.74	100-year Detained to 10-year	Modeled with InfoSWMM	Does not overtop - max volume detained 1.3 AF
P8-2	Upper Sage Valley Pond D	0.56	100-year Detained to 10-year	Modeled with InfoSWMM	Does not overtop - max volume detained 0.3 AF
P8-3	Upper Sage Valley Pond G	1.35	100-year Detained to 10-year	Modeled with InfoSWMM	Overtops in 25 YR event by cfs; 33 cfs in 100 YR
P8-4	Sage Valley Detention R2	3.54	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 0.6 AF
P8-5	I-90 Inadvertent Detention 1	4.5	N/A	Modeled with InfoSWMM	Does not overtop - max volume detained 1.3 AF
P8-6	I-90 Inadvertent Detention 3	2.06	N/A	Modeled with InfoSWMM	Overtops in 100 YR event by < 1 cfs
P8-7	I-90 Inadvertent Detention 5	7.7	N/A	Modeled with InfoSWMM	Does not overtop - max volume detained 3.3 AF
P8-8	I-90 Inadvertent Detention 6	5.99	N/A	Modeled with InfoSWMM	Does not overtop - max volume detained 0.7 AF
P8-9	Silverado Detention	12.75	100-year	Modeled with InfoSWMM	Does not overtop - max volume detained 1.7 AF
P8-10	I-90 Inadvertent Detention 4	2.05	N/A	Modeled with InfoSWMM	Does not overtop - max volume detained 1.0 AF
P8-11	Sage Valley Park R1	13.05	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 393 cfs
P8-12	Cottonwood Park R3	6.92	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 255 cfs
P8-13	Sage Bluffs Park R4	19.43	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 64 cfs
P8-14	Sunflower Park R5	10.8	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 121 cfs
P8-15	Sunflower Park R6	6.0	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 204 cfs
P8-16	Mitchell Pond	2.87	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 249 cfs
P8-17	Private Pond	1.25	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 1.0 AF
N/A	Wal-Mart Expansion	N/A	Unknown	Not Modeled - Private	N/A
	Campbell County Detention Center	N/A	Unknown	Not Modeled - too small	N/A

Table 3.6
Existing Detention Pond Summary

Basin 9

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P9-1	Westover Hills	1.1	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 0.9 AF
P9-4	SH 50 Inadvertent	5.3	N/A	Modeled with InfoSWMM	Does not overtop - max volume detained 4.3AF
P9-2	Castle Heights Estates	4.2	25year	Modeled with InfoSWMM	Does not overtop - max volume detained 4.1 AF
P9-3	Sutherland Estates	7.9	Unknown	Modeled with InfoSWMM	Overtops in 100 YR event by 145 cfs - **Overflow goes into Basin 8**
P9-5	Pronghorn Estates Pond 1	1.3	25 year	Modeled with InfoSWMM	Overtops in 100 YR event by 16 cfs
P9-6	Pronghorn Estates Pond 2	2.9	25 year	Modeled with InfoSWMM	Overtops in 100 YR event by 0.1 cfs
P9-7	Pronghorn Estates Pond 3	0.9	25 year	Modeled with InfoSWMM	Does not overtop in 100 YR event - max volume detained 0.8 AF
P9-8	Pronghorn Estates Pond 4	1.1	25 year	Modeled with InfoSWMM	Overtops in 100 YR event by 5 cfs

Basin 10

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P10-1	Doud Ranch	0.9	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 4.1 AF

Basin 11

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
N/A	Copper Estates 100	N/A	N/A	Not Modeled - Future	N/A
N/A	Copper Estates 150	N/A	N/A	Not Modeled - Future	N/A
P11-1	Copper Estates 240	2.2	100-year	Modeled with InfoSWMM	Overtops in 100 YR event by 110 cfs
N/A	Copper Estates 250	N/A	N/A	Not Modeled - Future	N/A
N/A	Copper Estates 350	N/A	N/A	Not Modeled - Future	N/A
N/A	Copper Estates 360	N/A	N/A	Not Modeled - Future	N/A
N/A	Copper Estates 430	N/A	N/A	Not Modeled - Future	N/A
N/A	Copper Estates 450	N/A	N/A	Not Modeled - too small	N/A
N/A	Copper Estates 460	N/A	N/A	Not Modeled - too small	N/A
N/A	Copper Estates 470	N/A	N/A	Not Modeled - too small	N/A

Table 3.6
Existing Detention Pond Summary

Basin 11 (cont.)

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
N/A	Copper Estates 490	N/A	N/A	Not Modeled - too small	N/A
P11-2	Copper Estates 500	9.3	100-year	Modeled with InfoSWMM	Overtops in 10YR event by 65 cfs; 345 in 100YR event

Basin 12

ID	Name	Capacity (ac-ft.)	Design Storm	Approach	Results
P12-1	Bel Nob Dam & Reservoir	244	100-yr	Modeled with InfoSWMM	Assumed initial condition is full - overtops through spillway by 40 cfs
P12-2	Doud Ranch 1	1.6	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 0.7 AF
P12-3	Doud Ranch 2	0.7	Unknown	Modeled with InfoSWMM	Does not overtop - max volume detained 0.07 AF

Table 3.7
Typical Weir and Orifice Coefficients

	Coefficient
Orifice	0.6
Weir	3.2

Many of the playas have been ignored for flood hazard delineations; however three playas are so large that they must be incorporated into the model.

Burlington Lake (Basin 5) and the Unnamed Playa near the intersection of Spruce Avenue and Kluver Road (Basin 4) are large enough to contain the entire 100 year inflow volume and are modeled as outfalls. The third playa is near the intersection of E. Boxelder Road and S. Butler Spaeth Road (Basin 6) and does not contain the 100 year flood volume. This playa was modeled similarly to the City and County ponds, with a stage- elevation curve that was developed from the existing topography. The playa does not have an outlet, instead it overtops directly into a downstream channel.

3.4.3 Inadvertent Detention

Except for the inadvertent areas upstream of the I-90 crossings, and a large inadvertent detention upstream of Highway 50, inadvertent detention areas have been ignored. Because of the high I-90 embankment, these detention areas can be up to 6 feet deep and have potential to provide significant volume and flood attenuation. Similar to the City and County detention ponds, they are modeled with a stage-storage curve developed from existing topography, and outlets through an orifice and overtopping through a weir. For inadvertent areas that are ignored, flow that is in excess of the capacity of the crossing structure overtops the road or embankment and is routed downstream with no attenuation.

3.5 HYDROLOGIC ANALYSIS RESULTS

3.5.1 Results for this Study

InfoSWMM output, including peak flows and volumes for each conveyance element for all design storms throughout the Gillette study area for both existing and future conditions models, is in Appendix B on a CD. Generally, the largest peak flow and volume increases occur in the central portion of the study area in response to development. Peak flows and volumes are based on existing channel and conveyance element geometry, and detention storage routing, as modeled in InfoSWMM. The effectiveness of existing detention ponds is summarized in Table 3.8. Peak flow rates for selected design points and hydraulic evaluation of conveyance elements are further described in Section 4.

Table 3.8
Existing Detention Effectiveness

Basin 2

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Maximum Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P2-1	I-90 Inadvertent Detention	12.4	184.5	12.5	0	12.5	93%	4,498.8

Basin 3

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Maximum Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P3-1	Ash Meadows	1.5	129	33	93	126	2%	4,467.3

Basin 4

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Maximum Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P4-1	County Pond	3.9	33	20	0	20	40%	4,505.6

Basin 5

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Maximum Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P5-1	South Stocktrail Elem.	21.3	405	170	0	170	58%	4,641.7
P5-2	Westover Hills	8.4	467	19	216	235	50%	4,600.9
P5-3	Iron Horse Sub	3	121	31	41	72	40%	4,628.4
P5-4	Camplex Pond	10.6	413	50	0	50	88%	4,512.7

Table 3.8
Existing Detention Effectiveness

Basin 5 (cont.)

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Maximum Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P5-5	West Valley Sub	5.8	170	12	13	25	85%	4,586.1
P5-6	Campbell Cty Mem Hospital	4.7	46	4	0	4	91%	4,604.0
P5-7	Lasting Legacy Park	0.5	205	16	182	198	4%	4,535.2
P5-8	District 42	2.6	68	2	64	66	3%	4,529.6
P5-9	Energy Park	10.1	319	30	0	30	91%	4,518.5
P5-10	Lakeland Hills Sub	10.8	204	17	0	17	92%	4,535.3

Basin 6

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Maximum Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P6-1	Moon Shadow Regional	7.9	252	210	0	210	17%	4,508.5
P6-2	Moon Meadows Estates	1.9	33	13	0	13	62%	4,510.3
P6-3	Fishing Lake	6.4	5903	0	5823	5823	1%	4,520.8
P6-4	I-90 Inadvertent Detention	139	87	12	0	12	86%	4,506.3
P6-5	Depression Playa	20.8	160	46	0	46	71%	4,525.8

Basin 7

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Maximum Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P7-1	Willamette Park Pond	0.8	34	18	0	18	46%	4,561.1
P7-2	Remington Pond D1	3.2	90	13	27	40	56%	4,565.3
P7-3	Remington Pond D2	4.6	189	82	0	82	57%	4,571.7
P7-4	GHS South Campus Pond	22.0	31	7	0	7	77%	4,538.4
P7-5	Campbell County Recreation Center Pond	10.6	50	17	0	17	65%	4,550.5
P7-6	RC Ranch NE (Business Park)	3.2	37	10	0	10	74%	4,552.3
P7-8	RC Ranch Detention E	1.3	89	7	17	25	72%	4,558.1

Table 3.8
Existing Detention Effectiveness

Basin 8

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Max Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P8-1	Upper Sage Valley Pond A	1.3	63	16	0	16	74%	4,630.4
P8-2	Upper Sage Valley Pond D	0.3	22	11	0	11	48%	4,625.7
P8-3	Upper Sage Valley Pond G	1.8	61	14	33	47	23%	4,626.1
P8-4	Sage Valley Detention R2	0.6	58	26	0	26	54%	4,564.8
P8-5	I-90 Inadvertent Detention 1	1.3	145	119	0	119	18%	4,604.9
P8-6	I-90 Inadvertent Detention 3	0.9	122	77	1	77	37%	4,602.3
P8-7	I-90 Inadvertent Detention 5	3.3	143	47	0	47	67%	4,528.7
P8-8	I-90 Inadvertent Detention 6	0.7	42	22	0	22	47%	4,529.6
P8-9	Silverado Detention	1.7	24	5	0	5	81%	4,543.1
P8-10	I-90 Inadvertent Detention 4	1.0	25	5	0	5	79%	4,550.3
P8-11	Sage Valley Park R1	9.5	446	23	393	415	7%	4,556.8
P8-12	Cottonwood Park R3	5.1	359	94	255	349	3%	4,564.5
P8-13	Sage Bluffs Park R4	12.5	823	243	64	307	63%	4,537.6
P8-14	Sunflower Park R5	10.8	334	150	121	271	19%	4,535.6
P8-15	Sunflower Park R6	6.0	369	148	204	352	5%	4,532.1
P8-16	Mitchell Pond	2.4	249	53	197	249	0%	4,519.5
P8-17	Private Pond	1.0	5	4	0	4	10%	4,519.4

Basin 9

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Max Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P9-1	Westover Hills	1.1	29	4	0	4	87%	4,721.3
P9-2	Castle Heights Estates	4.2	150	54	0	54	64%	4,653.7
P9-3	Sutherland Estates	7.9	295	65	145	210	29%	4,541.6
P9-4	Skyline Rd/ SH 50 Inadvertent	5.3	190	73	0	73	62%	4,542.6
P9-5	Pronghorn Estates Pond 1	1.3	244	81	16	97	60%	4,628.0

Table 3.8
Existing Detention Effectiveness

Basin 9 (cont.)

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Max Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P9-6	Pronghorn Estates Pond 2	2.9	97	81	0.1	81	16%	4,622.0
P9-7	Pronghorn Estates Pond 3	0.8	82	79	0	79	3%	4,618.8
P9-8	Pronghorn Estates Pond 4	1.1	80	73	5	78	1%	4,617.5

Basin 10

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Max Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P10-1	Doud Ranch	0.9	10	8	0	8	19%	4,639.7

Basin 11

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Max Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P11-1	Copper Estates 240	2.2	526	77	343	420	20%	4,648.0
P11-2	Copper Estates 500	9.3	394	14	110	124	69%	4,679.0

Basin 12

ID	Name	Capacity (ac-ft.)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Overtopping/ Weir (cfs)	Max Outflow (cfs)	Peak Reduction (%)	Maximum HGL (ft.)
P12-1	Golf Course Dam	244	209	0	40	40	81%	4,697.5
P12-2	Doud Ranch 1	1.6	44	26	0	26	40%	4,616.2
P12-3	Doud Ranch 2	0.7	14	11	0	11	21%	4,632.4

3.5.2 Comparison with Previous Studies

The results of the hydrologic analysis in this study were compared with the results from selected other study reports available from the City, as presented in Table 3.9. The most important of these is the 2008 FIS (Nelson et al. 2008). The 2008 FIS, the 1996 Donkey Creek Flood Study, and the 1988 FIS all use the hydrology developed in the 1978 Plan. In some cases the original hydrology was extrapolated or interpolated. The 1978 Plan hydrology is based on an 8-hour storm with 3.25 inches of precipitation for the 100-year frequency (or 1% chance) storm. This study uses a more common 24-hour storm, with 4.0 inches of precipitation for the 100-year storm. In order to compare the results, URS developed a scenario in InfoSWMM that included the 8-hour 1978 Plan (or FIS) hydrology. Under this scenario, the InfoSWMM results were within 15% of the 1978 Plan future conditions results. These results are shown in Table 3.9 for design points 6-200, 6-208, 9-200 and 12-001.

A limited effort was made to investigate the hydrology on Donkey Creek that was done as part of the mine plan for the WYODAK mine, which lies just downstream of the study limit east of the City. The WYDEQ has more than 20 volumes of documents on the mine plan, and a thorough review was beyond the needs of the City. A 1999 mine plan estimated 4,500 cfs at the western mine boundary using the SCS triangular hydrograph method, rainfall from the NOAA Atlas 2 (Reference 122) and a 12-hour storm duration, and a tributary watershed of 77 square miles with a curve number of 75. This use of the SCS method and a storm duration longer than 8 hours (from the 1978 Plan) is consistent with the current approach.

No major studies are available for Basins 2, 3, 10 and 11 that provide any points for comparison. The remainder of the basins have at least one comparison point. Multiple design points along Donkey Creek corresponded with design points in the 1978 Plan, 1996 Donkey Creek Floodway Study, and the 2008 FEMA Flood Insurance Study. At all comparison points this study found flow rates higher than the previous studies. Both the 1996 and 2008 studies use the 1978 Plan hydrology, which is consistently lower.

Stonepile Creek was also compared with the 2008 FEMA FIS and the 1978 Plan at numerous locations. Similar to Donkey Creek, this study consistently determined flow rates greater than both of these studies. There are, however, two comparison points where this study determined lower flow rates than the 1978 Plan: the storm sewer at N. Brooks Avenue and 2nd Street, and the Industrial Park Tributary at the BNSF railroad. At both locations, differences can be attributed to changes in the sub-basin delineations and routing methods.

Little Rawhide Creek and the large playa east of Spruce Ave in Basin 4 were studied in the Little Rawhide Creek Flood Study and the 1978 Plan. Peak flows along Rawhide Creek and into the playa determined in this analysis are consistently lower than those determined by the Little Rawhide Creek Flood Study and consistently higher than those in the 1978 Plan. This result was expected because the Little Rawhide Creek Flood Study used Rational Method hydrology, which typically results in higher flow rates than the TR55 methodology. The 1978 Plan used an 8 hour storm with a lower rainfall depth, which resulted in overall lower flow rates. The one exception is at Kluver Road, where the 1978 Plan found higher flows than this study. This discrepancy can be attributed to a change in basin boundaries due to development.

North Donkey Creek in Basin 8 was studied by the Homestead Trickle Channel Study by WWC Engineering in 2006. The results of this study are generally within 15% of peak flow rates determined by that study. The main differences between the studies are different sub-basin delineations and the routing method. The HTC report used WY-HYDRA.

Donkey Creek Tributary South (Basin 7) was compared with the Donkey Creek Floodway Study and the South Donkey Creek LOMR. Both of the previous studies use the 1978 Plan hydrology. Therefore, at all comparison locations this study found flow rates higher than both previous studies.

Table 3.9
Results Comparison for the Gillette Study Area

Major Basin and Design Point	Location	InfoSWMM Q_{100}	Reference Flow Rate	Reference
1. Fox Park				
1-2001	Study Outfall for Donkey Creek	7,929	4,500	WYODAK Mine Plan
2. Closed Basins				
2-203	Tributary 201 at Potter Avenue	332	269	Main_outfall, Collins Heights Indust. Park (Moore 2009)
2-105	02_215 outfall at Garner Lake Drive	75	56	Basin O-2, Longview RV Park (CEI 2008)
2-205	02_205 structure at Collins Road	71	12	Basin L, Collins Heights Industrial Park (Moore 2009)
3. Dry Fork Little Powder River				
3-204	North PL Bittercreek Estates II	261	66	North PL, Bittercreek Estates II (PCA 2007)
3-205		94	26	CM-H1, Bittercreek Estates II (PCA 2007)
		94	30	Link Trip, Ash Meadows (Falcon 2008)
3-203	03_103 outfall	96	36	Pond 1, Ash Meadows (Falcon 2008)
4. Little Rawhide Creek				
4-201	LRC at Powder River Road	802	1313	Little Rawhide Creek Flood Study (Bruce 2009)
4-201	LRC at Powder River Road	802	500	1979 Master Plan
4-202	LRC at Constitution Drive	553	674	Little Rawhide Creek Flood Study (Bruce 2009)
4-203	LRC at Orchid Ln.	300	328	Little Rawhide Creek Flood Study (Bruce 2009)
4-204	LRC at Kluver Road	196	251	Little Rawhide Creek Flood Study (Bruce 2009)
		196	250	1978 Plan
4-206	Little Rawhide Playa	150 AF	110 AF	1978 Plan Volume
4-206	Little Rawhide Playa	150 AF	57 AF	Little Rawhide Creek Flood Study (Bruce 2009)
5. Lower Stone Pile Creek				
5-203	SC at I-90 Downstream	4188	1434	FEMA FIS 2008, FIS 1988
5-204	SC at I-90 Upstream	3930	1166	FEMA FIS 2008, FIS 1988
		3930	2000	1978 Plan
5-210	Industrial Park Trib at BNSF RR	432	750	1978 Plan
5-215	SC at RR and Brooks	3883	1613	FEMA FIS 2008, FIS 1988
5-218	Storm at N. Brooks Ave and 2nd St.	448	780	1978 Plan
5-220	Storm at Gillette Ave and 1st St.	459	450	1978 Plan
5-221	SC at W. Warlow Drive	3644	1638	FEMA FIS 2008, FIS 1988 Pumphouse Lane

Table 3.9
Results Comparison for the Gillette Study Area

Major Basin and Design Point	Location	InfoSWMM Q_{100}	Reference Flow Rate	Reference
5-221	SC at W. Warlow Drive	3644	1950	Stonepile Creek Drainage Project As-Builts, 1985
5-226	SC at S. Burma Avenue	3815	1635	FEMA FIS 2008, FIS 1988
5-226	SC at Pumphouse Lane		1950	1978 Plan
5-225	Burlington Lake Diversion	642	300	1978 Plan
5-225	Burlington Lake Diversion	642	533	1986 Floodplain Analysis Upstream of Warlow Drive
5-227	Tributary at Confluence	3816	1200	1978 Plan
5-231	SC at US Highways 14/16	2740	1635	FEMA FIS 2008, FIS 1988
6. Antelope Butte Creek				
6-208	DC at Highway 59	5905	3460	Donkey Creek Floodway Study, 09/1996
		5905	5150	1978 Plan Future Conditions
6-200	DC at Confluence with SC	7800	5020	Donkey Creek Floodway Study, 09/1996
		7800	7030	1978 Plan Future Conditions
7. Donkey Creek Trib. South				
7-201	DCTS Outfall to Donkey Creek	1780	1400	Donkey Creek Floodway Study, 09/1996
7-201	DCTS Outfall to Donkey Creek	1780	1241	Floodplain Modeling of DCTS 04/2010
7-202	DCTS at Sinclair	1780	1830	WYDOT study for Sinclair Avenue Culvert.
7-209	DCTS at Southern Drive	1645	1203	Floodplain Modeling of DCTS 04/2010
7-213	DCTS at City Limits	1412	998	Floodplain Modeling of DCTS 04/2010
7-224	Sunburst at Kiowa Avenue	164	180	Sunburst West Addition Rpt. 09/2003
7-222	Sunburst at Arapahoe Avenue	255	328	Sunburst West Addition Rpt. 09/2005
7-220	Sunburst at Donkey Creek	556	508	Sunburst West Addition Rpt. 09/2006
7-231	Hitt Tributary at Southern Drive	115	286	Master DR for Legacy Ridge, Ph. I, 06/2006
7-241	Remington Pond D1	90	275	Remington Estates Ph. I, 09/2006
7-242	Remington Pond D2	189	54	Remington Estates Ph. I, 09/2006
7-212	Upstream of Remington Sub.	1399	962	Main Channel Modifications of DCTS, 10/2007

Table 3.9
Results Comparison for the Gillette Study Area

Major Basin and Design Point	Location	InfoSWMM Q_{100}	Reference Flow Rate	Reference
8. North Donkey Creek				
8-203	NDC and HWY 59	774	732	Homestead Trickle Channel, 01/2007 (WY-HYDRA)
			673	Homestead Trickle Channel, 01/2007 HEC-HMS
			811	Homestead Trickle Channel, 01/2007 USGS Regression
8-208	Discharge from Sunflower R6	463	524	Homestead Trickle Channel, 01/2007 (WY-HYDRA)
8-209	Discharge from Sunflower R5	203	371	Homestead Trickle Channel, 01/2007 (WY-HYDRA)
8-210	Discharge from Sage Bluffs Park	247	372	Homestead Trickle Channel, 01/2007 (WY-HYDRA)
8-231	Cottonwood Park inflow	351	254	Homestead Trickle Channel, 01/2007 (WY-HYDRA)
			269	
9. Donkey Creek DFA				
9-200				CEI 1996 DC Floodway Study
9-201	DC at Douglas Highway	5905	3400	CEI 1996 DC Floodway Study
9-205	DC at Saunders Blvd.	5585	3100	CEI 1996 DC Floodway Study
	DC Basin 9 Confluence	-	3000	
10. Milne Valley				
None				
12. Upper Donkey Creek				
12-201	DC and Highway 50	3720	2850	FEMA FIS 2008, FIS 1988
		3720	2950	CEI 1996 DC Floodway Study
		3720	3300	1978 Plan Future Conditions

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SECTION FOUR
HYDRAULIC ANALYSIS

4.1 EVALUATION METHODS

Hydraulic analyses were conducted for the 2-, 5-, 10-, and 100-year recurrence interval flood events for study reaches shown in Figure 4.1. The hydraulic analysis was performed by dividing each basin into several reaches, which cover a total of approximately 78 miles from the headwaters near Highway 50 to the confluence of Stonepile Creek and Donkey Creek. With the exception of the main stem of Stonepile Creek, most major drainageways within the City are natural grass-lined swales, with well-defined channels near road crossings.

Stonepile Creek and several of its major tributaries have been channelized or concrete lined from Newton Road at the upstream end to I-90 at the lower end, about 14 miles. Study reaches were selected on a qualitative basis according to multiple criteria:

- Expressed interest by the City to include the reach
- Value of structures owned by the City as part of their storm network
- Presence (or absence) of existing FEMA regulation
- Presence of structures in or near the drainageway

Hydraulic evaluations were also performed for major structures on each study reach, such as bridges and culverts, and detention ponds and inadvertent detention areas such as playas.

4.1.1 Data Sources

In addition to URS observations, the City of Gillette provided the data used for hydraulic evaluations. Several extensive data sources were made available, which are described in Table 4.1.

Table 4.1
Hydraulic Data Sources and Descriptions

City of Gillette Data	Descriptions
URS Field Notes	Field notes from surveys by URS personnel in 2009 and 2010
Ortho rectified aerial photography	2008 and 2009 flights were rectified and provided in SID format for GIS
Digital Terrain Model (DTM)	2-foot contours from a 2003 aerial survey were available for most of the study area, and 1-foot contours were available for most of Donkey Creek from a LIDAR survey in 2010
As-built database	The City supplied a GIS polygon shapefile that linked TIF images of as-built drawings and URS converted the TIFs to PDF and adjusted the attribute data to link to both TIF and PDF
HEC-RAS models	The City supplied relatively recent HEC-RAS models for the main stems of the tributaries in major basins 4 (by Bruce Engineering) and 7 (by CEI)
Point and line GIS database	A 2005 survey by a consultant provided the basis for a stormwater geodatabase and the widespread data gaps and errors were corrected to a large extent by City GIS RTK survey

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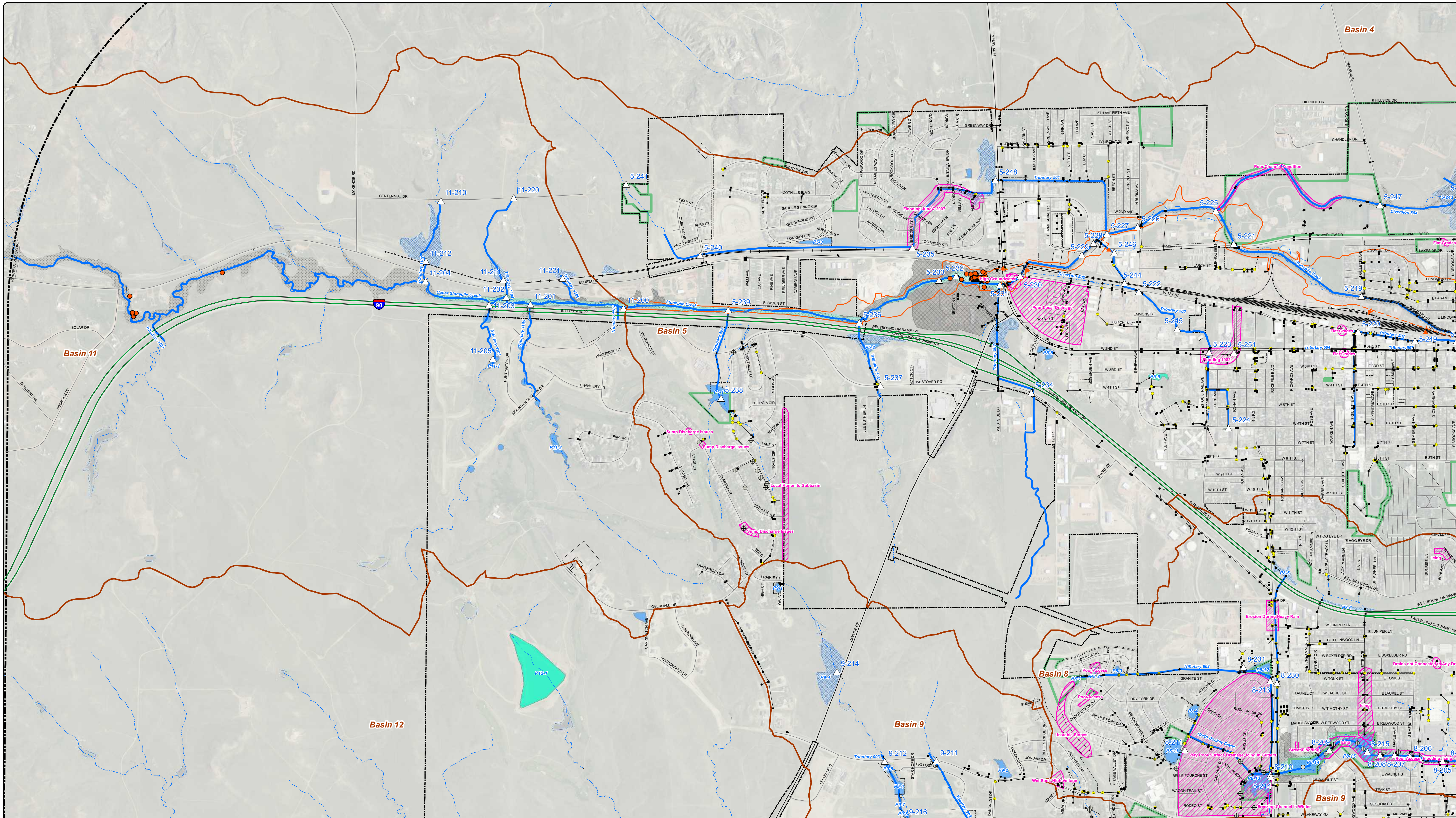


Design Points
Structures in the 100-Year Floodplain
Dewatering Wells
Inlet Structure
Manholes
Outlet Structures

Study Reaches
Existing Conduit
Existing Open Channel
Interstate
State or US Highway
Streets
Railroads

Areas of Interest
Basin 8 Major Basin
City Limits
Study Area
City Property
Existing Parks

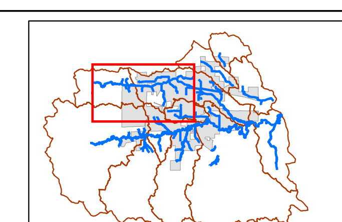
Detention Type
City
County
Private
Stock Pond
Road Inadvertent
Depression Playa

FIS Flood Zone
A; AE
AE FLOODWAY
X

Future Conditions Flooding Limits
Contained in Floodplain
Shallow (< 1-foot depth) Flooding Leaving Channel
Flow Direction Leaving Channel

URS

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364



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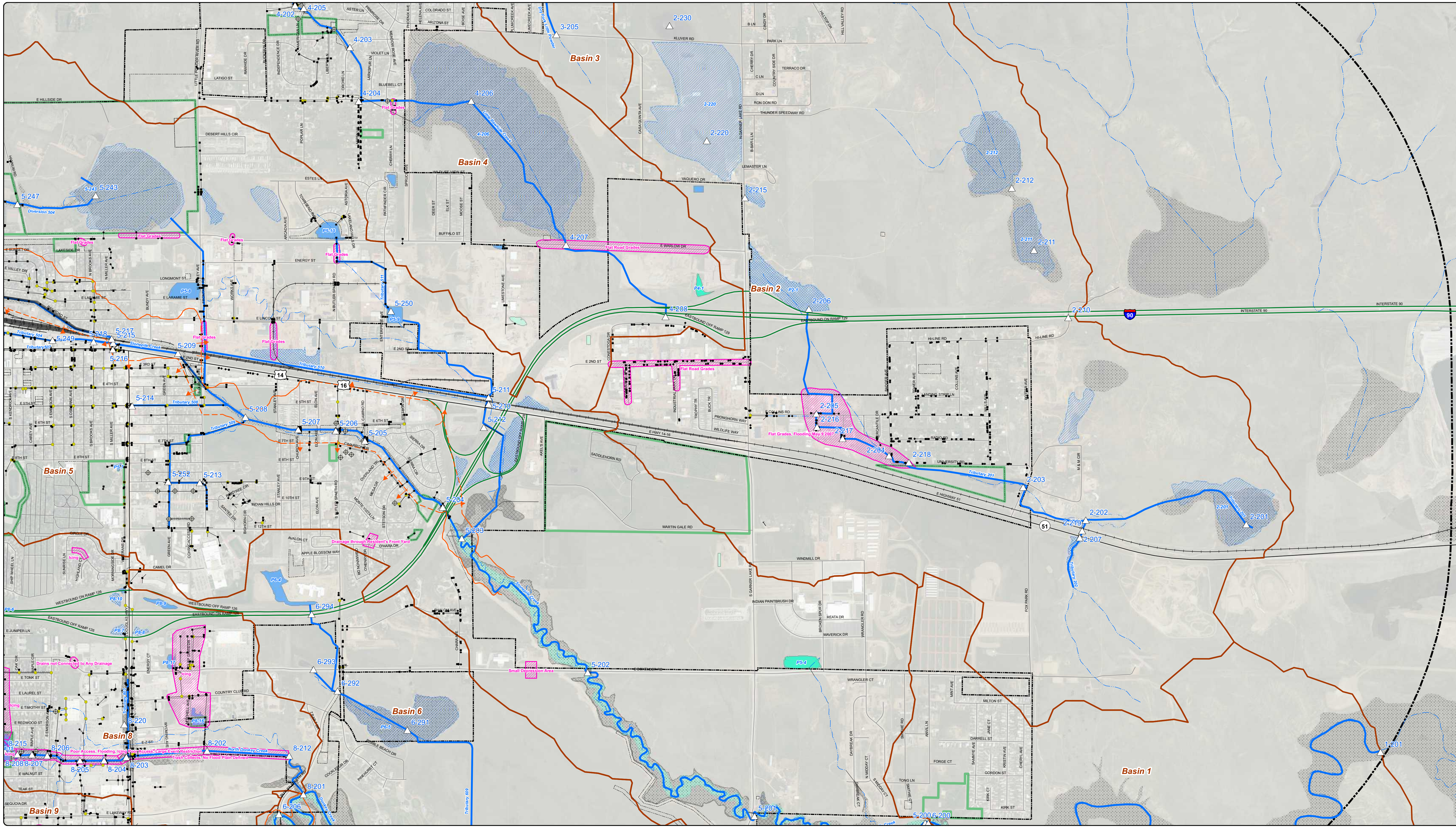
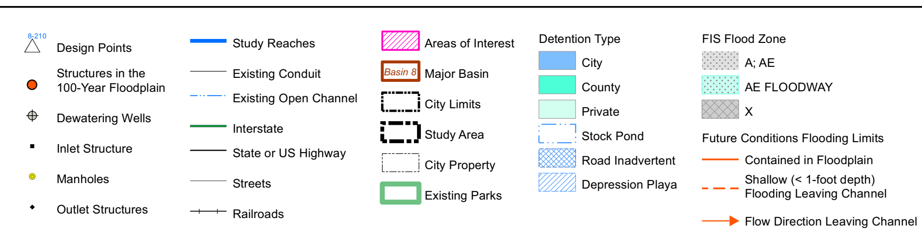
Areas of Interest
Page 1 of 4

Gillette Stormwater Master Plan

4.1





URS

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

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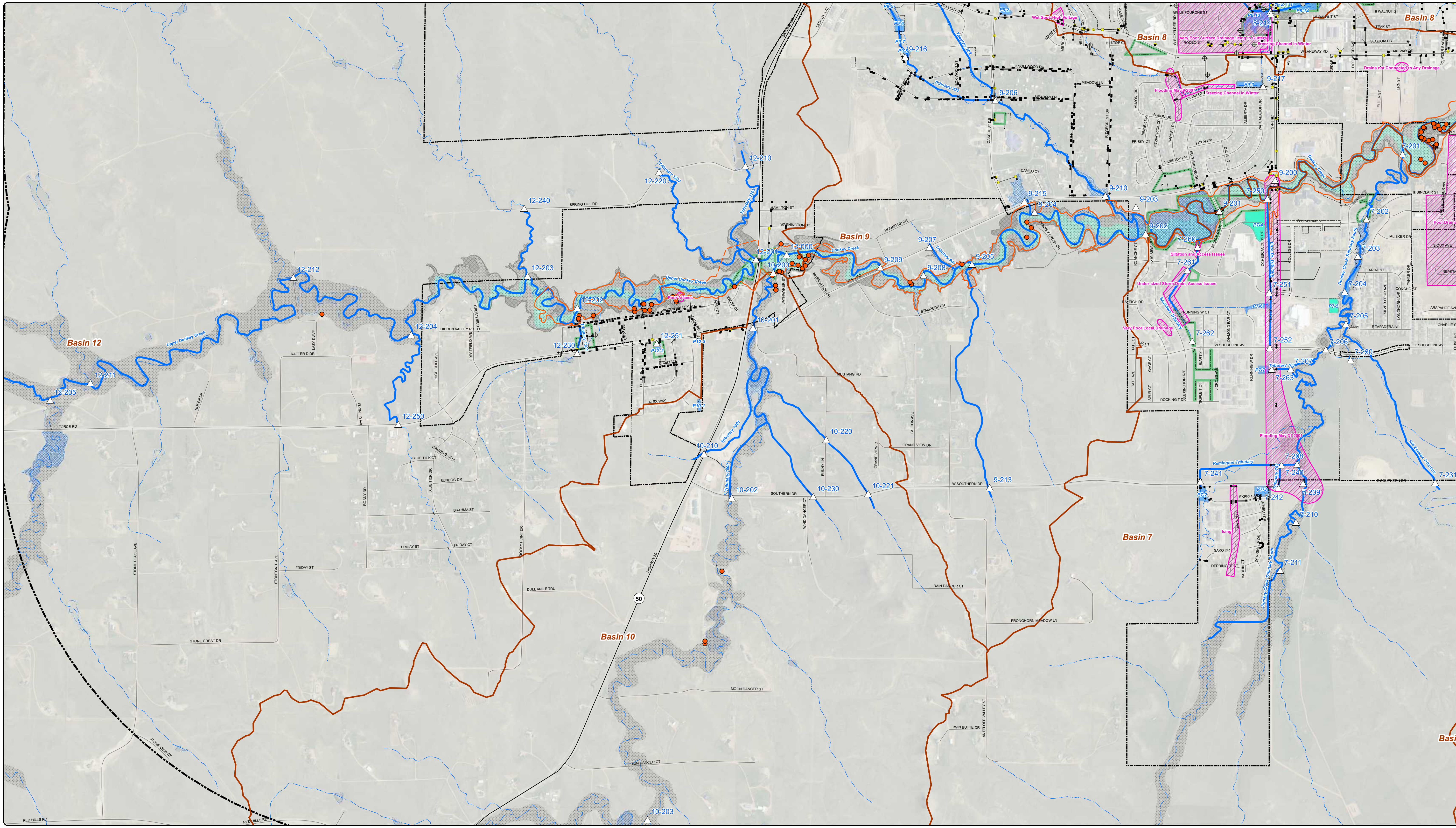
Areas of Interest
Page 2 of 4

Gillette Stormwater Master Plan

4.1



Design Points
Structures in the 100-Year Floodplain
Dewatering Wells
Inlet Structure
Manholes
Outlet Structures

Study Reaches
Existing Conduit
Existing Open Channel
Interstate
State or US Highway
Streets
Railroads

Areas of Interest
Major Basin
City Limits
Study Area
City Property
Existing Parks

Detention Type
City
County
Private
Stock Pond
Road Inadvertent
Depression Playa

FIS Flood Zone
A; AE
AE FLOODWAY
X

Future Conditions Flooding Limits
Contained in Floodplain
Shallow (< 1-foot depth) Flooding Leaving Channel
Flow Direction Leaving Channel

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GILLETTE, WY 82717 (307) 686-5364

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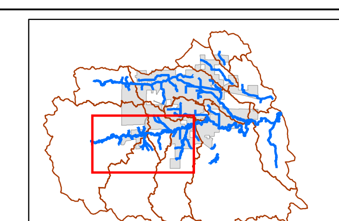

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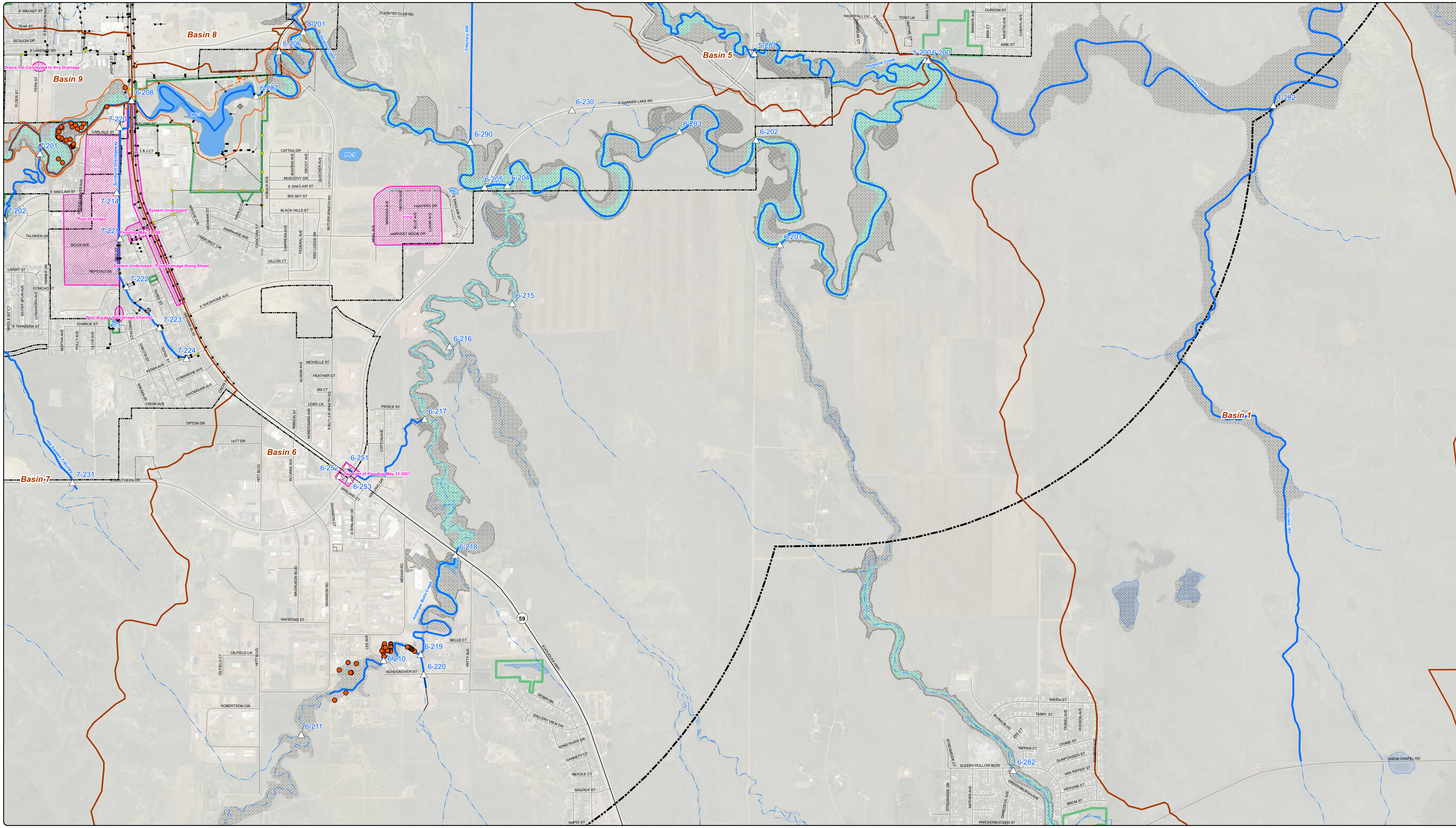
Areas of Interest
Page 3 of 4

Gillette Stormwater Master Plan

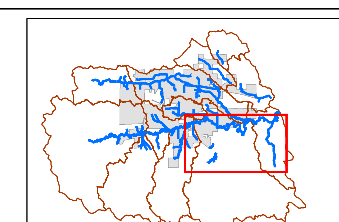
4.1



URS

Legend				
Design Points	Study Reaches	Areas of Interest	Detention Type	FIS Flood Zone
Structures in the 100-Year Floodplain	Existing Conduit	Major Basin	City	A; AE
Dewatering Wells	Existing Open Channel	City Limits	County	AE FLOODWAY
Inlet Structure	Interstate	Study Area	Private	X
Manholes	State or US Highway	City Property	Stock Pond	Future Conditions Flooding Limits
Outlet Structures	Streets	Existing Parks	Road Inadvertent	Contained in Floodplain
	Railroads		Depression Playa	Shallow (< 1-foot depth) Flooding Leaving Channel
				Flow Direction Leaving Channel

THE INFORMATION ON THIS DRAWING WAS OBTAINED FROM RECORD AND DESIGN DRAWINGS. THE CITY OF GILLETTE MAKES NO GUARANTEE REGARDING THE ACCURACY OF THIS DRAWING OR THE INFORMATION CONTAINED THEREIN.



0 800 1,600
Feet

Areas of Interest
Page 4 of 4

Gillette Stormwater Master Plan

4.1

Data for use in the hydraulic analysis was selected for each structure evaluation on a structure-by-structure basis. Where conflicting information was found and in general, the field notes were referenced first, followed by as-builts and the point and line database. Working tables of existing selected structure summaries were developed for each basin to note the parameters used for the evaluation, and the reasons they were selected. In many cases multiple data sources were used, such as when the point and line database was referenced for the pipe size and invert information, and the LIDAR data was used for the deck or roadway elevations.

4.1.2 Open Channels

Unless noted otherwise, open channels have been analyzed using FlowMaster (Reference 124) and Manning's equation.

4.1.3 Culverts

Unless noted otherwise, cross culverts have been analyzed using CulvertMaster (Reference 123) using the orifice, weir, and Manning's equations as appropriate, and the results incorporated into a HEC-RAS model of the drainageway or reported separately.

4.1.4 Storm Sewers

Storm sewers have been analyzed using StormCAD (Reference 125) or InfoSWMM using the orifice, weir, and Manning's equation as appropriate. Use of these computer models is consistent with City criteria.

4.1.5 HEC-RAS Modeling

Where a backwater or complex geometric condition exists, HEC-GeoRAS (Reference 141) was used to perform one-dimensional, steady flow hydraulic calculations. HEC-GeoRAS is a geospatially referenced river model from the USACE's Hydrologic Engineering Center. Existing HEC-RAS models provided by the City were used for this analysis in Basins 4 and 7. In general, HEC-GeoRAS models were developed to meet criteria that are normally required by FEMA.

Structures were modeled free of any major obstructions to reflect properly maintained conditions. However, many culverts throughout the City actually have reduced capacities due to sedimentation, vegetation growth, and the accumulation of debris. Cleaning and maintenance of these culverts is required to restore their flood flow capacities.

Ineffective flow areas were defined in certain cross-sections using the HEC-RAS cross-section data editor. Ineffective flow areas were defined to represent disconnected low lying areas that may contain water in a flood event but do not effectively convey flow.

4.2 MODELING CRITERIA

The criteria used to evaluate hydraulic conveyance and performance are the applicable sections in the City's *Storm Drainage Design Manual* (SDDM) (Revised January 2011). In addition, Manning's n values were estimated using the SDDM.

The design return period for this study is the 100-year existing land-use conditions rainfall event. The 24-hour rainfall depth for the 100-year event in Gillette is 4.0 inches (SDDM, Table 2.1).

4.3 SUMMARY OF RESULTS

The approximate 100-year floodplains for certain study reaches and other areas of interest are illustrated in Figure 4.1. Existing and future conditions peak flows and corresponding hydraulic conveyance for open channels and structures are summarized in Table 4.2 for key design points in each basin, and the results are discussed in the following paragraphs. The limiting hydraulic criterion for each channel and structure is noted in the comment column in Table 4.2.

4.4 DONKEY CREEK AND TRIBUTARIES

4.4.1 Donkey Creek Main Stem

Existing condition 100-year flow rates on Donkey Creek range from about 3,700 cfs at Highway 50 in Basin 12 to about 8,000 cfs at the downstream limit in Basin 1. Donkey Creek has six local and six arterial or collector roadway crossings within the study area. Of these, only the bridge at Garner Lake Road has adequate conveyance according to the evaluation criteria.

The only detention on the main stem of Donkey Creek is Fishing Lake, which has capacity of only about 6 ac-ft above the normal water surface elevation and does not affect the 100-year flow rates. For flood control purposes, Fishing Lake may be characterized as a frequent event retention facility. The “detention” indicated in Figure 4.1 around design point 9-202 was mentioned in Section 2.7.2, and is the “storage” above the Donkey Creek 100-year base flood elevation. This in-stream storage will not be allowed in the future.

It is important to note that the floodplain in the reach of Donkey Creek from Highway 59 to Butler Spaeth Road, which passes through Fishing Lake and Dalby Park, has not been mapped by FEMA. Both the upstream and downstream reaches have been mapped; see FEMA FIRMs in Appendix C. According to this analysis, the 100-year flood on Donkey Creek will not overtop Highway 59 or Butler Spaeth Road, but Fishing Lake Dam acts as a weir and creates shallow flooding (1 to 2 feet deep) to the north across Edwards Street, which would extend onto residences between Lakeway Road and Edwards Street. Other locations where there are structures in the currently defined FEMA floodplain are upstream of Donkey Creek Drive, near Jayhawker Street and along Hidden Drive.

Upstream from Fishing Lake, the bridge at Highway 59 does not meet current criteria but does not overtop, and there are a number of structures along Carlisle Street that are inundated by the back water from this bridge. There is fill in the channel that appears to be old stock dams at just upstream of Highway 59, which causes significant increases in the water surface elevations. The channel upstream from here is adequate to Donkey Creek Drive, and there are a number of structures in the floodplain between Donkey Creek Drive and the western City limits.

Most of the other structures upstream from Highway 59 are adequate for the 10-year event, but do not meet criteria. The four, 66″ CMPs at Brorby Road are clearly undersized, as is the one lane bridge at Donkey Creek Drive and the 10' x 4' CBC at Jayhawker Street. The other structures appear to have been adequately sized for the flow rates given in the FIS, but do not meet the current criteria and hydrologic conditions.

The channel configuration at the Highway 50 crossing results in water surface elevations for the 100-year event that nearly match the Zone AE limits in the current floodplain. There is fill in the channel that appears to be old stock dams at about Dade Road and again at the end of Hidden Valley Road. This fill causes significant increases in the water surface elevations.

4.4.2 Fox Park (Basin 1)

Only a tributary to the main stem of Donkey Creek in Basin 1 was evaluated, and it has sufficient capacity for the full 100-year event. This basin is primarily analyzed in order to provide consistent hydrology and flow rates for future development along Donkey Creek.

4.4.3 Antelope Butte Creek (Basin 6)

Antelope Butte Creek upstream of Highway 59 to Lee Avenue is the main study reach in Basin 6. The main stem of Donkey Creek was considered separately. There is no detention pond located on this reach. Antelope Butte Creek has a crossing at Highway 59 and a crossing at Lee Avenue. Under existing and future conditions, both crossings are inadequate for the 100-year event, but adequate for the 10-year event. The channel capacity between Highway 59 and Lee Avenue is severely limited by structures in the 100-year floodplain. There are at least 30 structures identified from the 2009 aerial photographs in the Antelope Butte Creek floodplain.

Of the existing detention ponds in Basin 6, all are effective in the 100-year event. None overtop, and the least effective is the Moon Shadow Regional Pond with a 17% reduction.

Icing conditions have been reported in the Moon Meadow neighborhood north of Harvest Moon Drive that is probably due to the flat road grades. Significant flooding was reported at the intersection of Douglas Highway and South Garner Lake Drive, where the crossing structures at design points 6-251, 6-252, and 6-253 for those tributaries of Antelope Butte Creek are inadequate.

Tributary 609 on the north side of Donkey Creek in Basin 6 consists of a constructed channel, a depression playa, and series of channels and road crossings that extend to the north of I-90. All of the crossing structures are inadequate, and no crossing structure was found at Boxelder Road. The constructed channel from the Playa to Donkey Creek was estimated as adequate for flows from the playa by visual inspection. The 100-year event raises the water surface elevation in the Playa by less than 1 foot, and the downstream channel is at least 2 feet deep. This channel will need to be evaluated in detail when future development is proposed.

4.4.4 Donkey Creek Tributary South (Basin 7)

Donkey Creek Tributary South (DCTS) was the main focus in this basin. Other tributaries studied include Hitt Estates Tributary, Sunburst Drainageway, Enzi Tributary, and the Saunders Tributary. Probably because development here is more recent, a greater percentage of the crossing structures meet the hydraulic criteria, as can be seen in Table 4.2. The crossings of DCTS at Southern Drive, Shoshone Avenue, and College Park Circle are inadequate for the 100-year event, as are a few of the local roadway crossings on the tributaries. Except for the DCTS reach between W. College Park Circle and Sinclair Street, all channel reaches are adequate. The relatively new Sunburst system is slightly inadequate at Arapahoe Road and at Sinclair Street.

The icing that occurs in the Remington subdivision is due to flat road grades, as is the very poor local drainage west of the Saunders Tributary. The system inadequacy reported along South Douglas Highway is probably a result of flooding that occurred during a storm in 2001 that was in excess of the 100-year event. Since the storm sewer is only sized for the minor event, the flooding during a major event was inevitable. Improvements made on the Sunburst Drainageway in response to the 2001 flooding should help conditions on South Douglas Highway.

The same 2001 storm produced flooding along Enzi Drive and in DCTS. Along the Saunders Tributary, the channel is inadequate due to inadequate cross-sectional area, and the sedimentation that is occurring is due to slow velocities at the end of the channel combined with uncontrolled earthwork construction in the upstream basin.

All of the detention ponds in Basin 7 are effective, but Remington Pond D1 and RC Ranch Detention E overtop Express Drive and Enzi Blvd., respectively, in the major event.

4.4.5 North Donkey Creek (Basin 8)

North Donkey Creek (NDC) begins at Sage Bluffs Park on the west side of 4-J Road and flows easterly through highly developed residential and commercial areas. Other tributaries studied include tributaries 802 and 803. There are many roadway crossings of NDC, and the creek's proximity to major local businesses, such as the Wal-Mart on Highway 59, has constrained the channel to a concrete lined section in certain reaches.

NDC open channel sections are adequate for the 100-year event, except for the reaches downstream of Highway 59 to Donkey Creek. The Douglas Highway Storm sewer system appears to be adequate.

The Sage Bluffs subdivision from design points 8-211 to 8-214 has flat road grades, resulting in poor surface drainage and icing in the gutters. Sage Bluffs Park is also an existing detention facility that is effective at reducing flows from the upstream watershed. However, the 4-J Road crossing is inadequate for even the 2-year event under the current criteria and 64 cfs overtops 4-J Road during the 100-year event. The NDC culvert crossings at Birch and Maple Avenues have limited capacity and are intended to overtop in larger events, which does not meet current criteria. Icing occurs along NDC here due to the combination of flat grades and dewatering pumps that operate all year.

Sunflower Park also acts as a detention area for NDC, but the crossings at Dogwood and Emerson Avenues are inadequate for the 100-year event, overtopping by 121 and 204 cfs, respectively.

Tributary 802 follows 4-J Road to the Cottonwood Park detention facility and north to Boxelder Avenue. There is a 36-inch and 27-inch diameter storm sewer system, which is not adequate for the 2-year event. Issues in this area are compounded by sediment from erosion of the scoria stockpiles in the County road facility on 4-J Road. The Cottonwood Park detention facility does not reduce peak flows appreciably for the 100-year event, nor do the Sage Valley Park pond, the Mitchell Pond or the Private Pond P8-18. All of these ponds overtop in the 100-year event.

The Upper Sage Valley Ponds at the western end of Tributary 802 have been modeled under existing conditions, and are effective; however, Pond G overtops by 33 cfs in the 100-year event. Of the 5 inadvertent detentions along I-90, all but Detention 1 reduced flows by at least 37%. The Silverado Detention reduced flows by 81%.

The unstable slopes noted in the northwest corner of Basin 8 are likely due to recent earthwork construction on steep slopes compounded by precipitation events before vegetation was re-established.

4.4.6 Direct Flow Areas (Basin 9)

The study reaches in Basin 9 are Tributaries 902 and 903, which extend from Donkey Creek to Lakeway Road. The majority of the crossings on these tributaries are under-sized, with the least effective being on Tributary 902 at Lakeway Road and 4-J Road. Of the eight ponds modeled, six are effective. The Pronghorn Estates Ponds 3 and 4 are the least effective. The 48″ outlet from the Sutherland Estates pond is inadequate and the pond overtops Lakeway Road and discharges 145 cfs in to Basin 8, contributing to the problems there.

The drainageway channels on Tributaries 902 and 903 are steep and well defined, and the channel was assessed as adequate by visual inspection and the fact that no flooding has been reported.

4.4.7 Milne Valley (Basin 10)

A majority of the culvert crossings in Basin 10 are under-sized, with the least effective structure at 4-J Road just west of Highway 50.

The Pond at Doud Ranch reduces the peak flow by 19% and does not overtop in the 100-year event. The only reach of channel assessed is the short section of Tributary 1001 upstream of Donkey Creek, and this channel was assessed as adequate when there is a nominal flow in Donkey Creek.

There are 3 structures in the current Zone A floodplain near Donkey Creek and design point 10-200, which would be further impacted by the floodplain resulting from this study. There are structures in the current Zone A floodplain farther upstream that were not assessed, since they are well outside the City limits and pre-annexation area.

4.4.8 Upper Donkey Creek (Basin 12)

None of the roadway crossing structures in Basin 12 is adequate for the 100-year flow.

The detention facility at the golf course, Bel Nob Reservoir, is more than adequate for the 100-year flows it receives, even if the pond is full, and both of the Doud Ranch ponds have capacity for the 100-year event.

4.5 STONEPILE CREEK MAIN STEM

The 100-year flow rates on Stonepile Creek range from about 2,500 cfs at the upstream study limit near I-90 to about 5,400 cfs at the confluence with Donkey Creek. Stonepile Creek has 6 local, 1 collector, and 10 arterial crossings within the study area, none of which are adequate for the 100-year flow. Split flows would occur at many of these crossings, but for the purposes of this study, the full flood flows for each event are assumed to remain in the channel and be conveyed downstream, so that each channel section and roadway crossing structure could be evaluated.

The reaches of Stonepile Creek from Donkey Creek to I-90 on the east and from Highway 14/16 to the upstream limit on the west have been mapped by FEMA using detailed methods. Between I-90 and Highway 14/16 in the central part of Gillette, the main stem of Stonepile Creek has been mapped by FEMA as a Zone A (approximate) floodplain, see FEMA FIRMs in Appendix C. There are many structures in the currently effective FEMA floodplain upstream of Highway

14/16. The 100-year future conditions floodplain from this analysis is much larger than the current FEMA Zone AE, and would include even more structures in this area, such as the Best Western Tower West.

Most of the culvert and bridge structures are only adequate for the 10-year event. The culverts at Church Avenue are undersized, as are the two 5’ RCP culverts at Commercial Drive, the 48” RCP arch at Newton Road, and the 48” CMP culvert at the gravel road upstream of Newton Road. The other structures appear to have been adequately sized for the current FIS 100-year event (from the 1978 Plan), but will not pass the 100-year event flows predicted by this model.

The floodplain for Stonepile Creek has many areas where split flows would occur causing shallow flooding outside the main channel. For example, large areas of the Meadow Hills, Northside, and Bundy Addition subdivisions would be flooded north of the BNSF tracks. On the south side of the tracks from Cimarron Drive to Highway 14/16, several subdivisions are subject to extensive shallow flooding due to flat grades and low channel banks. Significant backwater would form at the long structure under Railroad Street, at the BNSF railroad bridge and the long crossing of Highway 14/16, at Gurley Avenue and I-90. When the channel banks overtop, there is potential for split flows at each location. The backwater at I-90 has added significance because of the 5-foot height of the embankment. Split flows would cause flooding in areas away from the main channel and on adjacent tributaries.

The only *reported* problem area along the main stem of Stonepile Creek is between design points 5-230 at Echeta Road and 5-231 at Highway 14/16, where high groundwater and seepage are issues.

4.5.1 Upper Stonepile Creek (Basin 11)

There are 2 collector and 4 arterial crossings in this basin, and most are undersized. Only the three 54” CMP culverts on Tributary 1105 at I-90 are adequate for the 100-year event. The 18” CMP culvert on Tributary 1102 at Centennial Drive is the least effective, with capacity insufficient for even the 2-year event.

4.5.2 Lower Stonepile Creek Tributaries (Basin 5)

There are 21 local, 4 collector and 15 arterial culvert crossings along tributaries to Stonepile Creek that were evaluated in Basin 5, many of which are undersized. On Tributary 510, culvert crossing structures at I-90, Highway 14/16, and the BNSF railroad, at design points 5-212, 5-211, and 5-210 are inadequate. Because these structures do not pass the 2-year event, there is a strong possibility of significant attenuation of flood flows in the small depression areas in this sub-basin that has not been modeled. Also, there is a chance that surcharging flows from this tributary split and divert flow to the main stem upstream of I-90. The reach upstream of design point 5-210 is included to allow for split flows of the main stem along the BNSF railroad from design point 5-209.

Tributary 509 consists mostly of storm sewer that is undersized for the 2-year event, and most of the flow is surface flow on Green Avenue 7th Street, 6th Street and across Gurley Avenue. The storm sewer in 5th Street on Tributary 508 is adequate for the 5-year event. The 2nd Street and Brooks Street storm sewer and channel on Tributaries 507 and 504 have sufficient capacity for the 100-year future event, however, the Gillette Avenue storm sewer in Tributary 504, is not adequate, and significant flows at the lower end will be on the surface in Gillette Avenue and then 1st Avenue to the outfall channel. The 1st Avenue storm sewer upstream of Gillette Avenue is almost adequate, and excess flows will travel in 1st Avenue to the outlet channel.

There are many locations with flat roadway grades in Basin 5 that were reported as problem areas due to poor runoff conveyance causing icing. The potential for flooding on Tributary 502 at 2nd Street and Rohan Avenue, design point 5-223, was confirmed by this analysis. Although the two arch CMPs at this location have sufficient capacity for the 100-year event, the downstream channel does not have capacity for the 2-year event.

Also on Tributary 502, the two 6' x 5' concrete box culverts at Burma Avenue, two 90" x 58" CMP culverts at 2nd Street, two 7' CMP culverts at the BNSF railroad and two 90" x 58" CMP culverts at the gravel road upstream of 1st Street are adequately sized for the 100-year event. The 24" CMP culvert on Stonepile Creek Tributary 510 at the BNSF railroad is least effective, with capacity insufficient for even the 2-year event.

Tributary 501 has inadequate crossings and inadequate channels throughout, which is confirmed by the reported flooding in these areas. There is a commercial property in the drainageway upstream of Westover Road on Tributary 503 that could be in the floodplain of the tributary, but a more detailed survey of this site is necessary to confirm this. The channel upstream of this site was assessed as adequate by visual inspection, but the 2-48-inch CMP crossings of Westover Road, I-90, and Highway 50 downstream will carry only the 10-year event. Excess flows will be conveyed on the street in Highway 50 and continue on Highway 14/16 where they will discharge to the main stem of Stonepile Creek near design point 5-231.

On Tributary 506, the culvert crossings of I-90 are nearly adequate. The culvert crossing of Westover Road is inadequate, but the channel was assessed as adequate by visual inspection. On Tributary 505 the upstream South Stocktrail Elementary School detention pond provides enough protection for the flows downstream from it to I-90, and the culvert crossing of I-90 is nearly adequate.

The Burlington Ditch and Lake, Diversion 504, are discussed in the following subsection.

4.5.3 Burlington Ditch and Lake

Burlington Lake is fed by Burlington Ditch from a diversion off of Stonepile Creek, Diversion 504. Diversion 504 consists of a four foot tall earthen embankment in the main channel that acts as a weir. All flow in Stonepile Creek less than four feet in depth is diverted to Burlington Lake through the diversion channel. The diversion channel is a grass-lined trapezoidal channel with approximately 10 foot bottom width and 6 foot depth. The diversion channel is large enough to handle the 100-year event flow that is diverted from Stonepile Creek. The diversion channel has three culvert crossing structures, 2-60" CMPs under Hannum Road that is adequate for only the 2-year event, and two 36" CMP culvert crossings that are not adequate for the 2-year event.

A HEC-RAS analysis of the diversion structure indicates that flows in the diversion channel will overtop the south bank in the existing and future conditions 100-year events. These overtopping flows could cause the diversion channel bank to wash out, and even greater overtopping flows would then result. The diverted flows will spread out and create an area of shallow flooding that passes through the park on the south. Here the shallow flows may split again. Part of the flow would cross Warlow Drive and reenter Stonepile Creek and part of the flow would continue on to Burlington Lake. The existing condition InfoSWMM model does not include this potential split flow condition, and assumes all flows diverted from Stonepile Creek end up in Burlington Lake.

Burlington Lake has a capacity of approximately 425 ac-ft before it overtops Warlow Drive. During the existing conditions 100-year event 491 ac-ft is diverted to the lake, which would cause overtopping of Warlow Drive by about one foot. Any flood water from Burlington Lake would merely cross Warlow Drive and fill depression areas around the Campbell County School Aquatic Center.

4.6 EAST FORK LITTLE RAWHIDE CREEK (BASIN 4)

Nearly all of the structures on Little Rawhide Creek are adequate for the 100-year event. The exceptions are at I-90, Warlow Drive and Little Powder River Road, which are significantly undersized. All of the channels have sufficient capacity.

Only the County pond behind the WYDOT facility on Garner Lake Road was modeled as a detention pond in Basin 4, and it is adequate for the existing condition 100-year event. There are flat road grades reported on East Warlow Drive adjacent to this facility and at the north end of Cherry Lane, which results in poor surface conveyance.

4.7 DRY FORK LITTLE POWDER RIVER (BASIN 3)

There is not much development in Basin 3. The culvert crossing at Kluver Road is only adequate for the 5 year event. The detention pond at Ash Meadows Estates overtops in the 100-year event, but is adequate for the 10-year event. This pond was designed for the 100-year event using the 1-hour storm depth using different methods.

4.8 CLOSED BASINS (BASIN 2)

Many of the structures in this basin are inadequate even for the 2-year event, and flooding was reported on the Collins Road and Market Street in May 2007. The City's plans for improvements to the drainageways in the Collins Heights and Industrial Park subdivisions were evaluated as part of this stormwater master plan.

The culvert crossing at I-90 upstream of the Collins Heights subdivision causes inadvertent detention at the embankment, and detains approximately 10 ac-ft.

The many playas in Basin 2 have been modeled as outfalls where the total volume of runoff from the future 100-year event is reported. This can be used for future delineations of the floodplains at these playas when development is proposed.

Table 4.2
Main Stem Donkey Creek Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
SELECTED DESIGN POINTS																
6-200	223	Confluence of Stone Pile Creek & Donkey Creek	Confluence	NA	14189	NA	NA	6298	2905	2307	2125	6457	3535	2689	2426	
6-201	305	Confluence of Unnamed Tributary and Donkey Creek	Confluence	NA	3480	NA	NA	5499	1762	784	460	6061	2009	890	509	
6-203	305	Confluence of Unnamed Tributary and Donkey Creek	Confluence	NA	35385	NA	NA	5671	1854	825	522	6243	2102	928	584	
6-204	305	Confluence of Unnamed Tributary and Donkey Creek	Confluence	NA	35142	NA	NA	5863	1955	871	590	6445	2206	970	667	
9-205	301	Tributary 913 & Donkey Creek confluence	Donkey Creek confluence	NA	17675	NA	NA	5553	1946	860	375	6053	2165	972	491	
STRUCTURES																
6-202	305	Donkey Creek & Unnamed gravel road	2-48"CMP	Field Notes	33583	Local	260	5590	1811	806	493	6157	2058	910	549	Limited by 0.5' overtopping road.
6-205	305	Donkey Creek and Garner Lake Rd	Bridge and D/S Ped Crossing	As-built	28143	Arterial	6435	5853	1950	868	587	6435	2201	968	663	Capacity 2' below Low Chord.
6-206	309	Donkey Creek and Butler Spaeth Rd	1 Span Bridge	As-built	25739	Arterial	4000	5888	1973	854	497	6473	2223	965	579	Capacity 2' below Low Chord.
6-207	304	Fishing Lake Dam Rd.	No outlet	Aerial/LIDAR	25722	Local	~50	5823	1943	816	368	6405	2190	940	447	Model as a weir in HEC-RAS. Limited by 0.5' overtopping road.
6-208	204	Donkey Creek and South Douglas Highway	Bridge est 145' by 8' from LIDAR, w/ 3ft deck, 3 span, 1.5' piers	Field Notes	25590	Arterial	3500	5905	1969	825	371	6498	2218	951	453	Capacity 2' below Low Chord.
9-200	302	Donkey Creek & Enzi Dr.	CBC 3-10'x 10'	As built	19161	Arterial	3066	5710	1945	834	380	6258	2179	957	546	Limited by 1.2 HW/D
9-201	302	Donkey Creek & Saunders Blvd.	CMP 4-120"	Field Notes	18900	Local	4300	5658	1938	836	382	6194	2169	958	570	Limited by 0.5' overtopping depth
9-202	202	Donkey Creek & Brorby Blvd.	CMP 4-66"	Field Notes	18726	Local	700	5584	1929	839	385	6103	2155	960	606	Limited by 1.2 HW/D
9-204	301	Donkey Creek & Donkey Creek Dr.	Bridge (25' x 9.5')	DC Flood Study	17884	Local	1675	5566	1939	851	379	6074	2161	967	539	Limited by 2' WSEL freeboard
9-209	301	Donkey Creek & 4-J Rd.	Bridge (61' x 9')	DC Flood Study	17167	Arterial	3300	5542	1952	867	371	6035	2169	977	449	Capacity is 800 cfs with house out of bridge backwater. WSEL 2' below LC
12-000	Outfall	Upper Donkey Creek & Jayhawker St.	CBC 10'x4'	Field Notes	11607	Local	475	5533	1956	873	368	6022	2172	980	418	Limited by 0.5' overtopping depth.
12-201	210	Upper Donkey Creek & Highway 50	CMP 4-134"x88" elliptical	Field Notes	11508	Arterial	2765	3721	1354	615	263	4093	1523	700	303	Limited by 1.2 HW/D
CHANNELS																
1-201	305	Donkey Creek Channel Reach (DP 6-200 to study limit)	Native grass	Aerial/LIDAR	3692	NA	10000	7929	2385	1178	649	9785	3231	1543	872	Used Channel Element 306 flow rates.
6-206	309	Donkey Creek Channel Capacity (DP 6-207 to Butler Spaeth Rd.)	Natural Channel	Aerial/LIDAR	25739	NA	2190	5888	1973	854	497	6473	2223	965	579	
6-207	303	Fishing Lake Capacity (S. Douglas Hwy to DP 6-207)	Natural Channel	Aerial/LIDAR	25722	NA	447	5823	1943	816	368	6405	2190	940	447	Limited by overtopping dam road to north.
6-208	204	Donkey Creek Channel Capacity (Carlisel Rd DP 6-208)	Natural Channel	Aerial/LIDAR	25590	NA	453	5905	1969	825	371	6498	2218	951	453	Limited by structure in floodplain.
9-202	301	Donkey Creek Channel Capacity (Donkey Creek Rd to Brorby Rd)	Natural Channel	Aerial/LIDAR	18726	NA	6103	5584	1929	839	385	6103	2155	960	606	
9-204	301	Donkey Creek Channel Capacity (DP 9-205 to Donkey Creek Rd)	Natural Channel	Aerial/LIDAR	17771	NA	539	5566	1939	851	379	6074	2161	967	539	Limited by house in floodplain.
9-205	301	Donkey Creek Channel Capacity (DP 9-208 to DP 9-205)	Natural Channel	Aerial/LIDAR	17675	NA	6053	5553	1946	860	375	6053	2165	972	491	
9-208	316	Donkey Creek Channel Capacity (4-J Rd. to DP 9-208)	Natural Channel	Aerial/LIDAR	17133	NA	6044	5547	1949	863	373	6044	2167	975	469	
9-209	307	Donkey Creek Channel Capacity (Upstream limit to 4-J Rd.)	Natural Channel	Aerial/LIDAR	17675	NA	2169	5542	1952	867	371	6035	2169	977	449	Limited by structure in floodplain
12-000	308	Donkey Creek Channel Capacity (Hwy 50 to Jayhawker St)	Native grass	Aerial/LIDAR	12717	NA	2172	5533	1956	873	368	6022	2172	980	418	

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Main Stem Stonepile Creek Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)+				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
SELECTED DESIGN POINTS																
5-200	OUTFALL	Confluence of Lower Stone Pile Creek & Donkey Creek	Basin outfall	Field Notes/LIDAR	9229	NA	-	4460	788	412	244	5864	1219	583	360	
5-203	289	Confluence (Lower Stone Pile Creek & Tributary 510)	Confluence	Field Notes/LIDAR	8347	NA	-	3860	985	585	361	6525	1283	794	494	
5-208	270	Confluence of Stone Pile Creek & Tributary 509	Confluence	Field Notes/LIDAR	7619	NA	-	3308	882	533	323	6021	1069	693	438	
5-215	261	Lower Stonepile Creek & Tributary 504	Confluence	Field Notes/LIDAR	6490	NA	-	3276	608	370	223	5883	983	478	300	
5-225	229	Lower Stonepile Creek & Burlington Ditch	Inline weir	Field Notes	5718	NA	4335	3446	1118	531	208	4518	1518	772	329	Not limited by HW/D or overtopping criteria
5-227	251	Confluence of Stone Pile Creek & Tributary 501	Confluence	Field Notes/LIDAR	5498	NA	-	3425	1123	526	207	4380	1508	787	337	
11-204	201	Confluence of Tributary 1102 and Stonepile Creek	Confluence	Aerial/LIDAR	2893	NA	-	1968	664	275	104	2487	895	381	144	
11-202	204	Confluence of Tributary 1104 and Stonepile Creek	Confluence	Aerial/LIDAR	2610	NA	-	2391	746	320	119	3018	1022	436	167	
STRUCTURES																
5-201	299	Lower Stonepile Creek & S. Garner Lake Rd.	CBC 2 - 12' x 6'	Field Notes	8753	Arterial	1157	3815	775	415	246	6127	1192	568	359	Limited by HW/D ratio of 1.2
5-202	297	Lower Stone Pile Creek & S. Boxelder Rd.	CMP 4 - 10' x 7.5' Arch	As-built	8541	Arterial	1587	3811	794	474	301	6286	1179	624	416	Modeled as 123" x 81" arch, based on available sizes. Limited by 1' below roadway.
5-204	290	Lower Stonepile Creek & I-90	CBC 4 - 140" x 6'	Field Notes	7908	Arterial	2272	3669	779	465	287	5653	1055	586	370	Limited by HW/D ratio of 1.2
5-205	295	Lower Stonepile Creek & El Camino Rd.	CBC 4 - 15' x 40"	Field Notes	7720	Local	1208	3671	914	550	335	6016	1110	714	449	WS at High Chord (4512') because of HW/D restriction of 1.2
5-206	293	Lower Stonepile Creek & Butler Spaeth Rd.	CBC 6 - 11' x 4'	Field Notes	7699	Arterial	1739	3322	916	550	335	6021	1111	715	450	Limited by HW/D ratio of 1.2
5-207	271	Lower Stonepile Creek & Church Ave.	RCP 4 - 21", 2 - 19" x 30", 1 - 34" x 84"	As-built	7663	Local	295	3307	880	532	322	6013	1067	691	437	Limited by 0.5' above roadway
5-209	260	Lower Stonepile Creek & E 2nd St. (Hwy 51)	CBC 3 - 8' x 9.5'	Field Notes	6609	Arterial	1605	3199	608	367	223	5867	982	473	297	Modeled as 8' x 8' because assumed flow is barrel controlled. Limited by 1' below roadway. Crosses Gurley Ave also.
5-217	258	Lower Stonepile Creek & Railroad	Bridge	As-built	6467	Arterial	920	3196	580	214	93	5003	951	347	131	Limited by EG 2' below roadway.
5-219	255	Lower Stonepile Creek & Railroad Street	CBC 5 - 9' x 5'	Field Notes	6305	Local	1666	3145	576	209	76	5258	947	345	127	Limited by HW/D ratio of 1.2
5-221	253	Lower Stonepile Creek & Warlow Dr.	CBC 6 - 8' x 5'	As-built	5735	Arterial	1780	3073	561	187	46	4437	901	322	93	Limited by HW/D ratio of 1.2
5-226	227	Lower Stonepile Creek & Burma Ave.	CBC 1 - 9' x 7', 4 - 10' x 5'	As-built	5592	Arterial	2002	3424	1120	526	207	4379	1508	780	42	Limited by HW/D ratio of 1.2
5-228	225	Lower Stonepile Creek & Warlow Dr.	CBC 4 - 8' x 7'	Field Notes	5495	Arterial	1698	3042	946	442	171	3932	1336	683	250	Limited by HW/D ratio of 1.2
5-229	223	Lower Stonepile Creek & Commercial Dr.	RCP 2 - 5'	Field Notes	5493	Local	305	3042	946	442	171	3932	1336	684	250	Limited by HW/D ratio of 1.2
5-230	221	Lower Stonepile Creek & Echeta Rd./Railroad	RCP 3 - 9'	Field Notes	5107	Collector	1940	3044	947	442	171	3933	1336	716	250	Limited by HW/D ratio of 1.2
5-231	220	Lower Stonepile Creek & Hwy 14/16	CBC 4 - 9' x 5'	Field Notes	5098	Arterial	1307	3020	935	436	168	3855	1318	709	241	Limited by HW/D ratio of 1.2
5-232	217	Lower Stonepile Creek & Newton Rd.	RCP 1 - 48" Arch	As-built	4661	Local	185	2812	871	396	156	3573	1206	696	215	Limited by 0.5' above roadway
5-233	207	Lower Stonepile Creek & gravel road	CMP 1 - 48"	As-built	4649	Local	97	2812	871	393	156	3575	1206	732	216	Limited by HW/D ratio of 1.5
CHANNELS																
5-203	391	Lower Stonepile Channel Capacity (I-90 to DP 5-203)	Partial Cement & Natural Channel	Field Notes/LIDAR	8347	NA	5408	3666	777	464	286	6225	1055	585	370	
5-204	397	Lower Stonepile Channel Capacity (El Camino Rd. to I90)	Concrete Channel	Field Notes/LIDAR	7908	NA	<273	3642	742	448	276	5619	1040	560	355	Limited by structures in floodplain.
5-205	395	Lower Stonepile Channel Capacity (Butler Spaeth to El Camino Rd.)	Concrete Channel	Field Notes/LIDAR	7720	NA	1282	3671	914	550	335	6016	1110	714	449	
5-206	393	Lower Stonepile Channel Capacity (Church St. to Butler Spaeth)	Concrete Channel	Field Notes/LIDAR	7699	NA	1273	3306	877	530	322	6001	1063	687	434	
5-207	372	Lower Stonepile Channel Capacity (4th St to Church St.)	Concrete Channel	Field Notes/LIDAR	7663	NA	1276	3307	880	532	322	6013	1067	691	437	
5-209	362	Lower Stonepile Channel Capacity (DP 5-215 to DP 5-209)	Grass Channel	Field Notes/LIDAR	6609	NA	1185	3199	608	367	223	5867	982	473	297	
5-217	359	Lower Stonepile Channel Capacity (Brooks St. to Railroad)	Concrete Channel	Field Notes/LIDAR	6467	NA	329	3148	572	208	75	4985	943	342	126	Limited by structures near floodplain; channel configuration
5-219	357	Lower Stonepile Channel Capacity (Warlow Dr. to Railroad St.)	Concrete Channel	Field Notes/LIDAR	6305	NA	1124	3111	562	201	68	5207	926	331	114	
5-221	355	Lower Stonepile Channel Capacity (DP 5-225 to Warlow Dr.)	Concrete Channel	Field Notes/LIDAR	5735	NA	1172	3067	558	186	45	4429	897	320	89	Limited by channel configuration, flooding leaves channel.
5-225	325	Lower Stonepile Channel Capacity (DP 5-226 to DP 5-225)	Concrete Channel	Field Notes/LIDAR	5718	NA	4279	3421	1104	525	205	4489	1506	763	314	Wide channel, no structures near floodplain.
5-226	352	Lower Stonepile Channel Capacity (DP 5-227 to Burma Ave.)	Concrete Channel	Field Notes/LIDAR	5592	NA	1810	3424	1120	526	207	4379	1508	780	336	Limited by structures in floodplain.
5-227	324	Lower Stonepile Channel Capacity (Warlow Dr. to DP 5-498)	Concrete Channel	Field Notes/LIDAR	5498	NA	1546	3119	963	452	175	4022	1360	695	255	
5-228	320	Lower Stonepile Channel Capacity (Commercial Dr. to Warlow Dr.)	Concrete Channel	Field Notes/LIDAR	5495	NA	1417	3042	946	442	171	3932	1336	683	250	
5-229	321	Lower Stonepile Channel Capacity (Echeta Rd. to Commercial Dr.)	Concrete Channel	Field Notes/LIDAR	5493	NA	1417	3042	946	442	171	3932	1336	684	250	
5-230	318	Lower Stonepile Channel Capacity (Hwy 14-16 to Echeta Rd)	Concrete Channel	Field Notes/LIDAR	5107	NA	1411	3030	941	439	169	3915	1327	710	246	Limited by structures in floodplain.
5-231	316	Lower Stonepile Channel Capacity (Newton Rd. to Hwy 14-16)	Concrete Channel	Field Notes/LIDAR	5098	NA	<297	2812	871	396	156	3571	1206	638	215	Limited by structures in floodplain.
5-232	315	Lower Stonepile Channel Capacity (DP 5-233 to Newton Rd)	Grass Channel	Field Notes/LIDAR	4661	NA	<297	2812	871	396	156	3573	1206	696	215	Limited by structures in floodplain.
5-233	312	Lower Stonepile Channel Capacity (DP 5-236 to DP 5-233)	Grass Channel	Field Notes/LIDAR	4649	NA	294	2788	861	387	153	3542	1192	721	210	Limited by structures in floodplain.
5-236	308	Lower Stonepile Channel Capacity (DP 5-239 to DP 5-236)	Natural Channel	Field Notes/LIDAR	4507	NA	1165	2677	845	372	145	3348	1125	494	196	
11-200	322, 305, 303, 302, 307, 301, 300	Upper Stonepile Creek Channel (DP 11-204 to DP 11-200)	Rural Channel	Aerial/LIDAR	3539	NA	2449	2489	785	343	134	3143	1059	460	182	Will convey 100-yr without impacing adjacent structures or roadways.

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 1 Fox Park Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)+				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
1-202	300, 301, 302	Donkey Creek Tributary 101 (Union Chapel Rd to Confluence with Donkey Creek)	Native grass	Aerial	2613	NA	10000	780	152	37	8	1070	230	57	13	Used Channel Element 300 flow rates.

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 2 Closed Basins Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)*				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
STRUCTURES																
Tributary 201																
2-202	222	Confluence of Tributaries 201 & 202	Confluence	Aerial/LIDAR	1085	NA	NA	907	344	165	95	1527	702	365	174	
2-203	213	Tributary 201 & Potter Ave.	45"x25" RCP Ellipse	Field notes	482	Local	37	371	174	106	69	439	194	111	69	Limited by HW/D ratio of 1.5
2-218	223	Tributary 201 & University Rd.	2-30" CMP	Gillette Survey	401	Local	60	330	166	105	72	381	183	109	72	Limited by HW/D ratio of 1.5
2-204	210	Tributary 201 & Badger Ave.	2-30" CMP	Gillette Survey	361	Collector	49	330	166	105	72	381	183	109	72	Limited by HW/D ratio of 1.5
2-217	315	Tributary 201 & Market St.	2-30" CMP	Field notes	371	Local	210	62	13	3	1	123	30	7	1	Limited by 0.5' overtopping road.
2-216	315	Tributary 201 & Wall Street Ct.	2-30" CMP	Field notes	362	Local	185	62	13	3	1	123	30	7	1	Limited by 0.5' overtopping road.
2-205	209	Tributary 201 & Collins Rd.	24" CMP	Field notes	237	Collector	180	71	16	3	0	136	36	8	1	Limited by 0.5' overtopping road. Allowing overtopping of the road may impact homes downstream.
2-206	P2-1outflow	Tributary 201 & I-90	36" RCP	Field notes	107	Arterial	50	7	1	0	0	13	2	0	0	Limited by HW/D ratio of 1.5
2-206	P2-1	I-90 Inadvertent detention	Inadvertent detention	Aerial/LIDAR	107	NA	12 acft	128	43	17	6	185	69	29	10	9.75 acft in 100 yr storm
Tributary 202																
2-219	219	Tributary 202 & Railroad	RCP 2-42"	Field notes	579	Arterial	156	702	263	120	47	1311	644	341	160	Limited by HW/D ratio of 1.5
2-207	216	Tributary 202 & Hwy 51	RCP 48"	Field notes	579	Arterial	90	703	263	118	47	1311	644	341	156	Limited by HW/D ratio of 1.5
DEPRESSION PLAYAS																
2-201	217	Sub-basin 2-117, depression playa	Playa	Aerial/LIDAR	1439	NA	260 acft	1070	357	170	93	1855	756	364	160	182 acft in 100yr storm
2-211	207	Sub-basin 2-107, depression playa	Playa	Aerial/LIDAR	554	NA	NA	439	143	56	19	478	159	63	22	
2-212	204	Sub-basin 2-104, depression playa	Playa	Aerial/LIDAR	384	NA	NA	307	103	41	14	338	116	47	16	
2-220	228	Sub-basin 2-102, depression playa	Playa	Aerial/LIDAR	506	NA	178 acft	384	139	63	27	442	171	78	34	56 acft
2-230	201	Sub-basin 2-101, depression playa	Playa	Aerial/LIDAR	102	NA	69 acft	482	171	77	31	553	206	91	40	70 acft in 100 yr storm
2-210	208	Hi-Line Rd and I-90	Underpass	Aerial/LIDAR	55	Arterial	NA	77	31	15	7	80	32	16	7	
CHANNELS																
Tributary 201																
2-202	326	Channel Capacity (Potter Ave. to DP 2-202)	Rural Channel	Aerial/LIDAR	1085	NA	400	370	173	105	69	438	193	110	69	Channel has capacity for 100-year flow, but culvert at Potter Ave. is overtopped. Culvert capacity partially limited by tailwater condition caused by high channel invert.
2-203	314	Channel Capacity (University Rd. to Potter Ave.)	Rural Channel	Aerial/LIDAR	482	NA	332	283	139	87	59	332	155	91	59	
2-218	312	Channel Capacity (Badger Ave. to University Rd)	Rural Channel	Aerial/LIDAR	401	NA	<61	290	144	90	61	343	161	94	61	Limited by overtopping University Rd.
2-204	315	Channel Capacity (Market St. to Badger Ave.)	Rural Channel	Aerial/LIDAR	361	NA	<1	62	13	3	1	123	30	7	1	Limited by mobile homes in the floodplain.
2-217	315	Channel Capacity (Wall St. to Market St.)	Rural Channel	Aerial/LIDAR	371	NA	<1	62	13	3	1	123	30	7	1	Limited by homes in the floodplain.
2-216	315	Channel Capacity (Collins Rd to Wall St)	Rural Channel	Aerial/LIDAR	362	NA	7	62	13	3	1	123	30	7	1	Limited by channel configuration; low-lying areas
2-205	315	Channel Capacity (Upstream Limit to Collins St)	Rural Channel	Aerial/LIDAR	237	NA	123	62	13	3	1	123	30	7	1	

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 3 Dry Fork Little Powder River Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
SELECTED DESIGN POINTS																
3-200	OFALL-12	Basin 3 outfall	Basin outlet	Aerial/LIDAR	1627	NA	NA	1293	409	162	56	1599	538	225	80	
3-202	207	Sub-basin 3-105 outfall	Basin outlet	USGS Quad	574	NA	NA	572	168	57	16	687	213	76	22	
3-203	211	Sub-basin 3-103, outfall	Basin outlet	Aerial/LIDAR	94	NA	NA	96	36	16	6	163	52	24	10	
3-204	209	Sub-basin 3-102, outfall	Basin outlet	Aerial/LIDAR	282	NA	NA	261	113	62	33	278	122	67	36	
3-205	210	Dry Fork Little Powder & Kluver Rd	24" CMP	Field notes.	133	Arterial	15	94	35	16	6	102	40	18	7	Limited by HW/D ratio of 1.5
3-206	206	Sub-basin 3-104, outfall	Basin outlet	Aerial/LIDAR	197	NA	NA	257	94	42	16	341	133	61	24	

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 4 Little Rawhide Creek Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)+				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
SELECTED DESIGN POINTS																
4-200	213	Basin 4 outfall	Basin outfall	Aerial/LIDAR	2044	NA	NA	1062	378	171	78	1298	491	228	109	
4-213	214	Confluence of Sub-basin 4-114 & Little Rawhide Crk.	Confluence	Aerial/LIDAR	489	NA	NA	883	338	167	81	1044	442	223	110	
4-204	203	Sub-basin 4-105 outfall	Basin outfall	Aerial	766	NA	NA	178	84	50	30	219	110	68	43	
STRUCTURES																
4-201	212	Little Rawhide Creek & Little Powder River Rd.	36" CMP	Field Notes	367	Arterial	44	690	301	161	85	764	349	193	106	Limited by HW/D ratio of 1.5
4-209	210	Little Rawhide Creek & Buckskin Dr.	2-7.5'x4'; 1-6'x5' CBC	Bruce Eng. HEC-RAS model	262	Local	603	453	187	94	46	507	265	116	60	Limited by HW/D ratio of 1.2
4-202	208	Little Rawhide Creek & Constitution Dr.	2-8'x4'; 1-6'x5' CBC	Bruce Eng. HEC-RAS model	224	Local	634	458	188	95	47	511	222	118	61	Limited by HW/D ratio of 1.2
4-205	206	Little Rawhide Creek & American Ln.	2-8'x4'; 1-6'x5' CBC	Bruce Eng. HEC-RAS model	214	Local	618	253	107	57	31	394	134	76	44	Limited by HW/D ratio of 1.2
4-203	204	Little Rawhide Creek & Orchid Ln.	2-8'x5' CBC	Bruce Eng. HEC-RAS model	109	Local	573	255	108	58	32	296	135	77	46	Limited by HW/D ratio of 1.2
4-207	201	Little Rawhide Creek & E. Warlow Dr.	3-24" CMP	As-built	244	Arterial	37	269	109	52	23	420	203	111	52	Limited by 1' freeboard.
4-208	200	Little Rawhide Creek & I-90	2-24" RCP	Field Notes	108	Arterial	19	183	81	43	22	135	116	66	35	Limited by HW/D ratio of 1.5
DEPRESSION PLAYAS																
4-206	202	Sub-basin 4-104, depression playa	Playa	Aerial/LIDAR	105	NA	428 acft	741	287	130	52	910	379	181	74	120 acft in 100yr storm
CHANNELS																
4-201	310	Little Rawhide Creek (Little Powder River Rd. to Buckskin St.)	Constructed grass channel	Bruce Eng. HEC-RAS model	367	NA	498	445	182	89	41	498	218	112	56	
4-209	308	Little Rawhide Creek (Buckskin St. to Constitution St.)	Constructed grass channel with trickle channel	Bruce Eng. HEC-RAS model	262	NA	507	453	187	94	46	507	265	116	60	
4-202	306	Little Rawhide Creek (Constitution St. to American St.)	Constructed concrete channel	Bruce Eng. HEC-RAS model	224	NA	294	253	107	57	31	294	134	76	44	
4-205	304	Little Rawhide Creek (American St. to Orchid St.)	Constructed grass channel with trickle channel	Bruce Eng. HEC-RAS model	214	NA	294	253	107	57	31	294	134	76	44	
4-203	302	Little Rawhide Creek (Orchid St. to Kluver Rd.)	Constructed grass channel with trickle channel	Bruce Eng. HEC-RAS model	109	NA	219	178	83	49	30	219	110	68	43	

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 5 Lower Stonepile Creek Tributaries Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
STRUCTURES																
Tributary 501																
5-248	232	Tributary 501 &Hwy 1416.	CBC 9' x 8'	SW db	486	Arterial	870	666	234	141	85	769	304	194	123	Limited by HW/D ratio of 1.2
5-241	200	Headwaters of Tributary 501	Headwaters	Field Notes/LIDAR	75	NA	NA	118	38	13	3	118	38	13	3	
5-240	201	Tributary 501 & Foothills Blvd.	CMP 36" x 24" Arch	SW db	215	Local	26	305	96	33	9	332	108	38	10	Limited by HW/D ratio of 1.5
Tributary 502																
5-246	243	Tributary 502 & W. Warlow Dr.	RCP 1 - 6'	As-built	194	Arterial	134	432	204	117	68	470	234	139	85	Limited by 1' below roadway.
5-244	241	Tributary 502 & Railroad	CMP 2 - 7'	Field Notes	188	Arterial	631	433	205	117	68	471	234	140	85	Limited by HW/D ratio of 1.2
5-245	247	Tributary 502 & Unnamed gravel crossing	CMP 2 - 90" x 58" Arch	Field Notes	156	Local	465	268	126	68	38	286	140	80	45	Limited by HW/D ratio of 1.2
5-222	245	Tributary 502 & Burma Ave.	CBC 2 - 6' x 5'	Field Notes	181	Arterial	446	292	131	70	37	318	146	83	45	Limited by HW/D ratio of 1.2
5-223	246	Tributary 502 & 2nd St.	CMP 2 - 90" x 58" Arch	Field Notes	160	Arterial	408	306	164	106	75	323	178	117	82	Limited by HW/D ratio of 1.2
5-224	252	Tributary 502 & 6th St.	Storm sewer	As-built	74	Arterial	13	172	92	60	39	181	100	66	44	
Tributary 503																
5-234	233	Tributary 503 & Westover Rd.2	CMP 2 - 48"	As-built	309	Arterial	196	465	164	69	25	759	314	144	56	Limited by HW/D ratio of 1.5
Tributary 504																
5-218	335	Tributary 504 & Brooks St.	CBC 4'x14'	As-built	290	Collector	430	446	227	154	106	424	237	162	112	Limited by 0.5' overtopping roadway.
5-220	262	Gillette Ave. Storm Sewer	Storm sewer	SW DB	129	Collector	18	203	124	86	59	203	124	86	59	Capacity limited by backwater
5-245	263	1st Ave. Storm Sewer	Storm sewer	SW DB	129	Collector	97	389	229	156	107	400	239	164	114	
Tributary 505																
5-239	202	Tributary 505 & I-90	CMP 1 - 6'	Gillette Survey	318	Arterial	268	2678	848	374	146	3355	1128	496	197	Limited by HW/D ratio of 1.5
Tributary 506																
5-236	206	Tributary 506 & I-90	CMP 1 - 6'	Field Notes	279	Arterial	269	2804	867	386	153	3591	1216	521	213	Limited by HW/D ratio of 1.5
5-237	212	Tributary 506 & Westover	CMP 36"	Gillette Survey	226	Arterial	47	289	99	39	12	511	215	96	33	Limited by HW/D ratio of 1.5
Tributary 507																
5-216	265	2nd Street Storm Sewer (Tributary 507)	Storm sewer	As-built	100	Arterial	305	287	167	116	82	305	186	134	99	
Tributary 508																
5-214	267	5th Street Storm Sewer (Tributary 508)	Storm sewer	As-built	117	Arterial	89	235	125	78	42	275	157	106	68	
Tributary 509																
5-252	273	Green Avenue Storn Sewer	Storm sewer	SW db	94	Arterial		203	110	72	48	230	135	94	66	
5-213	272	Tributary 509 & Gurley Ave.	Storm sewer	As-built	36	Arterial	8	88	46	29	19	100	56	38	26	
Tributary 510																
5-210	285	Stonepile Creek Tributary 510 & HWY 51	CMP 1-24"	Field Notes	279	Arterial	24	432	198	138	96	578	289	196	138	Limited by HW/D ratio of 1.5
5-211	282	Stonepile Creek Tributary 510 & Railroad	CMP 1 - 30"	Field Notes	279	Arterial	8	432	201	140	100	578	289	199	141	Limited by HW/D ratio of 1.5; Affected by DP-210 tailwater
5-212	284	Stonepile Creek Tributary 510 & I-90	CMP 2-24"	Field Notes	280	Arterial	21	469	207	140	97	632	317	209	143	Limited by HW/D ratio of 1.5
Diversion 504																
5-247	230	Diversion 504 & Hannum Rd.	CMP 2-5'	SW db	178	Collector	271	672	547	346	161	708	628	440	224	Limited by HW/D ratio of 1.2
5-243	P5-14	Burlington Pond	Detention	Field Notes/LIDAR	485	NA	425 acft	982	588	359	167	1083	660	453	235	491af in 100yr storm
CHANNELS																
Tributary 501																
5-235	205	Tributary 501 & on Bridger Rd.	Street Capacity	LIDAR	324	Local	<27	375	126	52	27	402	137	57	27	
Tributary 502																
5-222	247	Tributary 502 Channel Capacity (2nd to Burma)	Grass Channel	Field Notes/LIDAR	181	NA	<90	268	126	68	38	286	140	80	45	Flows pass over banks to cause shallow flooding.
5-246	243	Tributary 502 Channel Capacity (Burma to Warlow)	Grass Channel	Field Notes/LIDAR	194	NA	129	432	204	117	68	470	234	139	85	Flows pass over banks to cause shallow flooding.
Tributary 511																
5-211	334	Tributary 511 Channel Capacity (Warlow to Enterpr	30" RCP	SW db	80	NA	10	9	1	0	0	10	2	0	0	
5-250	312	Tributary 511 Channel Capacity (Enterprise to Railr	Roadside ditch	LIDAR	130	NA	31	22	9	5	3	31	15	8	4	
Diversion 504																
5-247	326	Channel Capacity (DP 5-225 to Hannum)	Grass Channel	Field Notes/LIDAR	178	NA	271	638	539	342	160	636	619	435	222	Flows pass over banks to cause shallow flooding.
5-243	328	Channel Capacity (Hannum to Burlington Pond)	Natural Channel	Field Notes/LIDAR	485	NA	447	671	548	346	161	705	628	439	224	Flows pass over banks to cause shallow flooding.

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 6 Antelope Butte Creek Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
SELECTED DESIGN POINTS																
6-217	215	Confluence	Confluence	NA	4335	NA	NA	1853	460	140	47	2232	583	187	70	
6-215	221	Confluence, Sub-basin 6-121 outfall	Confluence	NA	8442	NA	NA	2942	682	193	47	3931	955	275	65	
6-216	216	Confluence, Sub-basin 6-116 outfall	Confluence	NA	8284	NA	NA	3004	683	192	46	4005	957	273	64	
6-211	P6-6	Proposed Detention Sub-basin 6-201	Proposed Detention	NA	2690	NA	NA	1376	363	110	24	1568	424	130	29	
6-282	212	Sleepy Hollow Creek and Sleepy Hollow Rd	Unknown Culvert	No Data	2049	Local	NA	677	179	56	13	1061	306	99	24	
6-283	213	Sleepy Hollow Creek and Sleepy Hollow Rd	Unknown Culvert	No Data	1761	Local	NA	55	20	7	3	61	22	9	3	
6-284	211	Sleepy Hollow Creek and Union Chapel Rd	Unknown Culvert	No Data	247	Local	NA	657	170	50	9	1040	296	93	20	
6-285	206	Unnamed Tributary and Union Chapel Rd	Unknown Culvert	No Data	1725	Local	NA	623	163	50	12	985	282	91	22	
6-241	205	Unnamed Tributary and Union Chapel Rd	2- 24" CMP	Field notes.	2814	Local	37	1273	276	70	17	1878	430	108	26	Limited by 1.5 HW/D.
6-242																
6-243	207	Unnamed Tributary and Douglas Hwy	6'x4' CBC	Field notes.	64	Arterial	196	367	26	9	2	596	62	11	3	Limited by 1.5 HW/D
6-245	204	Unnamed Tributary and Douglas Hwy	2-36" RCP	Field notes.	795	Arterial	57	494	148	49	11	711	233	80	18	Limited by 1' freeboard below road.
6-246	203	Unnamed Tributary and Douglas Hwy	2- 24" RCP	Field notes.	318	Arterial	40	169	25	3	0	309	51	6	1	Limited by 1.5 HW/D
6-230	233	Unnamed Tributary and Garner Lake Rd	3- 42" RCP FES	Field notes.	252	Arterial	236	172	70	36	19	246	107	58	31	Limited by 1' freeboard
6-220	208	Unnamed Tributary and Schoonover Rd	2 - 48" CMP FES	Field notes.	590	Local	210	353	59	8	1	498	89	13	2	Limited by 1.5 HW/D.
STRUCTURES																
						Main Stem										
6-210	201	Antelope Butte Creek and Lee Ave.	2- 9'x6' arch CMP, 0' deck	Field notes.	2890	Local	850	1376	363	110	24	1568	424	130	29	Standard size available for arch pipe. Limited by 0.5' overtopping road.
6-218	214	Antelope Butte Creek & S. Douglas Hwy	3-8'x3' CBC	Field notes.	3947	Arterial	565	1739	442	131	38	2044	540	168	48	Limited by 1.2 HW/D
Tributary 605																
6-251	220	Unnamed Tributary and Garner Lake Rd	9.8'x1.6' CBC	Field notes.	57	Arterial	23	73	15	2	0	82	18	3	0	Limited by 1' freeboard below road.
6-252	219	Unnamed Tributary and Southern Dr	18" RCP	Field notes.	115	Arterial	2	224	89	41	16	280	120	58	24	Field notes. Limited flat area and low road el.
6-253	218	Unnamed Tributary and Douglas Hwy	No Culvert	Field notes.	75	Arterial	0	138	51	21	7	138	51	21	7	No culvert present.
Tributary 609																
6-290	263	Confluence of Tributary 601 & Donkey Creek Confluence	Confluence	NA	562	NA	NA	2349	2114	2049	2024	2742	2436	2336	2291	Limited by 1' freeboard below road.
6-291	P6-5	Playa/Detention, Sub-basin 6-134	Playa/Detention	Aerial/LIDAR	309	NA	21 acft	160	28	6	6	263	56	14	3	11 acft in 100yr storm
6-292	270	Tributary 609 and Butler Spaeth	18" RCP	Field Notes	36	Arterial	8	40	10	4	1	65	18	8	3	Limited by 1.5 HW/D
6-293	268	Tributary 609 and Boxelder Rd.	Silted-up size unknown	Field notes.	15	Arterial	NA	19	7	3	1	28	13	6	3	silted-up size unknown
6-294	P6-4	Tributary 609 and I-90.	36" RCP FES	Field notes.	76	Arterial	55	87	18	3	0	141	35	6	1	Limited by 1.5 HW/D
CHANNELS																
Main Stem																
6-210	201	Antelope Butte Creek Channel Capacity (Upstream limit to Lee Ave.)	Natural Channel	Aerial/LIDAR	2890	NA	130	1376	363	110	24	1568	424	130	29	Limited by structures in floodplain.
6-219	325	Antelope Butte Creek Channel Capacity (Lee Ave. to DP 6-219)	Natural Channel	Aerial/LIDAR	3730	NA	419	1365	358	108	24	1554	419	128	29	Limited by structures in floodplain.
6-218	326	Antelope Butte Creek Channel Capacity (DP 6-219 to S. Douglas Hwy)	Natural Channel	Aerial/LIDAR	3947	NA	513	1673	419	121	26	1966	513	157	32	

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 7 Donkey Creek Tributary South (DCTS) Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)				Comment
			Description	Data Source^	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	25-year	10-year	2-year	100-year	25-year	10-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
STRUCTURES																
Main Stem																
7-202	DIV-126_Overflow	DCTS & Sinclair St.	CBC 8'x10' & 8'X9'	SW db	4736	Arterial	1925	1780	522	206	76	1977	633	272	118	Limited by 1' freeboard
7-203	DIV-122_College_O.F._Divider	DCTS & College Park Cir.	CBC 14' x 9'	SW db	4723	Local	1300	1764	517	205	76	1956	619	266	113	Limited by 1.2 HW/D
7-204																
7-206	DIV-112-Overtopping	DCTS & Shoshone Ave.	CBC 2-14' x 5'	SW db	4415	Local	625	1738	509	209	73	1879	604	259	105	Limited by 1.2 HW/D
7-209	JCT-24	DCTS & Southern Dr.	4'X6.3' Ellipse RCP, 2-54" RCP, 96" RCP & 114"	SW db	4195	Arterial	550	1654	503	189	60	1889	547	215	73	Limited by 1.2 HW/D
Tributaries																
7-214	DIV-76	Sunburst Tributary & Sinclair St.	CBC 12'x 5'	As built	248	Arterial	492	534	246	133	69	739	403	266	172	Limited by 1.2 HW/D
7-222	JCT-144	Sunburst Tributary & Arapahoe Rd.	CBC 10'x 2.5'	SW db	108	Local	172	292	146	86	45	355	202	132	85	Limited by 1.2 HW/D
7-224	DIV-46_OVERFLOW	Sunburst Tributary & Kiowa Ave.	CMP 2-48"	SW db	69	Local	181	164	75	42	23	185	91	55	33	Limited by 1.5 HW/D
7-223	JCT-136	Sunburst Tributary & Shoshone Ave.	RCP 3-48"	SW db	106	Local	275	161	75	42	22	180	90	55	33	Limited by 1.5 HW/D
7-242	DIV-152_Overflow	Remington Pond D2 & Southern Dr.	RCP 3-30"	SW db	204	Arterial	112	40	11	10	8	63	21	12	10	Limited by 1.5 HW/D
7-240	JCT-28	Remington Trib. & Enzi Dr.	RCP 2-48"	SW db	190	Arterial	105	81	29	11	3	124	83	53	34	Limited by 1' freeboard
7-241	STOR-10	Remington Pond D1 & Southern Dr.	RCP 2-48"	SW db	149	Arterial	95	82	30	11	3	124	83	53	34	Limited by 1.5 HW/D
7-231	JCT-132	Hitt Estates Trib. & Southern Dr.	CMP 54"	Field Notes	105	Arterial	156	115	37	12	3	124	38	13	3	Limited by 1.5 HW/D
7-230	CDT-81	Hitt Estates Trib. & Shoshone Ave.	RCP 2-30"	Field Notes	4676	Local	304	100	27	8	2	106	29	9	2	Confirm Size. Limited by overtopping depth
7-252	DIV-96	Enzi Dr. Trib. & Shoshone Ave.	CMP 18"	SW db	67	Local	5	17	0	0	0	61	8	0	0	Limited by 1.5 HW/D
7-251	DIV-102	Enzi Dr. Trib. & CCHSS Access	RCP 48" x 30" Elliptical*	SW db	98	Local	67	27	6	4	2	72	16	6	5	Limited by 1.5 HW/D
7-250	DIV-12***	Enzi Dr. Trib. Outfall to DC	RCP 36"	SW db	4736	Local	300	103	47	26	14	187	72	46	30	Within DC Floodplain. Limited by overtopping depth
7-261	DIV-68	Saunders Trib. & Christinick	RCP 42"	SW db	164	Local	52	161	60	32	17	277	132	77	44	Limited by 1.5 HW/D
7-207	DIV-10	Enzi Trib. & Enzi Dr.	2-RCP 36"	SW db	67	Arterial	181	7	6	5	4	8	7	7	6	Limited by 1.5 HW/D
7-205	JCT-38	Confluence of DCTS & Hitt Estates Trib.	Confluence	Aerial	4651	NA	-	1762	517	207	75	1951	615	265	110	
7-262	JCT-48	Basin 7-122 outfall	Basin outfall	Aerial	103	NA	-	63	14	3	0	171	83	49	29	
CHANNELS																
Main Stem																
7-201	CDT-71	DCTS Channel Reach W. Sinclair St.to Confluence	Native Grass	Aerial	5341	NA	4918	1770	514	205	75	1966	625	269	116	
7-202	CDT-67	DCTS Channel Reach W. College Park Cir. To Sinclair St.	Native Grass	Aerial	4736	NA	1395	1766	517	205	76	1953	619	266	113	
7-203	CDT-63	DCTS Channel Reach W. Shoshone Ave. to College Park Cir.	Native Grass	Aerial	4723	NA	1770	1764	517	205	76	1956	619	266	113	
7-206	CDT-49	DCTS Channel Reach Southern Dr. to W. Shoshone Ave.	Native Grass	Aerial	4415	NA	1778	1703	495	206	71	1845	582	250	99	
Saunders Tributary																
7-260	CDT-169	Saunders outfall channel from Christinick Ave. to Confluence	Native Grass	Aerial	174	NA	351	163	59	32	17	277	137	76	44	
7-261	CDT-165	Saunders outfall channel from RC Ranch Pl. to Christinick Ave.	Native Grass	Aerial	164	NA	1983	61	13	3	0	169	81	48	28	
Enzi Tributary																
7-207	CDT-47	Enzi Trib Channel from Enzi to Confluence	Lawn	Aerial	76	NA	175	7	6	5	4	8	7	7	6	
Remington Tributary																
7-208	CDT-119	Remington Trib. Reach Enzi Dr. to Confluence	Native Grass	Aerial	206	NA	280	115	40	20	11	185	94	63	44	
7-240	CDT-113	Remington Trib. Reach Southern Dr. to Enzi Dr.	Native Grass	Aerial	190	NA	243	81	29	11	3	124	83	53	34	
Hitt Estates Tributary																
7-205	CDT-81	Hitt Estates Trib. Shoshone Ave. to Confluence	Native Grass	Aerial	4676	NA	635	100	27	8	2	106	29	9	2	

*arch pipe modeled as boxes to enable culvert characteristics
*** Within DC Floodplain
^Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source

Table 4.2
Basin 8 North Donkey Creek (NDC) Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates(cfs)				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classificatio	Capacity cfs	100-year	25-year	10-year	2-year	100-year	25-year	10-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
STRUCTURES																
Main Stem																
8-201	1821	NDC at Butler Spaeth Rd	CBC 12' x 7'	As-Builts	1213	Arterial	500	1358	1039	793	372	1482	1112	878	439	Limited by 1.2 HW/D, 10-yr flow in DC downstream
8-203	1800	NDC at S Douglas Hwy South of E-Z St	CBC 2- 12 x 6'	Field notes	756	Arterial	690	944	608	493	252	1117	613	497	265	Limited by 1' freeboard
8-204	1897	NDC at Private Drive. West of S Douglas Hwy (Perkins)	CONC 14' x 7'	Field notes	723	Local	640	853	346	285	169	1054	347	284	180	Limited by 0.5' overtopping depth
8-205	1895	NDC at Powder Basin Ave North of E Lakeway Dr. (Walmart)	CONC 2- 5'x7'	Field notes	688	Local	770	924	348	287	167	1072	348	287	180	Limited by 0.5' overtopping depth
8-206	1804	NDC at Emerson Ave	CONC 12' x 3'	Field notes	654	Local	360	924	348	289	169	1075	349	289	183	Limited by 0.5' overtopping depth
8-207	1806	NDC at Maple Ave	CMP 2-30"	Field notes	648	Local	70	850	313	264	158	1065	320	263	170	Limited by 1.5 HW/D
8-208	1809	NDC at Birch Ave	CONC 2-24"	SW db	642	Local	160	810	269	202	124	958	320	200	124	Limited by 0.5' overtopping depth
8-215	P8-15	Outlet of Sunflower Park R6 Detention. West of Birch Ave, North of E Walnut St.	CONC 5' x 3'	Field notes	639	NA	117	914	305	236	185	1067	383	235	187	Limited by 1.5 HW/D
8-209	P8-14	Outlet of Sunflower Park R5 Detention. Under Dogwood Ave	CMP 2- 66" x 52"	SW db	536	Local	230	798	276	207	90	950	339	201	105	Limited by 1' freeboard
8-214	P8-13	Outlet of Sage Bluffs Park R4 Detention. Under S 4-J Rd South of Frontier Dr	RCP 42" x 26", 60"x 36", 60" x 44"	SW db	299	Arterial	110	824	490	257	143	945	546	264	172	Limited by 1' freeboard
8-211	P8-11	Outlet of Sage Valley Park R1	CONC 27"	SW db	191	Arterial	28	451	348	266	126	470	348	266	126	Limited by 1.5 HW/D
Tributary 802																
8-210	P8-13 outlet	Outlet of Sage Bluffs Park R4 Detention. West of 4J Rd.		SW db	455	Arterial	177	824	490	257	143	945	546	264	172	
8-230	1630	4-J storm system	CMP 36"	SW db	57	NA	7	69	69	69	7	69	69.2	68.5	42.2	Limited at entrance to system
8-213	P8-12	Outlet of Cottonwood Park R3 Detention. West of S 4-J Rd North of Granite St.	CPP 36"	SW db	180	Local	45	361	273	208	100	398	301	235	124	Limited by 1.5 HW/D
8-231	1818	Under Boxelder outfalling into Cottonwoord Park R3 Detention	CMP 72"	SW db	122	Arterial	213	27	22	19	12	37	22	19	14	Limited by 1.2 HW/D
Douglas Highway																
8-220	1631	Douglas Hwy storm system	CBC 3'x6'	SW db	41	NA	40	42	29	18	14	42	35	29	14	Limited at low point in road at Country Club Rd
CHANNELS																
Main Stem																
8-201	1793	NDC Channel Reach Confluence to End of Constructed Channel	Native Grass	Aerial	1213	NA	2000	1043	800	620	292	1252	835	665	338	
8-212	1415	NDC Channel Reach Constructed Channel End to End of E-Z St.	Native Grass	Aerial	1117	NA	222	1044	802	622	293	1253	837	666	339	Flat slope and shallow flooding to the south.
8-202	1413	NDC Channel Reach End of E-Z St. to S. Douglas Highway	Native Grass	Aerial	1066	NA	755	939	622	502	260	1157	626	506	275	
8-203	1400	NDC Channel Reach S. Douglas Highway to Wal-Mart E.	Concrete	Aerial	756	NA	1555	886	346	285	168	1054	346	284	179	
8-204	1405	NDC Channel Reach Wal-Mart E. to Wal-Mart W.	Concrete	Aerial	723	NA	1310	853	346	285	169	1054	347	284	180	
8-205	1408	NDC Channel Reach Powder Basin to Emerson Ave.	Concrete	Aerial	688	NA	1356	924	348	287	167	1072	348	287	180	
8-206	1397	NDC Channel Reach Emerson Ave. to Maple Ave.	Lawn	Aerial	654	NA	1065	850	312	262	159	1063	320	261	170	
8-207	1395	NDC Channel Reach Maple Ave. to Birch Ave.	Lawn	Aerial	648	NA	1394	851	313	264	159	1065	320	263	172	

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 9 Donkey Creek Direct Flow Areas Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
SELECTED DESIGN POINTS																
9-203	218	Tributary 902 outfall	Sub-basin outfall	NA	614	NA	NA	729	316	169	93	787	334	174	93	
9-217	P9-3	Outlet from Sutherland Estates, Pond P9-3	RCP 58"	SW DB	132	Arterial	20	295	153	97	62	296	154	97	62	InfoSWMM
STRUCTURES																
Tributary 901																
9-207	209	Donkey Creek Tributary 901 & 4-J Rd.	CMP 66"	Field Notes	145	Arterial	113	115	32	10	2	230	80	29	7	Limited by 1' freeboard
Tributary 902																
9-210	216	Donkey Creek Tributary 902 & 4-J Rd.	RCP 2-48"	Field Notes	610	Arterial	255	725	317	171	94	782	333	175	94	Limited by 1.5 HW/D
9-206	208	Donkey Creek Tributary 902 & Oakcrest Dr.	RCP elliptical 60" x 38"	As built	420	Collector	400	417	201	125	79	465	211	125	79	Limited by 0.5' overtopping depth
9-211	206	Donkey Creek Tributary 902 & Lakeway Rd.	CMP 42"	Field Notes	55	Arterial	5	73	27	12	5	122	56	29	12	Limited by 1' freeboard
Tributary 903																
9-216	236	Outlet of Pronghorn Ponds	Outlet Structure	Field Notes	218	NA	73	124	63	18	11	183	78	51	16	
9-212	205	Donkey Creek Tributary 903 & Lakeway Rd.	CMP 84"	Field Notes	218	Arterial	303	244	93	41	15	346	156	75	31	Limited by 1.3 HW/D
9-214	P9-4	Donkey Creek Tributary 902 & Skyline Rd. (SH 50)	CMP 36"	Field Notes	129	Arterial	50	190	73	33	13	241	101	48	20	Limited by 1.5 HW/D
Tributary 904																
9-215	215	Donkey Creek Tributary at 4-J Rd.	CMP 24"	Field Notes	73	Arterial	13	115	44	20	8	130	51	24	9	Limited by 1.5 HW/D
Tributary 905																
9-213	212	Donkey Creek Tributary 905 & Southern Dr.	RCP 60"	Field Notes	130	Arterial	224	215	82	37	15	215	82	37	15	Limited by 1.5 HW/D

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 10 Milne Valley Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)+				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
SELECTED DESIGN POINTS																
10-200	208	Basin 10 outfall	Basin outfall	NA	5500	NA	NA	3060	976	384	137	3249	1061	424	153	
10-203	201	Sub-basin 10-102 outfall	Sub-basin outfall	NA	3887	NA	NA	2350	723	277	98	2432	753	292	104	
STRUCTURES																
10-201	207	Tributary 1000 & 4-J Rd.	RCP 2-86"*	Field Notes	5483	Arterial	708	3060	975	383	136	3248	1060	423	153	Limited by 1.2 HW/D
10-202	202	Tributary & Southern Dr.	2-CMP 96", 1-CMP 84"	Field Notes	5040	Arterial	991	2968	934	363	127	3129	1004	394	139	Limited by 1.2 HW/D (Overtopping flows may affect structure at NE corner of Southern Dr. & Hwy 50)
Tributary 1001																
10-210	204	Tributary 1001 & U.S. Highway 50	RCP 45"x32" elliptical	Field Notes	86	Arterial	24	114	37	13	3	159	56	21	5	Limited by 1' freeboard
Tributary 1002																
10-220	206	Unnamed Tributary & Bunny Ln.	No culvert - 0.5' overtopping only	Field Notes	120	Local	100	100	58	27	11	106	59	27	11	Limited by overtopping depth
10-221	203	Unnamed Tributary & Southern Dr.	CMP 36"	Field Notes	98	Arterial	50	142	55	26	11	142	55	26	11	Limited by 1.5 HW/D
Tributary 1003																
10-230	205	Unnamed Tributary & Southern Dr.	CMP 24"	Field Notes	21	Arterial	17	100	18	8	3	100	18	8	3	Limited by 1.5 HW/D
CHANNELS																
10-200	208	Tributary 1000 (Confluence to 4-J Rd)	Grass Channel	Aerial/LIDAR	5500	NA	3249	3060	976	384	137	3249	1061	424	153	

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels

Table 4.2
Basin 11 Upper Stonepile Creek Tributaries Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)+				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
STRUCTURES																
Tributary 1102																
11-210	208	Tributary 1102 & Centennial Dr.	18" CMP	Field notes	118	Collector	9	245	96	45	19	245	96	45	19	Limited by 1.5 HW/D
11-212	202	Tributary 1102 and Railroad & Echeta Rd	42" CMP	Field notes	215	Arterial	75	399	149	64	22	399	149	64	22	Limited by 1.5 HW/D
Tributary 1103																
11-203	214	Tributary 1103 and I-90	3-54" CMP	Gillette survey	563	Arterial	322	416	84	46	19	526	142	57	25	Limited by 1.2 HW/D
Tributary 1104																
11-211	203	Tributary 1104 and Railroad & Echeta Rd	36" CMP	Gillette survey	59	Arterial	51	79	26	10	2	79	26	10	2	Limited by 1.5 HW/D
11-220	209	Tributary 1104 and Centennial Dr.	No Structure	Field notes	16	Collector	25	25	9	4	1	25	9	4	1	Limited by 0.5' overtopping road.
Tributary 1105																
11-201	218	Tributary 1105 & I-90	3-54" CMP	Gillette survey	272	Arterial	319	81	12	10	8	103	12	10	8	Limited by 1.2 HW/D
Tributary 1106																
11-221	207	Tributary 1106 and Railroad & Echeta Rd	No Structure	Field notes	34	Collector	25	54	16	5	0	54	16	5	0	Limited by 0.5' overtopping road.
Copper Estates																
11-205	P11-1	Copper Estates, Sub-basin 11-103	Detention	Copper Estates Drainage Report	447	NA	2 acft	381	128	51	17	478	170	70	24	72 acft in 100 yr storm

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
Downstream design point is given for channels
Stonepile Creek Main Stem can be found on separate table.

Table 4.2
Basin 12 Upper Donkey Creek Tributaries Existing Conditions Summary

Design Point	Element ID	Location	Existing Structure					Existing Condition Flow Rates (cfs)				Future Condition Flow Rates (cfs)[*]				Comment
			Description	Data Source*	Contributing Area (ac)	Road Classification	Capacity cfs	100-year	10-year	5-year	2-year	100-year	10-year	5-year	2-year	
								Green = Sufficient Capacity				Green = Sufficient Capacity				
SELECTED DESIGN POINTS																
12-202	207	Confluence of Tributary 1201 and Donkey Creek	Confluence	NA	10366	NA	NA	4341	1640	746	338	4725	1803	835	379	
12-203	205	Unnamed Tributary & Upper Donkey Creek confluence	Confluence	NA	10109	NA	NA	4313	1622	744	348	4689	1792	828	370	
12-204	204	Unnamed Tributary and Upper Donkey Creek Confluence	Confluence	NA	9156	NA	NA	632	216	88	31	906	343	148	54	
12-211	214	Sub-basin 12-114 outfall & Donkey Creek	Confluence	NA	7042	NA	NA	4198	1563	717	306	4525	1717	795	343	
STRUCTURES																
Tributary 1201																
12-230	206	Upper Donkey Creek Tributary 1201 & Force Rd.	Basin Outlet	Aerial/LIDAR	184	Collector	NA	136	51	23	10	140	53	24	10	
Tributary 1202																
12-220	208	Upper Donkey Creek Tributary 1202 & Spring Hill Rd.	No culvert	Field Notes	444	Local	175	307	104	42	15	349	122	51	18	Limited by overtopping depth.
Tributary 1203																
12-210	211	Upper Donkey Creek Tributary 1203 & Spring Hill Rd.[1]	CMP 2x18" HDPE	Field Notes	262	Local	17	312	117	52	21	366	143	66	27	Limited by 1.0 HW/D
Tributary 1240																
12-240	204	Upper Donkey Creek Tributary 1240 & Spring Hill Rd.	*CMP 48"	Aerial	733	Local	530	632	216	88	31	906	343	148	54	Limited by overtopping depth.
Tributary 1250																
12-250	203	Upper Donkey Creek Tributary 1250 & Force Rd.	24" RCP	Field Notes	281	Collector	12	391	152	71	30	403	158	74	31	Limited by 1.0 HW/D
Tributary 1251																
12-251	P12-2	Unnamed Tributary & Force Rd.	24" RCP	As-built	30	Collector	25	44	18	9	4	55	24	12	6	Limited by pond outlet
12-212	215	Upper Donkey Creek & Lazy D Ave.	CMP 36"	Field Notes	849	Local	50	4302	1539	694	300	4658	1677	768	337	Limited by 1.5 HW/D
CHANNELS																
12-201	310	Donkey Creek Channel Capacity(DP12-202 to Hwy 50)	Natural Channel	Aerial/LIDAR	11508	NA	1802	4363	1636	727	317	4764	1802	820	357	Limited by structures in floodplain.
12-202	306	Donkey Creek Channel Capacity(DP12-203 to DP 12-202)	Natural Channel	Aerial/LIDAR	10366	NA	1780	4291	1620	735	333	4671	1780	823	373	Limited by structures in floodplain.

*Selected source based on the hierarchy order of "Field Notes", "As-builts", and "Other" unless otherwise stated in the "Comments/Source Selection Reasoning" section.
1Spring Hill Rd is on the top of a dam for an existing stock pond that was not modeled. Outlet to the pond is perched on left abutment of the dam. Road is the dam spillway.
Downstream design point is given for channels
Donkey Creek Main Stem can be found on a separate sheet.

SECTION FIVE

FUTURE SYSTEM DEVELOPMENT AND EVALUATION

5.1 ALTERNATIVE DEVELOPMENT PROCESS

To manage increases in runoff in the study area from future development, alternatives for flood control have been developed conceptually so that feasibility and cost of flood control alternatives can be determined and compared. A minimum of two alternative plans to mitigate the flood hazards and improve water quality aspects within each basin have been developed. These plans include regional detention, channel improvements, selected structural improvements, floodplain management, and other options that were suggested by the City and project stakeholders within each basin.

The objectives of this alternatives evaluation are to identify cost effective measures to control developed runoff from the watersheds such that: 1) developed runoff rates can be conveyed safely within existing and proposed infrastructure, 2) potential for damages to conveyances and structures within the watershed from the design flood is reduced, and 3) flood control measures can be implemented effectively as development occurs. Once a feasible alternative is identified, it is developed conceptually according to established project criteria and modeled using InfoSWMM and other hydraulic software to confirm performance.

Conceptual-level cost estimates have been prepared for each alternative so the financial feasibility of each can be screened and assessed. This evaluation includes a listing of structural and conveyance improvements, together with an estimated total cost and a qualitative evaluation of the benefits for the alternative. The costs account for property acquisition required for locating detention facilities, and an estimated cost to construct the project. Additional costs, such as operation and maintenance, are considered qualitatively.

Benefits identified will include the number and type of structures taken out of the floodplain, positive effects on water quality, and opportunities for multi-use and community usage of drainageways and flood control facilities, opportunities for enhancement of wetlands, wildlife habitat, and reduction of long-term maintenance costs. Implementation costs and benefits associated with each alternative were reviewed and one alternative for each basin will be recommended to the City.

5.2 GOALS, CRITERIA AND CONSTRAINTS

Generally, the criteria and methods used to develop detention and conveyance requirements follow the Gillette SDDM. Culverts were designed to meet the criteria listed in Table 8.1, Allowable Street Overtopping Depths at Culvert Crossings, from the SDDM. For bridges, a minimum of 1-foot of freeboard between the computed water-surface elevation and the minimum low-chord elevation is required. Each alternative was developed to reduce impacts to private property, especially property that is highly developed. Alternatives have been developed to address flood impacts, and consider stream stability, cost effectiveness, implementation, and opportunities for multiple uses.

5.2.1 Flood Impacts

Development will cause stormwater flows to increase, which in turn causes impacts to channels and culverts within the watersheds and downstream receiving streams. Damage to conveyance channels and structures could potentially occur due to an increase in the flood flows. The flood impacts within each basin along channels and crossings as well as impacts to downstream reaches need to be mitigated as development occurs.

5.2.2 Stream Stability

Generally, drainageways in the City of Gillette are stable except where they have been disturbed by development. Upland areas are steeper, therefore more susceptible to erosion as development occurs. Lower reaches are stable where they have low flow or trickle channels, however the lower reaches have flatter slopes and are subject to sedimentation from erosion in the upper watersheds.

5.2.3 Cost Effectiveness

Construction costs are estimated for each alternative and compared to other alternatives along with an evaluation of how well each alternative addresses the other criteria. The criteria and process for estimating right-of-way and the financial costs, such as use of assessor's data for property costs in Campbell County, was established in discussions with the City. Cost effectiveness depends not only on the bottom line construction cost but also the benefits of the cost expenditure in achieving all the goals of this Drainage Master Plan. In certain cases, the most cost effective alternative might be to grant a variance to the drainage design criteria for an existing structure.

5.2.4 Implementation

To be effective, the preferred alternative must be implementable prior to development or as development occurs, so that the adverse impacts to the watershed are controlled. If a developer is dependent on improvements disconnected from the site to mitigate impacts, other requirements may be placed on the developer to control stormwater release rates. The overall purpose of the Drainage Master Plan is to create a plan to address flood impacts on a regional basis, which can be implemented cost effectively by individual developers. Alterations to this plan can be made, but should not reduce the effectiveness for flood control.

5.2.5 Opportunities for Multiple Uses

Drainageways and flood control facilities present opportunities for recreation, enhancement of wildlife habitat and wetlands, open space, groundwater recharge and other uses. Aesthetics of the proposed conveyance channels, detention facilities and structures is important. Grass-lined channels are more consistent with the characteristics of the natural major drainageways within the City, and are the preferred channel type. Generally, concrete channels do not fit well with the aesthetics of the surrounding environment, and their use should be limited to areas that are developed and constrained by right-of-way. In areas that have not been disturbed by development, the preferred conveyance facility is the existing natural drainageway and floodplain management will be a key component of the preferred plan. Design of proposed improvements will be coordinated with the City's Parks Department so that appropriate access and provision for other uses is incorporated into the facility.

5.2.6 Evaluation Parameters

Evaluation parameters for comparing alternatives include:

- Cost
- Maintenance requirements
- Flood damage reduction
- Channel stability, near-term and long-term
- Impact upon known environmental resources
- Impact upon major thoroughfares, existing and future
- Right-of-way and property acquisition
- Jurisdictional boundaries
- Regulatory issues
- Trails and open space
- Stormwater quality

These parameters have been considered for each structure, detention facility and planning reach.

5.3 DESIGN METHODS

A conceptual design was prepared for the detention and conveyance alternatives for each basin. The conceptual design consists of preliminary engineering analyses to support the preparation of conceptual-level cost estimates. The conceptual design includes grading plans, profiles and typical sections and hydraulic modeling of proposed elements.

Culverts and channels have been designed using the methods discussed in the following paragraphs. These conceptual designs have been engineered for the 100-year storm event or the frequent minor storm event, per current City design criteria and standards. Proposed channels and structures could require addition of low flow channels, inlets and storm drains, and additional erosion protection throughout each basin.

5.3.1 Channel Design

Generally, open channel geometry was developed according to the SDDM. Grass-lined channels consist of a trapezoidal section with a minimum bottom width of 4 feet, side slopes 3:1 or greater, and a design depth of less than 5 feet. Concrete-lined channels have a rectangular section with a minimum bottom width of 5 feet and a maximum depth of 5 feet. Manning's roughness coefficients for each channel type were estimated from typical values for each material from the Gillette SDDM. The selected "n' values used for design are listed in Table 5.1.

Table 5.1
Constructed Channel Manning's Roughness Coefficients

Channel Linings	Manning's Roughness Coefficients
Grass	0.030
Riprap	0.047
Concrete	0.013

Side slopes are 4:1(H:V) for most grass-lined channels, (although 3:1 is used in some cases to reduce right-of-way requirements) and 2:1 or vertical for concrete linings. The design flow depth is assumed to be at normal depth. Freeboard is based on Section 4.4.4 of the SDDM and rounded up to the nearest even foot. Grass-lined channels were calculated to be the most cost effective in terms of capital cost for most cases, and are the preferred channel type for the study area. Grass-lined channels also mimic the existing channels and their side slope requirement will reduce head-cutting into tributary channels when compared to other channel linings.

5.3.2 Culvert Design

Culvert sizes for use in alternative evaluation were estimated based on capacity of reinforced concrete pipe or box culverts with a longitudinal slope matching existing and the most limiting HW/D ratio or freeboard. Culverts were designed using either the computer software CulvertMaster or HEC-RAS depending on upstream and downstream conditions. In general, culverts that had a potential to be affected by backwater were designed in HECRAS, but the majority were designed using CulvertMaster. In all cases, reinforced concrete pipes or box culverts were assumed to have a headwall and 45 degree wingwalls. Other physical parameters, such as slope and headwater to depth ratio, of the culvert design were site specific. The proposed longitudinal slope was assumed to be the same as the existing slope and the headwater to depth ratio depended on the most limiting restriction outlined in Chapter 8, Culverts, of the Gillette SDDM.

5.3.3 Bridge Design

Channels with flow rates higher than about 3,000 cfs were determined to require bridges. All bridges were designed using the computer software HEC-RAS, with the exception of several that were sized based on similar structures. Bridges were designed to meet all criteria outlined in Chapter 9.5, Bridges, of the Gillette SDDM. Proposed bridges have only a span and width presented. The width is based on the roadway classification as follows: 1) local and collector streets, 66 ft., 2) minor arterial, 82 ft., and 3) arterial, 106 ft. The number of the piers, the deck width, and the scour depth and countermeasures should all be evaluated when a structural design of the proposed bridge is performed.

5.3.4 Detention Pond Design

All detention pond design is based on Chapter 10, Detention, of the Gillette SDDM. Design criteria for major detention ponds are listed in Table 5.2.

Table 5.2
Detention Pond Design Criteria

Criteria	City Detention Value	Jurisdictional Dam Value
Capacity	Detain to allow continued use of downstream structures or to pre development flow rates. Note that the stated goals given as reasons are to establish a numeric goal, the detention typically provides benefits to other structures downstream.	50 acre feet or more to be jurisdictional, unless dams are less than 6 feet high.
Min. Crest Width	3', 12' is min. Equip width	10' min., 20' used on Bell Nob
U/S Side Slope	***4h:1V***	3H:1V
D/S Side Slope	***4h:1V***	2H:1V
Free Board Above Spillway Invert	1'	5' (3' at Bell Nob)
Max. Depth	***8' (pedestrian safety concerns)***	20' or higher is jurisdictional
Access Ramp Slope	***10H:1V***	None
Min. Bottom Slope	***0.5% for conc. channel slope***	None
Low Level Outlet	***18" Diameter or larger***	18" diameter or larger
Water Quality	Recommended to Incorporate water quality features such as WQCV outlet to extend pond use, but not required.	None
Note: Values in ***bold italic*** above are used for all detention ponds.		
Basin 5 - Tributary 503 Regional Detention		
Capacity	Detain 19 acre-feet. Combined with Tributary 505 and 506 Detentions and Burlington Lake Detention, it allows continued use of Highway 14/16 and Railroad St. Crossings.	
Crest Width	N/A, excavation only.	
Free Board Above Spillway Invert	1', per City Detention Criteria.	
Water Quality	Recommended, per City Detention Criteria.	
Basin 5 - Tributary 505 Regional Detention		
Capacity	Detain 27 acre-feet. Combined with Tributary 503 and 506 Detentions and Burlington Lake Detention, it allows continued use of Highway 14/16 and Railroad St. Crossings.	
Crest Width	25', per equipment access, safety on high embankment, concept level conservatism.	
Free Board Above Spillway Invert	1', per City Detention Criteria.	
Water Quality	Recommended, per City Detention Criteria.	
Basin 5 - Tributary 506 Regional Detention		
Capacity	Detain 31 acre-feet. Combined with Tributary 503 and 505 Detentions and Burlington Lake Detention, it allows continued use of Highway 14/16 and Railroad St. Crossings.	
Crest Width	12', per equipment access.	
Free Board Above Spillway Invert	1', per City Detention Criteria.	
Water Quality	Recommended, per City Detention Criteria.	

Table 5.2
Detention Pond Design Criteria

Basin 5 - Burlington Regional Detention	
Capacity	Detain 543 acre-feet to allow continued use of Railroad St. and Railroad Crossings.
Min Crest Width	N/A, closed Basin, no embankment modifications required.
Free Board Above Spillway Invert	N/A, closed Basin.
Max Depth	N/A, maintain existing water surface.
Min. Bottom Slope	N/A, maintain existing lake bottom.
Water Quality	Retention, closed Basin.
Basin 5 - Church Regional Detention	
Capacity	Detain 91 acre-feet to allow continued El Camino Crossing and Downstream Channel capacity.
Min Crest Width	12’, per equipment access.
Free Board Above Spillway Invert	N/A, channel expansion and constriction only.
Water Quality	None, per park use for entire area.
Basin 6 - Antelope Butte Creek Regional Detention	
Capacity	Detain 117 acre-feet to allow continued use of Lee Avenue Crossing.
Min Crest Width	20’, per equipment access, concept level conservatism.
Free Board Above Spillway Invert	5’, jurisdictional dam value.
Max Depth	None, per cost concerns.
Water Quality	None, per no impervious area upstream.
Basin 6 - School Detention	
Capacity	Detain 5 acre-feet. Formalize the inadvertent detention behind I-90 to allow discontinued use the existing Providence Crossing Subdivision detention immediately upstream.
Min Crest Width	20’, per equipment access, concept level conservatism.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.
Basin 7 - City Land Detention	
Capacity	Detain 130 acre-feet to allow continued use of Lee Avenue Crossing (benefits other crossings and channel capacities).
Min Crest Width	12’, per equipment access.
Free Board Above Spillway Invert	5’, per jurisdictional dam value.
Max Depth	None, per cost.
Water Quality	None, per no impervious area upstream.

Table 5.2
Detention Pond Design Criteria

Basin 7 - Saunders Detention	
Capacity	Detain 15 acre-feet to reduce the size of proposed conveyance downstream at Christinck Avenue.
Min Crest Width	N/A, excavation only.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.
Basin 7 - Sunburst Detention	
Capacity	Detain 9 acre-feet to allow continued use of Sunburst Storm System under Arapahoe, Sioux and Sinclair Avenue with addition of parallel 36” RCP.
Min Crest Width	N/A, excavation only.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.
Basin 7 - Hitt Estates Detention	
Capacity	Detain 5 acre-feet to allow continued use of Southern Avenue Crossing and development upstream without on-site detention.
Min Crest Width	12’, per equipment access.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per development proposed upstream, City Detention Criteria.
Basin 8 - I-90 Formalized Detention 1	
Capacity	Detain 6 acre-feet. To reduce the size of proposed storm sewer conveyance downstream under 4-J Road.
Min Crest Width	12’, per equipment access.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per development proposed upstream, City Detention Criteria.
Basin 8 - I-90 Formalized Detention 4	
Capacity	Detain 6 acre-feet to allow continued use of downstream storm sewer in South Douglas Highway.
Min Crest Width	12’, per equipment access.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.
Basin 8 - I-90 Formalized Detention 2 & 3	
Capacity	Detain 6 acre-feet to allow continued use of downstream storm sewer in Wagonhammer Lane and Juniper Street.
Min Crest Width	N/A, excavation only.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.

Table 5.2
Detention Pond Design Criteria

Basin 8 - Sage Valley Park R1 Detention	
Capacity	Detain 18 acre-feet to reduce the size of proposed storm sewer conveyance downstream under Frontier Drive.
Min Crest Width	N/A, excavation only.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.
Basin 8 - Sunflower Park R5 Detention	
Capacity	Detain 14 acre-feet to reduce the size of proposed conveyance downstream under Dogwood, Birch, Maple and Emerson Avenues.
Min Crest Width	N/A, excavation only.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.
Basin 8 - Upper Sage Detention	
Capacity	Detain 5 acre-feet to reduce the size of proposed storm sewer conveyance downstream to Cottonwood park and further under 4-J Road.
Min Crest Width	12’, per equipment access.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per development proposed upstream, City Detention Criteria.
Basin 9 - Hwy 50 Formalized Detention	
Capacity	Detain 6 acre-feet to allow continued use of Highway 50 Road Crossing and other downstream structures.
Min Crest Width	N/A, no earthwork expected.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.
Basin 9 - Sutherland Estates Detention	
Capacity	Detain 13 acre-feet to allow continued use of most of the storm sewer in 4-J Road to Donkey Creek.
Min Crest Width	N/A, excavation only.
Free Board Above Spillway Invert	1’, per City Detention Criteria.
Water Quality	Recommended, per City Detention Criteria.
Basin 10 - Milne Valley Lower Regional Detention	
Capacity	Detain 133 acre-feet to benefit road crossings and channel sections on Donkey Creek.
Min Crest Width	20’, per equipment access, safety on high embankment, concept level conservatism.
Free Board Above Spillway Invert	5’, per Jurisdictional Dam Value.
Max Depth	None, per cost concerns.
Water Quality	None, per nil impervious area upstream.

Table 5.2
Detention Pond Design Criteria

Basin 10 - Milne Valley Mid Regional Detention	
Capacity	Detain 135 acre-feet to allow continued use of 4-J Road and Donkey Creek Crossing (benefits other crossings and channel capacities).
Min Crest Width	20’, per equipment access, safety on high embankment, concept level conservatism.
Free Board Above Spillway Invert	5’, per Jurisdictional Dam Value.
Max Depth	None, per existing structure close to channel.
Water Quality	None, per nil impervious area upstream.
Basin 11 - Beltway Regional Detention	
Capacity	Detain 198 acre-feet, combined with Tributary 503, 505, and 506 Detentions, to allow continued use of Highway 14/16 and Railroad St. crossings (benefits other crossings and channel capacities).
Crest Width	200’, allow for beltway road to be on top.
Free Board Above Spillway Invert	5’, per Jurisdictional Dam Value.
Max Depth	None, per cost.
Water Quality	None, per nil impervious area upstream.
Basin 12 - Hidden Valley Regional Detention	
Capacity	Detain 603 acre-feet. To allow continued use of Highway 50 Crossings of Donkey Creek (benefits other crossings and channel capacities).
Min Crest Width	20’, per equipment access, safety on high embankment, concept level conservatism.
Free Board Above Spillway Invert	5’, per channel constriction only.
Max Depth	None, per cost.
Water Quality	None, per nil impervious area upstream.

The hydrograph method was used to size each detention facility. The inflow hydrographs were determined using InfoSWMM and the peak outflow was limited to match the capacity of the existing downstream conveyance system, as listed in Table 5.2, as much as possible. For the Donkey Creek main stem model, basins were subdivided where necessary to obtain accurate inflow hydrographs. Figure B-14 in Appendix B shows the additional sub-basin delineations necessary for the Donkey Creek main stem regional detention model.

Grading plans were developed for each potential pond site according to the criteria listed in Table 5.2. The corresponding area was increased to account for grading buffers and access. The preferred detention pond plans are presented in Appendix E.

5.4 CONCEPTUAL ALTERNATIVES

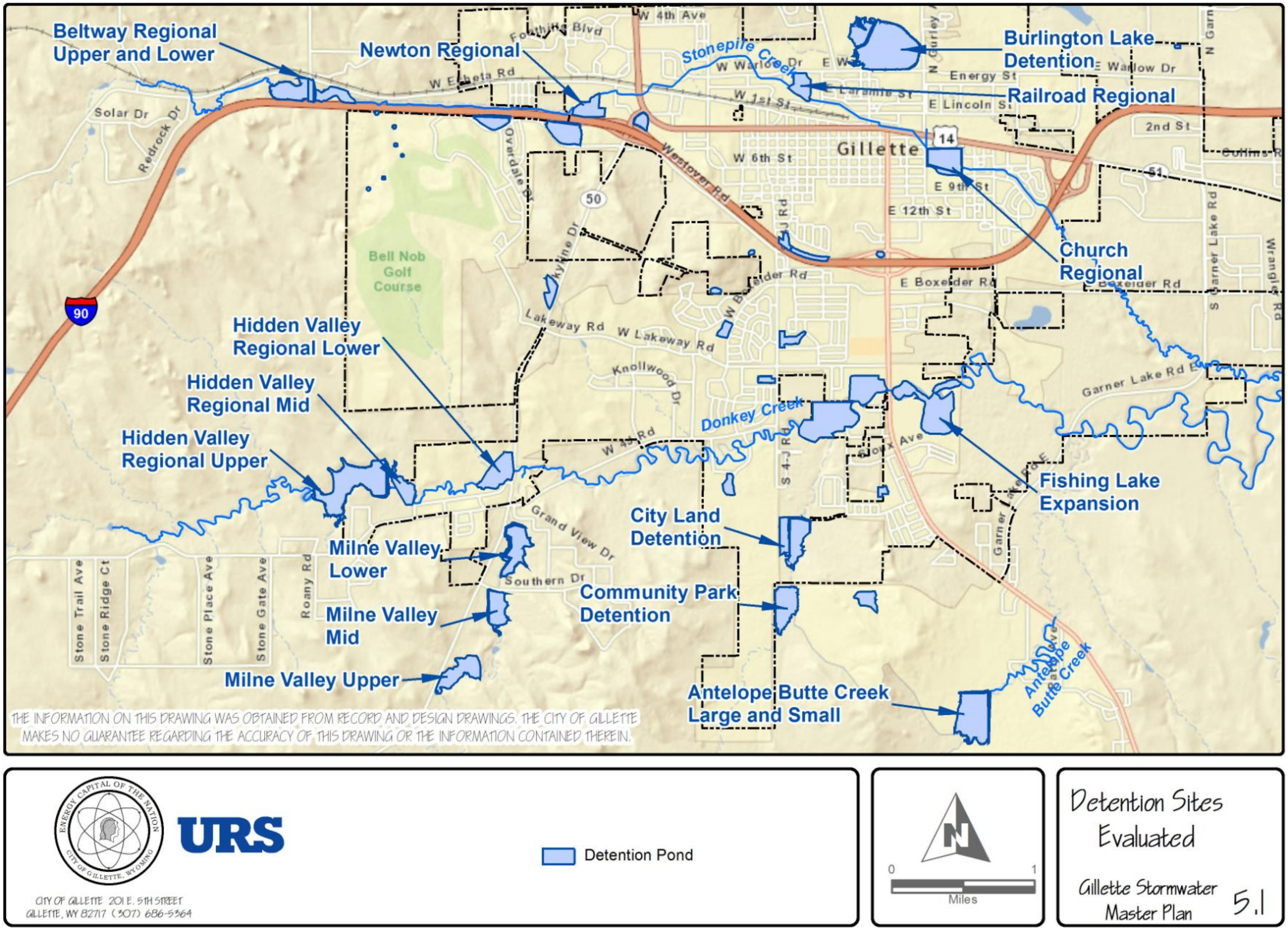
Basic alternative flood control concepts considered for each basin are listed in Table 5.3. The Conveyance Improvements alternative consists of releasing all developed flows without any new detention. This alternative would require that channels and culverts downstream of the developing areas be sized to convey future developed peak flows. Development in the City is occurring in the upper watershed areas and to a lesser extent in the lower watershed areas, therefore these downstream improvements would need to be in place before development occurs in the upper watershed areas, in order to mitigate potential flooding and stream stability problems. This alternative does not satisfy the implementation criterion (paragraph 5.2.4) for Stonepile Creek and Donkey Creek main stem channels, and therefore is considered to be infeasible by itself. Detention is required in order to control stormwater flows from development in the larger watersheds, and the Detention and Structure Improvements alternative examines this scenario for regional detention.

Table 5.3
Basic Flood Control Alternatives

Basin	Detention & Structure Improvements	Conveyance Improvements	Local Structure Improvements	Floodplain Management
Donkey Ck. Main	X	X		X
Stonepile Ck. Main	X	X		X
1				X
2			X	X
3			X	X
4			X	X
5- Tributaries	X	X	X	X
6	X	X	X	X
7	X	X		X
8	X	X	X	X
9	X	X	X	X
10	X		X	X
11		X	X	X
12	X		X	X

5.4.1 Detention and Structure Improvements

For this alternative, regional detention ponds are located and sized to address existing and future conditions flooding potential. Locations of proposed regional detention ponds considered in this alternative are shown in Figure 5.1. Some pond sites considered in Basins 5, 6, 7, 8, 10, 11 and 12 were eliminated because of poor efficiencies. Characteristics and performance metrics for all ponds considered are listed in Table E-1, Evaluated Pond Summary, in Appendix E. Characteristics and performance metrics for the preferred regional detention ponds are summarized in Table 5.4.



Beltway Regional Upper and Lower
Newton Regional
Burlington Lake Detention
Railroad Regional
Church Regional
Hidden Valley Regional Lower
Hidden Valley Regional Mid
Hidden Valley Regional Upper
Fishing Lake Expansion
City Land Detention
Milne Valley Lower
Community Park Detention
Milne Valley Mid
Milne Valley Upper
Antelope Butte Creek Large and Small
Stonepile Creek
Donkey Creek
Antelope Butte Creek
Gillette
Bell Nob Golf Course
90
14
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THE INFORMATION ON THIS DRAWING WAS OBTAINED FROM RECORD AND DESIGN DRAWINGS. THE CITY OF GILLETTE MAKES NO GUARANTEE REGARDING THE ACCURACY OF THIS DRAWING OR THE INFORMATION CONTAINED THEREIN.
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Table 5.4
Detention Pond Summary

Model ID	Name	Capacity (ac-ft)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Peak Reduction	Maximum HGL (ft)
Basin 5						
P5-13	Church Detention	100.2	2010	1178	41%	4517.8
P5-14	Burlington Lake	495.8	1910	303	84%	4,529.4
P5-17	Burlington Lake Northwest	47.3	22	0	100%	4,529.4
P5-16	Trib 505 Detention	26.9	266	17	94%	4,617.6
P5-2	Trib 506 Detention	30.6	636	39	94%	4,602.8
P5-18	Trib 503 Detention	19.4	949	473	50%	4,585.3
Basin 6						
P6-6	Antelope Butte Creek Detention	117.5	1568	375	76%	
P6-4	School Detention (Formalized Inadvertent)	5.4	141	24	83%	4,526.1
Basin 7						
STOR-CITY_LAND_POND	City Land Detention	130.4	2016	1094	46%	4,555.9
STOR-SAUNDERS_POND	Saunders Detention	15.3	277	61	78%	4,553.1
STOR-SUNBURST_POND	Sunburst Detention	9.4	355	154	57%	4,543.7
HITT_ESTATES_POND	Hitt Estates Detention	4.5	125	10	92%	4,645.9
Basin 8						
1729	Future I-90 Formalized Detention 1	5.6	145	48	67%	4,604.7
1845	Future I-90 Formalized Detention 4	5.6	160	30	81%	4,547.5
1998	Future Sage Valley Park R1	17.5	446	188	58%	4,556.4
2012	Future Sunflower Park R5	14.1	298	141	53%	4,535.2
3010	Future Upper Sage	4.5	125	22	82%	4,625.4
3020	Future I-90 2 & 3	7.3	199	29	86%	4,599.7
Basin 9						
P9-4	Future Hwy 50 Formalized Detention	5.9	241	79	67%	4,570.2
P9-3	Sutherland Estates	12.8	296	128	57%	4,539.7
Basin 10						
P10-2	Regional Detention Lower	133.2	1229	914	26%	4,592.2
P10-3	Regional Detention Mid	134.7	2047	1180	42%	4,612.0

Table 5.4
Detention Pond Summary

Model ID	Name	Capacity (ac-ft)	Pond Inflow Q_{100} (cfs)	Pond Outlet Discharge (cfs)	Peak Reduction	Maximum HGL (ft)
Basin 11						
P11-6	Upper Beltway Detention	197.6	2556	237	91%	4,667.8
Basin 12						
P12-6	Hidden Valley Upper	603.4	2995	862	71%	4,614.7

Regional ponds were sized using the InfoSWMM method described above. In this alternative, all proposed channels and culverts are sized for the future conditions 100-year peak flow rates with detention. Within proposed developments, it is necessary to provide conveyance for developed flow rates. Flood impacts for the 100-year peak flow downstream of the regional detention ponds will decrease in most cases.

Also, in this alternative, conveyance improvements are proposed only where needed or where existing conveyance elements are undersized for existing conditions. As with the channels, culverts through proposed developments will need to be designed for developed conditions flows.

5.4.2 Conveyance

For this alternative, all channels and structures in the study reaches need to have capacity for the full 100-year developed conditions flow. No new on-site or regional detention is proposed. Only existing City detention ponds were included in this model, and all “inadvertent” roadway detention was removed from the model. Channels and structures required to convey future conditions and 100-year peak flows were sized according to current City criteria.

5.4.3 Local Structure Improvements and Floodplain Management

Local structure improvements are considered in closed basins and tributaries without detention for inadequate roadway crossings that are isolated and located in sparsely developed areas.

Floodplain management is an activity applicable to all study reaches. It is an administrative approach to manage development such that existing drainageways are preserved and protected.

5.5 COST ESTIMATES

The detention and structure improvements, conveyance, and local structure improvements alternatives have been evaluated by assembling necessary design requirements using the previously discussed criteria and estimating the capital cost of each set of improvements. Proposed improvements for structural and detention facilities are based on future conditions peak flow rates.

Unit costs have been developed based on an average of bid tabulations published by WYDOT for 2007 through 2009, two local WYDOT projects, four recent City of Gillette projects and 2009 Colorado Department of Transportation cost data. These unit costs are presented in the "Unit Cost Database" spreadsheet in Appendix D. Land acquisition costs were included only for the detention facilities in the alternatives analysis, because channel improvements would essentially be in floodplain areas not otherwise developable. Land acquisition costs for detention ponds are listed in the "Land Costs" spreadsheet and shown in Figure D1, Land Costs, in Appendix D.

Channel costs for each alternative are based on cubic yards of excavation, plus the cost of the channel lining and drop structures. Culverts costs are based on a per linear foot of pipe or box culverts with two flared end sections or two wing walls as appropriate, complete-in-place. Bridge costs are estimated at $150 per square foot of surface area based on the required span length and width according to roadway classification. The cost of detention ponds is based on the cubic yards of excavation and embankment, an estimated cost for an outlet structure, and the cost of the land required for the facility.

Design Engineering costs are added to the total construction cost of each alternative as 15% of the construction costs. Construction contingencies (30%) are also added to the total construction cost of each alternative to account for such items as utility relocations, mobilization, temporary erosion control, and construction engineering.

The total estimated capital costs for each alternative are based on the sum of the cost of the proposed facilities, plus costs for engineering and construction contingencies. Detailed cost estimates for each alternative for each basin are included in the spreadsheets in Appendix D.

These costs for alternatives in each basin are summarized in the Tables in the following paragraphs.

5.6 ALTERNATIVE PLANS BY BASIN

Alternative plans examined for each major basin and the main stems of Donkey and Stonepile creeks are described in the following paragraphs. Most basins have proposed improvements on tributaries that simply provided 100-year conveyance. These improvements are classified as local structure improvements.

The preferred alternatives are illustrated schematically on Figure 5.2 at the end of this Section.

Some general notes regarding alternative plans are:

- While there are proposed structures for crossing I-90 and other WYDOT roads, it is recognized that the City has limited influence in the implementation or selection of WYDOT improvements. The proposed structures are provided so that the City may have a planned structure and flow rate should WYDOT choose to consider it. The same is true for proposed crossings of the BNSF railroad.
- Existing inadvertent detention was modeled only behind WYDOT highways, whose policy allows detention upstream of a culvert, and behind railroad embankments. All other inadvertent detention, including stock ponds and CBM ponds, has been ignored for estimation of future and existing flow rates for alternative evaluation, unless noted otherwise.

- Over-detention is proposed in Basins 5, 6, 7, 10, 11 and 12 so that upstream development will not require onsite detention facilities. However, upstream development that is more dense and impervious than assumed for this plan may require onsite detention per City review.

5.6.1 Donkey Creek Main Stem

Future conditions 100-year peak flows in main stem of Donkey Creek originate in the upper watershed, Basins 10 and 12. The detention alternative for Donkey Creek main stem includes the two large detention facilities in Basin 10, labeled Milne Valley – Mid and Milne Valley Lower, and a detention facility in Basin 12, Hidden Valley Upper. Other options were evaluated, as shown in Figure 5.1, but these three are the most effective. These large detention facilities are needed in both valleys to reduce 100-year peak flows to a rate that can be conveyed through most of the downstream crossing structures on the main stem. All three proposed detention facilities are large enough to require a permit from Wyoming's Office of the State Engineer in order to construct them. They have included design aspects, such as a 20-foot wide crest, that are compatible with this expectation. All include excavated basins as part of the design. Initial plans for multiple detentions in each basin that did not require basin excavation were discarded as land intensive and inefficient. The Hidden Valley Upper detention was located to allow development along Force Road and to be upstream of the future beltway road on the west side of town.

The Donkey Creek main stem detention alternative model did not include any other proposed detentions (such as the City Land detention in Basin 7), but it did include the existing detentions that were government owned and maintained. The detention option reduces downstream flows in Donkey Creek to rates that are similar to the flows in the existing FIS, and in locations just downstream of the detention ponds the 100-year peak flows are significantly reduced. Nevertheless, new structures are required at 5 locations and channel improvements are needed in 3 reaches of Donkey Creek, as listed in Table 5.5.

The conveyance option on the main stem of Donkey Creek requires 9 new bridges. Only the existing bridges at Garner Lake Road and South Douglas Highway are adequate. It also requires significant channel improvements in 6 reaches. Proposed structure and channel improvements for the conveyance alternative are listed in Table 5.6.

Both alternatives include new outlet structures for Fishing Lake. These are needed to alleviate the potential overtopping and shallow flooding that would occur to the north at this location in a 100-year event. The current 18" CMP low level outlet would be replaced with a 10' x 6' CBC and a 14' x 14' grated box inlet weir structure in the lake. The existing dam road and parking lot would be raised to elevation 4524.0, and a 440 foot emergency spillway section would be constructed at elevation 4521.0 on the east embankment. The existing road currently acts as a spillway at least once a year. The configuration shown on Figure E1, Fishing Lake, in Appendix E shows an 8% slope for the roadway connection to the proposed spillway.

Table 5.5
Detention Alternative Structure Summary
Donkey Creek - Main Stem

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Detention Alternative Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
6-202	305	Donkey Creek and Unnamed road	2-48"CMP	CBC 5-10'x7' L =55'	CM	2603	2603	1323	838	491	TOR raise required.
6-207	304	Fishing Lake Dam Rd.	18" CMP	New spillway and low level outlet	CM, FM	3900	2883	1328	721	400	Low level outlet for 2 year event capacity = 503 cfs
9-202	202	Donkey Creek & Brorby Blvd.	CMP 4-66"	CBC 5-10'x7' L=90'	CM	2509	2509	1229	687	389	Limited by 1.2 HW/D
9-204	301	Donkey Creek & Donkey Creek Dr.	Bridge Span =23' Width = 25'	Bridge Span = 50' Width = 66'	H	2294	2294	1207	686	381	Limited by 2' WSEL freeboard. No TOR raise required.
12-000	201	Upper Donkey Creek & Jayhawker St.	CBC 10'x4'	CBC 6-10'x4' L = 40'	CM	1897	1897	1168	683	366	Limited by overtopping depth.
Channels											
6-206	348	Donkey Creek Channel Capacity (DP 6-207 to Butler Spaeth Rd.)	Natural Channel	100' BW, 4:1 SS. 5.5' deep grass lined channel	FM	2943	2943	1375	857	554	
6-208	204	Donkey Creek Channel Capacity (Carlisle Rd to DP 6-208)	Natural Channel	170' BW, 4:1 SS. 6' deep grass lined channel	FM	3929	3929	1333	725	401	Existing Douglas Hwy bridge will work with U/S channel improvements.
9-204	301	Donkey Creek Channel Capacity (DP 9-205 to Donkey Creek Rd)	Natural Channel	65' BW, 4:1 SS. 6' deep grass lined channel	FM	2294	2294	1207	686	381	

Notes:
CM = CulvertMaster
FM = FlowMaster
H = HECRAS

Table 5.6
Conveyance Alternative Structure Summary
Donkey Creek

Design Point	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Condition Flow Rates (cfs)				Comment
						100-year	10-year	5-year	2-year	
						Green = Sufficient Capacity				
Structures										
6-202	Donkey Creek and Unnamed road	2-48"CMP	Bridge Span =170' Width = 66'	NM	6157	6157	2058	910	549	Local road. TOR raise required. Size based on similar structure
6-206	Donkey Creek and Butler Spaeth Rd	Bridge Span = 90' Wdith = 83'	Bridge Span = 200' Width = 82	H	6473	6473	2223	965	579	Minor Arterial. Improvement assumes U/S and D/S channel are also improved
6-207	Fishing Lake Dam Rd.	18" CMP	New outlet structure and spillway	CM, FM	6405	6405	2190	940	447	Low Level outlet for 2 year event capacity = 503 cfs
9-200	Donkey Creek & Enzi Dr.	CBC 3-10'x 10'	Bridge Span =170' Width = 82'	NM	6258	6258	2179	957	546	Minor Arterial
9-201	Donkey Creek & Saunders Blvd.	CMP 4-120"	Bridge Span =170' Width = 66'	NM	6194	6194	2169	958	570	Local road
9-202	Donkey Creek & Brorby Blvd.	CMP 4-66"	Bridge Span =170' Width = 66'	H	6103	6103	2155	960	606	Local road
9-204	Donkey Creek & Donkey Creek Dr.	Bridge Span =23' Width = 25'	Bridge Span =120' Width = 66'	H	6074	6074	2161	967	539	Local road. TOR raise required
9-209	Donkey Creek & 4-J Rd.	Bridge Span =61' Width = 45'	Bridge Span = 225' Width = 82'	H	6035	6035	2169	977	449	Minor Arterial
12-000	Upper Donkey Creek & Jayhawker St.	CBC 10'x4'	Bridge Span = 400' Width = 66'	H	6022	6022	2172	980	418	Local road. Requires TOR raise
12-201	Upper Donkey Creek & Highway 50	CMP 4-134"x88" elliptical	Bridge Span = 60' Width = 106	H	4093	4093	1523	700	303	Major Arterial
Channels										
6-206	Donkey Creek Channel Capacity (DP 6-207 to Butler Spaeth Rd.)	Natural Channel	160' BW, 4:1 SS. 6' deep grass lined channel	FM	6473	6473	2223	965	579	
6-207	Fishing Lake Capacity (S. Douglas Hwy to DP 6-207)	Natural Channel	280' BW, 4:1 SS. 6' deep grass lined channel	FM	6405	6405	2190	940	447	
6-208	Donkey Creek Channel Capacity (Carlisle Rd to DP 6-208)	Natural Channel	280' BW, 4:1 SS. 6' deep grass lined channel	FM	6498	6498	2218	951	453	
9-204	Donkey Creek Channel Capacity (DP 9-205 to Donkey Creek Rd)	Natural Channel	260' BW, 4:1 SS. 6' deep grass lined channel	FM	6074	6074	2161	967	539	
9-208	Donkey Creek Channel Capacity (4-J Rd. to DP 9-208)	Natural Channel	210' BW, 4:1 SS. 6' deep grass lined channel	FM	6044	6044	2167	975	469	
12-000	Donkey Creek Channel Capacity (Hwy 50 to Jayhawker St)	Native grass	260' BW, 4:1 SS. 6' deep grass lined channel	FM	6022	6022	2172	980	418	

Notes:
CM = CulvertMaster
FM = FlowMaster
H = HECRAS
NM = Not Modeled, size estimated

Estimated costs for the alternatives are summarized in Table 5.7. The detention alternative is the more cost effective approach for flood control on the Donkey Creek main stem.

Table 5.7
Alternative Cost Estimates – Donkey Creek Main Stem

Item	Alternative Costs (x $1,000)	
	Detention & Structure Improvements	Conveyance Improvements
Channel Improvements	$1,425	$4,234
Drop Structures	$434	$1,582
Culverts	$940	$0
Bridges	$495	$18,470
Detention Ponds	$11,510	$0
Subtotal Construction (rounded)	**$14,804**	**$24,526**
Engineering & Permitting (15%)	$2,220	$3,679
Construction Contingency (30%)	$4,441	$7,358
Land Acquisition	$1,638	$0
Total Cost (rounded)	**$23,103**	**$35,563**

5.6.2 Antelope Butte Creek Basin (Basin 6)

Two detention options were evaluated on Antelope Butte Creek main stem. The first proposed a detention facility that over-detained so that the structure at Lee Avenue could convey the peak 100-year flow. The second proposed a smaller facility that detained the future 100-year flow back to the existing condition rate, so that future development would not require additional detention. Since both options were efficient and neither required a large amount of land outside the existing floodplain, the larger facility is preferred because it has more benefits in terms of savings of downstream structure and channel improvements. As an embankment dam only (with no excavated basin), the Antelope Butte Creek – Large option is relatively inexpensive. The "Large" facility requires no downstream channel improvements and only an improved structure at Douglas Highway, see Table 5.8. This alternative provides a plan that combines over-detention and floodplain management, and 100-year conveyance structures would be required in new development. This alternative allows development in the Antelope Butte Creek main stem basin without the need for onsite detention.

One detention option was also considered on Tributary 609, which is a north bank tributary to Donkey Creek, and consists of formalizing the inadvertent detention on the school property adjacent to I-90 (Pond P6-4) and maintaining the depression playa detention (Pond P6-5). P6-4 detention is controlled by the culvert under I-90 and causes ponding on the school property. Formalizing this detention would allow the City to abandon the existing Providence Crossing detention cell just north of the school property. Maintaining the depression playa, P6-5, is a floodplain management activity, and future development would be required to maintain the 100-year floodplain limit of the playa or provide equivalent detention capacity on the site.

As noted previously in Table 3.8, existing detention ponds P6-1 and P6-2 can handle the 100-year peak flow, but these ponds discharge to Donkey Creek and not Antelope Butte Creek. It is recommended that these ponds be converted to water quality facilities at some future time, since their major detention capability is inconsequential to the Donkey Creek floodplain.

As listed in Table 5.9, the conveyance option on the Antelope Butte Creek main stem includes new structures at Douglas Highway and Lee Avenue, as well as channel improvements for the entire study reach. Other local conveyance improvements are recommended on Tributaries 602, 605 and 610, as listed in Table 5.10.

Table 5.8
Detention Alternative Structure Summary
Basin 6 Antelope Butte Creek

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Detention Alternative Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Antelope Butte Creek											
6-218	214	Antelope Butte Creek and Douglas Hwy	3- 8'x3' CBC, FES	6- 10'x4' CBC L= 130'	CM	1115	1111	350	167	48	Limited by 1' Freeboard

Note:
CM = CulvertMaster

Table 5.9
Conveyance Alternative Structure Summary
Basin 6 Antelope Butte Creek

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Conveyance Alternative Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Antelope Butte Creek											
6-218	214	Antelope Butte Creek and Douglas Hwy	3- 8'x3' CBC, FES	9- 12x4' CBC, L= 125'	CM	2045	2045	540	168	48	Limited by 1.2 HW/D
6-210	201	Antelope Butte Creek and Lee Ave.	2-8.7'x6' arch	4- 10'x6' CBC, L=50'	CM	1568	1568	424	130	29	Limited by 0.5' overtopping road.
Tributary 609											
6-294	312	Tributary 609 and I-90	36" RCP FES	54" RCP, L=415'	CM	141	141	35	6	1	Limited by 1.5 HW/D
Channels											
Antelope Butte Creek											
6-210	201	Antelope Butte Creek Channel Capacity (Upstream limit to Lee Ave.)	Natural Channel	45' BW, 4:1 SS, 6' Deep, grass lined	FM	1568	1568	424	130	29	
6-219	325	Antelope Butte Creek Channel Capacity (Lee Ave. to DP 6-219)	Natural Channel	45' BW, 4:1 SS, 6' Deep, grass lined	FM	1554	1554	419	128	29	
6-218	326	Antelope Butte Creek Channel Capacity (DP 6-219 to S. Douglas Hwy)	Natural Channel	65' BW, 4:1 SS, 6' Deep, grass lined	FM	1967	1967	513	157	32	

Notes:
CM = CulvertMaster
FM = FlowMaster
H = HECRAS

Table 5.10
Local Improvement Structure Summary
Basin 6 Antelope Butte Creek

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Tributary 602											
6-220	275	Tributary 602 and Schoonover Rd	2 - 48" CMP FES	54" RCP L=685'	CM	498	498	89	13	2	Limited by 0.5' overtopping road.
Tributary 605											
6-251	220	Tributary 605 and Garner Lake Rd	9.8'x1.6' CBC	3- 4'x2' CBC L=204'	CM	82	82	18	3	0	Limited by 1' freeboard below road.
6-252	219	Tributary 605 and Southern Dr	18" RCP	3- 6'x3' CBC L=104'	CM	280	280	120	58	24	Field notes. Limited flat area and low road elevation.
6-253	218	Tributary 605 and Douglas Hwy	No Culvert	3- 6'x3' CBC L=104'	CM	138	138	51	21	7	Limited by 1' freeboard
Tributary 610											
6-293	268	Tributary 610 and Boxelder Rd.	Silted-up size unknown	30" RCP L=100'	CM	28	28	13	6	3	silted-up size unknown

Note:
CM = CulvertMaster

Estimated costs for the alternatives are summarized in Table 5.11. The detention alternative and the conveyance alternatives are comparable in terms of construction cost for flood control on the Antelope Creek main stem.

Table 5.11
Alternative Cost Estimates – Basin 6

Item	Alternative Costs (x $1,000)		
	Detention & Structure Improvements	Conveyance Improvements	Local Structure Improvements
Channel Improvements	$0	$706	$0
Drop Structures	$0	$157	$0
Culverts	$703	$1,798	$705
Bridges	$0	$0	$0
Detention Ponds	$1,931	$0	$0*
Subtotal Construction (rounded)	**$2,634**	**$2,661**	**$705**
Engineering & Permitting (15%)	$395	$399	$106
Construction Contingency (30%)	$790	$798	$212
Land Acquisition	$84	$0	$0
Total Cost (rounded)	**$3,903**	**$3,858**	**$1,023**

*Administrative cost for Ponds P6-4 and P6-5

5.6.3 Fox Park (Basin 1)

The main stem of Donkey Creek through Basin 1 has capacity for the full 100-year future conditions peak flow, and there is little development within the Basin. No conveyance or structure improvements are required until driven by development, and continued floodplain management is the recommended course of action to manage growth and preserve the natural drainageways in this Basin.

5.6.4 Donkey Creek Tributary South (DCTS, Basin 7)

For the Detention and Structure Improvements alternative, three options for major regional detention facilities were considered on the main stem of DCTS that reduce 100-year peak flow rates enough to allow most of the downstream main channel reaches and existing structures to meet criteria and remain in place without improvement.

Option I, the Community Park Pond, places the regional detention just south of Southern Drive in a location shown on the Gillette Parks Plan as a future community park. The Remington Pond D2 (Pond P7-3) outlet would be redirected to this pond and the existing detention cell could then be redeveloped. The Community Park Pond was located to allow extension of Enzi Drive to the south.

Option II, the City Land Pond, proposes regional detention just south of Shoshone Avenue on land owned by the City. This would be a combined use facility with new outlet works under Shoshone Avenue and a new major crossing of Southern Drive. Flows from Remington Ponds D1 and D2 and the RC Ranch Detention E Pond (Ponds P7-2, P7-3 and P7-7, respectively) would be redirected to the City Land Pond and those existing detention cells could then be redeveloped. The City Land regional pond allows for a 300-foot wide buffer for development on the east side Enzi Drive.

Option III considered implementing smaller versions of both Option I and II ponds. Of these options, the City Land Pond was found to be the most cost effective. The Detention Alternative also proposes new detention facilities for the Saunders Tributary, the Hitt Estates Tributary, and the Sunburst Tributary, which allow the existing downstream structures to meet criteria for these systems without modification. The proposed Hitt Estates Pond is an existing produced water pond that would be formalized as detention as a part of this alternative. Onsite detention upstream of the Hitt Estates pond and the Regional City Land Pond will not be required under this alternative. The necessary structure and channel improvements for this alternative are listed in Table 5.12.

The DCTS conveyance alternative calls for increased conveyance at nearly all major crossings, as listed in Table 5.13. College Park Cir., Shoshone Ave., Southern Dr. and the Oilfield Road all require improved or replaced structures on the main stem of DCTS in order to safely pass the future conditions 100-year flows. The main stem DCTS channel also requires improvements in all reaches except the reach from the mouth to Sinclair to convey future 100-year peak flows.

The local conveyance improvements, listed in Table 5.14, consist of new culverts at Remington Tributary and Enzi Drive, and at Enzi Drive Tributary and Shoshone Avenue.

As noted previously in Table 3.8, existing detention ponds P7-1 through P7-8 can handle the 100-year peak flow, but these ponds are not effective in reducing 100-year peak flows in DCTS or the tributaries. It is recommended that these ponds be converted to water quality facilities at some future time.

Estimated costs for the alternatives are summarized in Table 5.15. The detention alternative and the conveyance alternatives are comparable in terms of construction cost for flood control on the DCTS main stem.

Table 5.12
Detention Alternative Structure Summary
Basin 7 Donkey Creek Tributary South (DCTS)

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Detention Alternative Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
Sunburst Drainageway											
Donkey Creek Tributary South											
7-206	DIV-112-Overtopping	DCTS & Shoshone Ave.	CBC 2-14' x 5'	CBC 2- 14' x 6' L=140'	H	1094	1094	473	212	93	Limited by 1.2 HW/D
7-209	DIV-86	DCTS & Southern Dr.	4'X6.3' Ellipse RCP, 2-54" RCP, 96" RCP & 114" RCP	CBC 3- 10' x 7' L=140'	H	1801	1801	576	224	74	Limited by 1.2 HW/D
Saunders Tributary											
7-261	DIV-68	Saunders Outfall & Christinick	RCP 42"	CBC 5' x 4' L=395'	HY8	61	61	28	14	7	Limited by 1' freeboard

Notes:
H = HECRAS

Table 5.13
Conveyance Alternative Structure Summary
Basin 7 Donkey Creek Tributary South (DCTS)

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Condition Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
Sunburst Drainageway											
7-214	DIV-76	Sunburst & Sinclair St.	CBC 12'x 5'	CBC 2-10'x 5' L=1915'	HY8	740	739	403	266	172	Limited by HW/D
7-222	JCT-144	Sunburst & Arapahoe Ave.	CBC 10'x 2.5'	CBC 2-10'x 2.5' L=60'	HY8	355	355	202	132	85	Limited by HW/D
Donkey Creek Tributary South											
7-203	DIV-122_College_O.F._Divider	DCTS & College Park	CBC 14' x 9'	CBC 2- 14' x 9' L=75'	H	1956	1956	619	266	113	Limited by HW/D
7-206	DIV-112-Overtopping	DCTS & Shoshone Ave.	CBC 2-14' x 5'	CBC 3-14'x 7' L=141'	H	1879	1879	604	259	105	Limited by HW/D
7-209	JCT-24	DCTS & Southern Dr.	4'X6.3' Ellipse RCP, 2-54" RCP, 96" RCP & 114" RCP	CBC 3-10'x 8' L=50'	H	1889	1889	547	215	73	Limited by HW/D
Saunders Tributary											
7-261	DIV-68	Saunders Outfall & Christinick	RCP 42"	CBC 12' x 4' L=60'	HY8	277	277	132	77	44	Limited by HW/D 1.2
Channels											
Donkey Creek Tributary South											
7-206	CDT-49	DCTS Channel Reach Southern Dr. to W. Shoshone Ave.	Native Grass	Grass-lined Channel, 110' BW, SS 4:1, 3' Normal depth, 135' WS	FM	1845	1845	582	250	99	
7-203	CDT-63	DCTS Channel Reach W. Shoshone Ave. to College Park Cir.	Native Grass	Grass-lined Channel, 50' BW, SS 4:1, 5.5' Normal depth, 95' WS	FM	1956	1956	619	266	113	
7-202	CDT-67	DCTS Channel Reach W. Sinclair St. to College Park Cir.	Native Grass	40' BW, 4:1 SS, 6' Deep, grass lined	FM	1953	1953	619	266	113	

Notes:
FM = FlowMaster
H = HECRAS

Table 5.14
Local Improvement Structure Summary
Basin 7 Donkey Creek Tributary South (DCTS)

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Remington Tributary											
7-240	JCT-28	Remington Trib & Enzi Dr.	RCP 2-48"	Add RCP 48" L=118'	H	124	124	83	53	34	Limited by 1' freeboard
Enzi Tributary											
7-252	DIV-96	Enzi Dr. Trib. & Shoshone Ave.	CMP 18"	CBC 7'x 2.5' L=110'	HY8	61	61	8	0	0	Limited by 1.5 HW/D

Note:
H = HECRAS

Table 5.15
Alternative Cost Estimates – Basin 7

Item	Alternative Costs (x $1,000)		
	Detention & Structure Improvements	Conveyance Improvements	Local Structure Improvements
Channel Improvements	$0	$772	$0
Drop Structures	$0	$118	$0
Culverts	$1,146	$4,628	$117
Bridges	$0	$0	$0
Detention Ponds	$3,119	$0	$0
Subtotal Construction (rounded)	**$4,265**	**$5,518**	**$117**
Engineering & Permitting (15%)	$640	$828	$18
Construction Contingency (30%)	$1,280	$1,655	$36
Land Acquisition	$270	$0	$0
Total Cost (rounded)	**$6,455**	**$8,001**	**$171**

5.6.5 North Donkey Creek (Basin 8)

The North Donkey Creek watershed has numerous small existing detentions, including several inadvertent detentions created by I-90, and many conveyance systems inadequate for the 100-year event. For the detention alternative, providing a single upstream regional detention facility is not feasible because the basin is highly developed and there is no good location available. Therefore, the detention alternative proposes expanding existing detention pond at Sage Valley Park R1 and Sunflower Park R5, formalizing the inadvertent detention ponds north of I-90, and adding one new pond west of the County Maintenance Facility.

The most effective existing expansion is the Sage Valley Park R1 detention. This proposes to remove the existing playground and completely re-grade the area, which helps to reduce the shallow flooding that occurs in the neighborhood downstream from this pond when it overtops. The expansion of the Sunflower Park pond adds volume on the east side of 4-J Road., and a new pond, Upper Sage Valley, is proposed to replace the existing detention cells in the Upper Sage Valley neighborhood Although very efficient, the Cottonwood Park ponds still overflows by approximately 50 cfs into 4-J Road with it in place.

The I-90 inadvertent detention ponds should be formalized to the extent practicable. WYDOT's design guidance includes using detained flow rates for culverts that create significant back water. Also, there is precedent in the existing Silverado Detention, which is within the gore area of the I-90 interchange with Douglas Highway in North Donkey Creek watershed. Formalizing these detention facilities would require an agreement to keep the size of the existing structure the same and allow the City to grade the area within the WYDOT right-of-way. I-90 Ponds 1 and 4 will also require design and construction of the pond and outlet works.

Even with the increased detention, several local conveyance structures will need improvement to safely pass the 100-year event, as listed in Table 5.16. Most notable are the need to replace the 36" storm sewer from Cottonwood Park to NDC with 7' x 5' CBC, replace the 27" outfall of Sage Valley Park to Sage Bluffs Park with 6' x 5' CBC, and replace the NDC crossings at Birch, Maple and Emerson. Additionally, the NDC channel from the end of E-Z Street to the end of the constructed reach will need to be enlarged.

The North Donkey Creek conveyance alternative assumes that none of the inadvertent detentions exist along I-90, i.e., that WYDOT completes improvements that convey the future conditions 100-year flows though the embankment. There are only 2 significant differences between the Conveyance Alternative and the Detention Alternative for Basin 8. The first is that the section of NDC channel from Douglas Highway to the end of E-Z Street will need to be improved to a trapezoidal grass lined channel with a top width of 50 feet plus access, whereas it does not need improvement under the Detention Alternative unless access is desired. The second is that the existing storm sewer system in Douglas Highway from Country Club to NDC will need to be replaced with a much larger CBC. Proposed conveyance structures are listed in Table 5.17.

There are also two upgrades to existing detention ponds included in the conveyance alternative. First, an improved outlet works is proposed for the Cottonwood R3 pond. In the detention alternative, only the spillway improvements proposed and the new storm sewer outlet from the pond is included in the "Culverts" line item. Improvements to the Sage Valley Park R1 detention ponds are also proposed, but with different outlet works. The pond ends up being about a foot deeper in the Detention alternative than in the Conveyance alternative.

Table 5.16
Detention Alternative Structure Summary
Basin 8 North Donkey Creek

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Detention Alternative Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
North Donkey Creek											
8-206	1805	Under Emerson Ave North of E Walnut St.	CONC. 12' x 3'	CBC 20' x 3' L =60'	H	469	457	296	209	159	Limited by overtopping depth
8-207	1807	Under Maple Ave North of E Walnut St.	CMP, 2-30"	CBC 15' x 3' L = 60'	H	458	458	298	209	157	Limited by 1.2 HW/D
8-208	1809	Under Birch Ave North of E Walnut St	CONC, 2-24"	CBC 7' x 3' L = 62'	H	231	238	195	179	157	Limited by overtopping depth
8-211	886	Outlet of Sage Valley Park R1	CONC, 27"	CBC 6' x 5' L =1687	CM	188	174	87	51	30	Limited by 1.2 HW/D
Tributary 802											
8-213	DIV-170	Outlet of Cottonwood Park R3 Detention. West of S 4-J Rd North of Granite St.	CPP, 36"	CBC 7' x 5' L = 1800'	CM	294	232	184	150	111	Limited by 1.2 HW/D
8-231	903	Outlets of Existing Upper Sage Valley Ponds to Future Upper Sage Detention	Storm Sewer	36" RCP, L= 330' 42" RCP L = 660'	I	76	76	49	33	23	
4-J Storm System											
8-230	1952	4-J storm system	CMP 36"	CMP 36" L= 500'	I	48	48	22	12	6	36" will work if 500 ft of pipe at the north end is redesigned at a steeper slope. Street Capacity = 17 cfs*
Channels											
North Donkey Creek											
8-212	1415	Channel Reach End of E-Z St. to constructed channel end.	Native Grass	30' BW, 4:1 SS. 5.5' deep grass lined channel	FM	1125	1125	693	487	328	

Notes:
*Assumes flattest longitudinal slope
CM = CulvertMaster
FM = FlowMaster
H = HECRAS
I = InfoSWMM

Table 5.17
Conveyance Alternative Structure Summary
Basin 8 North Donkey Creek

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Conveyance Alternative Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
North Donkey Creek											
8-206	1805	Under Emerson Ave North of E Walnut St.	CONC. 12' x 3'	CBC 42' x 4.5', L=60'	H	569	569	388	291	222	Limited by overtopping depth 1.2' TOR raise required
8-207	1807	Under Maple Ave North of E Walnut St.	CMP, 2-30"	CBC 32' x 3', L=60'	H	569	569	388	291	224	Limited by HW/D
8-208	1809	Under Birch Ave North of E Walnut St	CONC, 2-24"	CBC 11' x 3', L=62'	H	323	323	234	201	177	Limited by overtopping depth
8-211	886	Outlet of Sage Valley Park R1	CONC, 27"	CBC 2-7'x5', L=1687'	C	444	444	235	179	120	Limited by HW/D
Tributary 802											
8-213	DIV-170	Outlet of Cottonwood Park R3 Detention. West of S 4J Rd North of Granite St.	CPP, 36"	CBC 2-5'x5', L=1800'	CM	419	419	266	190	140	Limited by 1' freeboard
8-214	P8-13 outflow	Outlet of Sage Bluffs Park R4 Detention. Under S 4J Rd South of Frontier Dr	RCP, 42" x 26", 60"x 36", 60" x 44"	CBC 2-8'x4', L=180'	CM	342	342	207	143	101	Limited by 1' freeboard
Tributary 803											
8-220	1631	Douglas Hwy storm system	CBC 6'x3'	CBC 10'x4' L=630' CBC 12'x4' L=360' CBC 15'x4' L=435'	I	211	211	125	87	62	Street Capacity =0 cfs (Sump condition)
4-J Storm System											
8-230	1952	4-J storm system	CMP 36"	CBC 6'x5' L= 670' CBC 4'x3' L=2600'	I	145	145	90	66	50	Street Capacity = 17 cfs*, Steepen slope at north end of system.
Channels											
North Donkey Creek											
8-212	1415	Channel Reach End of E-Z St. to constructed channel end.	Native Grass	30 BW, 4:1 SS, 6' Deep, grass lined	FM	1457	1457	918	659	456	
8-202	1413	Channel Reach S. Douglas Highway to End of E-Z St.	Native Grass	15' BW, 4:1 SS, 6' Deep, grass lined	FM	1192	1192	753	549	400	

Notes:
*Assumed flattest longitudinal slope
CM = CulvertMaster
FM = FlowMaster
H = HECRAS
I = InfoSWMM

Estimated costs for the alternatives are summarized in Table 5.18. The detention alternative is more cost effective than the conveyance alternative in terms of construction cost for flood control on the NDC.

Table 5.18
Alternative Cost Estimates – Basin 8

Item	Alternative Costs (x $1,000)	
	Detention & Structure Improvements	Conveyance Improvements
Channel Improvements	$119	$347
Drop Structures	$0	$0
Culverts	$3,311	$9,396
Bridges	$0	$0
Detention Ponds	$1,131	$86
Subtotal Construction (rounded)	**$4,561**	**$9,829**
Engineering & Permitting (15%)	$684	$1,474
Construction Contingency (30%)	$1,368	$2,949
Land Acquisition	$47	$0
Total Cost (rounded)	**$6,660**	**$14,252**

5.6.6 Direct Flow Areas (Basin 9)

Two detention facilities are proposed for the detention pond alternative for this basin. The first requires formalization of the inadvertent detention behind Highway 50. The second is an increase in the existing Sutherland Estates detention facility capacity. It requires a 6' x 4' CBC sewer in 4-J Road. Also, Tributary 902 will require new box culverts at 4-J Road.

The conveyance alternative in this basin requires a 10 x 4 CBC storm sewer in 4-J Road, and 4 other culvert improvements along Tributary 902.

Two culverts on 4-J Road and 1 culvert on Lakeway Road are included in this basin as local conveyance improvements.

Table 5.19
Detention Alternative Structure Summary
Basin 9 Donkey Creek Tributaries

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Detention Alternative Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
Tributary 902											
9-210	216	Donkey Creek Tributary 902 & 4-J Rd.	RCP 2-48"	CBC 2- 7'x5' L = 110'	CM	725	671	301	168	94	Limited by 1.2 HW/D
Enzi Drive Sewer											
9-217	242	4-J Rd. Sewer from Vivian to Enzi	RCP 48"	CBC 6'x4' L = 2160'	I	128	128	62	38	24	Street Capacity =93 cfs* Redesign sewer to constant slope

Notes:
*Assumes flattest longitudinal slope
CM = CulvertMaster
I = InfoSWMM

Table 5.20
Conveyance Alternative Structure Summary
Basin 9 Donkey Creek Direct Flow Areas

Design Point	Element ID	Location	Existing Structure	Proposed Structure	Analysis Method	Capacity (cfs)	Conveyance Alternative Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
Tributary 902											
9-210	216	Donkey Creek Tributary 902 & 4-J Rd.	RCP 2-48"	CBC 2- 12'x5', L=110'	CM	845	669	301	168	94	Limited by 1.2 HW/D
9-206	208	Donkey Creek Tributary 902 & Oakcrest Dr.	RCP elliptical 38"x60"	CBC 6- 5'x3', L=130'	CM	654	459	210	127	79	Limited by 0.5' overtopping road.
9-212	205	Donkey Creek Tributary 902 & Lakeway Rd.	CMP 84"	Add RCP 42" L=140'	CM	419	419	182	88	37	Limited by 1.2 HW/D
9-214	310	Donkey Creek Tributary 902 & Skyline Rd. (SH 50)	CMP 36"	RCP 66", L=262'	CM	257	241	101	48	20	Limited by 1.2 HW/D
Enzi Drive Sewer											
9-217	242	Sewer from Vivian to Enzi	RCP 48"	CBC 10'x4', L=2160	I	265	246	136	88	57	Street Capacity =93 cfs* Redesign sewer to constant slope

Notes:
*Assumed flattest longitudinal slope
CM = CulvertMaster
I = InfoSWMM

Table 5.21
Local Improvement Structure Summary
Basin 9 Donkey Creek Direct Flow Areas

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Tributary 901											
9-207	209	Donkey Creek Tributary 901 & 4-J Rd.	CMP 66"	Add RCP 66" L=90'	CM	230	230	80	29	7	Limited by 1' freeboard
Tributary 902											
9-215	215	Donkey Creek Tributary 902 & 4-J Rd.	CMP 24"	RCP 54" L=120'	CM	145	130	51	24	9	Limited by 1.5 HW/D
Tributary 905											
9-211	206	Donkey Creek Tributary 905 & Lakeway Rd.	CMP 42"	Add RCP 2- 42" L=140'	CM	125	122	56	29	12	Limited by 1' freeboard

Note:
CM = CulvertMaster

Estimated costs for the alternatives are listed in Table 5.22. Overall, the detention alternative is more cost-effective in terms of construction cost for flood control.

Table 5.22
Alternative Cost Estimates – Basin 9

Item	Alternative Costs (x $1,000)		
	Detention & Structure Improvements	Conveyance Improvements	Local Structure Improvements
Channel Improvements	$0	$0	$0
Drop Structures	$0	$0	$0
Culverts & Storm Sewers	$1,746	$2,625	$111
Bridges	$0	$0	$0
Detention Ponds	$181	$0	$0
Subtotal Construction (rounded)	**$1,927**	**$2,625**	**$111**
Engineering & Permitting (15%)	$289	$394	$17
Construction Contingency (30%)	$578	$788	$33
Land Acquisition	$91	$0	$0
Total Cost (rounded)	**$2,885**	**$3,807**	**$161**

5.6.7 Milne Valley (Basin 10)

Milne Valley (Basin 10) is a major tributary to Donkey Creek and the major drainageway was considered as part of the overall Donkey Creek watershed discussed in Section 5.6.1. The two large proposed detention facilities, Milne Valley-Lower and Milne Valley-Mid, are part of the detention alternative for Donkey Creek main stem, and serve Basin 10 as well. Selection of the detention alternative on the main stem of Donkey Creek will also determine this alternative selection for Basin 10. As in Basin 6, this plan combines over-detention and floodplain management with providing 100-year conveyance structures in new development. The plan then allows development in Basin 10 without the need for onsite detention.

The roadway crossing improvements at 4-J Road and at Southern Drive are still necessary but smaller in the detention alternative, Table 5.23, than those listed for the conveyance alternative for Basin 10, Table 5.24. There are also new culverts proposed on Tributaries 1001, 1002, and 1003 as a part of the local conveyance improvements, as listed in Table 5.25.

Estimated costs for the conveyance and local conveyance improvements are listed in Table 5.26.

Table 5.23
Detention Alternative Structure Summary
Basin 10 Milne Valley Detention Alternative Summary

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity	Detention Alternative Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Tributary 1000											
10-201	207	Upper Donkey Creek Tributary 1000 & 4-J Rd.	RCP 2-86"	Add 2-84" RCP L = 150'	CM	1415	1118	660	342	144	Limited by 1.2 HW/D
10-202	202	Upper Donkey Creek Tributary 1000 & Southern Dr.	2-CMP 96", 1-CMP 84"	2- 12' x 7' CBC L= 225'	CM	1435	1435	762	368	139	Limited by 1.2 HW/D

Note:
CM = CulvertMaster

Table 5.24
Conveyance Alternative Structure Summary
Basin 10 Milne Valley

Design Point	Element ID	Location	Existing Structure	Proposed Structure	Analysis Method	Capacity (cfs)	Future Conditiom Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Tributary 1000											
10-201	207	Upper Donkey Creek Tributary 1000 & 4-J Rd.	RCP 2-86"	3- 12' x 10' CBC, L=150'	CM	3667	3250	1060	423	153	Limited by 1.2 HW/D
10-202	202	Upper Donkey Creek Tributary & Southern Dr.	2-CMP 96", 1-CMP 84"	3- 12' x 10' CBC, L=225'	CM	3667	3129	1004	394	139	Limited by 1.2 HW/D

Note:
CM = CulvertMaster

Table 5.25
Local Improvement Structure Summary
Basin 10 Milne Valley - Local Improvements Summary

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Tributary 1001											
10-210	204	Upper Donkey Creek Tributary 1001 & U.S. Highway 50	RCP 45"x32" elliptical	2- 4'x3' CBC L=90'	CM	170	159	56	21	5	Limited by 1' freeboard
Tributary 1002											
10-220	206	Upper Donkey Creek Tributary 1002 & Bunny Ln.	No culvert	RCP 24" L=40'	CM	150	150	59	28	11	Limited by overtopping depth
10-221	203	Upper Donkey Creek Tributary 1002 & Southern Dr.	CMP 36"	60" RCP L=350'	CM	153	142	55	26	11	Limited by 1.5 HW/D
Tributary 1003											
10-230	205	Upper Donkey Creek Tributary 1003 & Southern Dr.	CMP 24"	RCP 36" L=140'	CM	65	45	18	8	3	Limited by 1.5 HW/D

Note:
CM = CulvertMaster

Table 5.26
Alternative Cost Estimates – Basin 10

Item	Alternative Costs (x $1,000)		
	Detention & Structure Improvements	**Conveyance Improvements**	**Local Structure Improvements**
Channel Improvements	$0	$0	$0
Drop Structures	$0	$0	$0
Culverts	$857	$1,655	$307
Bridges	$0	$0	$0
Detention Ponds	See Donkey Creek Main Stem	$0	$0
Subtotal Construction (rounded)	**$857**	**$1,655**	**$307**
Engineering & Permitting (15%)	$129	$248	$46
Construction Contingency (30%)	$257	$497	$92
Land Acquisition	$0	$0	$0
Total Cost (rounded)	**$1,243**	**$2,400**	**$445**

5.6.8 Upper Donkey Creek (Basin 12)

Basin 12 is the upper Donkey Creek watershed and a major tributary to Donkey Creek. The major drainageway was considered as part of the overall Donkey Creek watershed discussed in Section 5.6.1. The largest proposed detention pond in the project area, Hidden Valley-Upper, is part of the detention alternative for Donkey Creek main stem, and serves Basin 12 as well. Selection of the detention alternative on the main stem of Donkey Creek will also determine this alternative selection for Basin 12. As in Basins 6 and 10, this plan combines over-detention and floodplain management with providing 100-year conveyance structures in new development. The plan then allows development in Basin 12 without the need for onsite detention.

The conveyance alternative for Basin 12 includes 2 reaches of channel improvements along the Hidden Valley subdivision, as listed in Table 5.27. These channel improvements are not required in the detention alternative. Structure improvements for the conveyance alternative were included in the Donkey Creek main stem evaluation.

The local conveyance improvements, listed in Table 5.28, include 6 new culverts, all on separate tributaries to Donkey Creek. Three are proposed along Spring Hill Road, 2 along Force Road, and one on Lazy D Avenue.

Estimated costs for the alternatives are listed in Table 5.29. Overall, the detention alternative is more cost-effective in terms of construction cost for flood control.

Table 5.27
Conveyance Alternative Structure Summary
Basin 12 Upper Donkey Creek

Design Point	Element ID	Location	Existing Structure	Proposed Structure	Analysis Method	Capacity (cfs)	Future Condition Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Channels											
Upper Donkey Creek											
12-202	306	Donkey Creek Channel Capacity (DP12-203 to DP 12-202)	Natural Channel	200' BW, 4:1 SS, 6' Deep, grass lined	FM	4579	4579	1738	818	375	
12-201	310	Donkey Creek Channel Capacity (DP12-202 to Hwy 50)	Natural Channel	180' BW, 4:1 SS, 6' Deep, grass lined	FM	4615	4615	1753	816	361	

Note:
FM = FlowMaster

Table 5.28
Local Improvement Structure Summary
Basin 12 Donkey Creek Direct Flow Areas - Local Improvements Summary

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Tributary 1201											
12-230	206	Upper Donkey Creek Tributary 1201 & Force Rd.	24" RCP	48" RCP L=650'	CM	140	140	53	24	10	Limited by 0.5' overtopping road.
Tributary 1202											
12-220	208	Upper Donkey Creek Tributary 1202 & Spring Hill Rd.	No culvert	RCP 2-36" L=100'	CM	350	349	122	51	18	Limited by 0.5' overtopping road.
Tributary 1203											
12-210	211	Upper Donkey Creek Tributary 1203 & Spring Hill Rd.	CMP 24", 18" HDPE	Add 36" culvert L=87'	CM	366	366	143	66	27	Proposed includes roadway overtopping
Tributary 1240											
12-240	204	Upper Donkey Creek Tributary 1240 & Spring Hill Rd.	*CMP 48"	Add 3-48" RCP L=68'	CM	910	906	343	148	54	Limited by 0.5' overtopping road.
Tributary 1250											
12-250	203	Upper Donkey Creek Tributary 1250 & Force Rd.	CMP 24"	CBC 5-4'x2' L=100'	CM	405	403	158	74	31	Limited by 0.5' overtopping road.

Note:
CM = CulvertMaster

Table 5.29
Alternative Cost Estimates – Basin 12

Item	Alternative Costs (x $1,000)	
	Conveyance Improvements	**Local Structure Improvements**
Channel Improvements	$1,767	$0
Drop Structures	$288	$0
Culverts	$0	$327
Bridges	$0	$0
Detention Ponds	See Donkey Creek Main Stem	$0
Subtotal Construction (rounded)	**$2,055**	**$327**
Engineering & Permitting (15%)	$308	$49
Construction Contingency (30%)	$617	$98
Land Acquisition	$0	$0
Total Cost (rounded)	**$2,980**	**$474**

5.6.9 Stonepile Creek Main Stem

The detention alternative for the main stem of Stonepile Creek through Basin 5 was developed to reduce future conditions peak 100-year flows to be within the capacity of the existing channel reaches and crossing structures in the established areas of the City of Gillette. These reaches have been channelized with extensive concrete-lined and grassed-lined channel sections and large culvert structures that represent significant investments. Residential, commercial and industrial development has occurred in the larger Stonepile Creek floodplain area adjacent to the channelized reaches. Future conditions 100-year flow rates are significantly higher than the capacity of the existing Stonepile Creek infrastructure, and there is potential for significant flood damage in a major flood event.

For the detention alternative, six potential regional detention sites were identified and modeled to achieve peak flow reduction to approximate the capacity of the existing conveyances. An excellent location for a regional facility for Stonepile Creek, labeled Beltway-Upper, was identified in the valley west of town where the creek runs between I-90 and Echeta Road in Basin 11. The location is adjacent to the future Western Drive (beltway) alignment, and it is possible to use the detention embankment for the future roadway, and the outlet works as a crossing structure of Stonepile Creek instead of a bridge. This detention facility will require a permit from Wyoming's Office of the State Engineer. A spillway could be located upstream of the beltway and a discharge chute could be routed under the bridge structure for I-90.

In addition to this detention facility, three new detention facilities are proposed on Tributaries 503, 505, and 506, located upstream of a crossing of Highway 14/16 and the city center. These are labeled Tributary 503 detention, Tributary 505 detention, and Tributary 506 detention. All these detention facilities over-detain in order to reduce flows to the main stem of Stonepile Creek in Basin 5. Other locations for detention were evaluated on the main stem of Stonepile Creek upstream of a crossing of Highway 14/16, labeled Beltway-Lower and Echeta Road detention, but were rejected due to inefficiencies.

Also as part of the detention alternative, several options were evaluated in exploring the use of the closed depression that is Burlington Lake. These included use of the Lake:

- Without modifications
- With a berm on the south side to keep water from overflowing on the south side, and thereby increasing its capacity
- With dredging to increase the capacity
- With an accompanying structure through the existing dam to allow storage on the northwest side of the dam
- With an outlet to the north and to the Rawhide Creek basin
- With an outlet to the south back to Stonepile Creek

Evaluation of the use of the lake without modifications found that the capacity was not enough to reduce flows in Stonepile Creek that would allow continued use of many of the existing crossing structures. A new berm proposed on the south side was discarded since it would block the view of the Lake from Warlow Road, and impacted the Children's Garden on the southwest corner of the Lake. Dredging was discarded as more expensive than the other options, and because it is not currently called for in the maintenance plan for this park.

An outlet from the Lake to the north into Little Rawhide Creek basin was evaluated and discarded due to a potential water rights issue, and because it is against the policy of trans-basin diversions stated in the criteria manual.

The proposed plan under the detention alternative for Stonepile Creek main stem calls for 4-9' x 5' CBC through the existing dam to allow flooding of the area on the northwest side of the dam. The properties in this northwest depression area consist of a radio station and a trap shooting range. These properties that will be in the 100-year floodplain will require flood insurance or relocation.

The diversion structure in Stonepile Creek to Burlington Ditch is expected to consist of a new diversion weir in the Stonepile Creek channel and un-gated opening to an enlarged Burlington Ditch diversion channel. This is similar to the current configuration, but the current Burlington Ditch does not have the capacity to carry the approximately 1,700 cfs needed to reduce flows in downstream reaches of Stonepile Creek. The proposed Burlington Ditch channel has a 40-foot wide bottom width, is 6 feet deep, 3H:1V side slopes, and has a 12' access road that could double as a rec trail. The improved channel follows the alignment of the existing ditch.

The detention alternative for Stonepile Creek proposes a new outlet from Burlington Lake to Stonepile Creek. The new Burlington Lake outlet is proposed as a storm sewer set at the elevation of the existing water surface that would extend down North Gurley Avenue to discharge into Stonepile Creek at the Church Detention.

Another proposed detention facility, labeled Church detention, is proposed in the vacant land between Gurley and Stanley Avenues. This facility will essentially act as a wide overbank area in the floodplain with approximately 90 acre feet of volume. A constriction on the downstream end would regulate flows, and enough embankments constructed on the north side to prevent flooding into Highway 14. Another proposed detention site, labeled Railroad, was evaluated and rejected due to other uses proposed at the site.

As in Basins 6, 10 and 12 this alternative combines over-detention and floodplain management with 100-year conveyance structures in new development. The plan then allows development in the Stonepile Creek basin without the need for further onsite detention.

Even with these 6 detention facilities totaling more than 900 acre-feet of capacity, 6 culvert crossings would need replacement or improvement, including a culvert is required to be jacked or bored under the BNSF Railroad to provide increased conveyance at this crossing. In addition, 10 reaches of channel would need improvement to meet criteria, mainly the reaches between Burma Avenue upstream to where Stonepile Creek starts to parallel I-90, but also further downstream, from 2nd Avenue upstream to the railroad bridge at about Miller Avenue. These channel reaches are mostly concrete-lined with walls and grass bottom, and range from 25 to 50 feet in width. These conveyance improvements are listed in Table 5.30.

With only existing detention modeled in the total watershed, the conveyance alternative would require reconstruction of most of Stonepile Creek through the City. As listed in Table 5.31, 16 new bridges and one new culvert are required to meet criteria. New channel sections from 1-90 downstream to nearly McKenzie Road upstream, or about 3.5 miles of channelization through the heart of town are also necessary. These channels are mostly concrete-lined with walls and grass bottoms, ranging from 80 to 170 feet in width, and would require a significant amount of property acquisition to construct.

Proposed improvements to the Burlington Diversion Ditch and Burlington Lake in the Detention alternative are listed in Table 5.32. No improvements to the Burlington Lake are proposed under the Conveyance Alternative; however, conveyance improvements are needed, as listed in Table 5.33. To use the existing detention available in Burlington Lake, the Burlington Ditch would be improved to safely convey flows to Burlington Lake under the conveyance alternative, which are required to eliminate the shallow flooding potential that currently exists south of the ditch.

Estimated costs for these alternatives are listed in Table 5.34. Overall, the detention alternative is most cost effective in terms of construction cost for flood control.

Table 5.30
Detention Alternative Structure Summary
Stonepile Creek

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Detention Alternative Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
5-201	299	Lower Stonepile Creek & S. Garner Lake Rd.	CBC 2 - 12' x 6'	Add CBC 12'x6' L =145'	CM	1704	1673	737	477	307	
5-207	271	Lower Stonepile Creek & Church Ave.	RCP 4 - 21", 2 - 19" x 30", 1 - 34" x 84"	CBC 3 - 10' x 3.5' L=55'	H	1255	1255	582	400	282	TOR raise 1.5 ft. Limited by overtopping depth
5-217	258	Lower Stonepile Creek & Railroad	Bridge Span = 44' Width = 35'	Bridge Span = 85' Width = 82'	H	1186	1144	343	219	140	Minor Arterial
5-225	229	Lower Stonepile Creek & Burlington Ditch	Inline weir	Diversion Structure	H	2802	2665	1128	635	347	Cuttoff wall, top el at 4551.5
5-226	227	Lower Stonepile Creek & Burma Ave.	CBC 1 - 9' x 7', 4 - 10' x 5'	Add CBC 9'x7' and CBC 10'x 5' L =75'	H	2731	2578	1092	634	350	Limited by HW/D ratio of 1.2
5-229	223	Lower Stonepile Creek & Commercial Dr.	RCP 2 - 5'	CBC 2 - 10'x5' L=125'	H	1666	1446	634	255	125	Limited by HW/D ratio of 1.2
5-232	217	Lower Stonepile Creek & Newton Rd.	RCP 1 - 48" Arch	CBC 6 - 10'x4' L=110'	H	1125	1122	466	115	59	
Channels											
5-209	362	Lower Stonepile Channel Capacity (DP 5-215 to DP 5-209)	Concrete/Grass Channel	50' BW, 6' deep grass/concrete lined channel	FM	1352	1352	739	488	313	
5-217	359	Lower Stonepile Channel Capacity (Brooks St. to Railroad)	Concrete/Grass Channel	40' BW, 5.5' deep grass/concrete lined channel	FM	1121	1121	312	199	127	
5-226	352	Lower Stonepile Channel Capacity (DP 5-227 to Burma Ave.)	Concrete/Grass Channel	70' BW, 3:1 SS. 6' deep grass lined channel	FM	2731	2578	1092	634	350	
5-227	324	Lower Stonepile Channel Capacity (Warlow Dr. to DP 5-227)	Concrete/Grass Channel	50' BW, 3:1 SS. 5.5' deep grass lined channel	FM	2002	1599	669	346	183	
5-228	320	Lower Stonepile Channel Capacity (Commercial Dr. to Warlow Dr.)	Concrete/Grass Channel	45' BW, 3:1 SS. 5.5' deep grass lined channel	FM	1830	1477	634	255	125	
5-229	321	Lower Stonepile Channel Capacity (Echeta Rd. to Commercial Dr.)	Concrete/Grass Channel	45' BW, 3:1 SS. 6' deep grass lined channel	FM	1666	1446	634	255	125	
5-230	318	Lower Stonepile Channel Capacity (Hwy 14-16 to Echeta Rd)	Concrete/Grass Channel	45' BW, 3:1 SS. 5.5' deep grass lined channel	FM	1644	1426	628	233	115	
5-231	316	Lower Stonepile Channel Capacity (Newton Rd. to Hwy 14-16)	Grass Channel	25' BW, 3:1 SS. 5.5' deep grass lined channel	FM	1125	1122	466	155	59	
5-232	315	Lower Stonepile Channel Capacity (DP 5-233 to Newton Rd)	Grass Channel	25' BW, 3:1 SS. 5.5' deep grass lined channel	FM	1125	1122	466	115	59	
5-233	312	Lower Stonepile Channel Capacity (DP 5-236 to DP 5-233)	Grass Channel	25' BW, 3:1 SS. 6' deep grass lined channel	FM	1087	1084	452	63	29	

Notes:
CM = CulvertMaster
FM = FlowMaster
H = HECRAS

Table 5.31
Conveyance Alternative Structure Summary
Stonepile Creek

Design Point	Element ID	Location	Existing Structure	Proposed Structure	Analysis Method	Capacity (cfs)	Future Condition Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
5-201	299	Stone Pile Creek & S. Garner Lake Rd.	CBC 2 - 12' x 6'	Bridge Span = 120' Width = 82'	H	6129	6127	1192	568	359	1.75 'TOR raise required. Minor Arterial
5-202	297	Stone Pile Creek & S. Boxelder Rd.	CMP 4 - 10' x 8'	Bridge Span = 120' Width = 82'	H	6286	6286	1179	624	416	Minor Arterial
5-204	290	Stone Pile Creek & I-90	CBC 4 - 140" x 6'	Bridge Span = 115' Width = 106'	H	5653	5653	1055	586	370	Major Arterial
5-205	295	Stone Pile Creek & El Camino Rd.	CBC 4 - 15' x 40"	Bridge Span = 125' Width = 66'	H	6112	6016	1110	714	449	Local
5-206	293	Stone Pile Creek & Butler Spaeth Rd.	CBC 6 - 11' x 4'	Bridge Span = 125' Width = 82'	H	6119	6021	1111	715	450	Minor Arterial
5-207	271	Stone Pile Creek & Church Ave.	No field data	Bridge Span =95' Width = 66'	H	6113	6013	1067	691	437	Local
5-209	260	Stone Pile Creek & E 2nd St.	CBC 3 - 8' x 9.5'	CBC 9-12' x 8', L=850'	H	5890	5867	982	473	297	Limited by 1' freeboard
5-217	258	Stonepile Creek & Railroad	Bridge Span = 44' Width = 35'	Bridge Span =160' Width = 82'	H	5006	5003	951	347	131	Minor Arterial
5-219	255	Stonepile Creek & Railroad Street	CBC 5 - 9' x 5'	Bridge Span =160' Width = 66'	H	5409	5258	947	345	127	Local
5-221	253	Stonepile Creek & Warlow Dr.	CBC 6 - 8' x 62"	Bridge Span =135' Width = 82'	H	4472	4437	901	322	93	Minor Arterial
5-226	227	Stonepile Creek & Burma Ave.	CBC 4-10-x62"; 1-111"x86"	Bridge Span =160' Width = 82'	H	4424	3932	1336	683	250	Minor Arterial
5-228	225	Stonepile Creek & Warlow Dr.	CBC 4 - 8' x 7'	Bridge Span =100' Width = 82'	H	3937	3932	1336	684	250	Minor Arterial
5-229	223	Stonepile Creek & Commercial Dr.	RCP 2 - 5'	Bridge Span =105' Width = 66'	H	3937	3933	1336	716	250	Local
5-230	221	Stonepile Creek & Echeta Rd.	RCP 3 - 9'	Bridge Span =115' Width = 66'	H	3939	3855	1318	709	241	Collector
5-230	221	Stonepile Creek & Railroad	RCP 3 - 9'	Bridge Span =115' Width = 82'	H	3939	3855	1318	709	241	Minor Arterial
5-231	220	Stonepile Creek & Hwy 14/16	CBC 4 - 9' x 5'	Bridge Span =115' Width = 106'	H	3861	3573	1206	696	215	Major Arterial
5-232	217	Stonepile Creek & Newton Rd.	RCP 1 - 48" Arch	Bridge Span = 115' Width = 66'	H	3575	3575	1206	732	216	Local

Notes:
FM = FlowMaster
H = HECRAS

Table 5.31
Conveyance Alternative Structure Summary
Stonepile Creek

Design Point	Element ID	Location	Existing Structure	Proposed Structure	Analysis Method	Capacity (cfs)	Future Condition Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Channels											
5-203	391	Lower Stonepile Channel Capacity (I-90 to DP 5-203)	Grass/Concrete Channel	65' BW, 4:1 SS, 6' Deep, grass lined	FM	6225	6225	1055	585	370	
5-204	397	Lower Stonepile Channel Capacity (El Camino Rd. to I90)	Concrete Channel	115' BW, 5' Deep, concrete channel	FM	5619	5619	1040	560	355	
5-205	395	Lower Stonepile Channel Capacity (Butler Spaeth to El Camino Rd.)	Concrete Channel	125' BW, 6' Deep, concrete channel	FM	6112	6016	1110	714	449	
5-206	393	Lower Stonepile Channel Capacity (Church St. to Butler Spaeth)	Concrete Channel	95' BW, 5' Deep, concrete channel	FM	6098	6001	1063	687	434	
5-207	372	Lower Stonepile Channel Capacity (4th St to Church St.)	Grass Channel	120' BW, 5' Deep, concrete channel	FM	6113	6013	1067	691	437	
5-209	362	Lower Stonepile Channel Capacity (DP 5-215 to DP 5-209)	Grass Channel	80' BW, 6' Deep, concrete channel	FM	5890	5867	982	473	297	
5-217	359	Lower Stonepile Channel Capacity (Brooks St. to Railroad)	Grass/Concrete Channel	80' BW, 5.5' Deep, concrete channel	FM	4986	4985	943	342	126	
5-219	357	Lower Stonepile Channel Capacity (Warlow Dr. to Railroad St.)	Grass/Concrete Channel	160' BW, 3:1 SS, 6' Deep, grass lined	FM	5354	5207	926	331	114	
5-221	355	Lower Stonepile Channel Capacity (DP 5-225 to Warlow Dr.)	Grass/Concrete Channel	135' BW, 3:1 SS, 6' Deep, grass lined	FM	4464	4429	897	320	89	
5-225	325	Lower Stonepile Channel Capacity (DP 5-226 to DP 5-225)	Grass/Concrete Channel	170' BW, 3:1 SS, 6' Deep, grass lined	FM	4560	4489	1506	763	314	
5-226	352	Lower Stonepile Channel Capacity (DP 5-227 to Burma Ave.)	Grass/Concrete Channel	160' BW, 3:1 SS, 5' Deep, grass lined	FM	4424	4379	1508	780	336	
5-227	324	Lower Stonepile Channel Capacity (Warlow Dr. to DP 5-227)	Grass/Concrete Channel	100' BW, 3:1 SS, 6' Deep, grass lined	FM	4067	4022	1360	695	255	
5-228	320	Lower Stonepile Channel Capacity (Commercial Dr. to Warlow Dr.)	Grass/Concrete Channel	105' BW, 3:1 SS, 5.5' Deep, grass lined	FM	3937	3932	1336	683	250	
5-229	321	Lower Stonepile Channel Capacity (Echeta Rd. to Commercial Dr.)	Grass/Concrete Channel	115' BW, 3:1 SS, 5.5' Deep, grass lined	FM	3937	3932	1336	684	250	
5-230	318	Lower Stonepile Channel Capacity (Hwy 14-16 to Echeta Rd)	Grass/Concrete Channel	115' BW, 3:1 SS, 5.5' Deep, grass lined	FM	3921	3915	1327	710	246	
5-231	316	Lower Stonepile Channel Capacity (Newton Rd. to Hwy 14-16)	Grass/Concrete Channel	115' BW, 3:1 SS, 5.5' Deep, grass lined	FM	3571	3571	1206	638	215	
5-232	315	Lower Stonepile Channel Capacity (DP 5-233 to Newton Rd)	Grass/Concrete Channel	115' BW, 3:1 SS, 5.5' Deep, grass lined	FM	3573	3573	1206	696	215	
5-233	312	Lower Stonepile Channel Capacity (DP 5-236 to DP 5-233)	Grass Channel	115' BW, 3:1 SS, 5.5' Deep, grass lined	FM	3542	3542	1192	721	210	
5-236	308	Lower Stonepile Channel Capacity (DP 5-239 to DP 5-236)	Natural Channel	110' BW, 3:1 SS, 5' Deep, grass lined	FM	3348	3348	1125	494	196	
11-200	322, 305, 303, 302, 307, 301, 300	Upper Stonepile Creek Channel (DP 11-204 to DP 11-200)	Rural Channel	80' BW, 3:1 SS, 6' Deep, grass lined	FM	3143	3143	1059	460	182	

Notes:
FM = FlowMaster
H = HECRAS

Table 5.32
Detention Alternative Structure Summary
Basin 5 Lower Stonepile Creek Tributaries

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Detention Alternative Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Burlington Diversion											
5-247	230	Diversion 504 & Hannum Rd.	CMP 2-5'	CBC 4- 9'x5' L= 100'	H	1704	1704	1123	606	328	Limited by HW/D ratio of 1.2
5-243	N\A	Burlington Lake outflow to BL Northwest	None	CBC 4- 9'x5, L =120'	I	1704	1704	1123	606	328	
5-243	278	From Burlington Lake outlet to Stonepile Creek	None	72" RCP L = 1980'	I	300	300	209	63	34	
Channels											
Burlington Diversion											
5-247	230	Diversion 504 Channel Capacity (DP 5-225 to Hannum)	Grass Channel	40' BW,3:1 SS. 6' deep grass lined channel	H	1704	1704	1123	606	328	
5-247	230	Diversion 504 Channel Capacity (Hannum to Burlington Pond)	Natural Channel	40' BW,3:1 SS. 6' deep grass lined channel	H	1704	1704	1123	606	328	

Notes:

H = HECRAS
I = InfoSWMM

Table 5.33
Conveyance Alternative Structure Summary
Basin 5 Lower Stonepile Creek Tributaries

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Condition Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Burlington Diversion											
5-247	230	Diversion 504 & Hannum Rd.	CMP 2-5'	2-10'x5' CBC, L= 90'	CM	789	727	632	434	229	Limited by HW/D < 1.2
Tributary 505											
5-239	213	Tributary 505 & I-90	CMP 1 - 6'	2 - 9'x5' CBC, L=285'	CM	650	591	195	40	11	Limited by HW/D < 1.2
Tributary 506											
5-236	P5-16 outflow	Tributary 506 & I-90	CMP 1 - 6'	8'x6' CBC, L = 285'	CM	379	351	168	83	33	Limited by HW/D < 1.2
Channels											
Burlington Diversion											
5-247	326	Diversion 504 Channel Capacity (DP 5-225 to Hannum)	Grass Channel	Grass-lined channel, 40' BW, 4.5' Normal Depth, SS 3:1	FM	640	636	623	430	227	
5-247	328	Diversion 504 Channel Capacity (Hannum to Burlington Pond)	Natural Channel	Grass-lined channel, 40' BW, 4.5' Normal Depth, SS 3:1	FM	730	726	632	434	229	

Notes:
CM = CulvertMaster
FM = FlowMaster

Table 5.34
Alternative Cost Estimates – Stonepile Creek

Item	Alternative Costs (x $1,000)	
	Detention & Structure Improvements	Conveyance Improvements
Channel Improvements	$2,532	$15,465
Drop Structures	$377	$1,044
Culverts	$3,250	$10,943
Bridges	$0	$25,295
Detention Ponds	$9,200	$0
Diversion Structure & Channel	$580	$420
Subtotal Construction (rounded)	**$15,939**	**$53,167**
Engineering & Permitting (15%)	$2,391	$7,975
Construction Contingency (30%)	$4,782	$15,950
Land Acquisition	$812	Not Estimated
Total Cost (rounded)	**$23,924**	**$77,092**

5.6.9.1 Upper Stonepile Creek Tributaries (Basin 11)

Basin 11 is the upper Stonepile Creek watershed and a major tributary to the Stonepile Creek main stem through the City. The major drainageway was considered as part of the overall Stonepile Creek watershed discussed in Section 5.6.9. The largest proposed detention pond in the project area, Beltway-Upper, is part of the detention alternative for Stonepile Creek main stem, and serves Basin 11 as well. Selection of the detention alternative on the main stem of Stonepile Creek will also determine this alternative selection for Basin 11. As in Basins 6 and 10, and 12, this plan combines over-detention and floodplain management with providing 100-year conveyance structures in new development. The plan then allows development in Basin 11 without the need for onsite detention.

The tributaries of Upper Stonepile Creek are all addressed as local conveyance improvements. No detention facilities were proposed outside the facilities discussed above for the main stem of Stonepile Creek. Six improvements to culverts are recommended, at I-90, Centennial Drive, and where tributaries cross the railroad and Echeta Road, as listed in Table 5.35.

Construction cost estimates are listed in Table 5.36.

Table 5.35
Local Improvement Structure Summary
Basin 11 Upper Stonepile Creek Selected Structure Summary

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Tributary 1102											
11-212	202	Tributary 1102 and Railroad & Echeta Rd	42" CMP, L= 155.8'	12'x5' CBC, L=155'	CM	432	399	149	64	22	Limited by HW/D < 1.2
11-210	208	Tributary 1102 & Centennial Dr.	18" CMP	Add 24" RCP L=60'	CM	245	245	96	45	19	Limited by 0.5' overtopping road.
Tributary 1103											
11-203	214	Tributary 1103 and I-90	3-54" CMP	2-12'x4' CBC L=172'	CM	520	519	161	79	29	Limited by 1.2 HW/D
Tributary 1104											
11-211	203	Tributary 1104 and Railroad & Echeta Rd	36" CMP, 123.4'	Add 1- 36" CMP, L=125'	CM	107	79	26	10	2	Limited by HW/D < 1.5
11-220	209	Tributary 1104 and Centennial Dr.	No structure	36" RCP L=100'	CM	56	25	9	4	1	No Structure
Tributary 1106											
11-221	207	Tributary 1106 and Railroad & Echeta Rd	No structure	42" RCP, L= 320'	CM	56	54	16	5	0	Limited by 0.5' overtopping road.

Note:
CM = CulvertMaster

Table 5.36
Alternative Cost Estimates – Basin 11

Item	Alternative Costs (x $1,000)
	Local Structure Improvements
Channel Improvements	$0
Drop Structures	$0
Culverts	$803
Bridges	$0
Detention Ponds	See Stonepile Creek
Subtotal Construction (rounded)	**$803**
Engineering & Permitting (15%)	$120
Construction Contingency (30%)	$241
Land Acquisition	$0
Total Cost (rounded)	**$1,164**

5.6.9.2 Lower Stonepile Creek Tributaries (Basin 5)

Tributary study reaches in Basin 5 were considered separately from the Stonepile Creek main stem, and do not include any new detention because the sub-basins are highly developed and generally do not have suitable sites for regional detention facilities.

The Conveyance Alternative in the Basin 5 tributaries involves new storm sewer and open channel improvements, and includes conveyance improvements on Tributaries 505 and 506 that are needed without the proposed detention facilities there. Proposed storm sewer improvements are typically not intended for 100-year conveyance, but have been sized for the difference between the 100-year peak flow and the capacity of the existing street section at the minimum longitudinal grade and 12 inches maximum depth, per criteria.

There local structure improvements on the tributary study reaches in the Lower Stonepile Creek Basin, listed in Table 5.37, include the following elements:

- The plan on Tributary 501 includes a proposed storm sewer conveyance under Bridger Street and Foothills Blvd. to Highway 14/16 that alleviates the documented flooding that frequently occurs here. Upstream, a new crossing is proposed under Foothills Blvd. near where it intersects with Echeta Road.
- On Tributary 502, improved channels from Warlow Drive to 2nd Street are needed, with an improved crossing at Warlow Drive and new storm sewer upstream from 2nd Street to 6th Street that augments the street capacity to safely carry the future 100-year peak flow.
- New CBCs are proposed on Tributaries 503 and 506 at Westover Road.
- New storm sewer is proposed along Tributary 504 under 1st Street from Emerson Avenue to Gillette Avenue, and from Gillette Ave to Richards Ave. New storm sewer is also proposed in Gillette Avenue from 2nd Street to 7th Street.

- The existing storm sewer is proposed to be upgraded on Tributary 508 under 5th Street from Gurley Avenue to Douglas Highway to provide for conveyance of the 100-year peak flows.
- Similarly, on Tributary 509, the existing storm sewer is proposed to be upgraded under 7th Street, Green Avenue, and 9th Street to provide for conveyance of the 100-year flow.
- On Tributary 510, only improved crossings near the downstream end at I-90, Highway 14/16, and the BNSF railroad are proposed. Peak flow rates on this tributary will be reduced by construction of the new outlet proposed for Burlington Lake.
- Where there is currently no well-defined channel in Tributary 511 through some private properties, a new channel is proposed on the end, from existing Detention Facility P5-9 downstream to the junction with Tributary 510.

Construction cost estimates are listed in Table 5.38.

Table 5.37
Local Improvement Structure Summary
Basin 5 Lower Stonepile Creek Tributaries

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
Tributary 501											
5-235	205	Tributary 501 on Bridger Rd.	Street Capacity	CBC 8' x 4' L=2000'	I	402	402	137	57	27	Street Capacity = 68 cfs*
5-240	201	Tributary 501 & Foothills Blvd.	CMP 36" x 24" Arch	CBC 5- 7' x 3' L= 95'	CM	332	332	108	38	10	Limited by overtopping depth
Tributary 502											
5-246	243	Tributary 502 & W. Warlow Dr.	RCP 1 - 6'	Add 2 - 6' RCP L=300'	CM	555	555	305	206	141	Limited by 1' freeboard
5-224	252	Tributary 502 & 6th St.	Storm sewer	CBC 9' x 2' L=1560'	I	200	181	100	66	44	Street Capacity = 62 cfs*
Tributary 503											
5-234	233	Tributary 503 & Westover Rd.	CMP 2 - 48"	CBC 2- 12' x 5' L=148'	CM	864	864	364	173	70	Limited by 1.2 HW/D
Tributary 506											
5-237	212	Tributary 506 & Westover Rd.	CMP 36"	CBC 3- 10' x4' L=50'	CM	588	511	215	96	33	Limited by 1' freeboard
Tributary 508											
5-214	267	5th Street Storm Sewer (Tributary 508)	Storm sewer	CBC 8' x 4' L=1875'	I	280	269	152	101	64	Street Capacity = 53 cfs*
Tributary 509											
5-213	272	Tributary 509 & Gurley Ave.	Storm sewer	CBC 5' x 3' L=1025'	I	100	100	56	38	26	Street Capacity =11 cfs*
Tributary 510											
5-212	284	Stonepile Creek Tributary 510 & I-90	CMP 2-24"	CBC 2-7' x 6' L=420'	CM	616	616	309	198	143	Limited by 1.2 HW/D
5-210	285	Stonepile Creek Tributary 510 & HWY 51	CMP 1-24"	CBC 12' x 6' L=110'	CM	582	578	292	196	138	Limited by 1.2 HW/D
5-211	282	Stonepile Creek Tributary 510 & Railroad	CMP 1 - 30"	CBC 12' x 6' L = 75'	CM	582	578	293	199	141	Limited by 1.2 HW/D
Tributary 504											
5-249	263	1st Ave. Storm Sewer	Storm sewer	CBC 5' x 4' L=1140' CBC 2-4' x 10' L=1200'	I	475	475	285	195	135	Street Capacity = 43 cfs*
5-220	262	Gillette Ave. Storm Sewer	Storm sewer	CBC 8' x 2' L=2210'	I	205	203	124	86	59	Street Capacity = 40 cfs*
Channels											
Tributary 502											
5-246	345	Tributary 502 Channel Capacity (Burma to Warlow)	Grass Channel	20' BW, 4:1 SS, 5' Deep, Grass Lined	FM	395	394	217	144	98	
5-222	347	Tributary 502 Channel Capacity (2nd to Burma)	Grass Channel	5' BW, 4:1 SS, 4.5' Deep, Grass Lined	FM	245	245	194	127	87	
Tributary 511											
5-211	312	Tributary 511 Channel Capacity (DP 5-211 to DP 5-250)	Grass Channel	4:1 SS, 3' Deep, Grass Lined Triangular Channel	FM	31	31	15	8	4	

Notes:
*Assumed flattest longitudinal slope
CM = CulvertMaster
FM = FlowMaster
I = InfoSWMM

Table 5.38
Alternative Cost Estimates – Basin 5 Tributaries

Location & Type	Alternative Costs (x $1,000)	
	Local Structure Improvements	Channel Improvements
Tributary 501 – Structure & Storm Sewer	$1,713	$0
Tributary 502 – Structure & Channel	$1,130	$164
Tributary 503 – Structure	$425	$0
Tributary 504– Storm Sewer	$7,454	$0
Tributary 506 – Structure	$168	$0
Tributary 508 – Storm Sewer	$1,259	$0
Tributary 509 – Storm Sewer	$399	$0
Tributary 510 – Structure	$949	$0
Tributary 511 – Channel	$0	$141
Subtotal Construction (rounded)	**$13,497**	**$305**
Engineering & Permitting (15%)	$2,025	$46
Construction Contingency (30%)	$4,049	$92
Total Cost (rounded)	**$19,571**	**$443**

5.6.10 East Fork Little Rawhide Creek (Basin 4)

The East Fork of Little Rawhide Creek, Basin 4, has sufficient conveyance capacity through most of its reaches. Consequently, only local structure improvements are proposed at I-90, Warlow Road, and Little Powder River Road, as listed in Table 5.39.

Construction cost estimates are listed in Table 5.40.

Table 5.39
Local Improvement Structure Summary
Basin 4 Little Rawhide Creek

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
Structures											
Little Rawhide Creek											
4-201	212	Little Rawhide Creek & Little Powder River Rd.	36" CMP	2-8' x 6' CBC, L=68'	CM	799	764	349	193	106	Limited by HW/D ratio of 1.2
4-207	201	Little Rawhide Creek & E. Warlow Dr.	3-24" CMP	9-4'x2' CBC, L=104'	CM	430	420	203	111	52	Limited by 1' freeboard.
4-208	200	Little Rawhide Creek & I-90	2-24" RCP	2-6'x4' CBC, L=200'	CM	298	234	116	66	35	Limited by HW/D ratio of 1.2

Note:
CM = CulvertMaster

Table 5.40
Alternative Cost Estimates – Basin 4

Item	Alternative Costs (x $1,000)
	Local Structure Improvements
Channel Improvements	$0
Drop Structures	$0
Culverts	$816
Detention Ponds	$0
Subtotal Construction (rounded)	**$816**
Engineering & Permitting (15%)	$122
Construction Contingency (30%)	$245
Total Cost (rounded)	**$1,183**

5.6.11 Dry Fork Little Powder River (Basin 3)

Little of Basin 3 has been developed and much of the existing channels, and consequently the only proposed improvement is the local conveyance improvement of a new culvert at Kluver Road, as listed in Table 5.41.

One structure is proposed at Kluver Road. The Ash Meadows Subdivision is in the City and drains to the playa then into the coal mine. There are City-owned detention cells in Ash Meadows that will be maintained.

The estimated construction cost is summarized in Table 5.42.

Table 5.41
Local Improvement Structure Summary
Basin 3 Dry Fork Little Powder River

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Future Flow Rates (cfs)				Comment
							100-year	10-year	5-year	2-year	
							Green = Sufficient Capacity				
3-205	210	Dry Fork Little Powder & Kluver Rd	24" CMP	2- 36" RCP, L=88'	CM	109	102	40	18	7	Limited by HW/D < 1.5

Note:
CM = CulvertMaster

Table 5.42
Alternative Cost Estimates – Basin 3

Item	Alternative Costs (x $1,000)
	Local Structure Improvements
Channel Improvements	$0
Drop Structures	$0
Culverts	$20
Detention Ponds	$0
Subtotal Construction (rounded)	**$20**
Engineering & Permitting (15%)	$3
Construction Contingency (30%)	$6
Total Cost (rounded)	**$29**

5.6.12 Closed Basins (Basin 2)

The reach of Tributary 201 as it passes from Collins Road to design point 2-202 and out of the City is being addressed as a series of local conveyance improvements to be constructed in 2011. A comparison was made of the current design and the proposed local structure improvements in this plan, and this plan is more conservative. However, either set of improvements would be much better than the existing undersized channels and culverts in the study reach. The proposed structures in the Local Structure Improvement alternative consist of 2 new CBCs, and 3 locations where added culverts are needed. There are also 7 reaches of channel improvements, 5 of which are concrete lined due to land availability on either side of the channel, as listed in Table 5.43. Existing inadvertent detention upstream of I-90 was taken into account in the hydrology for these proposed structures.

Further improvements should assume inadvertent detention upstream of I-90 is in place and maintained. Future development should limit flow to capacity of 36” pipe under I-90. URS will note in the plan what goes on in Basin 02_116, which affects the structures under the highway and the BNSF RR. 100-year volumes will be provided for the playa with the delivery of the electronic model.

Construction cost estimates are listed in Table 5.44.

Table 5.43
Local Improvement Structure Summary
Basin 2 Closed Basins

Design Point	Element ID	Location	Existing Structure Description	Proposed Structure Description	Analysis Method	Capacity (cfs)	Conveyance* Flow Rates (cfs) 100-year	10-year	5-year	2-year	Comment
							Green = Sufficient Capacity				
Structures											
Tributary 201											
2-203	213	Tributary 201 & Potter Ave.	45"x25" RCP Ellipse	2-7'x5' CBC, L=59'	CM	520	518	210	107	59	Limited by HW/D ratio of 1.2
2-218	223	Tributary 201 & University Rd.	2-30" CMP	Add 30" RCP, L= 54'	CM	470	468	200	105	61	Limited by HW/D ratio of 1.5
2-204	210	Tributary 201 & Badger Ave.	2-30" CMP	4-7'x3' CBC, L=80'	CM	470	469	200	105	61	Limited by HW/D ratio of 1.2
2-205	209	Tributary 201 & Collins Rd.	24" CMP	Add 2- 24" RCP, L= 50'	CM	237	237	75	27	8	
2-206	P2-1	Tributary 201 & I-90	36" RCP	Add 3-36" RCP, L=350'	CM	185	185	69	29	10	Limited by HW/D ratio of 1.2
Tributary 202											
2-219	219	Tributary 202 & Railroad	RCP 2-42"	4- RCP 84", L=120	CM	1363	1311	644	341	160	Limited by HW/D ratio of 1.2
2-207	216	Tributary 202 & Hwy 51	RCP 48"	4- RCP 84", L=120	CM	1357	1311	644	341	156	Limited by HW/D ratio of 1.2
Channels											
Tributary 201											
2-202	326	Channel Capacity (Potter Ave. to DP 2-202)	Rural Channel	20' BW, 4:1 SS. 4.5' deep, grass lined, L= 1700'	FM	517	517	210	96	59	
2-203	314	Channel Capacity (University Rd. to Potter Ave.)	Rural Channel	20' BW, 4:1 SS. 5.5' deep, grass lined, L=2290'	FM	460	460	196	91	59	
2-218	312	Channel Capacity (Badger Ave. to University Rd)	Rural Channel	15' BW, 5' deep, concrete, L=330	FM	470	468	200	94	61	
2-204	315	Channel Capacity (Market St. to Badger Ave.)	Rural Channel	10' BW, 4' deep, concrete, L = 950	FM	235	235	74	26	7	
2-217	315	Channel Capacity (Wall St. to Market St.)	Rural Channel	10' BW, 4' deep, concrete, L = 660	FM	235	235	74	26	7	
2-216	315	Channel Capacity (Collins Rd to Wall St)	Rural Channel	10' BW, 4' deep, concrete, L = 250	FM	235	235	74	26	7	

Notes:
*Assumes no inadvertent detention upstream of I-90
CM = CulvertMaster
FM = FlowMaster

Table 5.44
Alternative Cost Estimates – Basin 2

Item	Alternative Costs (x $1,000)
	Local Structure Improvements
Channel Improvements	$669
Drop Structures	$166
Culverts	$691
Detention Ponds	$0
Subtotal Construction (rounded)	**$1,527**
Engineering & Permitting (15%)	$229
Construction Contingency (30%)	$458
Total Cost (rounded)	**$2,214**

5.7 ALTERNATIVE EVALUATIONS AND RECOMMENDATIONS

Based on the evaluation of flood impacts, stream stability, and cost effectiveness, the regional detention alternative is preferred and recommended for implementation on the main stems of Donkey Creek and Stonepile Creek, and in Basins 6, 7, 8 and 9. Regional detention, which is primarily over-detention in the upper watershed areas, will reduce potential flood impacts from existing and future conditions 100-year flows on the main channels of these streams through central Gillette, and on the tributary channels. Floodplain management, which is the process of identifying floodplains associated with major drainageways and playas and preserving them, together with selected local structural improvements is recommended for the study reaches in Basins 1, 2, 3, 4. By implementing this plan, numerous small detention cells in existing developed areas can be removed, and these cells can be avoided within future development (or provided for water quality purposes only). Approximately 55 structures would be removed from the floodplain of Donkey Creek, approximately 30 structures would be removed from the Antelope Butte Creek floodplain south of Douglas Highway, and scores of structures would be removed from the Stonepile Creek floodplain through central Gillette. Other documented flooding problems on tributaries to Stonepile Creek, Antelope Butte Creek and Donkey Creek and other study reaches would also be addressed by implementing this plan.

The larger detention facilities and stream corridor improvements proposed in Donkey Creek and Stonepile Creek watersheds also offer opportunities for multiple uses, including open space, recreation, wetlands and wildlife habitat enhancement. With larger detention facilities and improved channels on the main drainageway and fewer small detention cells, access would be improved and operations and maintenance would become more efficient.

Generally drainage improvement plans are implemented from the downstream end up. In this case however, it is recommended that the priorities would be to construct the detention facilities in Basins 5, 10, 11 and 12, and make the proposed modifications to Fishing Lake and Burlington Lake. All of the other improvements are sized assuming that all these detentions are in place. Also, building the detention ponds in the Stonepile Creek and Donkey Creek watersheds removes the largest number of structures from the identified problem areas. The remaining improvements on the study reaches and tributaries should then be implemented from downstream to upstream.

Environmental impacts due to construction of the larger detention facilities are not anticipated to be prohibitive, and it is anticipated that any mitigation required can be accomplished on each site as part of the project.

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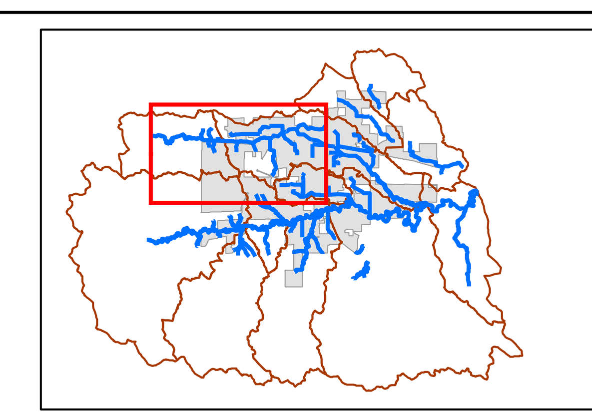

- Design Points
- Structures in the 100-Year Floodplain
- Dewatering Wells
- Inlet Structure
- Manholes
- Outlet Structures
- Study Reaches
- Existing Conduit
- Existing Open Channel
- Interstate
- State or US Highway
- Streets
- Railroads
- Major Basin
- Subbasin
- City Limits
- Study Area
- City Property
- Existing Parks

Existing Detention

- City
- County
- Private
- Stock Pond
- Road Inadvertent
- Depression Playa
- Proposed Structure
- Proposed Channel Improvements

Future Conditions Flooding Limits

- Contained in Floodplain
- Shallow (< 1-foot depth) Flooding Leaving Channel
- Flow Direction Leaving Channel
- Proposed Detentions

THE INFORMATION ON THIS DRAWING WAS OBTAINED FROM RECORD AND DESIGN DRAWINGS. THE CITY OF GILLETTE MAKES NO GUARANTEE REGARDING THE ACCURACY OF THIS DRAWING OR THE INFORMATION CONTAINED THEREIN.

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Feet

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

Proposed Plan
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Gillette Stormwater Master Plan

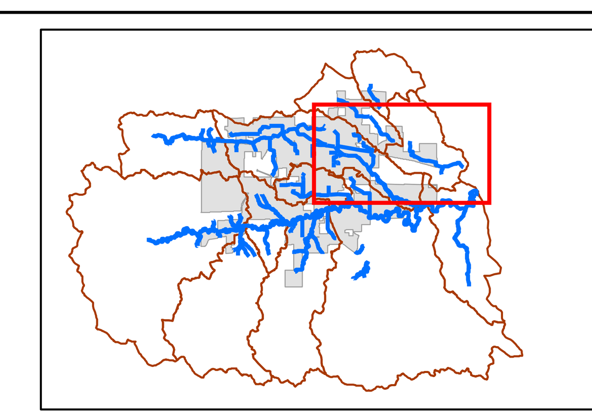
5.2

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

URS

Design Points	Study Reaches	Major Basin	Existing Detention	Proposed Structure
Structures in the 100-Year Floodplain	Existing Conduit	Subbasin	City	Proposed Channel Improvements
Dewatering Wells	Existing Open Channel	City Limits	County	Future Conditions Flooding Limits
Inlet Structure	Interstate	Study Area	Private	Contained in Floodplain
Manholes	State or US Highway	City Property	Stock Pond	Shallow (< 1-foot depth) Flooding Leaving Channel
Outlet Structures	Streets	Existing Parks	Road Inadvertent	Flow Direction Leaving Channel
	Railroads		Depression Playa	Proposed Detentions

THE INFORMATION ON THIS DRAWING WAS OBTAINED FROM RECORD AND DESIGN DRAWINGS. THE CITY OF GILLETTE MAKES NO GUARANTEE REGARDING THE ACCURACY OF THIS DRAWING OR THE INFORMATION CONTAINED THEREIN.



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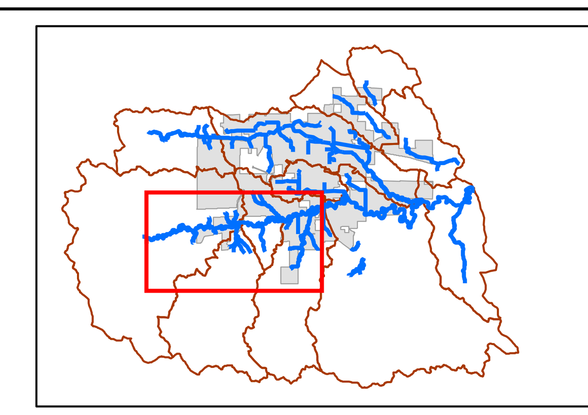
Proposed Plan
Page 2 of 4

Gillette Stormwater Master Plan

5.2



Design Points
Structures in the 100-Year Floodplain
Dewatering Wells
Inlet Structure
Manholes
Outlet Structures

Study Reaches
Existing Conduit
Existing Open Channel
Interstate
State or US Highway
Streets
Railroads

Basin 8 Major Basin
08_101 Subbasin
City Limits
Study Area
City Property
Existing Parks

Existing Detention
City
County
Private
Stock Pond
Road Inadvertent
Depression Playa

Proposed Structure
Proposed Channel Improvements
Future Conditions Flooding Limits
Contained in Floodplain
Shallow (< 1-foot depth) Flooding Leaving Channel
Flow Direction Leaving Channel
Proposed Detentions

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

URS

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N

0 800 1,600
Feet

Proposed Plan
Page 3 of 4

Gillette Stormwater Master Plan

5.2

Design Points

Structures in the 100-Year Floodplain

Dewatering Wells

Inlet Structure

Manholes

Outlet Structures

Study Reaches

Existing Conduit

Existing Open Channel

Interstate

State or US Highway

Streets

Railroads

Basin 8 Major Basin

08_101 Subbasin

City Limits

Study Area

City Property

Existing Parks

Existing Detention

City

County

Private

Stock Pond

Road Inadvertent

Depression Playa

Proposed Structure

Proposed Channel Improvements

Future Conditions Flooding Limits

Contained in Floodplain

Shallow (< 1-foot depth) Flooding Leaving Channel

Flow Direction Leaving Channel

Proposed Detentions

URS

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Proposed Plan
Page 4 of 4

Gillette Stormwater Master Plan

5.2

SECTION SIX

SELECTED PLAN

6.1 OVERVIEW

Based on the evaluation of flood impacts, stream stability, and cost effectiveness, the detention alternative is preferred and recommended for implementation on the main stems of Stonepile and Donkey Creeks, as well as in Basins 6, 7, 8 and 9. Proposed new detention ponds are shown in Figure 6.1. With these larger detention ponds in place, fewer channel and culvert improvements are required to convey future conditions flood flows, and development can occur anywhere within these watersheds without the need to provide small, local detention cells. In addition, some existing detention cells can be removed and redeveloped. Regional detention is the most cost effective way to meet all the criteria of the Stormwater Master Planning Study.

In the other Basins and certain study reaches, channel improvements, storm sewer improvements and selected local structural improvements are proposed. The overall plan is illustrated in Figure 6.2 (in the map pockets at the end of this section). Continued floodplain management is an inherent component of this Master Plan in all study reaches.

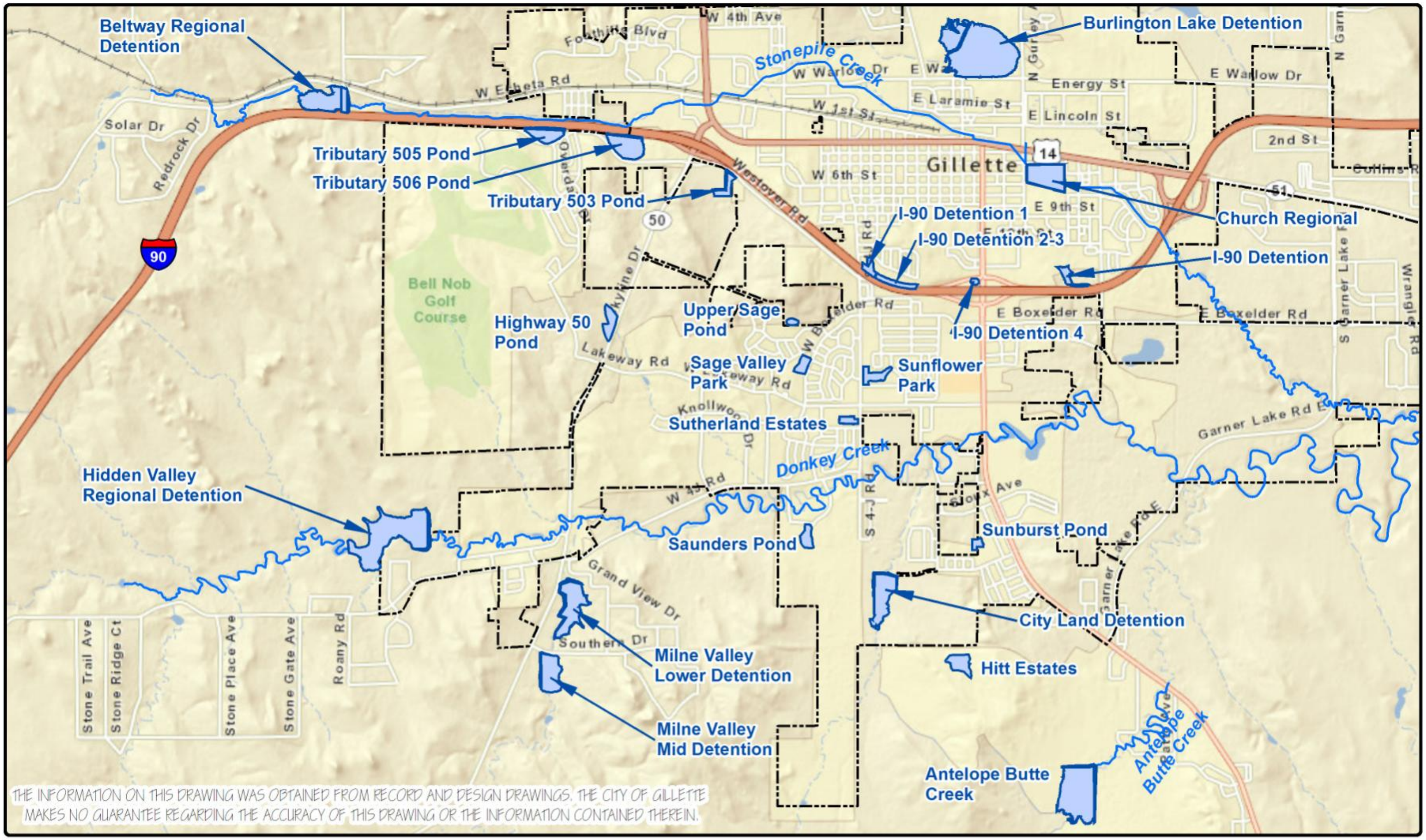
The overall goal for this Stormwater Master Plan for the City of Gillette is to minimize potential for flood damages, provide facilities that make periodic maintenance more efficient, and create opportunities for public amenities, open space and enhancement of wildlife habitat and wetlands. During the process of developing the alternatives, the City chose elements in each basin as a basis for the preparation of conceptual design.

The elements of the conceptual design are summarized in this section. The proposed improvements have been designed to meet the stated objectives and qualitatively evaluated, and presented to the City of Gillette and other interested agencies and individuals. Conceptual plans for the recommended detention ponds, channel improvements and storm sewer improvements are shown on the drawings contained in Appendix G.

6.1.1 General Recommendations

As part of master planning for urbanizing watersheds, it is generally recommended that the City and Campbell County implement the following:

- Take steps to stabilize all major drainageways as the watersheds urbanize, rehabilitate existing degraded reaches of the major drainageways and their tributaries, and to aggressively control erosion and sediment transport during construction activities. Existing natural drainageways should be preserved as much as possible.
- The City should require new land development, significant redevelopment and publicly funded projects to provide runoff volume control practices (i.e., minimize directly connected impervious areas and employ Best Management Practices (BMPs)) whenever site conditions permit.
- The City should take steps to require that all new development, redevelopment, and publicly funded projects provide stormwater quality BMPs as recommended in Sections 11 and 12 of the Gillette SDDM.



URS

CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

Proposed Detention Pond

N

0 1
Miles

Proposed Detention Sites

Gillette Stormwater Master Plan 6.1

- The City should continue to enforce floodplain management regulations, including regulation of the 100-year floodplain and floodway, and continue to participate in FEMA's flood insurance Community Rating System and public education programs. Floodplain information is provided in this document for several playas within the City, and development proposed in and around playas should be done so as not to reduce the available major flood storage volumes.
- The City should also initiate a new detailed study of Stonepile Creek from its confluence with Donkey Creek to the western limit of the current detailed study, and a detailed study of the reach of Donkey Creek between Butler Speath Road and Douglas Highway.
- Land-use changes to the contributing watersheds affect the flood hazard nature (i.e., runoff rates, volumes and depths), the transport of sediment, and the water quality of the receiving natural drainageways. The City and County, who have land use control powers in the watershed, should monitor land use changes and whenever the land-use changes result in imperviousness ratios that exceed the projections identified in this study, steps should be taken to further limit increases in stormwater runoff through the use of additional on-site detention BMPs, thereby reducing runoff rates, volumes and potential for increasing future flood damages.

6.2 CONCEPTUAL DESIGN OF PROPOSED IMPROVEMENTS

Details of recommended detention, channel and storm sewer improvements listed in the Detention Alternative tables in Chapter 5 were reviewed with the City, and the elements shown in Figure 6.2 and described in the following paragraphs were selected for inclusion in the master plan. A conceptual design of these elements includes provision for trails and access, drop and check structures, right-of-way and easements. Re-vegetation will be an important component of each improvement project, but is not specifically detailed in this plan.

6.2.1 Summary of Criteria

The criteria used to evaluate hydraulic conveyance and performance are the applicable sections in the City's *Storm Drainage Design Manual* (SDDM) (Revised January 2011). The design storm for these improvements is the 100-year future land use conditions rainfall event. The 24-hour rainfall depth for the 100-year event in Gillette is 4.0 inches (SDDM, Table 2.1).

Generally, open channel geometry was developed according to the SDDM. Grass-lined channels consist of a trapezoidal section with a minimum bottom width of 4 feet, side slopes 3:1 or greater, and a design depth of less than 5 feet. Proposed culverts have been designed assuming the proposed longitudinal slope is the same as the existing slope and the headwater to depth ratio depends on the most limiting restriction outlined in Chapter 8, Culverts, of the Gillette SDDM. All detention ponds are designed based on Chapter 10, Detention, of the Gillette SDDM. Characteristics of each detention pond are listed on the design drawings in Appendix G.

6.2.2 Detention Ponds and Conveyance Elements

The proposed regional and sub-regional detention ponds shown in Figure 6.1 are located and sized to address existing and future conditions flooding potential. Characteristics and performance metrics for the preferred regional and sub-regional detention ponds are summarized previously in Table 5.4.

All ponds have been sized using the InfoSWMM for the future conditions 100-year peak flow rates. In most cases, the ponds are sized to overdetain such that the majority of existing downstream infrastructure can safely convey the peak 100-year discharge. Within proposed new developments, it will be necessary to provide conveyance for developed peak flow rates to the receiving drainageway. Flood impacts for the 100-year peak flow downstream of the regional detention ponds will decrease in most cases, but will not be completely eliminated.

Channel improvements on the major drainageways are proposed only where needed *with proposed detention in place*, or where existing conveyance elements are undersized for future conditions flows. As with the channels, proposed culverts are sized for future conditions flows. Storm sewer system improvements are sized for the future conditions minor storm assuming street conveyance for the surcharges in the major event, estimated using allowable flow depths for the existing street section.

A list and discussion of existing detention ponds that can be removed or redeveloped as part of this plan is in Appendix D.

6.2.3 Donkey Creek Main Stem

To control flood potential on Donkey Creek, three large regional detention facilities were proposed, two in major Basin 10, Milne Valley –lower and Milne Valley –mid, and one in Basin 12, Hidden Valley. These are shown on Figures G-1, G-2 and G-3, respectively. Upon further hydrologic modeling that included all detention proposed on the tributaries, it was recommended that the Milne Valley –lower pond be removed from the plan. With all proposed detention in place in the Donkey Creek watershed, only two large detention facilities in the upper watershed are needed to reduce 100-year peak flows to a rate that allows use of most of the downstream channel sections and crossing structures on the main stem. These two detention facilities will be large enough to require a permit from Wyoming's Office of the State Engineer in order to construct them. The conceptual designs include 20-foot wide crests and spillways that are compatible with this expectation. All include excavated basins as part of the design.

The Hidden Valley Upper detention pond was located to allow development to the southeast along Force Road and to be upstream of the future Western Drive beltway on the west side of town. It is expected that Western Drive would be built after the detention pond.

The Donkey Creek main stem detention proposed condition InfoSWMM model includes the other proposed detention hydrographs from the tributary basins (such as the City Land detention in Basin 7), and the existing detention basins that were government owned and maintained. The detention option reduces downstream flows in Donkey Creek to rates that are similar to or less than the flows in the existing FIS, and in locations just downstream of the detention ponds peak flows in the major events are significantly less.

On the main stem of Donkey Creek, channel improvements are proposed in two locations. The first is the reach between Fishing Lake and Butler Speath Road, shown in Figure G-4. The channel length is approximately 1,700 feet on two parcels, one owned by the City. There are constrictions in the channel reach that limit its capacity, and the City has plans to build a rec trail across the creek on an existing berm across the channel. The proposed rec trail is not shown on the drawing. Although the proposed channel has a trapezoidal section, it is recommended that the channel be laid out to preserve the existing low flow channel as much as possible.

The proposed improvements also include a new outlet structure and spillway for Fishing Lake. These are needed to alleviate shallow flooding potential to the north at this location. The current 18" CMP low level outlet would be replaced with a 10' x 6' CBC and a 14' x 14' grated box inlet weir structure in the lake. The existing dam road and parking lot would be raised to elevation 4524.0, except for a 440 foot section that would be lowered to 4521.0 to act as an emergency spillway. An 8% slope would connect the proposed road/spillway to the dam road. The flood frequency for the new spillway is a 2-year event, which means the frequency of roadway overtopping will be reduced from the existing condition. Hydraulic calculations for the design of the outlet structure and spillway are in Appendix D.

The second location where channel improvements are recommended for Donkey Creek is upstream of Douglas Highway to approximately Carlisle Blvd., shown on Figure G-5. Although the capacity issue is mostly related to the berm across Tract A, approximately 1,700 linear feet of channel grading is recommended. Currently, a developer is proposing a project on Tract 4, which offers the opportunity to incorporate some channel improvements with site improvements.

Another location where channel improvements were proposed in Table 5.5 is upstream of Donkey Creek Drive. This reach is all privately owned, and the creek meanders between and behind existing residential structures for about 1,600 feet. There was also a recommendation for enlarging the bridge crossing on Donkey Creek Dr. Because this area is all privately owned and outside the City limits, the preferred option here is continued floodplain management in combination with flood insurance for these private properties within Campbell County.

6.2.4 Antelope Butte Creek Basin (Basin 6)

On the main stem of Antelope Butte Creek, the plan proposes a regional detention facility, Antelope Butte Creek Detention shown on Figure G-6, which over-detains enough flow so that the structure at Lee Avenue can convey the 100-year peak discharge. This is an embankment dam only (with no excavated basin), and is relatively inexpensive. With this detention pond in place, no channel improvements are required downstream and the only structure improvement necessary is at Douglas Highway. The intent is to provide a combination of over-detention and floodplain management, with developed conditions 100-year conveyance facilities in all new development. The plan then allows development in the Antelope Butte Creek basin without the requirement for onsite detention.

On Tributary 609, which is a north bank tributary to Donkey Creek, the plan includes formalizing the inadvertent detention on the Hillcrest Elementary School property adjacent to I-90 (Pond P6-4) and maintaining the depression playa detention (Pond P6-5). P6-4 detention is controlled by the culvert under I-90 and causes ponding on the school property. Formalizing this detention in agreement with the School District would allow the City to abandon the existing Providence Crossing detention cell just north of the school property. Maintaining the depression playa, P6-5, is a floodplain management activity, and future development should be required to maintain the 100-year floodplain limit of the playa or provide an equivalent detention capacity of approximately 11 ac-ft on the site.

Existing detention ponds P6-1 and P6-2 can handle the 100-year peak flows, but these ponds discharge to Donkey Creek and not Antelope Butte Creek. It is recommended that these ponds be converted to water quality facilities at some future time, since their major detention capability is inconsequential to the Donkey Creek floodplain.

Other local roadway drainage improvements are proposed on Tributaries 602, 605 and 610, as previously listed in Table 5.10.

6.2.5 Donkey Creek Tributary South (DCTS, Basin 7)

Of the three options considered in the Detention and Structure Improvements alternative on the main stem of DCTS, the City selected Option II, the City Land Pond, for major regional detention. This pond, shown on Figure G-7, is sized to reduce 100-year peak flow rates enough to allow the downstream main channel reaches and existing structures to meet criteria and remain in place without further improvement. The City Land Pond is located just south of Shoshone Avenue on land owned by the City, would be a combined use facility with new low level outlet culvert under Shoshone Avenue. Upstream of the pond, a new major culvert crossing of Southern Drive is required. As shown on Figure G-7, the City Land regional pond allows for a 300-foot wide buffer for development on the east side Enzi Drive.

Flows from Remington Ponds D1 and D2 and the RC Ranch Detention E Pond (Ponds P7-2, P7-3 and P7-7, respectively) would be redirected to the City Land Pond and those existing detention cells could then be redeveloped. As noted previously, existing detention ponds P7-1 through P7-8 can handle the 100-year peak flow, but these ponds are not effective in reducing 100-year peak flows in DCTS or the tributaries. It is recommended that these ponds be converted to water quality facilities at some future time.

New detention facilities are also proposed for the Saunders Tributary, the Hitt Estates Tributary, and the Sunburst Tributary, as shown on Figures G-8, G-9 and G-10, respectively. Each new pond detains developed flows such that the existing downstream conveyance facilities have capacity to meet 100-year criteria for these systems without modification. The proposed Hitt Estates Pond is an existing produced water pond that would be formalized as permanent stormwater detention when development of the surrounding land occurs. The proposed Saunders and Sunburst ponds are necessary for existing development and runoff conditions.

Necessary roadway drainage structure improvements for the DCTS main stem and tributaries are as listed previously in Tables 5.12 and 5.14.

6.2.6 North Donkey Creek (Basin 8)

The selected plan for North Donkey Creek, Basin 8, proposes expanding existing detention ponds at Sage Valley Park R1 and Sunflower Park R5, formalizing the inadvertent detention that occurs north of I-90, and adding one new pond south of the new Boxelder Road extension, labeled Upper Sage Valley. The locations of these are shown on Figure 6.1.

The most effective pond expansion is the Sage Valley Park R1 detention. This plan is to remove the existing playground and completely re-grade the area, which increases the storage volume and helps to reduce the potential for shallow flooding in the neighborhood downstream from this pond when it overtops. A new outlet structure is necessary, as well as a new major storm sewer from the Sage Valley Park R1 detention facility to the existing Sunflower Park detention facility.

Details are shown on Figure G-11. Expansion of the Sunflower Park pond, also shown on Figure G-11, is proposed to add volume on the east side of 4-J Road.

A new pond, Upper Sage Valley shown on Figure G-12, is proposed to replace the existing detention cells in the Upper Sage Valley neighborhood to the west. The City currently has plans to extend Boxelder Road west of 4-J Road. The Upper Sage Valley pond should be constructed as part of the earthwork project for the roadway that is currently underway. The proposed conditions Info SWMM model has been updated to include the storm sewer trunk main proposed in Boxelder Road, and the changes proposed for Cottonwood Park by this project. Although very efficient, the Cottonwood Park ponds still overflows by approximately 50 cfs into 4-J Road with it in place, so a new outlet storm sewer is proposed from Cottonwood Park to Sunflower Park as shown in the Figure.

The inadvertent detention ponds along the north side of I-90 should be formalized to the extent practicable as part of the plan. Four ponds are proposed by grading within the WYDOT right-of-way and providing new inlet and outlet structures as necessary to connect to existing storm sewer systems and cross culverts, as shown in Figure G-13. Formalizing these detention facilities would require an agreement with WYDOT to allow the grading, allow maintenance access, and keep the size of the existing cross culverts the same. It was recommended that a portion of the existing storm sewer in 4-J Road downstream of the I-90 Pond 1 be reconstructed to reduce surcharging potential of the existing storm sewer. However, the potential surcharging in 4-J Road could also be conveyed for approximately 250 feet in a roadside ditch, as shown on Figure G-13.

Even with the increased detention, several conveyance structures on NDC will need improvement to safely pass the 100-year event. It is necessary to replace the NDC crossings at Birch, Maple and Emerson. The only channel improvement recommended is the lower reach from E-Z Street to Butler Speath Road. This is all on one tract and would require an easement. The City has plans to extend Mitchell St. to the south, which would require a new culvert crossing, and this channel improvement could be made in conjunction with that project. This channel improvement is illustrated on sheet G-14 in Appendix G.

6.2.7 Direct Flow Areas (Basin 9)

Two detention facilities are proposed for the detention pond alternative for this basin. The first requires formalization of the inadvertent detention upstream of Highway 50, pond P9-4 shown on Figure 6.1. This would not require any grading, but probably would require a drainage easement for the ponding area adjacent to the highway.

The second detention improvement is to increase the volume in the existing Sutherland Estates detention facility, as shown on Figure G-15. To reduce the potential for flooding in 4-J Road during major storm events, a new outlet structure and storm sewer in 4-J Road is proposed, as shown in the Figure.

New roadway drainage structures are proposed in Basin 9 as listed previously in Table 5.21.

6.2.8 Upper Donkey Creek and Milne Valley (Basins 10 and 12)

Two large proposed detention facilities, Milne Valley-Mid and Hidden Valley, are primarily for flood control on the downstream reaches of Donkey Creek, but will serve for existing and future development Basins 10 and 12 as well. This plan combines over-detention and floodplain management with requiring 100-year conveyance structures in new development.

Necessary roadway drainage structure improvements within Basins 10 and 12 are as previously listed in Tables 5.23, 5.25 and 5.28.

6.2.9 Stonepile Creek Main Stem (Basins 5 and 11)

The selected plan for the main stem of Stonepile Creek in Basins 5 and 11 proposes six new regional and sub-regional detention facilities totaling more than 900 acre-feet of capacity. This will reduce future conditions peak 100-year flows to be within the capacity of most existing channel reaches and crossing structures on Stonepile Creek in the established areas of the City of Gillette. As with Donkey Creek, this plan combines over-detention and floodplain management with the requirement to provide 100-year conveyance structures in new development. With these new detention ponds in place, the plan allows development in the Stonepile Creek basin without the need for further onsite detention.

The Beltway-Upper pond in Basin 11, shown on Figure G-16, is proposed in the Stonepile Creek valley west of town between I-90 and Echeta Road. The location is upstream of the future Western Drive (beltway) alignment, and the detention pond embankment could be used for the future roadway. The grading plan shown in Figure G-16 indicates a 150 foot top width aligned with McKenzie Road, which would accommodate the future beltway. If the pond is constructed before the beltway, the top width of the embankment could be reduced to 25 feet. If the roadway is constructed before the pond, the location of the embankment would dictate the configuration of the pond, but the pond would need to have at least 198 acre feet of storage volume.

This detention facility will require a permit from Wyoming’s Office of the State Engineer. A spillway could be located upstream of the beltway and a discharge chute could be routed under the bridge structure for I-90.

Other new sub-regional detention facilities are proposed on Tributaries 505, 506, and 503 located on tributaries to Stonepile Creek upstream of I-90. These are shown on Figures G-17, G-18, and G-19, respectively.

In addition, the selected plan includes using Burlington Lake for regional detention, as shown on Figure G-20. The proposed plan calls for providing 4 - 9’ x 5’ box culverts through the existing embankment to allow flooding of the area on the northwest side of the dam, which would provide up to 543 acre feet of storage above the normal water surface in the lake. The properties in this northwest depression area consist of a radio station and a trap shooting range, and would be in the 100-year floodplain. The plan includes acquisition of these properties. The connection of the north and south storage areas could also be accomplished by removing a portion of the embankment.

To direct more stormwater to Burlington Lake, a new diversion structure in Stonepile Creek is proposed, consisting of a new diversion weir in the Stonepile Creek channel and un-gated opening to an enlarged Burlington Ditch diversion channel. The proposed enlarged Burlington Ditch channel, shown on Figure G-20, has a 40-foot wide bottom width, is 6 feet deep, 3H: 1V side slopes, and has a 12’ access road that could double as a recreational trail. The enlarged channel follows the alignment of the existing ditch, and includes a new, larger crossing structure under Hannum Road.

Since the lake currently has no outlet, a new outlet from Burlington Lake to Stonepile Creek is proposed, as shown on Figure G-21. A 72-inch storm sewer with an invert set at the elevation of the existing water surface in Burlington Lake would extend to the southeast and down Gurley Avenue to discharge into Stonepile Creek at 4th Street. The alignment of the outlet from Burlington Lake to Stonepile Creek, including its section and location, was discussed with the City. There is a power line along the east side of Gurley Avenue, so the best location for the proposed 72" RCP outlet pipe appears to be 10 feet to the east of the power line. The pipe would need to be jacked under the BNSF railroad and under Highway 16/14. An easement would be required to cross the parking lot of the hotel on the south side of Highway 16/14. The upper end of the alignment is shown to cross diagonally across the corner of the American Legion Baseball Park, which is a County facility. There is a large diameter water main and sanitary sewer laterals that would need to be considered in the design of the outfall. The utilities and the HGL of the proposed outlet are shown on the Figure.

The last new detention facility is proposed in the vacant land between Gurley and Stanley Avenues southeast of 4th and Gurley, labeled Church detention, shown on Figure G-22. This facility will essentially act as a wide area in the floodplain with approximately 90 acre feet of storage volume. A constriction on the downstream end would regulate flows, and enough embankments constructed on the north side to prevent flooding into Highway 14. The outlet from Burlington Lake would discharge into this pond.

Even with these new detention facilities, conveyance improvements consisting of new open channel sections and new roadway crossing structures are required in certain reaches on Stonepile Creek. Channel reaches needing improvements to increase conveyance are between upstream of Burma Avenue to the confluence with Tributary 506. The channel reach between Gurley Avenue and the BNSF railroad is adequate for the proposed conditions flow, but it is recommended that the channel be straight graded to eliminate the flat grades. New structures are needed at Garner Lake Road, Church Avenue, Burma Avenue, Commercial Drive, Newton Road and a private drive, as previously listed in Table 5.30.

As shown on Figure G-24, the channel improvements recommended between Burma and the BNSF railroad will fit within existing tracts and easements between Burma and Commercial Drive. Upstream of Commercial Drive, the existing channel is partially on BNSF right-of-way. Channel improvements in this reach will be done on City owned tracts adjacent to the railroad, and no work is proposed on railroad right-of-way.

West of the BNSF railroad, Figure G-25, the widened channel would require new easements, and needs to be aligned to avoid existing structures. New box culverts are required at the crossings of Newton Road and a private access drive. The channel upstream of the private access drive to Tributary 506 should be designed to contain the 100-year flow within a natural section.

6.2.9.1 Upper Stonepile Creek Tributaries (Basin 11)

Local conveyance improvements consisting of new roadway drainage structures are proposed in certain locations on the tributaries of Upper Stonepile Creek. New culverts are recommended at I-90, Centennial Drive, and where tributaries cross the BNSF railroad and Echeta Road, as previously listed in Table 5.35.

6.2.9.2 Lower Stonepile Creek Tributaries (Basin 5)

Proposed improvements on the Stonepile Creek Tributaries consist of selected storm sewer, structure and channel improvements.

Tributary 501

To address an area where street flooding has been a problem, new storm sewer improvements are proposed on Bridger St. and Foothills Blvd., as shown in Figure G-26 in Appendix G. The City will need to acquire an easement from the owners to perform this work as the streets are privately owned. A new intake structure at the upper end of the system is required adjacent to the BNSF railroad to capture approximately the flows from the upstream watershed that discharge onto Bridger St. Upstream, a new crossing is proposed under Foothills Blvd. near where it intersects with Echeta Road, as previously listed in Table 5.37.

Tributary 501 from Highway 14/16 downstream to Stonepile Creek has capacity for the 100-year event.

Tributary 502

To convey the 100-year event, channel improvements consisting of a City standard concrete low flow channel, 2 feet in depth, with 4:1(H:V) grass-lined side slopes above it are proposed on Tributary 502 in the reach between Warlow Dr. and the BNSF railroad, as shown on Figure G-27. The conduit in Warlow Dr. to Stonepile Creek needs to be upsized to convey the 100-year flow without surcharging onto Warlow Rd.

A partially concrete lined channel section is recommended downstream of the BNSF railroad. The existing 60" RCP outlet pipe connects to the CBC at Warlow Dr., however a more hydraulically efficient option would be to discharge into Stonepile Creek across a "Tract A" to the north, as shown on Figure G-27. The channel improvements for the existing "Burlington Ditch" channel south from Burma to Second Avenue appear to fit within available tracts, although ownership has not been confirmed. It is recommended that the culvert in the middle of this channel reach be removed, and that a maintenance access road be built at a minimum elevation of 4,570 along the northeast side to provide a minimum of 1 foot of freeboard for the 100-year event.

Upstream from Second Avenue, storm sewer improvements are proposed, as shown on Figure G-28. The proposed storm sewer improvements south from Second Avenue were discussed with the City, and the City wants to extend the system south to 8th Avenue.

Tributaries 503 and 506

New CBCs are proposed on Tributaries 503 and 506 at Westover Road, as previously listed in table 5.37.

Tributary 504

New storm sewer is proposed along Tributary 504 from 1st Street to 7th Street in Gillette Avenue. The storm sewer is sized for the 100-year event less the estimated capacity of the street section, which varies considerably with longitudinal slope. The City proposes a street improvement project for Gillette Avenue, and the storm sewer system should be upgraded as part of that project. The new system, which is shown on sheet G-29, consists of an 8' x 4' CBC where the street grade is very flat from 1st Street to 3rd Street. The box should be connected to the existing box culvert under this sidewalk at the north side of 1st Street. Grades along Gillette Avenue south of 3rd Street are steeper, so smaller diameter pipe can be used to convey storm flows. Altogether, the system should be designed to intercept 160 cfs in the 100-year event for conveyance in the CBC at 3rd Street.

The pavement on 1st Avenue has been recently reconstructed, so it is unlikely any major storm sewer improvements will be made in that street. However, some reconstruction will be necessary to connect the proposed CBC in Gillette Avenue to the existing box, and to add interception capacity along 1st Street to the west. The existing CBC along 1st Street can convey the majority of the 100-year event, but minor surcharging would occur.

Tributary 509

The storm sewer system improvement project, shown on Figure G-30, consists of new major conveyance in East 9th Street, Green Avenue, and from Bevins Park to the proposed Church detention facility on Stonepile Creek. This would be done as a stand-alone City project to provide more interception capacity and conveyance for the upper watershed, near design point 5-213. Because grades in Green Avenue are very flat, larger box culverts are proposed to provide for conveyance of the 100-year flow.

Grades in Gurley Avenue are steeper, but there is a rise in the profile that would cause a storm sewer excavation to be very deep. An alternative to jack or bore the 42-inch pipe in Gurley Avenue has not been evaluated, but could be more cost effective.

Tributary 510

Only improved crossings near the downstream end at I-90, Highway 14/16, and the BNSF railroad are proposed on Tributary 510, as previously listed in Table 5.37. Peak flow rates on this tributary will be reduced by construction of the new outlet proposed for Burlington Lake.

Tributary 511

A new channel is proposed in the poorly drained area from existing Detention Facility P5-9 downstream to the junction with Tributary 510, as previously listed in Table 5.37.

6.2.10 East Fork Little Rawhide Creek (Basin 4)

Roadway drainage structure improvements are proposed at I-90, Warlow Road, and Little Powder River Road, as previously listed in Table 5.39.

6.2.11 Dry Fork Little Powder River (Basin 3)

The only roadway drainage improvement proposed is a new culvert at Kluver Road, as previously listed in Table 5.41.

The City-owned detention cells in the Ash Meadows subdivision will need to be maintained.

6.2.12 Closed Basins (Basin 2)

The reach of Tributary 201 as it passes from Collins Road to design point 2-202 and out of the City is being addressed as a series of local conveyance improvements to be constructed in 2011. The channel and culvert improvements have a capacity ranging from 30 cfs along Wall Street to 120 cfs at the lower end at Badger and University. This corresponds, according to the flows in Table 4.2, to approximately a 10-year event under existing conditions.

To limit increases in major storm flows from future development, all new development in Basin 2 should be required to provide private on-site detention. In addition, the City should manage the inadvertent detention area upstream of I-90 (Pond P2-1) so that it remains effective. No new channel or structure improvements are proposed for the Industrial Park area.

The channel improvement recommended downstream of University Road to Potter Avenue were also discussed with the City. This channel is on a tract owned by the CAM Plex, and will likely not be developed (note that it is shown as single family residential on the City's future land use plan). No channel improvements are proposed on this reach.

However, the new crossing at Potter previously listed in Table 5.43 was also discussed with the City. The plan for improving the crossing includes new channel improvements downstream, as shown on Figure G-31. A short reach of channel improvements would encroach into the BNSF railroad right-of-way downstream to the confluence with Tributary 202.

6.3 COST ESTIMATES

The proposed plan was reduced first to separate projects and then to the major construction elements to which a unit cost could be assigned. Unit costs for each major construction element in the project were estimated based on unit rates established for and accepted by the City. These unit costs are presented in the "Unit Cost Database" spreadsheet in Appendix D.

Each project was then assigned intangible costs for development including: costs for contingencies, utility relocations, construction signing and traffic control, and mobilization. Design and construction engineering costs are then added to the total construction cost of each project as 15% of the construction costs.

Land acquisition costs are included in the estimates for the detention ponds, and are estimated based on assessor's valuations for the affected parcels. The calculations are in the "Land Costs" spreadsheet and parcel values are shown in Figure D1, Land Costs, in Appendix D.

The total estimated capital costs for each project in the master plan are based on the sum of the cost of the proposed facilities including construction contingencies, plus costs for engineering and land costs as appropriate. Detailed cost estimates for each alternative for each basin are included in the spreadsheets in Appendix D.

Project costs for each project are summarized for the Donkey Creek watershed in Table 6.1, for the Stonepile Creek watershed in Table 6.2, and for Basins 2, 3 and 4 in Table 6.3.

Table 6.1
Selected Plan Cost Estimates - Donkey Creek Watershed

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
Donkey Creek Main Stem							
Detention							
Hidden Valley	$ 5,735,646	$ 1,720,694	$ 7,456,340	$ 1,118,451	$ 870,014	$ 9,445	1
Milne Valley -mid	$ 1,992,321	$ 597,696	$ 2,590,017	$ 388,502	$ 551,540	$ 3,530	1
Channel Improvements							
U/S of Butler Speath	$ 385,612	$ 115,684	$ 501,295	$ 75,194		$ 576	2
U/S of Douglas Highway	$ 227,548	$ 68,264	$ 295,812	$ 44,372		$ 340	2
Structure Improvements							
Unnamed Road (DP 6-202)	$ 273,750	$ 82,125	$ 355,875	$ 53,381		$ 409	4
Brorby Blvd. (DP 9-202)	$ 422,500	$ 126,750	$ 549,250	$ 82,388		$ 632	4
Jayhawker St. (DP 12-000)	$ 244,000	$ 73,200	$ 317,200	$ 47,580		$ 365	4
Structure Improvements							
Fishing Lake Dam	$ 612,954	$ 183,886	$ 796,840	$ 119,526		$ 916	2
Donkey Creek Main Stem - Total Cost	$ 9,894,330	$ 2,968,299	$ 12,862,630	$ 1,929,394	$ 1,421,554	$ 16,214	
Antelope Butte Creek Main Stem (Basin 6)							
Detention							
Antelope Butte Creek	$ 1,931,231	$ 579,369	$ 2,510,600	$ 376,590	$ 83,590	$ 2,971	1
Structure Improvements							
Douglas Highway (DP 6-218)	$ 703,000	$ 210,900	$ 913,900	$ 137,085		$ 1,051	4
Antelope Butte Creek Main Stem - Total Cost	$ 2,634,231	$ 790,269	$ 3,424,500	$ 513,675	$ 83,590	$ 4,022	

Table 6.1
Selected Plan Cost Estimates - Donkey Creek Watershed

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
Antelope Butte Creek Tributaries (Basin 6)							
Detention							
Tributary 609							
Pond P6-4	$ -	$ -	$ -	$ -		$ -	1
Pond P6-5	$ -	$ -	$ -	$ -		$ -	1
Structure Improvements							
Tributary 602							
Schoonover Rd. (DP 6-220)	$ 134,670	$ 40,401	$ 175,071	$ 26,261		$ 201	4
Tributary 605							
Garner Lake Rd. (DP 6-251)	$ 254,200	$ 76,260	$ 330,460	$ 49,569		$ 380	4
Southern Dr. (DP 6-252)	$ 149,200	$ 44,760	$ 193,960	$ 29,094		$ 223	4
Douglas Hwy. (DP 6-253)	$ 149,200	$ 44,760	$ 193,960	$ 29,094		$ 223	4
Tributary 610							
Boxelder Rd. (DP6-293)	$ 18,200	$ 5,460	$ 23,660	$ 3,549		$ 27	4
Antelope Butte Creek Tributaries - Total Cost	$ 705,470	$ 211,641	$ 917,111	$ 137,567	$ -	$ 1,055	
Donkey Creek Tributary South (Basin 7)							
Detention							
City Land	$ 2,436,417	$ 730,925	$ 3,167,342	$ 475,101	$ -	$ 3,642	1
Saunders	$ 301,693	$ 90,508	$ 392,201	$ 58,830	$ -	$ 451	2
Hitt Estates	$ 123,486	$ 37,046	$ 160,532	$ 24,080	$ 5,462	$ 190	2
Sunburst	$ 257,485	$ 77,245	$ 334,730	$ 50,210	$ 264,239	$ 649	2
Structure Improvements							
Donkey Creek Trib. South							
Shoshone Ave. (DP 7-214)	$ 432,000	$ 129,600	$ 561,600	$ 84,240		$ 646	2
Southern Dr. (DP 7-209)	$ 397,000	$ 119,100	$ 516,100	$ 77,415		$ 594	3
Saunders Tributary							
Christinck Ave. Outfall	$ 316,500	$ 94,950	$ 411,450	$ 61,718		$ 473	4
Remington Tributary							
Enzi Dr. (DP 7-240)	$ 26,756	$ 8,027	$ 34,783	$ 5,217		$ 40	4
Enzi Tributary							
Shoshone Ave. (DP 7-252)	$ 117,000	$ 35,100	$ 152,100	$ 22,815		$ 175	4
Donkey Creek Tributary South - Total Cost	$ 4,408,337	$ 1,322,501	$ 5,730,838	$ 859,626	$ 269,701	$ 6,860	

Table 6.1
Selected Plan Cost Estimates - Donkey Creek Watershed

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
North Donkey Creek Tributary (Basin 8)							
Detention							
Sage Valley Park R1	$ 198,880	$ 59,664	$ 258,545	$ 38,782	$ -	$ 297	2
Sunflower Park	$ 197,043	$ 59,113	$ 256,156	$ 38,423	$ -	$ 295	2
Upper Sage Valley	$ 234,514	$ 70,354	$ 304,868	$ 45,730	$ -	$ 351	2
I-90 (1)	$ 89,933	$ 26,980	$ 116,912	$ 17,537	$ -	$ 134	2
I-90 (2 - 3)	$ 169,624	$ 50,887	$ 220,511	$ 33,077	$ -	$ 254	2
I-90 (4)	$ 241,024	$ 72,307	$ 313,331	$ 47,000	$ -	$ 360	2
Structure Improvements							
Emerson Ave. (DP 8-206)	$ 220,000	$ 66,000	$ 286,000	$ 42,900		$ 329	4
Maple Ave. (DP 8-207)	$ 124,000	$ 37,200	$ 161,200	$ 24,180		$ 185	4
Birch Ave. (DP 8-208)	$ 83,400	$ 25,020	$ 108,420	$ 16,263		$ 125	4
Outlet of Sage Valley Park R1	$ 363,280	$ 108,984	$ 472,264	$ 70,840		$ 543	4
Tributary 802							
Outlet of Cottonwood Park R3 Detention, 4-J Rd.	$ 1,030,000	$ 309,000	$ 1,339,000	$ 200,850		$ 1,540	4
Outlets of Existing Upper Sage Valley Ponds to Upper Sage Detention (DP 8-231)	$ 103,720	$ 31,116	$ 134,836	$ 20,225		$ 155	4
Outlets of Upper Sage Valley Ponds to Boxelder Storm (DP 8-231)	$ 43,660	$ 13,098	$ 56,758	$ 8,514		$ 65	4
4-J Roadside Ditch (DP 8-230)	$ 3,291	$ 987	$ 4,278	$ 642		$ 5	4
Channel Improvements							
E-Z St. to constructed channel end	$ 118,848	$ 35,654	$ 154,502	$ 23,175	$ 47	$ 178	4
North Donkey Creek Tributary - Total Cost	$ 3,221,216	$ 966,365	$ 4,187,581	$ 628,137	$ 47	$ 4,816	

Table 6.1
Selected Plan Cost Estimates - Donkey Creek Watershed

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
Donkey Creek Tributary (Basin 9)							
Detention							
Pond P9-4 (Highway 50)	$ -	$ -	$ -	$ -		$ -	1
Sutherland Estates	$ 162,985	$ 48,896	$ 211,881	$ 31,782	$ 90,675	$ 334	2
Sutherland Estates Pond outlet in 4-J Road to DC (DP 9-217)	$ 776,000	$ 232,800	$ 1,008,800	$ 151,320		$ 1,160	2
Structure Improvements							
Tributary 902							
4-J Rd. (DP 9-210)	$ 194,000	$ 58,200	$ 252,200	$ 37,830		$ 290	4
Lakeway Rd. (DP 9-211)	$ 44,160	$ 13,248	$ 57,408	$ 8,611		$ 66	4
Tributary 901							
4-J Rd. (DP 9-207)	$ 35,200	$ 10,560	$ 45,760	$ 6,864		$ 53	4
Tributary 904							
4-J Rd. (DP 9-215)	$ 31,840	$ 9,552	$ 41,392	$ 6,209		$ 48	4
Donkey Creek Tributary, Basin 9 - Total Cost	$ 1,244,185	$ 373,256	$ 1,617,441	$ 242,616	$ 90,675	$ 1,951	
Basin 10 Milne Valley							
Structure Improvements							
Tributary 1000							
4-J Rd. (DP 10-201)	$ 187,000	$ 56,100	$ 243,100	$ 36,465		$ 280	4
Southern Dr. (DP 10-202)	$ 670,000	$ 201,000	$ 871,000	$ 130,650		$ 1,002	4
Tributary 1001							
U.S. Highway 50 (DP 10-210)	$ 99,760	$ 29,928	$ 129,688	$ 19,453		$ 149	4
Tributary 1002							
Bunny Ln. (DP 10-220)	$ 42,367	$ 12,710	$ 55,077	$ 8,262		$ 63	4
Southern Dr. (DP 10-221)	$ 111,542	$ 33,463	$ 145,004	$ 21,751		$ 167	4
Tributary 1003							
Southern Dr. (DP 10-230)	$ 53,419	$ 16,026	$ 69,445	$ 10,417		$ 80	4
Donkey Creek Basin 10 - Total Cost	$ 1,164,088	$ 349,226	$ 1,513,314	$ 226,997	$ -	$ 1,740	

Table 6.1
Selected Plan Cost Estimates - Donkey Creek Watershed

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
Basin 12 Donkey Creek Direct Flow Areas							
Structure Improvements							
Tributary 1201							
Force Rd. (DP 12-230)	$ 92,584	$ 27,775	$ 120,359	$ 18,054		$ 138	4
Tributary 1202							
Spring Hill Rd. (DP 12-220)	$ 20,604	$ 6,181	$ 26,785	$ 4,018		$ 31	4
Tributary 1203							
Spring Hill Rd. (DP 12-210)	$ 9,078	$ 2,723	$ 11,801	$ 1,770		$ 14	4
Tributary 1240							
Spring Hill Rd. (DP 12-240)	$ 29,252	$ 8,776	$ 38,028	$ 5,704		$ 44	4
Tributary 1250							
Force Rd. (DP 12-250)	$ 175,700	$ 52,710	$ 228,410	$ 34,262		$ 263	4
Donkey Creek Basin 12 - Total Cost	$ 327,218	$ 98,165	$ 425,383	$ 63,808	$ -	$ 489	

Table 6.2
Selected Plan Cost Estimates - Stonepile Creek Watershed

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
			Stonepile Creek Main Stem				
Detention							
Beltway Regional	$ 3,159,552	$ 947,866	$ 4,107,417	$ 616,113	$ 104,045	$ 4,828	1
Tributary 505 Detention	$ 918,576	$ 275,573	$ 1,194,149	$ 179,122	$ -	$ 1,373	1
Tributary 506 Detention	$ 2,303,595	$ 691,078	$ 2,994,673	$ 449,201	$ 258,831	$ 3,703	1
Tributary 503 Detention	$ 681,055	$ 204,317	$ 885,372	$ 132,806	$ 191,432	$ 1,210	1
Church Detention	$ 1,264,282	$ 379,285	$ 1,643,567	$ 246,535	$ 7,342	$ 1,897	2
Burlington Lake		$ -	$ -	$ -	$ 104,045	$ 104	2
Burlington Ditch	$ 531,147	$ 159,344	$ 690,491	$ 103,574		$ 794	
Burlington Ditch Diversion Structure	$ 49,000	$ 14,700	$ 63,700	$ 9,555		$ 73	
Burlington Ditch @ Hannum	$ 114,250	$ 34,275	$ 148,525	$ 22,279		$ 171	
Burlington Lake Embankment Culvert	$ 448,000	$ 134,400	$ 582,400	$ 87,360		$ 670	
Burlington Lake Outlet	$ 1,248,382	$ 374,515	$ 1,622,897	$ 243,435		$ 1,866	
Subtotal - Burlington Lake	$ 2,390,779	$ 717,234	$ 3,108,013	$ 466,202	$ 104,045	$ 3,678	
Subtotal - Detention						$ 16,689	
Channel Improvements							
DP5-209 to BNSF Railroad	$ 195,714	$ 58,714	$ 254,428	$ 38,164		$ 293	4
Burma to Warlow Road	$ 200,158	$ 60,047	$ 260,205	$ 39,031		$ 299	3
Warlow Rd. to BNSF	$ 201,520	$ 60,456	$ 261,976	$ 39,296		$ 301	3
Echeta to DP5-233	$ 147,795	$ 44,338	$ 192,133	$ 28,820		$ 221	3
DP5-233 to DP5-236	$ 154,067	$ 46,220	$ 200,287	$ 30,043		$ 230	4
Structure Improvements							
Garner Lake Road	$ 228,500	$ 68,550	$ 297,050	$ 44,558		$ 342	3
Church Ave.	$ 193,000	$ 57,900	$ 250,900	$ 37,635		$ 289	3
BNSF Railroad	$ 280,000	$ 84,000	$ 364,000	$ 54,600		$ 419	4
Burma Ave.	$ 193,000	$ 57,900	$ 250,900	$ 37,635		$ 289	3
Commercial Dr.	$ 252,500	$ 75,750	$ 328,250	$ 49,238		$ 377	3
Newton	$ 300,500	$ 90,150	$ 390,650	$ 58,598		$ 449	3
Private Drive	$ 300,500	$ 90,150	$ 390,650	$ 58,598		$ 449	3
Stonepile Creek Main Stem - Total Cost	$ 15,755,870	$ 4,726,761	$ 20,482,631	$ 3,072,395	$ 769,740	$ 20,647	

Table 6.2
Selected Plan Cost Estimates - Stonepile Creek Watershed

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
Stonepile Creek Tributaries							
Tributary 501							
Storm Sewer Improvements							
Foothills Blvd. (DP5-240)	$ 206,250	$ 61,875	$ 268,125	$ 40,219		$ 308	4
Bridger Rd. (DP5-235)	$ 723,640	$ 217,092	$ 940,732	$ 141,110		$ 1,082	4
Tributary 502							
Storm Sewer Improvements							
Warlow Rd. (DP5-246)	$ 116,320	$ 34,896	$ 151,216	$ 22,682		$ 174	4
8th and Rohan (DP5-224)	$ 406,980	$ 122,094	$ 529,074	$ 79,361		$ 608	4
Channel Improvements							
U/S Warlow to BNSF	$ 66,567	$ 19,970	$ 86,537	$ 12,981		$ 100	4
Burma Ave. to 2nd St.	$ 97,133	$ 29,140	$ 126,274	$ 18,941		$ 145	4
Tributary 503							
Structure Improvements							
Westover Rd. (DP5-234)	$ 424,800	$ 127,440	$ 552,240	$ 82,836		$ 635	4
Tributary 506							
Structure Improvements							
Westover Rd. (DP5-237)	$ 167,500	$ 50,250	$ 217,750	$ 32,663		$ 250	4
Tributary 504							
Storm Sewer Improvements							
Gillette Avenue (DP5-220)	$ 612,800	$ 183,840	$ 796,640	$ 119,496		$ 916	4
Tributary 509							
Storm Sewer Improvements							
9th Street	$ 137,600	$ 41,280	$ 178,880	$ 26,832		$ 206	4
Green Avenue and Outfall	$ 1,015,000	$ 304,500	$ 1,319,500	$ 197,925		$ 1,517	4

Table 6.2
Selected Plan Cost Estimates - Stonepile Creek Watershed

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
Tributary 510							
Structure Improvements							
I-90 (DP5-212)	$ 628,000	$ 188,400	$ 816,400	$ 122,460		$ 939	4
SH 14/16 (DP5-210)	$ 183,000	$ 54,900	$ 237,900	$ 35,685		$ 274	4
BNSF RR (DP5-211)	$ 137,500	$ 41,250	$ 178,750	$ 26,813		$ 206	4
Tributary 511							
Channel Improvements							
DP5-211 to P5-9	$ 66,000	$ 19,800	$ 85,800	$ 12,870		$ 99	4
Tributary 1102							
Structure Improvements							
BNSF RR & Echeta Rd. (DP11-212)	$ 241,500	$ 72,450	$ 313,950	$ 47,093		$ 361	4
Centennial Dr. (DP11-210)	$ 5,120	$ 1,536	$ 6,656	$ 998		$ 8	4
Tributary 1103							
Structure Improvements							
I-90 (DP11-203)	$ 487,200	$ 146,160	$ 633,360	$ 95,004		$ 728	4
Tributary 1104							
Structure Improvements							
BNSF RR & Echeta Rd. (DP11-211)	$ 14,950	$ 4,485	$ 19,435	$ 2,915		$ 22	4
Centennial Dr. (DP11-220)	$ 12,400	$ 3,720	$ 16,120	$ 2,418		$ 19	4
Tributary 1106							
Structure Improvements							
BNSF RR & Echeta Rd. (DP11-221)	$ 41,640	$ 12,492	$ 54,132	$ 8,120		$ 62	4
Stonepile Creek Tributaries - Total Cost	$ 5,791,900	$ 1,737,570	$ 7,529,470	$ 1,129,421	$ -	$ 8,659	

Table 6.3
Selected Plan Cost Estimates - Basins 2, 3 and 4

Projects	Construction Cost	Construction Contigency (30%)	Subtotal Construction Cost	Design Contigency (15%)	Land Cost	Total Cost (x$1,000)	Priority
Little Rawhide Creek - Basin 4							
Structure Improvements							
Little Powder River Road (DP4-201)	$ 128,400	$ 38,520	$ 166,920	$ 25,038		$ 192	4
Warlow Rd. (DP4-207)	$ 367,600	$ 110,280	$ 477,880	$ 71,682		$ 550	4
I-90 (DP4-208)	$ 320,000	$ 96,000	$ 416,000	$ 62,400		$ 478	4
Subtotal - Basin 4						**$ 1,220**	
Dry Fork Powder River - Basin 3							
Structure Improvements							
Kluver Road (DP3-205)	$ 20,152	$ 6,046	$ 26,198	$ 3,930		$ 30	4
Subtotal - Basin 3		$ -	$ -	$ -		**$ 30**	
Closed Depression Playas - Basin 2							
Tributary 201							
Structure Improvements							
Potter Ave. (DP2-203)	$ 157,000	$ 47,100	$ 204,100	$ 30,615		$ 235	4
Channel Improvements							
Potter to DP 2-202	$ 46,597	$ 13,979	$ 60,576	$ 9,086		$ 70	4
Subtotal - Tributary 201						**$ 304**	
Tributary 202							
Structure Improvements							
BNSF RR (DP2-219)	$ 78,160	$ 23,448	$ 101,608	$ 15,241		$ 117	4
SH 51 (DP2-207)	$ 78,160	$ 23,448	$ 101,608	$ 15,241		$ 117	4
Subtotal - Basin 2						**$ 842**	

6.4 STORMWATER QUALITY

Stormwater quality is an increasing concern with the City and Campbell County because of impairments to Donkey Creek, Stonepile Creek and Fishing Lake. Certain elements of this plan are permanent water quality "Best Management Practices" (BMPs) as described in Chapter 12 of the SDDM, and can help improve stormwater quality on these and other City drainageways.

Generally, closed depressions are “retention ponds”, and should continue to be treated as such. The playas in Basins 2, 3, 4 and 6 should be considered flood control and water quality facilities. Likewise, certain open water bodies, such as Fishing Lake and Burlington Lake, act as retention ponds and provide a water quality benefit for the downstream reaches. By constructing the low level outlet from Burlington Lake back to Stonepile Creek, low flows in Stonepile Creek downstream of Gurley Avenue will increase, which in turn would improve dilution and consequently general water quality of Stonepile Creek downstream of the sewage treatment plant. Constructed wetlands could be used downstream of the sewage treatment plant to improve overall water quality in Stonepile Creek before it flows into Donkey Creek. Constructed wetlands and other measures are currently being used by the City to improve water quality in Donkey Creek and Fishing Lake.

The proposed detention facilities in Basins 7, 8 and 9 and on Tributaries 503, 505 and 506 of Stonepile Creek could provide water quality benefits if planned as part of the projects. This would require special low flow capture volumes and outlet structures to specifically provide Extended Dry Detention BMPs in these facilities. In addition, certain existing detention cells that are to be retained, such as those in Basin 6, could be retrofitted to provide Extended Dry Detention BMPs for subareas of the City. Detention of stormwater allows larger suspended sediment particles to settle out of the water. In addition, any proposed channel improvements and drop structures and would result in decreased flow velocities through the drainageways. Decreasing discharge rates and flow velocities will result in less erosion and sediment transport, thereby enhancing water quality.

At some point, the City will require that permanent stormwater quality BMPs be implemented for all new development and redeveloping properties. Development plans should be required to propose and discuss solutions to permanently enhance the quality of stormwater runoff from the site. The stormwater quality plans should be developed by applying the BMPs described in Chapter 12 of the SDDM. All new developments and redevelopments should also prepare Stormwater Pollution Prevention Plans (SWPPPs) associated with construction activities. The SWPPPs must be submitted for approval prior to obtaining a Stormwater Discharge Permit from the City, per Chapter 11 of the SDDM. Controlling erosion and sediment discharged from construction sites will go a long way toward helping the City meet water quality goals.

6.5 OPERATION AND MAINTENANCE

The City currently performs routine maintenance items for detention cells and some open channels that includes debris removal, mowing, and channel stability issues as they arise. The City also provides routine maintenance on City owned storm sewer systems and those within WYDOT right-of-way, and periodically removes sediment from the inlets and storm sewer systems. Regular street sweeping is also performed by the City, which benefits the storm drain system and water quality.

Operations and maintenance costs have not been specifically estimated for the improvements proposed in this plan, and there are no specific recommendations to increase or enhance the current level of service. Operations and maintenance costs have been estimated for various levels of service, and presented separately to the City in the *Stormwater Management Program Development* technical memorandum (URS 2010). In general, there will be new costs for maintenance of large detention facilities as they are built and put into operation, which will be at least partially off-set by savings in maintenance costs associated with smaller detention cells and repair costs associated with damage to channels and structures caused by flooding.

6.6 PRIORITIZATION AND PHASING

The City suggested prioritizing the projects listed in Tables 6.1, 6.2 and 6.3 according to "bang for the buck", i.e. most cost effective projects having the highest priority (priority "1").

The large regional detention facilities proposed in the Donkey Creek and Stonepile Creek main stems are the most effective in preventing flood damage in the downstream reaches through Gillette and should be priority "1" for the City. These facilities also represent the lion's share of the cost associated with the plan. Therefore, alternatives for financing these facilities should be considered. One or more of these flood control facilities may eligible for funding by a flood control grant (e.g., PDM grant) from FEMA. Some of the cost could be recovered through the use of Basin Fees, discussed in the following paragraphs. The City should also start buying land for the regional detention ponds.

The proposed modifications to Burlington Lake, including the diversion structure, diversion ditch, dam modification and associated property acquisition, and the outlet pipe, should all be undertaken as one project following the completion of the Beltway Regional pond. The various components, although estimated separately, need to be built as one large project in order to function properly. Likewise, the detention ponds in Basin 10, Milne Valley, should be constructed from upstream to downstream, i.e. Milne Valley – mid should be built before Milne Valley –lower, so that the lower pond is not subject to more flooding than it is designed for.

The modifications to Fishing Lake and other, smaller detention ponds proposed in Basins 6, 7, 8, 9 and on the Tributaries to Stonepile Creek are priority "2" facilities, because their benefits are to the structures themselves and mainly immediately downstream on the drainageways. These are all "stand alone" projects, and should be constructed as capital improvement project funds become available.

Priority "3" projects are the proposed channel and structure improvements on the main stems of Donkey Creek and Stonepile Creek where there are structures in the floodplain. Although these improvements could be built as "stand alone" projects at any time, their effectiveness in removing properties from the floodplain depends on the upstream regional detention being in place.

All other proposed channel and structure improvements are "stand alone" local improvement projects and are priority "4", which means they are generally not dependent on any upstream facility being in place. These projects could be initiated as part of other projects, such as roadway improvements, or they could be built by developers when an adjacent property develops.

6.7 BASIN FEE CALCULATIONS

Funding for the proposed infrastructure presented in this master plan could come from a variety of sources, which are discussed in the *Stormwater Management Program Development* technical memorandum (URS 2010). One of the potential funding mechanisms for the master plan improvements are basin fees, which would be a fee charged to developers based on the percent imperviousness of the proposed project over and above existing site conditions. The calculations for basin fees are summarized by basin in Table 6.4.

The fee calculation is based on new impervious area due to development, by basin as noted in the table. Because the master plan recommends regional detention in the upper Donkey Creek, Antelope Butte Creek and Stonepile Creek watersheds, which over-detains to protect existing downstream infrastructure, proposed improvements are more expensive than what would be required simply to handle increased runoff from new development. Consequently, basin fees based just on new impervious areas are expensive, and would saddle new development with funding all necessary flood control improvements to fix existing problems.

Therefore, basin fees are pro-rated according to the increase in peak 100-year flow rates between existing conditions and future conditions. As an example, existing 100-year discharge on Stonepile Creek is 4,460 cfs and future conditions peak 100-year discharge is 5,864, an increase of approximately 31%. The peak 100-year detained flow is 1,742 cfs, which is 2,718 cfs less than the existing condition peak rate, and 4,122 cfs less than the future condition peak rate. So, the basin fee is based on a pro-rated share of the reduction in peak flow rates, where the City would pay ([4,460 – 1,742]/4,122), or 66% of the total cost and the development community pay 34% of the cost. In the case of Stonepile Creek, the basin fee is $3,357 per impervious acre. Similarly, basin fees for Donkey Creek are $1,608 per impervious acre. No basin fees are proposed in Basins, 2, 3 and 4 because only local structure improvements are proposed. Basin fees are shown by area in Figure 6.3.

Table 6.4
Drainage Basin Fees

Basin	Exclude Sub-basins (See Note 1)	Net Area Acres	New Imp. Acres	Ex. 100-year Peak Flow	Fut. 100-year Peak Flow	Detained 100-year Peak Flow	Master Plan Project Cost (x$1,000)	Development Share of Project Cost (%)	Basin Fee (per Impervious Acre)
Stonepile Creek									
11	11_101	2532.5	146						
5	None	5658.1	1949.4						
Total:		**8190.6**	**2095.4**	4460	5864	1742	**$ 20,647**	**34%**	**$ 3,357**
Donkey Creek									
12	12_101, 12_113, 12_114, 12_118	5685.3	910.3						
10	10-101	1612.9	245.7						
9	None	2032.3	158.9						
6	Include 06_117, 06_123, 06_124, 06_125, 06_127, 06_128, 06_129, 06_130, 06_131, 06_132, 06_133, 06_134, 06_135, 06_136, 06_137, 06_138	3652.1	952.5						
Subtotal:		**12982.6**	**2267.4**	5888	6473	2210	**$ 16,214**	**14%**	**$ 981**
Antelope Butte Creek									
6	All except:								
	06_108, 06_114,06_115, 06_116 06_118, 06_119, 06_120, 06_121, 06_122, 06_126	2320	727.7						
Subtotal:		**2320.0**	**727.7**	5863	6445	3588	**$ 4,022**	**20%**	**$ 1,126**
Donkey Creek Tributary South									
7		5340.7	674.4						
	07_109	3324.6	114.6						
Subtotal:		**2016.1**	**559.8**	1770	1966	1183	**$ 6,860**	**25%**	**$ 3,070**
Donkey Creek Tributary North									
8	None	1203.3	269.9						
Subtotal:		**1203.3**	**269.9**	1044	1253	1125	**$ 4,816**	**22%**	**$ 4,002**
DC Total:		**18522.0**	**3824.8**	5888	6473	2210	**$ 31,912**	**18%**	**$ 1,608**

Note:
1. For Stonepile Creek, Donkey Creek, and Basin 7, listed subbasins in the upper watershed are outside the planning boundary and not included in the calculation of impervious area. For Antelope Butte Creek, only the listed sub-basins have been used to calculate impervious area.

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Design Points
Structures in the 100-Year Floodplain
Dewatering Wells
Inlet Structure
Manholes
Outlet Structures

Study Reaches
Existing Conduit
Existing Open Channel
Interstate
State or US Highway
Streets
Railroads

Major Basin
Subbasin
City Limits
Study Area
City Property
Existing Parks

Existing Detention
City
County
Private
Stock Pond
Road Inadvertent
Depression Playa

Proposed Structure
Proposed Channel Improvements
Future Conditions Flooding Limits
Contained in Floodplain
Shallow (< 1-foot depth) Flooding Leaving Channel
Flow Direction Leaving Channel
Proposed Detentions

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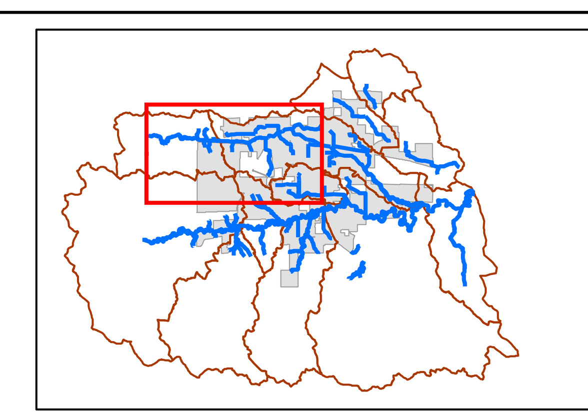

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CITY OF GILLETTE 201 E. 5TH STREET
GILLETTE, WY 82717 (307) 686-5364

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Master Plan
Page 1 of 4

Gillette Stormwater Master Plan

6.2

Design Points	Study Reaches	Major Basin	Existing Detention	Proposed Structure
Structures in the 100-Year Floodplain	Existing Conduit	Subbasin	City	Proposed Channel Improvements
Dewatering Wells	Existing Open Channel	City Limits	County	Future Conditions Flooding Limits
Inlet Structure	Interstate	Study Area	Private	Contained in Floodplain
Manholes	State or US Highway	City Property	Stock Pond	Shallow (< 1-foot depth) Flooding Leaving Channel
Outlet Structures	Streets	Existing Parks	Road Inadvertent	Flow Direction Leaving Channel
	Railroads		Depression Playa	Proposed Detentions

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CITY OF GILLETTE 201 E. 5TH STREET
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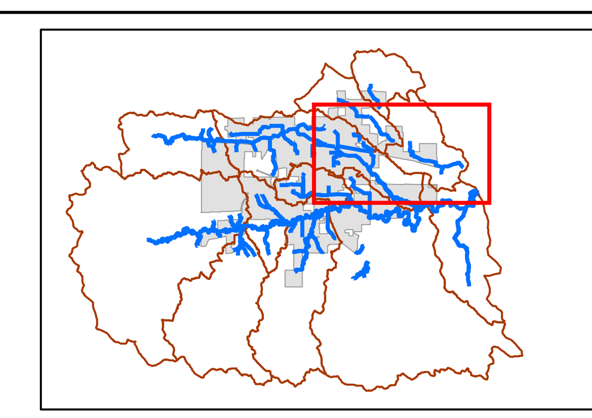

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Master Plan
Page 2 of 4

Gillette Stormwater
Master Plan

6.2

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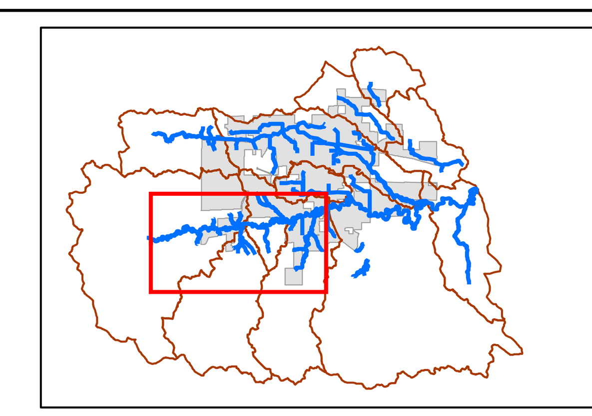

Design Points	Study Reaches	Major Basin	Existing Detention	Proposed Structure
Structures in the 100-Year Floodplain	Existing Conduit	Subbasin	City	Proposed Channel Improvements
Dewatering Wells	Existing Open Channel	City Limits	County	Future Conditions Flooding Limits
Inlet Structure	Interstate	Study Area	Private	Contained in Floodplain
Manholes	State or US Highway	City Property	Stock Pond	Shallow (< 1-foot depth) Flooding Leaving Channel
Outlet Structures	Streets	Existing Parks	Road Inadvertent	Flow Direction Leaving Channel
	Railroads		Depression Playa	Proposed Detentions

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Master Plan Page 3 of 4

Gillette Stormwater Master Plan

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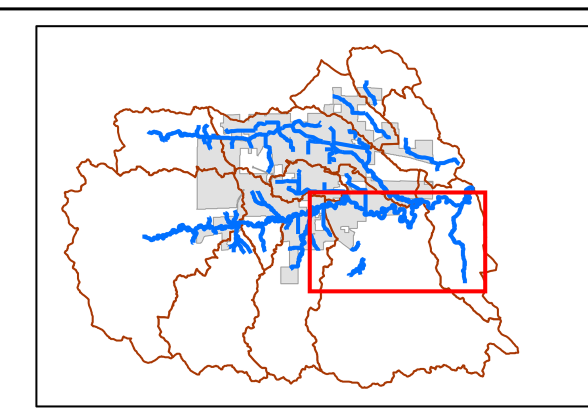

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8-210 Design Points	Study Reaches
Structures in the 100-Year Floodplain	Existing Conduit
Dewatering Wells	Existing Open Channel
Inlet Structure	Interstate
Manholes	State or US Highway
Outlet Structures	Streets
	Railroads

Basin 8 Major Basin	**Existing Detention**
08_101 Subbasin	City
City Limits	County
Study Area	Private
City Property	Stock Pond
Existing Parks	Road Inadvertent
	Depression Playa

Proposed Structure
Proposed Channel Improvements
Future Conditions Flooding Limits
Contained in Floodplain
Shallow (< 1-foot depth) Flooding Leaving Channel
Flow Direction Leaving Channel
Proposed Detentions

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Master Plan
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Gillette Stormwater Master Plan

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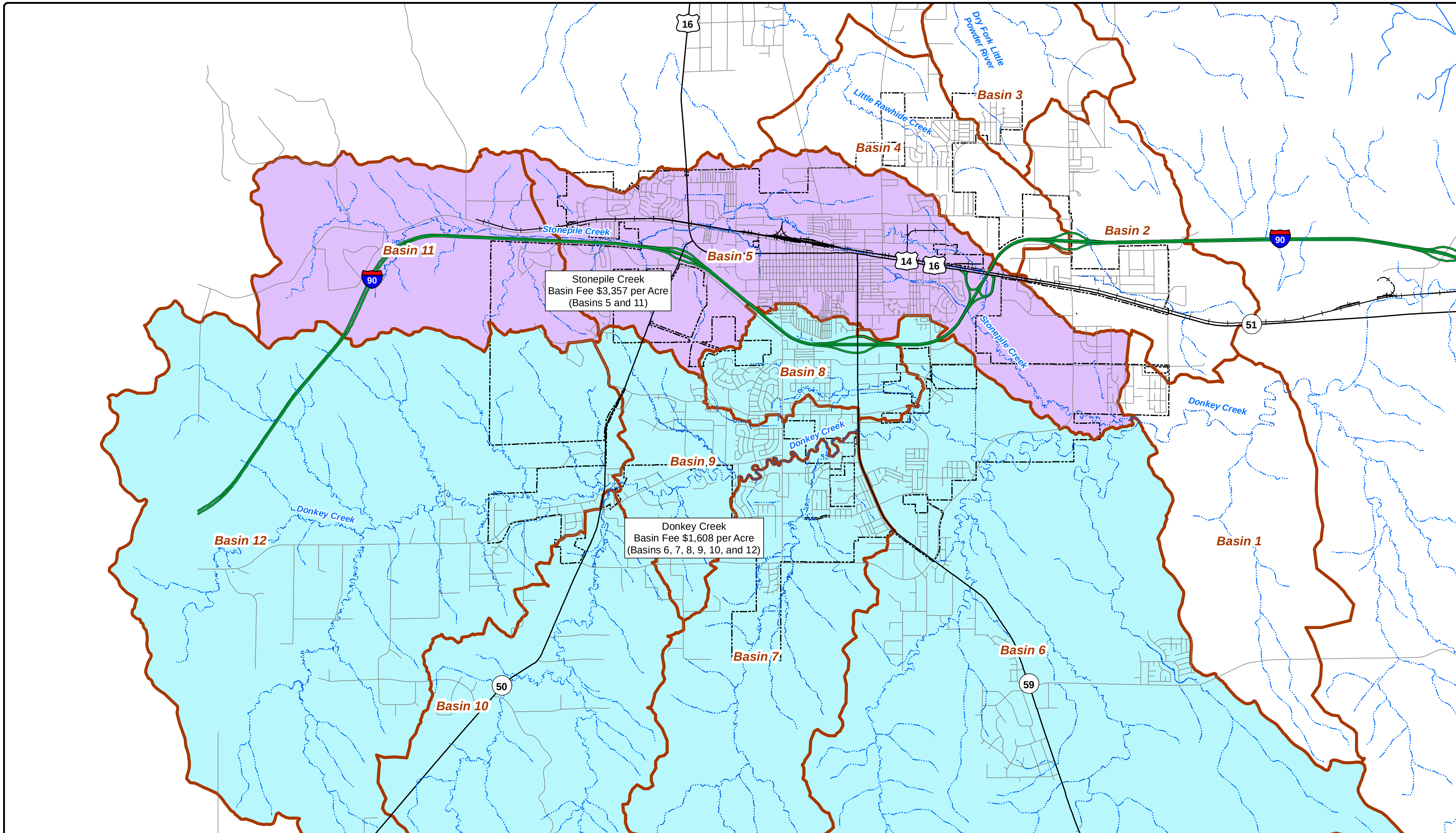

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GILLETTE, WY 82717 (307) 686-5364

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Open Channel
Interstate
State or US Highway
Streets
Railroad

Basin 8 Major Basin
City Limits

Basin Fee Areas
Stonepile Creek
Donkey Creek

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Basin Fees

Gillette Stormwater Master Plan

6.3

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SECTION SEVEN

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144.	WYDEQ. 1999. Hydrology, WYODAK Mine, WYODAK Resource Development Corp. P. D6.3-2 to D6.3-54.
145.	WYDEQ and City of Gillette, (Draft) Gillette Fishing Lake TMDL For Sediment and Total Phosphorus; HDR, December 2009.

7.8 MEETING NOTES AND MEMOS

Reference Number	Reference (Author. Date. Title)
146.	URS. 2009. Stormwater Strategic Plan – Data Needs COMPLETED
147.	URS. 2009. Stormwater Strategic Plan – Questionnaires COMPLETED
148.	URS. 2009. Stormwater Strategic Plan – Stakeholders Survey COMPLETED

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Appendix A

Gillette Comprehensive Plan Land Use Maps, Photographs and Field Notes

Appendix B

Sub-basin Data, t_c Calculations, Routing Schematics and InfoSWMM Output

Table B.1
Subwatershed Characteristics

Sub-basin ID	Contributing Drainage Area (acres)	Curve Number (CN)	NRCS Lag Time (min)
Basin 1			
01_101	678.0	64	48
01_102	895.9	67	86
01_103	430.4	64	62
01_104	608.8	67	43
01_105	216.3	70	72
01_106	176.6	68	69
01_107	251.1	67	71
01_108	435.2	67	102
Basin 2			
02_101	102.8	74	43
02_102	155.2	74	22
02_103	199.0	75	31
02_104	384.3	72	57
02_105	48.9	77	32
02_106	123.4	72	39
02_107	139.3	65	37
02_108	55.4	72	29
02_109	84.6	67	30
02_110	152.9	90	67
02_111	38.9	67	26
02_112	17.8	67	9
02_113	120.8	68	36
02_114	121.6	65	45
02_115	33.4	70	22
02_116	579.2	74	37
02_117	216.1	66	34
Basin 3			
03_101	54.6	72	18
03_102	133.0	75	20
03_103	93.7	69	23
03_104	196.7	68	24
03_105	377.6	72	32
03_106	513.2	72	65
03_107	258.4	74	32

Table B.1
Subwatershed Characteristics

Sub-basin ID	Contributing Drainage Area (acres)	Curve Number (CN)	NRCS Lag Time (min)
Basin 4			
04_101	108.0	81	34
04_102	127.5	76	15
04_103	8.1	89	8
04_104	489.3	78	36
04_105	33.0	75	27
04_106	15.4	85	18
04_107	17.5	85	12
04_108	53.8	74	8
04_109	104.6	78	20
04_110	142.8	76	31
04_111	351.9	71	56
04_112	89.7	62	34
04_113	95.4	62	11
04_114	406.6	74	64
Basin 5			
05_101	75.0	68	12
05_102	139.6	72	24
05_103	41.4	78	15
05_104	21.4	82	13
05_105	43.9	83	8
05_106	38.3	82	41
05_107	58.0	80	29
05_108	62.7	73	21
05_109	39.3	78	33
05_110	58.2	75	33
05_111	215.7	78	9
05_112	82.4	80	27
05_113	167.9	83	28
05_114	52.4	81	22
05_115	33.9	79	30
05_116	220.6	72	27
05_117	74.2	70	11
05_118	309.3	75	26
05_119	53.8	73	18
05_120	66.3	79	41
05_121	59.7	87	16
05_122	195.5	83	27
05_123	97.6	81	24

Table B.1
Subwatershed Characteristics

Sub-basin ID	Contributing Drainage Area (acres)	Curve Number (CN)	NRCS Lag Time (min)
05_124	19.9	77	33
05_125	91.2	84	22
05_126	65.5	88	28
05_127	19.7	90	37
05_128	12.6	81	20
05_129	72.8	90	10
05_130	74.4	88	32
05_131	16.4	91	7
05_132	35.4	93	23
05_133	46.7	93	24
05_134	86.5	73	9
05_135	178.0	67	25
05_136	307.4	75	33
05_137	77.4	91	7
05_138	100.3	92	27
05_139	74.1	83	33
05_140	43.2	94	46
05_141	72.5	89	29
05_142	83.0	86	12
05_143	57.0	90	37
05_144	36.5	86	27
05_145	35.3	88	34
05_146	23.8	74	32
05_147	27.5	78	15
05_148	124.4	82	19
05_149	52.2	78	43
05_150	80.3	86	19
05_151	129.1	82	26
05_152	50.7	77	12
05_153	158.4	84	25
05_154	25.6	0	28
05_157	21.3	77	7
05_158	12.3	0	25
05_159	311.0	71	7
05_160	162.4	71	9
05_161	289.4	66	62
05_162	124.2	76	14
05_163	242.9	0	32

Table B.1
Subwatershed Characteristics

Sub-basin ID	Contributing Drainage Area (acres)	Curve Number (CN)	NRCS Lag Time (min)
Basin 6			
06_101	2890.0	66	73
06_102	338.9	69	40
06_103	317.7	61	33
06_104	455.8	68	27
06_105	1701.8	63	78
06_106	1725.3	62	89
06_107	64.2	76	31
06_108	590.5	71	45
06_109	203.9	81	37
06_110	196.2	78	58
06_111	247.2	61	32
06_112	40.7	75	34
06_113	35.4	72	21
06_114	217.1	73	30
06_115	216.2	63	71
06_116	523.5	67	86
06_117	1431.7	67	62
06_118	75.0	81	25
06_119	115.2	77	19
06_120	56.6	79	26
06_121	214.6	62	47
06_122	249.2	80	33
06_123	425.3	70	97
06_124	74.2	76	31
06_125	315.4	77	49
06_126	62.3	62	39
06_127	11.0	90	20
06_128	229.0	79	46
06_129	146.7	60	94
06_130	82.5	62	57
06_131	131.6	80	62
06_132	17.1	75	60
06_133	252.0	65	66
06_134	197.6	76	46
06_135	76.1	78	30
06_136	226.0	61	69
06_137	15.4	76	39
06_138	20.3	76	13

Table B.1
Subwatershed Characteristics

Sub-basin ID	Contributing Drainage Area (acres)	Curve Number (CN)	NRCS Lag Time (min)
Basin 7			
07_01	149.6	76	27
07_03	65.7	81	14
07_04	167.7	70	34
07_05	72.1	67	82
07_06	107.4	79	79
07_07	86.4	69	18
07_09	3324.4	69	107
07_10	672.2	72	66
07_11	40.8	70	38
07_12	49.4	86	43
07_13	70.4	80	30
07_14	150.4	69	22
07_21	27.7	75	44
07_22	103.5	64	42
07_23	25.8	87	39
07_24	31.2	74	37
07_25	10.7	86	13
07_26	68.6	81	18
07_27	100.4	80	80
07_28	20.0	91	33
Basin 8			
08_00	94.4	91	30
08_01	135.7	90	23
08_02	107.4	94	30
08_03	57.5	94	20
08_04	125.9	90	35
08_05	16.5	93	17
08_06	37.3	93	16
08_07	21.2	92	11
08_08	34.6	95	23
08_09	44.0	93	34
08_10	30.9	93	13
08_11	47.2	92	23
08_12	87.7	91	47
08_13	101.9	96	21
08_14	1.0	95	16
08_15	14.8	93	23
08_16	12.0	91	13

Table B.1
Subwatershed Characteristics

Sub-basin ID	Contributing Drainage Area (acres)	Curve Number (CN)	NRCS Lag Time (min)
08_17	23.7	91	31
08_18	5.9	87	8
08_19	15.1	91	7
08_20	11.1	86	7
08_21	13.9	91	7
08_22	78.6	91	18
08_23	15.3	91	67
08_24	11.0	94	16
08_25	16.5	94	34
08_26	7.2	92	18
08_27	49.8	93	13
Basin 9			
09_101	11.3	80	15
09_102	33.5	76	24
09_103	40.9	75	28
09_104	43.1	74	16
09_105	88.8	74	35
09_106	54.7	74	32
09_107	57.4	90	29
09_108	147.9	85	21
09_109	147.2	68	43
09_110	60.7	71	30
09_111	159.1	71	36
09_112	130.4	74	22
09_113	207.1	71	39
09_114	222.6	71	37
09_115	72.9	74	24
09_116	132.2	78	32
09_117	16.0	78	10
09_118	10.0	61	23
09_119	116.0	87	32
09_120	59.8	78	24
09_121	150.3	87	65
09_122	70.5	87	53
Basin 10			
10_101	3887.0	73	62
10_102	1152.6	73	105
10_103	97.9	75	30
10_104	85.8	70	22

Table B.1
Subwatershed Characteristics

Sub-basin ID	Contributing Drainage Area (acres)	Curve Number (CN)	NRCS Lag Time (min)
10_105	20.9	74	11
10_106	22.0	74	7
10_107	213.0	76	46
10_108	16.9	71	17
10_109	3.8	76	6
Basin 11			
11_101	1006.4	--	--
11_102	1303.5	--	--
11_103	447.0	--	--
11_104	115.8	--	--
11_105	97.0	--	--
11_106	117.9	--	--
11_107	15.9	--	--
11_108	43.0	--	--
11_109	192.3	--	--
11_110	79.6	--	--
11_111	87.0	--	--
11_112	33.5	--	--
Basin 12			
12_101	3583.2	74	98
12_102	876.4	74	54
12_103	280.7	75	32
12_104	732.6	72	52
12_105	321.0	74	53
12_106	184.2	74	75
12_107	100.3	74	35
12_108	338.7	72	49
12_109	105.3	78	22
12_110	263.9	76	46
12_111	261.9	74	38
12_112	98.9	75	34
12_113	1999.4	74	95
12_114	1576.2	74	119
12_115	848.6	74	48
12_116	29.6	76	31
12_117	5.7	76	10

Notes:
ID = identification number
min = minutes
sq. mi. = square miles

Appendix C

FEMA Flood Insurance Rate Maps

Appendix D
HEC-RAC and Hydraulic Models

Appendix D
HEC-RAC and Hydraulic Models

Appendix E
Cost Estimates

Appendix F
Meeting Minutes

Appendix F
Meeting Minutes

Appendix G

Drawings

URS

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