City of Boulder

2016 Stormwater Master Plan

City of Boulder, Colorado
December 22, 2016

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Glossary of Acronyms

ac-ft	acre-feet
BMP	best management practice
BTV	Boulder Transit Village
BVCP	Boulder Valley Comprehensive Plan
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Department of Public Safety
CFS	Comprehensive Flood and Stormwater Utility Master Plan
cfs	cubic feet per second
CFU	colony forming units
CIP	Capital Improvement Plan
City	the City of Boulder
CMMS	Computerized Maintenance Management System
CRM	Community Relations Management
Cu	Copper
CRS	Colorado Revised Statute
CUHP	Colorado urban hydrograph procedure
DCS	design and construction standards
DTM	digital terrain model
EMC	event mean concentration
EPA	Environmental Protection Agency

Glossary of Acronyms

FAM	Facilities asset management
HGL	hydraulic grade line
IDDE	illicit discharge detection and elimination
KICP	Keep It Clean Partnership
lbs/ac/yr	pounds per acre per year
LID	low impact development practices
MCM	minimum control measures
mg/L	milligrams per liter
µg/L	micrograms per liter
MS4	municipal separate storm sewer system
msl	mean sea level
NOAA	National Oceanic & Atmospheric Administration
NPDES	National pollutant discharge elimination system
NRCS	Natural Resources Conservation Service (formerly the Soil Conservation Service)
O&M	Operations and Maintenance
OSMP	Open Space and Mountain Parks
P	Phosphorous
PACE	Partners for A Clean Environment
Pb	Lead
PPD	program description document
Q_{Ratio}	ratio of peak flow capacity to full flow capacity
Q(wq)	water quality design storm peak flow (cfs)
ROW	right-of-way
SMP	Stormwater Master Plan
SOP	standard operating procedure
SSURGO	Soil Survey Geographic (database)
SMP	Stormwater Master Plan
SUSTAIN	System for Urban Stormwater Treatment and Integration Analysis
SWMM	Stormwater Management Model
TDP	total dissolved phosphorus
TKN	total Kjeldahl nitrogen
TMCC	Two Mile Canyon Creek
TMs	technical memorandums
TP	total phosphorus
TSS	total suspended solids

Glossary of Acronyms

TMDL	Total Maximum Daily Load
UDFCD	Urban Storm Drainage Criteria Manual
USDA	United States Department of Agriculture
USGS	U.S. Geological Survey
WLA	Waste load allocation
WQCV	Water quality capture volume
WQES	Water Quality and Environmental Services
WQIMP	water quality improvement projects
Zn	zinc

Executive Summary

This 2016 Boulder Stormwater Master Plan (SMP) replaces all previous stormwater master plans. The primary goal of the SMP is to provide the City of Boulder (city) with a guide to proactively address existing and future stormwater drainage and stormwater quality through a series of recommended improvements to the city's stormwater collection system. In 1984, the City developed a stormwater collection system master plan to guide upgrades and expansion to the system through a capital improvement program. While this plan had been a useful document, in 2007 it was recognized that new data and analysis tools were available, land use conditions had changed and new environmental regulations needed to be addressed. With this in mind, the 2007 Boulder SMP was developed to replace the 1984 plan with a document that was more in line with current problems and opportunities and the city's overarching environmental, economic and social goals.

The 2007 Stormwater Master Plan (SMP) was developed to provide the necessary planning tools and capital improvement projects to manage stormwater drainage and water quality throughout the city. Specifically, the 2007 SMP focused on assessment of the city's collector storm sewer system, consisting of storm sewers 18" in diameter and greater, and larger open channel drainage systems that are not a part of the city's major drainageways. The 2007 SMP did not analyze the local stormwater drainage systems (storm drain less than 18") or assess areas of non-existent drainage systems unless a historic drainage problem location was identified.

The 2016 SMP addresses this gap in the analysis of the local stormwater drainage systems by expanding on the 2007 SMP through additional analysis of where under-served or non-existent drainage systems create potential conveyance problems and develops improvements and associated estimates of capital costs needed to increase the level of service in these local drainage system areas. While the 2016 SMP did not re-analyze the entire collector storm sewer system or change those system recommendations, several local drainage systems overlapped the collector storm sewer system. In these instances, the collector system model and recommendations were updated as a part of the 2016 SMP.

Major activities undertaken in the development of the SMP include the following:

- Develop system analysis and problem identification criteria for both collector and local drainage systems
- Develop hydrologic, hydraulic and water quality models of the collector storm sewer system and extensions of that model to select areas of the local stormwater drainage system
- Assess post-flood problem areas within the stormwater drainage system based on Boulder 2013 Flood Survey data
- Evaluate the system and rank problem areas
- Perform alternatives analysis and develop a recommended plan
- Prepare a capital improvement plan
- Review new water quality regulations and their respective impact
- Develop an operation and maintenance assessment and provide recommendations
- Review current construction stormwater program and provide recommendations for standardizing the program across the city

- Provide recommendations for implementing the revised MS4 permit
- Provide recommendations for implementing other new water quality regulations

Study Area Characterization

The City of Boulder (city) has a population of approximately 100,000 and an area of nearly 25.5 square miles. Within the city, there are 12 subbasin and 15 major drainageways that generally flow from west to east as they converge on Boulder Creek, which is the primary major drainageway through the city. Runoff is conveyed to major drainageways by the city's collector storm sewer system and overland flow. Upstream of the collector storm sewer system are local drainage systems which generally consist of storm sewers less than 18" in diameter or areas with limited or no sub-surface drainage system.

At present, Boulder is nearly fully built-out with much of the future development expected to occur as site redevelopment. The city-wide existing condition impervious percentage was estimated to be 32% and is projected to be 34% under the 2006 Boulder Valley Comprehensive Plan as determined with the 2007 SMP analysis. However, considering the city's Design and Construction Standards (DCS) requirement for development to mitigate new impervious area through on-site best management practices (BMPs), the resulting net future condition imperviousness was determined to be 33%.

Planning and Analysis Criteria

A master planning analysis was performed to identify potential stormwater conveyance and water quality improvements within the city. The analysis was guided by a set of criteria used to identify problem areas and to evaluate potential improvements. These criteria included quantitative assessments of storm sewer surcharging, culvert overtopping, channel and irrigation ditch flooding, structure flooding (buildings, etc), reported drainage problems, and pollutant loadings.

Analysis Approach

The focus of the 2007 SMP was the collector storm sewer system, which included storm sewers 18" in diameter and larger and open channel systems that are not part of the city's major drainageways. Two levels of service associated with system capacity were provided based on land use, per the BVCP, and roadway category. For areas that are mainly residential in land use, the 2-year design storm was used to identify problems in the downstream conveyance system. For areas draining mainly commercial, industrial and collector and arterial roadways, the 5-year event was used.

Areas within the city that experience localized flooding (e.g., undersized pipes that are less than 18 inches in diameter; roadside ditches; and clogged catch basins) were addressed with the 2016 SMP as part of the local drainage system analysis. As with the collector storm sewer system analysis, the 2-yr and 5-yr storms were used to define the level of service based on 2006 BVCP land use and roadway category.

Modeling Approach

The modeling approach for the SMP integrated GIS as a pre- and post-processing tool with an EPA-based Storm Water Management Model (SWMM) as the hydrologic, hydraulic and water quality analysis tool. The analysis software used for the project was XPSWMM which is a proprietary version of EPA-SWMM software that provided an efficient GIS interface that EPA-SWMM does not have at this date. Workflow began in GIS, where the input parameters for the SWMM model were developed. This data was transferred out of GIS to SWMM for the evaluation of the system hydraulics and water quality. Model results were ultimately brought back into GIS for post processing and storage for future reference by the City.

The 2007 SMP model was used as the basis for modeling performed with the 2016 analysis. Hydrologic data remained unchanged for the 2016 analysis with the exception of subbasins that were re-delineated with the local stormwater drainage system analysis. For these re-delineated subbasins, model parameters of area, basin width, slope, and imperviousness were recalculated; no other hydrologic parameters were modified. The 2016 analysis also updated the 2007 SMP model to reflect improvements to the storm sewer system constructed since the completion of the 2007 SMP analysis.

Future Land Use and Development Criteria

Land use is a key factor in assessing stormwater runoff because it affects both the quantity (volume and peak) and quality of water being routed through the stormwater system. The future conditions land use scenario, used in the 2007 SMP, was based on the 2006 Boulder Valley Comprehensive Plan and represents a fully developed urban area. Although there have been updates to the BVCP since 2006, updates to the future land use were verified to have little effect stormwater modeling parameters. In addition, the future land use scenario also incorporates the city's DCS, which requires detention and water quality treatment for all new impervious areas that preserve pre-development runoff characteristics.

Hydraulic Problem Areas and Ranking

The stormwater drainage system hydraulic analysis was accomplished in two phases: 1) a collector system analysis performed with the 2007 SMP and 2) a local system analysis performed with the 2016 SMP.

Collector System Analysis

Utilizing the XPSWMM model, runoff, hydraulic, and water quality calculations were completed for existing and future condition land use scenarios using the 2- and 5-yr storms events. These results were then evaluated with respect the previously noted system analysis criteria to identify specific system deficiencies within the city's collector storm sewer system.

Model results for existing conditions indicate that 572 nodes out of 1635 nodes within the model violate one or more of the problem threshold criteria. Deficient model nodes and links were grouped together into problem locations based on their hydraulic connectivity. This resulted in a total of 51 hydraulic problem locations for the collector storm sewer system. Irrigation ditch segments were also added to the problem identification list if the corresponding design storm resulted in overtopping while the ditch was conveying irrigation water.

Due to the relatively large number of collector storm sewer system problem locations identified through the modeling and GIS analysis, and due to limitations within the city's capital budget, a ranking was performed on the problem areas to prioritize the conveyance problems. This process resulted in identifying three problem priority levels; Tier 1, Tier 2 and Tier 3 indicating severe, major or minor problem areas, respectively. The process of ranking problem areas into tiers utilized a point-based matrix using a weighted criteria approach. Six criteria were used to rank the problem areas and include:

- Extent of the problem
- Flooded volume
- Impact to neighboring structures
- Length of under capacity pipe
- Confidence in the underlying data
- Proximity of a hydraulic problem to water quality area of concern

The problem prioritization process resulted in five Tier 1 problem areas, 17 Tier 2 problem areas, and 31 Tier 3 problem areas. These collector storm sewer system problem locations are shown on Figure ES-1.

Local System Analysis

A GIS-based analysis evaluated city-reported problem areas from the city's Community Relations Management (CRM) database, 2013 flood survey data, and GIS storm sewer data to identify areas that have limited stormwater drainage systems and/or have observed local flooding issues. Fact sheets were developed to characterize the stormwater drainage system issues and potential opportunities. Site visits to the local system problem areas were made to confirm and better assess the system issues.

The analysis process identified forty two (42) local drainage system problem areas. To assist in the development of improvement recommendations, a prioritization process was used to assess the risk of future drainage related impacts in these 42 areas. Seven criteria were used to rank the problem areas and include:

- Known problem areas reported in the CRM database
- Known problem areas reported in the CRM database and observed flooding in the 2013 flood Reports, and/or modeled problem area in the collector storm sewer system
- Irrigation ditch storm flow reduction
- Underserved area
- Recorded problem area in 2013 Flood Reports
- Recorded problem area in 2013 Flood Reports and modeled problem area in the collector storm sewer system
- Severity and consequences of flooding

This analysis process resulted in identifying three problem levels, Tier I, Tier II, and Tier III. The prioritization process resulted in 10 Tier I problem areas, 11 Tier II problem areas and 14 Tier III problem areas. Seven problem areas were removed following a site visit which revealed that analysis assumptions for those areas did not match actual field conditions. The resulting 35 local stormwater drainage system problem locations are shown on Figure ES-2.

Water Quality Analysis and Problem Areas

The water quality analysis, performed with the 2007 SMP analysis, included two separate approaches to identify problem locations within the collector system: 1) a buildup-washoff analysis using the XPSWMM model to identify water quality areas of concern that produce high pollutant loads and 2) targeted outfall approach focusing on the collector system outfalls to Boulder Creek. The water quality area of concern approach used the XPSWMM model to identify areas within the city having comparatively higher pollutant concentrations and/or loads. This approach identified 12 locations within the city that were characterized as water quality areas of concern. The Boulder Creek outfall approach identified 17 collector system outfalls that do not currently receive pollution reduction through regional water quality facilities. The water quality areas of concern and Boulder Creek outfall sites are shown on Figure ES-3.

Capital Improvement Plan

The Capital Improvement Plan (CIP) is separated into two general categories: 1) collector storm sewer system improvements and 2) local drainage system improvements. Figures ES-4 through ES-8 present the collector, local and water quality system improvements. Estimates of capital construction costs included in this plan are considered planning level estimates to be used in developing stormwater capital budget requirements.

Collector Storm Sewer System CIP

The collector storm sewer system improvement recommendations were categorized as 1) Hydraulic, 2) Combined Hydraulic/Water Quality projects or 2) Water Quality Improvement projects.

The implementation plan for the Hydraulic and Combined Hydraulic/Water Quality CIP projects follows the Tier 1, 2 and 3 problem areas. Tier 1 CIP projects are considered high priority improvements as they resolve severe collector storm sewer system problems and in some instances also address stormwater quality problems. Tier 1 problem areas are anticipated to a) have a high social benefit by resolving street and property flooding issues, b) have a high economic benefit by reducing flooding risk and property damage, and c) provide an environmental benefit by addressing stormwater quality issues. Note that not all Tier 1 locations included a water quality problem site and that the overriding criterion for prioritization was resolving flooding issues. Table ES-1 identifies the Tier 1 CIP projects; Tier 2 and 3 projects are identified in the main report.

Table ES-1: Collector Storm Sewer System Tier 1 Hydraulic and Combined Hydraulic/Water Quality CIP Projects

Ranking	Improvement ID	Location	Improvement Type	Capital Cost
1	GC_02	Upper Goose Creek	Pipe Replacement New Storm Drain Channel Improvement	$8,269,000
3	MBC_14	Arapahoe and 28th Street	Pipe Replacement Storm Drain Re-Routing/Extension Proprietary BMP	$2,076,000
4	DC_01	Gunbarrel – Spine Road, Lookout and 63rd Systems	Pipe Replacement Storm Drain Re-Routing/Extension Constructed Wetland	$7,195,000

Table ES-1: Collector Storm Sewer System Tier 1 Hydraulic and Combined Hydraulic/Water Quality CIP Projects

Ranking	Improvement ID	Location	Improvement Type	Capital Cost
			TOTAL	**$17,540,000**

Local Drainage System CIP

The implementation plan for the local drainage system improvement projects was prioritized based on reported problem areas, observed flooding, stormwater removal from irrigation ditches, lack of existing stormwater infrastructure, and field observations. Table ES-3 identifies the Tier I local drainage system CIP projects; Tier II and III projects are identified in Tables 7.2-2 and 7.2-3 within Section 7 of the main report.

Table ES-2: Tier I Local Drainage System CIP Projects

Ranking	Project ID	Location	Improvement Type	Capital Cost
1	Wonderland Creek -1	Broadway Street from Rosewood Ave to Violet Ave	New Storm Sewer Replacement Storm Sewer	$318,000
2	Elmer's Twomile Creek-2	Farmer's Ditch – Iris Ave to Linden Ave and Broadway St to Cloverleaf Drive	New Storm Sewer Replacement Storm Sewer	$3,874,000
3	Goose Creek-1	Intersection of 8th St and Dellwood Ave	New Storm Sewer Replacement Storm Sewer	$1,585,000
4	Goose Creek-2	Alpine Ave to Dellwood Ave and 3rd St to 7th St	New Storm Sewer Replacement Storm Sewer	$2,417,000
5	Goose Creek-3	Dewey Ave from 4th St to 9th St	New Storm Sewer Replacement Storm Sewer	$984,000
6	Middle Boulder Creek-2	Vicinity of Pine Street from 16th St to 21st St	New Storm Sewer Replacement Storm Sewer	$3,175,000
7	Dry Creek No, 2-1	Intersection of Chippewa Dr and Caddo Pkwy east of Inca Pkwy	New Storm Sewer Replacement Storm Sewer	$1,837,000
8	Dry Creek No 2-3	Intersection of Chippewa Dr Baseline and 55th St from Foothills Hwy to Arapahoe Ave	New Storm Sewer Replacement Storm Sewer	$6,505,000
9	Bear Canyon Creek-3	Vicinity of Kohler Dr from south of Dartmouth Ave	Hydraulic Improvement	$2,265,000
10	Bear Canyon Creek-5	Vicinity of Wildwood and Ithaca Drive	Hydraulic Improvement	$267,000
			TOTAL	**$23,227,000**

Water Quality Improvement CIP

The implementation plan for the Water Quality Improvement (WQIMP) projects was prioritized based on problem severity as identified by pollutant load. The WQIMP category was developed since many of the water quality project sites were not adjacent to hydraulic problem and improvement locations. In addition, many of these WQIMP projects could be defined as a small capital projects since the estimated construction costs are less than $100,000.

Table ES-3: Water Quality Improvement CIP Projects

Improvement ID	Location	Capital Cost
WQIMP 2	Boulder Creek 1,400’ East of 75th Street	$133,000
WQIMP 3	Boulder Creek & 28th Street	$104,000
WQIMP 5	Boulder Creek & 75th Street	$97,000
WQIMP 6 & WQIMP 9	Boulder Creek & East Broadway Street & Arapahoe Avenue	$201,000
WQIMP 8	Boulder Creek 200’ West of Folsom Street	$108,000
WQIMP 12	Boulder Creek & Folsom Street	$100,000
WQIMP 14	Boulder Creek & 9th Street	$93,000
WQIMP 15	Broadway & Skunk Creek	$93,000
WQIMP 16	Boulder Creek & 13th Street	$104,000
WQIMP 18	Boulder Creek & 11th Street	$65,000
	TOTAL	**$1,098,000**

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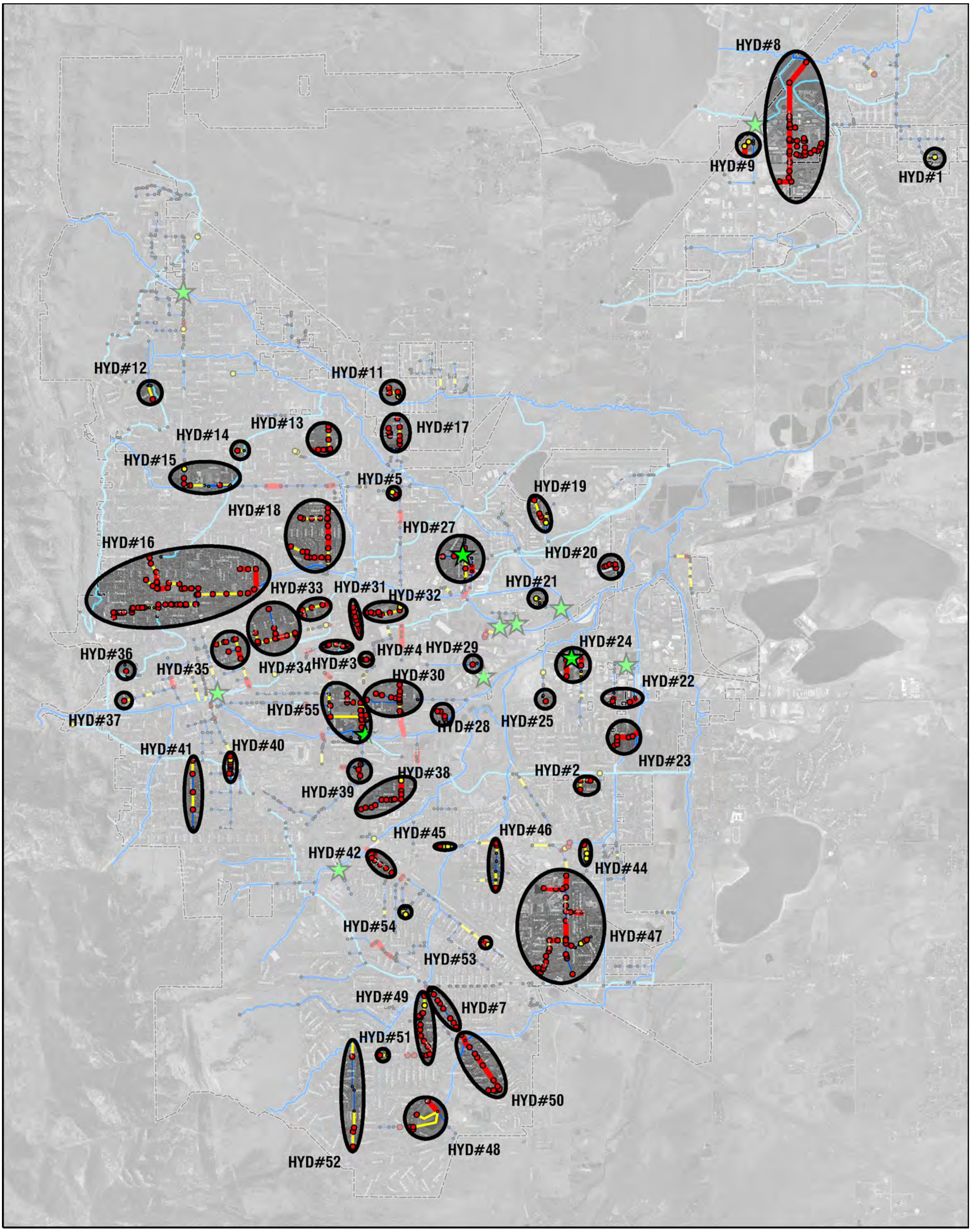


Legend

Hydraulic Problem Areas
Flooded
Surcharged
OK

Conveyance Capacity
Sufficient Capacity
Under Capacity
Severely Under Capacity

Modeled network
Canal/ Ditch
Major drainageway
Major Roads

City Limits
Lakes
Water Quality Areas of Concern

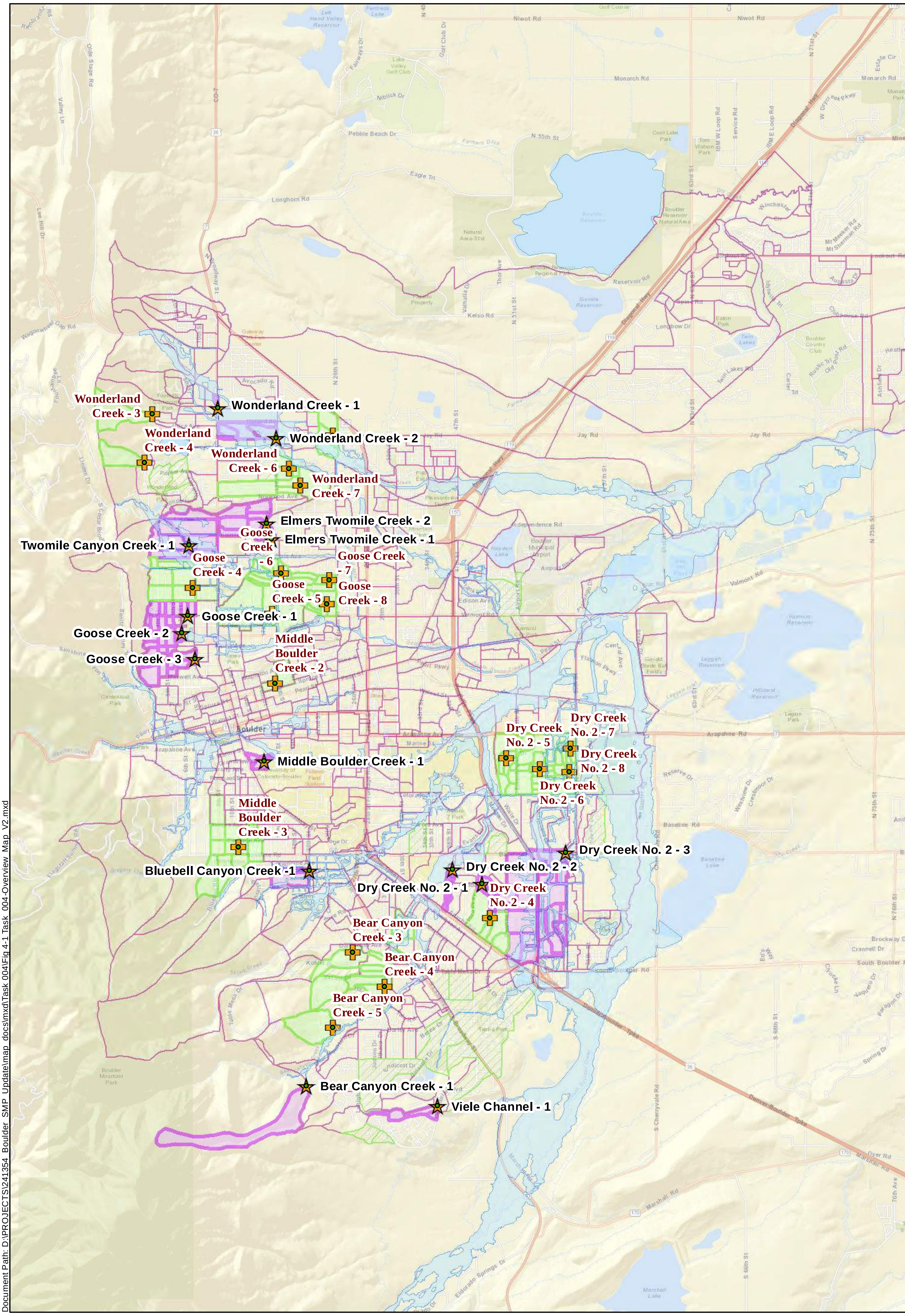
0 4,000
1 inch equals 3,500 feet

N

Collector Storm Sewer System
Hydraulic Problem Summary Map

Figure ES-1

HDR
ONE COMPANY | *Many Solutions*℠



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0 4,000 8,000 Feet

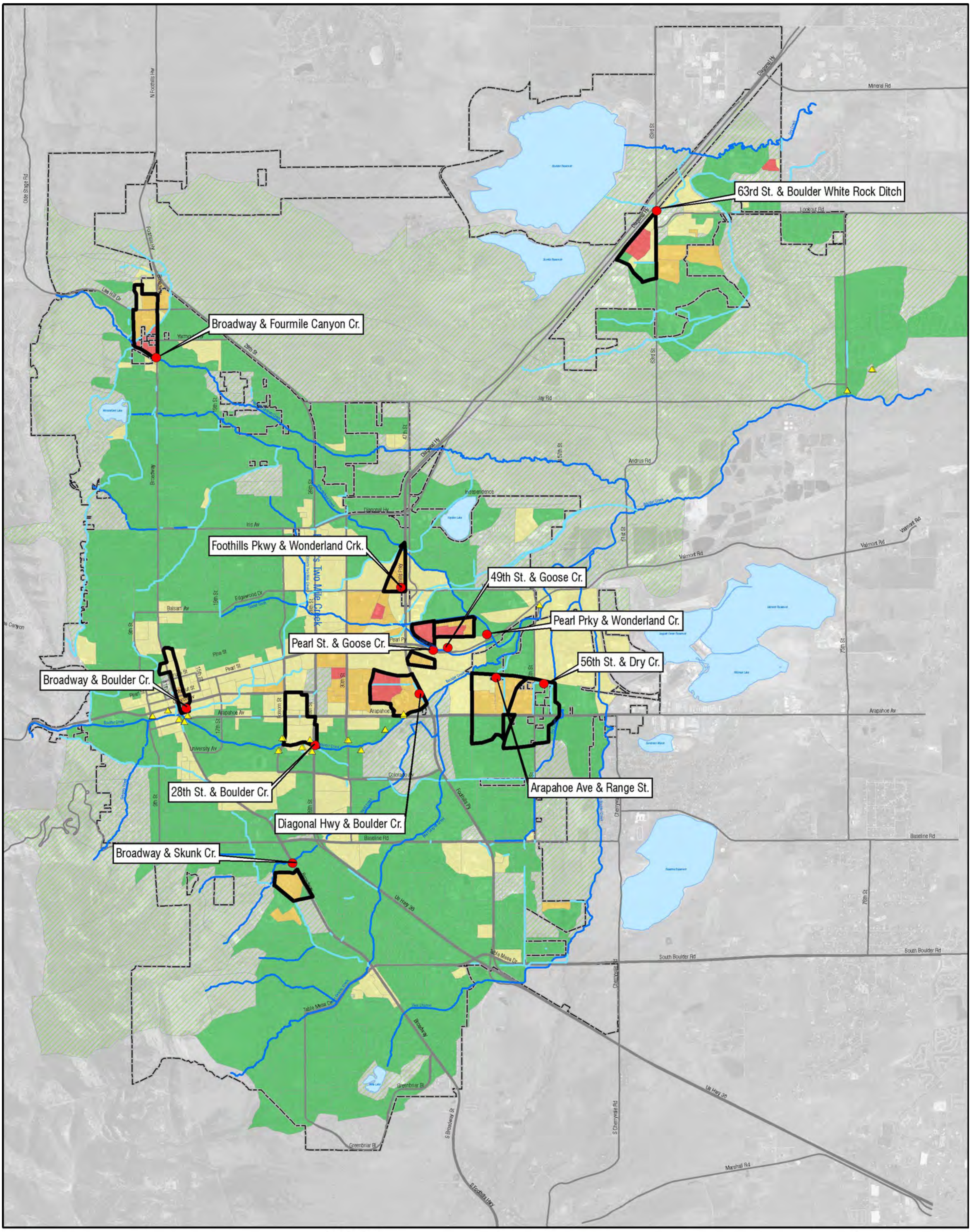
N

- Type A - Local Drainage Problem Area
- Type B - Local Drainage Problem Area
- 2013 Flood Extents
- Subcatchment
- Type A Priority Subbasin
- Type B Priority Subbasin
- Type B Override

Local Storm Sewer System Problem Locations

Figure ES-2

Date: 1/8/2016



Legend

- Key Pollutant Load Outfalls
- Outfall Catchments
- Modeled network
  - Canal/ Ditch
  - Major drainageway
- Major Roads
- City Limits
- Lakes
- Boulder Creek Outfalls

Load (Lbs TSS/Ac/Yr)

- 0 - 250
- 251 - 500
- 501 - 750
- 751 - 1000
- 1001 +

0 4,000
1 inch equals 4,000 feet

N

Collector Storm Sewer System
Water Quality Areas of Concern Map
Figure ES-3

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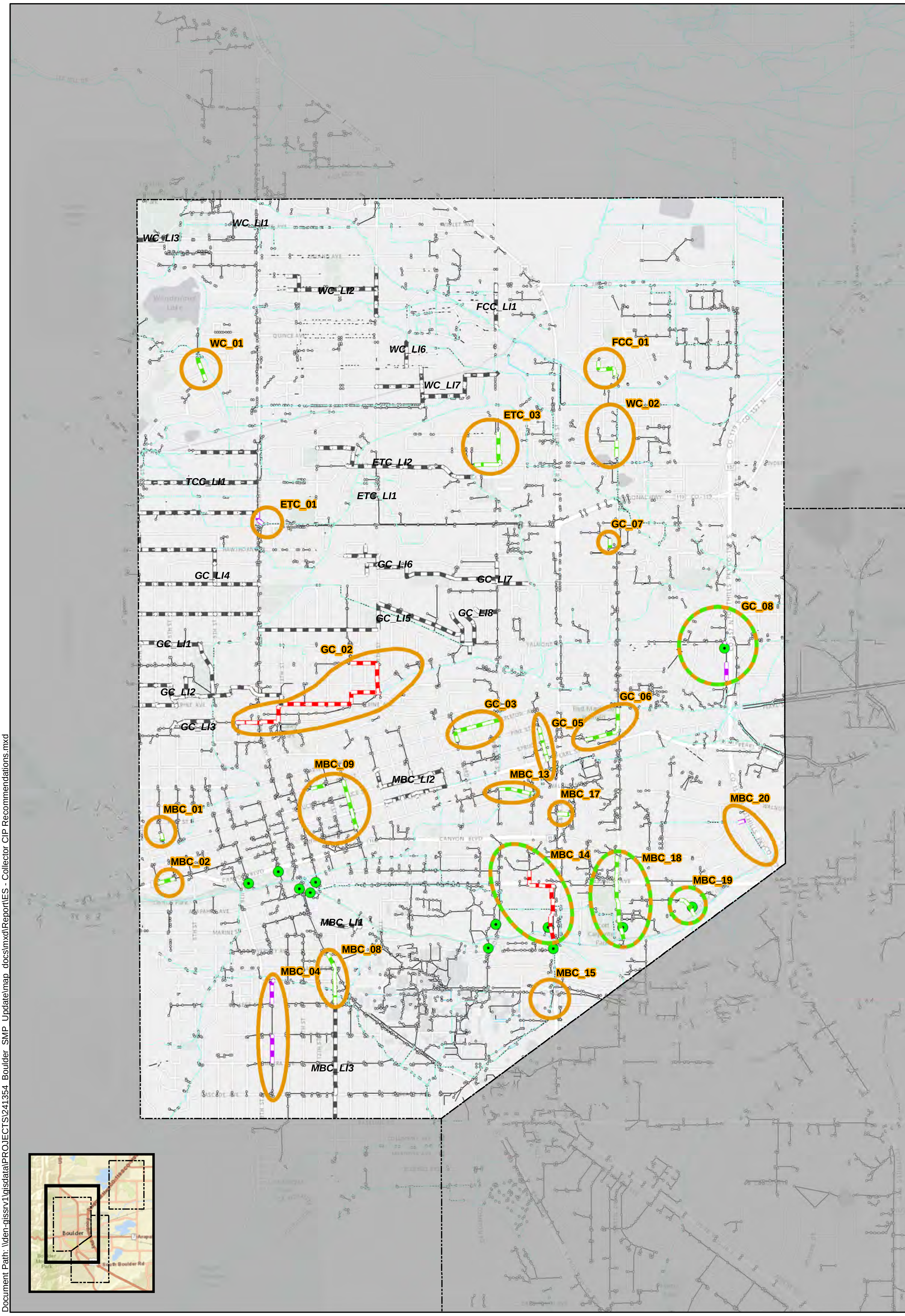

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HDR

N

0 1,200 2,400 Feet

Collector System Improvement Area

Local Storm Sewer Improvements

Collector Storm Sewer System Improvements

Tier I Pipes

Tier II Pipes

Tier III Pipes

Water Quality Manholes

Water Quality Surface BMP

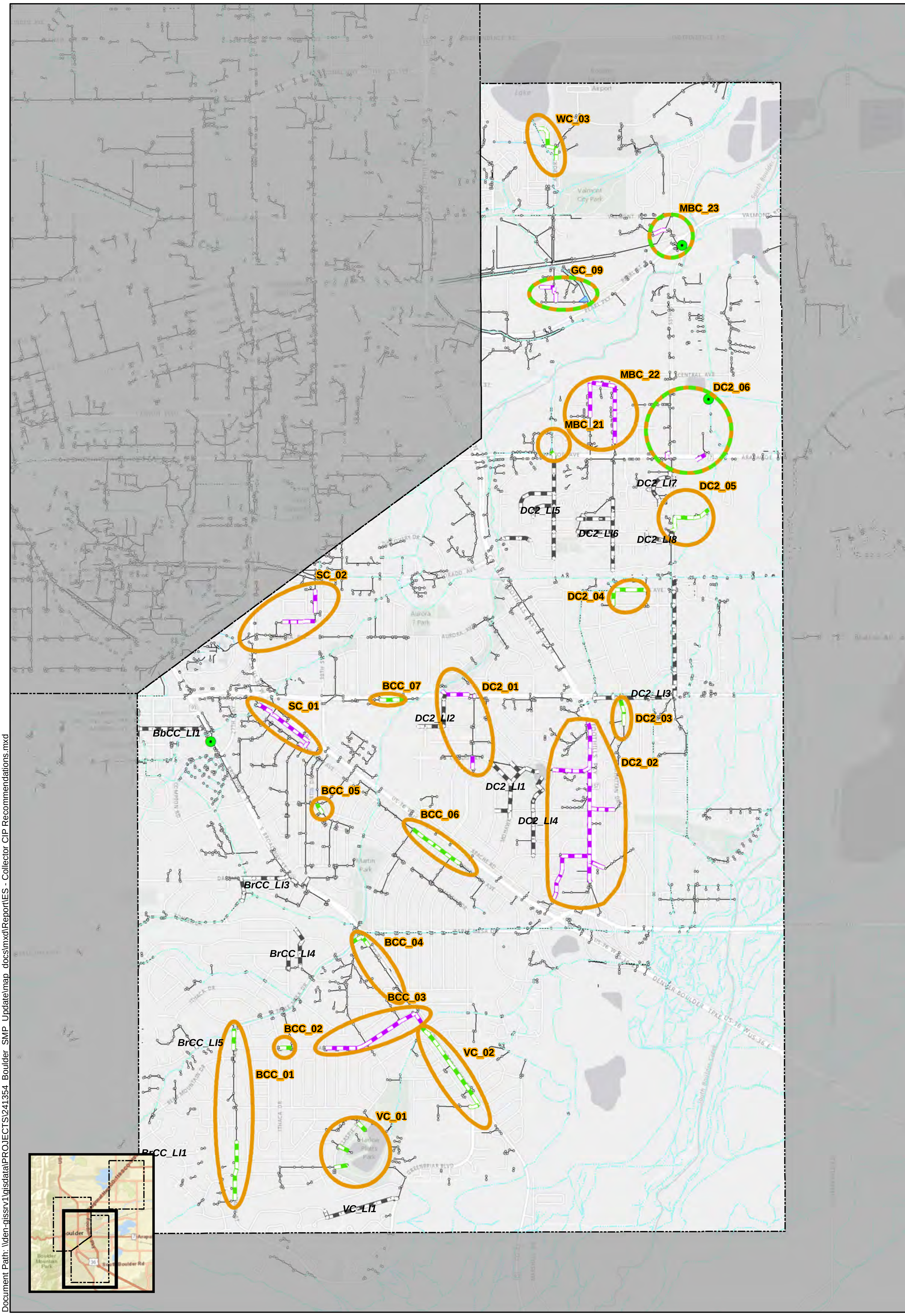
Creek/Ditch

Existing Storm Sewer

Existing Open Channel

Collector Storm Sewer System Improvements, 1 of 3

Figure ES-4



0 1,200 2,400 Feet

N

Collector System Improvement Area
Local Storm Sewer Improvements

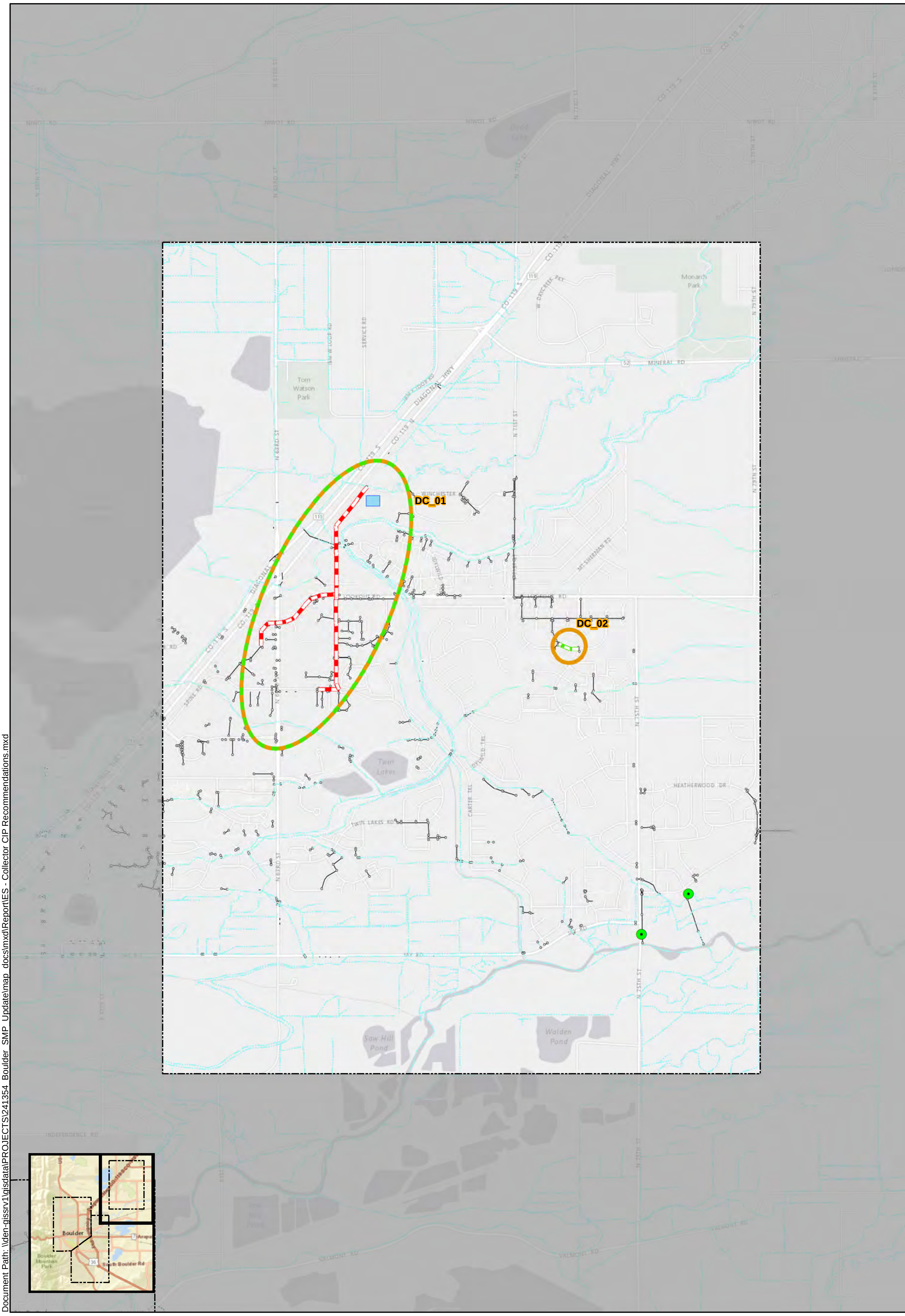
Collector Storm Sewer System Improvements

Tier I Pipes
Tier II Pipes
Tier III Pipes
Water Quality Manholes
Water Quality Surface BMP

Creek/Ditch
Existing Storm Sewer
Existing Open Channel

Collector Storm Sewer System Improvements, 2 of 3

Figure ES-5



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Collector System Improvement Area
Local Storm Sewer Improvements

Collector Storm Sewer System Improvements

Tier I Pipes
Tier II Pipes
Tier III Pipes
Water Quality Manholes
Water Quality Surface BMP

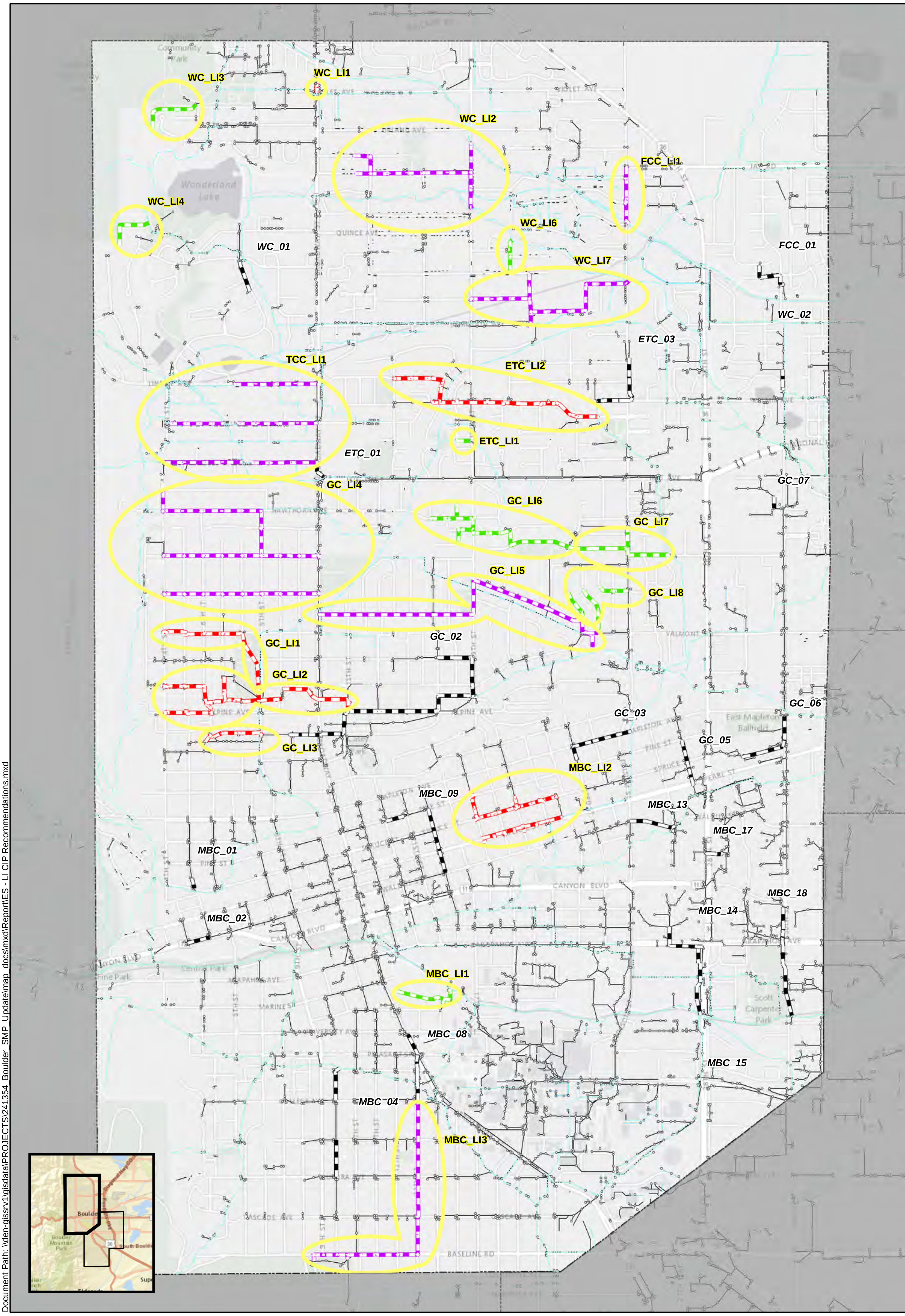
Creek/Ditch
Existing Storm Sewer
Existing Open Channel

N

0 1,200 2,400 Feet

Collector Storm Sewer System Improvements, 3 of 3

Figure ES-6



N

0 900 1,800
Feet

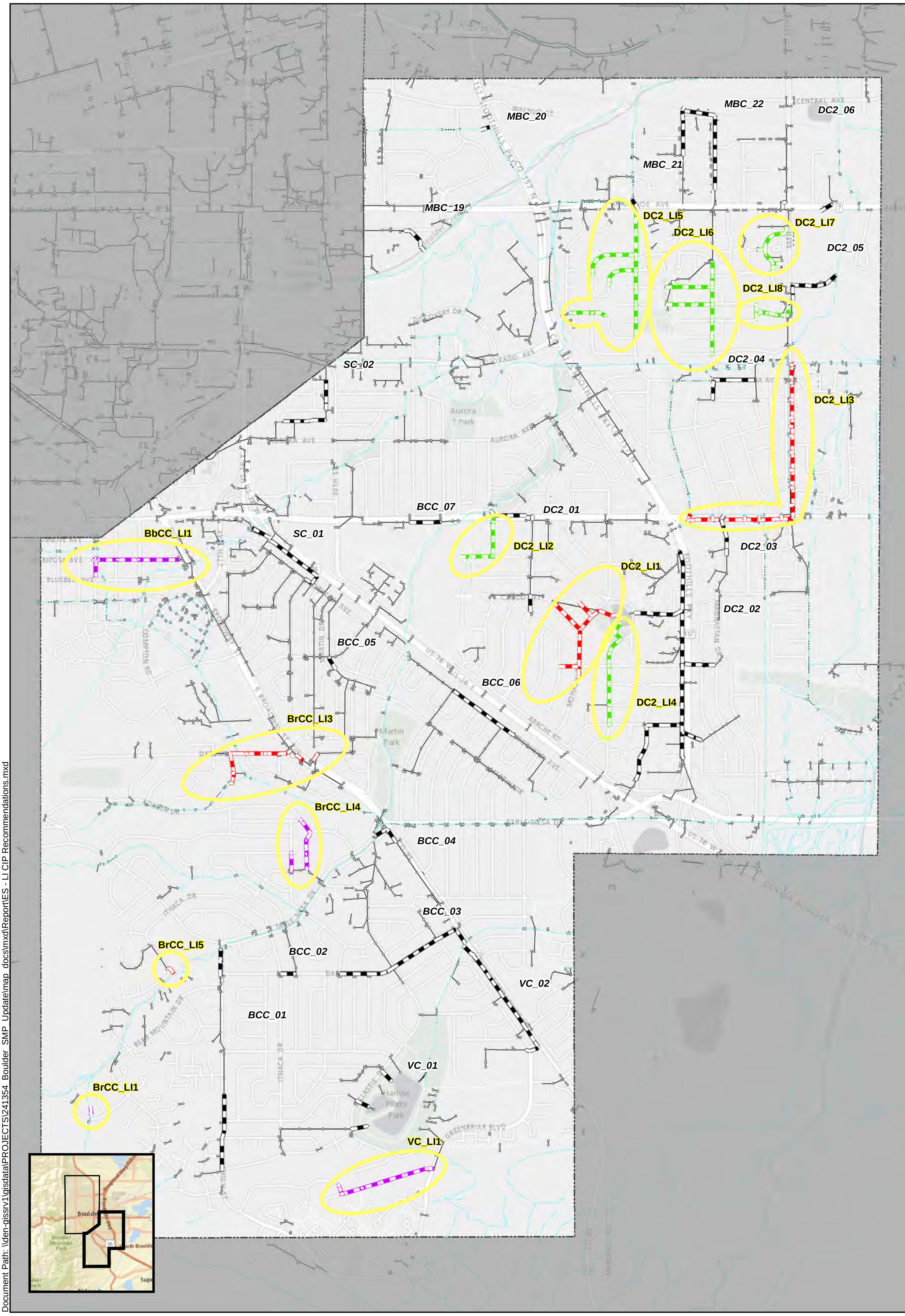
Local System Improvement Area
Collector Storm Sewer System Improvements

Local System Improvements

Tier I Pipes
Tier II Pipes
Tier III Pipes

Creek/Ditch
Existing Storm Sewer
Existing Open Channel

Local System Improvements - North
Figure ES-7



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N

0 900 1,800 Feet

Local System Improvement Area
Collector Storm Sewer System Improvements

Local System Improvements

Tier I Pipes
Tier II Pipes
Tier III Pipes

Creek/Ditch
Existing Storm Sewer
Existing Open Channel

Local System Improvements - South
Figure ES-8

1 Introduction

This 2016 Boulder Stormwater Master Plan (SMP) replaces all previous stormwater master plans. Recent history of the stormwater master planning process started in 1984 when the city developed a master plan to guide upgrades and expansion to the storm sewer system. While this plan had been a useful document, in 2007 it was recognized that new data and analysis tools were available, land use conditions had changed and new environmental regulations needed to be addressed. With this in mind, the 2007 Boulder SMP was developed to replace the 1984 plan with a document that was more in line with current problems and opportunities and the city's overarching environmental, economic and social goals.

The 2007 SMP provided the City with the necessary planning tools and capital improvement projects to address flood management and water quality. Specifically, the 2007 SMP focused on assessment of the city's existing collector storm drainage conveyance system, consisting of storm sewer 18" and greater and larger open channel drainage systems that are not a part of the city's major drainageways. The 2007 SMP did not analyze the local storm drainage conveyance systems (storm drain less than 18") or assess areas of non-existent drainage systems unless a historic drainage problem location was identified.

This 2016 SMP updated the 2007 SMP analyses to address portions of the local drainage system that are considered "underserved" in regards to stormwater infrastructure and/or lacking in the protection provided by a sufficient stormwater collection and conveyance system. As described in Boulder's Design and Construction Standards (DCS), the level of service specified for residential areas is the 2-year design storm. All other areas of local and collector storm sewer system are provided a 5-year storm level of service.

1.1 Goals and Objectives

The goal of the SMP is to proactively manage stormwater runoff to protect water quality and to minimize impacts of localized and downstream flooding by identifying infrastructure improvements for the collection, conveyance and treatment of stormwater within the city limits. The development of the SMP expanded and built upon the city's goals to address environmental, economic and social issues through the following planning objectives:

- Develop a master plan for the collector storm sewer system and local drainage systems that alleviates current capacity and flooding problems.
- Develop a master plan such that the stormwater drainage system can accommodate additional runoff generated from future development or redevelopment.
- Identify site specific improvements that address stormwater quality to improve receiving water quality for environmental and recreational benefit.
- Incorporate social implications in the prioritization of recommended projects by focusing on problem locations that impact key community facilities, major transportation corridors and protection of private property.
- Recommend improvements that are sustainable from an operations and maintenance perspective.

1.2 Stormwater Planning Process

The 2007 SMP analyzed and developed recommendations for the collector storm sewer system which was defined as the storm sewer system generally 18-inches in diameter and greater. The process used in preparing this 2016 SMP involved updating the 2007 SMP to reflect current conditions and address upstream local drainage systems that are smaller than 18 inches in diameter and that were not evaluated with the 2007 SMP analyses.

The SMP process was based on a series of steps as described below. Additionally, through a progression of workshops at the onset and completion of key steps, input from city staff was gathered and incorporated into the SMP to ensure the overall goals and objectives were met.

- Collect and review existing information, including previous studies, designs, survey information (including new survey), drainage reports and other data to support development of the plan.
- Establish a set of goals, policies and analysis criteria that will guide the analysis and development of a recommended plan.
- Develop a hydrologic, hydraulic and water quality model of the collector storm sewer system.
- Identify and assess reported problem areas within the local stormwater drainage system.
- Evaluate the existing stormwater infrastructure with respect to the system analysis criteria and rank each problem in terms of severity.
- Develop alternatives for each problem area.
- Prepare a recommended plan, documenting the preferred alternatives, detailed cost estimates, and significant implementation.

The format of the SMP report is based on the project workflow starting with project goals and ending with a recommended plan. The city's Project Planning and Approval Process Handbook for Capital Improvement Program Projects (July 2003) presents a general framework for master plans. The SMP report modified the suggested framework to accommodate the project scope, purpose and needs.

2 Analysis and Problem Identification Criteria

The SMP identifies improvements to the city's collector and local drainage systems. The evaluation was guided by a set of system analysis criteria used to identify conveyance and water quality problem areas and to evaluate potential improvements. These criteria included quantitative assessments of storm drain surcharging, culvert overtopping, channel/ditch flooding, structure flooding (buildings, etc) and pollutant loadings.

This section presents a description of the study area, the criteria used in the analysis of the stormwater drainage system and the criteria used for identifying problems within the system.

2.1 Study Area

The City of Boulder, with a population of approximately 100,000 and an area of nearly 25.5 square miles, is located along the front range of the Rocky Mountains, northwest of Denver, Colorado. Within the city, there are 12 subbasin and 15 major drainageways that generally flow from west to east as they converge on Boulder Creek, which is the main tributary flowing through the city. Runoff is conveyed to these major drainageways by the city's collector storm sewer system and overland flow. Upstream of the collector storm sewer system are local drainage systems which consist of storm sewers less than 18" in diameter or areas with limited or no sub-surface drainage system.

2.1.1 Topography

Topographically, Boulder sits roughly 5,430 feet above sea level. Elevations in the city range from over 6,400 feet mean sea level (msl) above Wonderland Lake on the west side of the city to approximately 5,100 feet (msl) near Boulder Reservoir in the northeast corner of town. Surface slopes within the city are generally flat with few areas exceeding 5% except for the area abutting the foothills, where slopes nearing 1:1 are not uncommon (Figure 2-2).

2.1.2 Land Use

The city is nearly fully "built-out" with the majority of the land use in the basin as residential. The highest density commercial areas are located along Boulder Creek in the central downtown core area and along 28th Avenue, Foothills Highway, and Gunbarrel. The University of Colorado is also located within Boulder and occupies roughly 1 square mile of land in the southwestern portion of the city. At present, because the city is almost fully developed, anticipated future land use is not expected to substantially change with construction activities mainly involving site redevelopment.

2.1.3 Soils

The City of Boulder is located at the foothills of the Rocky Mountains. Its underlying geologic unit is classified as young Quaternary deposits of stream gravels and sand, slope wash, terrace gravels and landslides and was deposited approximately 65 million years ago. The surface soils are mainly composed of poorly cemented and unconsolidated sands and gravels. Hydrologically speaking, the soils are largely classified as Type C according to the Natural Resources Conservation System (NRCS, formerly the Soil Conservation Service), however all other hydrologic soils type classifications can be found in the city.

2.1.4 Climate

The climate of the Boulder Valley area is typical of the Front Range. During the summer months, the average temperature is approximately 66 F; during the winter months, the average temperature is about 35 F but freezing temperatures are not uncommon. The average annual precipitation in Boulder is approximately 20 inches with nearly 60% occurring as rain between March and July. Significant summer rainfall events are typically thunderstorms and are characterized as high in intensity and short in duration. On average, 54 thunderstorms occur annually between April and September (NOAA, 2005).

2.2 System Analysis Criteria

Stormwater planning was accomplished using a set of planning and design criteria. The following information summarizes these criteria, including design storms, modeling assumptions and other system analysis criteria that were used for the Boulder SMP.

2.2.1 Design Storms

Design storm analysis criteria influence runoff volume, pipe capacity requirements, and water quality treatment criteria. As noted in the UDFCD Volume 1 criteria manual, intense rainfall events in the Denver/Boulder area often are less than one or two hours in duration and can produce brief periods of high rainfall intensities. Thus, the UDFCD 2-hour design storm was used for the Boulder SMP.

Table 2.2-1 summarizes the 1-hour precipitation depths for the Boulder area for the 2- and 5-year recurrence interval events and the water quality storm based on NOAA Atlas II, current at the time of the 2007 SMP. The UDFCD Volume 1 procedure was used to generate 2-hour rainfall distributions for 2-year and 5-year storms based on these 1-hour precipitation values.

Table 2.2-1 Rainfall Depth-Duration-Frequency Values, NOAA Atlas II

Return Frequency (yr)	1-Hour Precipitation (in)
WQ	0.43
2	1.05
5	1.48

In 2004, the Boulder Creek Climatology study evaluated rainfall depth, duration, frequency and spatial distribution across the city. The findings from this study were compared to the temporal distribution of rainfall in the UDFCD 2-hour design storm, which is a front weighted distribution with peak precipitation occurring 25 minutes after the onset of the event. The measured rainfall data from the South Boulder Creek design storm evaluation validated the use of the UDFCD designs storm temporal distribution. Similarly, the spatial distribution of rainfall from the South Boulder Creek study was observed to be uniformly spread across the central core of the city. This observation validates the use of a design storm applied uniformly to the modeled subbasin across the entire study area.

For the water quality design storm, the UDFCD criteria manual recommends a total depth of 0.43 inches, which represents the average runoff producing storm in the Boulder area (Figure SQ-3, Volume 3 of UDFCD). This precipitation was distributed into 5-minute increments using the 2-year rainfall distribution noted above. The resulting hyetograph for this storm is shown on Figure 2-3.

NOAA Atlas II versus NOAA Atlas 14

In 2013, NOAA published *NOAA Atlas 14 Precipitation-Frequency Atlas of the United States, Volume 8 Version 2: Midwestern States* (NOAA Atlas 14, 2013). NOAA Atlas 14 is intended to supersede the previous NOAA Atlas II (1973) due having many more years of data, higher frequencies of data collection, refined statistical methods, more robust software packages, etc. NOAA Atlas 14 data provides, among other things, point rainfall depths for various rainfall recurrence intervals and durations and 90 percent confidence intervals to these depths and is provided on a rain gaging station basis. The nearest gaging station to the city has a station name of Boulder, a site ID of 05-0848, and is located off Lawrence Road near Skunk Creek on the south side of town. 1-hour 2- and 5-year recurrence interval rainfall depth estimates are 0.782 (upper 90 percent confidence limit 0.946) and 1.04 (upper 90 percent confidence limit 1.27), respectively.

In a memorandum[1] produced by the UDFCD on September 11, 2013, the district's position was to maintain the continued use of the Atlas II 1-hour rainfall depths for two reasons:

1. The Atlas II data produced greater 1-hour rainfall depths across the recurrence intervals. The 90 percent confidence intervals from the Atlas 14 and Atlas II datasets also overlap and are therefore not statistically significantly different.
2. All existing hydraulic/hydrologic infrastructure and floodplain mapping in the past 40 years as well as forensic review of major flooding events and drainage infrastructure performance are based on Atlas II.

In keeping with the UDFCD's position on Atlas 14 as well as the Boulder rain gaging station being consistent with this position in having 1-hour rainfall depths associated with Atlas 14 being lower than Atlas II, the Boulder SMP continues to use the Atlas II rainfall depths.

2.2.2 Continuous Simulation Modeling

In addition to the event-based design storm criteria, a year-long continuous rainfall event was also developed. This event was used to estimate annual pollutant loadings at key locations throughout the city as a part of the stormwater quality analysis performed with the 2007 SMP. Rain gage data, from a gage located in the north area of the city, was available for 57 years of record (1949 – 2005). Data for 2003 was selected for the continuous rainfall event as it best represents a typical year in terms of total depth during the wet months of April through September (10.4 inches) and the total number of storms with more than an inch of precipitation during a 6-hour period (two events). Because the stormwater quality analysis was not re-evaluated with the 2016 SMP, this rainfall analysis and model scenario were not updated.

2.2.3 Stormwater Conveyance Elements

The SMP analysis addresses both the collector and local stormwater drainage systems. The collector stormwater drainage system was analyzed using two level of services based on land use and roadway category. For areas that are mainly residential in land use, the 2-year recurrence interval design storm was used to identify problems in the conveyance system. For areas draining

[1] MacKenzie, Ken. *UDFCD Position on the NOAA Atlas 14 Precipitation-Frequency Atlas, Volume 8*. 2013. http://udfcd.org/wp-content/uploads/uploads/resources/position%20papers/UDFCD_Position_on_the_2013_NOAA_Precipitation-Frequency_Atlas.pdf

mainly commercial, industrial and collector and arterial roadways, the 5-year event was used. Figure 2-4 illustrates the recurrence interval used throughout the city's collector storm sewer system.

For the local stormwater drainage system, the existing storm sewer network was not analyzed explicitly with SMP hydraulic or specific design storms. Rather, the local system analysis focused on reported problem areas as documented in the city's CRM database with a supporting GIS-based desktop analysis.

Irrigation ditches throughout the city play a major role in the conveyance of stormwater runoff. Many ditches receive stormwater from storm drains that outfall directly to the ditch system and from overland flow. Since irrigation ditches receive storm runoff from collector storm sewer outfalls, a 5-year design storm criteria was used to provide continuity with the collector system criteria.

2.2.4 Land Use and Imperviousness

Land use affects both the quantity (volume and peak rate) and quality of water running off and routed through the city's stormwater drainage system. The effect land use has on water quantity is generally linked to the amount of impervious area for a particular land use category. The more impervious the area, the faster the water will be routed to the storm water collection system due to the lower surface roughness of the ground. It will also increase the total volume of runoff since infiltration cannot occur through impervious surfaces. Consequently, an area with a higher percentage of impervious surfaces will produce higher peak flows and large volumes over a shorter period of time than will similar area with a lower percentage of impervious surfaces. Areas of higher impervious coverage are also a byproduct of development and the associated land use based pollutants that affect water quality. In order to identify problem areas within the stormwater drainage system, two land use scenarios with their associated impervious coverage values, were used in the SMP.

Existing Conditions

As developed with the 2007 SMP, the existing conditions scenario represents 2006 land use (Figure 2-5) within the city limits and reflects existing condition problems within the system. To supplement the land use data within the city's GIS database, an actual impervious surfaces layer based on 2005 aerial photography was also incorporated into this scenario.

Future Conditions

The future conditions land use scenario was developed with the 2007 SMP and was based on the 2006 Boulder Valley Comprehensive Plan to represent a fully developed urban area (Figure 2-6). Although there have been updates to the BVCP since 2006, updates to the future land use were verified to have little effect stormwater modeling parameters. In addition, the future land use scenario also incorporates the city's DCS, which requires detention and water quality treatment for all new impervious areas that preserve pre-development runoff characteristics.

2.3 Problem Identification Criteria – Collector Storm Sewer System

The SMP was guided by a set of criteria used to identify and categorize storm drain collector system conveyance and water quality problem areas and to evaluate potential improvements. This section describes each of the hydraulic and water quality problem identification criteria.

2.3.1 Hydraulic Problem Identification Criteria

Hydraulic deficiencies are generally related to insufficient system storage, excessive runoff generated from highly impervious land covers or flooded backwater conditions from the major drainageways; however, they can also result from an undersized or poorly designed conveyance system. To identify system deficiencies, results from the hydraulic model compared to hydraulic problem identification criteria within ArcGIS. Other problem areas were also added to the system deficiency list if they were known flooding locations within the collector system, as provided by the City. Depending on the type of the conveyance element being investigated, the following criteria were used.

Storm Sewer Surcharging

Surcharge conditions for the piped system are acceptable only for demonstrating the adequacy of the system to convey the peak runoff for the corresponding design storms, provided that the hydraulic grade line (HGL) is one foot lower than the manhole rim elevation. If the HGL is within, or higher, than one foot below the manhole rim elevation, that particular section of pipe was identified as undersized.

Culvert Overtopping

There are several locations within the city where open channel flow is conveyed through a culvert under a public roadway. Culverts at locations where the estimated HGL will inundate the road sub-grade were classified as undersized. The roadway sub-grade elevation was determined by subtracting one foot from the roadway crown elevation as determined from the DTM coverage supplied by the city. Culverts were evaluated to the 2-year event for residential drainage systems and the 5-year event for commercial and industrial systems.

Irrigation Ditches and Open Channel Flooding

Open channel conveyance elements, including primary irrigation ditches, were added to the problem identification list if the corresponding design storm causes the channel to overtop its banks and flood the surrounding area. It should be noted that it was outside the scope of this project to complete a detailed capacity analysis of the primary irrigation ditches.

Structure Flood Risk

Buildings or other structures that are within 100 feet of a flooded manhole and whose ground elevation is at or below the adjacent water surface elevation of that flooded manhole or open channel were added to the problem identification list. Areas within the city that exhibit significant potential structural flooding risk are considered high priority areas in terms of conveyance system improvements.

2.3.2 Water Quality

In addition to evaluating localized flooding potential, a buildup-washoff model analysis was used to evaluate stormwater pollutant loading at outfalls throughout the city. The primary goal of the water quality model and analysis was to identify drainage basins and the associated outfalls within the city where relatively high pollutant loads are expected. These locations of high pollutant loads were identified as Water Quality Areas of Concern. In addition to the model results, other factors considered during the evaluation included:

- Recent development and construction of water quality BMPs
- Areas where development is likely in the near future
- Areas where property ownership will likely preclude BMP construction
- Proximity to Boulder Creek

Using the model results and these other factors, specific outfalls were identified for further analysis including recommendations for water quality BMPs. These BMPs can be integrated into the capital program, and projects can be targeted throughout the city to maximize the system-wide water quality benefit.

2.4 Problem Identification Criteria – Local Drainage System

The purpose of this analysis was to identify subbasins within Boulder that have limited stormwater drainage systems and/or have observed local drainage system flooding issues where the benefits of future stormwater infrastructure would be greatest. The datasets used for this analysis consisted of:

- City-reported problem areas (CRM database)
- 2013 flood survey data
- Existing city GIS stormwater drainage system infrastructure data

The problem area subbasins were categorized as either Type A or Type B based on the following:

- Type A subbasins consisted of those containing a drainage problem reported directly to the City by residents.
- The Type B subbasins consisted of those having problems that were inferred from multiple observed instances of shallow, localized flooding and an observed lack of stormwater infrastructure but have not been explicitly reported to the City.

The following sections provide a description of both the data and how it was utilized to identify the Type A and Type B priority subbasins.

2.4.1 Type A Priority Subbasins

A summary of the problem areas was reported to City staff by residents was provided and was used to identify the Type A priority subbasins. This dataset consisted of problem areas as reported through the city's Customer Relationship Management (CRM) database. Specifically, the dataset was obtained in electronic form with information describing the location, approximate number of properties affected, and issues experienced for each of the reported problem areas. A georeferenced dataset was generated within the GIS based on the CRM address to provide a dataset with spatial reference.

All subbasins containing the City Reported Problem Areas and their tributary subbasins were identified as Type A priority subbasins for further analysis. Table 2.4.1 displays the information contained within the CRM dataset and Type A problem areas.

Table 2.4.1 – City Reported Problem Area Data

Problem ID	Location	Description of Issue
Wonderland Creek -1	Broadway - Rosewood to Violet	Lack of storm sewer on east side of Broadway from Fourmile Creek to Violet. Runoff continues across Violet and floods properties on south side of street.
Wonderland Creek - 2	19th & Sumac	Runoff from Sumac flows across 19th and inundates residences on east side of 19th which are below road grade. There is existing storm sewer on the N side of the intersection, however, runoff is predominantly on south side.
Elmers Twomile Creek - 1	3490 Catalpa Way	Catalpa way south of Clover Circle flows towards cul-de-sac where there is no storm system causing cul-de-sac and adjacent homes to flood.
Elmers Twomile Creek - 2	Iris Ave to Linden Ave and Broadway to Cloverleaf Dr.	Entire neighborhood drains to Farmer's irrigation ditch which becomes overwhelmed by the runoff during heavy rains and overflows into downstream properties.
Twomile Canyon Creek - 1	Kalmia and Juniper Ave west of Broadway	Streets have no curb and gutter and surface runoff collects in irrigation ditch laterals which parallel the roads. During heavy rains runoff overwhelms the laterals causing storm water to flood the homes in the downstream sections of the lateral near Broadway.
Goose Creek - 1	8th St and Dellwood Ave	Intersection is a collection point for neighborhood surface drainage. Even smaller storms overwhelm the existing storms ewers at this intersection and cause flooding of the roadway to the point that the crown of the road is several inches below water.
Goose Creek - 2	Alpine to Dellwood and 3rd to 7th St.	Steep slopes and inadequate existing storm sewer network causes high surface runoff flows. Homes at intersections are threatened from runoff jumping curbs and entering the homes. Many alley s have low points in the middle of the block meaning they collect runoff and send it through yards and homes. Steep slopes means heavy storms can cause hazardous conditions for pedestrians and due to the high velocity flows. Runoff from 3rd St collects at low point in 3rd St south of Cedar and then flows through yards and homes to the east.
Goose Creek - 3	Dewey from 4th St to 9th St	4th St from Maxwell to Dewey has insufficient inlets and surface runoff is moving too quickly to make it into the existing inlets. A lot of runoff from the hospital complex is also directed this way making the problem worse. Additionally there is a bottleneck (orifice plate) in storm sewer at 6th St and North St which backs-up the storm sewers causing street flooding.
Middle Boulder Creek - 1	Grandview Ave from 13th to 15th St	Street Drainage and storm sewer discharge to the hillside south of the Boulder High School football field. During heavy rains this runoff flows across the football field to Boulder Creek and damages the school property.
Bluebell Canyon Creek - 1	20th & Mariposa	Anderson ditch culvert under Mariposa is too tall which caused a crown perpendicular to the slope on the east side of the intersection. This crown acts as a dam and floods the intersection and adjoining properties.
Dry Creek No. 2 - 1	Chippewa Dr. and Caddo Pkwy east of Inca Pkwy	Grading of Chippewa Dr. and Caddo Pkwy is from south side of street to the north. During heavy rains all drainage flows on north side and overwhelms the inlets on the north side causing water to flood yards and garages.
Dry Creek No. 2 - 2	Erie Dr. & Pinon Dr.	Runoff from Erie Dr. flows N towards Pinon Dr. where Pinon acts as a dam and causes flooding of the intersection.

Dry Creek No. 2 - 3	Baseline Rd from Foothills Pkwy to 55th St and 55th St from Baseline Rd to Arapahoe Ave	The storm sewer system for western Frasier Meadows and Keewaydin Medaows (bounded by Baseline to South Boulder RD & Inca to 55th St) discharges to two large detention basins at the intersection of Baseline Rd and Foothills Pkwy. From the detention basins the storm water discharges to the west to an open drainage swale on the north side of Baseline. This swale flows to the west and discharges to Dry Creek Ditch #2. Dry Creek Ditch #2 conveys the storm water to the north along 55th St, through the flatirons golf course open space to South Boulder Creek. Several sections of the drainage swale and Dry Creek Ditch #2 are capacity limited and cause storm water to back up through the detention basins and into the upstream collection system.
Bear Canyon Creek - 1	1575 Stony Hill Drive	A 48" storm culvert was constructed in 1973 under Stony Hill Drive as part of the Devil's Thumb subdivision. The culvert was not built as specified on the plans and the outlet alignment is aimed at directly at some residences instead of down the creek bed. During heavy storms flow from the outlet can over-shoot the creek and flow directly into the nearest house. Additionally, the creek was not excavated as called out on the plans. Six homes may flood during heavy rainfall.
Viele Channel - 1	Longwood Ave and Lafayette Dr from Lehigh St to Greenbriar Blvd	Approximately 1.5 miles of roadway and residential drainage flows down Lafayette Dr. and Longwood Ave towards Greenbrier Blvd. There are no storm sewers to capture this runoff and there is insufficient street capacity for the volume of flow. Runoff frequently floods sidewalks and creates hazardous conditions due to the steepness of the road and the velocity that the runoff achieves. The problem is exacerbated by the pitch and crown of the roads which causes almost all runoff to flow on the north side of Longwood Ave.

2.4.2 Type B Priority Subbasins and 2013 Flood Survey Data

This portion of the analysis utilized a city GIS dataset describing location of reported flooding occurrences during the 2013 flood. To focus the review on the local and collector drainage system, the dataset was screened to represent data for only the shallow and localized flooding. The dataset screening used the 2013 flood extent polygon layer to filter out data points attributed to Major Drainageway flooding as was prevalent during the 2013 event. The resulting dataset was intended to represent rainfall induced flooding within the local stormwater drainage system.

Upon review of the flooding descriptions with the resulting local flooding dataset, the following general observations were made:

- A majority of the initial data set was a direct result of local and collector system drainage issues and not impacted by the major drainageway flooding issues.
- Some data points, outside the surveyed major drainageway flood extents were still related to impacts created by the major drainageways.
- Some data points were a result of major drainageway spill locations where floodwaters were conveyed within the street system, local storm sewer, and collector storm sewer networks.
- Flooding impacts from many of the data points can be attributed to irrigation ditch systems overflowing into the local and collector drainage systems.
- Some data points were a result of steep hillsides from open space or similar open lands draining into private properties.

Even though the local flooding dataset has some inconsistencies (damage type comments or flood depth comments not correlating to other dataset information), the majority of the points provide a good representation of impacts resulting from local and collector system conveyance issues. This was validated in several instances where the local flooding data points were within a CRM reported problem subbasin or adjacent to a modeled collector storm sewer system problem area. Given the correlation between local flooding dataset, CRM reported problem areas, and collector system model results, the following criteria were used to identify Type B subbasins based on flood survey data:

- Subbasins containing more than three locations of local flooding points (outside the 2013 flood extents polygon).
- Subbasins with a density of 0.3 observations/acre and greater.

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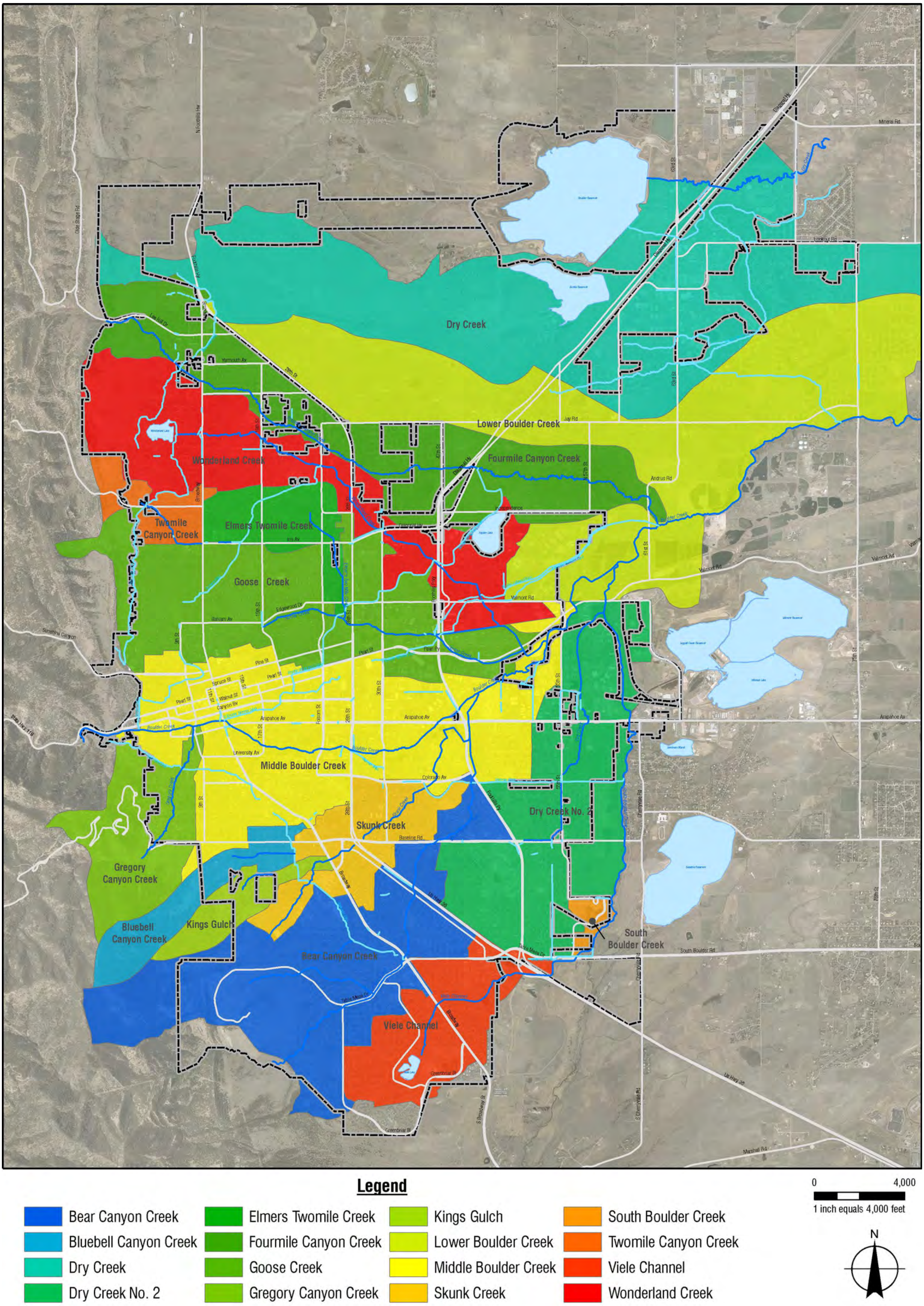
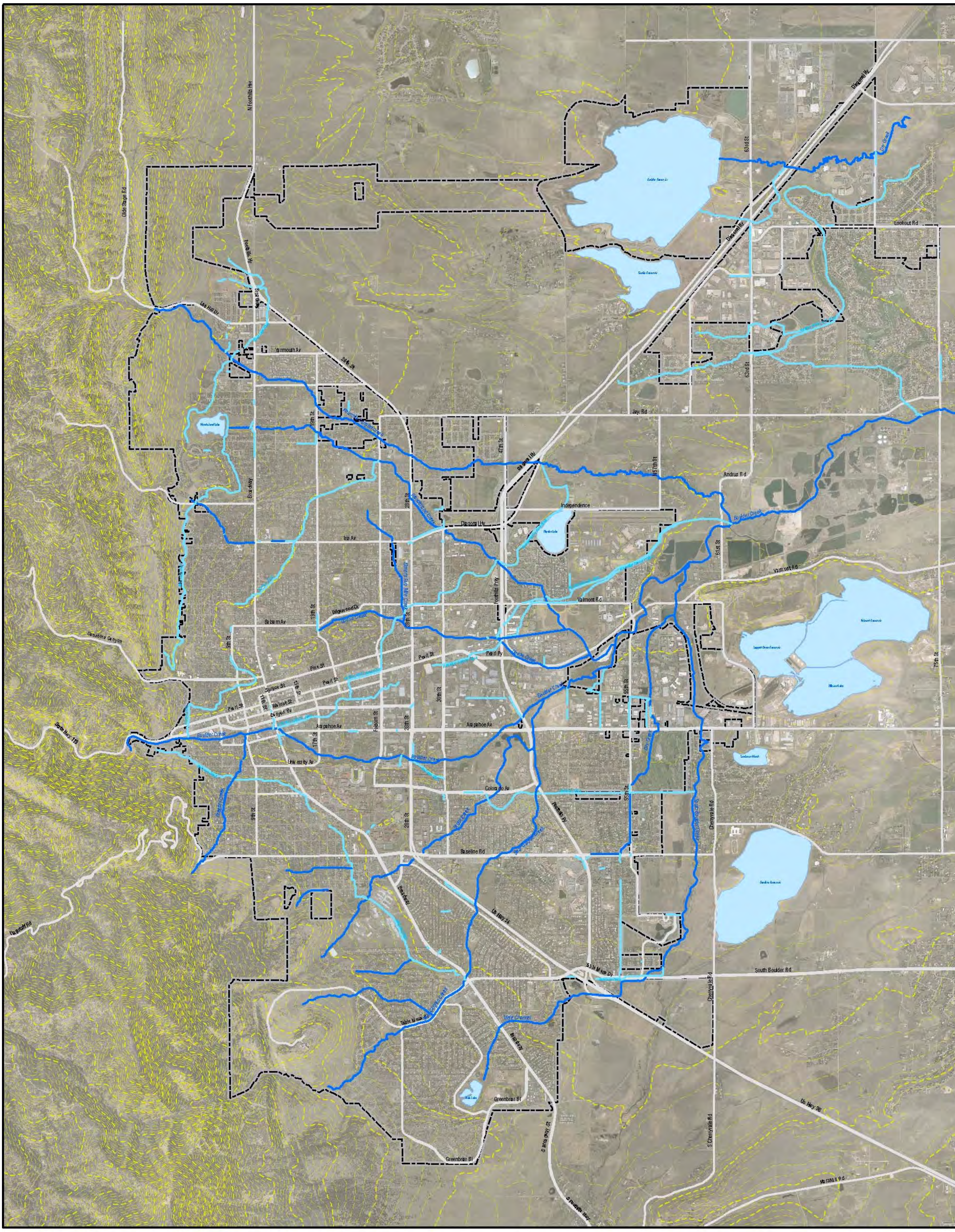


Study Area Subbasins

Figure 2-1



Legend

- Canal/ Ditch
- Major drainageway
- Major Roads
- City Limits
- Lakes
- Major (200')
- Minor Contours (40')

0 4,000

1 inch equals 4,000 feet

N

Existing Contours and Major Drainageways

Figure 2-2

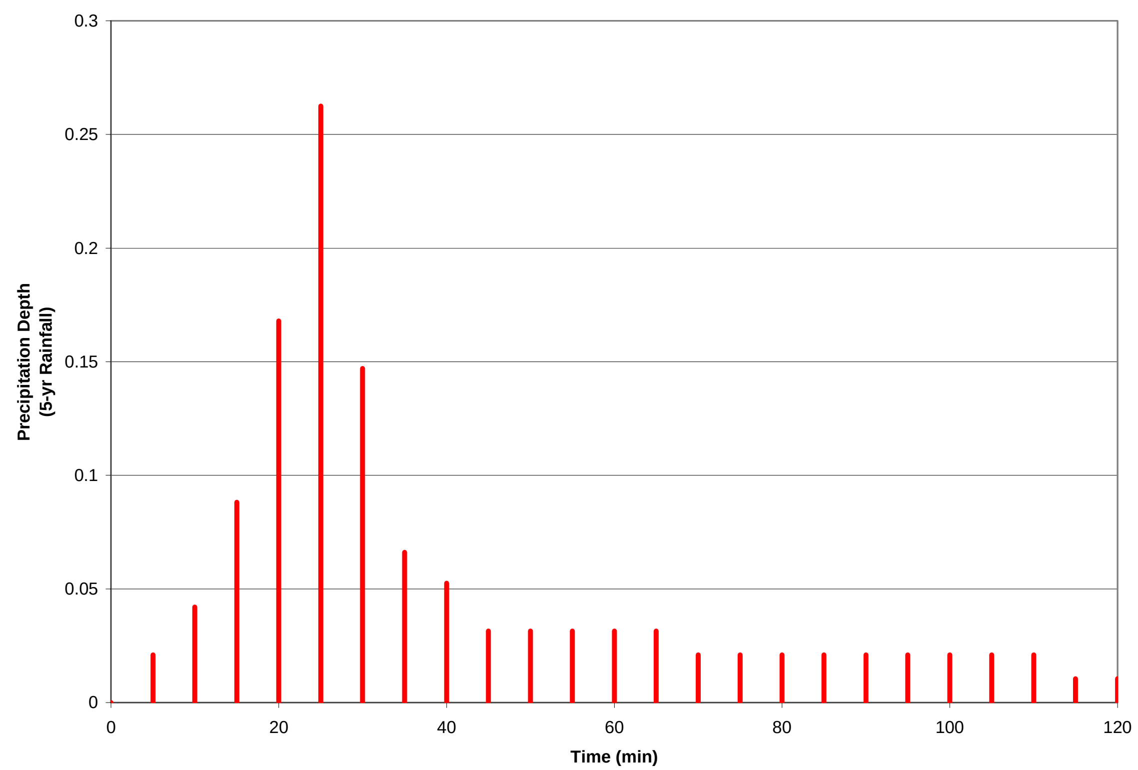


Figure 2-3. 2-yr Event

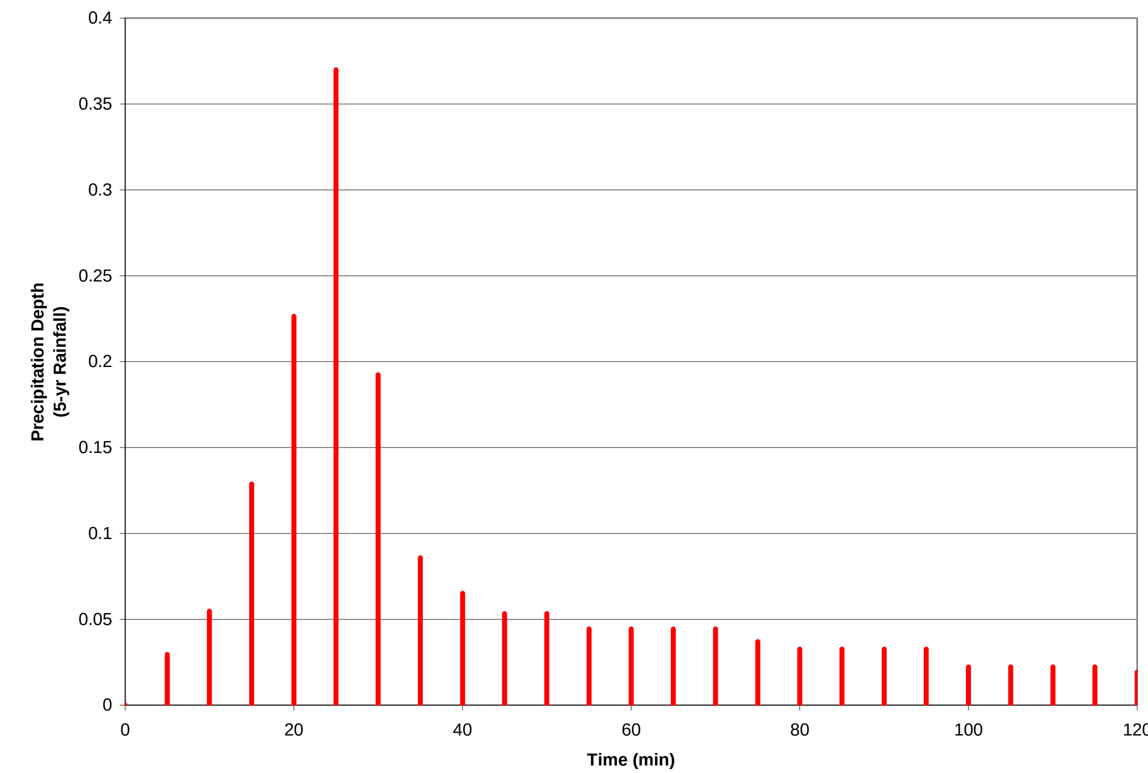


Figure 2-4. 5-yr Event

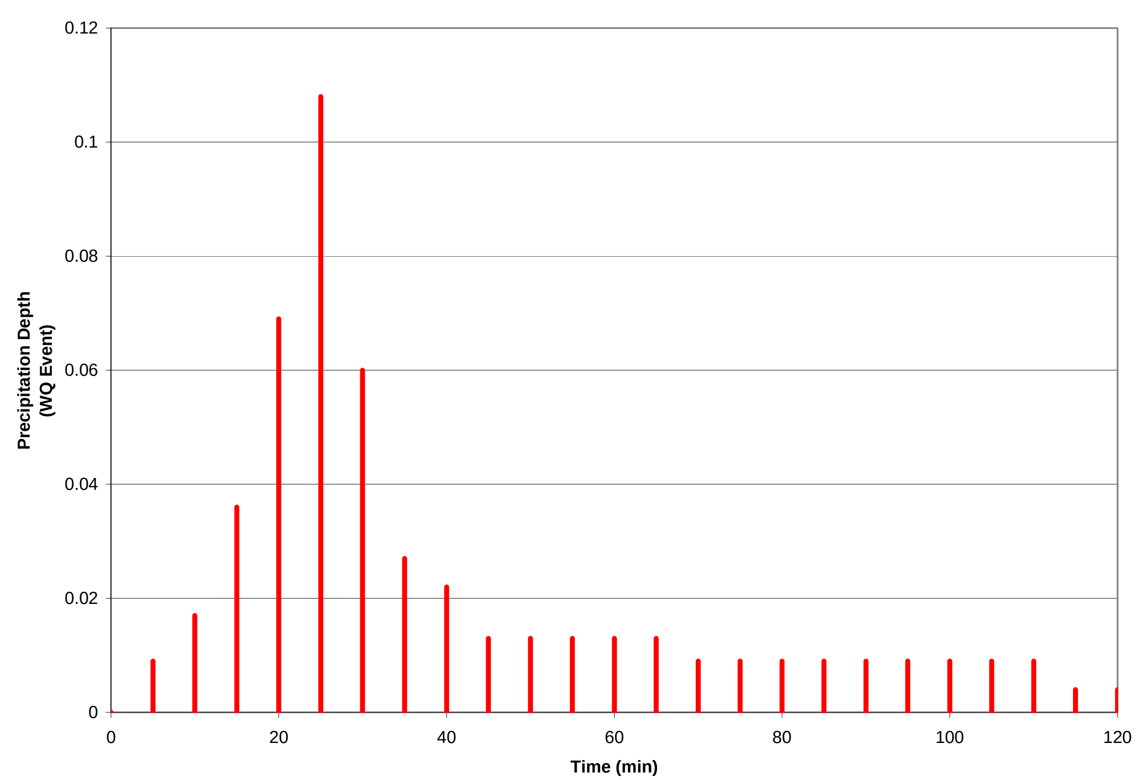


Figure 2-5. Water Quality Event

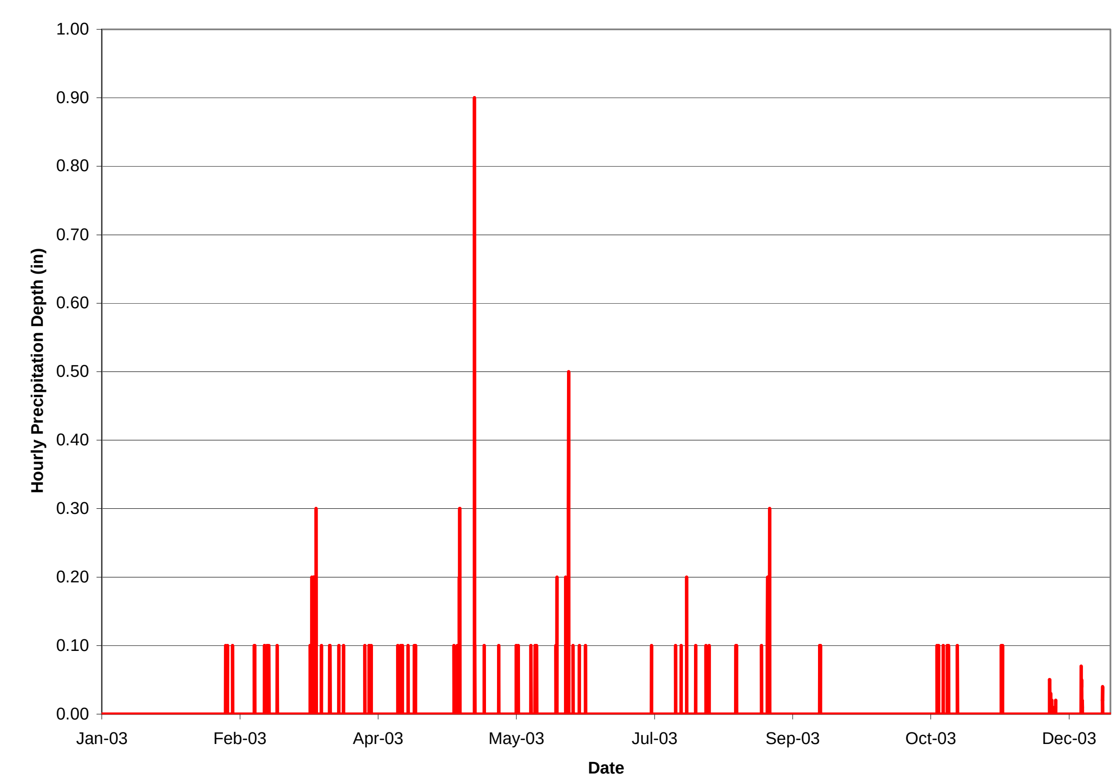
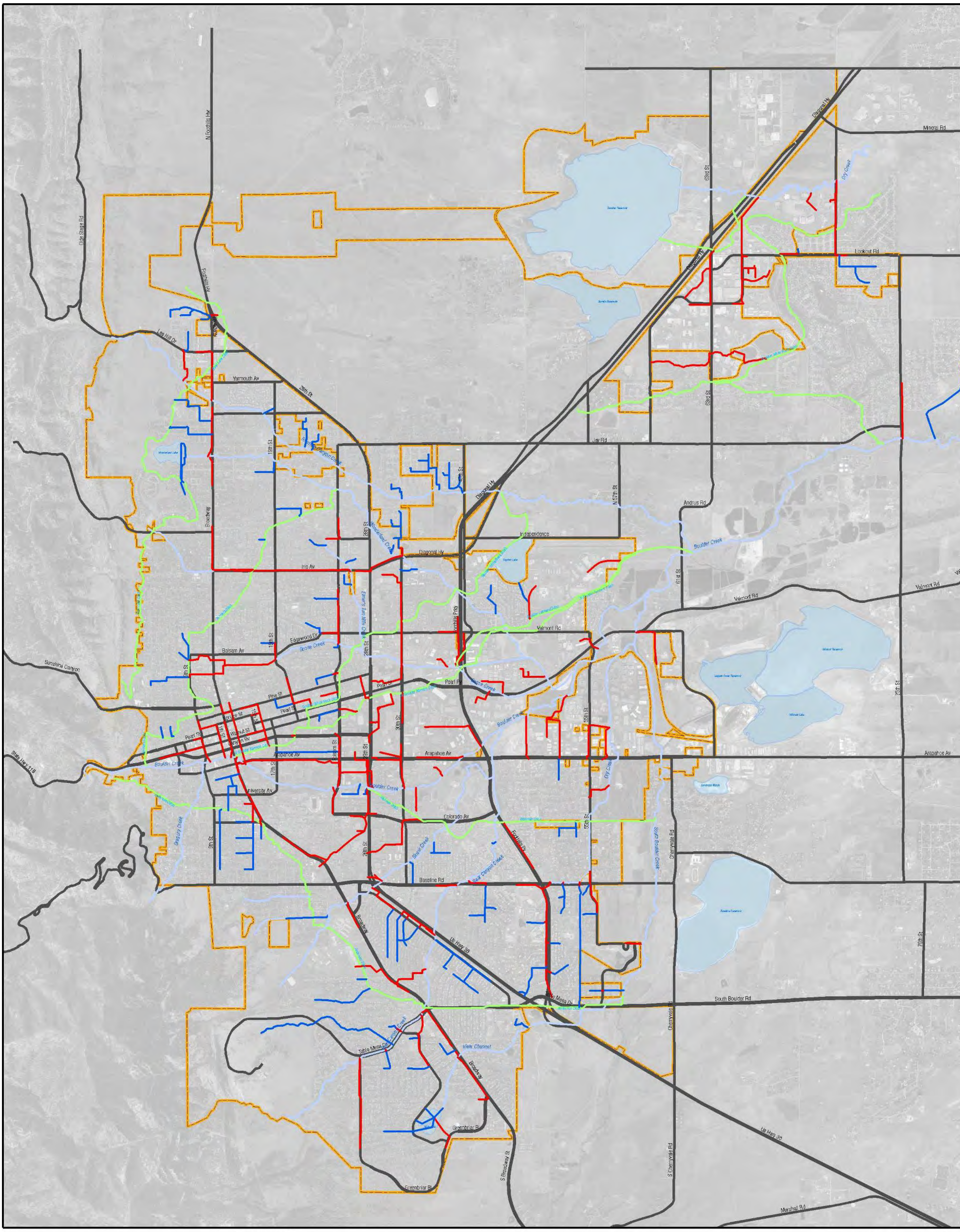


Figure 2-6. Annual Event

Design Storm Hyetographs (2- and 5-yr, Water Quality and Annual Events)

Figure 2-3



Legend

Storm Classification

- Major Drainageway (not modeled)
- Irrigation Canals (2-yr Storm)
- Storm Drain (2-year Storm)
- Storm Drain (5-year Storm)
- Collector, Arterial or Highway
- Lakes
- CityLimits

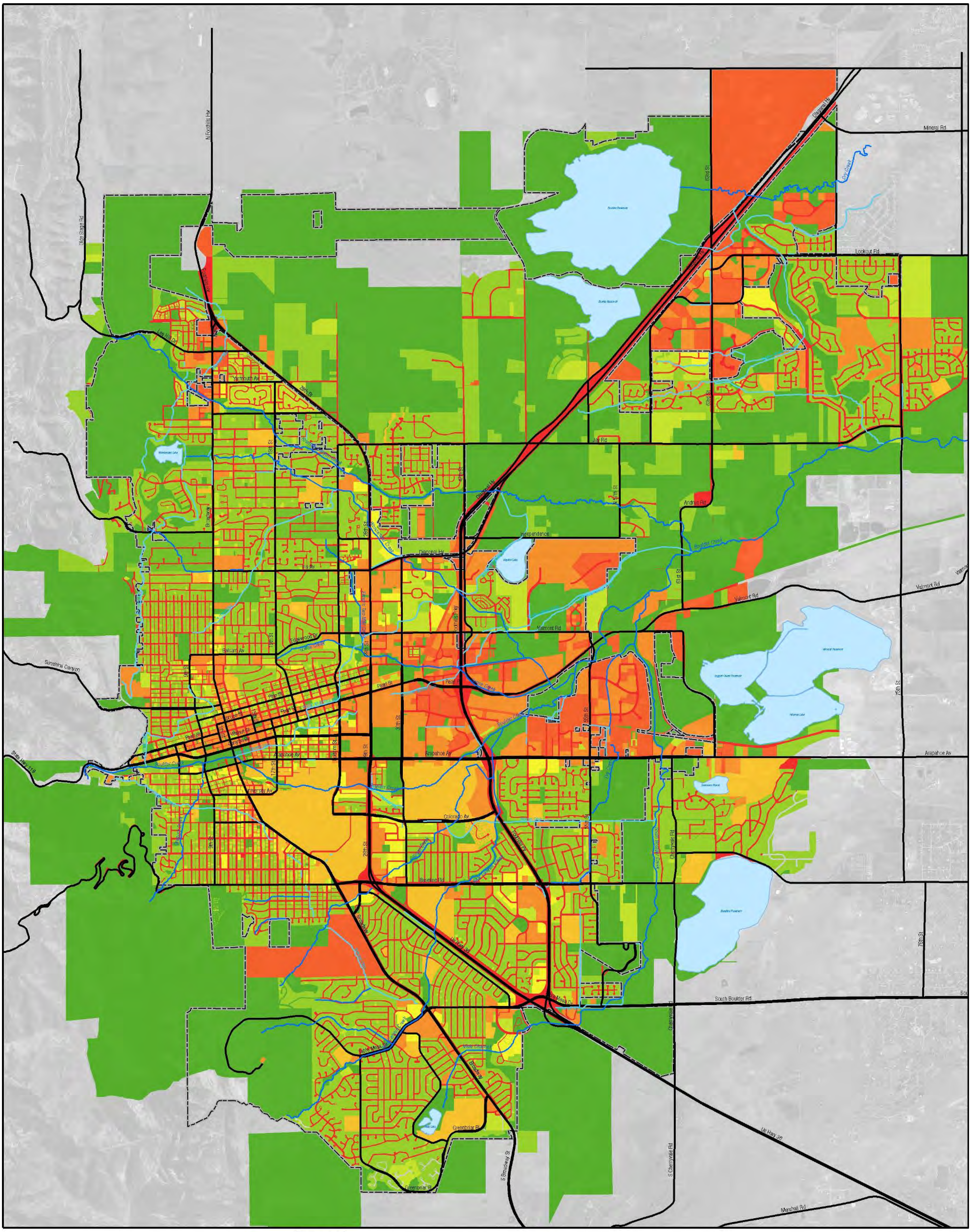
0 1,0002,000 4,000

1 inch equals 4,000 feet

N

Collector Storm Sewer System
Design Storm Criteria

Figure 2-4



Legend

- Open Space (OPEN)
- Rural Residential (RR)
- Low Density Residential (LDR)
- Mediam Density Residential (MDR)
- High Density Residential (HDR)
- Educational (EDU)
- Commercial (COM)
- Industrial (IND)
- Right-of-Way (TRANS)
- Major Roads
- Lakes
- City Limits
- Ditches
- Major Drainageways

0 4,000

1 inch equals 4,000 feet

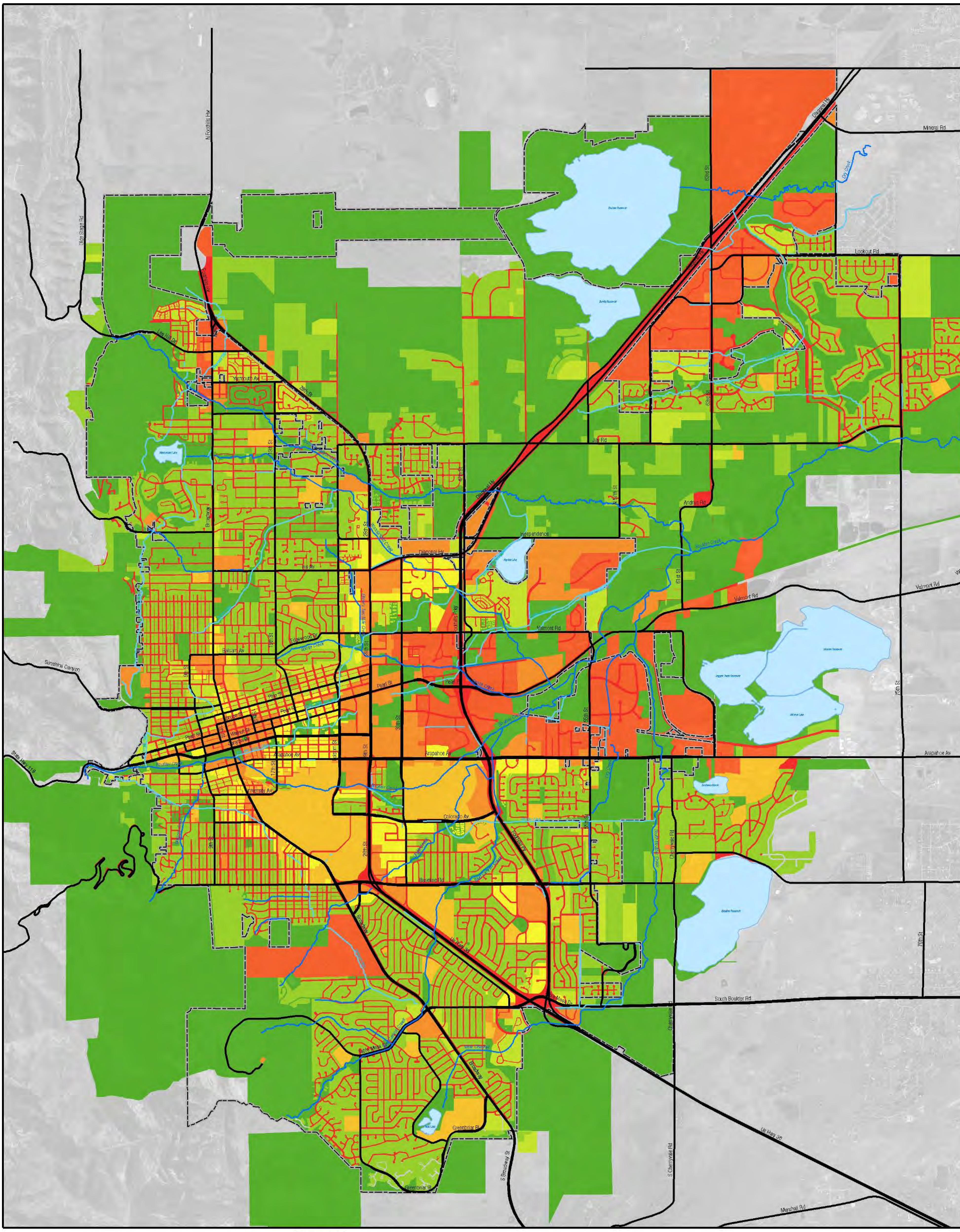
N

Existing Land Use Map

Figure 2-5

HDR

ONE COMPANY | *Many Solutions*℠



Future Land Use Map (Boulder Comprehensive Plan)

Figure 2-6

3 Model Development

The 2007 SMP modeling approach integrated ArcGIS as a pre- and post-processing tool with an EPA-based stormwater management model (SWMM) as the hydrologic, hydraulic and water quality analysis tool. A software review comparing EPA-SWMM to XPSWMM was included in the 2007 SMP. Resulting from this review, it was determined that XPSWMM provided a more efficient means for pre- and post-processing data for ArcGIS integration, better water quality analysis tools, and compatibilities for 2-dimensional analysis. XPSWMM was therefore selected as the modeling platform for the SMP.

Since the 2007 SMP, the city has continued to use XPSWMM, integrated with ArcGIS, to conduct hydrologic and hydraulic analyses for the stormwater drainage system. Boulder has invested significant time and resources into the development and maintenance of the hydrologic, hydraulic, and water quality components of the current model in combination with the supporting ArcGIS data. As a result, XPSWMM (Version 2014) was selected as the model platform for the 2016 SMP Update.

This section presents the development and verification of the stormwater hydraulic model from the 2007 SMP and updates to the model associated with the 2016 SMP analysis.

3.1 Data and Basis of Model Construction

Workflow for model development began in GIS, where the input parameters for XPSWMM were pre-processed. Data were transferred out of ArcGIS to XPSWMM, for the evaluation of the system hydraulics and potential improvements. Model results were ultimately brought back into ArcGIS for post processing and storage for future reference by the city. The following section describes the approach in more detail.

The primary sources of data used in this master plan originated from 1) the city's GIS database, 2) supplemental field survey data collected in 2006 by Merrick & Company, 3) the city's 2' contour data and associated digital terrain model (DTM), 4) previous storm sewer and flood studies completed for the city, and 5) discussions with city staff.

Of the city's original manhole database, there were 541 manholes missing invert or ground elevation data. Supplemental field survey collected 383 of those 541 data gaps. Of the remaining 158 data gaps, interpolation from the surrounding manholes was required to populate invert elevations, and rim elevation were extracted from the city's DTM. These data were not considered critical to the overall master planning analysis and primarily used to enhance the model results.

All other elevation data used in the analysis was derived from the city's 2' contour data and DTM. This included manhole rim elevations; ditch, channel and drainageway cross-sections; and pond/lake area-volume relationships. Due to the lack of actual field survey information for these areas, city staff visually compared several irrigation ditch cross-sections as a means to confirm the contour data's accuracy for the purposes of this study. Therefore, it should be noted the data used for the open channel analysis is relatively coarse as compared to the storm sewer and manhole data.

3.2 Hydrologic and Hydraulic Model

This section presents the data requirements and approach for construction of the existing conditions model, the model validation approach, and future condition model construction as developed with the 2007 SMP.

3.2.1 Existing Condition Model Construction

The hydrologic (rainfall-runoff) and hydraulic (routing) portions of the analysis and are summarized in the following sections.

Hydrologic Parameters

Modeling the rainfall-runoff process in XPSWMM involves a series of steps to determine appropriate model parameters in GIS prior to model execution.

Subcatchment Boundaries

One of the key tasks in building a hydrologic model is to allocate flows from individual subcatchments to their respective conveyance element. In addition, the spatial arrangement between these subcatchments in the model must represent ground conditions. Gridded elevation data, (provided by the city as a DTM), was processed using GIS software to initially examine the topography of each catchment. For areas with significant relief, the GIS delineation was used directly. Irrigation ditches and roadways were used to delineate subcatchment boundaries. For areas where topography alone could not accurately delineate the subcatchment boundary, aerial photos and the existing drainage network map were also reviewed and the subcatchment boundaries were adjusted manually. Ultimately, approximately 590 subcatchments were used to delineate the existing condition stormwater drainage system (Figure 3-1). It should be noted that some of these subcatchments were redefined as a part of the recommended system improvements based on storm sewer extensions or other similar recommendations.

Basin Width

Basin width represents the physical width of overland flow and is a variable in determining the time lag between peak precipitation and peak runoff. The basin width parameter was calculated by dividing the length of the longest flow path by the subcatchment area. Flow path length was determined as the distance from the upper-most point in the subcatchment, along the overland flow and stormwater conveyance path, and ending at the most downstream point in the subcatchment.

Slope

Subcatchment slope also influences the runoff travel time and resulting hydrograph shape. Subcatchment slopes were determined by intersecting the longest flow path length with the city's DTM data and then dividing the total elevation difference by the flow path length.

Impervious Percentage (Existing Conditions)

The existing conditions impervious data were developed to represent 2006 land use conditions. The existing impervious percentages for each subcatchment were determined by overlaying the subcatchments with the city's impervious area database (Figure 3-3) and determining a weighted average for each subcatchment. The existing impervious percentage across the city was calculated to be 32.3% and is graphically shown by subcatchment on Figure 3-4.

In addition to developing individual impervious percentages for each subcatchment, it was also necessary to estimate impervious percentages by land use to be used as a baseline for the future conditions analysis. This was accomplished by combining 1) the city and county parcel maps, 2) a set of lookup Tables that link building and land classification with nine generalized land use categories and 3) the impervious area database provided by the city.

The results of this analysis are listed below in Table 3.2-2 and compared to the original 1984 Stormwater Master Plan as well as the published impervious percentages recommended in the 2005 UDFCD Urban Storm Drainage Criteria Manual, Volume 1. In general, the impervious area database results are uniformly lower as compared to the other references.

Table 3.2-1: Comparison of Impervious Percentages

Land Use	Description	Impervious Percentages			Land Use Distribution w/in City
		1984 Master Plan	2005 UDFCD Manual	2005 Aerial Data	
RR	Rural Residential	34.0%	*	30.2%	1.3%
LDR	Low Density Residential	39.0%	*	31.5%	24.2%
MDR	Medium Density Residential	43.0%	67.5%	47.4%	4.8%
HDR	High Density Residential	58.0%	80.0%	57.6%	1.8%
COM	Commercial	88.0%	90.0%	64.5%	9.6%
IND	Industrial	70.0%	85.0%	44.9%	8.7%
EDU	Educational/College	25.0%	50.0%	38.5%	5.3%
OPEN	Open Space	5.0%	2.0%	7.3%	29.7%
TRANS	Transportation Right-of-Way	n/a	100.0%	70.3%	14.6%

* Variable depending on acreage and home type

Soil Infiltration

Infiltration is the process by which surface water percolates into the subsurface soil and groundwater column. Infiltration is an important hydrologic process because it governs groundwater recharge, soil moisture storage, and surface water runoff volume. As modeled in the XPSWMM runoff block, soil infiltration is one of several processes that represent a withdrawal of a portion of total storm precipitation that could otherwise generate surface runoff.

Information on soil types and characteristics within the city were compiled and grouped from the NRCS SSURGO dataset (Figure 3-2). Using GIS, the predominant hydrologic soil type in each subcatchment was identified. For each soil group, a set of Horton infiltration parameters including Max Infiltration Rate, Asymptotic Infiltration Rate and Decay Rate of Infiltration were assigned (Table 3.3.1) based on UDFCD guidance. The Horton infiltration method was used because parameters can be estimated from existing soil surveys without extensive field testing.

Table 3.2-2: Horton Infiltration Parameters

NRCS Hydrologic Soil Group	Infiltration (in/hr)		Decay Coefficient
	Initial	Final	
A	5.0	1.0	0.0007
B	4.5	0.6	0.0018
C	3.0	0.5	0.0018
D	3.0	0.5	0.0018

Other Hydrologic Parameters

In addition to the soil infiltration rates, impervious percentages, and subcatchment geometric parameters, XPSWMM also requires surface parameters that control the amount of immediate runoff and the rate of runoff from overland areas. There are three parameters required: depression storage, zero detention and Manning's "n".

DEPRESSION STORAGE

Depression storage defines the amount of rain that must fall before runoff can occur in a subcatchment. These values were assigned for pervious areas (0.35 inches) and impervious areas (0.1 inches) respectively, based on UDFCD guidance.

ZERO DETENTION

The zero detention parameter controls the amount (area) of a subcatchment that has immediate runoff, or the area that has no depression storage. Based on guidance in the XPSWMM users manual, this parameter was uniformly set to 10%.

MANNING'S ROUGHNESS

Manning's roughness, or "n", is used to calculate the time it takes for precipitation to be transformed to runoff. Higher values of Manning's "n" represent rougher surfaces like grass where runoff times will be delayed. Low values represent impervious areas such as roads or parking lots and produce higher peak flows with little or no runoff delay. These values were assigned for pervious areas (0.2) and impervious areas (0.03) respectively, based on guidance in the XPSWWM user's manual.

Hydraulic Parameters

The collector stormwater drainage system includes natural and manmade conveyance and storage elements (Figure 3-5). XPSWMM models these features together as a completed hydraulic system as defined by storm sewer and manhole geometric data, open channel geometry, storm sewer and channel roughness, and detention ponds. In addition to model data that represents the physical system characteristics, boundary conditions are also required to define initial flow conditions within the modeled system.

Storm Sewer and Manhole Data

The storm sewer pipe and manhole data used for model construction were developed from two sources. At the planimetric level, the city's GIS storm sewer and manhole data layers were used to develop a system schematic map. With this in hand, the existing manhole database, supplemented by additional field surveys made at each key manhole within the system, was used to determine manhole invert and rim elevations as well as pipe invert elevations. Generally, the 2007 collector storm sewer model excluded pipes less than 18" in diameter.

Open Channel Geometry

Open channel data, including major roadside ditches, irrigation ditches and major drainageways were extracted from the city's DTM. The DTM data was used to determine channel cross-sections as well as overall reach slopes. Roughness estimates for each open channel element were derived from the city's high resolution aerial photography. The stormwater model includes the major drainageways for model connectivity and definition of outfall hydraulics only; major drainageway capacities were not analyzed in this study.

Storm Sewer and Channel Roughness

Roughness characteristics for each model segment were assigned based on material and its' associated Manning's roughness coefficient, "n" according to Table 3.3-3.

Table 3.2-3: Manning's Roughness Values

ID	Description	Manning's "n"	Description
NAT	Natural Channel	Variable (0.025 – 0.08)	Chapter 7 (UDFCD Storm Drainage Criteria Manual)
BOX	Box Culvert	0.015	Assume Concrete: From Section 7.08 in Boulder D&C Standards
CIP	Cast In Place	0.015	Assume Concrete: From Section 7.08 in Boulder D&C Standards
CMP	Corrugated Metal Pipe	0.026	Handbook of Hydraulics, 7th Edition (Table 6.4)
CONC	Concrete Pipe	0.015	From Section 7.08 in Boulder D&C Standards
DIP	Ductile Iron Pipe	0.014	Handbook of Hydraulics, 7th Edition (Table 6.4)
NJP	Unknown	0.015	Assume Concrete
PPVC	Polyvinyl Chloride Pipe	0.013	From Section 7.08 in Boulder D&C Standards
PVC	Polyvinyl Chloride Pipe	0.013	From Section 7.08 in Boulder D&C Standards
RCP	Reinforced Concrete Pipe	0.015	From Section 7.08 in Boulder D&C Standards
VCP	Vitrified Clay Pipe	0.015	Handbook of Hydraulics, 7th Edition (Table 6.4)
UNK	Unknown Material	0.015	Assume Concrete

Detention Ponds

According to the city's GIS database used in the preparation of the 2007 SMP model, 713 detention ponds exist within the city limits (Figure 3-6). To account for this additional storage during the system modeling two methods were used; 1) for subcatchments with a relatively small storage volume as compared to the subcatchments area, the depression storage parameter was adjusted to account for the additional volume and 2) for individually larger facilities, or subcatchments that have a significant cumulative storage as compared to their area, a synthetic pond approach was used.

To determine the appropriate pond simulation method, the total storage volume within each subcatchment was calculated by intersecting the detention pond and subcatchment layers and summing the total storage volumes. This volume was compared to the total subcatchment area. If the ratio of the storage volume to the subcatchment area was less than 1815 cu-ft/acre (0.5 in/acre), then method 1 was used to simulate the collective effect of the detention ponds; otherwise, scenario

2 was used to simulate individual ponds. For method 1, the total storage volume was converted to an average depth across the subcatchment and added to the depression storage parameter. For method 2, the total storage volume was explicitly included as a detention pond and modeled with appropriate outlet conditions and stage-storage relationships derived from average conditions within the city.

In addition to incorporating the detention storage volume into the XPSWMM analysis, the performance of each facility was included. Based on a detention pond inventory completed by the city prior to the 2007 SMP, it was determined that 22% of all the existing facilities are either failing to the point of needing major rehabilitation (9%) or completely failed (13%) and requiring total replacement (Figure 3-7). To account for this trend under existing conditions, the volume of any storage facility within these two categories was removed from the total subcatchment storage. Under future conditions, any new storage volume being added to a subcatchment will be uniformly reduced by 22%.

Boundary Conditions

Boundary conditions are an important part of the system analysis criteria because they establish flows and water levels at the upstream and downstream limits of the city-wide hydraulic model.

UPSTREAM BOUNDARY CONDITIONS

Upstream boundary conditions include inflows for Boulder Creek and South Boulder Creek where they enter the city. These flows were set to the maximum mean monthly discharge as per USGS gauge records. These flows rates were deemed appropriate because it was assumed that 2- and 5-year rainfall events within the city would not occur simultaneously with large flow events in Boulder and South Boulder Creeks.

INTERIOR BOUNDARY CONDITIONS (IRRIGATION DITCHES)

Interior boundary conditions are represented in the Boulder SWMM model as constant diversion flows into the primary irrigation ditches within the city. The actual flow rates are based on five years of measured diversions (recorded as ac-ft over the irrigation season and converted to an average flow in cfs) in the ditches and represent a typical condition during the irrigation season. These interior boundary conditions were provided by the city for use in the system analysis.

DOWNSTREAM BOUNDARY CONDITIONS

The upstream and interior boundary conditions also effect the piped collector system at outfall locations to major the noted drainageways and irrigation ditches. By routing flows from the major drainageways and ditches in the hydraulic model, boundary conditions at each storm drain outfall are included in the model simulation and do not require an individual boundary condition.

At the downstream limit of the model (Boulder Creek at the eastern city limits), normal depth boundary conditions were applied. This condition establishes a variable depth based on the channel slope, geometry and roughness and the contributing discharge.

3.2.2 Model Validation Parameters and Results

Development of hydrologic and hydraulic models typically relies on a calibration process to verify that model results represent actual conditions within the study area. Calibration consists of adjusting a set of model parameters so that measured data (e.g., pipe flow, streamflow, rainfall) match the predicted runoff or flows from the corresponding model calculation. For the modeled stormwater sewer system, flow measurement data does not exist, and calibration could not be performed.

In lieu of calibration, a validation process was used to verify model accuracy in simulating hydrologic conditions within the basin. Validation of the Boulder XPSWMM model consisted of comparing the calculated peak flow and runoff volume results from the model at six selected locations within the city (Figure 3-8) to results from other analytical models. The analytical models used for validation were:

- The Colorado Urban Hydrograph Procedure (CUHP method)
- The USGS regional regression equations
- The City of Boulder 1984 Storm Water Master Plan SWMM model results

CUHP Method

The CUHP is a method of hydrologic analysis based upon the unit hydrograph principle. It has been developed and calibrated using rainfall-runoff data collected in Colorado (mostly in the Denver/Boulder metropolitan area) and is a standard procedure outlined in UDFCD criteria.

The CUHP computer program requires the input of a design storm and a set of hydrologic parameters that describe the subcatchment characteristics. The subcatchment characteristics include: area, flow path length, centroid flow path link, impervious percentage, basin slope, pervious and impervious depression storage and infiltration rates (Horton initial and final infiltration rate and the Horton decay rate). Table 3.3-4 summarizes these parameters for each of the six validation subcatchments.

Table 3.2-4: CUHP Validation Subcatchment Parameters

Basin ID	Area (sq-mi)	Flow Length (mi)	Centroid Length (mi)	Impervious Percent (%)	Slope (ft/ft)	Depression Storage[1] (in)	Horton Infiltration[2]
VAL_1	0.081	0.483	0.177	41.8	0.0627	0.35 / 0.1	5.0 / 1.0 / 0.0007
VAL_2	0.140	0.729	0.365	47.3	0.0478	0.35 / 0.1	4.75 / 0.8 / 0.0007
VAL_3	0.241	1.052	0.454	1.4	0.1559	0.35 / 0.1	4.75 / 0.8 / 0.0007
VAL_4	0.120	0.702	0.333	34.9	0.0084	0.35 / 0.1	3.0 / 0.5 / 0.0018
VAL_5	0.111	0.627	0.341	41.5	0.0169	0.35 / 0.1	3.0 / 0.5 / 0.0018
VAL_6	0.089	0.726	0.287	49.2	0.0112	0.35 / 0.1	3.0 / 0.5 / 0.0018

1. (A / B) A is pervious depression storage, B is impervious depression storage
2. (A / B / C) A is initial infiltration rate (in/hr), B is final infiltration rate (in/hr), C is decay rate

Table 3.3-5 compares the XPSWMM model results with the CUHP method for the 5-year event. The XPSWMM peak flow results are similar to the CUHP values for all catchments with the largest difference being approximately 14%. In terms of runoff volume, the average difference between the two calculation procedures for all six catchments is less than 2%. Such small differences between the two methods suggest the parameters used within the XPSWMM model are appropriate as validated by CUHP hydrology.

Table 3.2-5: Validation Results: 5-yr Peak Flow Summary

Basin ID	Runoff Volume (ac-ft)		Peak Flow (cfs)	
	XPSWMM Model	CUHP	XPSWMM Model	CUHP
VAL_1	2.87	2.39	57.2	62.8
VAL_2	5.97	5.23	105.6	115.0
VAL_3	0.49	0.75	11.7	13.6
VAL_4	4.91	4.54	74.8	73.5
VAL_5	4.41	4.98	90.4	96.0
VAL_6	3.98	4.42	69.9	79.9

Regional Regression Method

The USGS Regional Regression equations present another method for verifying peak discharges in the stormwater drainage system. The Colorado Plains region-specific regression equations were selected to provide a statistical approximation of peak runoff from the selected subcatchment within the city. It should be noted that because the regional regression equations are intended for subcatchments significantly larger that those within the Boulder city limits, the following results should be considered for comparison purposes only.

Table 3.3-6 compares the XPSWMM model results with the regional regression method for the 5-year event. In general, the two methods compare reasonably well to one another. With the exception of basin VAL_3, which has nearly no impervious cover and very permeable soils, peak flow results from the remaining five basins are within 20% for the two methods. This is well within the standard error range of the regional regression equations (± 34%) and supports the validation of the XPSWMM model.

Table 3.2-6: Validation Results: 5-yr, 1-hr, Peak Flow Summary

Basin ID	Peak Flow (cfs)	
	XPSWMM Model	Regional Regression
VAL_1	57.2	71.8
VAL_2	105.6	89.4
VAL_3	11.7	111.0
VAL_4	74.8	84.0
VAL_5	90.4	81.5
VAL_6	69.9	74.6

1984 City of Boulder SWMP

The 1984 City of Boulder Storm Water Collection System Master Plan modeled runoff for Boulder using EPA SWMM software. As a part of the 1984 study, the EPA-SWMM model results were verified using the CUHP program to produce SWMM flood peaks to within 15% of the CUHP results.

The results from the XPSWMM model and the 1984 SWMP are similar, but because the contributing areas vary between the two studies, a direct comparison of peak flows is not possible. Rather, a unit discharge comparison was also performed using data referenced in the appendix of the 1984 SWMP. Figure 3-9 displays the unit discharge vs. percent impervious for the 5-year, 1-hour event with the data points from the XPSWMM model plotted to show their conformance to the established discharge/impervious area relationship. The XPSWMM values are similar to the 1984 EPA-SWMM result, illustrating the similarity between the two data sets.

3.2.3 Future Condition Model Construction

The future conditions model represents a fully developed urban area according to the 2006 BVCP. This scenario represents the worst case from a stormwater perspective because it encompasses the maximum planned level of development and the corresponding highest level of imperviousness.

Impervious Percentage (Future Conditions)

In a similar method to that outlined for existing conditions, a unique impervious percentage was assigned for each catchment. Instead of directly calculating an impervious percentage from the impervious area database, the individual percentages were determined by joining the project parcels dataset with the average impervious percentage for each general land use and intersecting that with the subcatchment coverage to establish a future net impervious percentage for each subcatchment (Figure 3-10). City-wide, the future impervious percentage was estimated to be approximately 33%. Table 3.3-7 provides a summary of the calculated future condition imperviousness percentages by land use.

Table 3.2-7: Future Condition Imperviousness by Land Use

Land Use	Description	% Impervious	Land Use Distribution w/in City
		30.2%	1.3%
LDR	Low Density Residential	31.5%	24.2%
MDR	Medium Density Residential	47.4%	4.8%
HDR	High Density Residential	57.6%	1.8%
COM	Commercial	64.5%	9.6%
IND	Industrial	44.9%	8.7%
EDU	Educational/College	38.5%	5.3%
OPEN	Open Space	7.3%	29.7%
TRANS	Transportation Right-of-Way	70.3%	14.6%

* Variable depending on acreage and home type

3.3 Water Quality Model

The primary goal of the water quality model development and analysis was to identify areas within the city having comparatively high pollutant concentrations and/or loads. With this information, locations of BMPs or capital projects were targeted throughout the city to maximize the system-wide water quality benefit.

The water quality analysis was incorporated into the XPSWMM model by estimating the washoff and transport of pollutants in stormwater runoff, pollutant removal by existing BMPs, and calculations of annual pollutant loadings into the city's receiving waters. The following section describes the modeled constituents, event mean concentrations, and incorporation of existing quality facilities within XPSWMM.

3.3.1 Modeled Constituents

The stormwater quality analysis modeled five water quality constituents: total suspended solids (TSS), total phosphorus (P), and three metals – lead (Pb), copper (Cu), and zinc (Zn).

Total Suspended Solids

Total Suspended Solids (TSS) represents the amount of suspended organic and inorganic matter in the runoff. It includes all sediments and other constituents that are attached to the sediments or suspended in the water column itself. TSS is also a frequently reported parameter as a surrogate for other stormwater pollutants, including metals, nutrients, and various organic compounds.

Total Phosphorus

Phosphorus (P) is a relatively common element that is found uniformly throughout land uses as it is widely used in fertilizers and pesticides and as a cleanser. Phosphorus is also found to occur naturally in soils and groundwater.

Metals

Metals such as Lead (Pb), Copper (Cu) and Zinc (Zn) are relatively common in urban storm runoff. Lead is often found in paints used on older homes. Zinc is found on roadways due to its use as a galvanizing agent on automobiles and metal structures and is also used in tires and oil. Copper is a commonly used metal in electrical wires, paints, and in several automobile applications (such as brakes and wires).

3.3.2 Event Mean Concentrations

Event mean concentration (EMC) values are the typical concentrations in stormwater runoff for a particular land use and provides an industry standard method to model land-use-based water quality constituents in XPSWMM. EMC values were determined for industrial, commercial, residential, undeveloped and transportation land use categories through a review of the UDFCD Drainage Design Criteria Manual and other applicable reference documents (Table 3.4-1).

To incorporate these parameters into XPSWMM, the percentage of each land use category was determined using GIS for each individual subcatchment, and the model determined the corresponding net pollutant concentration for each subcatchment.

Table 3.3-1: Event Mean Concentrations (EMC) Values

Constituent	Land Use				
	Industrial	Commercial	Residential	Undeveloped	Transportation
Total Suspended Solids, TSS (mg/L)	399	225	240	400	150
Total Phosphorus, P (mg/L)	0.43	0.42	0.65	0.40	0.376
Copper, Cu (μg/L)	84	43	29	40	28
Lead, Pb (μg/L)	130	59	53	100	8
Zinc, Zn (μg/L)	520	240	180	100	197

1. Data source for all land uses except transportation: UDFCD Drainage Design Criteria, Volume 3.
2. Data source for transportation: Analysis of Oregon Water Quality Monitoring Data (ACWA, 1997).
3. mg/L = milligrams per liter. μg/L = micrograms per liter.

3.3.3 Existing Water Quality Facilities

Within the city, there are generally two different categories of water quality facilities. The most predominate facility type is the detention pond; there are numerous detention ponds located throughout the city. The other common facility type is the proprietary BMP, which is often referred to as a "water quality manhole."

Detention and Water Quality Ponds

According to the city's stormwater facility database used with the 2007 SMP analysis, 713 detention ponds exist within Boulder. Although not all off these ponds were originally designed with water quality treatment in mind, some level of pollution reduction can be expected at nearly all functioning facilities. This is due to storage volume and drawdown time, and the tendency for pollutants to settle out of suspension in this environment.

For all but the largest detention ponds, the depression storage concept was used. Depression storage reduces the net runoff and pollutant loads from each catchment by uniformly subtracting the total storage volume and associated pollutant loads within that catchment from the runoff hydrograph. For the larger facilities, each was modeled explicitly, with as-built stage-storage-volume curves, actual outlet structure configurations, and pollutant removal percentages as shown below in Table 3.4-2. Although the approach used draws upon the significant data within the stormwater facility database, the lack of detailed information regarding the design of individual detention ponds is a limiting factor.

Proprietary BMPs

Within the city, four sites exist where proprietary BMPs have been installed as a water quality treatment device. Each PRF was modeled explicitly in XPSWMM to account for pollutant removal efficiency as well as treatment and bypass flow capacities. The type, size and location of each PRF are described below in Table 3.4-3 with their associated pollutant removals listed in Table 3.4-2.

Table 3.3-2: BMP Pollutant Removal Efficiencies

BMP Type	Design Flow Rate (cfs)	Removal Efficiency (%)		
		Total Suspended Solids (*TSS*)	Total Phosphorus (*P*)	Metals (Lead, *Pb*; Zinc *Zn*; Copper, *Cu*)
Detention Ponds[1]	n/a	50%	30%	30%
Vortechs 3000	4.5	80%	50%	25%
Stormceptor 6000	1.8	80%	50%	50%
Stormceptor 11000	3.5	77%	50%	50%
Stormceptor 13000	3.5	71%	50%	50%

1. Removal efficiencies are for synthetic ponds. All other detention ponds remove pollutants through depression storage, which completely removes runoff volume in the simulation.

Table 3.3-3: Proprietary BMP Locations

Location	Description
14th Street at Fourmile Canyon Creek	Two Vortechnics Vortechs 3000 units.
29th Street Mall	Two Stormceptor units. One located at the north end of the 29th Street Mall (STC 13000) and one located at the south side of the 29th Street Mall (STC 11000).
Broadway at Boulder Cr	A single Stormceptor 6000 unit located at Broadway and Boulder Creek.

3.4 2016 SMP Model Updates

The model developed for the 2007 SMP was used as the basis for the 2016 SMP analysis. The model updates associated with the local system analysis for the 2016 SMP include the following:

- Upgrade the XPSWMM model to software Version 2014
- Update the existing condition model with post 2007 SMP projects
- Revise subcatchments and update based on local system analysis problem areas and update hydrology parameters based on 2007 SMP existing condition land use and revised subcatchment geometry.
- Update future condition hydrologic model based on 2007 SMP future condition land use scenario.
- Update the future condition hydraulic model of the 2007 SMP recommended improvements to include proposed local system improvements

This SMP uses the model files developed for the 2007 SMP as the base for updating both the existing conditions and the future conditions/recommended plan models. Since a thorough model validation process was conducted as part of the 2007 SMP, no further model validation was conducted.

3.4.1 Post 2007 SMP Project Updates

The 2016 SMP existing conditions and recommended plan models were updated to reflect storm sewer improvements constructed since the completion of the 2007 SMP. This included updates to both the hydrologic and hydraulic aspects of the model resulting from the following storm sewer improvements:

- Arapahoe Avenue, 15th Street to Folsom Street

  As-built drawings were used to update the storm sewer elements on the model since the city's GIS did not contain this data at the time of the analysis. The as-built drawings were georeferenced into ArcGIS and conveyance features were digitized in to ArcGIS. Relevant hydraulic information was then attributed to the specific features within the ArcGIS database and directly imported into the model. Subcatchment boundaries from the 2007 SMP correlated well with system manholes and were therefore not re-delineated.

- North Broadway Street, Iris Avenue to Balsam Avenue

The 2014 storm sewer infrastructure ArcGIS database was used to update the portion of storm sewer system within Broadway Street from Iris Avenue to Balsam Avenue. Manhole rim elevation and pipe invert elevation data was contained within the GIS data. Subcatchment boundaries from the 2007 SMP correlated well with system manholes and were therefore not re-delineated.

- Iris and North Broadway Intersection Improvements

  The 2014 storm sewer infrastructure ArcGIS database was used to update the portion of storm sewer system in the Iris/Broadway intersection that conveys runoff from the Two-mile Canyon Creek open channel west of Broadway. These improvements discharge to the open channel along the north side of Iris and are conveyed to the east.

- Anderson Ditch Inlet at Kohler Drive

  The stormwater drainage inlet improvements with this project did not result in changes to the hydraulic model. During the design of the inlet improvements, the subcatchment delineation was re-evaluated and modifications made. These revisions were incorporated into the 2016 SMP model.

3.4.2 Model Updates for Local System Analysis

Updates to the hydrologic and hydraulic portions of the 2007 SMP Recommended Plan model were required to conduct a representative hydraulic assessment of selected local system problem areas and size associated system improvements.

The updated subbasin boundaries result from storm sewer extensions or other system modifications needed to analyze city-identified local system conveyance problem areas. Of the 590 subcatchments from the 2007 SMP, the updates resulted in approximately 50 subcatchments being modified. For the re-delineated subcatchments, values for basin area and slope were re-calculated. Note the modified subcatchments were verified to have very similar characteristics to the larger area from which they were re-delineated/derived. Therefore, model inputs for modified subcatchments associated with infiltration, impervious percentage, zero detention, and Manning’s roughness for overland flow were not recalculated as part of this effort and were attributed to the 2007 SMP subcatchments from which they originated.

3.5 2006 and 2011 Boulder Valley Comprehensive Plan Land Use Comparison

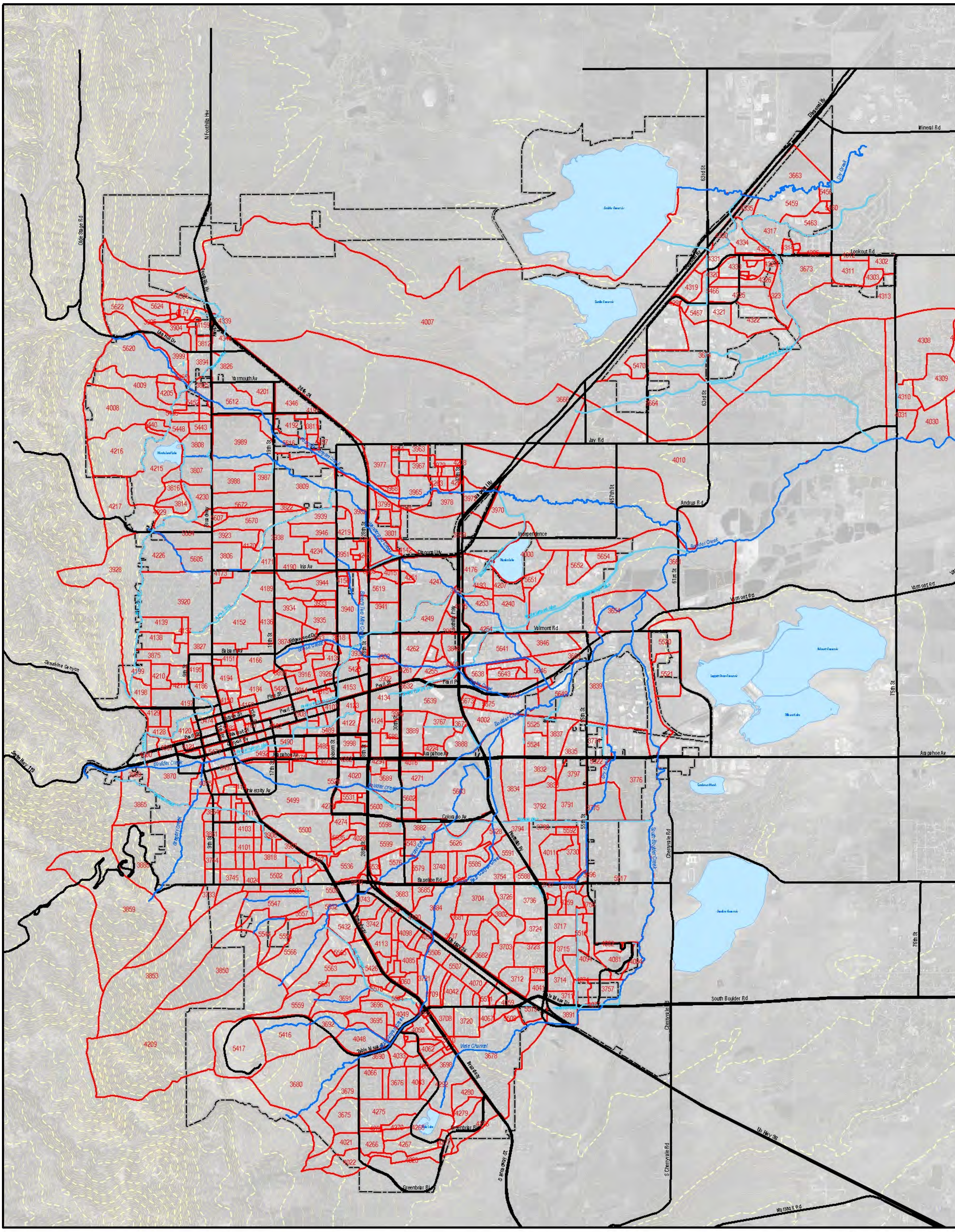
The impervious percentage used in 2007 SMP model was based on future condition land use as defined by the 2006 BVCP. With the 2016 SMP, a comparison of projected land use differences between the 2006 and 2011 BVCP was performed. These differences in land use are discussed in terms of their impact on the resulting impervious percentage. Land use imperviousness affects both the quantity (volume and peak) and quality of water being routed though the stormwater collection system. The more impervious the area, the less water that will be infiltrated on the landscape, the more water that will generally runoff into the stormwater collection system, and the faster the water will be routed to the storm water collection system (due to the lower surface roughness of the ground). Consequently, an area with a higher percentage of impervious surfaces will produce higher peak flows and greater volumes of runoff over a shorter period of time than a similar area with a lower percentage of impervious surfaces.

The 2011 BVCP contains similar land use definitions as the 2006 BVCP. These land use definitions, the associated parcel land use classifications, and average impervious percentages were used to compare the 2006 to the 2011 BVCPs. Based on this analysis, the following observations were made:

- Of the 39,020 parcels in the modeling area, there are 370 parcels that are impacted by the BVCP change from 2006 to 2011 (roughly 1 percent of the parcels), with 210 parcels having a land use difference that indicate a decrease in impervious percentage and 160 parcels having a land use difference that indicate an increase in impervious percentage.
- Of the 22,880 acre modeled area, the total parceled area that saw decreases in impervious percentages between the 2006 and 2011 BVCPs is equal to approximately 48 acres (roughly 0.2 percent) while the total parceled areas that saw increases is equal to approximately 126 acres (roughly 0.6 percent).
- Calculating the associated impervious area of these parcels (impervious percentage multiplied by parcel area) results in a total decrease of impervious acreage of 5.3 acres and a total increase in impervious acreage of 32.8 acres from the 2006 to the 2011 BVCP projected land use. This results in a net increase of 27.5 acres of projected impervious acreage of the total 22,880 acre modeled area.

Figure 3-11 illustrates the spatial extent of the parcels with a differing projected land use change between the 2006 and 2011 BVCPs.

This comparative analysis concluded that the observed differences in impervious area are considered relatively minor in the overall extent of the model and would have negligible impacts on the overall model results. The projected land use differences from the 2006 to 2011 BVCP are also in locations that will not affect model results for project areas. As a result, it is therefore recommended that model updates are not required reflect these land use differences.



Legend

Contours

Major (200')

Minor (40')

Major Roads

Ditches

Major Drainageways

Lakes

City Limits

Subcatchment

0 4,000

1 inch equals 4,000 feet

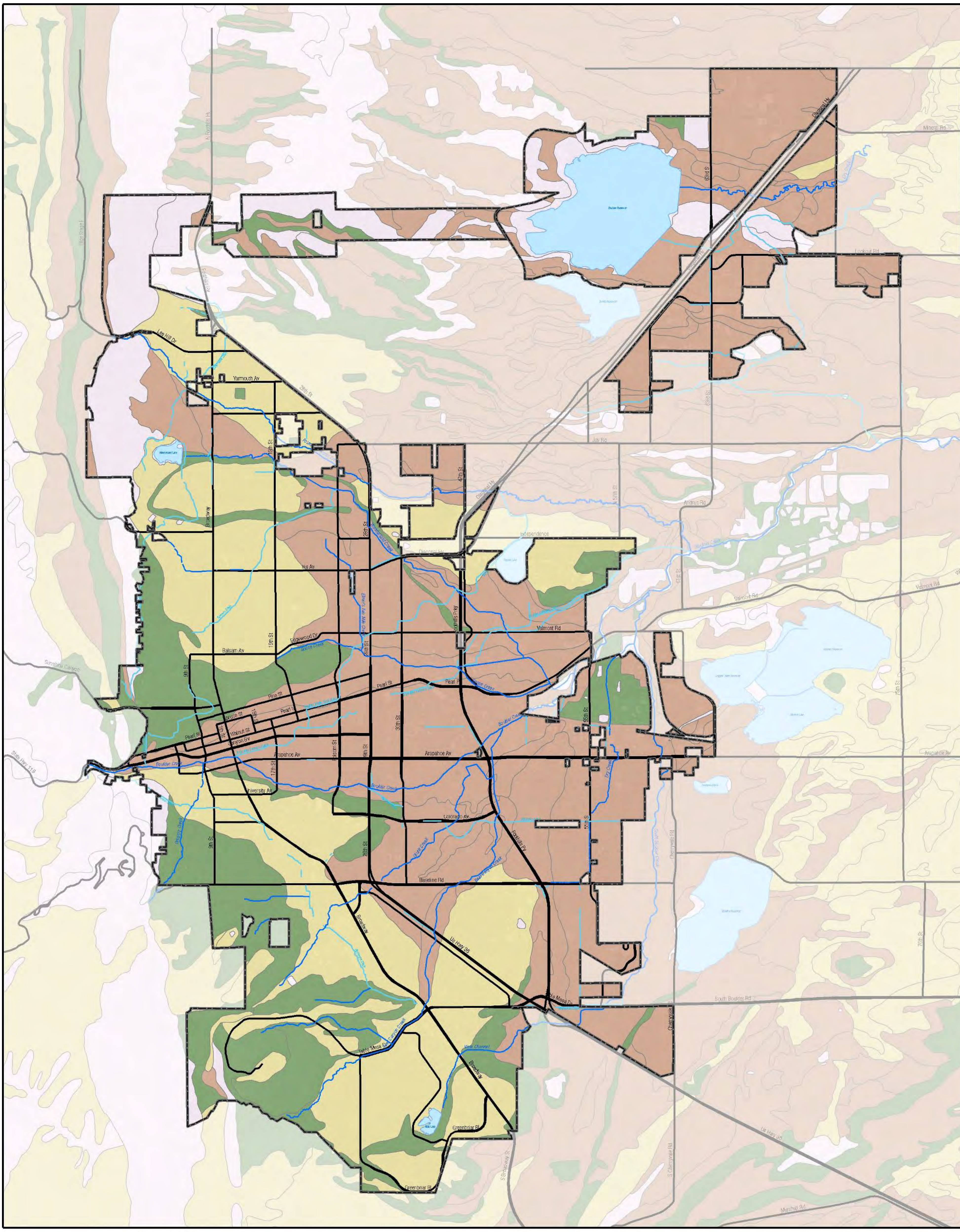
N

Summary of Model Subcatchments

Figure 3-1

Stormwater Master Plan | City of Boulder

HDR ONE COMPANY | *Many Solutions*℠



Legend

City Limits
Lakes
Major Roads
Ditches
Major Drainageways

Hydrologic Soil Type

A
B
C
D

0 4,000
1 inch equals 4,000 feet

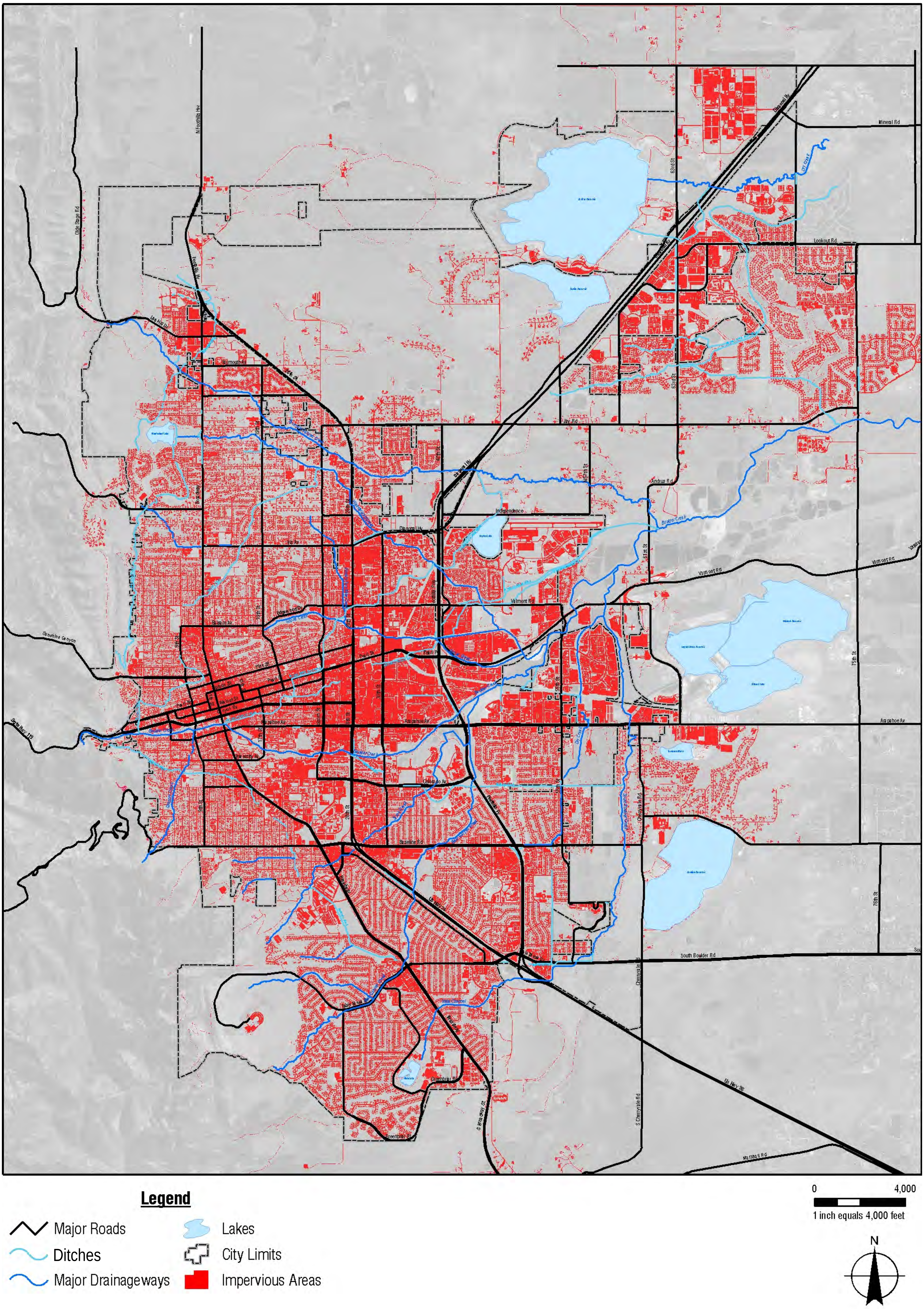
N

Hydrologic Soil Map

Figure 3-2

Stormwater Master Plan | City of Boulder

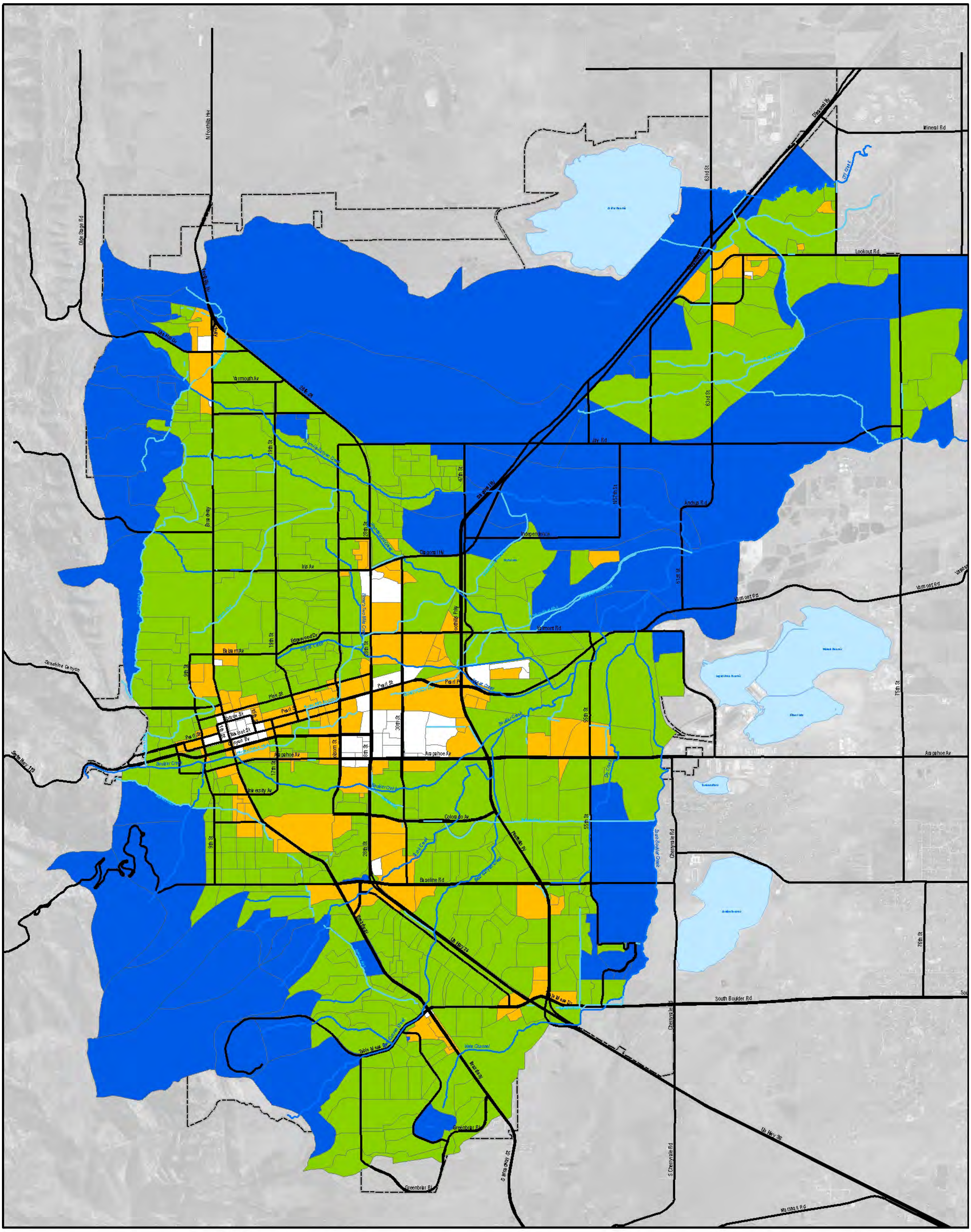
HDR ONE COMPANY | *Many Solutions*℠



Existing Impervious Areas

Figure 3-3

Stormwater Master Plan | City of Boulder



Legend

Major Roads
Ditches
Major Drainageways
Lakes
CityLimits

Impervious Percentage

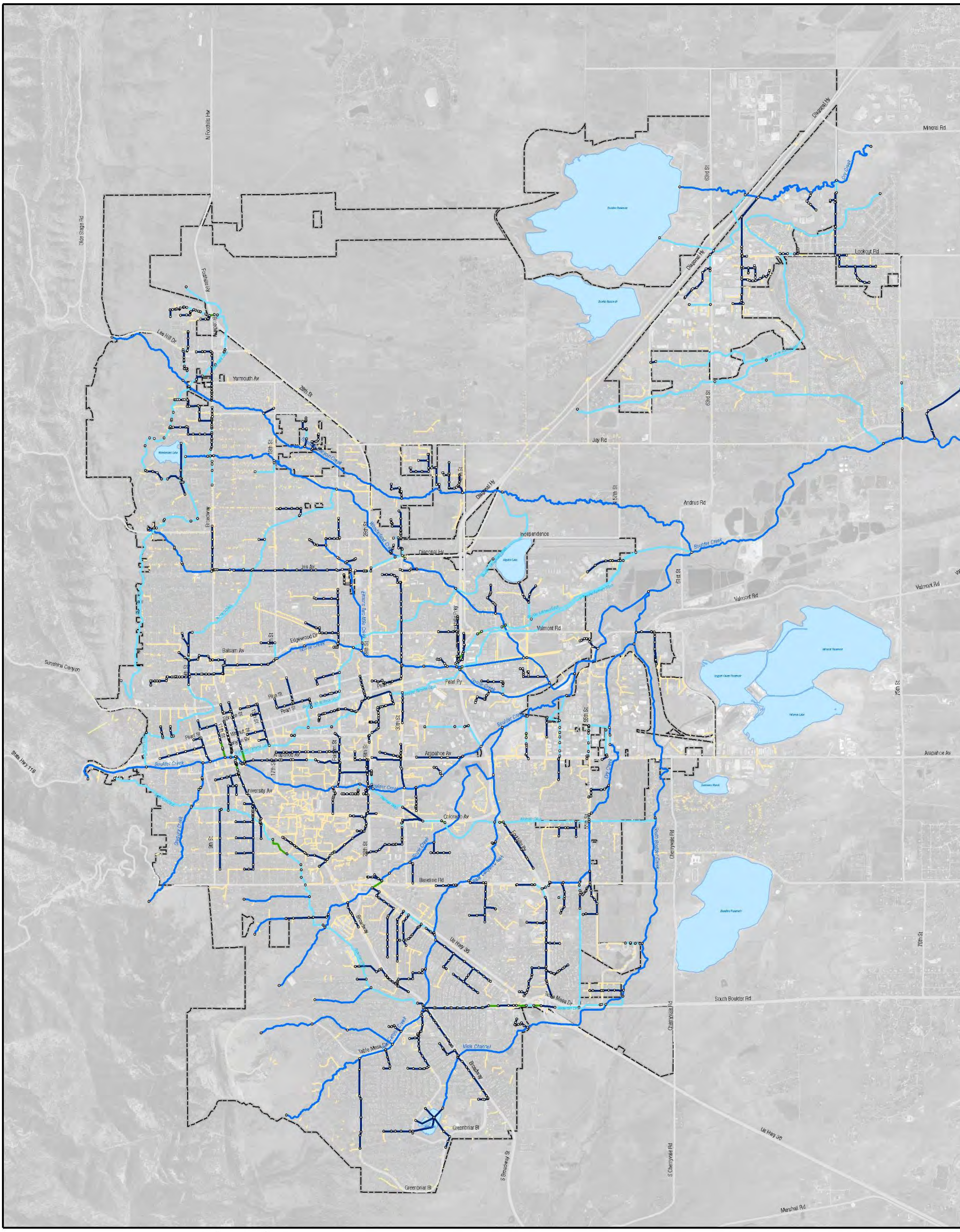
0 - 20%
20 - 40%
40 - 60%
60 - 80%
80 - 100%

0 4,000
1 inch equals 4,000 feet

N

Existing Impervious Percentage by Subcatchment

Figure 3-4



Legend

Modeled network
- Pipe
- Culvert
- Ditch
- Major drainageway

- Model nodes
- Local Storm Sewer (not modeled)
- Major Roads
- Lakes
- City Limits

0 4,000
1 inch equals 4,000 feet

N

Hydraulic Model Network Map

Figure 3-5

Stormwater Master Plan | City of Boulder

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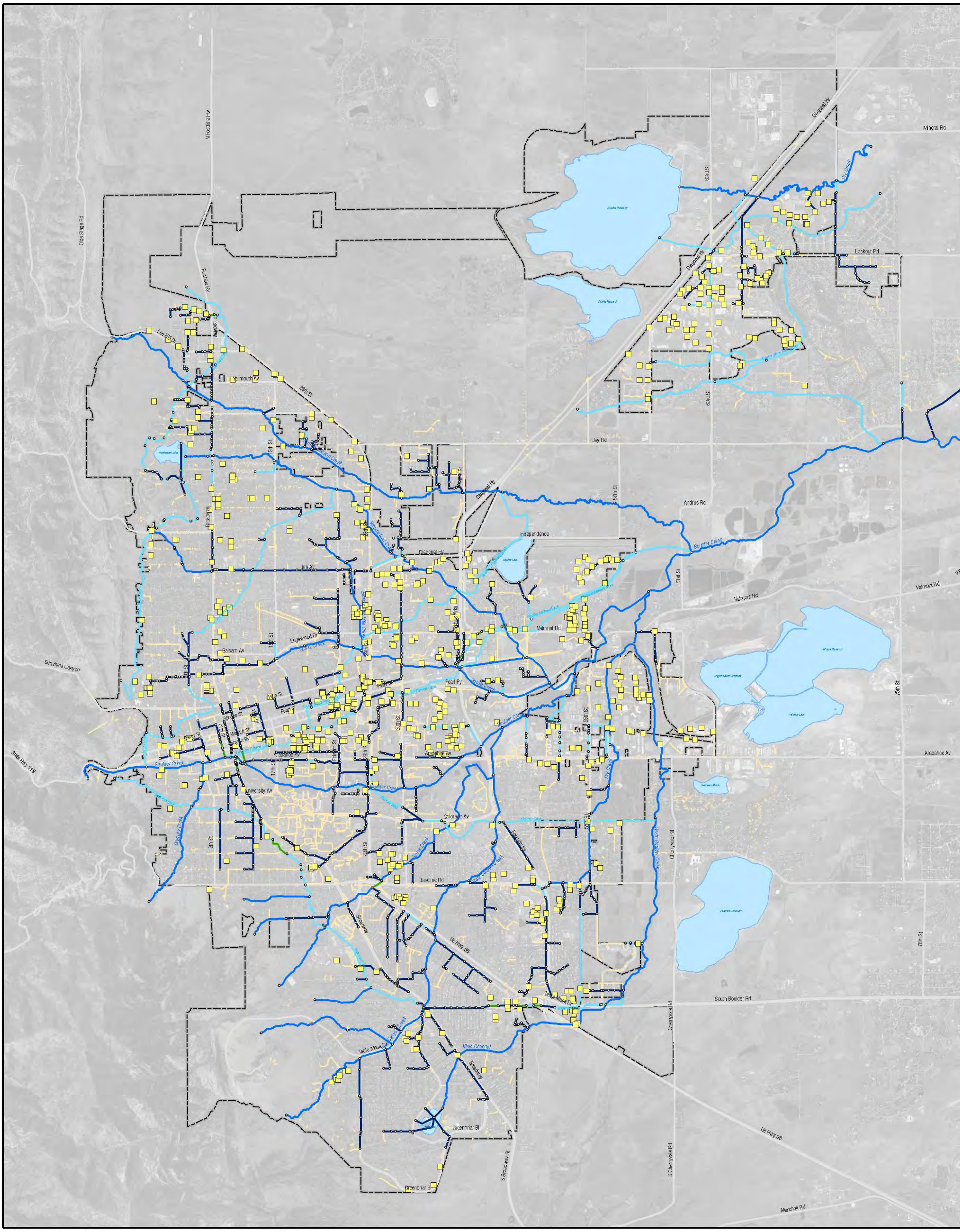


Legend

- Detention ponds
- Model nodes
- Minor storm drain (not modeled)

Modeled network

- Pipe
- Culvert
- Ditches
- Major drainageway

- Major Roads
- Lakes
- City Limits

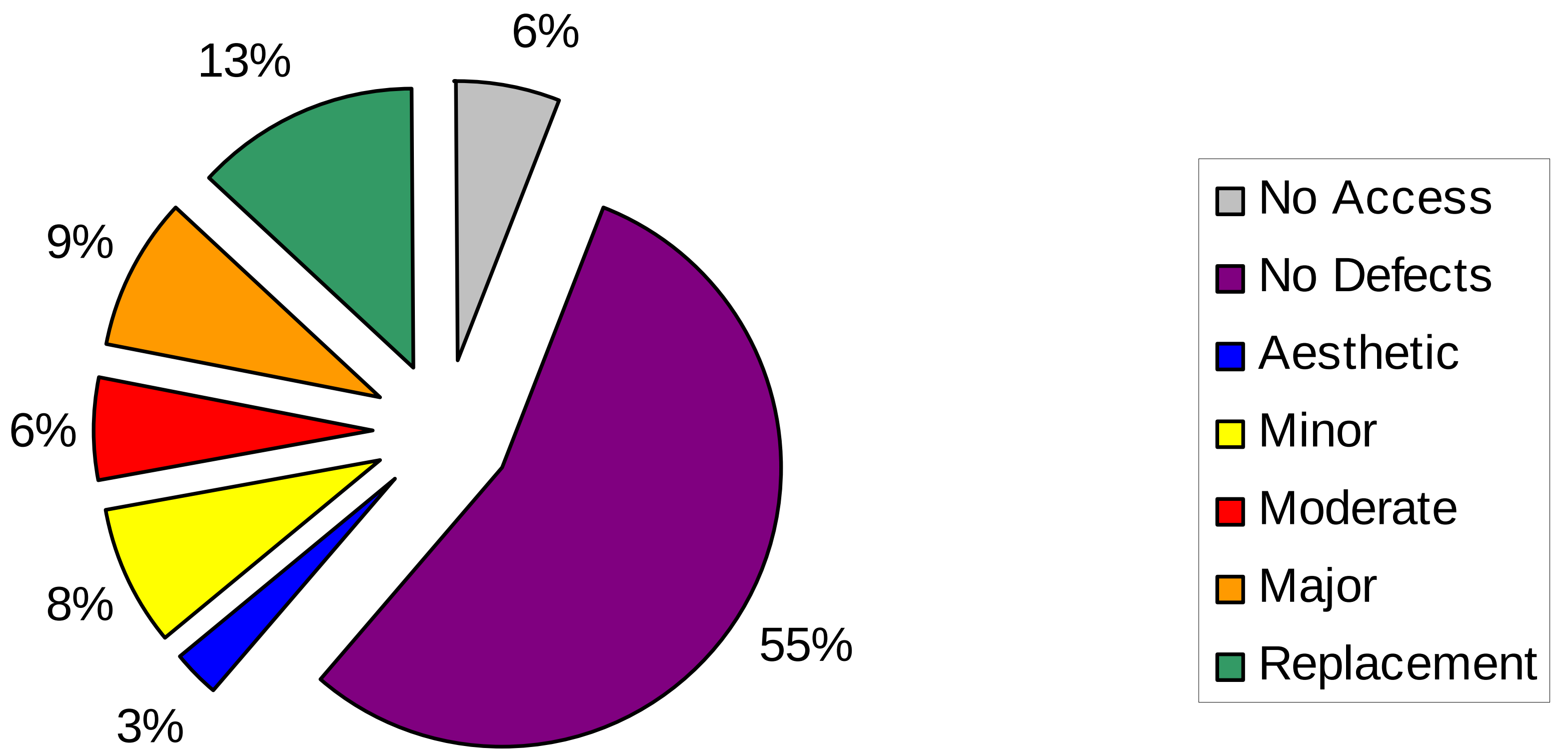
0 4,000

1 inch equals 4,000 feet

N

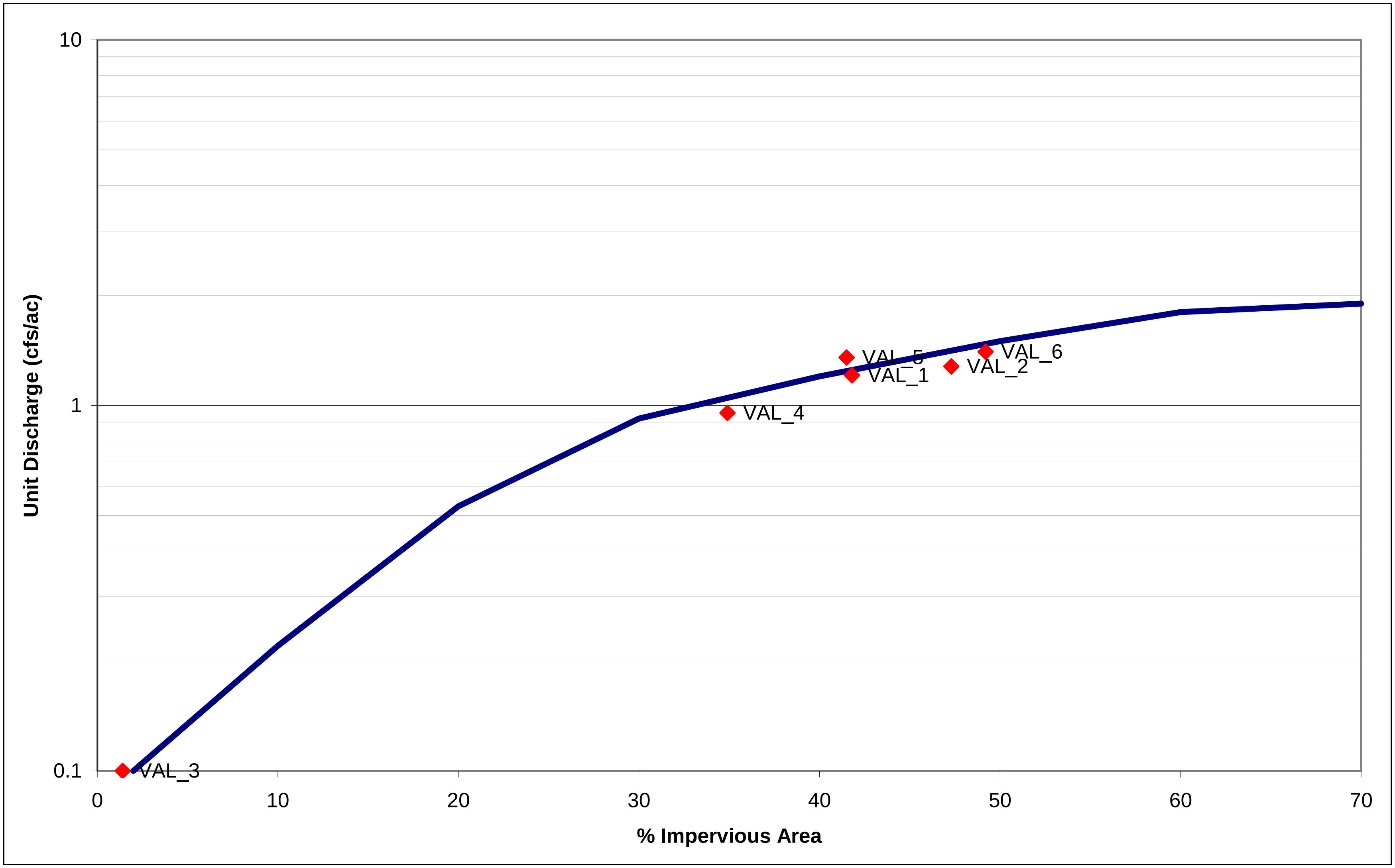
Map of Detention Ponds within Boulder

Figure 3-6



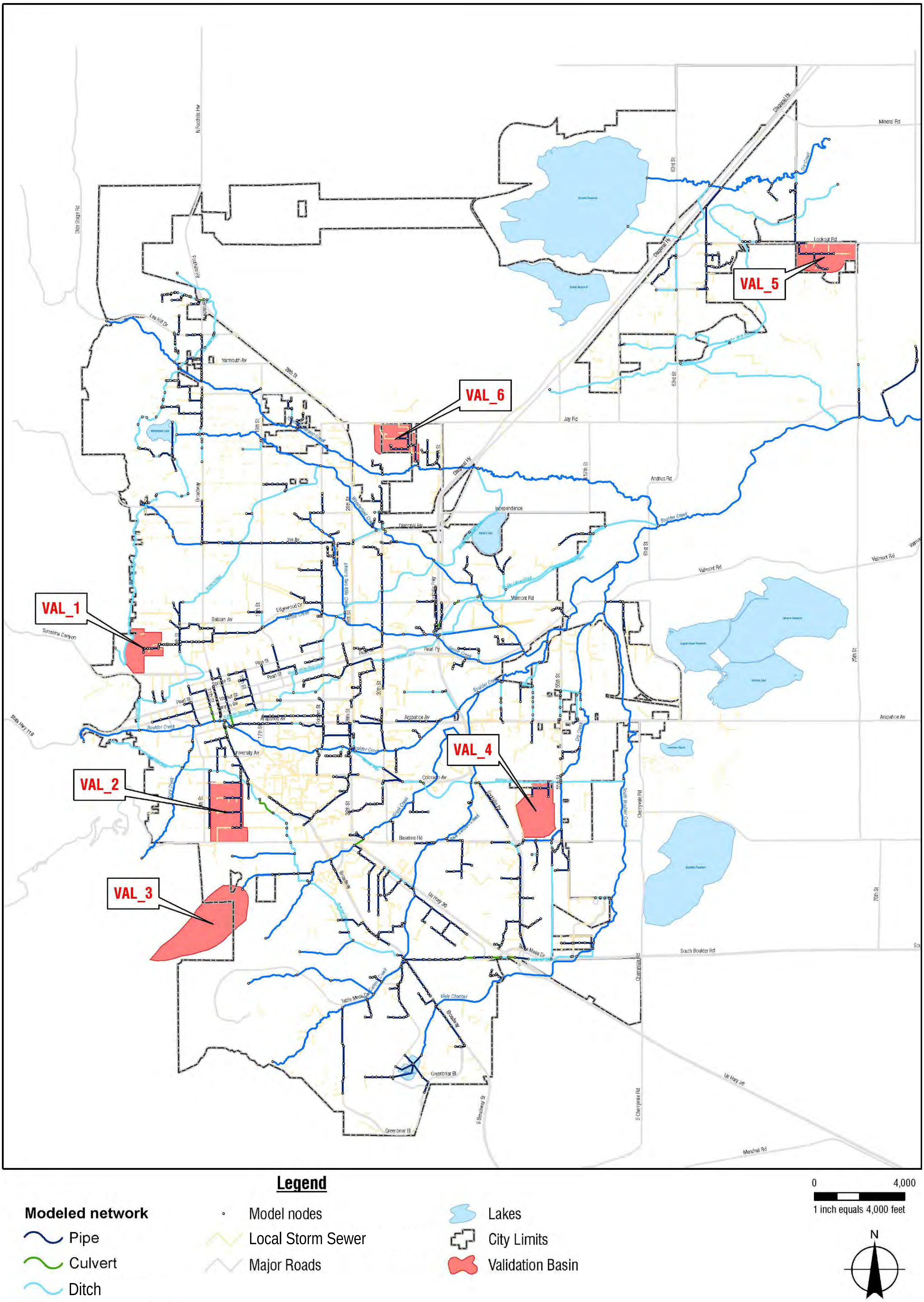
Estimate of Pond Conditions in Boulder

Figure 3-7



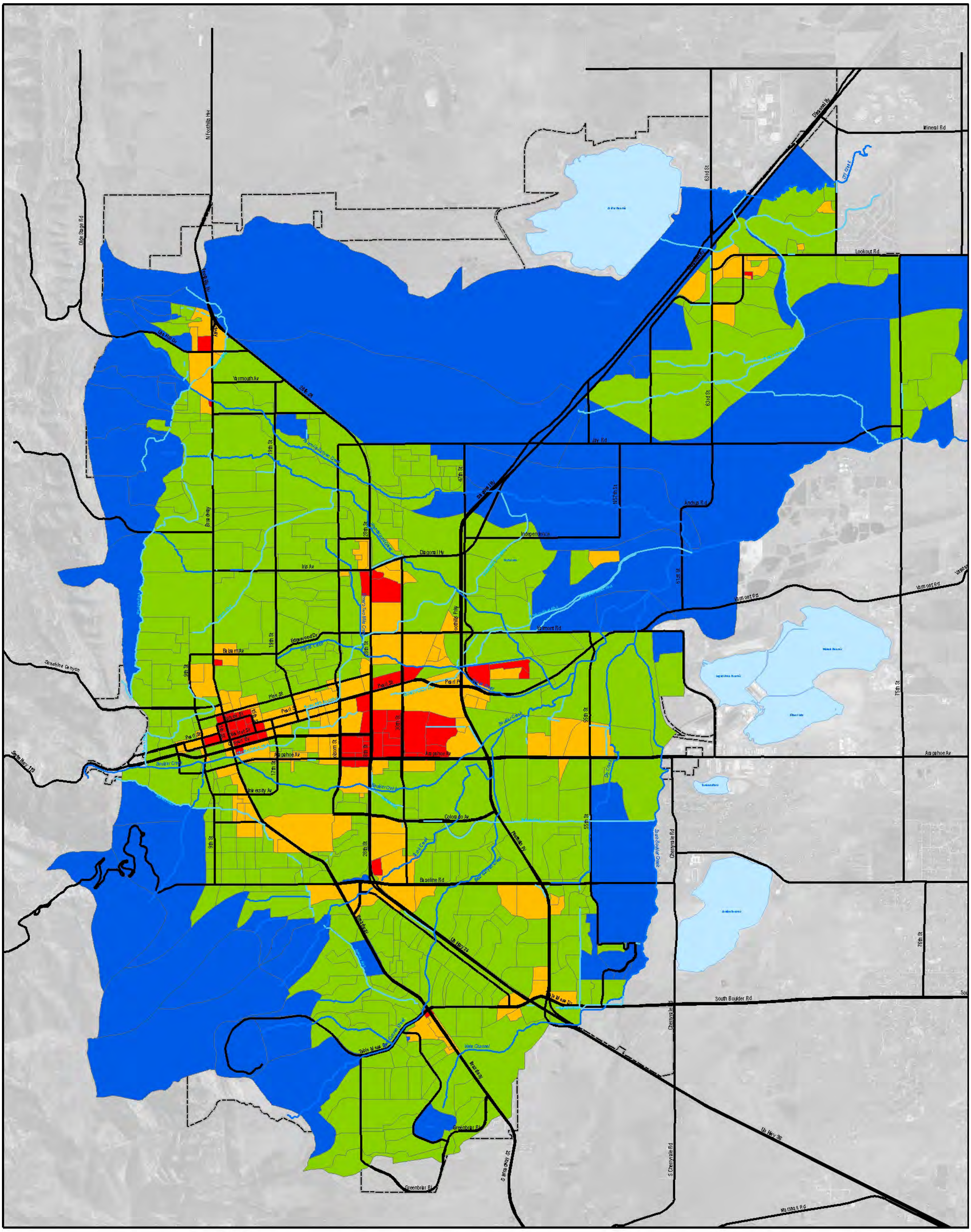
Unit Discharge vs. Percent Impervious Area, 5-year Frequency

Figure 3-9



Model Verification Location map

Figure 3-8



Legend

- Major Roads
- Canals
- Major Drainageways
- Lakes
- CityLimits

Impervious Percentage

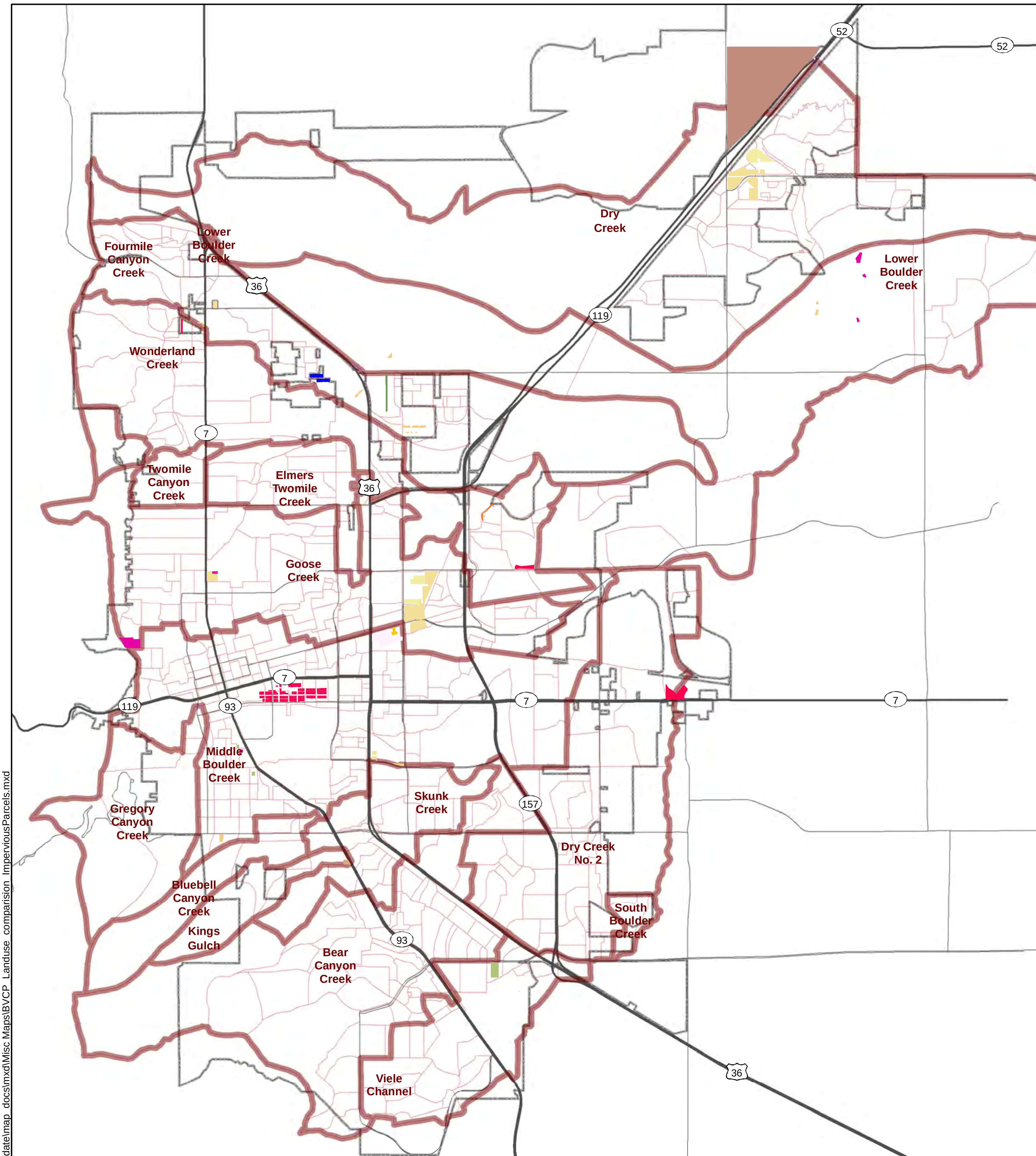
- 0 - 20%
- 20 - 40%
- 40 - 60%
- 60 - 80%
- 80 - 100%

0 4,000
1 inch equals 4,000 feet

N

Future Impervious Percentage by Subcatchment

Figure 3-10



	Change in Imperviousness from 2006 to 2011 BVCP	Total Parceled Acres of Land Use Change from 2006 BVCP to 2011 BVCP (Area of Impacted Parcels)
Land use changes representing a DECREASE in impervious percentages		
Business (2006) to Open Space (2011)	-57.2%	1.2
Medium Density Residential (2006) to Open Space or Park (2011)	-40.1%	0.9
High Density Residential (2006) to Light Industrial (2011)	-12.7%	8.1
High Density Residential (2006) to Medium Density Residential (2011)	-10.2%	24.2
Public (2006) to Low Density Residential (2011)	-7.0%	9.6
Community Business (2006) to High Density Residential (2011)	-6.9%	0.5
Low Density Residential (2006) to Very Low Density Residential (2011)	-1.3%	3.4
Total Parceled Area (Acres) with a Land Use Change Associated with a Decrease in Imperviousness (Area of Impact):		**48.0**
Total DECREASE in Impervious Acreage went from 24.9 to 19.6 Acres (Within the 22,880 Acre Modeled Area)		
Land use changes representing a INCREASE in impervious percentages		
Very Low Density Residential (2006) to Low Density Residential (2011)	1.3%	2.5
High Density Residential (2006) to Mixed Use Business (2011)	6.9%	0.7
Low Density Residential (2006) to Public (2011)	7.0%	0.3
Public (2006) to Medium Density Residential (2011)	8.9%	4.5
Industrial (2006) to High Density Residential (2011)	12.7%	15.7
Mixed Use Residential (2006) to Mixed Use Business (2011)	17.1%	2.4
Public (2006) to High Density Residential (2011)	19.1%	3.5
Light Industrial (2006) to Mixed Use Business (2011)	19.6%	46.3
Open Space, Park (2006) to Low Density Residential (2011)	24.2%	5.2
Low Density Residential (2006) to High Density Residential (2011)	26.1%	0.8
Low Density Residential (2006) to Transitional Business (2011)	33.0%	1.1
Open Space (2006) to Light Industrial (2011)	37.6%	30.0
Open Space (2006) to Medium Density Residential (2011)	40.1%	1.2
Open Space (2006) to Regional Business (2011)	57.2%	11.4
Total Parceled Area (Acres) with a Land Use Change Associated with a Increase in Imperviousness (Area of Impact):		**125.6**
Total INCREASE in Impervious Acreage went from 37.4 to 70.2 Acres (Within the 22,880 Acre Modeled Area)		

Document Path: \\den-gissrv1\gisdata\PROJECTS\241354_Boulder_SMP_Update\map_docs\mxd\Misc Maps\BVCP_Landuse_comparision_ImperviousParcels.mxd

N

0 2,000 4,000
Feet

Parcels (2007) with Projected Landuse Differences Between 2006 and 2011 BVCP (with Parcel Count)

DECREASES in projected impervious percentages (magnitude of decrease)
- -57.2% (2)
- -40.1% (2)
- -12.7%; -10.2% (186)
- -7.0%; -6.9% (15)
- -1.3% (4)

INCREASES in projected impervious percentages (magnitude of increase)
- 1.3% (10)
- 6.9%; 7.0%; 8.9% (5)
- 12.7% (9)
- 17.1%; 19.1%; 19.6% (48)
- 24.2%; 26.1% (34)
- 33.0% (1)
- 37.6% (1)
- 40.1% (40)
- 57.2% (2)

Major Basins
- Major Basins
- Future Base Catchments
- City Limits

Projected Land Use Differences Between 2006 and 2011 BVCP

Figure 3-11

4 Collector Storm Sewer System Analysis and Results

This section presents a characterization of the existing and future hydraulic and water quality problem areas within the existing stormwater drainage system that will be used as a baseline for the development of recommended improvements.

4.1 System Description

As previously noted, the focus of the SMP is the collector stormwater drainage system, which includes pipe 18” in diameter and larger and primary open channel systems that are not part of the city’s major drainageways. The following sections provide an overview of those portions of the city’s stormwater drainage system that were included in the model and analyzed as part of this project.

4.1.1 Major Drainageways

From a storm drainage perspective, the city is generally split north-south by Boulder Creek, which is the ultimate discharge point for much of the city’s stormwater runoff. In addition to Boulder Creek, the city’s other major creeks include Gregory Creek, Bluebell Creek, Skunk Creek, Bear Canyon Creek and South Boulder Creek to South and Goose Creek, Twomile Canyon Creek, Elmer’s Two Mile Creek, Wonderland Creek and Fourmile Canyon Creek to the North. Although the major drainageways and creeks within the city were not evaluated as part of this plan, they were still incorporated into the hydraulic analysis to provide system connectivity and serve as boundary conditions at outfalls and other points of discharge. Figure 4-1 illustrates the major drainageways.

4.1.2 Irrigation Ditches

The presence of irrigation ditches within the city plays an important role in the collection and conveyance of stormwater runoff. Because the ditches tend to run perpendicular to the surrounding ground slope, they can often intercept a substantial portion of runoff and transfer it to neighboring basins. The major irrigation ditches within the city, including Farmers Ditch, Silver Lake Ditch, Boulder White Rock Ditch, North Boulder Farmers Ditch, Anderson Ditch and Wellman Ditch were included in the hydraulic analysis and evaluated for flooding problems. Figure 4-1 illustrates the primary irrigation ditches as included in the hydraulic analysis.

4.1.3 Storm Sewers

The existing stormwater drainage system within the city includes nearly 160 miles feet of sewer ranging in size from less than 12” to 72” in diameter. Of that, approximately 52 miles of 18” in diameter and larger sewer was included in the hydraulic model and evaluated for system problems. Figure 4-1 identifies the modeled and non-modeled storm sewers.

4.2 Storm Sewer Problem Identification

Utilizing the XPSWMM model, runoff, hydraulic, and water quality calculations were completed for two different land use scenarios: existing conditions and future conditions, and three different design storms: the 2- and 5-yr events and the water quality storm. These results were then evaluated with respect the problem identification criteria to identify specific system deficiencies within the city's stormwater drainage system.

Initially, a comparison of hydraulic problems for the existing and future land use condition scenario was performed. Model results indicated no additional problems areas resulted from the slight increase in imperviousness between the existing and future condition land use scenarios. However, it was observed that there was a slight increase in problem severity. *As a result, the collector storm sewer system problem identification used only the future condition land use scenario.*

Model results indicate that 572 nodes out of 1635 nodes within the city violate one or more of the SMP system analysis criteria provided in Section 2.2. In most cases, a number of these deficient nodes and links were grouped together into a single problem area. This resulted in 50 hydraulic problem locations as shown on Figure 4-2.

In general, the collector storm sewer system areas that were identified as most severely under capacity or the areas that potentially flood the most include:

- Upper Goose Creek between North Boulder Park and Folsom St,
- Spine Road and N. 63rd Street in the Gunbarrel part of town,
- Spruce St between 18th St and Boulder White Rock Ditch, and
- 28th St. between Arapahoe Ave and Boulder Creek.

4.3 Storm Sewer Problem Prioritization

Due to the large number of problem locations and limitations within the city's capital budget, a ranking was performed on the problem areas to group the conveyance problems into three tiers defined as: Tier 1 = severe problem area, Tier 2 = major problem area, and Tier 3 = minor problem area. Detailed alternatives and design solutions were developed for the Tier 1 and Tier 2 priority problems areas. However, storm sewer sizes and design criteria are also provided for the Tier 3 problem area based on a pipe replacement improvement. The following paragraphs summarize the criteria used to identify and rank the high priority conveyance problems within the city's collector system.

As noted above, model results identified 572 problem nodes that were either surcharged or flooding based on the project hydraulic criteria. Further investigation of the problem nodes showed locations where the hydraulic criteria were violated by matter of inches and/or for a relatively short duration. Considering those nodes that were only slightly exceeding the project hydraulic criteria were not identified as system problem locations by the city, an additional screening criterion was developed to remove these minor capacity restrictions from the problem identification list.

Prior to ranking and identification each problem area, a *problem override criterion* was applied to nodes that were either 1) flooded or surcharged for less than 15 minutes and/or 2) only violated the HGL surcharge criteria by less than two tenths of a foot and were isolated with respect to other flooded problem areas. The problem override criterion and removed 60 model nodes, or 4% of the total model nodes, from the problem identification process.

4.3.1 Criteria and Definitions

The process of prioritizing system problems into tiers utilized a point-based matrix using a weighted criteria approach. The problem prioritization criteria and their definitions are presented in Table 4.3-1. The process of prioritizing the identified hydraulic problem locations assigned a relative score of 1 to 10 to each of the prioritization criterion. The following sections describe the criteria scoring process and graphically compare the relative score for each problem location.

Table 4.3-1: Problem Prioritization Criteria and Definitions

Criterion	Definition
Problem Extent	Length of the stormwater drainage system that is identified as a hydraulic problem. This is intended to be a measure of the extent of the street and associated inlets that are impacted by the surcharged hydraulic grade line. This criterion is determined for each problem location by calculating the length of the stormwater drainage system between surcharged and/or flooded nodes.
Flooded Volume	Volume of flow that exceeds the rim elevation. This is intended to be a measure of the problem severity by evaluating the volume of runoff that could potentially escape the stormwater drainage system into the street and result in localized flooding. This criterion is determined as direct output from XPSWMM summed for all flooded nodes with in a problem location. Note this does not include surcharged nodes (HGL within 1-ft of the rim) and identifies locations with severe flooding potential.
Structure Impact	Number of buildings or structures potentially impacted by system flooding. This measures the problem severity for flooded nodes by differentiating node flooding in densely developed areas or where development is well above the rim of the stormwater drainage system. This criterion is calculated using flooded node HGL elevations intersected with the surrounding building elevations in the project GIS.
Length of High Q_{Ratio}	The Q_{Ratio} is defined as the peak system flow divided by the manning's full flow capacity of the pipe. The higher the Q_{Ratio} the more severe the capacity problem is in the pipe segment. This is intended to be another measure of problem severity for a surcharged or flooded system and typically identifies the cause of the flooded volume and problem extent criterion. This criterion is calculated as direct output from XPSWMM by multiplying the Q_{Ratio} by length for each pipe segment where the Q_{Ratio} is greater than 1.1.
Data Confidence	General ranking of the amount of data gaps remaining that are adjacent to a problem node or pipe. This would be a measure of the level of confidence in how the model is predicting actual system hydraulics with respect to the best available data. For example, if a problem location is a result or partial result of a model element that was not able to be surveyed, it would rank as a less severe issue. A resulting recommendation would be for additional data collection in that area.
Water Quality Area of Concern	Identifies problem locations that may have multi-objective solutions. This identifies if the hydraulic problem area is adjacent to or contains a Water Quality Area of Concern.

4.3.2 Criteria Weights and Ranking

Weighting factors were used to identify those criteria that are of a higher concern with respect to basin characteristics and the level of service provided by the city's collector system. For example, the *Length of* Q_{Ratio} criterion is a representation of amount of under-capacity pipe within a problem location but does not necessarily indicate a problem. Therefore, this criterion would be weighted less than *Flooded Volume* or *Structural Flooding* for example, which represent the severity of a system deficiency and the potential impacts created by system flooding. Weighting factors were developed on a percentage basis for each of the six criteria such that the sum of all the weights totaled 100%. The ranking scores for each problem location were calculated by multiplying the criteria scores by the criteria weight percentages and converted to a percentage. In theory, the maximum rank a problem area could attain would be 100% thus attaining the maximum score for all of the criteria. Table 4.3-2 provides a summary of the weighting criteria.

Table 4.3-2: Weighting Criteria

Scoring Criteria	Weight
Problem Extent	13%
Flooded Volume	25%
Structure Impact	31%
Length of High Q_{Ratio}	6%
Data Confidence	9%
Water Quality Area of Concern	16%

4.3.3 Problem Area Priorities

The process of identifying the Tier 1, 2 and 3 priority locations was developed to identify the severe, major and minor problems within the city's collector storm sewer system. This approach was necessitated due to the large number of problem locations, the anticipated high cost associated by addressing all problems and the limited budget available within the city's stormwater utility.

Identifying the breakpoint between the Tier 1, 2 and 3 problem locations was intended to identify the point of diminishing returns with respect to capital expenditures and problem severity. A comparison of the ranking score for each of the problem locations was made to identify if there were breakpoints in the distribution problem location score. This comparison of ranking score for each problem location was made graphically using a histogram. A natural break was observed between the problem locations scores around 25% thus indicating the problem severity significantly decreases past a 25% score. In addition, there is another grouping of scores above the 45% point indicating a series of very severe problem locations. With observed breakpoints identified, Table 4.3-3 was used to identify the Tier 1, 2 and 3 problem locations. This is also shown on Figure 4-3.

Table 4.3-3: Summary of Problem Area Ranking Results

Problem ID	Score	Rank	Tier 1	Tier 2	Tier 3
HYD#16	73.1	1	×		
HYD#34	50.0	2	×		
HYD#55	49.7	3	×		
HYD#8	48.8	4	×		
HYD#42	40.6	5		×	
HYD#41	40.0	6		×	
HYD#19	39.1	7		×	
HYD#24	35.9	8		×	
HYD#29	35.0	9		×	
HYD#47	35.0	9		×	
HYD#27	33.4	11		×	
HYD#21	32.5	12		×	
HYD#9	31.3	13		×	
HYD#15	30.6	14		×	
HYD#20	30.6	14		×	
HYD#22	29.7	16		×	
HYD#38	29.4	18		×	
HYD#35	27.8	19		×	
HYD#18	27.5	20		×	
HYD#49	27.2	21		×	
HYD#48	26.3	22			×
HYD#50	25.9	23			×
HYD#30	21.6	25			×
HYD#46	20.9	26			×
HYD#7	19.4	27			×
HYD#23	19.4	27			×
HYD#32	19.1	29			×
HYD#2	18.8	30			×
HYD#3	18.8	30			×
HYD#33	18.8	30			×
HYD#17	18.1	33			×
HYD#52	18.1	33			×
HYD#11	17.8	35			×
HYD#1	16.9	36			×
HYD#5	16.9	36			×
HYD#12	16.9	36			×
HYD#14	16.9	36			×
HYD#28	16.9	36			×
HYD#37	16.9	36			×
HYD#45	16.9	36			×

Table 4.3-3: Summary of Problem Area Ranking Results

Problem ID	Score	Rank	Tier 1	Tier 2	Tier 3
HYD#51	16.9	36			×
HYD#53	16.9	36			×
HYD#54	16.9	36			×
HYD#13	16.3	48			×
HYD#31	15.9	49			×
HYD#39	15.0	50			×
HYD#40	15.0	50			×
HYD#44	15.0	50			×
HYD#36	14.1	53			×
HYD#25	13.1	54			×
HYD#4	8.4	55			×

4.4 Irrigation Ditch Problem Identification

Irrigation ditch segments were added to the problem identification list if the corresponding design storm causes the channel to overtop its banks and flood the surrounding area. These processes identified approximately 13 locations where ditch flooding might occur. Figure 4-4 illustrates these ditch flooding locations graphically.

4.5 Water Quality Areas of Concern

The primary goal of the water quality model development and analysis was to identify areas within the city having comparatively higher pollutant concentrations and/or loads. With this information, specific capital projects or BMPs could be selected and located within the city to maximize their system-wide water quality benefit. A detailed presentation of the water quality analysis approach and problem identification process is included in TM 3.5 Water Quality Model and Construction Results.

Initially, the pollutant loadings for both the existing and future land use conditions were evaluated. However, by considering the limited amount of new development or redevelopment expected within the city, and by acknowledging that the city's Design and Construction Standards tend to mitigate pollutant loading from new impervious surfaces, it was recognized that both scenarios would produce similar water quality results. This conclusion was supported by the model, which indicated a difference of less than 2 percent in city-wide total pollutant washoff between the two scenarios. Consequently, it was determined that a single scenario would provide an appropriate basis for comparison in the subsequent analysis. *Therefore, all water quality problem area identifications and improvements utilize the future conditions land use scenario.*

4.5.1 Catchments

Identifying the catchments that generate the highest pollutant loadings per acre was an important first step in selecting specific sites where water quality treatment would be most beneficial. Figure 4.-5 illustrates the normalized pollutant loads (per acre) for each of the subcatchments used in the SWMM model.

In general, the highest pollutant loadings are located in the central core of the city, between Valmont Road and Arapahoe Avenue (north-south) and 28th Street and 55th Street (east-west). This area includes significant industrial developments, high-traffic-volume roadways, and the proposed Boulder Transit Village site. In addition to this central core area, two other areas were identified as having comparatively high pollutant loads. These include 63rd Street and the Diagonal Highway in the Gunbarrel area and Broadway and Fourmile Creek in the northwestern corner of the city.

4.5.2 Outfalls

Although identifying the catchments with the highest comparative washoff load is important from a source control standpoint, identifying the specific outfalls that are discharging these high concentration pollutants can help to identify site-specific locations where water quality treatment facility would be most beneficial and could be included in the city's capital improvement program. The storm sewer outfalls with the highest pollutant load concentrations were identified as the Water Quality Areas of Concern and are shown on Figure 4-6 and summarized in Table 4.5-1 listed by outfall location.

Table 4.5-1: Top 12 Pollutant Contributing Outfalls

Rank	Location	Pollutant Load (lbs/ac/yr)				
		TSS	P	Cu	Pb	Zn
1	Broadway & Fourmile Canyon Creek	1,970	3.16	0.35	0.52	2.13
2	49th Street & Goose Creek	1,249	1.39	0.25	0.39	1.55
3	Foothills and Wonderland Creek	1,334	1.77	0.17	0.33	0.71
4	Pearl Parkway & Wonderland Creek	980	1.29	0.20	0.29	1.22
5	Diagonal Highway & Boulder Creek	957	1.30	0.20	0.28	1.18
6	Arapahoe and Range Street	912	1.55	0.16	0.24	0.99
7	Pearl Street & Goose Creek	806	0.96	0.17	0.24	1.05
8	Broadway & Skunk Creek	763	0.85	0.16	0.24	0.99
9	Broadway at Boulder Creek	730	1.66	0.11	0.14	0.68
10	56th Street & Dry Creek	712	1.20	0.13	0.19	0.81
11	28th Street & Boulder Creek	687	1.32	0.13	0.17	0.75
12	63rd Street & Boulder White Rock Ditch	682	0.84	0.15	0.22	0.94

The existing 36-inch storm sewer running south along Broadway and discharging into Fourmile Canyon Creek was predicted to have the highest pollutant loadings with 1,970 pounds of TSS per acre per year. The next six highest contributing outfalls are all located in the central downtown area of the city, and discharging into Goose Creek, Boulder Creek, and North Boulder Farmer's Ditch.

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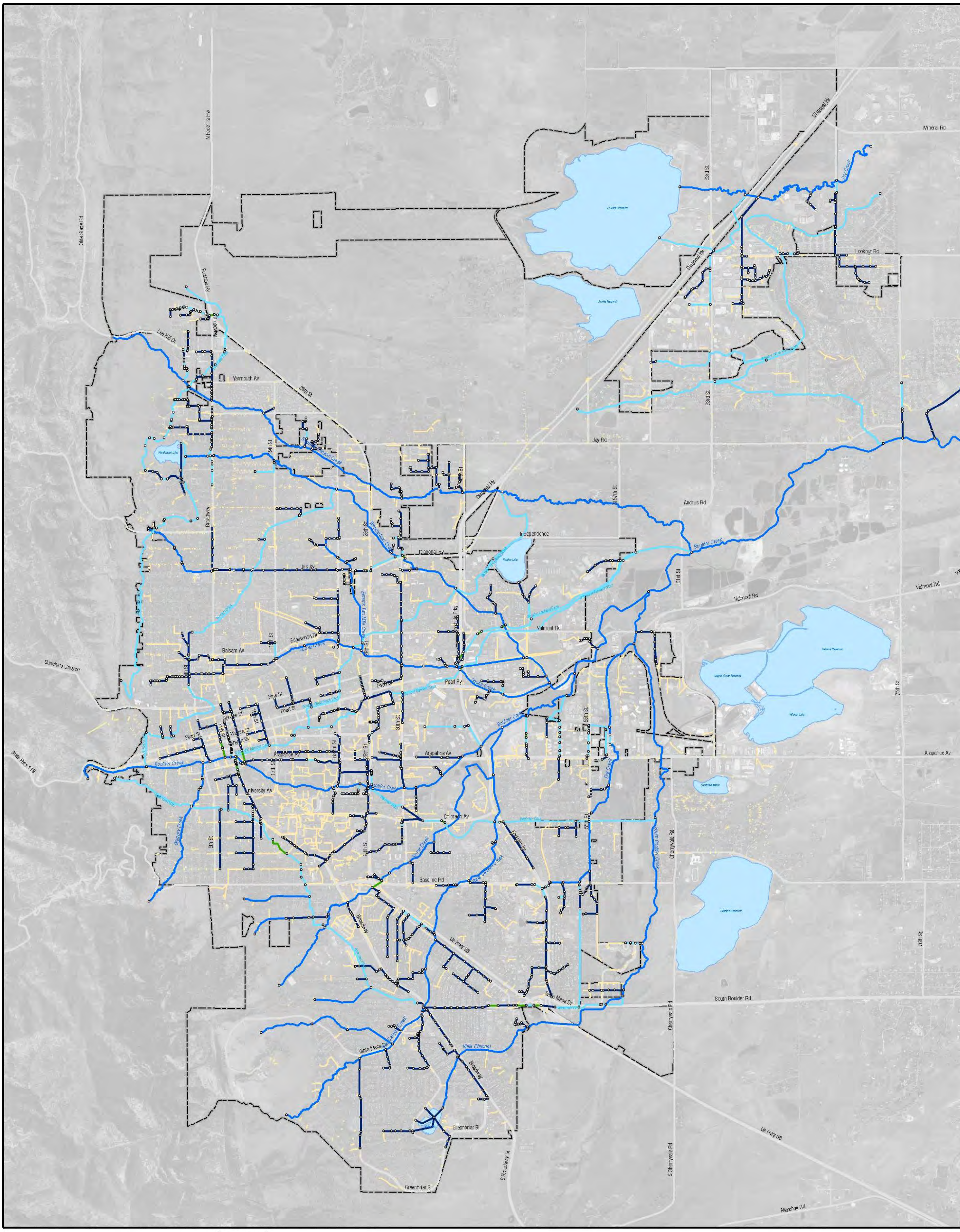

Legend

Modeled network

- Pipe
- Culvert
- Ditch
- Major drainageway

- Model nodes
- Local Storm Sewer (not modeled)
- Major Roads
- Lakes
- City Limits

0 4,000

1 inch equals 4,000 feet

N

Hydraulic Model Network Map

Figure 4-1

Stormwater Master Plan | City of Boulder

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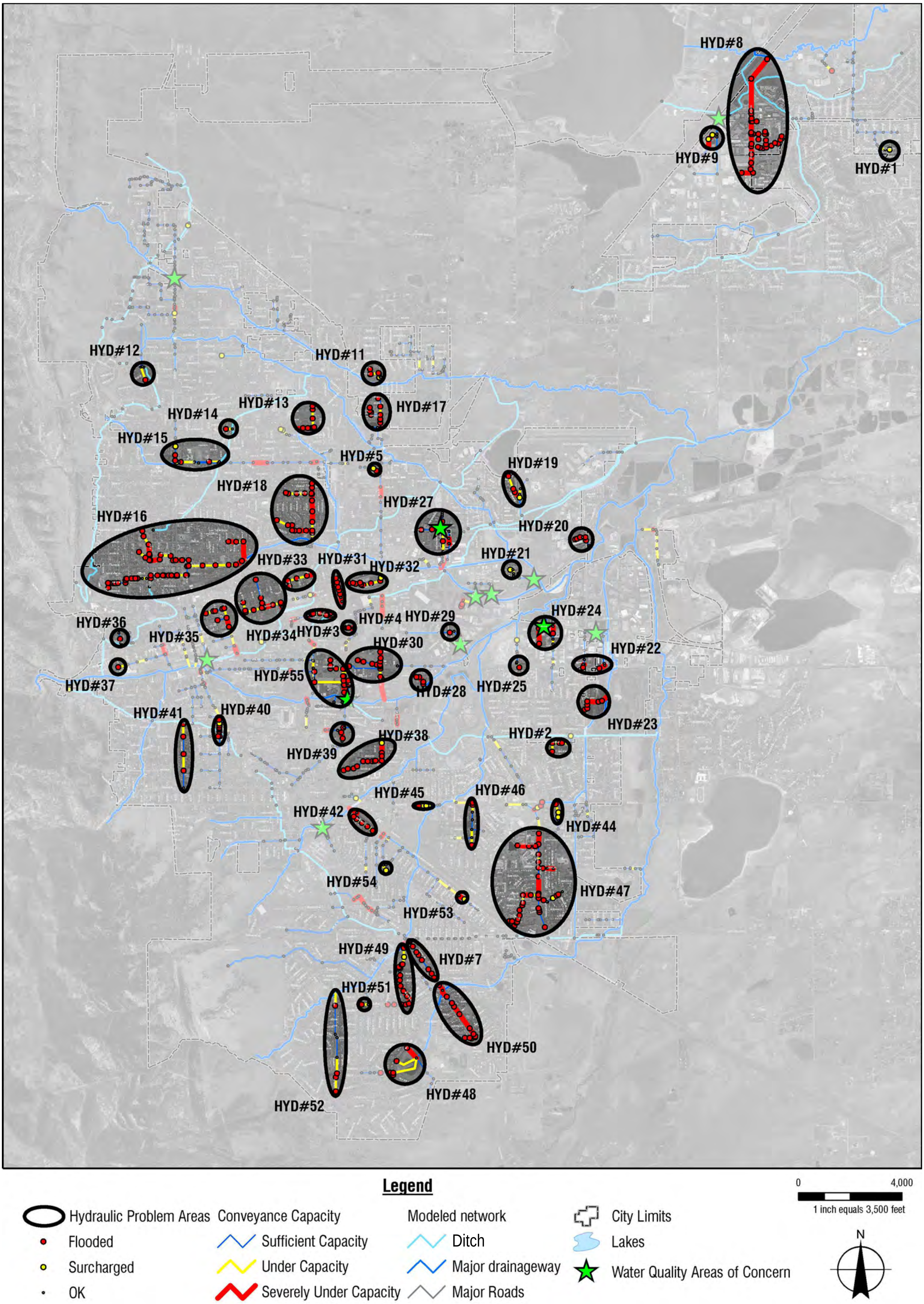

Collector System

Summary Map of Hydraulic Problem Areas

Figure 4-2

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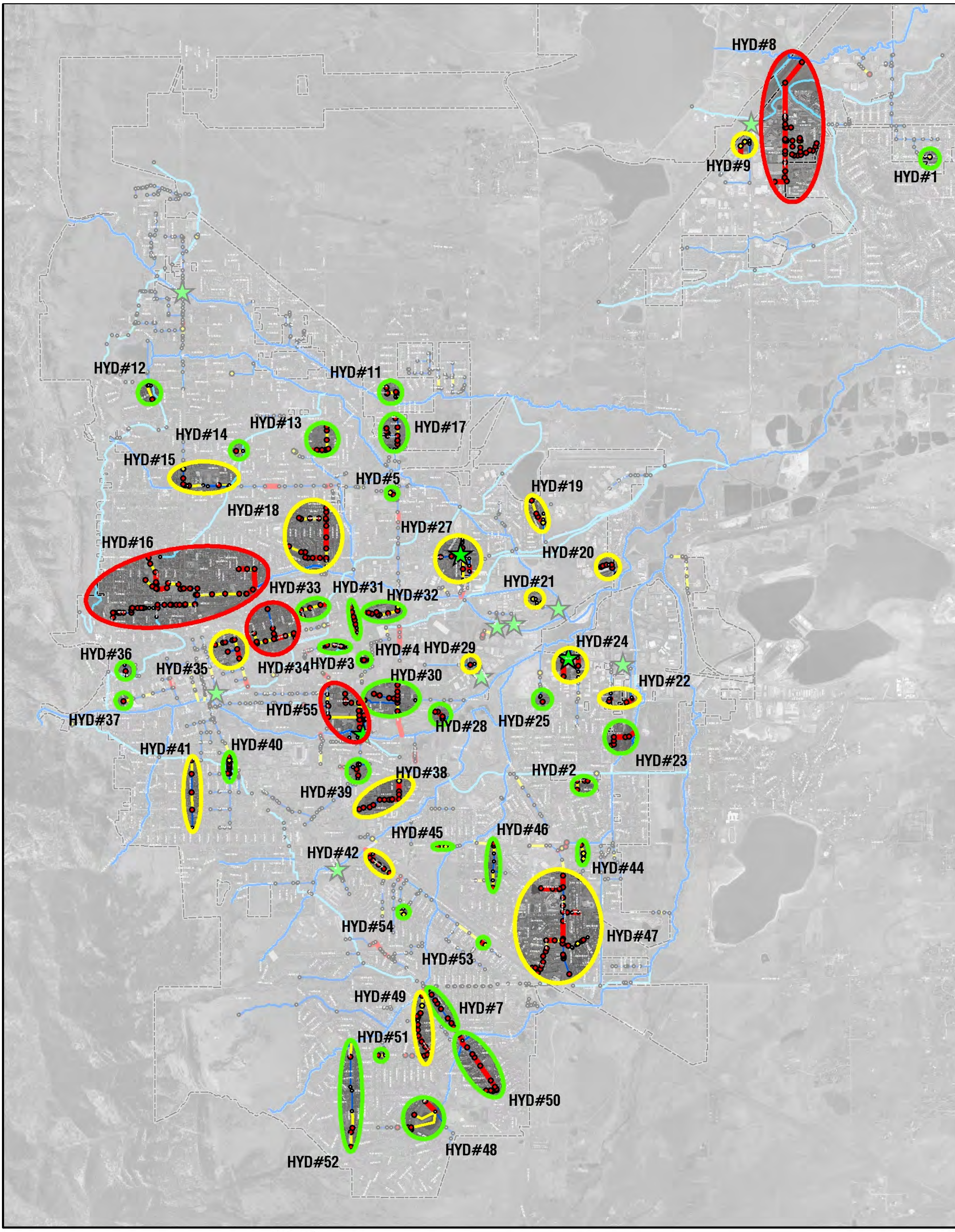

Legend

Hydraulic Problem Area
Tier 1 | Tier 2 | Tier 3
Flooded
Surcharged
OK

Conveyance Capacity
Sufficient Capacity
Under Capacity
Severely Under Capacity

Modeled network
Ditch
Major drainageway
Major Roads

City Limits
Lakes
Water Quality Areas of Concern

0 4,000
1 inch equals 3,500 feet

N

Collector System
Summary of Problem Area Ranking Results

Figure 4-3

Stormwater Master Plan | City of Boulder

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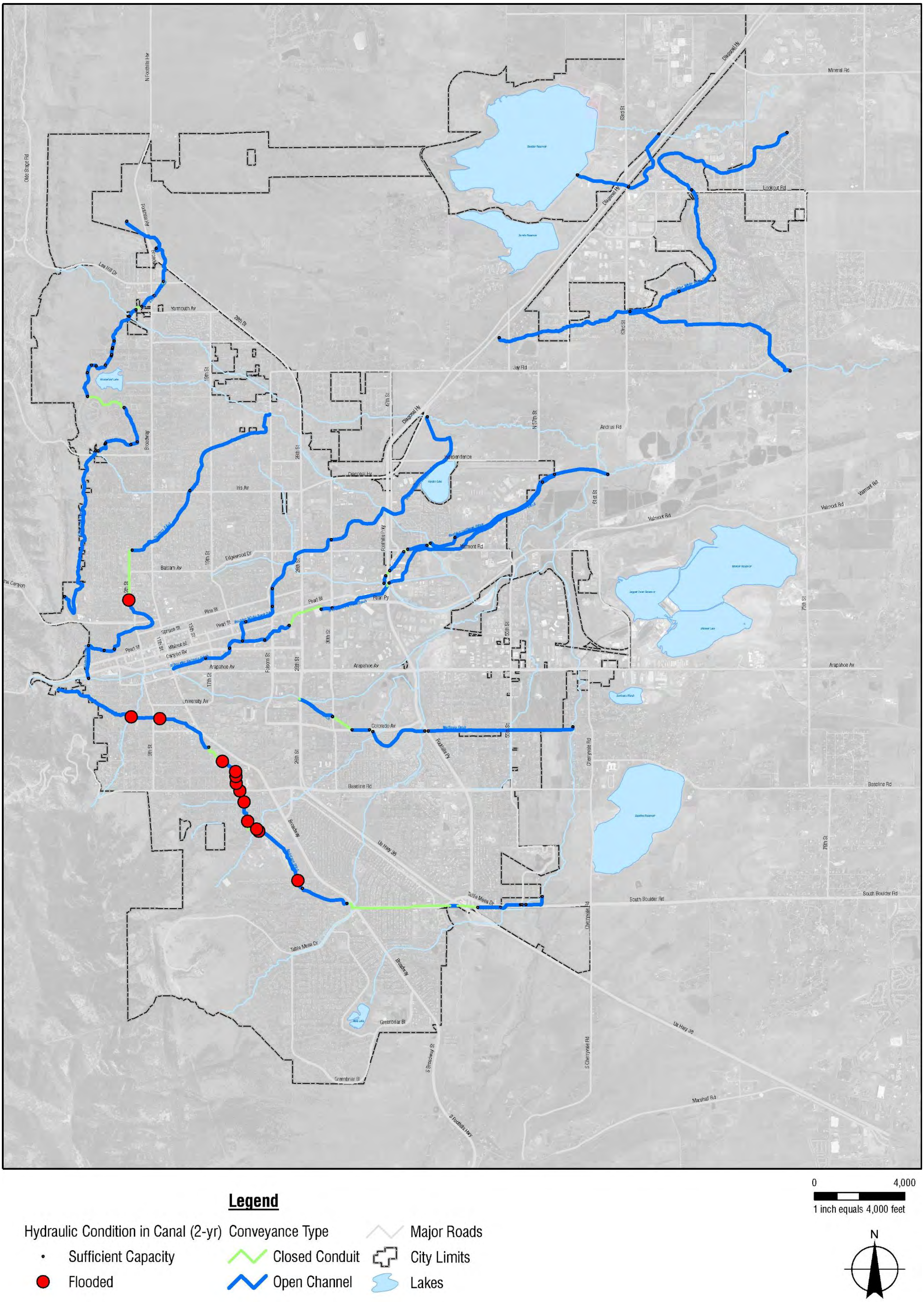
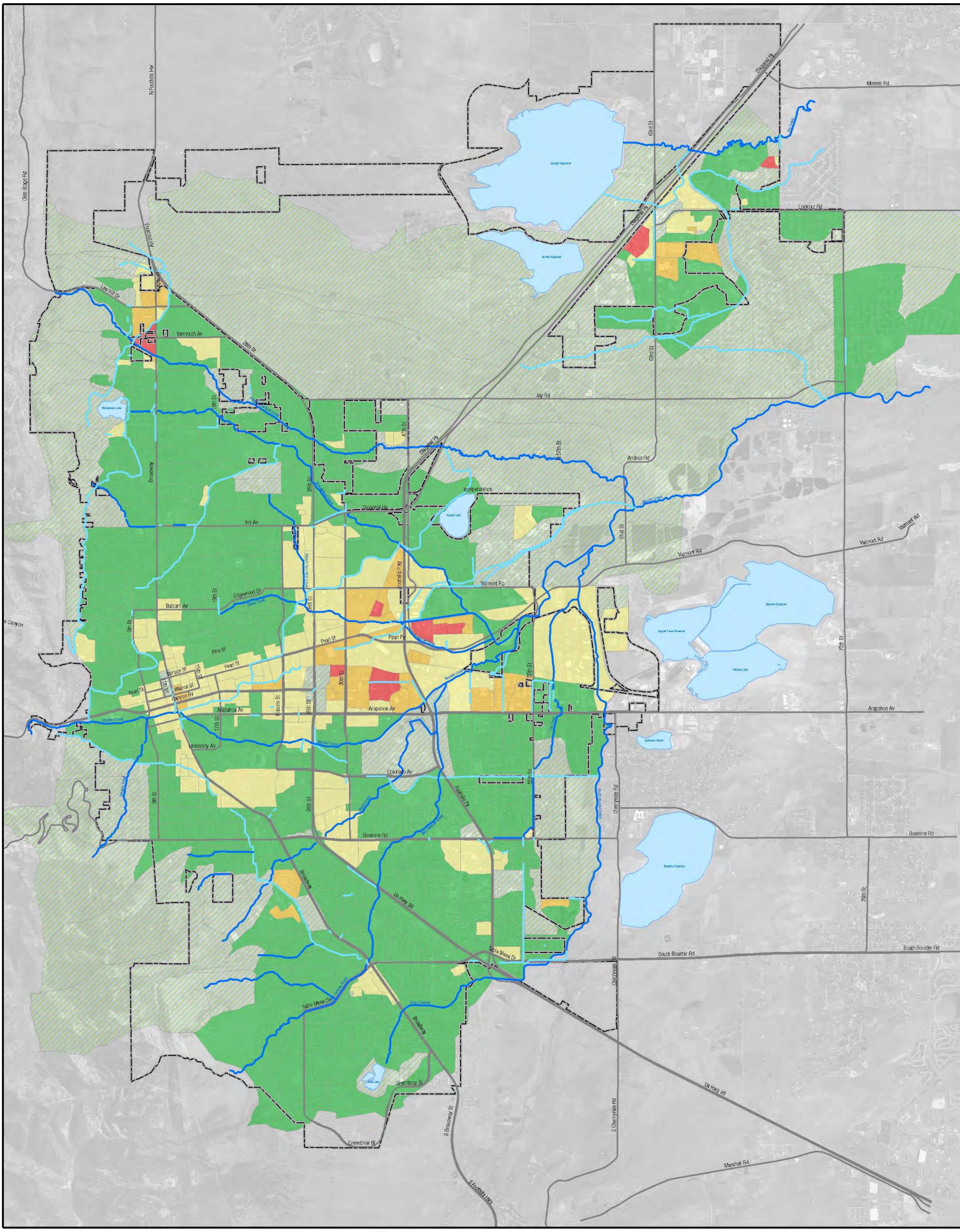


Summary of Ditch Problem Areas

Figure 4-4



0 4,000
1 inch equals 4,000 feet

Legend

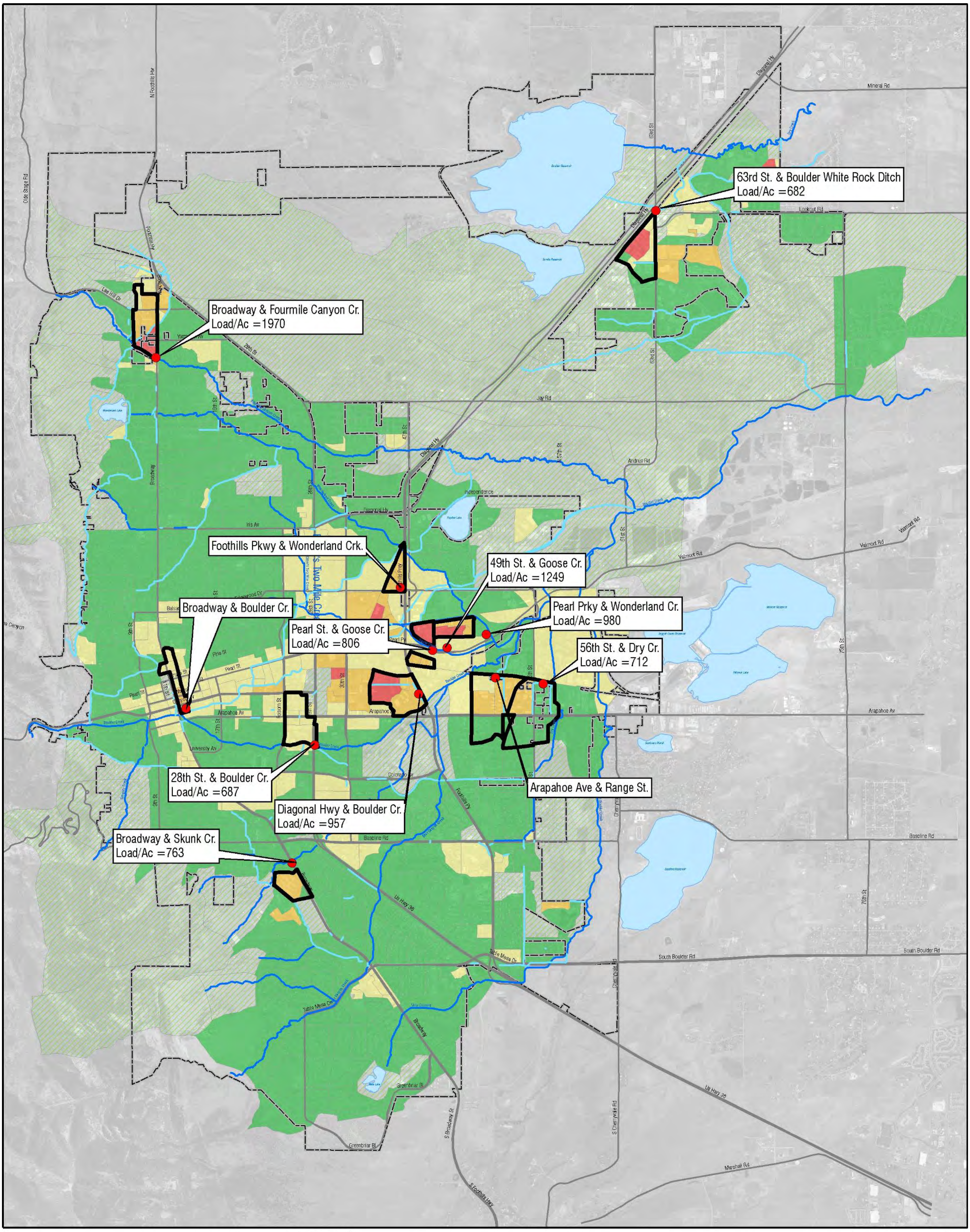
Load (Lbs TSS/Ac/Yr)

- 0 - 250
- 251 - 500
- 501 - 750
- 751 - 1000
- 1001 +
- Ditch
- Major drainageway
- Major Roads
- Lakes
- City Limits

N

Summary of Water Quality Areas of Concern (Catchments)

Figure 4-5



Legend

- Key Pollutant Load Outfalls
- Outfall Catchments
- Modeled network
  - Canal/ Ditch
  - Major drainageway

Load (Lbs TSS/Ac/Yr)

- 0 - 250
- 251 - 500
- 501 - 750
- 751 - 1000
- 1001 +

- Major Roads
- Lakes
- City Limits

0 4,000

1 inch equals 4,000 feet

N

Summary of Water Quality Areas of Concern (Outfalls)

Figure 4-6

5 Local System Analysis and Results

A GIS-based desktop analysis was conducted to provide a more detailed understanding of the local system problem area characteristics. The analysis reviewed the existing storm sewer network, irrigation and open channel systems, topography via 2013 1-ft LiDAR contours, and aerial photography. For the Type A areas, city staff provided problem descriptions based on CRM database information. For the Type B problem areas, problem descriptions were based on 2013 flood observation data combined with a review of the storm sewer network and area topography. Based on this analysis, modeled subcatchments tributary to the Type A and Type B problem areas were refined to better represent the local drainage conditions. Figure 5-1 provides an overview of the Type A and Type B problem areas.

5.1 Type A Problem Area Characterization

Fact sheets are provided in this section summarize information regarding each local system problem area to facilitate development of improvement alternatives. These fact sheets are grouped together by drainage basin and include the following information:

- ***Problem Location***. Summarizes the location and extent of the problem with respect to city streets and other key landmarks.
- ***Problem Description***. Summarizes the type and extend of the drainage system problems as initially provided by city staff and expended upon through further investigations by HDR staff.
- ***Constraints***. Identifies issues that would affect implementation of improvements. Issues include storm sewer depth, major utility relocations, construction impacts to stakeholders, etc.
- ***Opportunities***. Identifies potential opportunities for developing improvement alternatives. The preferred alternative is shown in italics.
- ***Land Ownership.*** Summarizes existing land ownership and potential land acquisition required to resolve local system problems.

5.1.1 Wonderland Creek

Problem ID and Name	Wonderland Creek – 1
Problem Location	Broadway from Rosewood Avenue to Violet Avenue
Problem Description	Due to a lack of stormwater infrastructure along the east side of Broadway Street from Fourmile Creek to Violet Ave, and poor capture of stormwater by the existing storm sewer system north of Fourmile creek, runoff continues across Violet Ave and has the potential to flood properties on the south side of the street. Runoff also continues east along Violet and spills south along 13th Avenue. The contributing area to the identified problem area is approximately 2 acres.
Constraints	Capacity constraints were identified within the collector portion of the downstream system just south of the intersection of Violet Ave and Broadway Street within the previous 2007 SMP Update. The capacity required for the additional drainage area may not be available within downstream drainage system, potentially requiring additional system upgrades.
Opportunities	*Provide collection and conveyance infrastructure (inlets, manholes, and storm sewer) along the east side of Broadway and convey to the existing system along the west side of Broadway.* If the downstream system cannot receive the additional flow, the new collection and conveyance system could discharge to a detention system at the northwest corner of Broadway and Violet for control of runoff west of Broadway. Add inlets along the east side of Broadway, north of Fourmile Creek and connect into the existing storm sewer system along the west side of Broadway with discharge to Fourmile Creek. Note this option would reduction the identified drainage problem but may not be a sole solution as the drainage area below Fourmile Creek is contributor to the problem area.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way. If detention is pursued, land acquisition will likely be required.

Problem ID and Name	Wonderland Creek – 2
Problem Location	Intersection of 19th Street and Sumac Avenue
Problem Description	During larger storm events, runoff from Sumac Ave flows across 19th Street and has the potential to flood properties that are below road grade on the east side of 19th Street. Currently, there is existing storm sewer on the north side of the intersection, but none provided on the south where the issue is predominantly observed. The contributing area to the identified problem area is approximately 70 acres.
Constraints	Information pertaining to the depth of existing storm sewer and roadside ditch system is not recorded in the available GIS data. Connection of proposed collection and conveyance features to the existing downstream system could be limited if the downstream system is discovered to be too shallow. Capacity of the existing system in 19th Street is unknown and may be limited by the driveway culverts and roadside ditch.
Opportunities	*Provide collection and conveyance infrastructure (inlets and conveyance pipe) at the southwest corner of intersection and extending west in Sumac Ave to collect and convey into the existing system along the west side of 19th Street. Depending on the capacity of the existing system along 19th Street, the capacity of the existing system may need to be increased to discharge into Wonderland Creek.* Provide a detention and water quality facility located at the southwest corner of Crestview Park, adjacent to Sumac Avenue that detains stormwater conveyed in Tamarac Avenue that appears to discharge currently into the park property.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way. Proposed detention and water quality facility is located on Parks Department property.

5.1.2 Elmer's Twomile Creek

Problem ID and Name	**Elmer's Twomile Creek – 1**
Problem Location	Catalpa Way south of Clover Circle and Clover Circle cul-de-sac
Problem Description	Runoff flowing south along Catalpa Way, east from Clover Circle, flows south to the Catalpa Way dead-end. Catalpa Way south of Clover Circle does not have an existing storm system which causes potential flooding of the southern most homes on Catalpa Way. An irrigation lateral runs east-west along the south side of the parcels and it is presumed this small basin drained to that facility when the area was originally developed. The contributing area to the identified problem area is approximately 1 acre.
Constraints	The introduction of the additional drainage area could compromise the existing downstream conveyance system and require additional upgrades to the downstream system. Connection of the proposed collection and conveyance features to the existing downstream system could be limited if the downstream system is discovered to be too shallow.
Opportunities	*Provide collection and conveyance infrastructure (inlets and storm sewer) at the southern end of Catalpa Way and convey runoff via open channel to the existing system in 19th Street.* Collect runoff at the cul-de-sac low point and pipe to the irrigation lateral.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.

Problem ID and Name	**Elmer's Twomile Creek – 2**
Problem Location	Farmer's Ditch - Iris Avenue to Linden Avenue and Broadway Street to Cloverleaf Drive
Problem Description	Entire neighborhood bounded to the north, west, and south by Cloverleaf Drive, Broadway Street, and Kalmia Ave, respectively drains easterly to the Farmer's irrigation ditch. Specifically, runoff from the area described above is discharged to the ditch via four outfalls of 12, 18, 21, and 48-inches in diameter. The ditch system can become overwhelmed during heavy rains and cause potential overflows, causing flooding of downstream properties. The total contributing area is approximately 76 acres.
Constraints	Providing conveyance of flow from the existing discharge locations to the stormwater conveyance system to the east of the irrigation ditch would require the system to either be piped underneath the existing irrigation ditch via gravity flow or siphon. Some of the storm sewer outfall alignments are located on existing side lot lines. The existing storm sewer system downstream of Farmer's Ditch in 19th Street is relatively small (size range) and would likely require upsizing to accommodate additional flow. The closest major drainageway to accept additional flow is Elmer's Twomile Creek approximately 2,500 ft east of the Farmer's Ditch.
Opportunities	*Remove stormwater outfalls to the ditch. Construct new collection system in the problem area with a new storm sewer in Kalmia with outfall to Elmer's Twomile Creek.* Introduce a flow control weir within Farmers Ditch upstream of the existing outfalls for diversion of an equivalent amount of flow to the existing stormwater conveyance system within Iris Avenue, providing the necessary conveyance system capacity for inflows at the identified problem location. Limit discharge to Famer's Ditch. Provide additional collection and conveyance infrastructure (inlets, manholes, and conveyance pipe) within the upstream subbasin and convey flow south in 16th St to and connect to the existing storm sewer in Iris Ave. Control ditch capacity at the Boulder Creek headgate via automated system based on ditch flow depth/capacity and rainfall gages.
Land Ownership	This reach of the Farmer's Ditch is located along private property and is assumed to be contained within an easement.

5.1.3 Twomile Canyon Creek

Problem ID and Name	Twomile Canyon Creek – 1
Problem Location	Kalmia Avenue and Juniper Avenue west of Broadway Street
Problem Description	Kalmia Avenue and Juniper Avenue do not have curb and gutter and surface runoff collects in irrigation ditch laterals which parallel these roads. During heavy rains runoff can overwhelm the laterals if they are not operated properly to convey runoff rather than irrigation water.. The approximate contributing area to the identified Kalmia Ave and Juniper Ave problem areas are 30 and 21 acres, respectively.
Constraints	Any new storm water infrastructure would have to accommodate the continued operation and capacity of the existing irrigation ditch lateral.
Opportunities	*Provide increased overall system capacity through retrofitting the existing open channel conveyance network from Twomile Creek to Broadway Street along Kalmia Ave and Juniper Ave.* *Introduce sewer collection and conveyance (inlets and pipes) from Twomile Creek to Broadway Street along Kalmia Ave and Juniper Ave.*
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.

5.1.4 Goose Creek

Problem ID and Name	Goose Creek – 1
Problem Location	Intersection of 8th Street and Dellwood Avenue
Problem Description	The existing local stormwater conveyance system is undersized and reported as reaching capacity during relatively minor storm events. The inadequacy of the system has lead to frequent roadway flooding, to the point that the crown of the road is inundated several inches. This intersection is a low point, creating an exacerbated flooding condition during storm events. The total contributing area to the problem area described above is approximately 32 acres.
Constraints	The existing system located within Dellwood Avenue is assumed to be shallow and could therefore create problems for potential extensions/connections of proposed collection and conveyance features. Capacity constraints were identified within the collector portion of the downstream system just south of the intersection of 8th Street and Dellwood Avenue within the previous 2007 SMP Update. The downstream system capacity will not be able to accommodate increased peak flows resulting from upstream conveyance improvements.
Opportunities	*Improve/provide a stormwater collection and conveyance system along Dellwood Avenue between 3rd to 8th Street, eventually connecting into the existing conveyance system at the intersection of 8th Street and Dellwood Avenue. Upsize existing system south of Dellwood Avenue through North Boulder Park to just south of Balsam Street..* Create detention and water quality facility in North Boulder Park to mitigate increased runoff peaks associated with improved upstream conveyance in Dellwood Ave.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way. A detention/water quality facility at the downstream area would be located on Parks Department property.

Problem ID and Name	Goose Creek – 2
Problem Location	Alpine Avenue to Dellwood Ave and 3rd Street to 7th Street
Problem Description	Steep slopes and an inadequate existing storm sewer network cause high surface runoff flows, threatening pedestrians and residences at intersections where runoff is currently unmanaged. Many alleys contain low points, localized to the center of the block, and have been observed to collect runoff and spill it into adjacent residences. The total

	contributing area to the problem area described above is approximately 48 acres.
Constraints	Portions of the conveyance system within the extent of the problem area described above do not have elevation information attributed to conveyance features within available city GIS data. Therefore, these portions of the existing system (Balsam Avenue and Dellwood Avenue) are assumed to be shallow and could therefore create problems for potential connections of proposed collection and conveyance features. Capacity constraints were identified within the collector portion of the downstream system at North Boulder Park within the previous 2007 SMP Update. The downstream system capacity may not be available to accommodate increased peak flows resulting from upstream conveyance improvements and removal of existing inadvertent detention. Numerous existing utilities may affect the design and construction of a new storm sewer system in the developed neighborhood.
Opportunities	*Extend the existing stormwater collection and conveyance system along Balsam Avenue and Alpine Avenue west to 4th Street, connecting to the existing systems.* *Formalize the existing inadvertent detention that occurs in North Boulder Park and increase the volume to mitigate the increased runoff peaks created by improving the upstream storm sewer conveyance.*
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.

Problem ID and Name	**Goose Creek – 3**
Problem Location	Dewey Avenue from 4th Street to 9th Street
Problem Description	The existing stormwater infrastructure along 4th Street from Maxwell Avenue to Dewey Avenue has been identified as insufficient through observations of runoff bypassing the inlets during high rainfall storm events. Additionally, a bottleneck in the storm sewer at 6th Street and North Street where the storm sewer transitions from 30” to 12” sewer has been identified, which creates a local roadway flooding condition as a result of back-ups within the system. The area of concern is also perceived to receive a significant portion of runoff from adjacent impervious areas, exacerbating the flooding condition. The total contributing area to the problem area described above is approximately 64 acres.
Constraints	Capacity constraints were identified within the collector portion of the downstream system at North Boulder Park within the previous 2007 SMP Update. The downstream system capacity may not be available to accommodate increased peak flows resulting from upstream conveyance improvements and removal of existing inadvertent detention. The drop in elevation required over the significant distance of new conveyance system required could potentially inhibit effective tie-in to the existing downstream system.
Opportunities	*Remove orifice plate in manhole in 6th Street just south of North Street. Provide additional stormwater infrastructure (inlets and conveyance pipe) from 6th Street to North Street then extending east in North Street to 9th Street. Connect to existing system at intersection of 9th Street and North Street. Existing system from 6th Street to 9th Street between North Street and Dewey Avenue to remain in service.* Introduce new stormwater collection and conveyance systems along Concord Avenue and Maxwell Avenue from 4th Street and connecting to the existing system in 9th Street. Separation of runoff tributary to these local areas would alleviate the stress currently experienced on the Dewey Ave system during significant storm events. Develop a detention facility west of 3rd Street at the T-intersection with Dewey Avenue.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way. Detention would be located on private property requiring land acquisition.

5.1.5 Middle Boulder Creek

Problem ID and Name	**Middle Boulder Creek – 1**
Problem Location	Boulder High School - Grandview Avenue from 13th Street to 15th Street
Problem Description	Roadway runoff and an existing storm sewer discharge to the hillside to the south of the Boulder High School football field. The existing downstream open channel system to Boulder Creek has been determined to have insufficient conveyance capacity, creating a localized flooding condition during heavy rains, potentially flooding Boulder High School property. The total contributing area to the problem area described above is approximately 11 acres.
Constraints	Due to the small diameter conveyance pipe and anticipated shallow grades, the existing downstream system may not have the available capacity required if additional drainage area is directed toward that system. Increasing the existing storm sewer size would require construction adjacent to Colorado University (CU) classroom/office buildings. Terrain east of the football field, between Grandview and Boulder Creek, is steep making a proposed open channel system problematic.
Opportunities	*Construct an open channel system to intercept runoff with an alignment on the south side of the football field bleachers to the existing storm sewer outlet conveying runoff to Boulder Creek. Extend the storm sewer system from the existing outlet to Boulder Creek.*
Land Ownership	Review of the GIS parcel data revealed that the land required for the potential projects is comprised of both city right-of-way and private property. The existing storm sewer is shown to be on private property but assumed to be contained within an easement.

5.1.6 Bluebell Canyon Creek

Problem ID and Name	**Bluebell Canyon Creek – 1**
Problem Location	Intersection of 20th Street and Mariposa Avenue
Problem Description	The Anderson Ditch culvert under Mariposa Avenue is too tall, causing a crown perpendicular to the slope on the east side of the intersection. This crown impedes conveyance of gutter flow and surface runoff, creating a localized flooding condition within the intersection and adjoining properties. The total contributing area to the culvert is approximately 65 acres.
Constraints	Removal of the existing crown in the road/gutter profile would pass additional flow east, down Mariposa that would exceed current conditions. However, the steep roadway grade and downstream inlet system were adequate to convey 2013 flood flows.
Opportunities	*Construct a new storm sewer in 20th from Bluebell Ave north to Mariposa, then east in Mariposa connecting to the existing system in Broadway. Inlets would be located upstream of the Anderson Ditch intercepting flow before entering the ditch and sized such that intersection ponding would not create flooding.*
Land Ownership	This reach of Anderson Ditch is located on both city right-of-way and private property with private property areas assumed to be contained within an easement.

5.1.7 Dry Creek No. 2

Problem ID and Name	**Dry Creek No. 2 – 1**
Problem Location	Intersection of Chippewa Drive and Caddo Parkway east of Inca Parkway
Problem Description	Chippewa Drive and Caddo Parkway, east of Inca Parkway, are currently graded such that runoff is collected primarily along the north side of the roadway. During heavy rains the inlets on the north side of the roadway become overwhelmed, causing localized flooding of adjacent properties. The total contributing area to the problem area described above is approximately 15 acres.
Constraints	Capacity constraints were identified within the collector portion of the downstream system at Baseline Road in the 2007 SMP Update. Improvements within this local area may need to be connected with collector system improvements.
Opportunities	*Provide a new storm sewer system in Chippewa Drive and Caddo Parkway that drains to a new system Mohawk Drive that discharges to Thunderbird Lake. Combine this improvement with the Type B problem area improvement opportunity that also increases flows to the lake and improves water quality in the lake which has had issues with insufficient replenishment and stagnation.* Provide inlets and storm sewer in Chippewa Drive and Caddo Parkway to convey flow to the existing system in Inca Parkway.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.

Problem ID and Name	**Dry Creek No. 2 – 2**
Problem Location	Intersection of Erie Drive and Pinon Drive
Problem Description	The Pinon Drive roadway section currently acts as dam, impeding runoff from Erie Drive to be effectively conveyed to the existing downstream drainage system, and leading to a flooding condition at properties adjacent to the intersection. The total contributing area to the problem area described above is approximately 5 acres.
Constraints	A significant amount of stormwater infrastructure would be required (approximately 1,600 lineal feet of storm sewer) to provide connection into the existing downstream system. The drop in elevation required over the significant distance of new conveyance system could potentially inhibit effective tie-in to the existing downstream system. Capacity constraints were identified within the collector portion of the downstream system at Baseline Road in the 2007 SMP Update. Improvements within this local area may need to be connected with collector system improvements.
Opportunities	*Provide a storm sewer system in Pinon Drive west of Erie Drive to Meadowbrook and then north in Meadowbrook extending to the existing system in Baseline Road.* Provide a stormwater collection and conveyance system along Erie Drive from Chippewa to Pinon Drive and along Pinon Drive from Erie Drive to Inca Parkway, connecting into the existing conveyance system within Inca Parkway. Provide a storm sewer system in Erie Drive from Chippewa to Pinion, then extending north of Pinon across the existing parking lot and across Baseline Road with discharge to Bear Canyon Creek.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way with the exception of a system extending north at Erie Drive/Pinon Drive intersection which would require land acquisition. Infiltration facilities would likely require additional land acquisition.

Problem ID and Name	Dry Creek No. 2 – 3
Problem Location	Baseline and 55th Street from Foothills Hwy to Arapahoe Avenue
Problem Description	Several sections of the existing open channel system on the north side of Baseline Road and Dry Creek Ditch #2 along 55th St north of Baseline are capacity limited and can cause stormwater to back up into the upstream conveyance and detention facilities. The total contributing area to the problem area described above is approximately 314 acres. The 2007 SMP identified the existing storm sewer systems are under capacity in Manhattan, under Foothills Parkway, near Broadway, and south along Foothills Parkway.
Constraints	Capacity constraints were identified within the collector portion of the downstream system at Baseline Road in the 2007 SMP Update. The capacity required for the potential additional drainage areas discussed in other problem areas may not be available within downstream drainage system, potentially requiring additional system upgrades.
Opportunities	*Construct new storm sewer in Baseline from Brooklawn Drive to 55th Street and within 55th Street from Baseline to approximately 300 feet north of Pennsylvania Avenue with a new outfall to Wellman Ditch.* Increase the capacity of the open channel conveyance system on the north side of Baseline Road between Brooklawn Drive and Dry Creek No. 2 and portion of Dry Creek No. 2 along 55th Street north of Baseline.
Land Ownership	This portion of the open channel conveyance system and Dry Creek No. 2 reach is located on both city right-of-way and private property. The portion of the problem area located on private property is assumed to be contained within an easement.

5.1.8 Bear Canyon Creek

Problem ID and Name	Bear Canyon Creek – 1
Problem Location	Bear Canyon Creek, downstream of Stony Hill Court crossing, located approximately 250 feet east of the intersection of Stony Hill Drive and Rockmont Circle.
Problem Description	A 48-inch diameter storm sewer culvert under Stony Hill Drive providing conveyance for a tributary ofBear Canyon Creek was not built as specified on the original design plans. Specifically, the outlet is aligned directly at residences located along the right bank instead of down the creek main channel. During significant storms events, flow from the outlet has to the potential to overshoot the creek and flood adjacent properties. In addition to the misalignment of the culvert, creek excavation may not have been done according to the original design, further exacerbating the flooding condition. Potentially, six properties may flood during heavy rainfall. The total contributing area to the culvert is approximately at 104 acres.
Constraints	The culvert and channel are located in a designated wetland and high quality natural area. Environmental impacts need to be addressed, avoided or mitigated with additional permitting requirements.
Opportunities	*Maintain existing culvert alignment and introduce a structure at the location of the originally designed center of the downstream channel and provide 42-inch-diameter conveyance pipe oriented with a properly determined alignment. This option would also require realignment of the downstream channel and sufficient downstream channel protection.*
Land Ownership	The problem area is located on private property in an open space subdivision tract owned by the Devil’s Thumb Homeowner’s Association.

5.1.9 Viele Channel

Problem ID and Name	Viele Channel – 1
Problem Location	Longwood Ave and Lafayette Drive from Lehigh Street to Greenbriar Boulevard
Problem Description	Runoff from the local roadway and residential parcels is currently conveyed easterly towards Greenbriar Boulevard via roadway section along Lafayette Drive and Longwood Avenue. The roadway section contains no stormwater infrastructure and has been identified as having insufficient capacity to convey runoff through frequent observations of flooding of local sidewalks. The problem is exacerbated by the pitch and crown of the roads which causes almost all runoff to flow on the north side of Longwood Ave. The total contributing area to the system described above is approximately 21 acres.
Constraints	Capacity constraints were identified within the collector portion of the downstream system near Viele Lake in the 2007 SMP Update. Impacts on the downstream drainage system will need to be evaluated to ensure capacity is available.
Opportunities	*Provide a stormwater collection and conveyance system in Lafayette Drive 160 feet north of Longwood Avenue and eastward along Longwood Avenue from Lafayette Drive to Greenbriar Boulevard to alleviate local flooding through effective conveyance of runoff to the existing downstream system.*
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way with the exception of the existing storm sewer that cut across the high school parking lot. The parking lot alignment is assumed to be contained within an easement.

5.2 Type B Problem Characterization

Similar to the Type A problem areas, Type B problem areas utilize fact sheets to summarize the analysis of problem area characterization and facilitate development of alternatives for improvements. The information provided within the Type B problem area fact sheets are listed and described below:

- ***Problem Location.*** Summarizes the location and extent of the problem with respect to city streets and other key landmarks.
- ***Underserved Area.*** Identifies if the problem area has a current widespread lack of existing stormwater infrastructure. An area which has existing stormwater system that may be under-sized due to development or introduction of other additional stormwater flows is not considered an underserved area.
- ***2013 Flood Reports.*** Describes the nature of the flooding issues experienced during the 2013 storm event, including types of damages and range of flooding depths.
- ***2013 Flood Report Area with 2007 SMP Improvement.*** Identifies problem areas containing both observations of flooding during the 2013 event and locations of 2007 SMP recommended stormwater infrastructure improvements.
- ***Problem Description.*** Summarizes the potential source/cause of the drainage problem based on a review of the base GIS data and 2013 flood reports.
- ***Opportunities.*** Identifies potential opportunities for developing improvement alternatives. The preferred alternative is shown in italics.
- **Irrigation Ditch Storm Flow Reduction**. Summarizes the potential for removing stormwater entering the existing ditch system through local system improvements within the local problem area.

Following the Type B problem area analysis and fact sheet summaries, a site visit was performed by city and HDR staff to validate the identified problem areas and assess potential solutions. This site visit resulted in several Type B problem areas being removed from further consideration where the actual street, storm sewer and drainage ditch conveyance system characteristics did not provide evidence of drainage problems. These problem areas were included in the following tables to provide a record that they were investigated but are identified by a "Field Observation Overrides" statement to indicate that further analysis was not deemed necessary at this time.

5.2.1 Fourmile Canyon Creek

Problem Name and ID	**Fourmile Canyon Creek – 1 (FCC-1)**
Problem Location	Vicinity of Jay Road and 26th Street.
Underserved Areas	Yes, considering the 43 +/- acres of tributary area. The existing drainage system is limited, mainly consisting of roadside ditches and driveway culverts.
2013 Flood Reports	Yes, one instance of shallow localized flooding during the 2013 event was reported. The reported flood depth was estimated at about 1 inch with reported damages mainly to house features such as drywall and carpet.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Limited drainage infrastructure, combined with the potentially capacity-limited roadside ditch and culvert system, was presumed to contribute to 2013 flooding reports.
Opportunities	*Provide a stormwater collection and closed conveyance system along 26h Street from Jay Rd to approximately 300 feet south of Topaz Drive, discharging to the Fourmile Canyon Creek Drainageway.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

5.2.2 Wonderland Creek

Problem Name and ID	**Wonderland Creek – 3 (WC-3)**
Problem Location	Boulder Open Space to the northeast of the cul-de-sac located at the eastern extent of Utica Avenue.
Underserved Areas	No, the subbasin has an existing drainage system of surface conveyance and storm sewers which appear to be adequate for the subbasin and land use. The problem appears to be caused by an isolated area of run-on from an adjacent parcel and not a basin-wide lack of drainage infrastructure.
2013 Flood Reports	Yes, three instances of shallow localized flooding during the 2013 event were reported. Reported flood depths were estimated at about 2 feet with reported damages mainly to house features such as drywall, carpet, and paint.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	During the 2013 flood, runoff from Boulder Open Space appears to have travelled across the private properties and inundated homes.
Opportunities	*Provide open channel conveyance to the west of the residences where flooding during the 2013 event was observed to collect surface runoff from hillside. Route flows northeasterly, eventually connecting to the existing system located approximately 100 feet northwest of the intersection of 6th Street and Locust Avenue.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed. Storm flow does not enter the Silver Lake Ditch.

Problem Name and ID	**Wonderland Creek – 4 (WC-4)**

Problem Location	Promontory Court and Poplar Avenue.
Underserved Areas	No, the subbasin is served by an existing drainage system, however, it appears to be undersized and catch basins are not located in low-lying areas. The problem also appears to be caused by an isolated area of run-on from an adjacent parcel and not a basin-wide lack of drainage infrastructure.
2013 Flood Reports	Yes, four instances of shallow localized flooding during the 2013 event were reported within the problem area. Reported flood depths were estimated from 4 inches to 3 feet with reported damages mainly to house features such as drywall, carpet, and insulation.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	During the 2013 flood, runoff from Boulder Open Space appears to have travelled across the private properties and inundated homes. The northern cul-de-sac also does not appear to have adequate drainage to convey runoff from the originating from the southern portion of Promontory Ct causing street and property flooding. Current inlets are also not located in low-lying areas.
Opportunities	*Provide open channel conveyance to the west of the residences where flooding during the 2013 event was observed to collect surface runoff from hillside. Route flows northeasterly to Silver Lake Ditch.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed. Storm flow does not enter the Silver Lake Ditch.

Problem Name and ID	**Wonderland Creek – 5 (WC-5) Field Observation Override**
Problem Location	Vicinity of 19th Street and Quince Avenue.
Underserved Areas	No, area is served by roadside ditches which appear adequate for the subbasin and land use..
2013 Flood Reports	Yes, two instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 4 inches to 1.5 feet with damages mainly to house features such as walls and carpet. Groundwater issues were reported at one location as well.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Problem appears to be due to lack of maintenance of ditches on private property.
Opportunities	*Provide a stormwater collection and closed conveyance system along Quince Avenue from 17th Street to 19th Street and along 19th Street from Quince Avenue to approximately 150 feet north of Redwood Avenue, eventually discharging to the Wonderland Creek Drainageway.* Retrofit existing open channel conveyance features along the south wide of Quince Avenue from 17th Street to 19th Street and along 19th Street from Quince Avenue to approximately 150 feet north of Redwood Avenue, eventually discharging to the Wonderland Creek Drainageway.
Irrigation Ditch Storm Flow Reduction	No opportunities observed.
Field Observation Override	Site visit identified the drainage issue as a maintenance issue of drainage features on private property and not a utilities conveyance issue.

Problem Name and ID	**Wonderland Creek – 6 (WC-6)**

Problem Location	Vicinity of Poplar Avenue and 20th Street.
Underserved Areas	Yes, considering the 30 +/- acres of tributary area. The existing drainage system is limited, mainly consisting of roadside ditches and driveway culverts that may be inadequate for the subbasin and land use.
2013 Flood Reports	Yes, one instance of shallow localized flooding during the 2013 event was reported within the problem area. Based on the available flood survey data, observed flood depths were estimated at 4 inches with reported damages mainly to house features such as drywall and carpet.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Limited drainage infrastructure, combined with the potentially capacity-limited roadside ditch and culvert system, was presumed to contribute to 2013 flooding reports.
Opportunities	*Provide a stormwater collection and closed conveyance system along 20th Street from Orchard Avenue to approximately 170 feet north of Poplar Avenue, eventually discharging to the Wonderland Creek Drainageway.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	**Wonderland Creek – 7 (WC-7)**
Problem Location	Vicinity of Oak Avenue and 21st Street.
Underserved Areas	Yes, considering the 53 +/- acres of tributary area. The existing drainage system is limited, mainly consisting of roadside ditches and driveway culverts that may be inadequate for the subbasin and land use.
2013 Flood Reports	Yes, two instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 3 to 6 inches with damages mainly to house features such as walls, drywall, and carpet.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Limited drainage infrastructure, combined with the potentially capacity-limited roadside ditch and culvert system, was presumed to contribute to 2013 flooding reports. Roadway flooding of Norwood Ave has also been observed by city staff during other heavy rainfalls.
Opportunities	*Provide a stormwater collection and closed conveyance system along Oak Avenue from Oak Place to 21st Street and along Norwood Avenue from 21st Street to 26th Street, eventually discharging to the Wonderland Creek Drainageway.*
Irrigation Ditch Storm Flow Reduction	Yes, stormwater discharge to the Farmer's Ditch can be reduced through implementation of the proposed conveyance system discussed above.

Problem Name and ID	**Wonderland Creek – 8 (WC-8) Field Observation Override**

Problem Location	Vicinity of Wright Avenue and Franklin Drive.
Underserved Areas	No, the subbasin has an existing drainage system of surface conveyance and storm sewers which appear to be adequate for the subbasin and land use.
2013 Flood Reports	Yes, five instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1 inch to 1 foot with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	The problem may be attributable to irrigation ditch overtopping.
Opportunities	*Provide a stormwater collection and closed conveyance system along Franklin Drive from Tesla Court to Wright Avenue and upgrade current system along Franklin Drive from Wright Avenue to approximately 200 feet south of Noble Court, eventually discharging to the Wonderland Creek Drainageway. Additionally, provide collection and closed conveyance along Noble Court and Wright Avenue from Franklin Drive to the proposed system discussed above within Franklin Drive.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.
Field Observation Override	Field observations and review of 2013 Flood data indicate this is a potential irrigation ditch capacity/overtopping issue and not a local drainage system conveyance issue.

5.2.3 Goose Creek

Problem Name and ID	**Goose Creek – 4 (GC-4)**
Problem Location	Vicinity of Forest Avenue between 3rd Street and Broadway Street
Underserved Areas	Yes, considering the 98 +/- acres of tributary area. The existing drainage system is limited, mainly consisting of curb and gutter, roadside ditches and driveway culverts.
2013 Flood Reports	Yes, ten instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1 inch to 5 feet with damages mainly to house features such as walls, drywall, carpet, and flooring. Additionally, damage to electrical systems, water heaters, and landscaping was reported.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Limited drainage infrastructure, yielding relatively no removal of surface waters from the roadway was presumed to contribute to 2013 flooding reports.
Opportunities	*Construct a new storm sewer system in Forest Avenue from 4th Street to Broadway Street and Hawthorn Avenue, from 4th Street and connecting to the proposed system in Forest Avenue, eventually discharging to the existing system in Broadway Street.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	**Goose Creek – 5 (GC-5)**

Problem Location	Vicinity of Cedar Avenue and 19th Street
Underserved Areas	No, the subbasin is served by an existing drainage system, however, it may be inadequate for the subbasin and land use.
2013 Flood Reports	Yes, nine instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 2 inches to 2 feet with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	Yes, the problem area is located within the vicinity of a 2007 SMP project recommendation.
Problem Description	2013 flooding reports exceeded the level of service of the drainage system along local collector streets.
Opportunities	*Per the recommendations provided in the 2007 SMP, construct a new storm sewer system in Elder Avenue from Broadway Street to 19th Street and along Floral Drive from 19th Street to approximately 300 feet south of Edgewood Drive, eventually discharging to the Goose Creek Drainageway.* Also per the 2007 SMP, upgrade the existing storm sewer system along Cedar Avenue and 19th Street between 17th Street and 19th Street and Cedar Avenue and Balsam Street, respectively.
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	**Goose Creek – 6 (GC-6)**
Problem Location	Vicinity of Cedar Avenue and 19th Street
Underserved Areas	Yes, considering the 55 +/- acres of tributary area. The existing drainage system is limited, mainly consisting of curb and gutter and minimal closed conveyance.
2013 Flood Reports	Yes, four instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 2 inches to 5 feet with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Limited drainage infrastructure along local collector streets, combined with the potentially capacity-limited downstream conveyance system, was presumed to contribute to 2013 flooding reports. Overland spill from Twomile Canyon Creek also contributed to flooding of this problem location.
Opportunities	*Extend existing storm sewer system in Glenwood Drive west along Grape Avenue and Hawthorn Avenue to Hawthorn Place. Additionally, provide local collection and conveyance along Hawthorn Place and Garland Lane with connections to the proposed system mentioned above. Improve existing system in Glenwood Drive from 20th Street to 23rd Street. Addressing overland spill of Twomile Canyon Creek may eliminate need for or reduce extent of these improvements.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	**Goose Creek – 7 (GC-7)**

Problem Location	Vicinity of Glenwood Drive and Folsom Street.
Underserved Areas	No, the subbasin is served by an existing drainage system, however, it may be inadequate for the subbasin and land use.
2013 Flood Reports	Yes, two instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 4 inches to 3 feet with damages mainly to house features such as walls, drywall, carpet, and flooring. Additionally damage to furnaces and water heaters were reported.
2013 Flood Report Area with SMP Improvement	Yes, the problem area is located within the vicinity of a 2007 SMP project recommendation.
Problem Description	2013 flooding was reported to exceed the level of service of the drainage system along local collector streets which may have been exacerbated by the potentially capacity-limited downstream conveyance system.
Opportunities	*Per the recommendations provided in the 2007 SMP, upgrade the existing storm sewer system along Glenwood Drive and Folsom Street between 23rd Street and Folsom Street and Hawthorn Avenue and Glenwood Drive, respectively. Additionally, the plan also called for construction of a new storm sewer along Glenwood Drive between Folsom Street and Westwood Court. This alternative would route a portion of the flow within the Folsom Street system east to Elmer's Two Mile Creek, alleviating the pressure experienced in the existing Folsom Street system.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	**Goose Creek – 8 (GC-8)**
Problem Location	Vicinity of 22nd Street between Forest Avenue and Valmont Road.
Underserved Areas	Yes, considering the 65 +/- acres of tributary area. The existing drainage system is limited, mainly consisting of curb and gutter and minimal closed conveyance.
2013 Flood Reports	Yes, six instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 3 inches to 1.5 feet with damages mainly to house features such as walls, drywall, carpet, and flooring. Additionally, damage to furnaces and water heaters was reported.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Limited drainage infrastructure along local collector streets, combined with the potentially capacity-limited downstream conveyance system, was presumed to contribute to 2013 flooding reports.
Opportunities	*Provide new collection and conveyance system in Fremont Street, connecting to the existing Folsom Street system. Additionally, provide new collection and conveyance within 23th Street and 24th Street, extending to the existing system in Edgewood Drive.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

5.2.4

5.2.5 Middle Boulder Creek

Problem Name and ID	Middle Boulder Creek – 2 (MBC-2)
Problem Location	Vicinity of Spruce Street and Pearl Street near 18th Street.
Underserved Areas	No, the subbasin is served by an existing drainage system, however, it may be inadequate for the subbasin and land use.
2013 Flood Reports	Yes, four instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 9 inches to 2.5 feet with damages mainly to house features such as walls, drywall, carpet, and flooring. Additionally damage to furnaces and water heaters were reported.
2013 Flood Report Area with SMP Improvement	Yes, the problem area is located within the vicinity of a 2007 SMP project recommendation.
Problem Description	2013 flooding was reported to exceed the level of service of the drainage system along local collector streets which may have been exacerbated by the potentially capacity-limited downstream conveyance system.
Opportunities	*Improve existing storm sewer in 18th Street from Pine Street to Spruce Street, in 20th Street from Spruce Street north halfway to Pine Street, and in Spruce Street from 18th Street to the manhole east of 21st Street.* *Introduce new storm sewer system along Pearl Street from 18th Street to 21st Street, conveying flows easterly into the Boulder White Rock Ditch.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	Middle Boulder Creek – 3 (MBC-3)
Problem Location	Vicinity of Cascade Avenue from College Avenue to Chautauqua Reservoir Road.
Underserved Areas	No, the subbasin is served by an existing drainage system, however, it may be inadequate for the subbasin and land use.
2013 Flood Reports	Yes, fifteen instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1 inch to 1.5 feet with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	Yes, the problem area is located within the vicinity of a 2007 SMP project recommendation.
Problem Description	2013 flooding reports exceeded the level of service of the drainage system along local collector streets and combined with the potentially capacity-limited downstream conveyance system.
Opportunities	*Construct new collection and conveyance system along Baseline Road from Grant Place to 13th Street and along 13th Street between Baseline Road and Cascade Avenue, eventually discharging to the existing system within 13th Street.* Per the recommendations provided in the 2007 SMP, upgrade existing storm sewer system along Lincoln Place between Aurora Avenue and Euclid Avenue.
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

5.2.6 Bear Canyon Creek

Problem Name and ID	Bear Canyon Creek – 2 (BCC-2) Field Observation Override
Problem Location	Vicinity of Mohawk Drive from Pitkin Drive to Talbot Drive
Underserved Areas	No, the existing drainage system appears adequate for the subbasin and land use.
2013 Flood Reports	Yes, three instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 3 inches to 3 feet with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Bear Canyon Creek may have spilled south of Baseline and contributed to flood report problems.
Opportunities	*Improve existing collection and conveyance system in Mohawk Drive and extend further south. Construct laterals in Inca Parkway and Talbot Drive. Improvement in Inca Parkway will route runoff to discharge in Bear Canyon Creek downstream of problem area.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.
Field Observation Override	Field observations noted adequate street grade to convey flow to existing storm sewer system and houses are well above street grade. In the 2013 Flood, the Bear Canyon Creek major drainageway may have spilled and contributed to the local flooding reports. Considered an isolated incident during a historic event.

Problem Name and ID	Bear Canyon Creek – 3 (BCC-3)
Problem Location	Vicinity of Kohler Drive from south of Dartmouth Avenue
Underserved Areas	Yes, considering the steep grades and 36 +/- acres of tributary area. The existing drainage system is limited, mainly consisting of curb and gutter, shallow open channels and minimal closed conveyance.
2013 Flood Reports	Yes, two instances of localized flooding during the 2013 event were reported uphill of Anderson Ditch and four instances downhill. Based on the available flood survey data, reported flood depths of only a few inches were estimated uphill of Anderson Ditch, however downhill of the ditch, depths up to 6 feet were reported. Damages mainly to house features such as walls, drywall, carpet, and flooring as well as furniture.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Steep terrain drains to sump condition in Kohler Drive with stormwater discharging to Anderson Ditch. Closed conveyance is inadequate and overflow path runs to properties downhill in Dover Drive.
Opportunities	*Improve existing collection and conveyance system in sump condition of Kohler Drive. Route to Dartmouth Avenue and connect to system in Broadway Street. Improvements in Kohler will alleviate downhill flooding in Dover.* *Additionally, upsize portions of the existing system where throttling occurs due to reduced pipe diameters.*
Irrigation Ditch Storm Flow Reduction	Yes, improvements will remove stormwater from Anderson Ditch.

Problem Name and ID	Bear Canyon Creek – 4 (BCC-4)
Problem Location	Vicinity of Yale Road and Hartford Drive
Underserved Areas	Yes, entire 27 +/- acres of the subbasin are routed to series of only six inlets at the intersection of Baylor Drive and Yale Road.
2013 Flood Reports	Yes, four instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1/2 to 12 inches with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Potential flooding from surface run-off.
Opportunities	*Construct collection and conveyance system in Hartford Drive and Baylor Drive to reduce volume of surface flow through the neighborhood to existing collection point.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	Bear Canyon Creek – 5 (BCC-5)
Problem Location	Vicinity of Wildwood Road
Underserved Areas	No, the existing drainage system appears adequate for the subbasin and land use, however, localized hydraulic issues at the downstream end of the system may be causing the problem.
2013 Flood Reports	Yes, five instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1/2 to 6 inches with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Runoff to Wildwood Drive sump/sag locations may exceed storm sewer capacity and major storm overflow paths.
Opportunities	*Install and/or improve discharge locations to Bear Canyon Creek.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

5.2.7 Dry Creek No. 2

Problem Name and ID	Dry Creek No. 2 – 4 (DC2-4)
Problem Location	Vicinity of Mohawk Drive and Sioux Drive north of US-36
Underserved Areas	Yes, no local collection and conveyance system exists. On-street drainage appears to be only method of conveyance to Thunderbird Lake/existing system in Thunderbird Drive.
2013 Flood Reports	Yes, five instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 2 to 6 inches with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Collection and conveyance system appears to be undersized in Type A problem areas downhill of subbasin
Opportunities	*Improvements proposed in Dry Creek No.2-1 may alleviate or address flood report issues. Provide local collection and conveyance system in Pawnee Drive discharging into existing Thunderbird Lake.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	Dry Creek No. 2 – 5 (DC2-5)
Problem Location	Vicinity of Eisenhower Drive and 48th Street south of Arapahoe Avenue
Underserved Areas	Yes, no local collection and conveyance system exists for 56 +/- acre subbasin.
2013 Flood Reports	Yes, seven instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1 to 4 inches and one case of 2 feet with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Large subbasin with no collection and conveyance system. Overflow of Wellman Ditch to the south may have added to the flooding.
Opportunities	*Construct collection and conveyance system in McKinley Drive, Eisenhower Drive and 48th Street and extend laterals into cross streets.* *Additionally construct collection and conveyance system in Harrison Avenue. Connect to existing system discharging to Bear Canyon Creek.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	Dry Creek No. 2 – 6 (DC2-6)
Problem Location	Vicinity of Merritt Drive south of Arapahoe Avenue
Underserved Areas	Yes, no local collection and conveyance system exists for 20 +/- acre subbasin.
2013 Flood Reports	Yes, two instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1 to 4 inches with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Large subbasin with no collection and conveyance system. Overflow of Wellman Ditch to the south may have added to the flooding.
Opportunities	*Construct collection and conveyance system in Merritt Drive with collection from Arapahoe Ridge Park. Extend laterals into cross streets. Connect to existing system north of Patton Drive.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	Dry Creek No. 2 – 7 (DC2-7)
Problem Location	Vicinity of Lodge Lane and 55th Street south of Arapahoe Avenue
Underserved Areas	No, the subbasin is served by an existing drainage system, however, it may be inadequate for the subbasin and land use.
2013 Flood Reports	Yes, seven instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1 to 21 inches with damages mainly to house features such as walls, drywall, carpet, and flooring as well as personal property and furniture.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Existing collection and conveyance system assumed to be undersized to handle the level of service required for the 2013 flooding.
Opportunities	*Improve existing collection and conveyance system to address capacity issues.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

Problem Name and ID	Dry Creek No. 2 – 8 (DC2-8)
Problem Location	Vicinity of White Place and 55th Street south of Arapahoe Avenue
Underserved Areas	No, the subbasin is served by an existing drainage system, however, it may be inadequate for the subbasin and land use.
2013 Flood Reports	Yes, four instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 2 to 24 inches with damages mainly to house features such as walls, drywall, carpet, and flooring as well as personal property and furniture.
2013 Flood Report Area with SMP Improvement	Yes, 2007 SMP improvement at the downstream end of the problem.
Problem Description	Existing collection and conveyance system assumed to be undersized to handle the level of service required for the 2013 flooding.
Opportunities	*Construct new collection and conveyance system in Holmes Place and White Place. Connect to existing system in 55th Street.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.

5.2.8 Viele Channel

Problem Name and ID	**Viele Channel – 2 (VC-2) Field Observation Override**
Problem Location	Vicinity of Lehigh Street from Galena Way to Hardscrabble Drive
Underserved Areas	No, the existing drainage system appears adequate for the subbasin and land use.
2013 Flood Reports	Yes, four instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1 to 8 inches with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Subdivision green space/private open space may have drained into back of lots.
Opportunities	*Construct channels along back of lots to route surface flow around neighborhood.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.
Field Observation Override	Field observations noted adequate street grade to convey flow to existing storm sewer system and houses are well above street grade. Considered an isolated incident during the historic 2013 Flood event.

Problem Name and ID	**Viele Channel – 3 (VC-3) Field Observation Override**
Problem Location	Vicinity of Iliff Street and Juilliard Street from Ithaca Drive to Lehigh Street.
Underserved Areas	No, the existing drainage system appears adequate for the subbasin and land use.
2013 Flood Reports	Yes, three instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 3 to 4 inches with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Overland flows from south may have sheeted across roads and private property impacting homes.
Opportunities	*Extend collector and conveyance system from Ithaca Drive west in Juilliard Street.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.
Field Observation Override	Field observations noted adequate street grade to convey flow to existing storm sewer system. Considered an isolated incident during the historic 2013 Flood event. Flood impacts may have been a result of groundwater.

Problem Name and ID	Viele Channel – 4 (VC-4) Field Observation Override
Problem Location	Vicinity of Emerson Avenue and Heidelberg Drive from Gillaspie Drive to Lehigh Street.
Underserved Areas	No, the existing drainage system appears adequate for the subbasin and land use.
2013 Flood Reports	Yes, one instance of significant flood depth, 6 feet 7 inches, reported from the 2013 flood event.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Source not apparent. Flood depth of 6 feet 7 inches to be investigated.
Opportunities	*Improvement to be determined once source is identified.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.
Field Observation Override	Considered an isolated incident during the historic 2013 Flood event.

Problem Name and ID	Viele Channel – 5 (VC-5) Field Observation Override
Problem Location	Vicinity of Grinnell Avenue and Ludlow Street from Knox Drive to Broadway Street
Underserved Areas	No, the existing drainage system appears adequate for the subbasin and land use.
2013 Flood Reports	Yes, two instances of shallow localized flooding during the 2013 event were reported within the problem area. Based on the available flood survey data, reported flood depths were estimated from 1 to 4 inches with damages mainly to house features such as walls, drywall, carpet, and flooring.
2013 Flood Report Area with SMP Improvement	No, the problem area is not located within the vicinity of a 2007 SMP project recommendation.
Problem Description	Offsite flows south of Ludlow Street and from Broadway Street entered back of homes.
Opportunities	*Construct channel or extend storm drain south of private properties on south side of Ludlow Street to the west. 2007 SMP improvement can be relocated to Toedtli Drive south of Ludlow Street.*
Irrigation Ditch Storm Flow Reduction	No opportunities observed.
Field Observation Override	Field observations noted adequate street grade to convey flow to existing storm sewer system. Considered an isolated incident during the historic 2013 Flood event. Flood reports may likely be a result of groundwater and/or major drainageway impacts. Location where improvements could have positive impact is on school and/or private property, outside of city Public Works jurisdiction.

5.3 Type A and Type B Problem Priorities

To assist in the analysis and development of improvement recommendations for the Type A and B problem areas, a prioritization process was used to assess the risk of future drainage related impacts. Problem prioritization criteria and the associated criteria weight for this process are summarized below.

Table 5.3-1: Local System Problem Prioritization Criteria

Criteria	Description	Weight
Type A Problem Areas - CRM	Known problem areas identified by city staff through Community Relations Management (CRM) database reports.	3
Type A Problem Areas – 2013 Flood Report Area with SMP Improvement	Type A problem areas containing observations of flooding during the 2013 event and/or modeled collector storm sewer system problem areas.	4
Type A and B Problem Areas – Irrigation Ditch Storm Flow Reduction	Type A and B problem areas where improvements have the potential to remove stormwater from irrigation ditches	2
Type A and B Problem Areas – Underserved Area	Type A and B problem areas that have been identified as having an observed lack of existing stormwater infrastructure.	4
Type B Problem Areas – 2013 Flood Reports	Type B problem areas containing observations of flooding during the 2013 event	2
Type B Problem Area – 2013 Flood Report Area with SMP Improvement	Type B problem areas containing observations of flooding during the 2013 event and within modeled collector storm sewer system problem areas.	3
Severity and Consequence of Flooding	Projects ranked by city staff based on field observations and system knowledge. Scored as High = 3, Medium = 2, and Low = 1	10

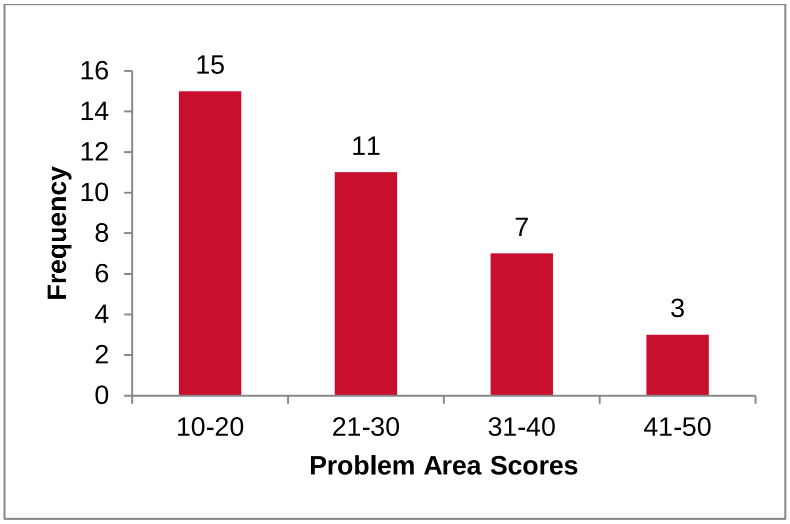
Problem areas that met the criteria noted above were assigned an individual scope of 1 where those that did not were assigned a score of 0, with the exception of Severity and Consequence of Flooding criteria. A tabular summary of the individual criteria scoring and weighted score results are summarized in the following table.

Table 5.3-2: Local System Problem Area Scoring

Type	Problem ID (Characteristic Weight)	Severity and Consequence of Flooding (10)	Type A Problem Areas - CRM (3)	Type A Problem Areas – 2013 Flood Report Area with SMP Improvement (4)	Type A and B Problem Areas – Underserved Area (4)	Type B Problem Area – 2013 Flood Report Area with SMP Improvement (3)	Type B Problem Areas – 2013 Flood Reports (2)	Type A and B Problem Areas – Irrigation Ditch Storm Flow Reduction (2)	Weighted Totals
A	Elmer's Twomile Creek - 2	3	1	1	1	0	0	1	43
A	Goose Creek - 1	3	1	1	1	0	0	0	41
A	Goose Creek - 2	3	1	1	1	0	0	0	41
A	Dry Creek No. 2 - 3	3	1	1	0	0	0	1	39
B	Bear Canyon Creek - 3	3	0	0	1	0	1	1	38
A	Dry Creek No. 2 - 1	3	1	1	0	0	0	0	37
A	Goose Creek - 3	3	1	1	0	0	0	0	37
B	Middle Boulder Creek - 2	3	0	0	0	1	1	0	35
A	Wonderland Creek - 1	3	1	0	0	0	0	0	33
B	Bear Canyon Creek - 5	3	0	0	0	0	1	0	32
B	Goose Creek - 5	2	0	0	1	1	1	0	29
B	Wonderland Creek - 7	2	0	0	1	0	1	1	28
A	Twomile Canyon Creek - 1	2	1	1	0	0	0	0	27
A	Viele Channel - 1	2	1	1	0	0	0	0	27
A	Wonderland Creek - 2	2	1	0	1	0	0	0	27
B	Bear Canyon Creek - 4	2	0	0	1	0	1	0	26
B	Goose Creek - 4	2	0	0	1	0	1	0	26
B	Middle Boulder Creek - 3	2	0	0	0	1	1	0	25
B	Fourmile Canyon Creek - 1	2	0	0	1	0	0	0	24
A	Bear Canyon Creek - 1	2	1	0	0	0	0	0	23
A	Bluebell Canyon Creek -1	2	1	0	0	0	0	0	23
A	Dry Creek No. 2 - 2	1	1	1	0	0	0	0	17
B	Dry Creek No. 2 - 4	1	0	0	1	0	1	0	16
B	Dry Creek No. 2 - 5	1	0	0	1	0	1	0	16
B	Dry Creek No. 2 - 6	1	0	0	1	0	1	0	16
B	Goose Creek - 6	1	0	0	1	0	1	0	16
B	Goose Creek - 8	1	0	0	1	0	1	0	16
B	Wonderland Creek - 6	1	0	0	1	0	1	0	16
B	Dry Creek No. 2 - 8	1	0	0	0	1	1	0	15
B	Goose Creek - 7	1	0	0	0	1	1	0	15
A	Elmer's Twomile Creek - 1	1	1	0	0	0	0	0	13
A	Middle Boulder Creek - 1	1	1	0	0	0	0	0	13
B	Dry Creek No. 2 - 7	1	0	0	0	0	1	0	12
B	Wonderland Creek - 3	1	0	0	0	0	1	0	12
B	Wonderland Creek - 4	1	0	0	0	0	1	0	12

In an effort to assist in prioritizing the Type A and B problem areas for future improvement priorities and determine the level of analysis necessary within the context of the SMP scope of work, a histogram approach was used to determine if there were break points in the scoring distribution for the problem areas.

In reviewing the histogram chart below and individual scores in the preceding table, it was observed that 25% of the total project areas had scores above 30 while the remaining 75% were distributed across a range from 12 to 30 increasing in frequency as the score dropped. This would indicate the more acute problem areas (higher scores) are fewer and more isolated within the city where the lower scored problem areas may be generally less severe but have a greater frequency of occurrence.



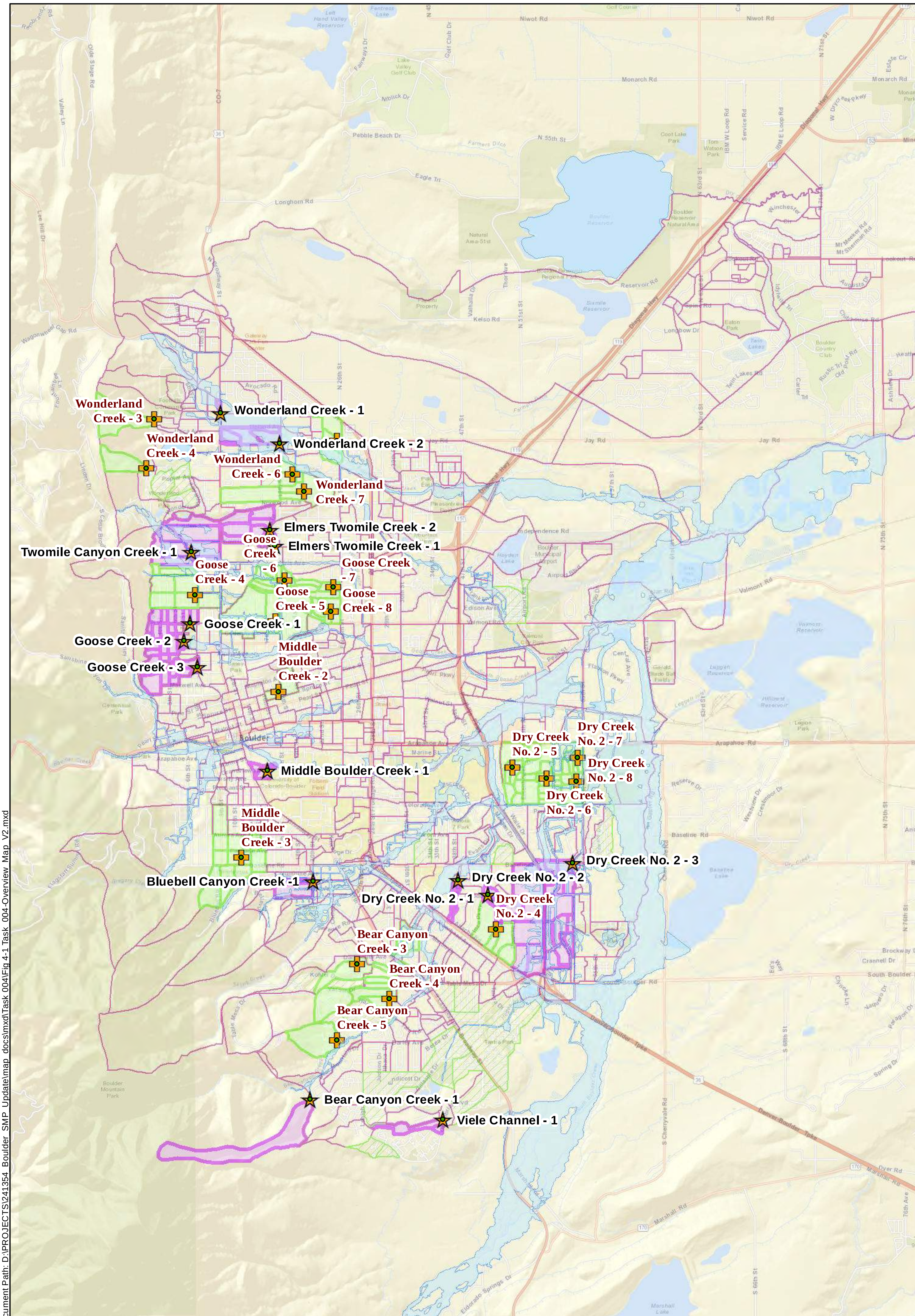
Based on the problem area characterization, problem area scoring process, and results problem area score histogram, it is recommended that problem areas with score of 30 and greater be identified as Tier I local drainage problems with Tier II and Tier III local drainage problems being separated at a problem score of 20 with problem areas with a score below 20 making up the lowest-priority Tier III.

Within the context of the SMP scope of work, the Tier I problems would receive additional modeling and analysis to develop a recommended improvement size and alignments and ultimately refine the planning level construction cost estimate.

The Tier II and Tier III problem areas would not be explicitly modeled within the XPSWMM hydrologic and hydraulic model; rather those improvements would be estimated on existing condition model flows, unit flow per acre estimates, and other approximate methods to estimate the conveyance system size. These estimates of conveyance system size would be combined with the improvement alignments to develop an order-of-magnitude level estimate of construction cost. A summary of the resulting Tier I, II and III improvement priorities are listed in the following table and shown on Figure 5-2.

Table 5.3-3: Local System Tier I, II and III Problem Area Priorities

Problem ID	Local System Problem Priorities
Elmer's Twomile Creek - 2	Tier I
Goose Creek - 1	Tier I
Goose Creek - 2	Tier I
Dry Creek No. 2 - 3	Tier I
Bear Canyon Creek - 3	Tier I
Dry Creek No. 2 – 1	Tier I
Goose Creek – 3	Tier I
Middle Boulder Creek - 2	Tier I
Wonderland Creek - 1	Tier I
Bear Canyon Creek - 5	Tier I
Goose Creek - 5	Tier II
Wonderland Creek - 7	Tier II
Twomile Canyon Creek - 1	Tier II
Viele Channel - 1	Tier II
Wonderland Creek - 2	Tier II
Bear Canyon Creek - 4	Tier II
Goose Creek - 4	Tier II
Middle Boulder Creek - 3	Tier II
Fourmile Canyon Creek - 1	Tier II
Bear Canyon Creek - 1	Tier II
Bluebell Canyon Creek -1	Tier II
Dry Creek No. 2 - 2	Tier III
Dry Creek No. 2 - 5	Tier III
Dry Creek No. 2 - 6	Tier III
Goose Creek - 6	Tier III
Goose Creek - 8	Tier III
Wonderland Creek - 6	Tier III
Dry Creek No. 2 - 8	Tier III
Goose Creek - 7	Tier III
Elmer's Twomile Creek - 1	Tier III
Middle Boulder Creek - 1	Tier III
Dry Creek No. 2 - 4	Tier III
Dry Creek No. 2 - 7	Tier III
Wonderland Creek - 3	Tier III
Wonderland Creek - 4	Tier III



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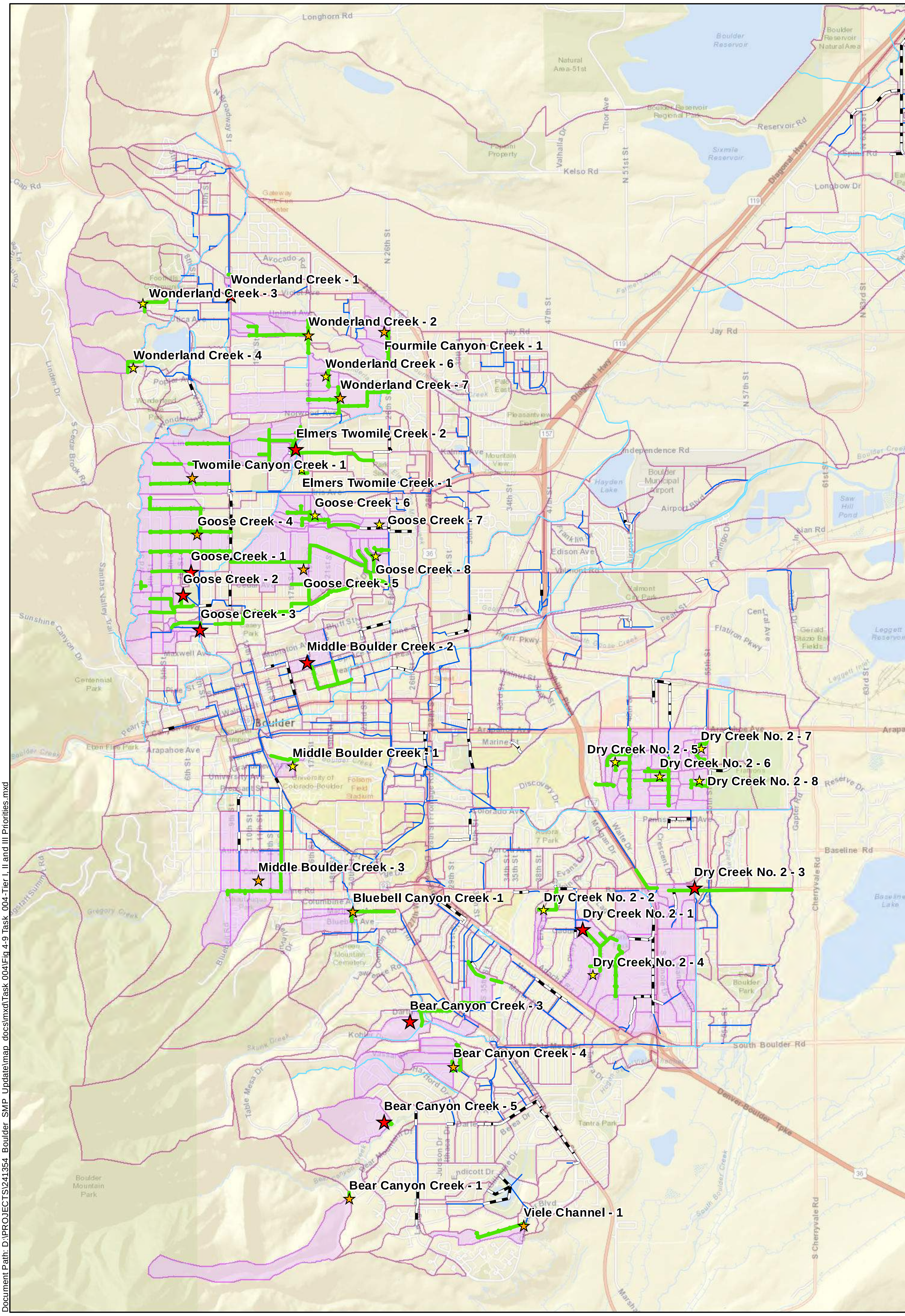
Type A - Local Drainage Problem Area
Type B - Local Drainage Problem Area
2013 Flood Extents
Subcatchment
Type A Priority Subcatchment
Type B Priority Subcatchment
Type B Override

Local System Problem Area Overview Map

Figure 5-1

Date: 1/8/2016



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0 1,500 3,000 Feet

Local System Improvement Priorities

- Tier I
- Tier II
- Tier III
- Proposed Local System Improvements
- 2007 SMP Proposed STM
- Modeled Collector Storm Sewer
- Modeled Open Channel
- Subcatchment
- Local Improvement Subcatchment

Local System Tier I, II and III Problem Area Priorities Overview Map

Figure 5-2

Date: 1/8/2016

6 Collector Storm Sewer System Improvement Recommendations

This section summarizes the development and evaluation of various alternatives intended to resolve the collector storm sewer deficiencies. In addition, this section presents the recommended plan for storm sewer and water quality improvements.

6.1 Collector System Hydraulic Alternatives

Improvement alternatives were developed for the Tier 1 and Tier 2 priority problem areas and the identified irrigation ditch problem areas. Detailed summaries of the alternatives are included in TM 5.1 – Conceptual Hydraulic Alternatives, which includes improvement descriptions, design data, benefits and issues.

6.1.1 Alternative Development Process

Conceptual alternatives for the hydraulic problem areas were developed and evaluated using a combination of the project GIS and the XPSWMM model. Conceptual alternatives include pipe replacement, hydraulically parallel storm sewers, flow diversions and detention. The alternatives for each of the Tier 1 and 2 problem areas were summarized in a fact sheet format. Alternatives for the Tier 3 problem areas were not developed; rather, the Tier 3 problem areas were resolved via pipe replacement.

Multiple factors were considered in developing each alternative. Although each problem area had unique constraints and required a different set of improvements, a number of common themes were followed:

- To minimize capital expenditures, the existing infrastructure was used to the maximum extent possible.
- Land acquisition, in terms of size and ownership and potential development pressures, was considered when locating system improvements.
- Where feasible, system improvements were located in public property, right-of-way.
- Where irrigation ditch capacity problems exist, storm drain flows entering the ditch system were eliminated if practical.
- For problem areas that discharge to an irrigation ditch, alternatives were investigated that remove the outfall to the ditch by diverting flow to a major drainageway or storm drain with sufficient capacity.

Tier 1 problem areas received a more detailed analysis at this concept alternative stage as the problems are generally more severe. Alternatives for Tier 1 problem areas were modeled using XPSWMM and mapped in GIS to more clearly define the alignments of the alternatives. The Upper Goose Creek problem area (Tier 1) was further analyzed using a 2-dimensional model to optimize the system improvement with respect to major drainageway conveyance issues. Alternatives for Tier 2 problem areas were sized based on normal depth calculations using future base condition model results stored in the GIS with the alignments described in the fact sheets.

6.1.2 Alternative Evaluation Process

Fact sheets were used to summarize information regarding each alternative and then to used that information to qualitatively evaluate the alternatives. Each fact sheet includes the problem area identification code that can be referenced to TM 4.1b. Fact sheets also include the information regarding the following topics:

- ***Problem Location.*** Summarizes the location and extent of the problem with respect to city streets and other key landmarks.
- ***Problem Summary.*** Summarizes the system problems as developed using the problem identification criteria.
- ***Alternative Summary.*** Provides a narrative of the components for each alternative developed. This includes a description of alignment corridors, pipe diameters and lengths, and other improvement-related information needed to implement the project.
- ***Technical Data.*** Summarizes the hydraulic data needed to evaluate the viability of the conceptual alternative. This includes design flows, pipe slopes, pipe diameters and storage volumes.
- ***Benefits.*** Identifies if the problems are resolved. Also identifies the benefits relative to another alternative described for the same problem location.
- ***Land Ownership.*** Summarizes existing land ownership and any land acquisition required to implement the alternative.
- ***Permitting.*** Summarizes any permitting or mitigation issues likely to be associated with the alternative.
- ***Issues.*** Identifies issues that would affect construction and maintenance for each alternative. Examples include major utility relocations, high groundwater, significant roadway closures, etc. Also identifies special construction techniques necessary to implement the alternatives. Also identifies if the alternative does not alleviate deficiencies within a problem area.

The identification of the preferred alternative was based a qualitative assessment of the information presented in the fact sheets. In addition, factors including alignment opportunities, utility constraints, land ownership, perceived cost and whether the project could be connected with other planned city capital improvements were also considerations in identifying the preferred alternative.

6.1.3 Upper Goose Creek – Alternative Analysis

The Upper Goose Creek collector system extends west of 19th Avenue in Alpine Avenue and then branches near Broadway south toward Dewey Street and north toward North Boulder Park. Collector system improvement alternatives were developed, as described previously, to address the hydraulic problems within the Upper Goose Creek collector system. The alternative evaluation process identified the preferred alternative of tying into the future major drainageway open channel improvement (Edgewood reach channel improvements) as defined in the 1988 Major Drainageway Plan (Greenhorne and O'mara, Inc). The 1988 Major Drainageway Plan also required capacity improvements downstream in Goose Creek between 19th Avenue and Folsom, along Edgewood Avenue. The improvements along this 19th to Folsom reach present many challenges including property acquisition and lack public support. As a result, a more detailed analysis of potential collector system improvements was required. The goals of the Upper Goose Creek alternative analysis were as follows:

- Develop collector system improvement alternatives upstream of 19th that are located within the ROW.
- Develop alternatives that minimize construction impacts in Goose Creek between 19th and Folsom.
- Identify collector system improvements that maximize storm conveyance and balances constructability, capital cost, private property concerns, and flooding risk.
- Minimize and reduce major storm flooding depths within the collector system upstream of 19th Avenue for storm events greater than the 5-yr collector system design storm requirement.

A 2-dimensional hydraulic model was developed to efficiently evaluate surface flow in conjunction with collector system improvement alternatives. The XP-2D module was added onto the XPSWMM collector system model as the analysis tool to assist in the alternative development and evaluation. The 2-D limits of the model extended from 19th Avenue 6th Avenue. Alternatives were developed and modeled using the 2-year, 5-year, 10-year and 100-year design storms to evaluate the flooding depths and downstream impacts. In addition, estimates of construction costs were developed for two alternatives.

The alternative evaluation process resulted in the least cost alternative that did not increase flooding risk to residents along the Edgewood reach of Goose Creek. Details regarding the model development, results, and alternatives are included in TM 5.1c Goose Creek 2-D Analysis.

The 2016 SMP further refined the Upper Goose Creek system analysis to more closely evaluate the local stormwater drainage system and reported problem areas. This analysis resulted in extending the storm sewer system into underserved areas of the basin.

6.1.4 Irrigation Ditch Separation Conceptual Alternatives

Potential locations to separate the storm sewer system from the irrigation ditches were also evaluated. The areas investigated were ditch reaches that are know system problem locations and/or that were identified in the hydraulic model as under capacity sections. In addition to identifying potential sites, a process of ranking each storm drain outfall that discharges to a ditch with respect to relocating the outfall to a neighboring major drainageway was also investigated.

Identifying the outfalls that discharge directly to the ditch system was accomplished in GIS by intersecting the storm drain (pipe) layer with the ditch layer. The resulting point database included 24 outfalls, had diameters greater than 18” and represents the collector system stormwater pipes that discharge directly into the ditch system.

The process used to identify the most opportune sites for separation involved four criteria. Each criterion was estimated using GIS, with the highest ranking sites identified qualitatively. The criteria include *Distance to major drainageway*, *existing problem area*, *contributing drainage area* and *known ditch flooding*.

By applying the criteria in GIS to each of the outfalls, a thematic map was created to illustrate which outfalls represent the best opportunity for separate from the ditch system. This GIS mapping process indicated the top four sites for separation were:

- Iris Ave and Farmer's Ditch
- 9th Street and Anderson Ditch
- Mapleton Ave and Boulder White Rock Ditch
- 5th St and Farmers Ditch.

Fact sheets, shown in TM 5.1b – Storm Drain / Canal Separation Alternatives, were developed to provide conceptual alternatives for improvements at 9th Street and Anderson Ditch (#2) and 5th Street and Farmers Ditch (#4). Conceptual alternatives were developed for these two sites as they provided the best opportunity for system improvements. Alternatives for the other site locations become more problematic to implement and have a reduced system benefit. However, the conceptual alternative fact sheets for the 9th Street and Anderson Ditch (#2) and 5th Street and Farmers Ditch (#4) sites provide an illustration of the general approach that could be applied to other sites if needed.

6.2 Water Quality Alternatives

The water quality analysis identified twelve (12) locations as Water Quality Areas of Concern (Figure 6-1). For these locations, improvement alternatives were developed to evaluate the most appropriate solution considering the contributing area and site constraints.

In addition to the Water Quality Areas of Concern, HDR performed an analysis of the 18 collector system outfalls on Boulder Creek, focusing on the use of proprietary BMPs (a.k.a. water quality manholes) that utilize hydrodynamic forces to remove TSS and associated pollutants from stormwater runoff. This second approach to addressing stormwater quality was developed to evaluate the potential benefit of focusing on a single, high priority stream system instead of a city-wide approach.

A summary of the key elements of the water quality alternatives analysis and recommendations is presented below. The analysis is described in more detail in TM 3.6.2 Water Quality Alternatives and Recommendations and in TM 3.6.3 Water Quality Improvement Recommendations.

6.2.1 Alternative Development – Water Quality Areas of Concern

Conceptual alternatives were developed to address the modeled stormwater pollutants using aerial photography and GIS data, and summarized in a fact sheet format. The BMP Toolbox developed for this project (TM 4.3 – Structural BMP Toolbox) was used as a list of potential BMPs which resulted in primary BMP recommendations consisting of constructed wetland detention ponds (extended detention basins), grass swales with check structures, and proprietary BMPs. Constructed wetland detention ponds were recommended because they are large enough to provide water quality treatment for an entire basin. Grass swales with check structures are recommended for situations where the available area is a long, thin strip of land. Proprietary BMPs are listed as alternatives for each of the sites because of their ability to be constructed in a retro-fit application with minimal site impacts or land acquisition requirements.

The fact sheets include the problem location (illustrated with a map), problem summary, benefits, technical data, land ownership, implementation issues, and capital costs.

For the twelve (12) Water Quality Areas of Concern, there are six particular basins that are expected to undergo significant redevelopment: sites 1, 2, 6, 8, 9, and 10. In these basins, HDR accounted for the possibility of stormwater BMPs being built as part of the development process, and, in some cases, these sites were given lower priority for city constructed BMPs due to their potential for re-development.

6.2.2 Alternative Development Process – Boulder Creek Outfalls

In addition to the twelve (12) sites identified as Water Quality Areas of Concern by the XP-SWMM model, HDR conducted an analysis of seventeen (17) proprietary BMPs at outfalls on Boulder Creek (Figure 6-1). Two of these outfalls overlap with the water quality area of concern approach; these are listed in Table 6.2-1. Note there is an existing proprietary BMP located Broadway and Boulder Creek and was identifies as site BC3.

Table 6.2-1: Common Water Quality Area of Concern and Boulder Creek Outfalls

WQ Area of Concern ID	WQ Area of Concern Description	Boulder Creek Site Number
WQ4	Broadway and Boulder Creek	BC6
WQ5	28th Street and Boulder Creek	BC11

Fact sheets were developed for each site and are included in TM 3.6.3 – Water Quality Improvement Recommendations. The fact sheets show conceptual locations for the water quality manholes. Siting these facilities assumed the water quality manhole would be an off-line system and therefore would require a diversion manhole and connecting influent and effluent pipes.

6.2.3 Alternative Evaluation and Recommendations

Alternatives for the 27 sites (12 Water Quality Areas of Concern and 15 Boulder Creek outfalls) were further evaluated and recommendations for each site were developed. The recommended BMPs are the result of a field visit as well as workshops with city staff.

To assist in the prioritization of improvements, a cost/benefit analysis was performed for the Water Quality Areas of Concern as well as the Boulder Creek outfalls. Each of the 27 sites and the respective recommended BMPs were analyzed in terms of pollutant loading at the outfall and pollutant removal by the BMP. TSS was used as the representative pollutant for the analysis. Annual loading of TSS to each of the sites was determined using the XPSWMM model and the annual rainfall series. Removal of TSS by recommended water quality BMPs was determined using the model results and an Excel spreadsheet tool.

The spreadsheet tool evaluated the water quality storm peak flow being diverted to a facility and then applied a removal effectiveness to arrive at a load reduction. Some of the BMPS were not sized for the entire water quality peak due to site constraints or other facility sizing issues. If the water quality peak flow in the system was greater than the size of the BMP, the spreadsheet tool accounted for the peak of the pollutograph not receiving pollution reduction through the BMP. The following quantities of removal effectiveness were used in the analysis through the spreadsheet tool as determined from a literature search,

- 80 percent removal of TSS for detention ponds and constructed wetland ponds.
- 50 percent removal of TSS for proprietary BMPs.
- 50 percent removal of TSS for vegetated swales with check structures.

For comparison purposes, conceptual construction costs for the recommended BMPs at each of the sites were estimated. Table 6.2-2 lists the TSS removal and costs for the recommended BMPs for the Water Quality Areas of Concern and the Boulder Creek Outfalls approaches. It should be noted that WQ4 is the same as BC6 and WQ5 is the same as BC11. All four rows are listed in this table to develop a cost/benefit for each approach; however, this redundancy is removed in the Recommended Plan in the following section. The results indicate the cost per pound of removal is comparable for the two approaches – approximately $5 per pound of TSS per year.

Table 6.2-2: TSS Removal and Costs for Recommended BMPs

Outfall ID	Annual TSS Removal (pounds)	Conceptual Capital Cost (1)	Cost per Pound (1)
Water Quality Area of Concern			
WQ1	14,831	$ 54,000	$ 3.64
WQ2	124,805	$ 635,000	$ 5.09
WQ3	14,970	$ 54,000	$ 3.61
WQ4	9,770	$ 81,000	$ 8.29
WQ5	15,854	$ 92,000	$ 5.80
WQ6	58,009	$ 289,000	$ 4.98
WQ7	7,924	$ 98,000	$ 12.37
WQ8	9,846	$ 137,000	$ 13.91
WQ9	20,128	$ 81,000	$ 4.02
WQ10	41,004	$ 54,000	$ 1.32
WQ11	25,472	$ 77,000	$ 3.02
WQ12	11,024	$ 73,000	$ 6.62
	353,637	$ 1,725,000	$ 4.88
Boulder Creek Outfalls			
BC1	11,690	$ 73,000	$ 6.24
BC2	7,242	$ 51,000	$ 7.04
BC4	21,749	$ 84,000	$ 3.86
BC5	17,956	$ 73,000	$ 4.07
BC6	9,770	$ 81,000	$ 8.29
BC7	19,530	$ 84,000	$ 4.30
BC8	13,503	$ 78,000	$ 5.78
BC9	2,542	$ 73,000	$ 28.72
BC10	26,193	$ 81,000	$ 3.09
BC11	15,854	$ 92,000	$ 5.80
BC12	13,215	$ 104,000	$ 7.87
BC13	1,391	$ 47,000	$ 33.79
BC14	4,830	$ 47,000	$ 9.73
BC15	5,438	$ 61,000	$ 11.22
BC16	8,628	$ 39,000	$ 4.52
BC17	22,036	$ 76,000	$ 3.45
BC18	29,036	$ 104,000	$ 3.58
	230,604	$ 1,248,000	$ 5.41

(1) Cost presented for analysis is in 2007 dollars

Based on the Cost/Benefit Analysis, neither the Boulder Creek approach nor the Water Quality Areas of Concern approach is significantly better than the other approach in terms of reducing TSS loading to Boulder Creek and its tributaries. However, there are specific outfalls in each approach that have a comparatively high cost per pound ratio which include Sites WQ7, WQ8, BC9, BC13 and

BC15. These high cost per pound sites do not provide a cost effective approach to addressing stormwater quality.

Several of the Water Quality Area of Concern sites have the potential to undergo significant redeveloped as identified by city Staff. When redevelopment occurs, stormwater quality improvements would be required by the city's DCS which would address a majority of the subcatchment contributing pollutants to the Water Quality Area of Concern outfall. The potential redeveloped sites were identified as WQ1, WQ6 and WQ10. These site locations are shown on Figure 6-1. As a result, it is recommended that a subset of these sites be included in the Recommended Plan. The recommended sites include WQ2, WQ3, WQ4, WQ5, WQ9, WQ11, and WQ12. Of note, WQ2 is considered a high priority because the project routes stormwater flow away from an irrigation ditch and is part of a larger project, which is a solution to a hydraulic problem. WQ9 is considered a high priority because it is an excellent spot for a wetland pond on open city property. An additional benefit is that both of these high priority projects may provide wetlands mitigation credits.

The project team recognizes that water quality in Boulder Creek itself is of primary importance, and treating stormwater at outfalls that flow directly into Boulder Creek may be the most direct way to improve water quality in the most heavily used and regulated creek in the city. Furthermore, the proprietary BMPs identified for the Boulder Creek Outfall approach tend to be easier to site in an urban environment than ponds and swales. Therefore, it is recommended that the BMPs for the Boulder Creek outfalls be constructed with the exception of Sites BC9 and BC13. These exceptions are identified as the Cost/Benefit analysis shows sites BC9 and BC13 have very high costs per pound of TSS removal.

Considering the site constraints for the BMPs analyzed and the cost/benefit analysis, the following table summarizes the following sites for incorporation into the Recommended Plan.

Table 6.2-3: Recommended Water Quality Sites

Improvement Site ID	Outfall ID	Improvement Description	Annual TSS Load (pounds)	Annual TSS Removal (pounds)	Cost (1)
WQIMP 1	WQ2	Constructed Wetland	166,516	124,805	$635,000
WQIMP 2	BC18	Proprietary BMP	61,928	29,036	$104,000
WQIMP 3	BC10	Proprietary BMP	56,517	26,193	$81,000
WQIMP 4	WQ11	Proprietary BMP	54,467	25,472	$77,000
WQIMP 5	BC17	Proprietary BMP	46,152	22,036	$76,000
WQIMP 6	BC4	Proprietary BMP	45,712	21,749	$84,000
WQIMP 7	WQ9	Constructed Wetland	27,444	20,128	$81,000
WQIMP 8	BC7	Proprietary BMP	41,533	19,530	$84,000
WQIMP 9	BC5	Proprietary BMP	38,418	17,956	$73,000
WQIMP 10	WQ5	Proprietary BMP	34,242	15,854	$92,000
WQIMP 11	WQ3	Proprietary BMP	31,797	14,970	$54,000
WQIMP 12	BC8	Proprietary BMP	29,039	13,503	$78,000
WQIMP 13	BC12	Proprietary BMP	27,770	13,215	$104,000
WQIMP 14	BC1	Proprietary BMP	24,183	11,690	$73,000
WQIMP 15	WQ12	Proprietary BMP	22,814	11,024	$73,000
WQIMP 16	WQ4	Proprietary BMP	20,318	9,770	$81,000
WQIMP 17	BC16	Proprietary BMP	18,295	8,628	$39,000
WQIMP 18	BC2	Proprietary BMP	14,988	7,242	$51,000
WQIMP 19	BC14	Proprietary BMP	10,560	4,830	$47,000

(1) Cost presented for analysis is in 2007 dollars

6.3 Collector System Recommendations Summary

The collector system improvement plan is a compilation of all hydraulic and water quality improvements developed in this study. Figure 6-2 provides an overview of the recommended plan improvements with corresponding improvement project IDs. Improvement project IDs were assigned based on the subbasin the project was located in and a numerical identifier. Note the numerical identifiers within each subbasin were assigned spatially from upper left to lower right and do not indicate the improvement priority. The following table correlates improvement project ID with the hydraulic problem ID and/or the water quality problem outfall ID. This table can be used to reference the recommended improvement with the problem location and alternatives presented in this report and within the technical memoranda included in the report appendices.

Table 6.3-1: Collector System Improvement Summary

Hyd/WQ Problem ID	Rank	Project ID	Subbasin	Improvement Type	Priority
HYD#52	33	BCC_01	Bear Canyon Creek	Hydraulic Improvement	Tier 3
HYD#51	36	BCC_02	Bear Canyon Creek	Hydraulic Improvement	Tier 3
HYD#49	21	BCC_03	Bear Canyon Creek	Hydraulic Improvement	Tier 2
HYD#7	27	BCC_04	Bear Canyon Creek	Hydraulic Improvement	Tier 3
HYD#54	36	BCC_05	Bear Canyon Creek	Hydraulic Improvement	Tier 3
HYD#53	36	BCC_06	Bear Canyon Creek	Hydraulic Improvement	Tier 3
HYD#45	36	BCC_07	Bear Canyon Creek	Hydraulic Improvement	Tier 3
HYD#8, 9 & WQIMP 01	4	DC_01	Dry Creek	Hydraulic/Water Quality Improvement	Tier 1&2
HYD#1	36	DC_02	Dry Creek	Hydraulic Improvement	Tier 3
HYD#46	26	DC2_01	Dry Creek No. 2	Hydraulic Improvement	Tier 3
HYD#47	9	DC2_02	Dry Creek No. 2	Hydraulic Improvement	Tier 2
HYD#44	50	DC2_03	Dry Creek No. 2	Hydraulic Improvement	Tier 3
HYD#2	30	DC2_04	Dry Creek No. 2	Hydraulic Improvement	Tier 3
HYD#23	27	DC2_05	Dry Creek No. 2	Hydraulic Improvement	Tier 3
HYD#22 and WQIMP 04	16	DC2_06	Dry Creek No. 2	Hydraulic/Water Quality Improvement	Tier 2
HYD#15	14	ETC_01	Elmers Twomile Creek	Hydraulic Improvement	Tier 2
HYD#13	48	ETC_03	Elmers Twomile Creek	Hydraulic Improvement	Tier 3
HYD#11	35	FCC_01	Fourmile Canyon Creek	Hydraulic Improvement	Tier 3
HYD#16	1	GC_02	Goose Creek	Hydraulic Improvement	Tier 1
HYD#33	30	GC_03	Goose Creek	Hydraulic Improvement	Tier 3
HYD#31	49	GC_05	Goose Creek	Hydraulic Improvement	Tier 3
HYD#32	29	GC_06	Goose Creek	Hydraulic Improvement	Tier 3
HYD#5	36	GC_07	Goose Creek	Hydraulic Improvement	Tier 3

Table 6.3-1: Collector System Improvement Summary

Hyd/WQ Problem ID	Rank	Project ID	Subbasin	Improvement Type	Priority
HYD#27 and WQIMP 11	11	GC_08	Goose Creek	Hydraulic/Water Quality Improvement	Tier 2
HYD#21 and WQIMP 07	12	GC_09	Goose Creek	Hydraulic/Water Quality Improvement	Tier 2
WQIMP 15	8	KG_01	Kings Gulch	Water Quality Improvement	n/a
WQIMP 05	3	LBC_01	Lower Boulder Creek	Water Quality Improvement	n/a
WQIMP 02	1	LBC_02	Lower Boulder Creek	Water Quality Improvement	n/a
HYD#36	53	MBC_01	Middle Boulder Creek	Hydraulic Improvement	Tier 3
HYD#37	36	MBC_02	Middle Boulder Creek	Hydraulic Improvement	Tier 3
WQIMP 14	7	MBC_03	Middle Boulder Creek	Water Quality Improvement	n/a
HYD#41	6	MBC_04	Middle Boulder Creek	Hydraulic Improvement	Tier 2
WQIMP 18	10	MBC_05	Middle Boulder Creek	Water Quality Improvement	n/a
WQIMP 06 & WQIMP 09	4	MBC_06	Middle Boulder Creek	Water Quality Improvement	n/a
WQIMP 16	9	MBC_07	Middle Boulder Creek	Water Quality Improvement	n/a
HYD#40	50	MBC_08	Middle Boulder Creek	Hydraulic Improvement	Tier 3
HYD#35	19	MBC_09	Middle Boulder Creek	Hydraulic Improvement	Tier 2
WQIMP 08	5	MBC_11	Middle Boulder Creek	Water Quality Improvement	n/a
WQIMP 12	6	MBC_12	Middle Boulder Creek	Water Quality Improvement	n/a
HYD#3	30	MBC_13	Middle Boulder Creek	Hydraulic Improvement	Tier 3
HYD#55 and WQIMP 10	3	MBC_14	Middle Boulder Creek	Hydraulic/Water Quality Improvement	Tier 1
HYD#39	50	MBC_15	Middle Boulder Creek	Hydraulic Improvement	Tier 3
WQIMP 03	2	MBC_16	Middle Boulder Creek	Water Quality Improvement	n/a
HYD#4	55	MBC_17	Middle Boulder Creek	Hydraulic Improvement	Tier 3
HYD#30 and WQIMP 13	25	MBC_18	Middle Boulder Creek	Hydraulic/Water Quality Improvement	Tier 3
HYD#28 and WQIMP 19	36	MBC_19	Middle Boulder Creek	Hydraulic/Water Quality Improvement	Tier 3
HYD#29	10	MBC_20	Middle Boulder Creek	Hydraulic Improvement	Tier 2
HYD#25	54	MBC_21	Middle Boulder Creek	Hydraulic Improvement	Tier 3
HYD#24	8	MBC_22	Middle Boulder Creek	Hydraulic Improvement	Tier 2
HYD#20 and WQIMP 17	14	MBC_23	Middle Boulder Creek	Hydraulic/Water Quality Improvement	Tier 2
HYD#42	5	SC_01	Skunk Creek	Hydraulic Improvement	Tier 2
HYD#38	18	SC_02	Skunk Creek	Hydraulic Improvement	Tier 2

Table 6.3-1: Collector System Improvement Summary

Hyd/WQ Problem ID	Rank	Project ID	Subbasin	Improvement Type	Priority
HYD#48	22	VC_01	Viele Channel	Hydraulic Improvement	Tier 3
HYD#50	23	VC_02	Viele Channel	Hydraulic Improvement	Tier 3
HYD#12	36	WC_01	Wonderland Creek	Hydraulic Improvement	Tier 3
HYD#17	33	WC_02	Wonderland Creek	Hydraulic Improvement	Tier 3
HYD#19	7	WC_03	Wonderland Creek	Hydraulic Improvement	Tier 2

The process for developing the recommended plan involved refining the hydraulic alternative recommendations for the Tier 1 and 2 problems area to resolve conflicts with existing water and sewer utilities. Potential conflicts with sanitary sewers were resolved by identifying locations where storm sewer improvements cross sanitary sewers. At these sewer crossings, the proposed storm sewer was graded to provide a minimum of 18” of vertical clearance. There were several locations where this storm/sanitary sewer clearance could not be obtained and the existing sewer was re-graded and lowered to accommodate the proposed storm sewer improvement. Waterline lowerings were identified for locations where the new storm sewer crosses a water transmission line (16” diameter and greater) where the proposed storm sewer was within 4’ of the ground surface. The focus on the transmission mains were identified as the larger lines are more problematic and expensive to relocate than smaller diameter water distribution lines.

In addition to resolving utility conflicts, development of the recommended plan included addition of Tier 3 hydraulic improvements and water quality improvements.

The following report sections and associated tables are intended to be a summary of the recommended plan for each subbasin and include a Project ID, along with a description of the project improvement and capital cost.

6.3.1 Recommendations – Bear Canyon Creek Subbasin

The recommended plan for the Bear Canyon Creek Subbasin includes seven individual CIP projects, which are summarized in the following table. All of the projects are hydraulic improvement projects.

Table 6.3-2: Summary of Recommended Improvements - Bear Canyon Creek Subbasin

ID	Improvement Category	Capital Cost ($)
BCC_01	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$1,132,000
BCC_02	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$184,000
BCC_03	Tier 2 and 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$1,512,000

ID	Improvement Category	Capital Cost ($)
	Storm Sewer Re-Routing/Extension	
BCC_04	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$540,000
BCC_05	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$200,000
BCC_06	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$373,000
BCC_07	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$428,000
	Total	**$4,369,000**

6.3.2 Recommendations – Dry Creek Subbasin

The recommended plan for the Dry Creek Subbasin includes two individual CIP projects, which are summarized in the following table. One project is a combined hydraulic/water quality improvement project and the other is a hydraulic improvement project.

Table 6.3-3: Summary of Recommended Improvements - Dry Creek Subbasin

ID	Improvement Category	Capital Cost ($)
DC_01	Tier 1 and 2 Combined Hydraulic/Water Quality Improvement Storm Sewer: Pipe Replacement Storm Sewer Re-Routing/Extension Constructed Wetland	$7,195,000
DC_02	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$411,000
	Total	**$7,606,000**

6.3.3 Recommendations – Dry Creek No. 2 Subbasin

The recommended plan for the Dry Creek No. 2 Subbasin includes six individual CIP projects, which are summarized in the following table. Five of the projects are hydraulic improvement projects and one is a combined hydraulic/water quality improvement project.

Table 6.3-4: Summary of Recommended Improvements - Dry Creek No. 2 Subbasin

ID	Improvement Category	Capital Cost ($)
DC2_01	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$1,226,000

ID	Improvement Category	Capital Cost ($)
DC2_02	Tier 2 Hydraulic Improvement Storm Sewer: Pipe Replacement	$5,364,000
DC2_03	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$603,000
DC2_04	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$664,000
DC2_05	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$770,000
DC2_06	Tier 2 Combined Hydraulic/Water Quality Improvement Storm Sewer: Pipe Replacement Proprietary BMP	$637,000
	Total	**$9,264,000**

6.3.4 Recommendations – Elmers Twomile Creek Subbasin

The recommended plan for the Elmers Twomile Creek Subbasin includes three individual CIP projects, which are summarized in the following table. All of the projects are hydraulic improvements projects.

Table 6.3-5: Summary of Recommended Improvements - Elmers Twomile Creek Subbasin

ID	Improvement Category	Capital Cost ($)
ETC_01	Tier 2 Hydraulic Improvement Storm Sewer: Pipe Replacement, Diversion to Major Drainageway	$639,000
ETC_03	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$1,109,000
	Total	**$1,748,000**

6.3.5 Recommendations – Fourmile Canyon Creek Subbasin

The recommended plan for the Fourmile Canyon Creek Subbasin includes one individual CIP project, which is summarized in the following table. It is a hydraulic improvement project.

Table 6.3-6: Summary of Recommended Improvements - Fourmile Canyon Creek Subbasin

ID	Improvement Category	Capital Cost ($)
FCC_01	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$836,000
	Total	**$863,000**

6.3.6 Recommendations – Goose Creek Subbasin

The recommended plan for the Goose Creek Subbasin includes seven individual CIP projects, which are summarized in the following table. Seven of the projects are hydraulics improvement projects and two are combined hydraulic/water quality projects.

Table 6.3-7: Summary of Recommended Improvements - Goose Creek Subbasin

ID	Improvement Category	Capital Cost ($)
GC_02	• Tier 1 • Hydraulic Improvement • Storm Sewer: • Pipe Replacement • New, Hydraulically Parallel Storm Sewer • Channel Improvement	$8,269,000
GC_03	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$819,000
GC_05	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$810,000
GC_06	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$933,000
GC_07	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$184,000
GC_08	• Tier 2 • Combined Hydraulic/Water Quality Improvement • Storm Sewer: Pipe Replacement • Proprietary BMP	$476,000
GC_09	• Tier 2 • Combined Hydraulic/Water Quality Improvement • Storm Sewer: Pipe Replacement • Constructed Wetland	$957,000
	Total	**$12,448,000**

6.3.7 Recommendations – Kings Gulch Subbasin

The recommended plan for the Kings Gulch Subbasin includes one individual CIP project, which is summarized in the following table. It is a water quality improvement project.

Table 6.3-8: Summary of Recommended Improvements - Kings Gulch Subbasin

ID	Improvement Category	Capital Cost ($)
WQIMP_15 (KG_01)	Water Quality Improvement Proprietary BMP	$93,000
	Total	**$93,000**

6.3.8 Recommendations – Lower Boulder Creek Subbasin

The recommended plan for the Lower Boulder Creek Subbasin includes two individual CIP projects, which are summarized in the following table. Both of the projects are water quality improvement projects.

Table 6.3-9: Summary of Recommended Improvements - Lower Boulder Creek Subbasin

ID	Improvement Category	Capital Cost ($)
WQIMP_05 (LBC_01)	Water Quality Improvement Proprietary BMP	$97,000
WQIMP_02 (LBC_02)	Water Quality Improvement Proprietary BMP	$133,000
	Total	**$230,000**

6.3.9 Recommendations – Middle Boulder Creek Subbasin

The recommended plan for the Middle Boulder Creek Subbasin includes twenty three individual CIP projects, which are summarized in the following table. Twelve of the projects are hydraulic improvement projects, seven are water quality improvement projects, and four are combined hydraulic/water quality improvement projects.

Table 6.3-10: Summary of Recommended Improvements - Middle Boulder Creek Subbasin

ID	Improvement Category	Capital Cost ($)
MBC_01	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$177,000
MBC_02	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$267,000
WQIMP_14 (MBC_03)	• Water Quality Improvement • Proprietary BMP	$93,000
MBC_04	• Tier 2 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$733,000
WQIMP_18 (MBC_05)	• Water Quality Improvement • Proprietary BMP	$65,000
WQIMP_06 WQIMP_09 (MBC_06)	• Water Quality Improvement • Proprietary BMP	$201,000
WQIMP_16 (MBC_07)	• Water Quality Improvement • Proprietary BMP	$104,000
MBC_08	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$1,209,000
MBC_09	• Tier 2 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$1,224,000
WQIMP_08 (MBC_11)	• Water Quality Improvement • Proprietary BMP	$108,000
WQIMP_12	• Water Quality Improvement	$100,000

ID	Improvement Category	Capital Cost ($)
(MBC_12)	• Proprietary BMP	
MBC_13	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$754,000
MBC_14	• Tier 1 • Combined Hydraulic/Water Quality Improvement • Storm Sewer: • Pipe Replacement • Storm Sewer Re-Routing/Extension • Proprietary BMP	$2,076,000
MBC_15	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$139,000
WQIMP_03 (MBC_16)	• Water Quality Improvement • Proprietary BMP	$104,000
MBC_17	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$480,000
MBC_19	• Tier 3 • Combined Hydraulic/Water Quality Improvement • Storm Sewer: Pipe Replacement • Proprietary BMP	$408,000
MBC_20	• Tier 2 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$88,000
MBC_21	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$221,000
MBC_22	• Tier 2 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$2,298,000
MBC_23	• Tier 2 • Combined Hydraulic/Water Quality Improvement • Storm Sewer: Pipe Replacement • Proprietary BMP	$445,000
	Total	**$11,294,000**

6.3.10 Recommendations – Skunk Creek Subbasin

The recommended plan for the Skunk Creek Subbasin includes two individual CIP projects, which are summarized in the following table. Both of the projects are hydraulic improvement projects.

Table 6.3-11: Summary of Recommended Improvements - Skunk Creek Subbasin

ID	Improvement Category	Capital Cost ($)
SC_01	• Tier 2 • Hydraulic Improvement • Storm Sewer: • Pipe Replacement • Diversion to Major Drainageway	$1,250,000
SC_02	• Tier 2 • Hydraulic Improvement	$1,135,000

ID	Improvement Category	Capital Cost ($)
	• Storm Sewer: Pipe Replacement	
	Total	**$2,385,000**

6.3.11 Recommendations – Viele Channel Subbasin

The recommended plan for the Viele Channel Subbasin includes two individual CIP projects, which are summarized in the following table. Both of the projects are hydraulic improvement projects.

Table 6.3-12: Summary of Recommended Improvements - Viele Channel Subbasin

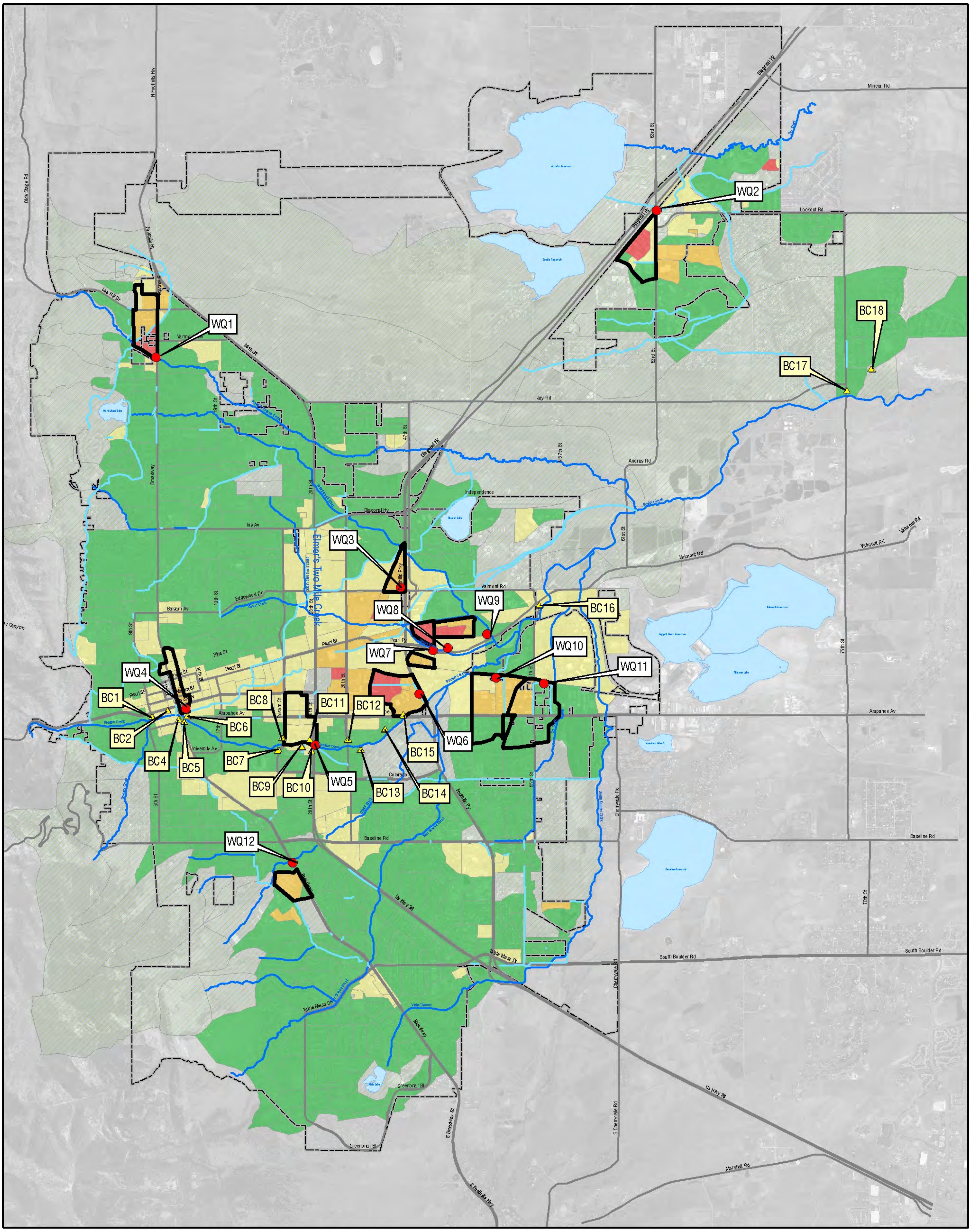
ID	Improvement Category	Capital Cost ($)
VC_01	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$1,296,000
VC_02	Tier 3 Hydraulic Improvement Storm Sewer: Pipe Replacement	$1,655,000
	Total	**$2,951,000**

6.3.12 Recommendations – Wonderland Creek Subbasin

The recommended plan for the Wonderland Creek Subbasin includes three individual CIP projects, which are summarized in the following table. All three of the projects are hydraulic improvement projects.

Table 6.3-13: Summary of Recommended Improvements - Wonderland Creek Subbasin

ID	Improvement Category	Capital Cost ($)
WC_01	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$324,000
WC_02	• Tier 3 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$402,000
WC_03	• Tier 2 • Hydraulic Improvement • Storm Sewer: Pipe Replacement	$810,000
	Total	**$1,536,000**



Legend

- Key Pollutant Load Outfalls
- Outfall Catchments
- Modeled network
  - Ditch
  - Major drainageway
- Major Roads
- City Limits
- Lakes
- Boulder Creek Outfalls

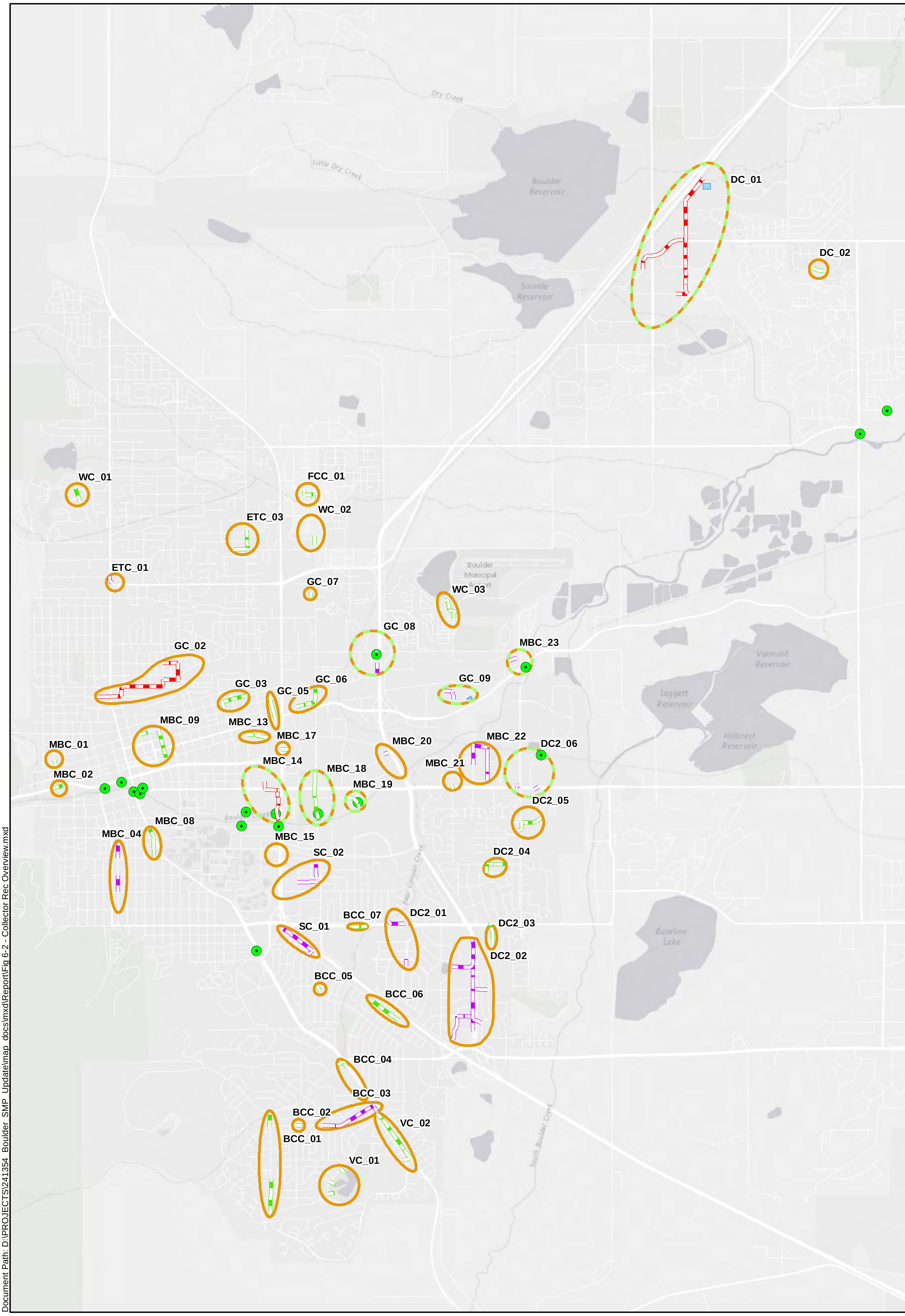
Load (Lbs TSS/Ac/Yr)	
0 - 250	501 - 750
251 - 500	751 - 1000
	1001 +

0 4,000
1 inch equals 4,000 feet

N

Collector System
Water Quality Improvement Summary Map

Figure 6-1



Document Path: D:\PROJECTS\241354_Boulder_SMP_Update\map_docs\mxd\Report\Fig 6-2 - Collector Rec Overview.mxd

0 1,150 2,300 Feet

N

2007 SMP Collector System Improvements (Updated)

- Tier 1 Pipes
- Tier 2 Pipes
- Tier 3 Pipes
- Water Quality Manhole
- Water Quality Surface BMP
- Collector System Improvement Area
- Combined Collector and WQ Improvement Area

Collector System Recommended Plan Overview Map

Figure 6-2

7 Local System Improvement Recommendations Summary

Recommended improvements for the local system problem areas were developed and are presented in on Figure 7-1. Consistent with the collector system recommendations, itemized cost estimates were developed for each improvement recommendation with an anticipated level of accuracy of +50% to –30% (order-of-magnitude cost estimates). The cost estimate worksheets are included in the appendix for reference.

The local system improvements were prioritized through a series of evaluation criteria with the result being the Tier I projects having the highest priority in this analysis. As a result, the Tier I improvement projects received additional modeling and analysis using the XPSWMM model in an effort to refine recommended improvement size, alignment, and profile. In addition, the modeling approach evaluated if downstream problems were created by the proposed local system improvements as a result of increased flows. This downstream analysis evaluated the capacity of the existing system and improvements to the collector syste. If downstream conveyance problems were created in the existing system, improvements to those downstream conveyances were developed and added to the overall project recommendation. Similarly, if capacity increases were required in the 2007 SMP collector system recommendations as a result of these local system improvements, those collector system improvements were updated to account for peak flow increases.

The sizing of the recommended improvements for the Tier II and Tier III problem areas were not based on the results of the XPSWMM hydrologic and hydraulic model in an effort to minimize the level of effort associated with developing planning level, order-of-magnitude costs for these relatively lower problem priority areas. Rather, these improvements have been estimated on existing condition modeled flows, unit flow per acre estimates, and other approximate methods to estimate the conveyance system size. These estimates of conveyance system size were combined with the improvement alignments to develop a conceptual or order-of-magnitude level estimate of construction cost.

7.1 Tier I Improvements

The following tables provide a summary of the recommended plan for each subbasin and include a Project ID, a description of the project improvement, technical and implementation comments, and planning level capital cost estimate.

Table 7.1-1: Tier I Improvement Summary

	Problem Name	ID	Improvement Type	Priority	Cost
1	Wonderland Creek - 1	WC_LI1	New and Replacement Storm Sewer	Tier I	$318,000
2	Elmer’s Twomile Creek - 2	ETC_LI2	New and Replacement Storm Sewer	Tier I	$3,874,000
3	Goose Creek - 1	GC_LI1	New and Replacement Storm Sewer	Tier I	$1,585,000
4	Goose Creek - 2	GC_LI2	New and Replacement Storm Sewer	Tier I	$2,417,000
5	Goose Creek - 3	GC_LI3	New and Replacement Storm Sewer	Tier I	$984,000
6	Middle Boulder Creek - 2	MBC_LI2	New and Replacement Storm Sewer	Tier I	$3,175,000
7	Dry Creek No. 2 - 1	DC2_LI1	New and Replacement Storm	Tier I	$1,837,000

			Sewer		
8	Dry Creek No. 2 - 3	DC2_LI3	New and Replacement Storm Sewer	Tier I	$6,505,000
9	Bear Canyon Creek - 3	BrCC_LI3	Hydraulic Improvement	Tier I	$2,265,000
10	Bear Canyon Creek - 5	BrCC_LI5	Hydraulic Improvement	Tier I	$267,000
	TOTAL				**$23,227,000**

7.2 Tier II Improvements

The following tables provide a summary of the recommended plan for each subbasin and include a Project ID, a description of the project improvement, technical and implementation comments, and planning level capital cost estimate.

Table 7.2-1: Tier II Improvement Summary

	Problem Name	ID	Improvement Type	Priority	Cost
11	Goose Creek - 5	GC_LI5	New Storm Sewer	Tier II	$5,484,000
12	Wonderland Creek - 7	WC_LI7	New Storm Sewer	Tier II	$2,452,000
13	Twomile Canyon Creek - 1	TCC_LI1	New Storm Sewer	Tier II	$2,939,000
14	Viele Channel - 1	VC_LI1	New Storm Sewer	Tier II	$936,000
15	Wonderland Creek - 2	WC_LI2	New Storm Sewer	Tier II	$1,925,000
16	Bear Canyon Creek - 4	BrCC_LI4	New Storm Sewer	Tier II	$726,000
17	Goose Creek - 4	GC_LI4	New Storm Sewer	Tier II	$4,885,000
18	Middle Boulder Creek - 3	MBC_LI3	New and Replacement Storm Sewer	Tier II	$2,826,000
19	Fourmile Canyon Creek - 1	FCC_LI1	New Storm Sewer	Tier II	$688,000
20	Bear Canyon Creek - 1	BrCC_LI1	New Storm Sewer	Tier II	$69,000
21	Bluebell Canyon Creek - 1	BbCC_LI1	New and Replacement Storm Sewer	Tier II	$1,137,000
	TOTAL				**$24,067,000**

7.3 Tier III Improvements

The Tier III improvements are the lowest priority improvements and are shown on Figure 7-1. The following summary table provides a brief description of the recommended improvement and planning level capital cost estimate for each subbasin.

Table 7.3-1: Tier III Improvement Summary

	Problem Name	ID	Improvement Type	Improvement Description	Cost
22	Dry Creek No. 2 - 2	DC2_LI2	New and Replacement Storm Sewer	New system in Pinon and Meadowbrook, connect to existing system in Baseline Rd	$726,000
23	Dry Creek No. 2 - 5	DC2_LI5	New Storm Sewer	New system in McKinley, Eisenhower, and 4th St, connect to existing system in Arapahoe Ave	$2,386,000
24	Dry Creek No. 2 - 6	DC2_LI6	New Storm Sewer	New system in Merritt Dr with collection from	$1,689,000

				Arapahoe Ridge Park, connect to existing system north of Patton Dr	
25	Goose Creek - 6	GC_LI6	New and Replacement Storm Sewer	New system west of 20th St. Replace existing system in 20th St and Glenwood Dr west of 23rd St	$1,946,000
26	Goose Creek - 8	GC_LI8	New and Replacement Storm Sewer	New systems in 23rd and 24th St. Replace and extend existing system in Fremont St	$932,000
27	Wonderland Creek - 6	WC_LI6	New Storm Sewer	New system in 20th St north of Orchard Ave discharging into Wonderland Creek	$366,000
28	Dry Creek No. 2 - 8	DC2_LI8	New and Replacement Storm Sewer	New system in Holmes and White Place, connect to existing system in 55th St	$604,000
29	Goose Creek - 7	GC_LI7	New and Replacement Storm Sewer	New system in Glenwood Dr East of Folsom St. Replace system in Glenwood Dr west of Folsom and system in Folsom north of Glenwood Dr	$1,913,000
30	Elmers Twomile Creek - 1	ETC_LI1	New Storm Sewer and Open Channel	New storm sewer and open channel between residential parcels northwest of Del Rosa Ct and 19th St	$98,000
31	Middle Boulder Creek - 1	MBC_LI1	New Storm Sewer and Open Channel	New storm sewer and open channel north of Grandview Ave, discharging into Boulder Creek	$176,000
32	Dry Creek No. 2 - 4	DC2_LI4	New Storm Sewer	New system in Pawnee Dr discharging into existing Thunderbird Lake	$976,000
33	Dry Creek No. 2 - 7	DC2_LI7	Replacement Storm Sewer	Replace existing system in Lodge Lane	$801,000
34	Wonderland Creek - 3	WC_LI3	New Open Channel	New open channel in Boulder Open Space behind residential lots northwest of Utica Ave and Locust Pl	$24,000
35	Wonderland Creek - 4	WC_LI4	New Open Channel	New open channel in Boulder Open Space behind residential lots northwest of Promontory Ct	$20,000
	TOTAL				**$12,657,000**

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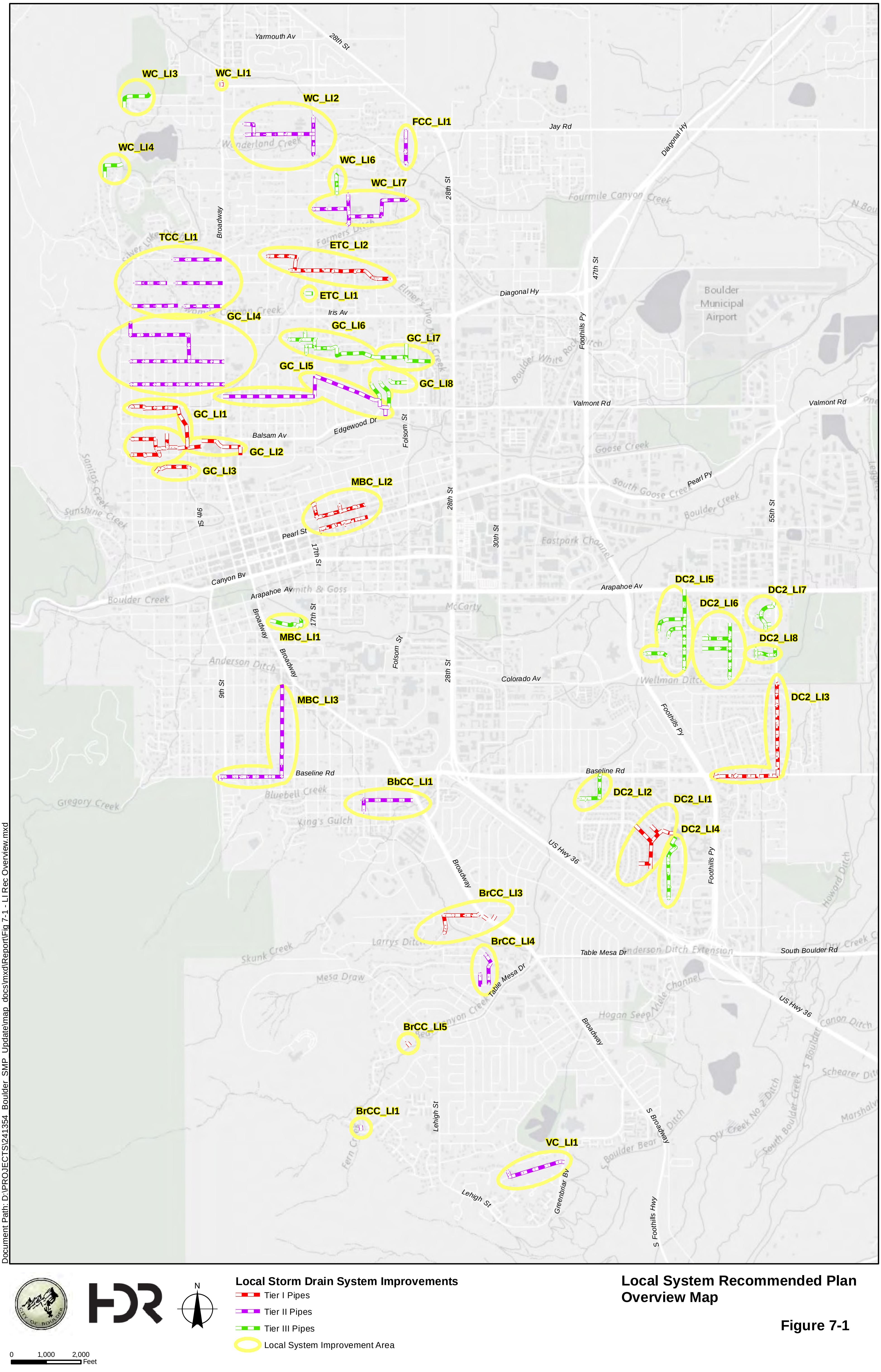


Local System Recommended Plan Overview Map

Figure 7-1

8 Capital Improvement Program

The capital improvement program provides a summary of the recommended local and collector system improvements, their respective priorities, and associated capital costs.

8.1 Cost Estimating

Itemized cost estimates were developed for each CIP project with an anticipated level of accuracy of +50% to –30% (order-of-magnitude cost estimates). The cost estimate worksheets are included in the appendix for reference. The estimates include capital construction costs and land acquisition estimates. Unit costs were obtained from recent bid tabs and *Site Work and Landscape Cost Data, RSMeans®*, and equipment suppliers. Unit costs for pipeline construction, manholes and inlets include material, excavation, and backfill. Surface restoration was developed as a separate cost item. Utility relocation cost were developed as a separate item for sewer line relocations and for watermain lowerings 16" in diameter and greater. Minor utility relocations including, water and sewer service laterals, were accounted for as an allowance of the total construction cost. Quantities for pipes, inlets, manholes, and water quality facilities were obtained from the project GIS.

The cost estimates also include a 30% construction contingency and an 18% allowance for engineering and administration. All estimates are in 2015 dollars and equate to an *Engineering News Record, Construction Cost Index* of 10092,

8.2 Collector System Implementation Plan

The implementation plan for the Hydraulic and Combined Hydraulic/Water Quality CIP projects follows the Tier 1, 2 and 3 problem areas. Tier 1 CIP projects are considered high priority improvements as they resolve severe conveyance system problems and in some instances address stormwater quality problems. Table 7.2-1 identifies the Tier 1, Tier 2 and 3 CIP projects and are shown on Figures 8-1 through 8-3.

Table 8.2-1: Collector System Tier 1, Tier 2 and Tier 3 CIP Projects Implementation Plan

Problem Priority	Ranking	Improvement ID	Location	Improvement Type	Capital Cost
Tier 1	1	GC_02	Alpine Avenue , west of 19th Avenue, in and near Broadway south towards Dewey Street and north towards North Boulder Park	Pipe Replacement New Storm Sewer Channel Improvements	$8,269,000
Tier 1	3	MBC_14	Arapahoe and 28th Street	Pipe Replacement Storm Sewer Re-Routing/Extension Proprietary BMP	$2,076,000
Tier 1/2	4/13	DC_01	Gunbarrel – Spine Road, Lookout and 63rd Systems	Pipe Replacement Storm Sewer Re-Routing/Extension Constructed Wetland	$7,195,000

Table 8.2-1: Collector System Tier 1, Tier 2 and Tier 3 CIP Projects Implementation Plan

Problem Priority	Ranking	Improvement ID	Location	Improvement Type	Capital Cost
Tier 2	5	SC_01	Moorhead and Moorhead frontage	Pipe Replacement Diversion to Major Drainageway	$1,250,000
Tier 2	6	MBC_04	Lincoln	Pipe Replacement	$733,000
Tier 2	7	WC_03	Vail and Independence	Pipe Replacement	$810,000
Tier 2	8	MBC_22	Arapahoe, Commerce, and Range	Pipe Replacement	$2,298,000
Tier 2	9	MBC_20	Parking structure between Foothills and 38th	Pipe Replacement	$88,000
Tier 2	9	DC2_02	Thunderbird, Osage, and Foothills	Pipe Replacement	$5,364,000
Tier 2	11	GC_08	Foothills and Valmont	Pipe Replacement Proprietary BMP	$476,000
Tier 2	12	GC_09	Industrial area near Pearl Parkway and Wonderland Creek	Pipe Replacement Constructed Wetland	$957,000
Tier 2	14	ETC_01	Broadway and Iris	Pipe Replacement Diversion to Major Drainageway	$639,000
Tier 2	14	MBC_23	Access road and 55th St/Pearl and Boulder Creek	Pipe Replacement Proprietary BMP	$445,000
Tier 2	16	DC2_06	Arapahoe/56th Street and Dry Creek	Pipe Replacement Proprietary BMP	$637,000
Tier 2	18	SC_02	Euclid and 30th	Pipe Replacement	$1,135,000
Tier 2	19	MBC_09	16th St.	Pipe Replacement	$1,224,000
Tier 2/3	21/23	BCC_03	Gillaspie and Darley	Pipe Replacement Storm Sewer Re-Routing/Extension	$1,512,000
Tier 3	22	VC_01	Gillaspie and Heidelberg	Pipe Replacement	$1,296,000
Tier 3	23	VC_02	Broadway and Viele Channel	Pipe Replacement	$1,655,000
Tier 3	26	DC2_01	Baseline and Inca	Pipe Replacement	$1,226,000
Tier 3	27	BCC_04	Broadway and Bear Creek	Pipe Replacement	$540,000
Tier 3	27	DC2_05	55th and Dry Creek Number 2	Pipe Replacement	$770,000
Tier 3	29	GC_06	Pearl and 30th	Pipe Replacement	$933,000
Tier 3	30	DC2_04	Pennsylvania and Crescent	Pipe Replacement	$664,000
Tier 3	30	MBC_13	Folsom and Walnut	Pipe Replacement	$754,000
Tier 3	30	GC_03	23rd and Mapleton	Pipe Replacement	$819,000
Tier 3	33	WC_02	Island and Kalmia	Pipe Replacement	$402,000
Tier 3	33	BCC_01	Lehigh and Bear Creek	Pipe Replacement	$1,132,000
Tier 3	35	FCC_01	Hoya, Corriente and 30th	Pipe Replacement	$863,000

Table 8.2-1: Collector System Tier 1, Tier 2 and Tier 3 CIP Projects Implementation Plan

Problem Priority	Ranking	Improvement ID	Location	Improvement Type	Capital Cost
Tier 3	36	DC_02	Clubhouse and Augusta	Pipe Replacement	$411,000
Tier 3	36	GC_07	30th and Corona	Pipe Replacement	$184,000
Tier 3	36	WC_01	Wonderland Hill and Poplar	Pipe Replacement	$324,000
Tier 3	36	MBC_19	Marine Avenue and Boulder Creek	Pipe Replacement Proprietary BMP	$408,000
Tier 3	36	MBC_02	4th and Canyon	Pipe Replacement	$267,000
Tier 3	36	BCC_07	36th and Baseline	Pipe Replacement	$428,000
Tier 3	36	BCC_02	Hartford and Darley	Pipe Replacement	$184,000
Tier 3	36	BCC_06	42nd and Moorhead	Pipe Replacement	$373,000
Tier 3	36	BCC_05	Martin and Ash	Pipe Replacement	$200,000
Tier 3	48	ETC_03	26th and Kalmia	Pipe Replacement	$1,109,000
Tier 3	49	GC_05	27th and Spruce	Pipe Replacement	$810,000
Tier 3	50	MBC_15	28th and Colorado	Pipe Replacement	$139,000
Tier 3	50	MBC_08	13th and Broadway	Pipe Replacement	$1,209,000
Tier 3	50	DC2_03	Manhattan and Baseline	Pipe Replacement	$603,000
Tier 3	53	MBC_01	5th and Mountain View	Pipe Replacement	$177,000
Tier 3	54	MBC_21	48th and Arapahoe	Pipe Replacement	$221,000
Tier 3	55	MBC_17	28th, 500’ north of Canyon	Pipe Replacement	$480,000

The implementation plan for the WQIMP projects were prioritized based on problem severity as identified by pollutant load. The WQIMP category was developed since many of the water quality project sites were not adjacent to hydraulic problem and improvement locations. In addition, many of these WQIMP projects could be defined as a small capital projects since the estimated construction costs are less than $100,000.

Table 8.2-2: Water Quality Improvements Implementation Plan

Improvement ID	Annual TSS Load (pounds)	Location	Capital Cost
WQIMP 2	61,900	Boulder Creek 1,400’ East of 75th Street	$133,000
WQIMP 3	56,500	Boulder Creek & 28th Street	$104,000
WQIMP 5	46,200	Boulder Creek & 75th Street	$97,000
WQIMP 6 WQIMP 9	45,700 & 38,400	Boulder Creek & East Broadway Street & Arapahoe Avenue	$201,000
WQIMP 8	41,500	Boulder Creek 200’ West of Folsom Street	$108,000

WQIMP 12	29,000	Boulder Creek & Folsom Street	$100,000
WQIMP 14	24,200	Boulder Creek & 9th Street	$93,000
WQIMP 15	22,800	Broadway & Skunk Creek	$93,000
WQIMP 16	20,300	Boulder Creek & 13th Street	$104,000
WQIMP 18	15,000	Boulder Creek & 11th Street	$65,000

8.3 Local System Implementation Plan

The implementation plan for the local drainage system CIP projects follows the Tier I, II and III problem areas. Tier I CIP projects are considered high priority improvements as they resolve more severe local system problems. The following table identifies the Tier I, Tier II and III local system CIP projects and are shown on Figures 8-4 and 8-5.

Table 8.3-3: Local System Tier I, Tier II and Tier III Projects Implementation Plan

Problem Priority	Ranking	Project ID	Location	Improvement Type	Capital Cost
Tier I	1	Wonderland Creek -1	Broadway Street from Rosewood Ave to Violet Ave	New Storm Sewer Replacement Storm Sewer	$318,000
Tier I	2	Elmer's Twomile Creek-2	Farmer's Ditch – Iris Ave to Linden Ave and Broadway St to Cloverleaf Drive	New Storm Sewer Replacement Storm Sewer	$3,874,000
Tier I	3	Goose Creek-1	Intersection of 8th St and Dellwood Ave	New Storm Sewer Replacement Storm Sewer	$1,585,000
Tier I	4	Goose Creek-2	Alpine Ave to Dellwood Ave and 3rd St to 7th St	New Storm Sewer Replacement Storm Sewer	$2,417,000
Tier I	5	Goose Creek-3	Dewey Ave from 4th St to 9th St	New Storm Sewer Replacement Storm Sewer	$984,000
Tier I	6	Middle Boulder Creek-2	Vicinity of Pine Street from 16th St to 21st St	New Storm Sewer Replacement Storm Sewer	$3,175,000
Tier I	7	Dry Creek No, 2-1	Intersection of Chippewa Dr and Caddo Pkwy east of Inca Pkwy	New Storm Sewer Replacement Storm Sewer	$1,837,000
Tier I	8	Dry Creek No 2-3	Intersection of Chippewa Dr Baseline and 55th St from Foothills Hwy to Arapahoe Ave	New Storm Sewer Replacement Storm Sewer	$6,505,000
Tier I	9	Bear Canyon Creek-3	Vicinity of Kohler Dr from south of Dartmouth Ave	Hydraulic Improvement	$2,265,000
Tier I	10	Bear Canyon Creek-5	Vicinity of Wildwood Rd	Hydraulic Improvement	$267,000

Table 8.3-3: Local System Tier I, Tier II and Tier III Projects Implementation Plan

Problem Priority	Ranking	Project ID	Location	Improvement Type	Capital Cost
Tier II	11	Goose Creek-5	Vicinity of Cedar Ave and 19th St	New Storm Sewer	$5,484,000
Tier II	12	Wonderland Creek-7	Vicinity of Oak Ave and 21st Ave	New Storm Sewer	$2,452,000
Tier II	13	Twomile Canyon Creek-1	Kalmia Ave and Juniper Av west of Broadway Ave	New Storm Sewer	$2,939,000
Tier II	14	Viele Channe-1	Longwood Ave an Lafayette Dr from Lehigh St to Greenbriar Blvd	New Storm Sewer	$936,000
Tier II	15	Wonderland Creek-2	Intersection of 19th St and Sumac Ave	New Storm Sewer	$1,925,000
Tier II	16	Bear Canyon Creek-4	Vicinity of Yale Rd and Hartford Dr	New Storm Sewer	$726,000
Tier II	17	Goose Creek-4	Vicinity of Forest Ave between 3rd St and Broadway St	New Storm Sewer	$4,885,000
Tier II	18	Middle Boulder Creek-3	Vicinity of Cascade Ave from College Ave to Chautauqua Reservoir Rd	New Storm Sewer Replacement Storm Sewer	$2,826,000
Tier II	19	Fourmile Canyon Creek-1	Vicinity of Jay Rd and 26th St	New Storm Sewer	$688,000
Tier II	20	Bear Canyon Creek-1	Bear Canyon Creek, downstream of Stony Hill Ct crossing	New Storm Sewer	$69,000
Tier II	21	Bluebell Canyon Creek-1	Intersection of 20th St and Mariposa Ave	New Storm Sewer Replacement Storm Sewer	$1,137,000
Tier III	22	Dry Creek No 2-2	Pinon and Meadowbrook	New Storm Sewer Replacement Storm Sewer	$726,000
Tier III	23	Dry Creek No 2-5	McKinley, Eisenhower, and 4th St	New Storm Sewer	$2,386,000
Tier III	24	Dry Creek No 2-6	Merritt Dr at Araphahoe Ridge Park	New Storm Sewer	$1,689,000
Tier III	25	Goose Creek-6	20th St and Glenwood Dr, west of 23rd St	New Storm Sewer Replacement Storm Sewer	$1,946,000
Tier III	26	Goose Creek-8	23rd St and 24th St at	New Storm Sewer Replacement Storm Sewer	$932,000
Tier III	27	Wonderland Creek-6	20th St north of Orchard Ave	New Storm Sewer	$366,000

Table 8.3-3: Local System Tier I, Tier II and Tier III Projects Implementation Plan

Problem Priority	Ranking	Project ID	Location	Improvement Type	Capital Cost
Tier III	28	Dry Creek No 2-8	Holmes and White Place	New Storm Sewer Replacement Storm Sewer	$604,000
Tier III	29	Goose Creek-7	Glenwood Dr east and west of Folsom St, Folsom St	New Storm Sewer Replacement Storm Sewer	$1,913,000
Tier III	30	Elmers Twomile Creek-1	Northwest of Del Rosa Ct and 19th St	New Storm Sewer New Open Channel	$98,000
Tier III	31	Middle Boulder Creek-1	North of Grandview Ave	New Storm Sewer New Open Channel	$176,000
Tier III	32	Dry Creek No 2-4	Pawnee Dr	New Storm Sewer	$976,000
Tier III	33	Dry Creek No 2-7	Lodge Lane	Replacement Storm Sewer	$801,000
Tier III	34	Wonderland Creek-3	Boulder Open Space northwest of Utica Ave and Locust Pl	New Open Channel	$24,000
Tier III	35	Wonderland Creek-4	Boulder Open Space northwest of Promontory Ct	New Open Channel	$20,000

8.4 Collector Storm Sewer System Recommended Plan Summary Tables

Summary tables were developed to provide details regarding each of the Tier 1 and Tier 2 problem priority areas. In addition, fact sheets were also developed for three Tier 3 problem priority areas that have associated WQIMP projects. These fact sheets provide the problem ID, improvement location and alignment, technical data for initiating the design process, land ownership and acquisition needs, implementation issues, and an estimate of the capital construction costs. The problem ID can be used with the technical memorandums TM 4.1a – Problem Prioritization and TM 5.1 Hydraulic Concept Alternatives, to research the problem causes and severity.

8.4.1 Tier 1 Priority Improvements

This section includes fact sheets that provide details for each of the Tier 1 problem priority areas in the Recommended Plan.

GC_02: UPPER GOOSE CREEK	
Subbasin/Outfall:	Goose Creek Subbasin, Outfall to Goose Creek
Problem ID:	**HYD#16 (Tier 1 Priority Level)**
Improvement Description	Construct a new collector storm sewer system from the outfall to the Upper Goose Creek channel (aka Edgewood Reach) at 19th Street extending west in Alpine Avenue to North Street and north to Cedar Street. The 19th Street to North Street system ranges from 4'x12' RCB to 48" RCP storm sewer. The 19th Street to Cedar Avenue system ranges in diameter from 60"x30" HERCP to 30" RCP storm sewer system. The existing system between North Street and Alpine Avenue is to remain in-service to provide local drainage conveyance for the private parcels/backyards.
Technical Data:	The system is required to convey the 5-yr storm (510 cfs at the 19th Street outfall).
Land Ownership:	All construction west of 19th Avenue would be within Public ROW.
Implementation Issues:	Restricted construction access for Edgewood reach channel improvements Large storm sewer sizes in an urbanized area will create traffic control and utility issues Phased construction due to high capital cost Potential for high groundwater
Capital Cost:	$8,269,000

MBC_14: ARAPAHOE AND 28TH STREET	
Subbasin/Outfall:	Middle Boulder Creek Subbasin, Outfall to Boulder Creek
Problem ID:	**HYD#55 (Tier 1 Priority Level), WQIMP 10 (Boulder Creek Outfall)**
Improvement Description	Construct a new diversion manhole on Folsom St, south of Arapahoe to tie the western storm sewer system into the existing 48" system along the west side of Folsom (with available capacity). Replace existing under capacity storm sewer along 26th, Arapahoe and 28th and construct a new 36" to 42" pipe along 28th Street between Arapahoe and Boulder Creek to convey both the eastern and western systems. Install a proprietary BMP along 28th Street near the outfall to Boulder Creek.
Technical Data:	The system is required to convey the 5-yr storm Q(wq) – 7.32 cfs Size of manhole: 10-foot Size of connector pipe: 30-inch
Land Ownership:	Public ROW and private property.
Implementation Issues:	Easement acquisition, approximately 500 ft, may be needed on the west side of 28th, south of the super market.
Capital Cost:	$2,076,000

DC_01: GUNBARREL – SPINE ROAD, LOOKOUT AND 63RD SYSTEMS	
Subbasin/Outfall:	Dry Creek Subbasin, Outfall to Dry Creek east of the Diagonal Highway
Problem ID:	**HYD#8 (Tier 1 Priority Level)**, **HYD#9 (Tier 2 Priority Level), WQIMP 01 (Hot Spot)**
Improvement Description	Replace the existing under capacity storm sewer system with pipe diameters that range from 30" to 60". Minor changes to existing pipe slopes are required to optimize the proposed diameters. The new storm sewer is typically located lower than the sanitary sewer to avoid conflicts with sewer mains and service laterals. Construct storm sewer along Lookout Rd to connect with system to east along Spine Road. Constructed wetland pond with discharge to Dry Creek.
Technical Data:	System is required to convey the 5-year storm. Pond Volume = 347,000 cu ft (8 acre feet) Pond surface area: 69,000 square feet
Land Ownership:	All construction would be within Public ROW south of Odel Road. North of Odel Road it is assumed the existing pipe is in an easement and no additional permanent easement acquisition would be required.
Implementation Issues:	Traffic control and business impacts (shipping/truck traffic) for construction in Spine Road and Lookout Road. Possible conflicts with existing sanitary sewers and 16 inch water main.
Capital Cost:	$7,195,000

8.4.2 Tier 2 Priority Improvements

This section includes fact sheets that provide details for each of the Tier 2 problem priority areas in the Recommended Plan.

SC_01: MOORHEAD AND MOORHEAD FRONTAGE	
Subbasin/Outfall:	Skunk Creek Subbasin, Outfall to Skunk Creek
Problem ID:	**HYD#42 (Tier 2 Priority Level)**
Improvement Description	Diversion to Bear Creek Ditch Construct a diversion manhole in the Moorhead/31st St. intersection to divert flow to a new storm sewer running northeast to discharge into the Bear Creek Ditch adjacent to Highway 36. Install a new storm sewer to replace the ditch. The alignment between the homes is to follow the existing storm sewers between 31st and 32nd. The existing ditch along Highway 36 could also be used instead of installing the 36" storm sewer. The ditch would need to be re-graded to flow consistently toward the north and the cross-section improved to convey the design flow.
Technical Data:	The system is required to convey the 5-yr storm
Land Ownership:	Construction through possible residential area
Implementation Issues:	Potential for relocating private utilities along Bear Creek Ditch. Construction on private property, between existing homes would require easement acquisition, approximately 160 ft. Limited space/width between the homes could also create difficulties during construction. Potential for high groundwater.
Capital Cost:	$1,250,000

MBC_04: LINCOLN	
Subbasin/Outfall:	Middle Boulder Creek Subbasin; Outfall to Anderson Ditch
Problem ID:	**HYD#41 (Tier 2 Priority Level)**
Improvement Description	Replace the existing under capacity storm sewer system between College and the Anderson Ditch and match existing grades.
Technical Data:	The system is required to convey the 2-yr storm
Land Ownership:	All construction would be within Public ROW.
Implementation Issues:	Construction in Lincoln would require traffic control. Limited cover north of College requires parallel pipes for the short connection to the Anderson Ditch. A transportation (road widening/bike lane) project is planned along 9th, west of Lincoln.
Capital Cost:	$733,000

WC_03: VAIL AND INDEPENDENCE	
Subbasin/Outfall:	Wonderland Creek Subbasin; Outfall to Boulder & Lefthand Ditch
Problem ID:	**HYD#19 (Tier 2 Priority Level)**
Improvement Description	Abandon the existing system that is routed under the existing trailers/mobile home and construct a new system in the street. The reservoir outlet needs to be confirmed prior to final design development. The reservoir was assumed to be full and therefore rainfall would spill into the outlet/storm sewer system.
Technical Data:	The system is required to convey the 2-yr storm
Land Ownership:	Construction would be within Public ROW.
Implementation Issues:	Probable water and sewer utility relocations and potential for relocating private utilities. A transportation (road widening/bike lane) project is planned adjacent to the existing storm sewer on the east side of Independence. Potential for high groundwater
Capital Cost:	$810,000

MBC_22: ARAPAHOE, COMMERCE, AND RANGE	
Subbasin/Outfall:	Middle Boulder Creek Subbasin, Outfall to a unknown tributary to Boulder Creek
Problem ID:	**HYD#24 (Tier 2 Priority Level)**
Improvement Description	Range Street System: Replace the existing under capacity storm sewer system along Range. Commerce Street System: Replace the existing under capacity storm sewer system along Commerce. As the 36" pipe crosses under the railroad embankment and is only slightly surcharge, it is recommended this pipe not be replaced.
Technical Data:	The system is required to convey the 5-yr storm
Land Ownership:	All construction would be within Public ROW.
Implementation Issues:	Potential for high groundwater
Capital Cost:	$2,298,000

MBC_20: PARKING STRUCTURE BETWEEN FOOTHILLS AND 38TH	
Subbasin/Outfall:	Middle Boulder Creek Subbasin, Outfall to Boulder Creek
Problem ID:	**HYD#29 (Tier 2 Priority Level)**
Improvement Description	Replace the existing under capacity storm sewer system and match existing grades.
Technical Data:	The system is required to convey the 5-yr storm
Land Ownership:	Private. Potential for pipe to be within a drainage easement.
Implementation Issues:	Potential for high groundwater
Capital Cost:	$88,000

DC2_02: THUNDERBIRD, OSAGE, AND FOOTHILLS	
Subbasin/Outfall:	Dry Creek Subbasin, Outfall Dry Creek No. 2 Ditch
Problem ID:	**HYD#47 (Tier 2 Priority Level)**
Improvement Description	(1) System Replacement - Along Foothills, Osage, and Qualla to Highway 36. Replace the under capacity and severely under capacity pipes. (2) System Replacement - Foothills to Thunderbird Lake. (3) System Replacement – Sioux between Iroquois & Seminole. (4) System Replacement – Across Foothills at Cherokee. Replace the existing under capacity storm sewer systems.
Technical Data:	(1) Foothills, 5-Year system. (2) Thunderbird Lake, 2-year system (3) Sioux, 2-Year system (4) Cherokee, 2 & 5-Year systems
Land Ownership:	Construction would be within Public ROW and some private/public lawn areas.
Implementation Issues:	Potential for high groundwater. Boring will be required to cross foothills. Thunderbird Lake system has shallow cover issues and may require a parallel HERCP system. Possible conflicts with existing sanitary sewers and 16 inch water main. Final design process should consider an alternative alignment evaluation to remove the upstream crossing under Foothills Parkway as this will be a bore crossing. Consider routing flow north to the Foothills crossing at Sioux.
Capital Cost:	$5,364,000

GC_08: FOOTHILLS AND VALMONT	
Subbasin/Outfall:	Goose Creek Subbasin, Outfall to Goose Creek
Problem ID:	**HYD#27 (Tier 2 Priority Level), WQIMP 11 (Hot Spot)**
Improvement Description	Replace the existing under capacity 18" diameter storm sewer in Foothills, under Valmont and 36" diameter storm sewer in Foothills and match existing grades. Install a proprietary BMP southwest of the intersection of Foothills and Valmont.
Technical Data:	The system is required to convey the 5-yr storm Q(wq) – 5.54 cfs Size of manhole: 8-foot Size of connector pipe: 24-inch
Land Ownership:	All construction would be within Public ROW.
Implementation Issues:	Construction in Valmont would require traffic control and closing of the east and westbound lanes. A transportation (multi-use path) project is planned along the west side of Foothills Highway from Valmont to the Federal facility.
Capital Cost:	$476,000

ETC_01: BROADWAY AND IRIS	
Subbasin/Outfall:	Elmers Two Mile Canyon Creek Subbasin, Outfall to Farmers Ditch
Problem ID:	**HYD#15 (Tier 2 Priority Level)**
Improvement Description	Diversion to Major Drainageway Improvement Construct a diversion manhole at the Broadway/Iris intersection to divert excess flow from the collector system south into the planned Two Mile Canyon Creek (TMCC) major drainageway improvement. The TMCC improvement consists on a 54" storm sewer the runs south of Iris in Broadway then turns east on Hawthorne and continues to eventually outfall to Goose Creek as shown in GC_04.
Technical Data:	• The system is required to convey the 5-yr storm • Increase in 5-year flow to the TMCC project is approximately 20 cfs totaling about a 10% in the original design capacity. This would require 2,640' of 24" RCP to be increased to 60" RCP.
Land Ownership:	All construction would be within Public ROW with the exception of a drainage easement identified in the TMCC major drainageway project.
Implementation Issues:	Construction in Broadway would require significant traffic control. Potential for high groundwater
Capital Cost:	$639,000

GC_09: INDUSTRIAL AREA NEAR PEARL PARKWAY AND WONDERLAND CREEK	
Subbasin/Outfall:	Goose Creek Subbasin, Outfall to Goose Creek
Problem ID:	**HYD#21 (Tier 2 Priority Level), WQIMP 07 (Hot Spot)**
Improvement Description	Construct a new system that abandons the system that is routed under the existing building. The new pipe system would be routed in the middle of the access road. Constructed wetland pond in the city Yards (to be redesigned). Flow would be diverted from the collector systems to the pond via a diversion manhole and storm sewer. Flow from the water quality pond would be discharged to Wonderland Creek via the collector system. Flows in excess of the WQ storm would not be routed through the pond.
Technical Data:	The system is required to convey the 5-yr storm Pond volume = 40,800 cubic feet (0.9 acre feet) Pond surface area: 14,000 square feet
Land Ownership:	Private property. Being the system goes under a building it is doubtful an easement exists.
Implementation Issues:	Probable water and sewer utility relocations and potential for relocating private utilities. Little to no room may be available for relocation. An easement, approximately 220 ft, for Link 1748 will be needed.
Capital Cost:	$957,000

MBC_23: ACCESS RD AND 55TH ST/PEARL AND BOULDER CREEK	
Subbasin/Outfall:	Middle Boulder Creek Subbasin & 100-year flood zone, Outfall to Boulder Creek
Problem ID:	**HYD#20 (Tier 2 Priority Level), WQIMP 17 (Boulder Creek Outfall)**
Improvement Description	Replace the existing under capacity storm sewer system and match existing grades. Install a proprietary BMP along 55h Street near the outfall.
Technical Data:	The system is required to convey the 5-yr storm Q(wq) – 2.95 cfs Size of manhole: 8-foot Size of connector pipe: 24-inch
Land Ownership:	Some construction would be within Public ROW; Other construction may be within an assumed drainage easement across private property within the industrial area.
Implementation Issues:	Potential for high groundwater
Capital Cost:	$445,000

DC2_06: ARAPAHOE/56TH STREET AND DRY CREEK	
Subbasin/Outfall:	Dry Creek No.2 Subbasin and 100-year Flood Zone, Outfall to Dry Creek
Problem ID:	**HYD#22 (Tier 2 Priority Level), WQIMP 04 (Hot Spot)**
Improvement Description	Replace the existing under capacity storm sewer system and match existing grades. Install a proprietary BMP at northeast corner of the basin. Requires two diversion structures from two systems.
Technical Data:	The system is required to convey the 5-yr storm Q(wq) – 6.5 cfs Size of manhole: 8-foot Size of connector pipe: 24-inch
Land Ownership:	All construction would be within Public ROW.
Implementation Issues:	Construction in Arapahoe would require traffic control and closing of the lane(s). A transportation (road widening/multi-use path) project is planned along Arapahoe.
Capital Cost:	$637,000

SC_02: EUCLID AND 30TH	
Subbasin/Outfall:	Skunk Creek Subbasin, Outfall to Wellman Ditch
Problem ID:	**HYD#38 (Tier 2 Priority Level)**
Improvement Description	Replace the existing under capacity storm sewer system.
Technical Data:	The system is required to convey the 5-yr storm
Land Ownership:	Assumed located within drainage easement(s) through private property. May need to increase easement width as pipe diameters at downstream end are significantly larger.
Implementation Issues:	Confined construction behind condos and impacts to existing trees and landscaping would increase project costs and public involvement issues.
Capital Cost:	$1,135,000

MBC_09: 16TH ST.	
Subbasin/Outfall:	Middle Boulder Creek Subbasin, Outfall to North Boulder Farmers Ditch
Problem ID:	**HYD#35 (Tier 2 Priority Level)**
Improvement Description	System Replacement. Replace the existing under capacity storm sewer system in Pine and 16th Street,.
Technical Data:	The system is required to convey the 5-yr storm
Land Ownership:	All construction would be within Public ROW.
Implementation Issues:	Construction in 16th St. would require traffic control
Capital Cost:	$1,224,000

BCC_03: GILLASPIE AND SHOPPING CENTER PARKING	
Subbasin/Outfall:	Bear Canyon Creek Subbasin, Outfall to Bear Canyon Creek
Problem ID:	**HYD#49 (Tier 2 Priority Level), HYD#50 (Tier 3 Priority Level)**
Improvement Description	System Replacement/Diversion. Replace the existing under capacity storm sewer along Darley from Edinboro to Gillaspie. Construct a diversion manhole near the Darley/Gillaspie intersection to divert flow to a new storm sewer that continues northeast in Darley. This new storm sewer would connect with the existing storm sewer at the Darley/Toedtli intersection where it would eventually discharge into Viele Creek.
Technical Data:	• The system is required to convey the 2 and 5-yr storms
Land Ownership:	All construction would be within Public ROW.
Implementation Issues:	Construction in Darley and Broadway would require minor traffic control. Potential for high groundwater
Capital Cost:	$1,512,000

8.4.3 Water Quality Specific Projects

This section includes fact sheets for areas in the Recommended Plan that have only water quality improvements.

LBC_02: BOULDER CREEK 1,400' EAST OF 75TH STREET

Improvement Location: The basin for WQIMP 02 consists of the east half of the area encompassed by Heatherwood Dr and 75th.

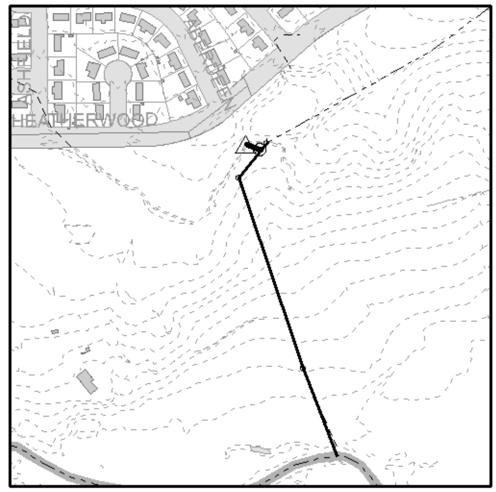
Improvement Description: **WQIMP 02 (Boulder Creek Outfall)** - Install a proprietary BMP east of 75th near Aberdeen and Heatherwood

Technical Data:
- Q(wq) – 19.41 cfs
- Size of manhole: 10-foot
- Size of connector pipe: 30-inch

Land Ownership:
- City of Boulder

Implementation Issues:
- Maintenance access may be problematic.

Capital Cost: $133,000



MBC_16: BOULDER CREEK & 28TH STREET

Improvement Location: The basin for WQIMP 03 includes the area south of Boulder Creek along 28th to Colorado.

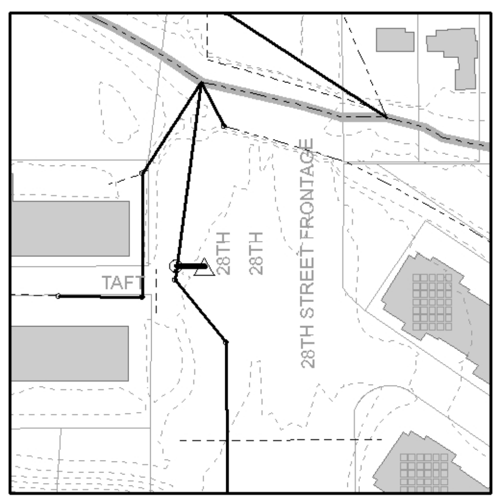
Improvement Description: **WQIMP 03 (Boulder Creek Outfall)** - Install a proprietary BMP west of 28th near Boulder Creek

Technical Data:
- Q(wq) – 14.49 cfs
- Size of manhole: 10-foot
- Size of connector pipe: 30-inch

Land Ownership:
- Public ROW

Implementation Issues:
- CDOT ROW

Capital Cost: $104,000



LBC_01: BOULDER CREEK & 75TH STREET

Improvement Location: The basin for WQIMP 05 includes the area about 450 ft wide along 75th from Boulder Creek north to Clubhouse.

Improvement Description: **WQIMP 05 (Boulder Creek Outfall)** - Install a proprietary BMP along 75th.

Technical Data:

- Q(wq) – 11.72 cfs
- Size of manhole: 10-foot
- Size of connector pipe: 30-inch

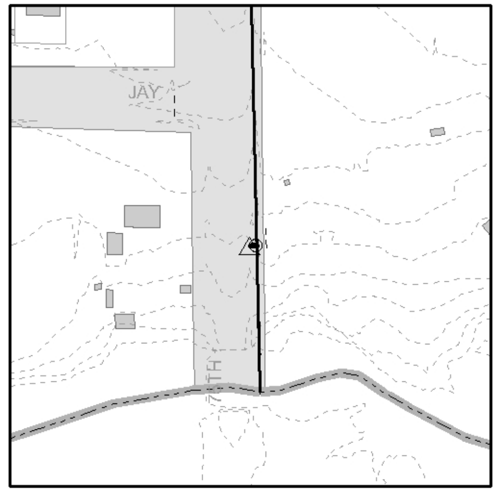
Land Ownership:

- Construction would be within Public ROW.

Implementation Issues:

- Property acquisition

Capital Cost: $97,000



MBC_06: BOULDER CREEK & EAST BROADWAY STREET & ARAPAHOE AVENUE

Improvement Location: The basins for WQIMP 06 and WQIMP 09 include a large area south of Boulder Creek to Cascade about 1,200 ft wide on the east side of Broadway.

Improvement Description: **WQIMP 06 and WQIMP 09 (Boulder Creek Outfalls)** - Install a proprietary BMP west of Broadway near Boulder Creek and a second south of Arapahoe near Boulder Creek

Technical Data:

Broadway BMP

- Q(wq) – 22.48 cfs
- Size of manhole: 10-foot
- Size of connector pipe: 30-inch

Arapahoe BMP

- Q(wq) – 23.91 cfs
- Size of manhole: 10-foot
- Size of connector pipe: 30-inch

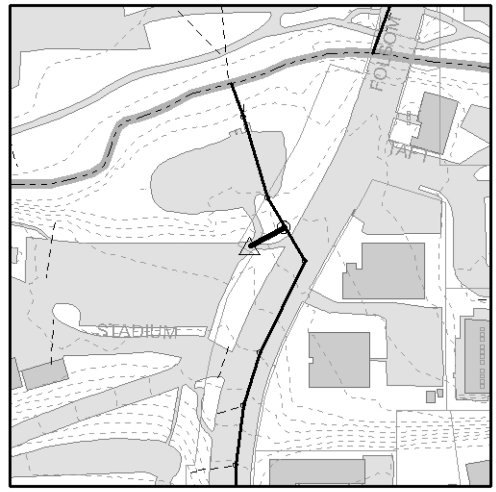
Land Ownership:

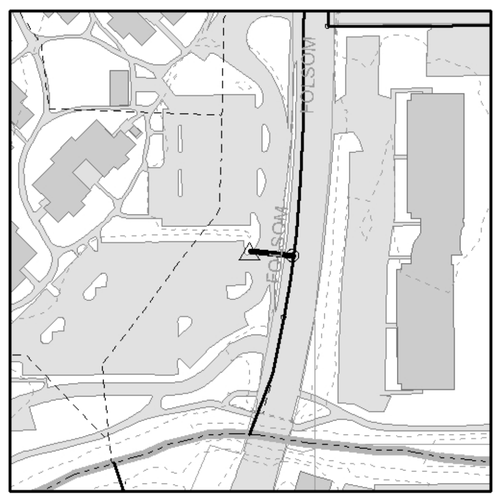
- City of Boulder

Implementation Issues:

- Construction in Broadway

Capital Cost: $201,000

MBC_11: BOULDER CREEK 200' WEST OF FOLSOM STREET		
Improvement Location:	The basin for WQIMP 08 includes the area south of Boulder Creek along Folsom to Colorado.	
Improvement Description:	**WQIMP 08 (Boulder Creek Outfall)** - Install a proprietary BMP west of Folsom south of Boulder Creek	
Technical Data:	• Q(wq) – 10.13 cfs • Size of manhole: 10-foot • Size of connector pipe: 30-inch	
Land Ownership:	• University of Colorado	
Implementation Issues:	• Property acquisition	
Capital Cost:	$108,000	

MBC_12: BOULDER CREEK & FOLSOM STREET		
Improvement Location:	The basin for WQIMP 12 includes the area north of Boulder Creek along Folsom to Arapahoe.	
Improvement Description:	**WQIMP 12 (Boulder Creek Outfall)** - Install a proprietary BMP west of Folsom north of Boulder Creek	
Technical Data:	• Q(wq) – 6.32 cfs • Size of manhole: 8-foot Size of connector pipe: 24-inch	
Land Ownership:	• University of Colorado	
Implementation Issues:	• Property acquisition.	
Capital Cost:	$100,000	

MBC_03: BOULDER CREEK & 9TH STREET

Improvement Location: The basin for WQIMP 14 includes the area 200 ft wide along 9th from Boulder Creek to Walnut and east from 9th about 1,100 ft.

Improvement Description: **WQIMP 14 (Boulder Creek Outfall)** - Install a proprietary BMP near 9th and Canyon.

Technical Data:

- Q(wq) – 10.71 cfs
- Size of manhole: 10-foot
- Size of connector pipe: 30-inch

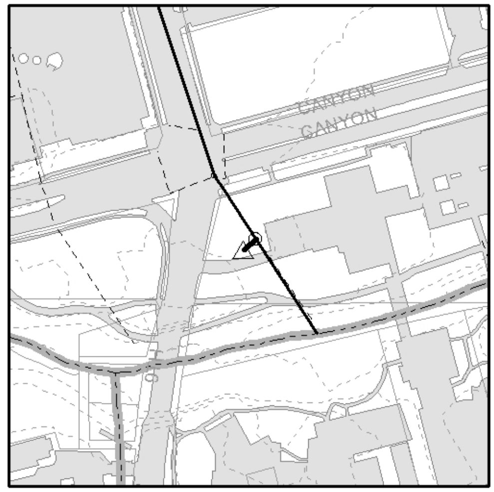
Land Ownership:

- City of Boulder

Implementation Issues:

- None identified

Capital Cost: $73,000



KG_01: BROADWAY & SKUNK CREEK

Improvement Location: The basin for WQIMP 15 encompasses the NIST facility west of Broadway and south of Bluebell Ave.

Improvement Description: **WQIMP 15 (Hot Spot)** - Install a proprietary BMP along Broadway.

Technical Data:

- Q(wq) – 5.34 cfs
- Size of manhole: 8-foot
- Size of connector pipe: 24-inch

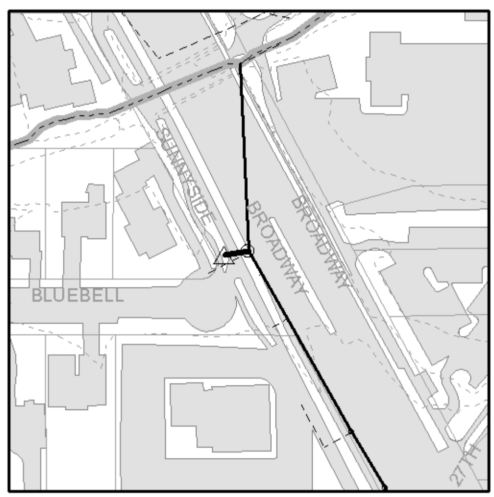
Land Ownership:

- Construction would be within the ROW.

Implementation Issues:

- None Identified

Capital Cost: $93,000



MBC_07: BOULDER CREEK & 13TH STREET

Improvement Location: The basin for WQIMP 16 includes the area encompassed by Arapahoe, 16th, Canyon, and 13th.

Improvement Description: **WQIMP 16 (Boulder Creek Outfall)** - Install a proprietary BMP west of 13th.

Technical Data:

- Q(wq) – 7.59 cfs
- Size of manhole: 10-foot
- Size of connector pipe: 30-inch

Land Ownership:

- City of Boulder

Implementation Issues:

- None Identified

Capital Cost: $104,000

MBC_05: BOULDER CREEK & 11TH STREET

Improvement Location: The basin for WQIMP 18 encompasses an area about 750 ft wide from Boulder Creek north to Pine St.

Improvement Description: **WQIMP 18 (Boulder Creek Outfall)** - Install a proprietary BMP near 11th and Canyon.

Technical Data:

- Q(wq) – 6.40 cfs
- Size of manhole: 8-foot
- Size of connector pipe: 24-inch

Land Ownership:

- City of Boulder

Implementation Issues:

- None identified

Capital Cost: $65,000

8.5 Local System Recommended Plan Summary Tables

Summary tables were developed to provide details regarding each of the Tier I and Tier II local system improvements. These tables provide the problem ID, description of the project improvement, technical and implementation comments and planning level capital cost estimate. The problem ID can be used with the technical memorandum titled *Task 4 – Local System Analysis* to research the problem causes and severity.

8.5.1 Tier I Priority Improvements

This section includes summary tables that provide details for each of the Tier I Local System Improvements.

Project ID (Subbasin)	**Wonderland Creek – 1 (WC_LI1)**
Problem Location	Broadway Street from Rosewood Avenue to Violet Avenue
Problem Description	Due to a lack of stormwater infrastructure along the east side of Broadway Street from Fourmile Creek to Violet Ave, and poor capture of stormwater by the existing storm sewer system north of Fourmile creek, runoff continues across Violet Ave and has the potential to flood properties on the south side of the street. Runoff also continues east along Violet and spills south along 13th Avenue. The contributing area to the identified problem area is approximately 2 acres.
Improvement Description	Provide collection and conveyance infrastructure (inlets, manholes, and storm sewer) along the east side of Broadway and convey to the existing system along the west side of Broadway.
Technical Data	The conveyance system is required to convey the 5-yr storm Storm sewer diameters range from 30 to 36-inch with 2 inlets
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 300 feet of both and water sewer line along Broadway Street from Violet Avenue to Rosewood Avenue.
Capital Cost	$318,000

Project ID (Subbasin)	Elmer's Twomile Creek – 2 (ETC_LI2)
Problem Location	Farmer's Ditch - Iris Avenue to Linden Avenue and Broadway Street to Cloverleaf Drive
Problem Description	Entire neighborhood bounded to the north, west, and south by Cloverleaf Drive, Broadway Street, and Kalmia Ave, respectively drains easterly to the Farmer's irrigation ditch. Specifically, runoff from the area described above is discharged to the ditch via four outfalls of 12, 18, 21, and 48-inches in diameter. The ditch system can become overwhelmed during heavy rains and cause potential overflows, causing flooding of downstream properties. The total contributing area is approximately 76 acres.
Improvement Description	Remove stormwater outfalls to the ditch. Construct new collection system in the subbasins and a new storm sewer in Kalmia with outfall to Elmer's Twomile Creek.
Technical Data	The conveyance system is required to convey the 2-yr storm Storm sewer diameters range from 18 to 36-inch with 25 inlets
Land Ownership	This reach of the Farmer's Ditch is located on private property and is assumed to be contained within an easement.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 2,300 feet of water and sewer lines along Linden Avenue from 16th Street to Cloverleaf Drive, along Cloverleaf Drive from Linden Avenue to Kalmia Avenue, and along Kalmia Avenue from Cloverleaf to 19th Street. Additionally, relocation of 6 water and 6 sewer laterals will likely be required along Kalmia Avenue from 19th Street to the outfall to Elmer's Twomile Creek.
Capital Cost	$3,874,000

Project ID (Subbasin)	Goose Creek – 1 (GC_LI1)
Problem Location	Intersection of 8th Street and Dellwood Avenue
Problem Description	The existing local stormwater conveyance system is undersized and reported as reaching capacity during relatively minor storm events. The inadequacy of the system has lead to frequent roadway flooding, to the point that the crown of the road is inundated several inches. This intersection is a low point, creating an exacerbated flooding condition during storm events. The total contributing area to the problem area described above is approximately 32 acres.
Improvement Description	Improve/provide a stormwater collection and conveyance system along Dellwood Avenue between 3rd to 8th Street, eventually connecting into the existing conveyance system at the intersection of 8th Street and Dellwood Avenue. Upsize existing system south of Dellwood Avenue through North Boulder Park to just south of Balsam Street.
Technical Data	The conveyance system is required to convey the 2-yr storm Storm sewer diameters consists of 18 to 36-inch with 16 inlets
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 330 feet of both and water sewer line along 5th Street from Dellwood Avenue to Cedar Avenue. Additionally, it is anticipated that approximately 500 feet of sewer line within the private property parcel, described above, would also require relocation.
Capital Cost	$1,585,000

Project ID (Subbasin)	Goose Creek – 2 (GC_LI2)
Problem Location	Alpine Avenue to Dellwood Ave and 3rd Street to 7th Street
Problem Description	Steep slopes and an inadequate existing storm sewer network cause high surface runoff flows, threatening pedestrians and residences at intersections where runoff is currently unmanaged. Many alleys contain low points, localized to the center of the block, and have been observed to collect runoff and spill it into adjacent residences. The total contributing area to the problem area described above is approximately 48 acres.
Improvement Description	Extend the existing stormwater collection and conveyance system along Balsam Avenue and Alpine Avenue west to 4th Street, connecting to the existing systems. Formalize the existing inadvertent detention that occurs in North Boulder Park and increase the volume to mitigate the increased runoff peaks created by improving the upstream storm sewer conveyance.
Technical Data	The conveyance system is required to convey the 2-yr storm Storm sewer diameters range from 18 to 36-inch with 29 inlets
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way. The associated detention/water quality facility would be located on Parks Department property.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 1,000 feet of water lines along Alpine Avenue from 4th Street to 6th Street. Additionally, it is anticipated that approximately 900 feet of sewer line along Balsam Avenue from 4th Street to 6th Street would need to be relocated.
Capital Cost	$2,417,000

Project ID (Subbasin)	Goose Creek – 3 (GC_LI3)
Problem Location	Dewey Avenue from 4th Street to 9th Street
Problem Description	The existing stormwater infrastructure along 4th Street from Maxwell Avenue to Dewey Avenue has been identified as insufficient through observations of runoff bypassing the inlets during high rainfall storm events. Additionally, a bottleneck in the storm sewer at 6th Street and North Street where the storm sewer transitions from 30” to 12” sewer has been identified, which creates a local roadway flooding condition as a result of back-ups within the system. The area of concern is also perceived to receive a significant portion of runoff from adjacent impervious areas, exacerbating the flooding condition. The total contributing area to the problem area described above is approximately 64 acres.
Improvement Description	Remove orifice plate in manhole in 6th Street just south of North Street. Provide additional stormwater infrastructure (inlets and conveyance pipe) from 6th Street to North Street then extending east in North Street to 9th Street. Connect to existing system at intersection of 9th Street and North Street. Existing system from 6th Street to 9th Street between North Street and Dewey Avenue to remain in service.
Technical Data	The conveyance system is required to convey the 2-yr storm Storm sewer diameters consists of 30-inch with 8 inlets
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way. Detention would be located on private property requiring land acquisition.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 320 feet of sewer

	line along 6th Street from Dewey Avenue to north Street. Additionally, it is anticipated that approximately 430 and 170 feet of water and sewer line, respectively, would require location along 9th Street from North Street to Dewey Avenue.
Capital Cost	$984,000

Project ID (Subbasin)	**Middle Boulder Creek – 2 (MBC_LI2)**
Problem Location	Vicinity of Pine Street from 16th Street to 21st Street.
Problem Description	2013 flooding was reported to exceed the level of service of the drainage system along local collector streets which may have been exacerbated by the potentially capacity-limited downstream conveyance system.
Improvement Description	Improve existing storm sewer in 18th Street from Pine Street to Spruce Street, in 20th Street from Spruce Street north halfway to Pine Street, and in Spruce Street from 18th Street to the manhole east of 21st Street. Introduce new storm sewer system along Pearl Street from 18th Street to 21st Street, conveying flows easterly into the Boulder White Rock Ditch.
Technical Data	The conveyance system is required to convey the 5-yr storm Storm sewer diameters range from 24 to 42-inch with 47 inlets
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 1,800 feet of water line along Spruce Street from 16th Street to 21st Street.
Capital Cost	$3,175,000

Project ID (Subbasin)	**Dry Creek No. 2 – 1 (DC2_LI1)**
Problem Location	Intersection of Chippewa Drive and Caddo Parkway east of Inca Parkway
Problem Description	Chippewa Drive and Caddo Parkway, east of Inca Parkway, are currently graded such that runoff is collected primarily along the north side of the roadway. During heavy rains the inlets on the north side of the roadway become overwhelmed, causing localized flooding of adjacent properties. The total contributing area to the problem area described above is approximately 15 acres.
Improvement Description	Provide a new storm sewer system in Chippewa Drive and Caddo Parkway that drain to a new system Mohawk Drive that discharges to Thunderbird Lake. Combine this improvement with the Type B problem area improvement opportunity that also increases flows to the lake and improves water quality in the lake which has had issues with insufficient replenishment and stagnation.
Technical Data	The conveyance system is required to convey the 2-yr storm Storm sewer diameters range from 18 to 36-inch with 24 inlets
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 840 feet of water line along Caddo Parkway from Mohawk Drive to Inca Parkway.
Capital Cost	$1,837,000

Project ID (Subbasin)	Dry Creek No. 2 – 3 (DC2_LI3)
Problem Location	Baseline and 55th Street from Foothills Hwy to Arapahoe Avenue
Problem Description	Several sections of the existing open channel system on the north side of Baseline Road and Dry Creek Ditch #2 along 55th St north of Baseline are capacity limited and can cause stormwater to back up into the upstream conveyance and detention facilities. The total contributing area to the problem area described above is approximately 314 acres. The 2007 SMP identified the existing storm sewer systems are under capacity in Manhattan, under Foothills Parkway, near Broadway, and south along Foothills Parkway.
Improvement Description	Construct new storm sewer in Baseline from Brooklawn Drive to 55th Street and within 55th Street from Baseline to approximately 300 feet north of Pennsylvania Avenue with a new outfall to Wellman Ditch.
Technical Data	The conveyance system is required to convey the 5-yr storm Storm sewer diameters range from 46 to 54-inch with 38 inlets
Land Ownership	This portion of the open channel conveyance system and Dry Creek No. 2 reach is located on both city right-of-way and private property. The portion of the problem area located on private property is assumed to be contained within an easement.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 2,300 feet of water and sewer lines along Baseline from Manhattan Drive to 55th Street. Additionally, relocation of approximately 3,400 feet of existing water line and 7 water and 2 sewer laterals would be required along 55th Street from Baseline to the northern extent of the project, as described above.
Capital Cost	$6,505,000

Project ID (Subbasin)	Bear Canyon Creek – 3 (BrCC_LI3)
Problem Location	Vicinity of Kohler Drive from south of Dartmouth Avenue
Problem Description	Steep terrain drains to sump condition in Kohler Drive with stormwater discharging to Anderson Ditch. Closed conveyance is inadequate and overflow path runs to properties downhill in Dover Drive.
Improvement Description	Improve existing collection and conveyance system in sump condition of Kohler Drive. Route to Dartmouth Avenue and connect to system in Broadway Street. Improvements in Kohler will alleviate downhill flooding in Dover. Additionally, upsize portions of the existing system where throttling occurs due to reduced pipe diameters.
Technical Data	Select portions of the conveyance system are required to convey either the 2 or 5-yr storm Storm sewer diameters range from 36 to 48-inch with 12 inlets
Land Ownership	This portion of the conveyance system is located on both city right-of-way and private property. The portion of the problem area located on private property is assumed to be contained within an easement.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project would likely require the relocation of approximately 1,500 feet of water and sewer lines along Kohler Drive from Stanford Drive to Dartmouth Avenue and along Dartmouth Avenue from Kohler Drive to South Broadway Street.
Capital Cost	$2,265,000

Project ID (Subbasin)	Bear Canyon Creek – 5 (BrCC_LI5)
Problem Location	Vicinity of Wildwood Road
Problem Description	Runoff to Wildwood Drive sump/sag locations may exceed storm sewer capacity and major storm overflow paths.
Improvement Description	Install and/or improve discharge locations to Bear Canyon Creek.
Technical Data	The conveyance system is required to convey the 2-yr storm Storm sewer diameters consists of 18-inch with 1 inlet.
Land Ownership	This portion of the conveyance system is located on both city right-of-way and private property. The portion of the problem area located on private property is assumed to be contained within an easement.
Implementation Challenges	Based on review of the city utility GIS data, it has been determined that this project may require the relocation of approximately 420 feet of sewer line along Ithaca Drive from Wildwood Road to Holyoke Drive.
Capital Cost	$267,000

8.5.2 Tier II Priority Improvements

This section includes summary tables that provide details for each of the Tier II Local System Improvements.

Problem Name and ID	**Fourmile Canyon Creek – 1 (FCC_LI1)**
Problem Location	Vicinity of Jay Road and 26th Street.
Problem Description	Limited drainage infrastructure, combined with the potentially capacity-limited roadside ditch and culvert system, was presumed to contribute to 2013 flooding reports.
Improvement Description	Provide a stormwater collection and closed conveyance system along 26h Street from Jay Rd to approximately 300 feet south of Topaz Drive, discharging to the Fourmile Canyon Creek Drainageway.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 30 to 36-inch with 11 inlets and 4 manholes.
Land Ownership	All work is contained within city ROW and existing easements
Implementation Challenges	None identified
Capital Cost	$ 688,000

Problem Name and ID	**Wonderland Creek – 2 (WC_LI2)**
Problem Location	Intersection of 19th Street and Sumac Avenue
Problem Description	During larger storm events, runoff from Sumac Ave flows across 19th Street and has the potential to flood properties that are below road grade on the east side of 19th Street. Currently, there is existing storm sewer on the north side of the intersection, but none provided on the south where the issue is predominantly observed. The contributing area to the identified problem area is approximately 70 acres.
Improvement Description	Provide collection and conveyance infrastructure (inlets and conveyance pipe) at the southwest corner of intersection and extending west in Sumac Ave to collect and convey into the existing system along the west side of 19th Street. Depending on the capacity of the existing system along 19th Street, the capacity of the existing system may need to be increased to discharge into Wonderland Creek.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 18 to 30-inch with 32 inlets and 13 manholes.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	None identified
Capital Cost	$ 1,925,000

Problem Name and ID	Wonderland Creek – 7 (WC_LI7)
Problem Location	Vicinity of Oak Avenue and 21st Street.
Problem Description	Limited drainage infrastructure, combined with the potentially capacity-limited roadside ditch and culvert system, was presumed to contribute to 2013 flooding reports. Roadway flooding of Norwood Ave has also been observed by city staff during other heavy rainfalls.
Improvement Description	Provide a stormwater collection and closed conveyance system along Oak Avenue from Oak Place to 21st Street and along Norwood Avenue from 21st Street to 26th Street, eventually discharging to the Wonderland Creek Drainageway.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 18 to 36-inch with 34 inlets and 16 manholes.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	None identified
Capital Cost	$ 2,452,000

Problem Name and ID	Twomile Canyon Creek – 1 (TCC_LI1)
Problem Location	Kalmia Avenue and Juniper Avenue west of Broadway Street
Problem Description	Kalmia Avenue and Juniper Avenue do not have curb and gutter and surface runoff collects in irrigation ditch laterals which parallel these roads. During heavy rains runoff can overwhelm the laterals if they are not operated properly to convey runoff rather than irrigation water. The approximate contributing area to the identified Kalmia Ave and Juniper Ave problem areas are 30 and 21 acres, respectively.
Improvement Description	Provide increased overall system capacity through retrofitting the existing open channel conveyance network from Twomile Creek to Broadway Street along Kalmia Ave and Juniper Ave. Introduce sewer collection and conveyance (inlets and pipes) from Twomile Creek to Broadway Street along Kalmia Ave and Juniper Ave.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 18 to 24-inch with 36 inlets and 23 manholes.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	None identified
Capital Cost	$ 2,939,000

Problem Name and ID	Goose Creek – 4 (GC_LI4)
Problem Location	Vicinity of Forest Avenue between 3rd Street and Broadway Street
Problem Description	Limited drainage infrastructure, yielding relatively no removal of surface waters from the roadway was presumed to contribute to 2013 flooding reports.
Improvement Description	Construct a new storm sewer system in Forest Avenue from 4th Street to Broadway Street and Hawthorn Avenue, from 4th Street and connecting to the proposed system in Forest Avenue, eventually discharging to the existing system in Broadway Street.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 18 to 36-inch with 93 inlets and 26 manholes.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	None identified
Capital Cost	$ 4,885,000

Problem Name and ID	Goose Creek – 5 (GC_LI5)
Problem Location	Vicinity of Cedar Avenue and 19th Street
Problem Description	2013 flooding reports exceeded the level of service of the drainage system along local collector streets.
Improvement Description	Per the recommendations provided in the 2007 SMP, construct a new storm sewer system in Elder Avenue from Broadway Street to 19th Street and along Floral Drive from 19th Street to approximately 300 feet south of Edgewood Drive, eventually discharging to the Goose Creek Drainageway.
Technical Data	The conveyance system is required to convey the 5-yr storm. Storm sewer diameters range from 60 to 66-inch with 28 inlets and 14 box base manholes.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	None identified
Capital Cost	$ 5,484,000

Problem Name and ID	Middle Boulder Creek – 3 (MBC_LI3)
Problem Location	Vicinity of Cascade Avenue from College Avenue to Chautauqua Reservoir Road.
Problem Description	2013 flooding reports exceeded the level of service of the drainage system along local collector streets and combined with the potentially capacity-limited downstream conveyance system.
Improvement Description	Construct new collection and conveyance system along Baseline Road from Grant Place to 13th Street and along 13th Street between Baseline Road and College Avenue, eventually discharging to the system within 13th Street identified for improvement with the 2007 SMP recommendations.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 18 to 36-inch with 36 inlets and 12 manholes.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	None identified
Capital Cost	$ 2,826,000

Problem Name and ID	Bluebell Canyon Creek – 1 (BbCC_LI1)
Problem Location	Intersection of 20th Street and Mariposa Avenue
Problem Description	The Anderson Ditch culvert under Mariposa Avenue is too tall, causing a crown perpendicular to the slope on the east side of the intersection. This crown impedes conveyance of gutter flow and surface runoff, creating a localized flooding condition within the intersection and adjoining properties. The total contributing area to the culvert is approximately 65 acres.
Improvement Description	Construct a new storm sewer in 20th from Bluebell Ave north to Mariposa, then east in Mariposa connecting to the existing system in Broadway. Inlets would be located upstream of the Anderson Ditch intercepting flow before entering the ditch and sized such that intersection ponding would not create flooding.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 18 to 36-inch with 14 inlets and 8 manholes.
Land Ownership	This reach of Anderson Ditch is located on both city right-of-way and private property with private property areas assumed to be contained within an easement.
Implementation Challenges	Installation requires tunneling under the existing Anderson Ditch culvert.
Capital Cost	$ 1,137,000

Problem Name and ID	**Bear Canyon Creek – 1 (BrCC_LI1)**
Problem Location	Bear Canyon Creek, downstream of Stony Hill Court crossing, located approximately 250 feet east of the intersection of Stony Hill Drive and Rockmont Circle.
Problem Description	The 48-inch diameter storm sewer culvert under Stony Hill Drive providing conveyance of Bear Canyon Creek was not built as specified on the original design plans. Specifically, the outlet is aligned directly at residences located along the right bank instead of down the creek main channel. During significant storms events, flow from the outlet has been observed to shoot overt the creek and flow directly into the nearest residence. In addition to the misalignment of the culvert, creek excavation was not done according to the original plans, further exacerbating the flooding condition. Potentially, six homes may flood during heavy rainfall. The total contributing area to the culvert is approximately at 104 acres.
Improvement Description	Maintain existing culvert alignment and introduce a structure at the location of the originally designed center of the downstream channel, and provide 42-inch-diameter conveyance pipe oriented with a properly determined alignment. This option would also require realignment of the downstream channel and sufficient downstream channel protection.
Technical Data	The conveyance system is required to convey the 2-yr storm. Includes open channel and 54-inch storm sewer with 1 manhole.
Land Ownership	The problem area is located on private property in an open space subdivision tract owned by the Devil's Thumb Homeowner's Association.
Implementation Challenges	None identified
Capital Cost	$ 69,000

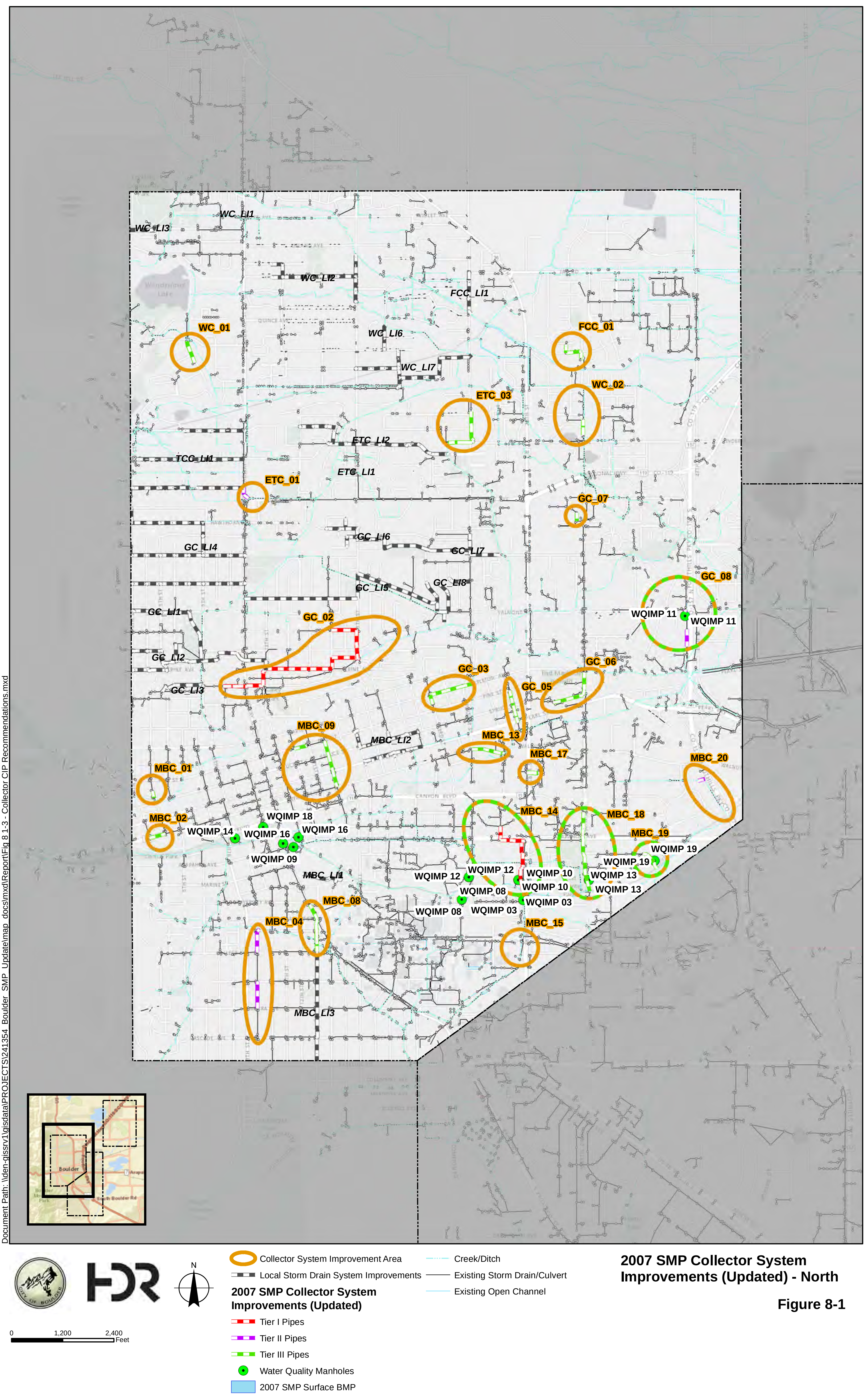
Problem Name and ID	**Bear Canyon Creek – 4 (BrCC_LI4)**
Problem Location	Vicinity of Yale Road and Hartford Drive
Problem Description	Potential flooding from surface run-off.
Improvement Description	Construct collection and conveyance system in Hartford Drive and Baylor Drive to reduce volume of surface flow through the neighborhood to existing collection point.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 18 to 24-inch with 13 inlets and 8 manholes.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way.
Implementation Challenges	None identified
Capital Cost	$ 726,000

Problem Name and ID	Viele Channel – 1 (VC_LI1)
Problem Location	Longwood Ave and Lafayette Drive from Lehigh Street to Greenbriar Boulevard
Problem Description	Runoff from the local roadway and residential parcels is currently conveyed easterly towards Greenbriar Boulevard via roadway section along Lafayaette Drive and Longwood Avenue. The roadway section contains no stormwater infrastructure and has been identified as having insufficient capacity to convey runoff through frequent observations of flooding of local sidewalks. The problem is exacerbated by the pitch and crown of the roads which causes almost all runoff to flow on the north side of Longwood Ave. The total contributing area to the system described above is approximately 21 acres.
Improvement Description	Provide a stormwater collection and conveyance system in Lafayette Drive 160 feet north of Longwood Avenue and eastward along Longwood Avenue from Lafayette Drive to Greenbriar Boulevard to alleviate local flooding through effective conveyance of runoff to the existing downstream system.
Technical Data	The conveyance system is required to convey the 2-yr storm. Storm sewer diameters range from 18 to 24-inch with 13 inlets and 7 manholes.
Land Ownership	Proposed storm sewer improvements are located within the city right-of-way with the exception of the existing storm sewer that cut across the high school parking lot. The parking lot alignment is assumed to be contained within an easement.
Implementation Challenges	None identified
Capital Cost	$ 936,000

8.5.3 Tier III Priority Improvements

This section includes a summary table for the Tier III Local System Improvements.

Problem Name		Improvement Type	Improvement Description	Cost
Dry Creek No. 2 - 2	DC2_LI2	New and Replacement Storm Sewer	New system in Pinon and Meadowbrook, connect to existing system in Baseline Rd	$ 726,000
Dry Creek No. 2 - 5	DC2_LI5	New Storm Sewer	New system in McKinley, Eisenhower, and 4th St, connect to existing system in Arapahoe Ave	$ 2,386,000
Dry Creek No. 2 - 6	DC2_LI6	New Storm Sewer	New system in Merritt Dr with collection from Arapahoe Ridge Park, connect to existing system north of Patton Dr	$ 1,689,000
Goose Creek - 6	GC_LI6	New and Replacement Storm Sewer	New system west of 20th St. Replace existing system in 20th St and Glenwood Dr west of 23rd St	$ 1,946,000
Goose Creek - 8	GC_LI8	New and Replacement Storm Sewer	New systems in 23rd and 24th St. Replace and extend existing system in Fremont St	$ 932,000
Wonderland Creek - 6	WC_LI6	New Storm Sewer	New system in 20th St north of Orchard Ave discharging into Wonderland Creek	$ 366,000
Dry Creek No. 2 - 8	DC2_LI8	New and Replacement Storm Sewer	New system in Holmes and White Place, connect to existing system in 55th St	$ 604,000
Goose Creek - 7	GC_LI7	New and Replacement Storm Sewer	A continuation of the Goose Creek – 6 system. New system in Glenwood Dr East of Folsom St. Replace system in Glenwood Dr west of Folsom and system in Folsom north of Glenwood Dr	$ 1,913,000
Elmers Twomile Creek - 1	ETC_LI1	New Storm Sewer and Open Channel	New storm sewer and open channel between residential parcels northwest of Del Rosa Ct and 19th St	$ 98,000
Middle Boulder Creek - 1	MBC_LI1	New Storm Sewer and Open Channel	New storm sewer and open channel north of Grandview Ave, discharging into Boulder Creek	$ 176,000
Dry Creek No. 2 - 4	DC2_LI4	New Storm Sewer	New system in Pawnee Dr discharging into existing Thunderbird Lake	$ 976,000
Dry Creek No. 2 - 7	DC2_LI7	Replacement Storm Sewer	Replace existing system in Lodge Lane	$ 801,000
Wonderland Creek - 3	WC_LI3	New Open Channel	New open channel in Boulder Open Space behind residential lots northwest of Utica Ave and Locust Pl	$ 24,000
Wonderland Creek - 4	WC_LI4	New Open Channel	New open channel in Boulder Open Space behind residential lots northwest of Promontory Ct	$ 20,000
TOTAL TIER III				**$12,657,000**



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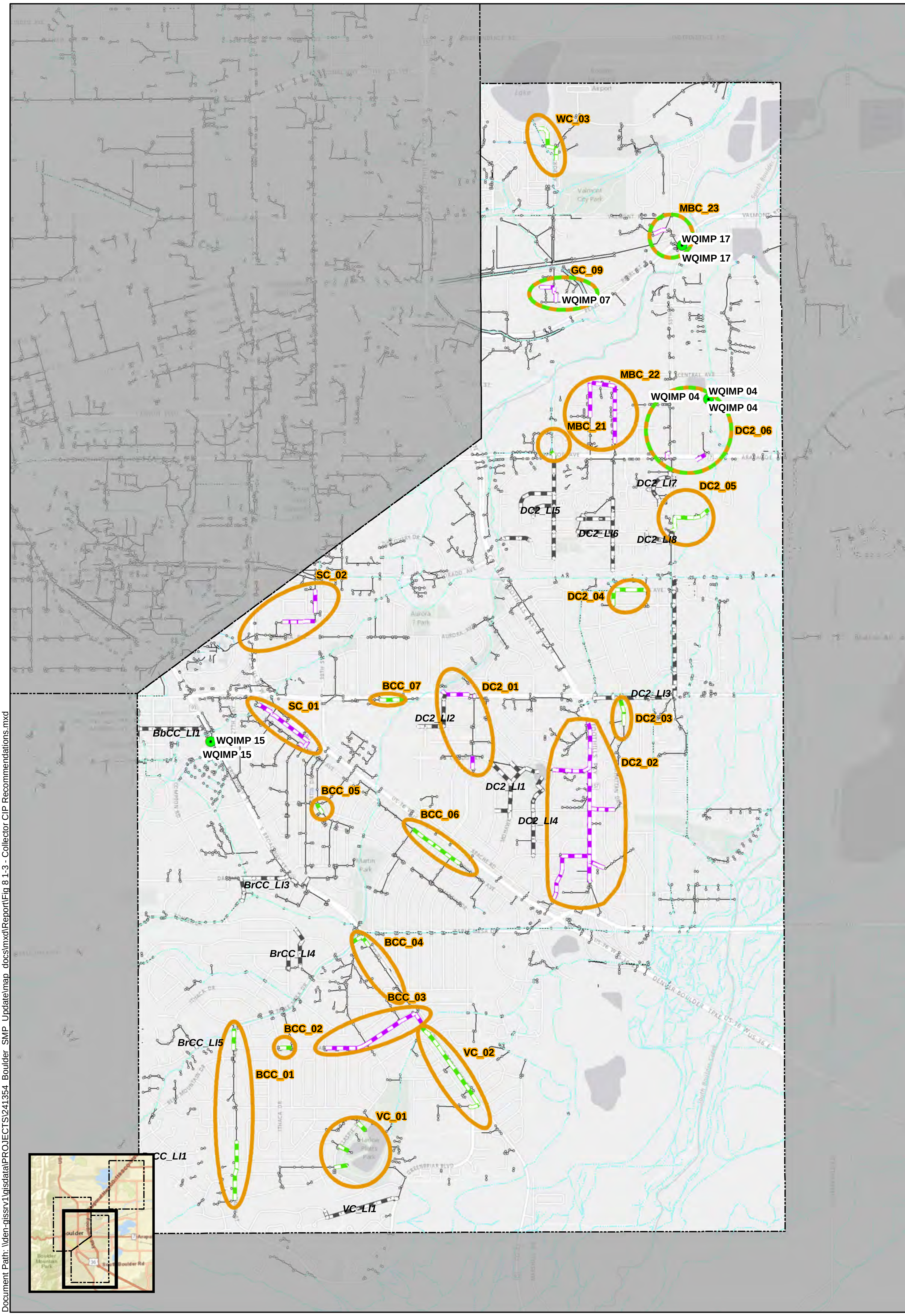
2007 SMP Collector System Improvements (Updated) - North

Figure 8-1



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Collector System Improvement Area
Local Storm Drain System Improvements

2007 SMP Collector System Improvements (Updated)

Tier I Pipes
Tier II Pipes
Tier III Pipes
Water Quality Manholes
2007 SMP Surface BMP

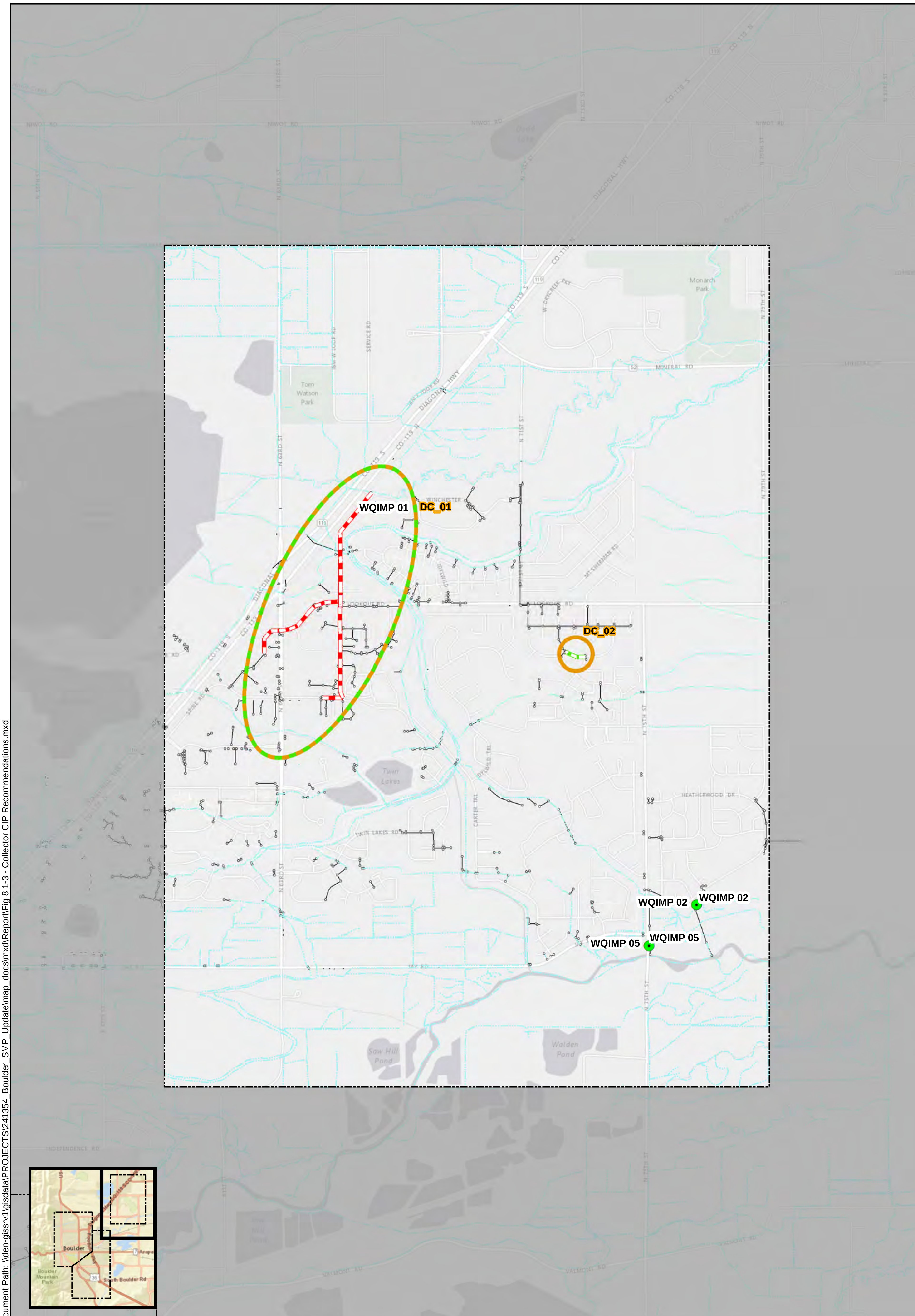
Creek/Ditch
Existing Storm Drain/Culvert
Existing Open Channel

N

0 1,200 2,400 Feet

2007 SMP Collector System Improvements (Updated) - South

Figure 8-2



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0 1,200 2,400 Feet

Collector System Improvement Area
Local Storm Drain System Improvements

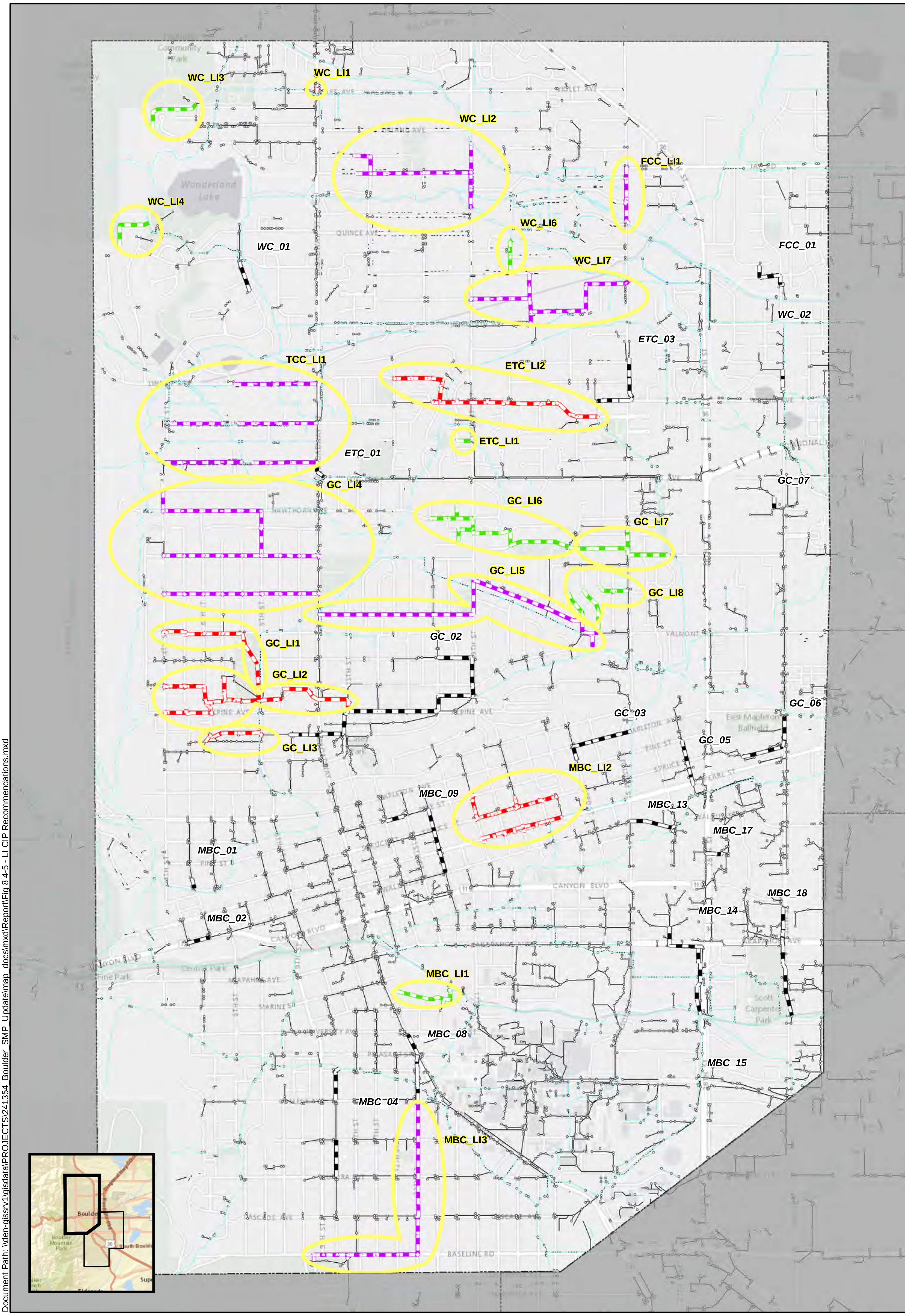
2007 SMP Collector System Improvements (Updated)

Tier I Pipes
Tier II Pipes
Tier III Pipes
Water Quality Manholes
2007 SMP Surface BMP

Creek/Ditch
Existing Storm Drain/Culvert
Existing Open Channel

2007 SMP Collector System Improvements (Updated) - Gunbarrel

Figure 8-3



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N

0 900 1,800 Feet

Local System Improvement Area

Collector Storm Sewer System Improvements

Local System Improvements

Tier I Pipes

Tier II Pipes

Tier III Pipes

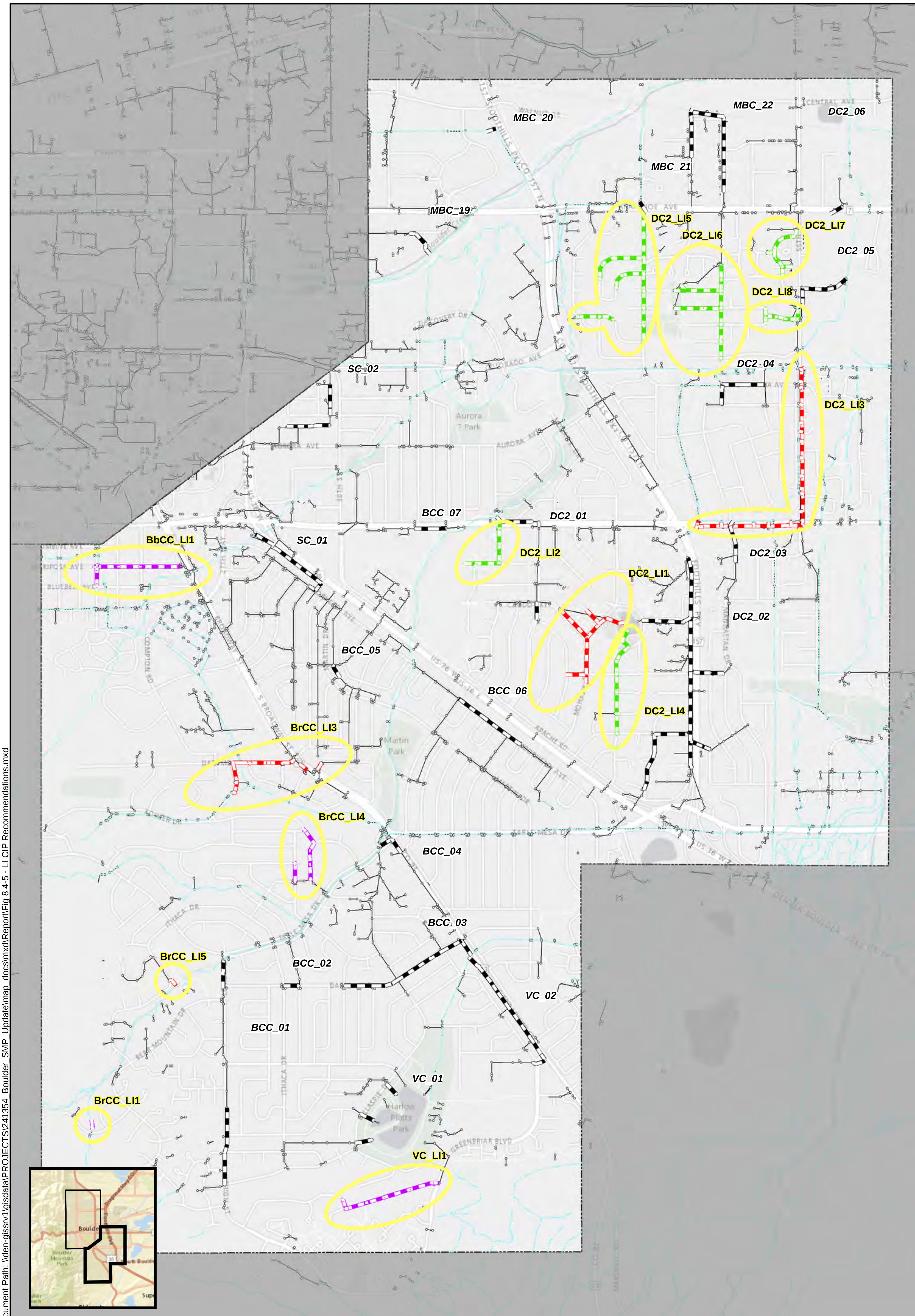
Ditch

Existing Storm Sewer

Existing Open Channel

Local System Improvements - North

Figure 8-4



Local System Improvement Area
Collector Storm Sewer System Improvements

Local System Improvements

Tier I Pipes
Tier II Pipes
Tier III Pipes

Ditch
Existing Storm Sewer
Existing Open Channel

N

0 900 1,800 Feet

Local System Improvements - South
Figure 8-5

9 Water Quality and Stormwater Program

This section outlines the stormwater quality regulatory requirements that will be incorporated in the City of Boulder's (city) Stormwater Master Plan (SMP) update. This memo combines Tasks 6-10 and forms the basis of the water quality regulatory compliance portion of the SMP update.

This update is partially driven by the upcoming reissuance of the state MS4 permit. The previous MS4 permit was issued in 2008 (2008 MS4 permit) and a new draft MS4 was issued in 2013 for comment and review. This 2013 draft MS4 received comments and a second draft was issued on May 5, 2015. The updated draft MS4 permit (2015 draft MS4 permit) is substantially longer and includes more stringent requirements for tracking and enforcement of stormwater quality requirements. The 2015 draft MS4 permit also contains new requirements for the city to report annually on how it is addressing the Total Maximum Daily Load (TMDL) for the *Escherichia coli* (*E. coli*) impairment on section 2b of Boulder Creek (from 13th Street to the confluence with South Boulder Creek). In addition to the MS4 permit, other changes to state water quality regulations are summarized in this document. The impacts of these upcoming regulation changes are detailed in this SMP update to help inform capital improvement program (CIP) projects.

9.1 Goals and Objectives

The primary goal of the SMP update is to identify a series of system improvements and maintenance recommendations to support the quantity and quality of stormwater runoff under current and future development. Within the context of the SMP, the strengths and weaknesses of the city's water quality and stormwater program were evaluated and a comparative analysis was conducted between the city's program and the programs of other Colorado Front Range cities. By fully integrating regulatory requirements with conveyance planning, the city can better prioritize funding for projects and staffing that simultaneously support conveyance, flood control, and stormwater quality.

The objectives of the water quality and stormwater program review are to:

- Review new water quality regulations (updated MS4 and other state regulations) and their respective impacts on the city.
- Perform an assessment of the city's operations and maintenance (O&M) program and provide recommendations.
- Review the city's current construction stormwater program and provide recommendations for standardizing the program across the city.
- Provide recommendations for implementing requirements in the 2015 draft MS4 permit.
- Provide recommendations for implementing requirements of other new water quality regulations.

9.2 Summary of Regulatory Drivers

Recent updates to the stormwater regulatory compliance requirements outlined in three main documents are a major driver for this SMP update. The requirements for each of the following regulations are discussed in more detail in subsequent sections of this TM.

- Phase II Municipal Separate Storm Sewer System (MS4) Permit.

- Boulder Creek *E. coli* Total Maximum Daily Load (TMDL) Reporting.
- Colorado Department of Public Health and Environment (CDPHE) Regulation 85.

Additional regulations and environmental issues that may have a future effect on the city's water quality and stormwater programs are summarized below. While these issues are not directly addressed within this TM, they do influence regulations developed within the Environmental Protection Agency (EPA) and the CDPHE.

- Colorado Revised Statute (CRS) §37-92-602 (8).
- Federal revisions to *E. coli* recreational water quality standard.
- Colorado Water Plan.
- State Engineers Office detention reporting requirements that could impact potential water rights, regional detention, and green infrastructure (GI).
- Ongoing impacts of dewatering remediation permitting.
- Potential for other 303(d) impaired stream listings.
- Arsenic with possible issues related to groundwater and infiltration into the storm sewer system.

9.3 MS4 Permit Requirements and Changes

This section briefly summarizes the requirements in each of the sections of the 2008 MS4 permit and outlines the changes made in the 2015 draft MS4 permit. The requirements are addressed according to the MS4 Minimum Control Measures (MCM) and then by additional permit requirements beyond the MCMs.

9.3.1 MCM 1: Public Education and Outreach

MCM 1, public education and outreach, describes activities that involve the public in developing, implementing, and reviewing MS4 management programs; and it describes ways to reduce stormwater pollution. The goal behind MCM 1 is to inform the public of common residential and commercial activities that contribute to stormwater pollution. The following sections describe the 2008 MS4 permit and the changes under the 2015 draft MS4 permit.

2008 MS4 Permit Summary

Currently, the 2008 MS4 permit requires permittees to implement a public education and outreach program to promote behavioral change by the general public and businesses to reduce water quality impacts associated with pollutants in stormwater runoff, illicit discharges, and improper disposal of waste. The program includes targeting specific pollutants and sources, active outreach efforts to inform the public of steps to take to reduce pollutants and their impacts, and informing businesses of what is prohibited and the water quality impacts associated with illegal discharges and improper disposal of wastes. Specific metrics are not required under the 2008 MS4 permit.

The 2008 MS4 permit does not have recordkeeping requirements.

Changes Under the 2015 Draft MS4 Permit

The 2015 draft MS4 permit lists targeted businesses for education and outreach. It also targets sources of nutrients and related education on how to reduce nutrients generated from these sources.

The 2015 draft MS4 permit includes an 'Education and Outreach Activities Table (Table 1 in the permit) that lists both passive and active/interactive outreach and requires the permittee to implement at least two education and outreach activities per year (either new or the same).

The 2015 draft MS4 permit includes the following recordkeeping requirements:

- The permittee must document and date public education and outreach activities.
- The permittee must set a priority level to public education and outreach activities.

9.3.2 MCM 2: Public Involvement and Participation

MCM 2, public participation and involvement, describes activities that involve the public in developing, implementing, and reviewing MS4 management programs and it names ways to reduce stormwater pollution. The goal behind MCM 2 is to involve interested citizens and groups to help spread the message of preventing stormwater pollution, to undertake group activities that highlight storm drain pollution, and to facilitate volunteer community actions to restore and protect local water resources. The following sections describe the 2008 MS4 permit and the changes under the 2015 draft MS4 permit.

2008 MS4 Permit Summary

Under the 2008 MS4 permit, the permittee must hold public hearings and allow public review and input when implementing the Colorado Department of Public Safety (CDPS) Stormwater Management Program. The permittee must define the mechanisms and processes by which the public has the opportunity to do this.

The 2008 MS4 permit does not have recordkeeping requirements.

Changes Under the 2015 Draft MS4 Permit

The 2015 draft MS4 permit requirements are similar to the 2008 MS4 permit. The only substantial addition refers to the Program Description Document (PPD), described in Section 9.4.1, and that it must be publically available on the permittee's website for review and comment.

9.3.3 MCM 3: Illicit Discharge Detection and Elimination

MCM 3, illicit discharge detection and elimination, describes activities for identifying and eliminating illicit discharges and spills to storm drain systems. Illicit discharges are generally any discharge into a storm drain system this is not composed entirely of stormwater, such as oil and grease, soaps, pressure wash water, and others. These discharges often contain pathogens, nutrients, surfactants, and various toxic pollutants. The following sections describe the 2008 MS4 permit and the changes under the 2015 draft MS4 permit.

2008 MS4 Permit Summary

Currently, MS4 permit holders must develop, implement, and enforce a program to detect and eliminate illicit discharges into the permittee's MS4. The program must:

- Develop and maintain a current storm sewer map.
- Prohibit and enforce regulations for illicit discharges.

- Develop, implement, and document a plan to detect and address non-stormwater discharges.
- Develop and implement a plan to train municipal staff to recognize and appropriately respond to illicit discharges observed during typical duties.
- Implement regulatory mechanisms to allow permittees to implement and enforce the permit requirements.

The 2008 MS4 permit also lists allowable non-stormwater discharges, such as landscape irrigation, diverted stream flows, irrigation return flow, groundwater, and several others.

The 2008 MS4 permit includes the following recordkeeping requirements:

- Develop a list of occasional incidental non-stormwater discharges and document any local controls or conditions placed on these discharges.
- Record the total number of enforcement actions performed.

Changes Under the 2015 Draft MS4 Permit

The 2015 draft MS4 permit includes the requirements under the 2008 MS4 permit and adds the following:

- Tracking and responding to illicit discharges and associated recordkeeping.
- Regulatory exemptions, waivers, or variances implemented by the permittee.
- A method of enforcement escalation if violators are not in compliance and associated recordkeeping.
- Additional non-stormwater exclusions.
- A requirement to list priority areas, or hot spots, of known or suspected illicit discharges and associated recordkeeping.
- Ability to request additional substances to be added to non-stormwater exclusions.
- A requirement that industrial polluters must be reported to the state within 90 days.
- Additional procedures and documents related to detection and elimination of illicit discharges.

The 2015 draft MS4 permit includes the following recordkeeping requirements:

- Procedures for determining illicit discharges.
- Additional recordkeeping requirements related to illicit discharge events and reports.

9.3.4 MCM 4: Construction Site Runoff Control

MCM 4, construction site runoff control, describes Best Management Practices (BMP) for MS4s and construction site operators to address stormwater runoff from active construction sites. MCM 4 requires permittees to develop a program to reduce sediment and other pollutants in stormwater runoff from construction sites disturbing one or more acres because of the impact uncontrolled runoff from construction sites can have on open water bodies. The following sections describe the 2008 MS4 permit and the changes under the 2015 draft MS4 permit.

2008 MS4 Permit Summary

Under the 2008 MS4 permit, for construction activities disturbing more than one acre of land that discharge into the MS4, the permit holder must develop, implement, and enforce a program to reduce pollutants in any stormwater runoff from construction sites that could potentially affect water quality. The permittee must develop a program to assure adequate design, implementation, and maintenance of BMPs at construction sites. This program must include an ordinance or regulatory mechanism for erosion and sediment controls, BMP requirements for handling construction wastes, compliance assessment procedures, and compliance assurance procedures. It also includes an education and training program requirement for municipalities, their representatives, and/or their construction contractors. Site plans and inspections must be performed under the 2008 MS4 permit; however, site inspection frequencies are not dictated.

The 2008 MS4 permit includes the following recordkeeping requirements:

- Total number of construction sites.
- Total number of inspections performed.
- Full level inspection assessing the adequacy of BMPs and overall site management.
- Inspections conducted to assess sites for indicators of non-compliance.
- Summary of compliance assurance activities, including the total number of enforcement actions performed.

Changes Under the 2015 Draft MS4 Permit

The 2015 draft MS4 permit clarifies the existing permit and includes definitions. The 2015 draft MS4 permit also includes the following:

- A list of exclusions such as pavement projects, large single-family lots, and underground utilities and recordkeeping associated with these exclusions.
- Regulatory mechanisms that must be implemented to the extent allowable by the law and associated recordkeeping.
- Requirements for erosion control plans and their review and associated recordkeeping of these plans and reviews.
- A requirement that site plans are updated within 72 hours of an on-site change.
- Site inspection requirements, such as a routine inspection every 45 days for active construction, a reduced frequency inspection every 90 days for post-construction/pre-stabilization, and compliance inspection within 14 days of a failure to comply (unless correction actions are observed during the initial inspection).
- Exclusions to accommodate staff vacancy or temporary leave.
- Requirements to provide information to operators of applicable construction activities.

The 2015 draft MS4 permit includes the following recordkeeping requirements:

- Training recordkeeping.
- Enforcement recordkeeping.

- Erosion control measures recordkeeping.

9.3.5 MCM 5: Post-Construction Stormwater Management

MCM 5, post-construction runoff control, describes BMPs for MS4s, developers, and property owners to address stormwater runoff after construction activities have ended. The goal behind MCM 5 is to mitigate stormwater impacts from new development due to increased impervious surfaces that increase stormwater volume and degrade water quality. The following sections describe the 2008 MS4 permit and the changes under the 2015 draft MS4 permit.

2008 MS4 Permit Summary

Under the 2008 MS4 permit, for new development and redevelopment projects disturbing more than one acre of land or less than one acre that is part of a larger common plan of development or sale that discharges into the MS4, the permit holder must ensure controls are in place to prevent or minimize water quality impacts. The permittee must develop and implement strategies to address discharges and maintain hydrologic conditions at sites. Strategies must include an ordinance and other regulatory mechanisms for post-construction runoff, proper BMP installation and maintenance, issues of non-compliance, and procedures for tracking and monitoring of both temporary and permanent BMPs.

The 2008 MS4 permit includes the following recordkeeping requirements:

- Total number of sites for which permanent BMPs were required or specific BMPs were implemented during the reporting period.
- Total number of permanent BMPs inspected throughout the jurisdiction to ensure compliance with long-term O&M requirements.
- Total number of enforcement actions.

Changes Under the 2015 Draft MS4 Permit

The 2015 draft MS4 permit includes the following:

- A number of applicability definitions.
- The types of work excluded from requiring permanent BMPs.
- Enforcement requirements for O&M.
- Control measures for applicable development projects that meet one of six base design standards:
    - Water Quality Capture Volume (WQCV) standard.
    - Pollutant removal standard.
    - Runoff reduction standard.
    - Applicable development project draining to a regional WQCV control measure.
    - Applicable development project draining to a regional WQCV facility.
    - Constrained redevelopment site standards.
- Site plans that provide documentation of O&M, including frequency of inspections.
- Documentation of easements or other legal means for access to control measures.

- Site plans review and construction inspection and final construction acceptance of control measures.
- Inspections of permanent BMPs at least once during the MS4 permit term.
- Tracking for control measures.
- Training for inspection staff.

The 2015 draft MS4 permit also includes the following recordkeeping requirements:

- Regulatory mechanisms.
- Permanent BMP requirement documents.
- Plans and construction acceptance.
- Post acceptance oversight.
- Maintenance training.
- Permanent BMP tracking.

9.3.6 MCM 6: Pollution Prevention and Good Housekeeping

MCM 6, pollution prevention and good housekeeping for municipal operations, describes BMPs for municipalities to use for preventing pollution from entering storm drain systems. Municipalities conduct such activities as winter road maintenance, minor road repairs, water and sewer rehabilitation and other infrastructure work, fleet maintenance, landscaping and park maintenance, and building maintenance that can pose a threat to water quality if practices and procedures are not in place to prevent pollutants from entering the MS4. Municipalities also conduct activities that remove pollutants from the MS4 when performed properly, such as parking lot and street sweeping and storm drain system cleaning. Finally, municipal facilities can be sources of stormwater pollutants if BMPs are not in place to contain spills, manage trash, and handle non-stormwater discharges. The following sections describe the 2008 MS4 permit and the changes under the 2015 draft MS4 permit.

2008 MS4 Permit Summary

The MS4 permit holder must develop and implement an O&M program that includes an employee training component and has the ultimate goal of preventing or reducing pollutants in runoff from municipal operations. The program must include written procedures to prevent or reduce pollutants in runoff and must specifically list the municipal operations that are impacted. There is also a requirement to list the industrial facilities owned or operated by the permittee that are subject to separate coverage under the state's general stormwater permit for stormwater discharges associated with industrial activities.

Recordkeeping is not clear or prescriptive in the 2008 MS4 permit.

Changes Under the 2015 Draft MS4 Permit

The 2015 draft MS4 permit includes the following requirements:

- Annual inspection of applicable municipal facilities.
- Written procedures for municipal operations.

- Bulk storage containment requirements.
- Training of staff with respect to pollution prevention and good housekeeping.
- Recordkeeping of pollution prevention practices at each facility.
- Inspection documentation recordkeeping.
- The 2015 draft MS4 permit also includes the following recordkeeping requirements:
- Training recordkeeping.
- Recordkeeping of control measures for operations.

9.4 Other Permit Requirements

In addition to the MCMs described above, there are several other requirements in the new MS4 permit. These requirements are described in the following sections.

9.4.1 Program Description Document

The 2008 MS4 permit required a stormwater management program description be submitted for new and renewing permittees. There is no requirement to maintain this description, and it is not required to be publically available.

The 2015 draft MS4 permit requires the development of a Program Description Document (PDD) that contains information pertaining to the city's compliance with the MS4 permit and that must be maintained to reflect current implementation. While the PDD does not need to be submitted to or approved by the Colorado Water Quality Control Division, unless specifically requested, the PDD must be publically available. The PDD must include the following:

- **Current Control Measure Implementation and Procedures:** The specific PDD content required for public involvement and participation; pollutant restrictions, prohibitions, and reduction requirements and associated recordkeeping; and the requirement applicable to the city's MS4 discharges to Boulder Creek.
- **Current Documents and Electronic Records:** A list of citations for documents and electronic records used to comply with permit requirements. It is not required that the PDD repeat the information included in the cited documents. The PDD must include the names of the most recent version of the documents, date of the document, and location where the supporting documentation is maintained.
- **Current Organizational Chart:** An organizational chart indicating responsibility over applicable departments by the legal contact.

The PDD must be available to the public at reasonable times during regular business hours and maintained in a format that can be submitted to the Division within 10 business days of a request. Information in the PDD may be revised by the permittee at any time. The permittee must modify the PDD as changes occur so that the information is up to date.

9.4.2 Boulder Creek *E. coli* TMDL

In 2011, a TMDL for *E. coli* was approved for Segment 2b of Boulder Creek from 13th Street to the confluence with South Boulder Creek. As a component of the TMDL, a Waste Load Allocation (WLA) was calculated for the city. According to the 2008 MS4 permit, the city is required, under its CDPS Stormwater Management Program, to implement specific management practices based on requirements of the TMDL. The city is also required to evaluate whether the requirements are being met through implementation of existing program areas or if additional or modified program areas are necessary.

The 2015 draft MS4 permit specifically addresses the city's MS4 discharges to Boulder Creek from 13th Street to South Boulder Creek, which is the reach covered by the COSPBO02 *E. coli* TMDL. The 2015 draft MS4 permit states that the city should conduct monitoring, as necessary, to identify progress towards meeting the WLA in the TMDL. As under the 2008 MS4 permit, the 2015 draft MS4 permit also states that the city needs to prepare an annual report to be submitted by March 10 of each year, covering January 1 through December 31 of the previous year. Specific requirements follow:

- For the first annual report only: A description of all control measures planned by the city to reduce the discharge of *E. coli* to COSPBO02 from 13th Street to South Boulder Creek, including specific target dates for implementation.
- A description of all control measures implemented by the city to reduce the discharge of *E. coli* to COSPBO02 from 13th Street to South Boulder Creek. The first annual report needs to include information on control measures implemented prior to the effective date of the permit.
- An identification of all illicit discharges identified by the city that contribute to discharges from the MS4 in exceedance of 126 colony forming units (CFU) of bacteria per 100 milliliters (100 mL) of water (the *E. coli* water quality standard). The first annual report needs to include information on discharges identified prior to the effective date of the permit.
- An indication that the illicit discharges identified above have been eliminated. If the discharge has not been eliminated, the report must include a description of any planned control measure that the city intends to take to address the discharge.
- A description of monitoring activities conducted, or planned, to meet the monitoring requirements. The first annual report must include information on monitoring prior to the effective date of the permit to identify progress toward meeting the WLA in the COSPB02 from 13th Street to South Boulder Creek *E. coli* TMDL. Data used in the development of the TMDL are not required to be addressed in this reporting.

9.4.3 Summary

The 2015 draft MS4 permit contains several changes from the 2008 MS4 permit. These changes are summarized below:

- MS4 permittees are required to have effluent limitations that meet water quality standards to the maximum extent practicable (MEP).
- MS4 permittees are required to conduct monitoring and must specify how monitoring is performed (equipment, methods, frequency, etc.), how monitoring records are maintained, and that monitoring activities are adequately performed.

- MS4 permittees have monitoring and recordkeeping requirements that include standard operating procedures (SOP) describing how to perform operations within the stormwater program. Policies, standards, processes, and procedures must be written down, approved, and communicated to all concerned and must provide step-by-step instructions and assure consistency, accuracy, and quality.
- The 2015 draft MS4 permit incorporated guidance directly into the permit rather than outside the permit in separate documents.
- The 2015 draft MS4 permit revises the pollutants of concern.
- The 2015 draft MS4 permit allows permittees to engage other permittees, consultants, or contractors to implement the stormwater program.

9.5 Public Education, Outreach, Involvement, and Participation

The city has an extensive Public Education, Outreach, Involvement, and Participation program that fulfill the requirements of the current MS4 permit. This program constitutes significant workload to maintain and develop program initiatives. The city additionally partners with Boulder County groups, such as the Keep It Clean Partnership (KICP) and Partners for A Clean Environment (PACE), to meet permit requirements, including school programs, maintaining a website, and community engagement through advertisements and events. A key event for the city's educational program each year is the Water Festival. The festival involves hundreds of students from the city who come to learn about such topics as identifying ways to protect and conserve water, determining where the city's water supply comes from, and discovering animals that live in and around Boulder's creeks.

The 2015 draft MS4 permit requires community engagement efforts like organizing stream-team cleanups and sending utility bill inserts. The 2015 draft MS4 permit also breaks required outreach into categories of actions that must be satisfied. While the new requirements are prescriptive, they are not the focus of the permit (comprising just 1 of 60 pages).

9.6 Boulder Creek E. coli TMDL

The Boulder Creek *E. coli* TMDL is specifically addressed in the 2015 draft MS4 permit from 13th Street to South Boulder Creek. The city's MS4 discharge is therefore impacted by this addition with *E. coli* reductions prioritized for specific outfalls within the jurisdictions of the City of Boulder, the University of Colorado, and the Boulder Valley School District for land within the sub-catchment outfall basins. The Boulder Creek *E. coli* TMDL is specifically addressed because it is believed that the MS4 is a source of much of the *E. coli* loading to Boulder Creek and applies to discharges subject to TMDL WLAs. This component of the 2015 draft MS4 permit was discussed in more detail in Section 9.4.2.

According to the 2015 draft MS4 permit, the city is required to keep a yearly log of outfalls within Boulder Creek and to monitor dry weather flows to help detect illicit sanitary connections. The following sections describe several ways the city's practices are concurrent with the permit requirements and include recommendations on how the program can be improved.

9.6.1 Illicit Sanitary Connections and SSOs (MCM 3)

The Environmental Protection Agency (EPA) MS4 website main page references several documents relating to Illicit Discharge Detection and Elimination (IDDE). Of particular application to this project is: *Illicit Discharge Detection and Elimination, A Guidance Manual for Program Development and Technical Assessments* (Center for Watershed Protection et al., 2004.).

According to the report, illicit discharges are defined as a storm drain that has measurable flow during dry weather that contains pollutants and/or pathogens. These discharges are frequently caused by illicit sanitary connections, or cross-connections between the sewage disposal system and the storm drain system.

Currently, the city is not aware of any direct cross-connections but continues to identify third-party utilities crossing through its storm sewer through its CCTV inspection program. These locations are addressed by having the third-party utility relocate the utility and repair the storm sewer.

9.6.2 TMDL Implementation Planning

The city's TMDL for Boulder Creek is summarized in the report, *Boulder Creek, Colorado Segment 2b: From 13th Street to the Confluence with South Boulder Creek, Escherichia coli Total Maximum Daily Load* (Tetra Tech, 2011). An implementation plan is provided in the report, *Boulder Creek, Segment 2B TMDL Implementation Plan* (Tetra Tech, 2011) (TMDL Implementation Plan). These reports identified management activities for the purpose of assisting the city in attaining *E. coli* water quality standards within Boulder Creek. This section of the report summarizes the recommendations made and the data that is currently available regarding the city's TMDL requirements. The objective is to determine if the city's development of BMPs since the previous report has helped them reach the required water quality standards. Additional or modified BMPs may be necessary to attain the TMDL requirements outlined in the 2015 draft MS4 permit.

Published *E. coli* Reduction Studies

The Center for Watershed Protection published a document, funded by the EPA, entitled *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments* (Center of Watershed Protection, 2004) that is intended to provide support and guidance to MS4 communities to establish IDDE programs, as well as procedures for locating non-stormwater entries into stormwater drainage systems. This document includes recommendations for reducing illicit discharges, including *E. coli*.

The EPA published a case study, *Stormwater Management for TMDLs in an Arid Climate: A Case Study Application of SUSTAIN in Albuquerque, New Mexico* (EPA, 2013). It describes a System for Urban Stormwater Treatment and Integration Analysis (SUSTAIN), a strategy to meet water quality goals while minimizing cost. The study concluded that of the structural BMPs studied, detention ponds provide the largest reduction in *E. coli* loading of the affected water body. Additionally, nonstructural BMPs, such as street sweeping and pet waste management provide significant reductions in *E. coli* levels.

The United States Department of Agriculture (USDA) National Resources Conservation Service (NRCS) published *Nutrient Management Technical Note Number 7, Reducing Risk of E. coli O157:H7 Contamination* (NRCS, 2007). While this document focuses on *E. coli* contamination of food supplies, there is discussion on reducing *E. coli* contamination with a watershed approach.

Specifically, this document discusses irrigation water management, as well as reducing pathogens, through such vegetated treatment systems as vegetated ponds, grassed waterways, filter strips, and constructed wetlands. The USDA NRCS has also published *Watershed Science Institute Technical Note 2- Waterborne Pathogens in Agricultural Watersheds* (NRCS, 2000).

The Urban Drainage and Flood Control District (UDFCD) has recommendations in Volume 3 of its Urban Storm Drainage Criteria Manual (UDFCD, 2015) for controlling illicit discharges and thereby reducing *E. coli* loads. This document discusses illicit discharge controls under the three general categories: public education to reduce illegal dumping and discharges, municipal actions to identify and remove illegal connections to the storm sewer system, and accidental spill response measures.

The *E. coli* Work Group of the Colorado published the white paper Synopsis of Recreational Water Quality Issues in Colorado: White Paper Summarizing Results of *E. coli* Work Group 2007-2009 (*E. coli* Work Group of the Colorado Water Quality Forum et al., 2009)[2]. This document discusses regulatory background; case studies of streams in Colorado identified as impaired due to elevated *E. coli*; sources of fecal indicator bacteria, monitoring and assessment of data, including modeling; BMPs to reduce fecal contamination of water bodies; and unresolved issues related to *E. coli* in Colorado.

Water Quality and Environmental Services (WQES) staff with the city has also identified raccoons as a contributor to high concentrations of *E. coli* to Boulder Creek. This led to a study with recommendations for controlling raccoon access into the storm drain system. These recommendations are summarized in the memorandum, *Raccoon Storm Drain Access Control-University Hill Subbasin Recommendations* (HDR, 2013)

Boulder Creek, Segment 2b TMDL Implementation Plan

The TMDL Implementation Plan outlines several current or recently completed implementation measures the city has taken to raise awareness, identify sources of bacteria, better characterize the MS4 system, and regulate stormwater discharges. Table 9.6-1 summarizes the implementation measures the city has completed previously or is actively applying in relation to the *E. coli* TMDL in Boulder Creek.

Table 9.6-1 Current Implementation Measures

Category	Implementation Measure	Description/Objective
Codes and Ordinances	Boulder Revised Code (B.R.C.)	Title 11.5, Stormwater and Flood Management Utility, includes regulation of non-stormwater discharge to the storm sewer system, defining allowable and prohibited connections to the stormwater utility system.
	Design and Construction Standards (DCS)	Chapter 7, Stormwater Design, provides for a comprehensive and integrated stormwater utility system to convey and manage stormwater to enhance water quality by storm runoff by mitigating erosion, sediment and pollutant transport and to control and manage increased runoff due to local development (City of Boulder, 2005a).
Stormwater Planning Efforts	Boulder Valley Comprehensive Plan	Protects the natural environment of the Boulder Valley and provides the foundation for all planning efforts within Boulder Valley.

[2] http://www.keepitcleanpartnership.org/wp-content/uploads/2011/07/E.-coli-Work-Group-White-Paper-October-2009.pdf

Table 9.6-1 Current Implementation Measures

Category	Implementation Measure	Description/Objective
	Comprehensive Flood and Stormwater Utility Master Plan	Provides a framework for evaluating, developing, and implementing various programs and activities in Utilities considering scope and available budget. Recommends stormwater program elements that may assist with TMDL implementation.
	Stormwater Master Plan	Provides the city with the necessary planning tools to address flood management and water quality within the collector portion of the stormwater drainage system.
	Water Utility Master Plan	Outlined five goals in a city-wide planning effort to address water quality policies and priorities: provide safe and high quality drinking water, manage pollutants from wastewater and other NPS, manage pollutants from stormwater and other NPS, protect, preserve, and restore natural water systems, and conserve water resources.
	Greenways Master Plan	Provides framework to implement the Greenways Program through coordinated planning, construction, maintenance, and funding sources of multiple city departments and outside agencies (City of Boulder, 2011b).
Education and Outreach	Keep it Clean Partnership (KICP)	A collaboration of communities in the Boulder and St. Vrain watersheds working together to implement a regional stormwater management program. The “Partners” include Boulder County, the cities of Boulder, Longmont, and Louisville and, towns of Superior and Erie. Ongoing efforts include public education and outreach, public participation, illegal discharge detection and elimination, construction runoff control, post-construction management, and pollution prevention and good housekeeping for municipal operations.
	Open Space and Mountain Parks (OSMP)	The city’s 43,000 acres of OSMP are a community investment in natural lands and resources (City of Boulder, 2005). Efforts include pet waste stations which are a means of reducing pollutant loadings.
Greenways Program	Greenways and Riparian Efforts	Allocates resources to specific CIP projects as well as general habitat maintenance that include removal of noxious weeds, planting of natives to discourage re-establishment of weeds, and generally maintaining the stream corridor for habitat.
Stormwater Outfalls	Outfall Inventories	Documents locations, size, and material of outfalls within the Boulder Creek. Continued inventories are critical in the characterization of discharges to Boulder Creek and identification of illicit discharges.
Outfall Monitoring	Extended Monitoring	*E. coli* samples and monitoring continue to be an important component of the adaptive management strategy used to continuously refine implementation planning based on the success of completed efforts and conditions in Boulder Creek.
Special Studies	Microbial Source Tracking[a]	Identified potential human sources of bacteria, looking primarily at storm sewer outfalls with discharges releasing to Boulder Creek during dry weather.
	In-System Sampling	Focused sampling effort began in 2011 and was prioritized in two specific storm drain basins that were identified as a concern by city monitoring and TMDL development. The objective of weekly sampling was to identify potential sources of bacteria, including cross-connections and wildlife contributions.

Table 9.6-1 Current Implementation Measures

Category	Implementation Measure	Description/Objective

Source: Tetra Tech, 2011
[a] *A Multifaceted Approach to Microbial Source Tracking within Secondary Environments* (Monroe, 2009)

Raccoon Storm Drain Access Control

The city's WQES staff has identified raccoons as a contributor to high concentrations of *E. coli* to Boulder Creek. The city found that restricting raccoon access and habitat within the storm drain system results in significant reductions in *E. coli*. In 2013, HDR prepared a technical memorandum for the city entitled, *Raccoon Storm Drain Access Control- University Hill Subbasin Recommendations* (HDR, 2013). The recommendations resulting from this study included coordinated inlet replacement that prevent raccoon entry with the improvements identified in the SMP, an implementation plan consisting of initial pilot area recommendations and subbasin buildout recommendations, and cost estimates. Control strategies to prevent raccoons from entering the storm drain system include inlet replacements, curb extensions, outfall controls, and check valves.

Over the last several years, the city has implemented the integration of raccoon proof inlet protection on future CIP project work and is continually evaluating pipe inverts, pipe condition, and cross-connections through lining and CCTV. The city has found that instream *E. coli* numbers have not decreased as a result of efforts to date. The main source of loading is still ultimately wildlife and the city will need to work with the Colorado Water Quality Control Division on these standards.

Recommendations

The TMDL Implementation Plan recommended several implementation opportunities to help reduce *E. coli* loading in Boulder Creek. Table 9.6-2 is extracted from this plan and summarizes these recommendations.

Table 9.6-2 TMDL Implementation Plan Recommended Opportunities

Phase	Activity	Recommendation	Notes
Phase 1	Illicit Discharge Detection and Elimination and Preventative Maintenance	Inspection of MS4 and Sanitary lines	Evaluation and refinement of existing program.
		Cleaning Sanitary and MS4 lines	Evaluation and refinement of existing program.
	Pet Waste Education and Outreach	Review number, location and use of pet waste stations	Coordinate with OSMP to identify additional locations and effective signage.
		Publicize city code penalties	Coordinate with OSMP to identify effective signage.
		Increase pet waste education	Evaluate refinement of existing program.

Table 9.6-2 TMDL Implementation Plan Recommended Opportunities

Phase	Activity	Recommendation	Notes
		Develop recognizable "Scoop the Poop" campaign	Evaluation and refinement of existing education program. Partner with KICP and PACE.
		Enforcement Codes	Evaluate the enforcement need and effectiveness. Coordinate efforts with OSMP.
	Residential Education and Outreach	Pet waste education	Evaluation and refinement of existing program
		Reducing irrigation overspray	Evaluation and refinement of existing program; review and revised regulations as necessary to prevent overspray.
		Downspout disconnection	Evaluation and refinement of existing codes, ordinances, and education programs.
	Restaurant Education and Outreach	Education focused on proper housekeeping of trash storage areas	Evaluation and refinement of existing education program. Partner with KICP and PACE.
		Fats, oil and grease management	Evaluation and refinement of existing education program. Partner with KICP and PACE.
		Guidance on washing of areas surrounding restaurants	Evaluation and refinement of existing education program. Partner with KICP and PACE.
	Wildlife Management	Develop wildlife management plan to include raccoons	Coordinate with Urban Wildlife Conservation Coordinator to include of raccoons to the urban wildlife management plan
		Wildlife relocation	Conduct relocation as necessary and in compliance with established city codes.
		Inlet protection	Coordinate with Utilities Maintenance and Transportation staff to minimize entry points for wildlife.
		Monitoring	Coordinate monitoring with Utilities Maintenance staff to monitor the effectiveness of wildlife management.
	Recreation and Transient Population Outreach	Targeted outreach	Evaluation and refinement of existing program.
		Improved facilities	Coordinate with other city departments to evaluate needs and opportunities of facilities surrounding high use areas.
	Riparian Enhancements	Continues maintenance and enhancement of riparian zone	Collaborate with the city's Greenways program to evaluate needs and opportunities for riparian enhancements.
		Monitoring water quality associated with CIP projects	Work with other city departments to coordinate monitoring studies to measure and document improvements related to CIP projects.

Table 9.6-2 TMDL Implementation Plan Recommended Opportunities

Phase	Activity	Recommendation	Notes
	Continued Monitoring	Continued weekly monitoring	Dedicate city staff and resources to continued weekly monitoring. In addition to the four weekly sites established, begin sampling near the Foothills Parkway to evaluate/narrow the downstream impairment.
		Continued Outfall Inventories	Dedicate city staff and resources to continued outfall inventories. May require temporary staffing. In addition to the four weekly sites established, begin sampling near the Foothills Parkway to evaluate/narrow the downstream impairment.
		Land Use Assessment	Coordinate existing and future monitoring studies to evaluate land use generation and the identification of bacteria 'hot spot' locations.
		In-System Monitoring	Continue in-system sampling. Efforts should be made to establish a monitoring cycle and document conducted monitoring with analysis of results in annual report.
Phase 2	Private Retrofits	Needs and Feasibility Study	Evaluate existing programs/partnerships to determine feasibility of private retrofits.
		Continued Monitoring	Characterize baseline conditions and evaluate effectiveness of private retrofits (include and evaluation of reduction in runoff volume and pollutant loads).
	Open Space Opportunities	Needs and Feasibility Study	Coordinate with OSMP, Parks and Recreation, and Greenways to evaluate needs and opportunities for BMP implementation of Open Space and public parks.
		Conceptual Design	Work with engineers to develop conceptual designs.
		Pilot Study	Monitor pre- and post-BMP implementation to evaluate implementation effectiveness.
	Urban Retrofits	Needs and Feasibility Study	Coordinate with Transportation and other city departments to evaluate needs and opportunities for the incorporation of proprietary BMPs in city rights-of-way.
		Conceptual Design	Work with engineers to develop conceptual designs.
		Pilot Study	Monitor pre- and post-BMP implementation to evaluate implementation effectiveness.
	Proprietary BMP	Needs and Feasibility Study	Coordinate with Transportation, Utilities, and other city departments to evaluate needs and opportunities for the incorporation of proprietary BMPs in city rights-of-way and/or end-of-pipe.
		Conceptual Design	Work with engineers to develop conceptual designs.

Table 9.6-2 TMDL Implementation Plan Recommended Opportunities

Phase	Activity	Recommendation	Notes
		Pilot Study	Monitor pre- and post-BMP implementation to evaluate implementation effectiveness.
Phase 3	Low Flow Diversions	Needs and Feasibility Study	Evaluate needs and opportunities after other stormwater BMPs have been implemented to their full capacity.
	Ultraviolet Treatment	Needs and Feasibility Study	Evaluate needs and opportunities after other stormwater BMPs have been implemented to their full capacity.
	Ozone Treatment	Needs and Feasibility Study	Evaluate needs and opportunities after other stormwater BMPs have been implemented to their full capacity.

Source: Tetra Tech, 2011

Since these recommended implementation opportunities were presented to the city in 2011, only the activities associated with the Phase 1- Illicit Discharge Detection and Elimination and Preventative Maintenance have been completed or are still being actively implemented.

The city will also need to implement the Boulder Creek TMDL reporting requirements in the 2015 draft MS4 permit, as discussed in Section 9.4.2.

9.7 Construction Stormwater and Operations and Maintenance

The city's current construction stormwater and operation and maintenance activities are summarized in this section. Recommendations are made for improvements to current programs given regulatory drivers and the 2008 MS4 permit update.

The city met with the Cities of Fort Collins and Loveland in a workshop on March 23, 2014, for input regarding stormwater related construction, inspection, and maintenance procedures. In addition, the city held an interdepartmental meeting between the Water Quality, Utilities, Transportation, Planning and Development Services (P&DS), and CIP groups to discuss their handling of construction stormwater and O&M activities. The city also developed a stormwater management program survey that was sent to several other Front Range communities. They were used to help form recommendations for the city's stormwater program.

9.7.1 Inspection Tracking Activities Associated with Construction Stormwater Program

One of the key issues identified through the interdepartmental meeting with the city was a current lack of consistency with how construction stormwater is handed between the different departments and especially with how private projects are handled compared to public projects. This inconsistency transfers over to inspection tracking activities. Given new construction stormwater requirements in the 2015 draft MS4 permit for regulatory mechanisms, erosion control plans, construction stormwater inspections, training, and extensive recordkeeping, consistency across the departments would be beneficial to ensure compliance. A summary of the city's current program, as well as recommendations for administration of the construction stormwater program, are provided in Section 9.8.

9.7.2 O&M Activities Related to Inspection and Maintenance of Permanent BMPs and the Stormwater Conveyance Systems

One of the key issues identified through the interdepartmental meeting with the city was an inadequate program for both inspecting and maintaining post-construction (permanent) BMPs and the stormwater conveyance system. Given new requirements for both MCM 5 (Post-Construction Stormwater Management) and MCM 6 (Pollution Prevention and Good Housekeeping) in the 2015 draft MS4 permit, a refined stormwater maintenance program would be of benefit to the city. For permanent BMPs, these requirements include enforcement of O&M; control measures that meet base design standards for applicable developments; site plan documentation of O&M that includes frequency of inspections, documentation of easements or other legal means for access to control measures; inspections of all permanent BMPs during each MS4 permit term, training; and extensive recordkeeping. For stormwater conveyance, these requirements focus on nutrient and pollutant reduction. A summary of the city's current program, as well as recommendations related to stormwater O&M are provided in Section 9.8.1.

Construction Stormwater Program (MCM 4)

The four departments within the city that are involved with construction stormwater are Public Works, Parks and Recreation, Facilities Asset Management (FAM), and Open Space and Mountain Parks (OSMP). The city's current erosion control standards are contained in the Design and Construction Standards (DCS) document, but the standards do not currently outline a process to document SWMP compliance.

There are three Divisions within the Public Works Department that are involved with construction stormwater: P&DS; Transportation; and Utilities. The P&DS Division handles private development projects within the city and the Transportation and Utilities Divisions handle CIP projects that construct and maintain public infrastructure related to the water, wastewater, and stormwater/flood utilities. In general, the DCS requires public/CIP projects to have the same level of construction stormwater documentation and permit compliance as private projects; however, in some instances Boulder Revised Code may make distinctions between public and private projects.

Private Construction Projects Process Summary

The city's current construction stormwater process for private construction projects includes the following:

- Review of technical documents and construction plans.
- Requirement for an erosion control permit from the city.
- Verification that the state construction stormwater permit has been obtained.
- A pre-construction meeting with the city relating to construction stormwater.

In addition, the city performs erosion control inspections for private construction projects every 14 days and/or after a precipitation event. All private construction inspections done performed by the city are tracked using the PermiTrack database.

The city currently issues a dewatering permit and has protocol for when stormwater may be discharged to sanitary sewers. In general, this permit matches the state's permit with an agreement that mirrors the state requirements, but can allow the city to be more stringent depending upon the location of discharge.

Public Construction Project Process Summary

The city does not currently have a formalized public construction process across all departments for stormwater. The Transportation and Utilities divisions within the Public Works Department, as well as other city departments, have different processes as summarized below.

Transportation: The Transportation Division typically follows Colorado Department of Transportation (CDOT) BMP standards rather than the UDFCD standards because CDOT contributes funds to many of its projects and CDOT oversight is required. The city manages all transportation construction, but ultimately the contractor completing the work is responsible for erosion control and pulls the stormwater construction permit.

Utilities: The Utilities and Greenways/Flood Work Groups within the Utilities Division generally follow the UDFCD Urban Storm Drainage Criteria Manual, Volume 3, standards as referenced in the DCS. The BMP processes for plan preparation, implementation, inspection, and closeout-checklist vary considerably between project managers. Currently, much of the BMP implementation/maintenance work done is directed verbally and not tracked. The contractor is responsible to pull the construction stormwater permit, and stormwater inspections are done either by the contractor completing the work or by a third party.

Other Departments in the City: Parks and Recreation, FAM, and OSMP are additional departments with projects that sometimes require a state stormwater permit and stormwater oversight. Again, with these departments, the contractor is responsible to pull the state construction stormwater permit, and stormwater inspections are conducted either by the contractor completing the work or by a third party.

Recommendations

Based on the information in the previous sections, recommendations are provided in Section 9.9.4 for improving the city's current private and public stormwater construction processes.

9.8.1 Operations and Maintenance Program (MCM 5 and 6)

This section describes the city's current stormwater O&M program. O&M is included in both MCM 5 and MCM 6 in the 2008 MS4 permit. The section describes standard maintenance of the stormwater system and permanent stormwater BMPs, the stormwater repair and rehabilitation program, and monitoring and sampling of the stormwater system.

Permanent BMP Inspection

Currently, the city follows a stormwater maintenance schedule for permanent BMPs in the city. Above-ground private BMPs are inspected per state requirements and the responsible party is expected to maintain them. Stormceptors™ and other proprietary BMPs are currently used in the city's storm drain system, but there is no stormwater maintenance schedule for these or any other city-owned BMPs. Private ponds are inspected and are entered into the city's database. The city does not perform in-depth inspections of private proprietary BMPs, such as Stormceptors™.

Recently, the city implemented a GIS-based asset management tool for tracking city-owned, proprietary, and other BMPs. The city is also trying to better organize and use as-built drawings for city projects. These are good first steps to creating consistency in maintenance and inspection schedules.

CCTV Inspection Program and Condition Assessment

The city has hired a contractor to perform a routine condition assessment of the storm sewer system. By the end of 2016, the city expects to have completed a condition assessment for 20 percent of the storm sewer system (University Hill, Downtown, Upper Goose Creek basins) and plans to continue this inspection program at a rate of 10 to 20 percent of the system per year. A maintenance plan, with defined stormwater program goals, has also been developed. The basic goal is to inspect the entire system every five to ten years with follow-up assessments. A summary of the city's program goals is described below:

Stormwater Cleaning:

- 870 days or 5 years with two trucks.
- 108,000 feet annually per truck.
- 1,800 catch basins annually per truck.

Stormwater Televising/Condition Rating:

- 270,000 feet annually.
- 4 years to complete the entire system at 1,500 feet daily.

Stormwater Construction:

- 20 spot repairs every 30 days.
- 10 culvert replacements every 30 days.
- 10 new install, local improvement projects every 30 days.
- Customer relationship management (CRM), Customer Calls, Internal Requests.

Repair and Rehabilitation Program and Improvements

Currently, the city's maintenance crews are responsible for cleaning storm sewers and inlets. Production goals are significantly lower than the goals for wastewater collection, primarily due both to a heavier amount of sediment and debris found in stormwater systems as well as a bigger range in pipe diameters.

The funding from the Utilities Division is given to the Transportation Division for street sweeping. Street sweeping on set routes is being performed.

For open channel maintenance, major drainage channels are maintained by contractors with funding from UDFCD. The Transportation Division is maintaining smaller drainage channels and ponds. The Transportation maintenance group is responsible for some maintenance of the numerous ditches that flow through the city. The Transportation maintenance crew is anticipated to combine with the Utilities maintenance group in the future.

Observations and Recommendations

The city has expressed the desire for increased communication and coordination between the WQES group and maintenance staff to foster better collaboration on requirements and needs for permanent BMP maintenance. Maintenance issues have not been given much attention mainly because there are no enforcement measures in place for BMP maintenance. Section 9.9.5 provides further recommendations for improvements to the city's stormwater O&M program.

9.8.2 Water Quality Monitoring

Instream and stormwater outfall water quality sampling is conducted under dry weather flow conditions on, or along, Boulder Creek to assess possible impacts from the city's MS4 system. Monthly monitoring has been conducted instream for a number of years and includes analyses for *E.coli*, nutrients (total nitrogen components and total phosphorus), and metals. Weekly *E.coli* monitoring at both instream and outfall locations has also been conducted for a number of years. Wet weather conditions have not been monitored to date.

Nutrients

As stated in the CDPHE Water Quality Control Commission (CWQCC) Regulation 85 – Nutrient Management Control Regulation (5 CCR 1002-85), September 30, 2012, all MS4 permit holders are required to perform a nutrient data gap analysis. Per Regulation 85, "The goal of the MS4 data collection requirements is to identify information that exists, and the need for additional monitoring to be conducted in the future, to determine the approximate nitrogen and phosphorus contribution to state waters due to discharges from the MS4." The city completed the data gap analysis and results are documented in the October 14, 2014, report titled *Regulation 85 Discharge Assessment Data Report* (HDR, 2014). Sampling locations and constituents for Boulder Creek nutrient monitoring are provided in Table 9.7-1 . All sample locations are analyzed for total phosphorus and all analytes required for calculating total nitrogen.

Table 9.7-1 City of Boulder's Water Quality Sampling Summary (2012 Monitoring Plan)

Sample Location	Type of Sample	Total Phosphorous	TKN	Nitrite	Nitrate	Fecal – *E. coli*
BC-Can (Boulder Creek at mouth of Boulder Canyon)	Instream	X	X	X	X	X
BC-CU (Boulder Creek at CU campus)	Instream	X	X[3]	X	X	X
BC-61st (Boulder Creek at 61st Street)	Instream	X	X	X	X	X
BC-aWWTP (Boulder Creek above the 75th Street WWTF)	Instream	X	X	X	X	X

E. coli

Weekly *E. coli* instream and outfall monitoring has been conducted on Boulder Creek since the mid-2000s—first, to obtain data to develop the Boulder Creek bacteria TMDL and then to determine compliance with the TMDL and the city's associated WLA. Regular sampling locations are shown in Table 9.7-2: . In addition to weekly monitoring, a monthly monitoring event captures *E. coli* levels for sites directly above and below the TMDL reach and also one location (BC-CU) located within that reach. Finally, outfall surveys have been conducted since the mid-2000s with the last survey conducted in 2015. During the 2015 survey, *E. coli* and optical brightener samples and flow measurements were taken at each flowing outfall along the stream to determine potential sources of pollutants and associated loads.

[3] TKN measurements using current methods were initiated at BC-CU in February of 2015.

Table 9.7-2: Boulder Creek Weekly and Monthly *E. coli* Sampling

Sample Location	Type of Sample	Weekly Sampling	Monthly Sampling
BC-Can (Boulder Creek at mouth of Boulder Canyon)	Instream		X
BC-Eben (Boulder Creek at Eben G Fine Park)	Instream	X	
BC-13th (Boulder Creek at 13th Street)	Instream	X	
OUT-Arap-S (Outfall near Arapahoe on south side of creek)	Outfall	X	
OUT-CU-SKI (Outfall west of CU football practice field on campus)	Outfall	X	
OUT-CU-POM (Outfall north of CU stadium on campus)	Outfall	X	
OUT-CU-FOLSOM (Outfall on CU at Folsom)	Outfall	X	
BC-CU (Boulder Creek at CU campus)	Instream	X	X
OUT-28th (Outfall at 28th Street)	Outfall	X	
OUT-Marine (Outfall at Marine Street)	Outfall	X	
BC-30th (Boulder Creek at 30th Street)	Instream	X	
BC-55th (Boulder Creek at 55th Street)	Instream	X	
BC-61st (Boulder Creek at 61st Street)	Instream		X

9.9 MS4 Permit Implementation and Water Quality Recommendations

This section includes a number of recommendations for improvements to the city's MS4 permit implementation and management. For assistance in implementing these measures, the city can review other successful programs. Information from a workshop with the City of Loveland and the City of Fort Collins is included in and provides input on successful implementation of some of these recommendations. Implementation of these measures will improve the city's current Stormwater Quality Program and ensure compliance with the updated 2015 draft MS4 permit.

9.9.1 MCM 1 – Public Education and Outreach Recommendations

This requirement is currently being met by city staff and KICP efforts. Under the current 2008 MS4 permit, the city is in 100 percent compliance and future requirements are much less prescriptive than the level of outreach the city currently achieves. New requirements can easily be met through minor changes in outreach delivery methods. It is likely possible for the city to divert some resources away from MCM 1 to achieve greater compliance in other areas while maintaining an exemplary outreach program.

9.9.2 MCM 2 – Public Involvement and Participation Recommendations

This requirement is currently being met under the 2008 MS4 permit by city staff and KICP efforts. Under the current 2008 MS4 permit, the city is in 100 percent compliance; however, under the 2015 draft MS4 permit, the city is 70 percent compliant because of the new requirement of a PPD. Therefore, the only addition is to develop a PPD and make it available to the public on the city's website.

9.9.3 MCM 3 – Illicit Discharge Detection and Elimination Recommendations

The city is improving in all areas of illicit discharge detection and elimination and is 50 percent compliant under the 2008 MS4 permit. However, based on the 2015 draft MS4 permit, the city will only be 33 percent compliant because of 31 new permit requirements. The following recommendations would fulfill the MCM 3 requirements:

- Develop an enforcement escalation process for violations of city code.
- Increase recordkeeping to comply with the requirements in the 2015 draft MS4 permit.
- Set up a program to target hot spots and business types that are known to pollute.

9.9.4 MCM 4 – Construction Site Recommendations

The city understands that there is great need for program development under this MCM, regardless of the new permit, especially on determining how stormwater construction is handled both between different city departments and between private and public construction projects. Under the current 2008 MS4 permit, the city is 61 percent compliant. However, based on the 2015 draft MS4 permit, the city will only be 41 percent compliant because of 28 new permit requirements. Based on the city's Private and Public Construction Processes described in Section 9.8 and changes with the 2015 draft MS4 permit, the following actions are recommended for improving the city's construction procedures.

City Projects

- Clarify responsibility for projects with multiple city groups as stakeholders. Define who takes responsibility for design review and maintenance of BMPs.
    - Formalize a stormwater checklist for site inspections through PermiTrack or other software. Create a critical inspection checkbox on every project to implement construction stormwater management.
- Develop methods to achieve better compliance for CIP project contractors:
    - Review and improve contract language and include new stormwater requirements and costs in bid documents.
    - Hold pre-construction meetings to layout expectations related to construction stormwater.
    - Potential oversight of inspections through PermiTrack.
- Develop written guidance to explain when city projects are required to go through the P&DS review process and receive erosion control inspections from right-of-way inspectors.

Private Projects

- Standardize the escalation enforcement process with respect to violations.
- Streamline the requirements for dewatering permits to achieve greater compliance by reducing resource intensity, contractor waiting period, and ditch company approval (where applicable).

Both City and Private Projects

- Consistently enforce erosion control permits, inspections, etc.
- Implement a single stormwater construction database (like PermiTrack) across both public and private city construction projects (FAM, Utilities, Transportation, etc.)
- Formalize documentation for the design review process, such as a stormwater checklist and standard operating procedures.
- Provide contractor education.
- Formalize training and implement a standard process to track short-term, long-term, and ongoing training.
- Add phasing to erosion control plan mapping for both city and private construction projects.
- Implement appropriate oversight of sites that do not have coverage under the state stormwater construction permit (under 1 acre) and require appropriate stormwater controls to prevent pollution.
- Formalize a checklist for transferring or closing state SWMP permits.
- Create a centralized database, such as PermiTrack, to track instances of compliance and non-compliance.

9.9.5 MCM 5 – Post-Construction Stormwater Management Recommendations

The city understands that there are areas that require improvement under this MCM, regardless of the new permit, especially on the frequency with which permanent BMPs are inspected, how public and private permanent BMPs are handled, and how permanent BMPs are transferred from the construction stormwater phase to permanent maintenance. Under the current 2008 MS4 permit, the city is 65 percent compliant. However, based on the 2015 draft MS4 permit, the city will only be 18 percent compliant because of 39 new permit requirements. Based on the city's private and public construction processes described in Section 9.8.1 and changes with the 2015 draft MS4 permit, the following actions are recommended for improving permanent BMP management:

- Implement standardized processes for requiring permanent BMPs on city projects. including:
    - Clear requirements for design and WQCV, including linear and other less traditional types of projects.
    - Process to transfer city-owned BMPs from project engineers to maintenance staff.
    - Establishment of inspection frequencies and parties responsible for routine inspections.

- Establish an understanding of maintenance requirements for underground BMPs for both public and private projects. This can be done by:
  - Training city staff for CIP project BMPs.
  - Developing a strategy to ensure compliance on private underground BMPs and other unconventional BMPs.
- Establish a schedule for the city's WQES Group to inspect private proprietary BMPs, such as Stormceptors™.
- Reinstate a true maintenance management system to provide better preventative maintenance.
- Create a consistent process to input permanent BMPs into GIS that is uniform across all departments.
- Move the inspection of private BMPs into the Stormwater Quality Program.
- As inspections and maintenance of post-construction BMPs are taken on by WQES and Utilities maintenance groups respectively, they should work with other departments to budget appropriately for maintenance costs and to ensure appropriate and easily maintained BMPs are installed in the future.
- Perform spot inspections of both construction and post-construction BMPs.

9.9.6 MCM 6 – Pollution Prevention and Good Housekeeping

The city understands that there are areas of improvement under this MCM, regardless of the new permit. Under the current 2008 MS4 permit, the city is 33 percent compliant. However, based on the 2015 draft MS4 permit, the city will only be in 19 percent compliant because of 18 new permit requirements. To fulfill the requirements of this MCM, the following recommendations are made:

- Implement site-specific permanent water quality measures for individual facilities that include BMPs specific to the activities conducted at each facility.
- Designate a point person at each facility to be stormwater lead, advised and supported by the WQES staff.
- Begin a planning and funding (budget procurement) process for new secondary containment requirements for chemical storage tanks.
- Provide and track training at city facilities through online training or similar efforts to reduce the reporting burden for any individual staff member and to create greater buy-in by management and staff.
- Better integrate the city's WQES staff into the street sweeping program.
- Equip trucks with spill kits and implement additional spill training for Municipal Service Center staff.

HDR reviewed the city's processes in 2009, as summarized in *TM 4.1b Stormwater System Operations and Maintenance Evaluation* (HDR, 2009). The following recommendations are extracted from that document.

- Maintain Up-to-Date Mapping of the Stormwater System
  - Make completion of the GIS database a priority. The current practice of correcting discrepancies by submitting a Utility Field Report to the supervisor or planner helps to maintain consistency between the existing GIS database and current conditions.

- Computerized Maintenance Management System (CMMS)
  - Update a database software program to collect maintenance findings by asset and support geographical work scheduling.
  - Update the database (e.g., CMMS database) to store condition data collected during maintenance and inspection visits. All data, such as trouble area cleaning records, need to be entered into the CMMS.
  - Create a detailed service request or work order form and provide it to crews who maintain the system assets. The work order would be specific to the type of work being performed and would collect code-based findings for each asset maintained.
  - Provide training to staff in the effective usage of GIS and Computerized Maintenance Management System (CMMS) software.
- Cleaning Program
  - Continue to move to a proactive cleaning schedule based on hydraulic connectivity, which should lead to fewer future reactive cleaning needs.
  - Develop maintenance goals to measure crew productivity annually. Establishing these goals would enable the city to benchmark current stormwater O&M activities.
  - Move to code-based collection of findings and this data in an upgraded CMMS. As the assets are visited, data could be collected and cleaning frequencies could be developed and/or optimized for individual assets.
  - Continue the proactive updates to CMMS, or other new database, and track all individual assets maintained.
- Inspection Program
  - Move to a universal industry-recognized defect coding system. This will enable the city to collect consistent records if there is turn-over on the CCTV crew and to provide a standard for contractors. Training should be provided initially and periodically to the CCTV crews and to any other personnel who might need to use the software or operate the equipment.
  - Use CCTV for quality control on maintenance and repair activities. This evaluation should be performed on 1 to 3 pipes per 100 pipes cleaned per cleaning crew.
- Rehabilitation and Replacement Program
  - Develop a standardized methodology to determine repair, rehabilitation, and replacement needs. To assure consistent decision-making in the city's repair, rehabilitation, and replacement project identification process, it is very important that the city processes future CCTV data based on a formal decision process. This can be done manually based on the decision flow diagram, or it can be built into an algorithm developed from the diagram.
  - Integrate the condition findings with the GIS.
  - When a backlog of CIP projects develops, it is a best practice to develop a formal project prioritization process so that highest risk and/or consequence assets are addressed to assure stakeholders that available resources are focused on the highest-priority projects.
- Training

- Develop a cleaning crew training program with components that focus on improving both the cleaning work process and the cleaning information process. Training should also be held for the CCTV coding system that the city chooses for its CCTV crews.

9.9.7 Other Regulatory and Water Quality Recommendations

The following are general recommendations for the city's MS4 program:

- Clearly define which group performs maintenance on various components of the stormwater system, including storm drains, ponds and other permanent above-ground BMPs, permanent below-ground BMPs, and open ditches.
- The WQES Group should facilitate water quality training as needed with other city departments that are involved with implementing the stormwater program throughout the city.

In addition to the above, the following sections include water quality recommendations for areas outside of the 2015 draft MS4 permit.

Regulation 85

CDPHE Regulation 85 promulgates control regulations on the concentration of total inorganic nitrogen and total phosphorus that can be discharged to state waters from point sources. Per Regulation 85, "The goal of the MS4 data collection requirements is to identify information that exists, and the need for additional monitoring to be conducted in the future, to determine the approximate nitrogen and phosphorus contribution to state waters due to discharges from the MS4."

To address possible future Regulation 85 requirements, the following recommendations are made:

- Update the GIS information for storm drains and outfalls.
- Update and maintain GIS land use data. The land use file should be examined to verify that the GIS-defined land uses reflect the corresponding land cover. Educational land uses, as well as industrial complexes with large amounts of green space, such as the IBM and Celestial Seasonings industrial campuses, should be segmented based their open space and building/parking lot components.
- Update and maintain the SMP and water quality tools, such as the XPSWMM model, which could include staff licensing and running the model in-house.
- Use the existing sources of Event Mean Concentration (EMC) data for the city's land use designations and use it in the XPSWMM water quality model. The city can incorporate newer EMC data as it becomes available.
- Consider studies to explore correlations with nutrient loading and areas of high irrigation and/or overlaps between areas where nutrient loading and *E. coli* loading (in the TMDL reach) are both elevated.

Monitoring and Sampling

The city is currently performing water quality sampling based on the current monitoring and sampling plan. However, recommendations are made to evaluate *E. coli* and nutrient (ortho phosphate, total dissolved phosphorus (TDP), total phosphorus (TP), total Kjeldahl nitrogen (TKN), nitrate (NO_3) and nitrite (NO_2), and ammonia (NH_3)) concentrations and associated flows to develop storm event-based loadings from the MS4. These monitoring and sampling recommendations are partly based on better understanding EMC nutrient loadings in association with Regulation 85. These nutrient loads can then be tied back to land use for updating EMC loads in the XPSWMM water quality model. Specific recommendations include the following:

- Set up a permanent flow monitor at the Boulder Creek sampling site BC-CU to determine loads at this location.
- Set up a flow monitor at the Boulder Creek sampling site BC-28th to determine the nutrient EMC loads at this location.
- Perform storm event-based nutrient and *E. coli* sampling and flow monitoring at all current instream sampling sites in Boulder Creek.
- Perform storm event-based nutrient and *E. coli* sampling and flow monitoring at select MS4 outfall locations, with a focus on outfalls 48 inches in diameter and greater.
- Monitor dry weather flow in MS4 outfalls to Boulder Creek and consider setting up temporary flow monitors at these locations.

Colorado Revised Statute (CRS) §37-92-602 (8)

The new CRS (CRS) §37-92-602 (8) effective on August 5, 2015, protects surface water in stormwater detention and infiltration facilities from water rights, provided that they are sufficiently reported to the state. This statute requires documentation such as location, approximate surface area at design volume, design storm, drainage times, and drainage area to protect permanent detention or infiltration facilities.

It is recommended that the P&DS, WQES, and Water Resources staff coordinate on documenting and reporting all stormwater detention and infiltration facilities to the extent required by the statute and that the city may want to protect from water rights.

Green Infrastructure

The city needs to look for additional ways to incorporate green infrastructure (GI) into both city and private projects. Recommendations related to GI include:

- Use information gained from an ongoing GI study to better understand how GI can satisfy city goals across departments.
- The current GI study and additional work should inform what initiatives/projects should be pursued to address multiple goals like localized flooding and water quality such as residential rain gardens and larger, neighborhood-scale GI projects.
- Identify methods to facilitate inclusion of water quality goals/projects from the SMP into various city projects. This might include facilitating meetings with city departments to discuss future projects, funding, and the potential for incorporating GI.

Climate and Resilience

As the city continues to evaluate the impacts of climate change and works toward greater resilience, adaptation and mitigation efforts continue to be a focus of the Stormwater Quality Program. Climate scientists have noted several issues, including the likelihood of greater variability in precipitation events, larger storm events due to more carrying capacity in warmer air systems during summer, and increased spring runoff due to rain-on-snow events or dust-on-snow events. While these impacts relate to the carrying capacity of the larger MS4, the Stormwater Quality Program may also play a role in helping to identify opportunities where GI may help work alongside of grey infrastructure to mitigate storm events in addition to continuing to leverage stormwater outreach with flood messaging to help with city adaptation efforts and overall resilience.

Appendix A: Stormwater Management Policies

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Stormwater Management Principles and Policies

The approach of this section is to present the general guiding principles, narrow these to policies, and then present the more specific aspects of the implementation measures. Note this document does not attempt to repeat previous published principles, policies, and implementation measures word for word, but rather to capture the general intent and to include the most relevant specifics within the SMP.

Guiding Principles

The Comprehensive Flood and Stormwater Utility Master Plan (CFS) presents guiding principles for stormwater drainage and water quality. These principles are listed below by topic along with additional guiding principles developed during SMP planning process. *Guiding principles from the CFS are italicized.*

Stormwater Drainage

3. *Maintain and preserve existing and natural drainage systems.*
4. *Reduce and manage developed runoff.*
5. *Eliminate drainage problems and nuisances.*

Stormwater Quality

6. *Protect public health and the environment.*
7. *Manage pollution at the source.*
8. *Protect and enhance natural resources associated with the stream environment.*
9. Prevent significant erosion resulting from stormwater outfalls and their adverse effects on water quality.

Multi-Objective Stormwater Planning

1. Integrate stormwater quantity and stormwater quality solutions.
2. Provide a regional approach to stormwater management that is consistent with other community goals and plans.
3. Assure an orderly implementation of improvements to the stormwater drainage system to serve existing and future development, both new development and redevelopment.

Irrigation Ditches

1. Address irrigation ditch issues relating to the stormwater collection system, water quality, conveyance of urban stormwater runoff, and contributions to groundwater conditions.

Stormwater Management Policies

Policies and implementation measures for stormwater management were developed in the BVCP and in the CFS. Some of the policies and implementation measures adopted in the SMP are based on those in the previous documents; others were developed by the project team to help guide the master planning process.

Stormwater Drainage Systems

Policies and implementation measures for stormwater drainage systems address the conveyance of stormwater runoff to the major drainageway system.

Policies from the Boulder Valley Comprehensive Plan

DESIGN STORM FREQUENCY (BVCP SECTION 3.D(III) - URBAN SERVICE STANDARDS)

All local collection systems shall be designed to transport the following storm frequency:

- Single family residential: 2-year storm
- All other areas: 5-year storm

Policies and Implementation Measures from the CFS

POLICY: UPDATE THE CITY'S STORMWATER DRAINAGE SYSTEM MASTER PLAN

- Update hydrology/hydraulic models from the 2007 SMP
- Prioritize projects with a focus on known problems and future development areas.
- Re-evaluate detention including the possibility of regional detention and increasing existing detention.
- Focus on smaller storms (less than 1-inch) because of the greater hydrologic impact of these storms.

SMP Policies and Implementation Measures

The following are policies and implementation measures used specifically for the development of the SMP. The policies or implementation measures that are a significant divergence from the BVCP, CFS or the Design and Construction Standards are highlighted in italics.

POLICY 1 – STORMWATER DRAINAGE SYSTEM INFRASTRUCTURE

The city will provide an adequate stormwater collection and conveyance system for existing and future development within the city.

Implementation Measures:

- Update the collection system hydrologic and hydraulic models. Use appropriate land use projections and associated imperviousness values to estimate the future stormwater runoff.
- Focus on problems areas created by smaller storms because of the greater hydrologic impact of these storms.
- Develop cost effective improvements to the existing stormwater drainage system resulting in a continuous drainage system that provides service to the upstream users.

- Size the storm sewer system to convey the runoff from 2-year storm events in residential areas and runoff from 5-year storm events in commercial areas. *At a minimum, collector and arterial roadways are to convey the 5-year storm event.*
- Prioritize CIP projects to develop a financing strategy to fund capital projects that improve the stormwater drainage system. Financing strategies will be in accordance with existing laws, rules and regulations, and may include an increase in the stormwater utility fee.

POLICY 2 – MAXIMIZE EXISTING INFRASTRUCTURE

The city will maximize the use of existing storm drainage infrastructure and optimize the size of required drainage system improvements.

Implementation Measures:

- Allow limited surcharging in the existing storm drain piped system to increase drainage system capacity. These minimum levels of surcharging will provide a sufficient safety factor as to prevent flooding under the design storm conditions by limiting the hydraulic grade line to be approximately *one foot below the ground surface*.
- Incorporate existing detention facilities in the system analysis.
- Utilize appropriate analysis and planning tools to evaluate the system capacity and identify system improvements.

POLICY 3 – OPEN CHANNEL DRAINAGE SYSTEMS

The city will strive to minimize flooding, stream bank and channel erosion within the open channel stormwater drainage system by controlling the rate and volume of stormwater runoff from development and redevelopment projects.

Implementation Measures:

- *Infiltrate storm runoff where site conditions allow as a means of reducing post development runoff volumes and associated flow rates.*
- Continue to provide detention facilities that limit post-development runoff rates to previous development rates.
- Continue to require the minimization of directly connected impervious area , as well as other development practices to reduce discharges from storm sewer systems into the receiving waters of the city, as specified in the DCS.

Stormwater Quality

Policies and implementation measures for stormwater quality address the reduction of pollutants and runoff volume inherent in urban stormwater runoff to help mitigate their negative impacts on the receiving waters.

Policies from the Boulder Valley Comprehensive Plan

2.33 ENVIRONMENTALLY SENSITIVE URBAN DESIGN

For capital improvements and private development, the city and county will strive to ensure that buildings, streets, utilities and other infrastructure are located and designed to protect natural systems, minimize energy use, urban heat island effects and air and water pollution, and support clean energy generation.

POLICY 3.24 PROTECTION OF WATER QUALITY

Water quality is a critical health, economic and aesthetic concern. The city and county will protect, maintain and improve water quality within the Boulder Creek watershed as a necessary component of existing ecosystems and as a critical resource for the human community. The city and county will seek to reduce point and non-point sources of pollutants, protect and restore natural water system, and conserve water resources. Special emphasis will be placed on regional efforts such as watershed planning and priority will be placed on pollution prevention over treatment.

Policies and Implementation Measures from the CFS

POLICY: UPDATE THE STORMWATER MANAGEMENT PLAN TO INCORPORATE A WATERSHED MANAGEMENT APPROACH

- Balance quantity and quality issues
- Prevention first, mitigation second – Prevent stormwater excessive runoff and pollution at the source using techniques tailored to each subbasin.
- Apply conservation principles. Shift the focus from stormwater disposal to prevention and conservation. Approach stormwater management as a resource to enhance natural systems and processes

SMP Policies and Implementation Measures

The following are policies and implementation measures used specifically for the development of the SMP. The policies or implementation measures that are a significant divergence from the BVCP, CFS or the Design and Construction Standards are highlighted in italics.

POLICY 4 – STORMWATER QUALITY CIP PROJECTS

The city will strive to protect the quality of water in the stormwater drainage system and receiving waters, including Boulder Creek, to maintain and enhance the environment, quality of life, and economic well-being of the City of Boulder by identifying and implementing stormwater quality CIP projects.

Implementation Measures:

- Identify and implement regional, post-construction stormwater quality facilities (best management practices or BMPs) that will reduce pollutants from existing impervious areas.
- Emphasize the use of surface oriented BMPs to manage stormwater quantity and quality in the city’s CIP projects.

- o Develop BMP Toolbox and user-friendly selection process, which will leverage other city capital projects (e.g., water, transportation, parks) to assist in implementing stormwater quality solutions. *Include identification of practical low impact development practices (LID) on a parcel level to mitigate impervious areas, runoff volume and associated pollutants.*

Multi-Objective Planning

Policies and implementation measures for multi-objective planning are intended to identify opportunities for including stormwater projects with other capital improvements in the city. This will improve the efficiency of implementing stormwater improvements.

Policies from the Boulder Valley Comprehensive Plan

POLICY 1.29 CHANNELING DEVELOPMENT TO AREAS WITH ADEQUATE INFRASTRUCTURE

In order to protect and use past investments in capital improvements, new development and redevelopment will be located in areas where adequate public services and facilities presently exist or are planned to be provided under the city's Capital Improvements Program.

POLICY 1.32 MULTI-PURPOSE USE OF PUBLIC LANDS

Multi-purpose use of public lands, facilities, and personnel services shall be emphasized. However, in consideration of potential use of parks and open space lands, only activities consistent with the original intent of acquisition will be considered.

POLICY 1.35 UTILITY PROVISION TO IMPLEMENT COMMUNITY GOALS

The city will consider the importance of the other objectives of the Boulder Valley Comprehensive Plan in the planning and operation of the water, wastewater and stormwater and floodplain management utilities. These other objectives include in-stream flow maintenance, enhancement of recreational opportunities, water quality management, preservation of natural ecosystems, open space and irrigated agricultural land, and implementation of desired timing and location of growth patterns.

POLICY 3.25 WATER RESOURCE PLANNING AND ACQUISITION

Water resource planning efforts will be regional in nature and incorporate the goals of water quality protection, and surface and ground water conservation. The city will continue to obtain additional municipal water supplies to insure adequate drinking water, maintain instream flows and preserve agricultural uses. The city will seek to minimize or mitigate the environmental, agricultural and economic impacts to other jurisdictions in its acquisition of additional municipal water supply to further the goals of maintaining instream flows and preventing the permanent removal of land from agricultural production elsewhere in the state.

Policies and Implementation Measures from the CFS

Update the Stormwater Management Plan by incorporating the following approaches:

- o Integrate water quality and other multi-objective issues.

- Use multiple objectives approach. Develop solutions that coordinate management of peak rates and volume, water quality, and maintenance.
- Integrate BMPs into site design process. Determine appropriate application of BMPs in prioritized subbasins in order to integrate BMPs into the first stages of site planning and overall subbasin planning.

SMP Policies and Implementation Measures

The following are policies and implementation measures used specifically for the development of the SMP. The policies or implementation measures that are a significant divergence from the BVCP, CFS or the Design and Construction Standards are highlighted in italics.

POLICY 5 – STORMWATER PLANNING AND COORDINATION

The city will continue to integrate the quantity and quality aspects of stormwater in the planning, design, and construction of development and redevelopment projects, and will look for opportunities to address stormwater issues when planning and designing other capital projects in the city, including projects involving water, wastewater, transportation, and parks.

Implementation Measures:

- Emphasize the use of surface oriented BMPs to manage stormwater quantity and quality in private development projects *through revisions to city ordinances and the development code*.
- Identify and implement regional, multi-use drainage and stormwater quality facilities that combine stormwater function with public and natural resource enhancements.
- *Investigate opportunities to remove pollutants and reduce runoff volume by identifying surface oriented BMPs in conjunction with acquisition of floodplain hazard properties.*
- Identify opportunities for drainage and water quality improvements related to transportation, water, and wastewater projects.
- Investigate an achievable level for implementation of low impact development practices for new development that would reduce the size and extent of required improvements to the existing stormwater drainage system.

Irrigation Ditches

Policies and implementation measures associated with irrigation ditches address the quantity of stormwater runoff discharged to the irrigation systems within the City and problems associated with ditch over-topping.

Policies from the Boulder Valley Comprehensive Plan

STORMWATER AND FLOOD MANAGEMENT (BVCP SECTION 3(D)(V) - URBAN SERVICE STANDARDS)

Storm runoff quantity greater than the 'historical' amount will not be discharged into irrigation ditches without the approval of the flood regulatory authority or the appropriate irrigation ditch company.

Policies and Implementation Measures from the CFS

UPDATE THE CITY'S STORMWATER COLLECTION SYSTEM MASTER PLAN

- The Stormwater Management Plan should address separating stormwater drainage from the irrigation ditches.

SMP Policies and Implementation Measures

The following are policies and implementation measures used specifically for the development of the SMP. The policies or implementation measures that are a significant divergence from the BVCP, CFS or the Design and Construction Standards are highlighted in italics.

POLICY 6 – SEPARATION OF STORMWATER OUTFALLS FROM IRRIGATION DITCHES

Storm sewer outfalls (point discharges) are to be separated from irrigation ditches within the city limits.

Implementation Measures:

- Continue to allow surface runoff from undeveloped areas within the city to enter the irrigation ditches via overland flow.
- Identify near-term opportunities for removing storm sewer outfalls from irrigation ditches that alleviate known ditch over-topping problem locations.
- Identify a time schedule for separating the storm sewer system from irrigation ditches.

Groundwater

Policies and implementation measures for groundwater are associated with the identification of high groundwater areas and associated water quality issues.

Policies from the Boulder Valley Comprehensive Plan

3.28 SURFACE AND GROUND WATER

Surface and ground water resources will be managed to prevent their degradation and to protect and enhance aquatic, wetland and riparian ecosystems. Land use and development planning and public land management practices will consider the interdependency of surface and groundwater and potential impacts to these resources from pollutant sources, changes in hydrology, and dewatering activities.

SMP Policies and Implementation Measures

The following are policies and implementation measures used specifically for the development of the SMP. (The policies or implementation measures that are a significant divergence from the BVCP, CFS or the Design and Construction Standards are highlighted in italics.)

POLICY 7 – GROUNDWATER IMPACTS RESULTING FROM DEVELOPMENT

The city will continue to address groundwater issues related to development proposals and the associated discharge locations of pump groundwater flows including water quality impacts due to potential groundwater quality issues at registered locations.

Implementation Measures:

- The Stormwater Management Plan will not include pumped groundwater discharge into the storm sewer system in the capacity analysis due to the level of complexity in determining actual pumped flow rates and discharge locations.
- Collect more accurate data on groundwater levels in potential problem areas, including seasonal fluctuations.
- Develop requirements, including groundwater quality, for disposal of pumped groundwater into the stormwater collection system from dewatering activities.
- Develop requirements for mitigation plans for problem areas such as areas where dewatering will impact wetlands and well levels.
- At relevant sites, incorporate groundwater sampling into an overall water quality monitoring plan.
- Address problems related to the interaction of irrigation ditches and groundwater, including groundwater contamination.

Appendix B: Cost Estimates

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COLLECTOR SYSTEM IMPROVEMENT COSTS

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Boulder SMP Collector System Recommended Plan Projects Tier 1 Cost

Rank	Subbasin	ID	Improvement Type	Priority	Cost
-	Goose Creek	GC_01	Hydraulic Improvement (Broadway Alternative 2)	-	
1	Goose Creek	GC_02	Hydraulic Improvement (Goose CR Alternative 2b)	Tier 1	$ 8,269,000
-	Middle Boulder Creek	MBC_10	Hydraulic Improvement	Tier 1	
3	Middle Boulder Creek	MBC_14	Combined Hydraulic/Water Quality Improvement	Tier 1	$ 2,076,000
4	Dry Creek	DC_01	Combined Hydraulic/Water Quality Improvement	Tier 1 and 2	$ 7,195,000
				Total	$ 17,540,000

Notes:
GC_01 replaced with Local System Improvement Goose Creek - 5
GC_02 modified to reflect overlap with Local System Improvement Recommendations
MBC_10 replaced with Local System Improvement Middle Creek - 2

Improvement ID: *GC_02 - Updated*

Description	Units	Quantity	Unit Cost (Updated)	Item Cost
General				
Insurance and Bonding (10%)				$ 452,584
Mobilization (6%)				$ 271,550
Traffic Control (5%)				$ 226,292
Misc. Utility Relocation (5%)				$ 226,292
Subtotal				$ 1,176,718
Demolition				
Sawcut	LF	8,931	$ 4.29	$ 38,269
Remove and Dispose of Asphalt	CY	862	$ 44.56	$ 38,398
Remove and Dispose of Curb and Gutter	LF	1,958	$ 8.74	$ 17,107
Remove and Dispose of Inlet	EA	84	$ 1,262	$ 106,008
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 29,024
Connect to Existing	Each	20	$ 1,200	$ 24,000
Removal and Disposal of Pipe (up to 36-inch)	LF	0	$ 30.67	$ -
Box				
4'x8' RCB - 10' Depth to Invert	LF	535	$ 680	$ 363,800
4'x12' RCB - 10' Depth to Invert	LF	1937	$ 1,130	$ 2,188,810
Pipe				
36" RCP - 10' Depth to Invert	LF	55	$ 187	$ 10,276
48" RCP - 10' Depth to Invert	LF	1381	$ 247	$ 341,104
54" RCP - 10' Depth to Invert	LF	60	$ 304	$ 18,217
60" RCP - 10' Depth to Invert	LF	347	$ 351	$ 121,649
Surface Restoration				
Type 1 (Asphalt Patch)	LF	4,112	$ 51	$ 211,273
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	2,428	$ 103	$ 250,145
Manholes				
72" and Larger	Each	12	$ 9,237	$ 110,842
Special/Box Base	Each	11	$ 13,855	$ 152,407
Curb Inlets (Type R)	Each	84	$ 7,274	$ 611,014
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041	$ 4,041
Subtotal				$ 4,525,838
Utility Relocation				
Water Line Relocation	LF	2,394		$ -
Subtotal				$ -
Subtotal Construction Costs				**$ 5,702,556**
Design Contingency (25%)				$ 1,425,639
Engineering and Administration (20%)				$ 1,140,511
Total Estimated Improvement Cost (Rounded)				**$ 8,269,000**

Improvement ID: *MBC_14*

Description	Units	Quantity	Unit Cost (Updated)	Item Cost
General				
Insurance and Bonding (10%)				$ 106,420
Mobilization (6%)				$ 63,852
Traffic Control (5%)				$ 53,210
Misc. Utility Relocation (5%)				$ 53,210
Subtotal				$ 276,691
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 18,381
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	895	$ 30.67	$ 27,450
Pipe				
24" RCP - 6' Depth to Invert	LF	291	$ 130.14	$ 37,871
30" RCP - 6' Depth to Invert	LF	602	$ 152.28	$ 91,673
36" RCP - 8' Depth to Invert	LF	848	$ 186.84	$ 158,440
42" RCP - 8' Depth to Invert	LF	364	$ 218.78	$ 79,634
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,780	$ 51.38	$ 91,456
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	215	$ 103.02	$ 22,150
Manholes				
60" Dia and Smaller	Each	14	$ 4,618.40	$ 64,658
Curb Inlets (Type R)	Each	56	$ 7,273.98	$ 407,343
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 1,006,696
Water Quality Manholes				
10-foot Diameter (13 cfs)	Each	1	$ 45,029.40	$ 45,029
Diversion Manhole	Each	1	$ 10,391.40	$ 10,391
Diversion and Return Piping	Each	1	$ 2,078.28	$ 2,078
Subtotal				$ 57,499
Subtotal Construction Costs				**$ 1,340,886**
Design Contingency (25%)				$ 335,221
Engineering and Administration (20%)				$ 268,177
Land Acquisition	SF	10,000	$ 13.12	$ 131,240
Total Estimated Improvement Cost (Rounded)				$ 2,076,000

Improvement ID: *DC_01*

Description	Units	Quantity	Unit Cost (Updated)	Item Cost
General				
Insurance and Bonding (10%)				$ 397,904
Mobilization (6%)				$ 238,742
Traffic Control (5%)				$ 198,952
Misc. Utility Relocation (5%)				$ 198,952
Subtotal				$ 1,034,550
Pipe Improvements				
Connect to Existing	Each	6	$ 1,200.00	$ 7,200
Removal and Disposal of Pipe (up to 36-inch)	LF	4,740	$ 30.67	$ 145,376
Pipe				
24" RCP - 6' Depth to Invert	LF	337	$ 130.14	$ 43,857
30" RCP - 6' Depth to Invert	LF	1,962	$ 152.28	$ 298,773
36" RCP - 8' Depth to Invert	LF	775	$ 186.84	$ 144,801
42" RCP - 6' Depth to Invert	LF	401	$ 211.16	$ 84,673
48" RCP - 6' Depth to Invert	LF	800	$ 231.49	$ 185,189
54" RCP - 8' Depth to Invert	LF	108	$ 295.38	$ 31,901
60" RCP - 10' Depth to Invert	LF	1,046	$ 350.57	$ 366,698
66" RCP - 10' Depth to Invert	LF	191	$ 387.59	$ 74,030
72" RCP - 12' Depth to Invert	LF	1,894	$ 459.80	$ 870,870
Surface Restoration				
Type 1 (Asphalt Patch)	LF	4,570	$ 51.38	$ 234,805
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	490	$ 103.02	$ 50,482
Manholes				
60" Dia and Smaller	Each	14	$ 4,618.40	$ 64,658
72" and Larger	Each	3	$ 9,236.80	$ 27,710
Special/Box Base	Each	8	$ 13,855.20	$ 110,842
Curb Inlets (Type R)	Each	100	$ 7,273.98	$ 727,398
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 3,473,305
Channel Improvements				
Excavation	CY	2,519	$ 17.76	$ 44,723
Vegetation	SF	25,600	$ 0.29	$ 7,389
Subtotal				$ 52,113
Water Quality Ponds				
Excavation and shaping	CY	12,852	$ 23.09	$ 296,775
Amended topsoil and preparation	CY	1,278	$ 18.47	$ 23,605
Wetland vegetation	SF	69,000	$ 1.85	$ 127,468
Outlet structure	EA	1	$ 5,773.00	$ 5,773
Subtotal				$ 453,621
Subtotal Construction Costs				**$ 4,961,476**
Design Contingency (25%)				$ 1,240,369
Engineering and Administration (20%)				$ 992,295
Total Estimated Improvement Cost (Rounded)				$ 7,195,000

Boulder SMP Collector System Recommended Plan Projects Tier 2 Cost

Rank	Subbasin	ID	Improvement Type	Priority	Cost
21	Bear Canyon Creek	BCC_03	Hydraulic Improvement	Tier 2	$ 1,512,000
9	Dry Creek No. 2	DC2_02	Hydraulic Improvement	Tier 2	$ 5,364,000
16	Dry Creek No. 2	DC2_06	Combined Hydraulic/Water Quality Improvement	Tier 2	$ 637,000
14	Elmers Twomile Creek	ETC_01	Hydraulic Improvement	Tier 2	$ 639,000
11	Goose Creek	GC_08	Combined Hydraulic/Water Quality Improvement	Tier 2	$ 476,000
12	Goose Creek	GC_09	Combined Hydraulic/Water Quality Improvement	Tier 2	$ 957,000
6	Middle Boulder Creek	MBC_04	Hydraulic Improvement	Tier 2	$ 733,000
9	Middle Boulder Creek	MBC_20	Hydraulic Improvement	Tier 2	$ 88,000
8	Middle Boulder Creek	MBC_22	Hydraulic Improvement	Tier 2	$ 2,298,000
14	Middle Boulder Creek	MBC_23	Combined Hydraulic/Water Quality Improvement	Tier 2	$ 445,000
5	Skunk Creek	SC_01	Hydraulic Improvement	Tier 2	$ 1,250,000
18	Skunk Creek	SC_02	Hydraulic Improvement	Tier 2	$ 1,135,000
19	Middle Boulder Creek	MBC_09	Hydraulic Improvement	Tier 3	$ 1,224,000
7	Wonderland Creek	WC_03	Hydraulic Improvement	Tier 3	$ 810,000
				Total	$ 17,568,000

Notes:
GC_04 replaced with Local System Improvement Goose Creek - 7 (Tier II)

Improvement ID: *SC_01*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 68,480
Mobilization (6%)				$ 41,088
Traffic Control (5%)				$ 34,240
Misc. Utility Relocation (5%)				$ 34,240
Subtotal				$ 178,048
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 7,245
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	740	$ 30.67	$ 22,696
Pipe				
36" RCP - 6' Depth to Invert	LF	1,341	$ 186.84	$ 250,552
42" RCP - 8' Depth to Invert	LF	770	$ 218.78	$ 168,457
Surface Restoration				
Type 1 (Asphalt Patch)	LF	145	$ 51.38	$ 7,450
Manholes				
60" Dia and Smaller	Each	4	$ 4,618.40	$ 18,474
Special/Box Base	Each	2	$ 13,855.20	$ 27,710
Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 684,801
Subtotal Construction Costs				**$ 862,849**
Design Contingency (30%)				$ 172,570
Engineering and Administration (20%)				$ 172,570
Land Acquisition	SF	3,200	$ 13.12	$ 41,997
Total Estimated Improvement Cost (Rounded)				$ 1,250,000

Improvement ID: *MBC_04*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 41,500
Mobilization (6%)				$ 24,900
Traffic Control (5%)				$ 20,750
Misc. Utility Relocation (5%)				$ 20,750
Subtotal				$ 107,901
Pipe Improvements				
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	1,284	$ 30.67	$ 39,380
Pipe				
24" RCP - 8' Depth to Invert	LF	1,133	$ 130.14	$ 147,449
30" RCP - 6' Depth to Invert	LF	151	$ 152.28	$ 22,994
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,220	$ 51.38	$ 62,683
Manholes				
60" Dia and Smaller	Each	4	$ 4,618.40	$ 18,474
Curb Inlets (Type R)	Each	16	$ 7,273.98	$ 116,384
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 415,005
Subtotal Construction Costs				**$ 522,906**
Design Contingency (30%)				$ 104,581
Engineering and Administration (20%)				$ 104,581
Total Estimated Improvement Cost (Rounded)				$ 733,000

Improvement ID: *WC_03*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 45,869
Mobilization (6%)				$ 27,522
Traffic Control (5%)				$ 22,935
Misc. Utility Relocation (5%)				$ 22,935
Subtotal				$ 119,261
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	275	$ 30.67	$ 8,434
Pipe				
30" RCP - 6' Depth to Invert	LF	800	$ 152.28	$ 121,824
36" RCP - 6' Depth to Invert	LF	393	$ 186.84	$ 73,428
Surface Restoration				
Type 1 (Asphalt Patch)	LF	600	$ 51.38	$ 30,828
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	150	$ 103.02	$ 15,454
Manholes				
60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 458,695
Subtotal Construction Costs				**$ 577,956**
Design Contingency (30%)				$ 115,591
Engineering and Administration (20%)				$ 115,591
Total Estimated Improvement Cost (Rounded)				$ 810,000

Improvement ID: *MBC_22*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 130,272
Mobilization (6%)				$ 78,163
Traffic Control (5%)				$ 65,136
Misc. Utility Relocation (5%)				$ 65,136
Subtotal				$ 338,707
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 12,315
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	2,025	$ 30.67	$ 62,107
Pipe				
30" RCP - 6' Depth to Invert	LF	1,751	$ 152.28	$ 266,642
36" RCP - 6' Depth to Invert	LF	884	$ 186.84	$ 165,167
42" RCP - 6' Depth to Invert	LF	1,704	$ 211.16	$ 359,810
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,265	$ 51.38	$ 64,995
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	600	$ 103.02	$ 61,815
Manholes				
60" Dia and Smaller	Each	9	$ 4,618.40	$ 41,566
Curb Inlets (Type R)	Each	36	$ 7,273.98	$ 261,863
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 1,302,720
Subtotal Construction Costs				**$ 1,641,428**
Design Contingency (30%)				$ 328,286
Engineering and Administration (20%)				$ 328,286
Total Estimated Improvement Cost (Rounded)				$ 2,298,000

Improvement ID: *MBC_20*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 4,967
Mobilization (6%)				$ 2,980
Traffic Control (5%)				$ 2,484
Misc. Utility Relocation (5%)				$ 2,484
Subtotal				$ 12,914
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,532
Removal and Disposal of Pipe (up to 36-inch)	LF	164	$ 30.67	$ 5,030
Pipe				
36" RCP - 6' Depth to Invert	LF	164	$ 186.84	$ 30,642
Surface Restoration				
Type 1 (Asphalt Patch)	LF	164	$ 51.38	$ 8,426
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 49,671
Subtotal Construction Costs				**$ 62,586**
Design Contingency (30%)				$ 12,517
Engineering and Administration (20%)				$ 12,517
Total Estimated Improvement Cost (Rounded)				$ 88,000

Improvement ID: *DC2_02*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 304,071
Mobilization (6%)				$ 182,442
Traffic Control (5%)				$ 152,035
Misc. Utility Relocation (5%)				$ 152,035
Subtotal				$ 790,583
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 22,989
Connect to Existing	Each	5	$ 1,200.00	$ 6,000
Removal and Disposal of Pipe (up to 36-inch)	LF	7,015	$ 30.67	$ 215,150
Pipe				
24" RCP - 6' Depth to Invert	LF	2,343	$ 130.14	$ 304,918
30" RCP - 6' Depth to Invert	LF	1,136	$ 152.28	$ 172,990
36" RCP - 6' Depth to Invert	LF	440	$ 186.84	$ 82,210
42" RCP - 6' Depth to Invert	LF	171	$ 211.16	$ 36,108
48" RCP - 8' Depth to Invert	LF	891	$ 239.24	$ 213,165
54" RCP - 8' Depth to Invert	LF	1,022	$ 295.38	$ 301,874
60" RCP - 10' Depth to Invert	LF	1,012	$ 350.57	$ 354,779
Surface Restoration				
Type 1 (Asphalt Patch)	LF	2,470	$ 51.38	$ 126,908
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	1,750	$ 103.02	$ 180,294
Manholes				
60" Dia and Smaller	Each	22	$ 4,618.40	$ 101,605
72" and Larger	Each	5	$ 9,236.80	$ 46,184
Curb Inlets (Type R)	Each	116	$ 7,273.98	$ 843,782
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 3,040,706
Water Line Relocation	LF	1,500	$ -	$ -
Subtotal				$ -
Subtotal Construction Costs				**$ 3,831,289**
Design Contingency (30%)				$ 766,258
Engineering and Administration (20%)				$ 766,258
Total Estimated Improvement Cost (Rounded)				$ 5,364,000

Improvement ID: *GC_08*

Description		Units	Quantity	it Cost (Updat	Item Cost
General					
	Insurance and Bonding (10%)				$ 26,957
	Mobilization (6%)				$ 16,174
	Traffic Control (5%)				$ 13,479
	Misc. Utility Relocation (5%)				$ 13,479
	Subtotal				$ 70,089
Pipe Improvements					
	Connect to Existing	Each	4	$ 1,200.00	$ 4,800
	Removal and Disposal of Pipe (up to 36-inch)	LF	458	$ 30.67	$ 14,047
	Pipe				
	30" RCP - 8' Depth to Invert	LF	399	$ 152.28	$ 60,760
	42" RCP - 8' Depth to Invert	LF	59	$ 218.78	$ 12,908
	Manholes				
	60" Dia and Smaller	Each	4	$ 4,618.40	$ 18,474
	Curb Inlets (Type R)	Each	16	$ 7,273.98	$ 116,384
	Subtotal				$ 227,372
Water Quality Manholes					
	8-foot Diameter (7.1 cfs)	Each	1	$ 29,730.95	$ 29,731
	Diversion Manhole	Each	1	$ 10,391.40	$ 10,391
	Diversion and Return Piping	Each	1	$ 2,078.28	$ 2,078
	Subtotal				$ 42,201
Subtotal Construction Costs					**$ 339,661**
	Design Contingency (30%)				$ 67,932
	Engineering and Administration (20%)				$ 67,932
Total Estimated Improvement Cost (Rounded)					$ 476,000

Improvement ID: *GC_09*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 50,931
Mobilization (6%)				$ 30,558
Traffic Control (5%)				$ 25,465
Misc. Utility Relocation (5%)				$ 25,465
Subtotal				$ 132,420
Pipe Improvements				
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	457	$ 30.67	$ 14,016
Pipe				
24" RCP - 6' Depth to Invert	LF	442	$ 130.14	$ 57,522
30" RCP - 6' Depth to Invert	LF	235	$ 152.28	$ 35,786
Surface Restoration				
Type 1 (Asphalt Patch)	LF	677	$ 51.38	$ 34,784
Manholes				
60" Dia and Smaller	Each	7	$ 4,618.40	$ 32,329
Curb Inlets (Type R)	Each	28	$ 7,273.98	$ 203,671
Subtotal				$ 379,308
Water Quality Ponds				
Excavation and shaping	CY	1,511	$ 23.09	$ 34,895
Amended topsoil and preparation	CY	756	$ 18.47	$ 13,958
Wetland vegetation	SF	40,800	$ 1.85	$ 75,372
Outlet structure	EA	1	$ 5,773.00	$ 5,773
Subtotal				$ 129,998
Subtotal Construction Costs				**$ 641,725**
Design Contingency (30%)				$ 128,345
Engineering and Administration (20%)				$ 128,345
Land Acquisition	SF	4,400	$ 13.12	$ 57,745
Total Estimated Improvement Cost (Rounded)				$ 957,000

Improvement ID: *ETC_01*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 36,188
Mobilization (6%)				$ 21,713
Traffic Control (5%)				$ 18,094
Misc. Utility Relocation (5%)				$ 18,094
Subtotal				$ 94,089
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 9,992
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	220	$ 30.67	$ 6,747
Pipe				
36" RCP - 6' Depth to Invert	LF	216	$ 186.84	$ 40,357
42" RCP - 8' Depth to Invert	LF	121	$ 218.78	$ 26,472
48" RCP - 8' Depth to Invert	LF	556	$ 239.24	$ 133,019
Manholes				
60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
Curb Inlets (Type R)	Each	16	$ 7,273.98	$ 116,384
Subtotal				$ 361,882
Subtotal Construction Costs				**$ 455,971**
Design Contingency (30%)				$ 91,194
Engineering and Administration (20%)				$ 91,194
Total Estimated Improvement Cost (Rounded)				$ 639,000

Improvement ID: *MBC_23*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 25,204
Mobilization (6%)				$ 15,122
Traffic Control (5%)				$ 12,602
Misc. Utility Relocation (5%)				$ 12,602
Subtotal				$ 65,531
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 2,284
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	300	$ 30.67	$ 9,201
Pipe				
30" RCP - 6' Depth to Invert	LF	300	$ 152.28	$ 45,684
Surface Restoration				
Type 1 (Asphalt Patch)	LF	300	$ 51.38	$ 15,414
Manholes				
60" Dia and Smaller	Each	4	$ 4,618.40	$ 18,474
Curb Inlets (Type R)	Each	16	$ 7,273.98	$ 116,384
Subtotal				$ 209,840
Water Quality Manholes				
8-foot Diameter (7.1 cfs)	Each	1	$ 29,730.95	$ 29,731
Diversion Manhole	Each	1	$ 10,391.40	$ 10,391
Diversion and Return Piping	Each	1	$ 2,078.28	$ 2,078
Subtotal				$ 42,201
Subtotal Construction Costs				**$ 317,572**
Design Contingency (30%)				$ 63,514
Engineering and Administration (20%)				$ 63,514
Total Estimated Improvement Cost (Rounded)				$ 445,000

Improvement ID: *DC2_06*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 36,110
Mobilization (6%)				$ 21,666
Traffic Control (5%)				$ 18,055
Misc. Utility Relocation (5%)				$ 18,055
Subtotal				$ 93,887
Pipe Improvements				
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	403	$ 30.67	$ 12,360
Pipe				
24" RCP - 6' Depth to Invert	LF	235	$ 130.14	$ 30,583
30" RCP - 6' Depth to Invert	LF	168	$ 152.28	$ 25,583
Surface Restoration				
Type 1 (Asphalt Patch)	LF	403	$ 51.38	$ 20,706
Manholes				
60" Dia and Smaller	Each	5	$ 4,618.40	$ 23,092
Curb Inlets (Type R)	Each	20	$ 7,273.98	$ 145,480
Subtotal				$ 261,404
Water Quality Manholes				
8-foot Diameter (7.1 cfs)	Each	1	$ 29,730.95	$ 29,731
10-foot Diameter (13 cfs)	Each	1	$ 45,029.40	$ 45,029
Diversion Manhole	Each	2	$ 10,391.40	$ 20,783
Diversion and Return Piping	Each	2	$ 2,078.28	$ 4,157
Subtotal				$ 99,700
Subtotal Construction Costs				**$ 454,990**
Design Contingency (30%)				$ 90,998
Engineering and Administration (20%)				$ 90,998
Total Estimated Improvement Cost (Rounded)				$ 637,000

Improvement ID: *SC_02*

Description		Units	Quantity	it Cost (Updat	Item Cost
General					
	Insurance and Bonding (10%)				$ 64,302
	Mobilization (6%)				$ 38,581
	Traffic Control (5%)				$ 32,151
	Misc. Utility Relocation (5%)				$ 32,151
	Subtotal				$ 167,185
Pipe Improvements					
	Dewatering (5% of Pipe Cost)				$ 12,128
	Connect to Existing	Each	3	$ 1,200.00	$ 3,600
	Removal and Disposal of Pipe (up to 36-inch)	LF	1,240	$ 30.67	$ 38,031
	Pipe				
	30" RCP - 6' Depth to Invert	LF	348	$ 152.28	$ 52,993
	36" RCP - 6' Depth to Invert	LF	379	$ 186.84	$ 70,812
	48" RCP - 6' Depth to Invert	LF	513	$ 231.49	$ 118,752
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	1,240	$ 51.38	$ 63,711
	Manholes				
	60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
	Curb Inlets (Type R)	Each	32	$ 7,273.98	$ 232,767
	Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
	Subtotal				$ 643,020
Subtotal Construction Costs					**$ 810,206**
	Design Contingency (30%)				$ 162,041
	Engineering and Administration (20%)				$ 162,041
Total Estimated Improvement Cost (Rounded)					$ 1,135,000

Improvement ID: *MBC_09*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 69,349
Mobilization (6%)				$ 41,609
Traffic Control (5%)				$ 34,674
Misc. Utility Relocation (5%)				$ 34,674
Subtotal				$ 180,306
Pipe Improvements				
Connect to Existing	Each	4	$ 1,200.00	$ 4,800
Removal and Disposal of Pipe (up to 36-inch)	LF	1,430	$ 30.67	$ 43,858
Pipe				
24" RCP - 6' Depth to Invert	LF	306	$ 130.14	$ 39,823
30" RCP - 8' Depth to Invert	LF	381	$ 152.28	$ 58,019
48" RCP - 10' Depth to Invert	LF	743	$ 247.00	$ 183,519
Surface Restoration				
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	1,430	$ 103.02	$ 147,326
Manholes				
60" Dia and Smaller	Each	3	$ 4,618.40	$ 13,855
Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
Subtotal				$ 693,486
Subtotal Construction Costs				**$ 873,792**
Design Contingency (30%)				$ 174,758
Engineering and Administration (20%)				$ 174,758
Total Estimated Improvement Cost (Rounded)				$ 1,224,000

Improvement ID: *BCC_03*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 85,692
Mobilization (6%)				$ 51,415
Traffic Control (5%)				$ 42,846
Misc. Utility Relocation (5%)				$ 42,846
Subtotal				$ 222,800
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	1,586	$ 30.67	$ 48,643
Pipe				
18" RCP - 8' Depth to Invert	LF	520	$ 94.50	$ 49,140
24" RCP - 10' Depth to Invert	LF	1,310	$ 130.14	$ 170,483
30" RCP - 8' Depth to Invert	LF	401	$ 152.28	$ 61,064
36" RCP - 6' Depth to Invert	LF	255	$ 186.84	$ 47,644
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,666	$ 51.38	$ 85,599
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	820	$ 103.02	$ 84,480
Manholes				
60" Dia and Smaller	Each	9	$ 4,618.40	$ 41,566
Curb Inlets (Type R)	Each	36	$ 7,273.98	$ 261,863
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 856,924
Subtotal Construction Costs				**$ 1,079,724**
Design Contingency (30%)				$ 215,945
Engineering and Administration (20%)				$ 215,945
Total Estimated Improvement Cost (Rounded)				$ 1,512,000

Improvement ID: *MBC_18*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 97,068
Mobilization (6%)				$ 58,241
Traffic Control (5%)				$ 48,534
Misc. Utility Relocation (5%)				$ 48,534
Subtotal				$ 252,378
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 20,722
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	1,866	$ 30.67	$ 57,230
Pipe				
30" RCP - 6' Depth to Invert	LF	542	$ 152.28	$ 82,536
42" RCP - 8' Depth to Invert	LF	118	$ 218.78	$ 25,815
30" RCP - 8' Depth to Invert	LF	397	$ 152.28	$ 60,455
54" RCP - 10' Depth to Invert	LF	809	$ 303.62	$ 245,628
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,866	$ 51.38	$ 95,875
Manholes				
60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
72" and Larger	Each	3	$ 9,236.80	$ 27,710
Curb Inlets (Type R)	Each	36	$ 7,273.98	$ 261,863
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 913,186
Water Quality Manholes				
10-foot Diameter (13 cfs)	Each	1	$ 45,029.40	$ 45,029
Diversion Manhole	Each	1	$ 10,391.40	$ 10,391
Diversion and Return Piping	Each	1	$ 2,078.28	$ 2,078
Subtotal				$ 57,499
Subtotal Construction Costs				**$ 1,223,063**
Design Contingency (30%)				$ 244,613
Engineering and Administration (20%)				$ 244,613
Land Acquisition	SF	800	$ 13.12	$ 10,499
Total Estimated Improvement Cost (Rounded)				$ 1,723,000

Improvement ID: *MBC_19*

Description	Units	Quantity	it Cost (Updat	Item Cost
General				
Insurance and Bonding (10%)				$ 28,003
Mobilization (6%)				$ 16,802
Traffic Control (5%)				$ 14,001
Misc. Utility Relocation (5%)				$ 14,001
Subtotal				$ 72,807
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 3,494
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	537	$ 30.67	$ 16,470
Pipe				
24" RCP - 8' Depth to Invert	LF	537	$ 130.14	$ 69,885
Surface Restoration				
Type 1 (Asphalt Patch)	LF	350	$ 51.38	$ 17,983
Manholes				
60" Dia and Smaller	Each	4	$ 4,618.40	$ 18,474
Curb Inlets (Type R)	Each	16	$ 7,273.98	$ 116,384
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 247,931
Water Quality Manholes				
6-foot Diameter (3 cfs)	Each	1	$ 19,628.20	$ 19,628
Diversion Manhole	Each	1	$ 10,391.40	$ 10,391
Diversion and Return Piping	Each	1	$ 2,078.28	$ 2,078
Subtotal				$ 32,098
Subtotal Construction Costs				**$ 352,836**
Design Contingency (30%)				$ 70,567
Engineering and Administration (20%)				$ 70,567
Land Acquisition	SF	800	$ 13.12	$ 10,499
Total Estimated Improvement Cost (Rounded)				$ 505,000

Boulder SMP Collector System Recommended Plan Projects Tier 3 Cost

Rank	Subbasin	ID	Improvement Type	Priority	Cost
33	Bear Canyon Creek	BCC_01	Hydraulic Improvement	Tier 3	$ 1,132,000
36	Bear Canyon Creek	BCC_02	Hydraulic Improvement	Tier 3	$ 184,000
27	Bear Canyon Creek	BCC_04	Hydraulic Improvement	Tier 3	$ 540,000
36	Bear Canyon Creek	BCC_05	Hydraulic Improvement	Tier 3	$ 200,000
36	Bear Canyon Creek	BCC_06	Hydraulic Improvement	Tier 3	$ 373,000
36	Bear Canyon Creek	BCC_07	Hydraulic Improvement	Tier 3	$ 428,000
36	Dry Creek	DC_02	Hydraulic Improvement	Tier 3	$ 411,000
26	Dry Creek No. 2	DC2_01	Hydraulic Improvement	Tier 2	$ 1,226,000
50	Dry Creek No. 2	DC2_03	Hydraulic Improvement	Tier 3	$ 603,000
30	Dry Creek No. 2	DC2_04	Hydraulic Improvement	Tier 3	$ 664,000
27	Dry Creek No. 2	DC2_05	Hydraulic Improvement	Tier 3	$ 770,000
48	Elmers Twomile Creek	ETC_03	Hydraulic Improvement	Tier 3	$ 1,109,000
35	Fourmile Canyon Creek	FCC_01	Hydraulic Improvement	Tier 3	$ 863,000
30	Goose Creek	GC_03	Hydraulic Improvement	Tier 3	$ 819,000
49	Goose Creek	GC_05	Hydraulic Improvement	Tier 3	$ 810,000
29	Goose Creek	GC_06	Hydraulic Improvement	Tier 3	$ 933,000
36	Goose Creek	GC_07	Hydraulic Improvement	Tier 3	$ 184,000
53	Middle Boulder Creek	MBC_01	Hydraulic Improvement	Tier 3	$ 177,000
36	Middle Boulder Creek	MBC_02	Hydraulic Improvement	Tier 3	$ 267,000
50	Middle Boulder Creek	MBC_08	Hydraulic Improvement	Tier 3	$ 1,209,000
30	Middle Boulder Creek	MBC_13	Hydraulic Improvement	Tier 3	$ 754,000
50	Middle Boulder Creek	MBC_15	Hydraulic Improvement	Tier 3	$ 139,000
55	Middle Boulder Creek	MBC_17	Hydraulic Improvement	Tier 3	$ 480,000
36	Middle Boulder Creek	MBC_19	Combined Hydraulic/Water Quality Improvement	Tier 3	$ 408,000
54	Middle Boulder Creek	MBC_21	Hydraulic Improvement	Tier 3	$ 221,000
22	Viele Channel	VC_01	Hydraulic Improvement	Tier 3	$ 1,296,000
23	Viele Channel	VC_02	Hydraulic Improvement	Tier 3	$ 1,655,000
36	Wonderland Creek	WC_01	Hydraulic Improvement	Tier 3	$ 324,000
33	Wonderland Creek	WC_02	Hydraulic Improvement	Tier 3	$ 402,000
				Total	$ 18,581,000

Improvement ID: *VC_01*

	Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 73,434
	Mobilization (6%)				$ 44,060
	Traffic Control (5%)				$ 36,717
	Misc. Utility Relocation (5%)				$ 36,717
	Subtotal				$ 190,928
Pipe Improvements					
	Connect to Existing	Each	4	$ 1,200.00	$ 4,800
	Removal and Disposal of Pipe (up to 36-inch)	LF	2,649	$ 30.67	$ 81,245
	Pipe				
	24" RCP - 10' Depth to Invert	LF	863	$ 130.14	$ 112,311
	36" RCP - 8' Depth to Invert	LF	1,786	$ 186.84	$ 333,696
	Manholes				
	60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
	Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
	Subtotal				$ 734,338
Subtotal Construction Costs					**$ 925,266**
	Design Contingency (30%)				$ 185,053
	Engineering and Administration (20%)				$ 185,053
Total Estimated Improvement Cost (Rounded)					$ 1,296,000

Improvement ID: *VC_02*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 93,788
Mobilization (6%)				$ 56,273
Traffic Control (5%)				$ 46,894
Misc. Utility Relocation (5%)				$ 46,894
Subtotal				$ 243,848
Pipe Improvements				
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	2,403	$ 30.67	$ 73,700
Pipe				
18" RCP - 6' Depth to Invert	LF	221	$ 94.50	$ 20,885
30" RCP - 6' Depth to Invert	LF	1,920	$ 152.28	$ 292,378
36" RCP - 6' Depth to Invert	LF	262	$ 186.84	$ 48,952
Surface Restoration				
Type 1 (Asphalt Patch)	LF	2,403	$ 51.38	$ 123,465
Manholes				
60" Dia and Smaller	Each	11	$ 4,618.40	$ 50,802
Curb Inlets (Type R)	Each	44	$ 7,273.98	$ 320,055
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 937,878
Subtotal Construction Costs				**$ 1,181,727**
Design Contingency (30%)				$ 236,345
Engineering and Administration (20%)				$ 236,345
Total Estimated Improvement Cost (Rounded)				$ 1,655,000

Improvement ID: *DC2_01*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 69,467
Mobilization (6%)				$ 41,680
Traffic Control (5%)				$ 34,734
Misc. Utility Relocation (5%)				$ 34,734
Subtotal				$ 180,615
Pipe Improvements				
Connect to Existing	Each	5	$ 1,200.00	$ 6,000
Removal and Disposal of Pipe (up to 36-inch)	LF	1,641	$ 30.67	$ 50,329
Pipe				
24" RCP - 10' Depth to Invert	LF	284	$ 130.14	$ 36,960
42" RCP - 8' Depth to Invert	LF	1,248	$ 218.78	$ 273,031
54" RCP - 10' Depth to Invert	LF	109	$ 303.62	$ 33,094
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,641	$ 51.38	$ 84,314
Manholes				
60" Dia and Smaller	Each	5	$ 4,618.40	$ 23,092
72" and Larger	Each	1	$ 9,236.80	$ 9,237
Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 694,674
Subtotal Construction Costs				**$ 875,290**
Design Contingency (30%)				$ 175,058
Engineering and Administration (20%)				$ 175,058
Total Estimated Improvement Cost (Rounded)				$ 1,226,000

Improvement ID: *BCC_04*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 30,600
Mobilization (6%)				$ 18,360
Traffic Control (5%)				$ 15,300
Misc. Utility Relocation (5%)				$ 15,300
Subtotal				$ 79,560
Pipe Improvements				
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	1,017	$ 30.67	$ 31,191
Pipe				
18" RCP - 6' Depth to Invert	LF	454	$ 94.50	$ 42,903
24" RCP - 6' Depth to Invert	LF	563	$ 130.14	$ 73,269
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,017	$ 51.38	$ 52,253
Manholes				
60" Dia and Smaller	Each	3	$ 4,618.40	$ 13,855
Curb Inlets (Type R)	Each	12	$ 7,273.98	$ 87,288
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 306,000
Subtotal Construction Costs				**$ 385,561**
Design Contingency (30%)				$ 77,112
Engineering and Administration (20%)				$ 77,112
Total Estimated Improvement Cost (Rounded)				$ 540,000

Improvement ID: *DC2_05*

Description		Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 43,615
	Mobilization (6%)				$ 26,169
	Traffic Control (5%)				$ 21,807
	Misc. Utility Relocation (5%)				$ 21,807
	Subtotal				$ 113,398
Pipe Improvements					
	Connect to Existing	Each	1	$ 1,200.00	$ 1,200
	Removal and Disposal of Pipe (up to 36-inch)	LF	1,191	$ 30.67	$ 36,528
	Pipe				
	30" RCP - 6' Depth to Invert	LF	955	$ 152.28	$ 145,427
	36" RCP - 6' Depth to Invert	LF	236	$ 186.84	$ 44,094
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	50	$ 51.38	$ 2,569
	Manholes				
	60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
	Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
	Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
	Subtotal				$ 436,146
Subtotal Construction Costs					**$ 549,543**
	Design Contingency (30%)				$ 109,909
	Engineering and Administration (20%)				$ 109,909
Total Estimated Improvement Cost (Rounded)					$ 770,000

Improvement ID: *GC_06*

Description		Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 52,857
	Mobilization (6%)				$ 31,714
	Traffic Control (5%)				$ 26,428
	Misc. Utility Relocation (5%)				$ 26,428
	Subtotal				$ 137,428
Pipe Improvements					
	Dewatering (5% of Pipe Cost)				$ 353
	Connect to Existing	Each	3	$ 1,200.00	$ 3,600
	Removal and Disposal of Pipe (up to 36-inch)	LF	1,247	$ 30.67	$ 38,245
	Pipe				
	24" RCP - 6' Depth to Invert	LF	41	$ 130.14	$ 5,336
	30" RCP - 6' Depth to Invert	LF	679	$ 152.28	$ 103,398
	42" RCP - 6' Depth to Invert	LF	527	$ 211.16	$ 111,279
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	1,247	$ 51.38	$ 64,070
	Manholes				
	60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
	Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
	Subtotal				$ 528,568
Subtotal Construction Costs					**$ 665,995**
	Design Contingency (30%)				$ 133,199
	Engineering and Administration (20%)				$ 133,199
Total Estimated Improvement Cost (Rounded)					$ 933,000

Improvement ID: *DC2_04*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 37,632
Mobilization (6%)				$ 22,579
Traffic Control (5%)				$ 18,816
Misc. Utility Relocation (5%)				$ 18,816
Subtotal				$ 97,844
Pipe Improvements				
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	1,056	$ 30.67	$ 32,388
Pipe				
24" RCP - 8' Depth to Invert	LF	1,056	$ 130.14	$ 137,428
Surface Restoration				
Type 1 (Asphalt Patch)	LF	715	$ 51.38	$ 36,736
Manholes				
60" Dia and Smaller	Each	5	$ 4,618.40	$ 23,092
Curb Inlets (Type R)	Each	20	$ 7,273.98	$ 145,480
Subtotal				$ 376,323
Subtotal Construction Costs				**$ 474,168**
Design Contingency (30%)				$ 94,834
Engineering and Administration (20%)				$ 94,834
Total Estimated Improvement Cost (Rounded)				$ 664,000

Improvement ID: *MBC_13*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 42,724
Mobilization (6%)				$ 25,634
Traffic Control (5%)				$ 21,362
Misc. Utility Relocation (5%)				$ 21,362
Subtotal				$ 111,081
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 2,029
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	774	$ 30.67	$ 23,739
Pipe				
36" RCP - 6' Depth to Invert	LF	264	$ 186.84	$ 49,326
42" RCP - 6' Depth to Invert	LF	510	$ 211.16	$ 107,689
Surface Restoration				
Type 1 (Asphalt Patch)	LF	774	$ 51.38	$ 39,768
Manholes				
60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
Subtotal				$ 427,236
Subtotal Construction Costs				**$ 538,318**
Design Contingency (30%)				$ 107,664
Engineering and Administration (20%)				$ 107,664
Total Estimated Improvement Cost (Rounded)				$ 754,000

Improvement ID: *GC_03*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 46,417
Mobilization (6%)				$ 27,850
Traffic Control (5%)				$ 23,209
Misc. Utility Relocation (5%)				$ 23,209
Subtotal				$ 120,685
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 148
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	1,255	$ 30.67	$ 38,491
Pipe				
24" RCP - 10' Depth to Invert	LF	229	$ 130.14	$ 29,802
30" RCP - 8' Depth to Invert	LF	1,026	$ 152.28	$ 156,239
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,255	$ 51.38	$ 64,482
Manholes				
60" Dia and Smaller	Each	5	$ 4,618.40	$ 23,092
Curb Inlets (Type R)	Each	20	$ 7,273.98	$ 145,480
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 464,175
Subtotal Construction Costs				**$ 584,860**
Design Contingency (30%)				$ 116,972
Engineering and Administration (20%)				$ 116,972
Total Estimated Improvement Cost (Rounded)				$ 819,000

Improvement ID: *WC_02*

Description		Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 22,758
	Mobilization (6%)				$ 13,655
	Traffic Control (5%)				$ 11,379
	Misc. Utility Relocation (5%)				$ 11,379
	Subtotal				$ 59,170
Pipe Improvements					
	Connect to Existing	Each	2	$ 1,200.00	$ 2,400
	Removal and Disposal of Pipe (up to 36-inch)	LF	352	$ 30.67	$ 10,796
	Pipe				
	24" RCP - 6' Depth to Invert	LF	352	$ 130.14	$ 45,809
	Manholes				
	60" Dia and Smaller	Each	5	$ 4,618.40	$ 23,092
	Curb Inlets (Type R)	Each	20	$ 7,273.98	$ 145,480
	Subtotal				$ 227,577
Subtotal Construction Costs					**$ 286,747**
	Design Contingency (30%)				$ 57,349
	Engineering and Administration (20%)				$ 57,349
Total Estimated Improvement Cost (Rounded)					$ 402,000

Improvement ID: *BCC_01*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 64,168
Mobilization (6%)				$ 38,501
Traffic Control (5%)				$ 32,084
Misc. Utility Relocation (5%)				$ 32,084
Subtotal				$ 166,837
Pipe Improvements				
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	1,785	$ 30.67	$ 54,746
Pipe				
24" RCP - 6' Depth to Invert	LF	546	$ 130.14	$ 71,056
30" RCP - 6' Depth to Invert	LF	776	$ 152.28	$ 118,169
42" RCP - 6' Depth to Invert	LF	463	$ 211.16	$ 97,765
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,165	$ 51.38	$ 59,857
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	620	$ 103.02	$ 63,875
Manholes				
60" Dia and Smaller	Each	5	$ 4,618.40	$ 23,092
Curb Inlets (Type R)	Each	20	$ 7,273.98	$ 145,480
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 641,682
Subtotal Construction Costs				**$ 808,520**
Design Contingency (30%)				$ 161,704
Engineering and Administration (20%)				$ 161,704
Total Estimated Improvement Cost (Rounded)				$ 1,132,000

Improvement ID: *FCC_01*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 48,884
Mobilization (6%)				$ 29,330
Traffic Control (5%)				$ 24,442
Misc. Utility Relocation (5%)				$ 24,442
Subtotal				$ 127,098
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	781	$ 30.67	$ 23,953
Pipe				
30" RCP - 6' Depth to Invert	LF	781	$ 152.28	$ 118,931
Surface Restoration				
Type 1 (Asphalt Patch)	LF	781	$ 51.38	$ 40,128
Manholes				
60" Dia and Smaller	Each	9	$ 4,618.40	$ 41,566
Curb Inlets (Type R)	Each	36	$ 7,273.98	$ 261,863
Subtotal				$ 488,840
Subtotal Construction Costs				**$ 615,939**
Design Contingency (30%)				$ 123,188
Engineering and Administration (20%)				$ 123,188
Total Estimated Improvement Cost (Rounded)				$ 863,000

Improvement ID: *DC_02*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 23,295
Mobilization (6%)				$ 13,977
Traffic Control (5%)				$ 11,648
Misc. Utility Relocation (5%)				$ 11,648
Subtotal				$ 60,568
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	451	$ 30.67	$ 13,832
Pipe				
24" RCP - 8' Depth to Invert	LF	451	$ 130.14	$ 58,693
Surface Restoration				
Type 1 (Asphalt Patch)	LF	451	$ 51.38	$ 23,172
Manholes				
60" Dia and Smaller	Each	4	$ 4,618.40	$ 18,474
Curb Inlets (Type R)	Each	16	$ 7,273.98	$ 116,384
Subtotal				$ 232,955
Subtotal Construction Costs				**$ 293,523**
Design Contingency (30%)				$ 58,705
Engineering and Administration (20%)				$ 58,705
Total Estimated Improvement Cost (Rounded)				$ 411,000

Improvement ID: *GC_07*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 10,426
Mobilization (6%)				$ 6,255
Traffic Control (5%)				$ 5,213
Misc. Utility Relocation (5%)				$ 5,213
Subtotal				$ 27,107
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	195	$ 30.67	$ 5,981
Pipe				
18" RCP - 6' Depth to Invert	LF	195	$ 94.50	$ 18,428
Surface Restoration				
Type 1 (Asphalt Patch)	LF	195	$ 51.38	$ 10,019
Manholes				
60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
Subtotal				$ 104,256
Subtotal Construction Costs				**$ 131,362**
Design Contingency (30%)				$ 26,272
Engineering and Administration (20%)				$ 26,272
Total Estimated Improvement Cost (Rounded)				$ 184,000

Improvement ID: *WC_01*

	Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 18,314
	Mobilization (6%)				$ 10,988
	Traffic Control (5%)				$ 9,157
	Misc. Utility Relocation (5%)				$ 9,157
	Subtotal				$ 47,616
Pipe Improvements					
	Connect to Existing	Each	2	$ 1,200.00	$ 2,400
	Removal and Disposal of Pipe (up to 36-inch)	LF	534	$ 30.67	$ 16,378
	Pipe				
	24" RCP - 6' Depth to Invert	LF	534	$ 130.14	$ 69,495
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	534	$ 51.38	$ 27,437
	Manholes				
	60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
	Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
	Subtotal				$ 183,138
Subtotal Construction Costs					**$ 230,754**
	Design Contingency (30%)				$ 46,151
	Engineering and Administration (20%)				$ 46,151
Total Estimated Improvement Cost (Rounded)					$ 324,000

Improvement ID: *MBC_02*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 15,110
Mobilization (6%)				$ 9,066
Traffic Control (5%)				$ 7,555
Misc. Utility Relocation (5%)				$ 7,555
Subtotal				$ 39,285
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	383	$ 30.67	$ 11,747
Pipe				
24" RCP - 6' Depth to Invert	LF	383	$ 130.14	$ 49,844
Surface Restoration				
Type 1 (Asphalt Patch)	LF	383	$ 51.38	$ 19,678
Manholes				
60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
Subtotal				$ 151,097
Subtotal Construction Costs				**$ 190,383**
Design Contingency (30%)				$ 38,077
Engineering and Administration (20%)				$ 38,077
Total Estimated Improvement Cost (Rounded)				$ 267,000

Improvement ID: *BCC_07*

	Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 24,258
	Mobilization (6%)				$ 14,555
	Traffic Control (5%)				$ 12,129
	Misc. Utility Relocation (5%)				$ 12,129
	Subtotal				$ 63,072
Pipe Improvements					
	Connect to Existing	Each	2	$ 1,200.00	$ 2,400
	Removal and Disposal of Pipe (up to 36-inch)	LF	527	$ 30.67	$ 16,163
	Pipe				
	24" RCP - 6' Depth to Invert	LF	527	$ 130.14	$ 68,584
	Surface Restoration				
	Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	527	$ 103.02	$ 54,294
	Manholes				
	60" Dia and Smaller	Each	3	$ 4,618.40	$ 13,855
	Curb Inlets (Type R)	Each	12	$ 7,273.98	$ 87,288
	Subtotal				$ 242,584
Subtotal Construction Costs					**$ 305,656**
	Design Contingency (30%)				$ 61,131
	Engineering and Administration (20%)				$ 61,131
Total Estimated Improvement Cost (Rounded)					$ 428,000

Improvement ID: *BCC_02*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 10,378
Mobilization (6%)				$ 6,227
Traffic Control (5%)				$ 5,189
Misc. Utility Relocation (5%)				$ 5,189
Subtotal				$ 26,983
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	160	$ 30.67	$ 4,907
Pipe				
24" RCP - 8' Depth to Invert	LF	160	$ 130.14	$ 20,822
Surface Restoration				
Type 1 (Asphalt Patch)	LF	160	$ 51.38	$ 8,221
Manholes				
60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
Subtotal				$ 103,779
Subtotal Construction Costs				**$ 130,762**
Design Contingency (30%)				$ 26,152
Engineering and Administration (20%)				$ 26,152
Total Estimated Improvement Cost (Rounded)				$ 184,000

Improvement ID: *BCC_06*

Description		Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 21,100
	Mobilization (6%)				$ 12,660
	Traffic Control (5%)				$ 10,550
	Misc. Utility Relocation (5%)				$ 10,550
	Subtotal				$ 54,859
Pipe Improvements					
	Connect to Existing	Each	3	$ 1,200.00	$ 3,600
	Removal and Disposal of Pipe (up to 36-inch)	LF	1,295	$ 30.67	$ 39,718
	Pipe				
	24" RCP - 20' Depth to Invert	LF	256	$ -	$ -
	36" RCP - 20' Depth to Invert	LF	1,039	$ -	$ -
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	1,295	$ 51.38	$ 66,537
	Manholes				
	60" Dia and Smaller	Each	3	$ 4,618.40	$ 13,855
	Curb Inlets (Type R)	Each	12	$ 7,273.98	$ 87,288
	Subtotal				$ 210,997
Subtotal Construction Costs					**$ 265,857**
	Design Contingency (30%)				$ 53,171
	Engineering and Administration (20%)				$ 53,171
Total Estimated Improvement Cost (Rounded)					$ 373,000

Improvement ID: *BCC_05*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 11,309
Mobilization (6%)				$ 6,785
Traffic Control (5%)				$ 5,654
Misc. Utility Relocation (5%)				$ 5,654
Subtotal				$ 29,403
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,594
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	245	$ 30.67	$ 7,514
Pipe				
24" RCP - 6' Depth to Invert	LF	245	$ 130.14	$ 31,884
Surface Restoration				
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	22	$ 103.02	$ 2,267
Manholes				
60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
Subtotal				$ 113,088
Subtotal Construction Costs				**$ 142,491**
Design Contingency (30%)				$ 28,498
Engineering and Administration (20%)				$ 28,498
Total Estimated Improvement Cost (Rounded)				$ 200,000

Improvement ID: *ETC_03*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 62,816
Mobilization (6%)				$ 37,689
Traffic Control (5%)				$ 31,408
Misc. Utility Relocation (5%)				$ 31,408
Subtotal				$ 163,321
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 2,896
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	1,317	$ 30.67	$ 40,392
Pipe				
24" RCP - 6' Depth to Invert	LF	700	$ 130.14	$ 91,098
30" RCP - 6' Depth to Invert	LF	454	$ 152.28	$ 69,135
36" RCP - 6' Depth to Invert	LF	163	$ 186.84	$ 30,455
Surface Restoration				
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	830	$ 103.02	$ 85,511
Manholes				
60" Dia and Smaller	Each	9	$ 4,618.40	$ 41,566
Curb Inlets (Type R)	Each	36	$ 7,273.98	$ 261,863
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 628,157
Subtotal Construction Costs				**$ 791,478**
Design Contingency (30%)				$ 158,296
Engineering and Administration (20%)				$ 158,296
Total Estimated Improvement Cost (Rounded)				$ 1,109,000

Improvement ID: *GC_05*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 45,917
Mobilization (6%)				$ 27,550
Traffic Control (5%)				$ 22,958
Misc. Utility Relocation (5%)				$ 22,958
Subtotal				$ 119,384
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 749
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	949	$ 30.67	$ 29,106
Pipe				
24" RCP - 6' Depth to Invert	LF	361	$ 130.14	$ 46,981
30" RCP - 6' Depth to Invert	LF	425	$ 152.28	$ 64,719
36" RCP - 6' Depth to Invert	LF	163	$ 186.84	$ 30,455
Surface Restoration				
Type 1 (Asphalt Patch)	LF	949	$ 51.38	$ 48,759
Manholes				
60" Dia and Smaller	Each	7	$ 4,618.40	$ 32,329
Curb Inlets (Type R)	Each	28	$ 7,273.98	$ 203,671
Subtotal				$ 459,169
Subtotal Construction Costs				**$ 578,553**
Design Contingency (30%)				$ 115,711
Engineering and Administration (20%)				$ 115,711
Total Estimated Improvement Cost (Rounded)				$ 810,000

Improvement ID: *MBC_15*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 7,848
Mobilization (6%)				$ 4,709
Traffic Control (5%)				$ 3,924
Misc. Utility Relocation (5%)				$ 3,924
Subtotal				$ 20,405
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 208
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	32	$ 30.67	$ 981
Pipe				
24" RCP - 6' Depth to Invert	LF	32	$ 130.14	$ 4,164
Surface Restoration				
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	32	$ 103.02	$ 3,297
Manholes				
60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
Subtotal				$ 78,480
Subtotal Construction Costs				**$ 98,884**
Design Contingency (30%)				$ 19,777
Engineering and Administration (20%)				$ 19,777
Total Estimated Improvement Cost (Rounded)				$ 139,000

Improvement ID: *MBC_08*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 68,486
Mobilization (6%)				$ 41,092
Traffic Control (5%)				$ 34,243
Misc. Utility Relocation (5%)				$ 34,243
Subtotal				$ 178,063
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ -
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	1,152	$ 30.67	$ 35,332
Pipe				
36" RCP - 6' Depth to Invert	LF	185	$ 186.84	$ 34,565
42" RCP - 6' Depth to Invert	LF	581	$ 211.16	$ 122,682
48" RCP - 8' Depth to Invert	LF	386	$ 239.24	$ 92,347
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,152	$ 51.38	$ 59,189
Manholes				
60" Dia and Smaller	Each	10	$ 4,618.40	$ 46,184
Curb Inlets (Type R)	Each	40	$ 7,273.98	$ 290,959
Pipe Outfall (Incl. permanent erosion protection)	Each	-	$ 4,041.10	$ -
Subtotal				$ 684,859
Subtotal Construction Costs				**$ 862,922**
Design Contingency (30%)				$ 172,584
Engineering and Administration (20%)				$ 172,584
Total Estimated Improvement Cost (Rounded)				$ 1,209,000

Improvement ID: *DC2_03*

Description		Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 34,163
	Mobilization (6%)				$ 20,498
	Traffic Control (5%)				$ 17,082
	Misc. Utility Relocation (5%)				$ 17,082
	Subtotal				$ 88,824
Pipe Improvements					
	Connect to Existing	Each	2	$ 1,200.00	$ 2,400
	Removal and Disposal of Pipe (up to 36-inch)	LF	722	$ 30.67	$ 22,144
	Pipe				
	24" RCP - 6' Depth to Invert	LF	116	$ 130.14	$ 15,096
	30" RCP - 6' Depth to Invert	LF	606	$ 152.28	$ 92,282
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	722	$ 51.38	$ 37,096
	Manholes				
	60" Dia and Smaller	Each	5	$ 4,618.40	$ 23,092
	Curb Inlets (Type R)	Each	20	$ 7,273.98	$ 145,480
	Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
	Subtotal				$ 341,631
Subtotal Construction Costs					**$ 430,454**
	Design Contingency (30%)				$ 86,091
	Engineering and Administration (20%)				$ 86,091
Total Estimated Improvement Cost (Rounded)					$ 603,000

Improvement ID: *MBC_01*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 9,984
Mobilization (6%)				$ 5,991
Traffic Control (5%)				$ 4,992
Misc. Utility Relocation (5%)				$ 4,992
Subtotal				$ 25,959
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	170	$ 30.67	$ 5,214
Pipe				
18" RCP - 6' Depth to Invert	LF	170	$ 94.50	$ 16,065
Surface Restoration				
Type 1 (Asphalt Patch)	LF	170	$ 51.38	$ 8,735
Manholes				
60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
Subtotal				$ 99,842
Subtotal Construction Costs				**$ 125,801**
Design Contingency (30%)				$ 25,160
Engineering and Administration (20%)				$ 25,160
Total Estimated Improvement Cost (Rounded)				$ 177,000

Improvement ID: *MBC_21*

Description		Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General					
	Insurance and Bonding (10%)				$ 12,497
	Mobilization (6%)				$ 7,498
	Traffic Control (5%)				$ 6,248
	Misc. Utility Relocation (5%)				$ 6,248
	Subtotal				$ 32,491
Pipe Improvements					
	Connect to Existing	Each	1	$ 1,200.00	$ 1,200
	Removal and Disposal of Pipe (up to 36-inch)	LF	197	$ 30.67	$ 6,042
	Pipe				
	30" RCP - 6' Depth to Invert	LF	197	$ 152.28	$ 29,999
	Surface Restoration				
	Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	197	$ 103.02	$ 20,296
	Manholes				
	60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
	Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
	Subtotal				$ 124,966
Subtotal Construction Costs					**$ 157,457**
	Design Contingency (30%)				$ 31,491
	Engineering and Administration (20%)				$ 31,491
Total Estimated Improvement Cost (Rounded)					$ 221,000

Improvement ID: *MBC_17*

Description	Units	Quantity	Unit Cost (Updated)	2007 SMP Unit Costs
General				
Insurance and Bonding (10%)				$ 27,154
Mobilization (6%)				$ 16,293
Traffic Control (5%)				$ 13,577
Misc. Utility Relocation (5%)				$ 13,577
Subtotal				$ 70,601
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,874
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	288	$ 30.67	$ 8,833
Pipe				
24" RCP - 6' Depth to Invert	LF	288	$ 130.14	$ 37,480
Surface Restoration				
Type 1 (Asphalt Patch)	LF	213	$ 51.38	$ 10,944
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	75	$ 103.02	$ 7,727
Manholes				
60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
Subtotal				$ 271,544
Subtotal Construction Costs				**$ 342,145**
Design Contingency (30%)				$ 68,429
Engineering and Administration (20%)				$ 68,429
Total Estimated Improvement Cost (Rounded)				$ 480,000

LOCAL SYSTEM IMPROVEMENT COSTS

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Boulder SMP Local System Recommended Plan Projects Tier I Cost

Order	Problem Name	ID	Improvement Type	Priority	Cost
1	Wonderland Creek - 1	WC_LI1	New and Replacement	Tier I	$ 318,000
2	Elmer's Twomile Creek - 2	ETC_LI2	New and Replacement	Tier I	$ 3,874,000
3	Goose Creek - 1	GC_LI1	New and Replacement	Tier I	$ 1,585,000
4	Goose Creek - 2	GC_LI2	New and Replacement	Tier I	$ 2,417,000
5	Goose Creek - 3	GC_LI3	New and Replacement	Tier I	$ 984,000
6	Middle Boulder Creek - 2	MBC_LI2	New and Replacement	Tier I	$ 3,175,000
7	Dry Creek No. 2 - 1	DC2_LI1	New and Replacement	Tier I	$ 1,837,000
8	Dry Creek No. 2 - 3	DC2_LI3	New and Replacement	Tier I	$ 6,505,000
9	Bear Canyon Creek - 3	BrCC_LI3	Hydraulic Improvement	Tier I	$ 2,265,000
10	Bear Canyon Creek - 5	BrCC_LI5	Hydraulic Improvement	Tier I	$ 267,000
				Total	**$ 23,227,000**

Improvement ID: *Wonderland Creek - 1*

Description		Units	Quantity	2016 Unit Cost	Item Cost
General					
	Insurance and Bonding (10%)				$ 16,790
	Mobilization (6%)				$ 10,074
	Traffic Control (5%)				$ 8,395
	Misc. Utility Relocation (5%)				$ 8,395
	Subtotal				$ 43,655
Pipe Improvements					
	Dewatering (5% of Pipe Cost)				$ 95
	Connect to Existing	Each	2	$ 1,200.00	$ 2,400
	Removal and Disposal of Pipe (up to 36-inch)	LF	131	$ 30.67	$ 4,018
	Pipe				
	18" RCP - 6' Depth to Invert	LF	206	$ 94.50	$ 19,467
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	206	$ 51.38	$ 10,584
	Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	27	$ 103.02	$ 2,782
	Manholes				
	60" Dia and Smaller	Each	2	$ 4,618.40	$ 9,237
	Curb Inlets (Type R)	Each	3	$ 7,273.98	$ 21,822
Utility Relocation					
	Water Line Relocation	LF	300	$ 125.00	$ 37,500
	Sanitary Sewer Relocation	LF	300	$ 200.00	$ 60,000
	Subtotal				$ 97,500
Subtotal Construction Costs					**$ 211,559**
	Design Contingency (30%)				$ 63,468
	Engineering and Administration (20%)				$ 42,312
Total Estimated Improvement Cost (Rounded)					**$ 318,000**

Improvement ID: *Elmer's Twomile Creek - 2*

Description	Units	Quantity	2016 Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 204,965
Mobilization (6%)				$ 122,979
Traffic Control (5%)				$ 102,482
Misc. Utility Relocation (5%)				$ 102,482
Subtotal				$ 532,909
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 3,655.40
Connect to Existing	Each	5	$ 1,200.00	$ 6,000
Removal and Disposal of Pipe (up to 36-inch)	LF	325	$ 30.67	$ 9,968
Pipe				
18" RCP - 6' Depth to Invert	LF	617	$ 94.50	$ 58,307
24" RCP - 6' Depth to Invert	LF	597	$ 130.14	$ 77,694
30" RCP - 6' Depth to Invert	LF	652	$ 152.28	$ 99,287
36" RCP - 6' Depth to Invert	LF	2,784	$ 186.84	$ 520,163
Surface Restoration				
Type 1 (Asphalt Patch)	LF	4,650	$ 51.38	$ 238,916
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	225	$ 103.02	$ 23,181
Manholes				
60" Dia and Smaller	Each	18	$ 4,618.40	$ 83,131
Curb Inlets (Type R)	Each	25	$ 7,273.98	$ 181,850
Utility Relocation				
Water Line Relocation	LF	2,300	$ 125.00	$ 287,500
Sanitary Sewer Relocation	LF	2,300	$ 200.00	$ 460,000
Subtotal				$ 747,500
Subtotal Construction Costs				**$ 2,582,558**
Design Contingency (30%)				$ 774,767
Engineering and Administration (20%)				$ 516,512
Total Estimated Improvement Cost (Rounded)				**$ 3,874,000**

Improvement ID: *Goose Creek - 1*

Description	Units	Quantity	2016 Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 83,852
Mobilization (6%)				$ 50,311
Traffic Control (5%)				$ 41,926
Misc. Utility Relocation (5%)				$ 41,926
Subtotal				$ 218,016
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,791.03
Connect to Existing	Each	4	$ 1,200.00	$ 4,800
Removal and Disposal of Pipe (up to 36-inch)	LF	1,563	$ 30.67	$ 47,937
Pipe				
18" RCP - 6' Depth to Invert	LF	1,053	$ 94.50	$ 99,509
24" RCP - 6' Depth to Invert	LF	301	$ 130.14	$ 39,172
30" RCP - 6' Depth to Invert	LF	906	$ 152.28	$ 137,966
36" RCP - 6' Depth to Invert	LF	428	$ 186.84	$ 79,968
Surface Restoration				
Type 1 (Asphalt Patch)	LF	2,688	$ 51.38	$ 138,109
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	144	$ 103.02	$ 14,836
Manholes				
60" Dia and Smaller	Each	11	$ 4,618.40	$ 50,802
Curb Inlets (Type R)	Each	16	$ 7,273.98	$ 116,384
Utility Relocation				
Water Line Relocation	LF	330	$ 125.00	$ 41,250
Sanitary Sewer Relocation	LF	330	$ 200.00	$ 66,000
Subtotal				$ 107,250
Subtotal Construction Costs				**$ 1,056,538**
Design Contingency (30%)				$ 316,961
Engineering and Administration (20%)				$ 211,308
Total Estimated Improvement Cost (Rounded)				**$ 1,585,000**

Improvement ID: *Goose Creek - 2*

Description	Units	Quantity	2016 Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 128,598
Mobilization (6%)				$ 77,159
Traffic Control (5%)				$ 64,299
Misc. Utility Relocation (5%)				$ 64,299
Subtotal				$ 334,355
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,857.38
Connect to Existing	Each	5	$ 1,200.00	$ 6,000
Removal and Disposal of Pipe (up to 36-inch)	LF	1,318	$ 30.67	$ 40,423
Pipe				
18" RCP - 6' Depth to Invert	LF	2,709	$ 94.50	$ 256,001
24" RCP - 6' Depth to Invert	LF	614	$ 130.14	$ 79,906
30" RCP - 6' Depth to Invert	LF	285	$ 152.28	$ 43,400
36" RCP - 6' Depth to Invert	LF	45	$ 186.84	$ 8,408
Surface Restoration				
Type 1 (Asphalt Patch)	LF	3,653	$ 51.38	$ 187,690
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	261	$ 103.02	$ 26,890
Manholes				
60" Dia and Smaller	Each	18	$ 4,618.40	$ 83,131
Curb Inlets (Type R)	Each	29	$ 7,273.98	$ 210,945
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 948,692
Channel Improvements				
Excavation	CY	410	$ 17.76	$ 7,281
Vegetation	SF	6,642	$ 0.29	$ 1,917
Subtotal				$ 9,198
Water Quality Ponds				
Excavation and shaping	CY	1,000	$ 23.09	$ 23,092
Subtotal				$ 23,092
Utility Relocation				
Water Line Relocation	LF	1,000	$ 125.00	$ 125,000
Sanitary Sewer Relocation	LF	900	$ 200.00	$ 180,000
Subtotal				$ 305,000
Subtotal Construction Costs				**$ 1,611,139**
Design Contingency (30%)				$ 483,342
Engineering and Administration (20%)				$ 322,228
Total Estimated Improvement Cost (Rounded)				**$ 2,417,000**

Improvement ID: *Goose Creek - 3*

Description	Units	Quantity	2016 Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 52,050
Mobilization (6%)				$ 31,230
Traffic Control (5%)				$ 26,025
Misc. Utility Relocation (5%)				$ 26,025
Subtotal				$ 135,330
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 2,148.56
Connect to Existing	Each	4	$ 1,200.00	$ 4,800
Removal and Disposal of Pipe (up to 36-inch)	LF	130	$ 30.67	$ 3,987
Pipe				
18" RCP - 6' Depth to Invert	LF	195	$ 94.50	$ 18,428
30" RCP - 6' Depth to Invert	LF	1,051	$ 152.28	$ 160,046
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,246	$ 51.38	$ 64,019
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	72	$ 103.02	$ 7,418
Manholes				
60" Dia and Smaller	Each	6	$ 4,618.40	$ 27,710
Curb Inlets (Type R)	Each	8	$ 7,273.98	$ 58,192
Subtotal				$ 346,749
Utility Relocation				
Water Line Relocation	LF	430	$ 125.00	$ 53,750
Sanitary Sewer Relocation	LF	600	$ 200.00	$ 120,000
Subtotal				$ 173,750
Subtotal Construction Costs				**$ 655,828**
Design Contingency (30%)				$ 196,748
Engineering and Administration (20%)				$ 131,166
Total Estimated Improvement Cost (Rounded)				**$ 984,000**

Improvement ID: *Middle Boulder Creek - 2*

Description	Units	Quantity	2016 Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 167,957
Mobilization (6%)				$ 100,774
Traffic Control (5%)				$ 83,978
Misc. Utility Relocation (5%)				$ 83,978
Subtotal				$ 436,688
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 3,451.21
Connect to Existing	Each	5	$ 1,200.00	$ 6,000
Removal and Disposal of Pipe (up to 36-inch)	LF	2,064	$ 30.67	$ 63,303
Pipe				
18" RCP - 6' Depth to Invert	LF	940	$ 94.50	$ 88,830
24" RCP - 6' Depth to Invert	LF	562	$ 130.14	$ 73,139
30" RCP - 6' Depth to Invert	LF	1,074	$ 152.28	$ 163,549
36" RCP - 6' Depth to Invert	LF	1,003	$ 186.84	$ 187,401
42" RCP - 8' Depth to Invert	LF	784	$ 218.78	$ 171,520
Surface Restoration				
Type 1 (Asphalt Patch)	LF	4,363	$ 51.38	$ 224,170
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	423	$ 103.02	$ 43,580
Manholes				
60" Dia and Smaller	Each	19	$ 4,618.40	$ 87,750
Curb Inlets (Type R)	Each	47	$ 7,273.98	$ 341,877
Subtotal				$ 1,454,568
Utility Relocation				
Water Line Relocation	LF	1,800	$ 125.00	$ 225,000
Subtotal				$ 225,000
Subtotal Construction Costs				**$ 2,116,255**
Design Contingency (30%)				$ 634,877
Engineering and Administration (20%)				$ 423,251
Total Estimated Improvement Cost (Rounded)				**$ 3,175,000**

Improvement ID: *Dry Creek No. 2 - 1*

Description	Units	Quantity	2016 Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 97,171
Mobilization (6%)				$ 58,303
Traffic Control (5%)				$ 48,586
Misc. Utility Relocation (5%)				$ 48,586
Subtotal				$ 252,646
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,936.46
Removal and Disposal of Pipe (up to 36-inch)	LF	2,150	$ 30.67	$ 65,941
Pipe				
18" RCP - 6' Depth to Invert	LF	1,958	$ 94.50	$ 185,031
24" RCP - 6' Depth to Invert	LF	625	$ 130.14	$ 81,338
30" RCP - 6' Depth to Invert	LF	317	$ 152.28	$ 48,273
36" RCP - 6' Depth to Invert	LF	370	$ 186.84	$ 69,131
Surface Restoration				
Type 1 (Asphalt Patch)	LF	3,270	$ 51.38	$ 168,012
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	216	$ 103.02	$ 22,253
Manholes				
60" Dia and Smaller	Each	10	$ 4,618.40	$ 46,184
Curb Inlets (Type R)	Each	24	$ 7,273.98	$ 174,576
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 866,715
Utility Relocation				
Water Line Relocation	LF	840	$ 125.00	$ 105,000
Subtotal				$ 105,000
Subtotal Construction Costs				**$ 1,224,360**
Design Contingency (30%)				$ 367,308
Engineering and Administration (20%)				$ 244,872
Total Estimated Improvement Cost (Rounded)				**$ 1,837,000**

Improvement ID: *Dry Creek No. 2 - 3*

Description	Units	Quantity	2016 Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 344,172
Mobilization (6%)				$ 206,503
Traffic Control (5%)				$ 172,086
Misc. Utility Relocation (5%)				$ 172,086
Subtotal				$ 894,846
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 7,032.11
Connect to Existing	Each	7	$ 1,200.00	$ 8,400
Removal and Disposal of Pipe (up to 36-inch)	LF	1,000	$ 30.67	$ 30,670
Pipe				
18" RCP - 6' Depth to Invert	LF	760	$ 94.50	$ 71,820
48" RCP - 8' Depth to Invert	LF	3,908	$ 239.24	$ 934,958
54" RCP - 10' Depth to Invert	LF	1,263	$ 303.62	$ 383,471
Surface Restoration				
Type 1 (Asphalt Patch)	LF	5,931	$ 51.38	$ 304,733
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	342	$ 103.02	$ 35,235
Manholes				
72" and Larger	Each	23	$ 9,236.80	$ 212,446
Curb Inlets (Type R)	Each	38	$ 7,273.98	$ 276,411
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 2,269,217
Utility Relocation				
Water Line Relocation	LF	5,700	$ 125.00	$ 712,500
Sanitary Sewer Relocation	LF	2,300	$ 200.00	$ 460,000
Subtotal				$ 1,172,500
Subtotal Construction Costs				**$ 4,336,564**
Design Contingency (30%)				$ 1,300,969
Engineering and Administration (20%)				$ 867,313
Total Estimated Improvement Cost (Rounded)				**$ 6,505,000**

Improvement ID: *Bear Canyon Creek - 3*

Description	Units	Quantity	2016 Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 119,821
Mobilization (6%)				$ 71,893
Traffic Control (5%)				$ 59,911
Misc. Utility Relocation (5%)				$ 59,911
Subtotal				$ 311,535
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,979.25
Connect to Existing	Each	6	$ 1,200.00	$ 7,200
Removal and Disposal of Pipe (up to 36-inch)	LF	723	$ 30.67	$ 22,174
Pipe				
18" RCP - 6' Depth to Invert	LF	240	$ 94.50	$ 22,680
36" RCP - 6' Depth to Invert	LF	1,110	$ 186.84	$ 207,392
42" RCP - 8' Depth to Invert	LF	558	$ 218.78	$ 122,076
48" RCP - 8' Depth to Invert	LF	148	$ 239.24	$ 35,408
Surface Restoration				
Type 1 (Asphalt Patch)	LF	2,056	$ 51.38	$ 105,637
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	108	$ 103.02	$ 11,127
Manholes				
60" Dia and Smaller	Each	13	$ 4,618.40	$ 60,039
72" and Larger	Each	3	$ 9,236.80	$ 27,710
Curb Inlets (Type R)	Each	12	$ 7,273.98	$ 87,288
Subtotal				$ 710,711
Utility Relocation				
Water Line Relocation	LF	1,500	$ 125.00	$ 187,500
Sanitary Sewer Relocation	LF	1,500	$ 200.00	$ 300,000
Subtotal				$ 487,500
Subtotal Construction Costs				**$ 1,509,746**
Design Contingency (30%)				$ 452,924
Engineering and Administration (20%)				$ 301,949
Total Estimated Improvement Cost (Rounded)				**$ 2,265,000**

Improvement ID: *Bear Canyon Creek - 5*

Description		Units	Quantity	2016 Unit Cost	Item Cost
General					
	Insurance and Bonding (10%)				$ 14,075
	Mobilization (6%)				$ 8,445
	Traffic Control (5%)				$ 7,038
	Misc. Utility Relocation (5%)				$ 7,038
	Subtotal				$ 36,595
Pipe Improvements					
	Dewatering (5% of Pipe Cost)				$ 774.90
	Connect to Existing	Each	1	$ 1,200.00	$ 1,200
	Removal and Disposal of Pipe (up to 36-inch)	LF	155	$ 30.67	$ 4,754
	Pipe				
	18" RCP - 6' Depth to Invert	LF	164	$ 94.50	$ 15,498
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	164	$ 51.38	$ 8,426
	Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	9	$ 103.02	$ 927
	Manholes				
	60" Dia and Smaller	Each	3	$ 4,618.40	$ 13,855
	Curb Inlets (Type R)	Each	1	$ 7,273.98	$ 7,274
	Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
	Subtotal				$ 56,751
Utility Relocation					
	Sanitary Sewer Relocation	LF	420	$ 200.00	$ 84,000
	Subtotal				$ 84,000
Subtotal Construction Costs					**$ 177,346**
	Design Contingency (30%)				$ 53,204
	Engineering and Administration (20%)				$ 35,469
Total Estimated Improvement Cost (Rounded)					**$ 267,000**

Boulder SMP Local System Recommended Plan Projects Tier II and Tier III Cost

Weighted Total	ObjId	Problem Name	ID	Improvement Type	Priority	Cost
29	11	Goose Creek - 5	GC_LI5	Hydraulic Improvement	Tier II	$ 5,484,000
28	12	Wonderland Creek - 7	WC_LI7	Hydraulic Improvement	Tier II	$ 2,452,000
27	13	Twomile Canyon Creek - 1	TCC_LI1	Hydraulic Improvement	Tier II	$ 2,939,000
27	14	Viele Channel - 1	VC_LI1	Hydraulic Improvement	Tier II	$ 936,000
27	15	Wonderland Creek - 2	WC_LI2	Hydraulic Improvement	Tier II	$ 1,925,000
26	16	Bear Canyon Creek - 4	BrCC_LI4	Hydraulic Improvement	Tier II	$ 726,000
26	17	Goose Creek - 4	GC_LI4	Hydraulic Improvement	Tier II	$ 4,885,000
25	18	Middle Boulder Creek - 3	MBC_LI3	Hydraulic Improvement	Tier II	$ 2,826,000
24	19	Fourmile Canyon Creek - 1	FCC_LI1	Hydraulic Improvement	Tier II	$ 688,000
23	20	Bear Canyon Creek - 1	BrCC_LI1	Hydraulic Improvement	Tier II	$ 69,000
23	21	Bluebell Canyon Creek - 1	BbCC_LI1	Hydraulic Improvement	Tier II	$ 1,137,000
17	22	Dry Creek No. 2 - 2	DC2_LI2	Hydraulic Improvement	Tier III	$ 726,000
16	23	Dry Creek No. 2 - 5	DC2_LI5	Hydraulic Improvement	Tier III	$ 2,386,000
16	24	Dry Creek No. 2 - 6	DC2_LI6	Hydraulic Improvement	Tier III	$ 1,689,000
16	25	Goose Creek - 6	GC_LI6	Hydraulic Improvement	Tier III	$ 1,946,000
16	26	Goose Creek - 8	GC_LI8	Hydraulic Improvement	Tier III	$ 932,000
16	27	Wonderland Creek - 6	WC_LI6	Hydraulic Improvement	Tier III	$ 366,000
15	28	Dry Creek No. 2 - 8	DC2_LI8	Hydraulic Improvement	Tier III	$ 604,000
15	29	Goose Creek - 7	GC_LI7	Hydraulic Improvement	Tier III	$ 1,913,000
13	30	Elmers Twomile Creek - 1	ETC_LI1	Hydraulic Improvement	Tier III	$ 98,000
13	31	Middle Boulder Creek - 1	MBC_LI1	Hydraulic Improvement	Tier III	$ 176,000
12	32	Dry Creek No. 2 - 4	DC2_LI4	Hydraulic Improvement	Tier III	$ 976,000
12	33	Dry Creek No. 2 - 7	DC2_LI7	Hydraulic Improvement	Tier III	$ 801,000
12	34	Wonderland Creek - 3	WC_LI3	Hydraulic Improvement	Tier III	$ 24,000
12	35	Wonderland Creek - 4	WC_LI4	Hydraulic Improvement	Tier III	$ 20,000
					Total	**$ 36,724,000**

Improvement ID: *Bluebell Canyon Creek - 1*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 60,109
Mobilization (6%)				$ 36,066
Traffic Control (5%)				$ 30,055
Misc. Utility Relocation (5%)				$ 30,055
Subtotal				$ 156,284
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,264.46
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	75	$ 30.67	$ 2,300
Pipe				
18" RCP - 6' Depth to Invert	LF	280	$ 94.50	$ 26,460
30" RCP - 8' Depth to Invert	LF	350	$ 152.28	$ 53,298
36" RCP - 8' Depth to Invert	LF	1,450	$ 186.84	$ 270,918
Surface Restoration				
Type 1 (Asphalt Patch)	LF	2,080	$ 51.38	$ 106,870
Manholes				
60" Dia and Smaller	Each	8	$ 4,618.40	$ 36,947
Curb Inlets (Type R)	Each	14	$ 7,273.98	$ 101,836
Subtotal				$ 601,093
Subtotal Construction Costs				**$ 757,378**
Design Contingency (25%)				$ 227,213
Engineering and Administration (20%)				$ 151,476
Total Estimated Improvement Cost (Rounded)				**$ 1,137,000**

Improvement ID: *Bear Canyon Creek - 1*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 4,092
Mobilization (6%)				$ 2,455
Traffic Control (5%)				$ 2,046
Misc. Utility Relocation (5%)				$ 2,046
Subtotal				$ 10,638
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 986.76
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Pipe				
54" RCP - 10' Depth to Invert	LF	65	$ 303.62	$ 19,735
Manholes				
72" and Larger	Each	1	$ 9,236.80	$ 9,237
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 35,200
Channel Improvements				
Excavation	CY	267	$ 17.76	$ 4,735
Vegetation	SF	3,400	$ 0.29	$ 981
Subtotal				$ 5,717
Subtotal Construction Costs				**$ 45,838**
Design Contingency (25%)				$ 13,751
Engineering and Administration (20%)				$ 9,168
Total Estimated Improvement Cost (Rounded)				**$ 69,000**

Improvement ID: *Bear Canyon Creek - 4*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 38,367
Mobilization (6%)				$ 23,020
Traffic Control (5%)				$ 19,183
Misc. Utility Relocation (5%)				$ 19,183
Subtotal				$ 99,754
Pipe Improvements				
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Pipe				
18" RCP - 6' Depth to Invert	LF	530	$ 94.50	$ 50,085
24" RCP - 6' Depth to Invert	LF	950	$ 130.14	$ 123,633
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,480	$ 51.38	$ 76,042
Manholes				
60" Dia and Smaller	Each	8	$ 4,618.40	$ 36,947
Curb Inlets (Type R)	Each	13	$ 7,273.98	$ 94,562
Subtotal				$ 383,669
Subtotal Construction Costs				**$ 483,423**
Design Contingency (25%)				$ 145,027
Engineering and Administration (20%)				$ 96,685
Total Estimated Improvement Cost (Rounded)				**$ 726,000**

Improvement ID: *Dry Creek No. 2 - 2*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 38,394
Mobilization (6%)				$ 23,036
Traffic Control (5%)				$ 19,197
Misc. Utility Relocation (5%)				$ 19,197
Subtotal				$ 99,825
Pipe Improvements				
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	172	$ 30.67	$ 5,275
Pipe				
18" RCP - 6' Depth to Invert	LF	430	$ 94.50	$ 40,635
24" RCP - 6' Depth to Invert	LF	1,115	$ 130.14	$ 145,106
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,545	$ 51.38	$ 79,382
Manholes				
60" Dia and Smaller	Each	7	$ 4,618.40	$ 32,329
Curb Inlets (Type R)	Each	11	$ 7,273.98	$ 80,014
Subtotal				$ 383,941
Subtotal Construction Costs				**$ 483,765**
Design Contingency (25%)				$ 145,130
Engineering and Administration (20%)				$ 96,753
Total Estimated Improvement Cost (Rounded)				**$ 726,000**

Improvement ID: *Dry Creek No. 2 - 4*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 51,726
Mobilization (6%)				$ 31,036
Traffic Control (5%)				$ 25,863
Misc. Utility Relocation (5%)				$ 25,863
Subtotal				$ 134,489
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,071.72
Pipe				
18" RCP - 6' Depth to Invert	LF	1,450	$ 94.50	$ 137,025
24" RCP - 6' Depth to Invert	LF	800	$ 130.14	$ 104,112
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,985	$ 51.38	$ 101,989
Manholes				
60" Dia and Smaller	Each	8	$ 4,618.40	$ 36,947
Curb Inlets (Type R)	Each	18	$ 7,273.98	$ 130,932
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 516,117
Channel Improvements				
Vegetation	SF	3,975	$ 0.29	$ 1,147
Subtotal				$ 1,147
Subtotal Construction Costs				**$ 650,606**
Design Contingency (25%)				$ 195,182
Engineering and Administration (20%)				$ 130,121
Total Estimated Improvement Cost (Rounded)				**$ 976,000**

Improvement ID: *Dry Creek No. 2 - 5*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 126,241
Mobilization (6%)				$ 75,745
Traffic Control (5%)				$ 63,121
Misc. Utility Relocation (5%)				$ 63,121
Subtotal				$ 328,228
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,177.59
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Pipe				
18" RCP - 6' Depth to Invert	LF	3,155	$ 94.50	$ 298,148
24" RCP - 6' Depth to Invert	LF	1,240	$ 130.14	$ 161,374
36" RCP - 6' Depth to Invert	LF	840	$ 186.84	$ 156,946
Surface Restoration				
Type 1 (Asphalt Patch)	LF	5,235	$ 51.38	$ 268,973
Manholes				
60" Dia and Smaller	Each	21	$ 4,618.40	$ 96,986
Curb Inlets (Type R)	Each	38	$ 7,273.98	$ 276,411
Subtotal				$ 1,262,415
Subtotal Construction Costs				**$ 1,590,642**
Design Contingency (25%)				$ 477,193
Engineering and Administration (20%)				$ 318,128
Total Estimated Improvement Cost (Rounded)				**$ 2,386,000**

Improvement ID: *Dry Creek No. 2 - 6*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 89,524
Mobilization (6%)				$ 53,714
Traffic Control (5%)				$ 44,762
Misc. Utility Relocation (5%)				$ 44,762
Subtotal				$ 232,763
Pipe Improvements				
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Removal and Disposal of Pipe (up to 36-inch)	LF	100	$ 30.67	$ 3,067
Pipe				
18" RCP - 6' Depth to Invert	LF	2,030	$ 94.50	$ 191,835
24" RCP - 6' Depth to Invert	LF	285	$ 130.14	$ 37,090
30" RCP - 6' Depth to Invert	LF	1,080	$ 152.28	$ 164,462
36" RCP - 6' Depth to Invert	LF	435	$ 186.84	$ 81,275
Surface Restoration				
Type 1 (Asphalt Patch)	LF	3,340	$ 51.38	$ 171,608
Manholes				
60" Dia and Smaller	Each	10	$ 4,618.40	$ 46,184
Curb Inlets (Type R)	Each	27	$ 7,273.98	$ 196,397
Subtotal				$ 893,119
Subtotal Construction Costs				**$ 1,125,882**
Design Contingency (25%)				$ 337,765
Engineering and Administration (20%)				$ 225,176
Total Estimated Improvement Cost (Rounded)				**$ 1,689,000**

Improvement ID: *Dry Creek No. 2 - 7*

	Description	Units	Quantity	Unit Cost	Item Cost
General					
	Insurance and Bonding (10%)				$ 42,374
	Mobilization (6%)				$ 25,425
	Traffic Control (5%)				$ 21,187
	Misc. Utility Relocation (5%)				$ 21,187
	Subtotal				$ 110,173
Pipe Improvements					
	Connect to Existing	Each	2	$ 1,200.00	$ 2,400
	Removal and Disposal of Pipe (up to 36-inch)	LF	900	$ 30.67	$ 27,603
	Pipe				
	18" RCP - 6' Depth to Invert	LF	1,605	$ 94.50	$ 151,673
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	1,515	$ 51.38	$ 77,840
	Manholes				
	60" Dia and Smaller	Each	15	$ 4,618.40	$ 69,276
	Curb Inlets (Type R)	Each	13	$ 7,273.98	$ 94,562
	Subtotal				$ 423,353
Channel Improvements					
	Vegetation	SF	1,350	$ 0.29	$ 390
	Subtotal				$ 390
Subtotal Construction Costs					**$ 533,527**
	Design Contingency (25%)				$ 160,058
	Engineering and Administration (20%)				$ 106,705
Total Estimated Improvement Cost (Rounded)					**$ 801,000**

Improvement ID: *Dry Creek No. 2 - 8*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 31,933
Mobilization (6%)				$ 19,160
Traffic Control (5%)				$ 15,967
Misc. Utility Relocation (5%)				$ 15,967
Subtotal				$ 83,026
Pipe Improvements				
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Pipe				
18" RCP - 6' Depth to Invert	LF	465	$ 94.50	$ 43,943
24" RCP - 6' Depth to Invert	LF	760	$ 130.14	$ 98,906
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,225	$ 51.38	$ 62,940
Manholes				
60" Dia and Smaller	Each	7	$ 4,618.40	$ 32,329
Curb Inlets (Type R)	Each	11	$ 7,273.98	$ 80,014
Subtotal				$ 319,332
Subtotal Construction Costs				**$ 402,358**
Design Contingency (25%)				$ 120,707
Engineering and Administration (20%)				$ 80,472
Total Estimated Improvement Cost (Rounded)				**$ 604,000**

Improvement ID: *Elmers Twomile Creek - 1*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 1,930
Mobilization (6%)				$ 1,158
Traffic Control (5%)				$ 965
Misc. Utility Relocation (5%)				$ 965
Subtotal				$ 5,019
Pipe Improvements				
Pipe				
18" RCP - 6' Depth to Invert	LF	35	$ 94.50	$ 3,308
Surface Restoration				
Type 1 (Asphalt Patch)	LF	10	$ 51.38	$ 514
Manholes				
Curb Inlets (Type R)	Each	1	$ 7,273.98	$ 7,274
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 15,136
Channel Improvements				
Excavation	CY	163	$ 17.76	$ 2,894
Vegetation	SF	4,410	$ 0.29	$ 1,273
Subtotal				$ 4,167
Subtotal Construction Costs				**$ 20,155**
Design Contingency (25%)				$ 6,047
Engineering and Administration (20%)				$ 4,031
Land Acquisition	SF	5,100	$ 13.12	$ 66,932
Total Estimated Improvement Cost (Rounded)				**$ 98,000**

Improvement ID: *Fourmile Canyon Creek - 1*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 36,398
Mobilization (6%)				$ 21,839
Traffic Control (5%)				$ 18,199
Misc. Utility Relocation (5%)				$ 18,199
Subtotal				$ 94,635
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 2,326.41
Pipe				
18" RCP - 6' Depth to Invert	LF	220	$ 94.50	$ 20,790
30" RCP - 6' Depth to Invert	LF	565	$ 152.28	$ 86,038
36" RCP - 6' Depth to Invert	LF	470	$ 186.84	$ 87,815
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,255	$ 51.38	$ 64,482
Manholes				
60" Dia and Smaller	Each	4	$ 4,618.40	$ 18,474
Curb Inlets (Type R)	Each	11	$ 7,273.98	$ 80,014
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 363,979
Subtotal Construction Costs				**$ 458,614**
Design Contingency (25%)				$ 137,584
Engineering and Administration (20%)				$ 91,723
Total Estimated Improvement Cost (Rounded)				**$ 688,000**

Improvement ID: *Goose Creek - 4*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 258,419
Mobilization (6%)				$ 155,051
Traffic Control (5%)				$ 129,209
Misc. Utility Relocation (5%)				$ 129,209
Subtotal				$ 671,889
Pipe Improvements				
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Pipe				
18" RCP - 6' Depth to Invert	LF	2,845	$ 94.50	$ 268,853
24" RCP - 6' Depth to Invert	LF	5,130	$ 130.14	$ 667,618
30" RCP - 6' Depth to Invert	LF	980	$ 152.28	$ 149,234
36" RCP - 6' Depth to Invert	LF	1,000	$ 186.84	$ 186,840
Surface Restoration				
Type 1 (Asphalt Patch)	LF	9,955	$ 51.38	$ 511,485
Manholes				
60" Dia and Smaller	Each	26	$ 4,618.40	$ 120,078
Curb Inlets (Type R)	Each	93	$ 7,273.98	$ 676,480
Subtotal				$ 2,584,189
Subtotal Construction Costs				**$ 3,256,078**
Design Contingency (25%)				$ 976,823
Engineering and Administration (20%)				$ 651,216
Total Estimated Improvement Cost (Rounded)				**$ 4,885,000**

Improvement ID: *Goose Creek - 5*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 290,147
Mobilization (6%)				$ 174,088
Traffic Control (5%)				$ 145,073
Misc. Utility Relocation (5%)				$ 145,073
Subtotal				$ 754,382
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 11,875
Connect to Existing	Each	2	$ 1,200	$ 2,400
Pipe and Asphalt Demo/Disposal	LF	5,960	$ 31	$ 182,793
Pipe				
24" RCP - 6' Depth to Invert	LF	320	$ 130	$ 41,645
60" RCP - 10' Depth to Invert	LF	2,640	$ 351	$ 925,510
66" RCP - 10' Depth to Invert	LF	3,320	$ 388	$ 1,286,801
Surface Restoration				
Type 1 (Asphalt Patch)	LF	949	$ 51	$ 48,759
Manholes				
Special/Box Base	Each	14	$ 13,855	$ 193,973
Curb Inlets (Type R)	Each	28	$ 7,274	$ 203,671
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041	$ 4,041
Subtotal				$ 2,901,470
Subtotal Construction Costs				**$ 3,655,852**
Design Contingency (25%)				$ 1,096,756
Engineering and Administration (20%)				$ 731,170
Total Estimated Improvement Cost (Rounded)				**$ 5,484,000**

Estimated quantities derived from GC_01 Twomile Creek Alt 2 costs from 2007 SMP

Improvement ID: *Goose Creek - 6*

Description		Units	Quantity	Unit Cost	Item Cost
General					
	Insurance and Bonding (10%)				$ 100,185
	Mobilization (6%)				$ 60,111
	Traffic Control (5%)				$ 50,093
	Misc. Utility Relocation (5%)				$ 50,093
	Subtotal				$ 260,481
Pipe Improvements					
	Connect to Existing	Each	4	$ 1,200.00	$ 4,800
	Removal and Disposal of Pipe (up to 36-inch)	LF	1,240	$ 30.67	$ 38,031
	Pipe				
	18" RCP - 6' Depth to Invert	LF	950	$ 94.50	$ 89,775
	24" RCP - 6' Depth to Invert	LF	3,130	$ 130.14	$ 407,338
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	3,810	$ 51.38	$ 195,757
	Manholes				
	60" Dia and Smaller	Each	18	$ 4,618.40	$ 83,131
	Curb Inlets (Type R)	Each	25	$ 7,273.98	$ 181,850
	Subtotal				$ 1,000,681
Channel Improvements					
	Vegetation	SF	4,050	$ 0.29	$ 1,169
	Subtotal				$ 1,169
Subtotal Construction Costs					**$ 1,261,162**
	Design Contingency (25%)				$ 378,349
	Engineering and Administration (20%)				$ 252,232
	Land Acquisition	SF	4,125	$ 13.12	$ 54,136
Total Estimated Improvement Cost (Rounded)					**$ 1,946,000**

Improvement ID: *Goose Creek - 7*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 101,203
Mobilization (6%)				$ 60,722
Traffic Control (5%)				$ 50,602
Misc. Utility Relocation (5%)				$ 50,602
Subtotal				$ 263,128
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 6,624.22
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Removal and Disposal of Pipe (up to 36-inch)	LF	760	$ 30.67	$ 23,309
Pipe				
18" RCP - 6' Depth to Invert	LF	880	$ 94.50	$ 83,160
24" RCP - 6' Depth to Invert	LF	1,454	$ 130.14	$ 189,224
30" RCP - 6' Depth to Invert	LF	847	$ 152.28	$ 128,981
Surface Restoration				
Type 1 (Asphalt Patch)	LF	1,541	$ 51.38	$ 79,176
Type 2 (Asphalt Patch/Curb-Gutter Replacement)	LF	760	$ 103.02	$ 78,299
Manholes				
60" Dia and Smaller	Each	11	$ 4,618.40	$ 50,802
Curb Inlets (Type R)	Each	44	$ 7,273.98	$ 320,055
Pipe Outfall (Incl. permanent erosion protection)	Each	-	$ 4,041.10	$ -
Subtotal				$ 962,031
Utility Relocation				
Sanitary Sewer Relocation	LF	250	$ 200.00	$ 50,000
Subtotal				$ 50,000
Subtotal Construction Costs				**$ 1,275,159**
Design Contingency (25%)				$ 382,548
Engineering and Administration (20%)				$ 255,032
Land Acquisition	SF	-	$ 13.12	$ -
Total Estimated Improvement Cost (Rounded)				**$ 1,913,000**

Improvement ID: *Goose Creek - 8*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 49,269
Mobilization (6%)				$ 29,562
Traffic Control (5%)				$ 24,635
Misc. Utility Relocation (5%)				$ 24,635
Subtotal				$ 128,100
Pipe Improvements				
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	300	$ 30.67	$ 9,201
Pipe				
18" RCP - 6' Depth to Invert	LF	2,180	$ 94.50	$ 206,010
Surface Restoration				
Type 1 (Asphalt Patch)	LF	2,180	$ 51.38	$ 112,008
Manholes				
60" Dia and Smaller	Each	13	$ 4,618.40	$ 60,039
Curb Inlets (Type R)	Each	14	$ 7,273.98	$ 101,836
Subtotal				$ 492,694
Subtotal Construction Costs				**$ 620,794**
Design Contingency (25%)				$ 186,238
Engineering and Administration (20%)				$ 124,159
Total Estimated Improvement Cost (Rounded)				**$ 932,000**

Improvement ID: *Middle Boulder Creek - 1*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 10,623
Mobilization (6%)				$ 6,374
Traffic Control (5%)				$ 5,312
Misc. Utility Relocation (5%)				$ 5,312
Subtotal				$ 27,621
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 637.50
Connect to Existing	Each	2	$ 1,200.00	$ 2,400
Pipe				
18" RCP - 6' Depth to Invert	LF	30	$ 94.50	$ 2,835
24" RCP - 6' Depth to Invert	LF	375	$ 130.14	$ 48,803
Manholes				
60" Dia and Smaller	Each	5	$ 4,618.40	$ 23,092
Curb Inlets (Type R)	Each	1	$ 7,273.98	$ 7,274
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 89,082
Channel Improvements				
Excavation	CY	607	$ 17.76	$ 10,786
Vegetation	SF	22,050	$ 0.29	$ 6,365
Subtotal				$ 17,151
Subtotal Construction Costs				**$ 116,703**
Design Contingency (25%)				$ 35,011
Engineering and Administration (20%)				$ 23,341
Total Estimated Improvement Cost (Rounded)				**$ 176,000**

Improvement ID: *Middle Boulder Creek - 3*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 149,501
Mobilization (6%)				$ 89,701
Traffic Control (5%)				$ 74,751
Misc. Utility Relocation (5%)				$ 74,751
Subtotal				$ 388,703
Pipe Improvements				
Connect to Existing	Each	3	$ 1,200.00	$ 3,600
Removal and Disposal of Pipe (up to 36-inch)	LF	2,240	$ 30.67	$ 68,701
Pipe				
18" RCP - 6' Depth to Invert	LF	795	$ 94.50	$ 75,128
24" RCP - 6' Depth to Invert	LF	715	$ 130.14	$ 93,050
30" RCP - 6' Depth to Invert	LF	1,870	$ 152.28	$ 284,764
36" RCP - 6' Depth to Invert	LF	2,010	$ 186.84	$ 375,548
Surface Restoration				
Type 1 (Asphalt Patch)	LF	5,390	$ 51.38	$ 276,937
Manholes				
60" Dia and Smaller	Each	12	$ 4,618.40	$ 55,421
Curb Inlets (Type R)	Each	36	$ 7,273.98	$ 261,863
Subtotal				$ 1,495,011
Subtotal Construction Costs				**$ 1,883,714**
Design Contingency (25%)				$ 565,114
Engineering and Administration (20%)				$ 376,743
Total Estimated Improvement Cost (Rounded)				**$ 2,826,000**

Improvement ID: *Twomile Canyon Creek - 1*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 155,488
Mobilization (6%)				$ 93,293
Traffic Control (5%)				$ 77,744
Misc. Utility Relocation (5%)				$ 77,744
Subtotal				$ 404,270
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 3,648.09
Connect to Existing	Each	5	$ 1,200.00	$ 6,000
Pipe				
18" RCP - 6' Depth to Invert	LF	1,630	$ 94.50	$ 154,035
24" RCP - 6' Depth to Invert	LF	5,175	$ 130.14	$ 673,475
Surface Restoration				
Type 1 (Asphalt Patch)	LF	6,805	$ 51.38	$ 349,639
Manholes				
60" Dia and Smaller	Each	23	$ 4,618.40	$ 106,223
Curb Inlets (Type R)	Each	36	$ 7,273.98	$ 261,863
Subtotal				$ 1,554,883
Subtotal Construction Costs				**$ 1,959,152**
Design Contingency (25%)				$ 587,746
Engineering and Administration (20%)				$ 391,830
Total Estimated Improvement Cost (Rounded)				**$ 2,939,000**

Improvement ID: *Viele Channel - 1*

Description		Units	Quantity	Unit Cost	Item Cost
General					
	Insurance and Bonding (10%)				$ 49,520
	Mobilization (6%)				$ 29,712
	Traffic Control (5%)				$ 24,760
	Misc. Utility Relocation (5%)				$ 24,760
	Subtotal				$ 128,752
Pipe Improvements					
	Dewatering (5% of Pipe Cost)				$ 628.32
	Connect to Existing	Each	1	$ 1,200.00	$ 1,200
	Pipe				
	18" RCP - 6' Depth to Invert	LF	260	$ 94.50	$ 24,570
	24" RCP - 6' Depth to Invert	LF	1,810	$ 130.14	$ 235,553
	Surface Restoration				
	Type 1 (Asphalt Patch)	LF	2,070	$ 51.38	$ 106,356
	Manholes				
	60" Dia and Smaller	Each	7	$ 4,618.40	$ 32,329
	Curb Inlets (Type R)	Each	13	$ 7,273.98	$ 94,562
	Subtotal				$ 495,198
Subtotal Construction Costs					**$ 623,950**
	Design Contingency (25%)				$ 187,185
	Engineering and Administration (20%)				$ 124,790
Total Estimated Improvement Cost (Rounded)					**$ 936,000**

Improvement ID: *Wonderland Creek - 2*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 101,846
Mobilization (6%)				$ 61,107
Traffic Control (5%)				$ 50,923
Misc. Utility Relocation (5%)				$ 50,923
Subtotal				$ 264,799
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,758.06
Pipe				
18" RCP - 6' Depth to Invert	LF	1,935	$ 94.50	$ 182,858
24" RCP - 6' Depth to Invert	LF	1,715	$ 130.14	$ 223,190
30" RCP - 6' Depth to Invert	LF	620	$ 152.28	$ 94,414
Surface Restoration				
Type 1 (Asphalt Patch)	LF	4,270	$ 51.38	$ 219,391
Manholes				
60" Dia and Smaller	Each	13	$ 4,618.40	$ 60,039
Curb Inlets (Type R)	Each	32	$ 7,273.98	$ 232,767
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 1,018,458
Subtotal Construction Costs				**$ 1,283,257**
Design Contingency (25%)				$ 384,977
Engineering and Administration (20%)				$ 256,651
Total Estimated Improvement Cost (Rounded)				**$ 1,925,000**

Improvement ID: *Wonderland Creek - 3*

	Description	Units	Quantity	Unit Cost	Item Cost
General					
	Insurance and Bonding (10%)				$ 6,031
	Mobilization (6%)				$ 3,619
	Traffic Control (5%)				$ 3,016
	Misc. Utility Relocation (5%)				$ 3,016
	Subtotal				$ 15,681
Channel Improvements					
	Excavation	CY	2,813	$ 17.76	$ 49,958
	Vegetation	SF	35,870	$ 0.29	$ 10,354
	Subtotal				$ 60,312
Subtotal Construction Costs					**$ 15,681**
	Design Contingency (25%)				$ 4,704
	Engineering and Administration (20%)				$ 3,136
Total Estimated Improvement Cost (Rounded)					**$ 24,000**

Improvement ID: *Wonderland Creek - 4*

Description		Units	Quantity	Unit Cost	Item Cost
General					
	Insurance and Bonding (10%)				$ 4,945
	Mobilization (6%)				$ 2,967
	Traffic Control (5%)				$ 2,473
	Misc. Utility Relocation (5%)				$ 2,473
	Subtotal				$ 12,857
Channel Improvements					
	Excavation	CY	2,307	$ 17.76	$ 40,961
	Vegetation	SF	29,410	$ 0.29	$ 8,489
	Subtotal				$ 49,450
Subtotal Construction Costs					**$ 12,857**
	Design Contingency (25%)				$ 3,857
	Engineering and Administration (20%)				$ 2,571
Total Estimated Improvement Cost (Rounded)					**$ 20,000**

Improvement ID: *Wonderland Creek - 6*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 19,418
Mobilization (6%)				$ 11,651
Traffic Control (5%)				$ 9,709
Misc. Utility Relocation (5%)				$ 9,709
Subtotal				$ 50,487
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 1,235.75
Pipe				
18" RCP - 6' Depth to Invert	LF	140	$ 94.50	$ 13,230
24" RCP - 6' Depth to Invert	LF	620	$ 130.14	$ 80,687
Surface Restoration				
Type 1 (Asphalt Patch)	LF	560	$ 51.38	$ 28,773
Manholes				
60" Dia and Smaller	Each	4	$ 4,618.40	$ 18,474
Curb Inlets (Type R)	Each	7	$ 7,273.98	$ 50,918
Subtotal				$ 193,317
Channel Improvements				
Vegetation	SF	3,000	$ 0.29	$ 866
Subtotal				$ 866
Subtotal Construction Costs				**$ 243,804**
Design Contingency (25%)				$ 73,141
Engineering and Administration (20%)				$ 48,761
Total Estimated Improvement Cost (Rounded)				**$ 366,000**

Improvement ID: *Wonderland Creek - 7*

Description	Units	Quantity	Unit Cost	Item Cost
General				
Insurance and Bonding (10%)				$ 129,730
Mobilization (6%)				$ 77,838
Traffic Control (5%)				$ 64,865
Misc. Utility Relocation (5%)				$ 64,865
Subtotal				$ 337,298
Pipe Improvements				
Dewatering (5% of Pipe Cost)				$ 2,268.78
Connect to Existing	Each	1	$ 1,200.00	$ 1,200
Pipe				
18" RCP - 6' Depth to Invert	LF	1,380	$ 94.50	$ 130,410
30" RCP - 6' Depth to Invert	LF	1,235	$ 152.28	$ 188,066
36" RCP - 6' Depth to Invert	LF	2,165	$ 186.84	$ 404,509
Surface Restoration				
Type 1 (Asphalt Patch)	LF	4,780	$ 51.38	$ 245,595
Manholes				
60" Dia and Smaller	Each	16	$ 4,618.40	$ 73,894
Curb Inlets (Type R)	Each	34	$ 7,273.98	$ 247,315
Pipe Outfall (Incl. permanent erosion protection)	Each	1	$ 4,041.10	$ 4,041
Subtotal				$ 1,297,299
Subtotal Construction Costs				**$ 1,634,597**
Design Contingency (25%)				$ 490,379
Engineering and Administration (20%)				$ 326,919
Total Estimated Improvement Cost (Rounded)				**$ 2,452,000**